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INTERNET PROTOCOL HANDBOOK

Volume Four

THE DOMAIN NAME SYSTEM (DNS) HANDBOOK

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13. ABSTRACT (Maximum 200 words)

The Internet Protocol Handbook explains the Domain Name System (DNS) and the Internet Host Table. This is volume 4 of the DDN PROTOCOL HANDBOOK four volume set. The first three volumes are a collection of documents on attaching computers to the DDN (Defense Data Network) using the DoD (Department of Defense) protocol suite. Volume four is divided into two sections. The first section covers the concepts and philosophy of the DNS as discussed in various articles and RFCs (Request for Comments). The second section focuses on the transition from the Internet Host Table to the DNS. Detailed information on DNS protocol standards and implementations are provided as are guidelines for the establishment and operation of domain name servers. The handbook concludes with a glossary of DNS acronyms.

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Volume Four

THE DOMAIN NAME SYSTEM (DNS) HANDBOOK

AUGUST 1989

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Additional copies of this document may be obtained from the Network Information Systems Center, SRI International, 333 Ravenswood Avenue, Room EJ291, Menlo Park, CA 94025 or from the Defense Technical Information Center (DTIC), Cameron Station, Alexandria, VA 22314.

PLEASE NOTE

The Internet Protocol Handbook is not in itself an official MIL STD. It is a compilation of DoD protocols collected for informational and reference purposes only. Potential contractors who use the material contained in the Handbook to respond to Requests for Proposals (RFPs) or to bid on government contracts, do so at their own risk. Unless this Handbook is specifically cited as the prescribed source to use, we strongly urge that you check with the contracting agency or the Naval Publications and Forms Center (NPFC) to verify that the versions of the MIL STD protocols on which you base your effort are, in fact, the latest versions. The postal address for NPFC is Naval Publications and Forms Center, Code 3015, 5801 Tabor Drive, Philadelphia, PA 19120.

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INTRODUCTION TO VOLUME 4

In the early days of the Internet, the management of names for hosts and other resources was carried out using a master host table, called the Internet Host Table, maintained by the Network Information Center (NIC) at SRI International. All sites in the Internet periodically received updated copies of this table. As the Internet grew in size, this centralized approach became unacceptable. To solve this problem, the domain name system (DNS) was introduced in the Internet. The DNS consists of the syntax to specify the names of entities in the Internet in a hierarchical manner, the rules used for delegating authority over names, and the system implementation that actually maps names to Internet addresses.

Volume Four of the Internet Protocol Handbook constitutes the most comprehensive source of information on the DNS to date. This volume is organized in two parts. Section 1 contains articles and Requests for Comments (RFCs) that introduce the main philosophy, concepts, and facilities of the DNS; describe in detail the DNS protocol standards and implementation; discuss the requirements that an Internet domain server must meet and the current organization of domains in the Internet; provide guidelines for establishing domains and for operating a domain name server; detail the changes to the Internet mail system related to domains; and describe how to obtain additional information about the DNS through electronic mail and points of contact in the Internet. Section 2 of this volume contains background reading that is useful in understanding the transition from the Internet Host Table to the DNS A glossary of DNS acronyms is provided at the end of this volume.

Each section of this volume provides a brief description of its overall contents and a summary of each of the articles and RFCs it includes. All of the reprints that appear in this volume bear their original page numbering; we have included the page numbering for the Handbook below the footer line.

1. THE DOMAIN NAME SYSTEM

Section 1 contains articles and RFCs that describe the design, standards, and implementation of the DNS; the administration and operation of domains; and how to obtain more information about the DNS.

The first article, by Paul Mockapetris, one of the main designers of the DNS, provides a brief authoritative introduction to the design philosophy of the DNS.

RFC 1034 introduces the domain-style names, how such names are used for Internet mail and host address support, and the protocols and servers used to implement domain name facilities. After providing an introduction to the history of the DNS and its design goals, it describes DNS elements, usage assumptions, and facets of the domain name space specifications and Resource Records (RRs). Details are provided regarding the functions of name servers and resolvers. An example scenario guides the reader through several sample queries and responses. This RFC is updated by RFC 1101, which is included in this volume, and obsoletes RFC 973, RFC 882, and RFC 883.

RFC 1035 provides details of the DNS and protocol. It first introduces the DNS and discusses common system configurations and conventions. It then covers the domain name space and Resource Record (RR) definitions, including a list of standard RRs. The RFC describes the format for communication within the domain protocol, the master files used to define zones, and implementations for a name server and resolver. RFC 1035 also includes some thoughts on mail support. This RFC is updated by RFC 1101, which is included in this volume, and obsoletes RFC 973, RFC 882, and RFC 883.

RFC 1101 presents two extensions to the current DNS. The first extension is a proposed restructuring of network names, addresses, and subnets to be compatible with expanded host name support systems. The second is a general suggestion that would allow mapping between given network numbers and network names. The role of the DDN NIC in allocating network names and numbers is briefly discussed. This RFC updates RFC 1034 and RFC 1035.

RFC 920 describes the requirements for establishing a new domain in the Internet. In addition, this RFC reviews the purpose of domains, gives examples of domains, introduces the set of top-level domains, and advises hosts on how to choose a domain.

RFC 1032 explains the roles and responsibilities of the Domain Administrator (DA) and the domain technical and zone contact, and discusses the different domain levels, the domain names, and DDN NIC policies regarding choosing both. This RFC also presents the exact procedures for registering a domain with the DDN NIC and provides a sample domain registration form and references to further information.

RFC 1033 provides specific guidelines for domain administrators, explaining how to operate a domain server and how to maintain their part of the hierarchical domain database. This RFC explains what a domain server needs to get started, how it figures out the zones it should pay attention to, and how it finds the root servers. It discusses RRs and explains the fields within RRs. It provides instructions for adding or deleting subdomains, hosts, and gateways, as well as for handling complaints. It also includes example domain-server database files.

RFC 974 describes how mailers route messages that are addressed to a domain name. This RFC first describes what domain servers know and general routing guidelines, then explains how mailers determine where to send a message. This determination is made by issuing a query for the Mail Exchange (MX) RRs for a destination host, and by interpreting the list of MX RRs received. This process is discussed and examples of message routing are given.

The last part of Section 1, by Jose Garcia-Luna and Mary Stahl, describes a number of different ways to obtain additional information about the DNS, including DNS implementations.

1.1. Domains

Domains

History

In any large internet, the task of orgar' ..ng and managing names for users, host. and other objects becomes increasingly im' rtant as the internet grows in size. The DARPA Internet started out with a system inherited from the ARPANET, in which the SRI Network Information Center (NIC) maintained a file called HOSTS.TXT listing all of the hosts, networks, and gateways, together with the corresponding addresses. The file was maintained by the NIC staff and distributed to all hosts via direct and indirect file transfer. As workstations and local networks came to dominate the internet population, the size, centralized maintenance and universal distribution of HOSTS.TXT became impractical. To solve this problem, a distributed service called the Domain Name System (DNS) was defined in 1983, and has been modified and extended since then.

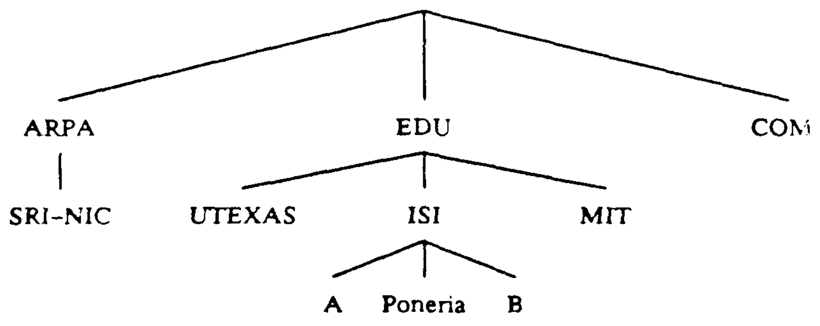
The HOSTS.TXT file is still maintained, but contains an ever-decreasing subset of the information available from the DNS. HOSTS.TXT currently has on the order of 6,000 entries while the DNS has over 100,000.

What is the basic scheme?

The basic idea behind the DNS is that name creation, control, and maintenance must be distributed, along with the ability to associate information with the names. The names created in this system are called domain names, and the information associated with them is called resource records (RRs).

To get the distribution of control while keeping administrators off of each other's toes, domain names use a hierarchical or tree structure. It's not too far off to think of this as creating a distributed "org chart" for all of the organizations, hosts, etc. in the Internet. The idea is that each administrator gets authority over a section of the total tree and is free to cut or add at and below that point. Of course, it's a bit more complicated than that, since an administrator can create and delegate control for a subsection of his subtree, and so on. Technically speaking, a domain is a full subtree in the name space (usually delegated to a particular organization), and a zone is a domain less subdomains which have been delegated away.

In the DNS tree structure, each node gets a label that must distinguish it from its brothers. The absolute name of any node is a list of its label together with the labels of all of its ancestors, all the way back to the root of the tree. When we type these unique names, we separate labels with dots. A sample tree might be:



(Note that this is a quite skimpy example; the real name space has over 100,000 names, and typical names have 4 or five levels. The root of the tree has a special, reserved, null label.)

The typical user doesn't see a graphical tree structure but instead sees names derived from the structure. In this tree, the bottom node, with the label "Poneria" has an absolute name of "Poneria.ISI.EDU". Note that since the requirement for uniqueness is only between brother nodes, we could create another "Poneria" under ARPA or any other node which does not already have one. The DNS doesn't restrict the use of interior nodes, so ISI.EDU is also a domain name.

Domain names, in themselves, don't define hosts, organizations, or any other object (although they are most often used for hosts). Instead, they provide "places" where this information may be kept. The information takes the form of a set of RRs; the set of RRs associated with a name may be empty, in which case the name is merely a placeholder or it may hold the Internet address, mail exchange, or a variety of other types of data. Thus you can tell that a name denotes a host by seeing if it has host information stored in it, rather than asking its type. In the case of a host, the name will have one address RR for each IP address the host has, and might also have a HINFO RR describing the host OS and CPU.

How does this affect the average user?

Side effects of distribution

The major effect that the average user sees is a lot of names with dots in them. Sometimes this is useful, since the parent domains will usually describe a geographical location or type of organization, although it sometimes means more typing. Users should be aware that just because a name has dots in it, and may even have hierarchical components, doesn't mean that the name is registered with the DNS. For example, ".UUCP" is a frequent top-level pseudo-domain, although it is not registered in the DNS.

The distribution of the database means that you can usually add hosts, change the name of your host, reconfigure IP addresses, or other database updates as a purely local matter (once you get control of a domain). All you need to do is get your local administrator to make the changes.

The price paid for the distributed control is that you will occasionally have to wait while information is retrieved from a distant source. The DNS eliminates much, but not all of this delay through a comprehensive caching strategy. In cases where the Internet is partitioned by routing problems or the like, it may be impossible to get information about a name until connectivity is restored.

Names aren't just for hosts anymore

While the DNS was created to replace HOSTS.TXT, it has also been used to store new types of information. The prime example is a new class of information called Mail Exchange or MX information. MX allows an organization to channel mail for all of its users to mail service machines, rather than individual user's workstations. In addition to providing redundant backups to speed mail delivery, it also allows organizations to have domain names without being directly connected to the DARPA Internet; they just use MX to direct their mail to the appropriate mail gateway.

What are the active components?

DNS services are provided by two new pieces of software: name servers and resolvers.

Name servers are repositories of information. They are usually independent server processes. Name servers load the information prepared by the local administrators and make it available via UDP queries. Name servers also have a *zone transfer* protocol that allows multiple name servers to automatically acquire redundant copies of zone data. This means that even if one of the name servers for a particular domain crashes, the other redundant ones will still answer queries for the domain.

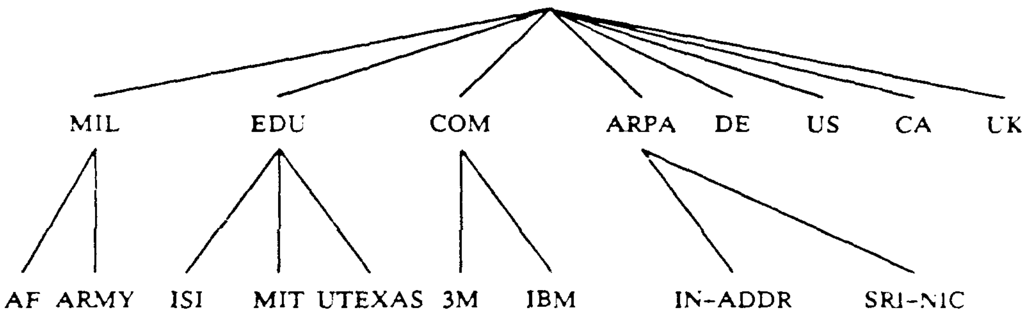
Resolvers are programs which take user requests and seek out the proper name server to answer the request. Resolvers may be autonomous processes or may be code linked into user programs. Since name servers typically only know about a small part of the whole name space, and since server crashes and network problems make retries and use of alternate name servers necessary, this important role insulates the user from the realities of the Internet.

This division is often logical, rather than actual. The DNS allows for most of the resolver functions to be included in special local name servers. This technique is used in BIND, the BSD name server.

How have domains been organized?

The DNS is a technical method for describing a large hierarchy in a distributed manner. As you might imagine, the reservation of familiar names, and issues related to who controls what generate a lot of discussion. The important point here is that technically, almost any organization is possible, and different styles may prevail in different parts of the name space.

The top levels of the name space were organized some time ago in RFC 920. An excerpt (there are over 30 domains under the root, and over 1000 delegated zones overall) of the top-level organization is shown below:



Three types of names appear immediately below the r :. The first type is the so-called "generic" domains such as EDU (Educational), COM (Commercial). These were defined in RFC 920, and are meant to divide by organization type. The main ones are shown below:

Domain	Purpose	Examples
MIL	US Military	ARMY.MIL, NAVY.MIL
GOV	Other US government	NASA.GOV
EDU	Educational	ISI.EDU, MIT.EDU
COM	Commercial	3M.COM, SUN.COM
NET	NICs and NOCs	Nyser.NET
ORG	Non-profit organizations	MITRE.ORG

All of these are at present administered by the SRI-NIC. The EDU and COM domains are the most popular, with several hundred subdomains delegated to various universities and companies. The MIL domain is in the midst of a reorganization mandated by DDN 42, which will give it a more substructure. Note that although the MIL and GOV domains are restricted to US use, the NIC has and will register non-US names in COM, EDU, etc.

The second type of top level domain is the ARPA domain. This was used to bootstrap old HOSTS.TXT names into the DNS world, and new registrations are strongly discouraged. Indeed, all MILNET hosts are being reorganized into the MIL domain.

The last type of domain is allocated by country. Every country has its ISO 3166 standard 2-letter acronym reserved for it, whether it has been claimed or not. The policies of these domains are as varied as the countries themselves.

The US domain

The country top-level domain for the United States is controlled by Jon Postel (Postel@ISI.EDU), who sets its policy and administered by Ann Westine (Westine@ISI EDU). At present, the US domain is organized geographically; states occur directly under US, cities under states, and individual names under cities. Although registration in the US domain does not imply authorization to connect to the DARPA Internet, small companies and individuals can register in the US domain, so long as they are not registered elsewhere. Since the US domain will accept MX-only entries, registration is independent of direct connection to the Internet.

At present, about 100 organizations are registered in the US domain. An example name is "fernwood.mpk.ca.us", which is the "fernwood" host in Menlo Park, California. States and cities may be delegated to local administrators in the future.

How do I find out more?

The philosophy and inner workings of the DNS are described in RFCs 1034 and 1035. RFC 920 describes the rationale for the design of the top levels of the name space. The NAMEDROPPERS@SRI-NIC.ARPA mailing list discusses general DNS issues, while questions more specific to BIND are discussed in BIND@UCBARPA.Berkeley.EDU. RFC 1101 describes a plan to extend domain names for network (and subnetwork) information, along with some discussion about possible future uses of the DNS for a variety of other information.

1.2. Domain Names - Concepts and Facilities [RFC1034]

Network Working Group P. Mockapetris
Request for Comments: 1034 ISI
Obsoletes: RFCs 882, 883, 973 November 1987

DOMAIN NAMES - CONCEPTS AND FACILITIES

1. STATUS OF THIS MEMO

This RFC is an introduction to the Domain Name System (DNS), and omits many details which can be found in a companion RFC, "Domain Names - Implementation and Specification" [RFC-1035]. That RFC assumes that the reader is familiar with the concepts discussed in this memo.

A subset of DNS functions and data types constitute an official protocol. The official protocol includes standard queries and their responses and most of the Internet class data formats (e.g., host addresses).

However, the domain system is intentionally extensible. Researchers are continuously proposing, implementing and experimenting with new data types, query types, classes, functions, etc. Thus while the components of the official protocol are expected to stay essentially unchanged and operate as a production service, experimental behavior should always be expected in extensions beyond the official protocol. Experimental or obsolete features are clearly marked in these RFCs, and such information should be used with caution.

The reader is especially cautioned not to depend on the values which appear in examples to be current or complete, since their purpose is primarily pedagogical. Distribution of this memo is unlimited.

2. INTRODUCTION

This RFC introduces domain style names, their use for Internet mail and host address support, and the protocols and servers used to implement domain name facilities.

2.1. The history of domain names

The impetus for the development of the domain system was growth in the Internet:

- Host name to address mappings were maintained by the Network Information Center (NIC) in a single file (HOSTS.TXT) which was FTPed by all hosts [RFC-952, RFC-953]. The total network bandwidth consumed in distributing a new version by this scheme is proportional to the square of the number of hosts in the network, and even when multiple levels of FTP are used, the outgoing FTP load on the NIC host is considerable. Explosive growth in the number of hosts didn't bode well for the future.

- The network population was also changing in character. The timeshared hosts that made up the original ARPANET were being replaced with local networks of workstations. Local organizations were administering their own names and addresses, but had to wait for the NIC to change HOSTS.TXT to make changes visible to the Internet at large. Organizations also wanted some local structure on the name space.

- The applications on the Internet were getting more sophisticated and creating a need for general purpose name service.

The result was several ideas about name spaces and their management [IEN-116, RFC-799, RFC-819, RFC-830]. The proposals varied, but a common thread was the idea of a hierarchical name space, with the hierarchy roughly corresponding to organizational structure, and names using "." as the character to mark the boundary between hierarchy levels. A design using a distributed database and generalized resources was described in [RFC-882, RFC-883]. Based on experience with several implementations, the system evolved into the scheme described in this memo.

The terms "domain" or "domain name" are used in many contexts beyond the DNS described here. Very often, the term domain name is used to refer to a name with structure indicated by dots, but no relation to the DNS. This is particularly true in mail addressing [Quarterman 86].

2.2. DNS design goals

The design goals of the DNS influence its structure. They are:

- The primary goal is a consistent name space which will be used for referring to resources. In order to avoid the problems caused by ad hoc encodings, names should not be required to contain network identifiers, addresses, routes, or similar information as part of the name.

- The sheer size of the database and frequency of updates suggest that it must be maintained in a distributed manner, with local caching to improve performance. Approaches that attempt to collect a consistent copy of the entire database will become more and more expensive and difficult, and hence should be avoided. The same principle holds for the structure of the name space, and in particular mechanisms for creating and deleting names; these should also be distributed.

- Where there tradeoffs between the cost of acquiring data, the speed of updates, and the accuracy of caches, the source of the data should control the tradeoff.

- The costs of implementing such a facility dictate that it be generally useful, and not restricted to a single application. We should be able to use names to retrieve host addresses, mailbox data, and other as yet undetermined information. All data associated with a name is tagged with a type, and queries can be limited to a single type.

- Because we want the name space to be useful in dissimilar networks and applications, we provide the ability to use the same name space with different protocol families or management. For example, host address formats differ between protocols, though all protocols have the notion of address. The DNS tags all data with a class as well as the type, so that we can allow parallel use of different formats for data of type address.

- We want name server transactions to be independent of the communications system that carries them. Some systems may wish to use datagrams for queries and responses, and only establish virtual circuits for transactions that need the reliability (e.g., database updates, long transactions); other systems will use virtual circuits exclusively.

- The system should be useful across a wide spectrum of host capabilities. Both personal computers and large timeshared hosts should be able to use the system, though perhaps in different ways.

2.3. Assumptions about usage

The organization of the domain system derives from some assumptions about the needs and usage patterns of its user community and is designed to avoid many of the the complicated problems found in general purpose database systems.

The assumptions are:

- The size of the total database will initially be proportional to the number of hosts using the system, but will eventually grow to be proportional to the number of users on those hosts as mailboxes and other information are added to the domain system.

- Most of the data in the system will change very slowly (e.g., mailbox bindings, host addresses), but that the system should be able to deal with subsets that change more rapidly (on the order of seconds or minutes).

- The administrative boundaries used to distribute responsibility for the database will usually correspond to organizations that have one or more hosts. Each organization that has responsibility for a particular set of domains will provide redundant name servers, either on the organization's own hosts or other hosts that the organization arranges to use.

- Clients of the domain system should be able to identify trusted name servers they prefer to use before accepting referrals to name servers outside of this "trusted" set.

- Access to information is more critical than instantaneous updates or guarantees of consistency. Hence the update process allows updates to percolate out through the users of the domain system rather than guaranteeing that all copies are simultaneously updated. When updates are unavailable due to network or host failure, the usual course is to believe old information while continuing efforts to update it. The general model is that copies are distributed with timeouts for refreshing. The distributor sets the timeout value and the recipient of the distribution is responsible for performing the refresh. In special situations, very short intervals can be specified, or the owner can prohibit copies.

- In any system that has a distributed database, a particular name server may be presented with a query that can only be answered by some other server. The two general approaches to dealing with this problem are "recursive", in which the first server pursues the query for the client at another server, and "iterative", in which the server refers the client to another server and lets the client pursue the query. Both approaches have advantages and disadvantages, but the iterative approach is preferred for the datagram style of access. The domain system requires implementation of the iterative approach, but allows the recursive approach as an option.

The domain system assumes that all data originates in master files scattered through the hosts that use the domain system. These master files are updated by local system administrators. Master files are text files that are read by a local name server, and hence become available through the name servers to users of the domain system. The user programs access name servers through standard programs called resolvers.

The standard format of master files allows them to be exchanged between hosts (via FTP, mail, or some other mechanism); this facility is useful when an organization wants a domain, but doesn't want to support a name server. The organization can maintain the master files locally using a text editor, transfer them to a foreign host which runs a name server, and then arrange with the system administrator of the name server to get the files loaded.

Each host's name servers and resolvers are configured by a local system administrator [RFC-1033]. For a name server, this configuration data includes the identity of local master files and instructions on which non-local master files are to be loaded from foreign servers. The name server uses the master files or copies to load its zones. For resolvers, the configuration data identifies the name servers which should be the primary sources of information.

The domain system defines procedures for accessing the data and for referrals to other name servers. The domain system also defines procedures for caching retrieved data and for periodic refreshing of data defined by the system administrator.

The system administrators provide:

- The definition of zone boundaries.

- Master files of data.

- Updates to master files.

- Statements of the refresh policies desired.

The domain system provides:

- Standard formats for resource data.

- Standard methods for querying the database.

- Standard methods for name servers to refresh local data from foreign name servers.

2.4. Elements of the DNS

The DNS has three major components:

- The DOMAIN NAME SPACE and RESOURCE RECORDS, which are specifications for a tree structured name space and data associated with the names. Conceptually, each node and leaf of the domain name space tree names a set of information, and query operations are attempts to extract specific types of information from a particular set. A query names the domain name of interest and describes the type of resource information that is desired. For example, the Internet uses some of its domain names to identify hosts; queries for address resources return Internet host addresses.

- NAME SERVERS are server programs which hold information about the domain tree's structure and set information. A name server may cache structure or set information about any part of the domain tree, but in general a particular name server has complete information about a subset of the domain space, and pointers to other name servers that can be used to lead to information from any part of the domain tree. Name servers know the parts of the domain tree for which they have complete information; a name server is said to be an AUTHORITY for those parts of the name space. Authoritative information is organized into units called ZONEs, and these zones can be automatically distributed to the name servers which provide redundant service for the data in a zone.

- RESOLVERS are programs that extract information from name servers in response to client requests. Resolvers must be able to access at least one name server and use that name server's information to answer a query directly, or pursue the query using referrals to other name servers. A resolver will typically be a system routine that is directly accessible to user programs; hence no protocol is necessary between the resolver and the user program.

These three components roughly correspond to the three layers or views of the domain system:

- From the user's point of view, the domain system is accessed through a simple procedure or OS call to a local resolver. The domain space consists of a single tree and the user can request information from any section of the tree.

- From the resolver's point of view, the domain system is composed of an unknown number of name servers. Each name server has one or more pieces of the whole domain tree's data, but the resolver views each of these databases as essentially static.

- From a name server's point of view, the domain system consists of separate sets of local information called zones. The name server has local copies of some of the zones. The name server must periodically refresh its zones from master copies in local files or foreign name servers. The name server must concurrently process queries that arrive from resolvers.

In the interests of performance, implementations may couple these functions. For example, a resolver on the same machine as a name server might share a database consisting of the the zones managed by the name server and the cache managed by the resolver.

3. DOMAIN NAME SPACE and RESOURCE RECORDS

3.1. Name space specifications and terminology

The domain name space is a tree structure. Each node and leaf on the tree corresponds to a resource set (which may be empty). The domain system makes no distinctions between the uses of the interior nodes and leaves, and this memo uses the term "node" to refer to both.

Each node has a label, which is zero to 63 octets in length. Brother nodes may not have the same label, although the same label can be used for nodes which are not brothers. One label is reserved, and that is the null (i.e., zero length) label used for the root.

The domain name of a node is the list of the labels on the path from the node to the root of the tree. By convention, the labels that compose a domain name are printed or read left to right, from the most specific (lowest, farthest from the root) to the least specific (highest, closest to the root).

Internally, programs that manipulate domain names should represent them as sequences of labels, where each label is a length octet followed by an octet string. Because all domain names end at the root, which has a null string for a label, these internal representations can use a length byte of zero to terminate a domain name.

By convention, domain names can be stored with arbitrary case, but domain name comparisons for all present domain functions are done in a case-insensitive manner, assuming an ASCII character set, and a high order zero bit. This means that you are free to create a node with label "A" or a node with label "a", but not both as brothers; you could refer to either using "a" or "A". When you receive a domain name or label, you should preserve its case. The rationale for this choice is that we may someday need to add full binary domain names for new services; existing services would not be changed.

When a user needs to type a domain name, the length of each label is omitted and the labels are separated by dots ("."). Since a complete domain name ends with the root label, this leads to a printed form which ends in a dot. We use this property to distinguish between:

- a character string which represents a complete domain name (often called "absolute"). For example, "poneria.ISI.EDU."

- a character string that represents the starting labels of a domain name which is incomplete, and should be completed by local software using knowledge of the local domain (often called "relative"). For example, "poneria" used in the ISI.EDU domain.

Relative names are either taken relative to a well known origin, or to a list of domains used as a search list. Relative names appear mostly at the user interface, where their interpretation varies from implementation to implementation, and in master files, where they are relative to a single origin domain name. The most common interpretation uses the root "." as either the single origin or as one of the members of the search list, so a multi-label relative name is often one where the trailing dot has been omitted to save typing.

To simplify implementations, the total number of octets that represent a domain name (i.e., the sum of all label octets and label lengths) is limited to 255.

A domain is identified by a domain name, and consists of that part of the domain name space that is at or below the domain name which specifies the domain. A domain is a subdomain of another domain if it is contained within that domain. This relationship can be tested by seeing if the subdomain's name ends with the containing domain's name. For example, A.B.C.D is a subdomain of B.C.D, C.D, D, and " ".

3.2. Administrative guidelines on use

As a matter of policy, the DNS technical specifications do not mandate a particular tree structure or rules for selecting labels; its goal is to be as general as possible, so that it can be used to build arbitrary applications. In particular, the system was designed so that the name space did not have to be organized along the lines of network boundaries, name servers, etc. The rationale for this is not that the name space should have no implied semantics, but rather that the choice of implied semantics should be left open to be used for the problem at hand, and that different parts of the tree can have different implied semantics. For example, the IN-ADDR.ARPA domain is organized and distributed by network and host address because its role is to translate from network or host numbers to names; NetBIOS domains [RFC-1001, RFC-1002] are flat because that is appropriate for that application.

However, there are some guidelines that apply to the "normal" parts of the name space used for hosts, mailboxes, etc., that will make the name space more uniform, provide for growth, and minimize problems as software is converted from the older host table. The political decisions about the top levels of the tree originated in RFC-920. Current policy for the top levels is discussed in [RFC-1032]. MILNET conversion issues are covered in [RFC-1031].

Lower domains which will eventually be broken into multiple zones should provide branching at the top of the domain so that the eventual decomposition can be done without renaming. Node labels which use special characters, leading digits, etc., are likely to break older software which depends on more restrictive choices.

3.3. Technical guidelines on use

Before the DNS can be used to hold naming information for some kind of object, two needs must be met:

- A convention for mapping between object names and domain names. This describes how information about an object is accessed.

- RR types and data formats for describing the object.

These rules can be quite simple or fairly complex. Very often, the designer must take into account existing formats and plan for upward compatibility for existing usage. Multiple mappings or levels of mapping may be required.

For hosts, the mapping depends on the existing syntax for host names which is a subset of the usual text representation for domain names, together with RR formats for describing host addresses, etc. Because we need a reliable inverse mapping from address to host name, a special mapping for addresses into the IN-ADDR.ARPA domain is also defined.

For mailboxes, the mapping is slightly more complex. The usual mail address <local-part>@<mail-domain> is mapped into a domain name by converting <local-part> into a single label (regardles of dots it contains), converting <mail-domain> into a domain name using the usual text format for domain names (dots denote label breaks), and concatenating the two to form a single domain name. Thus the mailbox

HOSTMASTER@SRI-NIC.ARPA is represented as a domain name by HOSTMASTER.SRI-NIC.ARPA. An appreciation for the reasons behind this design also must take into account the scheme for mail exchanges [RFC-974].

The typical user is not concerned with defining these rules, but should understand that they usually are the result of numerous compromises between desires for upward compatibility with old usage, interactions between different object definitions, and the inevitable urge to add new features when defining the rules. The way the DNS is used to support some object is often more crucial than the restrictions inherent in the DNS.

3.4. Example name space

The following figure shows a part of the current domain name space, and is used in many examples in this RFC. Note that the tree is a very small subset of the actual name space.

```
                                   |
                                   |
             +---------------------+------------------+
             |                     |                  |
            MIL                   EDU                ARPA
             |                     |                  |
             |                     |                  |
       +-----+-----+               |     +------+-----+-----+
       |     |     |               |     |      |           |
      BRL  NOSC  DARPA             |  IN-ADDR  SRI-NIC     ACC
                                   |
       +--------+------------------+---------------+--------+
       |        |                  |               |        |
      UCI      MIT                 |              UDEL     YALE
                |                 ISI
                |                  |
            +---+---+              |
            |       |              |
           LCS  ACHILLES  +--+-----+-----+--------+
            |             |  |     |     |        |
            XX            A  C   VAXA  VENERA Mockapetris
```

In this example, the root domain has three immediate subdomains: MIL, EDU, and ARPA. The LCS.MIT.EDU domain has one immediate subdomain named XX.LCS.MIT.EDU. All of the leaves are also domains.

3.5. Preferred name syntax

The DNS specifications attempt to be as general as possible in the rules for constructing domain names. The idea is that the name of any existing object can be expressed as a domain name with minimal changes. However, when assigning a domain name for an object, the prudent user will select a name which satisfies both the rules of the domain system and any existing rules for the object, whether these rules are published or implied by existing programs.

For example, when naming a mail domain, the user should satisfy both the rules of this memo and those in RFC-822. When creating a new host name, the old rules for HOSTS.TXT should be followed. This avoids problems when old software is converted to use domain names.

The following syntax will result in fewer problems with many applications that use domain names (e.g., mail, TELNET).

```
<domain> ::= <subdomain> | " "

<subdomain> ::= <label> | <subdomain> "." <label>

<label> ::= <letter> [ [ <ldh-str> ] <let-dig> ]

<ldh-str> ::= <let-dig-hyp> | <let-dig-hyp> <ldh-str>

<let-dig-hyp> ::= <let-dig> | "-"

<let-dig> ::= <letter> | <digit>

<letter> ::= any one of the 52 alphabetic characters A through Z in
upper case and a through z in lower case

<digit> ::= any one of the ten digits 0 through 9
```

Note that while upper and lower case letters are allowed in domain names, no significance is attached to the case. That is, two names with the same spelling but different case are to be treated as if identical.

The labels must follow the rules for ARPANET host names. They must start with a letter, end with a letter or digit, and have as interior characters only letters, digits, and hyphen. There are also some restrictions on the length. Labels must be 63 characters or less.

For example, the following strings identify hosts in the Internet:

A.ISI.EDU XX.LCS.MIT.EDU SRI-NIC.ARPA

3.6. Resource Records

A domain name identifies a node. Each node has a set of resource information, which may be empty. The set of resource information associated with a particular name is composed of separate resource records (RRs). The order of RRs in a set is not significant, and need not be preserved by name servers, resolvers, or other parts of the DNS.

When we talk about a specific RR, we assume it has the following:

owner which is the domain name where the RR is found.

type which is an encoded 16 bit value that specifies the type of the resource in this resource record. Types refer to abstract resources.

This memo uses the following types:

A	a host address
CNAME	identifies the canonical name of an alias
HINFO	identifies the CPU and OS used by a host
MX	identifies a mail exchange for the domain. See [RFC-974 for details.

NS
the authoritative name server for the domain

PTR
a pointer to another part of the domain name space

SOA
identifies the start of a zone of authority]

class which is an encoded 16 bit value which identifies a protocol family or instance of a protocol.

This memo uses the following classes:

IN	the Internet system
CH	the Chaos system

TTL which is the time to live of the RR. This field is a 32 bit integer in units of seconds, an is primarily used by resolvers when they cache RRs. The TTL describes how long a RR can be cached before it should be discarded.

RDATA which is the type and sometimes class dependent data which describes the resource:

A	For the IN class, a 32 bit IP address For the CH class, a domain name followed by a 16 bit octal Chaos address.
CNAME	a domain name.
MX	a 16 bit preference value (lower is better) followed by a host name willing to act as a mail exchange for the owner domain.
NS	a host name.
PTR	a domain name.
SOA	several fields.

The owner name is often implicit, rather than forming an integral part of the RR. For example, many name servers internally form tree or hash structures for the name space, and chain RRs off nodes. The remaining RR parts are the fixed header (type, class, TTL) which is consistent for all RRs, and a variable part (RDATA) that fits the needs of the resource being described.

The meaning of the TTL field is a time limit on how long an RR can be kept in a cache. This limit does not apply to authoritative data in zones; it is also timed out, but by the refreshing policies for the zone. The TTL is assigned by the administrator for the zone where the data originates. While short TTLs can be used to minimize caching, and a zero TTL prohibits caching, the realities of Internet performance suggest that these times should be on the order of days for the typical host. If a change can be anticipated, the TTL can be reduced prior to the change to minimize inconsistency during the change, and then increased back to its former value following the change.

The data in the RDATA section of RRs is carried as a combination of binary strings and domain names. The domain names are frequently used as "pointers" to other data in the DNS.

3.6.1. Textual expression of RRs

RRs are represented in binary form in the packets of the DNS protocol, and are usually represented in highly encoded form when stored in a name server or resolver. In this memo, we adopt a style similar to that used in master files in order to show the contents of RRs. In this format, most RRs are shown on a single line, although continuation lines are possible using parentheses.

The start of the line gives the owner of the RR. If a line begins with a blank, then the owner is assumed to be the same as that of the previous RR. Blank lines are often included for readability.

Following the owner, we list the TTL, type, and class of the RR. Class and type use the mnemonics defined above, and TTL is an integer before the type field. In order to avoid ambiguity in parsing, type and class mnemonics are disjoint, TTLs are integers, and the type mnemonic is always last. The IN class and TTL values are often omitted from examples in the interests of clarity.

The resource data or RDATA section of the RR are given using knowledge of the typical representation for the data.

For example, we might show the RRs carried in a message as:

```
    ISI.EDU.        MX      10 VENERA.ISI.EDU.
                    MX      10 VAXA.ISI.EDU.
    VENERA.ISI.EDU. A       128.9.0.32
                    A       10.1.0.52
    VAXA.ISI.EDU.   A       10.2.0.27
                    A       128.9.0.33
```

The MX RRs have an RDATA section which consists of a 16 bit number followed by a domain name. The address RRs use a standard IP address format to contain a 32 bit internet address.

This example shows six RRs, with two RRs at each of three domain names.

Similarly we might see:

```
    XX.LCS.MIT.EDU. IN      A       10.0.0.44
                    CH      A       MIT.EDU. 2420
```

This example shows two addresses for XX.LCS.MIT.EDU, each of a different class.

3.6.2. Aliases and canonical names

In existing systems, hosts and other resources often have several names that identify the same resource. For example, the names C.ISI.EDU and USC-ISIC.ARPA both identify the same host. Similarly, in the case of mailboxes, many organizations provide many names that actually go to the same mailbox; for example Mockapetris@C.ISI.EDU, Mockapetris@B.ISI.EDU, and PVM@ISI.EDU all go to the same mailbox (although the mechanism behind this is somewhat complicated).

Most of these systems have a notion that one of the equivalent set of names is the canonical or primary name and all others are aliases.

The domain system provides such a feature using the canonical name (CNAME) RR. A CNAME RR identifies its owner name as an alias, and specifies the corresponding canonical name in the RDATA section of the RR. If a CNAME PR is present at a node, no other data should be present; this ensures that the data for a canonical name and its aliases cannot be different. This rule also insures that a cached CNAME can be used without checking with an authoritative server for other RR types.

CNAME RRs cause special action in DNS software. When a name server fails to find a desired RR in the resource set associated with the domain name, it checks to see if the resource set consists of a CNAME record with a matching class. If so, the name server includes the CNAME record in the response and restarts the query at the domain name specified in the data field of the CNAME record. The one exception to this rule is that queries which match the CNAME type are not restarted.

For example, suppose a name server was processing a query with for USC-ISIC.ARPA, asking for type A information, and had the following resource records:

```
    USC-ISIC.ARPA   IN      CNAME   C.ISI.EDU

    C.ISI.EDU       IN      A       10.0.0.52
```

Both of these RRs would be returned in the response to the type A query, while a type CNAME or * query should return just the CNAME.

Domain names in RRs which point at another name should always point at the primary name and not the alias. This avoids extra indirections in accessing information. For example, the address to name RR for the above host should be:

```
    52.0.0.10.IN-ADDR.ARPA  IN      PTR     C.ISI.EDU
```

rather than pointing at USC-ISIC.ARPA. Of course, by the robustness principle, domain software should not fail when presented with CNAME chains or loops; CNAME chains should be followed and CNAME loops signalled as an error.

3.7. Queries

Queries are messages which may be sent to a name server to provoke a response. In the Internet, queries are carried in UDP datagrams or over TCP connections. The response by the name server either answers the question posed in the query, refers the requester to another set of name servers, or signals some error condition.

In general, the user does not generate queries directly, but instead makes a request to a resolver which in turn sends one or more queries to name servers and deals with the error conditions and referrals that may result. Of course, the possible questions which can be asked in a query does shape the kind of service a resolver can provide.

DNS queries and responses are carried in a standard message format. The message format has a header containing a number of fixed fields which are always present, and four sections which carry query parameters and RRs.

The most important field in the header is a four bit field called an opcode which separates different queries. Of the possible 16 values, one (standard query) is part of the official protocol, two (inverse query and status query) are options, one (completion) is obsolete, and the rest are unassigned.

The four sections are:

Question	Carries the query name and other query parameters.
Answer	Carries RRs which directly answer the query.
Authority	Carries RRs which describe other authoritative servers. May optionally carry the SOA RR for the authoritative data in the answer section.
Additional	Carries RRs which may be helpful in using the RRs in the other sections.

Note that the content, but not the format, of these sections varies with header opcode.

3.7.1. Standard queries

A standard query specifies a target domain name (QNAME), query type (QTYPE), and query class (QCLASS) and asks for RRs which match. This type of query makes up such a vast majority of DNS queries that we use the term "query" to mean standard query unless otherwise specified. The QTYPE and QCLASS fields are each 16 bits long, and are a superset of defined types and classes.

The QTYPE field may contain:

<any type>	matches just that type. (e.g., A, PTR).
AXFR	special zone transfer QTYPE.
MAILB	matches all mail box related RRs (e.g. MB and MG).
*	matches all RR types.

The QCLASS field may contain:

<any class>	matches just that class (e.g., IN, CH).
*	matches aLL RR classes.

Using the query domain name, QTYPE, and QCLASS, the name server looks for matching RRs. In addition to relevant records, the name server may return RRs that point toward a name server that has the desired information or RRs that are expected to be useful in interpreting the relevant RRs. For example, a name server that doesn't have the requested information may know a name server that does; a name server that returns a domain name in a relevant RR may also return the RR that binds that domain name to an address.

For example, a mailer tying to send mail to Mockapetris@ISI.EDU might ask the resolver for mail information about ISI.EDU, resulting in a query for QNAME=ISI.EDU, QTYPE=MX, QCLASS=IN. The response's answer section would be:

```
    ISI.EDU.        MX      10 VENERA.ISI.EDU.
                    MX      10 VAXA.ISI.EDU.
```

while the additional section might be:

```
    VAXA.ISI.EDU.   A       10.2.0.27
                    A       128.9.0.33
    VENERA.ISI.EDU. A       10.1.0.52
                    A       128.9.0.32
```

Because the server assumes that if the requester wants mail exchange information, it will probably want the addresses of the mail exchanges soon afterward.

Note that the QCLASS=* construct requires special interpretation regarding authority. Since a particular name server may not know all of the classes available in the domain system, it can never know if it is authoritative for all classes. Hence responses to QCLASS=* queries can never be authoritative.

3.7.2. Inverse queries (Optional)

Name servers may also support inverse queries that map a particular resource to a domain name or domain names that have that resource. For example, while a standard query might map a domain name to a SOA RR, the corresponding inverse query might map the SOA RR back to the domain name.

Implementation of this service is optional in a name server, but all name servers must at least be able to understand an inverse query message and return a not-implemented error response.

The domain system cannot guarantee the completeness or uniqueness of inverse queries because the domain system is organized by domain name rather than by host address or any other resource type. Inverse queries are primarily useful for debugging and database maintenance activities.

Inverse queries may not return the proper TTL, and do not indicate cases where the identified RR is one of a set (for example, one address for a host having multiple addresses). Therefore, the RRs returned in inverse queries should never be cached.

Inverse queries are NOT an acceptable method for mapping host addresses to host names; use the IN-ADDR.ARPA domain instead.

A detailed discussion of inverse queries is contained in [RFC-1035].

3.8. Status queries (Experimental)

To be defined.

3.9. Completion queries (Obsolete)

The optional completion services described in RFCs 882 and 883 have been deleted. Redesigned services may become available in the future, or the opcodes may be reclaimed for other use.

4. NAME SERVERS

4.1. Introduction

Name servers are the repositories of information that make up the domain database. The database is divided up into sections called zones, which are distributed among the name servers. While name servers can have several optional functions and sources of data, the essential task of a name server is to answer queries using data in its zones. By design, name servers can answer queries in a simple manner; the response can always be generated using only local data, and either contains the answer to the question or a referral to other name servers "closer" to the desired information.

A given zone will be available from several name servers to insure its availability in spite of host or communication link failure. By administrative fiat, we require every zone to be available on at least two servers, and many zones have more redundancy than that.

A given name server will typically support one or more zones, but this gives it authoritative information about only a small section of the domain tree. It may also have some cached non-authoritative data about other parts of the tree. The name server marks its responses to queries so that the requester can tell whether the response comes from authoritative data or not.

4.2. How the database is divided into zones

The domain database is partitioned in two ways: by class, and by "cuts" made in the name space between nodes.

The class partition is simple. The database for any class is organized, delegated, and maintained separately from all other classes. Since, by convention, the name spaces are the same for all classes, the separate classes can be thought of as an array of parallel namespace trees. Note that the data attached to nodes will be different for these different parallel classes. The most common reasons for creating a new class are the necessity for a new data format for existing types or a desire for a separately managed version of the existing name space.

Within a class, "cuts" in the name space can be made between any two adjacent nodes. After all cuts are made, each group of connected name space is a separate zone. The zone is said to be authoritative for all names in the connected region. Note that the "cuts" in the name space may be in different places for different classes, the name servers may be different, etc.

These rules mean that every zone has at least one node, and hence domain name, for which it is authoritative, and all of the nodes in a particular zone are connected. Given, the tree structure, every zone has a highest node which is closer to the root than any other node in the zone. The name of this node is often used to identify the zone.

It would be possible, though not particularly useful, to partition the name space so that each domain name was in a separate zone or so that all nodes were in a single zone. Instead, the database is partitioned at points where a particular organization wants to take over control of a subtree. Once an organization controls its own zone it can unilaterally change the data in the zone, grow new tree sections connected to the zone, delete existing nodes, or delegate new subzones under its zone.

If the organization has substructure, it may want to make further internal partitions to achieve nested delegations of name space control. In some cases, such divisions are made purely to make database maintenance more convenient.

4.2.1. Technical considerations

The data that describes a zone has four major parts:

- Authoritative data for all nodes within the zone.

- Data that defines the top node of the zone (can be thought of as part of the authoritative data).

- Data that describes delegated subzones, i.e., cuts around the bottom of the zone.

- Data that allows access to name servers for subzones (sometimes called "glue" data).

All of this data is expressed in the form of RRs, so a zone can be completely described in terms of a set of RRs. Whole zones can be transferred between name servers by transferring the RRs, either carried in a series of messages or by FTPing a master file which is a textual representation.

The authoritative data for a zone is simply all of the RRs attached to all of the nodes from the top node of the zone down to leaf nodes or nodes above cuts around the bottom edge of the zone.

Though logically part of the authoritative data, the RRs that describe the top node of the zone are especially important to the zone's management. These RRs are of two types: name server RRs that list, one per RR, all of the servers for the zone, and a single SOA RR that describes zone management parameters.

The RRs that describe cuts around the bottom of the zone are NS RRs that name the servers for the subzones. Since the cuts are between nodes, these RRs are NOT part of the authoritative data of the zone, and should be exactly the same as the corresponding RRs in the top node of the subzone. Since name servers are always associated with zone boundaries, NS RRs are only found at nodes which are the top node of some zone. In the data that makes up a zone, NS RRs are found at the top node of the zone (and are authcritative) and at cuts around the bottom of the zone (where they are not authoritative), but never in between.

One of the goals of the zone structure is that any zone have all the data required to set up communications with the name servers for any subzones. That is, parent zones have all the information needed to access servers for their children zones. The NS RRs that name the servers for subzones are often not enough for this task since they name the servers, but do not give their addresses. In particular, if the name of the name server is itself in the subzone, we could be faced with the situation where the NS RRs tell us that in order to learn a name server's address, we should contact the server using the address we wish to learn. To fix this problem, a zone contains "glue" RRs which are not part of the authoritative data, and are address RRs for the servers. These RRs are only necessary if the name server's name is "below" the cut, and are only used as part of a referral response.

4.2.2. Administrative considerations

When some organization wants to control its own domain, the first step is to identify the proper parent zone, and get the parent zone's owners to agree to the delegation of control. While there are no particular technical constraints dealing with where in the tree this can be done, there are some administrative groupings discussed in [RFC-1032] which deal with top level organization, and middle level zones are free to create their own rules. For example, one university might choose to use a single zone, while another might choose to organize by subzones dedicated to individual departments or schools. [RFC-1033] catalogs available DNS software an discusses administration procedures.

Once the proper name for the new subzone is selected, the new owners should be required to demonstrate redundant name server support. Note that there is no requirement that the servers for a zone reside in a host which has a name in that domain. In many cases, a zone will be more accessible to the internet at large if its servers are widely distributed rather than being within the physical facilities controlled by the same organization that manages the zone. For example, in the current DNS, one of the name servers for the United Kingdom, or UK domain, is found in the US. This allows US hosts to get UK data without using limited transatlantic bandwidth.

As the last installation step, the delegation NS RRs and glue RRs necessary to make the delegation effective should be added to the parent zone. The administrators of both zones should insure that the NS and glue RRs which mark both sides of the cut are consistent and remain so.

4.3. Name server internals

4.3.1. Queries and responses

The principal activity of name servers is to answer standard queries. Both the query and its response are carried in a standard message format which is described in [RFC-1035]. The query contains a QTYPE, QCLASS, and QNAME, which describe the types and classes of desired information and the name of interest.

The way that the name server answers the query depends upon whether it is operating in recursive mode or not:

- The simplest mode for the server is non-recursive, since it can answer queries using only local information: the response contains an error, the answer, or a referral to some other server "closer" to the answer. All name servers must implement non-recursive queries.

- The simplest mode for the client is recursive, since in this mode the name server acts in the role of a resolver and returns either an error or the answer, but never referrals. This service is optional in a name server, and the name server may also choose to restrict the clients which can use recursive mode.

Recursive service is helpful in several situations:

- a relatively simple requester that lacks the ability to use anything other than a direct answer to the question.

- a request that needs to cross protocol or other boundaries and can be sent to a server which can act as intermediary.

- a network where we want to concentrate the cache rather than having a separate cache for each client.

Non-recursive service is appropriate if the requester is capable of pursuing referrals and interested in information which will aid future requests.

The use of recursive mode is limited to cases where both the client and the name server agree to its use. The agreement is negotiated through the use of two bits in query and response messages:

- The recursion available, or RA bit, is set or cleared by a name server in all responses. The bit is true if the name server is willing to provide recursive service for the client, regardless of whether the client requested recursive service. That is, RA signals availability rather than use.

- Queries contain a bit called recursion desired or RD. This bit specifies specifies whether the requester wants recursive service for this query. Clients may request recursive service from any name server, though they should depend upon receiving it only from servers which have previously sent an RA, or servers which have agreed to provide service through private agreement or some other means outside of the DNS protocol.

The recursive mode occurs when a query with RD set arrives at a server which is willing to provide recursive service; the client can verify that recursive mode was used by checking that both RA and RD are set in the reply. Note that the name server should never perform recursive service unless asked via RD, since this interferes with trouble shooting of name servers and their databases.

If recursive service is requested and available, the recursive response to a query will be one of the following:

- The answer to the query, possibly preface by one or more CNAME RRs that specify aliases encountered on the way to an answer.

- A name error indicating that the name does not exist. This may include CNAME RRs that indicate that the original query name was an alias for a name which does not exist.

- A temporary error indication.

If recursive service is not requested or is not available, the non-recursive response will be one of the following:

- An authoritative name error indicating that the name does not exist.

- A temporary error indication.

- Some combination of:

  RRs that answer the question, together with an indication whether the data comes from a zone or is cached.

  A referral to name servers which have zones which are closer ancestors to the name than the server sending the reply.

- RRs that the name server thinks will prove useful to the requester.

4.3.2. Algorithm

The actual algorithm used by the name server will depend on the local OS and data structures used to store RRs. The following algorithm assumes that the RRs are organized in several tree structures, one for each zone, and another for the cache:

1. Set or clear the value of recursion available in the response depending on whether the name server is willing to provide recursive service. If recursive service is available and requested via the RD bit in the query, go to step 5, otherwise step 2.

2. Search the available zones for the zone which is the nearest ancestor to QNAME. If such a zone is found, go to step 3, otherwise step 4.

3. Start matching down, label by label, in the zone. The matching process can terminate several ways:

    a. If the whole of QNAME is matched, we have found the node.

       If the data at the node is a CNAME, and QTYPE doesn't match CNAME, copy the CNAME RR into the answer section of the response, change QNAME to the canonical name in the CNAME RR, and go back to step 1.

       Otherwise, copy all RRs which match QTYPE into the answer section and go to step 6.

    b. If a match would take us out of the authoritative data, we have a referral. This happens when we encounter a node with NS RRs marking cuts along the bottom of a zone.

       Copy the NS RRs for the subzone into the authority section of the reply. Put whatever addresses are available into the additional section, using glue RRs if the addresses are not available from authoritative data or the cache. Go to step 4.

    c. If at some label, a match is impossible (i.e., the corresponding label does not exist), look to see if a the "*" label exists.

       If the "*" label does not exist, check whether the name we are looking for is the original QNAME in the query or a name we have followed due to a CNAME. If the name is original, set an authoritative name error in the response and exit. Otherwise just exit.

If the "*" label does exist, match RRs at that node against QTYPE. If any match, copy them into the answer section, but set the owner of the RR to be QNAME, and not the node with the "*" label. Go to step 6.

4. Start matching down in the cache. If QNAME is found in the cache, copy all RRs attached to it that match QTYPE into the answer section. If there was no delegation from authoritative data, look for the best one from the cache, and put it in the authority section. Go to step 6.

5. Using the local resolver or a copy of its algorithm (see resolver section of this memo) to answer the query. Store the results, including any intermediate CNAMEs, in the answer section of the response.

6. Using local data only, attempt to add other RRs which may be useful to the additional section of the query. Exit.

4.3.3. Wildcards

In the previous algorithm, special treatment was given to RRs with owner names starting with the label "*". Such RRs are called wildcards. Wildcard RRs can be thought of as instructions for synthesizing RRs. When the appropriate conditions are met, the name server creates RRs with an owner name equal to the query name and contents taken from the wildcard RRs.

This facility is most often used to create a zone which will be used to forward mail from the Internet to some other mail system. The general idea is that any name in that zone which is presented to server in a query will be assumed to exist, with certain properties, unless explicit evidence exists to the contrary. Note that the use of the term zone here, instead of domain, is intentional; such defaults do not propagate across zone boundaries, although a subzone may choose to achieve that appearance by setting up similar defaults.

The contents of the wildcard RRs follows the usual rules and formats for RRs. The wildcards in the zone have an owner name that controls the query names they will match. The owner name of the wildcard RRs is of the form "*.<anydomain>", where <anydomain> is any domain name. <anydomain> should not contain other * labels, and should be in the authoritative data of the zone. The wildcards potentially apply to descendants of <anydomain>, but not to <anydomain> itself. Another way to look at this is that the "*" label always matches at least one whole label and sometimes more, but always whole labels.

Wildcard RRs do not apply:

- When the query is in another zone. That is, delegation cancels the wildcard defaults.

- When the query name or a name between the wildcard domain and the query name is know to exist. For example, if a wildcard RR has an owner name of "*.X", and the zone also contains RRs attached to B.X, the wildcards would apply to queries for name Z.X (presuming there is no explicit information for Z.X), but not to B.X, A.B.X, or X.

A * label appearing in a query name has no special effect, but can be used to test for wildcards in an authoritative zone; such a query is the only way to get a response containing RRs with an owner name with * in it. The result of such a query should not be cached.

Note that the contents of the wildcard RRs are not modified when used to synthesize RRs.

To illustrate the use of wildcard RRs, suppose a large company with a large, non-IP/TCP, network wanted to create a mail gateway. If the company was called X.COM, and IP/TCP capable gateway machine was called A.X.COM, the following RRs might be entered into the COM zone:

```
    X.COM           MX      10      A.X.COM

    *.X.COM         MX      10      A.X.COM

    A.X.COM         A       1.2.3.4
    A.X.COM         MX      10      A.X.COM

    *.A.X.COM       MX      10      A.X.COM
```

This would cause any MX query for any domain name ending in X.COM to return an MX RR pointing at A.X.COM. Two wildcard RRs are required since the effect of the wildcard at *.X.COM is inhibited in the A.X.COM subtree by the explicit data for A.X.COM. Note also that the explicit MX data at X.COM and A.X.COM is required, and that none of the RRs above would match a query name of XX.COM.

4.3.4. Negative response caching (Optional)

The DNS provides an optional service which allows name servers to distribute, and resolvers to cache, negative results with TTLs. For example, a name server can distribute a TTL along with a name error indication, and a resolver receiving such information is allowed to assume that the name does not exist during the TTL period without consulting authoritative data. Similarly, a resolver can make a query with a QTYPE which matches multiple types, and cache the fact that some of the types are not present.

This feature can be particularly important in a system which implements naming shorthands that use search lists beacuse a popular shorthand, which happens to require a suffix toward the end of the search list, will generate multiple name errors whenever it is used.

The method is that a name server may add an SOA RR to the additional section of a response when that response is authoritative. The SOA must be that of the zone which was the source of the authoritative data in the answer section, or name error if applicable. The MINIMUM field of the SOA controls the length of time that the negative result may be cached.

Note that in some circumstances, the answer section may contain multiple owner names. In this case, the SOA mechanism should only be used for the data which matches QNAME, which is the only authoritative data in this section.

Name servers and resolvers should never attempt to add SOAs to the additional section of a non-authoritative response, or attempt to infer results which are not directly stated in an authoritative response. There are several reasons for this, including: cached information isn't usually enough to match up RRs and their zone names, SOA RRs may be cached due to direct SOA queries, and name servers are not required to output the SOAs in the authority section.

This feature is optional, although a refined version is expected to become part of the standard protocol in the future. Name servers are not required to add the SOA RRs in all authoritative responses, nor are resolvers required to cache negative results. Both are recommended. All resolvers and recursive name servers are required to at least be able to ignore the SOA RR when it is present in a response.

Some experiments have also been proposed which will use this feature. The idea is that if cached data is known to come from a particular zone, and if an authoritative copy of the zone's SOA is obtained, and if the zone's SERIAL has not changed since the data was cached, then the TTL of the cached data can be reset to the zone MINIMUM value if it is smaller. This usage is mentioned for planning purposes only, and is not recommended as yet.

4.3.5. Zone maintenance and transfers

Part of the job of a zone administrator is to maintain the zones at all of the name servers which are authoritative for the zone. When the inevitable changes are made, they must be distributed to all of the name servers. While this distribution can be accomplished using FTP or some other ad hoc procedure, the preferred method is the zone transfer part of the DNS protocol.

The general model of automatic zone transfer or refreshing is that one of the name servers is the master or primary for the zone. Changes are coordinated at the primary, typically by editing a master file for the zone. After editing, the administrator signals the master server to load the new zone. The other non-master or secondary servers for the zone periodically check for changes (at a selectable interval) and obtain new zone copies when changes have been made.

To detect changes, secondaries just check the SERIAL field of the SOA for the zone. In addition to whatever other changes are made, the SERIAL field in the SOA of the zone is always advanced whenever any change is made to the zone. The advancing can be a simple increment, or could be based on the write date and time of the master file, etc. The purpose is to make it possible to determine which of two copies of a zone is more recent by comparing serial numbers. Serial number advances and comparisons use sequence space arithmetic, so there is a theoretic limit on how fast a zone can be updated, basically that old copies must die out before the serial number covers half of its 32 bit range. In practice, the only concern is that the compare operation deals properly with comparisons around the boundary between the most positive and most negative 32 bit numbers.

The periodic polling of the secondary servers is controlled by parameters in the SOA RR for the zone, which set the minimum acceptable polling intervals. The parameters are called REFRESH, RETRY, and EXPIRE. Whenever a new zone is loaded in a secondary, the secondary waits REFRESH seconds before checking with the primary for a new serial. If this check cannot be completed, new checks are started every RETRY seconds. The check is a simple query to the primary for the SOA RR of the zone. If the serial field in the secondary's zone copy is equal to the serial returned by the primary, then no changes have occurred, and the REFRESH interval wait is restarted. If the secondary finds it impossible to perform a serial check for the EXPIRE interval, it must assume that its copy of the zone is obsolete an discard it.

When the poll shows that the zone has changed, then the secondary server must request a zone transfer via an AXFR request for the zone. The AXFR may cause an error, such as refused, but normally is answered by a sequence of response messages. The first and last messages must contain the data for the top authoritative node of the zone. Intermediate messages carry all of the other RRs from the zone, including both authoritative and non-authoritative RRs. The stream of messages allows the secondary to construct a copy of the zone. Because accuracy is essential, TCP or some other reliable protocol must be used for AXFR requests.

Each secondary server is required to perform the following operations against the master, but may also optionally perform these operations against other secondary servers. This strategy can improve the transfer process when the primary is unavailable due to host downtime or network problems, or when a secondary server has better network access to an "intermediate" secondary than to the primary.

5. RESOLVERS

5.1. Introduction

Resolvers are programs that interface user programs to domain name servers. In the simplest case, a resolver receives a request from a user program (e.g., mail programs, TELNET, FTP) in the form of a subroutine call, system call etc., and returns the desired information in a form compatible with the local host's data formats.

The resolver is located on the same machine as the program that requests the resolver's services, but it may need to consult name servers on other hosts. Because a resolver may need to consult several name servers, or may have the requested information in a local cache, the amount of time that a resolver will take to complete can vary quite a bit, from milliseconds to several seconds.

A very important goal of the resolver is to eliminate network delay and name server load from most requests by answering them from its cache of prior results. It follows that caches which are shared by multiple processes, users, machines, etc., are more efficient than non-shared caches.

5.2. Client-resolver interface

5.2.1. Typical functions

The client interface to the resolver is influenced by the local host's conventions, but the typical resolver-client interface has three functions:

1. Host name to host address translation.

   This function is often defined to mimic a previous HOSTS.TXT based function. Given a character string, the caller wants one or more 32 bit IP addresses. Under the DNS, it translates into a request for type A RRs. Since the DNS does not preserve the order of RRs, this function may choose to sort the returned addresses or select the "best" address if the service returns only one choice to the client. Note that a multiple address return is recommended, but a single address may be the only way to emulate prior HOSTS.TXT services.

2. Host address to host name translation

   This function will often follow the form of previous functions. Given a 32 bit IP address, the caller wants a character string. The octets of the IP address are reversed, used as name components, and suffixed with "IN-ADDR.ARPA". A type PTR query is used to get the RR with the primary name of the host. For example, a request for the host name corresponding to IP address 1.2.3.4 looks for PTR RRs for domain name "4.3.2.1.IN-ADDR.ARPA".

3. General lookup function

   This function retrieves arbitrary information from the DNS, and has no counterpart in previous systems. The caller supplies a QNAME, QTYPE, and QCLASS, and wants all of the matching RRs. This function will often use the DNS format for all RR data instead of the local host's, and returns all RR content (e.g., TTL) instead of a processed form with local quoting conventions.

When the resolver performs the indicated function, it usually has one of the following results to pass back to the client:

- One or more RRs giving the requested data.

  In this case the resolver returns the answer in the appropriate format.

- A name error (NE).

  This happens when the referenced name does not exist. For example, a user may have mistyped a host name.

- A data not found error.

  This happens when the referenced name exists, but data of the appropriate type does not. For example, a host address function applied to a mailbox name would return this error since the name exists, but no address RR is present.

It is important to note that the functions for translating between host names and addresses may combine the "name error" and "data not found" error conditions into a single type of error return, but the general function should not. One reason for this is that applications may ask first for one type of information about a name followed by a second request to the same name for some other type of information; if the two errors are combined, then useless queries may slow the application.

5.2.2. Aliases

While attempting to resolve a particular request, the resolver may find that the name in question is an alias. For example, the resolver might find that the name given for host name to address translation is an alias when it finds the CNAME RR. If possible, the alias condition should be signalled back from the resolver to the client.

In most cases a resolver simply restarts the query at the new name when it encounters a CNAME. However, when performing the general function, the resolver should not pursue aliases when the CNAME RR matches the query type. This allows queries which ask whether an alias is present. For example, if the query type is CNAME, the user is interested in the CNAME RR itself, and not the RRs at the name it points to.

Several special conditions can occur with aliases. Multiple levels of aliases should be avoided due to their lack of efficiency, but should not be signalled as an error. Alias loops and aliases which point to non-existent names should be caught and an error condition passed back to the client.

5.2.3. Temporary failures

In a less than perfect world, all resolvers will occasionally be unable to resolve a particular request. This condition can be caused by a resolver which becomes separated from the rest of the network due to a link failure or gateway problem, or less often by coincident failure or unavailability of all servers for a particular domain.

It is essential that this sort of condition should not be signalled as a name or data not present error to applications. This sort of behavior is annoying to humans, and can wreak havoc when mail systems use the DNS.

While in some cases it is possible to deal with such a temporary problem by blocking the request indefinitely, this is usually not a good choice, particularly when the client is a server process that could move on to other tasks. The recommended solution is to always have temporary failure as one of the possible results of a resolver function, even though this may make emulation of existing HOSTS.TXT functions more difficult.

5.3. Resolver internals

Every resolver implementation uses slightly different algorithms, and typically spends much more logic dealing with errors of various sorts than typical occurances. This section outlines a recommended basic strategy for resolver operation, but leaves details to [RFC-1035].

5.3.1. Stub resolvers

One option for implementing a resolver is to move the resolution function out of the local machine and into a name server which supports recursive queries. This can provide an easy method of providing domain service in a PC which lacks the resources to perform the resolver function, or can centralize the cache for a whole local network or organization.

All that the remaining stub needs is a list of name server addresses that will perform the recursive requests. This type of resolver presumably needs the information in a configuration file, since it probably lacks the sophistication to locate it in the domain database. The user also needs to verify that the listed servers will perform the recursive service; a name server is free to refuse to perform recursive services for any or all clients. The user should consult the local system administrator to find name servers willing to perform the service.

This type of service suffers from some drawbacks. Since the recursive requests may take an arbitrary amount of time to perform, the stub may have difficulty optimizing retransmission intervals to deal with both lost UDP packets and dead servers; the name server can be easily overloaded by too zealous a stub if it interprets retransmissions as new requests. Use of TCP may be an answer, but TCP may well place burdens on the host's capabilities which are similar to those of a real resolver.

5.3.2. Resources

In addition to its own resources, the resolver may also have shared access to zones maintained by a local name server. This gives the resolver the advantage of more rapid access, but the resolver must be careful to never let cached information override zone data. In this discussion the term "local information" is meant to mean the union of the cache and such shared zones, with the understanding that authoritative data is always used in preference to cached data when both are present.

The following resolver algorithm assumes that all functions have been converted to a general lookup function, and uses the following data structures to represent the state of a request in progress in the resolver:

SNAME	the domain name we are searching for.
STYPE	the QTYPE of the search request.
SCLASS	the QCLASS of the search request.
SLIST	a structure which describes the name servers and the zone which the resolver is currently trying to query. This structure keeps track of the resolver's current best guess about which name servers hold the desired information; it is updated when arriving information changes the guess. This structure includes the equivalent of a zone name, the known name servers for the zone, the known addresses for the name servers, and history information which can be used to suggest which server is likely to be the best one to try next. The zone name equivalent is a match count of the number of labels from the root down which SNAME has in common with the zone being queried; this is used as a measure of how "close" the resolver is to SNAME.
SBELT	a "safety belt" structure of the same form as SLIST, which is initialized from a configuration file, and lists servers which should be used when the resolver doesn't have any local information to guide name server selection. The match count will be -1 to indicate that no labels are known to match.
CACHE	A structure which stores the results from previous responses. Since resolvers are responsible for discarding old RRs whose TTL has expired, most implementations convert the interval specified in arriving RRs to some sort of absolute time when the RR is stored in the cache. Instead of counting the TTLs down individually, the resolver just ignores or discards old RRs when it runs across them in the course of a search, or discards them during periodic sweeps to reclaim the memory consumed by old RRs.

5.3.3. Algorithm

The top level algorithm has four steps:

1. See if the answer is in local information, and if so return it to the client.

2. Find the best servers to ask.

3. Send them queries until one returns a response.

4. Analyze the response, either:

    a. if the response answers the question or contains a name error, cache the data as well as returning it back to the client.

    b. if the response contains a better delegation to other servers, cache the delegation information, and go to step 2.

    c. if the response shows a CNAME and that is not the answer itself, cache the CNAME, change the SNAME to the canonical name in the CNAME RR and go to step 1.

    d. if the response shows a servers failure or other bizarre contents, delete the server from the SLIST and go back to step 3.

Step 1 searches the cache for the desired data. If the data is in the cache, it is assumed to be good enough for normal use. Some resolvers have an option at the user interface which will force the resolver to ignore the cached data and consult with an authoritative server. This is not recommended as the default. If the resolver has direct access to a name server's zones, it should check to see if the desired data is present in authoritative form, and if so, use the authoritative data in preference to cached data.

Step 2 looks for a name server to ask for the required data. The general strategy is to look for locally-available name server RRs, starting at SNAME, then the parent domain name of SNAME, the grandparent, and so on toward the root. Thus if SNAME were Mockapetris.ISI.EDU, this step would look for NS RRs for Mockapetris.ISI.EDU, then ISI.EDU, then EDU, and then . (the root). These NS RRs list the names of hosts for a zone at or above SNAME. Copy the names into SLIST. Set up their addresses using local data. It may be the case that the addresses are not available. The resolver has many choices here; the best is to start parallel resolver processes looking for the addresses while continuing onward with the addresses which are available. Obviously, the design choices and options are complicated and a function of the local host's capabilities. The recommended priorities for the resolver designer are:

1. Bound the amount of work (packets sent, parallel processes started) so that a request can't get into an infinite loop or start off a chain reaction of requests or queries with other implementations EVEN IF SOMEONE HAS INCORRECTLY CONFIGURED SOME DATA.

2. Get back an answer if at all possible.

3. Avoid unnecessary transmissions.

4. Get the answer as quickly as possible.

If the search for NS RRs fails, then the resolver initializes SLIST from the safety belt SBELT. The basic idea is that when the resolver has no idea what servers to ask, it should use information from a configuration file that lists several servers which are expected to be helpful. Although there are special situations, the usual choice is two of the root servers and two of the servers for the host's domain. The reason for two of each is for redundancy. The root servers will provide eventual access to all of the domain space. The two local servers will allow the resolver to continue to resolve local names if the local network becomes isolated from the internet due to gateway or link failure.

In addition to the names and addresses of the servers, the SLIST data structure can be sorted to use the best servers first, and to insure that all addresses of all servers are used in a round-robin manner. The sorting can be a simple function of preferring addresses on the local network over others, or may involve statistics from past events, such as previous response times and batting averages.

Step 3 sends out queries until a response is received. The strategy is to cycle around all of the addresses for all of the servers with a timeout between each transmission. In practice it is important to use all addresses of a multihomed host, and too aggressive a retransmission policy actually slows response when used by multiple resolvers contending for the same name server and even occasionally for a single resolver. SLIST typically contains data values to control the timeouts and keep track of previous transmissions.

Step 4 involves analyzing responses. The resolver should be highly paranoid in its parsing of responses. It should also check that the response matches the query it sent using the ID field in the response.

The ideal answer is one from a server authoritative for the query which either gives the required data or a name error. The data is passed back to the user and entered in the cache for future use if its TTL is greater than zero.

If the response shows a delegation, the resolver should check to see that the delegation is "closer" to the answer than the servers in SLIST are. This can be done by comparing the match count in SLIST with that computed from SNAME and the NS RRs in the delegation. If not, the reply is bogus and should be ignored. If the delegation is valid the NS delegation RRs and any address RRs for the servers should be cached. The name servers are entered in the SLIST, and the search is restarted.

If the response contains a CNAME, the search is restarted at the CNAME unless the response has the data for the canonical name or if the CNAME is the answer itself.

Details and implementation hints can be found in [RFC-1035].

6. A SCENARIO

In our sample domain space, suppose we wanted separate administrative control for the root, MIL, EDU, MIT.EDU and ISI.EDU zones. We might allocate name servers as follows:

```
                             |(C.ISI.EDU,SRI-NIC.ARPA
                             | A.ISI.EDU)
             +---------------+------------------+
             |               |                  |
            MIL             EDU                ARPA
             |(SRI-NIC.ARPA, |(SRI-NIC.ARPA,    |
             | A.ISI.EDU     | C.ISI.EDU)       |
       +-----+-----+         |     +------+-----+-----+
       |     |     |         |     |      |           |
      BRL  NOSC  DARPA       |  IN-ADDR  SRI-NIC     ACC
                             |
       +--------+------------+--------------+--------+
       |        |            |              |        |
      UCI      MIT           |             UDEL     YALE
                |(XX.LCS.MIT.EDU, ISI
                |ACHILLES.MIT.EDU) |(VAXA.ISI.EDU,VENERA.ISI.EDU,
            +---+---+              | A.ISI.EDU)
            |       |              |
           LCS   ACHILLES +--+-----+-----+--------+
            |             |  |     |     |        |
            XX            A  C   VAXA  VENERA Mockapetris
```

In this example, the authoritative name server is shown in parentheses at the point in the domain tree at which is assumes control.

Thus the root name servers are on C.ISI.EDU, SRI-NIC.ARPA, and A.ISI.EDU. The MIL domain is served by SRI-NIC.ARPA and A.ISI.EDU. The EDU domain is served by SRI-NIC.ARPA. and C.ISI.EDU. Note that servers may have zones which are contiguous or disjoint. In this scenario, C.ISI.EDU has contiguous zones at the root and EDU domains. A.ISI.EDU has contiguous zones at the root and MIL domains, but also has a non-contiguous zone at ISI.EDU.

6.1. C.ISI.EDU name server

C.ISI.EDU is a name server for the root, MIL, and EDU domains of the IN class, and would have zones for these domains. The zone data for the root domain might be:

```
    .          IN      SOA     SRI-NIC.ARPA. HOSTMASTER.SRI-NIC.ARPA. (
                               870611          ;serial
                               1800            ;refresh every 30 min
                               300             ;retry every 5 min
                               604800          ;expire after a week
                               86400)          ;minimum of a day
                       NS      A.ISI.EDU.
                       NS      C.ISI.EDU.
                       NS      SRI-NIC.ARPA.

    MIL.       86400   NS      SRI-NIC.ARPA.
               86400   NS      A.ISI.EDU.

    EDU.       86400   NS      SRI-NIC.ARPA.
               86400   NS      C.ISI.EDU.

    SRI-NIC.ARPA.      A       26.0.0.73
                       A       10.0.0.51
                       MX      0 SRI-NIC.ARPA.
                       HINFO   DEC-2060 TOPS20

    ACC.ARPA.          A       26.6.0.65
                       HINFO   PDP-11/70 UNIX
                       MX      10 ACC.ARPA.

    USC-ISIC.ARPA.     CNAME   C.ISI.EDU.

    73.0.0.26.IN-ADDR.ARPA.  PTR    SRI-NIC.ARPA.
    65.0.6.26.IN-ADDR.ARPA.  PTR    ACC.ARPA.
    51.0.0.10.IN-ADDR.ARPA.  PTR    SRI-NIC.ARPA.
    52.0.0.10.IN-ADDR.ARPA.  PTR    C.ISI.EDU.
    103.0.3.26.IN-ADDR.ARPA. PTR    A.ISI.EDU.

    A.ISI.EDU. 86400 A      26 3.0.103
    C.ISI.EDU. 86400 A      10.0.0.52
```

This data is represented as it would be in a master file. Most RRs are single line entries; the sole exception here is the SOA RR, which uses "(" to start a multi-line RR and ")" to show the end of a multi-line RR. Since the class of all RRs in a zone must be the same, only the first RR in a zone need specify the class. When a name server loads a zone, it forces the TTL of all authoritative RRs to be at least the MINIMUM field of the SOA, here 86400 seconds, or one day. The NS RRs marking delegation of the MIL and EDU domains, together with the glue RRs for the servers host addresses, are not part of the authoritative data in the zone, and hence have explicit TTLs.

Four RRs are attached to the root node: the SOA which describes the root zone and the 3 NS RRs which list the name servers for the root. The data in the SOA RR describes the management of the zone. The zone data is maintained on host SRI-NIC.ARPA, and the responsible party for the zone is HOSTMASTER@SRI-NIC.ARPA. A key item in the SOA is the 86400 second minimum TTL, which means that all authoritative data in the zone has at least that TTL, although higher values may be explicitly specified.

The NS RRs for the MIL and EDU domains mark the boundary between the root zone and the MIL and EDU zones. Note that in this example, the lower zones happen to be supported by name servers which also support the root zone.

The master file for the EDU zone might be stated relative to the origin EDU. The zone data for the EDU domain might be:

```
    EDU.  IN SOA SRI-NIC.ARPA. HOSTMASTER.SRI-NIC.ARPA. (
                        870729 ;serial
                        1800 ;refresh every 30 minutes
                        300 ;retry every 5 minutes
                        604800 ;expire after a week
                        86400 ;minimum of a day
                        )
                NS SRI-NIC.ARPA.
                NS C.ISI.EDU.

    UCI 172800 NS ICS.UCI
                172800 NS ROME.UCI
    ICS.UCI 172800 A 192.5.19.1
    ROME.UCI 172800 A 192.5.19.31
    ISI 172800 NS VAXA.ISI
                    172800 NS A.ISI
                    172800 NS VENERA.ISI.EDU.
    VAXA.ISI 172800 A 10.2.0.27
                    172800 A 128.9.0.33
    VENERA.ISI.EDU. 172800 A 10.1.0.52
                    172800 A 128.9.0.32
    A.ISI 172800 A 26.3.0.103

    UDEL.EDU.  172800 NS LOUIE.UDEL.EDU.
                    172800 NS UMN-REI-UC.ARPA.
    LOUIE.UDEL.EDU. 172800 A 10.0.0.96
                    172800 A 192.5.39.3

    YALE.EDU.  172800 NS YALE.ARPA.
    YALE.EDU.  172800 NS YALE-BULLDOG.ARPA.

    MIT.EDU.  43200 NS XX.LCS.MIT.EDU.
                      43200 NS ACHILLES.MIT.EDU.
    XX.LCS.MIT.EDU.  43200 A 10.0.0.44
    ACHILLES.MIT.EDU. 43200 A 18.72.0.8
```

Note the use of relative names here. The owner name for the ISI.EDU. is stated using a relative name, as are two of the name server RR contents. Relative and absolute domain names may be freely intermixed in a master

6.2. Example standard queries

The following queries and responses illustrate name server behavior. Unless otherwise noted, the queries do not have recursion desired (RD) in the header. Note that the answers to non-recursive queries do depend on the server being asked, but do not depend on the identity of the requester.

6.2.1. QNAME=SRI-NIC.ARPA, QTYPE=A

The query would look like:

```
               +---------------------------------------------------+
    Header     | OPCODE=SQUERY                                     |
               +---------------------------------------------------+
    Question   | QNAME=SRI-NIC.ARPA., QCLASS=IN, QTYPE=A           |
               +---------------------------------------------------+
    Answer     | <empty>                                           |
               +---------------------------------------------------+
    Authority  | <empty>                                           |
               +---------------------------------------------------+
    Additional | <empty>                                           |
               +---------------------------------------------------+
```

The response from C.ISI.EDU would be:

```
               +---------------------------------------------------+
    Header     | OPCODE=SQUERY, RESPONSE, AA                       |
               +---------------------------------------------------+
    Question   | QNAME=SRI-NIC.ARPA., QCLASS=IN, QTYPE=A           |
               +---------------------------------------------------+
    Answer     | SRI-NIC.ARPA. 86400 IN A 26.0.0.73                |
               |               86400 IN A 10.0.0.51                |
               +---------------------------------------------------+
    Authority  | <empty>                                           |
               +---------------------------------------------------+
    Additional | <empty>                                           |
               +---------------------------------------------------+
```

The header of the response looks like the header of the query, except that the RESPONSE bit is set, indicating that this message is a response, not a query, and the Authoritative Answer (AA) bit is set indicating that the address RRs in the answer section are from authoritative data. The question section of the response matches the question section of the query.

If the same query was sent to some other server which was not authoritative for SRI-NIC.ARPA, the response might be:

```
               +---------------------------------------------------+
    Header     | OPCODE=SQUERY,RESPONSE                            |
               +---------------------------------------------------+
    Question   | QNAME=SRI-NIC.ARPA., QCLASS=IN, QTYPE=A           |
               +---------------------------------------------------+
    Answer     | SRI-NIC.ARPA. 1777 IN A 10.0.0.51                 |
               |               1777 IN A 26.0.0.73                 |
               +---------------------------------------------------+
    Authority  | <empty>                                           |
               +---------------------------------------------------+
    Additional | <empty>                                           |
               +---------------------------------------------------+
```

This response is different from the previous one in two ways: the header does not have AA set, and the TTLs are different. The inference is that the data did not come from a zone, but from a cache. The difference between the authoritative TTL and the TTL here is due to aging of the data in a cache. The difference in ordering of the RRs in the answer section is not significant.

6.2.2. QNAME=SRI-NIC.ARPA, QTYPE=*

A query similar to the previous one, but using a QTYPE of *, would receive the following response from C.ISI.EDU:

```
               +---------------------------------------------------+
    Header     | OPCODE=SQUERY, RESPONSE, AA                       |
               +---------------------------------------------------+
    Question   | QNAME=SRI-NIC.ARPA., QCLASS=IN, QTYPE=*           |
               +---------------------------------------------------+
    Answer     | SRI-NIC.ARPA. 86400 IN  A     26.0.0.73           |
               |                         A     10.0.0.51           |
               |                         MX    0 SRI-NIC.ARPA.     |
               |                         HINFO DEC-2060 TOPS20     |
               +---------------------------------------------------+
    Authority  | <empty>                                           |
               +---------------------------------------------------+
    Additional | <empty>                                           |
               +---------------------------------------------------+
```

If a similar query was directed to two name servers which are not
authoritative for SRI-NIC.ARPA, the responses might be:

```
               +---------------------------------------------------+
    Header     | OPCODE=SQUERY, RESPONSE                           |
               +---------------------------------------------------+
    Question   | QNAME=SRI-NIC.ARPA., QCLASS=IN, QTYPE=*           |
               +---------------------------------------------------+
    Answer     | SRI-NIC.ARPA. 12345 IN     A       26.0.0.73      |
               |                            A       10.0.0.51      |
               +---------------------------------------------------+
    Authority  | <empty>                                           |
               +---------------------------------------------------+
    Additional | <empty>                                           |
               +---------------------------------------------------+
```

and

```
               +---------------------------------------------------+
    Header     | OPCODE=SQUERY, RESPONSE                           |
               +---------------------------------------------------+
    Question   | QNAME=SRI-NIC.ARPA., QCLASS=IN, QTYPE=*           |
               +---------------------------------------------------+
    Answer     | SRI-NIC.ARPA. 1290 IN HINFO  DEC-2060 TOPS20      |
               +---------------------------------------------------+
    Authority  | <empty>                                           |
               +---------------------------------------------------+
    Additional | <empty>                                           |
               +---------------------------------------------------+
```

Neither of these answers have AA set, so neither response comes from
authoritative data. The different contents and different TTLs suggest
that the two servers cached data at different times, and that the first
server cached the response to a QTYPE=A query and the second cached the
response to a HINFO query.

6.2.3. QNAME=SRI-NIC.ARPA, QTYPE=MX

This type of query might be result from a mailer trying to look up routing information for the mail destination HOSTMASTER@SRI-NIC.ARPA. The response from C.ISI.EDU would be:

```
                 +---------------------------------------------------+
    Header       | OPCODE=SQUERY, RESPONSE, AA                       |
                 +---------------------------------------------------+
    Question     | QNAME=SRI-NIC.ARPA., QCLASS=IN, QTYPE=MX          |
                 +---------------------------------------------------+
    Answer       | SRI-NIC.ARPA. 86400 IN     MX      0 SRI-NIC.ARPA.|
                 +---------------------------------------------------+
    Authority    | <empty>                                           |
                 +---------------------------------------------------+
    Additional   | SRI-NIC.ARPA. 86400 IN     A       26.0.0.73      |
                 |                            A       10.0.0.51      |
                 +---------------------------------------------------+
```

This response contains the MX RR in the answer section of the response. The additional section contains the address RRs because the name server at C.ISI.EDU guesses that the requester will need the addresses in order to properly use the information carried by the MX.

6.2.4. QNAME=SRI-NIC.ARPA, QTYPE=NS

C.ISI.EDU would reply to this query with:

```
                 +---------------------------------------------------+
    Header       | OPCODE=SQUERY, RESPONSE, AA                       |
                 +---------------------------------------------------+
    Question     | QNAME=SRI-NIC.ARPA., QCLASS=IN, QTYPE=NS          |
                 +---------------------------------------------------+
    Answer       | <empty>                                           |
                 +---------------------------------------------------+
    Authority    | <empty>                                           |
                 +---------------------------------------------------+
    Additional   | <empty>                                           |
                 +---------------------------------------------------+
```

The only difference between the response and the query is the AA and RESPONSE bits in the header. The interpretation of this response is that the server is authoritative for the name, and the name exists, but no RRs of type NS are present there.

6.2.5. QNAME=SIR-NIC.ARPA, QTYPE=A

If a user mistyped a host name, we might see this type of query.

C.ISI.EDU would answer it with:

```
               +---------------------------------------------------+
    Header     | OPCODE=SQUERY, RESPONSE, AA, RCODE=NE             |
               +---------------------------------------------------+
    Question   | QNAME=SIR-NIC.ARPA., QCLASS=IN, QTYPE=A           |
               +---------------------------------------------------+
    Answer     | <empty>                                           |
               +---------------------------------------------------+
    Authority  | . SOA SRI-NIC.ARPA. HOSTMASTER.SRI-NIC.ARPA.      |
               |       870611 1800 300 604800 86400                |
               +---------------------------------------------------+
    Additional | <empty>                                           |
               +---------------------------------------------------+
```

This response states that the name does not exist. This condition is signalled in the response code (RCODE) section of the header.

The SOA RR in the authority section is the optional negative caching information which allows the resolver using this response to assume that the name will not exist for the SOA MINIMUM (86400) seconds.

6.2.6. QNAME=BRL.MIL, QTYPE=A

If this query is sent to C.ISI.EDU, the reply would be:

```
               +---------------------------------------------------+
    Header     | OPCODE=SQUERY, RESPONSE                           |
               +---------------------------------------------------+
    Question   | QNAME=BRL.MIL, QCLASS=IN, QTYPE=A                 |
               +---------------------------------------------------+
    Answer     | <empty>                                           |
               +---------------------------------------------------+
    Authority  | MIL.             86400 IN NS       SRI-NIC.ARPA.  |
               |                  86400    NS       A.ISI.EDU.     |
               +---------------------------------------------------+
    Additional | A.ISI.EDU.                A        26.3.0.103     |
               | SRI-NIC.ARPA.             A        26.0.0.73      |
               |                           A        10.0.0.51      |
               +---------------------------------------------------+
```

This response has an empty answer section, but is not authoritative, so it is a referral. The name server on C.ISI.EDU, realizing that it is not authoritative for the MIL domain, has referred the requester to servers on A.ISI.EDU and SRI-NIC.ARPA, which it knows are authoritative for the MIL domain.

6.2.7. QNAME=USC-ISIC.ARPA, QTYPE=A

The response to this query from A.ISI.EDU would be:

```
               +---------------------------------------------------+
    Header     | OPCODE=SQUERY, RESPONSE, AA                       |
               +---------------------------------------------------+
    Question   | QNAME=USC-ISIC.ARPA., QCLASS=IN, QTYPE=A          |
               +---------------------------------------------------+
    Answer     | USC-ISIC.ARPA. 86400 IN CNAME      C.ISI.EDU.     |
               | C.ISI.EDU.     86400 IN A          10.0.0.52      |
               +---------------------------------------------------+
    Authority  | <empty>                                           |
               +---------------------------------------------------+
    Additional | <empty>                                           |
               +---------------------------------------------------+
```

Note that the AA bit in the header guarantees that the data matching QNAME is authoritative, but does not say anything about whether the data for C.ISI.EDU is authoritative. This complete reply is possible because A.ISI.EDU happens to be authoritative for both the ARPA domain where USC-ISIC.ARPA is found and the ISI.EDU domain where C.ISI.EDU data is found.

If the same query was sent to C.ISI.EDU, its response might be the same as shown above if it had its own address in its cache, but might also be:

```
               +---------------------------------------------------+
    Header     | OPCODE=SQUERY, RESPONSE, AA                       |
               +---------------------------------------------------+
    Question   | QNAME=USC-ISIC.ARPA., QCLASS=IN, QTYPE=A          |
               +---------------------------------------------------+
    Answer     | USC-ISIC.ARPA.   86400 IN CNAME   C.ISI.EDU.      |
               +---------------------------------------------------+
    Authority  | ISI.EDU.         172800 IN NS      VAXA.ISI.EDU.  |
               |                           NS      A.ISI.EDU.      |
               |                           NS      VENERA.ISI.EDU. |
               +---------------------------------------------------+
    Additional | VAXA.ISI.EDU.    172800    A      10.2.0.27       |
               |                  172800    A      128.9.0.33      |
               | VENERA.ISI.EDU.  172800    A      10.1.0.52       |
               |                  172800    A      128.9.0.32      |
               | A.ISI.EDU.       172800    A      26.3.0.103      |
               +---------------------------------------------------+
```

This reply contains an authoritative reply for the alias USC-ISIC.ARPA, plus a referral to the name servers for ISI.EDU. This sort of reply isn't very likely given that the query is for the host name of the name server being asked, but would be common for other aliases.

6.2.8. QNAME=USC-ISIC.ARPA, QTYPE=CNAME

If this query is sent to either A.ISI.EDU or C.ISI.EDU, the reply would be:

```
               +---------------------------------------------------+
    Header     | OPCODE=SQUERY, RESPONSE, AA                       |
               +---------------------------------------------------+
    Question   | QNAME=USC-ISIC.ARPA., QCLASS=IN, QTYPE=A          |
               +---------------------------------------------------+
    Answer     | USC-ISIC.ARPA. 86400 IN CNAME      C.ISI.EDU.     |
               +---------------------------------------------------+
    Authority  | <empty>                                           |
               +---------------------------------------------------+
    Additional | <empty>                                           |
               +---------------------------------------------------+
```

Because QTYPE=CNAME, the CNAME RR itself answers the query, and the name server doesn't attempt to look up anything for C.ISI.EDU. (Except possibly for the additional section.)

6.3. Example resolution

The following examples illustrate the operations a resolver must perform for its client. We assume that the resolver is starting without a cache, as might be the case after system boot. We further assume that the system is not one of the hosts in the data and that the host is located somewhere on net 26, and that its safety belt (SBELT) data structure has the following information:

```
    Match count = -1
    SRI-NIC.ARPA.   26.0.0.73       10.0.0.51
    A.ISI.EDU.      26.3.0.103
```

This information specifies servers to try, their addresses, and a match count of -1, which says that the servers aren't very close to the target. Note that the -1 isn't supposed to be an accurate closeness measure, just a value so that later stages of the algorithm will work.

The following examples illustrate the use of a cache, so each example assumes that previous requests have completed.

6.3.1. Resolve MX for ISI.EDU.

Suppose the first request to the resolver comes from the local mailer, which has mail for PVM@ISI.EDU. The mailer might then ask for type MX RRs for the domain name ISI.EDU.

The resolver would look in its cache for MX RRs at ISI.EDU, but the empty cache wouldn't be helpful. The resolver would recognize that it needed to query foreign servers and try to determine the best servers to query. This search would look for NS RRs for the domains ISI.EDU, EDU, and the root. These searches of the cache would also fail. As a last resort, the resolver would use the information from the SBELT, copying it into its SLIST structure.

At this point the resolver would need to pick one of the three available addresses to try. Given that the resolver is on net 26, it should choose either 26.0.0.73 or 26.3.0.103 as its first choice. It would then send off a query of the form:

```
                  +---------------------------------------------------+
    Header        | OPCODE=SQUERY                                     |
                  +---------------------------------------------------+
    Question      | QNAME=ISI.EDU., QCLASS=IN, QTYPE=MX               |
                  +---------------------------------------------------+
    Answer        | <empty>                                           |
                  +---------------------------------------------------+
    Authority     | <empty>                                           |
                  +---------------------------------------------------+
    Additional    | <empty>                                           |
                  +---------------------------------------------------+
```

The resolver would then wait for a response to its query or a timeout. If the timeout occurs, it would try different servers, then different addresses of the same servers, lastly retrying addresses already tried. It might eventually receive a reply from SRI-NIC.ARPA:

```
                  +---------------------------------------------------+
    Header        | OPCODE=SQUERY, RESPONSE                           |
                  +---------------------------------------------------+
    Question      | QNAME=ISI.EDU., QCLASS=IN, QTYPE=MX               |
                  +---------------------------------------------------+
    Answer        | <empty>                                           |
                  +---------------------------------------------------+
    Authority     | ISI.EDU.        172800 IN NS       VAXA.ISI.EDU.  |
                  |                           NS       A.ISI.EDU.     |
                  |                           NS       VENERA.ISI.EDU.|
                  +---------------------------------------------------+
    Additional    | VAXA.ISI.EDU.   172800    A        10.2.0.27      |
                  |                 172800    A        128.9.0.33     |
                  | VENERA.ISI.EDU. 172800    A        10.1.0.52      |
                  |                 172800    A        128.9.0.32     |
                  | A.ISI.EDU.      172800    A        26.3.0.103     |
                  +---------------------------------------------------+
```

The resolver would notice that the information in the response gave a closer delegation to ISI.EDU than its existing SLIST (since it matches three labels). The resolver would then cache the information in this response and use it to set up a new SLIST:

```
    Match count = 3
    A.ISI.EDU.      26.3.0.103
    VAXA.ISI.EDU.   10.2.0.27       128.9.0.33
    VENERA.ISI.EDU. 10.1.0.52       128.9.0.32
```

A.ISI.EDU appears on this list as well as the previous one, but that is purely coincidental. The resolver would again start transmitting and waiting for responses. Eventually it would get an answer:

```
               +---------------------------------------------------+
    Header     | OPCODE=SQUERY, RESPONSE, AA                       |
               +---------------------------------------------------+
    Question   | QNAME=ISI.EDU., QCLASS=IN, QTYPE=MX               |
               +---------------------------------------------------+
    Answer     | ISI.EDU.               MX 10 VENERA.ISI.EDU.      |
               |                        MX 20 VAXA.ISI.EDU.        |
               +---------------------------------------------------+
    Authority  | <empty>                                           |
               +---------------------------------------------------+
    Additional | VAXA.ISI.EDU.   172800  A  10.2.0.27              |
               |                 172800  A  128.9.0.33             |
               | VENERA.ISI.EDU. 172800  A  10.1.0.52              |
               |                 172800  A  128.9.0.32             |
               +---------------------------------------------------+
```

The resolver would add this information to its cache, and return the MX RRs to its client.

6.3.2. Get the host name for address 26.6.0.65

The resolver would translate this into a request for PTR RRs for 65.0.6.26.IN-ADDR.ARPA. This information is not in the cache, so the resolver would look for foreign servers to ask. No servers would match, so it would use SBELT again. (Note that the servers for the ISI.EDU domain are in the cache, but ISI.EDU is not an ancestor of 65.0.6.26.IN-ADDR.ARPA, so the SBELT is used.)

Since this request is within the authoritative data of both servers in SBELT, eventually one would return:

```
               +---------------------------------------------------+
    Header     | OPCODE=SQUERY, RESPONSE, AA                       |
               +---------------------------------------------------+
    Question   | QNAME=65.0.6.26.IN-ADDR.ARPA.,QCLASS=IN,QTYPE=PTR |
               +---------------------------------------------------+
    Answer     | 65.0.6.26.IN-ADDR.ARPA.    PTR     ACC.ARPA.      |
               +---------------------------------------------------+
    Authority  | <empty>                                           |
               +---------------------------------------------------+
    Additional | <empty>                                           |
               +---------------------------------------------------+
```

6.3.3. Get the host address of poneria.ISI.EDU

This request would translate into a type A request for poneria.ISI.EDU. The resolver would not find any cached data for this name, but would find the NS RRs in the cache for ISI.EDU when it looks for foreign servers to ask. Using this data, it would construct a SLIST of the form:

```
    Match count = 3

    A.ISI.EDU.      26.3.0.103
    VAXA.ISI.EDU.   10.2.0.27       128.9.0.33
    VENERA.ISI.EDU. 10.1.0.52
```

A.ISI.EDU is listed first on the assumption that the resolver orders its choices by preference, and A.ISI.EDU is on the same network.

One of these servers would answer the query.

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Superceeded by this memo.

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1.3. Domain Names - Implementation and Specification [RFC 1035]

Network Working Group
Request for Comments: 1035

Obsoletes: RFCs 882, 883, 973

P. Mockapetris
ISI
November 1987

DOMAIN NAMES - IMPLEMENTATION AND SPECIFICATION

1. STATUS OF THIS MEMO

This RFC describes the details of the domain system and protocol, and assumes that the reader is familiar with the concepts discussed in a companion RFC, "Domain Names - Concepts and Facilities" [RFC-1034].

The domain system is a mixture of functions and data types which are an official protocol and functions and data types which are still experimental. Since the domain system is intentionally extensible, new data types and experimental behavior should always be expected in parts of the system beyond the official protocol. The official protocol parts include standard queries, responses and the Internet class RR data formats (e.g., host addresses). Since the previous RFC set, several definitions have changed, so some previous definitions are obsolete.

Experimental or obsolete features are clearly marked in these RFCs, and such information should be used with caution.

The reader is especially cautioned not to depend on the values which appear in examples to be current or complete, since their purpose is primarily pedagogical. Distribution of this memo is unlimited.

Table of Contents

2. INTRODUCTION

2.1. Overview

The goal of domain names is to provide a mechanism for naming resources in such a way that the names are usable in different hosts, networks, protocol families, internets, and administrative organizations.

From the user's point of view, domain names are useful as arguments to a local agent, called a resolver, which retrieves information associated with the domain name. Thus a user might ask for the host address or mail information associated with a particular domain name. To enable the user to request a particular type of information, an appropriate query type is passed to the resolver with the domain name. To the user, the domain tree is a single information space; the resolver is responsible for hiding the distribution of data among name servers from the user.

From the resolver's point of view, the database that makes up the domain space is distributed among various name servers. Different parts of the domain space are stored in different name servers, although a particular data item will be stored redundantly in two or more name servers. The resolver starts with knowledge of at least one name server. When the resolver processes a user query it asks a known name server for the information; in return, the resolver either receives the desired information or a referral to another name server. Using these referrals, resolvers learn the identities and contents of other name servers. Resolvers are responsible for dealing with the distribution of the domain space and dealing with the effects of name server failure by consulting redundant databases in other servers.

Name servers manage two kinds of data. The first kind of data held in sets called zones; each zone is the complete database for a particular "pruned" subtree of the domain space. This data is called authoritative. A name server periodically checks to make sure that its zones are up to date, and if not, obtains a new copy of updated zones from master files stored locally or in another name server. The second kind of data is cached data which was acquired by a local resolver. This data may be incomplete, but improves the performance of the retrieval process when non-local data is repeatedly accessed. Cached data is eventually discarded by a timeout mechanism.

This functional structure isolates the problems of user interface, failure recovery, and distribution in the resolvers and isolates the database update and refresh problems in the name servers.

2.2. Common configurations

A host can participate in the domain name system in a number of ways, depending on whether the host runs programs that retrieve information from the domain system, name servers that answer queries from other hosts, or various combinations of both functions. The simplest, and perhaps most typical, configuration is shown below:

```
                 Local Host                        |  Foreign
                                                   |
    +---------+               +----------+         |  +--------+
    |         | user queries  |          |queries  |  |        |
    |  User   |-------------->|          |---------|->|Foreign |
    | Program |               | Resolver |         |  |  Name  |
    |         |<--------------|          |<--------|--| Server |
    |         | user responses|          |responses|  |        |
    +---------+               +----------+         |  +--------+
                                |     A            |
                cache additions |     | references |
                                V     |            |
                              +----------+         |
                              |  cache   |         |
                              +----------+         |
```

User programs interact with the domain name space through resolvers; the format of user queries and user responses is specific to the host and its operating system. User queries will typically be operating system calls, and the resolver and its cache will be part of the host operating system. Less capable hosts may choose to implement the resolver as a subroutine to be linked in with every program that needs its services. Resolvers answer user queries with information they acquire via queries to foreign name servers and the local cache.

Note that the resolver may have to make several queries to several different foreign name servers to answer a particular user query, and hence the resolution of a user query may involve several network accesses and an arbitrary amount of time. The queries to foreign name servers and the corresponding responses have a standard format described in this memo, and may be datagrams.

Depending on its capabilities, a name server could be a stand alone program on a dedicated machine or a process or processes on a large timeshared host. A simple configuration might be:

```
                 Local Host                         |  Foreign
                                                    |
      +---------+                                   |
     /         /|                                   |
    +---------+ |             +-----------+         |  +--------+
    |         | |             |           |responses|  |        |
    |         | |             |   Name    |---------|->|Foreign |
    |  Master |-------------->|   Server  |         |  |Resolver|
    |  files  | |             |           |<--------|--|        |
    |         |/              |           | queries |  +--------+
    +---------+               +-----------+         |
```

Here a primary name server acquires information about one or more zones by reading master files from its local file system, and answers queries about those zones that arrive from foreign resolvers.

The DNS requires that all zones be redundantly supported by more than one name server. Designated secondary servers can acquire zones and check for updates from the primary server using the zone transfer protocol of the DNS. This configuration is shown below:

```
                 Local Host                         |  Foreign
                                                    |
      +---------+                                   |
     /         /|                                   |
    +---------+ |             +-----------+         |  +--------+
    |         | |             |           |responses|  |        |
    |         | |             |   Name    |---------|->|Foreign |
    |  Master |-------------->|   Server  |         |  |Resolver|
    |  files  | |             |           |<--------|--|        |
    |         |/              |           | queries |  +--------+
    +---------+               +-----------+         |
                                 A     |maintenance |  +--------+
                                 |     +------------|->|        |
                                 |      queries     |  |Foreign |
                                 |                  |  |  Name  |
                                 +------------------|--| Server |
                              maintenance responses |  +--------+
```

In this configuration, the name server periodically establishes a virtual circuit to a foreign name server to acquire a copy of a zone or to check that an existing copy has not changed. The messages sent for these maintenance activities follow the same form as queries and responses, but the message sequences are somewhat different.

The information flow in a host that supports all aspects of the domain name system is shown below:

```
                 Local Host                        |  Foreign
                                                   |
    +---------+               +----------+         |  +--------+
    |         | user queries  |          |queries  |  |        |
    |  User   |-------------->|          |---------|->|Foreign |
    | Program |               | Resolver |         |  |  Name  |
    |         |<--------------|          |<--------|--| Server |
    |         | user responses|          |responses|  |        |
    +---------+               +----------+         |  +--------+
                                |     A            |
                cache additions |     | references |
                                V     |            |
                              +----------+         |
                              |  Shared  |         |
                              | database |         |
                              +----------+         |
                                A     |            |
      +---------+     refreshes |     | references |
     /         /|               |     V            |
    +---------+ |             +----------+         |  +--------+
    |         | |             |          |responses|  |        |
    |         | |             |   Name   |---------|->|Foreign |
    |  Master |-------------->|  Server  |         |  |Resolver|
    |  files  | |             |          |<--------|--|        |
    |         |/              |          | queries |  +--------+
    +---------+               +----------+         |
                                A     |maintenance |  +--------+
                                |     +------------|->|        |
                                |      queries     |  |Foreign |
                                |                  |  |  Name  |
                                +------------------|--| Server |
                             maintenance responses |  +--------+
```

The shared database holds domain space data for the local name server and resolver. The contents of the shared database will typically be a mixture of authoritative data maintained by the periodic refresh operations of the name server and cached data from previous resolver requests. The structure of the domain data and the necessity for synchronization between name servers and resolvers imply the general characteristics of this database, but the actual format is up to the local implementor.

Information flow can also be tailored so that a group of hosts act together to optimize activities. Sometimes this is done to offload less capable hosts so that they do not have to implement a full resolver. This can be appropriate for PCs or hosts which want to minimize the amount of new network code which is required. This scheme can also allow a group of hosts can share a small number of caches rather than maintaining a large number of separate caches, on the premise that the centralized caches will have a higher hit ratio. In either case, resolvers are replaced with stub resolvers which act as front ends to resolvers located in a recursive server in one or more name servers known to perform that service:

```
                 Local Hosts                        |  Foreign
                                                    |
    +---------+                                     |
    |         | responses                           |
    | Stub    |<--------------------+               |
    | Resolver|                     |               |
    |         |----------------+    |               |
    +---------+ recursive      |    |               |
                queries        |    |               |
                               V    |               |
    +---------+ recursive     +----------+          |  +--------+
    |         | queries       |          |queries   |  |        |
    | Stub    |-------------->| Recursive|---------|->|Foreign |
    | Resolver|               | Server   |          |  | Name   |
    |         |<--------------|          |<--------|--| Server |
    +---------+ responses     |          |responses |  |        |
                              +----------+          |  +--------+
                              |  Central |          |
                              |  cache   |          |
                              +----------+          |
```

In any case, note that domain components are always replicated for reliability whenever possible.

2.3. Conventions

The domain system has several conventions dealing with low-level, but fundamental, issues. While the implementor is free to violate these conventions WITHIN HIS OWN SYSTEM, he must observe these conventions in ALL behavior observed from other hosts.

2.3.1. Preferred name syntax

The DNS specifications attempt to be as general as possible in the rules for constructing domain names. The idea is that the name of any existing object can be expressed as a domain name with minimal changes.

However, when assigning a domain name for an object, the prudent user will select a name which satisfies both the rules of the domain system and any existing rules for the object, whether these rules are published or implied by existing programs.

For example, when naming a mail domain, the user should satisfy both the rules of this memo and those in RFC-822. When creating a new host name, the old rules for HOSTS.TXT should be followed. This avoids problems when old software is converted to use domain names.

The following syntax will result in fewer problems with many

applications that use domain names (e.g., mail, TELNET).

```
<domain> ::= <subdomain> | " "

<subdomain> ::= <label> | <subdomain> "." <label>

<label> ::= <letter> [ [ <ldh-str> ] <let-dig> ]

<ldh-str> ::= <let-dig-hyp> | <let-dig-hyp> <ldh-str>

<let-dig-hyp> ::= <let-dig> | "-"

<let-dig> ::= <letter> | <digit>

<letter> ::= any one of the 52 alphabetic characters A through Z in
upper case and a through z in lower case

<digit> ::= any one of the ten digits 0 through 9
```

Note that while upper and lower case letters are allowed in domain names, no significance is attached to the case. That is, two names with the same spelling but different case are to be treated as if identical.

The labels must follow the rules for ARPANET host names. They must start with a letter, end with a letter or digit, and have as interior characters only letters, digits, and hyphen. There are also some restrictions on the length. Labels must be 63 characters or less.

For example, the following strings identify hosts in the Internet:

A.ISI.EDU XX.LCS.MIT.EDU SRI-NIC.ARPA

2.3.2. Data Transmission Order

The order of transmission of [illegible] header and data described in this document is resolved to the octet level. Whenever a diagram shows a group of octets, the order of transmission of those octets is the normal order in which they are read in English. For example, in the following diagram, the octets are transmitted in the order they are numbered.

```
     0                   1
     0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |       1       |       2       |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |       3       |       4       |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |       5       |       6       |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Whenever an octet represents a numeric quantity, the left most bit in the diagram is the high order or most significant bit. That is, the bit labeled 0 is the most significant bit. For example, the following diagram represents the value 170 (decimal).

```
     0 1 2 3 4 5 6 7
    +-+-+-+-+-+-+-+-+
    |1 0 1 0 1 0 1 0|
    +-+-+-+-+-+-+-+-+
```

Similarly, whenever a multi-octet field represents a numeric quantity the left most bit of the whole field is the most significant bit. When a multi-octet quantity is transmitted the most significant octet is transmitted first.

2.3.3. Character Case

For all parts of the DNS that are part of the official protocol, all comparisons between character strings (e.g., labels, domain names, etc.) are done in a case-insensitive manner. At present, this rule is in force throughout the domain system without exception. However, future additions beyond current usage may need to use the full binary octet capabilities in names, so attempts to store domain names in 7-bit ASCII or use of special bytes to terminate labels, etc., should be avoided.

When data enters the domain system, its original case should be preserved whenever possible. In certain circumstances this cannot be done. For example, if two RRs are stored in a database, one at x.y and one at X.Y, they are actually stored at the same place in the database, and hence only one casing would be preserved. The basic rule is that case can be discarded only when data is used to define structure in a database, and two names are identical when compared in a case insensitive manner.

Loss of case sensitive data must be minimized. Thus while data for x.y and X.Y may both be stored under a single location x.y or X.Y, data for a.x and B.X would never be stored under A.x, A.X, b.x, or b.X. In general, this preserves the case of the first label of a domain name, but forces standardization of interior node labels.

Systems administrators who enter data into the domain database should take care to represent the data they supply to the domain system in a case-consistent manner if their system is case-sensitive. The data distribution system in the domain system will ensure that consistent representations are preserved.

2.3.4. Size limits

Various objects and parameters in the DNS have size limits. They are listed below. Some could be easily changed, others are more fundamental.

labels	63 octets or less
names	255 octets or less
TTL	positive values of a signed 32 bit number.
UDP messages	512 octets or less

3. DOMAIN NAME SPACE AND RR DEFINITIONS

3.1. Name space definitions

Domain names in messages are expressed in terms of a sequence of labels. Each label is represented as a one octet length field followed by that number of octets. Since every domain name ends with the null label of the root, a domain name is terminated by a length byte of zero. The high order two bits of every length octet must be zero, and the remaining six bits of the length field limit the label to 63 octets or less.

To simplify implementations, the total length of a domain name (i.e., label octets and label length octets) is restricted to 255 octets or less.

Although labels can contain any 8 bit values in octets that make up a label, it is strongly recommended that labels follow the preferred syntax described elsewhere in this memo, which is compatible with existing host naming conventions. Name servers and resolvers must compare labels in a case-insensitive manner (i.e., A=a), assuming ASCII with zero parity. Non-alphabetic codes must match exactly.

3.2. RR definitions

3.2.1. Format

All RRs have the same top level format shown below:

```
                                    1  1  1  1  1  1
      0  1  2  3  4  5  6  7  8  9  0  1  2  3  4  5
    +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
    |                                               |
    /                                               /
    /                      NAME                     /
    |                                               |
    +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
    |                      TYPE                     |
    +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
    |                     CLASS                     |
    +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
    |                      TTL                      |
    |                                               |
    +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
    |                   RDLENGTH                    |
    +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--|
    /                     RDATA                     /
    /                                               /
    +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
```

where:

NAME	an owner name, i.e., the name of the node to which this resource record pertains.
TYPE	two octets containing one of the RR TYPE codes.
CLASS	two octets containing one of the RR CLASS codes.
TTL	a 32 bit signed integer that specifies the time interval that the resource record may be cached before the source of the information should again be consulted. Zero values are interpreted to mean that the RR can only be used for the transaction in progress, and should not be cached. For example, SOA records are always distributed with a zero TTL to prohibit caching. Zero values can also be used for extremely volatile data.
RDLENGTH	an unsigned 16 bit integer that specifies the length in octets of the RDATA field.

RDATA	a variable length string of octets that describes the resource. The format of this information varies according to the TYPE and CLASS of the resource record.

3.2.2. TYPE values

TYPE fields are used in resource records. Note that these types are a subset of QTYPEs.

TYPE	value and meaning
A	1 a host address
NS	2 an authoritative name server
MD	3 a mail destination (Obsolete - use MX)
MF	4 a mail forwarder (Obsolete - use MX)
CNAME	5 the canonical name for an alias
SOA	6 marks the start of a zone of authority
MB	7 a mailbox domain name (EXPERIMENTAL)
MG	8 a mail group member (EXPERIMENTAL)
MR	9 a mail rename domain name (EXPERIMENTAL)
NULL	10 a null RR (EXPERIMENTAL)
WKS	11 a well known service description
PTR	12 a domain name pointer
HINFO	13 host information
MINFO	14 mailbox or mail list information
MX	15 mail exchange
TXT	16 text strings

3.2.3. QTYPE values

QTYPE fields appear in the question part of a query. QTYPES are a superset of TYPEs, hence all TYPEs are valid QTYPEs. In addition, the following QTYPEs are defined:

AXFR	252 A request for a transfer of an entire zone
MAILB	253 A request for mailbox-related records (MB, MG or MR)
MAILA	254 A request for mail agent RRs (Obsolete - see MX)
*	255 A request for all records

3.2.4. CLASS values

CLASS fields appear in resource records. The following CLASS mnemonics and values are defined:

IN	1 the Internet
CS	2 the CSNET class (Obsolete - used only for examples in some obsolete RFCs)
CH	3 the CHAOS class
HS	4 Hesiod [Dyer 87]

3.2.5. QCLASS values

QCLASS fields appear in the question section of a query. QCLASS values are a superset of CLASS values; every CLASS is a valid QCLASS. In addition to CLASS values, the following QCLASSes are defined:

*	255 any class

3.3. Standard RRs

The following RR definitions are expected to occur, at least potentially, in all classes. In particular, NS, SOA, CNAME, and PTR will be used in all classes, and have the same format in all classes. Because their RDATA format is known, all domain names in the RDATA section of these RRs may be compressed.

<domain-name> is a domain name represented as a series of labels, and terminated by a label with zero length. <character-string> is a single length octet followed by that number of characters. <character-string> is treated as binary information, and can be up to 256 characters in length (including the length octet).

3.3.1. CNAME RDATA format

```
    +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
    /                     CNAME                     /
    /                                               /
    +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
```

where:

CNAME   A <domain-name> which specifies the canonical or primary
                name for the owner. The owner name is an alias.

CNAME RRs cause no additional section processing, but name servers may choose to restart the query at the canonical name in certain cases. See the description of name server logic in [RFC-1034] for details.

3.3.2. HINFO RDATA format

```
    +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
    /                      CPU                      /
    +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
    /                       OS                      /
    +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
```

where:

CPU   A <character-string> which specifies the CPU type.

OS   A <character-string> which specifies the operating
                system type.

Standard values for CPU and OS can be found in [RFC-1010].

HINFO records are used to acquire general information about a host. The main use is for protocols such as FTP that can use special procedures when talking between machines or operating systems of the same type.

3.3.3. MB RDATA format (EXPERIMENTAL)

```
    +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
    /                    MADNAME                    /
    /                                               /
    +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
```

where:

MADNAME   A <domain-name> which specifies a host which has the
                specified mailbox.

MB records cause additional section processing which looks up an A type RRs corresponding to MADNAME.

3.3.4. MD RDATA format (Obsolete)

```
    +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
    /                   MADNAME                     /
    /                                               /
    +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
```

where:

```
MADNAME         A <domain-name> which specifies a host which has a mail
                agent for the domain which should be able to deliver
                mail for the domain.
```

MD records cause additional section processing which looks up an A type record corresponding to MADNAME.

MD is obsolete. See the definition of MX and [RFC-974] for details of the new scheme. The recommended policy for dealing with MD RRs found in a master file is to reject them, or to convert them to MX RRs with a preference of 0.

3.3.5. MF RDATA format (Obsolete)

```
    +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
    /                   MADNAME                     /
    /                                               /
    +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
```

where:

```
MADNAME         A <domain-name> which specifies a host which has a mail
                agent for the domain which will accept mail for
                forwarding to the domain.
```

MF records cause additional section processing which looks up an A type record corresponding to MADNAME.

MF is obsolete. See the definition of MX and [RFC-974] for details ofw the new scheme. The recommended policy for dealing with MD RRs found in a master file is to reject them, or to convert them to MX RRs with a preference of 10.

3.3.6. MG RDATA format (EXPERIMENTAL)

```
    +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
    /                   MGMNAME                     /
    /                                               /
    +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
```

where:

MGMNAME   A <domain-name> which specifies a mailbox which is a
                member of the mail group specified by the domain name.

MG records cause no additional section processing.

3.3.7. MINFO RDATA format (EXPERIMENTAL)

```
    +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
    /                    RMAILBX                    /
    +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
    /                    EMAILBX                    /
    +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
```

where:

RMAILBX   A <domain-name> which specifies a mailbox which is
                responsible for the mailing list or mailbox. If this
                domain name names the root, the owner of the MINFO RR is
                responsible for itself. Note that many existing mailing
                lists use a mailbox X-request for the RMAILBX field of
                mailing list X, e.g., Msgroup-request for Msgroup. This
                field provides a more general mechanism.

EMAILBX   A <domain-name> which specifies a mailbox which is to
                receive error messages related to the mailing list or
                mailbox specified by the owner of the MINFO RR (similar
                to the ERRORS-TO: field which has been proposed). If
                this domain name names the root, errors should be
                returned to the sender of the message.

MINFO records cause no additional section processing. Although these
records can be associated with a simple mailbox, they are usually used
with a mailing list.

3.3.8. MR RDATA format (EXPERIMENTAL)

```
    +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
    /                   NEWNAME                     /
    /                                               /
    +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
```

where:

NEWNAME	A <domain-name> which specifies a mailbox which is the proper rename of the specified mailbox.

MR records cause no additional section processing. The main use for MR is as a forwarding entry for a user who has moved to a different mailbox.

3.3.9. MX RDATA format

```
    +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
    |                  PREFERENCE                   |
    +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
    /                   EXCHANGE                    /
    /                                               /
    +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
```

where:

PREFERENCE	A 16 bit integer which specifies the preference given to this RR among others at the same owner. Lower values are preferred.
EXCHANGE	A <domain-name> which specifies a host willing to act as a mail exchange for the owner name.

MX records cause type A additional section processing for the host specified by EXCHANGE. The use of MX RRs is explained in detail in [RFC-974].

3.3.10. NULL RDATA format (EXPERIMENTAL)

```
    +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
    /                  <anything>                   /
    /                                               /
    +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
```

Anything at all may be in the RDATA field so long as it is 65535 octets or less.

NULL records cause no additional section processing. NULL RRs are not allowed in master files. NULLs are used as placeholders in some experimental extensions of the DNS.

3.3.11. NS RDATA format

```
    +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
    /                   NSDNAME                     /
    /                                               /
    +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
```

where:

NSDNAME	A <domain-name> which specifies a host which should be authoritative for the specified class and domain.

NS records cause both the usual additional section processing to locate a type A record, and, when used in a referral, a special search of the zone in which they reside for glue information.

The NS RR states that the named host should be expected to have a zone starting at owner name of the specified class. Note that the class may not indicate the protocol family which should be used to communicate with the host, although it is typically a strong hint. For example, hosts which are name servers for either Internet (IN) or Hesiod (HS) class information are normally queried using IN class protocols.

3.3.12. PTR RDATA format

```
    +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
    /                   PTRDNAME                    /
    +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
```

where:

PTRDNAME	A <domain-name> which points to some location in the domain name space.

PTR records cause no additional section processing. These RRs are used in special domains to point to some other location in the domain space. These records are simple data, and don't imply any special processing similar to that performed by CNAME, which identifies aliases. See the description of the IN-ADDR.ARPA domain for an example.

3.3.13. SOA RDATA format

```
    +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
    /                     MNAME                     /
    /                                               /
    +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
    /                     RNAME                     /
    +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
    |                    SERIAL                     |
    |                                               |
    +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
    |                    REFRESH                    |
    |                                               |
    +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
    |                     RETRY                     |
    |                                               |
    +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
    |                    EXPIRE                     |
    |                                               |
    +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
    |                    MINIMUM                    |
    |                                               |
    +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
```

where:

MNAME	The <domain-name> of the name server that was the original or primary source of data for this zone.
RNAME	A <domain-name> which specifies the mailbox of the person responsible for this zone.
SERIAL	The unsigned 32 bit version number of the original copy of the zone. Zone transfers preserve this value. This value wraps and should be compared using sequence space arithmetic.
REFRESH	A 32 bit time interval before the zone should be refreshed.
RETRY	A 32 bit time interval that should elapse before a failed refresh should be retried.
EXPIRE	A 32 bit time value that specifies the upper limit on the time interval that can elapse before the zone is no longer authoritative.

```
MINIMUM         The unsigned 32 bit minimum TTL field that should be
                exported with any RR from this zone.
```

SOA records cause no additional section processing.

All times are in units of seconds.

Most of these fields are pertinent only for name server maintenance operations. However, MINIMUM is used in all query operations that retrieve RRs from a zone. Whenever a RR is sent in a response to a query, the TTL field is set to the maximum of the TTL field from the RR and the MINIMUM field in the appropriate SOA. Thus MINIMUM is a lower bound on the TTL field for all RRs in a zone. Note that this use of MINIMUM should occur when the RRs are copied into the response and not when the zone is loaded from a master file or via a zone transfer. The reason for this provison is to allow future dynamic update facilities to change the SOA RR with known semantics.

3.3.14. TXT RDATA format

```
    +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
    /                   TXT-DATA                    /
    +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
```

where:

```
TXT-DATA        One or more <character-string>s.
```

TXT RRs are used to hold descriptive text. The semantics of the text depends on the domain where it is found.

3.4. Internet specific RRs

3.4.1. A RDATA format

```
    +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
    |                    ADDRESS                    |
    +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
```

where:

```
ADDRESS         A 32 bit Internet address.
```

Hosts that have multiple Internet addresses will have multiple A records.

A records cause no additional section processing. The RDATA section of an A line in a master file is an Internet address expressed as four decimal numbers separated by dots without any imbedded spaces (e.g., "10.2.0.52" or "192.0.5.6").

3.4.2. WKS RDATA format

```
    +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
    |                    ADDRESS                    |
    +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
    |       PROTOCOL        |                       |
    +--+--+--+--+--+--+--+--+                       |
    |                                               |
    /                   <BIT MAP>                   /
    /                                               /
    +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
```

where:

ADDRESS	An 32 bit Internet address
PROTOCOL	An 8 bit IP protocol number
<BIT MAP>	A variable length bit map. The bit map must be a multiple of 8 bits long.

The WKS record is used to describe the well known services supported by a particular protocol on a particular internet address. The PROTOCOL field specifies an IP protocol number, and the bit map has one bit per port of the specified protocol. The first bit corresponds to port 0, the second to port 1, etc. If the bit map does not include a bit for a protocol of interest, that bit is assumed zero. The appropriate values and mnemonics for ports and protocols are specified in [RFC-1010].

For example, if PROTOCOL=TCP (6), the 26th bit corresponds to TCP port 25 (SMTP). If this bit is set, a SMTP server should be listening on TCP port 25; if zero, SMTP service is not supported on the specified address.

The purpose of WKS RRs is to provide availability information for servers for TCP and UDP. If a server supports both TCP and UDP, or has multiple Internet addresses, then multiple WKS RRs are used.

WKS RRs cause no additional section processing.

In master files, both ports and protocols are expressed using mnemonics or decimal numbers.

3.5. IN-ADDR.ARPA domain

The Internet uses a special domain to support gateway location and Internet address to host mapping. Other classes may employ a similar strategy in other domains. The intent of this domain is to provide a guaranteed method to perform host address to host name mapping, and to facilitate queries to locate all gateways on a particular network in the Internet.

Note that both of these services are similar to functions that could be performed by inverse queries; the difference is that this part of the domain name space is structured according to address, and hence can guarantee that the appropriate data can be located without an exhaustive search of the domain space.

The domain begins at IN-ADDR.ARPA and has a substructure which follows the Internet addressing structure.

Domain names in the IN-ADDR.ARPA domain are defined to have up to four labels in addition to the IN-ADDR.ARPA suffix. Each label represents one octet of an Internet address, and is expressed as a character string for a decimal value in the range 0-255 (with leading zeros omitted except in the case of a zero octet which is represented by a single zero).

Host addresses are represented by domain names that have all four labels specified. Thus data for Internet address 10.2.0.52 is located at domain name 52.0.2.10.IN-ADDR.ARPA. The reversal, though awkward to read, allows zones to be delegated which are exactly one network of address space. For example, 10.IN-ADDR.ARPA can be a zone containing data for the ARPANET, while 26.IN-ADDR.ARPA can be a separate zone for MILNET. Address nodes are used to hold pointers to primary host names in the normal domain space.

Network numbers correspond to some non-terminal nodes at various depths in the IN-ADDR.ARPA domain, since Internet network numbers are either 1, 2, or 3 octets. Network nodes are used to hold pointers to the primary host names of gateways attached to that network. Since a gateway is, by definition, on more than one network, it will typically have two or more network nodes which point at it. Gateways will also have host level pointers at their fully qualified addresses.

Both the gateway pointers at network nodes and the normal host pointers at full address nodes use the PTR RR to point back to the primary domain names of the corresponding hosts.

For example, the IN-ADDR.ARPA domain will contain information about the ISI gateway between net 10 and 26, an MIT gateway from net 10 to MIT's net 18, and hosts A.ISI.EDU and MULTICS.MIT.EDU. Assuming that ISI gateway has addresses 10.2.0.22 and 26.0.0.103, and a name MILNET-GW.ISI.EDU, and the MIT gateway has addresses 10.0.0.77 and 18.10.0.4 and a name GW.LCS.MIT.EDU, the domain database would contain:

```
    10.IN-ADDR.ARPA.           PTR MILNET-GW.ISI.EDU.
    10.IN-ADDR.ARPA.           PTR GW.LCS.MIT.EDU.
    18.IN-ADDR.ARPA.           PTR GW.LCS.MIT.EDU.
    26.IN-ADDR.ARPA.           PTR MILNET-GW.ISI.EDU.
    22.0.2.10.IN-ADDR.ARPA.    PTR MILNET-GW.ISI.EDU.
    103.0.0.26.IN-ADDR.ARPA.   PTR MILNET-GW.ISI.EDU.
    77.0.0.10.IN-ADDR.ARPA.    PTR GW.LCS MIT.EDU.
    4.0.10.18.IN-ADDR.ARPA.    PTR GW.LCS.MIT.EDU.
    103.0.3.26.IN-ADDR.ARPA.   PTR A.ISI.EDU.
    6.0.0.10.IN-ADDR.ARPA.     PTR MULTICS.MIT.EDU.
```

Thus a program which wanted to locate gateways on net 10 would originate a query of the form QTYPE=PTR, QCLASS=IN, QNAME=10.IN-ADDR.ARPA. It would receive two RRs in response:

```
    10.IN-ADDR.ARPA.           PTR MILNET-GW.ISI.EDU.
    10.IN-ADDR.ARPA.           PTR GW.LCS.MIT.EDU.
```

The program could then originate QTYPE=A, QCLASS=IN queries for MILNET-GW.ISI.EDU. and GW.LCS.MIT.EDU. to discover the Internet addresses of these gateways.

A resolver which wanted to find the host name corresponding to Internet host address 10.0.0.6 would pursue a query of the form QTYPE=PTR, QCLASS=IN, QNAME=6.0.0.10.IN-ADDR.ARPA, and would receive:

```
    6.0.0.10.IN-ADDR.ARPA.     PTR MULTICS.MIT.EDU.
```

Several cautions apply to the use of these services:

- Since the IN-ADDR.ARPA special domain and the normal domain for a particular host or gateway will be in different zones, the possibility exists that that the data may be inconsistent.

- Gateways will often have two names in separate domains, only one of which can be primary.

- Systems that use the domain database to initialize their routing tables must start with enough gateway information to guarantee that they can access the appropriate name server.

- The gateway data only reflects the existence of a gateway in a manner equivalent to the current HOSTS.TXT file. It doesn't replace the dynamic availability information from GGP or EGP.

3.6. Defining new types, classes, and special namespaces

The previously defined types and classes are the ones in use as of the date of this memo. New definitions should be expected. This section makes some recommendations to designers considering additions to the existing facilities. The mailing list NAMEDROPPERS@SRI-NIC.ARPA is the forum where general discussion of design issues takes place.

In general, a new type is appropriate when new information is to be added to the database about an existing object, or we need new data formats for some totally new object. Designers should attempt to define types and their RDATA formats that are generally applicable to all classes, and which avoid duplication of information. New classes are appropriate when the DNS is to be used for a new protocol, etc which requires new class-specific data formats, or when a copy of the existing name space is desired, but a separate management domain is necessary.

New types and classes need mnemonics for master files; the format of the master files requires that the mnemonics for type and class be disjoint.

TYPE and CLASS values must be a proper subset of QTYPEs and QCLASSes respectively.

The present system uses multiple RRs to represent multiple values of a type rather than storing multiple values in the RDATA section of a single RR. This is less efficient for most applications, but does keep RRs shorter. The multiple RRs assumption is incorporated in some experimental work on dynamic update methods.

The present system attempts to minimize the duplication of data in the database in order to insure consistency. Thus, in order to find the address of the host for a mail exchange, you map the mail domain name to a host name, then the host name to addresses, rather than a direct mapping to host address. This approach is preferred because it avoids the opportunity for inconsistency.

In defining a new type of data, multiple RR types should not be used to create an ordering between entries or express different formats for equivalent bindings, instead this information should be carried in the body of the RR and a single type used. This policy avoids problems with caching multiple types and defining QTYPEs to match multiple types.

For example, the original form of mail exchange binding used two RR types one to represent a "closer" exchange (MD) and one to represent a "less close" exchange (MF). The difficulty is that the presence of one RR type in a cache doesn't convey any information about the other because the query which acquired the cached information might have used a QTYPE of MF, MD, or MAILA (which matched both). The redesigned service used a single type (MX) with a "preference" value in the RDATA section which can order different RRs. However, if any MX RRs are found in the cache, then all should be there.

4. MESSAGES

4.1. Format

All communications inside of the domain protocol are carried in a single format called a message. The top level format of message is divided into 5 sections (some of which are empty in certain cases) shown below:

```
    +---------------------+
    |        Header       |
    +---------------------+
    |       Question      | the question for the name server
    +---------------------+
    |        Answer       | RRs answering the question
    +---------------------+
    |      Authority      | RRs pointing toward an authority
    +---------------------+
    |      Additional     | RRs holding additional information
    +---------------------+
```

The header section is always present. The header includes fields that specify which of the remaining sections are present, and also specify whether the message is a query or a response, a standard query or some other opcode, etc.

The names of the sections after the header are derived from their use in standard queries. The question section contains fields that describe a question to a name server. These fields are a query type (QTYPE), a query class (QCLASS), and a query domain name (QNAME). The last three sections have the same format: a possibly empty list of concatenated resource records (RRs). The answer section contains RRs that answer the question; the authority section contains RRs that point toward an authoritative name server; the additional records section contains RRs which relate to the query, but are not strictly answers for the question.

4.1.1. Header section format

The header contains the following fields:

```
                                    1  1  1  1  1  1
      0  1  2  3  4  5  6  7  8  9  0  1  2  3  4  5
    +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
    |                      ID                       |
    +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
    |QR|   Opcode  |AA|TC|RD|RA|   Z    |   RCODE   |
    +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
    |                    QDCOUNT                    |
    +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
    |                    ANCOUNT                    |
    +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
    |                    NSCOUNT                    |
    +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
    |                    ARCOUNT                    |
    +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
```

where:

ID	A 16 bit identifier assigned by the program that generates any kind of query. This identifier is copied the corresponding reply and can be used by the requester to match up replies to outstanding queries.
QR	A one bit field that specifies whether this message is a query (0), or a response (1).
OPCODE	A four bit field that specifies kind of query in this message. This value is set by the originator of a query and copied into the response. The values are:

0	a standard query (QUERY)
1	an inverse query (IQUERY)
2	a server status request (STATUS)
3-15	reserved for future use

AA Authoritative Answer - this bit is valid in responses, and specifies that the responding name server is an authority for the domain name in question section.

Note that the contents of the answer section may have multiple owner names because of aliases. The AA bit

	corresponds to the name which matches the query name, or the first owner name in the answer section.
TC	TrunCation - specifies that this message was truncated due to length greater than that permitted on the transmission channel.
RD	Recursion Desired - this bit may be set in a query and is copied into the response. If RD is set, it directs the name server to pursue the query recursively. Recursive query support is optional.
RA	Recursion Available - this be is set or cleared in a response, and denotes whether recursive query support is available in the name server.
Z	Reserved for future use. Must be zero in all queries and responses.
RCODE	Response code - this 4 bit field is set as part of responses. The values have the following interpretation:

0	No error condition
1	Format error - The name server was unable to interpret the query.
2	Server failure - The name server was unable to process this query due to a problem with the name server.
3	Name Error - Meaningful only for responses from an authoritative name server, this code signifies that the domain name referenced in the query does not exist.
4	Not Implemented - The name server does not support the requested kind of query.
5	Refuse[illegible] - [illegible]he name server refuses to perform [illegible] specified operation for policy reasons. For example, a name server may not wish to provide the information to the particular requester, or a name server may not wish to perform a particular operation (e.g., zone

```
                                transfer) for particular data.

                6-15            Reserved for future use.

QDCOUNT         an unsigned 16 bit integer specifying the number of
                entries in the question section.

ANCOUNT         an unsigned 16 bit integer specifying the number of
                resource records in the answer section.

NSCOUNT         an unsigned 16 bit integer specifying the number of name
                server resource records in the authority records
                section.

ARCOUNT         an unsigned 16 bit integer specifying the number of
                resource records in the additional records section.
```

4.1.2. Question section format

The question section is used to carry the "question" in most queries, i.e., the parameters that define what is being asked. The section contains QDCOUNT (usually 1) entries, each of the following format:

```
                                    1  1  1  1  1  1
      0  1  2  3  4  5  6  7  8  9  0  1  2  3  4  5
    +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
    |                                               |
    /                     QNAME                     /
    /                                               /
    +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
    |                     QTYPE                     |
    +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
    |                     QCLASS                    |
    +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
```

where:

```
QNAME           a domain name represented as a sequence of labels, where
                each label consists of a length octet followed by that
                number of octets.  The domain name terminates with the
                zero length octet for the null label of the root.  Note
                that this field may be an odd number of octets; no
                padding is used.

QTYPE           a two octet code which specifies the type of the query.
                The values for this field include all codes valid for a
                TYPE field, together with some more general codes which
                can match more than one type of RR.
```

QCLASS	a two octet code that specifies the class of the query. For example, the QCLASS field is IN for the Internet.

4.1.3. Resource record format

The answer, authority, and additional sections all share the same format: a variable number of resource records, where the number of records is specified in the corresponding count field in the header. Each resource record has the following format:

```
                                    1  1  1  1  1  1
      0  1  2  3  4  5  6  7  8  9  0  1  2  3  4  5
    +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
    |                                               |
    /                                               /
    /                      NAME                     /
    |                                               |
    +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
    |                      TYPE                     |
    +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
    |                     CLASS                     |
    +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
    |                      TTL                      |
    |                                               |
    +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
    |                   RDLENGTH                    |
    +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--|
    /                     RDATA                     /
    /                                               /
    +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
```

where:

NAME	a domain name to which this resource record pertains.
TYPE	two octets containing one of the RR type codes. This field specifies the meaning of the data in the RDATA field.
CLASS	two octets which specify the class of the data in the RDATA field.
TTL	a 32 bit unsigned integer that specifies the time interval (in seconds) that the resource record may be cached before it should be discarded. Zero values are interpreted to mean that the RR can only be used for the transaction in progress, and should not be cached.

RDLENGTH	an unsigned 16 bit integer that specifies the length in octets of the RDATA field.
RDATA	a variable length string of octets that describes the resource. The format of this information varies according to the TYPE and CLASS of the resource record. For example, the if the TYPE is A and the CLASS is IN, the RDATA field is a 4 octet ARPA Internet address.

4.1.4. Message compression

In order to reduce the size of messages, the domain system utilizes a compression scheme which eliminates the repetition of domain names in a message. In this scheme, an entire domain name or a list of labels at the end of a domain name is replaced with a pointer to a prior occurance of the same name.

The pointer takes the form of a two octet sequence:

```
    +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
    | 1  1|                OFFSET                   |
    +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
```

The first two bits are ones. This allows a pointer to be distinguished from a label, since the label must begin with two zero bits because labels are restricted to 63 octets or less. (The 10 and 01 combinations are reserved for future use.) The OFFSET field specifies an offset from the start of the message (i.e., the first octet of the ID field in the domain header). A zero offset specifies the first byte of the ID field, etc.

The compression scheme allows a domain name in a message to be represented as either:

- a sequence of labels ending in a zero octet

- a pointer

- a sequence of labels ending with a pointer

Pointers can only be used for occurances of a domain name where the format is not class specific. If this were not the case, a name server or resolver would be required to know the format of all RRs it handled. As yet, there are no such cases, but they may occur in future RDATA formats.

If a domain name is contained in a part of the message subject to a length field (such as the RDATA section of an RR), and compression is used, the length of the compressed name is used in the length calculation, rather than the length of the expanded name.

Programs are free to avoid using pointers in messages they generate, although this will reduce datagram capacity, and may cause truncation. However all programs are required to understand arriving messages that contain pointers.

For example, a datagram might need to use the domain names F.ISI.ARPA, FOO.F.ISI.ARPA, ARPA, and the root. Ignoring the other fields of the message, these domain names might be represented as:

```
       +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
    20 |           1           |           F           |
       +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
    22 |           3           |           I           |
       +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
    24 |           S           |           I           |
       +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
    26 |           4           |           A           |
       +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
    28 |           R           |           P           |
       +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
    30 |           A           |           0           |
       +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+

       +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
    40 |           3           |           F           |
       +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
    42 |           O           |           O           |
       +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
    44 | 1  1|                20                       |
       +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+

       +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
    64 | 1  1|                26                       |
       +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+

       +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
    92 |           0           |                       |
       +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
```

The domain name for F.ISI.ARPA is shown at offset 20. The domain name FOO.F.ISI.ARPA is shown at offset 40; this definition uses a pointer to concatenate a label for FOO to the previously defined F.ISI.ARPA. The domain name ARPA is defined at offset 64 using a pointer to the ARPA component of the name F.ISI.ARPA at 20; note that this pointer relies on ARPA being the last label in the string at 20. The root domain name is defined by a single octet of zeros at 92; the root domain name has no labels.

4.2. Transport

The DNS assumes that messages will be transmitted as datagrams or in a byte stream carried by a virtual circuit. While virtual circuits can be used for any DNS activity, datagrams are preferred for queries due to their lower overhead and better performance. Zone refresh activities must use virtual circuits because of the need for reliable transfer.

The Internet supports name server access using TCP [RFC-793] on server port 53 (decimal) as well as datagram access using UDP [RFC-768] on UDP port 53 (decimal).

4.2.1. UDP usage

Messages sent using UDP user server port 53 (decimal).

Messages carried by UDP are restricted to 512 bytes (not counting the IP or UDP headers). Longer messages are truncated and the TC bit is set in the header.

UDP is not acceptable for zone transfers, but is the recommended method for standard queries in the Internet. Queries sent using UDP may be lost, and hence a retransmission strategy is required. Queries or their responses may be reordered by the network, or by processing in name servers, so resolvers should not depend on them being returned in order.

The optimal UDP retransmission policy will vary with performance of the Internet and the needs of the client, but the following are recommended:

- The client should try other servers and server addresses before repeating a query to a specific address of a server.

- The retransmission interval should be based on prior statistics if possible. Too aggressive retransmission can easily slow responses for the community at large. Depending on how well connected the client is to its expected servers, the minimum retransmission interval should be 2-5 seconds.

More suggestions on server selection and retransmission policy can be found in the resolver section of this memo.

4.2.2. TCP usage

Messages sent over TCP connections use server port 53 (decimal). The message is prefixed with a two byte length field which gives the message length, excluding the two byte length field. This length field allows the low-level processing to assemble a complete message before beginning to parse it.

Several connection management policies are recommended:

- The server should not block other activities waiting for TCP data.

- The server should support multiple connections.

- The server should assume that the client will initiate connection closing, and should delay closing its end of the connection until all outstanding client requests have been satisfied.

- If the server needs to close a dormant connection to reclaim resources, it should wait until the connection has been idle for a period on the order of two minutes. In particular, the server should allow the SOA and AXFR request sequence (which begins a refresh operation) to be made on a single connection. Since the server would be unable to answer queries anyway, a unilateral close or reset may be used instead of a graceful close.

5. MASTER FILES

Master files are text files that contain RRs in text form. Since the contents of a zone can be expressed in the form of a list of RRs a master file is most often used to define a zone, though it can be used to list a cache's contents. Hence, this section first discusses the format of RRs in a master file, and then the special considerations when a master file is used to create a zone in some name server.

5.1. Format

The format of these files is a sequence of entries. Entries are predominantly line-oriented, though parentheses can be used to continue a list of items across a line boundary, and text literals can contain CRLF within the text. Any combination of tabs and spaces act as a delimiter between the separate items that make up an entry. The end of any line in the master file can end with a comment. The comment starts with a ";" (semicolon).

The following entries are defined:

```
    <blank>[<comment>]
    $ORIGIN <domain-name> [<comment>]

    $INCLUDE <file-name> [<domain-name>] [<comment>]

    <domain-name><rr> [<comment>]

    <blank><rr> [<comment>]
```

Blank lines, with or without comments, are allowed anywhere in the file.

Two control entries are defined: $ORIGIN and $INCLUDE. $ORIGIN is followed by a domain name, and resets the current origin for relative domain names to the stated name. $INCLUDE inserts the named file into the current file, and may optionally specify a domain name that sets the relative domain name origin for the included file. $INCLUDE may also have a comment. Note that a $INCLUDE entry never changes the relative origin of the parent file, regardless of changes to the relative origin made within the included file.

The last two forms represent RRs. If an entry for an RR begins with a blank, then the RR is assumed to be owned by the last stated owner. If an RR entry begins with a <domain-name>, then the owner name is reset.

<rr> contents take one of the following forms:

```
    [<TTL>] [<class>] <type> <RDATA>

    [<class>] [<TTL>] <type> <RDATA>
```

The RR begins with optional TTL and class fields, followed by a type and RDATA field appropriate to the type and class. Class and type use the standard mnemonics, TTL is a decimal integer. Omitted class and TTL values are default to the last explicitly stated values. Since type and class mnemonics are disjoint, the parse is unique. (Note that this order is different from the order used in examples and the order used in the actual RRs; the given order allows easier parsing and defaulting.)

<domain-name>s make up a large share of the data in the master file. The labels in the domain name are expressed as character strings and separated by dots. Quoting conventions allow arbitrary characters to be stored in domain names. Domain names that end in a dot are called absolute, and are taken as complete. Domain names which do not end in a dot are called relative; the actual domain name is the c ncatenation of the relative part with an origin specified in a $ORIGIN, $INCLUDE, or as an argument to the master file loading routine. A relative name is an error when no origin is available.

<character-string> is expressed in one or two ways: as a contiguous set of characters without interior spaces, or as a string beginning with a " and ending with a ". Inside a " delimited string any character can occur, except for a " itself, which must be quoted using \ (back slash).

Because these files are text files several special encodings are necessary to allow arbitrary data to be loaded. In particular:

```
                of the root.

@               A free standing @ is used to denote the current origin.

\X              where X is any character other than a digit (0-9), is
                used to quote that character so that its special meaning
                does not apply.  For example, "\." can be used to place
                a dot character in a label.

\DDD            where each D is a digit is the octet corresponding to
                the decimal number described by DDD.  The resulting
                octet is assumed to be text and is not checked for
                special meaning.

( )             Parentheses are used to group data that crosses a line
                boundary.  In effect, line terminations are not
                recognized within parentheses.

;               Semicolon is used to start a comment; the remainder of
                the line is ignored.
```

5.2. Use of master files to define zones

When a master file is used to load a zone, the operation should be suppressed if any errors are encountered in the master file. The rationale for this is that a single error can have widespread consequences. For example, suppose that the RRs defining a delegation have syntax errors; then the server will return authoritative name errors for all names in the subzone (except in the case where the subzone is also present on the server).

Several other validity checks that should be performed in addition to insuring that the file is syntactically correct:

1. All RRs in the file should have the same class.

2. Exactly one SOA RR should be present at the top of the zone.

3. If delegations are present and glue information is required, it should be present.

4. Information present outside of the authoritative nodes in the zone should be glue information, rather than the result of an origin or similar error.

5.3. Master file example

The following is an example file which might be used to define the ISI.EDU zone.and is loaded with an origin of ISI.EDU:

```
@   IN  SOA     VENERA      Action\.domains (
                                 20     ; SERIAL
                                 7200   ; REFRESH
                                 600    ; RETRY
                                 3600000; EXPIRE
                                 60)    ; MINIMUM

        NS      A.ISI.EDU.
        NS      VENERA
        NS      VAXA
        MX      10      VENERA
        MX      20      VAXA

A       A       26.3.0.103

VENERA  A       10.1.0.52
        A       128.9.0.32

VAXA    A       10.2.0.27
        A       128.9.0.33


$INCLUDE <SUBSYS>ISI-MAILBOXES.TXT
```

Where the file <SUBSYS>ISI-MAILBOXES.TXT is:

```
    MOE     MB      A.ISI.EDU.
    LARRY   MB      A.ISI.EDU.
    CURLEY  MB      A.ISI.EDU.
    STOOGES MG      MOE
            MG      LARRY
            MG      CURLEY
```

Note the use of the \ character in the SOA RR to specify the responsible person mailbox "Action.domains@E.ISI.EDU".

6. NAME SERVER IMPLEMENTATION

6.1. Architecture

The optimal structure for the name server will depend on the host operating system and whether the name server is integrated with resolver operations, either by supporting recursive service, or by sharing its database with a resolver. This section discusses implementation considerations for a name server which shares a database with a resolver, but most of these concerns are present in any name server.

6.1.1. Control

A name server must employ multiple concurrent activities, whether they are implemented as separate tasks in the host's OS or multiplexing inside a single name server program. It is simply not acceptable for a name server to block the service of UDP requests while it waits for TCP data for refreshing or query activities. Similarly, a name server should not attempt to provide recursive service without processing such requests in parallel, though it may choose to serialize requests from a single client, or to regard identical requests from the same client as duplicates. A name server should not substantially delay requests while it reloads a zone from master files or while it incorporates a newly refreshed zone into its database.

6.1.2. Database

While name server implementations are free to use any internal data structures they choose, the suggested structure consists of three major parts:

- A "catalog" data structure which lists the zones available to this server, and a "pointer" to the zone data structure. The main purpose of this structure is to find the nearest ancestor zone, if any, for arriving standard queries.

- Separate data structures for each of the zones held by the name server.

- A data structure for cached data. (or perhaps separate caches for different classes)

All of these data structures can be implemented an identical tree structure format, with different data chained off the nodes in different parts: in the catalog the data is pointers to zones, while in the zone and cache data structures, the data will be RRs. In designing the tree framework the designer should recognize that query processing will need to traverse the tree using case-insensitive label comparisons; and that in real data, a few nodes have a very high branching factor (100-1000 or more), but the vast majority have a very low branching factor (0-1).

One way to solve the case problem is to store the labels for each node in two pieces: a standardized-case representation of the label where all ASCII characters are in a single case, together with a bit mask that denotes which characters are actually of a different case. The branching factor diversity can be handled using a simple linked list for a node until the branching factor exceeds some threshold, and transitioning to a hash structure after the threshold is exceeded. In any case, hash structures used to store tree sections must insure that hash functions and procedures preserve the casing conventions of the DNS.

The use of separate structures for the different parts of the database is motivated by several factors:

- The catalog structure can be an almost static structure that need change only when the system administrator changes the zones supported by the server. This structure can also be used to store parameters used to control refreshing activities.

- The individual data structures for zones allow a zone to be replaced simply by changing a pointer in the catalog. Zone refresh operations can build a new structure and, when complete, splice it into the database via a simple pointer replacement. It is very important that when a zone is refreshed, queries should not use old and new data simultaneously.

- With the proper search procedures, authoritative data in zones will always "hide", and hence take precedence over, cached data.

- Errors in zone definitions that cause overlapping zones, etc., may cause erroneous responses to queries, but problem determination is simplified, and the contents of one "bad" zone can't corrupt another.

- Since the cache is most frequently updated, it is most vulnerable to corruption during system restarts. It can also become full of expired RR data. In either case, it can easily be discarded without disturbing zone data.

A major aspect of database design is selecting a structure which allows the name server to deal with crashes of the name server's host. State information which a name server should save across system crashes includes the catalog structure (including the state of refreshing for each zone) and the zone data itself.

6.1.3. Time

Both the TTL data for RRs and the timing data for refreshing activities depends on 32 bit timers in units of seconds. Inside the database, refresh timers and TTLs for cached data conceptually "count down", while data in the zone stays with constant TTLs.

A recommended implementation strategy is to store time in two ways: as a relative increment and as an absolute time. One way to do this is to use positive 32 bit numbers for one type and negative numbers for the other. The RRs in zones use relative times; the refresh timers and cache data use absolute times. Absolute numbers are taken with respect to some known origin and converted to relative values when placed in the response to a query. When an absolute TTL is negative after conversion to relative, then the data is expired and should be ignored.

6.2. Standard query processing

The major algorithm for standard query processing is presented in [RFC-1034].

When processing queries with QCLASS=*, or some other QCLASS which matches multiple classes, the response should never be authoritative unless the server can guarantee that the response covers all classes.

When composing a response, RRs which are to be inserted in the additional section, but duplicate RRs in the answer or authority sections, may be omitted from the additional section.

When a response is so long that truncation is required, the truncation should start at the end of the response and work forward in the datagram. Thus if there is any data for the authority section, the answer section is guaranteed to be unique.

The MINIMUM value in the SOA should be used to set a floor on the TTL of data distributed from a zone. This floor function should be done when the data is copied into a response. This will allow future dynamic update protocols to change the SOA MINIMUM field without ambiguous semantics.

6.3. Zone refresh and reload processing

In spite of a server's best efforts, it may be unable to load zone data from a master file due to syntax errors, etc., or be unable to refresh a zone within the its expiration parameter. In this case, the name server should answer queries as if it were not supposed to possess the zone.

If a master is sending a zone out via AXFR, and a new version is created during the transfer, the master should continue to send the old version if possible. In any case, it should never send part of one version and part of another. If completion is not possible, the master should reset the connection on which the zone transfer is taking place.

6.4. Inverse queries (Optional)

Inverse queries are an optional part of the DNS. Name servers are not required to support any form of inverse queries. If a name server receives an inverse query that it does not support, it returns an error response with the "Not Implemented" error set in the header. While inverse query support is optional, all name servers must be at least able to return the error response.

6.4.1. The contents of inverse queries and responses

Inverse queries reverse the mappings performed by standard query operations; while a standard query maps a domain name to a resource, an inverse query maps a resource to a domain name. For example, a standard query might bind a domain name to a host address; the corresponding inverse query binds the host address to a domain name.

Inverse queries take the form of a single RR in the answer section of the message, with an empty question section. The owner name of the query RR and its TTL are not significant. The response carries questions in the question section which identify all names possessing the query RR WHICH THE NAME SERVER KNOWS. Since no name server knows about all of the domain name space, the response can never be assumed to be complete. Thus inverse queries are primarily useful for database management and debugging activities. Inverse queries are NOT an acceptable method of mapping host addresses to host names; use the IN-ADDR.ARPA domain instead.

Where possible, name servers should provide case-insensitive comparisons for inverse queries. Thus an inverse query asking for an MX RR of "Venera.isi.edu" should get the same response as a query for "VENERA.ISI.EDU"; an inverse query for HINFO RR "IBM-PC UNIX" should produce the same result as an inverse query for "IBM-pc unix". However, this cannot be guaranteed because name servers may possess RRs that contain character strings but the name server does not know that the data is character.

When a name server processes an inverse query, it either returns:

1. zero, one, or multiple domain names for the specified resource as QNAMEs in the question section

   2. an error code indicating that the name server doesn't support
      inverse mapping of the specified resource type.

When the response to an inverse query contains one or more QNAMEs, the owner name and TTL of the RR in the answer section which defines the inverse query is modified to exactly match an RR found at the first QNAME.

RRs returned in the inverse queries cannot be cached using the same mechanism as is used for the replies to standard queries. One reason for this is that a name might have multiple RRs of the same type, and only one would appear. For example, an inverse query for a single address of a multiply homed host might create the impression that only one address existed.

6.4.2. Inverse query and response example The overall structure of an inverse query for retrieving the domain name that corresponds to Internet address 10.1.0.52 is shown below:

```
                  +-----------------------------------------+
    Header        |          OPCODE=IQUERY, ID=997          |
                  +-----------------------------------------+
   Question       |                 <empty>                 |
                  +-----------------------------------------+
    Answer        |        <anyname> A IN 10.1.0.52         |
                  +-----------------------------------------+
   Authority      |                 <empty>                 |
                  +-----------------------------------------+
  Additional      |                 <empty>                 |
                  +-----------------------------------------+
```

This query asks for a question whose answer is the Internet style address 10.1.0.52. Since the owner name is not known, any domain name can be used as a placeholder (and is ignored). A single octet of zero, signifying the root, is usually used because it minimizes the length of the message. The TTL of the RR is not significant. The response to this query might be:

```
                 +---------------------------------------------+
   Header        |          OPCODE=RESPONSE, ID=997            |
                 +---------------------------------------------+
  Question       |QTYPE=A, QCLASS=IN, QNAME=VENERA.ISI.EDU     |
                 +---------------------------------------------+
   Answer        |  VENERA.ISI.EDU  A IN 10.1.0.52             |
                 +---------------------------------------------+
  Authority      |                  <empty>                    |
                 +---------------------------------------------+
 Additional      |                  <empty>                    |
                 +---------------------------------------------+
```

Note that the QTYPE in a response to an inverse query is the same as the TYPE field in the answer section of the inverse query. Responses to inverse queries may contain multiple questions when the inverse is not unique. If the question section in the response is not empty, then the RR in the answer section is modified to correspond to be an exact copy of an RR at the first QNAME.

6.4.3. Inverse query processing

Name servers that support inverse queries can support these operations through exhaustive searches of their databases, but this becomes impractical as the size of the database increases. An alternative approach is to invert the database according to the search key.

For name servers that support multiple zones and a large amount of data, the recommended approach is separate inversions for each zone. When a particular zone is changed during a refresh, only its inversions need to be redone.

Support for transfer of this type of inversion may be included in future versions of the domain system, but is not supported in this version.

6.5. Completion queries and responses

The optional completion services described in RFC-882 and RFC-883 have been deleted. Redesigned services may become available in the future.

7. RESOLVER IMPLEMENTATION

The top levels of the recommended resolver algorithm are discussed in [RFC-1034]. This section discusses implementation details assuming the database structure suggested in the name server implementation section of this memo.

7.1. Transforming a user request into a query

The first step a resolver takes is to transform the client's request, stated in a format suitable to the local OS, into a search specification for RRs at a specific name which match a specific QTYPE and QCLASS. Where possible, the QTYPE and QCLASS should correspond to a single type and a single class, because this makes the use of cached data much simpler. The reason for this is that the presence of data of one type in a cache doesn't confirm the existence or non-existence of data of other types, hence the only way to be sure is to consult an authoritative source. If QCLASS=* is used, then authoritative answers won't be available.

Since a resolver must be able to multiplex multiple requests if it is to perform its function efficiently, each pending request is usually represented in some block of state information. This state block will typically contain:

- A timestamp indicating the time the request began. The timestamp is used to decide whether RRs in the database can be used or are out of date. This timestamp uses the absolute time format previously discussed for RR storage in zones and caches. Note that when an RRs TTL indicates a relative time, the RR must be timely, since it is part of a zone. When the RR has an absolute time, it is part of a cache, and the TTL of the RR is compared against the timestamp for the start of the request.

  Note that using the timestamp is superior to using a current time, since it allows RRs with TTLs of zero to be entered in the cache in the usual manner, but still used by the current request, even after intervals of many seconds due to system load, query retransmission timeouts, etc.

- Some sort of parameters to limit the amount of work which will be performed for this request.

  The amount of work which a resolver will do in response to a client request must be limited to guard against errors in the database, such as circular CNAME references, and operational problems, such as network partition which prevents the resolver from accessing the name servers it needs. While local limits on the number of times a resolver will retransmit a particular query to a particular name server address are essential, the resolver should have a global per-request counter to limit work on a single request. The counter should be set to some initial value and decremented whenever the resolver performs any action (retransmission timeout, retransmission, etc.) If the counter passes zero, the request is terminated with a temporary error.

Note that if the resolver structure allows one request to start others in parallel, such as when the need to access a name server for one request causes a parallel resolve for the name server's addresses, the spawned request should be started with a lower counter. This prevents circular references in the database from starting a chain reaction of resolver activity.

- The SLIST data structure discussed in [RFC-1034].

  This structure keeps track of the state of a request if it must wait for answers from foreign name servers.

7.2. Sending the queries

As described in [RFC-1034], the basic task of the resolver is to formulate a query which will answer the client's request and direct that query to name servers which can provide the information. The resolver will usually only have very strong hints about which servers to ask, in the form of NS RRs, and may have to revise the query, in response to CNAMEs, or revise the set of name servers the resolver is asking, in response to delegation responses which point the resolver to name servers closer to the desired information. In addition to the information requested by the client, the resolver may have to call upon its own services to determine the address of name servers it wishes to contact.

In any case, the model used in this memo assumes that the resolver is multiplexing attention between multiple requests, some from the client, and some internally generated. Each request is represented by some state information, and the desired behavior is that the resolver transmit queries to name servers in a way that maximizes the probability that the request is answered, minimizes the time that the request takes, and avoids excessive transmissions. The key algorithm uses the state information of the request to select the next name server address to query, and also computes a timeout which will cause the next action should a response not arrive. The next action will usually be a transmission to some other server, but may be a temporary error to the client.

The resolver always starts with a list of server names to query (SLIST). This list will be all NS RRs which correspond to the nearest ancestor zone that the resolver knows about. To avoid startup problems, the resolver should have a set of default servers which it will ask should it have no current NS RRs which are appropriate. The resolver then adds to SLIST all of the known addresses for the name servers, and may start parallel requests to acquire the addresses of the servers when the resolver has the name, but no addresses, for the name servers.

To complete initialization of SLIST, the resolver attaches whatever history information it has to the each address in SLIST. This will usually consist of some sort of weighted averages for the response time of the address, and the batting average of the address (i.e., how often the address responded at all to the request). Note that this information should be kept on a per address basis, rather than on a per name server basis, because the response time and batting average of a particular server may vary considerably from address to address. Note also that this information is actually specific to a resolver address / server address pair, so a resolver with multiple addresses may wish to keep separate histories for each of its addresses. Part of this step must deal with addresses which have no such history; in this case an expected round trip time of 5-10 seconds should be the worst case, with lower estimates for the same local network, etc.

Note that whenever a delegation is followed, the resolver algorithm reinitializes SLIST.

The information establishes a partial ranking of the available name server addresses. Each time an address is chosen and the state should be altered to prevent its selection again until all other addresses have been tried. The timeout for each transmission should be 50-100% greater than the average predicted value to allow for variance in response.

Some fine points:

- The resolver may encounter a situation where no addresses are available for any of the name servers named in SLIST, and where the servers in the list are precisely those which would normally be used to look up their own addresses. This situation typically occurs when the glue address RRs have a smaller TTL than the NS RRs marking delegation, or when the resolver caches the result of a NS search. The resolver should detect this condition and restart the search at the next ancestor zone, or alternatively at the root.

- If a resolver gets a server error or other bizarre response from a name server, it should remove it from SLIST, and may wish to schedule an immediate transmission to the next candidate server address.

7.3. Processing responses

The first step in processing arriving response datagrams is to parse the response. This procedure should include:

- Check the header for reasonableness. Discard datagrams which are queries when responses are expected.

- Parse the sections of the message, and insure that all RRs are correctly formatted.

- As an optional step, check the TTLs of arriving data looking for RRs with excessively long TTLs. If a RR has an excessively long TTL, say greater than 1 week, either discard the whole response, or limit all TTLs in the response to 1 week.

The next step is to match the response to a current resolver request. The recommended strategy is to do a preliminary matching using the ID field in the domain header, and then to verify that the question section corresponds to the information currently desired. This requires that the transmission algorithm devote several bits of the domain ID field to a request identifier of some sort. This step has several fine points:

- Some name servers send their responses from different addresses than the one used to receive the query. That is, a resolver cannot rely that a response will come from the same address which it sent the corresponding query to. This name server bug is typically encountered in UNIX systems.

- If the resolver retransmits a particular request to a name server it should be able to use a response from any of the transmissions. However, if it is using the response to sample the round trip time to access the name server, it must be able to determine which transmission matches the response (and keep transmission times for each outgoing message), or only calculate round trip times based on initial transmissions.

- A name server will occasionally not have a current copy of a zone which it should have according to some NS RRs. The resolver should simply remove the name server from the current SLIST, and continue.

7.4. Using the cache

In general, we expect a resolver to cache all data which it receives in responses since it may be useful in answering future client requests. However, there are several types of data which should not be cached:

- When several RRs of the same type are available for a particular owner name, the resolver should either cache them all or none at all. When a response is truncated, and a resolver doesn't know whether it has a complete set, it should not cache a possibly partial set of RRs.

- Cached data should never be used in preference to authoritative data, so if caching would cause this to happen the data should not be cached.

- The results of an inverse query should not be cached.

- The results of standard queries where the QNAME contains "*" labels if the data might be used to construct wildcards. The reason is that the cache does not necessarily contain existing RRs or zone boundary information which is necessary to restrict the application of the wildcard RRs.

- RR data in responses of dubious reliability. When a resolver receives unsolicited responses or RR data other than that requested, it should discard it without caching it. The basic implication is that all sanity checks on a packet should be performed before any of it is cached.

In a similar vein, when a resolver has a set of RRs for some name in a response, and wants to cache the RRs, it should check its cache for already existing RRs. Depending on the circumstances, either the data in the response or the cache is preferred, but the two should never be combined. If the data in the response is from authoritative data in the answer section, it is always preferred.

8. MAIL SUPPORT

The domain system defines a standard for mapping mailboxes into domain names, and two methods for using the mailbox information to derive mail routing information. The first method is called mail exchange binding and the other method is mailbox binding. The mailbox encoding standard and mail exchange binding are part of the DNS official protocol, and are the recommended method for mail routing in the Internet. Mailbox binding is an experimental feature which is still under development and subject to change.

The mailbox encoding standard assumes a mailbox name of the form "<local-part>@<mail-domain>". While the syntax allowed in each of these sections varies substantially between the various mail internets, the preferred syntax for the ARPA Internet is given in [RFC-822].

The DNS encodes the <local-part> as a single label, and encodes the <mail-domain> as a domain name. The single label from the <local-part> is prefaced to the domain name from <mail-domain> to form the domain name corresponding to the mailbox. Thus the mailbox HOSTMASTER@SRI-NIC.ARPA is mapped into the domain name HOSTMASTER.SRI-NIC.ARPA. If the <local-part> contains dots or other special characters, its representation in a master file will require the use of backslash quoting to ensure that the domain name is properly encoded. For example, the mailbox Action.domains@ISI.EDU would be represented as Action\.domains.ISI.EDU.

8.1. Mail exchange binding

Mail exchange binding uses the <mail-domain> part of a mailbox specification to determine where mail should be sent. The <local-part> is not even consulted. [RFC-974] specifies this method in detail, and should be consulted before attempting to use mail exchange support.

One of the advantages of this method is that it decouples mail destination naming from the hosts used to support mail service, at the cost of another layer of indirection in the lookup function. However, the addition layer should eliminate the need for complicated "%", "!", etc encodings in <local-part>.

The essence of the method is that the <mail-domain> is used as a domain name to locate type MX RRs which list hosts willing to accept mail for <mail-domain>, together with preference values which rank the hosts according to an order specified by the administrators for <mail-domain>.

In this memo, the <mail-domain> ISI.EDU is used in examples, together with the hosts VENERA.ISI.EDU and VAXA.ISI.EDU as mail exchanges for ISI.EDU. If a mailer had a message for Mockapetris@ISI.EDU, it would route it by looking up MX RRs for ISI.EDU. The MX RRs at ISI.EDU name VENERA.ISI.EDU and VAXA.ISI.EDU, and type A queries can find the host addresses.

8.2. Mailbox binding (Experimental)

In mailbox binding, the mailer uses the entire mail destination specification to construct a domain name. The encoded domain name for the mailbox is used as the QNAME field in a QTYPE=MAILB query.

Several outcomes are possible for this query:

1. The query can return a name error indicating that the mailbox does not exist as a domain name.

   In the long term, this would indicate that the specified mailbox doesn't exist. However, until the use of mailbox binding is universal, this error condition should be interpreted to mean that the organization identified by the global part does not support mailbox binding. The appropriate procedure is to revert to exchange binding at this point.

2. The query can return a Mail Rename (MR) RR.

   The MR RR carries new mailbox specification in its RDATA field. The mailer should replace the old mailbox with the new one and retry the operation.

3. The query can return a MB RR.

   The MB RR carries a domain name for a host in its RDATA field. The mailer should deliver the message to that host via whatever protocol is applicable, e.g., b,SMTP.

4. The query can return one or more Mail Group (MG) RRs.

   This condition means that the mailbox was actually a mailing list or mail group, rathe than a single mailbox. Each MG RR has a RDATA field that identifies a mailbox that is a member of the group. The mailer should deliver a copy of the message to each member.

5. The query can return a MB RR as well as one or more MG RRs.

   This condition means the the mailbox was actually a mailing list. The mailer can either deliver the message to the host specified by the MB RR, which will in turn do the delivery to all members, or the mailer can use the MG RRs to do the expansion itself.

In any of these cases, the response may include a Mail Information (MINFO) RR. This RR is usually associated with a mail group, but is legal with a MB. The MINFO RR identifies two mailboxes. One of these identifies a responsible person for the original mailbox name. This mailbox should be used for requests to be added to a mail group, etc. The second mailbox name in the MINFO RR identifies a mailbox that should receive error messages for mail failures. This is particularly appropriate for mailing lists when errors in member names should be reported to a person other than the one who sends a message to the list.

New fields may be added to this RR in the future.

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Describes a name service for CSNET which is independent from the DNS and DNS use in the CSNET.

Index

1.4. DNS Encoding of Network Names and Other Types [RFC 1101]

```
Network Working Group                                    P. Mockapetris
Request for Comments: 1101                                          ISI
Updates: RFCs 1034, 1035                                     April 1989
```

DNS Encoding of Network Names and Other Types

1. STATUS OF THIS MEMO

This RFC proposes two extensions to the Domain Name System:

- A specific method for entering and retrieving RRs which map between network names and numbers.

- Ideas for a general method for describing mappings between arbitrary identifiers and numbers.

The method for mapping between network names and addresses is a proposed standard, the ideas for a general method are experimental.

This RFC assumes that the reader is familiar with the DNS [RFC 1034, RFC 1035] and its use. The data shown is for pedagogical use and does not necessarily reflect the real Internet.

Distribution of this memo is unlimited.

2. INTRODUCTION

The DNS is extensible and can be used for a virtually unlimited number of data types, name spaces, etc. New type definitions are occasionally necessary as are revisions or deletions of old types (e.g., MX replacement of MD and MF [RFC 974]), and changes described in [RFC 973]. This RFC describes changes due to the general need to map between identifiers and values, and a specific need for network name support.

Users wish to be able to use the DNS to map between network names and numbers. This need is the only capability found in HOSTS.TXT which is not available from the DNS. In designing a method to do this, there were two major areas of concern:

- Several tradeoffs involving control of network names, the syntax of network names, backward compatibility, etc.

- A desire to create a method which would be sufficiently general to set a good precedent for future mappings, for example, between TCP-port names and numbers, autonomous system names and numbers, X.500 Relative Distinguished Names (RDNs) and their servers, or whatever.

It was impossible to reconcile these two areas of concern for network names because of the desire to unify network number support within existing IP address to host name support. The existing support is the IN-ADDR.ARPA section of the DNS name space. As a result this RFC describes one structure for network names which builds on the existing support for host names, and another family of structures for future yellow pages (YP) functions such as conversions between TCP-port numbers and mnemonics.

Both structures are described in following sections. Each structure has a discussion of design issues and specific structure recommendations.

We wish to avoid defining structures and methods which can work but do not because of indifference or errors on the part of system administrators when maintaining the database. The WKS RR is an example. Thus, while we favor distribution as a general method, we also recognize that centrally maintained tables (such as HOSTS.TXT) are usually more consistent though less maintainable and timely. Hence we recommend both specific methods for mapping network names, addresses, and subnets, as well as an instance of the general method for mapping between allocated network numbers and network names. (Allocation is centrally performed by the SRI Network Information Center, aka the NIC).

3. NETWORK NAME ISSUES AND DISCUSSION

The issues involved in the design were the definition of network name syntax, the mappings to be provided, and possible support for similar functions at the subnet level.

3.1. Network name syntax

The current syntax for network names, as defined by [RFC 952] is an alphanumeric string of up to 24 characters, which begins with an alpha, and may include "." and "-" except as first and last characters. This is the format which was also used for host names before the DNS. Upward compatibility with existing names might be a goal of any new scheme.

However, the present syntax has been used to define a flat name space, and hence would prohibit the same distributed name allocation method used for host names. There is some sentiment for allowing the NIC to continue to allocate and regulate network names, much as it allocates numbers, but the majority opinion favors local control of network names. Although it would be possible to provide a flat space or a name space in which, for example, the last label of a domain name captured the old-style network name, any such approach would add complexity to the method and create different rules for network names and host names.

For these reasons, we assume that the syntax of network names will be the same as the expanded syntax for host names permitted in [HR]. The new syntax expands the set of names to allow leading digits, so long as the resulting representations do not conflict with IP addresses in decimal octet form. For example, 3Com.COM and 3M.COM are now legal, although 26.0.0.73.COM is not. See [HR] for details.

The price is that network names will get as complicated as host names. An administrator will be able to create network names in any domain under his control, and also create network number to name entries in IN-ADDR.ARPA domains under his control. Thus, the name for the ARPANET might become NET.ARPA, ARPANET.ARPA or Arpa-network.MIL., depending on the preferences of the owner.

3.2. Mappings

The desired mappings, ranked by priority with most important first, are:

- Mapping a IP address or network number to a network name.

  This mapping is for use in debugging tools and status displays of various sorts. The conversion from IP address to network number is well known for class A, B, and C IP addresses, and involves a simple mask operation. The needs of other classes are not yet defined and are ignored for the rest of this RFC.

- Mapping a network name to a network address.

  This facility is of less obvious application, but a symmetrical mapping seems desirable.

- Mapping an organization to its network names and numbers.

  This facility is useful because it may not always be possible to guess the local choice for network names, but the organization name is often well known.

- Similar mappings for subnets, even when nested.

  The primary application is to be able to identify all of the subnets involved in a particular IP address. A secondary requirement is to retrieve address mask information.

3.3. Network address section of the name space

The network name syntax discussed above can provide domain names which will contain mappings from network names to various quantities, but we also need a section of the name space, organized by network and subnet number to hold the inverse mappings.

The choices include:

- The same network number slots already assigned and delegated in the IN-ADDR.ARPA section of the name space.

  For example, 10.IN-ADDR.ARPA for class A net 10, 2.128.IN-ADDR.ARPA for class B net 128.2, etc.

- Host-zero addresses in the IN-ADDR.ARPA tree. (A host field of all zero in an IP address is prohibited because of confusion related to broadcast addresses, et al.)

  For example, 0.0.0.10.IN-ADDR.ARPA for class A net 10, 0.0.2.128.IN-ADDR.arpa for class B net 128.2, etc. Like the first scheme, it uses in-place name space delegations to distribute control.

  The main advantage of this scheme over the first is that it allows convenient names for subnets as well as networks. A secondary advantage is that it uses names which are not in use already, and hence it is possible to test whether an organization has entered this information in its domain database.

- Some new section of the name space.

  While this option provides the most opportunities, it creates a need to delegate a whole new name space. Since the IP address space is so closely related to the network number space, most believe that the overhead of creating such a new space is overwhelming and would lead to the WKS syndrome. (As of February, 1989, approximately 400 sections of the IN-ADDR.ARPA tree are already delegated, usually at network boundaries.)

4. SPECIFICS FOR NETWORK NAME MAPPINGS

The proposed solution uses information stored at:

- Names in the IN-ADDR.ARPA tree that correspond to host-zero IP addresses. The same method is used for subnets in a nested fashion. For example, 0.0.0.10.IN-ADDR.ARPA. for net 10.

  Two types of information are stored here: PTR RRs which point to the network name in their data sections, and A RRs, which are present if the network (or subnet) is subnetted further. If a type A RR is present, then it has the address mask as its data. The general form is:

  ```
  <reversed-host-zero-number>.IN-ADDR.ARPA. PTR <network-name>
  <reversed-host-zero-number>.IN-ADDR.ARPA. A   <subnet-mask>
  ```

  For example:

  ```
  0.0.0.10.IN-ADDR.ARPA.  PTR     ARPANET.ARPA.
  ```

  or

  ```
  0.0.2.128.IN-ADDR.ARPA. PTR     cmu-net.cmu.edu.
                          A       255.255.255.0
  ```

  In general, this information will be added to an existing master file for some IN-ADDR.ARPA domain for each network involved. Similar RRs can be used at host-zero subnet entries.

- Names which are network names.

  The data stored here is PTR RRs pointing at the host-zero entries. The general form is:

  ```
  <network-name> ptr <reversed-host-zero-number>.IN-ADDR.ARPA
  ```

  For example:

  ```
  ARPANET.ARPA.           PTR     0.0.0.10.IN-ADDR.ARPA.
  ```

  or

  ```
  isi-net.isi.edu.        PTR     0.0.9.128.IN-ADDR.ARPA.
  ```

  In general, this information will be inserted in the master file for the domain name of the organization; this is a

```
        different file from that which holds the information below
        IN-ADDR.ARPA.  Similar PTR RRs can be used at subnet names.

      - Names corresponding to organizations.

        The data here is one or more PTR RRs pointing at the
        IN-ADDR.ARPA names corresponding to host-zero entries for
        networks.

        For example:

        ISI.EDU.          PTR     0.0.9.128.IN-ADDR.ARPA.

        MCC.COM.          PTR     0.167.5.192.IN-ADDR.ARPA.
                          PTR     0.168.5.192.IN-ADDR.ARPA.
                          PTR     0.169.5.192.IN-ADDR.ARPA.
                          PTR     0.0.62.128.IN-ADDR.ARPA.

4.1. A simple example

   The ARPANET is a Class A network without subnets.  The RRs which
   would be added, assuming the ARPANET.ARPA was selected as a network
   name, would be:

   ARPA.                      PTR     0.0.0.10.IN-ADDR.ARPA.

   ARPANET.ARPA.              PTR     0.0 0.10 IN-ADDR.ARPA.

   0.0.0.10.IN-ADDR.ARPA.     PTR     ARPANET.ARPA.

   The first RR states that the organization named ARPA owns net 10 (It
   might also own more network numbers, and these would be represented
   with an additional RR per net.)  The second states that the network
   name ARPANET.ARPA. maps to net 10.  The last states that net 10 is
   named ARPANET.ARPA.

   Note that all of the usual host and corresponding IN-ADDR.ARPA
   entries would still be required.

4.2. A complicated, subnetted example

   The ISI network is 128.9, a class B number.  Suppose the ISI network
   was organized into two levels of subnet, with the first level using
   an additional 8 bits of address, and the second level using 4 bits,
   for address masks of x'FFFFFF00' and X'FFFFFFF0'.

   Then the following RRs would be entered in ISI's master file for the
   ISI.EDU zone:
```

```
   ; Define network entry
   isi-net.isi.edu.               PTR  0.0.9.128.IN-ADDR.ARPA.

   ; Define first level subnets
   div1-subnet.isi.edu.           PTR  0.1.9.128.IN-ADDR.ARPA.
   div2-subnet.isi.edu.           PTR  0.2.9.128.IN-ADDR.ARPA.

   ; Define second level subnets
   inc-subsubnet.isi.edu.         PTR  16.2.9.128.IN-ADDR.ARPA.

   in the 9.128.IN-ADDR.ARPA zone:

   ; Define network number and address mask
   0.0.9.128.IN-ADDR.ARPA.        PTR  isi-net.isi.edu.
                                  A    255.255.255.0  ;aka X'FFFFFF00'

   ; Define one of the first level subnet numbers and masks
   0.1.9.128.IN-ADDR.ARPA.        PTR  div1-subnet.isi.edu.
                                  A    255.255.255.240 ;aka X'FFFFFFF0'

   ; Define another first level subnet number and mask
   0.2.9.128.IN-ADDR.ARPA.        PTR  div2-subnet.isi.edu.
                                  A    255.255.255.240 ;aka X'FFFFFFF0'

   ; Define second level subnet number
   16.2.9.128.IN-ADDR.ARPA.       PTR  inc-subsubnet.isi.edu.
```

This assumes that the ISI network is named isi-net.isi.edu., first level subnets are named div1-subnet.isi.edu. and div2-subnet.isi.edu., and a second level subnet is called inc-subsubnet.isi.edu. (In a real system as complicated as this there would be more first and second level subnets defined, but we have shown enough to illustrate the ideas.)

4.3. Procedure for using an IP address to get network name

Depending on whether the IP address is class A, B, or C, mask off the high one, two, or three bytes, respectively. Reverse the octets, suffix IN-ADDR.ARPA, and do a PTR query.

For example, suppose the IP address is 10.0.0.51.

1. Since this is a class A address, use a mask x'FF000000' and get 10.0.0.0.

2. Construct the name 0.0.0.10.IN-ADDR.ARPA.

3. Do a PTR query. Get back

```
0.0.0.10.IN-ADDR.ARPA.  PTR     ARPANET.ARPA.
```

4. Conclude that the network name is "ARPANET.ARPA."

Suppose that the IP address is 128.9.2.17.

1. Since this is a class B address, use a mask of x'FFFF0000' and get 128.9.0.0.

2. Construct the name 0.0.9.128.IN-ADDR.ARPA.

3. Do a PTR query. Get back

```
0.0.9.128.IN-ADDR.ARPA.        PTR     isi-net.isi.edu
```

4. Conclude that the network name is "isi-net.isi.edu."

4.4. Procedure for finding all subnets involved with an IP address

This is a simple extension of the IP address to network name method. When the network entry is located, do a lookup for a possible A RR. If the A RR is found, look up the next level of subnet using the original IP address and the mask in the A RR. Repeat this procedure until no A RR is found.

For example, repeating the use of 128.9.2.17.

1. As before construct a query for 0.0.9.128.IN-ADDR.ARPA. Retrieve:

```
0.0.9.128.IN-ADDR.ARPA.  PTR     isi-net.isi.edu.
                         A       255.255.255.0
```

2. Since an A RR was found, repeat using mask from RR (255.255.255.0), constructing a query for 0.2.9.128.IN-ADDR.ARPA. Retrieve:

```
0.2.9.128.IN-ADDR.ARPA.  PTR     div2-subnet.isi.edu.
                         A       255.255.255.240
```

3. Since another A RR was found, repeat using mask 255.255.255.240 (x'FFFFFFF0'). constructing a query for 16.2.9.128.IN-ADDR.ARPA. Retrieve:

```
16.2.9.128.IN-ADDR.ARPA. PTR     inc-subsubnet.isi.edu.
```

4. Since no A RR is present at 16.2.9.128.IN-ADDR.ARPA., there are no more subnet levels.

5. YP ISSUES AND DISCUSSION

The term "Yellow Pages" is used in almost as many ways as the term "domain", so it is useful to define what is meant herein by YP. The general problem to be solved is to create a method for creating mappings from one kind of identifier to another, often with an inverse capability. The traditional methods are to search or use a precomputed index of some kind.

Searching is impractical when the search is too large, and precomputed indexes are possible only when it is possible to specify search criteria in advance, and pay for the resources necessary to build the index. For example, it is impractical to search the entire domain tree to find a particular address RR, so we build the IN-ADDR.ARPA YP. Similarly, we could never build an Internet-wide index of "hosts with a load average of less than 2" in less time than it would take for the data to change, so indexes are a useless approach for that problem.

Such a precomputed index is what we mean by YP, and we regard the IN-ADDR.ARPA domain as the first instance of a YP in the DNS. Although a single, centrally-managed YP for well-known values such as TCP-port is desirable, we regard organization-specific YPs for, say, locally defined TCP ports as a natural extension, as are combinations of YPs using search lists to merge the two.

In examining Internet Numbers [RFC 997] and Assigned Numbers [RFC 1010], it is clear that there are several mappings which might be of value. For example:

```
<assigned-network-name> <==> <IP-address>
<autonomous-system-id>  <==> <number>
<protocol-id>           <==> <number>
<port-id>               <==> <number>
<ethernet-type>         <==> <number>
<public-data-net>       <==> <IP-address>
```

Following the IN-ADDR example, the YP takes the form of a domain tree organized to optimize retrieval by search key and distribution via normal DNS rules. The name used as a key must include:

1. A well known origin. For example, IN-ADDR.ARPA is the current IP-address to host name YP.

2. A "from" data type. This identifies the input type of the mapping. This is necessary because we may be mapping something as anonymous as a number to any number of mnemonics, etc.

3. A "to" data type. Since we assume several symmetrical mnemonic <==> number mappings, this is also necessary.

This ordering reflects the natural scoping of control, and hence the order of the components in a domain name. Thus domain names would be of the form:

```
<from-value>.<to-data-type>.<from-data-type>.<YP-origin>
```

To make this work, we need to define well-know strings for each of these metavariables, as well as encoding rules for converting a <from-value> into a domain name. We might define:

```
<YP-origin>      :=YP
<from-data-type>:=TCP-port | IN-ADDR | Number |
                   Assigned-network-number | Name
<to-data-type>   :=<from-data-type>
```

Note that "YP" is NOT a valid country code under [ISO 3166] (although we may want to worry about the future), and the existence of a syntactically valid <to-data-type>.<from-data-type> pair does not imply that a meaningful mapping exists, or is even possible.

The encoding rules might be:

TCP-port	Six character alphanumeric
IN-ADDR	Reversed 4-octet decimal string
Number	decimal integer
Assigned-network-number	Reversed 4-octet decimal string
Name	Domain name

6. SPECIFICS FOR YP MAPPINGS

6.1. TCP-PORT

```
$origin Number.TCP-port.YP.

23              PTR     TELNET.TCP-port.Number.YP.
25              PTR     SMTP.TCP-port.Number.YP.

$origin TCP-port.Number.YP.

TELNET          PTR     23.Number.TCP-port.YP.
```

```
   SMTP             PTR      25.Number.TCP-port.YP.
```

Thus the mapping between 23 and TELNET is represented by a pair of PTR RRs, one for each direction of the mapping.

6.2. Assigned networks

Network numbers are assigned by the NIC and reported in "Internet Numbers" RFCs. To create a YP, the NIC would set up two domains:

Name.Assigned-network-number.YP and Assigned-network-number.YP

The first would contain entries of the form:

```
   $origin Name.Assigned-network-number.YP.

   0.0.0.4          PTR      SATNET.Assigned-network-number.Name.YP.
   0.0.0.10         PTR      ARPANET.Assigned-network-number.Name.YP.
```

The second would contain entries of the form:

```
   $origin Assigned-network-number.Name.YP.

   SATNET.          PTR      0.0.0.4.Name.Assigned-network-number.YP.
   ARPANET.         PTR      0.0.0.10.Name.Assigned-network-number.YP.
```

These YPs are not in conflict with the network name support described in the first half of this RFC since they map between ASSIGNED network names and numbers, not those allocated by the organizations themselves. That is, they document the NIC's decisions about allocating network numbers but do not automatically track any renaming performed by the new owners.

As a practical matter, we might want to create both of these domains to enable users on the Internet to experiment with centrally maintained support as well as the distributed version, or might want to implement only the allocated number to name mapping and request organizations to convert their allocated network names to the network names described in the distributed model.

6.3. Operational improvements

We could imagine that all conversion routines using these YPs might be instructed to use "YP.<local-domain>" followed by "YP." as a search list. Thus, if the organization ISI.EDU wished to define locally meaningful TCP-PORT, it would define the domains:

<TCP-port.Number.YP.ISI.EDU> and <Number.TCP-port.YP.ISI.EDU>.

We could add another level of indirection in the YP lookup, defining the <to-data-type>.<from-data-type>.<YP-origin> nodes to point to the YP tree, rather than being the YP tree directly. This would enable entries of the form:

```
IN-ADDR.Netname.YP.   PTR      IN-ADDR.ARPA.
```

to splice in YPs from other origins or existing spaces.

Another possibility would be to shorten the RDATA section of the RRs which map back and forth by deleting the origin. This could be done either by allowing the domain name in the RDATA portion to not identify a real domain name, or by defining a new RR which used a simple text string rather than a domain name.

Thus, we might replace

```
$origin Assigned-network-number.Name.YP.

SATNET.         PTR     0.0.0.4.Name.Assigned-network-number.YP.
ARPANET.        PTR     0.0.0.10.Name.Assigned-network-number.YP.
```

with

```
$origin Assigned-network-number.Name.YP.

SATNET.         PTR     0.0.0.4.
ARPANET.        PTR     0.0.0.10.
```

or

```
$origin Assigned-network-number.Name.YP.

SATNET.         PTT     "0.0.0.4"
ARPANET.        PTT     "0.0.0.10"
```

where PTT is a new type whose RDATA section is a text string.

7. ACKNOWLEDGMENTS

Drew Perkins, Mark Lottor, and Rob Austein contributed several of the ideas in this RFC. Numerous contributions, criticisms, and compromises were produced in the IETF Domain working group and the NAMEDROPPERS mailing list.

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1.5. Domain Requirements [RFC920]

```
Network Working Group                                          J. Postel
Request for Comments: 920                                    J. Reynolds
                                                                     ISI
                                                            October 1984
```

Domain Requirements

Status of this Memo

This memo is a policy statement on the requirements of establishing a new domain in the ARPA-Internet and the DARPA research community. This is an official policy statement of the IAB and the DARPA. Distribution of this memo is unlimited.

Introduction

This memo restates and refines the requirements on establishing a Domain first described in RFC-881 [1]. It adds considerable detail to that discussion, and introduces the limited set of top level domains.

The Purpose of Domains

Domains are administrative entities. The purpose and expected use of domains is to divide the name management required of a central administration and assign it to sub-administrations. There are no geographical, topological, or technological constraints on a domain. The hosts in a domain need not have common hardware or software, nor even common protocols. Most of the requirements and limitations on domains are designed to ensure responsible administration.

The domain system is a tree-structured global name space that has a few top level domains. The top level domains are subdivided into second level domains. The second level domains may be subdivided into third level domains, and so on.

The administration of a domain requires controlling the assignment of names within that domain and providing access to the names and name related information (such as addresses) to users both inside and outside the domain.

General Purpose Domains

While the initial domain name "ARPA" arises from the history of the development of this system and environment, in the future most of the top level names will be very general categories like "government", "education", or "commercial". The motivation is to provide an organization name that is free of undesirable semantics.

After a short period of initial experimentation, all current ARPA-Internet hosts will select some domain other than ARPA for their future use. The use of ARPA as a top level domain will eventually cease.

Initial Set of Top Level Domains

The initial top level domain names are:

Temporary

ARPA	=	The current ARPA-Internet hosts.

Categories

GOV	=	Government, any government related domains meeting the second level requirements.
EDU	=	Education, any education related domains meeting the second level requirements.
COM	=	Commercial, any commercial related domains meeting the second level requirements.
MIL	=	Military, any military related domains meeting the second level requirements.
ORG	=	Organization, any other domains meeting the second level requirements.

Countries

The English two letter code (alpha-2) identifying a country according the the ISO Standard for "Codes for the Representation of Names of Countries" [5].

Multiorganizations

A multiorganization may be a top level domain if it is large, and is composed of other organizations; particularly if the multiorganization can not be easily classified into one of the categories and is international in scope.

Possible Examples of Domains

The following examples are fictions of the authors' creation, any similarity to the real world is coincidental.

The UC Domain

It might be that a large state wide university with, say, nine campuses and several laboratories may want to form a domain. Each campus or major off-campus laboratory might then be a subdomain, and within each subdomain, each department could be further distinguished. This university might be a second level domain in the education category.

One might see domain style names for hosts in this domain like these:

```
LOCUS.CS.LA.UC.EDU
CCN.OAC.LA.UC.EDU
ERNIE.CS.CAL.UC.EDU
A.S1.LLNL.UC.EDU
A.LAND.LANL.UC.EDU
NMM.LBL.CAL.UC.EDU
```

The MIT Domain

Another large university may have many hosts using a variety of machine types, some even using several families of protocols. However, the administrators at this university may see no need for the outside world to be aware of these internal differences. This university might be a second level domain in the education category.

One might see domain style names for hosts in this domain like these:

```
APIARY-1.MIT.EDU
BABY-BLUE.MIT.EDU
CEZANNE.MIT.EDU
DASH.MIT.EDU
```

MULTICS.MIT.EDU
TAC.MIT.EDU
XX.MIT.EDU

The CSNET Domain

There may be a consortium of universities and industry research laboratories called, say, "CSNET". This CSNET is not a network per se, but rather a computer mail exchange using a variety of protocols and network systems. Therefore, CSNET is not a network in the sense of the ARPANET, or an Ethernet, or even the ARPA-Internet, but rather a community. Yet it does, in fact, have the key property needed to form a domain; it has a responsible administration. This consortium might be large enough and might have membership that cuts across the categories in such a way that it qualifies under the "multiorganization rule" to be a top level domain.

One might see domain style names for hosts in this domain like these:

CIC.CSNET
EMORY.CSNET
GATECH.CSNET
HP-LABS.CSNET
SJ.IBM.CSNET
UDEL.CSNET
UWISC.CSNET

General Requirements on a Domain

There are several requirements that must be met to establish a domain. In general, it must be responsibly managed. There must be a responsible person to serve as an authoritative coordinator for domain related questions. There must be a robust domain name lookup service, it must be of at least a minimum size, and the domain must be registered with the central domain administrator (the Network Information Center (NIC) Domain Registrar).

Responsible Person:

An individual must be identified who has authority for the administration of the names within the domain, and who seriously takes on the responsibility for the behavior of the hosts in the domain, plus their interactions with hosts outside the domain. This person must have some technical expertise and the authority within the domain to see that problems are fixed.

If a host in a given domain somehow misbehaves in its interactions with hosts outside the domain (e.g., consistently violates protocols), the responsible person for the domain must be competent and available to receive reports of problems, take action on the reported problems, and follow through to eliminate the problems.

Domain Servers:

A robust and reliable domain server must be provided. One way of meeting this requirement is to provide at least two independent domain servers for the domain. The database can, of course, be the same. The database can be prepared and copied to each domain server. But, the servers should be in separate machines on independent power supplies, et cetera; basically as physically independent as can be. They should have no common point of failure.

Some domains may find that providing a robust domain service can most easily be done by cooperating with another domain where each domain provides an additional server for the other.

In other situations, it may be desirable for a domain to arrange for domain service to be provided by a third party, perhaps on hosts located outside the domain.

One of the difficult problems in operating a domain server is the acquisition and maintenance of the data. In this case, the data are the host names and addresses. In some environments this information changes fairly rapidly and keeping up-to-date data may be difficult. This is one motivation for sub-domains. One may wish to create sub-domains until the rate of change of the data in a sub-domain domain server database is easily managed.

In the technical language of the domain server implementation the data is divided into zones. Domains and zones are not necessarily one-to-one. It may be reasonable for two or more domains to combine their data in a single zone.

The responsible person or an identified technical assistant must understand in detail the procedures for operating a domain server, including the management of master files and zones.

The operation of a domain server should not be taken on lightly. There are some difficult problems in providing an adequate service, primarily the problems in keeping the database up to date, and keeping the service operating.

The concepts and implementation details of the domain server are given in RFC-882 [2] and RFC-883 [3].

Minimum Size:

The domain must be of at least a minimum size. There is no requirement to form a domain because some set of hosts is above the minimum size.

Top level domains must be specially authorized. In general, they will only be authorized for domains expected to have over 500 hosts.

The general guideline for a second level domain is that it have over 50 hosts. This is a very soft "requirement". It makes sense that any major organization, such as a university or corporation, be allowed as a second level domain -- even if it has just a few hosts.

Registration:

Top level domains must be specially authorized and registered with the NIC domain registrar.

The administrator of a level N domain must register with the registrar (or responsible person) of the level N-1 domain. This upper level authority must be satisfied that the requirements are met before authorization for the domain is granted.

The registration procedure involves answering specific questions about the prospective domain. A prototype of what the NIC Domain Registrar may ask for the registration of a second level domain is shown below. These questions may change from time to time. It is the responsibility of domain administrators to keep this information current.

The administrator of a domain is required to make sure that host and sub-domain names within that jurisdiction conform to the standard name conventions and are unique within that domain.

If sub-domains are set up, the administrator may wish to pass along some of his authority and responsibility to a sub-domain administrator. Even if sub-domains are established, the responsible person for the top-level domain is ultimately responsible for the whole tree of sub-domains and hosts.

This does not mean that a domain administrator has to know the details of all the sub-domains and hosts to the Nth degree, but simply that if a problem occurs he can get it fixed by calling on the administrator of the sub-domain containing the problem.

Top Level Domain Requirements

There are very few top level domains, each of these may have many second level domains.

An initial set of top level names has been identified. Each of these has an administrator and an agent.

The top level domains:

ARPA = The ARPA-Internet *** TEMPORARY ***

Administrator:	DARPA
Agent:	The Network Information Center
Mailbox:	HOSTMASTER@SRI-NIC.ARPA

GOV = Government

Administrator:	DARPA
Agent:	The Network Information Center
Mailbox:	HOSTMASTER@SRI-NIC.ARPA

EDU = Education

Administrator:	DARPA
Agent:	The Network Information Center
Mailbox:	HOSTMASTER@SRI-NIC.ARPA

COM = Commercial

Administrator:	DARPA
Agent:	The Network Information Center
Mailbox:	HOSTMASTER@SRI-NIC.ARPA

MIL = Military

Administrator:	DDN-PMO
Agent:	The Network Information Center
Mailbox:	HOSTMASTER@SRI-NIC.ARPA

```
    ORG  =  Organization

       Administrator:  DARPA
       Agent:          The Network Information Center
       Mailbox:        HOSTMASTER@SRI-NIC.ARPA
```

Countries

The English two letter code (alpha-2) identifying a country according the the ISO Standard for "Codes for the Representation of Names of Countries" [5].

As yet no country domains have been established. As they are established information about the administrators and agents will be made public, and will be listed in subsequent editions of this memo.

Multiorganizations

A multiorganization may be a top level domain if it is large, and is composed of other organizations; particularly if the multiorganization can not be easily classified into one of the categories and is international in scope.

As yet no multiorganization domains have been established. As they are established information about the administrators and agents will be made public, and will be listed in subsequent editions of this memo.

Note: The NIC is listed as the agent and registrar for all the currently allowed top level domains. If there are other entities that would be more appropriate agents and registrars for some or all of these domains then it would be desirable to reassign the responsibility.

Second Level Domain Requirements

Each top level domain may have many second level domains. Every second level domain must meet the general requirements on a domain specified above, and be registered with a top level domain administrator.

Third through Nth Level Domain Requirements

Each second level domain may have many third level domains, etc. Every third level domain (through Nth level domain) must meet the requirements set by the administrator of the immediately higher level domain. Note that these may be more or less strict than the general requirements. One would expect the minimum size requirements to decrease at each level.

The ARPA Domain

At the time the implementation of the domain concept was begun it was thought that the set of hosts under the administrative authority of DARPA would make up a domain. Thus the initial domain selected was called ARPA. Now it is seen that there is no strong motivation for there to be a top level ARPA domain. The plan is for the current ARPA domain to go out of business as soon as possible. Hosts that are currently members of the ARPA domain should make arrangements to join another domain. It is likely that for experimental purposes there will be a second level domain called ARPA in the ORG domain (i.e., there will probably be an ARPA.ORG domain).

The DDN Hosts

DDN hosts that do not desire to participate in this domain naming system will continue to use the HOSTS.TXT data file maintained by the NIC for name to address translations. This file will be kept up to date for the DDN hosts. However, all DDN hosts will change their names from "host.ARPA" to (for example) "host.DDN.MIL" some time in the future. The schedule for changes required in DDN hosts will be established by the DDN-PMO.

Impact on Hosts

What is a host administrator to do about all this?

For existing hosts already operating in the ARPA-Internet, the best advice is to sit tight for now. Take a few months to consider the options, then select a domain to join. Plan carefully for the impact that changing your host name will have on both your local users and on their remote correspondents.

For a new host, careful thought should be given (as discussed below). Some guidance can be obtained by comparing notes on what other hosts with similar administrative properties have done.

The owner of a host may decide which domain to join, and the administrator of a domain may decide which hosts to accept into his domain. Thus the owner of a host and a domain administrator must come to an understanding about the host being in the domain. This is the foundation of responsible administration.

For example, a host "XYZ" at MIT might possible be considered as a candidate for becoming any of XYZ.ARPA.ORG, XYZ.CSNET, or XYZ.MIT.EDU.

The owner of host XYZ may choose which domain to join, depending on which domain administrators are willing to have him.

The domain is part of the host name. Thus if USC-ISIA.ARPA changes its domain affiliation to DDN.MIL to become USC-ISIA.DDN.MIL, it has changed its name. This means that any previous references to USC-ISIA.ARPA are now out of date. Such old references may include private host name to address tables, and any recorded information about mailboxes such as mailing lists, the headers of old messages, printed directories, and peoples' memories.

The experience of the DARPA community suggests that changing the name of a host is somewhat painful. It is recommended that careful thought be given to choosing a new name for a host - which includes selecting its place in the domain hierarchy.

The Roles of the Network Information Center

The NIC plays two types of roles in the administration of domains. First, the NIC is the registrar of all top level domains. Second the NIC is the administrator of several top level domains (and the registrar for second level domains in these).

Top Level Domain Registrar

As the registrar for top level domains, the NIC is the contact point for investigating the possibility of establishing a new top level domain.

Top Level Domain Administrator

For the top level domains designated so far, the NIC is the administrator of each of these domains. This means the NIC is responsible for the management of these domains and the registration of the second level domains or hosts (if at the second level) in these domains.

It may be reasonable for the administration of some of these domains to be taken on by other authorities in the future. It is certainly not desired that the NIC be the administrator of all top level domains forever.

Prototypical Questions

To establish a domain, the following information must be provided to the NIC Domain Registrar (HOSTMASTER@SRI-NIC.ARPA):

Note: The key people must have computer mail mailboxes and NIC-Idents. If they do not at present, please remedy the situation at once. A NIC-Ident may be estaulished by contacting NIC@SRI-NIC.ARPA.

1) The name of the top level domain to join.

For example: EDU

2) The name, title, mailing address, phone number, and organization of the administrative head of the organization. This is the contact point for administrative and policy questions about the domain. In the case of a research project, this should be the Principal Investigator. The online mailbox and NIC-Ident of this person should also be included.

For example:

Administrator

Organization	USC/Information Sciences Institute
Name	Keith Uncapher
Title	Executive Director
Mail Address	USC/ISI 4676 Admiralty Way, Suite 1001 Marina del Rey, CA. 90292-6695
Phone Number	213-822-1511
Net Mailbox	Uncapher@USC-ISIB.ARPA
NIC-Ident	KU

3) The name, title, mailing address, phone number, and organization of the domain technical contact. The online mailbox and NIC-Ident of the domain technical contact should also be included. This is the contact point for problems with the domain and for updating information about the domain. Also, the domain technical contact may be responsible for hosts in this domain.

For example:

Technical Contact

Organization	USC/Information Sciences Institute
Name	Craig Milo Rogers
Title	Researcher
Mail Address	USC/ISI 4676 Admiralty Way, Suite 1001 Marina del Rey, CA. 90292-6695
Phone Number	213-822-1511
Net Mailbox	Rogers@USC-ISIB.ARPA
NIC-Ident	CMR

4) The name, title, mailing address, phone number, and organization of the zone technical contact. The online mailbox and NIC-Ident of the zone technical contact should also be included. This is the contact point for problems with the zone and for updating information about the zone. In many cases the zone technical contact and the domain technical contact will be the same person.

For example:

Technical Contact

Organization	USC/Information Sciences Institute
Name	Craig Milo Rogers
Title	Researcher
Mail Address	USC/ISI 4676 Admiralty Way, Suite 1001 Marina del Rey, CA. 90292-6695
Phone Number	213-822-1511
Net Mailbox	Rogers@USC-ISIB.ARPA
NIC-Ident	CMR

5) The name of the domain (up to 12 characters). This is the name that will be used in tables and lists associating the domain and the domain server addresses. [While technically domain names can be quite long (programmers beware), shorter names are easier for people to cope with.]

For example: ALPHA-BETA

6) A description of the servers that provides the domain service for translating name to address for hosts in this domain, and the date they will be operational.

A good way to answer this question is to say "Our server is supplied by person or company X and does whatever their standard issue server does".

For example: Our server is a copy of the server operated by the NIC, and will be installed and made operational on 1-November-84.

7) A description of the server machines, including:

(a) hardware and software (using keywords from the Assigned Numbers)

(b) addresses (what host on what net for each connected net)

For example:

(a) hardware and software

```
VAX-11/750   and  UNIX,     or
IBM-PC       and  MS-DOS,   or
DEC-1090     and  TOPS-20
```

(b) address

10.9.0.193 on ARPANET

8) An estimate of the number of hosts that will be in the domain.

(a) initially,
(b) within one year,
(c) two years, and
(d) five years.

For example:

```
(a) initially  =   50
(b) one year   =  100
(c) two years  =  200
(d) five years =  500
```

Acknowledgment

We would like to thank the many people who contributed to this memo, including the participants in the Namedroppers Group, the ICCB, the PCCB, and especially the staff of the Network Information Center, particularly J. Feinler and K. Harrenstien.

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1.6. Domain Administrators Guide [RFC 1032]

Network Working Group M. Stahl
Request for Comments: 1032 SRI International
November 1987

DOMAIN ADMINISTRATORS GUIDE

STATUS OF THIS MEMO

This memo describes procedures for registering a domain with the Network Information Center (NIC) of Defense Data Network (DDN), and offers guidelines on the establishment and administration of a domain in accordance with the requirements specified in RFC-920. It is intended for use by domain administrators. This memo should be used in conjunction with RFC-920, which is an official policy statement of the Internet Activities Board (IAB) and the Defense Advanced Research Projects Agency (DARPA). Distribution of this memo is unlimited.

BACKGROUND

Domains are administrative entities that provide decentralized management of host naming and addressing. The domain-naming system is distributed and hierarchical.

The NIC is designated by the Defense Communications Agency (DCA) to provide registry services for the domain-naming system on the DDN and DARPA portions of the Internet.

As registrar of top-level and second-level domains, as well as administrator of the root domain name servers on behalf of DARPA and DDN, the NIC is responsible for maintaining the root server zone files and their binary equivalents. In addition, the NIC is responsible for administering the top-level domains of "ARPA," "COM," "EDU," "ORG," "GOV," and "MIL" on behalf of DCA and DARPA until it becomes feasible for other appropriate organizations to assume those responsibilities.

It is recommended that the guidelines described in this document be used by domain administrators in the establishment and control of second-level domains.

THE DOMAIN ADMINISTRATOR

The role of the domain administrator (DA) is that of coordinator, manager, and technician. If his domain is established at the second level or lower in the tree, the DA must register by interacting with the management of the domain directly above his, making certain that his domain satisfies all the requirements of the administration under which his domain would be situated. To find out who has authority over the name space he wishes to join, the DA can ask the NIC Hostmaster. Information on contacts for the top-level and second-level domains can also be found on line in the file NETINFO:DOMAIN-CONTACTS.TXT, which is available from the NIC via anonymous FTP.

The DA should be technically competent; he should understand the concepts and procedures for operating a domain server, as described in RFC-1034, and make sure that the service provided is reliable and uninterrupted. It is his responsibility or that of his delegate to ensure that the data will be current at all times. As a manager, the DA must be able to handle complaints about service provided by his domain name server. He must be aware of the behavior of the hosts in his domain, and take prompt action on reports of problems, such as protocol violations or other serious misbehavior. The administrator of a domain must be a responsible person who has the authority to either enforce these actions himself or delegate them to someone else.

Name assignments within a domain are controlled by the DA, who should verify that names are unique within his domain and that they conform to standard naming conventions. He furnishes access to names and name-related information to users both inside and outside his domain. He should work closely with the personnel he has designated as the "technical and zone" contacts for his domain, for many administrative decisions will be made on the basis of input from these people.

THE DOMAIN TECHNICAL AND ZONE CONTACT

A zone consists of those contiguous parts of the domain tree for which a domain server has complete information and over which it has authority. A domain server may be authoritative for more than one zone. The domain technical/zone contact is the person who tends to the technical aspects of maintaining the domain's name server and resolver software, and database files. He keeps the name server running, and interacts with technical people in other domains and zones to solve problems that affect his zone.

POLICIES

Domain or host name choices and the allocation of domain name space are considered to be local matters. In the event of conflicts, it is the policy of the NIC not to get involved in local disputes or in the local decision-making process. The NIC will not act as referee in disputes over such matters as who has the "right" to register a particular top-level or second-level domain for an organization. The NIC considers this a private local matter that must be settled among the parties involved prior to their commencing the registration process with the NIC. Therefore, it is assumed that the responsible person for a domain will have resolved any local conflicts among the members of his domain before registering that domain with the NIC. The NIC will give guidance, if requested, by answering specific technical questions, but will not provide arbitration in disputes at the local level. This policy is also in keeping with the distributed hierarchical nature of the domain-naming system in that it helps to distribute the tasks of solving problems and handling questions.

Naming conventions for hosts should follow the rules specified in RFC-952. From a technical standpoint, domain names can be very long. Each segment of a domain name may contain up to 64 characters, but the NIC strongly advises DAs to choose names that are 12 characters or fewer, because behind every domain system there is a human being who must keep track of the names, addresses, contacts, and other data in a database. The longer the name, the more likely the data maintainer is to make a mistake. Users also will appreciate shorter names. Most people agree that short names are easier to remember and type; most domain names registered so far are 12 characters or fewer.

Domain name assignments are made on a first-come-first-served basis. The NIC has chosen not to register individual hosts directly under the top-level domains it administers. One advantage of the domain naming system is that administration and data maintenance can be delegated down a hierarchical tree. Registration of hosts at the same level in the tree as a second-level domain would dilute the usefulness of this feature. In addition, the administrator of a domain is responsible for the actions of hosts within his domain. We would not want to find ourselves in the awkward position of policing the actions of individual hosts. Rather, the subdomains registered under these top-level domains retain the responsibility for this function.

Countries that wish to be registered as top-level domains are required to name themselves after the two-letter country code listed in the international standard ISO-3166. In some cases, however, the two-letter ISO country code is identical to a state code used by the U.S. Postal Service. Requests made by countries to use the three-letter form of country code specified in the ISO-3166 standard will be considered in such cases so as to prevent possible conflicts and confusion.

HOW TO REGISTER

Obtain a domain questionnaire from the NIC hostmaster, or FTP the file NETINFO:DOMAIN-TEMPLATE.TXT from host SRI-NIC.ARPA.

Fill out the questionnaire completely. Return it via electronic mail to HOSTMASTER@SRI-NIC.ARPA.

The APPENDIX to this memo contains the application form for registering a top-level or second-level domain with the NIC. It supersedes the version of the questionnaire found in RFC-920. The application should be submitted by the person administratively responsible for the domain, and must be filled out completely before the NIC will authorize establishment of a top-level or second-level domain. The DA is responsible for keeping his domain's data current with the NIC or with the registration agent with which his domain is registered. For example, the CSNET and UUCP managements act as domain filters, processing domain applications for their own organizations. They pass pertinent information along periodically to the NIC for incorporation into the domain database and root server files. The online file NETINFO·ALTERNATE-DOMAIN-PROCEDURE.TXT outlines this procedure. It is highly recommended that the DA review this information periodically and provide any corrections or additions. Corrections should be submitted via electronic mail.

WHICH DOMAIN NAME?

The designers of the domain-naming system initiated several general categories of names as top-level domain names, so that each could accommodate a variety of organizations. The current top-level domains registered with the DDN Network Information Center are ARPA, COM, EDU, GOV, MIL, NET, and ORG, plus a number of top-level country domains. To join one of these, a DA needs to be aware of the purpose for which it was intended.

"ARPA" is a temporary domain. It is by default appended to the names of hosts that have not yet joined a domain. When the system was begun in 1984, the names of all hosts in the Official DoD Internet Host Table maintained by the NIC were changed by adding of the label ".ARPA" in order to accelerate a transition to the domain-naming system. Another reason for the blanket name changes was to force hosts to become accustomed to using the new style names and to modify their network software, if necessary. This was done on a network-wide basis and was directed by DCA in DDN Management Bulletin No. 22. Hosts that fall into this domain will eventually move to other branches of the domain tree.

"COM" is meant to incorporate subdomains of companies and businesses.

"EDU" was initiated to accommodate subdomains set up by universities and other educational institutions.

"GOV" exists to act as parent domain for subdomains set up by government agencies.

"MIL" was initiated to act as parent to subdomains that are developed by military organizations.

"NET" was introduced as a parent domain for various network-type organizations. Organizations that belong within this top-level domain are generic or network-specific, such as network service centers and consortia. "NET" also encompasses network management-related organizations, such as information centers and operations centers.

"ORG" exists as a parent to subdomains that do not clearly fall within the other top-level domains. This may include technical-support groups, professional societies, or similar organizations.

One of the guidelines in effect in the domain-naming system is that a host should have only one name regardless of what networks it is connected to. This implies, that, in general, domain names should not include routing information or addresses. For example, a host that has one network connection to the Internet and another to BITNET should use the same name when talking to either network. For a description of the syntax of domain names, please refer to Section 3 of RFC-1034.

VERIFICATION OF DATA

The verification process can be accomplished in several ways. One of these is through the NIC WHOIS server. If he has access to WHOIS, the DA can type the command "whois domain <domain name><return>". The reply from WHOIS will supply the following: the name and address of the organization "owning" the domain; the name of the domain; its administrative, technical, and zone contacts; the host names and network addresses of sites providing name service for the domain.

Example:

```
@whois domain rice.edu<Return>

   Rice University (RICE-DOM)
   Advanced Studies and Research
   Houston, TX 77001

   Domain Name: RICE.EDU

      Administrative Contact:
      Kennedy, Ken  (KK28)  Kennedy@LLL-CRG.ARPA (713) 527-4834
      Technical Contact, Zone Contact:
      Riffle, Vicky R.  (VRR)  rif@RICE.EDU
      (713) 527-8101 ext 3844

   Domain servers:

   RICE.EDU                      128.42.5.1
   PENDRAGON.CS.PURDUE.EDU       128.10.2.5
```

Alternatively, the DA can send an electronic mail message to SERVICE@SRI-NIC.ARPA. In the subject line of the message header, the DA should type "whois domain <domain name>". The requested information will be returned via electronic mail. This method is convenient for sites that do not have access to the NIC WHOIS service.

The initial application for domain authorization should be submitted via electronic mail, if possible, to HOSTMASTER@SRI-NIC.ARPA. The questionnaire described in the appendix may be used or a separate application can be FTPed from host SRI-NIC.ARPA. The information provided by the administrator will be reviewed by hostmaster personnel for completeness. There will most likely be a few exchanges of correspondence via electronic mail, the preferred method of communication, prior to authorization of the domain.

HOW TO GET MORE INFORMATION

An informational table of the top-level domains and their root servers is contained in the file NETINFO:DOMAINS.TXT online at SRI-NIC.ARPA. This table can be obtained by FTPing the file. Alternatively, the information can be acquired by opening a TCP or UDP connection to the NIC Host Name Server, port 101 on SRI-NIC.ARPA, and invoking the command "ALL-DOM".

The following online files, all available by FTP from SRI-NIC.ARPA, contain pertinent domain information:

- NETINFO:DOMAINS.TXT, a table of all top-level domains and the network addresses of the machines providing domain name service for them. It is updated each time a new top-level domain is approved.

- NETINFO:DOMAIN-INFO.TXT contains a concise list of all top-level and second-level domain names registered with the NIC and is updated monthly.

- NETINFO:DOMAIN-CONTACTS.TXT also contains a list of all the top level and second-level domains, but includes the administrative, technical and zone contacts for each as well.

- NETINFO:DOMAIN-TEMPLATE.TXT contains the questionnaire to be completed before registering a top-level or second-level domain.

For either general or specific information on the domain system, do one or more of the following:

1. Send electronic mail to HOSTMASTER@SRI-NIC.ARPA

2. Call the toll-free NIC hotline at (800) 235-3155

3. Use FTP to get background RFCs and other files maintained online at the NIC. Some pertinent RFCs are listed below in the REFERENCES section of this memo.

REFERENCES

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14. Reynolds, J., and Postel, J., "Assigned Numbers", RFC-1010 USC Information Sciences Institute, May 1986. [RFC:RFC1010.TXT]

15. Romano, S., and Stahl, M., "Internet Numbers", RFC-1020, SRI, November 1987. [RFC:RFC1020.TXT]

APPENDIX

The following questionnaire may be FTPed from SRI-NIC.ARPA as NETINFO:DOMAIN-TEMPLATE.TXT.

To establish a domain, the following information must be sent to the NIC Domain Registrar (HOSTMASTER@SRI-NIC.ARPA):

NOTE: The key people must have electronic mailboxes and NIC "handles," unique NIC database identifiers. If you have access to "WHOIS", please check to see if you are registered and if so, make sure the information is current. Include only your handle and any changes (if any) that need to be made in your entry. If you do not have access to "WHOIS", please provide all the information indicated and a NIC handle will be assigned.

(1) The name of the top-level domain to join.

For example: COM

(2) The NIC handle of the administrative head of the organization. Alternately, the person's name, title, mailing address, phone number, organization, and network mailbox. This is the contact point for administrative and policy questions about the domain. In the case of a research project, this should be the principal investigator.

For example:

Administrator

Organization	The NetWorthy Corporation
Name	Penelope Q. Sassafrass
Title	President
Mail Address	The NetWorthy Corporation 4676 Andrews Way, Suite 100 Santa Clara, CA 94302-1212
Phone Number	(415) 123-4567
Net Mailbox	Sassafrass@ECHO.TNC.COM
NIC Handle	PQS

(3) The NIC handle of the technical contact for the domain. Alternately, the person's name, title, mailing address, phone number, organization, and network mailbox. This is the contact point for problems concerning the domain or zone, as well as for updating information about the domain or zone.

For example:

Technical and Zone Contact

Organization	The NetWorthy Corporation
Name	Ansel A. Aardvark
Title	Executive Director
Mail Address	The NetWorthy Corporation 4676 Andrews Way, Suite 100 Santa Clara, CA. 94302-1212
Phone Number	(415) 123-6789
Net Mailbox	Aardvark@ECHO.TNC.COM
NIC Handle	AAA2

(4) The name of the domain (up to 12 characters). This is the name that will be used in tables and lists associating the domain with the domain server addresses. [While, from a technical standpoint, domain names can be quite long (programmers beware), shorter names are easier for people to cope with.]

For example: TNC

(5) A description of the servers that provide the domain service for translating names to addresses for hosts in this domain, and the date they will be operational.

A good way to answer this question is to say "Our server is supplied by person or company X and does whatever their standard issue server does."

For example: Our server is a copy of the one operated by the NIC; it will be installed and made operational on 1 November 1987.

(6) Domains must provide at least two independent servers for the domain. Establishing the servers in physically separate locations and on different PSNs is strongly recommended. A description of the server machine and its backup, including

(a) Hardware and software (using keywords from the Assigned Numbers RFC).

(b) Host domain name and network addresses (which host on which network for each connected network).

(c) Any domain-style nicknames (please limit your domain-style nickname request to one)

For example:

- Hardware and software

```
VAX-11/750   and  UNIX,    or
IBM-PC       and  MS-DOS,  or
DEC-1090     and  TOPS-20
```

- Host domain names and network addresses

```
BAR.FOO.COM 10.9.0.193 on ARPANET
```

- Domain-style nickname

```
BR.FOO.COM (same as BAR.FOO.COM 10.9.0.13 on ARPANET)
```

) Planned mapping of names of any other network hosts, other than the server machines, into the new domain's naming space.

For example:

```
BAR-FOO2.ARPA (10.8.0.193) -> FOO2.BAR.COM
BAR-FOO3.ARPA (10.7.0.193) -> FOO3.BAR.COM
BAR-FOO4.ARPA (10.6.0.193) -> FOO4.BAR.COM
```

(8) An estimate of the number of hosts that will be in the domain.

(a) Initially
(b) Within one year
(c) Two years
(d) Five years.

For example:

```
(a) Initially   =   50
(b) One year    =  100
(c) Two years   =  200
(d) Five years =  500
```

(9) The date you expect the fully qualified domain name to become the official host name in HOSTS.TXT.

Please note: If changing to a fully qualified domain name (e.g., FOO.BAR.COM) causes a change in the official host name of an ARPANET or MILNET host, DCA approval must be obtained beforehand. Allow 10 working days for your requested changes to be processed.

ARPANET sites should contact ARPANETMGR@DDN1.ARPA. MILNET sites should contact HOSTMASTER@SRI-NIC.ARPA, 800-235-3155, for further instructions.

(10) Please describe your organization briefly.

For example: The NetWorthy Corporation is a consulting organization of people working with UNIX and the C language in an electronic networking environment. It sponsors two technical conferences annually and distributes a bimonthly newsletter.

This example of a completed application corresponds to the examples found in the companion document RFC-1033, "Domain Administrators Operations Guide."

(1) The name of the top-level domain to join.

COM

(2) The NIC handle of the administrative contact person.

NIC Handle JAKE

(3) The NIC handle of the domain's technical and zone contact person.

NIC Handle DLE6

(4) The name of the domain.

SRI

(5) A description of the servers.

Our server is the TOPS20 server JEEVES supplied by ISI; it will be installed and made operational on 1 July 1987.

```
(6)  A description of the server machine and its backup:

        (a) Hardware and software

           DEC-1090T   and  TOPS20
           DEC-2065    and  TOPS20

        (b) Host domain name and network address

           KL.SRI.COM  10.1.0.2 on ARPANET, 128.18.10.6 on SRINET
           STRIPE.SRI.COM  10.4.0.2 on ARPANET, 128.18.10.4 on SRINET

        (c) Domain-style nickname

           None

(7)  Planned mapping of names of any other network hosts, other than
the server machines, into the new domain's naming space.

        SRI-Blackjack.ARPA (128.18.2.1) -> Blackjack.SRI.COM
        SRI-CSL.ARPA (192.12.33.2) -> CSL.SRI.COM

(8)  An estimate of the number of hosts that will be directly within
this domain.

        (a) Initially  =   50
        (b) One year   =  100
        (c) Two years  =  200
        (d) Five years =  500

(9)  A date when you expect the fully qualified domain name to become
the official host name in HOSTS.TXT.

        31 September 1987

(10)  Brief description of organization.

        SRI International is an independent, nonprofit, scientific
        research organization.  It performs basic and applied research
        for government and commercial clients, and contributes to
        worldwide economic, scientific, industrial, and social progress
        through research and related services.
```

1.7. Domain Administrators Operations Guide [RFC 1033]

Network Working Group M. Lottor
Request For Comments: 1033 SRI International
November 1987

DOMAIN ADMINISTRATORS OPERATIONS GUIDE

STATUS OF THIS MEMO

This RFC provides guidelines for domain administrators in operating a domain server and maintaining their portion of the hierarchical database. Familiarity with the domain system is assumed. Distribution of this memo is unlimited.

ACKNOWLEDGMENTS

This memo is a formatted collection of notes and excerpts from the references listed at the end of this document. Of particular mention are Paul Mockapetris and Kevin Dunlap.

INTRODUCTION

A domain server requires a few files to get started. It will normally have some number of boot/startup files (also known as the "safety belt" files). One section will contain a list of possible root servers that the server will use to find the up-to-date list of root servers. Another section will list the zone files to be loaded into the server for your local domain information. A zone file typically contains all the data for a particular domain. This guide describes the data formats that can be used in zone files and suggested parameters to use for certain fields. If you are attempting to do anything advanced or tricky, consult the appropriate domain RFC's for more details.

Note: Each implementation of domain software may require different files. Zone files are standardized but some servers may require other startup files. See the appropriate documentation that comes with your software. See the appendix for some specific examples.

ZONES

A zone defines the contents of a contiguous section of the domain space, usually bounded by administrative boundaries. There will typically be a separate data file for each zone. The data contained in a zone file is composed of entries called Resource Records (RRs).

You may only put data in your domain server that you are authoritative for. You must not add entries for domains other than your own (except for the special case of "glue records").

A domain server will probably read a file on start-up that lists the zones it should load into its database. The format of this file is not standardized and is different for most domain server implementations. For each zone it will normally contain the domain name of the zone and the file name that contains the data to load for the zone.

ROOT SERVERS

A resolver will need to find the root servers when it first starts. When the resolver boots, it will typically read a list of possible root servers from a file.

The resolver will cycle through the list trying to contact each one. When it finds a root server, it will ask it for the current list of root servers. It will then discard the list of root servers it read from the data file and replace it with the current list it received.

Root servers will not change very often. You can get the names of current root servers from the NIC.

FTP the file NETINFO:ROOT-SERVERS.TXT or send a mail request to NIC@SRI-NIC.ARPA.

As of this date (June 1987) they are:

SRI-NIC.ARPA	10.0.0.51	26.0.0.73	
C.ISI.EDU	10.0.0.52		
BRL-AOS.ARPA	192.5.25.82	192.5.22.82	128.20.1.2
A.ISI.EDU	26.3.0.103		

RESOURCE RECORDS

Records in the zone data files are called resource records (RRs). They are specified in RFC-883 and RFC-973. An RR has a standard format as shown:

```
<name>   [<ttl>]   [<class>]   <type>   <data>
```

The record is divided into fields which are separated by white space.

<name>

The name field defines what domain name applies to the given

RR. In some cases the name field can be left blank and it will default to the name field of the previous RR.

<ttl>

TTL stands for Time To Live. It specifies how long a domain resolver should cache the RR before it throws it out and asks a domain server again. See the section on TTL's. If you leave the TTL field blank it will default to the minimum time specified in the SOA record (described later).

<class>

The class field specifies the protocol group. If left blank it will default to the last class specified.

<type>

The type field specifies what type of data is in the RR. See the section on types.

<data>

The data field is defined differently for each type and class of data. Popular RR data formats are described later.

The domain system does not guarantee to preserve the order of resource records. Listing RRs (such as multiple address records) in a certain order does not guarantee they will be used in that order.

Case is preserved in names and data fields when loaded into the name server. All comparisons and lookups in the name server are case insensitive.

Parenthesis ("(",")") are used to group data that crosses a line boundary.

A semicolon (";") starts a comment; the remainder of the line is ignored.

The asterisk ("*") is used for wildcarding.

The at-sign ("@") denotes the current default domain name.

NAMES

A domain name is a sequence of labels separated by dots.

Domain names in the zone files can be one of two types, either absolute or relative. An absolute name is the fully qualified domain name and is terminated with a period. A relative name does not terminate with a period, and the current default domain is appended to it The default domain is usually the name of the domain that was specified in the boot file that loads each zone.

The domain system allows a label to contain any 8-bit character. Although the domain system has no restrictions, other protocols such as SMTP do have name restrictions. Because of other protocol restrictions, only the following characters are recommended for use in a host name (besides the dot separator):

"A-Z", "a-z", "0-9", dash and underscore

TTL's (Time To Live)

It is important that TTLs are set to appropriate values. The TTL is the time (in seconds) that a resolver will use the data it got from your server before it asks your server again. if you set the value too low, your server will get loaded down with lots of repeat requests. If you set it too high, then information you change will not get distributed in a reasonable amount of time. If you leave the TTL field blank, it will default to what is specified in the SOA record for the zone.

Most host information does not change much over long time periods. A good way to set up your TTLs would be to set them at a high value, and then lower the value if you know a change will be coming soon. You might set most TTLs to anywhere between a day (86400) and a week (604800). Then, if you know some data will be changing in the near future, set the TTL for that RR down to a lower value (an hour to a day) until the change takes place, and then put it back up to its previous value.

Also, all RRs with the same name, class, and type should have the same TTL value.

CLASSES

The domain system was designed to be protocol independent. The class field is used to identify the protocol group that each RR is in.

The class of interest to people using TCP/IP software is the class

"Internet". Its standard designation is "IN".

A zone file should only contain RRs of the same class.

TYPES

There are many defined RR types. For a complete list, see the domain specification RFCs. Here is a list of current commonly used types. The data for each type is described in the data section.

Designation	Description
SOA	Start Of Authority
NS	Name Server
A	Internet Address
CNAME	Canonical Name (nickname pointer)
HINFO	Host Information
WKS	Well Known Services
MX	Mail Exchanger
PTR	Pointer

SOA (Start Of Authority)

```
        <name>  [<ttl>]  [<class>]  SOA  <origin>  <person>  (
                         <serial>
                         <refresh>
                         <retry>
                         <expire>
                         <minimum> )
```

The Start Of Authority record designates the start of a zone. The zone ends at the next SOA record.

<name> is the name of the zone.

<origin> is the name of the host on which the master zone file resides.

<person> is a mailbox for the person responsible for the zone. It is formatted like a mailing address but the at-sign that normally separates the user from the host name is replaced with a dot.

<serial> is the version number of the zone file. It should be incremented anytime a change is made to data in the zone.

<refresh> is how long, in seconds, a secondary name server is to check with the primary name server to see if an update is needed. A good value here would be one hour (3600).

<retry> is how long, in seconds, a secondary name server is to retry after a failure to check for a refresh. A good value here would be 10 minutes (600).

<expire> is the upper limit, in seconds, that a secondary name server is to use the data before it expires for lack of getting a refresh. You want this to be rather large, and a nice value is 3600000, about 42 days.

<minimum> is the minimum number of seconds to be used for TTL values in RRs. A minimum of at least a day is a good value here (86400).

There should only be one SOA record per zone. A sample SOA record would look something like:

```
@   IN   SOA   SRI-NIC.ARPA.   HOSTMASTER.SRI-NIC.ARPA. (
                45          ;serial
                3600        ;refresh
                600         ;retry
                3600000     ;expire
                86400 )     ;minimum
```

NS (Name Server)

```
<domain>   [<ttl>] [<class>]   NS   <server>
```

The NS record lists the name of a machine that provides domain service for a particular domain. The name associated with the RR is the domain name and the data portion is the name of a host that provides the service. If machines SRI-NIC.ARPA and C.ISI.EDU provide name lookup service for the domain COM then the following entries would be used:

```
COM.      NS      SRI-NIC.ARPA.
          NS      C.ISI.EDU.
```

Note that the machines providing name service do not have to live in the named domain. There should be one NS record for each server for a domain. Also note that the name "COM" defaults for the second NS record.

NS records for a domain exist in both the zone that delegates the domain, and in the domain itself.

GLUE RECORDS

If the name server host for a particular domain is itself inside the domain, then a 'glue' record will be needed. A glue record is an A (address) RR that specifies the address of the server. Glue records are only needed in the server delegating the domain, not in the domain itself. If for example the name server for domain SRI.COM was KL.SRI.COM, then the NS record would look like this, but you will also need to have the following A record.

```
        SRI.COM.      NS       KL.SRI.COM.
        KL.SRI.COM.   A        10.1.0.2
```

A (Address)

```
        <host>    [<ttl>] [<class>]    A    <address>
```

The data for an A record is an internet address in dotted decimal form. A sample A record might look like:

```
        SRI-NIC.ARPA.          A       10.0.0.51
```

There should be one A record for each address of a host.

CNAME (Canonical Name)

```
        <nickname>    [<ttl>] [<class>]    CNAME    <host>
```

The CNAME record is used for nicknames. The name associated with the RR is the nickname. The data portion is the official name. For example, a machine named SRI-NIC.ARPA may want to have the nickname NIC.ARPA. In that case, the following RR would be used:

```
        NIC.ARPA.       CNAME   SRI-NIC.ARPA.
```

There must not be any other RRs associated with a nickname of the same class.

Nicknames are also useful when a host changes it's name. In that case, it is usually a good idea to have a CNAME pointer so that people still using the old name will get to the right place.

```
HINFO (Host Info)

        <host>   [<ttl>] [<class>]   HINFO   <hardware>   <software>

   The HINFO record gives information about a particular host.  The data
   is two strings separated by whitespace.  The first string is a
   hardware description and the second is software.  The hardware is
   usually a manufacturer name followed by a dash and model designation.
   The software string is usually the name of the operating system.

   Official HINFO types can be found in the latest Assigned Numbers RFC,
   the latest of which is RFC-1010.  The Hardware type is called the
   Machine name and the Software type is called the System name.

   Some sample HINFO records:

           SRI-NIC.ARPA.           HINFO   DEC-2060 TOPS20
           UCBARPA.Berkeley.EDU.   HINFO   VAX-11/780 UNIX

WKS (Well Known Services)

        <host> [<ttl>] [<class>] WKS <address> <protocol> <services>

   The WKS record is used to list Well Known Services a host provides.
   WKS's are defined to be services on port numbers below 256.  The WKS
   record lists what services are available at a certain address using a
   certain protocol.  The common protocols are TCP or UDP.  A sample WKS
   record for a host offering the same services on all address would
   look like:

   Official protocol names can be found in the latest Assigned Numbers
   RFC, the latest of which is RFC-1010.

           SRI-NIC.ARPA.   WKS  10.0.0.51  TCP  TELNET FTP SMTP
                           WKS  10.0.0.51  UDP  TIME
                           WKS  26.0.0.73  TCP  TELNET FTP SMTP
                           WKS  26.0.0.73  UDP  TIME

MX (Mail Exchanger)  (See RFC-974 for more details.)

        <name>   [<ttl>] [<class>]   MX   <preference>   <host>

   MX records specify where mail for a domain name should be delivered.
   There may be multiple MX records for a particular name.  The
   preference value specifies the order a mailer should try multiple MX
   records when delivering mail.  Zero is the highest preference.
   Multiple records for the same name may have the same preference.
```

A host BAR.FOO.COM may want its mail to be delivered to the host PO.FOO.COM and would then use the MX record:

```
        BAR.FOO.COM.    MX      10      PO.FOO.COM.
```

A host BAZ.FOO.COM may want its mail to be delivered to one of three different machines, in the following order:

```
        BAZ.FOO.COM.    MX      10      PO1.FOO.COM.
                        MX      20      PO2.FOO.COM.
                        MX      30      PO3.FOO.COM.
```

An entire domain of hosts not connected to the Internet may want their mail to go through a mail gateway that knows how to deliver mail to them. If they would like mail addressed to any host in the domain FOO.COM to go through the mail gateway they might use:

```
        FOO.COM.        MX      10      RELAY.CS.NET.
        *.FOO.COM.      MX      20      RELAY.CS.NET.
```

Note that you can specify a wildcard in the MX record to match on anything in FOO.COM, but that it won't match a plain FOO.COM.

IN-ADDR.ARPA

The structure of names in the domain system is set up in a hierarchical way such that the address of a name can be found by tracing down the domain tree contacting a server for each label of the name. Because of this 'indexing' based on name, there is no easy way to translate a host address back into its host name.

In order to do the reverse translation easily, a domain was created that uses hosts' addresses as part of a name that then points to the data for that host. In this way, there is now an 'index' to hosts' RRs based on their address. This address mapping domain is called IN-ADDR.ARPA. Within that domain are subdomains for each network, based on network number. Also, for consistency and natural groupings, the 4 octets of a host number are reversed.

For example, the ARPANET is net 10. That means there is a domain called 10.IN-ADDR.ARPA. Within this domain there is a PTR RR at 51.0.0.10.IN-ADDR that points to the RRs for the host SRI-NIC.ARPA (who's address is 10.0.0.51). Since the NIC is also on the MILNET (Net 26, address 26.0.0.73), there is also a PTR RR at 73.0.0.26.IN-ADDR.ARPA that points to the same RR's for SRI-NIC.ARPA. The format of these special pointers is defined below along with the examples for the NIC.

PTR

```
        <special-name>   [<ttl>] [<class>]   PTR   <name>
```

The PTR record is used to let special names point to some other location in the domain tree. They are mainly used in the IN-ADDR.ARPA records for translation of addresses to names. PTR's should use official names and not aliases.

For example, host SRI-NIC.ARPA with addresses 10.0.0.51 and 26.0.0.73 would have the following records in the respective zone files for net 10 and net 26:

```
        51.0.0.10.IN-ADDR.ARPA.  PTR   SRI-NIC.ARPA.
        73.0.0.26.IN-ADDR.ARPA.  PTR   SRI-NIC.ARPA.
```

GATEWAY PTR's

The IN-ADDR tree is also used to locate gateways on a particular network. Gateways have the same kind of PTR RRs as hosts (as above) but in addition they have other PTRs used to locate them by network number alone. These records have only 1, 2, or 3 octets as part of the name depending on whether they are class A, B, or C networks, respectively.

Lets take the SRI-CSL gateway for example. It connects 3 different networks, one class A, one class B and one class C. It will have the standard RR's for a host in the CSL.SRI.COM zone:

```
        GW.CSL.SRI.COM.    A    10.2.0.2
                           A    128.18.1.1
                           A    192.12.33.2
```

Also, in 3 different zones (one for each network), it will have one of the following number to name translation pointers:

```
        2.0.2.10.IN-ADDR.ARPA.       PTR   GW.CSL.SRI.COM.
        1.1.18.128.IN-ADDR.ARPA.     PTR   GW.CSL.SRI.COM.
        2.33.12.192.IN-ADDR.ARPA.    PTR   GW.CSL.SRI.COM.
```

In addition, in each of the same 3 zones will be one of the following gateway location pointers:

```
        10.IN-ADDR.ARPA.             PTR   GW.CSL.SRI.COM.
        18.128.IN-ADDR.ARPA.         PTR   GW.CSL.SRI.COM.
        33.12.192.IN-ADDR.ARPA.      PTR   GW.CSL.SRI.COM.
```

INSTRUCTIONS

Adding a subdomain.

To add a new subdomain to your domain:

Setup the other domain server and/or the new zone file.

Add an NS record for each server of the new domain to the zone file of the parent domain.

Add any necessary glue RRs.

Adding a host.

To add a new host to your zone files:

Edit the appropriate zone file for the domain the host is in.

Add an entry for each address of the host.

Optionally add CNAME, HINFO, WKS, and MX records.

Add the reverse IN-ADDR entry for each host address in the appropriate zone files for each network the host in on.

Deleting a host.

To delete a host from the zone files:

Remove all the hosts' resource records from the zone file of the domain the host is in.

Remove all the hosts' PTR records from the IN-ADDR zone files for each network the host was on.

Adding gateways.

Follow instructions for adding a host.

Add the gateway location PTR records for each network the gateway is on.

Deleting gateways.

Follow instructions for deleting a host.

Also delete the gateway location PTR records for each network the gateway was on.

COMPLAINTS

These are the suggested steps you should take if you are having problems that you believe are caused by someone else's name server:

1. Complain privately to the responsible person for the domain. You can find their mailing address in the SOA record for the domain.

2. Complain publicly to the responsible person for the domain.

3. Ask the NIC for the administrative person responsible for the domain. Complain. You can also find domain contacts on the NIC in the file NETINFO:DOMAIN-CONTACTS.TXT

4. Complain to the parent domain authorities.

5. Ask the parent authorities to excommunicate the domain.

EXAMPLE DOMAIN SERVER DATABASE FILES

The following examples show how zone files are set up for a typical organization. SRI will be used as the example organization. SRI has decided to divided their domain SRI.COM into a few subdomains, one for each group that wants one. The subdomains are CSL and ISTC.

Note the following interesting items:

There are both hosts and domains under SRI.COM.

CSL.SRI.COM is both a domain name and a host name.

All the domains are serviced by the same pair of domain servers.

All hosts at SRI are on net 128.18 except hosts in the CSL domain which are on net 192.12.33. Note that a domain does not have to correspond to a physical network.

The examples do not necessarily correspond to actual data in use by the SRI domain.

```
                     SRI Domain Organization

                           +--------+
                           |  COM   |
                           +--------+
                               |
                           +--------+
                           |  SRI   |
                           +--------+
                               |
                  +----------++-----------+
                  |           |           |
              +--------+  +-------+  +--------+
              |  CSL   |  | ISTC  |  | Hosts  |
              +--------+  +-------+  +--------+
                  |           |
              +--------+  +--------+
              | Hosts  |  | Hosts  |
              +--------+  +--------+
```

[File "CONFIG.CMD". Since bootstrap files are not standardized, this file is presented using a pseudo configuration file syntax.]

```
load root server list             from file ROOT.SERVERS
load zone SRI.COM.                from file SRI.ZONE
load zone CSL.SRI.COM.            from file CSL.ZONE
load zone ISTC.SRI.COM.           from file ISTC.ZONE
load zone 36.192.IN-ADDR.ARPA.    from file SRINET.ZONE
load zone 1.32.128.IN-ADDR.ARPA.  from file SRI-CSL-NET.ZONE
```

[File "ROOT.SERVERS". Again, the format of this file is not standardized.]

```
;list of possible root servers
SRI-NIC.ARPA        10.0.0.51    26.0.0.73
C.ISI.EDU           10.0.0.52
BRL-AOS.ARPA        192.5.25.82  192.5.22.82   128.20.1.2
A.ISI.EDU           26.3.0.103
```

```
[File "SRI.ZONE"]

SRI.COM.            IN      SOA     KL.SRI.COM. DLE.STRIPE.SRI.COM. (
                                    870407  ;serial
                                    1800    ;refresh every 30 minutes
                                    600     ;retry every 10 minutes
                                    604800  ;expire after a week
                                    86400   ;default of an hour
                                    )

SRI.COM.            NS      KL.SRI.COM.
                    NS      STRIPE.SRI.COM.
                    MX      10      KL.SRI.COM.

;SRI.COM hosts

KL                  A       10.1.0.2
                    A       128.18.10.6
                    MX      10      KL.SRI.COM.

STRIPE              A       10.4.0.2
STRIPE              A       128.18.10.4
                    MX      10      STRIPE.SRI.COM.

NIC                 CNAME   SRI-NIC.ARPA.

Blackjack           A       128.18.2.1
                    HINFO   VAX-11/780      UNIX
                    WKS     128.18.2.1      TCP TELNET FTP

CSL                 A       192.12.33.2
                    HINFO   FOONLY-F4       TOPS20
                    WKS     192.12.33.2     TCP TELNET FTP SMTP FINGER
                    MX      10      CSL.SRI.COM.
```

```
   [File "CSL.ZONE"]

   CSL.SRI.COM.     IN      SOA     KL.SRI.COM. DLE.STRIPE.SRI.COM. (
                                    870330  ;serial
                                    1800    ;refresh every 30 minutes
                                    600     ;retry every 10 minutes
                                    604800  ;expire after a week
                                    86400   ;default of a day
                                    )

   CSL.SRI.COM.     NS                      KL.SRI.COM.
                    NS                      STRIPE.SRI.COM.
                    A                       192.12.33.2

   ;CSL.SRI.COM hosts

   A                CNAME   CSL.SRI.COM.
   B                A       192.12.33.3
                    HINFO   FOONLY-F4       TOPS20
                    WKS     192.12.33.3     TCP TELNET FTP SMTP
   GW               A       10.2.0.2
                    A       192.12.33.1
                    A       128.18.1.1
                    HINFO   PDP-11/23       MOS
   SMELLY           A       192.12.33.4
                    HINFO   IMAGEN          IMAGEN
   SQUIRREL         A       192.12.33.5
                    HINFO   XEROX-1100      INTERLISP
   VENUS            A       192.12.33.7
                    HINFO   SYMBOLICS-3600  LISPM
   HELIUM           A       192.12.33.30
                    HINFO   SUN-3/160       UNIX
   ARGON            A       192.12.33.31
                    HINFO   SUN-3/75        UNIX
   RADON            A       192.12.33.32
                    HINFO   SUN-3/75        UNIX
   [File "ISTC.ZONE"]

   ISTC.SRI.COM.    IN   SOA      KL.SRI.COM. roemers.JOYCE.ISTC.SRI.COM. (
                                  870406      ;serial
                                  1800        ;refresh every 30 minutes
                                  600         ;retry every 10 minutes
                                  604800      ;expire after a week
                                  86400       ;default of a day
                                  )

   ISTC.SRI.COM.    NS                KL.SRI.COM.
                    NS                STRIPE.SRI.COM.
                    MX                10      SPAM.ISTC.SRI.COM.

   ; ISTC hosts

   joyce            A       128.18.4.2
                    HINFO   VAX-11/750 UNIX
   bozo             A       128.18.0.6
                    HINFO   SUN UNIX
   sundae           A       128.18.0.11
                    HINFO   SUN UNIX
   tsca             A       128.18.0.201
                    A       10.3.0.2
                    HINFO   VAX-11/750 UNIX
                    MX      10  TSCA.ISTC.SRI.COM.
   tsc              CNAME   tsca
   prmn             A       128.18.0.203
                    A       10.2.0.51
                    HINFO   PDP-11/44 UNIX
   spam             A       128.18.4.3
                    A       10.2.0.107
                    HINFO   VAX-11/780 UNIX
                    MX      10  SPAM.ISTC.SRI.COM.
   [File "SRINET.ZONE"]

   18.128.IN-ADDR.ARPA.    IN   SOA  KL.SRI.COM  DLE.STRIPE.SRI.COM. (
                                870406  ;serial
                                1800    ;refresh every 30 minutes
                                600     ;retry every 10 minutes
                                604800  ;expire after a week
                                86400   ;default of a day
                                )

   18.128.IN-ADDR.ARPA.    NS       KL.SRI.COM.
                           NS       STRIPE.SRI.COM.
                           PTR      GW.CSL.SRI.COM.

   ; SRINET [128 18.0.0] Address Translations

   ; SRI.COM Hosts
   1.2.18.128.IN-ADDR.ARPA.        PTR      Blackjack.SRI.COM.

   ; ISTC.SRI.COM Hosts
   2.4.18.128.IN-ADDR.ARPA.        PTR      joyce.ISTC.SRI.COM.
   6.0.18.128.IN-ADDR.ARPA.        PTR      bozo.ISTC.SRI.COM.
   11.0.18.128.IN-ADDR.ARPA.       PTR      sundae.ISTC.SRI.COM.
   201.0.18.128.IN-ADDR.ARPA.      PTR      tsca.ISTC.SRI.COM.
   203.0.18.128.IN-ADDR.ARPA.      PTR      prmh.ISTC.SRI.COM.
   3.4.18.128.IN-ADDR.ARPA.        PTR      spam.ISTC.SRI.COM.

   ; CSL.SRI.COM Hosts
   1.1.18.128.IN-ADDR.ARPA.        PTR      GW.CSL.SRI.COM.
   [File "SRI-CSL-NET.ZONE"]

   33.12.192.IN-ADDR.ARPA. IN  SOA KL.SRI.COM  DLE.STRIPE.SRI.COM. (
                               870404  ;serial
                               1800    ;refresh every 30 minutes
                               600     ;retry every 10 minutes
                               604800  ;expire after a week
                               86400   ;default of a day
                               )

   33.12.192.IN-ADDR.ARPA. NS       KL.SRI.COM.
                           NS       STRIPE.SRI.COM.
                           PTR      GW.CSL.SRI.COM.

   ; SRI-CSL-NET [192.12.33.0] Address Translations

   ; SRI.COM Hosts
   1.33.12.192.IN-ADDR.ARPA          PTR     CSL.SRI.COM.

   ; CSL.SRI.COM Hosts
   1.33.12.192.IN-ADDR.ARPA.         PTR     GW.CSL.SRI.COM.
   3.33.12.192.IN-ADDR.ARPA.         PTR     B.CSL.SRI.COM.
   4.33.12.192.IN-ADDR.ARPA.         PTR     SMELLY.CSL.SRI.COM.
   6.33.12.192.IN-ADDR.ARPA.         PTR     SQUIRREL.CSL.SRI.COM.
   7.33.12.192.IN-ADDR.ARPA.         PTR     VENUS.CSL.SRI.COM.
   10.33.12.192.IN-ADDR.ARPA.        PTR     HELIUM.CSL.SRI.COM.
   31.33.12.192.IN-ADDR.ARPA.        PTR     ARGON.CSL.SRI.COM.
   32.33.12.192.IN-ADDR.ARPA.        PTR     RADON.CSL.SRI.COM.
```

APPENDIX

BIND (Berkeley Internet Name Domain server) distributed with 4.3 BSD UNIX

This section describes two BIND implementation specific files; the boot file and the cache file. BIND has other options, files, and specifications that are not described here. See the Name Server Operations Guide for BIND for details.

The boot file for BIND is usually called "named.boot". This corresponds to file "CONFIG.CMD" in the example section.

```
-----------------------------------------------------
cache           .                           named.ca
primary         SRI.COM                     SRI.ZONE
primary         CSL.SRI.COM                 CSL.ZONE
primary         ISTC.SRI.COM                ISTC.ZONE
primary         18.128.IN-ADDR.ARPA         SRINET.ZONE
primary         33.12.192.IN-ADDR.ARPA      SRI-CSL-NET.ZONE
-----------------------------------------------------
```

The cache file for BIND is usually called "named.ca". This corresponds to file "ROOT.SERVERS" in the example section.

```
----------------------------------------------
;list of possible root servers
.       1           IN    NS    SRI-NIC.ARPA.
                          NS    C.ISI.EDU.
                          NS    BRL-AOS.ARPA.
                          NS    C.ISI.EDU.
;and their addresses
SRI-NIC.ARPA.             A     10.0.0.51
                          A     26.0.0.73
C.ISI.EDU.                A     10.0.0.52
BRL-AOS.ARPA.             A     192.5.25.82
                          A     192.5.22.82
                          A     128.20.1.2
A.ISI.EDU.                A     26.3.0.103
----------------------------------------------
```

REFERENCES

[1] Dunlap, K., "Name Server Operations Guide for BIND", CSRG, Department of Electrical Engineering and Computer Sciences, University of California, Berkeley, California.

[2] Partridge, C., "Mail Routing and the Domain System", RFC-974, CSNET CIC BBN Laboratories, January 1986.

[3] Mockapetris, P., "Domains Names - Concepts and Facilities", RFC-1034, USC/Information Sciences Institute, November 1987.

[4] Mockapetris, P., "Domain Names - Implementations Specification", RFC-1035, USC/Information Sciences Institute, November 1987.

1.8. Mail Routing and the Domain System [RFC 974]

Network Working Group Craig Partridge
Request for Comments: 974 CSNET CIC BBN Laboratories Inc
January 1986

MAIL ROUTING AND THE DOMAIN SYSTEM

Status of this Memo

This RFC presents a description of how mail systems on the Internet are expected to route messages based on information from the domain system described in RFCs 882, 883 and 973. Distribution of this memo is unlimited.

Introduction

The purpose of this memo is to explain how mailers are to decide how to route a message addressed to a given Internet domain name. This involves a discussion of how mailers interpret MX RRs, which are used for message routing. Note that this memo makes no statement about how mailers are to deal with MB and MG RRs, which are used for interpreting mailbox names.

Under RFC-882 and RFC-883 certain assumptions about mail addresses have been changed. Up to now, one could usually assume that if a message was addressed to a mailbox, for example, at LOKI.BBN.COM, that one could just open an SMTP connection to LOKI.BBN.COM and pass the message along. This system broke down in certain situations, such as for certain UUCP and CSNET hosts which were not directly attached to the Internet, but these hosts could be handled as special cases in configuration files (for example, most mailers were set up to automatically forward mail addressed to a CSNET host to CSNET-RELAY.ARPA).

Under domains, one cannot simply open a connection to LOKI.BBN.COM, but must instead ask the domain system where messages to LOKI.BBN.COM are to be delivered. And the domain system may direct a mailer to deliver messages to an entirely different host, such as SH.CS.NET. Or, in a more complicated case, the mailer may learn that it has a choice of routes to LOKI.BBN.COM. This memo is essentially a set of guidelines on how mailers should behave in this more complex world.

Readers are expected to be familiar with RFCs 882, 883, and the updates to them (e.g., RFC-973).

What the Domain Servers Know

The domain servers store information as a series of resource records (RRs), each of which contains a particular piece of information about a given domain name (which is usually, but not always, a host). The simplest way to think of a RR is as a typed pair of datum, a domain name matched with relevant data, and stored with some additional type information to help systems determine when the RR is relevant. For the purposes of message routing, the system stores RRs known as MX RRs. Each MX matches a domain name with two pieces of data, a preference value (an unsigned 16-bit integer), and the name of a host. The preference number is used to indicate in what order the mailer should attempt deliver to the MX hosts, with the lowest numbered MX being the one to try first. Multiple MXs with the same preference are permitted and have the same priority.

In addition to mail information, the servers store certain other types of RR's which mailers may encounter or choose to use. These are: the canonical name (CNAME) RR, which simply states that the domain name queried for is actually an alias for another domain name, which is the proper, or canonical, name; and the Well Known Service (WKS) RR, which stores information about network services (such as SMTP) a given domain name supports.

General Routing Guidelines

Before delving into a detailed discussion of how mailers are expected to do mail routing, it would seem to make sense to give a brief overview of how this memo is approaching the problems that routing poses.

The first major principle is derived from the definition of the preference field in MX records, and is intended to prevent mail looping. If the mailer is on a host which is listed as an MX for the destination host, the mailer may only deliver to an MX which has a lower preference count than its own host.

It is also possible to cause mail looping because routing information is out of date or incomplete. Out of date information is only a problem when domain tables are changed. The changes will not be known to all affected hosts until their resolver caches time out. There is no way to ensure that this will not happen short of requiring mailers and their resolvers to always send their queries to an authoritative server, and never use data stored in a cache. This is an impractical solution, since eliminating resolver caching would make mailing inordinately expensive. What is more, the out-of-date RR problem should not happen if, when a domain table is changed, affected hosts (those in the list of MXs) have their resolver caches flushed. In other words, given proper precautions, mail looping as a result of domain information should be avoidable, without requiring mailers to query authoritative servers. (The appropriate precaution is to check with a host's administrator before adding that host to a list of MXs).

The incomplete data problem also requires some care when handling domain queries. If the answer section of a query is incomplete critical MX RRs may be left out. This may result in mail looping, or in a message being mistakenly labelled undeliverable. As a result, mailers may only accept responses from the domain system which have complete answer sections. Note that this entire problem can be avoided by only using virtual circuits for queries, but since this situation is likely to be very rare and datagrams are the preferred way to interact with the domain system, implementors should probably just ensure that their mailer will repeat a query with virtual circuits should the truncation bit ever be set.

Determining Where to Send a Message

The explanation of how mailers should decide how to route a message is discussed in terms of the problem of a mailer on a host with domain name LOCAL trying to deliver a message addressed to the domain name REMOTE. Both LOCAL and REMOTE are assumed to be syntactically correct domain names. Furthermore, LOCAL is assumed to be the official name for the host on which the mailer resides (i.e., it is not a alias).

Issuing a Query

The first step for the mailer at LOCAL is to issue a query for MX RRs for REMOTE. It is strongly urged that this step be taken every time a mailer attempts to send the message. The hope is that changes in the domain database will rapidly be used by mailers, and thus domain administrators will be able to re-route in-transit messages for defective hosts by simply changing their domain databases.

Certain responses to the query are considered errors:

Getting no response to the query. Th[illegible]ain server the mailer queried never sends anything back. (T[illegible] is distinct from an answer which contains no answers to the query, which is not an error).

Getting a response in which the truncation field of the header is set. (Recall discussion of incomplete queries above). Mailers may not use responses of this type, and should repeat the query using virtual circuits instead of datagrams.

Getting a response in which the response code is non-zero.

Mailers are expected to do something reasonable in the face of an error. The behaviour for each type of error is not specified here, but implementors should note that different types of errors should probably be treated differently. For example, a response code of "non-existent domain" should probably cause the message to be returned to the sender as invalid, while a response code of "server failure" should probably cause the message to be retried later.

There is one other special case. If the response contains an answer which is a CNAME RR, it indicates that REMOTE is actually an alias for some other domain name. The query should be repeated with the canonical domain name.

If the response does not contain an error response, and does not contain aliases, its answer section should be a (possibly zero length) list of MX RRs for domain name REMOTE (or REMOTE's true domain name if REMOTE was a alias). The next section describes how this list is interpreted.

Interpreting the List of MX RRs

NOTE: This section only discusses how mailers choose which names to try to deliver a message to, working from a list of RR's. It does not discuss how the mailers actually make delivery. Where ever delivering a message is mentioned, all that is meant is that the mailer should do whatever it needs to do to transfer a message to a remote site, given a domain name for that site. (For example, an SMTP mailer will try to get an address for the domain name, which involves another query to the domain system, and then, if it gets an address, connect to the SMTP TCP port). The mechanics of actually transferring the message over the network to the address associated with a given domain name is not within the scope of this memo.

It is possible that the list of MXs in the response to the query will be empty. This is a special case. If the list is empty, mailers should treat it as if it contained one RR, an MX RR with a preference value of 0, and a host name of REMOTE. (I.e., REMOTE is its only MX). In addition, the mailer should do no further processing on the list, but should attempt to deliver the message to REMOTE. The idea here is that if a domain fails to advertise any information about a particular name we will give it the benefit of the doubt and attempt delivery.

If the list is not empty, the mailer should remove irrelevant RR's from the list according to the following steps. Note that the order is significant.

For each MX, a WKS query should be issued to see if the domain name listed actually supports the mail service desired. MX RRs which list domain names which do not support the service should be discarded. This step is optional, but strongly encouraged.

If the domain name LOCAL is listed as an MX RR, all MX RRs with a preference value greater than or equal to that of LOCAL's must be discarded.

After removing irrelevant RRs, the list can again be empty. This is now an error condition and can occur in several ways. The simplest case is that the WKS queries have discovered that none of the hosts listed supports the mail service desired. The message is thus deemed undeliverable, though extremely persistent mail systems might want to try a delivery to REMOTE's address (if it exists) before returning the message. Another, more dangerous, possibility is that the domain system believes that LOCAL is handling message for REMOTE, but the mailer on LOCAL is not set up to handle mail for REMOTE. For example, if the domain system lists LOCAL as the only MX for REMOTE, LOCAL will delete all the entries in the list. But LOCAL is presumably querying the domain system because it didn't know what to do with a message addressed to REMOTE. Clearly something is wrong. How a mailer chooses to handle these situations is to some extent implementation dependent, and is thus left to the implementor's discretion.

If the list of MX RRs is not empty, the mailer should try to deliver the message to the MXs in order (lowest preference value tried first). The mailer is required to attempt delivery to the lowest valued MX. Implementors are encouraged to write mailers so that they try the MXs in order until one of the MXs accepts the message, or all the MXs have been tried. A somewhat less demanding system, in which a fixed number of MXs is tried, is also reasonable. Note that multiple MXs may have the same preference value. In this case, all MXs at with a given value must be tried before any of a higher value are tried. In addition, in the special case in which there are several MXs with the lowest preference value, all of them should be tried before a message is deemed undeliverable.

Minor Special Issues

There are a couple of special issues left out of the preceding section because they complicated the discussion. They are treated here in no particular order.

Wildcard names, those containing the character '*' in them, may be used for mail routing. There are likely to be servers on the network which simply state that any mail to a domain is to be routed through a relay. For example, at the time that this RFC is being written, all mail to hosts in the domain IL is routed through RELAY.CS.NET. This is done by creating a wildcard RR, which states that *.IL has an MX of RELAY.CS.NET. This should be transparent to the mailer since the domain servers will hide this wildcard match. (If it matches *.IL with HUJI.IL for example, a domain server will return an RR containing HUJI.IL, not *.IL). If by some accident a mailer receives an RR with a wildcard domain name in its name or data section it should discard the RR.

Note that the algorithm to delete irrelevant RRs breaks if LOCAL has a alias and the alias is listed in the MX records for REMOTE. (E.g. REMOTE has an MX of ALIAS, where ALIAS has a CNAME of LOCAL). This can be avoided if aliases are never used in the data section of MX RRs.

Implementors should understand that the query and interpretation of the query is only performed for REMOTE. It is not repeated for the MX RRs listed for REMOTE. You cannot try to support more extravagant mail routing by building a chain of MXs. (E.g. UNIX.BBN.COM is an MX for RELAY.CS.NET and RELAY.CS.NET is an MX for all the hosts in .IL, but this does not mean that UNIX.BBN.COM accepts any responsibility for mail for .IL).

Finally, it should be noted that this is a standard for routing on the Internet. Mailers serving hosts which lie on multiple networks will presumably have to make some decisions about which network to route through. This decision making is outside the scope of this memo, although mailers may well use the domain system to help them decide. However, once a mailer decides to deliver a message via the Internet it must apply these rules to route the message.

Examples

To illustrate the discussion above, here are three examples of how mailers should route messages. All examples work with the following database:

```
A.EXAMPLE.ORG     IN    MX     10     A.EXAMPLE.ORG
A.EXAMPLE.ORG     IN    MX     15     B.EXAMPLE.ORG
A.EXAMPLE.ORG     IN    MX     20     C.EXAMPLE.ORG
A.EXAMPLE.ORG     IN    WKS    10.0.0.1     TCP     SMTP

B.EXAMPLE.ORG     IN    MX     0       B.EXAMPLE.ORG
B.EXAMPLE.ORG     IN    MX     10      C.EXAMPLE.ORG
B.EXAMPLE.ORG     IN    WKS    10.0.0.2     TCP     SMTP

C.EXAMPLE.ORG     IN    MX     0      C.EXAMPLE.ORG
C.EXAMPLE.ORG     IN    WKS    10.0.0.3     TCP     SMTP

D.EXAMPLE.ORG     IN    MX     0      D.EXAMPLE.ORG
D.EXAMPLE.ORG     IN    MX     0      C.EXAMPLE.ORG
D.EXAMPLE.ORG     IN    WKS    10.0.0.4     TCP     SMTP
```

In the first example, an SMTP mailer on D.EXAMPLE.ORG is trying to deliver a message addressed to A.EXAMPLE.ORG. From the answer to its query, it learns that A.EXAMPLE.ORG has three MX RRs. D.EXAMPLE.ORG is not one of the MX RRs and all three MXs support SMTP mail (determined from the WKS entries), so none of the MXs are eliminated. The mailer is obliged to try to deliver to A.EXAMPLE.ORG as the lowest valued MX. If it cannot reach A.EXAMPLE.ORG it can (but is not required to) try B.EXAMPLE.ORG. and if B.EXAMPLE.ORG is not responding, it can try C.EXAMPLE.ORG.

In the second example, the mailer is on B.EXAMPLE.ORG, and is again trying to deliver a message addressed to A.EXAMPLE.ORG. There are once again three MX RRs for A.EXAMPLE.ORG, but in this case the mailer must discard the RRs for itself and C.EXAMPLE.ORG (because the MX RR for C.EXAMPLE.ORG has a higher preference value than the RR for B.EXAMPLE.ORG). It is left only with the RR for A.EXAMPLE.ORG, and can only try delivery to A.EXAMPLE.ORG.

In the third example, consider a mailer on A.EXAMPLE.ORG trying to deliver a message to D.EXAMPLE.ORG. In this case there are only two MX RRs, both with the same preference value. Either MX will accept messages for D.EXAMPLE.ORG. The mailer should try one MX first (which one is up to the mailer, though D.EXAMPLE.ORG seems most reasonable), and if that delivery fails should try the other MX (e.g. C.EXAMPLE.ORG).

1.9. Sources of Information on the DNS

For more information about the DNS, including information regarding existing implementations of the DNS, the reader can participate in online discussion groups, participate in Internet working groups, and contact the the DDN Network Information Center (DDN NIC) at SRI International in Menlo Park, California, in a number of ways. In the following, we provide more details on each of these three possibilities.

1.9.1. Online Discussion Groups

1.9.1.1. NAMEDROPPERS mailing list

The NAMEDROPPERS online mailing list was established in 1983 to foster technical discussion about the concepts, design, and implementation of the domain naming system. Originally conceived as a convenient means for the DNS developers to review the many draft documents describing the system, the list is now the main avenue of correspondence among both developers and implementors who are actively involved in the ongoing development of the DNS.

Members of the list are expected to participate in discussions from time to time; it is not meant for observers.

All previous NAMEDROPPERS discussions can be found in files on host NIC.DDN.MIL (formerly named SRI-NIC.ARPA) at Internet host address 26.0.0.73 or 10.0.0.51. Filenames follow the format:

```
NAMEDROPPERS:NAMEDROPPERS.yymmdd
NAMEDROPPERS:NAMEDROPPERS.yy
```

Archives exist for the years 1983 through 1988. For most years, the whole archive may fit in a single file; those archives will have only the "yy" extension. The file NAMEDROPPERS:NAMEDROPPERS.MAIL contains the most current NAMEDROPPERS dialog. All files can be accessed via anonymous FTP; new members may wish to copy and read these archives before joining the discussion.

To participate in discussions, users should send e-mail to NAMEDROPPERS@NIC.DDN.MIL. To be added to the mailing list, users should send e-mail to NAMEDROPPERS-REQUEST@NIC.DDN.MIL. Requests to be deleted from the mailing list, or problem report, should be sent to NAMEDROPPERS-REQUEST@NIC.DDN.MIL. List maintenance is performed by NIC systems personnel at SRI International; the list is coordinated by the DDN NIC Hostmaster, HOSTMASTER@NIC.DDN.MIL.

1.9.1.2. BIND mailing list

The Berkeley Internet Name-Domain (BIND) resolver and server for UNIX 4BSD is one of the most prominent implementations of the DNS. The University of California maintains the BIND mailing list for questions, answers, and comments about the BIND nameserver. It includes BIND maintainers and site administrators using BIND. Discussions include current bugs and fixes, questions and answers about domain configuration and server, and announcements of new software releases. Archives for the mailing list can be obtained via anonymous FTP from host ucbarpa.Berkeley.EDU from the directory pub/bind.mail.

To be added to the mailing list, users should send an online e-mail message to bind-request@ucbarpa.Berkeley.EDU. To participate in discussions on the mailing list, users should send e-mail messages to bind@ucbarpa.Berkeley.EDU.

1.9.2. Internet Working Groups

The Internet Engineering Task Force (IETF) has an ad-hoc working group to address domain issues. The group meets at regularly scheduled IETF meetings as needed to discuss current DNS problems and solutions. To learn more about the work of this group, users should contact the IETF chairperson, currently Phill Gross, gross@SCCGATE.SCC.COM.

1.9.3. The DDN NIC

1.9.3.1. DDN NIC domain name services

The DDN NIC currently serves as the registration authority for all top-level domains in the DDN Domain Naming System (DNS) under contract to the Defense Communications Agency (DCA). The DDN NIC is responsible for administrative and technical matters concerning the top-level domains GOV, ORG, NET, EDU, COM, MIL, and ARPA, and registers second-level domains and their domain servers under these domains. In addition to providing data files for use by the root servers, the DDN NIC also maintains and provides a machine-readable host name-to-address translation table for emergency backup purposes, and lists of administrative and technical points of contact for all registered domains.

1.9.3.2. Domain registration

Organizations that wish to register a domain with the DDN NIC should complete the domain application form, which can be obtained from Internet host NIC.DDN.MIL at Internet addresses 26.0.0.73 and 10.0.0.51. The pathname for retrieving the file via online file transfer is NETINFO:DOMAIN-TEMPLATE.TXT. A copy of the application may also be obtained by sending an e-mail request to HOSTMASTER@NIC.DDN.MIL or to the mailbox SERVICE@NIC.DDN.MIL.

1.9.3.3. Online informational files

Several informational files that domain implementors will find useful are available online from host NIC.DDN.MIL.

Top-Level Domains: The file NETINFO:DOMAINS.TXT contains a machine-readable table in RFC 952 format of top-level domains and the network addresses of their domain name servers. The file NETINFO:DOMAIN-INFO.TXT lists all registered top-level domains and their second-level subdomains in alphabetical order.

Domain Points of Contact: Online file NETINFO:DOMAIN-CONTACTS.TXT lists the points of contact for each domain registered with the DDN NIC, and the file NETINFO:DOMAIN-TEMPLATE.TXT contains the registration form to be used in registering a top-level or second-level domain with the DDN NIC.

Root Servers: The file NETINFO:ROOT-SERVERS.TXT lists the hostnames and network addresses of the machines that provide root-level domain name service for the DNS.

Registered IP Networks: The file NETINFO:NETWORKS.TXT provides a list of all registered IP networks that are permitted to pass traffic on the DDN/DARPA Internet.

DNS Implementations: The file NAMEDROPPERS:DNS-SOFTWARE.TXT contains the domain software catalog, started by Paul Mockapetris. For each DNS implementation, this catalog lists the name of the system, version, applicable OS/CPU, availability, name server and resolver types, whether zone transfers are supported, the transport protocol used, other software required for use, limitations, source of information, e-mail and postal-mail address of contact, and phone number of contact. Some entries of the catalog include, in addition, the programming language used, filenames to FTP (documentation, code, or others), and special features.

1.9.3.4. Online WHOIS service

The DDN NIC provides an electronic white-pages service for Internet users. This service, called WHOIS (or NICNAME at some sites), delivers data to network users by means of a fast query/response transaction over the network. Domain, host, TAC, and network information may be obtained from WHOIS in addition to information about individual registered users and points of contact for various registered entities.

Remote users can use a WHOIS program on their local hosts, if available, or telnet to NIC.DDN.MIL and invoke the WHOIS program there. For help using the program, users type "whois help" (or "nicname help") at the "@" system prompt. WHOIS user programs for several operating systems are available; users should contact the DDN NIC for copies.

To obtain information about a specific domain, a user invokes WHOIS from a local host or telnets to host NIC.DDN.MIL, then issues the command at "@" prompt:

```
whois domain <domain-name> <Return>
```

In response, the WHOIS server will display the name of the organization that registered the domain, NIC "handle" (a unique database identifier) of the domain, and the address of organization; the name of domain; the administrative and technical contacts for the domain; a list of registered domain name servers for domain; and any registered subdomains or hosts.

For example:

```
whois domain gov <Return>
U.S. Government Domain (GOV-DOM)

 Domain Name: GOV

 Administrative Contact:
    Ohle, William A.  (WAO4)  ohle@OSI.ICST.NBS.GOV
    (202) 566-0220
 Technical Contact, Zone Contact:
     Hostmaster  (HOSTMASTER)  HOSTMASTER@NIC.DDN.MIL
     (800) 235-3155 (415) 859-3695

  Domain servers in listed order:

  NIC.DDN.MIL                   26.0.0.73, 10.0.0.51
  A.ISI.EDU                     26.3.0.103
  C.NYSER.NET                   192.33.4.12
  TERP.UMD.EDU                  10.1.0.17, 128.8.10.90
  GUNTER-ADAM.AF.MIL            26.1.0.13
  NS.NASA.GOV                   128.102.16.10
  AOS.BRL.MIL                   128.20.1.2, 192.5.25.82
```

```
Would you like to see the known domains under this top-level domain? y

     There are 30 known sub-domains:

     ANL.GOV           Argonne National Laboratory
     BLDRDOC.GOV       National Institute of Standards and Technology
     BNL.GOV           Brookhaven National Laboratory
     CEBAF.GOV         Continuous Electronic Beam Accelerator Facility
     CSS.GOV           Center for Seismic Studies
There are 25 more matches.  Show them? no
```

1.9.3.5. Further Information

For further information, contact the DDN NIC directly by U.S. postal mail:

SRI International
DDN Network Information Center
333 Ravenswood Avenue, Room EJ291
Menlo Park, CA 94025

By e-mail:

NIC@NIC.DDN.MIL for general information
HOSTMASTER@NIC.DDN.MIL for domain-specific information

By telephone:

(800) 235-3155
(415) 859-3695

2. THE INTERNET HOST TABLE

Section 2 contains RFCs that describe the Internet Host Table, which was used to map host names to Internet addresses in the past, before the DNS was developed.

RFC 952 specifies the format for the official Internet Host Table and is used by the DoD Hostname Server. The Internet Host Table is a machine-readable file that contains data about networks, gateways, and hosts connected to the DDN Internet. This RFC shows examples of the format of the entries and syntax used in the Internet Host Table, and explains the methods used to obtain copies of the table via FTP or by using the Hostname Server Protocol described in RFC 953. This RFC obsoletes RFC 810.

RFC 953 describes the Hostname Server Protocol that delivers, by way of a TCP connection, machine-readable name and address data on networks, gateways, hosts, and domains in the Internet that are registered with the DDN NIC. This RFC describes the query/response format and command/response keywords that are recognized by the server, and gives examples of common types of possible transactions, including how to get the full Internet Host Table. This RFC obsoletes RFC 811.

2.1. DOD Internet Host Table Specification [RFC 952]

Network Working Group K. Harrenstien (SRI)
Request for Comments: 952 M. Stahl (SRI)
E. Feinler (SRI)
Obsoletes: RFC 810, 608 October 1985

DOD INTERNET HOST TABLE SPECIFICATION

STATUS OF THIS MEMO

This RFC is the official specification of the format of the Internet Host Table. This edition of the specification includes minor revisions to RFC-810 which brings it up to date. Distribution of this memo is unlimited.

INTRODUCTION

The DoD Host Table is utilized by the DoD Hostname Server maintained by the DDN Network Information Center (NIC) on behalf of the Defense Communications Agency (DCA) [See RFC-953].

LOCATION OF THE STANDARD DOD ONLINE HOST TABLE

A machine-translatable ASCII text version of the DoD Host Table is online in the file NETINFO:HOSTS.TXT on the SRI-NIC host. It can be obtained via FTP from your local host by connecting to host SRI-NIC.ARPA (26.0.0.73 or 10.0.0.51), logging in as user = ANONYMOUS, password = GUEST, and retrieving the file "NETINFO:HOSTS.TXT". The same table may also be obtained via the NIC Hostname Server, as described in RFC-953. The latter method is faster and easier, but requires a user program to make the necessary connection to the Name Server.

ASSUMPTIONS

1. A "name" (Net, Host, Gateway, or Domain name) is a text string up to 24 characters drawn from the alphabet (A-Z), digits (0-9), minus sign (-), and period (.). Note that periods are only allowed when they serve to delimit components of "domain style names". (See RFC-921, "Domain Name System Implementation Schedule", for background). No blank or space characters are permitted as part of a name. No distinction is made between upper and lower case. The first character must be an alpha character. The last character must not be a minus sign or period. A host which serves as a GATEWAY should have "-GATEWAY" or "-GW" as part of its name. Hosts which do not serve as Internet gateways should not use "-GATEWAY" and "-GW" as part of their names. A host which is a TAC should have "-TAC" as the last part of its host name, if it is a DoD host. Single character names or nicknames are not allowed.

2. Internet Addresses are 32-bit addresses [See RFC-796]. In the

host table described herein each address is represented by four decimal numbers separated by a period. Each decimal number represents 1 octet.

3. If the first bit of the first octet of the address is 0 (zero), then the next 7 bits of the first octet indicate the network number (Class A Address). If the first two bits are 1,0 (one,zero), then the next 14 bits define the net number (Class B Address). If the first 3 bits are 1,1,0 (one,one,zero), then the next 21 bits define the net number (Class C Address) [See RFC-943].

This is depicted in the following diagram:

```
+-+------------+--------------+--------------+--------------+
|0|  NET <-7-> |          LOCAL ADDRESS <-24->              |
+-+------------+--------------+--------------+--------------+

+---+----------+--------------+--------------+--------------+
|1 0|       NET  <-14->       |   LOCAL ADDRESS <-16->      |
+---+----------+--------------+--------------+--------------+

+-----+--------+--------------+--------------+--------------+
|1 1 0|             NET  <-21->              | LOCAL ADDRESS|
+-----+--------+--------------+--------------+--------------+
```

4. The LOCAL ADDRESS portion of the internet address identifies a host within the network specified by the NET portion of the address.

5. The ARPANET and MILNET are both Class A networks. The NET portion is 10 decimal for ARPANET, 26 decimal for MILNET, and the LOCAL ADDRESS maps as follows: the second octet identifies the physical host, the third octet identifies the logical host, and the fourth identifies the Packet Switching Node (PSN), formerly known as an Interface Message Processor (IMP).

```
+-+------------+--------------+--------------+--------------+
|0|  10 or 26  |     HOST     | LOGICAL HOST |   PSN (IMP)  |
+-+------------+--------------+--------------+--------------+
```

(NOTE: RFC-796 also describes the local address mappings for several other networks.)

6. It is the responsibility of the users of this host table to translate it into whatever format is needed for their purposes.

7. Names and addresses for DoD hosts and gateways will be negotiated and registered with the DDN PMO, and subsequently with the NIC,

before being used and before traffic is passed by a DoD host. Names and addresses for domains and networks are to be registered with the DDN Network Information Center (HOSTMASTER@SRI-NIC.ARPA) or 800-235-3155.

The NIC will attempt to keep similar information for non-DoD networks and hosts, if this information is provided, and as long as it is needed, i.e., until intercommunicating network name servers are in place.

EXAMPLE OF HOST TABLE FORMAT

```
NET · 10.0.0.0 : ARPANET :
NET : 128.10.0.0 : PURDUE-CS-NET :
GATEWAY : 10.0.0.77, 18.10.0.4 : MIT-GW.ARPA,MIT-GATEWAY : PDP-11 :
          MOS : IP/GW,EGP :
HOST : 26.0.0.73, 10.0.0.51 : SRI-NIC.ARPA,SRI-NIC,NIC : DEC-2060 :
       TOPS20 :TCP/TELNET,TCP/SMTP,TCP/TIME,TCP/FTP,TCP/ECHO,ICMP :
HOST : 10.2.0.11 : SU-TAC.ARPA,SU-TAC : C/30 : TAC : TCP :
```

SYNTAX AND CONVENTIONS

; (semicolon)	is used to denote the beginning of a comment. Any text on a given line following a ';' is a comment, and not part of the host table.
NET	keyword introducing a network entry
GATEWAY	keyword introducing a gateway entry
HOST	keyword introducing a host entry
DOMAIN	keyword introducing a domain entry
:(colon)	is used as a field delimiter
::(2 colons)	indicates a null field
,(comma)	is used as a data element delimiter
XXX/YYY	indicates protocol information of the type TRANSPORT/SERVICE.

where TRANSPORT/SERVICE options are specified as

"FOO/BAR"	both transport and service known

"FOO"	transport known; services not known
"BAR"	service is known, transport not known

NOTE: See "Assigned Numbers" for specific options and acronyms for machine types, operating systems, and protocol/services.

Each host table entry is an ASCII text string comprised of 6 fields, where

Field 1	KEYWORD indicating whether this entry pertains to a NET, GATEWAY, HOST, or DOMAIN. NET entries are assigned and cannot have alternate addresses or nicknames. DOMAIN entries do not use fields 4, 5, or 6.
Field 2	Internet Address of Network, Gateway, or Host followed by alternate addresses. Addresses for a Domain are those where a Domain Name Server exists for that domain.
Field 3	Official Name of Network, Gateway, Host, or Domain (with optional nicknames, where permitted).
Field 4	Machine Type
Field 5	Operating System
Field 6	Protocol List

Fields 4, 5 and 6 are optional. For a Domain they are not used.

Fields 3-6, if included, pertain to the first address in Field 2.

'Blanks' (spaces and tabs) are ignored between data elements or fields, but are disallowed within a data element.

Each entry ends with a colon.

The entries in the table are grouped by types in the order Domain, Net, Gateway, and Host. Within each type the ordering is unspecified.

Note that although optional nicknames are allowed for hosts, they are discouraged, except in the case where host names have been changed and both the new and the old names are maintained for a suitable period of time to effect a smooth transition. Nicknames are not permitted for NET names.

GRAMMATICAL HOST TABLE SPECIFICATION

A. Parsing grammar

```
<entry> ::= <keyword> ":" <addresses> ":" <names> [":" [<cputype>]
   [":" [<opsys>]  [":" [<protocol list>] ]]] ":"
<addresses> ::= <address> *["," <address>]
<address> ::= <octet> "." <octet> "." <octet> "." <octet>
<octet> ::= <0 to 255 decimal>
<names> ::= <netname> | <gatename> | <domainname> *[","
   <nicknames>]
   | <official hostname> *["," <nicknames>]
<netname>  ::= <name>
<gatename> ::= <hname>
<domainname> ::= <hname>
<official hostname> ::= <hname>
<nickname> ::= <hname>
<protocol list> ::= <protocol spec> *["," <protocol spec>]
<protocol spec> ::= <transport name> "/" <service name>
   | <raw protocol name>
```

B. Lexical grammar

```
<entry-field> ::= <entry-text> [<cr><lf> <blank> <entry-field>]
<entry-text>  ::= <print-char> *<text>
<blank> ::= <space-or-tab> [<blank>]
<keyword> ::= NET | GATEWAY | HOST | DOMAIN
<hname> ::= <name>*["."<name>]
<name>  ::= <let>[*[<let-or-digit-or-hyphen>]<let-or-digit>]
<cputype> ::= PDP-11/70 | DEC-1080 | C/30 | CDC-6400...etc.
<opsys>   ::= ITS | MULTICS | TOPS20 | UNIX...etc.
<transport name> ::= TCP | NCP | UDP | IP...etc.
<service name> ::= TELNET | FTP | SMTP | MTP...etc.
<raw protocol name> ::= <name>
<comment> ::= ";" <text><cr><lf>
<text>    ::= *[<print-char> | <blank>]
<print-char>  ::= <any printing char (not space or tab)>
```

Notes:

1. Zero or more 'blanks' between separators " , : " are allowed. 'Blanks' are spaces and tabs.

2. Continuation lines are lines that begin with at least one blank. They may be used anywhere 'blanks' are legal to split an entry across lines.

BIBLIOGRAPHY

1. Feinler, E., Harrenstien, K., Su, Z. and White, V., "Official DoD Internet Host Table Specification", RFC-810, Network Information Center, SRI International, March 1982.

2. Harrenstien, K., Stahl, M., and Feinler, E., "Hostname Server", RFC-953, Network Information Center, SRI International, October 1985.

3. Kudlick, M. "Host Names Online", RFC-608, Network Information Center, SRI International, January 1973.

4. Postel, J., "Internet Protocol", RFC-791, Information Sciences Institute, University of Southern California, Marina del Rey, September 1981.

5. Postel, J., "Address Mappings", RFC-796, Information Sciences Institute, University of Southern California, Marina del Rey, September 1981.

6. Postel, J., "Domain Name System Implementation Schedule", RFC-921, Information Sciences Institute, University of Southern California, Marina del Rey, October 1984.

7. Reynolds, J. and Postel, J., "Assigned Numbers", RFC-943, Information Sciences Institute, University of Southern California, Marina del Rey, April 1985.

2.2. Hostname Server [RFC 953]

```
Network Working Group                              K. Harrenstien (SRI)
Request for Comments: 953                               M. Stahl (SRI)
Obsoletes:  RFC 811                                   E. Feinler (SRI)
                                                          October 1985
```

HOSTNAME SERVER

STATUS OF THIS MEMO

This RFC is the official specification of the Hostname Server Protocol. This edition of the specification includes minor revisions to RFC 811 which brings it up to date. Distribution of this memo is unlimited.

INTRODUCTION

The NIC Internet Hostname Server is a TCP-based host information program and protocol running on the SRI-NIC machine. It is one of a series of internet name services maintained by the DDN Network Information Center (NIC) at SRI International on behalf of the Defense Communications Agency (DCA). The function of this particular server is to deliver machine-readable name/address information describing networks, gateways, hosts, and eventually domains, within the internet environment. As currently implemented, the server provides the information outlined in the DoD Internet Host Table Specification [See RFC-952]. For a discussion of future developments see also RFC-921 concerning the Domain Name System.

PROTOCOL

To access this server from a program, establish a TCP connection to port 101 (decimal) at the service host, SRI-NIC.ARPA (26.0.0.73 or 10.0.0.51). Send the information request (a single line), and read the resulting response. The connection is closed by the server upon completion of the response, so only one request can be made for each connection.

QUERY/RESPONSE FORMAT

The name server accepts simple text query requests of the form

```
<command key> <argument(s)> [<options>]
```

where square brackets ("[]") indicate an optional field. The command key is a keyword indicating the nature of the request. The defined keys are explained below.

The response, on the other hand, is of the form

```
<response key> : <rest of response>
```

where <response key> is a keyword indicating the nature of the response, and the rest of the response is interpreted in the context of the key.

NOTE: Care should be taken to interpret the nature of the reply (e.g, single record or multiple record), so that no confusion about the state of the reply results. An "ALL" request will likely return several hundred or more records of all types, whereas "HNAME" or "HADDR" will usually return one HOST record.

COMMAND/RESPONSE KEYS

The currently defined command keywords are listed below. NOTE: Because the server and the features available will evolve with time, the HELP command should be used to obtain the most recent summary of implemented features, changes, or new commands.

Keyword	Response
HELP	This information.
VERSION	"VERSION: <string>" where <string> will be different for each version of the host table.
HNAME <hostname>	One or more matching host table entries.
HADDR <hostaddr>	One or more matching host table entries.
ALL	The entire host table.
ALL-OLD	The entire host table without domain style names.
DOMAINS	The entire top-level domain table (domains only).
ALL-DOM	Both the entire domain table and the host table.
ALL-INGWAY	All known gateways in TENEX/TOPS-20 INTERNET.GATEWAYS format.

Remember that the server accepts only a single command line and returns only a single response before closing the connection. HNAME and HADDR are useful for looking up a specific host by name or address; VERSION can be used by automated processes to see whether a "new" version of the host table exists without having to transfer the whole table. Note, however, that the returned version string is only guaranteed to be unique to each version, and nothing should currently be assumed about its format.

Response Keys:

ERR	entry not found, nature of error follows
NET	entry found, rest of entry follows
GATEWAY	entry found, rest of entry follows
HOST	entry found, rest of entry follows
DOMAIN	entry found, rest of entry follows
BEGIN	followed by multiple entries
END	done with BEGIN block of entries

More keywords will be added as new needs are recognized. A more detailed description of the allowed requests/responses follows.

QUERY/RESPONSE EXAMPLES

1. HNAME Query - Given a name, find the entry or entries that match the name. For example:

```
HNAME SRI-NIC.ARPA <CRLF>
```

where <CRLF> is a carriage return/ linefeed, and 'SRI-NIC.ARPA' is a host name

The likely response is:

```
HOST : 26.0.0.73, 10.0.0.51 : SRI-NIC.ARPA,SRI-NIC,NIC :
       DEC-2060 : TOPS20 : TCP/TELNET,TCP/SMTP,TCP/TIME,TCP/FTP,
       TCP/ECHO,ICMP :
```

A response may stretch across more than one line. Continuation lines always begin with at least one space.

2. HADDR Query - Given an internet address (as specified in RFC 796) find the entry or entries that match that address. For example:

```
HADDR 26.0.0.73 <CRLF>
```

where <CRLF> is a carriage return/ linefeed, and '26.0.0.73' is a host address.

The likely response is the same as for the previous HNAME request.

3. ALL Query - Deliver the entire internet host table in a machine-readable form. For example:

```
ALL <CRLF>    ;where <CRLF> is a carriage return/linefeed
```

The likely response is the keyword 'BEGIN' followed by a colon ':', followed by the entire internet host table in the format specified in RFC-952, followed by 'END:'.

ERROR HANDLING

ERR Reply - may occur on any query, and should be permitted in any access program using the name server. Errors are of the form

```
ERR : <code> : <string> :
  as in
ERR : NAMNFD : Name not found :
```

The error code is a unique descriptor, limited to 8 characters in length for any given error. It may be used by the access program to identify the error and, in some cases, to handle it automatically. The string is an accompanying message for a given error for that case where the access program simply logs the error message. Current codes and their associated interpretations are

NAMNFD	Name not found; name not in table
ADRNFD	Address not found; address not in table
ILLCOM	Illegal command; command key not recognized
TMPSYS	Temporary system failure, try again later

REFERENCES

1. Harrenstien, K., Stahl, M., and Feinler, E., "Official DoD Internet Host Table Specification," RFC-952, DDN Network Information Center, SRI International, October 1985.

2. Pickens, J., Feinler, E., and Mathis, J., "The NIC Name Server," A Datagram-Based Information Utility, RFC-756, Network Information Center, SRI International, July 1979.

3. Postel, J., "Address Mappings," RFC-796, Information Sciences Institute, University of Southern California, Marina del Rey, September 1981.

4. Postel, J., "Domain Name System Implementation Schedule", RFC-921, Information Sciences Institute, University of Southern California, Marina del Rey, October 1984.

DOMAIN NAME ACRONYMS

A	Internet Address
AA	Authoritative Answer
ARPA	Advanced Research Projects Agency
ASN	Automomous System Number
AXFR	Special zone transfer QTYPE
BIND	Berkeley Internet Name Domain server
CH	The Chaos system
CNAME	Canonical Name (nickname pointer)
COM	Commercial
CPU	Central Processing Unit
CS	CSNET class (obsolete--seen in obsolete RFCs)
CSNET	Computer Science Network
DA	Domain Administrator
DARPA	Defense Advanced Research Projects Agency
DDN NIC	Defense Data Network - Network Information Center
DDN PMO	Defense Data Network Program Management Office
DNS	Domain Name System
EDU	Education
EGP	Exterior Gateway Protocol
FTP	File Transfer Protocol
GGP	Gateway-to-Gateway Protocol
GOV	Government
HINFO	Host Information
HS	Hesiod class
IETF	Internet Engineering Task Force
IMP	Interface Message Processor (see PSN)
IN	Internet
IP	Internet Protocol
MAILA	Mail Agent RRs (obsolete-see MX)
MAILB	Mailbox (request for records-MB, MG, or MR)
MB	Mailbox Domain name
MD	Mail Destination (obsolete-use MX)
MF	Mail Forwarder (obsolete-use MX)
MG	Mail Group
MIL	Military
MINFO	Mailbox or mail list information
MR	Mail Rename
MX	Mail Exchanger
NE	Name Error
NIC	Network Information Center
NS	Name Server
NULL	Null RR
ORG	Organization
OS	Operating System

PSN	Packet Switched Node (formerly IMP)
PTR	Pointer
QCLASS	Query Class
QNAME	Query Domain Name
QR	Query or Response
QTYPE	Query Type
RA	Recursion Available
RCODE	Response Code
RD	Recursion Desired
RDATA	Resource Data
RDLENGTH	RDATA Length
RFC	Request for Comments
RR	Resource Record
SBELT	Safety Belt
SCLASS	the Class of the Search request
SLIST	Structure describing name servers and the zone which the resolver is trying to query
SNAME	Domain name search
SOA	Start Of Authority
STYPE	the QTYPE of the search request
TC	TrunCation
TCP	Transmission Control Protocol
TTL	Time To Live
TXT	Text
UDP	User Datagram Protocol
WKS	Well Known Services
Z	Zero all queries and responses