Dynamic Control of Service Delivery for Ad Hoc Systems

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ABSTRACT

After description of the deployment of forces on a theatre of operation, the paper addresses the organisation of the sub-networks in such a deployment, and the generic network architecture required for bring together the different network capabilities. The paper shows how dynamic control of the architecture can provide an efficient solution for Service Delivery, through a description of three services for ad hoc systems able to adapt rapidly to mobile environments:

Messaging and Mobile Multimedia Services. The architecture describes the technical solutions for Localisation of mobile entities and propagation of information for routing the service in a mobile environment.

Ad hoc Data Dissemination System able to provide an optimised dissemination service for different Communities of Interest (CoI). The system handles registration of mobile subscribers and publishers that can join and leave different CoI depending on their rights (that can be accessed through the directory system). To cope with the mobility of the Dissemination Nodes on the field, the system dynamically adapts to establish and maintain a Dissemination Overlay Network able to link together the publisher and subscriber for each CoI.

As a conclusion, the paper identifies additional challenges under study for dynamic QoS mechanisms in order to provide a "deterministic" Dissemination Service based on resource reservation mechanisms activated between the Dissemination Overlay Network and the real networks below.

1.0 INTRODUCTION

Military communications are more and more carried over the Internet Protocol, and the vision is to migrate where it is possible these communications to an integrated network infrastructure based on IP.

This implies that applications having very strong requirements in the domain of security, mobility, and quality of Service are migrating to an IP based infrastructure built with a wide variety of sub-networks (Deployable Backbone, satellite Network, High Capacity Data Radio, …). This infrastructure will be shared in order to provide services to users grouped in different communities (example : Command and Control Applications [C2], Logistics, Intelligence…).

However certain sub-networks will not migrate to IP, in order to keep the efficiency level reached by the legacy architectures and protocols. The objective is to integrate in a seamless architecture the services provided over IP and the efficient legacy solutions, in order to provide the users with a high level of service without wasting the resources affected to the battlefield (frequencies, throughput, …).

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When the service is available, the interface provided to the final user by the Integrated Infrastructure have seamless capabilities wherever the final user is connected.

The architecture of the Integrated Infrastructure has also as a main objective, to adapt to evolving situations where changes relative to the mission or to available resources (sub-network resources, inter-network topology) have to be managed dynamically. A lack of resources may create temporary situations where not all the requirements can be met, in such a case the Integrated Infrastructure will manage the flows according to their military precedence.

In order to manage these evolving situations, the Integrated Infrastructure controls dynamically the topology, the resources available on the topology, the configuration of the network (SLA, user profiles, …), the localisation of the users in order to deliver the services and to make for each flow the best decision when forwarding from source to destination over the topology.

Dynamic Control of an Integrated Infrastructure is managed by the nodes of the infrastructure. These nodes integrate added value components able to control the behaviour of the application layer relays (messaging, Web proxies, multimedia relays, Data Dissemination Relays).These added value components play the role of a system control plane that, thanks to the configuration present in the Directory, generalised mobility management, and resource management, controls the relays present in the architecture.

Thanks to these basic principles, this integrated architecture will comply with the undergoing work defining the Global Information Grid (GIG), and can easily interwork with allied forces deploying Network Enabled Capabilities.

2.0 DEPLOYMENTS ON THE TACTICAL FIELD

The objective of this paragraph is to show a view of the deployment of units present on a theatre of operation. This view presents the diversity of deployed networks that is composed of:

• Reach-Back capabilities : this sub-network is in charge to interconnect the theatre of operation with the home-base,

• Deployable Networks : these sub-networks are deployed on the field, they are in charge to provide the IP connectivity and high bandwidth for Head-Quarters units and Division and Brigades units. The trunks of a deployable network scale from 2 to 34 Mbps.

• Theatre satellite Network : This sub-network takes into account the lacunary aspects of the theatre, and will also bring higher elongation and bandwidth for interconnection of the battalion level with the HQ. Such capabilities enable deployment of more services at battalion level (multimedia services, Web services, Presence services, …)

• VHF CNR radio networks : The deployment of these sub-networks is in charge of the interconnection of Mobile Tactical Units (Battalion, Company and Section Level). The main characteristics of these networks are : enhanced mobility capabilities enabled with Adhoc Networking technologies, enhanced protection of the flows in hostile environment (TRANSEC), very constrained bandwidth. These networks have not the capability to carry any type of service. Main services carried over VHF networks are messaging and CNR voice conferences.

• HF theatre radio Networks : HF theatre radio sub-networks allow interconnection of any area of the theatre with the HQ units. The main advantage of HF networks is the elongation that is much more important. Like VHF sub-networks, these networks have not the capability to carry any type of service. Main services carried over HF networks are messaging and HF voice services.

- High Capacity Data Radio : HCDR sub-networks are an alternative to VHF sub-networks, that allows higher capacity, larger networks, and more services. HCDR sub-networks are based on Adhoc technologies.

- The enhanced civilian radio sub-networks (S-WIFI, S-WIMAX) : These technologies will bring more bandwidth in the access network in order to allow remote applications requiring high bandwidth capabilities (remote users, video-surveillance, …)

The following diagram gives an idea in which way the deployment will be addressed
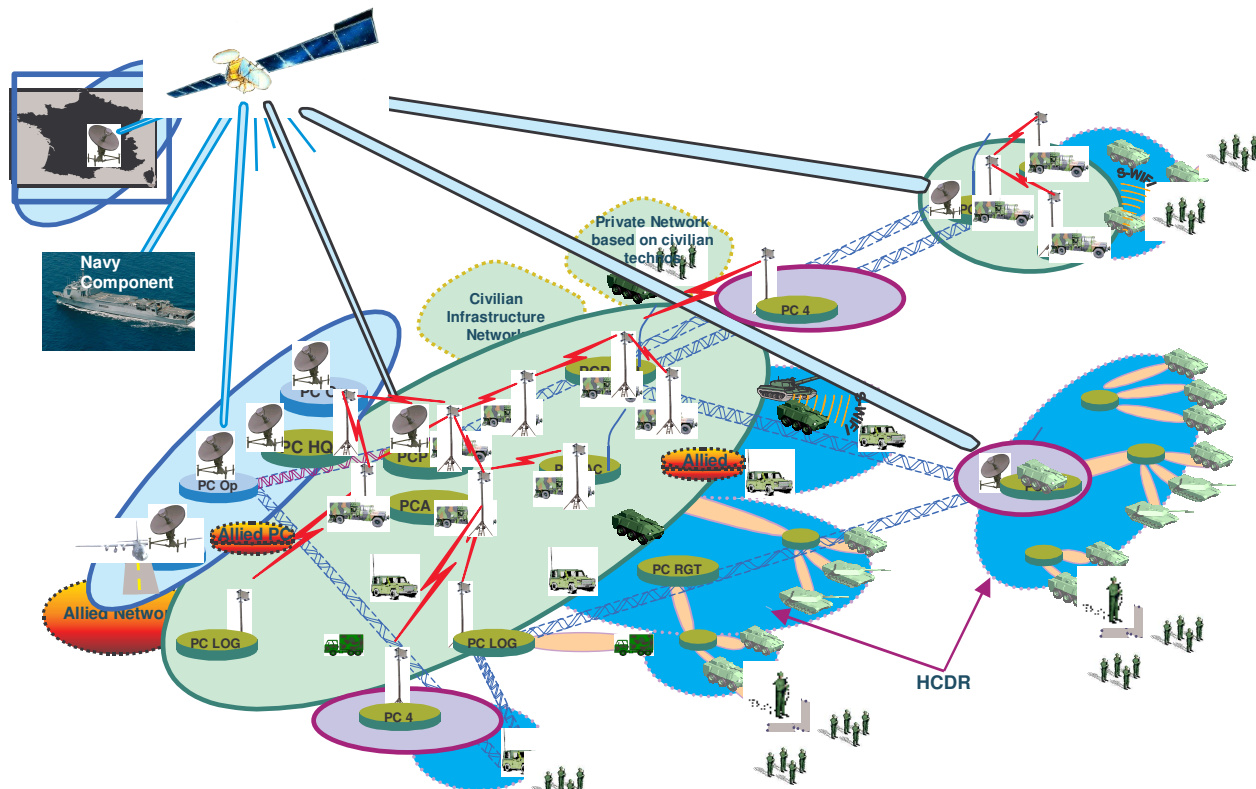

Figure 1: Network Deployment on a Theatre of Operation

The Integrated Infrastructure is in charge to cope with the different characteristics of all these sub-networks in order to provide seamlessly end to end services to the users, wherever they are connected. In order to reach this objective the Integrated Infrastructure has to control dynamically the localisation of the users, the topology of the network, and the availability of the resources.

3.0   GENERIC NETWORK ARCHITECTURE IN MOBILE TACTICAL INTERNET

This paragraph will introduce the principles of the Integrated Infrastructure architecture, this architecture is composed of three main layers:

- Sub-networks (deployable network, satellite network, radio networks, civilian infrastructure networks, allied external networks, …). All these sub-networks are not able to provide the IP basic services (IP forwarding, routing, Interconnection with adjacent IP networks, …), and have implemented efficient

legacy protocols that take into account all the constraints of the sub-network (channel access delay due to shared access, latency, poor bandwidth, …).

- An IP infrastructure composed of the IP capable sub-networks. This IP Infrastructure will provide a seamless IP service on the theatre. This infrastructure is also in charge to manage mobility of the Service Nodes

- An Intranet Service Network in charge to provide the basic services to the users connected to the system., these services are : messaging, instant messaging, multimedia, publish-subscribe and Web. This network is composed of Service Nodes (SN) reachable either through the IP Infrastructure or reachable via legacy networks. This service plane may be instantiated according to the different levels of security that have to be deployed on the theatre of operation.

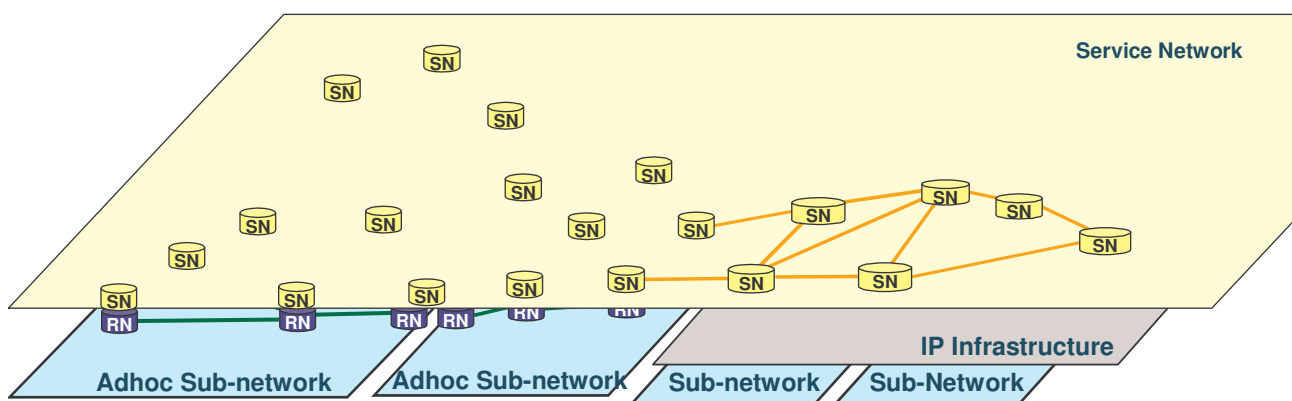This layered network and service organisation is shown by the following diagram.

Figure 2: Layered Networking Organisation

In this architecture Dynamic Control will solves the following basic problems:

- Management of Quality of Service in the sub-networks, in the IP Infrastructure, and in the Service Network. Quality of Service management requires :

  - dynamic management (allocation and de-allocation) of resources with a signalling protocol that indicates the amount of resources required for a communication and the precedence of the flow that requires these resources

  - a routing protocol able to take into account the resources reserved on the topology and the importance of the reserved resources.

  - An appropriate mechanism that makes sure that the flows use the resources that have been reserved thanks to the signalling protocol.

- Generalised mobility management in the Service Plane according to the localisation of the users (the users may move from one Service Node to an other) and according to the topology of the service plane which may rely on different sub-networks (the service nodes may move and connect to any sub-network. of the topology). Generalised mobility is explained in the following paragraph

- Dynamic management of the user rights according to a Directory that precise for each user its profile (the services he is allowed to use, the data he is allowed to access, the conferences or chat-room he is allowed to enter, …). Dynamic control of user rights requires that the system controls each flow issued by the user, if that flow is allowed according to the directory. If the flow is authorised than the system

may dynamically get from the directory the precedence that is assigned for this flow.

4.0 DYNAMIC CONTROL OF SERVICE DELIVERY

4.1 Mobility management in a Service Network

Mobility inside a service network is composed of the mobility of Service Node inside the service network and the mobility of the users, functions, servers, and information inside the service Network. :

- Mobility of Service Nodes inside a service Network is seen in the architecture from two different points of view : mobility provided by the IP Infrastructure and mobility of the service network topology,

- Mobility of the users, functions, servers, information is more related to operational mobility requirement on a theatre of operation for example:

  - The localisation of a user may change during the mission, this change will impact all the communications destined to that user, because these communications must be forwarded to the right localisation of the user

  - The localisation of a function may change often during the mission, in the same way the communications destined to a function have to forwarded to the localisation where this function is active

  - The localisation of a portal may change due to stepup, the remote users who wish to connect to the portal shall not have to know where the portal is reachable, for these reasons the requests issued by the browser must be routed in an appropriate way to the active localisation of the portal

In order to control dynamically the forwarding/routing of the user communications to the right destination, the service nodes have to provide an enhanced solution that takes into account the service network topology, and the localisation of the users/functions/servers/information.

The objective is also to elaborate a solution that provides the capability to distribute, in an optimised way, a message to multiple recipients according to the localisation of the recipients, and according to available resources and connectivity in the topology of the service network.

4.2 Basic principles of dynamic mobility management

Dynamic control of mobility shall address: user-function-server-information mobility, distribution of flows having multiple recipients via a distribution tree set up dynamically according to the distribution list, and the interconnection of the service nodes via a topology that may evolve.

The recipients are mobile on a whole mobility domain composed of multiple sub-networks (see figure 2), dynamic mobility management shall take into account the context of network heterogeneity. Dynamic mobility management gives an answer to two basic questions:

- Where (on which servers) are connected the recipients of a communication (user-function-information) ?

- How shall the flow be routed/forwarded from the source server to the destination servers where the users-functions-information are located ?

The answer to the first question is a simple access to a database that indicates for each user-function-information its localisation. In a tactical environment, where availability and mobility constraints are very high, it is required that the database is replicated on each site, unlike classical implementations known in

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the civilian world that are based on a centralised database.

The answer to the second question could be very easy, and consist in propagating the flow from source to each destination by using basic IP forwarding. However such a solution : requires the IP connectivity, is not suitable for optimisation of flow distribution between one source and many recipients, and doesn't integrate the possibility to adapt the flows according to the capabilities of the bearer network.

Dynamic mobility control shall also propose a global solution that takes into account routing and user-function-information localisation issues for each service (Multimedia, Messaging, Web, Data Dissemination).

Dynamic mobility control of all the services, is called LOC on the diagrams here after. This component provides the Services with the routing information. At each hop this routing information is composed of the identification of the "next hop", and if required the information relative to transfer gateways (xTG on the figure) that have to be used for this next hop, these transfer gateways are required especially when the next hop goes over a Sub-Network (directly attached to the service node), having no IP forwarding capabilities (Example : Combat radio networks).

The following diagram shows an example of a flow that has multiple destination. On this example the source of the flow in connected to Service Node $_B$, and has to be distributed to users connected to Service Node $_C$ and Service Node $_G$. This flow is carried over a first Network Element via the Transfer Gateways (xTG) $_{12}$, $_{13}$ and $_{14}$, forwarded by Service Node $_E$ to Service Node $_F$ via the transfer gateways $_{31}$ and $_{32}$, and relayed by Service Node $_F$ to destination Service Node $_G$.

Dynamic mobility control deals with localisation of the user-function-information, and with service layer routing. This solution integrates the capability to setup dynamically a distribution tree relative to a multiple recipient flow, while taking into account the localisation of the users and the current topology of the network.
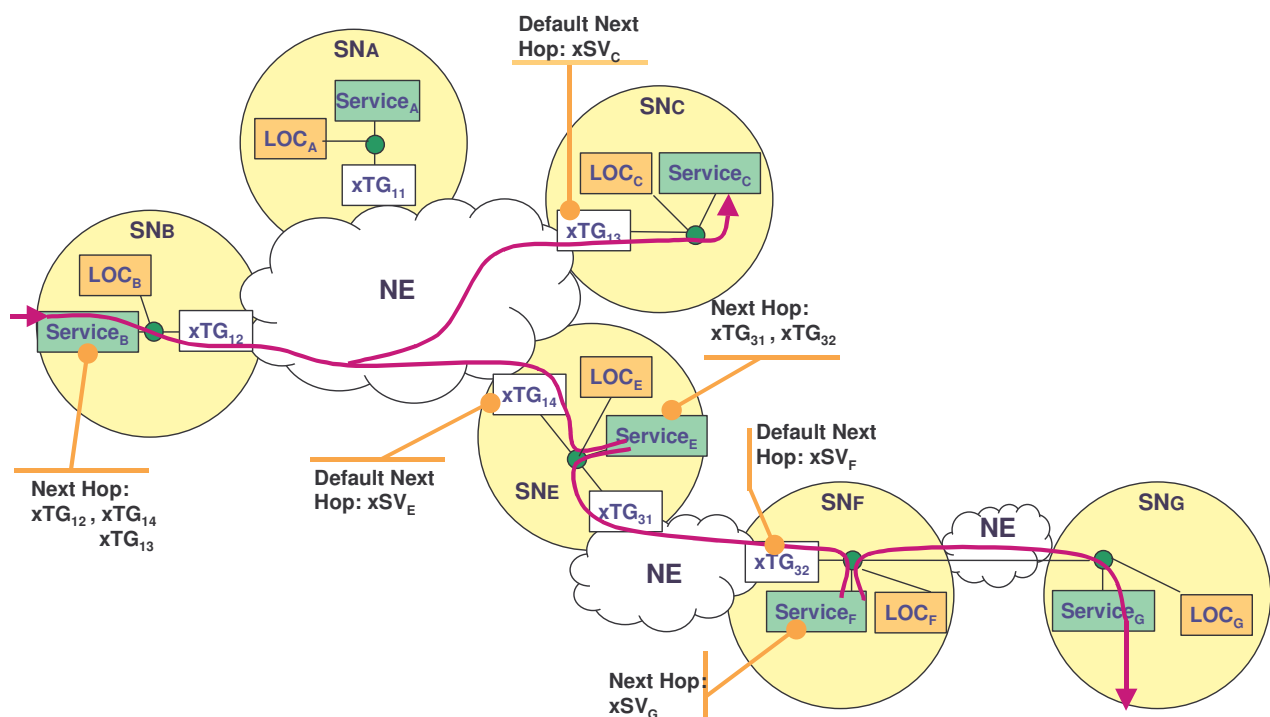
Figure 3 : Example of routing and forwarding of a multiple recipient flow

Dynamic elaboration of the distribution tree takes into account : the localisation of the users-functions-information (which have been exchanged between the LOC servers), and the topology information. The flow is forwarded hop by hop, at each hop the LOC server provides the "Service" with the optimal path to each recipient. The "Service" is in charge to relay the flow to the next hops issued by LOC, for each next hop the flow is only forwarded once.

The LOC software provides also a DNS interface that will be used for localisation of a server on the network or for localisation of Information addressed via URLs. Thanks to this DNS interface the LOC software is able to interface and control dynamically, in a standard way, the software developed for service relaying (SMTP relay, Web proxies, …).

4.2   Multimedia

The Multimedia Service provided by the architecture shall cope with standard solutions. These services may be present in head quarters and also in small Command Posts.

Mainly multimedia services cover :

- Voice over IP services

- Videoconference over IP with white board functionalities

- Telephony conference over IP with the use of Multicast Conference Units

- Share of applications (white board, …)

- Interoperability with voice services provided by external networks (civilian, allied forces, …)

- Interoperability with legacy voice services (Eurocom, CNR, …)

- Mobility of the users and of the conferences thanks to the affiliation solution developed by the LOC software

These services are provided by integration of standard COTS solutions provided by the vendors (Microsoft, Cisco, …) with the complementary requirements necessary for a deployment on a theatre of operation. These complementary requirements deal with limited bandwidth, pre-emption according to communication precedence, mobility of the users on the battlefield, quality of service and security of the communications.

The architecture brings together the high level of service present in the COTS solutions with the complementary services required by the constraints of a theatre of operation.

The multimedia architecture is based on the following principles :

- The multimedia services are based on standard H323 and SIP solutions. Theses services rely on a Multimedia Server, a Multimedia Relay, and standard MCU capabilities, that integrate both protocols and that also integrate the added value required for operation in a constrained environment

- The multimedia relay present in this architecture interfaces :

  - The Quality of Service Agent, which manages the resource reservation according to the precedence of the communication and to the available topology of the network

- The solutions provided by the vendors (Example : IP PBX VoIP solutions, …)

- The Gateways in order to provide interoperability with :

  - Legacy voice solutions developed for combat radio networks

  - legacy voice solutions developed in allied or national solutions

  - legacy civilian solution (ISDN, PSTN)

- The Multicast Conference Unit in order to bring together the users of a conference

- The directory in order to check if the communication is authorised for a specific user who is willing to establish the communication (dynamic control of multimedia service delivery)

- The LOC software in order to get the localisation of the destination user and the path to the destination multimedia server (dynamic control for multimedia service delivery)

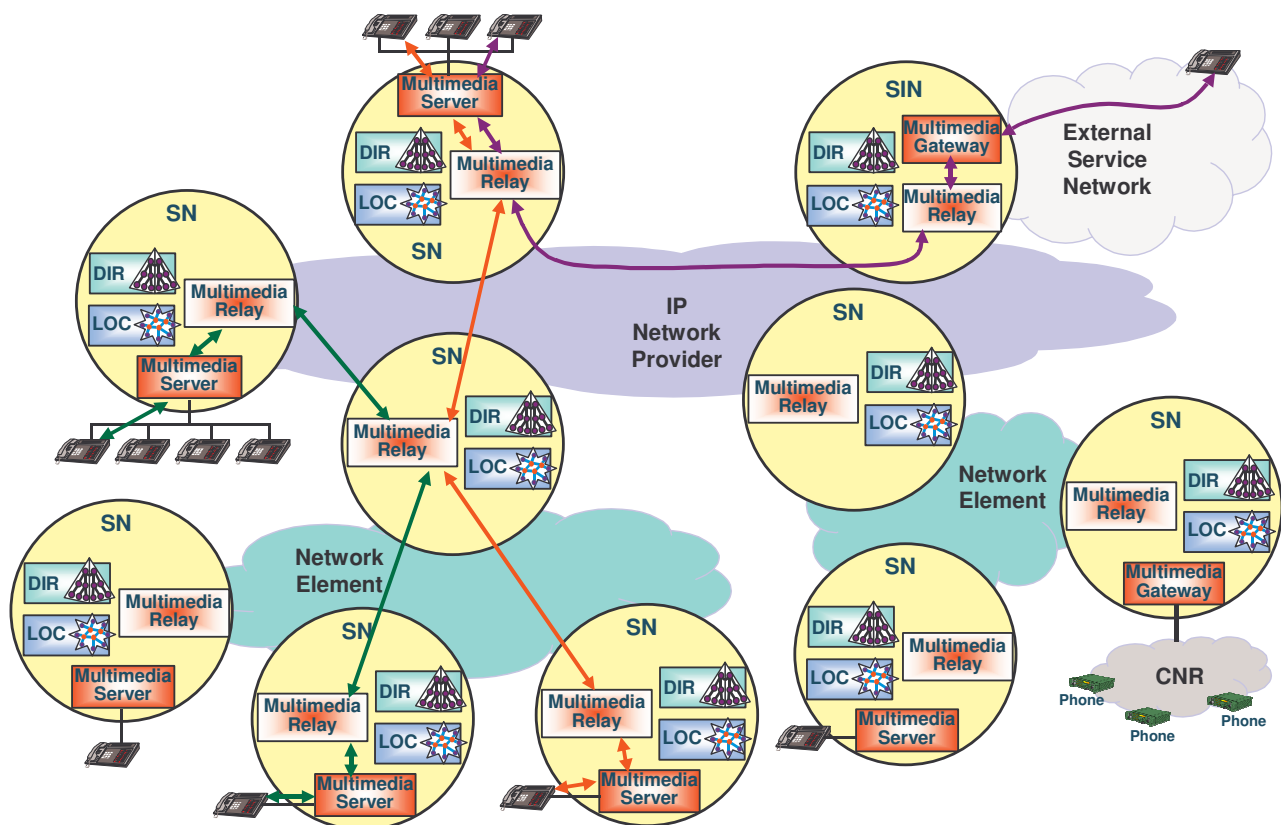The following diagram shows the system organisation of the multimedia service

Figure 4 : Multimedia System view

The system view shows the main functionalities present in the architecture for multimedia. The multimedia relay takes into account the interconnection of the servers and the gateways, the multimedia servers may be based on different technologies provided by different vendors or provided by COTS software solution (SIP Server, Gatekeeper), and the gateways in charge of interconnection with external or legacy systems. The arrows on the diagram show different possible multimedia communications.

4.3   Messaging

Dynamic control for messaging service delivery is based on following principles:

- The Messaging architecture shall allow selection of different COTS or MOTS messaging implementation in order to be able to provide a solution for messaging that copes with the requirements of the tactical field :

  - Provide interpersonal messaging capabilities (compliant with the service available at home on the Internet)

  - Provide formal tactical messaging capabilities having the capability to manage : message precedence, message signature, message encryption, …

- The architecture shall allow interconnection of a messaging service included in a service network with adjacent external messaging services. This interconnection is managed by a Service Interconnection Node present in Interconnection Centres. Interconnection with external networks may require specialised gateways able to manage the transfer of responsibility between the local messaging system and the external messaging system (protocol translation, address translation, signature transcription, exchange of contacts…)

- The messaging service, as provided to the users, is configured in the directory. This configuration takes into account the users, the functions and the rights. Dynamic control for messaging service delivery will control the rights attributed to users or functions before sending each message (example : is the user allowed to send a message having this size?)

- The Service Node defined in architecture hosts :

  - The COTS or MOTS messaging server in charge to provide the messaging service to the Information System (C2IS, Blue Force Tracking, …), and to the final users, according to the configuration of the directory (DIR on the figure)

  - A messaging relay which is in charge to forward the messages to the destination messaging servers while taking into account the topology of the service network and the localisation of the recipients of the message (LOC on the diagram). This requires dynamic elaboration of the distribution tree according to the localisations of the recipients and also according to the topology, in that way the relay propagates the message from source to destinations through one or multiple intermediary hops. Thanks to this capability the relay makes sure that a same message is always sent once over a constrained network path (satellite link, radio broadcast VHF network, …)

  - The relay takes also into account the specificities of the sub-networks which will carry the packets (broadcasting capabilities, point to multipoint capabilities, frame size, channel access time, …), and selects the adequate and optimised transport protocol at each hop (ESMTP, PMUL, HMTP, …)

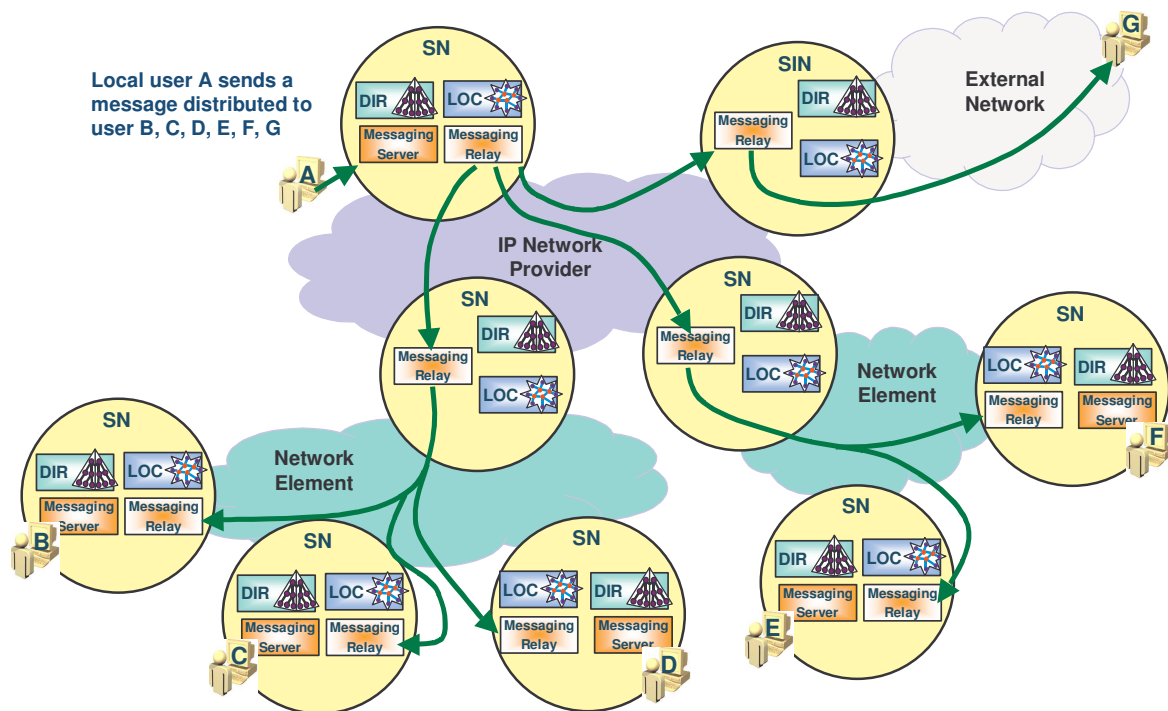The following diagram shows these mechanisms.

Figure 5 : Message distribution system view

This diagram shows the interconnection of the Service Nodes either via the IP infrastructure or directly via a sub-network. The Service Node hosts the messaging service which is configured via the directory, the messaging relay which in relation with LOC, forwards the message to the next hops and elaborates dynamically a distribution tree to the recipients.

- The service connects standard COTS messaging client software (Outlook, Thunderbird).

4.4   Data Dissemination

Data Dissemination is a service used by "Subscribers" wanting to get Information relative to a "Topic". The Information relative to that "Topic" are published by "Publishers". The Publishers and the Subscribers are applications that are not directly interconnected, these applications share through the "Topic" the information available for a same "Community of Interest".

"Topics" are basic technical information relative to an object having evolving attributes, for example a vehicle is a "topic" that has attributes like : position, direction, speed, fuel level, ammunition, …

The Topics are grouped in domains also called "Topic Spaces", for example : Tactical situation, Enemy localisation, radar information, …

The Community of Interests (CoI) are defined according to operational requirements. A Community of Interest is defined by its identification, and by the publisher and subscribers included inside that community. This community may address many different Topics and Topic spaces.

Data Dissemination is provided by a Data Dissemination Network, which is composed of following basic technical components :

- The Dissemination brokers which are in charge to distribute and exchange the Information relative to the "Topics" over the wide area Network. For each CoI the Dissemination Brokers create a Virtual Dissemination Network (VDN)

- The overlay network router, which is in charge to forward the Information disseminated while taking into account the network capabilities through gateways that are in charge to adapt the transport protocol to the sub-network.

  The overlay network may carry Information generated by other applications (instant messaging, messaging, …). The Overlay Network Router (ONR) takes into account :

  - routing according to the topology of the network Elements thanks to interaction with the LOC software

  - QoS requirements for flow transfer thanks to interaction with a Quality of Service Agent.

  - Transfer over constrained network elements via protocol adaptation in Gateways.

Dynamic control of Data Dissemination is based on :

- the configuration present in the directory, this configuration gives a precise description of the CoI, and of who is allowed to publish and subscribe in a specific VDN

- the routing and distribution capabilities present in LOC

The following diagram shows the position of these elements in the service layer network.
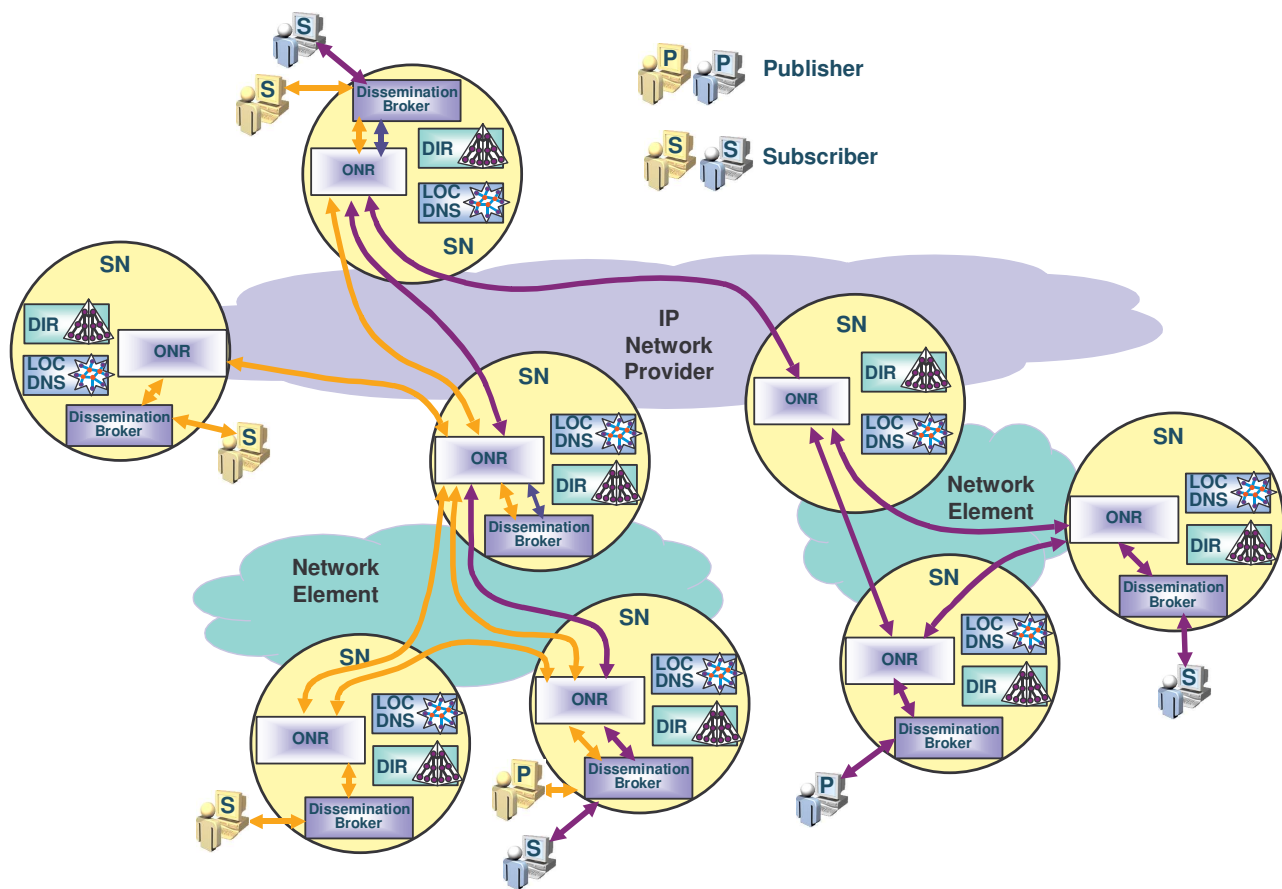
Figure 6 : Data Dissemination system view

5.0   CONCLUSION AND CHALLENGES OF THIS ARCHITECTURE

Dynamic Control must be present in each node of the architecture : at the sub-network layer, in the IP Infrastructure layer, and in the Service Network layer.

The objective is to control the behaviour of the nodes according to :

- The resources available in the core network
- The topology of the network
- The communications that are requested by the end users (type of service, precedence, …)
- The localisation of the users
- The rights assigned to the users in the Directory.

Control of the architecture creates interfaces with :

- The equipments (routers, switches, firewalls, …), in order to configure them according to the policy present in the directory

- The communication servers (Multimedia servers, Mail Relays, Web proxies, Overlay routers, …) in order to provide the routing information for the relays which have to forward the flows from source user to the destinations.

The main challenges introduced by such an architecture are :

- The ability to introduce real time flows in the dissemination organisation, and also to make use of the multicast capabilities provided by the IP sub-network

- The ability to manage resources in the different layers of the architecture, and to forward the user demand for resources between the layers of the architecture (cross-layer request for service)

- The capability to manage inside a sub-network, a QoS routing protocol, that takes into account : the demand of resources issued via the user signalling protocol, load balancing according to reserved resources on the topology

- The capability to manage an applicative routing protocol in charge to localise the users, and to route the flows over an always evolving topology. This routing protocol has to be managed for each security level.

- The Directory of the Theatre of Operation that contains the configuration of the theatre (deployed units, functions, users, groups, generic configuration of the equipments, …)

These challenges are main issues that the community working on the Global Information Grid has to face.