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A Packet Speech

Measurement Facility

Semi-Annual Technical Report 1

January 1, 1978

to

June 30, 1978

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## 1. Introduction

The Packet Speech Measurement Facility (PSMF) is an investigative tool designed to be used by researchers in packet network studies. The PSMF facilitates experiments dealing with the timing and composition of packet flow, and will help elucidate the interactions between the conceptual structures of protocol design and the physical exigencies of network implementation.

This report summarizes efforts undertaken by the Computer Corporation of America during the first phase: January 1, 1978 to June 30, 1978, of the second year of PSMF development. These efforts have been aimed at the generalization of existing PSMF functions to serve a larger community of packet network experimenters, and have culminated in the design specification for the augmented features, the implementation of additional protocols, and the installation of some server facilities.

Chapter 2 reviews the design philosophy and structure of the PSMF as it was operational at the end of the first year of development. Chapter 3 outlines the goals and approaches of the second year of development. Chapter 4

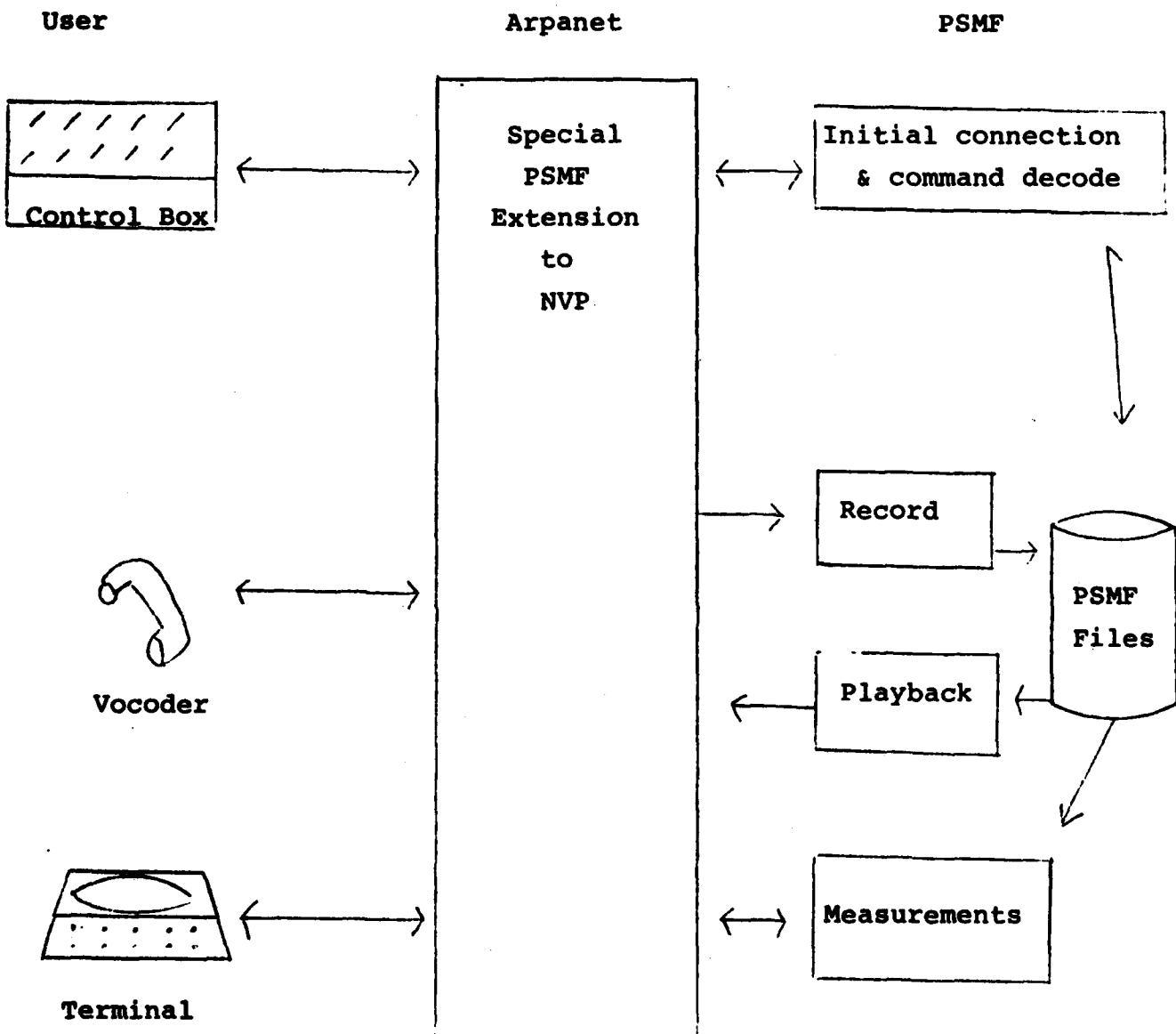
describes the procedures for PSMF access, while Chapter 5 details implementation specifies, reviews recent experiments, and presents a schedule for remaining implementation. Chapter 6 provides a summary of PSMF efforts and plans.

## 2. PSMF - First Year Design Review

The operational goal of the first year of PSMF development was to provide a facility whereby Network Secure Communications (NSC) participants could vigorously examine network effects on real time encoded packet speech streams. Three primary functions were designed to satisfy this goal:

1. The provision for recording speech segments along with time stamps reflecting network perturbations.
2. The provisions for playback of speech segments to enable subjective judgments of network distortions.
3. The provision of statistical functions which analyze recorded speech segments to determine the characteristics of network interaction.

These functions are illustrated in Figure 2.1 and are outlined below. A detailed description can be found in [LOW].



## 2.1 Recording Function

The PSMF provides a facility for recording a stream of encoded speech messages. Provision is also made to record special PSMF control messages in addition to, or instead of, the speech stream.

The PSMF time-stamps the incoming message stream, classifies it, and later sorts it by user's time stamp. This information is available via the measurement functions described in Section 2.3.

The recording protocol provides a mechanism for:

- a. Specifying the file name and access password of the file to be recorded.
- b. Conducting voice parameter negotiations as per NVP conventions [COHEN].
- c. Time-stamping and recording all elements of the control/voice streams.

- d. Terminating the recording session and closing the file.

## 2.2 Playback Function

A previously recorded file can be opened for playback. The user can selectively specify which elements of the recorded file are to be retrieved.

The playback protocol provides a mechanism for:

- a. Specifying the file name and access password of the file to be opened.
- b. Specifying the types of messages to be retrieved.
- c. Conducting voice parameter negotiations if the user specified the retrieval of voice messages.
- d. Transmitting stored packets at a rate determined by negotiated parameters.
- e. Permitting file closure or rescan at the user's option.

### 2.3 Measurement Functions

A previously recorded file can be opened for measurement. The user can then specify the file which will receive the measurement data and the measurement function. On completion of the measurement, the resulting file can be played back.

The file created during execution of a measurement function may itself be subjected to further measurement. Measurements may thus be compounded. For instance, a file of relative delay times might be created, followed by another measurement creating a file of its histogram.

The measurement protocol provides mechanism for:

- a. Specifying the input file name and access password.
- b. Specifying the output file name and access password.
- c. Specifying the measurement function and associated parameters.

The available functions are illustrated in Figure 2.2 and are outlined below.

### 2.3.1 Measurement of Relative Delays

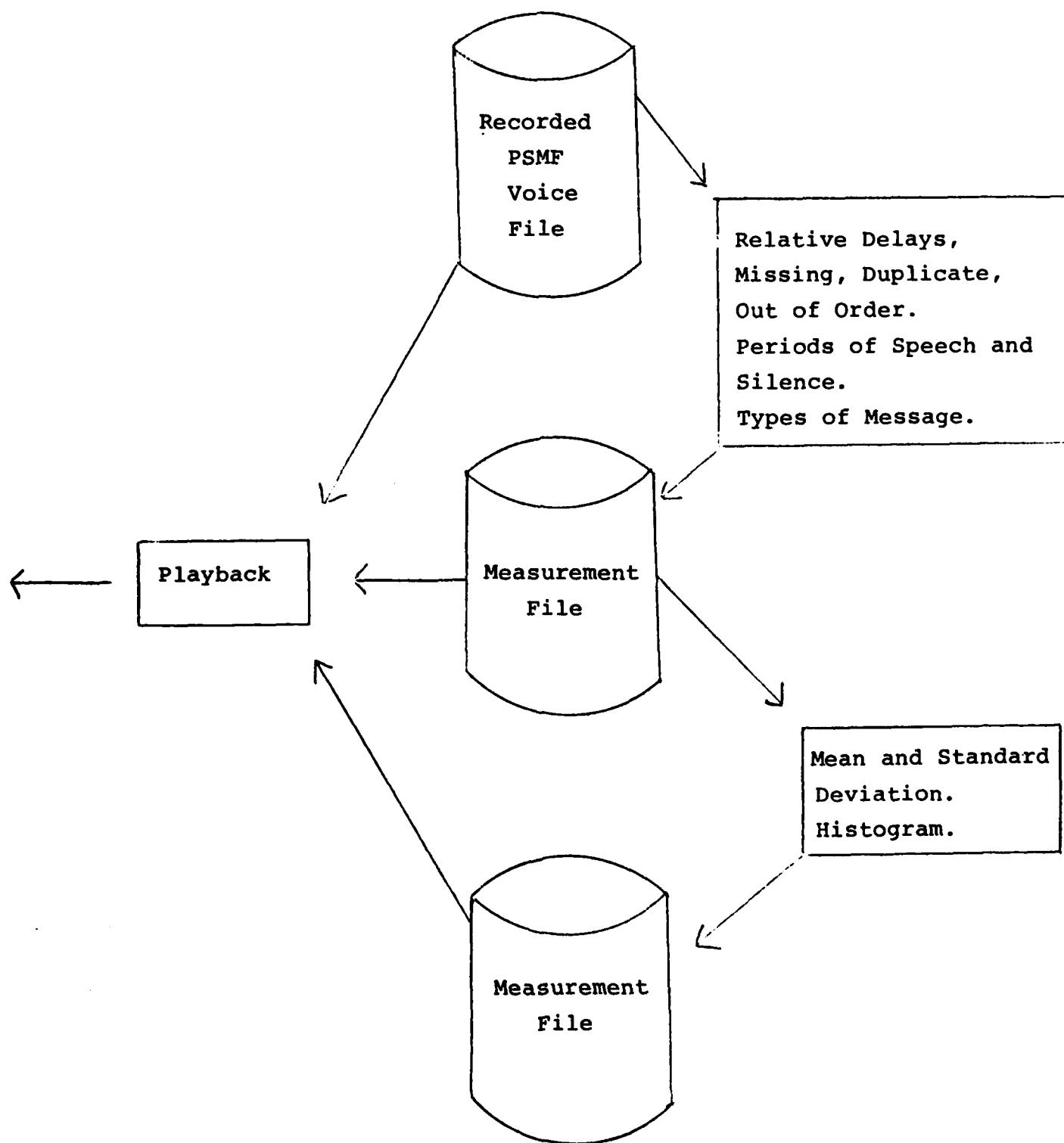
The absence of an absolute time standard means that delay times have to be measured relative to some standard. The PSMF relative delay function produces a file of delays relative to that experienced by the first voice packet:

relative delay = (PSMF timestamp for this message -  
                  PSMF timestamp for first message) -  
                  (user's timestamp for this message -  
                  user's timestamp for first message)

An output record containing this value is created for each input voice packet.

PSMF - First Year Measurement Functions

Figure 2.2



### 2.3.2 Measurement of Missing, Duplicate, or Out of Order Packets

This measurement gives some indication of voice stream integrity. All inputs packets are classified into:

- a. Missing (inferred on basis of user's time stamp)
- b. Duplicate (inferred on basis of sorted input)
- c. Out-of-order (inferred when the sort by user's time stamp resulted in a backwards link)
- d. Other

An output file is created containing classifications of respective input packets.

### 2.3.3 Measurement of Periods of Speech and Silence

This measurement function scans the input file for indications that the user stopped vocoding during periods of silence. The length of these periods, as well as the previous and subsequent voiced periods, is computed and recorded in the output file.

### 2.3.4 Computation of Mean and Standard Deviation

This is one of two measurement functions which normally use a previously created measurement file as input. The input file is scanned for records of a particular type (that type created by measurement functions). A field in each such record is extracted and subjected to a conclusion of the input file, an output file is created consisting of three records specifying mean, standard deviation, and count.

### 2.3.5 Computation of Histogram

This measurement function also normally uses a previously created measurement file as input. When the user specifies this particular measurement, he also states the lower bound and interval size of the histogram. The measurement then scans the input file for data records of a special computational type. A histogram of data contained in these records is computed and written to the output file on conclusion of the input.

### 3. PSMF - Second Year Design Goals

It should be noted again that the original PSMF design, as summarized above, restricted analyses to packet streams transmitted under Network Voice Protocol (NVP) [COHEN]. In addition, an extension of this protocol was necessary to access the PSMF at all. These restrictions limited the scope of PSMF utilization.

The primary goal of the second year of PSMF development is to provide a generalized facility, free of the restrictions described above. The steps being taken to achieve this goal are as follows:

1. Generalization of the PSMF recording facility to transcribe packet streams other than those sent under the NVP.
2. Creation of a generalized measurement system with user-definable functions and access via common network protocols.

3. Enhancement of PSMF scope and robustness by means of an on-line backup and archival large scale database system.

These approaches are described in detail below.

### 3.1 Generalization of the Recording Facility

The original PSMF recording facility was designed to transcribe packet streams sent under the Network Voice Protocol. There are other protocols, both developmental and standard, for which an experimental recording facility would be useful. A generalization of the PSMF recording function is being undertaken in order to provide this facility.

There are two ways in which the PSMF can participate in a recording session. One situation involves the PSMF as an active participant in a dialog or conference, e.g. an NVP of NVCP session. In this case the PSMF implements the protocol of interest, and experiments can be performed to evaluate the effects of the user's parameters on packet flow.

In the other case the PSMF may act as a non-participatory intermediary for a packet stream. In this mode the PSMF functions as a recording and forwarding station, and needs to know only those elements of the protocol which enable it to perform this function unobtrusively.

The generalization of the PSMF recording facility includes provision for both these situations. Protocols being prepared are, in addition to the NVP, the Network Voice Conference Protocol (NVCP), Arpanet host-host protocol (incorporated in a Network Control Program (NCP)), and internetwork host-host protocol (incorporated in a Transmission Control Program (TCP)). For recording sessions under an arbitrary protocol, the Record and Relay (RAR) facility gives experimenters PSMF access without the need for time-consuming and expensive software specialization.

Each of these enhancements to the PSMF is discussed below.

### 3.1.1 Network Voice Conferencing Protocol

The PSMF is being augmented to accommodate the Network Voice Conferencing Protocol (NVCP) [COHEN]. An extension to the NCVP has been provided to allow a file name/password specification in the "please join my conference" message. On receiving this message, the PSMF:

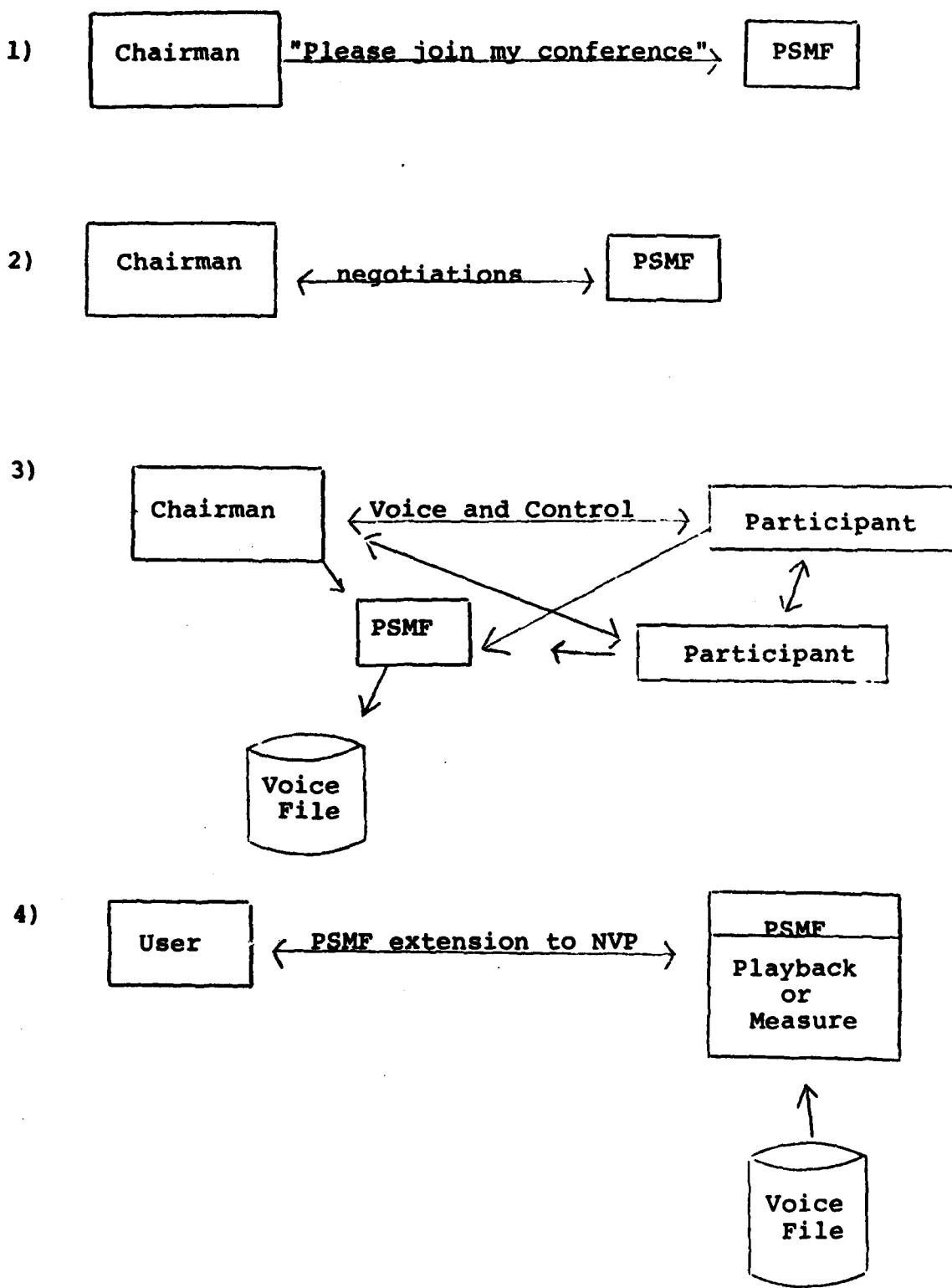
- a. Opens the requested file
- b. Initiates a connection with the conference chairman
- c. Carries on voice negotiations with the chairman
- d. Records all such negotiations and ensuing voice messages in a format amenable to the playback and measurement functions of the old NVP accessible PSMF.
- e. Closes the file on receipt of a "good-bye" message.

This procedure is illustrated in Figure 3.1.

The incorporation of an NVCP facility in the PSMF will provide experimenters with a variety of services. Aside from the obvious use of the facility as a "stenographer",

NVCP Operations

Figure 3.1



the NCVP recorder will help resolve problems resulting from a dissimilarity amongst user implementations. In addition, problems arising from network idiosyncrasies will be subject to methodical diagnoses and therapy.

### 3.1.2 Network Control Program

The standard Arpanet host-host protocol is being incorporated into the PSMF in the form of a converted Network Control Program. The NCP is being included primarily as a means to access the generalized measurement system (Section 3.2). There may be, however, situations in which a comparative evaluation of higher level protocols is desirable. Use of the Record and Relay facility (Section 3.1.4) will permit analyses of the unfiltered packet stream, but a recording tap on the NCP will facilitate studies of information flow at other levels. For instance, it may be surmised that a TELENET operating over an NCP will process data with a different efficiency than a TELENET over a TCP. The hypothesis that this difference derives from the versions of TELENET, rather than the efficiencies of the respective host-to host protocols, could be tested by the use of a PSMF recording facility at the top level of the NCP and TCP.

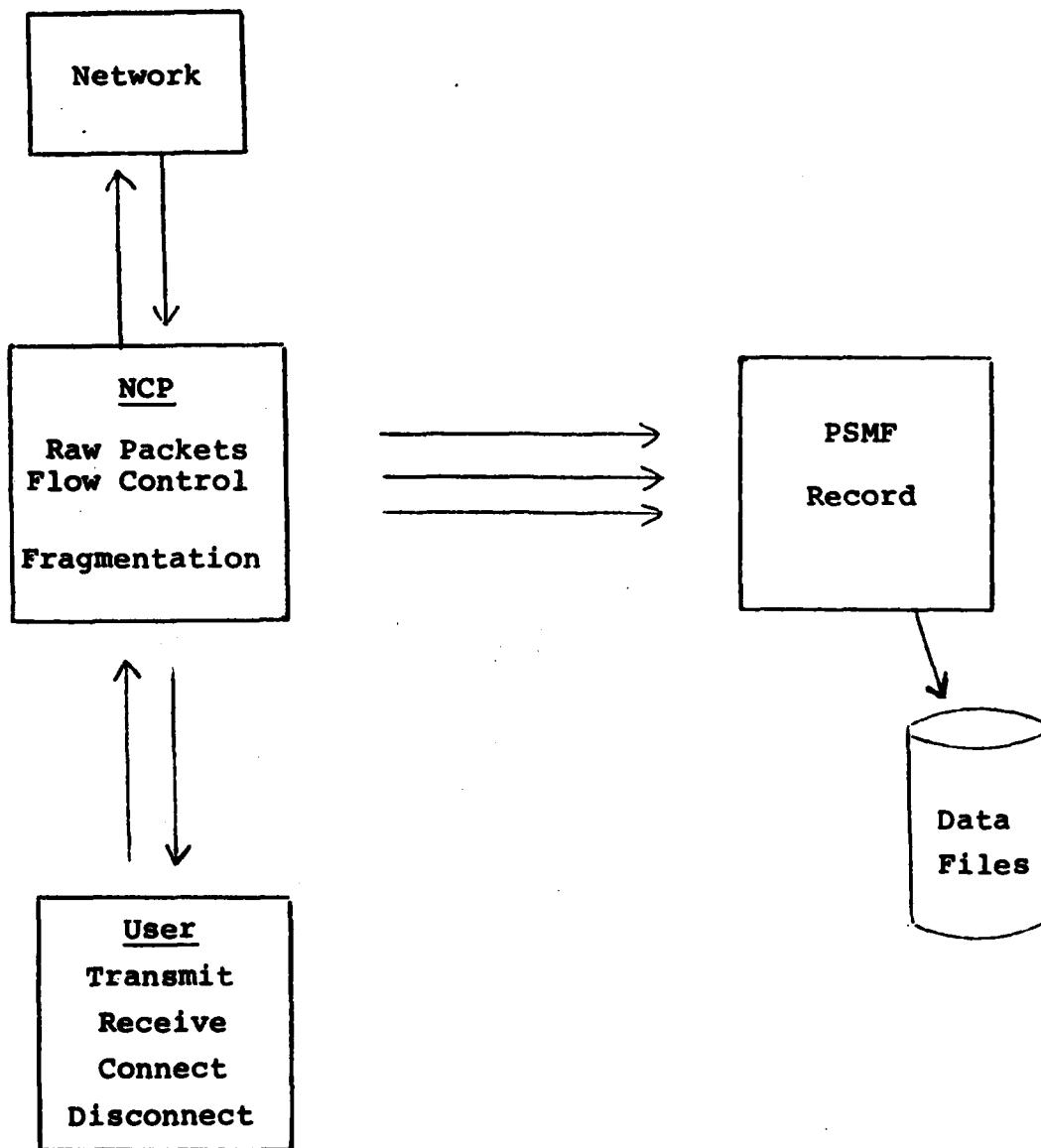
In the same way, the processed and filtered message streams communicated to any other high-level protocol will be accessible via the same facility. This is illustrated in Figure 3.2.

### 3.1.3 Transmission Control Program

A Transmission Control Program (TCP - SRI - versions 2.5 and 4.0) is being converted to be compatible with the RSX-11M operating system under which the PSMF function. This conversion is being undertaken in anticipation of eventually being able to offer high-level protocols on top of TCP. As mentioned above, however, a recording facility integrated into the TCP could help to elucidate the nature of the interface between the TCP and, say, a TELNET or FTP. Correlations could also be drawn between manipulation of local parameters (buffer space, etc.) and the efficiency of this interface.

## PSMF NCP Recording

Figure 3.2



### 3.1.4 Record and Relay Facility

A common approach to protocol design and implementation often involves loop-back self testing as well as trials with another test site. The PSMF provides a facility with which such packet streams can be recorded for future analyses. The "Record and Relay" (RAR) feature will: (see Figure 3.3)

- a. Intercept a raw packet stream.
- b. Perform a first transformation on each packet.

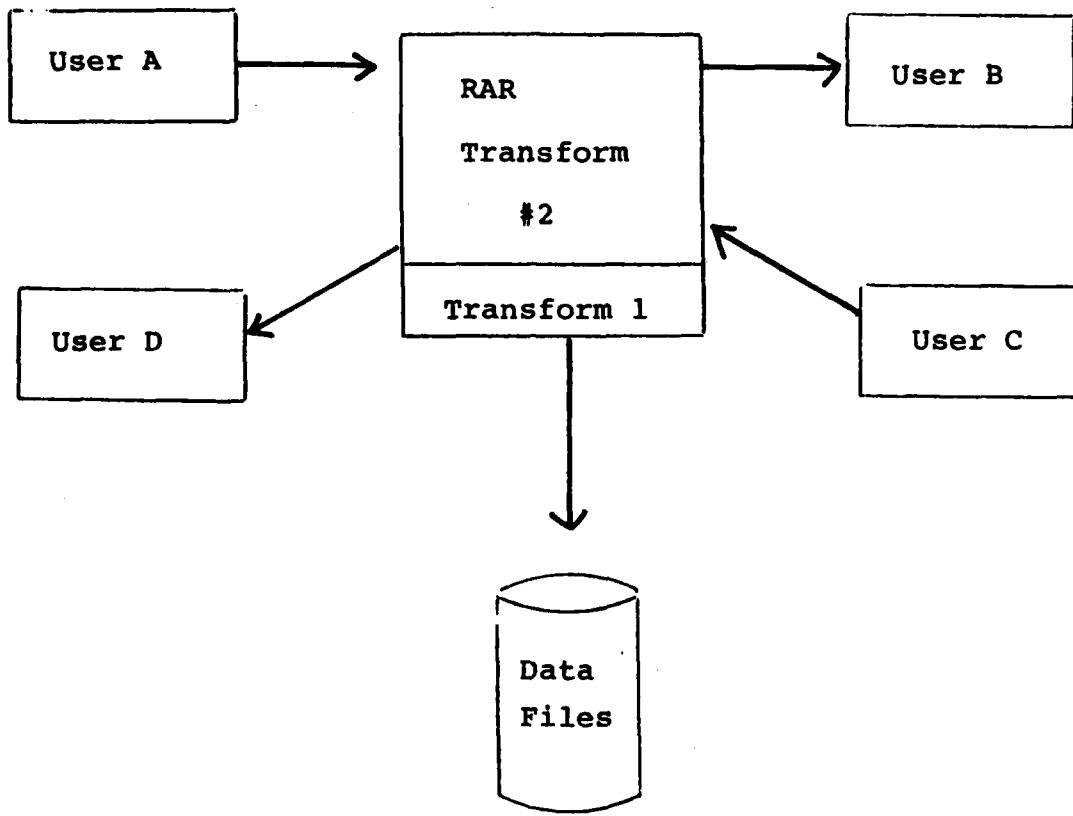
This normally discards some control packets, such as RFNMs, and alters others which may be critical to source identification in a protocol.

- c. Relay the transformed stream to a designated host.

The RAR is implemented as a series of four processes (see Figure 3.4), each of which completes its own manipulation of a packet before passing its address onto the next process. In particular, it should be noted that the two transformation processes are user definable and may be arbitrarily complex. There is not necessity for a

## Record and Relay Facility - Packet Flow

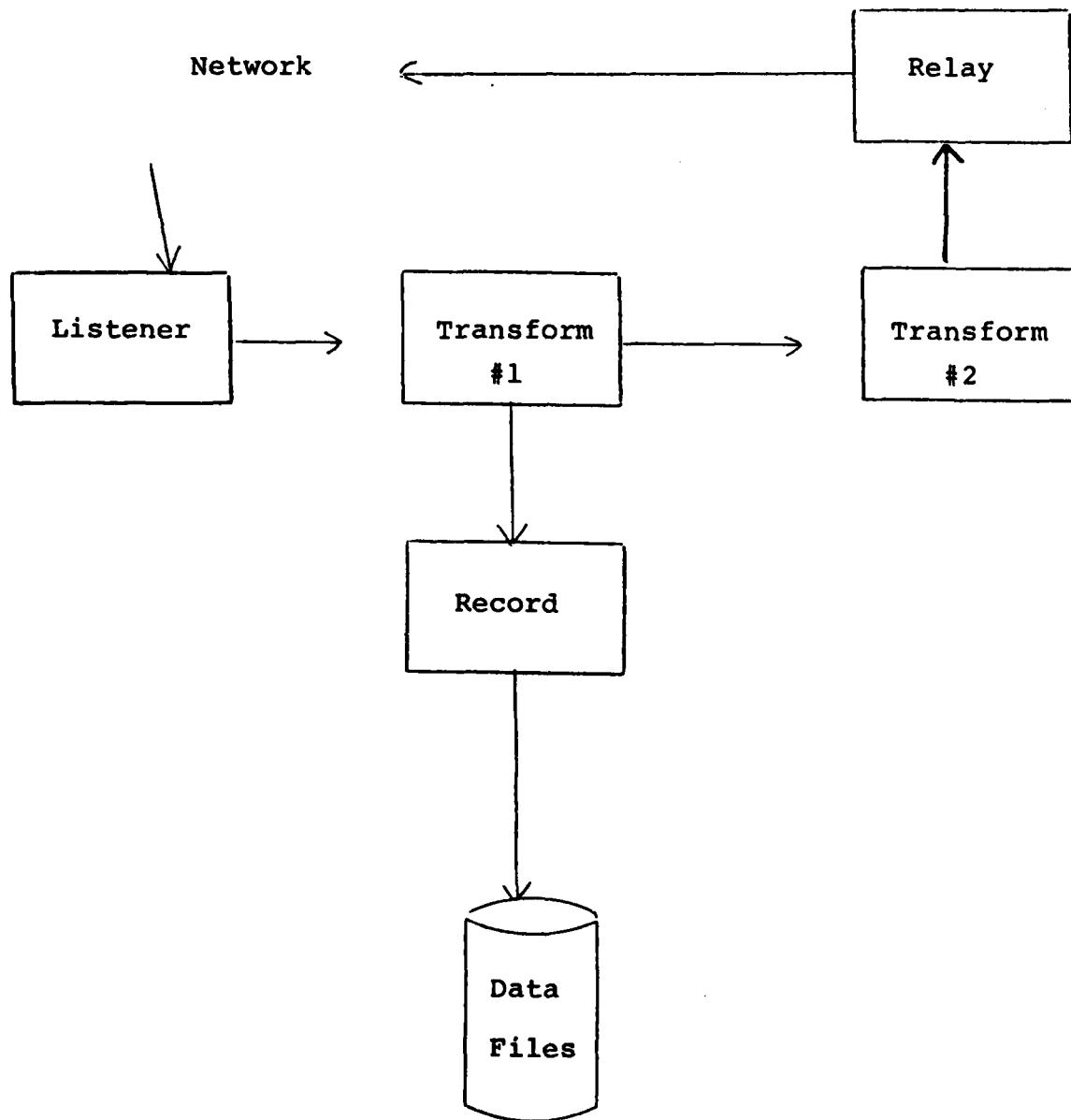
Figure 3.3



Users A, B, C, D need not be distinct.

(In particular, A=D, B=C or A=B=C=D is allowed.)

Record and Relay Facility - Process Communication Figure 3.4



one-to-one relationship between input and output packets, so, for example, the second transformation process may incorporate part or all of a protocol.

Such a protocol might include some means of terminating an RAR session, but ordinarily this is done using the access method described in Section 3.2.1. Specification of the RAR via this method occurs when the user logs in at the PSMF and supplies:

- a. A request for the RAR facility.
- b. The names of the source hosts.
- c. The names of the respective destination hosts.
- d. The name of the file to be recorded.
- e. The names of the transformation functions.

These are standard library functions or are created by the user during normal PSMF operation. They are constructed in the same way as measurement functions.

- f. The time slot during which the recording will take place.

As mentioned above, unless a means of terminating the session is included in one of the transformation functions, the recorded file will be closed only when this time slot expires.

At the specified time, the PSMF will stop all other activity. This is done during any PSMF recording session in order to eliminate interactions among different packet streams. It is especially critical to the RAR, which may deal with experimental protocols that are incompatible with standard ones.

After opening the specified file, all packets received will be transformed (which may involve rejection), recorded, transformed again (which may also involve rejection), and relayed to the respective destination hosts. At the end of the time slot, the file is closed and normal PSMF functions resume. The recorded file may then be accessed for measurements as described below.

### 3.2 User Defined Measurement System

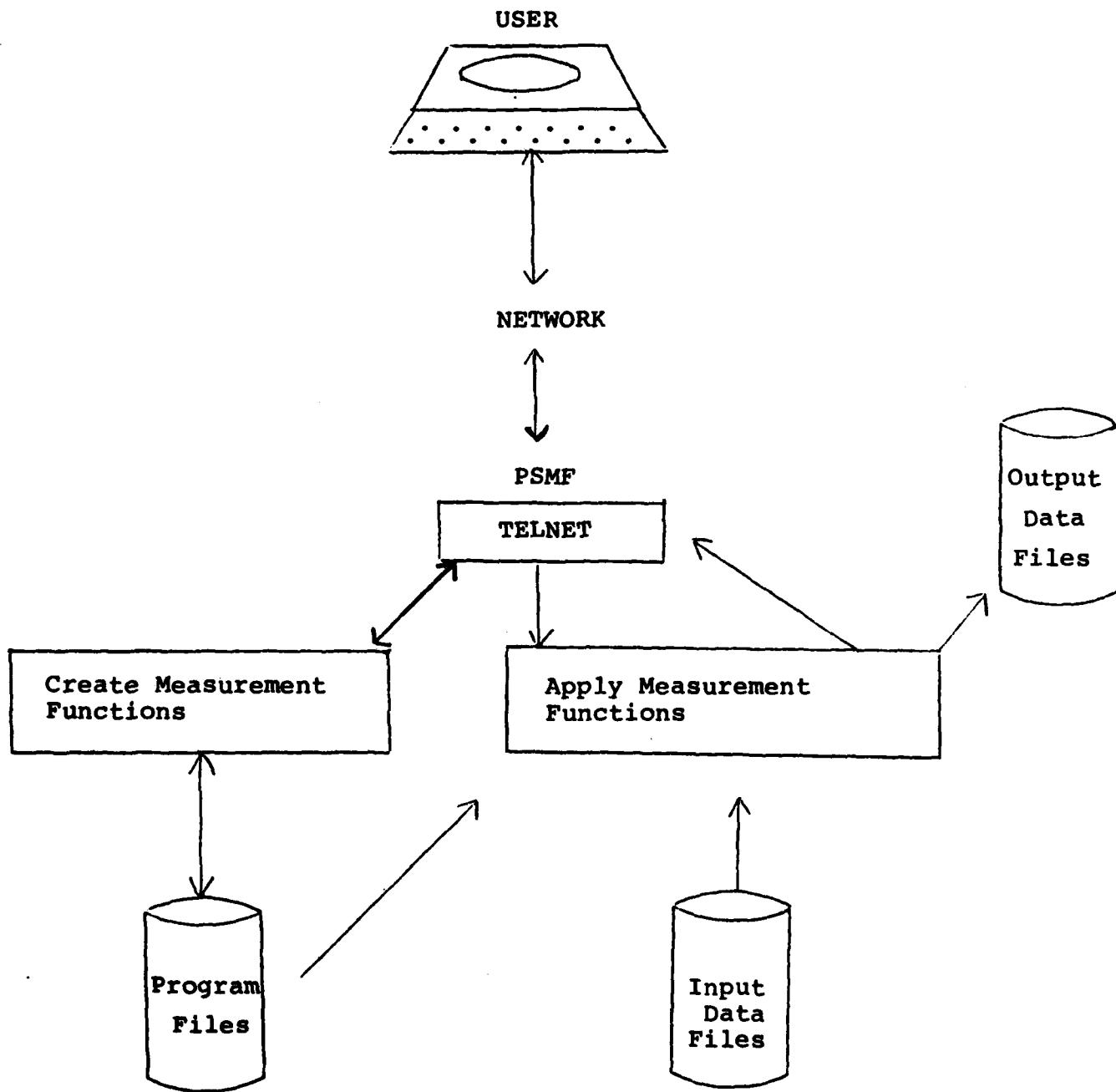
The power of a facility such as the PSMF lies in the research questions it engenders as well as answers. In order to explore avenues opened during the course of investigation, the measurement capabilities must be flexible to the immediate needs of the investigator. On the one hand it must be simple enough for naive users, and on the other it must offer depth to the sophisticated researcher.

The PSMF approach is to offer a library of hierarchical functions and data descriptors. The user can employ these directly, or assemble them into a higher-level function, which can itself be incorporated into a library. This is illustrated in Figure 3.5.

By far the greatest amount of processing will concern elements of the recorded packet stream. Data in this stream is not likely to be in fixed format. The very existence of a datum may depend on the species of packet involved; its position and length may change from packet to packet. In order to free the user from concern for these details, PSMF data references will involve functions

User Defined Measurement Facility

Figure 3.5



which dynamically adjust for these parameters. The following example may prove instructive:

Use of the Record and Relay facility will create a file of individual raw packets. It may be that these raw packets constitute a stream transmitted under the aegis of a Transmission Control Program. Now, data transmitted via a TCP is first wrapped in a TCP header, then an Internet header, and finally (for the Arpanet) in an Arpanet host-to-host header. (The subnet header can be considered to be invisible for our purposes.) The Internet header and TCP header are both of variable length, and in addition, the TCP packet may be fragmented.

PSMF measurement functions reflect this hierarchy:

**GETRAW (BUFFER\_AREA,BUFFER\_LENGTH,PACKET\_SIZE)**

will try to get the next raw packet in a file. If the file is not at "end of file", and if BUFFER\_LENGTH is large enough for it, GETRAW will return a "true" indication, transfer the data into BUFFER\_AREA, and return the actual PACKET\_SIZE.

The function

**GETINTERNET (BUFFER\_AREA,BUFFER\_LENGTH,PACKET\_SIZE)**

will try to get the next Internet packet in a manner analogous to GETRAW above. In fact, GETINTERNET will be constructed from GETRAW calls.

In a similar way,

**GETTCP (BUFFER\_AREA,BUFFER\_LENGTH,PACKET\_SIZE)**

can be constructed from GETINTERNET calls to assemble a TCP packet.

In addition, the PSMF library contains function definitions for all elements of standard headers, so that, for instance, the function

**URGENT (BUFFER\_AREA)**

will return the value of that bit in the TCP header.

So, if the user wants to count all occurrences of the "urgent" bit, the following function will suffice:

```
SUM = 0;  
WHILE (GETTCP(BUFFER_AREA,BUFFER_LENGTH,PACKET_SIZE))  
    SUM = SUM + URGENT (BUFFER_AREA);
```

When the definitions of the Internet and TCP headers are changed, only the low-level library definitions need be altered: a task which may be performed by PSMF personnel. The users' functions remain the same.

There may, of course, be a variety of protocols under consideration, some of which might be slight modifications of others. The PSMF provides the user with the ability to create and specify sub-libraries of protocol dependent definitions.

The discussion of the Record and Relay Facility in Section 3.1.4 mentioned that the "transformation" functions were created in the same way as measurement functions. It can be noted here that this equivalence extends to use of the same library functions. Two examples follow:

The second RAR transform usually works on a packet by packet basis. Some packets, such as RFNMs, are discarded as being unsuitable for relaying. Others may require a modification to headers before forwarding. Internet packets, for instance, require some such computation:

- a. The Arpanet header has to be transformed to reflect the new destination host/gateway.
  
- b. The Internet header has to be transformed to indicate the new source and destination networks and addresses.

c. The Internet header checksum has to be recomputed.

All these tasks necessitate access to fields in headers which are subject to reformatting. The transformation function can thus employ the same low-level library definitions to access these headers as the measurement functions do, thus obviating the need for high-level reprogramming for low-level changes.

In another example, although the second RAR transform usually works on a packet-to-packet basis, it is not constrained to do so. Thus, as in the measurement function outlined above, the transform function could collect an entire TCP packet before forwarding. Given some element of retransmission protocol, it is not unreasonable to think of the RAR, in this case, as a gateway.

### 3.3 PSMF Backup and Archival

PSMF experiments will often involve the creation and analysis of large files. Because of the finite size of local PSMF mass storage, these files will have to be periodically archived. Also, in order to assure robustness of the data base and program libraries, all PSMF files will have to be "backed up". Both these problems are approached through PSMF access to the CCA Datacomputer.

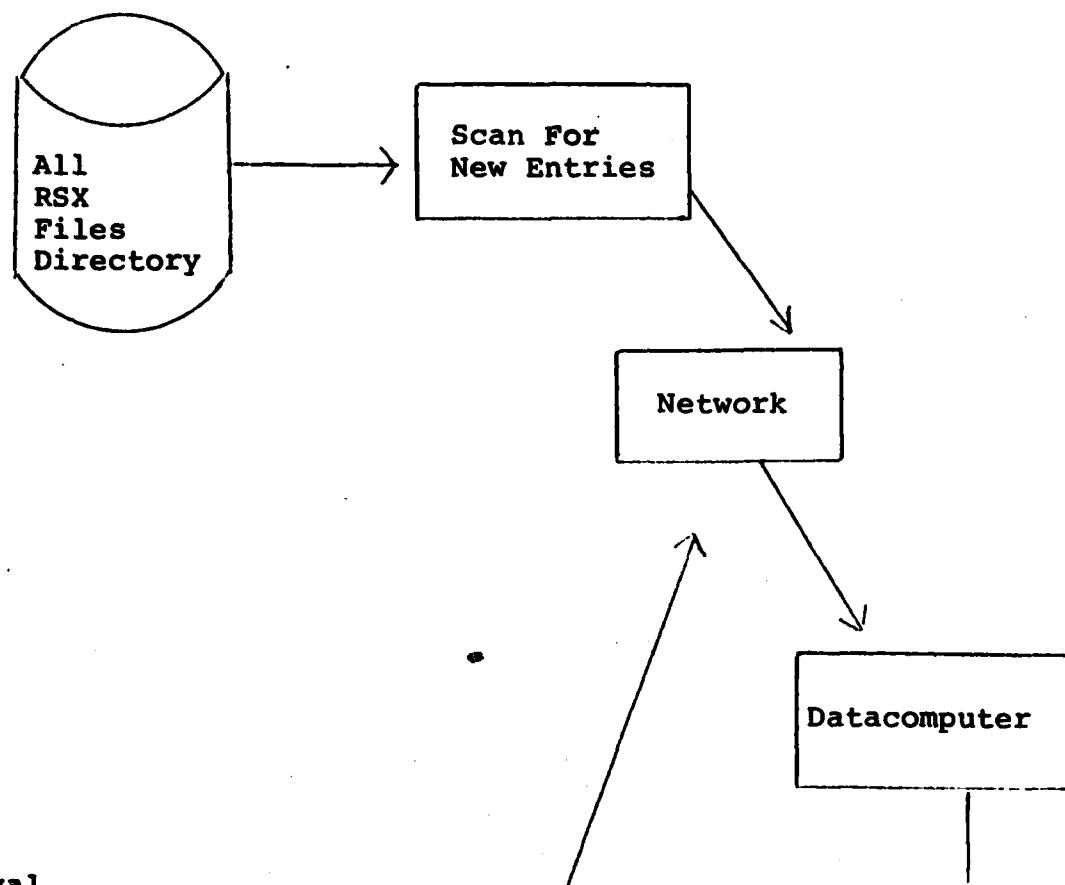
When a PSMF data file is created, an entry is made in a PSMF directory. This directory contains, among other things, the latest date of access and the residence status for each data file. During off hours, this directory is scanned to see if any "disk" resident data file has been inactive for a period of time (normally two weeks). If so, this data file is archived to the Datacomputer and the directory entry flagged as referring to a Datacomputer resident file.

The next time this data file is reference, it will be staged from the Datacomputer, but will be flagged as "deletable", and will be deleted as soon as possible after

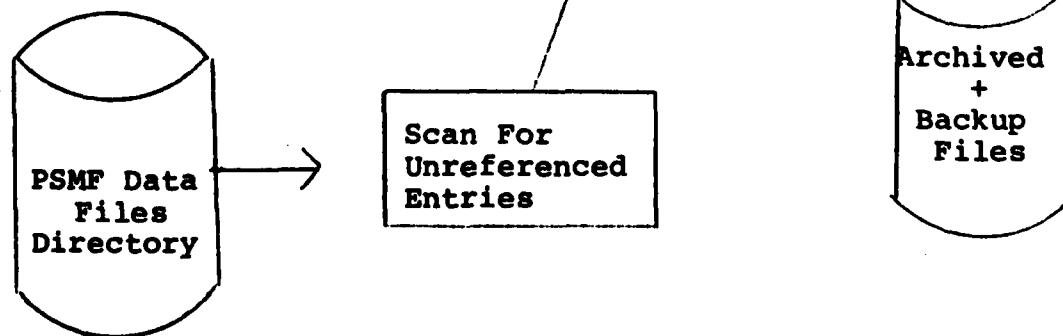
PSMF Backup and Archival Facility

Figure 3.6

1) Backup



2) Archival



file closure. With this approach, the user has the facility to sequentially analyze large off-line databases with no deliberate effort on his part.

An automatic backup facility is provided in a similar manner. The RSX directory, containing references for all PSMF files, is scanned during off hours for files which have been created or updated since the previous backup. Each such file is copied to the Datacomputer. Thus the user is assured of data viability in the eventuality of catastrophic hardware or operating-systems failure.

#### 4. PSMF Access Procedures

There are two important modes of PSMF access. The first entails a recording session. Because packet timing is often important in such a session, and because of the difficulty of working simultaneously with different host-to-host protocols, all other PSMF access is locked out during recording. The procedure for this access is as follows:

- a. The user logs in on the PSMF using TELNET (currently on top of NCP). User names and passwords are arranged with PSMF personnel.
- b. The user requests a reservation, specifying the time slot and the nature of the reservation (protocol to be used, file name to be created, etc.).
- c. If the PSMF detects no conflict, the reservation is made.

- d. Before the time slot reserved, the PSMF requests all other users to log off. At the beginning of the slot, all remaining jobs are terminated.
- e. The necessary software is installed and the recording session begins.
- f. At the end of the time slot, the recording session is terminated.

This eliminates any need for a special protocol extension, but if a user should wish to establish such an extension to enable remote session termination, he may do so.

- g. Standard network software is reinstalled and users may log in for measurements.

The second kind of PSMF access involves the creation and use of measurement transformation (for the RAR) functions. The procedure for such access is:

- a. The user logs in on the PSMF using TELNET. Again, user names and passwords are arranged with PSMF personnel.

- b. If the PSMF is not in a recording session, the user can specify the measurement to be made or construct his own measurement function. Such construction entails specifications of the libraries to be included and the functions and arguments to be employed.
- c. Before the time a recording session is scheduled, the user will be asked to log off and will be notified of the session duration. Information about the recording schedule will be available to each user at any time, thus enabling him to make decisions regarding his own needs for processor time.

## 5. PSMF Operations

### 5.1 Implementation Specifics

The PSMF as implemented in the first year of development has been operational during the period covered in this report. Scheduling has been by request, and some of the experiments which have been performed are described in the next section.

Second year efforts have included:

- a. Adaptation of the PSMF to the Network Voice Conferencing Protocol. This adaptation has been completed.
  
- b. Conversion of Air Force Systems Control (AFSC) Arpanet software to RSX-11M/V3 operating system. The NCP is complete, the server and user FTP are operational, and work on TELNET is underway.

- c. Design of user-defined measurement facility. A "C" compiler for RSX-11M has been obtained from Yourdon, Inc. The design and implementation of the measurement facility is underway.
- d. Conversion of SRI Transmission Control Program to RSX-11M. This work is underway.
- e. Implementation of the Record and Relay (RAR) facility. This work is underway.

## 5.2 Experiments

While the above second-year efforts have been underway, the PSMF as implemented in the first year of development has been available for operation by request, and several experiments have been performed, in conjunction with ISI, using the PSMF extension to the NVP.

- a. Experiments were undertaken to test the network handling of packet streams of varying size and frequency [LOW]. These experiments demonstrated non-linear relationships between such parameters and the number of missing or out-of-order packets.

- b. In concert with the Network Control Center, experiments were performed to investigate the relationships between IMP buffering procedures and delays on subtype 3 packets [COLE]. These experiments revealed a sharp and important relationship which has far-reaching implications for packet voice communications.
- c. Experiments using the PSMF as a participant in NVCP conferences revealed peculiarities in some users' protocols that helped explain difficulties in communication. In this case, the PSMF was used in the role of a protocol debugger.

### 5.3 Implementation Schedule

The initial release of the Record and Relay facility is scheduled for September 15, 1978. This release will consist of:

- a. The RAR facility itself.
- b. A set of measurement functions sufficient for simple analyses of packets sent under Internet in TCP format. This includes both the functional descriptions of the packets themselves and some statistical analysis functions.
- c. A server TELNET with which to access the measurement facility.

In addition, the schedule calls for release of the following features:

- a. July 1: Installation of a dedicated PDP11/34 for PSMF development and operations.

## 6. Summary

This report has described the work performed at CCA on the Packet Speech Measurement Facility during the second year of its development.

A review of the initial design considerations was followed by an exposition of the motivations guiding the development of the second phase. A description of the implementation approach was followed by an outline of the scheduling priorities.

During its first year of operation, the PSMF showed its potential as a research utility, despite the limited means of access to its facilities. The generalization phase described herein will bring the PSMF to the service of packet network investigators from a variety of disciplines, and will help unravel some of the vagueness of this evolving technology.

- b. October 20: An expansion of the measurement functions to analyze NVP, NVCP and NCP format packets. This includes a functional description of these packet headers as well as an expanded set of analytical functions.
- c. November 17: A conversion of TCP version IV. This conversion, again, is primarily intended to pave the way for high-level protocols (TELNET) on top of TCP. In the interim, however, it will be possible to attach a recording facility to any level (see Section 3.1.3).
- d. December 15: Creation of the Datacomputer backup and archival facility. This will, in most respects, be invisible to the user.

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