Signaling Performance Measurements of an Interactive Multi-Media Retrieval Service in a Broadband Intelligent Network

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Abstract

In this paper, we report on the results of performance measurements for an integrated B-ISDN / Intelligent Network signaling network. The specification, implementation and realization as well as the performance measurements are all part of a European project named INSIGNIA. The results reported in this paper pertain to the signaling system built in the second trial of the project and pertain to one of the demonstrated services: the Interactive Multimedia Retrieval service. In the performance analysis, the results are presented with different 'perspectives', each serving a different purpose. For instance, the 'message processing' perspective which helps implementers to optimize the systems and provides parameter values for performance modeling. The 'service procedure' perspective takes a more service oriented view which helps in evaluating the service and gives a clear view of the contribution of each physical entity involved in the provisioning of the service.

1. INTRODUCTION

In this paper, we report on the performance of the Interactive Multimedia Retrieval (IMR) service deployed in the INSIGNIA project [1]. INSIGNIA stands for Intelligent Networks and B-ISDN Signaling Integration on ATM platforms, it is a European project in which fourteen partners from industry as well as research institutes collaborate. The project is sponsored by the European Committee in the context of the ACTS program.

The main objectives of the project are: to research and develop prototypes of Broadband Service Switching Points (B-SSPs), Broadband Service Control Points (B-SCPs), Broadband Intelligent Peripherals (B-IPs) and Customer Premises Equipments (CPEs) using available ATM platforms and equipment. This equipment is deployed in the context of different National Hosts (NHs), interconnected and exposed to real users.

A two phased technical approach is taken in the project. In the first phase B-SSPs, B-SCPs and B-IPs have been deployed in the context of three National Hosts (NHs) in different countries. This provided an opportunity to verify the interoperability of B-SSP prototypes of different manufacturers in a real network environment. The second phase provided the users with ATM switched connections between NHs with network-wide IN services controlled by remote B-SCPs via a signaling network. This is a unique opportunity to validate on the one hand the concept of specialized, remote B-SCPs and on the other hand a signaling network for broadband services. Several services have been deployed, IMR being one of them. Other services deployed were: Braodband Video Conferencing and Broadband Virtual Private Networks.

In order to allow feasibility studies of the approach taken (e.g. scalability studies and congestion avoidance studies), a considerable amount of project resources have been assigned to performance modeling activities in which e.g. scalability issues are being studied, and to performance measurements. The results of performance measurements are being used for several purposes: to provide data, i.e. parameter values, for the performance models and studies; to evaluate the network as well as individual physical network components quantitatively; and to evaluate the services quantitatively.

For further details on the INSIGNIA project and the network architecture developed, we refer to [1-7].

There is a reasonable literature-base on ATM performance, however most articles concentrate on performance modeling issues and results of model analysis. Literature on results on performance measurements is quite limited and mainly concentrate on ATM traffic measurements, we refer to [8] and [9]. Papers on ATM signaling performance are even more difficult to find, we refer to [10]. The main cause of the rather small literature-base on results of ATM performance measurements lies in the competitive nature of the market place.

The main goals of this paper are to present the utilized signaling architecture, the test architecture, the methodology for performance evaluation and to present measurement results.

This paper is organized as follows. In Chapter 2, we discuss the architecture of the Broadband Intelligent Network proposed by the INSIGNIA consortium. The service subject to performance evaluation in this paper is the Interactive Multimedia Retrieval (IMR) service; it is described in Chapter 3. The performance measurement experiment is highlighted in Chapter 4; it discusses the adopted methodology, the measurement equipment used and the performance measurement configuration. In Chapter 5, we present the analysis results of the performance measurements. Finally, the evaluation and conclusions are given in Chapter 6.

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2 BROADBAND INTELLIGENT NETWORK ARCHITECTURE

2.1 System interconnection

The INSIGNIA service provisioning chain is centered around several system categories, that is, end systems, switching systems and intelligent network devices [1]. The reference configuration is outlined in Fig. 1.

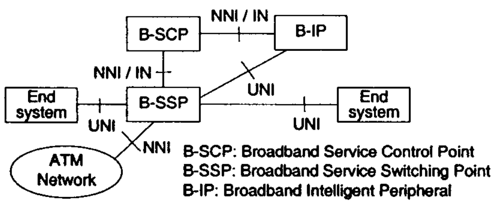

Fig. 1 - INSIGNIA elements for service provision

The end systems are used in order to access an INSIGNIA service. They are connected to the switching systems via UNI interfaces. In the C-Plane, standard signaling protocols are used. U-Plane flows are adapted to ATM by means of AAL5 for all the INSIGNIA services. Commercial platforms are used for all end systems. In general, partner-provided applications are used in order to demonstrate the INSIGNIA services. The B-SSP is an ATM switch with added IN functionality corresponding to the Service Switching Point. The node offers standard UNIs to the users and is connected to other switches via ITU-T NNI interfaces based on the B-ISUP protocol [11-13]. An IN interface allows the connection to the B-SCP [1]. The B-SSP offers SDH (STM1), PDH (E3) and TAXI line interfaces. Users are normally connected via STM1 or TAXI, while the NNIs towards other switches can be either 34.368 Mbit/s PDH interfaces or STM1 links. The interface towards the B-SCP is based on STM1. The B-SSP implements the ITU-T CS2.1 protocol stacks for UNI and NNI signaling [11-13]. The INSIGNIA object-oriented Switch State Model (SSM), able to support INSIGNIA IN services by implementing service sessions and related objects (legs, bearers, parties), is used. The INSIGNIA SSM contains an abstraction of the resources needed in order to compose a service session and interacts with the Call Control Function for call setup/tear down purposes [1]. The INSIGNIA broadband INAP (and related protocol stack), which allows the dialogue between the B-SSP and the B-SCP and drives the SSM evolution [1], is also supported. INSIGNIA services are controlled by a B-SCP. The B-SCP hosts the service logic able to guide the service provisioning process by giving appropriate instructions to the B-SSP [1]. A Broadband Intelligent Peripheral (B-IP) is employed in order to handle user interactions. The actual type of B-IP behavior depends on the service being accessed. A connection between B-IP and B-SCP is needed in order to allow the transfer of user choices performed on the B-IP towards the B-SCP [1].

2.2 System interaction

Within INSIGNIA, a service instance corresponds to multiple, coordinated CS1 calls, this is referred to as a "session". A session is always started by a user by dialing an appropriate number which triggers an IN service. After recognizing an IN call, the B-SSP requests assistance to the B-SCP, which takes control of the service and gives appropriate instructions to the B-SSP. Depending on the selected service, these instructions may involve asking the B-SSP to route the user-originated call towards a B-IP or towards another user and to establish new calls between the end systems for services having a need for multi-connection sessions. In case a B-IP is contacted, information selected by the user when performing a dialogue with the B-IP itself is transferred to the B-SCP by means of the available interface.

2.3 Implementation of the ITALTEL B-SSP

The B-SSP is composed of two distinct subsystems:

- the Switching Matrix, that is an ATM cross connect without signaling capabilities and
- the Signaling/IN Server; that hosts all the protocols for the signaling message handling, and performs the establishment and tear-down of the required VC connections.

The currently used ATM Switch platform is an ITALTEL prototype, the UT-ASM, that is the result of the RACE BRAVE project.

The Signaling/IN Server collects all the signaling information making use of a standard optical STM-1 interface. In fact, all the signaling VC channels of the B-SSP both from user and from network line interfaces are cross-connected with the Signaling/IN Server line interface. As a result of the signaling message handling, the Signaling/IN Server controls the ATM Switching Matrix making use of a proprietary API, based on RPC, for the communication between the two subsystems via Ethernet.

The hardware platform of the Signaling/IN Server (for the second trial of INSIGNIA) consists of a Single Board Computer RIO2 8061 from CES. The board is equipped with a CPU PowerPC604 100 MHz, 32Mbyte DRAM, and an Ethernet interface. The ATM connectivity for this board is performed by the ATM 8468 PCI Mezzanine Card from CES equipped with the IDT77201 NICStAR and the Sierra SUNI Lite chips.

In the B-SSP for the INSIGNIA project a complete set of protocols has been implemented, starting from the ATM layer until the application layers. Obviously, given the goals of the trials and the requirements of the services, in some cases only a subset of the procedures and messages of the already standardized protocols has been implemented. Relevant IN features supported by the Signaling Server are **service session** (bundling several calls providing ATM connections to users within the context of a single service instance) and **third-party call** (SCP-initiated call establishment towards the users).

In more detail, the Signaling/IN server for the second trial of INSIGNIA project offers the following functionality (Fig. 2):

- UNI signaling (ATM Forum 3.1, ITU-T Q.2931) including procedures from CS2 like bandwidth negotiation and modification, and Generic Functional Protocol in the COBI, COBR and CLBI version;
- NNI signaling (ITU-T B-ISUP); concerning the Network-Node Interface, some CS2 functionality has been implemented: bandwidth negotiation and modification procedures;
- the IN stacks enriched with the Broadband INAP layer specified and implemented in INSIGNIA;
- Call Control (interworking between UNI/NNI, UNI/IN, NNI/IN, UNI/UNI, NNI/NNI);
- Switching State Model (SSM) developed according to INSIGNIA object oriented model.

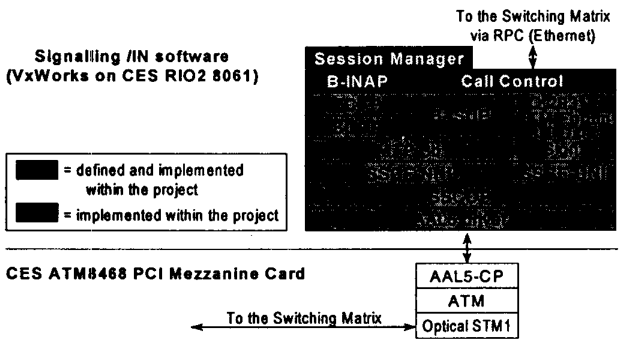

Fig. 2 - Functionality of the Signaling/IN Server

In the INSIGNIA SSM, a **session** is the representation of a complex call configuration, as it is seen by an IN Service. The **parties**, that can either be an end user or a network component, can join a session and a **bearer connection** can be established between the parties.

The software modules are running on the Signaling/IN Server as **tasks** that may evolve concurrently. The interface between modules is based on exchange of messages, named **signals** according to SDL terminology. No shared memory is used for the cooperation of the modules. The transmission and reception of signals are based on routines of the support library that process the information contained in the header of the signals. This kind of interface simplifies monitoring of B-SSP operation and the insertion of internal measurement points . It allows also the simulation of a selected subset of modules of the B-SSP by sending appropriate messages through the interface (e.g. during the test phase). In case of modules modeled as SDL processes, the incoming signals automatically trigger the appropriate call-back routine. The library includes routines for the handling of timers and for the generation of multiple instances of the same SDL process. The replication can be performed during the start-up phase, or the instances can be created at run-time (e.g. to handle an incoming call from a user). The implemented mechanism has a low impact on the resource allocation since only a small amount of memory is required for the new instances. The routines allow also the control of the level of verbosity of the applications for debug and test purposes.

3. Interactive Multimedia Retrieval Service

To clarify the experiment that we have carried out and the performance measures that we have considered, some elementary knowledge of the IMR service is presented. The IMR service is conveniently described in terms of so called service procedures that may be executed in specific sequences. The message flow is reported in Annex A. These (signaling) service procedures of the IMR service are:

- Connect to B-IP (**C2IP**): through this procedure you start up the IMR service by establishing a connecting between the Set-Top-Box (STB) and the B-IP. Here you can select the IMR Broker of your choice (this selection is via user plane interaction).
- Disconnect from B-IP and Connect to Video Server (**DIP&C2VS**): the connection between the STB and the B-IP is released. Subsequently, through a third party initiated call (i.e. initiated by the B-SCP) two connections (one for service control and the other for the data) are being set-up between the STB and the Video Server (VS).
- Modify Connection (**MC**): Depending on your specific wishes, you may want to modify the connections between your STB and the VS, e.g. to increase the bandwidth (on the connection used for the data) to obtain better video quality.
- Disconnect from Video Server and Reconnect to B-IP (**DVS&R2IP**): the user can initiate termination of IMR content viewing. The two connections between the STB and the VS are released and (through a third party initiated call) a new connection between the STB and the B-IP is set-up. The user may now select to continue with the DIP&C2VS service procedure or the 'Disconnect from B-IP' (DIP) service procedure.
- Disconnect from B-IP (**DIP**): This procedure stops the IMR service session through releasing the connection between the STB and the B-IP.

Having these five service procedures, an IMR service-session consists of a particular sequence of these procedures. It is possible to specify all valid IMR service session sequences by a so called regular expression. However, we present its graphical counterpart as shown in Fig. 3.

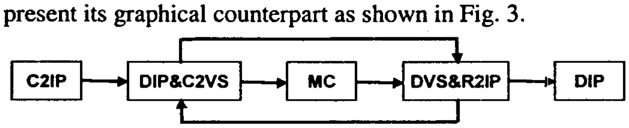

Fig. 3 - Generator for valid Service Procedure Sequences

4. The Experiment

4.1 Performance measurement methodology

The main objectives of the INSIGNIA performance measurement activity have been:

- to determine the performance of the realized prototypes
- to determine the performance of the realized services
- to derive guidelines for the implementers
- to compare first and second trial performance results
- to give input to the performance modeling for parameterization and validation.

The first two points are quite important for the assessment of what has been realized. The outcome of the performance measurements provide guidelines for the implementers in order to enhance what has been realized. In fact, on basis of comparison with the first trial we have observed modifications and considerable performance improvements of the second trial prototypes. The last objective is quite important for the project; the behavior of the realized system in conditions different from those adopted during the tests can be forecasted. So, it is fundamental for studies of the scalability of the system, of the congestion control mechanisms and of others.

To reach these objectives, a performance measurement & analysis team developed and executed a methodology consisting of the following steps:

1. definition of the objectives
2. definition of the "test scenario" to be executed
3. definition of the measurement points location
4. test scenario execution and data collection
5. automatic processing of the log files
6. definition of the measures on the basis of the observed message flow
7. analysis of the defined measures

As far as the measurement points location is concerned, two classes of measurement points have been considered: external and internal measurement points.

In order to get external measurement points, the measurement equipment that has been selected is the Siemens Atea's ATM Traffic Simulator (ATS). The internal measurement points were used mainly in the second trial and they were located between the protocol stack and the signaling application part. So, the percentage of processing time that is spent for the execution of the protocol stack can be determined. In this paper, the results are limited to the external measurement points.

Each test scenario was executed a given number of times in order to characterize statistically the various measures. In our experience, it was sufficient to perform a same test scenario around 60 times to reach a sound statistical characterization.

4.2 Measure classes and evaluation perspectives

In the analysis, we have considered different measure classes:

- processing time required from the receipt of a message to the generation of the next outgoing message;
- total processing time used by each physical entity;
- time to complete each procedure.

With the first type of measures our aim was to answer the question about how much time is needed (by a physical entity) to process incoming messages in order to generate each single message (or a set of messages) outgoing from that entity. So this type of measure gives detailed information about each single entity composing the realized system and it allows the messages that require higher processing time to be identified or, in other words, where a software optimization could be very useful for a real global system performance improvement.

The total processing time used by each physical entity is an aggregation of the single message processing time. It allows a comparison of the processing times by the various physical entities.

At a higher level, the third measure class provides information about the total time required to complete a service procedure. In particular, for this measure class, we have excluded the user interaction times, i.e. the times spent by the users to answer the questions foreseen in the service, e.g. accept an incoming call.

We have defined measures for each service procedure executed in the experiment and determined the processing time needed by each physical entity (hence: STB, B-SSP, B-SCP, B-IP and VS) in the execution of that service procedure. Given a Service Procedure (SP) and a Physical Entity (PE), the measure 'SP@PE' denoted this processing time needed by PE during the execution of SP. In addition to this, we have also determined the 'total signaling-time' needed for the execution of each service procedure, these measures were denoted 'SP@TS'.

4.3 ATM Traffic Simulator

The ATS (ATM Traffic Simulator) [14,15] is a broadband protocol load tester and line monitor. As such it provides facilities for protocol conformance tests, signaling tests and load tests. When used for load-testing, the ATS can reach up to 150,000 BHCA, also the call attempts can be invoked according to some probabilistic regime. Although the ATS has been specifically designed for UNI and NNI signaling tests, it can also perform U-plane tests at the ATM layer.

The ATS consists of a number of System Units (SU), which provide the facilities to run tests. A SU can be controlled remotely by a PC running a Graphical User Interface (GUI), which allows for the preparation and control of tests through so called scenarios. A SU contains up to eight Digital Interface Units (DIU) that provide the test ports. A large number of DIU types are supported. A DIU can be configured to operate in protocol test mode or in line monitor mode using the GUI.

A signaling test is specified by means of a scenario, this is a behavioral description of the test to be performed. The ATS includes a toolbox for scenario development and testing. A large number of features are supported in scenario development, such as:

- predefined and user-defined messages;
- predefined actions, states and timers;
- basic scenario's (e.g. call set-up and release);
- conditional branching, to allow alternative scenario paths to be executed;
- loops, to allow a scenario to be executed repeatedly (either a fixed or 'infinite' number of times).

The ATS is able to log a wide variety of information such as: commands, scenario information, alarms, events and received and sent messages, and timestamps. All logging information is stored on the hard disk of the SU. Furthermore, during the execution of a test it is possible to monitor messages as seen by the scenario via the GUI.

Monitoring may display all scenario output of a scenario instance. If a tracing point condition is met, a limited number of messages before, around or after (as selected) the tracing point can be viewed and stored upon request via the GUI.

In order to use the ATS for protocol testing and monitoring within the INSIGNIA project, it has been enhanced successfully to meet INSIGNIA's protocol specifications. Especially the capability of specifying user-defined message formats allowed the specification, monitoring and logging of B-INAP messages.

In the INSIGNIA project, two main test types have been exploited: line monitoring and load tests. Line Monitoring has been used for the performance measurements of a single service session, such as IMR and broadband Video Conferencing (BVC). Load tests have been used for performance measurements of the B-SCP under stress conditions.

4.4 Measurement configuration and experiment

From a logical point of view, there exists a number of signaling channels between the various entities. These have to be monitored by the ATS. This *logical* configuration is illustrated in Fig. 4 The IMR experiment conducted includes all five service procedures, the sequence followed is: C2IP, DIP&C2VS, MC, DVS&R2IP, DIP.

5. RESULTS OF ANALYSIS

5.1 Information Flow

Given the measurement configuration and the IMR experiment as discussed above, we can obtain the information flow of the IMR service from the log file of the ATS. We have included this information flow in Appendix A.

In order to allow concise denotations for measure definitions, in this document, we have assigned a unique number to each message in the information flow. If we refer to the message itself we write m# and if we refer to the time stamp of that message we write t#.

5.2 Analysis of Quantitative Results

The experiment described in the previous chapter has been executed successfully 68 times. Hence we have a sample size of 68, all analysis results presented here are based on this sample. The results are presented utilizing two perspectives: the service procedure perspective and the message processing perspective.

5.2.1 Service Procedure Perspective

The IMR service consists of five service procedures (see section 3). For each procedure we have considered the amount of time it takes to execute this procedure. On basis of the performance measure denotations defined in the previous section, we present here some examples of the performed analysis. In particular, we present the mean value and standard deviation of the processing time of each service procedure for the B-SSP (Fig. 5) and for the total signaling (Fig. 6). In all cases, the standard deviation is low relative to the value of the mean, this demonstrates the stability of the IN system considered and the validity of the performance measurement results.

The reader should not make the mistake thinking that the processing time of the total system (TS) is simply the sum of processing times of each (physical) entity. In fact, due to parallelism that occurs in the message flows, several entities can be busy with processing simultaneously.

The 'Degree of Parallelism' is a measure that gives information about how much parallel processing is going on in the network during the execution of a service procedure. This measure is defined by construction:

- Given a service procedure SP,
- Let the Physical Entities that are involved, i.e. active, in the execution of the service procedure be ActiveSPE (this means that a physical entity 'PE' is an element of ActiveSPE, w.r.t. a service procedure SP, if 'SP@PE'>0),

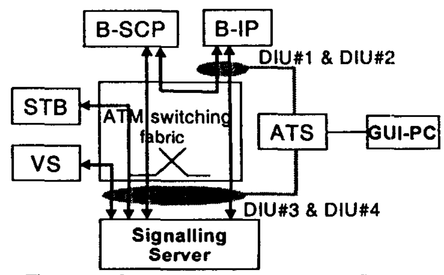

Fig. 4 - Performance Measurements Configuration

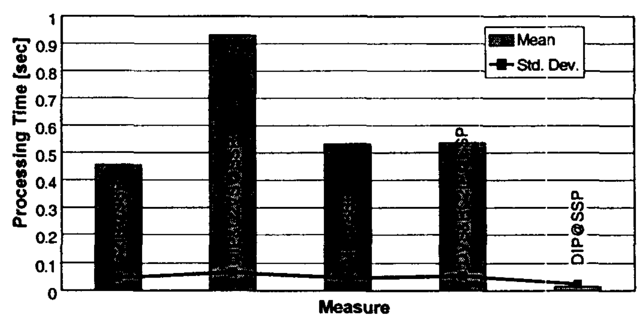

Fig. 5 - B-SSP Processing Times

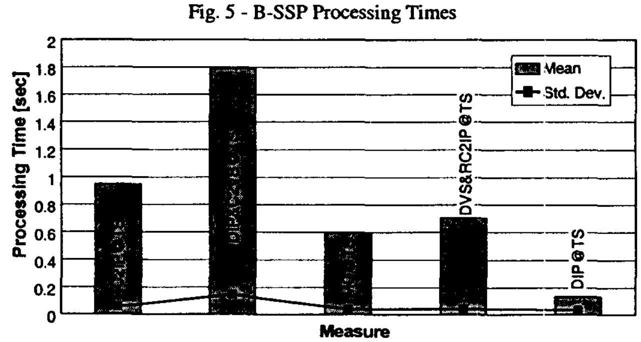

Fig. 6 - Total Signaling Processing Times

- The Degree of Parallelism, denoted DoP%, with respect to the service procedure SP is defined as:

$$DoP\% = \frac{1}{\#ActiveSPE} \times \frac{\left(\sum_{pe \in ActiveSPE} SP@PE\right) - SP@TS}{SP@TS} \times 100$$

Hence, DoP% is a percentage that gives information on the amount of parallel processing within the network. A percentage of 0 indicates that the considered service procedure SP is executed in an entirely sequential way. The theoretical maximum is 100%, which means that all active physical entities (hence all physical elements that are in ActiveSPE) are busy processing during the entire duration of the service procedure.

In Fig. 7, the results of calculating DoP% for each service procedure are shown. It shows that the MC service procedure is close to pure sequential. Higher levels of parallelism are realized by the service procedures: DVS&R2IP and DIP.

5.2.2 B-SSP Message Processing Perspective

In the message processing perspective, we consider the statistics of the time it takes to process each message in the observed message flows of the IMR service. In most cases, the definition of the measure is straightforward: it is simple the time difference of an outgoing message in reaction to an incoming message.

However, there are a few cases where this is not correct. For instance, in some cases an outgoing message mx is generated in response to two incoming messages my and mz. An example of such a case is message m12 (Prompt&CollInf) (see Appendix A) which is generated in response to m10 (ReportSSCh) and m11 (Assist_Req_Instr), that is, the processing to generate m12 starts when both incoming messages, m10 and m11, have arrived. The correct definition of the measure associated with this is: t12-max(t10, t11).

Another case that deviates from the standard cases is related to connect messages arriving at the B-SSP and the connect_ack messages departing from the B-SSP. It took some detailed analysis of the results and discussion with the implementers to figure out the correct definition of the measure. As an example of this case consider the messages m25, m26, m27 and m28. The message flow is given in Fig. 8. Initially, we considered the measures t27-t25 and t28-t26. What we observed was a very large difference in mean values of these measures and, moreover, a very large standard deviation. We learned to interpret these type of phenomena as incorrect measure definitions. Further study of the logs showed that m25 and m26 always arrive at almost the same time. We observed that the time needed to generate the connect_ack in response to the connect that arrived last was consistently higher than the time needed to generate the connect_ack in response to the connect that arrived first. This is explained on the basis of the B-SSP operation mode:

1. At arrival of the first connect, processing starts to generate the associated connect_ack;
2. After completion the B-SSP immediately starts with creating the cross-connect and the second connect, that has already arrived, must wait for processing;
3. After completion of creating the cross-connect, the second connect is being processed resulting in an outgoing connect_ack.

These three processes are shown in Fig. 8 by shaded ellipses. We reformulated the measures into a single measure: max(t27,t28)-min(t25,t26). For this new measure we observed a small standard deviation, this confirmed the correctness of the newly adopted measure definition.

The results of statistical analysis of the B-SSP message processing times are shown in Fig. 9. The measures at the x-axis correspond to the numbering scheme of the message flow as defined in Appendix A.

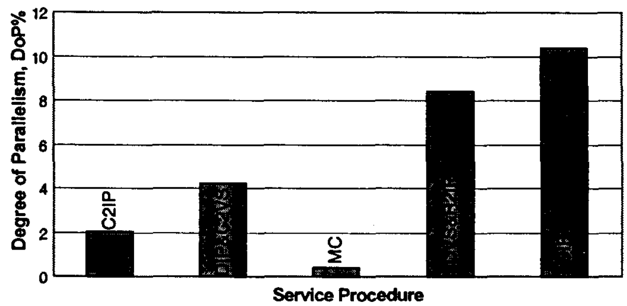

Fig. 7 - The Degree of Parallelism (DoP%)

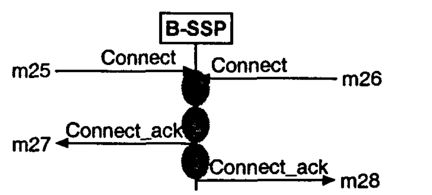

Fig. 8 - Observed Connect Messages and B-SSP Processing

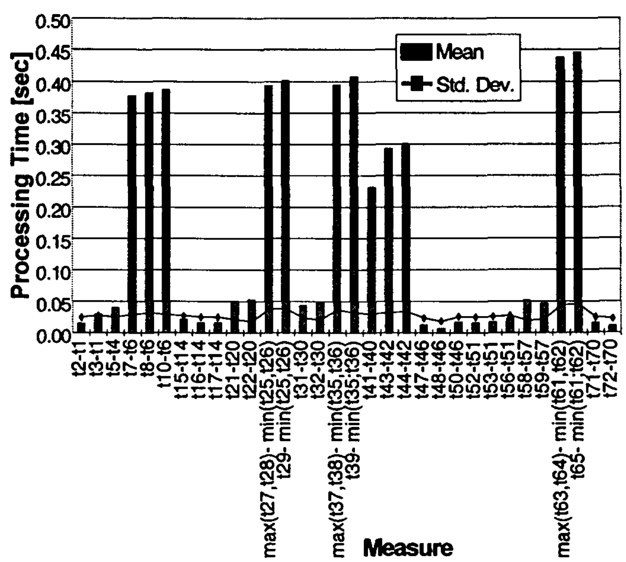

Fig. 9 - Message processing times of the B-SSP

For the mean, in the graph, we can distinguish three different groups of values. One group of values is between 0 and about 50 ms. The second group of values is between 230 and 300 ms and they relate to the processing of messages for modification of a connection (the measures are: t41-t40, t43-t42, t44-t42). The third group shows values between 380 ms and 450 ms and this group relates to the processing of messages for making cross-connects. All the messages that take more processing time (i.e. the second and third group) involve changes in the switching matrix which are performed by the switching management function.

So, all the higher values are due to the time spent for the communication between the signaling server and the switching matrix via the management connection. By integrating the signaling server in the switching system, a significant reduction of these times is expected. It is to be noted that for all the measures a low standard deviation is observed. This confirm the stability of the realized prototype.

6. Evaluation and Conclusions

In this paper we have outlined the architecture of an integrated B-ISDN / IN signaling network and its implementation. Furthermore, results of quantitative evaluation of the signaling network, with respect to the IMR-service, through measurements were presented. In itself the architecture is unique and so are the results of performance measurements.

We have succeeded in conducting the performance measurements, analysis and presentation of the results in a well organized and systematic way. Especially, the evaluation of results and using performance measures that reflect different perspectives have helped a great deal in understanding the performance of the signaling network and also allowed us to fulfill the different objectives of the activity. With the message processing perspective we provided input for the analysis of network performance and scalability studies based on performance models. This same perspective can be used to set out directions for future implementation improvements. The service procedure perspective allows a more global evaluation of both network and service performance. As such, it gives information relevant to real users, and it also identifies which part of the service (i.e. service procedure) and which physical entity (or entities) are most critical in the provisioning of the service.

To tackle the complexity of the measurement activity, we formed a measurement team consisting of experts from different fields: implementers of the systems, measurement equipment experts and performance analysts. The multi-disciplinary nature of the team and the co-operative attitude of the team members was a key to success. Part of the analysis could already been done while the performance measurements were progressing. These on-site analysis activities helped a great deal in fine-tuning the definitions of performance measures.

The results reported in this paper for the IMR service concern a prototype network. Nevertheless, the results lead us to believe that the proposed integrated B-ISDN / IN signaling system is, from a performance perspective, a feasible network architecture because the processing overhead due to IN is relatively small. While on the other hand, the integrated B-ISDN / IN architecture offers all benefits offered by IN, such as the relatively rapid development and deployment of new services.

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APPENDIX A – IMR SERVICE MESSAGE FLOW