PERFORMANCE EVALUATION OF INTELLIGENT NETWORK SERVICES

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Abstract. The Intelligent Network (IN) concept provides a new architectural framework which allows rapid introduction of new and complex services. Service completion is carried out over a network of physically distributed elements, connected by a C7 signalling network.
The impact of the IN-concept on service and network performance is not obvious. Also, the fact that the IN-concept has not been introduced in the Netherlands yet, precludes measuring the performance. Therefore we have made a generic model of the IN-concept which is presented in this paper. The model is based on queueing network theory and contains the IN physical elements together with the C7 signalling aspects. By implementing the model in a simulation environment, a tool has been constructed for planning and design purposes.

Introduction. The IN-concept is a new architecture that allows rapid introduction of complex telecommunications services [CCITT91]. It gives PNOs the benefit of directly reacting on changes in market demands. Services can be introduced much faster because PNOs are able to develop new and more complex services, independent of the switch manufacturers.
But besides benefits, the concept also has some drawbacks. On top of the conventional telecommunications networks, which have been examined thoroughly in the past, the IN-concept introduces several specialized service processing functions. The functions which are distributed over the network, take over call control, thereby allowing flexible call handling. The ability of flexible call handling in a distributed environment makes it difficult to predict performance issues necessary for planning and design. The problem has been recognized and is receiving more and more attention [Hoang90], [Pierce88], [Mishra90], [Pham92], [Tsolas92].

After a short introduction on IN, this paper presents a generic model for the IN physical elements and three IN-services. The Intelligent Network model can be made up of the individual models for the PEs and the IN-services. We implemented the model in a simulation environment, herewith providing a tool for network planners and service designers. The implementation of the model has been verified by examining a hypothetical IN. The results of the simulation have been compared with the results of an analytical approximation for the same case.

The Intelligent Network. The main reason for the introduction of IN is that it is difficult to introduce complex supplementary services in the conventional telecommunications network. In the Intelligent Network, the processing of services is separated from the processing of calls. A computer-based platform has the intelligence for handling complex services, independent of the call processing in the telecommunications switches. Thus, services can be developed and deployed rapidly, independent of the switch manufacturers. In a physical view of the IN (Figure I), the call processing and service processing functions are implemented in different Physical Entities (PEs):

• The *Service Control Point* (SCP) implements the service processing. It contains the service logic programs that are used for the execution of services.

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- The *Service Switching Point* (SSP) implements the call processing. It deals with user access to the network and performs switching functions. Important for the IN concept is that it contains a trigger detection facility to recognize requests for IN services. At SSP level, the IN service processing will be initiated.
- The *Service Data Point* (SDP) is a database containing customer and network data for realtime access by the service logic programs in the SCP.
- The *Intelligent Peripheral* (IP) provides resources for the customization of services. Examples are digit receiving and playing announcements.

Communication between PEs is based on Common Channel Signalling System No. 7 (C7) [Modaressi90], [Jabbari91]. Messages are transferred between the entities by a network consisting of signalling links and transfer points, called Signal Transfer Points (STP).
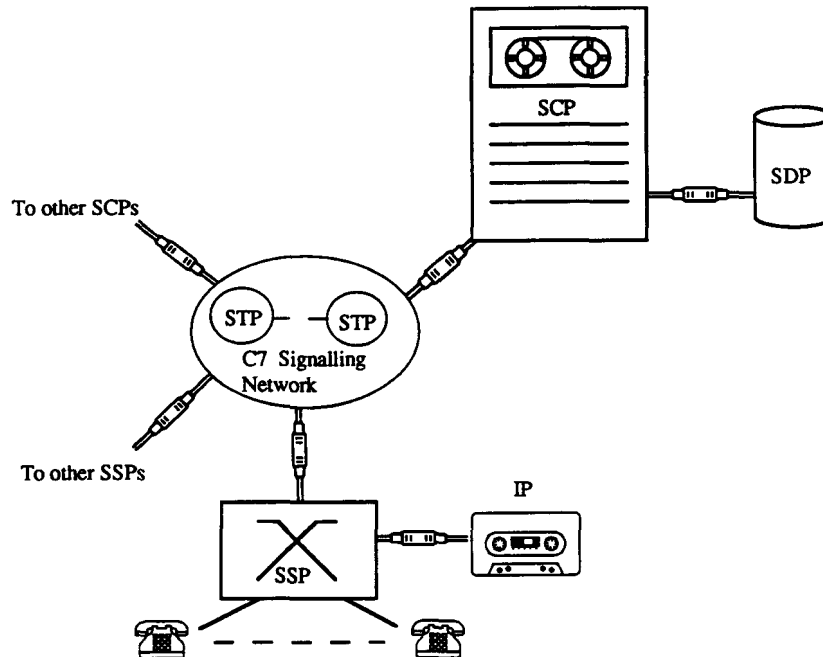

Figure I The Intelligent Network physical view

When implementing the IN architecture in the existing telecommunications network, the network operator has to determine the number and type of PEs and their location. The SSPs are placed adjacent to switches in the existing PSTN network, so they are able to detect request for IN services. The other components do not all have a direct relationship with the existing network. PEs like the SCP are connected to SSPs using C7 signalling communication.

Model of the Intelligent Network. Queueing network theory is used to determine performance of a system where resources with limited capacity are shared by multiple users. In this section we present a model for the PEs and the workload. One or more Central Processing Units (CPUs) are present in all the PEs. A message sent to a PE causes actions to be performed. An incoming message will be stored, examined and subsequently a job will be formulated. One of the CPUs in the PE will then perform the necessary actions to complete the job. If necessary, the last action will be the assembly of a response message.

The SSP
In our model the SSP and IP are combined (figure II). The communication processor for transmission purposes is modelled together with the signalling link and is not part of the SSP. The SSP consists of a number of parallel CPUs in series with the IP.

The actions performed by the CPU can be modelled by a queue and server system where the queue has limited buffersize and the server uses First Come First Served scheduling (GIMI1lm|∞|FCFS queueing system) [Jain91]. A job releases the CPU after it has been executed.

The IP is modelled as a GIMI1l∞|∞|FCFS queueing system. When a job (as a result of an IN service request) enters the SSP, two possible actions can be taken. The job either needs SSP processing only, or an additional announcement has to be played. Playing the announcement is modelled by accessing the IP after SSP processing has taken place.
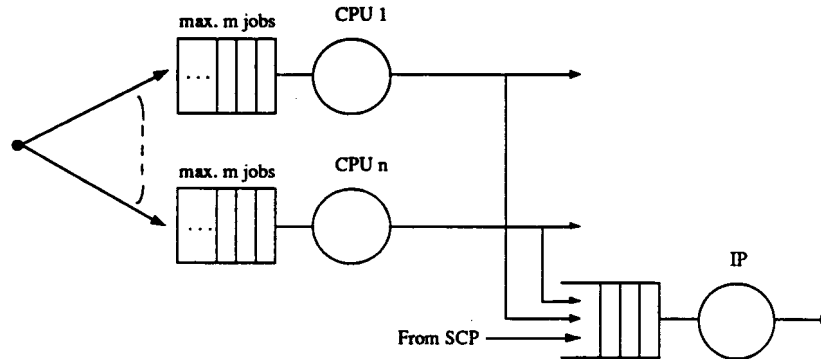

Figure II Model of the SSP

The SCP
The SCP and SDP are modelled together as depicted in figure III. The SCP is modelled by a number of parallel CPUs, in series with a model of the SDP. The CPU is modelled the same way as the CPUs in the SSP. The SDP is modelled as a GIDI1l∞|∞|FCFS queueing system and is looped back to the CPUs. A job requiring SCP service transaction can be one of two kinds: It either needs SCP processing only, or a database-query has to be taken as well. In the second case, additional processing is required to deal with the database results.
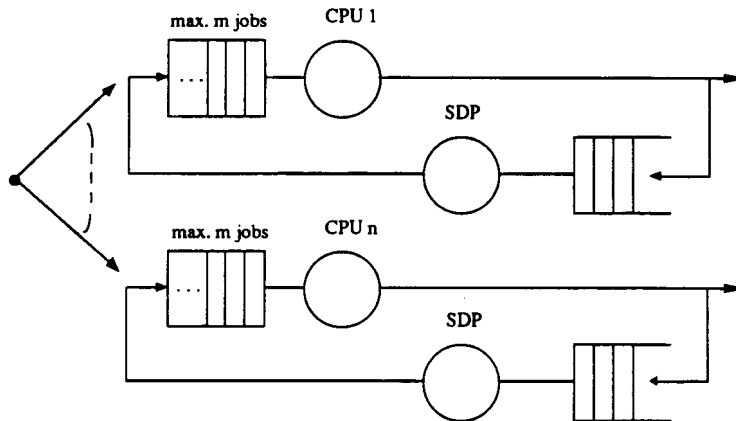

Figure III Model of the SCP

The C7 signalling aspects
Communication between PEs is based on C7 signalling using links and STPs . A message transmitted between two physically separated PEs passes through two links and one STP.
Each STP is modelled by a number of parallel CPUs. The signalling links are modelled in combination with the communication processors of the different PEs. These processors handle the queueing, caused by temporary unavailabilty of the signalling links. Because the C7 signalling is full duplex, the up- and downward direction of the links are separately modelled as a GIDl1 queueing systems.

The workload
The requests for service are the workload. A request results in actions that have to be taken for each component as part of the dialogue between the PEs. The services we have modelled are: Number Translation (NTS), Credit Card Calling (CCC) and Virtual Private Network (VPN). Each of these services can be represented by a message sequence chart in which the signalling messages flowing between the PEs (as a result of the service request) are shown. This kind of service description allows us to decompose a service into actions for PEs. Subsequently we translate the actions into jobs entering the PEs of the queueing network.
The relationship between one service request and its impact on load for the several PEs in terms of elementary actions can be e.g.:

	SSP	SCP	SDP	IP
NTS	4	2	1	0
CCC	7	7	3	4
VPN	4	4	2	0

Table I Relation between service request and PE actions

Output of the model
The output of the model are performance metrics as defined below:
• *Utilization*: Percentage of utilization for a PE.
• *PE response time*: The time interval between the receipt of a message and the end of the processing of the same message.
• *Total service response time*: The time interval between a user interaction and the subsequent corresponding action of the network perceived by the user.

Simulation. The simulation has been executed on a workstation using SIMSCRIPT[1] as simulation language, for the following case:
A hypothetical implementation of an IN consisting of:

• 8 SSPs and IPs
• 2 STPs
• 1 SCP and SDP, where the SCP contains the services NTS, CCC and VPN.

A pair of four SSPs and IPs are each connected to one STP and the STPs and SCPs are fully connected.
The total network load in terms of service requests per second are 10 NTS calls/second, 12 VPN calls/second and 5 CCC calls/second.

The results of the simulation will be dealt with in the next section, where the analytical approximation is introduced.

Analytical approximation. An analytical approximation is used to compare the simulation results with. The performance metrics utilisation, PE response time and total service response time have been calculated.

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[1] SIMSCRIPT is a CACI product.

Utilisation
The utilisation for each of the PEs can be calculated under the condition that jobs are distributed uniformly over the PEs. The utilisation is calculated as follows:

$$\text{Utilisation PE} = \frac{1}{\#PEs} \sum_{i=1}^{services} \frac{\lambda_i . j_i}{m . \mu}$$

where λ_i is the arrival rate for service i,

m is the number of CPUs in a PE,

μ is the service rate for the CPU and

j_i is the number of actions for a CPU as a result of service i (see Table I)

The analytical and simulation results for the SSP and SCP utilization are:

Utilisation	SSP	SCP
Simulation	76.9 %	51.5 %
Analytical	76.9 %	51.5 %

Table II Comparison of utilisation

PE response time
The PE repsonse time is calculated using the formula for the mean response time of the M|M|m queue [Jain91]. This approximation is done under the assumption that jobs arrive independently at the PEs as a Poisson proces.

$$\text{Mean response time } E[r] = \frac{1}{\mu}(1 + \frac{\zeta}{m(1-\rho)})$$

where μ is the service rate for the PE,

m is the number of CPUs in a PE,
ζ is the probability of queueing[Jain91]
and ρ is the PE utilization

The results for the SSP and SCP response time:

response time	SSP	SCP
Simulation	208.2 msec.	50.5 msec.
Analytical	216.2 msec.	50.4 msec.

Table III Comparison of mean response time

Total service response time
The total service response time is calculated by combining the individual PE response times. The message sequence charts for the services are interpreted in terms of PE actions, then the individual PE response times can be combined into the total service response time.

Additional value of the simulation.The verification of the simulation results by the analytical calculations indicate that the constructed simulation model is a proper implementation of the queueing model. From both the simulations and the calculations it is possible to gain insight into average performance measures like utilization and average response times. The simulation model however as constructed with the SIMSCRIPT language provides additional performance metrics. One very useful performance metric is the estimation of the response time distribution of a service. In figure IV, the distribution for the response time for the NTS service is presented. The response time in this figure consists of the time necessary for the IN part of the telephone call. Another advantage is the capability of introducing complex network features like call gapping.
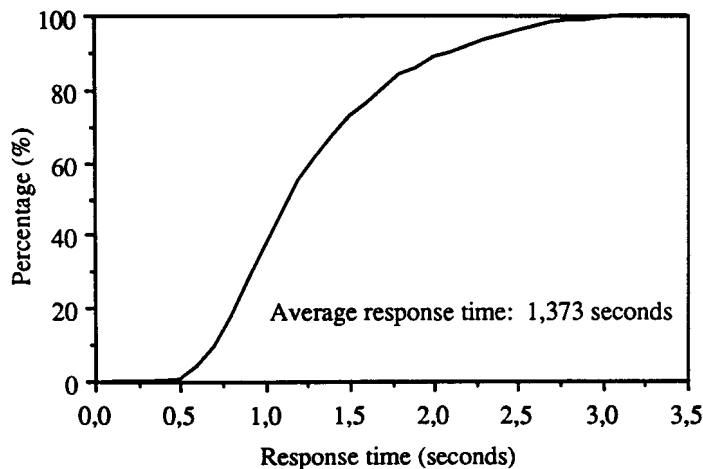
Figure IV Response time distribution for the NTS service

Conclusions and recommendations. In this paper a model is presented to determine performance metrics for an Intelligent Network. The model has been constructed using queueing network theory. The model can be solved for a certain configuration by either simulation or analytical calculation. At PTT Research a simulation model was built using the SIMSCRIPT language. The simulation model was verified by analytical calculations. This verification indicates that the simulation model was correct. The simulation model provides besides performance metrics like utilization and average response times, estimations of response time distributions. These distributions may be very useful in order to assure a certain quality of service towards PTT customers.

Using the model it is possible to get some hands-on experience for capacities needed in the Intelligent Network, guaranteeing a good quality of service. With simulation it is possible to get on-line experience with the parametrizing of the IN. The effect of adding a new service or installing new equipment can be shown.

The following step the authors foresee, is a verification of the model with performance tests carried out with operational IN equipment. In this way, the simulation tool will evolve towards a reliable network planning tool. Also, benchmark tests can be used to get reliable input data for the tool.

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