A COMPARATIVE STUDY OF THE SWITCHING PERFORMANCE OF CONNECTION-MODE NETWORK LAYER RELAYS

Authors:
Mário Bernardes, Edmundo Monteiro,
André Rodrigues, and Fernando Boavida

Affiliation and Address:
Laboratório de Informática e Sistemas
Universidade de Coimbra
Urb. Quinta da Boavista, Lote 1, 1º
P-3000 COIMBRA
PORTUGAL

Tel.: +351 39 701775 Fax: +351 39 701266 e-mail: boavida@mercurio.uc.pt

Abstract

This paper presents a simulation-based comparative study of two different approaches for connection-mode network layer relays - the service relay approach and the protocol relay approach - for LAN/WAN interconnection, that are currently the subject of standardization activities. In order to evaluate the relative performance characteristics of the two different relay types, a number of simulation studies were carried out, using several traffic conditions and relay models. In spite of the architectural overhead associated with service relays, the obtained results show that this type of relays behaves well even under considerable load, and so more attention should be given to the service relay approach by standards developers and relay implementors.

KEY WORDS: Internetworking, service relay, protocol relay, network layer relays

1. Introduction

To prevent incompatibilities between different LAN/WAN interconnection solutions, there is an ongoing functional standardization activity in ISO aiming at the development of International Standardized Profiles (ISP), that benefits from the harmonized input of regional workshops (EWOS[1], NIST OIW[2], and AOW[3]). This will, hopefully, lead to standardized and compatible implementations of relays for the interconnection of those types of networks.

This paper presents a simulation-based study of the switching performance of connection-mode relay systems for LAN/WAN interworking. The study is focused on CSMA/CD LANs and X.25 PSDNs but its results can be easily extended to other subnetwork types. For this particular interworking scenario, two different relay approaches are possible: the service relay and the protocol relay, classified, according to the ISO taxonomy [1], as RB51.1xxx and RC51.1xxx, respectively (the xxx stands for the identifier of the X.25 PSDN access method).

One of the objectives of the work described in this paper is to evaluate the impact of each of the above mentioned solutions in terms of the switching performance of the relay system.

In this paper, section 2 introduces some basic concepts regarding network layer relays. Section 3 presents a description of the relay models, traffic conditions and simulation strategies used in the presented work. The study results are presented and analyzed in section 4. Section 5 presents the study conclusions and future work directions.

[1] European Workshop for Open Systems

[2] National Institute for Standards and Technology - OSI Implementors Workshop

[3] Asian and Oceanic Workshop

2. Network layer relaying

Depending on the way in which the information relaying is performed, relays may be grouped in two different types [2]:

- *protocol relays*, that relay the information on the basis of the semantics of protocol data units (PDUs) of a given layer, establishing a correspondence between the PDUs of one subnetwork to the PDUs of other subnetworks;
- *service relays*, that relay the information on the basis of the semantics of the service supported by the protocols of the layer in which the relay operates. This approach requires the definition and use of an (N)-*Internal Layer Service* ((N)-ILS), that results from the addition of the necessary relaying functionality to the normal layer service.

These types of relays can be used for the interconnection of different types of subnetworks, operating at one of several layers, and relaying one of the two service modes (connection-mode or connectionless-mode service).

ISO/IEC Technical Report 10000-2 [1] defines a taxonomy for relay system classification. At the present moment, several functional standardization activities address network layer relaying, covering CLNS relaying (RAp.q profiles), CONS relaying (RBp.q profiles) and X.25 Packet Level Protocol relaying (RCp.q profiles).

3. Study description

The relay study that is being carried out by the team addresses several aspects - not all of them covered by this paper - like, for instance, relays formal specifications, congestion control techniques [3] [4], switching performance evaluation, management, functional standardization [5] and prototype implementations. In this paper we will address only the performance evaluation part.

In order to predict and evaluate the switching performance of network layer relays that use the service relay or protocol relay approaches, several simulation studies were carried out, based on different traffic conditions and relay models.

The models take into account the effects of the physical and data link layers, that must be present in a real relay system (and that are, normally, taken care by dedicated communication controllers, with independent processing capabilities), as well as the effects of the particular building entities that exist in the network layer, that perform the relay functions described in [6] for the service relay case, and in [7] for the protocol relay case.

The two subnetworks to which each of the relays is attached are, on one side, a CSMA/CD LAN and, on the other, a PSDN accessed via a permanent PSTN/CSDN leased line at 128 kbps (see Fig. 1). Note that this 128 kbps leased line can represent the effect of several PSDN/CSDN attachments at lower baud rates. Each of the relay models can deal with segmenting and reassembling operations.

For the purpose of the study, several operating facilities and parameters were modeled. This enabled the performance study to address different aspects of relay operation, and to highlight the behavior differences between service and protocol relays, under various relay configurations. For instance, the simulation models accommodated the use of several machine processing powers, line baud rates, and packet processing times. Window flow control mechanisms were not modeled, in order to extend the scope of the study to congestion collapse regions.

The relays under study were submitted to various load patterns, representing a variety of network users and typical applications (e.g., electronic mail, file transfer, remote database access, virtual terminal).

Call generation obeyed a normal distribution, which, due to the fact that the number of events per unit time was relatively high, is equivalent, with good approximation, to a Poisson distribution. The mean call inter arrival time

ranged from 20 to 300 ms. This call request rate was deliberately high, in order to stress the switching capabilities of the relays under study.

In 40% of the calls, the data packets were small packets, representing traffic of interactive nature (e.g., virtual terminal applications, database queries). In 40% of the calls, the data packets were medium-size packets, that did not require segmenting or reassembly operations at the relay, and that represented e-mail or database access traffic. In 20% of the calls, the data packets were large packets, representing file transfer applications traffic.

The simulation studies were organized in two main stages. Table 1 summarizes the simulation conditions used in each stage.

The objective of the first stage was to determine the critical factors affecting the two types of relays under study and to obtain their general behavior characteristics. In this stage, the influence of the machine processing power - expressed in terms of executed operations per unit time - and the influence of the PSDN attachment line baud rate were studied. This permitted to choose the simulation parameters and conditions for the following simulation stage.

In the second stage the objective was to concentrate the analysis on the switching capacity of the relay systems under study. In this stage the data transfer

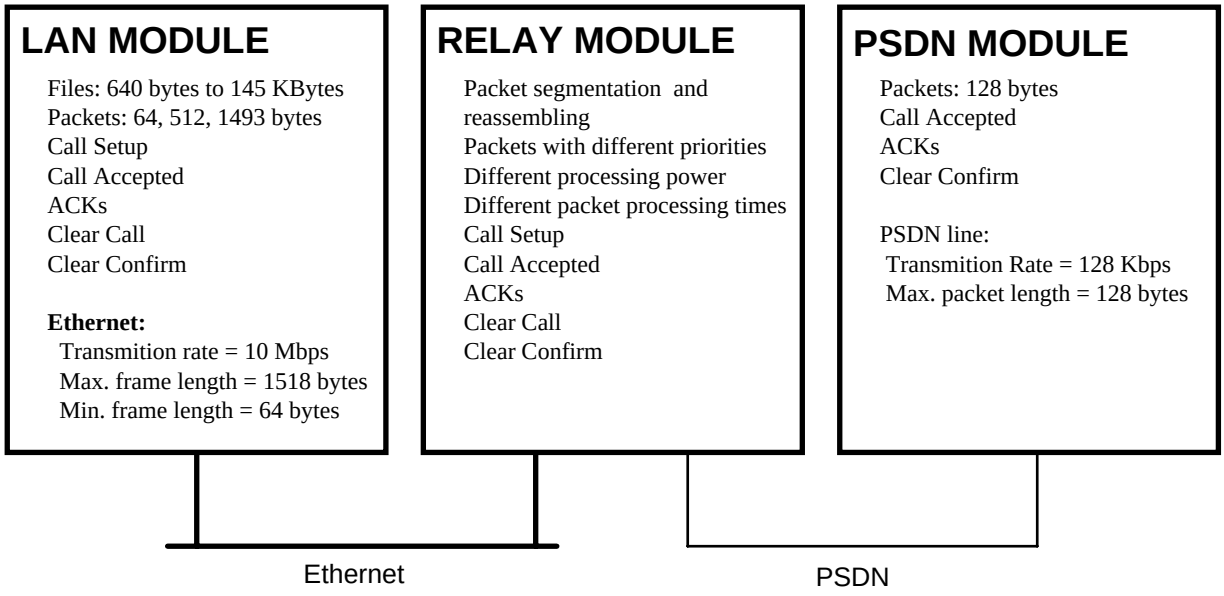


Figure 1 - LAN-RELAY-PSDN operational characteristics

Simulation Conditions	Stage 1	Stage 2
Unidirectional/Bi-directional traffic	unidirectional	unidirectional
File size (number of packets)	10 - 100	10 - 100
File size statistical distribution	Uniform	Uniform
Mean call inter-arrival time (mseg)	100 ms	100 - 300 ms
LAN packet size (bytes)	64, 128, 1493	64, 128, 1493
RELAY packet size (bytes)	128	128
Processing power (M ops/sec)	1 - 40	1
Packet processing time	fixed	fixed
Relay packet segmentation	yes	yes
Relay packet assembling	yes	yes
Call Setup	-	-
Call Accepted	-	-
ACKs	yes	yes
Clear Call	-	-
Clear Confirm	-	-

TABLE 1 - Simulation stages

was unidirectional, with acknowledgments, but there were no call setup or clear call procedures.

4. Study results

One of the factors that was studied in the first stage was the influence of the PSDN attachment line baud rate. The simulation studies revealed that for baud rates up to 64 Kbps the service relay and protocol relay approaches are basically equivalent. This is due to the fact that the leased line baud rate constitutes a limiting factor for the amount of data that traverses the relay, which results in a very low relay utilization. Under these circumstances, the influence of the relay architectural choices is negligible, and thus the performances of the service relay and protocol relay are equivalent. At higher leased line baud rates the amount of data that passes through the relay becomes significant, and the relaying capacity may appear as a significant factor in the relay performance. In the subsequent simulation stages a 128 kbps baud rate line was used on the PSDN side.

The influence of the machine processing power was also addressed in this stage. The call inter arrival time and the number of basic operations necessary to process a packet were fixed. The machine processing power varied from 1 million operations/second (ops/sec) to 40 million ops/sec.

The first stage results pointed to an intuitive preliminary conclusion: on one hand, for relatively

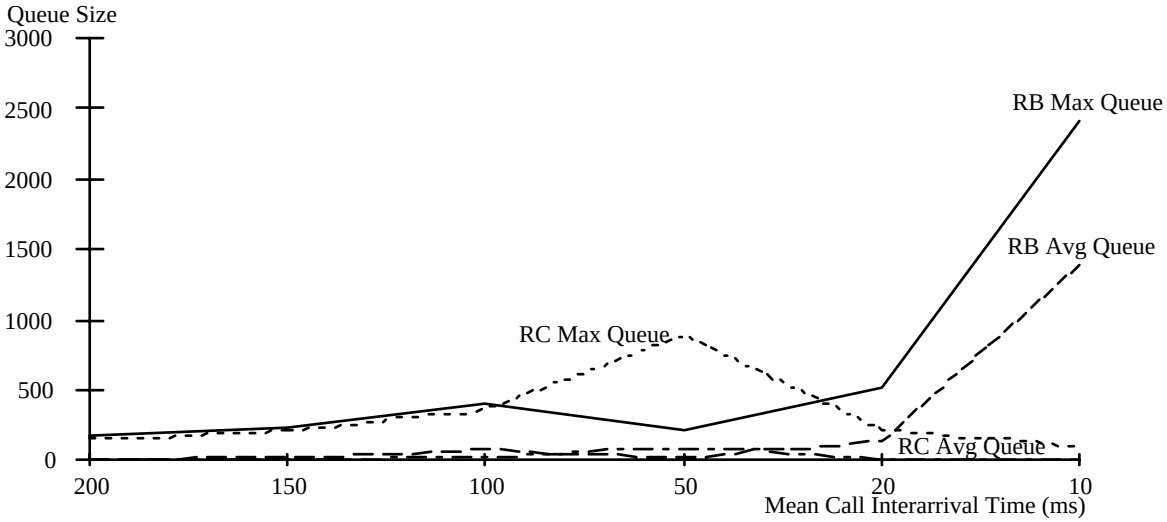
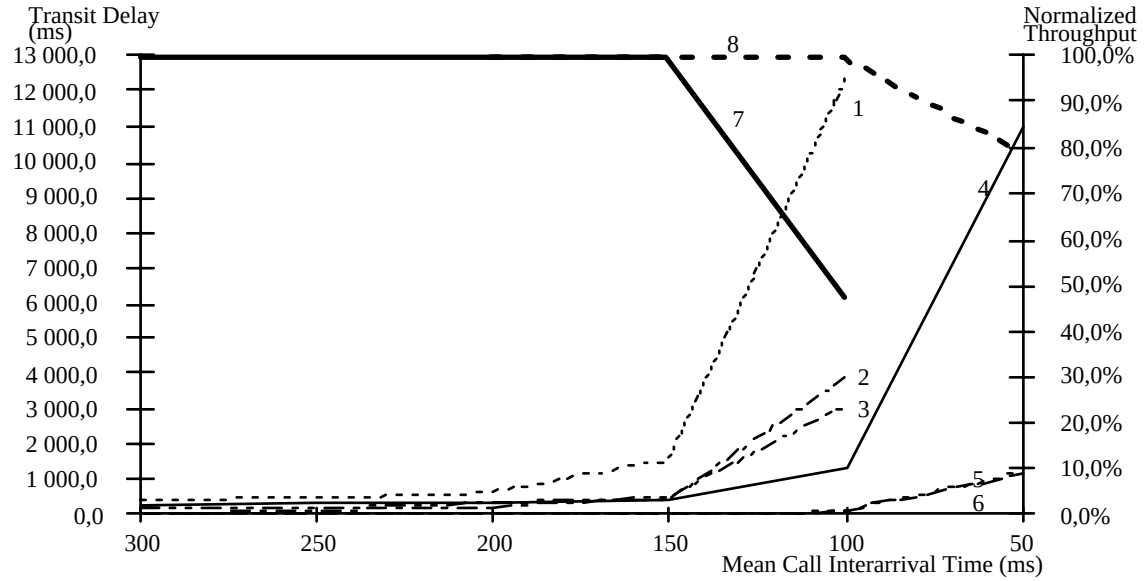


Figure 2 a)



Transit delays:

1 - RB big packets 2 - RB medium packets 3 - RB small packets
4 - RC big packets 5 - RC medium packets 6 - RC small packets

Normalized Throughput:

7 - RB relay 8 - RC relay

Figure 2 b)

low load conditions (i.e., low percent utilization), the protocol relay and service relay approaches can be looked at as equivalent in terms of overall performance; on the other hand, the two relay approaches behave quite differently when the load is increased, with important consequences in terms of queue sizes, throughput and transit delay.

In light of the simulation results of the first stage, the subsequent simulation stages were aimed at the study of the two relay types under heavy load conditions, in order to clearly characterize the behavior of the two types of relays, and to identify performance bottlenecks. In order to do this, all subsequent simulations used a simulated machine processing power of 1 M ops/sec and call inter arrival times below and above 100 ms.

Figure 2 shows some of the simulation results of the second stage. In this stage the call inter arrival times ranged from 300 ms to 10 ms, and the packet processing time was fixed and equal to 1 ms.

The graphics shown in this figure highlight the better switching capacity of the protocol relay approach which, for a given load, presents smaller queue sizes, higher throughput and smaller transit delay. Nevertheless, the difference in the performance of the service relay and protocol relay approaches remains quite small up to considerably high traffic loads.

The above mentioned results point to the conclusion that the service relay approach may be adequate for a relatively large number of cases. On the other hand, this simulation stage confirmed the expected superiority of the protocol relay approach to serve as a base for the implementation of network layer switching devices, when very heavy load conditions are present.

5. Conclusion

The simulation study of the service relay and protocol relay philosophies for the interconnection of CSMA/CD LANs and PSDNs highlighted some aspects of their relative performance, that may influence standardization activities, as well as implementation options and user selection decisions.

As a general conclusion, the presented study showed that both the service relay and the protocol relay types are valid and useful approaches to subnetworks interconnection. The choice should depend on a number of factors like, for instance, expected traffic loads, desired performance, available processing power, and implementation cost.

The study also revealed the sensitivity of the relay performance in relation to the architectural options involved. Processing entities, layer and sub layer interactions, and modularity are important and well established concepts, but can represent a handicap when very high switching capacity is required.

The presented work has also shown that the use of the service relay approach is adequate in a large number of cases, even when the traffic load is considerably high, requiring an amount of memory not much higher than that required by protocol relays, and having equivalent throughput and transit delay. This, and the fact that service relays have an architecture that derives from the OSI principles of layer interactions and structured approach, indicates that this type of relays requires a greater interest in what concerns functional standardization activities and product developers.

The simulation study pointed out several topics and key areas that can be addressed in subsequent studies like, for instance, flow and congestion control capabilities, and interconnection of other types of subnetworks, with emphasis in the study of relay approaches for high speed network interconnection. These will be explored in parallel with the current work.

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