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THE VIRTUAL LAYER ARCHITECTURE APPLIED TO TOKEN RING REDUNDANCY

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Abstract

This paper describes an original protocol (called PLASMA) which will make local area networks both more trustworthy and more operational, while at the same time adapting them to the context of real time systems based on interconnected computers.

This protocol in the link layer fits between the LLC and MAC sublayers specified by the standards. For this purpose, we have introduced the notion of virtual layer, which enables the new layer to remain completely transparent and compatible with all the OSI protocols and concepts.

This protocol relies on the redundancy of communication devices (two token rings), to correct both major faults (by a process of switching over), and minor faults (by a process of retransmission).

We have designed our protocol using the Regular Petri Nets, in order to validate it by means of the appropriate tools developed in our laboratory.

Introduction

Because of their rather low cost, microcomputers are more and more widespread within the firms. However, the geographic dispersal requires the installation of a local area network to allow the different computers to communicate with one another. Moreover, the development of multiprocessor machines brings about a greater local processing power.

Nevertheless, the communication medium between the different computers and the protocol that manages the medium should face some requirements, especially as regards the throughput and the reliability. The emergence of new technologies such as fiber optics allow one not to consider the throughput as a major obstacle (for the while, the token ring throughput is 4Mb/s, but it will be 100 Mb/s with fiber optics). The reliability of the transmission is decreased by any fault that can occur during the transfer of a message. Transmission failures come from either minor faults (noise, disconnection...), or major faults (broken link, component failure...). To ensure the transmission reliability, we propose the protocol PLASMA that relies on the use of redundant mediums and communication devices (4).

In normal phase, the load is distributed among all the communication devices, and this assures a fast service. In failure phase, the load is distributed among the remaining devices, which must be able to maintain the service.

Obviously, the use of multi-medium entails many problems : redundancy management, synchronisation, loading balance, preservation of the service quality

(sequencing, unicity). The PLASMA protocol enables these problems to be solved.

This protocol meets the following requirements :

- 1) The integration of the protocol within a new sublayer compatible with the concept found in the Open System Interconnection standard (7).
- 2) The transparency of the protocol in the relation to the upper layers and their classes, in order to support any applications.
- 3) Maximum simplicity of the protocol, so as to reduce the slowing down of the transmission, and also to facilitate specification and validation.

Our new PLASMA layer is virtual, and fits between the MAC sublayer (8) and its upper LLC sublayer (9) and has the same interface primitives as the MAC sublayer. In this way, the virtual layer can improve the efficiency of the MAC sublayer, while the LLC sublayer is unaware that it is communicating with the virtual layer.

This choice of structuring has been guided by performance considerations. To switch over at the layer where the failures are detected is more efficient than at a higher layer.

We have chosen the token ring protocol as the medium protocol because its access method and its priority management are especially suitable for our requirements. In the current version, the protocol is designed to manage a single redundancy, that is, the doubling up of all the devices needed for communication. Each Plasma entity assures the Service required by the LLC entities, using two MAC entities (Figure 0.1).

1.- General Architecture

The connection of several workstations through a communication medium must face time and quality constraints. The use of specialized units allows a greater execution speed, and the reliability is improved on the one hand by doubling up the medium and on the other hand by installing redundant workstations.

1.1- The workstation architecture

Each workstation is a micro-computer with the following structure : several processors share a common memory that can be accessed through a bus (Figure 1.1). Each processor (based on 32 bit processing units) belongs to one of the following subsets :

- the main or secondary treatment units support the applications specific of a workstation;
- the coupling units enable a computer to access the communication medium.

Each workstation accesses the mediums through the associated coupling units which manage the higher layers of the protocol. Each coupling unit is connected to both

rings through an **adapter** which manages the lower layers of the protocol.

1.2- The token ring architecture

The protocol is based on the circulation of a token between the different adapters of a ring. When an adapter wants to send a frame, it removes the token from the ring and replaces it by its frame. This frame is transmitted from an adapter to the following one. The receiving adapter detects the frame and indicates that it has been copied. It then passes it to the following adapter. When the message comes back to the sending adapter, the token is put back on the ring. During the circulation of the frame on the ring, this frame can be lost or altered. The cases of perturbation are the following ones :

- the message arrives on the receiving adapter, but cannot be copied (receiver congestion, receiver failure, etc...);
- a perturbation of the ring brings about the loss or degradation of the message (inconsistency due to the insertion or the removal of a workstation, a broken link, failure of the active monitor, etc...).

2.- Presentation of PLASMA

2.1- The PLASMA environment

In accordance with our transparency requirement and the notion of virtual layer, the interface primitives between LLC/PLASMA and PLASMA/MAC are those defined by the standard for LLC/MAC (Figure 2.1) :

PLASMA-LLC Interface

PLASMA-MAC Interface

PL-DATA Req	: Request to transmit a frame	: MA_DATA Req
PL-DATA Conf	: Request confirmed	: MA_DATA Conf
PL-DATA Ind	: Indication of frame reception	: MA_DATA Ind

The standards for local area networks specify a third interface with an entity called "Network Manager". This entity is responsible for the overall management of the network : indication of faults, reconfiguration, statistics, etc... The inclusion in it, of a module called "**BISON**" providing the supplementary functions needed by the PLASMA protocol, arises as a natural consequence.

BISON directs the transfer of messages on the different supports in relation to the amount of traffic and any faults it detects. Specifically, BISON is informed through the Network Manager of all changes in the state of the communication devices, and oversees the operations of switching over links from one ring to the other (in our terminology "**the switching**") :

PLASMA-BISON Interface

Switch : BISON requests the switching over to PLASMA

2.2- The functions of PLASMA

Our protocol PLASMA should, in order to maintain (increase)the reliability of service, face two types of failures :

- **Minor failures** occur on a short and irregular basis and in only a few frames. They are induced by momentary events, or by the self-correction of devices;
- **Major failures** cause incoherence on the overall flow of information. They are mainly induced by device failures and are detected globally by the Network Manager.

According to these two types of failures, the protocol has two correction mechanisms :

- For minor failures, the immediate **retransmission** of the faulty frame onto the other support proves to be an efficient technique;
- For major failures, the **switching** is designed to switch over all the transfers of a virtual link (linking two PLASMA-sap) from the faulty physical support onto the other.

Unfortunately, these two mechanisms may produce two adverse effects :

- The retransmission of a frame correctly transmitted, yet where the confirmation is lost, results in the **duplication** of this frame;
- The difference in speed of transfer obtainable between the two mediums (which are not synchronised) and the possible loss of frames, can cause the **misordering** of these frames.

These two disadvantages are corrected by the following procedures:

- At the sending phase, the frames are numbered in order to identify them.
- At the reception phase, the number of the frame received is compared with the number of the frame expected. If the frame received is late or has been duplicated, it is rejected; if it is early it can be buffered for a short while; if it has the expected number, of course, it is transmitted to the upper layer.

These procedures are deliberately simple and are well known, and we intend to prove that they are sufficiently effective for solving our problems.

3.- Modelling and Analysis

To specify PLASMA, we have selected Regular coloured Petri nets (6). Regular coloured Petri nets are coloured Petri nets (10) that manage classes of colours, and which colour functions are restricted to

- identity
- predecessor / successor function
- diffusion function

and linear combinations of these functions. For each class, the number of colours is a parameter.

In our models, we use the following colours :

<r> : Identity of Ring $\in \{A, B\}$ <s> : Identity of Sender
<x> : Information frame $\in \mathbb{N}$ <d> : Identity of Receiver

3.1.-Model of services of the MAC sublayer (figure 3.1)

MAC - Sender Process : The sender process <r,s> is associated with the entity belonging to the ring <r>. This process performs the sending of the frames coming from <s>.

When a sending request is taken into account (MA_Req transition), the sender process transmits it to the transfer process which sends back a confirmation which is either positive (MA_Conf(+)) transition) or negative (MA_Conf(-) transition);

MAC - Transfer process : The transfer process manages the ring <r>. As soon as the token is available (TR_Req), the frame is transmitted to the receiver process belonging to the addressee <d>. If the transmission is successful (TR_Ind), a positive confirmation is sent, otherwise a negative confirmation is sent. Pert_mess and Pert_transf transitions model the loss of a frame before or after its delivering.

MAC - Receiver process : The receiver process <r,d> is

associated with the entity <d> belonging to the ring <r>. The receiver entity of PLASMA is informed of a frame reception (MA_Ind transition).

Initial state:

$$M_0(\text{Repos}) = \sum_{dr,ds} \langle r,s \rangle$$

$$M_0(\text{Jeton}) = \sum_{dr} \langle r \rangle \quad M_0(\text{Attente}) = \sum_{dr,dd} \langle r,d \rangle$$

dr,ds et dd are respectively the domains of <r>,<s> and <d>

3.2.-Model of PLASMA sending treatment (figure 3.2)

BISON switching : According to the state of the network, BISON determines the sending ring for each link (characterized by <s,d>). **Switching** operation and sending treatment are independently processed.

Numbering management : In order to simplify the model expression and avoid the increase of the tuple size, we assimilate the frame information to an integer which corresponds to the frame number managed by PLASMA. Thus, on each link, the frames are numbered in increasing order (with infinite upper bound). We associate with each link <s,d> the current value <x> of the counter (SX place).

Ring choice : Once the numbering, the sender process sends the frame to the ring <A> or according to the BISON choice. Thus token colours are <A,s,d,x> or <B,s,d,x>.

PLASMA-MAC Interface (first sending attempt) : Once the frame has been transmitted to the MAC sublayer (MA-Req/a transition), the PLASMA process waits for confirmation. If it is positive (MA-Conf(+)/a transition), it is transmitted, after a preparatory treatment (E7 place), towards the LLC entity (PL-Conf(+)) transition). If the confirmation is negative (MA-Conf(-)/a transition), a retransmitting treatment on the other ring is tried (E5u place).

PLASMA-MAC Interface (retransmitting attempt) : According to the retransmitting attempt status, a positive or a negative confirmation (E7 or E8 place) is prepared for the LLC entity.

Initial state:

$$M_0(\text{Aa}) + M_0(\text{Ab}) = \sum_{ds,dd} \langle s,d \rangle$$

$$M_0(\text{Sx}) = \sum_{ds,dd} \langle s,d,0 \rangle \quad M_0(\text{E1}) = \sum_{ds} \langle s \rangle$$

3.3.-Model of PLASMA receiving treatment (figure 3.3)

The receiving treatment basically consists of verifying the frame numbering. On each link <s,d>, a reception range is managed like a window with fixed size. This mechanism allows **duplicated** and **misordered** frames to be treated.

Management of the receiving window : For each link, we define a range of N consecutive numbers. Each number corresponds to a frame which must be received. The lower bound (RX place) corresponds to the next frame which is expected. We call this bound "current".

In our model, the place **Illegal** contains the references of all numbers which are not included in the receiving window.

The window management uses two subsets :

- The subset of the expected frames (**Expected place**)
- The subset of the received frames which have not yet been delivered to the LLC sublayer (**Received place**).

The range is modified by increasing the lower bound (and consequently the upper one) in two cases :

- When the "current" frame is delivered to LLC (**PL-Ind transition**).
- When the time-out associated with the "current" frame occurs (**Time-out transition**).

Analysis of the numbering of the received frames : A PLASMA process, associated with the receiving entity <d>, analyses the number of the received frame (**MA-Ind transition**). We observe three cases :

- The frame was expected (**OK transition**)
- The frame has already been received (**Duplication transition**). The frame is rejected.
- The frame does not match to the receiving window (**Out-of-range transition**). This transition prevents the misordering of frames.

Initial state:

$$\begin{aligned}
 M_0(\mathbf{Rx}) &= \sum_{ds,dd} \langle s,d,0 \rangle & M_0(\mathbf{R1}) &= \sum_{dd} \langle d \rangle \\
 M_0(\mathbf{Illegal}) &= \sum_{ds,dd,d1x} \langle s,d,x \rangle & & \text{where } d1x = [N, \infty] \\
 M_0(\mathbf{Expected}) &= \sum_{ds,dd,d2x} \langle s,d,x \rangle & & \text{where } d2x = [0, N[
 \end{aligned}$$

3.4.- Conclusion of the analyses

The overall behaviour of PLASMA can be assessed by the properties issued from the studies of the previous model. A coloured base of invariants and a symbolic coverability graph have been automatically computed, with the laboratory tools (2). We find thirteen parametrized invariants using generalized successor functions.

The basic properties are :

- Transparency : PLASMA transmits to the LLC Layer the interface primitives expected by the specification of the MAC service.

- Misordering : PLASMA does not produce misordering by the sending process and the window management assures the sequencing of the reception process.

- Duplication : PLASMA identifies the frames in a unique way and corrects the duplication induced by the process of retransmission.

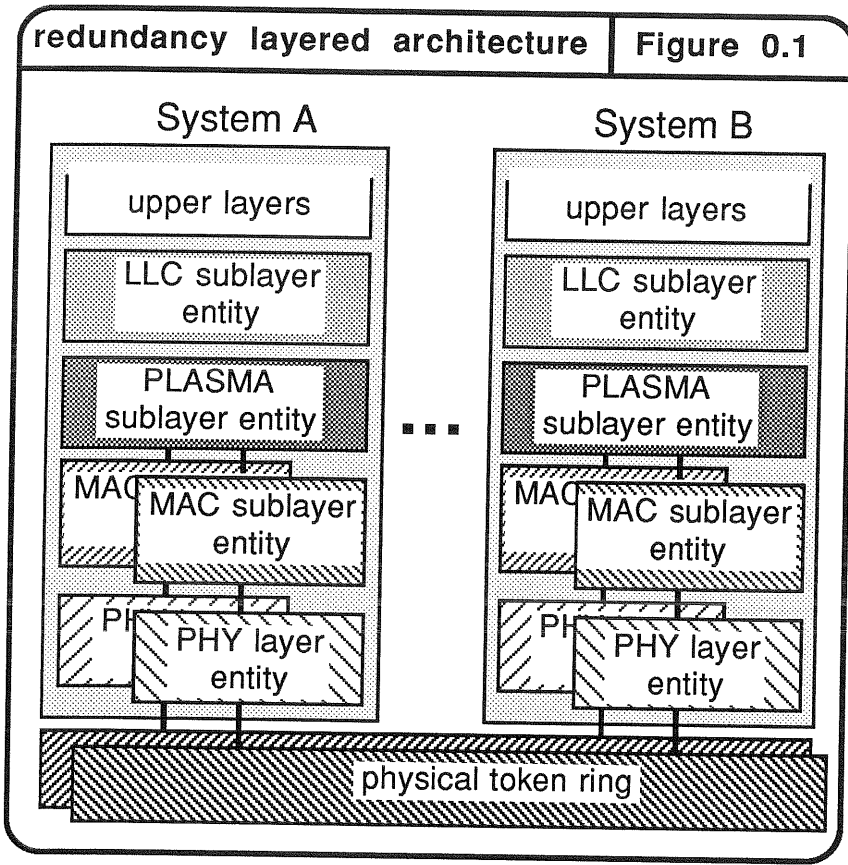
4.- Conclusion

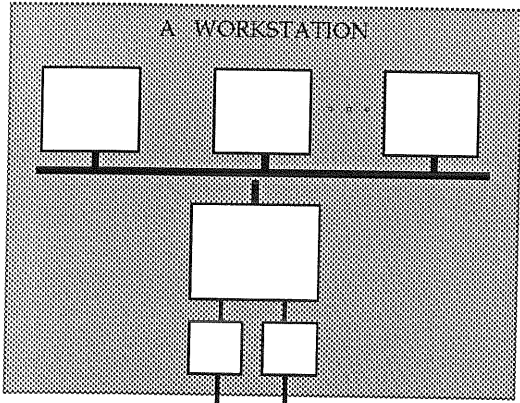
The protocol PLASMA validation allows the verification of some advantages of the virtual layer concept. PLASMA retains the properties of the MAC sublayer (sequencing, non-duplication) and preserves the interface primitives of the LLC sublayer. Moreover, the applications ignore that the protocol manages more than one physical ring , all the more reason for them not to know on which ring their messages are sent. The only tangible effect for the application is the improvement of the performance due to the switching and the retransmitting processes.

Because of its transparency, the virtual layer concept is now ready to be extended to other layers than the MAC and LLC sublayers and to other standards than the OSI standards for local area networks (e.g. CSMA/CD for Ethernet).

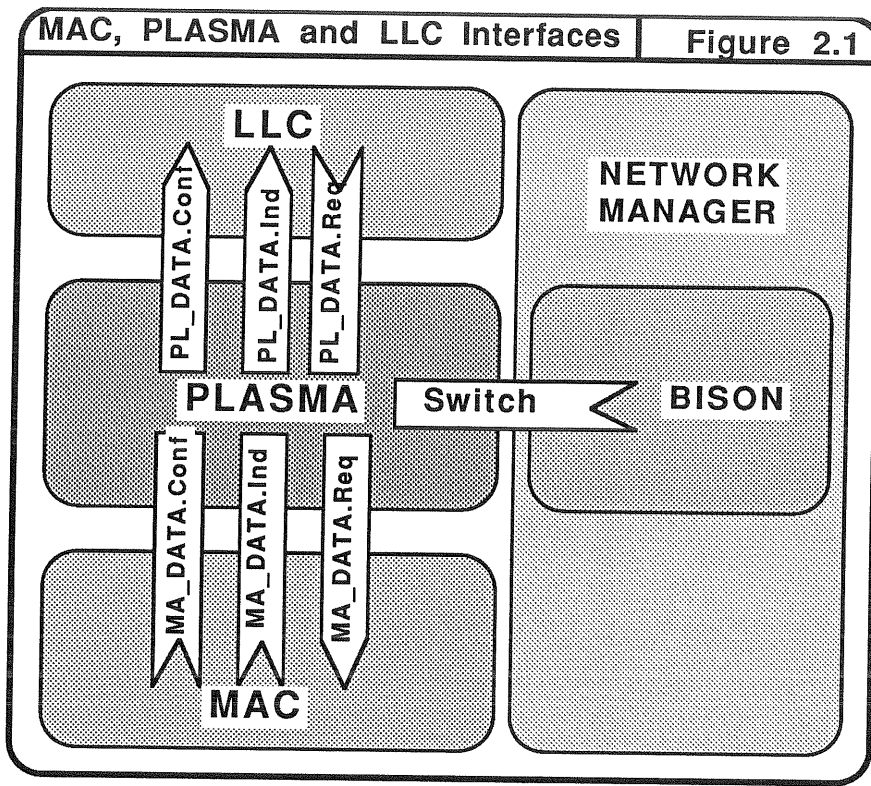
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Double TOKEN RING



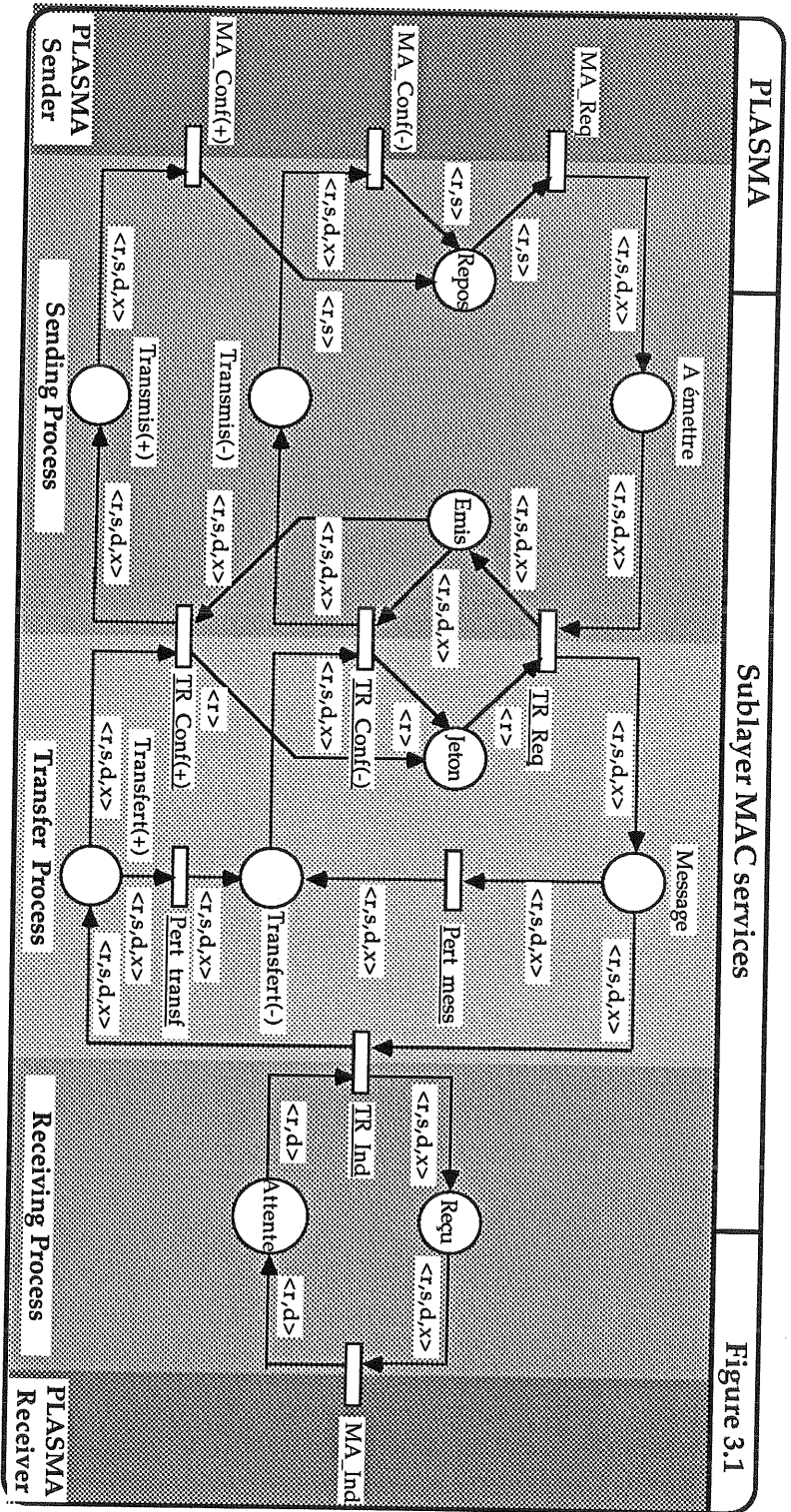


Figure 3.1

