An architecture of QoS services for a Core Internet Network over DTM

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ABSTRACT

The Differentiated Services (*DiffServ*) model brings the flexibility of the definition of a variety of QoS services through PHBs (*Per Hop Behaviours*) and Traffic Conditioners. It integrates gracefully with the Integrated Services (*IntServ*) model, that can have functions of QoS signalling, admission control, channel management, resource estimation and dynamic traffic contract agreement. With this integration we can have a scalable, flexible and dynamic IP Core QoS environment.

The transport network and switching solution used in the architecture proposed, DIPQoS (*DTM IP QoS*) architecture, is the DTM, a fast circuit switching technology. It's simple, cost effective and have attractive QoS performance.

Four simplex services are defined in DIPQoS: the DSG (*DTM Strict Guarantee*), that guarantees the signalled peak rate and delay tolerance; the DGF (*DTM Guaranteed Forwarding*), that guarantees a minimum forwarding of packets based on pre-signalled QoS specifications and SLAs (*Service Level Agreements*) between customer and provider. Another one is the DLF (*DTM Loose Forwarding*) that provides a loose forwarding of the packets based on discard priorities and also on guaranteed pre-signalled QoS specifications and SLAs. And the last one is the DBE (*DTM Best Effort*), like the traditional Internet service, there isn't any QoS support.

The purpose of this paper is to present a functional architecture of QoS services based on DiffServ and IntServ models for a Core Internet network over the DTM technology.

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KEYWORDS

Quality of Service, Integrated Services, Differentiated Services, Core Internet, DTM

1. INTRODUCTION

The DIPQoS architecture is based on the sharing of resources (buffer and bandwidth), so the dynamics are based on the marking of packets not on reservations.

The IETF (*Internet Engineering Task Force*) DiffServ model [1] as is simple and scalable, is the IP QoS solution at the border of the architecture, where the flows are policed, remarked, classified and scheduled to be transmitted on a specific DTM channel. The QoS provided is based on the DSCP (*DiffServ Code Point*) bits [2] marked on any point of the access network or by the customer. These DSCP bits are defined during the traffic contract agreement, when is done the mapping of the IntServ service to the DiffServ service inside the "DIPQoS domain". The RSVP (*Resource Reservation Protocol*) [3] is the application QoS signaller, admission controller, DTM channels establishment/torn down and resource estimator based on the IntServ guaranteed (GS) [4] and controlled-load services (CL) [5]. Inside the Core Network there aren't any RSVP messages processing nor state storage, as the DTM technology provides a deterministic delay, low jitter and assured bandwidth during the channel life-time.

The DTM (*Dynamic Synchronous Transfer Mode*) [6,7] is a technology based on the high-speed circuit switching architecture, with dynamic reallocation of bandwidth. It provides multicast services, channels with varied bit-rates (from 512 Kbps until the capacity of the medium) and low time of circuit configuration (few milliseconds).

It can be used as an end-to-end solution or as a transport of protocols like ATM and IP.

The DTM technology guarantees a constant delay transmission, low jitter, bandwidth directly proportional to the number of slots that are on the channel and low losses rate [8]. Furthermore, the medium access is deterministic, so it can provide a fixed delay for the access medium. The switching is synchronous, we have an average constant switching delay of 125 μs on each hop [8]. The processing of control information occurs only in the channel establishment and disconnection phases. We have queues in the switches only in the case of clock synchronisation between buses, so there isn't congestion nor overflow.

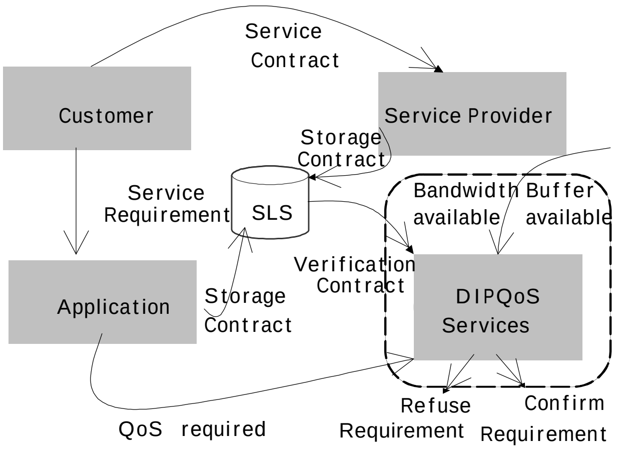

Figure 1 - Contract and verification of QoS requests

In figure 1 is shown a typical example of the interaction between the customer, the provider, the application and the network services from the service contract agreement phase until the phase of the refusal or confirmation of the QoS request.

The bounded region (dotted lines) in this figure is the goal of this paper. It represents the services provided by the DIPQoS architecture and its interaction with the service contracted defined on the SLS (*Service Level Specification*) database and the QoS signalled through the RSVP protocol. The contract, management and charging of the services and the QoS signalling on the access networks are out of the scope of this study. In figure 4, there's a global vision of the functional components of a "DIPQoS domain" that include only one ingress and one egress node. The functions of these components will be described along the paper.

On the next section we have the motivations for the development of this architecture and on section 3 and later are presented four services defined on the DIPQoS architecture and its interaction with the RSVP protocol, the DiffServ model and the DTM technology. In section 6 is described a scalability study of the proposed architecture and then we have the conclusions.

2. MOTIVATIONS

The ATM technology has its merit with the provision of a complete QoS support for a variety of traffics but it has to do per cell processing and queuing controls in the switches, generating performance problems. Furthermore, the mapping of the IntServ and DiffServ services to ATM services are not a straight forward task [9,10].

The DTM is a fast circuit switching that guarantees latency, a little jitter, traffic isolation and flexible resource reservation. The DTM only provides the traditional CBR (*Constant Bit Rate*) service. It allows a flexible and easy interaction with the IETF IntServ and Diffserv QoS models, providing other services like VBR(*Variable Bit Rate*) at the IP control level.

In figure 2, we can see some solutions for the integration of IP with the link and physical layers. The telecommunication community bets that the future is the IP applications on top of physical pipes like SDH/SONET, but some drawbacks like the static hierarchical structure has yet to be solved.

The IP over ATM has limited scalability due to the "n-squared" problem when a full mesh of VCs (*Virtual Circuits*) is provided. The IP/MPLS/ATM architecture is more appropriate for large networks, like on Core Internet, in terms of flexibility, scalability and manageability.

Another architecture presented is IP/DTM. As DTM automatically performs the rapid forwarding of packets by the time-switching slots, the MPLS (*Multiprotocol Label Switching*) does not have any functionality on this architecture. The Traffic Engineering feature provided by the MPLS, can be done for example by RSVP TE (*Traffic Engineering*) extensions [11]).

As any circuit switching technology, the DTM technology isolates the traffics of each circuit, it means that activities of each circuit don't affect the other one. This brings the possibility to have transmissions with guaranteed quality and with a constant transfer delay, as the DTM switching is synchronous.

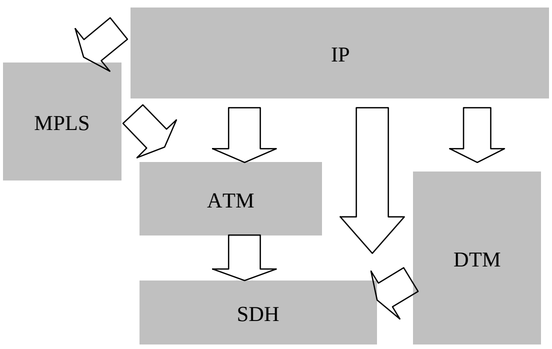

Figure 2 - *IP/Link Layers Solutions*

DTM channels are multirates, each one can have an arbitrary number of data slots; the capacity of each channel is a multiple of 512kb until the bus maximum capacity or the channel bandwidth maximum limit. Another interesting characteristic is that the DTM interfaces are multichannels, bringing scalability in a full-mesh physical topology.

Furthermore of the characteristics presented, the DTM integrates perfectly with the RSVP protocol, as many of the capacity of the latter are supported by DTM:

(1) Dynamic reservations: The DTM is based on the technique of fast circuit-switching with a dynamic reallocation of resources. It means that if a specific channel doesn't have sufficient resources for the transmission, it can ask for more resources to the neighbours nodes. Each node keeps a "status table" that contains information about the free slots in others nodes, when it needs more slots (*bandwidth*), verify this table to decide to each node it will ask for;

(2) Reservation receive oriented: The DTM technology is enough flexible in the handle of the creation of the channels, it can be initiated by the receivers or by the transmitters;

(3) Shared reservation or not: The DTM allows that more than one receiver share the same slot consequently adapts with the kinds of RSVP reservations: ´SE´ (*Shared Explicit*), selective multicast transmissions and the ´WF´ (*Wildcard Filter*), broadcast transmissions. We can also have exclusive slots per receiver, ´FF´ (*Fixed Filter*) reservations, that represents the DTM point-to-point transmissions;

(4) Multicast: The DTM uses the shared medium that inherently support multicast transmissions, as an unique slot can be read by multiple nodes in a bus;

(5) Reservation guaranteed: The DTM uses the strict scheme of reservation. The establishment of a channel is only accepted if there's enough bandwidth available, that is very important for applications that need strict guarantees. The RSVP protocol defines the "Blockade State", in situations when there isn't enough bandwidth but can be guaranteed some bandwidth. In the establishment of DTM channels, we have the option "minimum bandwidth".

The RSVP protocol in some aspects can be the solution that the DTM architecture doesn't offer, providing a great synergy between them:

(1) Life-time of a channel: The soft-state of the reservation and the explicit "Resv/Path Tear down" RSVP messages can be control of the life-time of the channels, as the DTM technology specifies that a high-level protocol has to control it;

(2) Resource available: The RSB (*Reserve State Block*) could provide information about the reservations established on the nodes. With this we could know the resources (slots) allocated. This facilitates the dynamic reallocation of slots;

(3) Control Switching oriented: Using the terminology of the Label Switching techniques, on this proposal we have a control switching oriented, as the RSVP Resv messages, control the establishment/torn down of the DTM channels;

(4) Traffic Engineering: The establishment of the path of the channel could be done at the IP level through RSVP Path messages. We could use the traffic engineering definitions to select the path that have more resources (slots). Of course it has to interact with the DTM slot allocation mechanism. On this proposal we don't have the processing of the Path messages inside the "DTM Cloud" so the path is elected based only on the short path.

(5) Traffic specification: The specification of the traffic helps on the correct and precise resource reservation. Using the IntServ/RSVP model, the application can specify the QoS (*Quality of Service*) required and at the edge of the "DTM Cloud" (ingress), the DTM control signalling can be forwarded until the "egress" edge, allocating the slots. The traffic specification can be used too as scheduling buffer admission control at the "ingress" node.

(6) Efficient use of the DTM channels: As the DTM permits the dynamic allocation of slots, the specification of the capacity of the channels could vary according to the traffic reservation by RSVP Resv messages and cleaning of reservation by RSVP Rtear and Ptear messages.

As in DTM all traffics are treated equally, the lack of service contract is completed by the DiffServ architecture. The conformance verification of the contract is also done by the DiffServ (policing and remarking). With this we can have a fair use of the bandwidth, that is not provided by the DTM technology.

The CBR service offered by DTM doesn't define any metric performance (e.g.: loss, delay). The DTM as a circuit switching technology has deterministic performance as loss, delay and jitter, depending only on the topology. This absence brings a great flexibility on the definition of services at the border of the "DIPQoS domain". The DiffServ together with the IntServ establish the service differentiation. In figure 3 we can see the RSVP protocol and DiffServ in a DIPQoS domain.

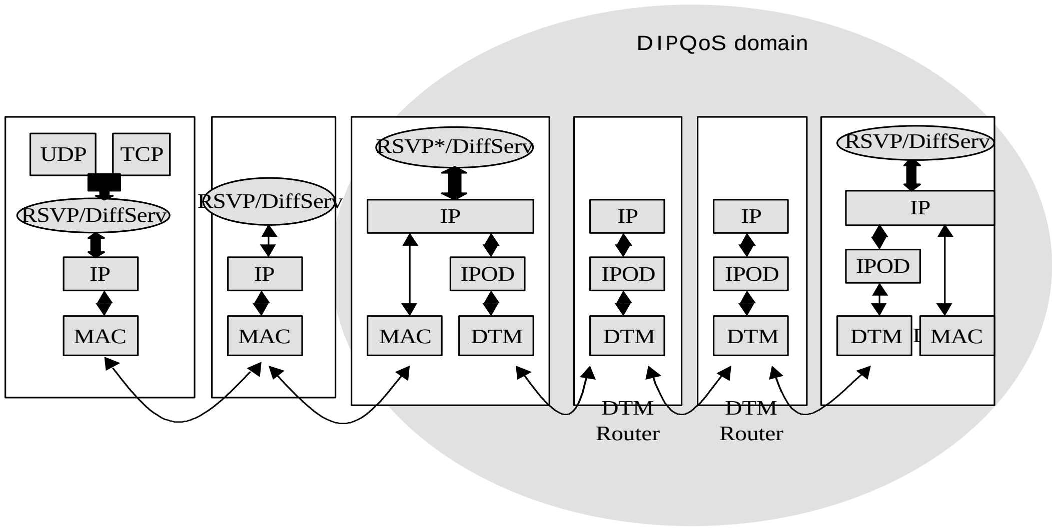

Figure 3 – Control phase in DIPQoS model

The allocation of bandwidth in the DiffServ PHBs is basically by provisioning only, but the interaction of the RSVP Protocol with the DiffServ using Admission Control and Policing can provide the bandwidth guarantee.

3. DSG SERVICE - DEFINITION

This service offers the traditional CBR (*Constant Bit Rate*) service. It guarantees the signalled peak rate and the delay tolerance. This service represents the GS Intserv Service inside the "DIPQoS domain". It's mapped to the DiffServ EF *(Expedited Forwarding*), DSCP bits="101110". These DSCP bits are the same of the DiffServ VLL (*Virtual Leased Line*) service defined on the EF [12], as this service has the same guarantees provided by this PHB.

At the border of the "DIPQoS domain", there's a per flow peak rate policing mechanism, based on the application SLS defined on the RSVP signalling phase.

The flows are aggregated based on {ingress, egress, "101110" bits}. The bandwidth provision and buffer admission control follow the GS IntServ service aggregation for a simple token bucket tb(r,b) and "n" aggregated flows [4]:

Below, 'R' is the bandwidth provision and 'B' is the buffer necessity for a lossless service. The 'b' parameter is the token bucket depth; dmax; the maximum queuing delay and 'C' and 'D' represent the rate-dependent and rate-independent deviations, respectively, of a packet-based scheduler from the perfect fluid model [13].

$$R = \frac{\sum_{i=1}^{n} b_i + C}{min(d_{max}) - D} \qquad (1)$$

$$B = \sum_{i=i}^{n} b_i \qquad (2)$$

4. DGF SERVICE - DEFINITION

The specification of flows based on peak rate "p" is a over allocation of bandwidth. Another alternative is to use the description of a leaky bucket (r,b).

The DGF service guarantees the bandwidth based on the token rate "r" and the burst size "b", maximum queuing delay and no losses on the border of the network. In this study the extension of the DGF domain is between its borders, so will not be mentioned the interaction of multiple domains.

This service doesn't extend into the domain as the DTM technology provides a deterministic transmission delay, without losses on the switches, minimum jitter and bandwidth guaranteed if is allocated the sufficient capacity.

The flows are aggregated based on the DSCP bits AF1*="001*" and {ingress, egress} nodes, multiplexed in a unique DTM channel controlled by a FIFO (*First In First Out*) scheduling. Is known that FIFO is not adequate for "not well behaved" traffics but is controlled the arrival of flows through a buffer management mechanism. These DSCP bits are the same of the DiffServ AF PHB [14] but in this service we don't have discarding priorities as we don't have losses for "in profile" packets.

The Admission Control, distributed among the border routers, is strict, based on the description of the RSVP Resv message of the CL IntServ service. There's a limited FIFO queue and a DTM channel for each {ingress node, egress node, DSCP bits "001*"}, which capacity is determined dynamically through RSVP Resv signalling.

The guarantees of this service in the "DIPQoS domain" are:

- Minimum data transmission, based on the token rate 'r' if ("N" flows aggregated) [15]:

$$k = \frac{B}{\sum_{i=1}^{N} b_i} \quad (3)$$

$$\frac{k * \sum_{i=1}^{N} r_i}{k-1} \leq Bw \quad (4)$$

The "B" is the buffer capacity. and "Bw" is the maximum allowed bandwidth for the DTM channel.

- Without losses on the border buffer ("N" flows aggregated) if :

$$\sum_{i=1}^{N} b_i \leq B \quad (5)$$

If any of these inequalities is not confirmed, the reservation is refused and is generated a RSVP ResvErr message.

- Queuing delay (per packet):

$$\frac{O(x)}{R} \quad (6)$$

The O(x) is the instantaneous shared occupation fraction of the buffer by the packet 'x'. We say "instantaneous" because the bandwidth capacity "R" is dynamic.

- Maximum queuing delay :

$$\frac{B}{R_{min}} \quad (7)$$

The "R_{min}" is the minimum DTM channel capacity that is 512Kb.

The guarantees are only preserved if the incoming flows are in conformance with the Leaky Bucket (r,b) and the peak rate "p" contracted. This service is no-conservative, the excess traffic is automatically discarded.

At the border of the "DIPQoS domain" we have a per flow peak rate policing mechanism, based on the application SLS defined on the RSVP signalling phase. The policing of the mean rate 'r' is done by the IntServ CL service on the border connections, as this service considers a non-conformant packet if the amount of data sent exceeds the rT+b bits, during "T" units of time.

This service is useful for applications that need a losseless service with a minimum rate guarantees.

4.1 DGF SERVICE - COMPONENTS FUNCTIONS

Below are described the functions of each component of this service, they are represented on figure 4 (components 1, 2, 3, 4, 5, 6 and 7). The service consists of two temporal phases, first the "signalling phase", where the RSVP messages are sent to the QoS signalling request, the admission control (buffer and bandwidth), the establishment or changing capacity of the correspondent {ingress, egress} DGF DTM channel, the configuration of the classifier and the traffic contract agreement. Secondly, the "transmission phase", where we have the verification of the conformance with the SLS contracted, the remarking, if necessary, and the classification of the packets into the appropriate DGF DTM channel.

In the description of the components functionalities we won't mention the RSVP error messages.

<u>Component 1: Ingress Node</u>

Downstream (Ingress ⇒ Egress)
("Path" Signalling phase)

- Convert "Path" RSVP messages (46) into RSVP_E2E_IGNORE. The same kind of protocol defined in [16];
- Traditional Path message processing and state update;
- Update of a new object defined here as "Latency Tolerance", that defines the application "latency tolerance" level (low="0", high="1"). This object is the differentiator between the DGF and DLF services as both are signalled as CL Intserv service.

Latency Tolerance Object
Class = ?, C_TYPE = 1

Latency Tolerance (1 bit)

- Forward the "Path" message.

("PathTear" Signalling phase).

- Decrease the correspondent {ingress, egress} DGF DTM channel capacity;
- If the capacity becomes null, turn down it;
- Convert "PathTear" RSVP messages (46) into RSVP_E2E_IGNORE;
- Forward the "PathTear" message.

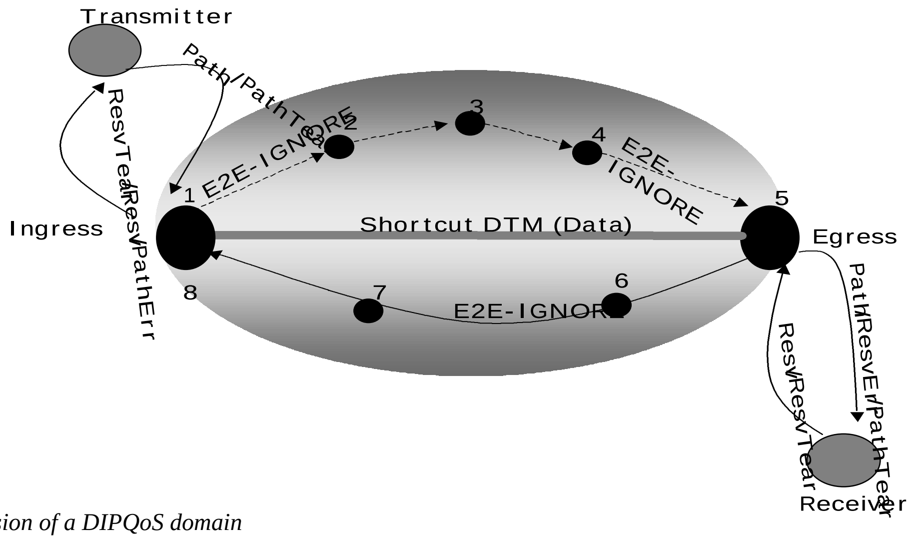

Figure 4 - Global vision of a DIPQoS domain

(Transmission phase)

- Remarking of DSCP bits if necessary;
- Verify the peak rate conformance with the contracted service (SLS). If in excess, the packets should be discarded;
- Forward into the FIFO queue of the correspondent {ingress, egress, "001*"} DGF channel.

Upstream (Egress ⇒ Ingress)
("Resv" Signalling phase)

- Map RSVP Resv messages to DSCP bits according to : IntServ CL service ⇒ DIPQoS DGF service (DSCP bits="001*");
- Establish a traffic contract agreement (SLS);
- Interact with the IPoD (*IP over DTM*) protocol, through the Traffic Control mechanism, to the buffer and bandwidth admission control;
- Increase the correspondent {ingress, egress} DGF channel capacity. If not possible, send a ResvErr message;
- Establish the DGF DTM channel correspondent {ingress, egress} if it doesn't exist;
- Convert "Resv" RSVP_E2E_IGNORE into RSVP;
- Forward the Resv message.

("ResvTear" Signalling phase).

- Decrease the correspondent {ingress, egress} DGF DTM channel capacity;
- If the capacity becomes null, turn down it;
- Convert "ResvTear" RSVP_E2E_IGNORE into RSVP;
- Forward the "ResvTear" message;

The components 2, 3, 4, 6 and 7 don't do any processing of the RSVP messages, only forward them.

In the "egress node" (component 5), we have the traditional processing of RSVP messages. Is only necessary to convert appropriately the messages types (RVSP/RSVP_E2E_IGNORE).

5. DLF SERVICE - DEFINITION

The DLF service guarantees a maximum queuing delay. Bandwidth and losses at the borders of the "DIPQoS model" are based on the priority discard and buffer occupation.

The customer requests this service specifying the average traffic rate "r" and the discard priority (DSCP bits).

The forwarding guarantee depends on the buffer load and the importance of the discard. The scheduling algorithm is the RIO (*Random Early Discard – In/Out*) [17].

In [18] is recommended the use of the RED algorithm with some end-to-end congestion control algorithm like the TCP protocol, as the RED reduces the discard of packets only if there's some end-to-end congestion control.

This service guarantees minimum data rate, based on the average, and maximum queuing delay like on DGF service. Low latency when there's a buffer managed by the RIO algorithm and losses based on the buffer load and the preference of the discard.

The discard preference can be specified as on the DiffServ AF PHB for the class 2: low discard importance = "010010" and high discard importance = "010100".

This service could be useful for supporting applications that are more loss and delay tolerant than the DGF service. The assurance of the bandwidth is statistical.

5.1 DLF SERVICE - COMPONENTS FUNCTIONS

The signalling occurs in the same manner as on DGF service, the differences are that there isn't the buffer and bandwidth admission control and on the transmission phase, the packets can be discarded conform to the discard priority and to the occupation of the buffer.

6. DBE SERVICE - DEFINITION

The DBE service doesn't guarantee any QoS like the typical Best-Effort service offered actually in the Internet.

DTM base channels with minimum capacity are pre-established. There are FIFO schedulers with limited buffers managed by Tail Drop algorithm.

6.1 DBE SERVICE - COMPONENTS FUNCTIONS

The only function is the forwarding of the flows on the correspondent hop-by-hop DTM base channel [19].

An observation, in the "DIPQoS model" the forwarding the RSVP messages is on the DTM Base channels. The main reason for sending the RSVP messages on best-effort channels is that they are bi-directional, compatible with RSVP protocol.

7. A SCALABILITY STUDY

As the internet is dynamic and grows rapidly, the increase of the number of access networks connected to a Core Network can bring some scalability problems principally in a full-mesh scenario. In this section is analysed the well-known SDH/SONET and the new DTM in this kind of topology.

The SDH/SONET is been used as a transport solution and it showed to be very simple and with low overhead.

Another transport solution, DTM, is fundamentally similar to SONET/SDH in terms of low complexity and low overhead, but includes signalling and switching to increase the flexibility and avoid the hierarchical structure of them.

The SDH technology does not support multichannel interfaces, so if we want a full-mesh environment, is necessary to provide a complete combination of physical connections, so it is not scalable.

To solve this problem, is necessary to build a topology where we have to pass through a number of routers to reach from one side of the network to another, which introduces delay and jitter, a problem for QoS sensitive traffic.

The DTM is an architecture based on the high-speed circuit switching architecture, with dynamic reallocation of resources, aspects that do not appear in the traditional solutions of circuit switching. It can be used as an end-to-end solution or as a transport of protocols like ATM and IP. The latter is our objective here.

The folded bus and ring topologies are unsuitable for large geographical distances. If a receiving node is located on the "wrong" side, the delay propagation can be large. To avoid it, can be established two rings, each one on a direction, and the information is transmitted on both rings, but this scheme spends more bandwidth. With a dual-bus topology the average distance between nodes is minimized. The bus can support full duplex communication. Moreover, two-dimensional mesh is significantly higher than the capacity of a linear topology with the same number of nodes [20].

Here we will study the bus only on one direction, as we can have the same conclusions about the other bus.

Assume a bus topology of 'M ' x 'N', where not every router is active. The inactive buses are on dotted lines and the buses necessaries to the full-interconnection between the active nodes (black nodes) are on highlight black lines (See fig. 5).

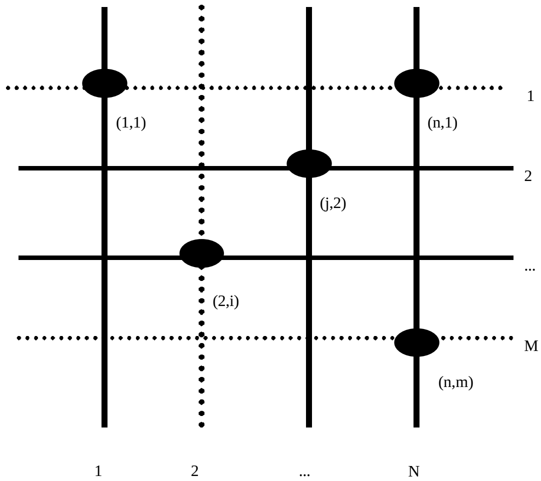

Figure 5 – Full-mesh topology

Suppose each router (node) has a geometric address (X_j, Y_i); $1 \leq j \leq M$ and $1 \leq i \leq N$.

A sufficient condition for the best connectivity is (Appendix A):

$$NB(R) > \frac{B}{2} \qquad (8)$$

Where, NB(R) = Set of buses seen by router 'R' and B = Total set of buses.

As we can see, the scalability doesn't depend on the number of nodes but on the number of buses and its distribution. In figure 5, each active node (black node) can see at least 3 buses, so they have the best full-interconnection.

As DTM uses a shared medium, the multicast transmission is easily supported. The number of multicast channels for a full-mesh scenario is independent of the number of nodes of the multicast group, as various senders can share the same channel, so is only necessary to establish a unique multicast tree per multicast group.

8. CONCLUSION

The DIPQoS architecture presented can be an alternative to the Internet Service providers that want to offer a competitive differentiated services to the users that need a better QoS than the traditional best-effort.

The architecture uses the dynamics of QoS signalling of the RSVP protocol to know the QoS petition of the application and to control the establishment and capacity of DTM channels. The IntServ together with the DiffServ can provide aggregated CBR and VBR services at IP level as DTM only provides the CBR service. With this we have an efficient use of the DTM channels bandwidth, exploiting the efficiency of DTM in respect to the dynamic bandwidth allocation.

As the DiffServ architecture does not include services definition, a network operator has the flexibility to define those services that suit its needs. As such there is no one particular service mapping that would satisfy the requirements of all the network providers. Therefore the decision to map the IP Service to the "DIPQoS domain" services is left for the network operator as long as the integrity of the IntServ end-to-end service is preserved. The DTM is enough flexible and opened in the interaction with the IntServ and DiffServ models, allowing the specification and control of the services at the border routers at IP level without any IP/Link level service mapping.

The DTM technology is the transport and switching solution inside the DIPQoS domain as it shows to be scalable, simple and has attractive QoS performance like deterministic delay transfer, low jitter and no losses. In the Core of the domain there isn't any RSVP messages nor DiffServ PHB processing so the delay depends only on the flow path topology and the bandwidth is guaranteed border-to-border.

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APPENDIX A

If all routers have the same Xj or Yi; they pertain to the same bus, so they are directly connected (fig 1, nodes (n,1) and (n,m)). If not, the worst case is that for all routers, they have different values of Xj and Yi.

The best connectivity is when each router reaches another one through only one more router. This is only satisfied if there is a bus that both can see.

Suppose ‘B’ a set of buses.

NB(R) a set of buses seen by router ‘R’.
NB(R1) a set of buses seen by router ‘R1’.
NB(R2) a set of buses seen by router ‘R2’.

To satisfy the connectivity between ‘R1’ and ‘R2’ :

$$NB(R1) \cap NB(R2) \neq 0$$

Suppose ‘SB’ an arbitrary subset of ‘B’.

NB(B,R) = NB(R) ∩ B

If $NB(R1) \cap NB(R2) = 0$

In particular, if

$$NB(SB, R1) \cap NB(SB, R2) = 0 \Rightarrow$$
$$NB(SB, R1) \cup NB(SB, R2) \leq SB$$

A sufficient condition for the best connectivity is :

$$NB(SB, R) > \frac{SB}{2}$$

If SB=B

$$NB(R) > \frac{B}{2}$$

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