PTSE RATES IN PNNI NETWORKS

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Abstract: *The Private Network Node Interface (PNNI), standardized by the ATM Forum (see [1]), provides a flexible and scaleable routing architecture for ATM networks comprising a routing protocol and a signaling protocol.*

In PNNI networks PTSEs are used to distribute topology information through the network. This paper investigates the PTSE rate in PNNI nodes due to flooding. Beside theoretical results, the paper also presents some measurements of example networks.

1 Introduction

The *Private Network Node Interface* (PNNI) defined by the ATM-Forum (see [1]) provides a flexible and scaleable routing architecture for ATM networks comprising a routing protocol and a signaling protocol. PNNI routing includes mechanisms for the autonomous exchange of aggregated topology information to form a hierarchical representation of the network. PNNI signaling is based on a subset of UNI 4.0 signaling.

To investigate the characteristics of PNNI networks two powerful and versatile tools, a PNNI emulator and a PNNI simulator, have been developed. While earlier investigations (see [2] and [3]) concentrated on the exploitation of the network capacity by PNNI routing mechanisms, this paper is focused on performance aspects of the PNNI routing protocol.

2 PNNI Topology Information Distribution

2.1 Topology Information

PNNI uses source routing to determine a path through a network. Hence, every node needs a complete description of the topology to perform the necessary computations.

The PNNI protocol provides a three leveled data structure for topology information. On the first level are the information groups (IG). Each IG only covers one specific part of a node,

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e.g. one port and its resources. On a second level, the IGs are bundled in PNNI Topology State Elements (PTSEs).

PTSEs are the units of flooding and retransmission. As they do not contain information about the originating node, they need some kind of envelope when being sent to a neighbor. The PNNI Topology State Packet (PTSP) is such an envelope that transports PTSEs including information about the node's identity.

2.2 Flooding

Flooding is a reliable method to distribute information within a network. Its main advantage, but also its main drawback is redundancy. There are two major reasons, why a node originally floods a PTSE:

- *Triggered Update*: Triggered flooding happens if a completely new PTSE is originated by a node or if there is a significant change in an information group within an existing PTSE.
- *Re-Origination (Refresh)*: To prevent the PTSE from being deleted from the topology database the originating node re-originates a PTSE periodically, even if the contents did not change.

On receipt of a PTSE that is not yet in its database, a node forwards this PTSE to all neighbors, except the one the PTSE has been received from.

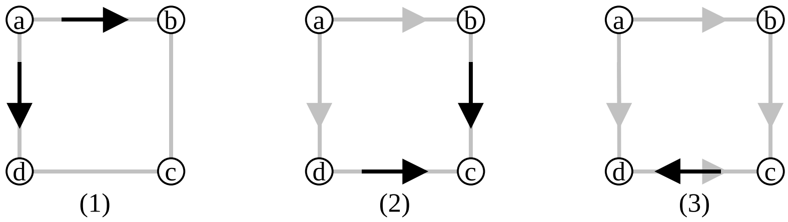

Figure 1: Example of the simple flooding Mechanism

Figure 1 shows the flooding of an information element originated by *node a* in an example network. In this example five information elements have to be processed by the network. Only three of them would have been sufficient to update the databases of the respective nodes.

If adj_i is the number of adjacent nodes of node i, every PTSE originated by node i must be

sent:	adj_i	times
received:	0	times

and every PTSE not originated by node i must be

sent:	$adj_i - 1$	times
received:	$adj_i - S$	times

S refers to the fact that, due to the nature of flooding, a particular PTSE is not flooded upstream on those links, which form the shortest path tree (SPT) with the originating node as the root. Thus the value of S depends on the considered originating node and receiving node.

3 Calculating the PTSE Rates per PNNI Node

3.1 Flooding of Address PTSEs

The main factors influencing the address PTSE rate in a PNNI node are:

- Number of address PTSEs in the network: *NoAddrPTSE*
- Time between the refresh flooding of PTSEs: *PTSERefreshInterval*
- Number of neighbors of the particular node: *NoNeighbors*
- The average value of *S* for that node: *AverS*

Hence the average rate for received address PTSEs on a particular node (*AverAddressPTSERate*) can be calculated as follows (the '≤' relation refers to the fact that some of the PTSEs are originated by the node itself):

$$AverAddressPTSERate \leq \frac{NoAddrPTSE \cdot (NoNeighbors - AverS)}{PTSERefreshInterval} \tag{1}$$

Within PNNI networks address summarization is applied to reduce the number of PTSEs to be flooded. Hence the address structure, i.e. the association of addresses to PNNI switches has a very big influence on the number of address PTSEs. Moving addresses within a network might deteriorate the summarization of addresses within peer groups, resulting in additional PTSE traffic.

3.2 Flooding of Link State PTSEs

Concerning the planning of the routing protocol processing capacity it is difficult to estimate the maximum rate of significant changes and thus the flooding rate, since this heavily depends on the dynamic behavior of the network and on the PNNI parameters. As an upper bound only the minimum interval between the flooding of a PTSE (*MinPTSEInterval*) can be taken. This results in the following formula for the maximum rate of received link state PTSEs (*MaxLsPTSERate*) in a node within a PNNI network consisting of *l* links (again, the '<' relation refers to the fact that some of the PTSEs are originated by the node itself):

$$MaxLsPTSERate < l \cdot \underbrace{2}_{\text{one for each direction}} \cdot \frac{NoNeighbors - AverS}{MinPTSEInterval} \tag{2}$$

Extensive simulation is needed to evaluate the different influence factors of the update rate and to find a sensible upper bound (or increase the *MinPTSEInterval*).

3.3 Measurements

The measurements have been done with the PNNI simulator, which is a very flexible tool to investigate topologies of up to 100 nodes. As the PNNI protocol is modeled in a very detailed way, it allows the measurement of values directly related to the protocol (like PTSE rate, redundancy of PTSEs etc), as well as crankback and call rejection probability, payload and signaling occupancy of the links and ports. Both traces and statistics are available for most of the values.

The network we have simulated has a square meshed topology with 16 nodes. All links are bi-directional and have a capacity of 155.52 Mbit/s (STM-1). Per node 1 address PTSE was generated containing several addresses. Hence there are 16 address PTSEs and 48 link state PTSEs in the network. The PNNI specific parameters are set to values recommended in the annex of [1]. The parameters for the three different traffic classes are shown in table 1. Call arrival and duration are modeled using a Poisson process.

Traffic Class	A	B	C
Bandwidth in MBit/sec	0.8	4.0	12.0
Call arrival (mean) in sec. (for 10% load)	72.72	755.28	6976.80
Call duration (mean) in sec.	480	480	480

Table 1: Source parameters

In figure 2 the mean and the 95% percent quantiles of the PTSE rate are shown for different load levels, comparing the PTSE rate in a center node versus a corner node.

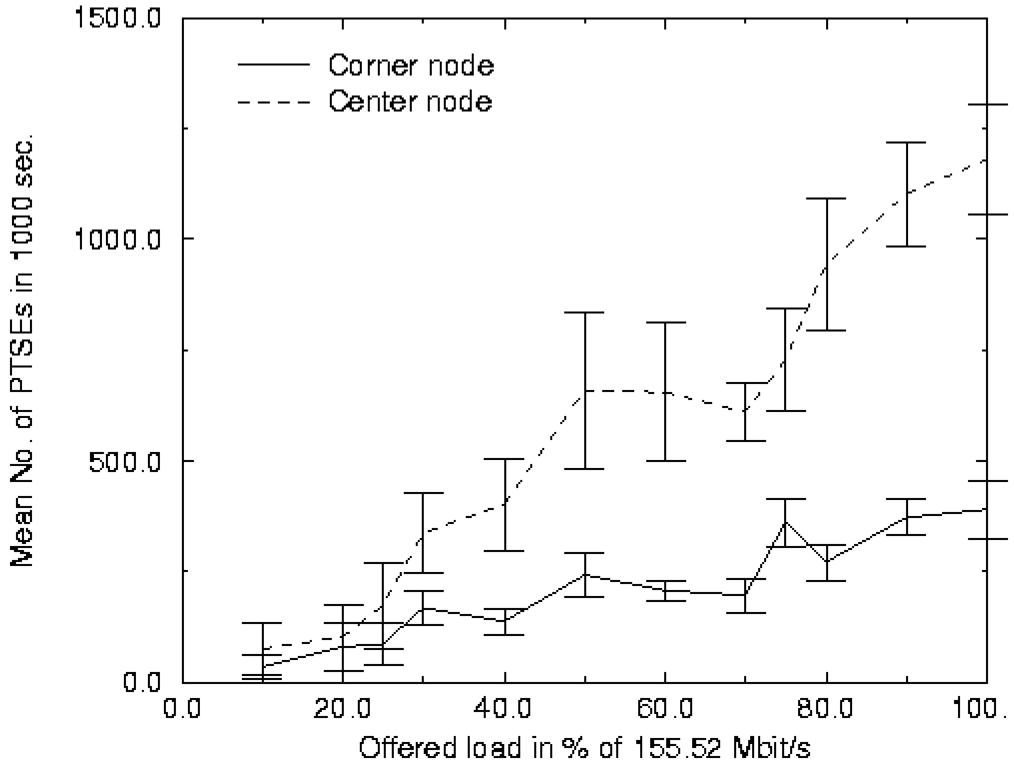

Figure 2: PTSE rate of a center node versus a corner node.

As expected the PTSE load in a center node is higher than in a corner node, because:

- A center node has more neighbors than a corner node.

- The position of a center node within the shortest path tree of a flooded PTSE is different from the position of a corner node. This influences *S*.

In this example the PTSE traffic is mainly determined by the number of triggered updates of link state PTSEs, which increases with the offered load. The refresh rate (offered load = 0) is quite low due to the small total number of PTSEs (*PTSERefreshInterval* = 1800 sec according to [1]).

4 Conclusion

In this paper performance aspects of the PNNI routing protocol have been presented focusing on the PNNI topology information elements and their flooding mechanism. The main factors determining the PTSE rate within a PNNI network are:

- the address structure (association of addresses to switches),
- the rate of significant changes on the links,
- the meshing of the network,
- the values of the various timers and thresholds defined in [1], Annex E.

An estimation of the routing protocol processing capacity as performed above yields only a lower bound for the necessary performance capacity of a PNNI node, due to the following reasons:

- PNNI timers are jittered but flooding is still bursty.
- PTSE retransmissions due to bit errors must be taken into account.
- Reserve capacity is needed for database synchronization (see [1]).
- In a multiple peer group environment logical group nodes demand for additional capacity.

Future work will concentrate on further measurements concerning PTSE performance aspects in PNNI networks, including the burstiness of the PTSE traffic.
Additionally, modified flooding mechanisms will be investigated and evaluated (e.g.: [4]).

References

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