ATM Switching in Tree-Structured Networks

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1 Introduction

HFC networks, today are mostly used to broadcast TV programs. In the near future, they may play a major role as communication infrastructure for multimedia applications to the home. Examples are telephony, conferencing systems, video on demand, and interactive games. Thus, HFC networks need to be able to handle QoS requirements demanded by these applications. Furthermore, a high degree of interactivity needs to be supported.

The structure of HFC networks and the MAC layer protocol employed (e.g., [2]) imply bottlenecks in the network in case of high load as pointed out in [3]. In a usual HFC network it is impossible for two subscriber stations to communicate directly with each other. All traffic has to pass the head end causing high head end load and increased probability of collision (cf., Home A and Home B in Fig. 1). This abstract suggests the replacement

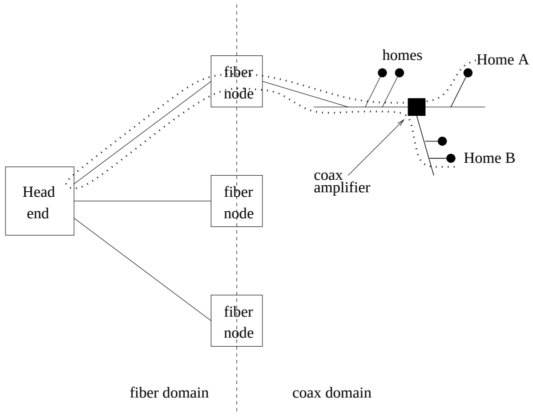


Figure 1: HFC network

of passive network elements like fiber nodes and signal amplifiers with ATM switches. This allows to shortcut traffic flows, and, thus, to reduce load and collision probability.

By replacing passive network elements with ATM switches the network is divided into two parts: a switched ATM network and subtrees based on a shared medium connecting subscriber stations to the ATM network (cf., Fig. 2). This subtree uses a MAC protocol, for example 802.14 [2].

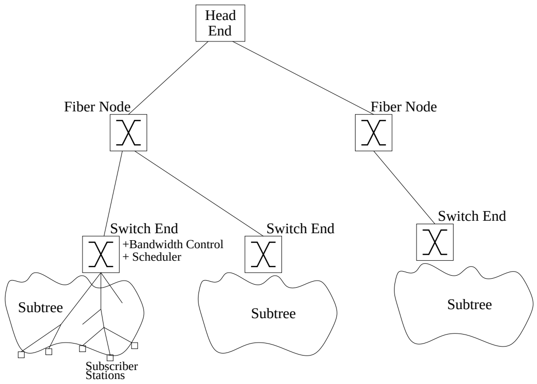


Figure 2: ATM switches connecting HFC subtrees

2 Simulation Model

The approach described in the introduction has been evaluated with respect to various network topologies. A simulation model has been developed at the Technical University of Braunschweig.

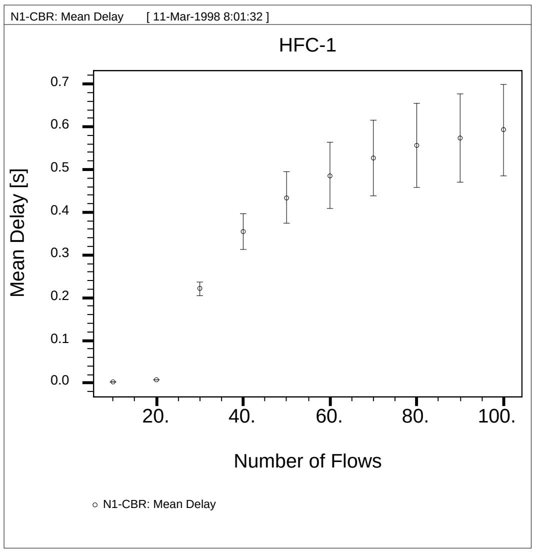


Figure 3: Mean Delay of CBR traffic in HFC-1

The simulation model has been used with different traffic patterns modelled according to measurements with WWW traffic as well as CBR traffic (cf., [1]). The following traffic generators have been implemented and used in the simulations:

- CBR: This traffic generator is parameterized by the rate r of the CBR traffic flow to be generated. It produces cells at fixed intervalls of $\frac{48*8}{r}$.
- WWW: The WWW traffic generator models WWW requests as described in [1]. It produces bursts of packets where each burst is described by its duration and the interarrival time of the burst's packets.

For each kind of traffic the number of generators have been varied to test the networks under different load conditions.

The simulation experiments have been conducted with different configurations of HFC networks. All configurations include the same number of subscriber stations but differ in the size of subtrees and the topology of the ATM switch network.

The following configurations of networks have been simulated:

1. HFC-1: HFC network that consists of a single subtree with 1024 stations, i.e., no ATM switches and transceivers are involved.
2. HFC-2: HFC network consisting of 4 subtrees, each one with 256 stations. The 4 subtrees are connected by a ring of ATM transceivers.
3. HFC-3: HFC network, similar to the previous one, consisting of 4 subtrees, but the subtrees are connected by a binary tree of ATM switches with a depth of 2 from the root of the tree to the roots of the subtrees (cf., Fig. 2).

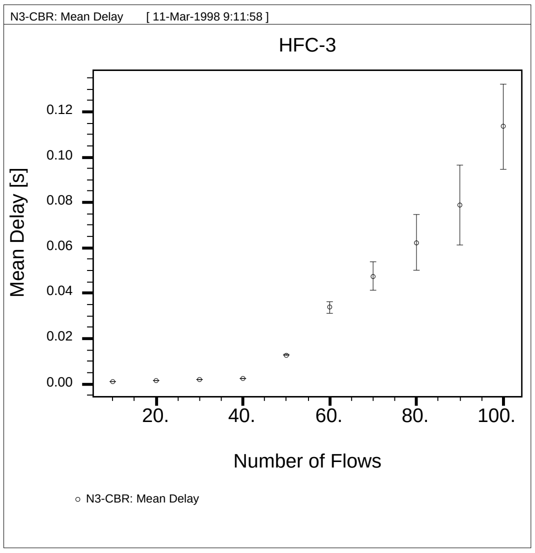
Parameters that had to be selected but were not varied between these configurations, include link lengths, upstream and downstream data rates of the HFC subtrees, and processing delays.

3 Simulation Results

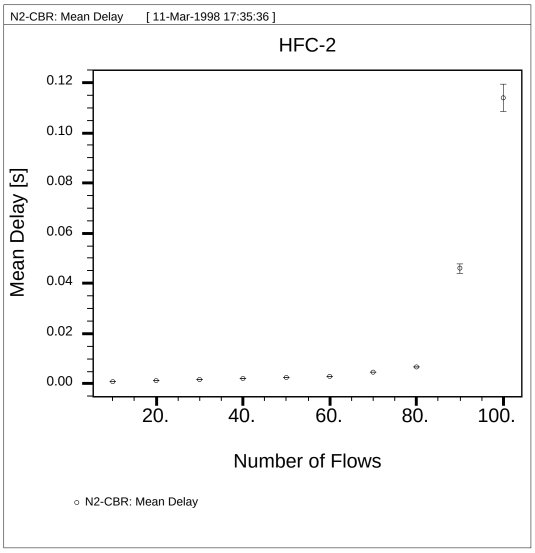
Figures 3 and 4(a) compare HFC-1 and HFC-3. The figures show the mean delay of cells sent between two subscriber stations for a number of 64 kbps CBR traffic flows. The X-axis shows the number of traffic flows generated and, thus, corresponds to the network load.

As can be seen clearly, the introduction of ATM transceivers into the HFC network improves its performance significantly. Up to a number of about 20 CBR traffic flows, the HFC-1 network without switches yields a mean delay of a few milliseconds with little variations. Increasing the number of traffic generators raises the delay to 600 ms with ± 100 ms jitter for 100 traffic flows. This is unacceptable for many applications and results in poor quality for bidirectional audio conversations, for example. The maximum number of CBR traffic flows of 64 kbps than can be sent through the 2 Mbps upstream channel without collisions is 31.

Figure 4(a) shows that in the case of the HFC-3 network about 40 CBR flows can be supported, before the mean delay rises drastically, thus, about 4 times as many as in the HFC-1 network.



(a) HFC-3: 4 subtrees connected by a binary tree



(b) HFC-2: 4 subtrees connected by a ring

Figure 4: Mean Delay of CBR traffic for HFC-3 and HFC-2

The performance can be improved further by varying the switching topology (cf., Fig. 4(a) and 4(b)). However, the effect of the ATM switching topology is smaller than the performance improvement that can be achieved by replacing fiber nodes with switches. Delay times are of the same order of magnitude. However, with a tree structured ATM switch network, increase of delay and jitter starts at a lower number of CBR connections.

This can be explained by observing that the HFC-3 network still has a central point of traffic accumulation at its root. Thus, the links adjacent to it are loaded more heavily than in the case of HFC-2. Also, in HFC-3, switches next to the HFC switch ends experience a higher load than switches in configuration HFC-2. Again, assuming uniformly distributed source and destination nodes, these switches are passed by 5/8 of the traffic, while only one half of the traffic is passing each switch in the HFC-2 network.

4 Summary and Outlook

Compared to other access network technologies, HFC provides high bandwidth in both, the upstream and downstream channels. However, the bandwidth available has to be shared among all active subscriber stations. Furthermore, as a consequence of physical characteristics and the MAC layer protocol, collisions can occur in the upstream channel. The head end concentrates all data flowing through the network and may easily become a bottleneck in case of high load. Introduction of ATM switching elements into network, replacing fiber nodes and coax amplifiers, can eliminate this single point of traffic concentration. The simulation results show that achievable quality of service can be improved with this approach.

Ongoing research will involve other access network technologies. ADSL is one of HFC's competitors in this market. Comparisons between HFC and ADSL, concerning the QoS they can deliver to applications, will be focus the of our near future's work.

References

[1] Shuang Deng, *Empirical Model of WWW Document Arrivals at Access Link*, IEEE ICC'96

[2] IEEE Std. 802.14 Draft1R3, May 1, 1997

[3] U. Thürmann, M. Zitterbart, T. Meuser *Distributed ATM Switching Topologies in Tree-Structured Networks*, SYBEN 98 International Symposium on Broadband European Networks, May 18–22, 1998.