2010 International Symposium on Nonlinear Theory and its Applications
NOLTA2010, Krakow, Poland, September 5-8, 2010

# Suppression of Nonlinear Traffic Pattern Generation using Dynamic Bandwidth Management Method

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**Abstract–** Generally, the elements in a network must be duplicated for securing reliability. However, in a private network, such as in a company, a partially duplicated method, which carries out dual-homing of the terminal to a node, is used in addition to considering reliability. The reason is that cost is important when considering the design of private network. With this method, if a certain node breaks down, the terminal will be switched to another node. In a dual-homing node, twice the amount of traffic will be quickly generated. In other words, a nonlinear traffic pattern is generated. Although current methods, such as a redundant bandwidth management method and a congestion-control method, are used to suppress nonlinear traffic pattern generation, they have advantages and disadvantages in bandwidth utilization ratio or service convenience.

We propose a new dynamic bandwidth management method, which combines high bandwidth utilization ratio and good service convenience. Specifically, our method uses the distributed management method, which divides the bandwidth of the entire network into two, for actual communication, and for spare communication, and the traffic-predicting management method, which is used to observe communication in real time in each node and to adjust the bandwidth of each node just enough for reserved bandwidth. We evaluated our method's effectiveness using a traffic simulation.

## 1. Introduction

Generally, elements in a network must be duplicated to guarantee reliability. That is, to secure reliability, it is necessary to duplicate all the elements that constitute communications, such as nodes and channels. On the other hand, in a private network, such as in a company, a partially duplicated method, which carries out dual-homing of the terminal to a node, is used in addition to considering reliability since cost is important when considering the design [1]-[3]. In this dual-homing method, when a certain node breaks down, the terminal will switch attribution to another node. In this case, the traffic of the node by which dual-homing was carried out increases rapidly and becomes about twice the usual amount. That is, a nonlinear traffic pattern is generated. Thus, if a nonlinear traffic pattern is generated, bandwidth will run short and service convenience will deteriorate, and call loss will occur. The redundant bandwidth management method and the congestion-control method have been studied to solve the problem of generating a nonlinear traffic pattern. However, in the redundant bandwidth management method, since bandwidth is too secure, the bandwidth utilization ratio worsens. In the congestion-control method, because of the restriction traffic in dual-homing, service convenience deteriorates.

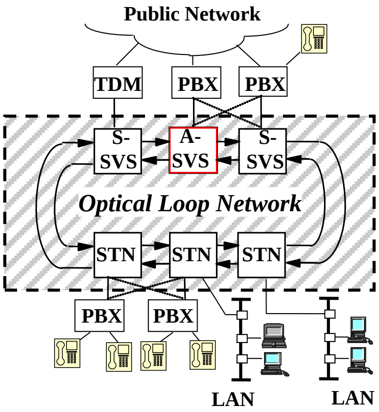
We propose a dynamic bandwidth management method, which combines high bandwidth utilization ratio and good service convenience. This method divides the bandwidth of the entire network into two, for actual communication, and for spare communication. The bandwidth assigned to actual communication measures the amount of bandwidth used in real time by each node and predicts a future traffic pattern. From the prediction results, the excess bandwidth of a node is returned to the bandwidth for spare communication, and a node with insufficient bandwidth requests bandwidth from spare communication. We conducted a traffic simulation of the proposed method to evaluate its effectiveness. The result of this simulation shows that the proposed method, which combines high bandwidth utilization ratio and good service convenience, suppresses nonlinear traffic pattern generation.

## 2. Multimedia LAN systems

Here, a multimedia LAN system is shown as the network configuration, which is the requisite for our proposed method. This system integrates a Private Branch Exchange (PBX) and the Internet, which is as general network configuration of a company. In this system, the node on the backbone LAN is set to the station (STN), and the terminal is set to the PBX and branch line LAN. The terminal, which carries out dual-homing, is the PBX.

### 2.1. Network configuration

As shown in Fig. 1, a multimedia LAN system consists of an optical loop network to relay PBXs and branch LANs. It achieves switching system scalability, in terms of the number of users, by distributing PBXs, being capable of integrating circuit and packet switching in multimedia LANs and contains highly reliable duplicated optical transmission lines.



(a) Multimedia LAN system

*Abbreviations:*
*A-SVS: Active SVS*
*S-SVS: Standby SVS*
*SVS: Supervisory station*
*STN: Station*

| | |
|---|---|
| Topology | *Ring network ->dual rings* |
| Speed | *100 Mbps 400 Mbps* |
| Switching | *Circuit switching ->TDMA Packet switching ->token passing* |
| Interface | *Circuit switching ->PBX, TDM Packet switching ->LAN: IEEE802.3* |
| Reliability | *Multi-homing (PBX) Loop control* |

(b) Main Specification

Fig. 1 Multimedia LAN system

The hashed area in Fig. 1 (a) is the optical loop network. It consists of stations and duplicated optical transmission paths. Two kinds of stations, usually STNs and supervisory stations (SVSs), can be used depending on the hardware configuration.

An STN possesses basic functions for transmission line access management and for connecting PBXs and branch LANs. An SVS has supervisory functions for frame creation, clock generation, and management of the entire optical loop network. To increase system reliability, several SVSs are set up in the loop. One of the SVSs is active (A-SVS) and manages the optical loop network, and the others are on standby (S-SVSs).

Figure 1 (b) shows the main specifications of this system.

### 2.2. Frame structure

The frame structure of the multimedia LAN system consists of a frame header (FH), an A-SVS address (SV), an information control (CT) area, a circuit-switching (CX) area, a packet-switching (PX) area, and a boundary value (BV) for the CX and PX areas. Since this structure provides circuit switching, a transmission frame has a period of 125 microseconds and consists of timeslots fixed at a length of 64 Kbps for all frames but the frame header.

In this frame structure, the CX and PX areas can be dynamically changed for effective bandwidth use, and maintenance operation information (e.g., loop control information) and user data can be individually exchanged by separating the CT area and the data area (Fig. 2).

We propose a dynamic bandwidth management method in the data area shown in Fig. 2, including the CX and PX areas.

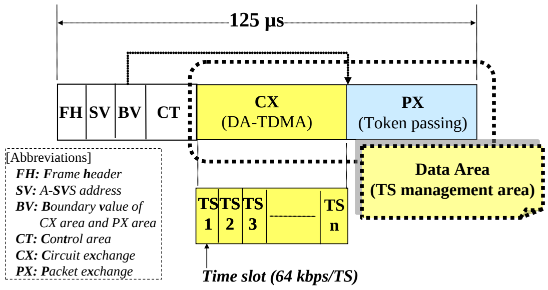


Fig. 2: Frame structure

### 2.3. Dual-homing composition

As shown in Fig. 3 (a), in order to secure the reliability of communication between PBX, dual-homing composition is adopted in the multimedia LAN system. With dual-homing composition, as shown in Fig. 3 (b), the case where a certain failure occurs in STN2, PBX2 can be immediately switched to normal STN1 and it can continue communication between PBX.

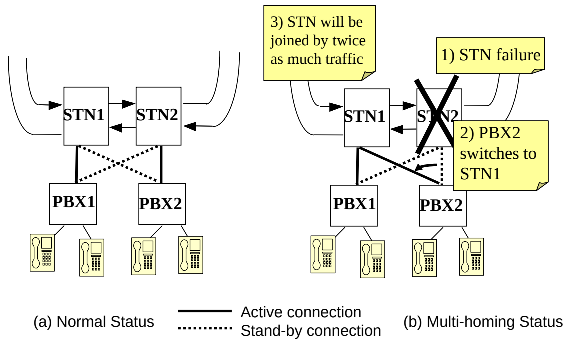


Fig. 3 Dual-homing composition

## 3. Suppression method of a nonlinear traffic pattern generation

When dual-homing, shown in Fig. 3 (b), occurs in an STN1, twice as much traffic occurs rapidly. That is, a nonlinear traffic pattern is generated. First, current suppression methods to this nonlinear traffic pattern generation are explained. However, there are some problems in these methods. Therefore, next, we explain the proposed method for solving these problems.

### 3.1 Current suppression methods

#### *3.1.1 Redundant bandwidth management method*

A redundant bandwidth management method always assigns a required bandwidth, when dual-homing occurs. By this method, even if generating of dual-homing, i.e., a nonlinear traffic pattern, occurs, since the bandwidth is assigned enough, so service convenience to a terminal is not deteriorated. However, in usual, an excessive bandwidth will exist and bandwidth use efficiency is bad.

#### *3.1.2 Congestion-control method*

By a congestion-control method, when dual-homing occurs, it directs to suppress traffic from STN to PBX. As a result, service convenience will be deteriorated.

However, in the case of the usual operation, since an excessive bandwidth does not exist, bandwidth use efficiency is high.

*3.1.3 Problem of current methods*

The problem of current methods explained until now is summarized as shown in Table 1.

Tab.1 Problem of current methods

| Method | Service convenience | Bandwidth use efficiency |
|---|---|---|
| Redundant bandwidth management method | good | low |
| Congestion-control method | poor | high |

### 3.2 Dynamic bandwidth management method

As shown in Table 1, it is difficult to be simultaneously satisfied with the current methods in terms of service convenience and bandwidth use efficiency. We propose a dynamic bandwidth management method for satisfying these requirements at the same time.

*3.2.1 Distributed management method*

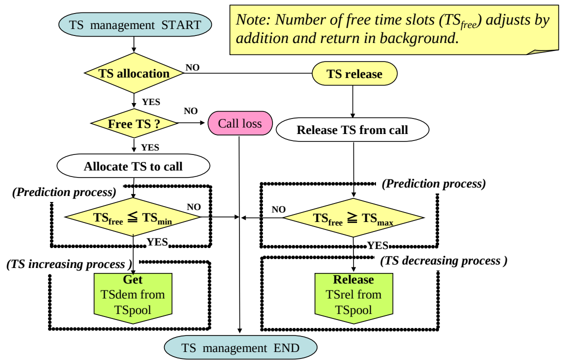
This proposed method installs two management authorities into the timeslots on a multimedia LAN. For the first authority, each STN individually manages the total number of timeslots of an STN ($TS_{STN}$) for distributed management to achieve real-time securing. As a result, at each individual STN, the timeslots can be allocated for the traffic generated.

For the other management authority, an A-SVS manages the remaining timeslots ($TS_{SVS} = TS_{all} - n * TS_{STN}$, where $TS_{SVS}$ is the total number of timeslots of an A-SVS, $TS_{all}$ is the total number of timeslots of the multimedia LAN system, and n is the number of STNs) for centralized control to efficiently manage timeslots. That is, only the timeslots necessary for normal operation at each station are allocated, and the A-SVS controls all of the remaining timeslots sharing them with the STNs. Thus, when the number of timeslots allocated at each STN decreases to a certain point, a timeslots-replenishment request is sent to the A-SVS beforehand. Conversely, when unused timeslots remain, each STN returns them to the A-SVS.

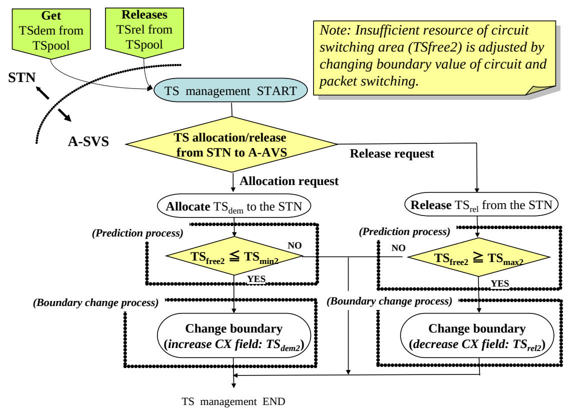
In this method, each STN can secure real time just as with the distributed management method by individually allocating timeslots to the communication between PBX.

*3.2.2 Traffic-predicting processing*

Our dynamic bandwidth management method predicts traffic at each STN. Predicting traffic dynamically controls the surplus and shortage of assigned timeslots by counting free TSs upon assignment and release. Figure 4 shows the algorithm for this method. Each STN counts the free timeslots when they are assigned or released. For assignment of timeslots, the system requests supplement timeslots ($TS_{dem}$: number of demand TSs from an STN to the A-SVS) from the A-SVS if the number of free TSs falls below the threshold ($TS_{min}$: lower limit); for release, the system returns the surplus timeslots (TSrel: number of release timeslots from an STN to the A-SVS) to the A-SVS if the number of free timeslots ($TS_{free}$: number of free timeslots at an STN) exceeds the threshold value ($TS_{max}$: Upper limit).




(a) Time slot allocation method at STN

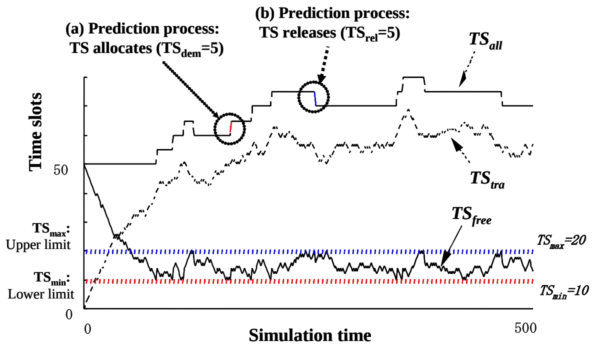



(b) Time slot allocation method at A-SVS

Fig. 4 Algorithm of traffic-predicting process

*3.2.3 Detailed explanation of proposed method*

Figure 5 qualitatively explains the algorithm of Fig. 4. With increasing traffic to stations, that is, requests for timeslots assignment, free timeslots in STNs decrease. The system requests supplement of timeslots from the A-SVS as background processing separately from call processing when the number of free timeslots falls below the minimum value ($TS_{min}$) by predicting traffic, then receives supplement timeslots from the A-SVS (Fig. 5 (a)). Conversely, free timeslots increase when traffic decreases, so the system returns surplus timeslots to the A-SVS when the number exceeds the maximum value ($TS_{max}$) by estimating traffic estimate (Fig. 5 (b)). Moreover, the delay time for supplement and return timeslots between the A-SVS and STN in Fig. 5 is assumed to be a few milliseconds [4]. Therefore, this simulation ignores it because the delay time is shorter than the time scale of the CX traffic to be considered insignificant. In our dynamic bandwidth management method, traffic predicting allows the system to continuously follow traffic fluctuation with room for several timeslots. As a result, proposed method simultaneously makes service convenience and bandwidth use efficiency.




$TS_{all}$: total TSs of STN, $TS_{tra}$: actual traffic, $TS_{free}$: number of free TSs at STN,
$TS_{dem}$: number of demand TSs from STN to A-SVS , $TS_{rel}$: number of release TSs from STN to A-SVS

Fig. 5 Qualitative explanation of proposed method

## 4 Evaluations

### 4.1 Simulation condition

As shown in Table 2, in order to simulate a switching system, we established the simulation conditions based on the design condition of PBX [5].

Tab.2 Simulation conditions (considering PBX design)

| Item | Condition |
|---|---|
| Traffic pattern | Circuit traffic: 1 TS/call |
| Generation of call | Poisson distribution |
| Holding time | Exponential distribution |
| Mean holding time | 80 sec/call |
| Mean mass of call | 0.11 erl/terminal |

### 4.2 Traffic simulation

The traffic simulation was performed for evaluating the proposed method. A nonlinear pattern was generated by carrying out dual-homing.

The traffic simulation result based on the simulation conditions of Table 2 is shown in Fig. 6. Although dual-homing, i.e., a nonlinear traffic pattern was generated, as shown in Fig. 6 (a), this nonlinear traffic pattern generation was suppressed with our proposed method. That is, call loss did not occur ($TS_{all}$ is always larger than $TS_{tra}$) even during dual-homing with a traffic-predicting method since the bandwidth was increased in advance. Therefore, service convenience of the proposed method is better than the congestion-control method.

After dual-homing, i.e., generation of a nonlinear traffic pattern, completed (Fig. 6 (b)), excess timeslots were returned to the bandwidth for spare communication. As a result, the bandwidth-use efficiency of the entire network improved more than with the redundant bandwidth management method. These results are listed in Table 3.

Tab.3 Evaluation result of proposed method

| Method | Service convenience | Bandwidth use efficiency |
|---|---|---|
| Proposed method | good | high |

## 5. Conclusion

We proposed a dynamic bandwidth management method, which can be used to simultaneously achieve high bandwidth-use efficiency and good service convenience, for suppressing nonlinear traffic pattern generation. Our proposed method uses the distributed management method and the traffic-predicting management method. The effectiveness of the proposed method was confirmed using a traffic simulation. The results of this evaluation confirmed that our proposed method is better than current methods and our method is also suitable for suppressing nonlinear traffic pattern generation in a private network.


### References

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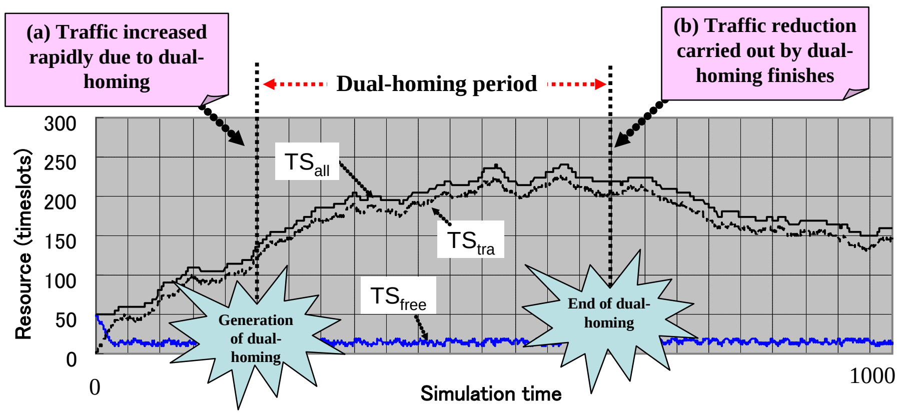


$TS_{all}$: Total timeslots of STN $TS_{tra}$: Actual traffic $TS_{free}$: Number of free timeslots at STN

Fig. 6 Traffic simulation of proposed method in dual-homing state