An Adaptive Ring Access Protocol for Super High-Speed Networks

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Abstract

As the number of World Wide Web (WWW) users have been growing, the network traffic over the Internet have been increased. As a result, the Internet has been suffering from a chronic congestion. To improve this situation, it is necessary to develop a super high-speed backbone network. In this work, we propose a media access protocol for super high-speed backbone networks such as terabit networks. The cost of network facilities for terabit networks is high. Therefore, we consider a shared media network such as ring topology in order to decrease the network cost. Our goal is to build an adaptive protocol with high throughput and good fairness. To achieve this, our protocol considers the traffic condition on the ring. If the traffic on the ring is low, each station can send a lot of packets. Otherwise, when the ring starts to become congested, the number of packets sent by stations starts to decrease. Performance evaluation via simulations shows that proposed protocol has a good behavior and can be used as a backbone network for high-speed networks.

1 Introduction

Recently, as the number of WWW users have been growing, the network traffic over the Internet have been increased. As a result, the Internet has been suffering from chronic congestion. To improve this situation, it is necessary to develop a super high-speed backbone networks. So far, for Local Area Networks (LANs), some media access protocols such as FDDI [1, 2], Fast Ethernet [3], Gigabit Ethernet [4] and ATM LAN [5] have been developed. But, for inter domain networks, the speed is still low (a few Mbps). If LANs speed will become gigabit, even ATM networks with hundreds Mbps bandwidth can not support the gigabit LANs. To deal with gigabit LANs [12, 13], it is necessary to develop a super high-speed backbone network such as a terabit network.

In this work, we propose a media access protocol for terabit networks. The cost of network facilities for terabit networks is high. Therefore, we consider a shared media network such as ring topology in order to decrease the network cost.

The protocol design is based on three policies. First, the protocol should have a high throughput in order to make a good use of the ring bandwidth. Second, the protocol should be able to adapt to the dynamic traffic. Third, the protocol should achieve a good fairness for each station in the ring.

We evaluate the proposed protocol by computer simulations. Performance evaluation via simulations shows that proposed protocol has good behavior and can be used as a backbone network for gigabit LANs.

The organization of this paper is as following.

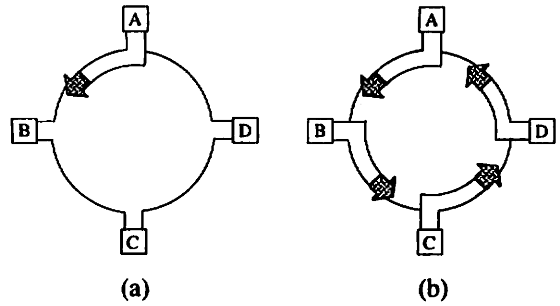

Figure 1: A conceptual idea for 1-st condition.

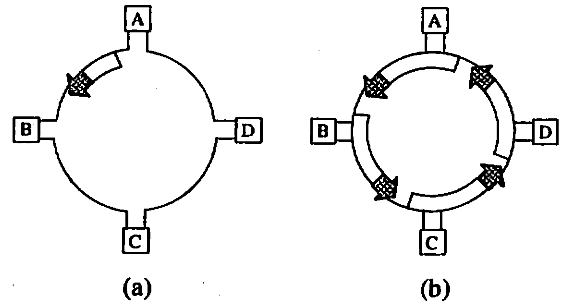

Figure 2: A conceptual idea for 2-nd condition.

The conditions to achieve a super high-speed ring network will be described in Section 2. The related works will be described in Section 3. In Section 4, the proposed method will be treated. The simulation results will be presented in Section 5. The conclusions will be given in Section 6.

2 Conditions for Super High-speed Ring Protocol

In this section, we show four conditions which need to be satisfied in order to design a super high-speed ring network protocol.

2.1 Throughput and Transfer Delay

In the design of the media access protocol for ring topology network, our goal is to get a high throughput and low transfer delay. To achieve this four conditions must be fulfilled.

As 1-st condition, the protocol should be able to access the ring concurrently for all stations. The conceptual idea for this condition is shown in Figure 1. A media access method which can transmit a packet by only one station at a moment of time is shown in Figure 1(a). An example of this media access method is token ring method. While, a media access method in which all stations can transmit packets concurrently is shown in Figure 1(b). In this method is assumed that packet length on the ring is shorter than total ring length (for super high speed networks) [6]. The concurrent access method shows good utilization of the ring compared with the single access method.

The 2-nd condition requires that many packets must exist on the ring. The conceptual idea is shown in Figure 2. A media access method for only one packet on the ring is shown in Figure 2(a) and for many packets on the ring is shown in Figure 2(b). It is easy to see that Figure 2(b) method is superior than the method in Figure 2(a). The FDDI method doesn't satisfy the 1-st condition, but satisfies the 2-nd one.

As 3-rd condition, the packet should use a shortest path for transmission (use a bidirectional

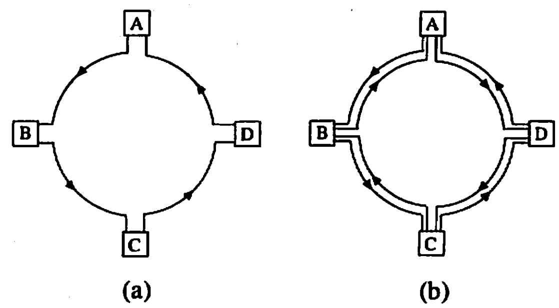

Figure 3: A conceptual idea for 3-rd condition.

dual ring). The conceptual idea for this condition is shown in Figure 3. In Figure 3(a) is shown the structure for a single ring network, while Figure 3(b) shows the structure for a bidirectional dual ring network. When the number of stations is N, the maximum transmission distance for a single ring is N-1 and the average transmission distance is $\lceil \frac{N}{2} \rceil$. On the other hand, the maximum transmission distance for the bidirectional dual ring is $\lceil \frac{N}{2} \rceil$ and the average transmission distance is $\lceil \frac{N}{4} \rceil$. Let consider an example, when station A sends a packet to station D, the distance for the single ring is 3, while the distance for bidirectional dual ring is 1. This means, the transmission distance of bidirectional dual ring is shorter than single ring. Also, from the combination of this condition and packet removal at the destination station (4-th condition), the protocol can achieve a high total throughput.

The 4-th condition requires that a packet must be removed at the destination station. The conceptual idea for the 4-th condition is shown in Figure 4. Figure 4(a) shows a packet removal at the source station, while Figure 4(b) shows a packet removal at the destination station. In the case of packet removal at a source station, the packet is removed after passing the whole ring. On the other hand, in the case of packet removal at a

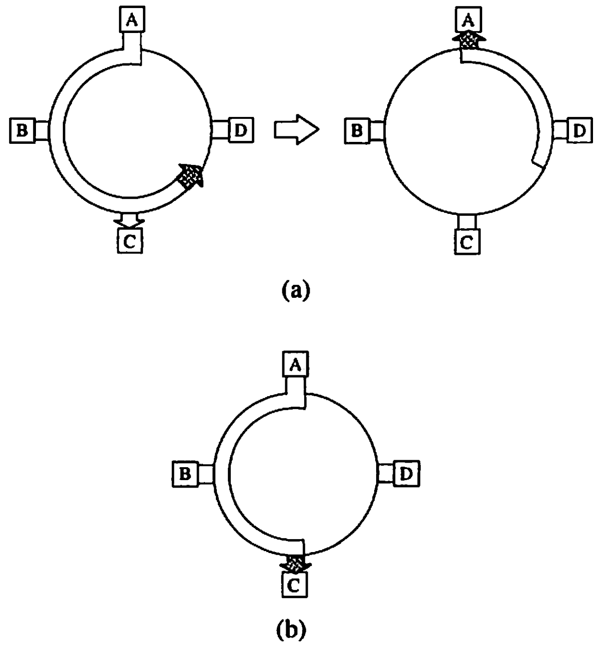

Figure 4: A conceptual idea for fourth condition.

destination station, for example, when station A sends a packet to station C, the packet passes only half of the ring. In case of combination with 1-st condition, the other stations can use the half of remained ring bandwidth. Therefore, the ring throughput can be increased.

2.2 Fairness

The fairness is also an important issue for designing a media access protocol. In shared media network such as a ring or a bus topology, it may occur that some stations transmit a large amount of packets and the other ones only few packets. To avoid this unbalance situation, the fairness is important function to be evaluated. The fairness means that each station is given the same priority for packet transmission.

3 Related Works

In this section, we compare the existing media access methods for ring topology such as token ring method, FDDI method, slotted ring method, buffer insertion method and MetaRing method. The comparison is done considering how much these methods satisfy the four conditions described in the previous section.

The comparison is shown in Table 1. The token ring method can not satisfy all conditions. Therefore, it doesn't suit for the super high-speed networks. The FDDI method satisfies the 2-nd condition because many packets exist on the ring, but the other conditions aren't satisfied. The slotted ring method satisfies the 1-st and 2-nd conditions. Also, some variations of slotted ring method can satisfy the 4-th condition. A drawback of slotted ring method is that when a station transmits variable length packets the ring utilization is decreased because the slot has a fixed length. Furthermore, the fairness of slotted ring method is no good. The buffer insertion method satisfies the 1-st, 2-nd and 4-th conditions. Therefore, it can be used for super high-speed networks. But, the pure buffer insertion method hasn't a good fairness. Also, the buffer insertion method uses a buffer for each station, so there is a delay in each buffer. The MetaRing method is an improved version of the slotted ring and buffer insertion methods. The MetaRing method satisfies all conditions and has a good fairness. For this reason, the MetaRing method is considered a good method for ring topology media access protocol. Therefore, in following, we will compare the proposed method with MetaRing method.

4 Proposed Method

In this section, we propose a new media access protocol which can satisfy all conditions described in Section 2. Our goal is to build a protocol which can be adaptive to traffic changes, has a high throughput and a good fairness.

4.1 Protocol Design Policy

For getting a high throughput, we consider the following policy.

- Use a bidirectional dual ring.
- Remove a packet at the destination station.
- Be able to transmit a packet concurrently for each station.

For achieving a good fairness, we consider that each station during one cycle is guaranteed to transmit the required number of packets. But, during the fairness control, the stations which already sent an amount of WSi packets in a cycle can not send packets until a new cycle token arrives even if some bandwidth still exist. Thus, the ring utilization and throughput are decreased. For avoiding this situation, we implement an adaptive control in which the window size is changed dynamically depending on the cycle token round trip time.

4.2 Proposed Method Description

The proposed method use a network with a bidirectional dual ring topology as shown in Figure 5. The cycle token exists in each ring. When the cycle token passes the whole ring, we consider it as one cycle. Each station is guaranteed to send

Table 1: Comparison of different media access methods.

Access Method	1-st Condition	2-nd Condition	3-rd Condition	4-th Condition	Fairness
Token ring	×	×	×	×	○
FDDI	×	○	×	×	○
Slotted ring	○	○	×	△	×
Buffer insertion	○	○	×	○	×
MetaRing	○	○	○	○	○

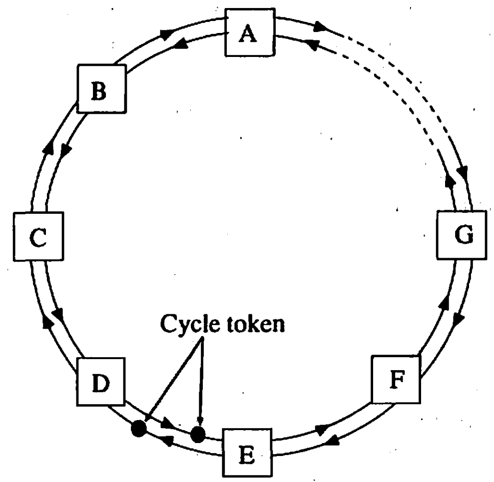

Figure 5: A bidirectional dual ring network.

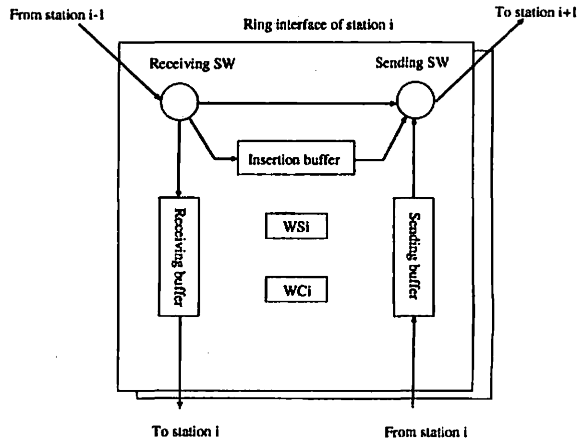

Figure 6: Ring interface structure.

the required number of packets during one cycle. The process is carried out as follows. The window size for station i (WSi) is assigned for each station. Thus, each station can send concurrently WSi packets for each cycle. When the cycle token arrives at station i, the following operations for fairness control are carried out.

- WSi = WCi

  Station i clears the WCi and sends a cycle token to the next station, then starts the next cycle.

- WSi > WCi

  Station i holds a cycle token and when the WCi equal to WSi, the station i sends a cycle token to the next station, then starts the next cycle.

The WCi is the counter for counting the number of transmitted packets.

In the following, we explain sending and receiving operations. Each station has a ring interface for sending and receiving operations as shown in Figure 6. The ring interface is shown only for the counterclockwise ring. For the clockwise ring, the ring interface also exists and operates in the same way as for counterclockwise ring. The ring interface consists of the sending switch (SW), receiving SW, sending buffer, receiving buffer, WSi buffer and WCi buffer.

The sending process for each station is carried out when WCi is less than WSi and in this case the WCi is incremented. During transmission, the relayed packets from the upstream stations are stored temporarily in the insertion buffer. After transmission is finished, they are relayed at the downstream stations. Each station checks the destination address of packets. When the destination address of packets is the same as its own address, the station gets these packets and remove the packets from the ring (4-th condition). While, when the destination address of packets is not the same as the station address, the station interface relays the packets. The sending operation can be concurrently executed (1-st condition). Therefore, the ring utilization and throughput can be increased.

During the fairness control, the stations which already sent an amount of WSi packets in a cycle can not send packets until a new cycle token arrives even if some packets still exist. Thus, the ring utilization and throughput are decreased. For avoiding this situation, we implement an adaptive control. The window size is changed dynamically depending on the cycle token round trip time as shown in following.

- Rct ≤ T
  WSi = WSi + Const
- Rct > T
  WSi = WSi - Const

The Rct is the round trip time of the cycle token, T is the threshold time and Const is a constant value. When the station i does not need more WSi than present allocated WSi, the window size increase procedure is not carried out. Also, when the WSi is equal to initial required window size, the window size decrease procedure is not carried out. This means that initial window size is guaranteed for each station. That is why fairness is maintained in our protocol. When the traffic in the ring changes and the ring has available bandwidth, this adaptive control gives more window size to stations which have many packets. While, when the ring is congested, the window size of each station is decreased. Thus, the ring can be used efficiently and the throughput will be increased.

5 Performance Evaluation

Computer simulation were used for performance evaluation. The transfer delay versus throughput characteristics was adopted as a performance measure. The transfer delay means the total time taken for packets to arrive at the sending stations, wait in the sending buffer, be sent out of the ring, and finally be received at the destination stations. Throughput means the number of bits carried by packets onto the ring during a unit of time (second).

We make the following assumptions for simulations.

- The packet length is generated by exponential distribution.
- The packet arrival rate is a Poisson process.
- For a source station, the destination stations are distributed uniformly on the ring.
- The total cable length is 100 km.
- The transmission rate is 1 Tera bps.

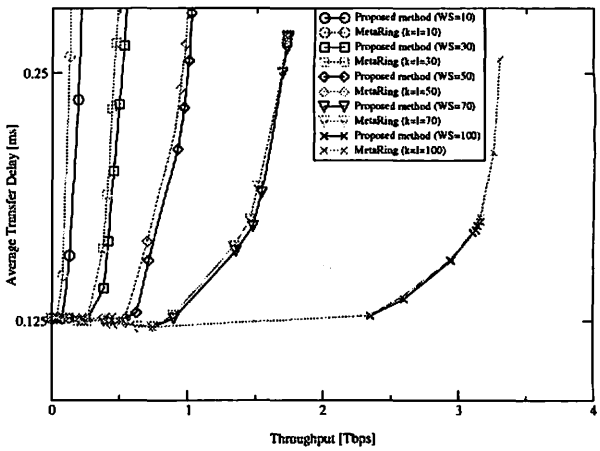

Figure 7: Performance characteristics for different window sizes.

5.1 Different Window Sizes

We compare the performance of the proposed method and MetaRing method for different window sizes. The throughput characteristics versus average transfer delay are shown in Figure 7. The average data length is 5000 bytes, the number of stations is 100 and the initial window size is changed from 10, 30, 50, 70 to 100. Both methods show that when window size is large the throughput become high. Also, when the window size is 100, both methods show the same characteristics, but for other window sizes our method has better behavior than MetaRing method. This is because in MetaRing method the initial window size is fixed. While, in our method the window size can be changed. Thus, the proposed method has an adaptive behavior which results in better characteristics compared with MetaRing method.

5.2 Different Number of Stations

The throughput characteristics versus average transfer delay for different number of stations are shown in Figure 8. The average data length is 5000 bytes, initial window size is 50, and the number of stations vary from 50, 100, 150 to 200. The throughput characteristics increase when the number of station is increased. This is because when the number of stations increases, the traffic on the ring is also increased. The proposed method shows better performance than MetaRing method.

6 Conclusions

We have proposed a media access protocol for terabit ring networks which has high throughput and good fairness. Also, we treated the necessary conditions for achieving a super high-

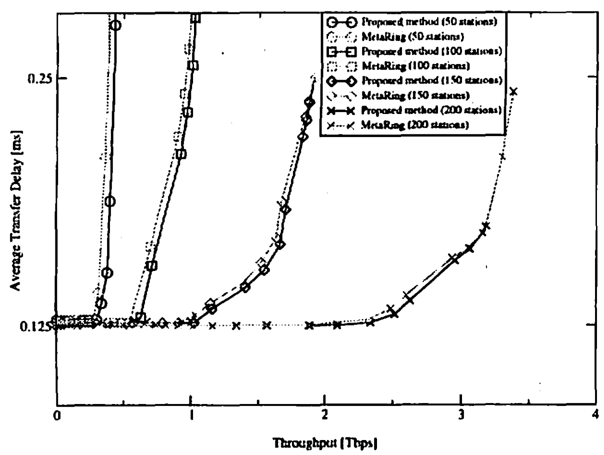

Figure 8: Performance characteristics for different number of stations.

speed ring network. The performance behavior of our method and MetaRing method was evaluated by simulations. From the simulation results, we conclude that proposed method shows better throughput characteristics than MetaRing method for different window sizes and number of stations. In the future, the authors plan to evaluate the proposed protocol for various traffic conditions.

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