DATA COMMUNICATIONS MANAGEMENT

HIGH-SPEED TOKEN RING

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INTRODUCTION
Although the population of 20 million desktops connected today by Token Ring may be dwarfed by the number of Ethernet connections that are out there, current users of Token Ring remain very loyal to the technology. The reasons are not hard to find — Token Ring's fault tolerance, manageability, performance, and efficient use of bandwidth get the job done. In large LAN installations where network availability is critical, one can depend on Token Ring to deliver.

The technology of Token Ring has been around for almost 15 years, and it is a testament to the robustness of the original design concept that many large networks today continue to make use of essentially the same network components that powered those first, early installations. But that is not to say that Token Ring technology has stood still. The demand for increasing network bandwidth drove the introduction in 1989 of 16Mbps Token Ring to quadruple the speed of the original 4Mbps offering. More recently, the development of Token Ring switching increased backbone capacity to hundreds of megabits per second, and added the possibility of dedicated, full duplex links carrying Token Ring traffic at 16Mbps in both directions at once.

By and large, this evolution of Token Ring technology has kept ahead of the growing demand for bandwidth in most LAN installations, but the anticipation of continued growth of traffic in the future has naturally made some large Token Ring users nervous. The availability of solutions based on ATM (Asynchronous Transfer Mode) that can switch Token Ring traffic may not have the luxury of a choice. With high-speed Token Ring and ATM to choose from, network planners are more likely to find a backbone solution that precisely fits their particular needs.
Ring traffic at speeds of 155M bps and beyond have provided some comfort; but to date, Token Ring users have not enjoyed a choice of high-speed solutions — unlike Ethernet, where Fast Ethernet and more recently Gigabit Ethernet offer a simpler and lower-cost alternative to ATM.

High-speed Token Ring (HSTR) addresses this imbalance. Supporting 100M bps and 1G bps Token Ring connections for interswitch links and for switch-to-server connections, HSTR provides the first simple and cost-effective alternative to ATM for dealing with capacity issues in Token Ring backbones.

THE EMERGING NEED FOR HIGH-SPEED TOKEN RING

Continual growth in traffic loads is a seemingly inescapable fact of Local Area Networks. PCs get faster and deal in more complex and information-rich data objects; intranet Web servers unlock corporate information resources for access by much wider communities of users; departmental server systems are displaced by corporate superservers. These and other trends contribute to a rising tide of data traffic that seems to devour all the bandwidth that can be thrown at it.

In Token Ring networks, switching is now the primary technology for tackling this growth in demand for LAN capacity. Shared 16M bps backbone rings that link multiple workgroup rings with corporate mainframe and server resources can now be replaced with switching systems that handle hundreds of megabits per second of Token Ring traffic. The effect on network performance can be dramatic because user access to central resources — which was once throttled through overloaded 16M bps backbone rings — now takes place at full wire speed through the fast backplane of a switch.

The 16M bps limitation of Token Ring does, however, limit the scalability of switched Token Ring networks. Connections between switches and connections from switches to servers represent traffic concentration points where 16M bps looks increasingly inadequate.

Some relief from overloaded interswitch connections can be obtained by taking advantage of the load-sharing capabilities that are inherent in Token Ring's source routing. Switches can be connected together with multiple parallel dedicated 16M bps Token Ring links, and the properties of source routing will ensure that network traffic is shared approximately equally between the multiple links.

But load sharing across multiple links provides only temporary relief from network overloads as traffic continues to grow. Each additional link adds only another 16M bps of capacity, and occupies another port on the switches at each end of the link. Furthermore, the use of multiple links does not provide a satisfactory solution to the problem of server access bottlenecks.
TODAY'S HIGH-SPEED OPTIONS FOR TOKEN RING USERS

To solve the problem of overloaded interswitch links and switch-to-server connections, a higher speed networking technology is needed. Until now, Token Ring users have effectively had a choice between FDDI (Fiber Distributed Data Interface) and ATM (Asynchronous Transfer Mode).

Fast Ethernet has not, so far, provided a satisfactory high-speed backbone solution for Token Ring users. Differences in frame format, address bit ordering, and maximum frame size make it very difficult to carry out a direct translation between Token Ring and Fast Ethernet without introducing unacceptable compromises. It is possible to use routers to connect the Token Ring environment to a Fast Ethernet backbone, but the software processing overhead of routers, and the necessity to carry out packet fragmentation to deal with differences in maximum frame size, result in severe performance limitations. This is also a costly solution.

FDDI offers a fault-tolerant, shared 100M bps medium and meets many of the backbone connectivity needs of Token Ring users. Its token-passing access mechanism, which is based on that of Token Ring, enables its full bandwidth potential to be realized, and its dual reconfiguring ring topology provides very effective protection against cable or transmission link faults.

However, FDDI suffers two disadvantages that are responsible for its fall from favor among Token Ring users over the last few years. First, the FDDI frame format is different from that of Token Ring, and Token Ring switches that support FDDI links must perform a number of complex packet translation functions to support connectivity. This makes FDDI a relatively expensive solution. Second, FDDI offers no scalability options beyond the existing 100M bps standard. Other technologies such as ATM and Fast Ethernet have next-generation standards that scale into the gigabit range, and FDDI appears far less future proof by comparison.

ATM looks like a much more promising candidate for Token Ring backbone and server connections. With its ability to scale to 2.4G bps and beyond, its inherent fault tolerance, and its support for native Token Ring frame formats (in LAN Emulation mode), ATM meets all of the key needs of large Token Ring backbone installations.

But ATM is not ideal for all situations. It is a far more complex technology than Token Ring; and although it can be relatively easy to install and configure, there is too much new information for network technicians to learn if they are to be able to troubleshoot ATM networks successfully. ATM may also be regarded by some as an overkill solution for many Token Ring needs, in terms of both its raw power and its sophisticated features for bandwidth reservation and Quality of Service support.
DEFINING THE REQUIREMENTS FOR HIGH-SPEED TOKEN RING

The requirements for a High-Speed Token Ring solution have been the subject of discussion and agreement among members of the High-Speed Token Ring Alliance, a consortium of Token Ring equipment vendors that was formed in August 1997. The objective of the Alliance is to define a simple, cost-effective, and scalable solution for switched Token Ring networks that preserves as much of the existing investment in Token Ring as possible, while providing a forward evolution path for Token Ring networks that meet all foreseeable applications needs.

In particular, the Alliance agreed to the following set of needs:

- Support for standard Token Ring frame formats
- Speeds of 100M bps and beyond
- Support for UTP, STP, and fiber cabling
- Support for existing maximum packet sizes as defined in the 802.5 Token Ring standard
- Support for all Token Ring bridging modes, including source routing, transparent, and SRT
- Compatibility with the 802.1Q standards effort for Virtual LAN tagging

The Alliance also agreed that the most urgent needs for High-Speed Token Ring were for interswitch and switch-to-server connections. Therefore, the focus of HSTR development would be on dedicated point-to-point full duplex links rather than shared media operation. This would reduce the time taken to arrive at a new standard and make it easier for vendors to bring products to market relatively quickly.

THE TECHNOLOGY AND TIMESCALES OF HIGH-SPEED TOKEN RING

The process of developing a new LAN standard can take years, but the need for HSTR is already here and demand is expected to grow rapidly during 1998. For this reason, the HSTR Alliance is cooperating very closely with the IEEE 802.5 committee on a “fast-track” resolution of technical issues to arrive at a completed standard as soon as possible.

Basing the standard as closely as possible on existing technologies is seen as the best way to get rapid agreement on the technical specification. The basis for HSTR is the existing 802.5r standard, which specifies full duplex point-to-point dedicated Token Ring operation at 4 and 16M bps. This will be adapted to operate first at 100M bps and then later at 1G bps.

The 100M bps speed was chosen in order to leverage the existing transmission technology on which Fast Ethernet is based. By making use of encoding schemes and transmission waveform specifications that have already been proven over both twisted pair and fiber optic cabling, the
The High-Speed Token Ring Alliance (HSTR Alliance) will minimize the amount of new technical thinking that needs to be done to arrive at a standard.

The first priority of the Alliance is to develop a specification for 100M bps HSTR over copper cabling, including both Category 5 UTP and IBM Type 1 STP. A specification for 100M bps HSTR over fiber cabling will follow soon after, based on the 802.5j Token Ring fiber standard adapted to run over the 100-Base-FX specification for Fast Ethernet on fiber.

Subsequent work will focus on Gigabit HSTR. As might be expected, this will leverage the transmission technologies that are being developed to support Gigabit Ethernet over both copper and fiber cabling.

At the time of this writing in October 1997, projections by the 802.5 committee suggested that the first HSTR standards would be completed by June 1998. The High-Speed Token Ring Alliance plans to demonstrate HSTR technology and multivendor interoperability at Networld+Interop in Las Vegas in May 1998, and vendors are predicting that HSTR products will begin shipping by the fourth quarter of 1998.

**THE DEPLOYMENT OF HIGH-SPEED TOKEN RING**

The first products supporting the new HSTR standards are likely to include 100M bps HSTR line cards for Token Ring switches, and 100M bps HSTR Network Interface Cards (NICs) for servers.

For most Token Ring users, the first application of HSTR will be for upgrading interswitch links. By installing HSTR line cards in existing Token Ring switches, interswitch links that are currently running at 16M bps can be very quickly upgraded to 100M bps.

HSTR provides full support for source routing, so backbone interswitch connections in fault tolerant networks with parallel load-sharing paths can be upgraded to 100M bps without compromising fault tolerance in any way. The HSTR connections between switches will behave in exactly the same way as existing 16M bps connections, except that they have more than six times the traffic capacity.

Some existing switched Token Ring networks make use of FDDI for interswitch connections. Because HSTR will offer both lower cost and better performance for interswitch connections, it may be desirable to use HSTR for future upgrades to these networks, and freeze any further investment in FDDI. Some Token Ring switches will support both FDDI and HSTR line cards, and this makes it relatively easy to carry out a phased migration to HSTR in the backbone, while preserving current investment in FDDI.

After upgrading interswitch links, the next area that may need attention is the connection to enterprise servers. If servers are already connected directly to Token Ring switches by full duplex 16M bps links, and these links are becoming overloaded, then the server connections may
be upgraded by installing a 100M bps HSTR adapter card and connecting directly to a port on a 100M bps HSTR line card in a Token Ring switch.

Some vendors are likely to introduce server NIC products that support 4, 16, and 100M bps on the same card. This provides excellent investment protection, because the server may be connected initially to a 16M bps switch port, and then moved later to a 100M bps switch port if greater throughput is needed.

HSTR is not initially targeted at desktop connections, but there is nothing to prevent it from being deployed at the desktop if needed. HSTR will be supported over both Category 5 UTP and IBM Type 1 STP cabling, and 100M bps HSTR NIC cards could be installed directly in desktop systems for connection to 100M bps HSTR switch ports. However, it is likely that 100M bps HSTR to the desktop would only be justifiable for exceptionally demanding applications such as very high-resolution imaging.

**HIGH-SPEED TOKEN RING AND VIRTUAL LANS**

In some situations, it may be useful to divide the Token Ring LAN into a number of separate broadcast domains or “Virtual LANs” that are defined logically, rather than physically, and to use routers to move traffic from one VLAN to another. Typically, VLANs are defined by assigning each switch port to a particular VLAN identity. Traffic arriving at that port from end stations is deemed to belong to the VLAN associated with that port.

If making use of VLANs, then in general, it is useful to be able to define VLANs that span multiple switches. The key property of a VLAN is that a broadcast or multicast packet originating within a given VLAN must only be delivered to switch ports that belong to the same VLAN. When using High-Speed Token Ring connections between switches, it becomes necessary to mark each packet with its VLAN affiliation so that one knows which switch ports this packet may be delivered to.

Where source routing is used, the originating ring number in the source routing information field of each packet is sufficient to identify the packet’s VLAN affiliation, and one does not need to do anything new or special. But packets that are being transparently switched do not contain any information from which VLAN information can be deduced. To solve this problem (for both Ethernet and Token Ring networks), the IEEE 802.1Q working group is defining a packet-tagging scheme that enables VLAN information to be associated with each packet.

The emerging 802.1Q standard is fully compatible with High-Speed Token Ring, and will enable VLAN-tagged packets to be carried between Token Ring switches. The 802.1Q specification is also expected to define a standard method for identifying Ethernet packets that are being carried over Token Ring links. The implication of this is that HSTR could provide a backbone solution that integrates Token Ring and Ethernet traffic across a common high-speed infrastructure.
HIGH-SPEED TOKEN RING AND QUALITY OF SERVICE

Until High-Speed Token Ring arrived on the scene, ATM was the first choice of Token Ring users looking for major upgrades to backbone switching capacity. This is because ATM can provide a high-capacity, scalable, fault-tolerant backbone that handles native Token Ring frame formats and source routing.

One additional capability of ATM has also been a factor in its adoption for Token Ring backbones: Quality of Service. ATM networks can provide not only “best effort” delivery of packet data like Ethernet and Token Ring LANs, but it can also deliver time-sensitive traffic streams like voice and video with a guaranteed upper limit on end-to-end delay.

This capability of ATM is being exploited today in a minority of ATM installations to provide backbone integration of voice or video trunks across campus LANs. However, Quality of Service cannot easily be exploited for packet-based LAN traffic because it requires much more sophisticated edge switches linking Ethernet and Token Ring to ATM than are currently available. This has not been an issue so far because there are few, if any, desktop applications in use today that can exploit Quality of Service.

However, there is growing interest in the deployment of desktop videoconferencing and voice telephony over the LAN, and network planners making backbone evolution decisions need to take into account the possible requirements of the enterprise looking several years forward. ATM has been seen as a safe choice for the large-scale LAN backbone because it is expected to have no problem accommodating future requirements for voice and video in the LAN.

So, how does HSTR stack up against ATM for handling integrated packet-based voice and video in the LAN? The answer is that although HSTR cannot provide the same level of guaranteed service for real-time traffic streams as ATM, it is likely to be good enough for most practical needs.

PRIORITY ACCESS FOR VOICE AND VIDEO TRAFFIC

The original designers of Token Ring had the foresight to build into the standard a feature that was intended to enable support for real-time traffic in the LAN. This capability, which allows prioritization of time-sensitive data packets, has been built into every Token Ring product since 1985 that complies with the 802.5 standard, but has remained effectively dormant for lack of applications that can exploit it.

The token-passing access mechanism of Token Ring is a deterministic protocol that guarantees a station will be able to access the medium to send a packet within some fixed time limit, depending on the number of stations on the ring and the speed of the ring. Under normal operation, when there are a number of stations on the ring waiting to send a packet, the token is passed from one station to the next around the ring, granting
the right to transmit a packet. The priority mechanism allows a station that is waiting to send a higher priority packet to preempt all the other stations and grab the token next. If one thinks of all the stations waiting to transmit packets on the ring as being in an orderly queue to access the medium, then a station wanting to send a higher priority packet effectively jumps the queue and can start transmitting as soon as the packet currently being transmitted by another station has finished.

The Token Ring priority mechanism supports eight levels of priority, 0–7. The code of practice adopted by the industry assigns normal data packets to priority 0, and ring management packets to priority 7. Packets being transmitted by a bridge port or switch port should be sent with priority 4. This is a recognition of the fact that when a ring is connected to a Token Ring switch, a high proportion of the traffic carried on the ring will come from the switch port. So, using a higher priority for transmissions from the switch port provides users with better overall performance.

Token priority levels 5 and 6 are intended for time-sensitive applications such as voice and video. Tests carried out on Token Ring networks with various populations of users connected to a ring have shown that the use of priority 5 or 6 for voice and video packets can guarantee access to the medium within a few milliseconds, provided that the overall bandwidth consumed by voice or video packets is kept within a reasonable proportion of the total bandwidth on the ring.

So, the token priority mechanism provides a means to support real-time traffic in the context of a single ring. But what happens when the network consists of many rings, interconnected by switches? Can the switches preserve the priority of voice and video packets end to end across the network? And can they also expedite the delivery of voice and video packets over normal data packets? The answers depend on how the switches have been designed.

PACKET PRIORITY AND TOKEN RING SWITCHES

When a switch receives a packet to be forwarded to another ring, it can establish what priority the packet was transmitted with by looking in the Logical Link Control (LLC) header that is part of the packet. It is therefore possible for the switch to preserve this priority across the switch fabric, and ensure that the same priority level is used to transmit the packet onto the destination ring. This ability to preserve packet priority across the switch fabric, and to transmit the packet onto the ring at the output port of the switch with the appropriate priority level, is the first prerequisite of a Token Ring switch for handling voice and video traffic.

But just preserving packet priority across the switch fabric is not enough. Token Ring switches have internal queuing mechanisms that buffer packets being sent to a particular output port when that port is congested. If there is only a single queue for an output port, then it is
possible for a high-priority packet to be trapped in a queue within the switch behind several lower priority packets. The result is likely to be that voice and video packets suffer unacceptable delay variations across the network at times of heavy traffic loading.

The solution to this is to implement multiple queues within the switch fabric, so that high-priority packets are sent to a different output queue than lower-priority packets. The switch must give precedence to the higher priority queues when selecting which packet to send next on a congested switch output port. This way, voice and video packets have their own queues and do not get trapped behind data packets. Provided that the total bandwidth of voice and video packets being sent to a particular switch output port is limited to a reasonable fraction of the speed of that port, there will not be a buildup of voice or video packets in the high-priority queues, so end-to-end transmission delays will be kept within acceptable limits.

This, then, is the second prerequisite of a Token Ring switch for handling voice and video traffic: the switch must implement multiple queues to enable higher priority voice and video packets to be expedited over normal priority data packets at congested switch ports.

**Packet Priority and High-Speed Token Ring**

As explained, the priority mechanisms embodied in Token Ring work in two distinct ways. First, high-priority packets enjoy privileged access to the shared medium when there are multiple stations connected to the ring. And second, an appropriately designed Token Ring switch can make use of the priority indication within the Token Ring packet to expedite delivery of high-priority packets over those with lower priority when switch ports become congested.

High-Speed Token Ring will not, initially, provide a shared media mode of operation, and therefore, the priority mechanism that provides privileged access to shared rings does not apply to HSTR.

However, priority information embedded in Token Ring packets is preserved across HSTR links, and Token Ring switches can be designed that support multiple queues on outgoing HSTR ports. Therefore, HSTR links for interswitch or switch-to-server connections can form part of an end-to-end transmission path that supports packet prioritization and expedited delivery of high-priority packets.

**Meeting the Needs of Voice and Video in the LAN**

Real-time interactive voice and video in the LAN requires both adequate bandwidth for the delivery of constant streams of packets containing voice and video information, and consistent low transmission delay end to end across the network.
ATM provides the most sophisticated solution for the delivery of voice and video in the LAN. An application can request that bandwidth be reserved for a voice or video stream, and place an upper limit on transmission delay. The ATM switches that make up the network assess whether there are sufficient resources to meet the request from the application, and either accept or refuse the request. Once a bandwidth reservation request has been accepted by the ATM network, resources are set aside on each link of the end-to-end transmission path to ensure that the voice or video stream is delivered within the requested delay bounds.

All this sophistication, of course, comes at a price. ATM is a substantially more complex and more costly technology than Token Ring. Because of this, ATM has made little impact at the desktop. And the popularity of ATM in the LAN backbone is based on other attributes of ATM besides Quality of Service: capacity, scalability, and fault tolerance.

Using end-to-end packet prioritization and expedited delivery of priority packets in the LAN is a much less sophisticated solution for voice and video than ATM can offer. However, it is also much simpler, and it leverages capabilities that are already built into the Token Ring network. The only circumstances under which it will not work so well are when bandwidth is very constrained and when voice and video traffic occupies a high proportion of the available bandwidth. But bandwidth in the LAN is relatively inexpensive, and it is generally cheaper and easier to over-provision capacity in the LAN to enable good voice and video performance with packet prioritization than it is to introduce a new and different technology for this purpose.

CONCLUSION
High-Speed Token Ring offers existing Token Ring users a simple incremental upgrade path for switched Token Ring backbones. Carrying native Token Ring frame formats with support for all Token Ring bridging schemes including source routing, HSTR is a logical extension of the Token Ring environment to 100M bps and 1G bps transmission speeds.

Both HSTR and ATM can meet all the practical backbone needs of large Token Ring installations in terms of capacity, scalability, and fault tolerance. HSTR will generally cost less than ATM for equivalent network capacity and involves less new knowledge to install and manage. ATM, on the other hand, can provide guaranteed Quality of Service, can be seamlessly extended over public and private WAN environments, and provides for a more peaceful coexistence with Ethernet in mixed-technology installations.

Token Ring users planning backbone upgrades now have the luxury of a choice. With HSTR and ATM to choose from, network planners are more likely to find a backbone solution that precisely fits their own particular needs.
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