Executive Summary

This paper describes the new technology of High Speed Token Ring. It is intended for network planners and systems integrators who are concerned with the evolution of Token Ring networks. The paper explains why a new, faster version of Token Ring is needed, describes the technology that lies behind the proposed new standard for High Speed Token Ring, and discusses the possible migration paths for evolving Token Ring networks.

About the Author

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1. The Need for High Speed Token Ring

Ever since its introduction in 1985, Token Ring has been the LAN technology of choice for large enterprises that regard the LAN as a strategic, mission-critical resource. True, Token Ring is both more complex and more costly than Ethernet, but its manageability, fault tolerance and excellent performance have justified its higher initial price tag by delivering lower lifetime cost of ownership.

All networking technologies must evolve in order to remain relevant to the changing needs of enterprises, and Token Ring is no exception. This evolution got under way in 1989, when the first 16 Mbps Token Ring adapters enabled users to quadruple the speed of their LANs, without needing any changes to equipment in the wiring closet. Then Token Ring switching arrived in 1995, providing high speed backbone connectivity between rings and enabling servers to benefit from dedicated full duplex 16 Mbps connections. Also in 1995, the ATM Forum published the specification for LAN Emulation over ATM (LANE), and this offered the means to connect Token Ring networks over ATM.

Despite all this progress, some of the more demanding users of Token Ring have been looking enviously over the fence at developments in the Ethernet world. The existence of 100 Mbps Fast Ethernet, and the imminent arrival of Gigabit Ethernet, appear to offer Ethernet users a greater choice of evolution paths for their LANs than is available to Token Ring shops.

1.1 Beyond Token Ring Switching

Over the last few years, growing traffic loads and shifting traffic patterns have encouraged a move away from the traditional bridged Token Ring backbone to a collapsed backbone architecture. Prior to the arrival of Token Ring switching, large routers provided the only viable solution for the collapsed backbone, but switching offers far higher performance at lower cost and with greater simplicity. Nowadays, high performance Token Ring LANs may be based on switching alone, or on some combination of switching and routing. (See Figure 1).

Token Ring switches provide high speed backbone connectivity between multiple 4 or 16 Mbps rings, typically with aggregate capacity of several hundred megabits per second. This represents a huge increase from the 16 Mbps capacity of a shared Token Ring backbone. Servers can be connected directly to the switch, benefiting from a dedicated 16 Mbps link which eliminates contention for shared bandwidth. Further performance gains can be made by running these dedicated links in full duplex mode, providing a clear transmission channel in both directions at the same time.

Token Ring backbone switches are available with up to 30 ports or more, but in larger installations two or more switches are needed. This may be because more than 30 rings must be interconnected, or because the rings are connected into different equipment rooms (for example, in a campus network). The question then is: how should we connect the switches together?

Clearly, Token Ring switches can be interconnected by Token Ring links. Full duplex dedicated connections between switches would be the obvious choice here. But this only provides 16 Mbps of capacity in each direction – and if each switch is serving up to 30 rings, each running at 16 Mbps, then this is unlikely to be enough.
One approach to solving the inter-switch link problem is to run multiple parallel Token Ring connections between switches. If we are using source routing, then the traffic load between the switches would automatically be shared among the parallel links. If, instead, we are using transparent switching techniques, then we would need some proprietary load-sharing technology to take advantage of all the aggregate link capacity.

However, using multiple parallel Token Ring links to interconnect switches occupies multiple ports on each switch. Beyond two or three parallel links, this becomes clumsy and costly, and could hardly be said to provide a scaleable solution. And linking Token Ring switches together is not the only area where the 16 Mbps limitation of Token Ring causes us problems. More and more organizations are investing in very high performance servers to support demanding data-intensive and time-critical applications, and these will need much higher speed connections than 16 Mbps if they are to deliver their full potential.

Since the maximum speed currently supported on Token Ring is 16 Mbps, we are forced to look to other technologies if we want a solution for inter-switch links and for high speed server connections.
1.2 High Speed Options

The high speed technologies that are available today to provide a solution for inter-switch links and server connections in Token Ring environments include FDDI, Fast Ethernet and ATM. None of these is ideal for all situations.

FDDI provides a useful combination of 100 Mbps capacity with excellent fault tolerance. However FDDI is seen as yesterday’s technology because of its cost and complexity, and because it lacks an upgrade path to speeds beyond 100 Mbps. Furthermore, FDDI and Token Ring use different packet formats and different address format conventions, so every packet passing between Token Ring and FDDI must be translated. Carrying out this translation requires substantial amounts of processing power, which has a serious negative impact on price/performance.

Fast Ethernet offers low cost and wide availability, but is far from ideal as a medium for interconnection in Token Ring environments. This is because Ethernet and Token Ring packet formats are different in a number of important respects. The bit order of every packet address is the opposite way round between the two technologies, necessitating extensive address translation on every packet. Ethernet does not support source routing, and this makes it impossible to support many of the fault tolerance and load-sharing mechanisms which depend on source routing and which are so valuable to enterprise LAN users. And finally, Ethernet supports a smaller maximum packet size than Token Ring, and this means that the networking software in every end station must be re-configured to limit the packet size, with a corresponding drop in the actual throughput performance achieved at each end station.

ATM offers a far better high-speed solution for Token Ring environments than either FDDI or Fast Ethernet. The ATM Forum specification for LAN Emulation supports the handling of Token Ring packets over ATM networks, providing full compatibility with Token Ring’s address format, maximum packet size and source routing capabilities. This makes it very easy to interconnect Token Ring switches using ATM, with excellent performance and without in any way compromising the special features of Token Ring. ATM itself is very scaleable, offering link speeds of 155 Mbps and 622 Mbps and the future possibility of 2.4 Gbps. ATM can also be used to build very fault tolerant networks, taking advantage of the sophisticated connection routing protocols that are built-in to the technology.

But ATM, too, has its downside. For many Token Ring users, ATM appears excessively complex and sophisticated. There is a cost incurred by introducing a new technology into the network, which arises from the need to learn and master a new subject, and to acquire the skills and the tools to properly manage and exploit it. For many Token Ring users today, the cost of introducing ATM is just too high.

To sum up: Token Ring users looking for high speed backbone solutions have been faced with a choice between obsolescent FDDI, problematic Ethernet and overly-complex ATM. It is perhaps not surprising that many of them have been expressing dissatisfaction with this state of affairs. But now the future holds a brand new option – High Speed Token Ring – which looks like providing a solution that is much closer to the ideal.
2. The Technology of High Speed Token Ring

We have outlined the problems that we are trying to solve – high speed inter-switch links and server connections in a Token Ring environments – and we have looked at the shortcomings of the existing solutions to these problems. It is therefore relatively easy to describe the characteristics of an ideal solution.

First, we want to preserve all the special capabilities of Token Ring that set it apart from other LAN technologies. Therefore the new solution should support source routing, packet priority and the larger frame sizes that are seen in Token Ring.

Secondly, we want a scaleable solution that holds the promise of higher speeds in the future, so we don’t have to worry about how we are going to be able to obtain even greater capacity from the LAN when applications demand it.

And finally, we want to minimize both the acquisition cost and the ownership cost of the new solution. This means that the solution should be based on existing Token Ring principles to minimize the learning curve, and make use of existing and widely-used component technologies to keep material costs low and development timescales short.

2.1 The High Speed Token Ring Solution

High Speed Token Ring is needed primarily to address the problems of inter-switch links and fast server connections. A point-to-point solution offering a dedicated high speed communications path is appropriate for both these needs.

The Token Ring standards already provide a model for full duplex dedicated point-to-point Token Ring operation, described in IEEE 802.5r, although of course this standard envisages a maximum speed of only 16 Mbps. In principal, then, all we need to do is to adapt this to run at a higher speed.

To keep costs to a minimum, and to shorten the time to completion of a new standard, it makes sense to base the new solution on an existing and widely available high speed transmission technology, such as 100 Mbps Fast Ethernet or 155 Mbps ATM. Of all the current high speed technologies, the simplicity and low cost of the Fast Ethernet transmission scheme make it the most attractive.

The High Speed Token Ring solution is therefore based on the IEEE 802.5r standard for Dedicated Token Ring, adapted to run over the 100 Mbps physical transmission scheme which is used by dedicated Fast Ethernet. And just as the Fast Ethernet standard is currently being adapted to run ten times as fast, so there will be a Gigabit Token Ring solution, based on IEEE 802.5r adapted to run over the Gigabit Ethernet transmission scheme.

So HSTR will provide inter-switch links and server connections at 100 Mbps, and, in the future, 1 Gbps. These links can be run in either half-duplex or full duplex modes, just like Dedicated Token Ring.
Since the principal purpose of HSTR is to address inter-switch links and fast server connections, it is not envisaged that HSTR will offer a shared mode of operation. While it could be argued that shared HSTR might provide a useful option for more demanding desktop systems, the addition of a shared mode of operation would vastly increase the complexity of the solution and would greatly delay the introduction of a standard. In any case, the rapidly falling cost of LAN switches suggests that a dedicated HSTR connection to the desktop will, in the future, offer a cost-justifiable solution to meet the needs of power users.

2.2 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” which 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 we are 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 we are using High Speed Token Ring connections between switches, it becomes necessary to mark each packet with its VLAN affiliation so that we know 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 we don’t need to do anything new or special. But packets that are being transparently switched don’t contain any information from which we can deduce VLAN information. To solve this problem (for both Ethernet and Token Ring networks) the IEEE 802.1Q working group are 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.

2.3 High Speed Token Ring Products

The intended application areas for HSTR, inter-switch links and fast server connections, suggest that the first HSTR products will consist of 100 Mbps HSTR uplink or port cards for Token Ring switches, and 100 Mbps HSTR adapter cards for servers.

It seems likely that HSTR server adapter cards will offer a range of speeds, i.e. 4/16/100 Mbps operation, to provide investment protection for customers who wish to connect servers at 16 Mbps today but would like the option to upgrade to 100 Mbps access in the future.

The need for compatibility with installed cabling is well recognized, and we can expect to see HSTR products that are compatible with both Category 5 UTP and IBM Type 1 STP cabling, and fiber versions of HSTR products for connection to 50/125 and 62.5/125 multimode fiber cabling.
3. Towards a High Speed Token Ring Standard

The need for HSTR among users of Token Ring is now perceived as being quite pressing, and the question of a standard for HSTR is being addressed by the industry as a matter of the greatest urgency.

In August 1997, a meeting of the major providers of Token Ring equipment including 3Com, Bay Networks, Cisco, IBM and Madge, agreed to the formation of the High Speed Token Ring Alliance. The charter of the HSTRA is to promote industry consensus on the technical specification for the HSTR standard, to facilitate interoperability testing of HSTR products, and to promote HSTR as a strategic solution for Token Ring users.

The HSTRA plans to present a detailed technical proposal to the IEEE 802.5 committee in November 1997 for a High Speed Token Ring standard, to operate at 100 Mbps. Since many of the working members of the HSTRA are also members of the IEEE 802.5 committee, progress towards an agreed standard is expected to be rapid.

Furthermore, the HSTRA has agreed to begin work in parallel on a Gigabit version of High Speed Token Ring.

The Alliance has invited the University of New Hampshire Interoperability Lab (UNH-IOL) to be a member of HSTRA, and members of the Alliance have committed to submit prototype products to UNH-IOL for pre-standard testing early in 1998.

A further aim of HSTRA is to demonstrate working and interoperable High Speed Token Ring products at Networld+Interop in Las Vegas in May 1998.
4. High Speed Token Ring and ATM

Until the emergence of the proposed High Speed Token Ring standard, ATM was the only technology that satisfactorily met the high capacity backbone needs of Token Ring users. Now that Token Ring users have a broader choice of evolution options in the future, where does this leave ATM?

ATM has been particularly valued by Token Ring users for its scaleability, fault tolerance, Quality of Service capabilities, ability to co-exist with Ethernet, and extensibility over the WAN. Let’s take a look at how HSTR stacks up against ATM in each of these areas. (See Figure 2).

4.1 ATM and Scaleability

Decisions to implement new LAN backbone technologies are not taken lightly, and one of the major considerations must be the ability of the chosen technology to accommodate growing traffic loads many years into the future. ATM offers today a degree of scaleability that lies well beyond the expected needs of most Token Ring users, both in terms of link speed and switching capacity.

The most common ATM link speed used in today’s LAN backbones is 155 Mbps, but 622 Mbps links are already available and work is in progress on 2.4 Gbps and 10 Gbps standards. ATM LAN backbone switches typically come with a minimum of 2.5 Gbps of switching capacity.

HSTR will scale to link speeds of 100 Mbps and 1 Gbps, which should be more than adequate to meet the future needs of the vast majority of Token Ring users. Token Ring switching capacities today are typically in the range of hundreds of megabits, but there are no technical barriers to the development of multi-gigabit Token Ring switches.

4.2 ATM and Fault Tolerance

ATM can provide a high degree of protection against the failure of network components by permitting meshed network topologies with alternative routing capabilities. If a switch or a link fails, the ATM end points that are affected will automatically re-establish connections over alternate paths through the network.

At times when all switches and links are operating normally, ATM’s connection routing protocols provide load-sharing across all available switch and link capacity.

Token Ring with source routing can offer similar capabilities for fault tolerance. Source routed Token Ring supports meshed or parallel redundant connections, and automatically shares load among the available paths. If a path fails for any reason, the end stations that are affected automatically attempt to re-establish connections across the network.

Since High Speed Token Ring provides full support for source routing, it is easy to build highly reliable backbones based on Token Ring switches linked by HSTR.
If transparent switching is used instead of source routing, then HSTR does not provide quite so fault tolerant a solution as ATM. Alternate paths can be provided with transparent switching by making use of the spanning tree protocol, but load sharing is not supported, and the time taken to recover from network faults may stretch into minutes, which is unacceptable in many situations.

Some Token Ring networks handle a mix of transparent and source routed traffic, making use of SRT (Source Route Transparent) capabilities in Token Ring switches. In this case, source routed traffic will benefit from load-sharing over parallel redundant paths, while transparent traffic will follow a single path through the network defined by the spanning tree protocols.

Figure 2: Token Ring network with ATM backbone
4.3 ATM and Quality of Service

The ability to guarantee the delivery of real-time traffic streams with very low end-to-end delay is one of the most outstanding features of ATM technology. However this capability is very little used in existing ATM LAN installations. There are two problems. First, most users are reluctant to incur the cost and disruption of bringing ATM to the desktop, and there are no hybrid network solutions available yet that can provide end-to-end Quality of Service over ATM backbones supporting Ethernet or Token Ring desktops. And secondly, there are few, if any, useful applications available today which can take advantage of Quality of Service.

Many network users believe that they will want to deliver real-time services such as videoconferencing and voice telephony over the LAN at some time in the future, and an investment in an ATM LAN backbone does at least provide some reassurance that this will be possible.

ATM does not, however, hold a monopoly on the concept of Quality of Service. The techniques of bandwidth reservation and flow-based queue management that were developed for ATM are now being applied in the frame-switching world. The Internet Engineering Task Force are close to defining a standard protocol for requesting bandwidth reservations for real-time flows in IP-based networks, and the IEEE 802 project which is responsible for LAN standards is developing a new specification for LAN switches to provide expedited delivery of high priority traffic.

While ATM’s proponents would argue that these new techniques can’t provide the hard guarantees of Quality of Service that ATM can, in practice they are very likely to prove quite good enough for videoconferencing and voice telephony over the LAN.

Token Ring enjoys some substantial advantages over Ethernet in its ability to handle real-time traffic. The concept of multiple levels of priority was built in to the IEEE 802.5 standard for Token Ring from the very beginning, something that is now having to be retro-fitted to Ethernet. Token Ring’s priority scheme, which all standards-compliant products must implement, enables a station on a shared ring waiting to send a real-time packet to “jump the queue” and grab the token ahead of other stations that are waiting to send lower priority data packets. Furthermore, the priority of a Token Ring packet can be preserved end-to-end across Token Ring switches and High Speed Token Ring links.

It now appears that proper exploitation of the Token Ring priority scheme across a switched Token Ring backbone incorporating HSTR can offer a viable alternative to ATM to meet future requirements for handling real-time voice and video streams.

4.4 ATM and Co-existence with Ethernet

The ATM Forum specification for LAN Emulation over ATM (LANE) defines how both Ethernet and Token Ring traffic can be carried over an ATM backbone. LANE allows both types of packet format to be carried on the same backbone at the same time. This means that physical Token Ring and Ethernet segments can be connected to the same ATM backbone. Furthermore, servers connected by ATM directly to the backbone can support both Ethernet and Token Ring LAN emulation concurrently, so that both Ethernet and Token Ring users can access the same server resources without the need for any kind of frame format translation.
This capability of ATM is very useful in situations where there are mixed LAN technologies at the same location. ATM can provide the glue that provides access to common server resources for both Ethernet and Token Ring desktops.

LANE supports the transport of both Ethernet and Token Ring traffic over ATM, but it does not intrinsically offer translation between the two. If an Ethernet user wishes to access a server that is physically attached to a Token Ring segment, then it would be necessary to provide a router in the network to link the Ethernet and Token Ring environments. This problem will be solved in the future by a more sophisticated method of carrying LAN traffic over ATM, known as MultiProtocol Over ATM (MPOA). With MPOA, the ATM network provides a distributed routing function which supports Ethernet to Token Ring connectivity.

These capabilities of LANE and MPOA make ATM a very good candidate technology for LAN backbones that must support mixed desktop technologies. High Speed Token Ring, on the other hand, provides no specific assistance with this problem.

4.5 ATM and Extensibility over the WAN

In certain situations, it becomes possible to extend the LAN environment over wide area links. Defense organizations, utilities and telecoms carriers may have their own fiber links between locations. Other enterprises may be able to lease dark fiber or high speed telecoms links such as 155 Mbps OC-3 lines.

ATM was designed to operate over long distance links at very high speeds, and the ATM interfaces that are most commonly used in LAN backbones are directly compatible with telecoms transmission facilities based on SONET (Synchronous Optical NETwork) or SDH (Synchronous Digital Hierarchy) standards. Not only that, but ATM LAN backbone interfaces may well be directly compatible with future ATM switched network service offerings from telecoms carriers.

This means that, where access to such high speed facilities is available, the ATM LAN backbone can be extended directly over the wide area. Users in one location can access server resources in another location with exactly the same level of high performance that they would see for locally-attached systems.

While it may be possible to extend HSTR over dark fiber connections or 155 Mbps OC-3 services in the future, it is likely that special, proprietary equipment would be needed to accomplish this. Connecting HSTR over switched ATM network services will require special edge switch devices.

While it will not be impossible to extend the High Speed Token Ring environment directly over fast WAN links and services in the future, it is clear that an ATM LAN backbone offers a superior solution in this area.

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5. High Speed Token Ring and Fast Ethernet Backbones

The falling cost and growing availability of Fast Ethernet switches, and the arrival of the first (pre-standard) Gigabit Ethernet switches on the scene, might suggest that these Ethernet technologies should be considered as possible backbone solutions for Token Ring networks.

5.1 Switched Ethernet and Address Bit Ordering

We have already discussed some of the issues relating to the use of Ethernet-based technologies for interconnecting Token Ring environments. The main cause of difficulty here is the bit order in the octets that make up the MAC address information in the packet headers. Ethernet uses the Canonical format, in which the first bit of each octet is the least significant, while Token Ring uses the Non-canonical format, in which the first bit is the most significant.

If bit-ordering in the MAC addresses were the only thing that needed translating to connect Token Ring to Fast Ethernet, it would be relatively easy to design silicon to carry out this conversion quickly and efficiently. But many types of packet carried on the LAN contain MAC address information embedded in the packet. For example, IP Address Resolution Protocol packets contain the MAC address of a target IP address, and this information would need to be converted when ARP packets move between Ethernet and Token Ring worlds. Also, the IPX protocol used by Novell NetWare includes MAC address information in each and every IPX packet header, and this must also be converted.

It is certainly possible to develop a translation algorithm that deals with most common types of LAN traffic passing between Token Ring and Fast Ethernet, but the algorithm is complex and involves a good deal of processing on each and every packet. The cost of carrying out this processing while maintaining adequate throughput is a major issue.

Connecting Token Ring by means of High Speed Token Ring links, on the other hand, requires no frame translation whatsoever. Fast and very cost-effective solutions for HSTR backbones can therefore be anticipated.

5.2 Switched Ethernet and Source Routing

Current standards for Ethernet and Fast Ethernet do not provide any support for source routing. Where source routing is used over Token Ring, the switches that connect to Fast Ethernet must remove source routing information from packets being sent over Ethernet links, and must put back source routing information from a route cache into packets coming from Ethernet links. This adds further to the complexity of the packet processing.

An attempt is currently being made by the IEEE 802.1Q working group to define a frame tagging standard that, among other things, allows source routing information to be encapsulated in a special tag attached to packets being sent over Ethernet links. This technique preserves source routing information end-to-end, but it does not allow for the load-sharing features of source routing to be exploited over the Ethernet links.

High Speed Token Ring, by contrast, supports the full native implementation of Token Ring source routing end-to-end.
5.3 Switched Ethernet and Frame Sizes

The Ethernet specification designates a maximum frame size of 1518 octets. The vast majority of Ethernet equipment is not able to handle frame sizes that are significantly larger than this. Token Ring, on the other hand, permits frame sizes up to 18k octets, although most practical applications of Token Ring use a maximum frame size of 4096 octets.

This creates a difficulty when attempting to use Fast Ethernet as a Token Ring backbone, in that the end stations on Token Ring must be reconfigured to limit their maximum frame size to 1518 octets for compatibility with the Ethernet portions of the network. Apart from the effort required to carry out this reconfiguration of every end station, there is also the issue that smaller frame sizes reduce efficiency and impair performance. Users will see data transfers running more slowly than they are used to following this change. (See Figure 3).

For networks that are running only routable protocols such as IP and IPX, routers can provide an alternative solution here. By connecting Token Ring to Fast Ethernet through a router, IP packets coming from Token Ring can be fragmented by the router before onward transmission over Ethernet. End stations using IPX to communicate through a router will automatically default to a packet size of 512 octets.

Using routers to create a Fast Ethernet backbone for Token Ring is, however, a costly approach that will deliver relatively poor performance. High Speed Token Ring, on the other hand, will support the full range of Token Ring packet sizes, and requires no end-station re-configuration or packet fragmentation techniques.

![Figure 3: Typical relationship between packet size and workstation data throughput (Win 95)]
Figure 4: Fault tolerant Token Ring network with High Speed Token Ring backbone
6. Conclusion

Token Ring users who need to upgrade backbone capacity and provide higher speed server connections now have a brand new technology option: High Speed Token Ring. HSTR is the only alternative to ATM that can provide really cost effective, fault tolerant, high performance backbones for Token Ring users. (See Figure 4).

ATM is likely to remain the preferred LAN backbone choice of those who need to accommodate mixed Ethernet and Token Ring in the LAN, those who must have guaranteed Quality of Service in the LAN, and those who need to extend the LAN backbone environment seamlessly across high speed WAN links. But other Token Ring users need look no further than HSTR.

First generation HSTR products provide a six-fold increase in link capacity over conventional 16 Mbps full duplex Token Ring, more than enough for a massive boost to backbone and server access capacity. And future generations of HSTR technology will deliver Gigabit speeds, dispelling any doubts about scaleability.

Supporting native Token Ring frame formats, Token Ring source routing and the larger packet sizes used on Token Ring, HSTR provides a no compromise backbone upgrade for the most demanding of Token Ring users.