Agilent Technologies

Fundamentals of Testing in Local Area Networks

White Paper

By Othmar Kyas
Product Marketing Manager

Agilent Technologies
Network Systems Test Division

Agilent Technologies

Contents

Introduction .... page 3

Basic Concepts .... page 3

LAN Topologies: Bus, Ring, Switch .... page 3

- **Data Communications Using the Broadcast Principle** .... page 4

Structure and Operation of Switching Systems .... page 5

- **Cell Switching and Frame Switching** .... page 5
- **Segment Switching (LAN Switching)** .... page 7
- **Full-Duplex Connections** .... page 8

Standards for Local-Area Data Networks .... page 9

Testing in Local-Area Data Networks .... page 10

- **Signal Condition Measurements** .... page 10
- **Protocol Analysis and Statistical Measurements** .... page 10

The Agilent Advisor LAN Analysis System .... page 13

- **Expert Advisor** .... page 13
- **Protocol Commentators.** .... page 14
- **LAN Advisor Feature Highlights** .... page 14

About the Author .... page 15

Introduction

Local-Area Networks (LANs) use digital data communication technologies to connect workstations and storage devices across multiple locations. LAN technology has progressed rapidly since its introduction in the 1980s, with new interfaces and techniques enabling systems to keep up with the growing use of multimedia and distributed applications in workgroups. This paper presents an overview of LAN technologies and how they have developed since the 1980s and discusses techniques and tools for testing LAN performance.

Basic Concepts

LANs operate over much shorter distances than those covered by wide-area networks. This is why only baseband systems are used in LANs. Baseband data communication involves the digital transmission of data as sequences of voltage states or light pulses that represent logical ones and zeros. In local-area networks, the digital data streams are encoded before transmission to optimize data rates and minimize transmission errors. The line encoding schemes used in the various LAN technologies include the following:

- Simple Manchester encoding (10base-T)
- Differential Manchester encoding (Token Ring)
- 4B5B encoding (FDDI, 100base-TX, 100base-FX)
- 8B6T encoding (100base-T4), 8B10B (Gigabit Ethernet)
- CAP-4, CAP-64 encoding (ATM over UTP3)
- NRZ encoding (ATM over UTP5, STP)

Another technique that can optimize data rates even in lower-quality cables such as UTP3 (Category 3 unshielded twisted-pair copper cable) involves using more than two data lines for transmission. For example, in a Fast Ethernet LAN with UTP3 cabling (100base-T4), three-wire pairs are used to transfer user data, while a fourth pair is used for collision detection. The 8B6T encoding technique reduces the transfer rate of the 100 Mbit/s data stream to 75 Mbit/s by encoding every 8 data bits in 6 tri-state symbols, which are then distributed over three-wire pairs at 25 Mbit/s per pair. The resulting bandwidth is barely higher than that of 10 Mbit/s Ethernet, which uses the simple Manchester scheme to encode 10 Mbit/s data streams in 20 Mbit/s signals.

LAN Topologies: Bus, Ring, Switch

Significant developments in LAN communication techniques and data speeds have taken place in recent years. In the 1980s, the classic 10 Mbit/s Ethernet bus topology led the field, joined later by Token Ring and FDDI ring topologies. The principle of network switching, originally implemented for wide-area networks, became established in the 1990s as a LAN technology.

At the beginning of the 1990s, more than 90% of LANs were still using technologies developed the decade before: 10 Mbit/s Ethernet (IEEE 802.3, 1982) and 4 or 16 Mbit/s Token Ring (IEEE 802.5, 1985). As microprocessors became ever faster, opening the door to increasing use of multimedia and distributed applications, the number of stations per network had to be reduced, since no corresponding increase in data speeds was supported in the relevant standards. Just a few years ago, it was not unusual to have more than 300 nodes in a 10 Mbit/s Ethernet/802.3 network. Today, the typical number of stations in a similarly equipped network segment is generally between 10 and 20, and the trend is toward even fewer.

A new LAN specification was developed at the end of the 1980s, called Fiber Distributed Digital Interface (FDDI). FDDI is a fiber-optic ring topology with a throughput of 100 Mbit/s. Although this technology made it possible to implement the first high-performance backbone structures, market acceptance was halting due to the expensive hardware components required, such as lasers in the network interface cards, and fiber optic cable infrastructures. Furthermore, it soon became evident that even a bandwidth of 100 Mbit/s, when shared among all network nodes, would not be sufficient for the emerging multimedia applications. This meant that FDDI was a medium-term solution at best. Still, for lack of a better alternative, a large number of backbones were restructured to use FDDI technology in the years following its introduction. This trend changed, however, as LAN switching, 100/1000 Mbit/s Ethernet, and ATM entered the market in the mid-1990s.

Data Communications Using the Broadcast Principle

The LAN technologies developed in the 1980s, such as Ethernet, Token Ring and FDDI, are based on the "broadcast“ principle: every data packet transmitted is received by every station in the network. Each station must analyze the destination address information in every packet to determine whether it should accept the packet, or simply ignore or forward it. The more nodes in a given network, the higher the network load, and the more time each node spends evaluating addresses in packets that turn out to be for other nodes. In the first few years following the introduction of local-area networks, this was not seen as a problem, because the amount of bandwidth available in the network nodes was huge, compared to the transmission capacity of any single station. More than a hundred network nodes could communicate over a single transport medium without difficulty. With the advances in computer system performance, however, bottlenecks soon developed (see Figures 1 and 2). This is why networks today are divided into segments, which are interconnected by selective devices such as bridges and routers. With this new technology, local data remains on the local segment, and neighboring segments are not unnecessarily burdened with foreign traffic.

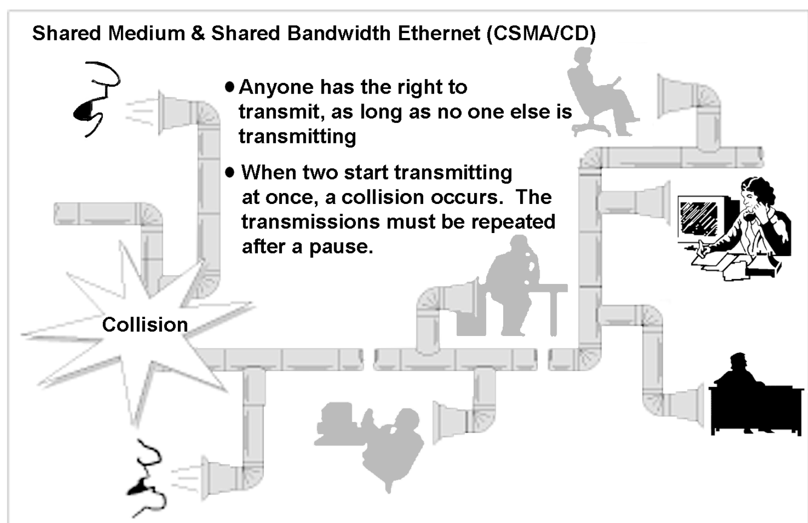

Figure 1: Principles of data communication in local-area networks in the 1980s: CSMA/CD and Ethernet

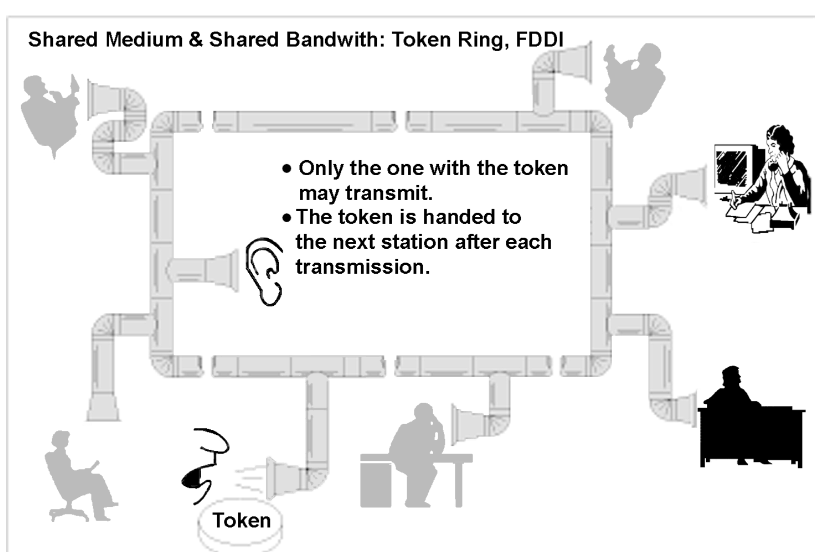

Figure 2: Principles of data communication in local-area networks in the 1980s: Token Ring and FDDI

Structure and Operation of Switching Systems

Wide-area networks have a different structure from local-area networks, due to the simple fact that WANs cover distances up to hundreds of kilometers, while LANs usually span no more than several hundred meters. The need for technologies that could transfer data over long distances led to the development of large network switching systems. WAN switches forward incoming packets directly to the switch output port that leads to the packet's destination segment, as illustrated in Figure 3. Outgoing packets are multiplexed with data from other connections and transmitted over high-speed lines.

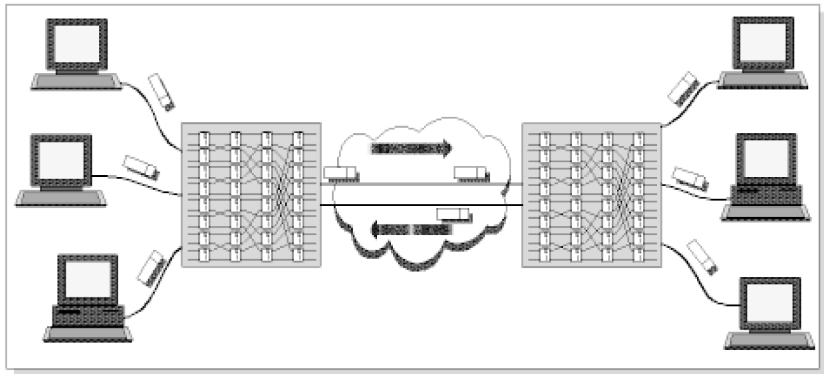

Figure 3: Switching and multiplexing in wide-area data communication

The development of economical, high-performance microprocessors and chipsets in the early 1990s paved the way for the development of complex switching and multiplexing technologies for data communication in local-area networks. Since then, the use of switching equipment in LANs has increased steadily.

The central component of switched networks is the switch, which has the task of forwarding incoming packets to the appropriate output port as quickly as possible, with a minimum of collisions. Switching technologies can be classified by distinguishing between cell switching and frame switching, as well as between single-frame and multi-frame switching.

Cell Switching and Frame Switching

In cell switching networks, all data packets, or "cells," have the same length. This allows cell-switching systems to achieve faster throughput than frame-switching systems, in which data packets can have varying lengths. Because the cells arriving synchronously on all input ports are all the same size, they can all be forwarded simultaneously to their output ports, in one working cycle of the switch.

This regular processing pace cannot be achieved in frames, since they may differ in length by as much as several hundred percent. Ethernet packets, for example, are from 64 to 1518 bytes long, while packet lengths in Token Ring and FDDI have even broader ranges (see Table 1).

Table 1: Variations in packet length: Ethernet, Token Ring, FDDI

Network Type	Minimum Packet Length	Maximum Packet Length	Ratio
Ethernet	64 bytes	1,518 bytes	1:23
Token Ring	13 bytes	4,500 bytes (4 Mbit/s)	1:346
		17,800 bytes (16 Mbit/s)	1:1369
FDDI	12 bytes	4,500 bytes	1:375
ATM	53 bytes	53 bytes	1:1

A frame-switching system cannot attain the processing efficiency of a cell-switching system (see Figure 4). A short packet can be switched from input port A to output port B in a fraction of the time it takes to transfer a longer packet from input C to output D. This increases the likelihood that packets will be blocked when two or more compete for the same output port. In the time it takes an Ethernet packet of maximum length to be sent over port D, up to 23 minimum-length packets of 64 bytes may be blocked while trying to reach the same output port (assuming the switch in question has two input ports and two output ports). The blocked packets are either stored in a buffer or discarded. In a comparable cell-based system, a given cell cannot block more than one other cell.

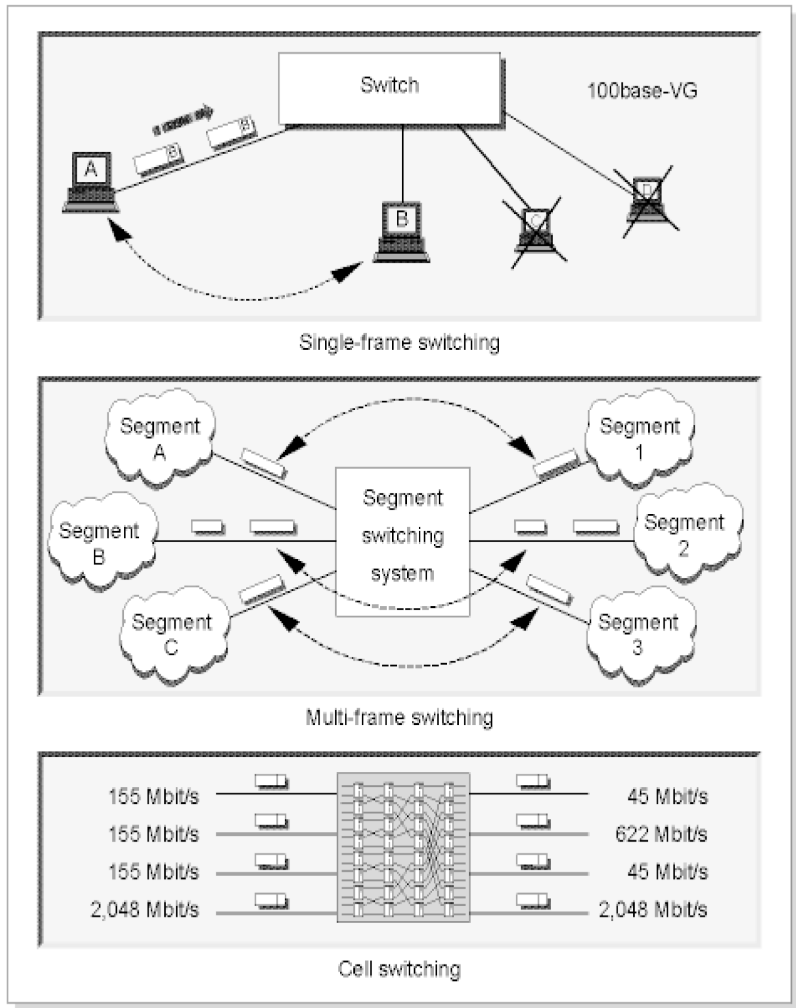

Figure 4: Frame switching and cell switching

Segment Switching (LAN Switching)

Segment switching is a special implementation of the switching principle, and is used to link traditional LAN topologies (Ethernet, Token Ring and FDDI) in a high-performance network. LAN segments are connected by switches that forward incoming packets to their destination segments. Like bridges, LAN switches stop packets from being sent to other connected segments if their destination is on the source segment. This allows multiple simultaneous communication connections between segments. This ability to process communications in parallel is the primary advantage of LAN switching. A LAN switch deployed in place of a bridge for inter-segment communication increases the available bandwidth several times over (see Figure 5).

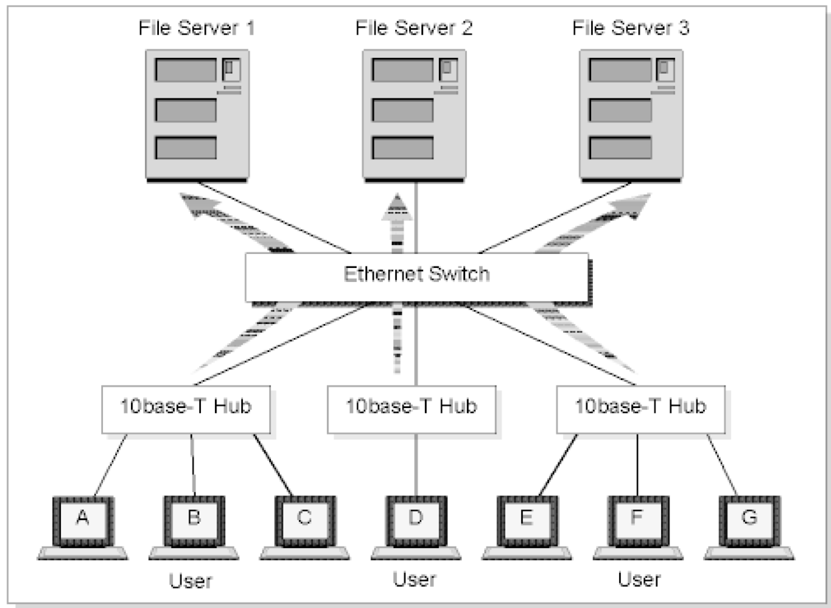

Figure 5: The principle of LAN switching systems

A six-port LAN switch, for example, can create up to three parallel data communication paths. If Station A accesses Server 1, Station B accesses Server 2 and Station C accesses Server 3 at the same time over 10 Mbit/s media (see Figure 5), the LAN switch provides three parallel 10 Mbit/s connections for a total bandwidth of 30 Mbit/s. Data packets are transferred within the switching systems at extremely high speeds by means of ASICs (application-specific integrated circuits). Packets are buffered only until the complete destination address is received. Once the address is complete, it is analyzed and the packet is forwarded immediately. This reduces the latency of each packet to about 40 µs.

In the example described above, the cumulative inter-segment bandwidth reaches 30 Mbit/s only because three independent communication paths are involved. If stations A, B and C all attempt to access Server 1, the available bandwidth remains 10 Mbit/s, even though a switch is used. Server 1 cannot use more than the 10 Mbit/s bandwidth theoretically available in its Ethernet segment.

LAN switching systems are available for all established LAN topologies: 10/100/1000 Mbit/s Ethernet, Token Ring and FDDI.

Full-Duplex Connections

By definition, all three of the traditional LAN types—Ethernet, Token Ring and FDDI—are half-duplex technologies. This means that a given station can either receive or transmit data, but not both simultaneously. Many switching systems, however, provide both half and full-duplex modes, especially for connecting server systems to LAN switches, and for increased throughput in connections between individual LAN switches. The full-duplex mode allows simultaneous transmission and reception of data, which effectively doubles the available bandwidth of the link.

Full-duplex techniques can only be used in point-to-point topologies, in which media access no longer needs to be regulated by CSMA/CD (in Ethernet) or token passing (in Token Ring and FDDI). This means that where full-duplex components are used, the network is no longer connected through passive hubs or concentrators, but only through full-duplex Ethernet, Token Ring or FDDI switches. Otherwise, only two network nodes (such as two servers, for example) can be connected using full-duplex technology. The full-duplex operating mode increases the theoretical bandwidth from 10 to 20 Mbit/s in Ethernet networks, from 4 (or 16) Mbit/s to 8 (or 32) Mbit/s in Token Ring, and from 100 to 200 Mbit/s in FDDI. In addition to the traditional LAN technologies, the newer high-speed networks can also be operated in full-duplex mode, so that Fast Ethernet can provide not 100 but 200 Mbit/s, and STM-1 ATM not 155 but 310 Mbit/s. Figure 6 shows segment switching in a full-duplex Token Ring system.

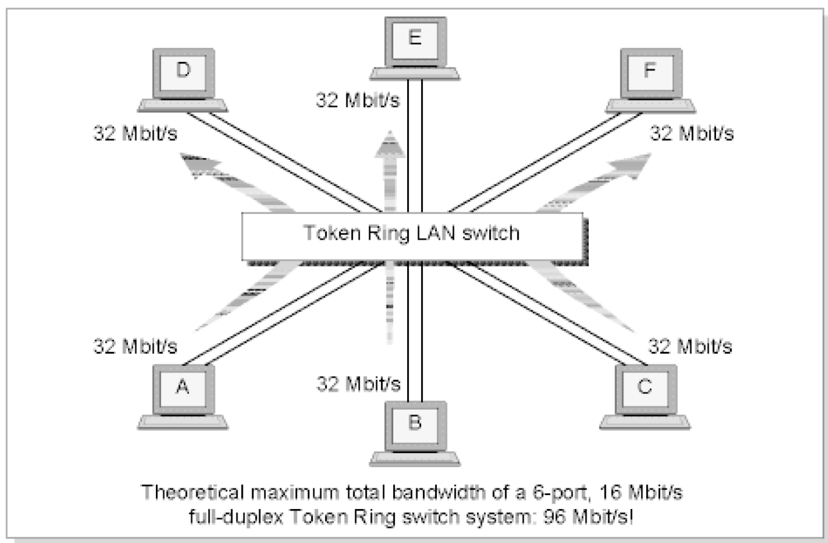

Figure 6: Segment switching and full-duplex Token Ring

Standards for Local-Area Data Networks

Unlike the specifications for wide-area networks, most of which are defined by ITU working groups, standards for LAN technologies are defined by the Institute of Electrical and Electronics Engineers (IEEE) and various industry forums. Table 2 gives an overview of the various LAN standards, along with their communication characteristics.

Table 2: Standards and Characteristics of LAN Technologies

Technology	Standard	Application	Architecture
ATM	ITU T Series recommendations / ATM Forum standards	Data, voice, multimedia	Multi-cell switching
100base-VG	IEEE 802.12	Data, multimedia	Single-frame switching DP protocol, half-duplex
100base-T	IEEE 802.30	Data	Shared media, half-duplex, CSMA/CD
Gigabit Ethernet	IEEE 802.3z	Data, limited multimedia	Shared media, half-duplex, CSMA/CD
1000base-T	IEEE 802.3ab ANSI X3T9.5	Data, limited multimedia	Shared media, half-duplex, CSMA/CD
FDDI	ISO 9314	Data, limited multimedia	Shared media, half-duplex, token passing
Fibre Channel	ANSI X3T9.3	Data	Multi-frame switching
Isochronous Ethernet combined	IEEE 802.9	Data, voice, limited multimedia	Shared media CSMA/CD with ISDN
Full duplex Ethernet 10/100/1000	IEEE 802.3x	Data, multimedia	Shared media, full-duplex point-to-point
Full duplex Token Ring	No standard, IEEE 802.5 data format	Data, multimedia	Shared media, full-duplex point-to-point
Full duplex FDDI	No standard, ANSI X3T9.5 data format	Data, multimedia	Shared media, full-duplex point-to-point
Switched 10base-T	No standard, IEEE 802.3 compatible	Data, limited multimedia	Multi-frame switching
Switched Token Ring	No standard, IEEE 802.3 compatible	Data, limited multimedia	Multi-frame switching
Switched FDDI	No standard, ANSI X3T9.5 compatible	Data, limited multimedia	Multi-frame switching
Switched 100base-T	No standard, IEEE 802.3 compatible	Data, limited multimedia	Multi-frame switching
Switched 100base-VG	No standard, IEEE 802.12 compatible	Data, multimedia	Multi-frame switching

Testing in Local-Area Networks

LAN testing provides information about the operational state of individual LAN components, as well as characteristics of the data packets being transmitted. The two testing methods discussed in this section are signal condition measurements, protocol analysis, and statistical measurements.

Signal Condition Measurements

Signal condition measurements involve using an oscilloscope to determine physical signal shapes. The signals can be measured either directly at a connector or on a coaxial or twisted-pair cable. For example, signals could be measured at transceivers, or at the interfaces of active network components, such as repeaters, bridges, or routers. Information about the quality of the cable infrastructure, media access unit, or interface under test can be determined from the signal shapes displayed on the oscilloscope. Signal condition measurements are not as significant in LANs as they are in WANs, however, because the signals only travel relatively short distances and deterioration is relatively minor. In troubleshooting, however, and especially in diagnosing faulty interfaces in network nodes, repeaters, or bridges, or when dealing with problems in the cable infrastructure, signal condition measurements are very useful for narrowing down the range of possible causes.

Protocol Analysis and Statistical Measurements

A protocol analyzer records and interprets data packets transmitted over the network. This process makes it a useful tool for monitoring packet types and protocol processes, as well as for collecting statistical data and identifying trends. The protocol analyzer is attached like any other network node to the LAN segment under test, as shown in Figure 7. In broadcast LAN topologies, such as 10/100/1000 Mbit/s Ethernet, 4/16 Mbit/s Token Ring and FDDI, the protocol analyzer can then monitor and analyze all communication on the segment.

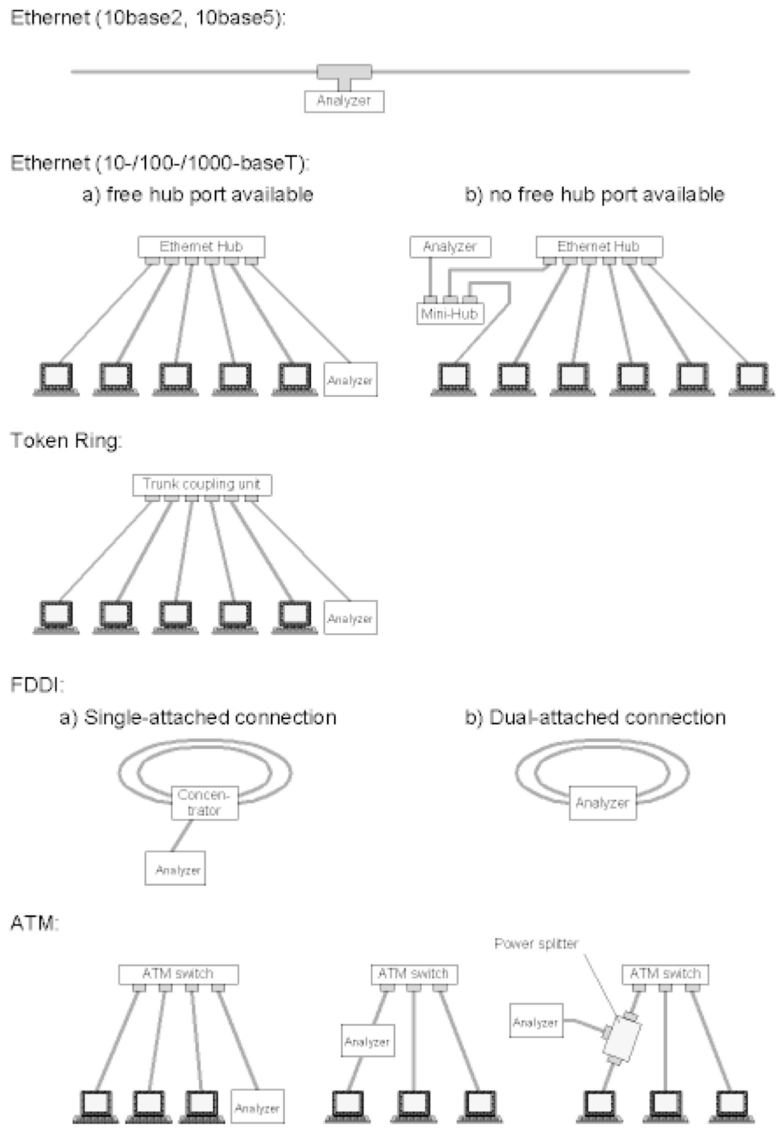

Figure 7: Connecting LAN protocol analyzer systems

The protocol analyzer can monitor only the segment in which it is installed. Traffic that is beyond a bridge or router cannot be tested because it is precisely the task of the router or bridge to limit local traffic to its segment of origin. To analyze traffic in two segments simultaneously—to observe inter-segment traffic as it crosses a particular router or bridge, for example—a protocol analyzing system with two ports is required. It is not possible to monitor several segments at once with a single-port device, for the simple reason that the device cannot be connected in two places at one time. Network-wide monitoring is performed by a system of probes, usually with agents installed in all LAN segments. These agents collect pertinent data and time-stamp it, then transmit it using the Simple Network Management Protocol (SNMP) to a central network monitoring station, where it is correlated and analyzed.

It is more difficult to perform network analyses in topologies based on the switching principle, such as switched LANs or ATM networks. Unlike Ethernet hub or ring concentrator ports, each port on a LAN or ATM switch transmits only those packets that are addressed to the connected segment or node. If a given LAN or ATM switch port is connected only to a single station, then each protocol analyzer port can monitor only one connection.

To monitor all switch ports simultaneously, a multiport analyzer system has been developed for use in switched-LAN environments. This sytem comes with 4, 8, 12 or more ports and can be used to monitor the corresponding number of switch ports. Alternatively, many switches offer the option of defining unused ports as test ports, and can be configured to copy data packets from the active ports to these designated test ports. This allows a single analyzer port to monitor data from a number of active switch ports. When the switch is operating at peak loads, however, the capacity of individual test ports is not sufficient to monitor all, or even a few, ports reliably, since the test port usually has the same total capacity as any one of the ports being monitored. Data packets that exceed the test port capacity are discarded at random. Figure 8 shows connection options for a protocol analyzer in a switched LAN.

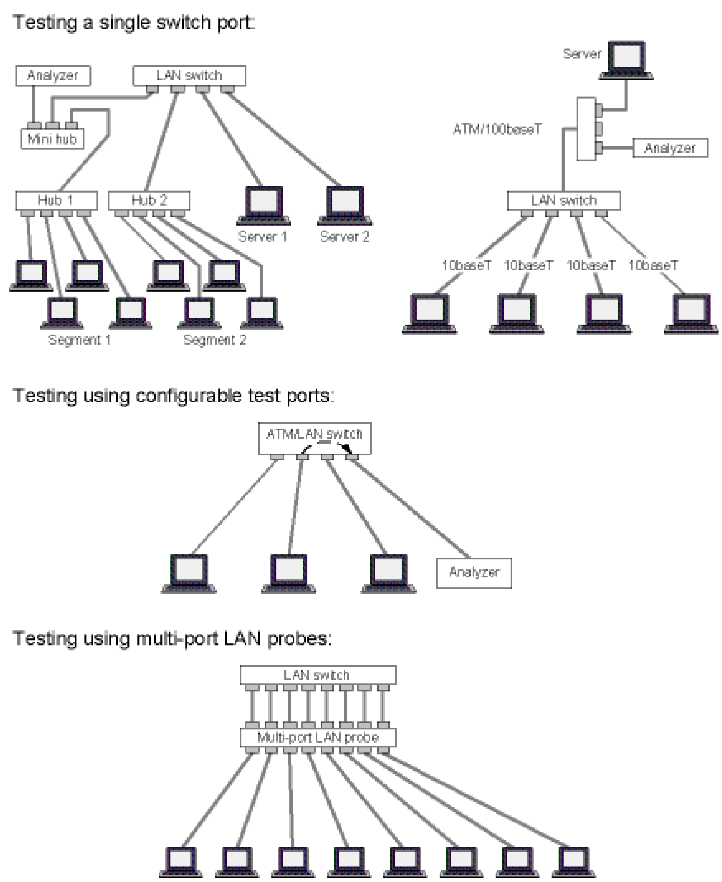

Figure 8: Connection options for protocol analyzer systems in switched LANs

LAN Analysis System
The Agilent Advisor

The Agilent LAN Advisor product suite makes it easier than ever before to get top performance, reliability, and uptime from your mission-critical networks. Ethernet, 4/16 Token Ring, or FDDI networks. With the LAN Advisor, you can connect virtually anywhere in the network and capture the data you need to clearly understand what is going on and what is required to solve and prevent networ.k problems

Expert Advisor

LAN Advisor is equipped with an Expert Advisor, a tool that gives you an instantaneous view of the key issues and overall health of the network. Use and significant events can be seen graphically and by protocol. You can obtain further details when focusing on specific items of interest, like the client-server connection with a slow file transfer rate.

As you monitor traffic, the LAN Advisor transforms data into meaningful diagnostic information, constantly monitoring the traffic on your network. The Expert Advisor (shown in Figure 9) reduces thousands of frames to a handful of significant events, including watching continuously for router misconfigurations, slow file transfers, inefficient window sizes, and connection resets. It can watch for all of these events in real time and for each protocol stack – as the events occur.

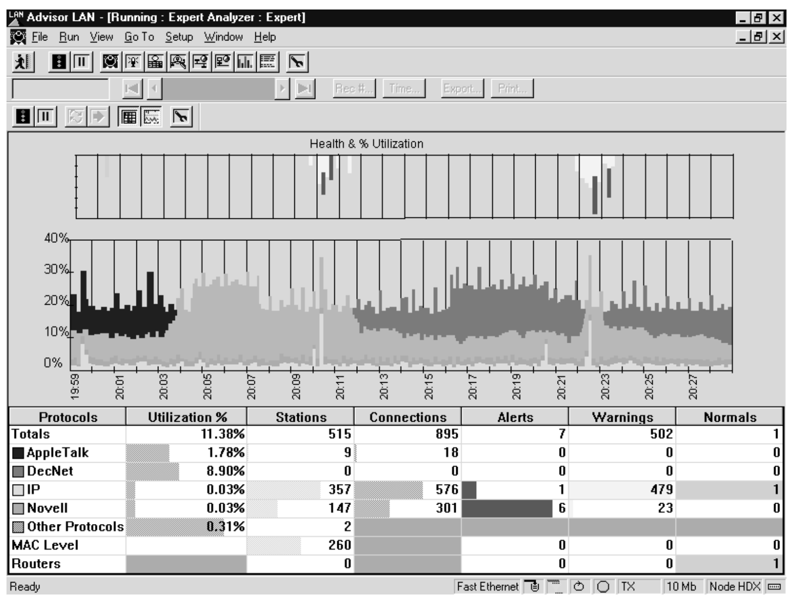

Figure 9: Agilent LAN Advisor Main Menu

Protocol Commentators

Need yet more detail than the Expert Advisor provides? The protocol commentators log and link events, corresponding captured frames. The result? You can easily scroll through the capture buffer to see the events that led up to the occurrence and view the details of the event itself.

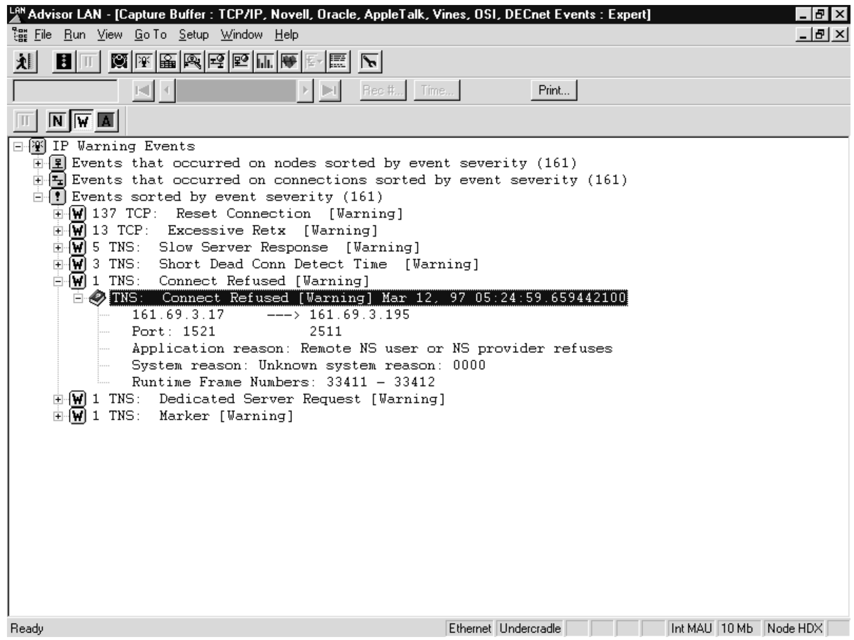

Figure 10: Protocol Commentator Main Screen

LAN Advisor Feature Highlights

Real-Time Data Capture and Display of Network Health

- Overview of network health indicates when action is required
- Clearly indicates who is using the bandwidth and how it is being used
- Rapid identification and resolution of errors keeps the network up and running
- Network use by protocol shows overall network activity

Guided Troubleshooting

- Continuous feedback on key network issues
- Problems identified by severity to prioritize troubleshooting
- Drill-down sequences enable fast fault isolation without extensive protocol knowledge
- Intuitive Windows® 98 user interface enhances productivity
- Extensive on-line help explains problems and recommends solution

Information for Understanding Network Issues

- Flexible filtering for selecting only the required data
- Connection analysis to understand traffic patterns
- Export statistics to the Internet Reporter for long-term trend analysis

Database Analysis and Optimization for Sybase and Oracle

- Identifies problems accessing the database
- Helps tune performance by showing response and transmission times
- Identifies security violations

Performance Measurements

- Expert Advisor – graphs utilization and health over time, provides summary information on connections, protocols, and network events of interest
- Commentator – detailed list of network events on connections and on nodes
- Protocol statistics – detailed view of the active protocols on the network, including utilization statistics, number of errors and average frame size

Advanced Traffic Generation and Packet Editing Functionality

- Active stimulus/response tests to troubleshoot a production network
- Test new equipment or configurations before deploying them in the network

Advisor Reporter

- Extends the capabilities of the LAN Advisor into the world of baselining and benchmarking
- Uses information gathered by the LAN Advisor to produce high quality, professional reports

About the Author

Othmar Kyas is the Product Marketing Manager for the Network Systems Test Division of Agilent Technologies. With over 11 years at Agilent (formerly Hewlett-Packard), Othmar has led the way in developing Agilent's telecommunications products. Othmar holds an M.S. degree in Electrical Engineering from the University of Technology, Vienna, which has enabled him to contribute significantly to Agilent's product offerings in WAN, LAN, and ATM technologies.

In addition to speaking at seminars and trade shows, Othmar is recognized internationally as a renowned author of several books in data communications and telecommunications. Many of these have been translated into Japanese, Danish, Russian, English, and German. Books authored by Othmar include the following:

- ATM Networks
- Internet Security
- Corporate Intranets
- Fast Ethernet
- Internet for Professionals
- LAN/WAN Troubleshooting

www.agilent.com

Agilent Technologies' Test and Measurement Support, Services, and Assistance

Agilent Technologies aims to maximize the value you receive, while minimizing your risk and problems. We strive to ensure that you get the test and measurement capabilities you paid for and obtain the support you need. Our extensive support resources and services can help you choose the right Agilent products for your applications and apply them successfully. Every instrument and system we sell has a global warranty. Support is available for at least five years beyond the production life of the product. Two concepts underlie Agilent's overall support policy: "Our Promise" and "Your Advantage."

Our Promise
Our Promise means your Agilent test and measurement equipment will meet its advertised performance and functionality. When you are choosing new equipment, we will help you with product information, including realistic performance specifications and practical recommendations from experienced test engineers. When you use Agilent equipment, we can verify that it works properly, help with product operation, and provide basic measurement assistance for the use of specified capabilities, at no extra cost upon request. Many self-help tools are available.

Your Advantage
Your Advantage means that Agilent offers a wide range of additional expert test and measurement services, which you can purchase according to your unique technical and business needs. Solve problems efficiently and gain a competitive edge by contracting with us for calibration, extra-cost upgrades, out-of-warranty repairs, and on-site education and training, as well as design, system integration, project management, and other professional engineering services. Experienced Agilent engineers and technicians worldwide can help you maximize your productivity, optimize the return on investment of your Agilent instruments and systems, and obtain dependable measurement accuracy for the life of those products.

By internet, phone or fax, get assistance with all your Test and Measurement needs.

Online assistance:
http://www.agilent.com/find/assist

United States:
(Tel) 1 800 452 4844

Canada:
(Tel) 1 877 894 4414
(Fax) (905) 282 6495

China:
(Tel) 800-810-0189
(Fax) 1-0800-650-0121

Europe:
(Tel) (31 20) 547 2323
(Fax) (31 20) 547 2390

Japan:
(Tel) (81) 426 56 7832
(Fax) (81) 426 56 7840

Korea:
(Tel) (82-2) 2004-5004
(Fax) (82-2) 2004-5115

Latin America:
(Tel) (305) 269 7500
(Fax) (305) 269 7599

Taiwan:
(Tel) 080-004-7866
(Fax) (886-2) 2545-6723

Other Asia Pacific Countries:
(Tel) (65) 375-8100
(Fax) (65) 836-0252

Printed in U.S.A. January 22, 2002

5980-1296E

Use this link to go directly to our network troubleshooting solutions:
http://www.agilent.com/comms/onenetworks

Agilent Technologies