1994
NASA/ASEE SUMMER FACULTY FELLOWSHIP PROGRAM

MARSHALL SPACE FLIGHT CENTER
THE UNIVERSITY OF ALABAMA

MSFC INSTITUTIONAL AREA NETWORK AND ATM TECHNOLOGY

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1. INTRODUCTION

The New Institutional Area Network (NEWIAN) at Marshall supports over 5000 end users with access to 26 file servers providing Work Presentation Services. It comprises of some 150 Ethernet LANs interconnected by bridges/routers which are in turn connected to servers over two dual FDDI rings. The network supports various higher level protocols such as IP, IPX, AppleTalk (AT), and DECNet. At present IPX and AT protocols packets are routed, and IP protocol packets are bridged, however work is in progress to route all IP packets. We examine the impact of routing IP packets on the network operation.

Broadband Integrated Services Data Network (BISDN), presently at various stages of development, is intended to provide voice, video, and data transfer services over a single network. BISDN will use Asynchronous Transfer Mode (ATM) as a data transfer technique which provides for transmission, multiplexing, switching, and relaying of small size data units called cells. Limited ATM Wide Area Network (WAN) services are offered by Wiltel, AT&T, and Sprint and others. NASA is testing a pilot ATM WAN with a view to provide Program Support Communication Network services using ATM. ATM supports wide range of data rates and quality of service requirements. It is expected that ATM switches will penetrate campus networks as well. However, presently products in these areas are at various stages of development and standards are not yet complete. We examine development of ATM to help assess its role in the evolution of NEWIAN.

2. ROUTING VERSUS BRIDGING OF IP IN THE NEWIAN

The Internet Protocol (IP) is the network layer protocol of the TCP/IP suite of protocols. The unit of the data transferred between network layer entities is called a packet. A host on the Internet has a globally unique 32-bit IP address and is typically written in the form $X3.X2.X1.X0$, where for $i = 0,1,2,3$ the value of Xi is between 0 and 255. The IP addresses are organized in hierarchical fashion in the form of (class, net-id, host-id), where the class is A, B, or C. The Class A addresses are intended for a small number of large size networks while the Class C addresses are intended for a large number of small size networks. An IP address of a network layer entity is globally unique and the net-ids are centrally administered. For example, Marshall with medium size network has a Class B net-id with address 128.158.0.0. Often it is the case, as with the NEWIAN, that host-ids within a network are organized by the network administrator so that the higher order bits of the host-id represent the subnet-id. A host on an Internet needs to know the IP address of the remote host to be able to send a packet to it. For transmission over an Ethernet, an IP packet is encapsulated in an Ethernet frame as shown in Figure 1.

LANs may be interconnected by Bridges at the link level or by Routers at the network level. A bridge/router, called Brouter, permits bridging of some protocols while routing of other protocols. In the NEWIAN a Brouter is used with two types of ports- an Ethernet port, and a FDDI port. A Brouter is connected to a number of 10Mbps Ethernets, and the Brouters are interconnected over one or two dual 100Mbps FDDI

rings. The file servers are connected to one of the FDDI ring and the end user devices are connected to Ethernets. Thus, all the end users are one or at most two Brouters away from the servers.

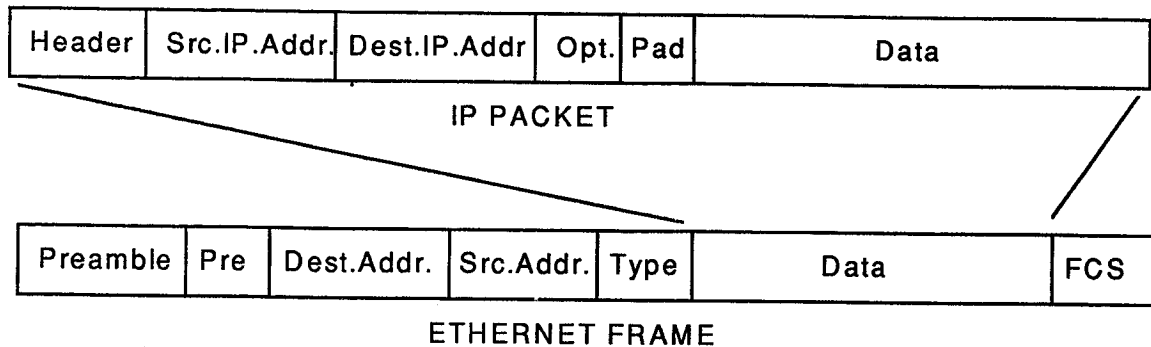## 2.1 Bridging of IP in the NEWIAN

Two or more Ethernets may be connected at the MAC layer by a *Bridge* to create what we will call an *Extended LAN*. Each LAN connects to a port on a Bridge. The Bridge receives frames from all the LANs connected to it. A routing table is maintained in the Bridge which associates with the MAC address of each end user on every LAN in the NEWIAN one of its ports. The action taken by the Bridge upon receipt of a frame is as follows. If the destination MAC address of the frame is associated with same port on which it was received, then the frame is discarded; otherwise, the frame is routed on the port associated with the destination MAC address on the frame in the routing table. When the LAN on which a frame is received is of different type than on which the frame is to be routed, a frame translation is performed at the Bridge. A broadcast frame or a frame with destination MAC address not in the forwarding table is forwarded on all other ports of the bridge.

Since bridging is independent of higher level protocols, it supports multiple higher level protocols in the network. It is seen that a broadcast frame on a LAN will be forwarded to every LAN in the network. This often creates much unnecessary traffic referred to as 'broadcast storm', unless some additional 'filtering' capability is provided in the bridge. Further, in a bridged network, a user must know the MAC address of the remote entity on the network to communicate. This creates a situation with IP packets which results in undesirable broadcast traffic. Suppose a source host on a LAN has to transmit a IP packet to a destination host, on the network, whose IP address is known but the MAC address is not known. The problem of mapping a given IP address to associated MAC address is referred to as the Address Resolution Problem. Address Resolution Protocol (ARP) permits a source host to obtain the MAC address of the destination host from the IP address of the destination host. An ARP packet broadcast is received by all the hosts on the network, and the destination host will respond to the ARP packet and send its MAC address to the source host. A recent occurrence of the following rather peculiar situation on the NEWIAN indicates how the effect of the broadcasts can be compounded. An X-terminal transmits a broadcast message to locate a server to setup an X-connection. A number of servers responding to the broadcast send ARP broadcast to determine the MAC address of the X-terminal, resulting in multiple broadcasts.

2.2 Routing of IP Packets in the NEWIAN

A Router is a device rooted in the TCP/IP view of the communication subnet as consisting of interconnected networks (Internet) in which routing between networks is provided by Routers connecting two or more networks. A Router port connecting to a network has a unique IP address on that network. A host on a network can send IP packet directly to another host on the same network, however a packet to a host on

another network is sent to a nearest Router on the same network. A Router maintains a table which associates one or more IP addresses of Routers with each network-id. A packet with destination net-id of a network connected to the Router is sent directly to the destination host, otherwise it is routed to an appropriate Router based on the routing table. A Router also provides segmentation when routing a packet over a network with maximum packet size is smaller than the received packet size. A Router provides the functionality's of the lower three layers of the ISO model, namely, the network, the link, and the physical layers. Earlier literature on TCP/IP refers to a Router as a Gateway. However, the term Gateway refers to a device which provides functionality's of all seven layers of the ISO Model.

Header	Src.IP.Addr.	Dest.IP.Addr	Opt.	Pad	Data

IP PACKET

Preamble	Pre	Dest.Addr.	Src.Addr.	Type	Data	FCS

ETHERNET FRAME

An IP Packet Encapsulated in an Ethernet Frame
Figure 1.

Two or more Ethernets may be interconnected at the network layer by a *Router* to create a subnetwork. A Router port connected to a LAN has a unique MAC address associated with that port as well a unique IP address. A Router maintains a routing table associating MAC address and the port-id with the IP address of each Router on the NEWIAN and of each IP host in the subnet defined by the Router. Routing of packets from source host to destination host on the network is based on the destination host-id contained in the packet header. A Router receives only those frames on a port that are addressed to it. A received frame is processed and the packet is routed based on the destination IP address on the packet. Routing a packet over a LAN requires encapsulation of the IP packet in an Ethernet frame as shown in Figure 1. A packet with destination net-id other than that of MSFC is routed to the PSCN Router. A packet is routed directly to the destination host over associated port if the destination subnet-id is the same as the of the receiving Router, otherwise it is routed to the Router with the same subnet-id as its destination subnet-id.

2.3 A Comparison of Bridging versus Routing of IP in the NEWIAN

A comparison of routing and bridging of IP packets is presented with respect to its impact on processing requirements, network traffic, and network operations.
1) In a bridged network, to send a packet, a source host needs to know the MAC address of the destination host; while in a routed network a source host needs to know only the MAC address of the subnet Router.

2) A broadcast frame on a LAN will be broadcast on every LAN on the NEWIAN in a bridged network, while a broadcast frame will be restricted to that LAN only in a routed network.

3) An ARP request will be broadcast on every LAN for a bridged network, while for a routed network the ARP request will be routed to the Router of the subnetwork where the destination host resides. The ARP may have to broadcast to all LANs on the subnetwork only if the Router can not respond to the ARP from its routing table.

4) Both a Bridge and a Router provide for store and forward of frames and packets , respectively. A Bridge needs to forward /discard each frame on each of the LANs connected to it. A Router, on the other hand, receives only frames addressed to it on each of its LANs, however, a Router will have to process each received frame and route the packet based on the destination host-id contained in the packet header.

5) When an end user WS/PC is moved from one LAN to another, in a bridged network the MAC address of its Ethernet interface remains unchanged but is now associated with different port of the same or different Bridge in the network. This requires all the bridges to update their forwarding tables, however this is not a problem since the bridges are learning bridges which update the forwarding tables based on the source MAC address of frames it receives on its ports. When a end user WS/PC is moved from one LAN to another, in a routed network its IP address needs to be changed only if the new LAN is connected to a different Router (and hence is a host in a different subnetwork). This would have required power-down of the Router, but with the new generation of the Wellfleet Routers which are being installed this can be done on-line.

3. ATM TECHNOLOGY AND EVOLUTION OF THE NEWIAN

The ATM WAN services in a limited form are available from a number of carriers. However use of ATM switches in campus networks is found only in experimental networks. This is in part due the lack of standards for Private Network-to-Network Interfaces (P-NNI) and for LAN emulation, however they are expected to be completed by the end of 1994 [5]. The LAN emulation standards will facilitate development of Adapters for Ethernet-ATM conversion as an integral module in an ATM switch and as a stand-alone module such as Synoptics Ether-Cell. And P-NNI standard will make ATM switches from different vendors inter-operable. With the ATM backbone network, high speed 100-155Mbps full-duplex ATM adapters for the Servers will be needed. These are either already available or are in testing for various machines such as SUN, Silicon Graphics, HP7000, DEC Turbochannel, and IBM RS6000. ATM adapters are expected for PCI bus widely used in 486 and Pentium systems, and for DEC Alpha PC's. While ATM adapters and drivers are available for TCP/IP, drivers for Novell Netware are in testing, and drivers for Windows NT and Windows Workgroups are expected soon.

The connections of end user's devices (PC/) to the Servers can take one of many forms. A number of single user Ethernets can be connected to an Ether-Cell which in turn connects through it's ATM port to the backbone ATM switch. An Ethernet frame is switched either to the ATM port (with Ethernet-ATM conversion) or another Ethernet port on the Ether-Cell. This permits a PC 10Mbps bandwidth and direct access to the

backbone ATM switch without requiring adapters and drivers for the PC. It should be noted that for a Switched Ethernet with Servers either directly connected to the switch or through a FDDI will provide the similar capability. Thus, with or without ATM in the backbone, one can provide 10Mbps bandwidth to end users. Thus, the applications which justify ATM capabilities are those that require bandwidth over 10Mbps range such as required in real time analysis/display of high density images, or multimedia application such as personal video-conferencing.

Experimental ATM networks are presently at various stages of development at a number of universities [2,4]. The primary application for these networks appears to be high speed transfer of medical images for instructional or diagnosis purposes. In addition, these also serve as test bed for products developed by vendors or by the universities and thereby help the development of the ATM technology. As standards are developed, cost of equipment come down, and most importantly new applications emerge, use of ATM is expected to gain momentum. Among expected benefits of ATM deployment are 1) it enables new applications, 2) it leads to lower operational costs, and 3) it is appears to be a long term solution. At the same among concerns expressed by users include 1) incomplete standards, 2) lack of interoperable products and services, and 3) high equipment costs.

4. CONCLUSION

The NEWIAN network is undergoing updating with new generation Routers and routing of IP protocols. While routing entails increased processing over bridging, it also results in reduced traffic by limiting broadcast within a LAN and limiting an ARP to at most a subnet. The current activities with Switched Ethernet and ATM pilot Network will yield valuable experience to guide the future development of NEWIAN and especially help determine the role ATM in it.

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