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The MITRE Cablenet Project

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Introduction

MITRE has initiated a local network and internetting research project, which is supported by the Defense Communications Agency. The intent of the project is to investigate the advisability of connecting major Command Center components with a cable-bus, and the interconnection of these Command Centers to eachother. A cable-bus network (Cablenet) has been installed at MITRE, and is being attached to the ARPANET, to establish a test-bed for experimentation. One of the major areas of investigation is a determination of what protocols are best suited to a local network broadcast environment, and how these protocols interwork with the protocols in the global packet- switched network. The cable-bus architecture will be compared with alternative configurations for a local network, such as a centralized architecture, from the viewpoint of security, performance, and other characteristics important in a command center environment.

The Command Center Environment

An understanding of this project is incomplete without a very short digression on our view of the Command Center components to be connected. Present and future Command Centers consist of a number of devices which for many reasons aren't easily inter-connected. During the latter 1980's, the World Wide Military Command and Control System (WWMCCS) Command Center is likely to include the present WWMCCS Honeywell 6000 computers, a future generation WWMCCS system, an Automated Text Message Handling (ATMH) system, which provides electronic mail, an intelligent terminals, dumb terminals, a data base machine for information retrieval, and possibly an intelligence system. In addition, access will be needed to long-haul networks, such as AUTODIN II. Each of the components may be a single machine, a group of machines, or a simple peripheral device which contributes to the component function.

The role of the cable-bus is to provide a "friendly" interface to each of these devices so that they may be unified into a more useful tool without unduly affecting component performance. This implies that in some sense the cable-bus must be all things to all devices. It should be able to emulate terminals, RJE stations, and simple twisted pair communications wires. The versatility of the cable-bus interface unit and its capability for complex data transformation are the keys to the cable-bus success in these roles.

The Cable-Bus System

The MITRE/Washington Cablenet system is based on a technology developed at MITRE/Bedford. Similar cable-bus systems are in operation at a number of government sites, e.g. Walter Reed Army Hospital, and the NASA Johnson Space Center, but these are all standalone, local-only networks.

The system uses standard Community Antenna Television (CATV) coaxial cable and microprocessor based Bus Interface Units (BIUs) to connect subscriber computers and terminals to the cable. Coaxial cable as a transmission medium is very attractive for a number of reasons: it is relatively inexpensive, approximately $500/mile; it can support multimegabit transmissions; and is relatively immune to noise. It is well suited for the transmission of digital, as well as analog signal. The cable bus consists of two parallel coaxial cables, one inbound and the other outbound. The inbound cable and outbound cable are connected at one end, the headend, and electrically terminated at their other ends. This architecture takes advantage of the well developed unidirectional CATV components. The topology is dendritic (i.e. branched like a tree).

The BIU is designed to transmit on the inbound cable and receive on the outbound cable. Each BIU implements a contention algorithm, reliable packet communication, and user device interface firmware. Other functions, such as intra-net routing, are either inherent in the broadcast nature of the cable-bus, or implemented by the user device. Certain BIUs directly interface terminals to the cable-bus.

A broadcast contention scheme is used on the cable, with all subscribers concurrently competing for the transmission media. The BIU uses a Carrier Sense Multiple Access (CSMA) mechanism to detect a busy cable. It also uses a Listen-While-Talk (LWT) scheme to detect concurrent transmissions (collisions). Due to signal propagation delay, it is possible for a BIU to start transmitting without detecting the presence of a concurrent transmission on the channel. The LWT technique minimizes the time lost when a BIU has to abort a transmission due to collisions. A transmitting BIU reads the initial portion of its own transmission (listens while talking) from the outbound channel, and compares it with the information sent on the inbound channel: if the comparison indicates that the transmission has not been interferred with, the BIU assumes that the cable-bus has been acquired, disables its receivers, and continues transmission; if the comparision indicates that a collision has occurred, the BIU backs off for a pseudo-random amount of time, and then attempts to retransmit.

The coaxial cable (JA-3412) consists of a copper clad aluminum center conductor, polystyrene dialectric, and an aluminum sheath shield. It has a loss figure of 1.6dB per hundred feet. Analog signals can be effectively transmitted in a frequency range of from 5MHz to 300MHz. The BIUs contain Radio Frequency (RF) modems which modulate a carrier signal to transmit digital information using 1MHz of the available bandwidth in the 24Mhz frequency range. The remainder of the 294MHz bandwidth can be used to carry other information channels, such as off-the-air TV, FM, closed circuit TV, or a voice telephone system, or, other digital channels. The data rate of our test-bed system is 307.2kbps.

The central processing unit of the BIU is a MOS Technology MCS6502A microprocessor. The 6502A has a cycle time of 500 nanoseconds. It has a bidirectional 8-bit data bus which is interfaced to a MCS6522 Versatile Interface Adapter (VIA); this VIA has 2 - 8-bit parallel ports and dual interval timers, and is used for high-speed parallel transfers from computers. Additionally, there are two Motorola 6950 Asynchronous Communications Interface Adapters (ACIAs): one of these ACIAs allows terminal access to the network via an RS-232-C port, with a selectable baud rate from 75-9600 bits per second; the other ACIA is used for very high-speed communication with the cable.

The 6502 is capable of addressing 65K bytes of memory. Peripheral control and data registers are addressed as memory locations. There are 2K bytes of Random Access Memory (RAM) in low order memory. The first 512 bytes are used for variable storage and stack, and the remaining 1.5K bytes are used for packet buffers. The upper 2K of memory is Programmable Read Only Memory (PROM) which contains the BIU firmware.

The Design Goals

The next generation of microprocessors (e.g., Zilog 8000, Motorola 68000, Intel 8086), the increasing availability of larger, faster memories, and the longer term (5-10 yrs.) availability of Josephson junction and three-dimensional logic, make it increasingly attractive to off-load specialized processing functions from the WWMCCS H6000 computer to other separate computers within a command center. Our test bed is being designed to provide the required inter-connection capability for the command center of the future, which takes advantage of this technological trend. With this in mind the following goals have been defined:

- There should be inordinately large amounts of processing power at each node.

- The cost of a bus interface unit should not be prohibitive.

- The construction should be modular to enable stepwise replacement of functions with advancing technology.

- The cable-bus should provide a full range of layered protocols (e.g. datagram, virtual circuit, virtual terminal, mail, teleconferencing, file transfer, and user defined) which embody state-of-the-art networking mechanisms (e.g. flow control, routing, addressing). Furthermore, the layers should provide interfaces promoting extensible higher level usage.

- The bus interface units should be able to support a wide variety of backend devices and communications line disciplines (e.g. RS232, parallel, HDLC, X.25).

- The resulting architecture should be fundamentaly securable so that information classified at various levels and compartments can be transported simultaneously.

Our investigation of the applicability of the cable-bus to the Command Center environment will encompass an assessment of the extent to which these characteristics apply to the MITRE cable-bus system. Where feasible, the system will be improved to more closely meet those goals. An assessment will be made to discover any advantages in a distributed cable-bus interconnection archtecture over a star inter-connection architecture.

The result of our efforts will be a cable-bus system that embodies a substantial number of the goals defined above. The cable-bus system will: (1) provide the required nodal processing capability, (2) implement cleanly layered transport and virtual circuit protocols (the significance of this statement cannot be underestimated), (3) interface to parallel and RS232 devices with the capability for development of other user device communication disciplines, (4) result in a bus interface unit that is in the early stages of program verification, and (5) effectively communicate with other networks via network gateways.

The Test Bed

Our MITRE cable-bus test-bed includes a PDP-11/70 minicomputer running the Network UNIX operating system, and three LSI-11s. The Network UNIX system will contain implementations of the Transmission Control Protocol (TCP) Version 4.0 and a modified version of the Internet Protocol (c.f. Realignment of Bus Interface Unit Protocols). The gateway functions will be minimal. The modified Internet Protocol will pass through packets to hosts on the ARPANET and cable. These hosts are expected to contain the necessary higher level protocol software to establish and maintain direct communications circuits. The LSI-11 microcomputers will be paired with three bus interface units to provide the futuristic nodal processing capabilities. The architecture of the test bed is shown in figure 1.

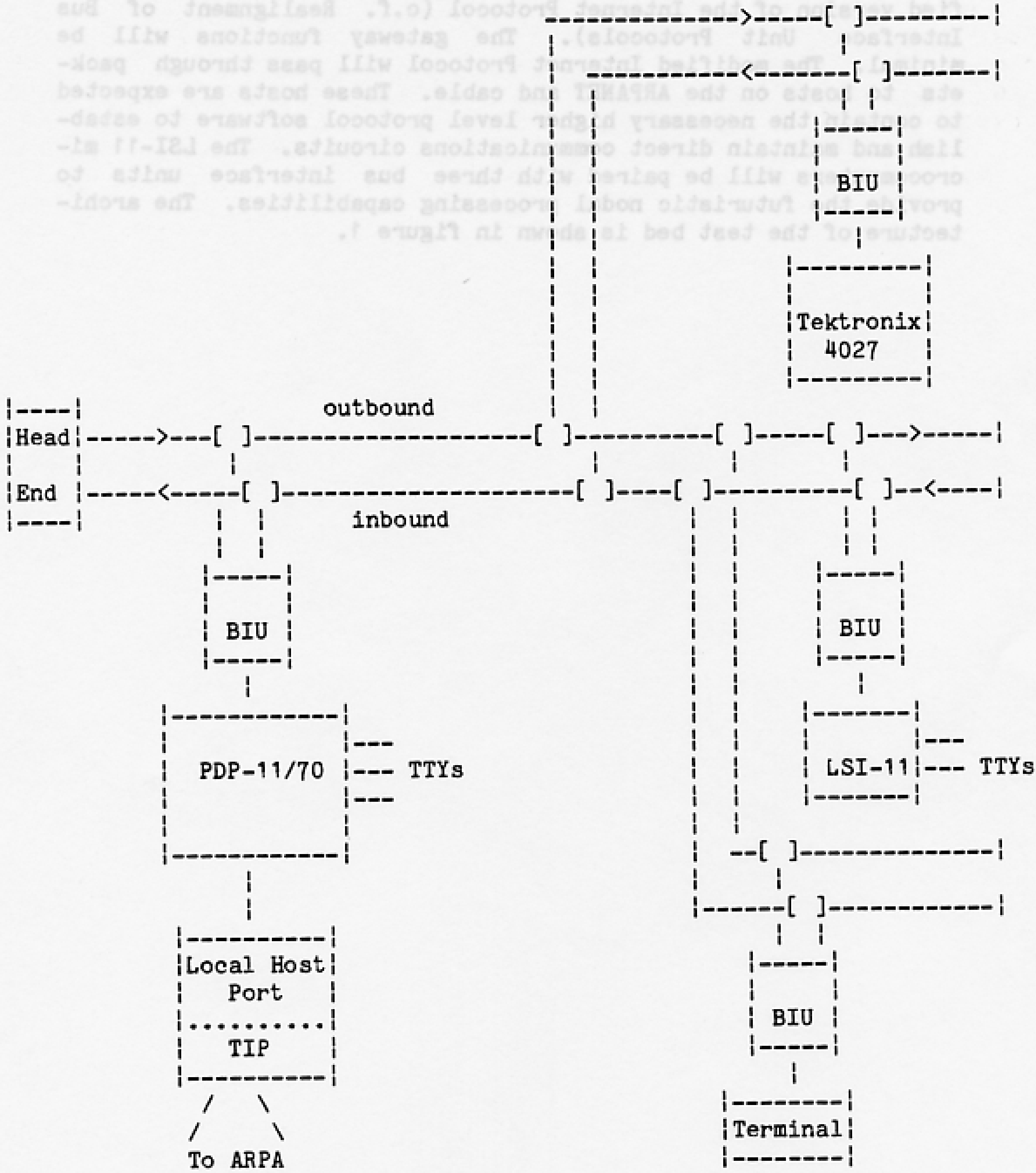

Figure 1. Cablenet Architecture

Initial Areas of Concentration

Realignment of Bus Interface Unit Protocols. MITRE's existing BIU-BIU protocols are ad hoc in nature. Various problems, such as, inadequate addressing structure, missing or antiquated flow control mechanisms, and missing out-of-band signaling, prevent interfacing the cable-bus to long-haul networks in any reasonable manner. Transport and virtual circuit protocols suited to the high speed cable bus are needed to provide the functions for interfacing to existing long- haul networks.

Using the TCP version 4.0 and the Internetwork Protocol as a starting point, a Flexible Datagram Protocol (FDP) has been designed (See IEN-97). The FDP is motivated by a need to support a cable-bus user community with widly varying transport protocol requirements. It should be emphasized that the generation of a new set of protocols was not our intent. However the urgent need for a flexible transport protocol on the cable, and the feeling that the state-of-the-art in local area networking protocols is such that no existing protocols may be adopted as a whole, led to the conceptual merging of the local network protocol layer with the internet layer, to yield a transport datagram protocol which can be layered under TCP. In its simplest form, FDP can function in a local broadcast environment, and in its expanded form, the FDP assumes all the characteristics of the Internet Protocol.

Internet Software Development. In order to achieve a full internetworking capability between the Cablenet and ARPANET, TCP 4.0 and the FDP will be installed on the 11/70 and on the LSI-11s. (We are adopting BBN's UNIX "C"/TCP and SRI's MOS/TCP in an attempt to get these internetworking capabilities operating as expeditiously as possible.)

High-speed 11/70 - Cable Interface. The 11/70 is interfaced to the cable-bus with a low speed (9600 baud) terminal line. All terminals accessing the 11/70 via the cable are multiplexed over this line. To test the bandwidth and throughput of the cable-bus system, a high-speed interface between the PDP11/70 and the cable-bus is being installed. The interface bandwidth must be greater than the basic cable bandwidth so as not to bottleneck data and affect measurements.

A UMC-Z80, from Associated Computer Consultants, will be used to provide the hardware interface between the cable-bus and the PDP-11 UNIBUS. Data transfer rates on the order of 500 Kbits should be available through the UMC-Z80. Since the basic data rate of the existing cable-bus is approximately 300 Kbits, it is believed that bottleneck problems associated with the PDP-11 to cable interface will be non-existent.

Security. No secure cable-bus installations currently exist. Particular attention is being given to investigating ways of securing a cable-bus to meet the security requirements of a command center. The following areas have been identified for study:

1. The use of DES and Public Key encryption systems to provide secure virtual circuit data paths.

2. BIU software verification.

3. Methods for physically securing the BIU and the cable.

4. A suggested architecture for an integrated network control center and security officers station.

Because of the "intelligence" of each BIU, a number of security measures are possible that are difficult to implement in other architectures. Dynamic key modification, logical address assignment, carrier frequency hopping, and distributed specifications of interconnectivity, are all measures that strengthen the overall cable-bus security. The extent to which each of these measures is needed is part of our research.

Performance Analysis and Experimentation. There is a long standing need for a knowledge of the end-to-end speed of the existing MITRE cable-bus system. Our initial measurement of bandwidth and throughput will satisfy this need, as well as to provide a metric for our newly implemented transport and virtual circuit protocols. Subsequent measurements will not only focus on our evolved transport and virtual circuit protocols, but will deal with the internet environment.

The Cablenet of the Future

Our ultimate goal is a cable-bus design that is capable of high-speed transmission (greater than 1Mbps), extensible, secure, and supports both voice and video transmissions which are fully integrated with the digital data. A voice message system coupled with interactive TV/graphics displays are some of the elements of our postulated fully automated command center. The next generation cable-bus interface units will support a multitude of devices, including page oriented and color graphics terminals; we will implement a virtual terminal protocol in an expanded BIU.

We are interested in developing the capability to dynamically regulate resource access and machine loading, and we envision a fully-distributed prototype cable-bus network being installed at a command center site to test these resource sharing concepts.