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Networking and Communication Technology Application to Training Devices Report

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This report presents a summary of research topics where new networking and communications technologies might be applied to training devices.

Real-time/Interoperable Network Profiles

A network approach that is worthy of investigation, in the context of distributed interactive simulation (DIS), is that of the SAFENET network developed by U.S. Navy to provide standard network profiles for the Navy computer-based systems. SAFENET offers two standard profiles, each of which can be implemented as any of the following three protocol suites: OSI, lightweight, or a combination of both. The OSI suite is intended to provide fully ISO-compliant (interoperable) networking. The lightweight suite is more geared towards real-time communications requirements. Each SAFENET profile covers the full seven layer ISO model.

SAFENET has a number of design features which include using fiber optics as the basic medium for transmission, providing high interconnectivity, allowing easy upgrading, and using off-the-shelf components. The SAFENET model therefore seems worthy of evaluation and adaptation for DIS applications.

Conformance and Interoperability Testing

A service that is currently badly needed for DIS is the conformance and interoperability testing of DIS products. Abstract test suites (ATS) and the associated means of testing (MOT) are ideally developed in concert with a standard and should follow the standard into implementation forums where feedback can be gathered and used to update the ATS/MOT. ATS/MOT should be designed and performed by qualified and neutral agencies. This would help achieve interoperability of multiple vendor equipments and give buyers a broad base of vendors to choose from, thereby lowering the product costs.

IST is now exceptionally qualified to participate in the efforts to establish DIS conformance and interoperability testing capability and play a key role in the design and maintenance of the test suites for DIS. The neutral nature of IST and its active involvement and leadership role in organizing the recent Standards for the Interoperability of Defense Simulations workshops and in developing the Draft Military Standard for DIS Protocol Data Units will certainly contribute to the effectiveness of IST

in the development of DIS testing capability. Furthermore, IST has a well established Networking and Communications Technology Laboratory and has been actively involved with basic research dealing with different issues in the design and evaluation of network and communications services for DIS. It is natural, therefore, to utilize the resources of IST in boosting the effort to establish conformance and interoperability testing for DIS.

The Applicability of OSI to Networked Training Devices

The current surges in computer technologies have created greater demands for numerous baseline computer operating environments. It has always been desirable for computer designers to investigate efficient computer architectures and ideas to achieve the processing objectives for computerizable applications. Invariably, the need for computer communications emerges as a key part of these applications-driven solutions. The use of computer communications is not new to computer professionals, and, indeed, many different implementations of various communications architectures exist today, ranging from well-understood serial interfaces between systems, such as RS-232C to fiber optic links operating in the fiber distributed data interface (FDDI) environment which have the potential to dramatically increase the quantity and type of information exchanged between systems. The proliferation of new computer technologies together with the rapidity of their introduction into the user marketplace has created some interesting, and sometimes costly, problems for computer users with applications involving the interconnection of multiple computer systems.

It is instructive to examine some of the major problems with computer communications which are actively being addressed today.

Interoperability relates to the successful exchange of information between two applications which execute on different computer hardware platforms. A major problem with most computer systems in the marketplace today lies in their inability to interoperate. This problem is a direct consequence of the design decisions made by the computer manufacturers who generally follow their own proprietary instincts throughout the life cycles of their products.

Lack of standards has led, in the past, to a multiplicity of computer communications architectures which generally serve narrowly defined problem domains. Thus, an organization would typically require several different computing systems using different communications protocols in order to successfully perform its work. Today, there is no real problem with a lack of communications standards. There is, however, a problem with the extent to which computer designers are embracing them. Specifically, the Open Systems Interconnection (OSI) model is widely referred to as the embodiment of numerous communications standards and protocols which have been endorsed by international organizations. A growing number of computer designers are beginning to incorporate many of the recommendations from the OSI reference model into the design of their computer products.

Computer costs have not significantly decreased as dramatic new computer technologies have emerged with higher capacity and processing power. Instead, new dimensions in costs are having major impact on the overall cost of computer equipment and usage. Typically, equipment from numerous computer vendors are used throughout an organization. Problems with systems incompatibilities often lead to large maintenance costs. The impact on the productivity of the workers is obvious.

It is interesting to note that a common problem in computer communications today derives from the fact that a non-adherence to standards and protocols quickly leads to computer products which do not interoperate which, in turn, leads to higher costs for networked computer systems.

The problems and discussions above are extremely relevant to the applications of networked training devices. It is a common activity to establish a network of training devices to accomplish certain objectives within an organization. Training devices from different computer manufacturers may not interoperate, and problems with the interoperability of training devices are widely acknowledged. Failure of the designers of the training devices to use open systems standards and protocols has led to interoperability problems with expensive solutions. The OSI reference model provides a well-documented framework for communications standards and protocols which are available to all computer designers.

Fiber Distributed Data Interface Technology

One very promising implementation of ring networks using optical fiber is the Fiber Distributed Data Interface (FDDI). FDDI is a 100 Mbit/sec token ring LAN protocol that is rapidly becoming accepted as the premier high speed LAN standard. With its embedded extensibility to support even higher speeds (500 to 1000 Mbit/sec), FDDI is poised to become the dominant high-end LAN of the 1990s. The paradigm for FDDI topology is known as a "dual counter-rotating ring of trees." The physical layer topology consists of independent, full-duplex, point-to-point physical connections, while the logical layer consists of one or two rings. The FDDI MAC (medium access control) protocol provides data services similar to those of the IEEE 802.5 token rings. An extension to FDDI (called FDDI II) is currently being investigated to add isochronous data transmission capabilities to the network, thus enabling it to handle both voice and data.

In the short term, FDDI backbones appear to be ideal for connecting existing networkable simulation systems (e.g., ETHERNET based simulation networks) and would therefore provide an effective tool for increasing the capability of these systems without introducing any changes to the individual simulator units. In the long term, FDDI can be fully incorporated into the simulators of future training networks, thus improving their real-time performance and increasing their capacity to support larger number of simulators.

The following are some FDDI-related topics that are important to simulation networks worthy of investigation.

- ✓ Investigate the design of intelligent gateway and filtering algorithms to be employed in conjunction with FDDI backbones for simulation networks. Such algorithms are needed to reduce traffic into each of the slower local networks connected by the FDDI backbone. Techniques based on "filtering at reception" have the advantage of simplicity and ease of implementation while those based on "filtering at transmission" may significantly reduce the traffic load on the FDDI backbone. Further research is needed to evaluate the performance of these two schemes as well as other hybrid methods that use a combination of both schemes.
- ✓ Investigate approaches to utilize the timed token rotation protocol of the FDDI MAC layer in supporting integrated voice and normal data transmission.
- ✓ Investigate the performance of FDDI when used to support different higher level network protocols such as XTP or TCP/IP.
- ✓ Investigate the impact of the FDDI technology on enhancing the performance of DIS and estimate the reduction in data loss rates and packet delays when FDDI replaces ETHERNET in future simulation networks.

Integrated Multi-Media Networking

Future communication networks are expected to handle a variety of data traffic types, covering a range of applications as diverse as very low bit-rate control and alarm signals for the home and business, interactive information services, electronic mail, digital voice, facsimile, file transfers and wideband digital video services, among many others. These networks have been termed integrated services digital networks (ISDNs).

Networks that interconnect simulation devices are required to operate in an integrated services networking environment. As a result, networks interconnecting simulation devices must be integrated services digital networks. Currently, simulation devices require the transmission of both data traffic (state information) and voice traffic (FM radio). It is also suggested that simulation networking should be capable of handling video traffic as well. This need will arise whenever a simulation device requests terrain data information.

Currently, IST is conducting research in the performance of LANs (e.g., Ethernet) and HSLANs (e.g., FDDI) in an integrated traffic environment (data, voice, images). In particular, the implementation of an Ethernet network that supports voice and data is underway.

At the long-haul network level, there are two prominent candidates for integrating a wide mix of traffic. One candidate protocol which seems worthy of

investigation is the newly emerging ATM (Asynchronous Transfer Mode) protocol. ATM is expected to be the key element of the future optical-fiber based multi-media networks. ATM is a multiplexing and switching technique that will run directly on top of the physical layer and will be common to all higher-level protocol layers. ATM is currently still in the design phase and intensive research is being conducted to enhance its effectiveness as a universal protocol for all types of data services.

Another protocol candidate for long-haul mixed traffic is called Hybrid Switching (HS), hybrid meaning either circuit or packet. HS seems to be a practical short term approach because present network facilities are based on circuit and packet technologies and HS is capable of handling different types of traffic.

Digitized Voice Transmission, Manipulation, and Reception

The efficient transmission of voice (intercom, FM radio, etc.) over a local and/or long haul network is an absolute requirement for DIS. Current techniques of sending analog voice information over standard telephone lines are not acceptable as a long-term solution. Besides the high cost of many phone lines required to support this scheme, analog voice information does not lend itself readily to manipulation via a digital computer.

Existing and newly introduced digital voice representation approaches (i.e., Linear Predictive Coding (LPC), Code Excited Linear Predictive Coding (CELP), Adaptive Pulse Code Modulation (ADPCM), FFT/Walsh Mixed-Transforms, etc.) are being studied and implemented from the efficient utilization of the channel bandwidth point of view. Performance comparisons of these techniques are planned for the generation, transmission and reception of digital voice with respect to real-time situations, hardware requirements, robustness under non-ideal conditions and delay imposed by the coding technique, the channel as well as the protocol.

Correction of the non-ideal effects, particularly the loss of voice packets, is under consideration. These include bit padding using different interpolation methods. Development, simulation, quantitative and subjective testing of these are being performed under different protocols and transmission environments.

IST has acquired equipment to support integration of voice and data traffic over an Ethernet network. This equipment consists of two AT compatibles, two DSP 56001 boards and two 3Com Etherlink II adapters. We have completed the task of transmitting packetized voice between the two computers via the Ethernet network. Our immediate research goals include: (1) integration of voice and data over Ethernet, (2) speech compression at the transmitter site, (3) speech decompression and reconstruction at the receiver site. Furthermore, we intend to examine the effect of the delay variability of voice packets on the reconstruction of the speech signal. The candidate protocols are Ethernet and FDDI.

Electronic Warfare Simulated Effects

The simulation of electronic warfare (i.e. communications jamming) is a requirement of the CCTT and is an area where much research is needed. Currently, the DIS protocol supports only a limited number of electromagnetic effects (i.e., radar radiation information) and no electronic warfare capabilities. Creation of an Electronic Warfare DIS node may be a possible approach to this problem.

Research in the areas of electronic warfare effects which will be required for future training devices goes hand-in-hand with IST's role in the development of Standards for the Interoperability of Defense Simulations. IST will be actively involved in the sub-group which will address Simulation network Protocol Refinements and Extensions.

Wide Area Networking

There are many problems associated with the wide area networking (WAN) of real-time simulation systems such as DIS. Delays associated with transmission of data over long distances which might compromise the real-time nature of the DIS simulation cannot be tolerated. Also, the bandwidth associated with transmitting large quantities on simulation network data can be extremely expensive. Research into efficient techniques for solving these problems will be required. The following topics point to more specific areas of interest.

Data Compression/Reduction

Investigations must be made into realistic and effective schemes for reducing the amount of data required to traverse the WAN, as well as compressing the data that must be transmitted. There are many techniques for compressing/reducing data. However, all are not suited for real-time applications.

For example, one of the problems associated with WAN is the efficient handling of intra- and inter-network traffic. Consider the interconnection of two simulation network LANs. A node at one LAN may generate heavy traffic because it is the accumulation point of the internetwork traffic from the other LAN (i.e., gateway node). Two types of multiplexing might be used to address this problem and require in-depth research. *Deterministic multiplexing*, where the capacity of the local LAN is divided among the intra-network traffic and the gateway node, and *statistical multiplexing* where the intra- and inter-network traffic are allowed to access the same channel. In either of these two cases, different protocols and their performance should be examined in detail.

Intelligent Long-Haul Gateways

New and innovative algorithms must be developed to provide long haul gateways with the ability to intelligently decide which data packets are required to traverse the WAN and which are not, thus reducing the quantity of WAN traffic.

Satellite Communications

Research in this area is drastically needed if a world-wide simulation network is to become a reality. For example, delays associated with satellite transmission and reception must be evaluated to assess their effects on the real-time nature of the DIS concept. The entire issue of DIS satellite WAN must be fully investigated.

Non-Homogeneous Simulation Network Interfacing

The interfacing of dissimilar types of simulators opens the door to a wide area of research topics. Issues such as network protocol translation, inferring information when none is available, omitting information when it is not required, etc., pose many unanswered questions concerning inter-simulator network communications. The two topics below appear to be natural extensions to the ongoing IST research.

Protocol Translation

Protocol translation involves building an interface between two dissimilar simulator networks which can intelligently transform data packets from one network to the format required by the other network and vice versa.

As more and more simulations become “networkable” and until simulation network protocol standards become a reality, there will be a requirement to conduct research into efficient ways to perform real-time network protocol translations.

Inference Gateways

When attempting to interconnect simulations with varying degrees of fidelity, it is not realistic to believe the network protocol can provide all the data required by all simulations. Therefore, intelligent “front-end” network processors will be required to “infer” or make assumptions concerning non-present information required by the simulation. We have named this front-end an Inference Gateway. This gateway will also be required to transmit only the information stipulated by DIS and maintain adherence to that protocol.

High Speed Local Area Networks (HSLANs)

Advancement in real-time technology will undoubtedly impact the design of future simulation and training networks. During the last decade, more than 60 different

media access protocols operating in the 50 to 5,000 Mbit/s range have been developed. These protocols are capable of supporting the exchange of information in HSLANs. Their high transmission speed makes them most suitable for real-time applications and mixed traffic communications. Primarily, these protocols are fiber optic based and are divided into three main classes: demand assignment, fixed assignment, and adaptive assignment access protocols.

Demand assignment access protocols order message transmissions on the media by serving the attached stations in a cyclic or non-cyclic order. These protocols are based on ring or bus topologies. Examples of the ring systems are token-ring FDDI operating at 100 Mbit/s and the slotted ring Cambridge Backbone Network (CBN) operating at 600 Mbit/s.

IST is actively involved in the performance evaluation of the FDDI protocol under various traffic requirements that pertain to simulation devices. FDDI is viewed as an alternative to LANs, like Ethernet, whose bandwidth capabilities are limited (10 Mbit/s). One of the advantages of FDDI compared to existing token-ring systems is that it guarantees timely delivery of messages that have strict delay constraints. This is an invaluable attribute in networks that interconnect simulation devices because not all generated messages are the same. For example, a state update message generated by a highly moving vehicle is more urgent than a state update message produced by a slowly moving vehicle. We have completed the modeling that allows us to simulate a network of voice and data sources and assess the performance of the FDDI protocol. When the simulation program is written, the parameters of the FDDI protocol will be chosen so as to optimize its performance.

In the subclass of unidirectional bus systems, we distinguish the Attempt and Defer Access, Polled Access and Reservation Access with representative examples being the Bellcore METROCORE Network (150 Mbit/s), the Local Integrated Optical Network (LION) (280 and 636 Mbit/s) and the Distributed Queue Dual Bus (DQDB) (155 Mbit/s).

The next main class of channel access is Fixed Assignment Access Protocols. Here, the total network bandwidth is divided among the attached stations in the time, frequency or code domain, in a fixed manner. These access schemes are well-suited for future ultra-fast (10-500 Gbit/s) fiber optic networks. A representative member of this class is the synchronous TDM Loop which is a 200 Mbit/s TDMA ring network.

The last main class of media access protocols is Adaptive Assignment Access Protocols. These protocols are hybrids that combine random and controlled access features. An example of this type of network is the 100 Mbit/s fiber optic based HYPERchannel-100 network. This network uses a bus topology and employs an access protocol that starts in CSMA/CD mode and then switches to TDMA mode when a collision occurs.

There is a need to perform research on the above mentioned protocol prototypes to examine their performance in the application of real-time simulation

networking. This implies the examination of delay, throughput and fairness characteristics of these protocols. Another important issue which should be addressed is the implementation aspects of these protocols. Typically, complicated access procedures and data buffering must be executed very quickly to match the data transmission speeds of optical communications technology. Such implementation-related problems can introduce data throughput bottlenecks in the network nodes or make it necessary to modify the original access scheme.

One example is the XTP (eXpress Transfer Protocol) which is designed for implementation via a VLSI chip manufactured by Protocol Engines, Inc. XTP runs as layers 3 and 4 of the OSI protocol and conforms to both the OSI reference model as well as the French Real-Time LAN Standard. It is believed that XTP will be the basis protocol for supporting later generations of LANs (including FDDI) with speeds approaching 1 Gbit/s. The suitability and impact of XTP on future simulation networks needs to be investigated.