ABSTRACT

The communication interface between the computers and the displays for Navy tactical systems has used Navy unique hardware and data transmission protocols. These unique hardware and software protocols limited the ability of these systems to support improved transmission capabilities such as multicast. In addition, certain new capabilities such as multiple radar displays and the use of graphical displays of maps were not possible.

As part of the LHA Amphibious Assault Ship (General-Purpose) Display Upgrade program, the communication interface between the computers and the displays was changed to use a commercial Local Area Network (LAN) protocol. To enhance the data communication interface, the use of reliable unicast and reliable multicast were added. In addition, the display hardware was changed to use Commercial Off the Shelf (COTS) Unix workstations with Local Area Network (LAN) interfaces. These new Unix workstations would use emulation software to provide the existing capabilities of the standard tactical displays while allowing the implementation of the new capabilities such as graphical color maps.

To minimize the changes to the operational software being development for the tactical computer, it was required that the display interface implemented within the tactical computer software not change from the previous version. This required the development of a new unit, one that would convert the existing display interface protocols that were transmitted from the tactical computer to the LAN protocols that were being used by the displays. In addition, a LAN interface card was developed that provided both unicast and multicast transmission protocols along with the LAN interface protocol.

The architecture of the new display system along with the definition of the commercial protocols is described. The ability of commercial products in this application to support tactical data requirements is reviewed in terms of the issues raised such as testing and logistics supportability.

EXISTING SYSTEM DESCRIPTION

The legacy display system consists of a military computer (AN/UYK-43A(VI)) connected to a set of military displays (AN/UYQ-21), as shown in the simple block diagram in Figure 1. (This Figure represents a simple logical representation, not the physical implementation. Many additional connections are not shown.) The tactical program within the AN/UYK-43 computer generates tactical symbols that are transmitted to the displays for use by the shipboard system operators. As shown in the block diagram, the specific equipment that connects this computer to the display units is called a Central Data Buffer (CDB). The CDB’s primary function is to receive display data from the UYK-43, through the use of redundant data channels (using a standard military serial protocol (MIL-STD-1397 Type E), and to convert the single input data stream to multiple data streams as data is passed forward to the display consoles. The connection between the CDB and the display consoles uses a vendor unique interface, at a specified data rate of 10 Mbps. All of the data transferred from the computer to the displays consists of graphic display symbols. To provide for the outline of specific geographical areas, the displays also allow for the generation of line segments. Each of the display consoles is able to display radar video data through a separate interface, again as shown in Figure 1. However, system performance is constrained due to the fact that radar data is limited in scope to a single radar video at a time, and requires the use of motor driven switches to switch from one radar video source to another.
EXISTING SYSTEM PROBLEMS

This legacy display system is installed on many ships in the U.S. Navy and has been in use for many years. However, there are significant problems with this system.

1) The display consoles are expensive, and have very limited capability in the use of color, and the display of other graphical data (such as maps overlays), could not be accomplished on these units.
2) The Central Data Buffer is limited both to the number of computers and the number of consoles that can be connected together. (Note: for simplicity, only one computer and a single CDB is shown in Figure 1).
3) The radar selection system used to put radar data on the display requires the use of motor driven switches. The display consoles can display data from only one radar video at any point in time.

UPDATED LHA DISPLAY SYSTEM DESCRIPTION

In recent years, the Navy has been directed to use COTS based equipment for new designs and planned system upgrades. This policy has been implemented for two primary reasons, 1) quick and up-to-date technology improvements with standard open systems products and 2) cost effectiveness. The use of COTS products can further be extended to encompass commercial software and commercial LAN protocols. These Navy wide COTS directives were embraced and implemented in the upgraded LHA display system, especially in the area of LAN (Local Area Networks) design and implementation.

NEW IMPLEMENTATIONS (FUNCTIONAL VIEW)

Figure 2 modifies the basic block diagram in Figure 1 to show the display system after the integration of COTS products. This figure represents a simple logical representation, not the physical implementation. Many additional connections are not shown. For example, four FDDI LANs, not one, physically implement the actual LAN, shown as a large oval in the Figure. Other system functionality’s such as the Tactical Data Control Processor (TDCP) used for providing navigation data, GeoServer (Map server) used for providing color map overlays, and LAN Manager (LAN Mgmt) used for LAN Management are listed for completeness, but not explained further. As can be seen, new functionality has been added, as well as existing functionality (radar inputs, for example) implemented in a different fashion. A quick overview of some of the new equipment is addressed below.

RADAR VIDEO INPUT (FUNCTIONAL VIEW)

In place of the original radar video connections to the motor driven switchboard, as shown in Figure 1, the analog radar video data is now connected to the input of the specialized radar digitizer card located in a standard alone unit called the Radar Broadcaster Equipment, simply denoted as a “Radar” enclosure in Figure 2. The radar digitizer VME card, used in this enclosure, is based upon previous commercial development done for the Federal Aviation Agency (FAA). The analog radar video is digitized and made available as a series of 2048-byte packets sent via the FDDI LANs to the Tactical Display Consoles. When the radar data has been digitized and is available for transmission, the radar digitizer transfers this data to the VME FDDI card via a DMA process, both cards being located within the “Radar” enclosure and connected via a VME backplane. After the data is sent to the FDDI card, this card packages the data into a FDDI packet and transmits it on the FDDI LAN using a connectionless multicast mode of transmission. The connectionless multicast mode of transmission met the requirement since any data that could be lost on the original transmission could be retransmitted during the next sweep of the radar antenna. Any display console that needs to receive that radar data can receive it by setting its receive address to the appropriate multicast address in the FDDI frame. After this setting, any radar packets received at the FDDI card within the console would be directly transferred by the VME DMA process to the radar digitizer receivers.

In addition to the radar video data that is available on the FDDI LANs, these LANs also contain Identification Friend or Foe (IFF) data. This data is transmitted using the reliable multicast form of data transmission as specified in eXpress Transfer Protocol (XTP). This is done to insure that all operators, who need this information, receive it in the most reliable and time critical fashion possible.

CENTRAL DATA BUFFER (CDB) (FUNCTIONAL VIEW)

As mentioned before, primarily for cost reasons, it was required that the tactical program within the military computer not be
changed. Therefore, it was necessary that the communication protocol implemented within the tactical computer for communication with the Central Data Buffer not be changed. Thus, the new CDB still needed to be capable of responding to all of the communication requirements that the tactical program could request. A specific timing issue was resolved by having the CDB poll the Tactical Display Consoles for inputs and supplying the latest data when requested by the tactical computer program. Operator actions at the consoles were sent to CDB using reliable unicast. To minimize the any latency in transmitting operator actions to the tactical program, the synchronous priority data transfer method available in FDDI was used.

**Detailed System Implementation**

Figure 2 is now modified to show the detailed display layout. This layout is shown in Figure 3 below. As can be seen, other equipment consoles (KCMX, printers, and an entire Ethernet network) were also added during the course of the LHA Display upgrade. The functionality of these components will not be discussed.

![Figure 3 Detailed Layout](image)

**NEW DISPLAY REQUIREMENTS**

Below are listed the nine primary new display requirements that were analyzed by the system architects at the program's inception. All these requirements were met in the final system implementation.

1) Change from the unique hardware display console equipment to the use of Unix workstations, which emulated the old display hardware.
2) Enhance the operator utilization of these workstations by providing the ability to use graphic display data with color.
3) Provide for other display enhancement items (such as map overlays).
4) Implement COTS technology with the use of commercial hardware and software.
5) Replace vendor unique data communication protocols with industry standard data transmission protocols.
6) Provide additional capability for the display of Identification Friend or Foe (IFF) symbols.
7) Provide new display technology as is found in the use of Large Screen Displays (LSD).
8) Reduce system cost and risk by NOT changing the tactical software within the military computer.
9) Create a highly survivable system with network management capabilities.

**LOCAL AREA NETWORK IMPLEMENTATION**

**LOCAL AREA NETWORK MEDIA ACCESS (MAC) SELECTION**

The nature of information transfer in a combat direction system environment requires three fundamental issues be addressed; throughput, latency and survivability. With these three issues in mind, the system designers must comply with Navy direction in the use of commercial standard protocols. A number of Media Access technologies were evaluated, with the conclusion of the study recommending the used of Fiber Distributed Data Interface (FDDI). FDDI is a 100 Megabit per second (Mbps), token based fiber optic network, which has been standardized as ISO 9314. FDDI products are in their 3rd generation of maturity, and are available from multiple sources in the commercial world. FDDI has been used extensively as a backbone network for connecting Ethernet and Token Ring subnetworks together. It has a dual ring architecture that implements a reconfiguration concept for single fiber faults. One method of reconfiguration with the use of FDDI concentrators called “dual homing” allows for automatic reconfiguration in case of multiple link failures. The “dual homing” mode of FDDI was the chosen configuration for the Display Upgrade implementation.

**LOCAL AREA NETWORK DATA TRANSFER PROTOCOL SELECTION**

In today's commercial world, the most common data transport protocols are the Transmission Control Protocol (TCP) and the User Datagram Protocol (UDP). Both these protocols operate over the Internet Protocol (IP). It was recognized early in the design phase that these protocols could support specific system information exchange requirements as well as network management information exchanges. However, in order to conserve LAN bandwidth and to minimize latency, there was a requirement to be able to send data reliably to multiple users. This functionality is known as “reliable multicast”. TCP has the capability to transfer data reliably to a single user but does not have the capability to multicast to multiple users. UDP, on the other hand, can multicast to multiple users but only with an unreliable method of data transfer. A study was initiated to address this issue in protocol implementation. After reviewing the status of available protocols, it was found that the eXpress Transfer Protocol (XTP) from the XTP Forum had the capability of providing both reliable and connectionless multicast modes of transmission. An implementation of XTP (commercially available) was chosen as the data transport protocol.

**SYSTEM HARDWARE CONFIGURATIONS**
One of the issues with the utilization of COTS products is the ability of the COTS components to meet shipboard requirements for both shock and vibration. Previous approaches have been to take standard COTS elements (such as boards) and repackage them into formats that would support the shock and vibration requirements. However, this approach results in unique government owned designs and does not allow for easy technology improvements.

To address this issue, the US Navy, as well as other navies, have developed a “rugged” enclosure where standard COTS elements can be located. The enclosure allows these COTS elements to meet the shock and vibration requirements without the redesign of these COTS elements themselves. For the LHA Display System Upgrade, a new enclosure was designed that would hold four (4) twenty (20) slot VME chassises. When an application requires limitation of the VME backplane traffic, the twenty slot VME chassises are split into multiple independent backplane slot versions, such as 10/10 or 5/15 configurations, with the corresponding reconfiguration of the appropriate cards. These enclosures, with the necessary backplane implementations, are used to support specific elements of the LHA Display System Upgrade.

**TACTICAL DISPLAY CONSOLES (PHYSICAL VIEW)**

The implementation of the Tactical Display Consoles presented some new and unique problems. As would be expected, the legacy display equipment located within the Combat Information Center (CIC) previously contained their electronics and unique serial data transfer interfaces within each of the enclosures. However, with the use of fiber optics and the cooling requirements of the new system, a different approach was needed. These factors resulted in the placement of all of the electronics for each of the consoles into separate enclosures located in remote equipment spaces. The new display consoles would continue to be located in the normal operating spaces (CIC). Connectivity between the equipment in the remote equipment spaces and the man machine interfaces and display was provided using multi conductor and coax cables. This included such components such as the keyboard and trackball, both located physically on the display consoles. The man machine interface was remoted using video amplifiers to allow connection of the display data available at the enclosures to the video display at the console.

The remote electronics for each of the Tactical Display Consoles is contained within two separate 10-slot VME backplanes with one called a Host backplane and the other called the Non-Host backplane. The Host backplane, contained cards that performed data processing and Display/LAN support for display graphics. The Non-Host backplane, contains LAN/Radar display cards for receipt of radar data. This allowed the console operator to select up to 3 different radars and/or IFF for display. When specific data is received that is to be transferred to the Host processor in the Host backplane, it is sent via a standard commercial VME bridge.

**FDDI Concentrator Units (Dual Homing)**

The “dual homing” approach was used for survivability. The use of a VME P2 connector bus allows for the interconnection of these cards in each enclosure to form a FDDI ring network. The FDDI topology rules require the B ports have priority over the A ports. Any failure of a B port on a card due to either fiber or port failure results in an automatic switchover and data transfer from the B port to the A port on that card. See Figure 4 for a simplified block diagram of this configuration.

![Figure 4 Dual Homing FDDI architecture](image)

**SYSTEM SOFTWARE DEFINITIONS**

**OPERATING SYSTEMS**

VxWorks is used as the operating system in the Radar Broadcaster Enclosures. Both HP-UX and HP-RT are used as the Operating Systems in the other units. The choice between these two Operating Systems depends upon the applications that are being implemented.

**NETWORK MANAGEMENT**

SMT 7.3 is being used for the Station Management Function for the FDDI cards. This is the standard “low-level” management functionality implemented in FDDI. HP OpenView along with SNMP is being used for the overall network management. These powerful tools allow for graphical network monitoring and control.

**SYSTEM PERFORMANCE REQUIREMENTS**

The issue of performance was related to a number of issues, including, but not limited to the following:

1. The number of FDDI LANs needed to transmit all of the radar video/IFF data (Modeling and Simulation used)
2. The data transfer rate through the FDDI card (FDDI Performance)
3. VME backplane/bridge concerns
Each of these concerns is addressed briefly below.

**MODELING AND SIMULATION**

Modeling of the data characteristics for the data carried on each LAN was done to identify potential bottlenecks using a commercial LAN modeling program. This modeling showed that three radar FDDI LANs were sufficient to carry the required radar/IFF data and that there was sufficient bandwidth for the fourth FDDI LAN to carry all of the tactical graphics data and map data.

**FDDI CARD PERFORMANCE**

The performance of the FDDI card (latency and throughput) parameters needed to be measured at typical operation levels, in order that the complete system could be designed. For example, measurements showed the FDDI board would support 39 Megabits/sec max throughput in connectionless mode of operation, and only 18 Megabits/sec in connection oriented mode. Thus, the entire system needed to be analyzed to take into account how these parameters would affect system operation.

**VME BACKPLANE/BRIDGE PERFORMANCE**

Another issue was the VME backplane bandwidth. The current design is implemented with up to 3 FDDI boards operating at the same time over the same VME backplane. The method of backplane transfer (DMA 32, DMA 64, etc) was studied, as well as Host Processor utilization of the VME backplane. Since the VME bridge was used to pass data between the Host and Non-Host backplanes, the throughput of VME bridge needed to be measured and addressed.

**COTS TESTING**

Specific problems were found with a number of COTS products used in this development. It was expected that since both FDDI and VME were well-known standards within the commercial world that all of the problems associated with these standards would have been well known and understood. However, significant problems were found with the FDDI card, the FDDI concentrators and the VME bridge. All of the items had firmware implementations of software located within Programmable Read Only Memory (PROM). Specific problems were found in the firmware of these products. (The manufacturer of these products had not fully tested their products in the valid configurations used by this program). Fixes to these PROMs required exchanging existing PROM units with revised PROM units provided by the manufacturer after problem resolution. The time to identify problems, consult with the manufacturer on the problem and replace the PROMs when new devices were available, was significant.

The use of a commercial FDDI LAN analyzer also contributed significantly to the speedy resolution of problems. The ability of the analyzer to be programmed to both store and display LAN data in a readable format, vice a display of bytes, was essential to understanding issues of data transfer on the LANs.

While the implementation of the eXpress Transfer Protocol (XTP) provided the reliable multicast capability that was needed for this project, elements of reliable multicast needed further understanding. This is true in the case where the slowest receiver in a multicast group can inhibit the rapid transfer of data.

**COTS LOGISTICS SUPPORTABILITY**

At project inception, the current versions of the HP-UX, HP-RT and VxWorks, operating systems were established as the baseline operating systems. However, during the project development cycle, various upgraded versions of the operating systems became available. Typically these new versions had functional improvements that were desired and/or required by the program (such as SNMP). For these reasons, the newer operating system versions were adopted. However, in some cases, this “upgrade” action, created new “problems” with current versions of the applications being used and developed. That is, applications that worked fine under the older versions, did not necessarily respond the same under the newer operating systems. Also, the newer operating systems sometimes required a short “learning curve” that impacted the schedule.

**LHA Display System Upgrade Conclusions and Benefits**

The LHA Display System Upgrade is an excellent example of the successful use of COTS based technologies in the Navy environment. Not only was the functionality of the Combat Direction System improved, but also the use of COTS based technologies allowed for a reliable cost-effective solution to be implemented.

**LHA DISPLAY SYSTEM UPGRADE STATUS**

As of August 1998, the second LHA Display System Upgrade was successfully installed on the second of the five LHA class ships. The new system has been well received by the operators with no significant problems reported.

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