NETWORKED DATA ACQUISITION SYSTEMS FOR THE ARMY FCS PROGRAM

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ABSTRACT

Teletronics Technology Corp. has been involved in the research and development of networked data acquisition systems for use in airborne instrumentation for several years. Recently, TTC successfully applied the advanced technology that was developed during these airborne efforts to a terrestrial application involving Army ground vehicles. The Future Combat Systems Program (FCS) for the U.S. Army recently solicited a networked-based solution to the problem of acquiring real-time data specific to the training of soldiers operating visual targeting systems within Bradley Armored Vehicles and Abrams Battle Tanks. This paper describes the High-Speed Digital Recording system, a network-based data acquisition system designed to allow for the recording of high-resolution (up to 1600x1280) RGB video, user-selected Ethernet packets, along with audio and GPS time information.

Keywords: *Ethernet, High Definition Video, Training, IP, Network, Instrumentation*

INTRODUCTION

Future Combat Systems (FCS) is the primary modernization program of the US Army. It is designed to be a networked system of systems, encompassing air and terrestrial components. The program consists of eight new manned ground vehicles, a family of unmanned air and ground vehicles, launch system, and advanced tactical and urban sensors. Using a state-of-the-art network, these systems work together to help soldiers share real-time information across the battlefield. Technical field tests are currently underway. The first brigade combat team equipped with the complete FCS is expected in 2015 with full rate production expected in 2017.

Since its inception in 2003, the Network Products Division of Teletronics has been on the forefront of acquisition technology. Driven by requirements for networked based airborne data acquisition solutions, NPD has created rugged network equipment including Ethernet switches, IP recorders and data acquisition devices. To complete the system, Teletronics provides user-friendly software for configuration, management, data recovery, and playback. Recent deliveries to FCS have proven these solutions to be flexible and practical for ground-based adaptation in addition to flight test.

The concept of network-based data acquisition and recording systems is not new. Its efficiency and cost-effectiveness has been proven by the telecommunications industry. However, its application within the commercial aviation, military, and aerospace sectors is relatively recent. Given that network technology is the cornerstone of FCS, network-based data acquisition systems are a natural fit.

BACKGROUND

The Operational Test Command (OTC), Air Defense Artillery Test Directorate (ADATD) was tasked to provide video data collection capabilities to support the Future Combat Systems (FCS) operational testing. The data collection occurs on FCS platforms that range from small robotics to full scale tactical equipments and systems. The requirements called for small footprint instrumentation systems that are modular, rugged and allow for future expansion to acquire one or more video streams, audio streams, and various other data types. In May, 2008, Teletronics was awarded a contract to produce the High Resolution Video and Audio Recording System (HRVARS). After a six month development effort, the system was delivered to the Army. The successful deployment of HRVARS has led to additional contracts, expanding the network architecture and adding support for additional network data types.

INSTRUMENTATION SYSTEM REQUIREMENTS

Minimum system requirements called for:

- Network-based architecture with built-in flexibility for future growth.
- Separate acquisition and recording units with a solid state removable data cartridge.
- Modular packaging to facilitate field service.
- Hardware tools for PC-based data download in a lab environment, powered with 110VAC at 60Hz.
- Software tools for instrumentation setup, data download and playback.
- GPS-derived timing input used for measurement time-stamping and video time overlay insertion.
- Acquisition of RGB video data with separate sync, combined sync, or sync of green with resolution up to 1600 x 1280 at various refresh frequencies up to 80 Hz progressive scan. Video compression with minimal loss to approximately 4 frames per second using JPEG-2000 at user selectable ratios. Programmable amount of compression from 10:1 to 100:1. Compression minimizes the

recording rate so as to not exceed 20 Mbps (2.5 MBps). Compressed data includes video time overlay insertion using UTC time with the location, color and background programmable.

- Audio capture for up to two audio inputs, sampling at a sufficiently high rate to allow for good quality signal during playback.
- Scalable and expandable to allow for future additional network acquisition node(s) to monitor, time tag, and record data via 10/100/1000BaseT for other data types such as MIL-STD-1553, ARINC-429, Ethernet busses, Link-11, Link-11B, Link-16, and FAAD Data link.
- Compatibility with video compression techniques such as MPEG-2 and MPEG-4
- Recorder provided with removable solid state data cartridge supporting:
    - data aggregation from a single network based switch
    - data download using a 1000BaseT port
    - IEEE-1588 master time capable of providing time over the network
    - minimum recording throughput rate of 20 MB/s minimum
    - capacity up to 128 Gigabyte
    - scalable to achieve higher speed and storage capacity in the future
- a small form factor, with:
    - A single channel video acquisition unit occupying less than 50 cubic inches and weighing less than 2 pounds.
    - A recorder unit including the cartridge occupying less than 100 cubic inches and weighing less than 5 pounds.
- environmental limits as follows:
    - Operating Temperature Range: -40 to +85C.
    - Random Vibration: 15 g RMS from 20 to 2,000 Hz.
    - Relative Humidity: 10% to 95% RH, non-condensing.
    - Shock: Saw-tooth wave; six g's peak, 11 ms, three shocks in each axis
- 28VDC +/-4VDC electrical power, consuming less than 2 amperes.

SYSTEM ARCHITECTURE

The general architecture delivered to FCS incorporates a collection of Ethernet devices either directly connected, or interconnected by an Ethernet switch. Standard Internet Protocol (IP) is used to carry data across the network. Data is collected by devices specialized for each data type and multicast onto the Ethernet network. When a network switch is used, the switch is responsible for moving network traffic efficiently from its source to its destination. In a distributed acquisition system, the destination is generally an IP recorder. Absolute time is inserted into the system by GPS and time synchronization across all devices in the network is achieved by IEEE-1588. Prior to operating the system for data collection and recording, all devices on the network must be programmed to reflect the specific character of the network and data to be recorded. Configuration information typically includes data type specific settings as well as rules for data filtering and routing. To facilitate programming, specialized software is run on a PC or laptop temporarily connected to the network. After a data collection session, data recovery is achieved by removing the canister from the IP recorder for insertion into a

Data Transfer Unit (DTU) connected to a PC or laptop. The DTU provides a conduit for the PC to access data on the cartridge. Recordings can be transferred to local storage media, ground network storage media, or analysis software can be used to analyze data directly from the DTU.

The first FCS delivery was comprised of a simplified network with a single device directly connected to an IP recorder. This network was deployed initially to gain experience with the system while also collecting valuable audio and high resolution video data. Exploiting the IP recorder with 3 Ethernet ports and limited switching capabilities, the second FCS delivery expanded the system to 3 devices. The additional device was deployed to capture Ethernet traffic from the test article network (not the instrumentation network).

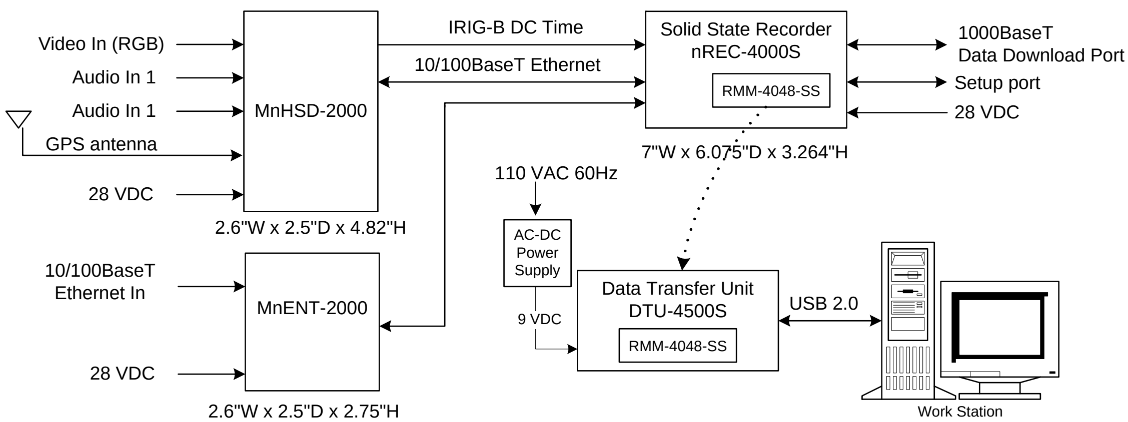

Figure 1: 2nd Phase Acquisition System: Audio/Video, Ethernet Data

A third delivery is expected by the end of 2008, expanding the system even further with the addition of a 5 port switch and additional MnDAU-2000s as depicted in Figure 2. The additions will support data types such as 1553 messaging and serial based protocols.

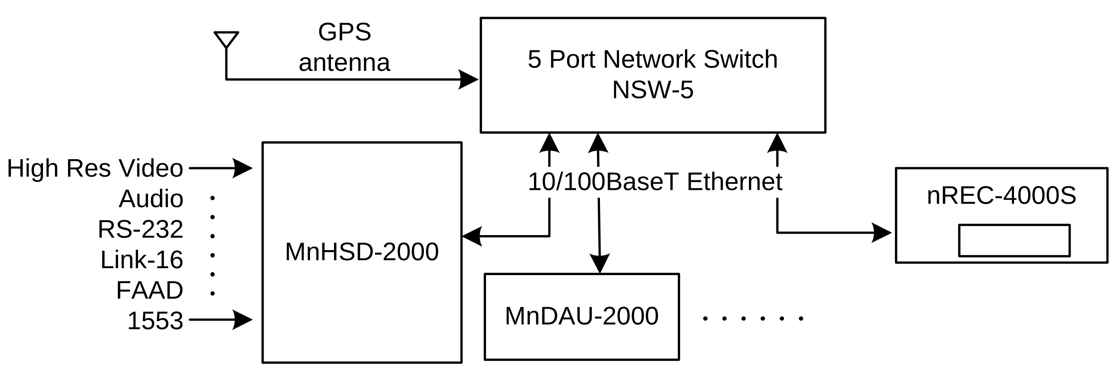

Figure 2: 3rd Phase Acquisition System: Switch Based

THE INSTRUMENTATION NETWORK

The network of instrumentation devices covers data acquisition, switching and recording. Telemetry was not a requirement. The Teletronics solution leveraged technology proven by the Boeing 787 flight test program, including a mixture of off-the-shelf and new hardware.

Data Collection – MnDAU-2000s

At the core of all data collection devices are the MPPC-500 and MGPI-500 based modules. In general, these modules provide processing power, Ethernet connectivity and 1588 timestamping for all of the MnDAU-2000s. MnDAU-2000 stacks become specialized with the addition of data type specific modules. Embedded software running on the host processor recognizes the additional modules giving each stack a personality specific to its data type.

For FCS a new type of MnDAU was created, the MnHSD-2000. This stack contains a controller for a new TTC proprietary high-speed bus accommodating up to 8 modules with aggregate data capture rates up to 50 Mb/s. A new module type was created to capture and compress RGB video and audio. Aside from the core modules and power supply, this miniature network acquisition stack is comprised of 3 data modules; the MVID-501J for high-resolution RGB video capture and JPEG-2000 compression, the MAUD-102N for audio capture and the MGPS-101A GPS receiver. Additional module types are being developed for MIL-STD-1553 and serial based protocols.

The MnENT-2000 was delivered as part of the second deployment of the FCS instrumentation network. This product is comprised of the core modules and the MFTB-500-1 data module for ethernet bus monitoring.

Ethernet Switching – NSW-5

Ethernet switches are required to extend the instrumentation network beyond a few devices. FCS will deploy a 5 port switch in each test article, expanding its network to include an IP recorder and up to 4 MnDAUs. Switches facilitate the transport of collected data to its destination, the IP recorder. The switch also provides 1588 timing to the network. Sourced by GPS, the switch guarantees that time is synchronized on all network devices to within 300 nanoseconds.

IP Data Recorder – NREC-4000S

Data collection and ethernet switching are meaningless without the means to record data. The IP Data Recorder provides this function to the network. FCS has deployed an IP recorder with a single canister capable of recording at rates up to 20 MB/s. Initial deployment began without the use of a switch. In this environment the NREC provides limited switch functionality, including 1588 time synchronization.

CONFIGURATION & MANAGEMENT

Before collecting and recording data, the instrumentation system must be programmed. Teletronics developed the Instrumentation Configuration and Management System (ICMS) for this purpose[1]. ICMS is platform independent software based on modern development technologies including Java, Javascript, HTTP, XML, and XSLT. It supports all network products developed by NPD. Using ICMS, the network design process for FCS is a simple operation. Users select the deployed devices from ICMS's catalog of supported products and add them to a diagram that graphically represents the deployed network. Once added, each device configuration can be edited. In a simple network, default data capture rules and multicast routes are sufficient. Only data type specific settings may require modification.

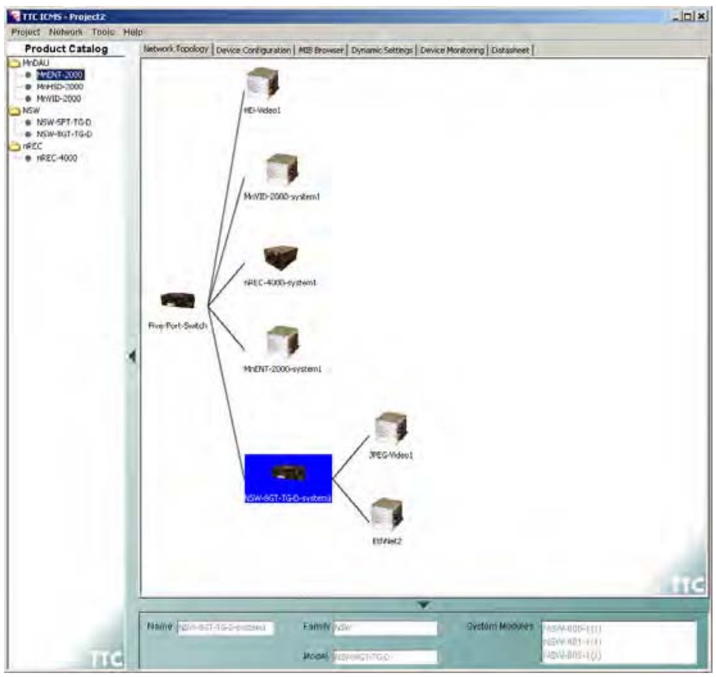

Figure 3: ICMS – Network Topology

ICMS projects are based on XML files. Device configuration is a matter of editing XML files in a user friendly environment. The resulting XML files contain all the configuration information required for each device in the network. ICMS triggers and manages the programming process. However, the programming task is actually relegated to each device individually. The distribution of work to each device provides a highly scalable environment. When the networked system is programmed, ICMS visits each device briefly using SNMP commands to setup a path to the devices configuration file. All configuration files reside on the ICMS machine and are accessible via FTP. As ICMS visits each device in the network, it sets the ICMS machine address and the XML filename containing the device's configuration. When ICMS triggers the load process, the device retrieves its configuration file via FTP and programs itself. ICMS can trigger all devices in a large network fairly quickly, facilitating near-simultaneous programming of multiple devices. Afterwards, ICMS uses SNMP again to monitor all devices for the results of their programming. Any errors in the process are relayed to the user for corrective action.

Beyond configuring the network, ICMS Project files also play an important role in data recovery and playback. Project files contain all that is needed to create self describing data files. When programming the network recorder, ICMS provides a copy of the entire network configuration. At the start of each recording session, the project is stored as part of the permanent record within the data file.

SNMP also provides realtime monitoring, an important feature for large, mission critical networks. This feature allows ICMS to convey faults or overload conditions present on the network during a test. Although it was not required, the FCS acquisition system inherits this functionality. Realtime monitoring can be tremendously useful but has a cost associated with it. To monitor, the ICMS machine must be deployed live as part of the instrumentation network. As such, ICMS would occupy space within the test article and also a port on the Ethernet switch, both of which are valuable and perhaps scarce resources. Currently, FCS uses ICMS for configuration but has not deployed it as part of the instrumentation network.

DATA RECOVERY & PLAYBACK

FCS required an easy to use tool for data download and audio/video playback. Teletronics created HDViewer to meet this requirement. It is an adaptation of TTC's Ground Station Software (GSS) product without the complexities required for comprehensive mission debrief. HDViewer provides data extraction on a channel by channel basis for all channels within a recording session. It supports multi-channel playback of the MJPEG 2000 video and audio captured by the MVID-501J modules deployed in the instrumentation network. IEEE-1588 time tags within the data are utilized to synchronize audio and video playback.

Data Format

DARv3 was defined by Teletronics for networked data acquisition. The FCS instrumentation network creates DARv3 recordings. By including the ICMS XML project, DARv3 data files are self-describing. The XML record supplies configuration information such as, Channel ID and Channel Type for all data streams within the file. Once the XML is imported, HDViewer maintains the information in its own database. This decreases startup time when replaying DARv3 files.

Data Playback

Using the Windows file browser, HDViewer can be launched to display recorded files either directly from the DTU or from local storage. Before displaying data, HDViewer performs the following:

- Parses the XML project, created by ICMS and stored in the recorded file.
- Creates a new HDViewer project and data definition for all channels.
- Creates a default view to play HD-MJPEG2000 video and audio.
- Open the default view.

HDViewer is able play video and audio data from a file or from a recorder directly. It is not limited to a single video or audio stream. Depending on machine power, HDViewer can play multiple video and audio streams at the same time. Users can play, pause or stop the playback, or use the slider bar to go to a specific place in a file.

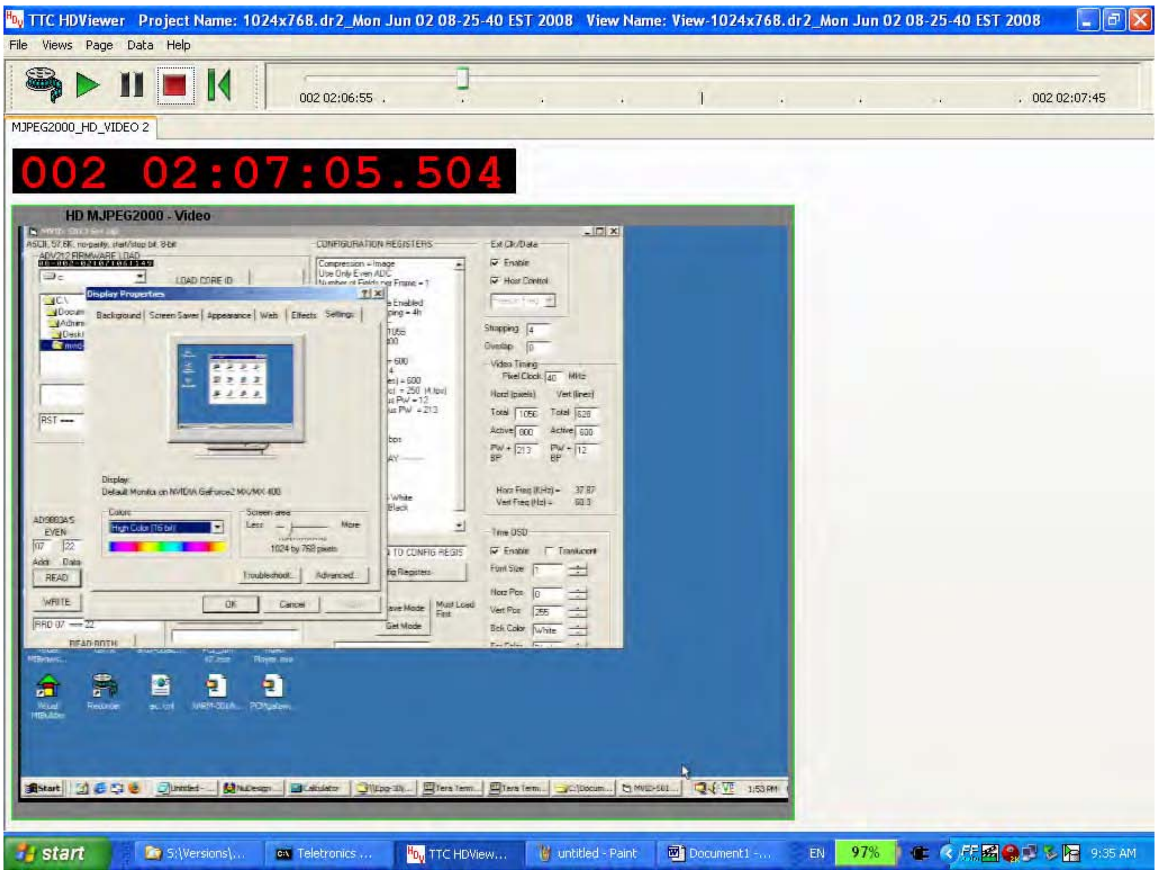

Figure 4: HDViewer Interface

Data Download

Downloading data from a recorder enables users to archive data. HDViewer provides this feature along with data extraction by channel or time range. Recorded Ethernet frames can be exported into PCAP files, an industry standard. Open source tools are freely available for browsing and analyzing the Ethernet packets in PCAP files.

Data Processing

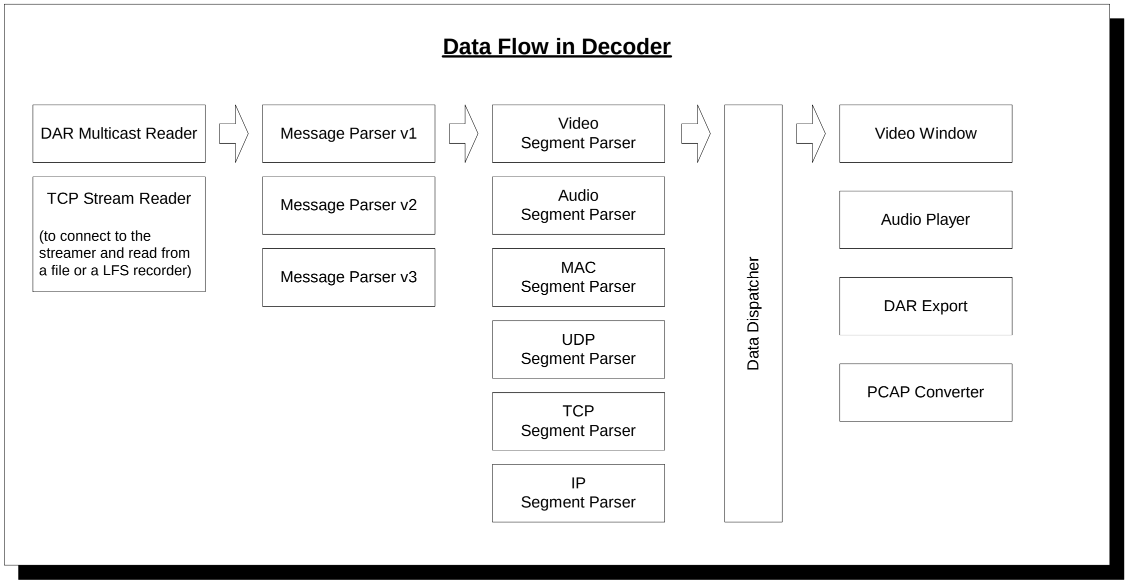

Figure 5: Data Flow Process in HDViewer

Detailed data processing has been discussed elsewhere [2]. However, a brief description of the process follows. Figure 5 demonstrates how data is processed by HDViewer. There are 5 layers, from the left to the right. The first layer is a collection of readers. One of the readers will be chosen based the data source type. It may be from a regular file, from a recorder or from a multicast network. The second layer is a collection of message parsers. According to a version number in the packet header, a proper parser will be used to process the incoming data. The third layer is a collection of segment parsers. HDViewer currently supports the following types:

- High Definition MJPEG-2000 Video
- Linear Audio
- Ethernet MAC packets
- Ethernet UDP packets
- Ethernet TCP packets
- Ethernet IP packets

GSS provides users with additional data types. The data dispatcher filters data into selected components in the fifth layer. It can be a display component, such as a video window or audio player. It also can be an export filter to output data into a DARv3 file or convert it into a PCAP file.

CONCLUSION

The successful deployment of HRVARS has led to additional contracts, expanding the network architecture and adding support for additional data types. Over the past several years, various forward-looking papers have been written describing network-based data acquisition elements and systems [2][3][4][5]. The success of the FCS instrumentation network has lent significant credence to the arguments and proposals put forth in those papers.

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