NETWORK-BASED DISTRIBUTED DATA ACQUISITION AND RECORDING FOR SMALL SYSTEMS

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ABSTRACT

Some of the first applications of network-based data acquisition systems have been for large aircraft. These systems contained numerous network nodes including data acquisition units, switches, recorders, network management units, and others. One of the desirable aspects of a networked-based system is the ability to scale such a system to meet increasing test requirements. Similarly, these systems lend themselves to scaling down, as well, to meet the testing needs of smaller test articles. These needs may include fewer nodes and/or physically smaller components. The testing of smaller vehicles places slightly different requirements on the testing process. In general, there is a greater need for real-time analysis, flexibility and ad-hoc testing. This paper will attempt to show how a small to medium sized test article can benefit from the same powerful, feature-rich network-based data acquisition and recording system as used on larger programs. The paper will also show how a smaller system can deliver on this promise without sacrificing performance and functionality.

KEY WORDS

Network, Data Acquisition, Switches, Recorders, Network Management

INTRODUCTION

Network-based data acquisition systems are proving to be affective data collection and analysis enablers. Their usefulness had been proven on several large test articles (e.g., Airbus A380). Due to the size of these test articles and the number of measurements being taken, the acquisition system to support testing was similarly large. To support the amount of data to be collected, these systems include a myriad of data acquisition units, network switches, recorders, network managers, telemetry transmitters, etc.

Due to their flexibility and scalability, network-based data acquisition systems can also provide an affective solution for small-scale test articles. This paper will attempt to show that a network-based solution is a viable option for small-to-moderate sized test articles. Several test article scenarios are presented to illustrate this point.

THE NETWORK ADVANTAGE

Over the past several years, various papers have been written describing the pros and cons of network-based data acquisition systems [1][2]. Some of the pros of this approach include leveraging existing commercial hardware and software, system scalability and bidirectional data flow to name a few. Being able to leverage the advancements of the commercial sector translates to lower risk of a proven technology. One example of this is the readily available hardware and software tools on the market. These tools include network analyzers, traffic modelers and data processors.

The network infrastructure, including switches and data acquisition nodes (endpoints) lends itself to scaling. A system designer may add or subtract ports (and switches) as the need for sensors and acquisition nodes increases and decreases. Programming of the system can be accomplished at a single point or node, similar to how systems, using CAIS Bus or serial RS-232/422/485, are programmed today. However, the user interface to the system can be greatly enhanced, again by leveraging existing commercial technologies. An example would be a laptop connected to the network using a web browser to configure a data acquisition unit. Figure 1 below shows an actual web page-based configuration screen from a TTC MPEG-2 Video Miniature Network DAU.

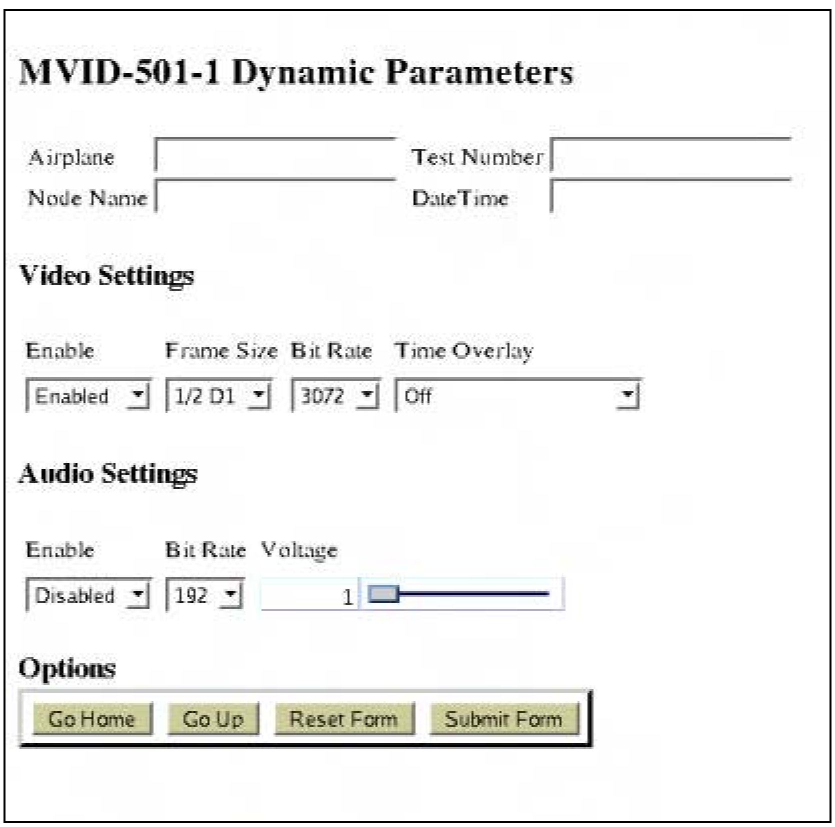

Figure 1. Network-Based Audio/Video Acquisition Configuration Web Page

Data moving seamlessly from DAU-to-recorder, recorder-to-ground station or ground station-to-DAU, allows the user to reconfigure system behavior on the fly. This can translate into getting more test data for a given mission. What may have taken multiple missions in the past could be accomplished in a single mission, cutting down on expensive test time. Taking advantage of this flexibility does not necessarily require a great deal of infrastructure.

SCALING TO SIZE

Within large test articles, for example a cargo aircraft, there may be thousands of measurements taken at any given time during a test flight. The system architected to acquire this data may require dozens of data acquisition units (DAUs). In this example, DAUs might be used to monitor avionic buses, and analog sensors, including audio and video feeds. In an IP-based system, each DAU would require a connection to the overall network. This connection to the network would typically involve a network switch port. As the number of required DAUs increases, so does the need for ports into the network. The network, therefore, would scale up to include additional switches.

Similarly, smaller test articles, for example small aircraft, missiles and ground vehicles, would have relatively fewer sensors and buses with which to interface. The requirement for connections into the network would be fewer as compared to the previous example. In this case, the same system advantages apply. Programming can be accomplished from a single point (e.g., a Network Management Terminal). On-the-fly reprogramming can take place. Advanced software tools can be used to enhance the user interface and hence the overall user experience. Because fewer nodes and smaller switches are needed, the system cost is reduced while the system flexibility affords a higher value proposition (i.e., accomplish more in a single mission).

The following section describes some example test scenarios that illustrate how network-based data acquisition systems can be adapted for a wide range of requirements.

EXAMPLE SCENARIOS

In this first example, a medium-to-large networked-based system is described. The block diagram in Figure 2 below shows the system.

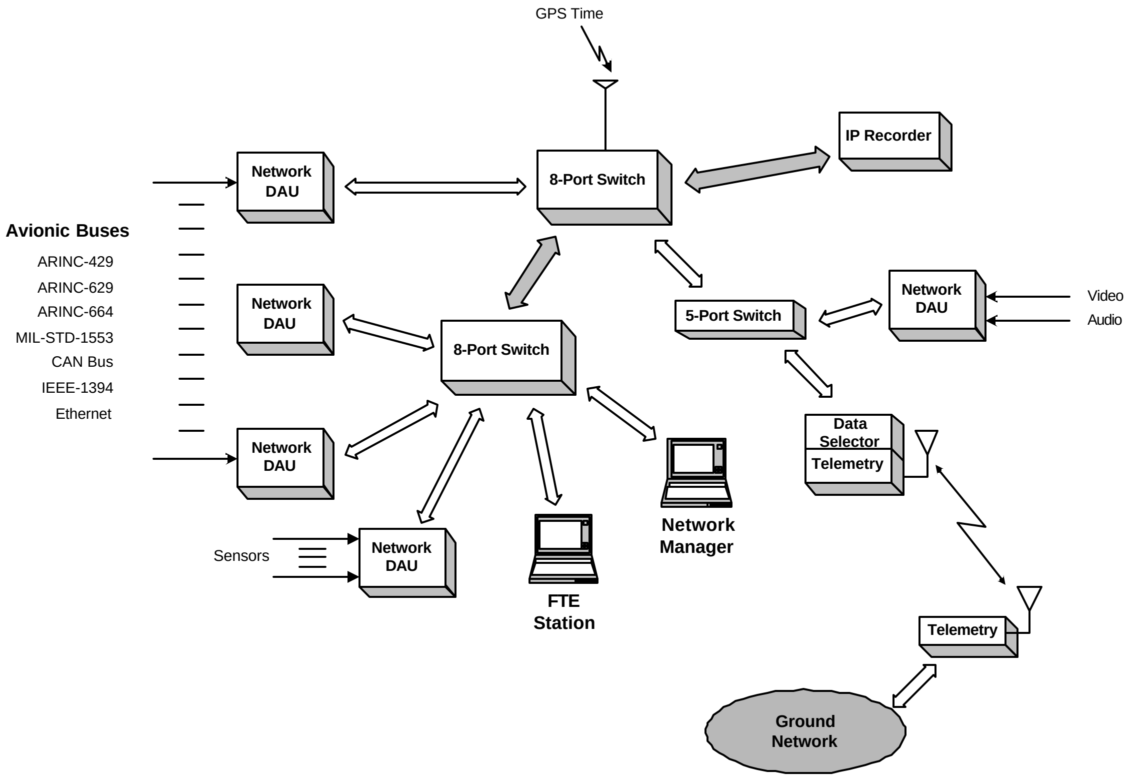

Figure 2. Large Airborne Network-Based Data Acquisition System Example

The core of this example system is an 8-port gigabit Ethernet switch with support for the IEEE-1588 Precision Time Protocol (PTP) and a built-in GPS receiver. This switch acts as the timing master in the system by using the PTP to distribute time throughout the network, based on the GPS time. This allows for a high level of time coherency between the various nodes within the network [3][4]. There are two types of communication links (Ethernet segments) between the switch and other devices. The un-shaded arrows represent 10/100Base-T links while the wider, shaded arrows represent gigabit capable Ethernet links (10/100/1000Base-T). The Ethernet links are shown as copper media, however, the media can also be fiber optic cables, depending on the customer's application. The edge of the network is mainly made up of data acquisition units (DAUs). These units interface directly to sensors and avionic buses on the test article. The DAUs are responsible for sampling and formatting the data for transmission onto the network. In addition, the DAUs receive timing information via the PTP that allow them to timestamp the acquired data. The formatted data is sent to the IP recorder with typically some subset of data passing to the telemetry transmitter.

Each DAU is programmed with various parameters related to the type of data it is acquiring. Additionally, the DAU is told where to send its formatted data. For example, sensor data from one DAU may be sent only to the IP recorder for storage while safety-of-flight data from another DAU may be sent to the recorder, the telemetry transmitter, and a Flight Test Engineer's (FTE) terminal for real-time analysis.

The IP (Internet Protocol) recorder attached to the system, in this example, is required to accept high bandwidth data, say an average rate of 100 Megabytes per second (MBps). In order to capture data over a 2-hour mission, the recorder would require about 720 GB of storage space. Based on the required record rate and capacity, such a recorder would require several physical drives, given today's technology.

The Network Manager terminal allows an operator to program, query and otherwise interact with nodes within the network. The Network Manager can be located within the test article itself or as part of the ground network.

The table below shows the volume required and the weight for the system described above (not including cabling and the ground elements).

Network Element	Volume (cubic in.)	Weight (lbs.)	Consumption (W)
Analog Network DAUs (2)	84.5	3.9	48
MPEG-2 Video Network DAU (1)	15.3	0.88	6.5
ARINC-429 Network DAU (1)	17.9	0.86	6.5
Ethernet Network DAU (1)	17.9	0.98	6.5
8-Port Gigabit Switches (2)	295	12.1	60
5-Port Switch (1)	22	1.0	14
IP Recorder (1)	347.7	18.0	60
Telemetry Transceiver (1)	11.4	0.75	84
Total	**811.7**	**38.47**	**285.5**

Table 1. Large Airborne System Example: Volume, Weight and Power

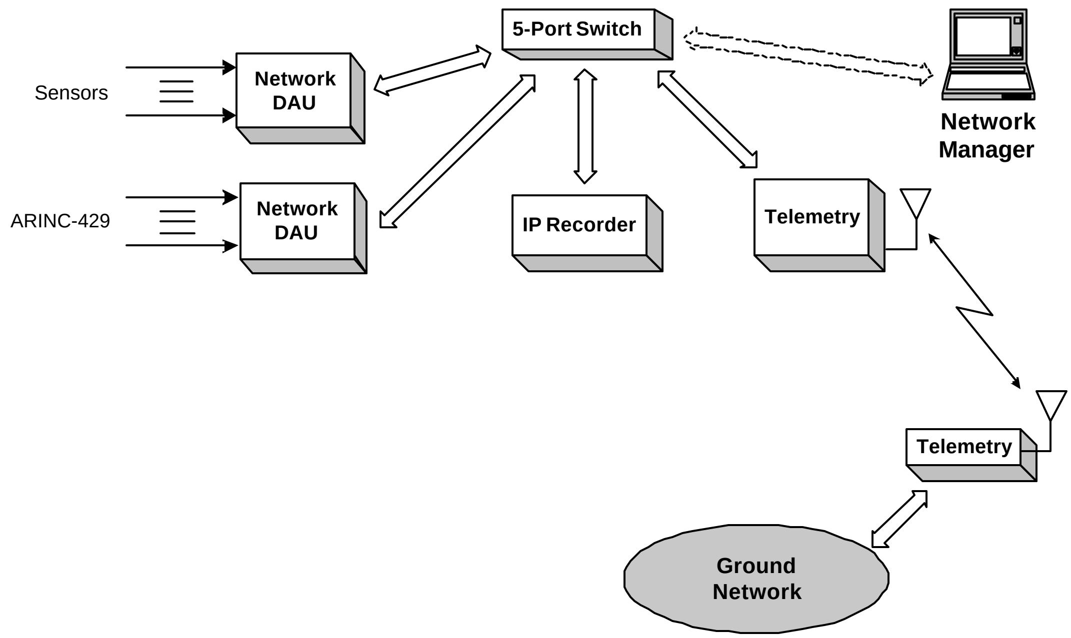

Figure 3. Small Airborne Network-Based Data Acquisition System Example

In the example shown in Figure 3, a single 5-port switch is used to connect a small number of network nodes together. Like the large system example, the switch is responsible for forwarding packets within the network and distributing time information. The 5-port switch supports the PTP. In addition, the switch acts as the timing master within the system. Although it is not shown here with a GPS receiver, it can generate its own time (free run) or have time jammed prior to the mission. Each link connecting the switch to the rest of the system is 10/100Base-T. Here, the DAUs generate a considerably lower average bandwidth, say 5 MBps (40 Mbps). At this data rate, a recorder capacity of about 36 GB would be required to support a 2-hour record time. For this capacity and rate, a smaller, single drive-based recorder would be adequate.

The link between the switch and the Network Manager terminal shown in Figure 2 represents a temporary connection. In this example, the network management function is performed as part of the pre-flight activity. The system is programmed and "checked out" prior to the mission/test flight. Critical real-time data is transmitted to the ground, via the telemetry link, for monitoring and analysis.

The table below shows the volume required and the weight for the system described above (not including cabling and the ground elements).

Network Element	Volume (cubic in.)	Weight (lbs.)	Max. Power Consumption (W)
Analog Network DAUs (1)	42.25	1.95	24
ARINC-429 Network DAU (1)	17.9	0.86	6.5
5-Port Switch (1)	22	1.0	14
IP Recorder (1)	139.2	9.5	25
Telemetry Transceiver (1)	4.8	0.75	44.8
Total	**226.15**	**14.06**	**114.3**

Table 2. Small Airborne System Example: Volume, Weight and Power

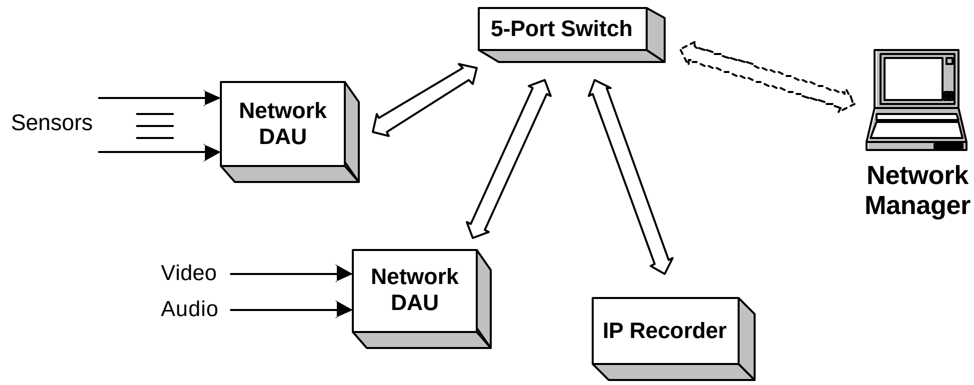

Figure 4. Small Ground-Based Network Data Acquisition System Example

In this last example, a small network-based data acquisition system is used to instrument a ground-based vehicle. Once again, a 5-port switch is used as the core network element. Two DAUs are shown acquiring and formatting data, and sending the data to a small IP recorder. As in the previous example, the data rate is relatively low. However, the required record time may be longer, e.g., 6 hours. A data rate of 5 Mbps, and a record time of 6 hours would require about 108 GB of data storage. Again, a small single media IP recorder would perform well for this application. As more sensors are added, additional DAUs and switch ports can be added to scale the system to meet the programs needs.

The table below shows the volume required and the weight for the system described above (not including cabling and the ground elements).

Network Element	Volume (cubic in.)	Weight (lbs.)	Max. Power Consumption (W)
Analog Network DAUs (1)	42.25	1.95	24
MPEG-2 Video Network DAU (1)	15.3	0.88	6.5
5-Port Switch (1)	22	1.0	14
IP Recorder (1)	139.2	9.5	25
Total	**218.75**	**13.33**	**69.5**

Table 3. Small Ground-Based System Example: Volume, Weight and Power

CONCLUSIONS

Network-based data acquisition systems are proving to be flexible feature-rich test solutions. By virtue of the network architecture, systems can be tailored to the test article. Large test articles can be equipped with multiple switches connected to dozens of DAUs and hundreds of sensors and buses. Smaller test articles can be instrumented using the same hardware building blocks and software tools. Customers can leverage proven, readily available software to model and test the data acquisition network. In addition, suppliers are developing data analysis tools to process the data collected from the network.

REFERENCES

[1] Berdugo, Albert A., Hildin, John J. “A System Approach to a Network Centric Airborne Data Acquisition System”, Proceedings of the International Telemetering Conference (ITC 2006), San Diego, CA USA, October 23-26, 2006.

[2] Delarue Xavier, “Network Telemetry: A New Digital Acquisition System for Airbus A380 Aircraft”, Proceedings of the 40th Annual International Telemetry Conference (ITC 2004), USA, October 18-21, 2004.

[3] Institute of Electrical and Electronics Engineers, Inc., IEEE Std. 1588 - 2002 IEEE Standard for a Precision Clock Synchronization Protocol for Networked Measurements and Control Systems, Nov. 8, 2002.

[4] Grim, Even T. “Achieving High-Accuracy Time Distribution In Network-Centric Data Acquisition and Telemetry Systems With IEEE 1588”, Proceedings of the International Telemetering Conference (ITC 2006), San Diego, CA USA, October 23-26, 2006.