ROLE OF A SMALL SWITCH IN A NETWORK-BASED DATA ACQUISITION SYSTEM

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ABSTRACT

Network switches are an integral part of most network-based data acquisition systems. Switches fall into the category of network infrastructure. They support the interconnection of nodes and the movement of data in the overall network. Unlike endpoints such as data acquisition units, recorders, and display modules, switches do not collect, store or process data. They are a necessary expense required to build the network.

The goal of this paper is to show how a small integrated network switch can be used to maximize the value proposition of a given switch port in the network. This can be accomplished by maximizing the bandwidth utilization of individual network segments and minimizing the necessary wiring needed to connect all the network components.

KEY WORDS

Data Acquisition, Network Switch, Network Infrastructure

INTRODUCTION

An Ethernet-based network data acquisition system is made up of network nodes (e.g., data acquisition units, recorders, etc.) interconnected by switches. While critical to the operation of the overall network, switches are a necessary expense added to the total cost of the system. One metric sometimes used to characterize the impact of the switch component is the cost-per-port. One goal of the instrumentation network designer should be to minimize the cost-per-port and maximize the value of the data system.

TYPICAL INSTRUMENTATION TOPOLOGY

A typical instrumentation network will include various data acquisition units (DAUs) located at the edge of the network. Using network switches, the DAUs are interconnected to other network nodes, for example, data recorders and IP transceivers. Figure 1 below depicts such a system. The diagram shows each device node connected, point-to-point, to its network peer.

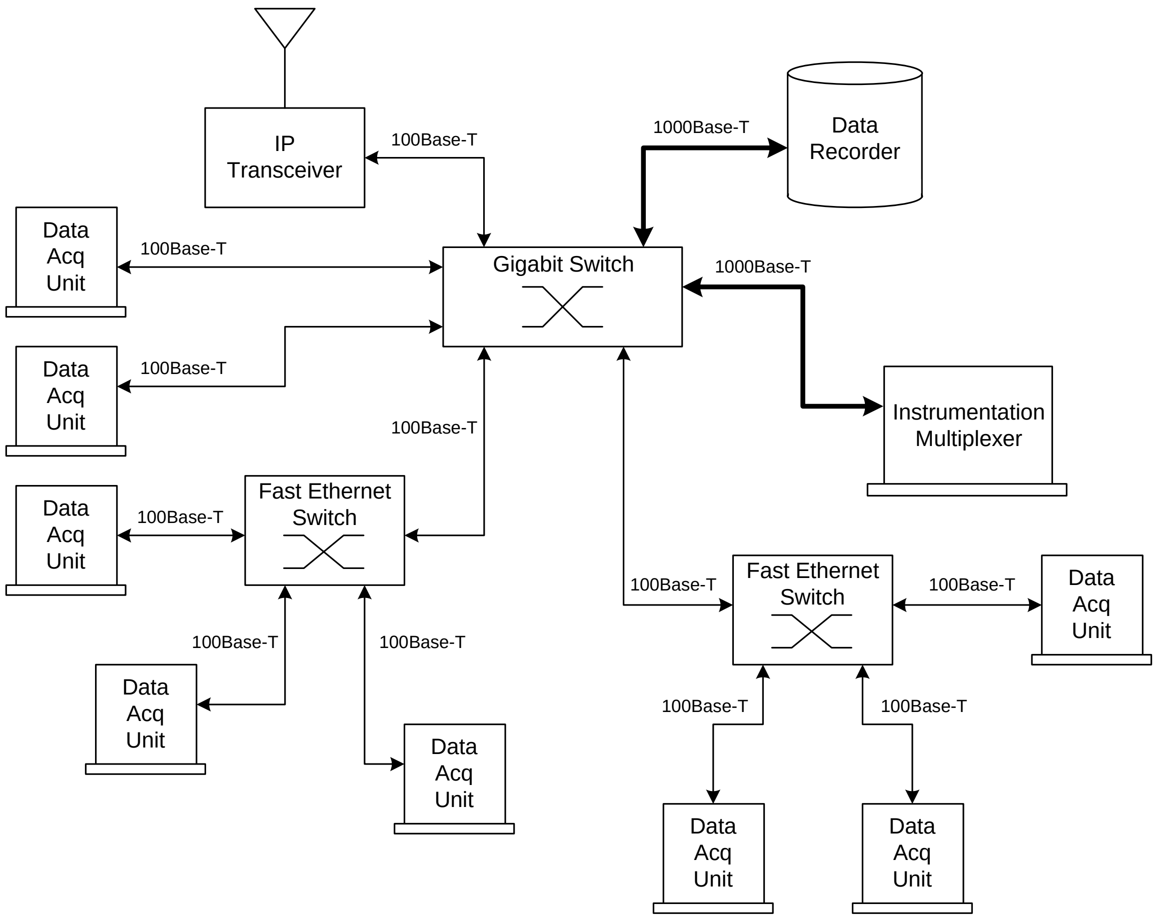

Figure 1. A Typical Instrumentation Network

BANDWIDTH CONSIDERATIONS

When architecting a network-based system, the system designer must consider the bandwidth requirements. The system, and any given bus segment, should be designed based on both average and peak data rates to guard against oversubscription. Failing to do so can lead to dropped packets and lost user data.

When designing a network of data acquisition units, it is important to know the characteristics of the data flowing through the system. Some units may generate a fairly constant bit rate, while other units may generate data in bursts. At the physical layer, the designer must choose the appropriate link speeds to support the anticipated traffic requirements. For example, if a device acquiring MIL STD 1553 data can generate up to 12 Mbps of traffic (data + packet overhead), the designer may choose to connect the device to a switch using a 100Base-T (100 Mbps) link.

Assuming a maximum sustained throughput of 70 Mbps, the 100Base-T link would be more than fast enough to handle the traffic from the 1553 acquisition unit. In fact, the link would be under utilized in this case.

USING A SMALL SWITCH IN THE NETWORK

In the example above, a data acquisition unit (DAU) at the edge of the network is connected to a switch via a 100Base-T link. The DAU is using a fraction of the capacity of the link. A small integrated switch could be employed to add more DAUs upstream from the switch port. This allows better utilization of the given network segment connected to the switch port. Figure 3 below shows two 3-port switches inserted into the bus segment. The switch is implemented as a module that is included in the DAU. In this way, the switch can take power from the DAU and share the footprint of the DAU within the test article, thereby not requiring it's own power supply and chassis (to save space, weight and cost). In Figure 2, one DAU is connected to the switch port sending 12 Mbps to the switch. In Figure 3, the switch port utilization has increased by adding two more DAUs and two 3-port switches. In this configuration, the Fast Ethernet Switch port sees 29 Mbps (peak) traffic moving to the network over the 100Base-T link.

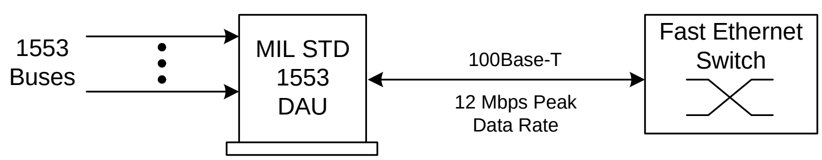

Figure 2. Original Bus Segment

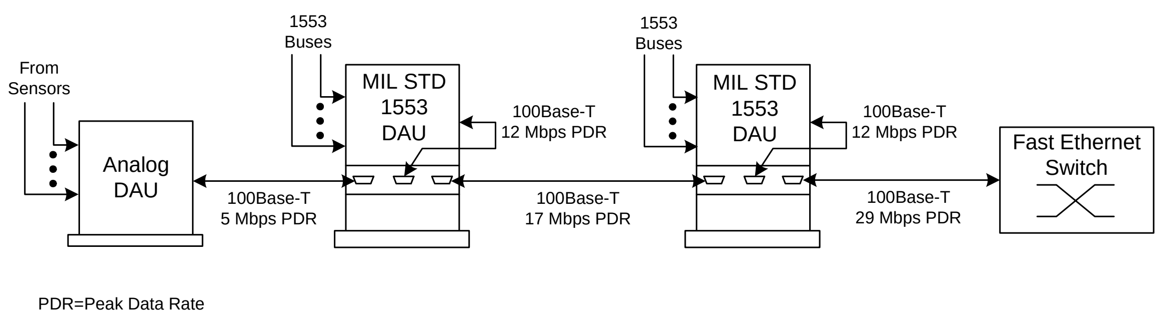

Figure 3. Bus Segment With Added DAUs and 3-Port Switches

In this example, we have cascaded additional DAUs onto an existing bus segment in an effort to better utilize the capacity of the associated switch port. In addition, fewer larger switches and less cabling would be required, depending on the number and type of DAUs used in the system and the physical layout.

Now that we have cascaded DAUs using integrated switches, what prevents the user from cascading dozens of DAUs onto a single dedicated switch port? The most obvious limitation is the sustainable throughput of the switch port. If we again use a figure of 70 Mbps, the user must ensure that the combined outputs of the cascaded DAUs do not exceed that figure. Doing so would result in over subscription of the switch port and cause packets to be dropped. Another consideration is the distribution of time to the DAUs. In this network-based data acquisition system, IEEE-1588 Precision Time Protocol (PTP) is used to synchronize the DAUs in the network. Each switch in the network delays packets moving through. This includes the PTP time packets. Accumulating delay can impact the level of synchronization between the DAUs in the network. Although switches, including the small integrated switches that are the subject of this paper, can be designed to minimize or compensate for the delay, the system designer needs to be aware of this effect and how it can impact the system design.

INSTRUMENTATION EXAMPLE

Depending on the particular application, using carefully located switch modules can reduce the number of larger switches and the amount of cabling. Figure 4 below shows a hypothetical connection diagram of an aircraft wing. The wing is fitted with twelve DAUs and interconnected to the network via one gigabit and three Fast Ethernet switches. Each DAU is connected point-to-point to a Fast Ethernet switch port and the Fast Ethernet switches are aggregated together using a gigabit switch.

Figure 5 shows the same twelve DAUs installed in the wing. However, nine of the DAUs are fitted with an integrated 3-port switch module. The switch modules allow other DAUs to be cascaded together, sharing the same Fast Ethernet switch port. The figure shows three groups of four DAUs connecting to three ports on the Fast Ethernet switch. The configuration in Figure 5 assumes the bandwidth required by the groups of DAUs does not exceed the sustainable bandwidth of the associated Fast Ethernet switch port. In many instances, DAUs collecting analog data (temperature, strain, pressure, etc.) will have relatively low bandwidth requirements. In contrast, DAUs used to monitor avionics buses (e.g., ARINC 664, IEEE-1394, etc.) can have significantly higher bandwidth requirements. The instrumentation engineer must consider these factors when designing the data acquisition system.

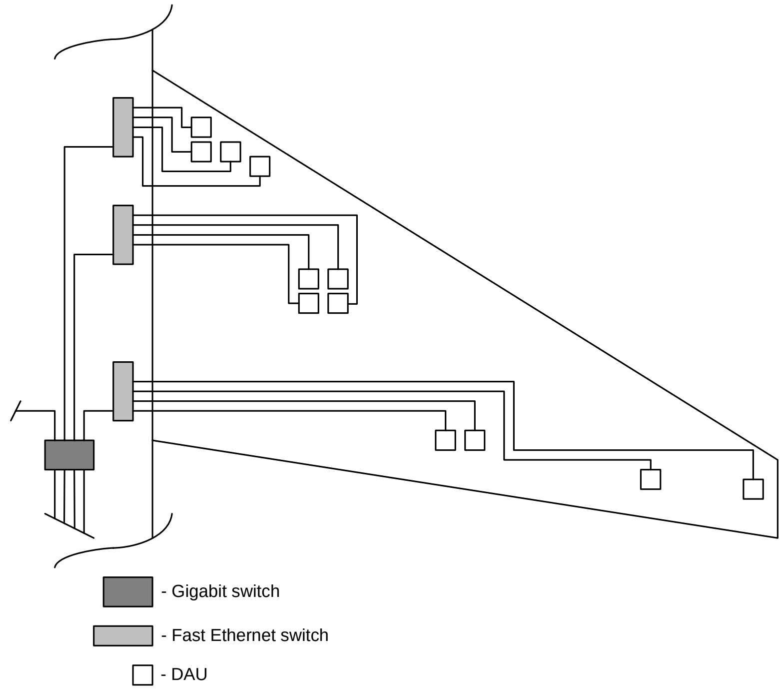

Figure 4. Instrumentation Example 1

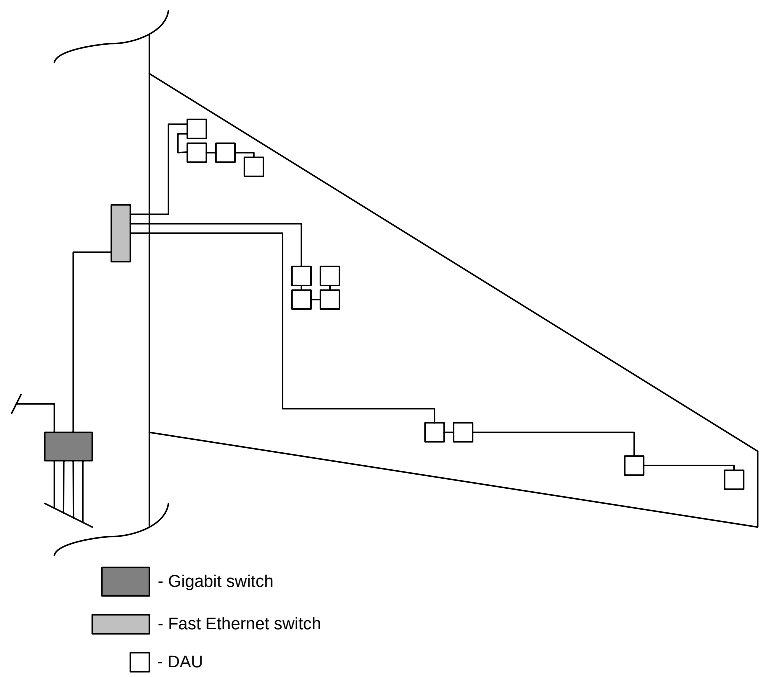

Figure 5. Instrumentation Example 2

OTHER APPLICATIONS

By reconfiguring the integrated 3-port switch, it can be used for other applications. One application is as an Ethernet tap or monitor. Here, the switch is used to capture or monitor Ethernet traffic between two nodes on a network segment. Monitored traffic can be processed by the DAU and sent to the network for recording, for example. Figure 6 below shows this configuration.

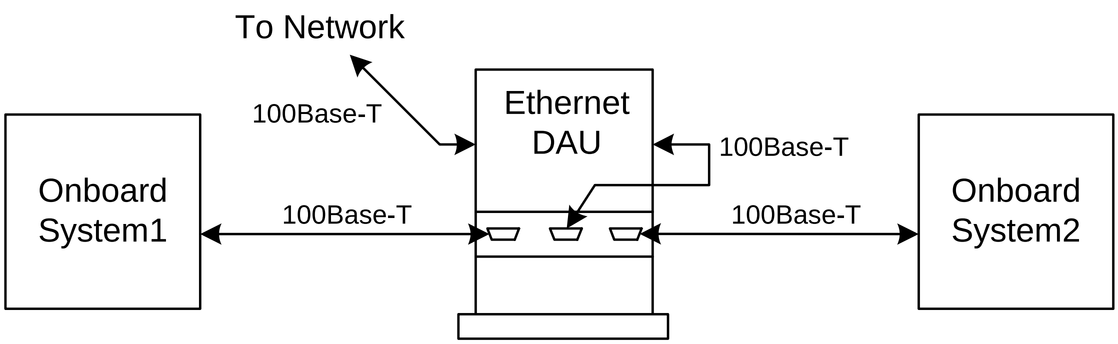

Figure 6. Ethernet Tap Configuration

Another possible application for a 3-port switch is as a traffic mirror. All traffic flowing into one port could be forwarded to both ports and directed to two DAUs. This could be useful when a DAU has limited processing capability and a second DAU is required to handle the processing load.

USE OF CAIS BUS WIRING FOR NETWORK INTERCONNECT

The CAIS Bus is used in many military test articles. It is a dual simplex type bus that uses two cables (one for command and one for reply). CAIS Bus compliant cables use a shielded twisted pair (STP) structure. Similarly, a 100Base-T Ethernet bus uses a twisted pair cable (2 differential pairs), one pair for transmit and a second pair for receive. Conceptually, it would seem possible to reuse the CAIS cabling to wire an Ethernet node.

The characteristic impedance (Z_o) of the CAIS Bus cable is specified in the range from 73 to 83 ohms [1]. For an Ethernet bus, on the other hand, specifically 100Base-T, the impedance specification is 100 ohms nominal. Despite the difference in Z_o, experiments using at least 100 ft of CAIS Bus cabling for 100Base-T communications have been successful. This opens up the possibility of reusing CAIS Bus wiring for connection of network nodes. When used in this way, the existing wiring would carry data, command, reply, health and status information as well as network timing, i.e., IEEE-1588 PTP to/from the network node.

CONCLUSION

A small switch can be a versatile, cost saving addition to a network-based data acquisition system. Used affectively, the small switch can increase the bandwidth utilization of core switch ports in the network. This equates to fewer overall core switches and reduced wiring, in many applications. With changes to its configuration, the small switch can play other roles in the network including traffic monitor and traffic mirror.

REFERENCES

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[2] IEEE Std 802.3, 2000 Edition, Part 3: Carrier sense multiple access with collision detection (CSMA/CD) access method and physical layer specifications, October 16, 2000.

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