Development of a High-Speed, Networked, Multi-Channel COTS Wireless Data Acquisition System

Robert L. Myers
ViaSat
Carlsbad, CA

ABSTRACT

Wireless data acquisition began with sensors connected to some form of radio. Emergence of the IEEE 802.11 specification made possible the evolution of a high-speed, multi-channel, wireless data acquisition system using COTS, Commercial Off-The-Shelf, technology. After developing a sub-miniature telemetry system in the S-band for the US Air Force, the system delivered to the Air Force evolved into a high-speed, wireless data acquisition system for the commercial market.

KEY WORDS

Wireless data acquisition, IEEE 802.11, high sampling rates, multi-channel, networked

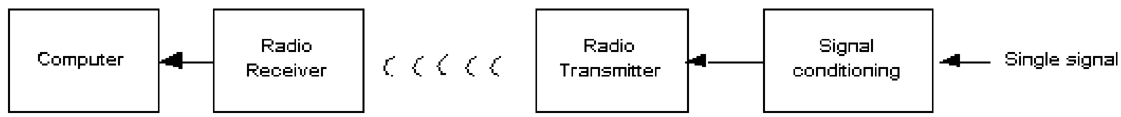
INTRODUCTION

Telemetry techniques were the foundation of the first wireless data acquisition products commercially available. Most of the systems were single-channel and slow speed. With the advent of wireless local area networking(WLAN) based on the IEEE 802.11 specification, a better wireless data transfer technique became available. Combining WLAN technology with the robust data acquisition(DAQ) and networking software capabilities of National Instruments, MiniDAT is a high-speed, networked, multi-channel, wireless DAQ system. Data enters as analog voltages and leaves as TCP/IP packets.

INITIAL DESIGN EFFORT

An initial effort by the US Air Force to develop a miniaturized telemetry system in the S-band for Eglin AFB produced a small sending unit with custom integrated circuits that worked, but was too expensive for mass production. Following this effort, the USAF issued an SBIR, Small Business Innovation Research, contract for the development of a commercial off the shelf miniature DAQ system.

The system was to have 4 channels, use COTS technology to keep costs down and be networked. Presently available systems used some form of telemetry, were single channel and slow. Low speed data transfer is adequate for applications where slowly changing data are acquired, but monitoring vibration and other signals that require a high sampling rate was not possible.



Data Acquisition via Radio

There were various permutations, but the basic technology was a carrier being modulated by a bit stream, transmitted to a receiver and demodulated at the receiving end. This provided single channel, low-speed data transfer, that typically offered long range and low cost. The radio receiver is connected to a computer, and data can be saved, analyzed and displayed. This was a great help in applications where wiring is difficult, expensive, dangerous or impossible.

In developing a networked, wireless data acquisition system, there are two problems to solve:

1. Acquiring the data
2. Transmitting the data in a networked environment.

ACQUIRING DATA

There is no need to develop analog to digital converters, multiplexers and other data acquisition hardware. National Instruments, the industry leader in data acquisition, had all the data acquisition hardware and software needed. A National Instruments PCMCIA form factor DAQCard 1200, multiplexes and digitizes 8 analog inputs at 12 bit resolution at 100 K Samples/second. A PCMCIA card was chosen for its small size.

Software to display, save and analyze the data must be developed by the user. National Instruments' LabView software is a powerful application/GUI builder that speeds software development.

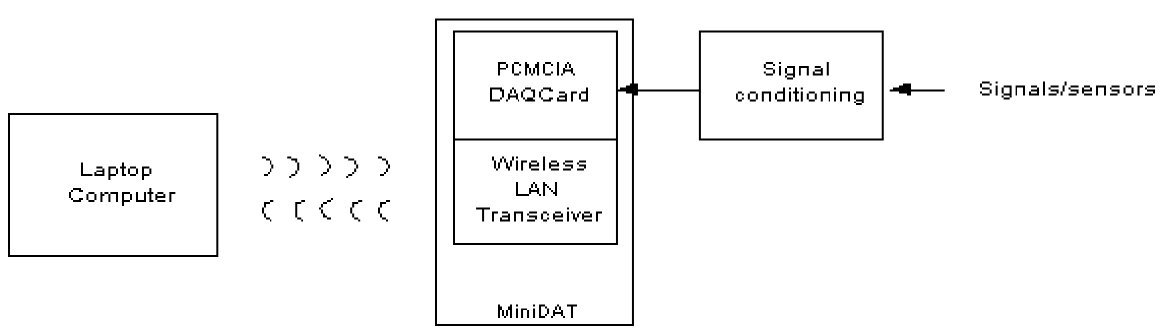
WIRELESSLY NETWORKING THE DATA

To transmit and receive the data, a WLAN chip set was purchased and a spread spectrum 2.4GHz transceiver was designed and packed in a PCMCIA form factor. The other end of the RF link was another PCMCIA WLAN card inserted into a laptop computer. This computer is called the Basestation, and runs a LabView program called a Virtual Instrument(VI). The VI records and displays the acquired data.

Using National Instruments networking software, a computer on a network can access instruments attached to another computer on the network. The data acquisition system being developed was called MiniDAT, Miniature Data Acquisition Transceiver, and is essentially a computer with no keyboard or monitor. Each MiniDAT is assigned its own IP address and can be addressed like any other computer on a network. Since the wireless connection is true TCP/IP, the instruments attached to a MiniDAT can be accessed by another computer on the wireless network exactly the same as on a hard-wired Ethernet network.

What are the network induced delays over a wireless network? Can you predict them? The answer is the same as for a hard-wired network, the delays are a function of the amount of traffic, the number of nodes in the network and the size of the packets. **ping** is network command that tests the reachability of another node on a network. Using the ping command on a Basestation, echo requests are transmitted to a MiniDAT. If the MiniDAT responds, a return message is sent back to the Basestation. ping tells you how long it took for the return to arrive. ping indicates a delay of 4 milliseconds with one MiniDAT and one Basestation on the network.

What does a ping delay of 4 msec predict about the network delays in acquiring data? Not much. Network delays are installation specific. Networking is not deterministic and therefore is not suitable for real-time applications.



Wireless NI Data Acquisition with MiniDAT

COMMERCIAL PRODUCT

The WLAN cards designed for MiniDAT were close to the IEEE 802.11 specification and it was decided to purchase IEEE 802.11 based WLAN cards. By purchasing WLAN cards and external antennas from the same supplier, a MiniDAT configuration is certified by the FCC. WLAN cards are available as ISA and PCI interface cards if a laptop is not being used as a Basestation. Access points will connect MiniDATs directly to a wired LAN, allowing any computer on the network to act as a Basestation.

Since MiniDAT uses TCP/IP, it can be connected to the Internet. If the Internet is not suitable for a remote application, satellite communications systems can connect a MiniDAT to a computer anywhere in the world.

INSTALLATION CONSIDERATIONS

FCC regulations limit the amount of power a WLAN transmitter can output. Will the output power be sufficient for a given application? Will the system be used indoors or out-of-doors? Will there be a line of sight between the Basestation and the MiniDAT?

What is the maximum rate at which data will be acquired? WLANs have a maximum data rate that typically varies between 1 Mbit/second and 11 Mbs. The trade-off is range. The faster the data transfer, the shorter the range.

A path must exist for RF energy between transceivers. Sometimes RF will bend around corners and sometimes in won't. A direct line of sight between transceivers provides the highest probability of a reliable link. In mobile applications, or industrial applications similar to the one described below, a consistent, reliable line of sight is problematic.

A MiniDAT may be located such that the internal antenna is surrounded by metal. External antennas can address this problem. They can add higher gain to increase the effective range, have a radiation pattern that provides better coverage and be located to provide a line of sight. A vertically oriented dipole omni-directional antenna can circumvent obstructions to an RF link for a moving platform. Directional antennas typically have higher gain, but must be pointed at the transmitter. The ability to attach external antennas to the WLAN transceiver card is a necessity for industrial applications.

INDUSTRIAL APPLICATION

AstenJohnson is a company that makes products and provides services for the paper industry. One of the many resources offered by AstenJohnson is the Diagnostic Service Group. This group is comprised of papermakers and diagnostic engineers that are charged with helping the customer troubleshoot, identify, and offer possible solutions to machine productivity issues.

When a problem can not be identified using conventional papermaking methods electronic diagnostic equipment is utilized to measure process instabilities. Through the introduction of pressure sensors into stock lines, triggers on stock delivery rotating elements, inline measurement of stock consistencies, placement of vibration sensors on machine structural elements, and electronic monitoring of machine process signals, such as basis weight and opacity, electronic data is simultaneously taken regarding machine performance.

All signals are conditioned using the National Instruments SCXI-1001, 12 slot chassis. This chassis provides 34 channels of signal conditioning for pressure, vibration, triggers, and several specialty sensors. The chassis is setup in multiplexed mode using the NI-DAQ software driver and is controlled by a DAQCard-AI-16XE-50 PCMCIA card. All signals are recorded and analyzed using a custom analysis package written specifically for AstenJohnson in LabView.

When testing is performed on a paper machine most of the required test points are located on the wet end of the machine in the stock approach system. The SCXI chassis and laptop computer are set up on the wet end of the machine and 100 foot cables are dispatched to the individual test points in the approach system, including the basement. To measure the impact the variations in the stock approach system have on the sheet quality, the on line basis weight signal is accessed on the dry end of the machine. The distance between the wet end and the dry end of many of the machines measured is typically 400 to 500 feet and requires stringing 100 foot cables together from one end of the machine to the other. The cables must be laid on the floor and routed around section drives, line shafts, and stock chests and poses an extreme safety hazard.

MiniDAT provides a high-speed, multi-channel, networked, wireless link between the dry end process signals and laptop computer simultaneously with data from the SCXI chassis. Utilizing the capability of the MiniDAT eliminates the need to run long cables from one end of the machine to the other making set up much easier, faster and safer. Each MiniDAT has its own IP address making it possible to access several devices at various locations on the machine.

Connecting the MiniDAT directly to the SCXI-1001 chassis allows direct access to all signals from a remote location. This is especially useful when making changes to machine operating parameters. The analyst and laptop computer can be located in the machine control room providing direct feed back from the changes to the papermaking process. Since every MiniDAT has its own IP address and supports Internet access, consideration has also been given to installing the diagnostic instrumentation at a mill site and troubleshooting over the Internet.

The MiniDAT is also used to access signals from an SCXI-1000, 4-slot chassis. This chassis provides 15 channels of pressure, trigger, and specialty sensor signal conditioning. This chassis is utilized at mill sites that provide no immediate access for the 100-foot cables to be run to pressure tap locations in the basement of the machine. By using the MiniDAT the signals are accessed from the SCXI-1000 chassis through the concrete machine room floor.

INTELLIGENT SENSORS

If sensors collecting data could process the raw data, they could send the results of their analysis to a Basestation instead of the raw data. This would significantly reduce the amount of data transmitted.

Networks have a maximum bandwidth which may be a limiting factor when multiple nodes on a single network are transmitting rapidly changing data.

Adding computing power to sensors will make the sensors larger and more expensive. If the sensors are wireless, adding transceiver capability will also increase size and cost. Small sensors will not be able to radiate at high power output, and the effective range will be lessened. Using the computing capacity of the CPU chip inside the MiniDAT will not make the sensors intelligent; however, it will bring intelligence close to the sensors.

Consider a machine with 12 bearings to be monitored. An accelerometer is placed on each bearing, and the vibration data sent to a MiniDAT located on the machine. If the vibration levels on all bearings is below a pre-defined value, MiniDAT sends a pass message to the Basestation. When the vibration on a bearing increases and exceeds a threshold value, a warning message is sent to the Basestation. Rather than filling the network with 12 vibration waveshapes, a few pass/warning/fail messages are sent.