

Unlike government bodies in the recent past, who specialized in collecting and storing data, users today seek to actively use the data for improved understanding and management of environmental conditions – for example, through modeling and projection work. For this reason it is imperative that monitoring agencies, scientists and researchers receive data in a reliable, timely and easy-to-understand manner.

The roll-out of wireless technology for data reporting is already underway in many areas. The need for more information on a timely basis has spurred counties and cities to establish wireless networks that enable real-time assessment capability. These easy-to-deploy networks also provide an infrastructure for real-time environmental data monitoring.

Intelligent environmental sensors and data collection platforms, several of which are already proven and on the market, offer compatibility with numerous wireless network protocols, including satellite and Bluetooth® communications. With many options available, it is important to understand the features, advantages and limitations of each in order to select the optimal solution for a given data collection system.

Essentially, wireless communication options are simple. They include a modem that provides a defined radio frequency (RF) and an antenna. However, radio waves or signals exhibit very different propagation characteristics depending on their frequency band, so engineers must take into consideration these characteristics when designing a wireless system.

The complication comes with the numerous types of communication modems built to capture these signals. These modems and their respective frequency bands include:

- Very High Frequency (VHF) - 30 to 300 MHz
- Ultra High Frequency (UHF) - 300 to 1,000 MHz
- Cellular – handset / modems: 824.01 to 848.97 MHz; cell towers: 869.01 to 893.97 MHz
- Spread Spectrum - 902 to 928 MHz and 2,400 to 2,483.5
- Bluetooth –2400 to 2483.5 MHz

- LEO (ORBCOMM) satellite - uplink: 148 to 150.05 MHz; downlink: 137 to 138 MHz
- GOES Geostationary satellite – uplink: 401.7010 to 402.0985 MHz; downlink: 1600 MHz

Factors to Consider

In addition to frequency band and modem output power, there are other factors to consider, which influence the optimal range of communication. One is “Line of Sight” which means one antenna must “see” the other, without obstructions. Line of sight is not mandatory, but when available, greatly improves performance and range. This is especially true with higher radio frequencies where signal strength is reduced from obstructions such as walls, trees, foliage and concrete and eliminated with metal objects or structures.

Positioning, gain, antenna tuning, atmospheric conditions, time of day, ambient frequency, noise, and terrain are also all important variables affecting RF signal and communication range.

VHF and UHF Radio Communications

Because of the flexibility and range (typically good for up to 30 miles) VHF / UHF systems are often used in environmental monitoring applications involving gate or pump control, and with SCADA (supervisory control and data acquisition) systems. Frequency bands are typically 66 - 79 MHz; 132 -174 MHz; 216 - 266 MHz; 380 - 512 MHz and 928 - 960 MHz.

It is important to carefully evaluate the condition of the remote site when configuring a VHF / UHF system. Typically an engineering firm performs a radio propagation study to determine the best configuration and whether additional repeater sites are required. Such additions could greatly increase the costs.

VHF / UHF telemetry systems also incur licensing costs from regulatory authorities such as the U.S. Federal Communications Commission. However, since the user is assigned a specific frequency, interference from other radios is low. In addition, users have control over their data and can define the frequency of interrogation and transmissions. Data packets are typically sent with transmission

confirmation and are error-checked and corrected. The configuration of the data packets is either done by the data logger or by a smart packet radio.

Cellular Telemetry

Telemetry is the science and technology of automatic measurement and transmission of data by wire, radio, or other means from remote sources, as from space vehicles, to receiving stations for recording and analysis. Originally designed for voice communication, the cellular infrastructure uses a network of base stations and antennas, called a "cell," to cover a large area. Cell sizes range from six-tenths of a mile to 30 miles (1km to 50km) in radius. The Global System for Mobile Communications (GSM) is growing in the United States and uses much smaller cells, fewer than 6 miles (10km) across.

Cellular telemetry in environmental monitoring applications works well in areas with strong and reliable cell coverage. Although cellular coverage is increasing, there are still many remote areas where it is not available or the signal is weak. Also, because the cellular infrastructure uses a control channel to send packets of data, cellular voice coverage does not always equate to quality data coverage. Therefore, it is critical to ensure quality data service is available before choosing this option.

Circuit-switched data services are billed by time and are suitable where infrequent connection is needed and large data files are transferred. Packet data service is suitable for data collection or alarming applications because small amounts of data are involved and remote systems often monitor continuously.

Spread Spectrum Radio Communications

The FCC has allocated some specific frequency bands for flexible use. Called Spread Spectrum, these bands have two primary advantages: they are unlicensed and free.

Spread Spectrum relies on one of two coding techniques: Direct Sequence or Frequency Hopping. Direct Sequence enables digital radio transmission on multiple radio channels. Frequency Hopping concentrates the radio power on one narrow channel at a time for a very short duration and typically are better in environmental monitoring applications where a strong penetrating radio signal is more important than high data rates.

The 900MHz band allows for a better radio propagation and penetration properties than 2.4GHz, however the 2.4GHz band is designed for much higher data rates. Bluetooth and Wi-Fi communications use the 2.4GHz band. For environmental monitoring applications, where the amount of data transmitted is small and the radio paths are not congested, the 900MHz band gives better performance.

A Spread Spectrum system is more easily set up than a VHF / UHF systems and a site radio propagation study is usually not required. However, because these bands are free, signals may be heavily polluted by

other unlicensed systems and may degrade signal integrity and range.

In a new type of water operation, two large golf courses in Augusta, Ga., use spread spectrum transmitters connected to data loggers to send data on soil moisture, salinity, and temperature from buried probes on the green to a PC in the maintenance building. The wireless data feed goes directly into a SCADA system, allowing the superintendents to view soil trends and trouble spots to help them optimize watering and fertilization.

Bluetooth

A relatively new radio protocol increasingly being used in environmental monitoring applications, Bluetooth is a low-cost, low-power, short-range radio link between mobile PCs, PDAs, mobile phones, and electronic instruments. This simple two-way radio solution allows different electronic instruments to "talk" to each other without cables or infrared.

When combined with data loggers through an RS232/RS485 Bluetooth serial port adapter with an external antenna, Bluetooth technology offers many other advantages. It eliminates the need to open enclosures that house the data logger, in order to establish communications. It can be used to collect data from a remote site or be employed as the link from the data collection platform to a nearby telemetry modem whose location is better positioned for RF performance. In monitoring applications, data logger communications also can be established without users leaving their vehicles, eliminating the need for field staff to hike up and down to rugged sites. For industrial water sites, strategically placed Bluetooth-enabled data loggers can replace cable solutions for data transmission to a central computer or laptop.

One example is Stevens Water Monitoring System's Class 1 RS232 Bluetooth adapter that enables a wireless link between any data logger with a serial port and another Bluetooth-enabled computer, PDA, telemetry modem or other device.



Stevens Bluetooth RS232/RS485 adapter attached to a datalogger in an industrial environment.

A U.S. Geological Survey (USGS) office uses a Bluetooth adapter connected to a data logger located in a stream gage house on the opposite side of the river from the access road. An external flushmount antenna connected to the adapter is mounted on the outside of the gage house. As a result of this installation, the USGS is able to communicate wirelessly with the data logger from the access road.

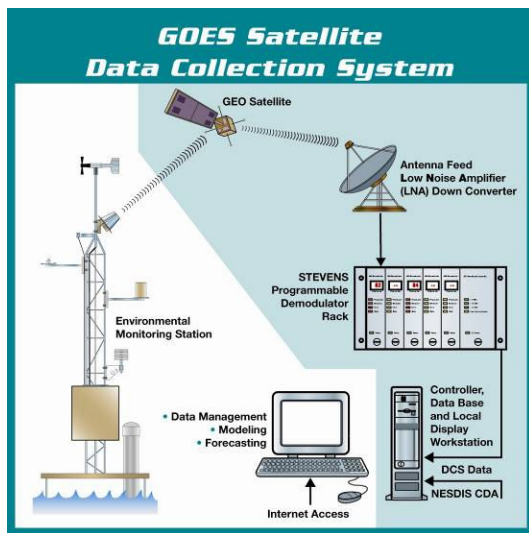
Eliminating the cable connection between a data logger and other equipment connected to the data logger's serial port makes for less cumbersome and more productive fieldwork. In another example, various governmental agencies have used an RS232 Bluetooth adapter connected to an instrument on a mini-catamaran platform for river discharge measurement. The Bluetooth wireless data link between the instrument and the user enables easy deployment and quick data collection as the mini-catamaran is pulled across the river with a tagline.

In areas where an RF signal is impeded, such as a sewer manhole, valley, or structural interference, a Bluetooth-enabled data logger can wirelessly relay data to a nearby radio, satellite, or cell modem, for long-range communication to or from a remote central office monitoring station.

One additional Bluetooth benefit minimizes costs even more. There is no need to purchase expensive environmental rugged computers/PDA enclosures for downloading data.

Satellite Telemetry

Bouncing an RF signal off a satellite is one of the best options for remote installations, especially in locations where no other reliable RF or telephone coverage is available, or the infrastructure cost, such as using repeaters, is not economically feasible. There are two primary satellite systems that offer remote environmental monitoring applications: Geosynchronous Earth Orbit (GEO) and Low-Earth Orbit (LEO).



GEO Satellites

GEO satellites are positioned at a fixed point approximately 22,000 miles (36,000 kilometers) above the earth's equator. This height matches the earth's rotation speed and allows the satellites a full-disc view at a stationary position. They are primarily used for weather imagery to enhance forecasting.

The United States normally operates two GEO meteorological satellites, named GOES (Geostationary Operational Environmental Satellite) West and GOES East. In addition to weather imagery, these satellites include instrumentation used in environmental monitoring communication via a relay system, known as the GOES Data Collection System (DCS).

Only Federal, state and local agencies and government sponsored environmental monitoring applications can apply to NOAA / NESDIS for permission to use the GOES DCS. Although the DCS is a one-way transmission and offers no transmission verification and no retransmission of missed data, the data transmissions are very reliable and data is easily shared among government users.

LEO Satellites

LEO Satellites typically orbit about 400 to 800 miles above the Earth's surface and orbit a local horizon in approximately 20 minutes. The orbiting periods range from 90 minutes to two hours, at approximately 17,000 mph. LEO systems use a satellite-to-satellite hand-off to maintain communications and are best for short, narrowband communications.

ORBCOMM, a leading LEO system used in environmental monitoring applications, provides global coverage with 30 satellites, and is capable of sending and receiving two-way data packets anywhere in the world. It verifies data transmission to minimize the risk of missing data. Unlike GEO satellites, most LEO satellite systems are commercial ventures; therefore, the data is proprietary.

Subscriber communicators pass data messages to and from Gateway Control Centers (GCC) over ORBCOMM satellites. GCCs then route messages to third party services such as one operated by Stevens, who then deliver the data message to users via Internet, e-mail or dedicated delivery lines. Since the lifespan of a LEO satellite is five to eight years, another important consideration for long-term users is the satellite maintenance and replacement plan the LEO provider offers.

The Texas Commission on Environmental Quality (TCEQ) has a goal of identifying trends and tracking loading reduction into the Bosque and Leon River watersheds, two central Texas watersheds affected by point and non-point sources. It uses the data to assist in implementation of environmental management plans.

To address this challenge the TCEQ has deployed four continuous water quality-monitoring stations in the watersheds for the two rivers. It uses Stevens - Greenspan AquaLab Analyzers to monitor physical and nutrient water quality parameters. AquaLab's

ability to provide frequent measurements is important to the program's emphasis on continuous monitoring.

TCEQ turns to Satellite Systems for Tracking Nutrient Loading Reduction

TCEQ relies on measurement accuracy and real time reporting of the parameters. They make full use of wireless capability by sending data over a GOES high data rate satellite transmitter hooked up to the analyzer's data logger unit. TCEQ is able to select how frequently they want the data transmitted. It was important that the water monitoring and data collection platforms they chose to deploy offer easy compatibility with wireless systems.

On the Horizon

The first version of a new short-range wireless technology called Zigbee was ratified in December 2004. Zigbee is not meant to replace Bluetooth but rather to offer a wireless option for organizations that might want to set up entire systems of low-data rate networked sensors that can communicate with each other as well as with a central computer or data collection platform.

Zigbee may be just the thing for industrial water and watershed monitoring alike – imagine a network of instruments and sensors that can “talk” with each other to automatically assess and respond to water related events. The chips are projected to be low-cost and offer major power savings for a lifetime of 5 years. The range of the radio is 50 meters.

Zigbee devices form star topology or even peer-to-peer local area networks, offering data rates of up to 250 kilobytes per second (kbps). The protocol supports up to 255 devices per network and operates using CSMA-CA (Carrier Sense Multiple Access/Collision Avoidance) channel access across 2.4GHz and 868/915MHz frequency bands. CSMA-CA requires a device to broadcast a signal onto the network in order to listen for collision scenarios and to tell other devices not to broadcast, keeping data transmission reliable.

New data loggers simplify applications

While most of today's data loggers can be configured for wireless communications, some are already optimized for wireless data communications. These loggers are smaller, cheaper, rugged and can be easily programmed using Windows based software for telemetry applications including satellite, radio, telephone, and Ethernet links. Data can even be accessed via a wireless internet connection. The new loggers can upload data to a PC for easy viewing in tabular or graphic format, or for importation into popular spreadsheets such as Microsoft's Excel.

Final considerations

One last factor to consider is ongoing cost. Of the various telemetry options, only cellular and LEO satellite systems involve a communication fee based on time or data transmission or both. Fees range from \$30 to \$70 per month. GOES Satellite, VHF, UHF,

Spread Spectrum, and Bluetooth communications do not incur monthly fees.

With information about the options at hand, only a few steps need to be taken to choose a system: evaluate the water monitoring application; outline data collection needs, making sure to include expansion expectations; and consider costs.

Scott South is president and CEO of Stevens Water Monitoring Systems Inc., headquartered in Beaverton, Ore. He can be reached by phone at (800) 452-5272, ext. 18, and via e-mail at ssouth@stevenswater.com.