STRATEGIC IMPLEMENTATION OF WIRELESS TECHNOLOGIES

Jim Gardner

FreeWave Technologies
Boulder, Colorado, USA

This SCADA design overview reviews the six key steps for specifying basic system requirements, followed by the primary considerations for developing a radio communications system that includes technology best meeting your objectives.

Defining Requirements for SCADA Systems

Designing a SCADA (supervisory control and data acquisition) communications systems starts by answering 6 key questions:

1. **Volume of data retrieved**: How much data will be requested each time a remote site is interrogated?
2. **Frequency of polling**: How often will each site be interrogated?
3. **Location of master**: Where does the data need to be brought back to?
4. **Location of slaves and repeaters:** What is the geographic location of the "slave" or remote sites?
5. **Number of remote sites**: What will be the total number of locations you want to retrieve data from when the system is completed?
6. **Cost**: What are you willing to spend to have "near real-time" data from remote locations?

Volume of data retrieved:

In gas measurement, 30-day historical records are usually small enough to be easily retrieved by a variety of communications devices, so this question alone should impose no limitations. A typical historical record can vary from 1 to 80 K of data. Either amount can be retrieved in a few seconds by most communication devices. Additional important factors to include in your evaluation include the length of time required to retrieve data from one data-gathering device, and the number of devices to be polled.

To estimate data retrieval requirements:

$$\frac{\text{\# bytes data required}}{\text{speed of communication device (bytes/second)}}$$

For example:

$$\frac{\text{40,000 bytes of data}}{\text{1,200 baud}} = \text{33 seconds}$$

This is the time required to retrieve the data per location. At 1200 baud, 100,000 bytes of data will take 83 seconds (1½ minutes) per location, and so forth.

Frequency of polling:

There are many ways to answer the question: "How often should a SCADA system be polled?" Some operators prefer to poll once a day and retrieve a three-day historical record of all flow measurement for this period. Others choose to poll hourly and retrieve a 24-hour flow record every hour. Still others poll as quickly as the system will allow (every few minutes) looking for status changes. (e.g. pressure drops, temperature changes, liquid level changes, etc.). The answer to this question, combined with data to be retrieved multiplied by number of sites to be polled, will help clarify which technologies are a "best fit" for your specific needs.

Location of the master:

Where will the master be in relation to the remote sites? This is the location where the polling engine, computer, data base, historical records, etcetera are kept? Will it be within 50 miles (80 kilometers) of the remote sites, or much farther away? This will impact which technologies or combination of technologies will provide your "best fit".

Location of slaves and repeaters:

Certainly some of the answer for the location of the slaves will depend upon where your wells are located. You may also face requirements for placement of repeaters, depending on the topography of your location. What is the terrain in the area? Are there hills, valleys and trees? What is the distance between locations? What is the overall distance across the field (width and length)? Distance and obstacles to "line-of-sight" will affect your decision on which technologies are applicable to the project. Every technology has its strengths and weaknesses. In some cases the "best fit" of technologies will be a combination of communications devices or a hybrid system of radios, satellite system and other tools.

Number of remote sites:

This item is closely related to the location question. The number of remote sites, and the amount of data retrieved at each site combined, will equal the total amount of data to be retrieved in every polling cycle. For example, if you have 250 sites and your data to be retrieved is 40,000 bytes/site, your total amount of data to be retrieved in a single complete cycle is 10,000,000 bytes. By knowing this total and knowing the speed of your proposed communication system, you can estimate at what intervals you will be able to poll the field. If you need to move 10,000,000 bytes every cycle, and your communication system works at 1,200 baud, the minimum amount of time required for each polling cycle is 139 minutes (2 1/2 hours). If your communication system and flow computer can both talk at 115.2 Kbaud, the minimum amount of cycle time drops to about 1 ½ minutes.

Cost:

Several "cost" factors must be considered when choosing a communication system. Some devices, such as radios, have a fixed cost. This is the capital cost to purchase and install the equipment. Others, such as cell phones, landlines, and satellite have both a capital cost component and a monthly expense fee for use. This fee is generally based on the number of data bytes sent through the system each month. Some systems have a monthly "all you can eat" fee for high-volume users, providing a fixed monthly charge regardless of usage.

Another "cost" is the less-tangible "cost of ownership." The most common cost of ownership not easily calculated results from using a system that is not your own, such as satellite or cell phone. In these systems, you are a subscriber – and if the system goes down, you must rely on an outside source for repairs. This may mean long delays before repairs are completed; during that time, you must collect your data by hand, or do without.

Other lifetime system costs to evaluate include your provider's track record with obsolescence, warranty, replacement program and field failure rate. All of these factors can end up costing much more than you originally budgeted. For example, if the field failure rate is high, you will be spending valuable time tracking and trading equipment.

Communication Technologies

Common technologies used for SCADA today include:

- Licensed radio
- Spread spectrum radio
- CDPD (cell phone)
- Land line (telephone)
- Satellite
- Microwave
- Hybrid systems (combinations of these)

Your answers to the previous six questions will determine which technologies are "best fit" for your specific needs. These answers, combined with an understanding of the relative strengths and weaknesses of each technology, will help you determine how to match technologies to your desired results. The commonly used technologies are reviewed below, with a brief description of each, and its key advantages and disadvantages .

<u>Licensed Radio</u>

The term "licensed radio" refers to a radio system where the purchase of a license from a regulatory agency is required (such as the US FCC). The license provides for a given frequency in a given geographic area. This is typically a 50-mile (80-km) circumference from the base station. The license holder is expected to provide locations, tower heights, and broadcast power information to a frequency coordinator to insure that no users overlap or cause interference on their assigned channel. The strength of this system is that it should have "clear channel," meaning that it is interference-free. But a major weakness is that it often is not.

The licensed radio system can use a large amount of radiated power (signal strength). The maximum power at the antenna can be as high as 20 Watts, which provides great range. A line-of-sight of 40 to 50 miles (60-80 km) is sometimes possible without a repeater. Licensed radios can have only one repeater in a system to expand range and area of coverage. However, a spread spectrum system can be added onto the "tail-end" of a licensed system to allow even greater range and flexibility.

In areas where all of the slave sites can see either the master location or the one repeater, licensed radio is a viable choice. In areas where long distance is a primary requirement (40-50 miles, or 60-80 km) line-of-sight, again licensed radios make an excellent choice. They provide a low-maintenance, low cost-of-ownership solution.

Other disadvantages to licensed radios are they are very susceptible to interference. If someone broadcasts on your frequency it will almost always stop your system from communicating. Another disadvantage is the one repeater limitation. If you have sites that cannot "see" (line-of-sight) the repeater, they will be unable to communicate with the rest of the system. With licensed radio systems, fees must be paid to the regulatory agency for the right to use the frequency. Licensed radio systems are fairly slow, with speeds of 1,200 baud in older models, and 9,600-19,200 baud in many of the newer models.

<u>Spread Spectrum Radio</u>

Spread spectrum radio is a system that requires no licenses or fees. The radio is a digital device that changes channels many times per second; each time it changes channels, it sends a packet of data. Advantages of spread spectrum include:

- Multiple repeaters (in some radio brands, this is unlimited);
- Every radio can act as both a slave and a repeater, so any flow computer can act as a repeater for any other

flow computer, dramatically reducing the cost for tower space, and allowing the user to reach a greater number of remote locations in rugged terrain (hills, mountains, valleys, buildings, etc.).

- The packets of data each have a "check sum" which provides built in error detection and auto retry in the event that a data packet encounters interference.

The biggest weakness to spread spectrum is power. Typically, regulators limit the maximum output power to 4 Watts at the antenna. This reduces the range to about 30 miles (48 km) with line-of-sight. The technology can sometimes reach up to 60 miles (96 km), but that is an exception. One way spread spectrum compensates for this is by using multiple repeaters. Pipeline operators often link multiple repeaters together to attain distances of up to 100 miles (160 km), or 10-20 miles (16-32 km) per link.

Another advantage of spread spectrum is that they have much lower power consumption: Some brands use ten times less power than licensed radios. This means you would need smaller solar panels and batteries to power the system, which means lower installation cost.

Greater throughput is available with most spread spectrum radios. Many can transmit and receive at up to 115.2 K-baud. They can unload data over the air at this speed, regardless of how fast the flow computer loads data to them. Many spread spectrum manufacturers can also handle multiple protocols through the same radio, such as RS-232, RS-485, ttl, and Ethernet. Some radios can act as a terminal server and convert serial data to Ethernet. At least one brand does digital alarms with no external RTU required.

<u>CDPD</u>

This technology was widely deployed a few years ago, and operates on the analog portion of the cell phone network. Its advantage is that no infrastructure is required. Any remote device within cell phone coverage can be polled from anywhere if there is access to a phone connection.

Another advantage is that the CDPD itself has an IP address, so can be polled over the Internet. The disadvantages are that there are fees for the amount of data passed through the system each month (fees can be as high a $50 US per month, per site.). Again, this is a subscription service where you purchase the hardware and then pay a monthly fee. If the system goes down, you must rely on someone else to provide service and repair. Probably the greatest disadvantage is that this service will be discontinued by AT&T in the near future. New cell phone services will be replacing it, but none are backwards-compatible to CDPD.

All of the old advantages and disadvantages will still apply to the new cell phone technologies, so many are skeptical that the new services (such as GRS) will also be obsolete in a few years. They fear that any new replacement will again fail to provide backwards compatibility to the technology that is arriving on the market today.

<u>Land Lines</u>

Land lines (traditional telephone lines), while not a primary communication device, can be used as a "backbone" or long-haul communication device in conjunction with other devices. For example, many systems will use radio to create a wireless link to the flow computer and, then, set up a hub or data concentrator that is accessible by telephone. This will allow the cost for the phone service to be split over dozens of sites.

Advantages are large bandwidth capability and accessibility from anywhere the user has access to a telephone. Disadvantages include the monthly costs and service to remote areas is often interrupted. When service is down, you must wait for someone else to repair it.

<u>Satellite</u>

Again, this is not a primary communication device because of the cost. Satellite providers typically charge by the byte of data transmitted, often making this cost prohibitive for one or two locations. The advantage is the very large bandwidth available; users often use satellite as a back-haul from remote areas where they have a concentration of sites, all talking through a data concentrator to one satellite modem.

Because the satellite can talk from anywhere to anywhere, it's the most universal of all communication devices, and is also very costly. The modems are expensive, and the monthly service fees can be significant.

<u>Microwave</u>

Microwave is not a primary communication device either. But it is a great way to create data hubs and move large volumes of data from hub locations. Advantages include huge bandwidth capability and high speed. You can do voice over IP (VoIP), data collection and as many other remote communication paths as you desire. The disadvantage:

Microwave is not available everywhere, so the cost to build infrastructure is high. Microwave is located on towers set high enough to have line-of-sight across remote areas, and can often be seen 200 or 300 feet (60-90 meters) above ground. Both the hardware costs and the tower space rental cost are quite high.

<u>Hybrid Solutions</u>

This is often the best SCADA communication route if you are collecting data from multiple locations and delivering it to offices over a widespread area.

No one communication system is able to accomplish this, but by combining technologies, you can create a seamless data stream from several locations, and share data over a LAN or WAN with multiple users.

System Design

Two of the most widely used data-collection devices are licensed radios and spread spectrum radios. These can be deployed at a relatively low cost, and used in remote areas where no other communications infrastructure (such as telephone or microwave) exists. Another reason for the wide use of radio is the migration of communication responsibility to the measurement technician. They often possess the skills required to install, troubleshoot, and maintain a radio system.

Radio Installation Considerations

Before setting up a radio network, development of a “path study” and a system design are critical. This starts with compiling the GPS coordinates for the sites. A qualified technician can process this data with software that sallow you to see any obstacles to line-of-sight, and to measure the distances between sites. This information will help you specify how high to place the antennas for each site in order to ensure they communicate with the other sites in the system.

Additionally, this will tell you where to locate repeaters, how many are needed, what types of antennas to use, and what type of cable to use to connect the radio to the antenna. This can also tell you if licensed radios or a spread spectrum system would be the ideal choice for your application.

It is worth noting that licensed radios can reach a greater distance, but allow only one repeater in a system. The spread spectrum system can include multiple repeaters, but will transmit over less distance on each link.

If you use licensed radios, you can hire a firm that specializes in performing path studies. Some will also submit required paperwork to the regulatory agency to obtain radio licenses on your behalf. Most spread spectrum manufacturers provide similar services. There are also spread spectrum radio resellers and integrators who will provide these services as part of a packed offering. Key takeaway: If there is one “must do” phase in the installation of a radio system, it’s the path study and system design phase.

Radio Equipment

Once you choose your radio type, you must specify what hardware will be required in conjunction with the radios. The key components are antennas, cables, filters, towers and antenna masts.

Antennas

There are two main types of antennas: Omni-directional (omni, for short) and Yagi. The omni antenna is capable of receiving or transmitting in a 360-degree circumference (similar to the radio antenna on your car). Omnis are typically used at the master site, and at repeater sites to allow reception of remote signals from all directions.

The yagi, or directional antenna, focuses radio energy in one direction only. A yagi will broadcast further than an omni of the same signal strength.

Signal Strength

Understanding the dynamics of signal strength requires understanding and coordination of three separate numbers: The first is the output power of the radio, the second is the “line loss” of the cable connecting the radio to the antenna, and the third is the gain of the antenna.

Line loss or cable loss: Several types of cable are used in gas measurement. The type being used depends on the distance the signal will have to travel over the cable. For short distances (10-30 feet, or 3-10 meters) it is common to use a ½-inch (1.25-cm) diameter coax cable with type N connections.

The types of coax are numerous. Commonly used is LMR-400 which will have a loss of 1dBm per 25 feet (8 meters). Another commonly used type is LMR-240. If your antenna is located more than 30 feet (10 meters) from the radio, you may prefer a 7/8-inch (2.2-cm) coax cable, which has 1dBm of loss per 50 ft (15 m).

Antenna gain: The broadcast power of an antenna is measured in “dBm”, often known as “db”. Antennas are ordered from a manufacturer by specifying the amount of “gain”, or signal amplification, they produce. Typical antennas used in gas measurement are 3dBm, 6dBm and 10 dBm.

The equation for signal strength is the sum of the output power, minus line loss, plus the antenna gain. Example calculation:

Output	1 Watt or 30 dBm
Line Loss	- 1dBm for 25 ft (8 m) cable
Antenna Gain	+ 6 dBm for the antenna

= Signal Strength: 35 dBm
(roughly 3 Watts output power)

Filters

Several types of filters are available for radio systems. “Notch” filters block out a specific frequency, and “band pass” filters allow signal over a band, or range of frequencies, but block out-of-band transmissions. Remember that all filters will reduce signal strength. Your "noise" or interference level will be reduced, but so will your overall signal strength. Some good news is that the noise or interference is reduced more than the signal.

Antenna Masts/Towers

Commercial towers are available in most geographic locations, with space on these towers available for rent. In the gas patch, it is common to see dozens of antennas on any given tower. Each antenna represents a customer's repeater site for a SCADA system. Tower rental charges depend on what elevation on the tower you locate your antenna - an antenna at 100 ft (30 m) is less expensive than one placed at a higher elevation). Often, the tower owner can place the antenna, or can provide contact information for a licensed tower climber. Most commercial towers are several hundred feet (> 100 meters) in height.

It's a good idea to avoid locating your antenna near microwave dishes or paging systems. Another common mistake is placing two or more antennas on the same frequency, at the same horizontal plane. Many systems fail because of this type of antenna placement. Always allow 10 ft (3 m) of vertical separation to insure antennas do not interfere with one another. Wherever possible, antennas should have both horizontal and vertical separation of 10 ft (3 m).

Private towers are available from many communication wholesalers, such as Hutton and Tessco. These are available in two types: guided and freestanding. The guided towers have guy wires running from anchors in the ground up to two or more locations, to secure the tower. These are less expensive, but a drawback is that the guy wires use a lot of ground space, and some locations cannot accommodate additional space requirements.

Freestanding towers use less space, but require more work to install. These towers have deep cement foundations extending 6 ft x 6 ft, with a 6-ft depth for a 100-ft tower (2m x 2m, and a 2-m depth). The greatest expense in buying towers is often not the hardware, but the labor to install them. A recent quote was $9,000 USD for a 100-foot (30-meter) guided tower, and $12,000 USD for a freestanding, 100-ft (30-m) tower.

Conclusion

To design a communication system for SCADA applications, you must first identify the objectives for the system. How much data needs to be moved, how often is it to be moved, from where is it being sent, and where is it going? Matching the "best fit" technology to the application is essential. In gas measurement this is most often a radio system, or possibly a hybrid radio system that ties to a microwave or phone backbone for long-distance data distribution.

Anytime radio is to be deployed, it is critical to the success of the project that a preliminary path study and system design be developed. When these phases are completed properly, the installers will have the information needed to: order the hardware required, "kit up" equipment for each location prior to deployment (set up kits with antennas cables and accessories for each location), and preprogram the radios for each specific location. The installation crews will know where repeaters are to be located. The end-user will be able to determine whether to use commercial towers or erect his own, and will have the necessary information to accurately forecast the coverage area and the cost of the system.

A properly designed system should be able to easily accommodate expansion. History has taught us that gas fields are not static: They change constantly as reserves are depleted, and new wells are drilled.

In addition to providing near-real time data acquisition for gas measurement, a properly designed system will allow the user to accept alarms as "cry-out-by-exception" alarms. When enabling this function, the most important radio feature to look for is an over-the-air data speed significantly faster than that of the flow computers. This will allow the open-air time required to let alarms slip through in real time.

The final determination is cost. You can match the features you need, and cover the area you want to cover, for the amount you have to spend. Today's lower-cost technology makes that an easier decision than ever before.