BASIC SCADA COMMUNICATION DESIGN

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This paper provides an overview of many aspects of SCADA systems. It begins with defining the systems while also covering communications technologies, system design and radio equipment.

DEFINING SCADA COMMUNICATIONS SYSTEMS

Defining SCADA communications systems starts with the understanding of six 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. How many 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 even 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 K of data 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 time required to retrieve the data from one data gathering device to the number of devices to be polled.

An equation to help estimate data retrieval requirements is:

$$\frac{\text{Number of bytes of data required}}{\text{The speed of communication device (bytes per second)}}$$

For example:

$$\frac{\text{40,000 bytes of data}}{\text{1200 baud}} =$$

33 seconds

This is the amount of time required to retrieve the data per location. 100,000 bytes of data at 1200 baud will take 83 seconds or 1 ½ minutes per location and so on.

Frequency of Polling

There are numerous answers to 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 times number of sites to be polled will help us clarify the technologies that 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 of the remote sites, 5 miles or hundreds of miles away? It may perhaps even be in a different city or state. This answer will impact which technologies or combination of technologies will provide your "Best Fit".

Location of the 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 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 & 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" comprised of radios, satellite system and other tools.

How many 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 per 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 10,000,00 bytes of data every cycle and your communication system works at 1200 baud the minimum amount of time required for each polling cycle is 139 minutes, or 2 1/2 hours. If your communication system and flow computer can both talk at 115.2 Kbaud the minimum amount of time for a cycle is about 1 ½ minutes.

Cost

There are several "cost" factors to consider when choosing a communication system. Some devices such as radio 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 to purchase them 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 which provides a fixed rate for the monthly fee regardless of usage. Another "cost" is the less tangible "cost of ownership." The most common cost of ownership not easily calculated is having 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 are reliant on an outside source for repairs. This may mean that the repairs may not happen for several days and during that time you must hand collect all of your data 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 you much more than you originally included in your budget. For example, if the field failure rate is high, you will be spending a lot more of your own valuable time tracking and trading equipment than you might have planned.

COMMUNICATION TECHNOLOGIES

The most common technologies used today in gas measurement are:

1. Licensed Radio
2. Spread Spectrum Radio
3. CDPD (Cell Phone)
4. Land Line (Telephone)
5. Satellite
6. Microwave
7. Hybrid Systems (combinations of these technologies)

The answers to the 6 questions we asked earlier will determine the technologies that are "Best Fit" for your specific needs. These answers combined with an understanding of the relative strengths and weaknesses of each technology will help tell you how to match technology with your desired results. This next section will give a brief description of each of the above-mentioned technologies with the significant advantages and disadvantages for each.

Licensed Radio

Licensed radio refers to a radio system where the purchase of a license from the FCC is required. The license provides for a given frequency in a given geographic area. This is typically a 50 a mile circumference from the base station. The license holder is expected to provide all locations, tower heights and broadcast power information to a frequency coordinator to insure that no two users overlap, and cause interference on their assigned channel. The strength of this system is that it should have "Clear Channel" or be interference free. A weakness is that it often is not. The user can petition the FCC to locate the source of interference.

The licensed radio system can use a very large amount of radiated power (Signal Strength). The maximum power at the antenna can be as high as 20 Watts! This power will provide great range. With Line of sight, 40 to 50 miles is sometimes possible without a repeater. Licensed systems can have only one repeater in the system to expand the range and the area of coverage. Licensed radios can have a Spread Spectrum system added onto the "Tail-end" of the 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 to 50 miles with line of site) again licensed radios make an excellent choice. They provide a low maintenance, low cost 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 not be able to communicate to the rest of the system. With licensed radio systems there are yearly fees paid to the FCC for the right to use the frequency. Licensed radio systems are fairly slow with speeds of 1200 baud in older models and speeds of only 9600 to 19200 baud in many of the newer models.

Spread Spectrum Radio

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

- It can have multiple repeaters (in some brands of spread spectrum this is unlimited);
- It can have every radio 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. The FCC mandates that the maximum output power be 4 watts at the antenna. This reduces the range to 25 to 30 miles with line of site (in some cases spread spectrum can reach up to 60 miles, but these are the exceptions). One way Spread Spectrum compensates for this lower power is by using multiple repeaters. Many pipeline companies will link multiple repeaters together to attain distances of up to 100 miles 10 to 20 miles per link.

Additional advantages to Spread Spectrum are they have much lower power consumption. Some brands use ten times less power than licensed radios. This means smaller solar panels and batteries are needed to power the system and that means lower cost per installation. Greater throughput is available with most spread spectrum radios. Many of these radios 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 also can handle multiple protocols through the same radio. These are 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 can actually do digital alarms with no external RTU required.

CDPD

This technology was widely deployed a few years ago and operates on the analog portion of the cell phone network. The advantage is that no infrastructure is required. Any remote device within cell phone coverage can be polled from anywhere that there is access to a phone connection. This allows a user in his office in Tulsa OK to poll a gas meter in Odessa TX. Another advantage is that the CDPD itself has an IP address so it 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 $50.00 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 this service is going to be turned off by AT&T in the near future. There are new technologies in cell phone coverage that will be replacing it, but none of them are backwards compatible to CDPD. All of the old disadvantages and advantages will still apply to the new cell phone technologies, and many people are skeptical that the new technologies such as GRS will also be obsolete in a few years and the new cell phone technology at that time will again not be backwards compatible to the "new" technology coming on the market today.

Land Lines

Line Lines or 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 wells. Advantages are large bandwidth capability and accessibility from anywhere the user has access to a telephone. The user can be in one state and the site in another and he still can poll it for information. Disadvantages include the monthly costs and service to remote areas is often interrupted. When service is down you are waiting for someone else to repair it.

Satellite

This again 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, so users often will use satellite as a back haul from remote areas where they have a concentration of wells all talking through a data concentrator to one satellite modem. The satellite can talk from anywhere to anywhere. It is the most universal of all communication devices *and* very costly. The modems are expensive and the service fees can be hundreds of dollars per site per month.

Microwave

Microwave is not a primary communication device either. 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; 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 up on towers; the hardware costs are high and the tower space cost is also very high.

Hybrid Solutions

This is often the best SCADA communication route if you have data being collected from multiple geographic locations such as East Texas and West Texas with the data delivery being made to offices in Houston or Oklahoma City. No one communication system is able to deliver 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

In Gas Measurement the two most widely used devices to collect data from flow computers are Licensed Radios and Spread Spectrum Radios. These can be deployed at a relatively low cost and can be used in remote areas where no other communication infrastructure such as phone or microwave exists. Another reason for the wide use of radio in the gas industry is the migration of the communication responsibility to the measurement technician. The measurement technician often has the skill sets required to install, trouble shoot and maintain a radio system.

Radio Installation Considerations

In radio, the old phrase “An ounce of prevention is worth a pound of cure” is a good adage to live by. Before setting up a radio system it is critical to do a “path study” and system design for the proposed system. This starts with compiling all the GPS coordinates for the sites. A qualified technician can import this into a software package that can allow you to see any obstacles to line of sight and the distances between sites. This information will help you know how high the antennas for each site will have to be placed to communicate with the other sites in the system. Additionally this will tell you where to locate repeaters, how many repeaters will be 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 a licensed system or a spread spectrum system would be the ideal choice for your application.

It may be important to remember that the licensed radios can reach greater distance but can only have one repeater in a system. The spread spectrum system can have multiple repeaters, but will transmit over less distance on each link.

If you use licensed radios there are companies that specialize in assisting users with path studies and will even complete and submit the paper work to the FCC for licenses on behalf of their clients.

Most Spread Spectrum manufacturers of the radios provide the same services. There are also spread spectrum radio resellers and integrators who will provide these services as a part of the package. If there is one “must do” phase in the installation of a radio system the path study/system design phase is it.

RADIO EQUIPMENT

Once you have chosen your radio type (Licensed or Spread Spectrum) it is important to understand the associated hardware that will be required in conjunction with the radio. These components are:

1. Antennas
2. Cables
3. Filters

4. 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 (it is similar to the antenna on your car for radio reception). The omni is typically used at the Master site and at repeater sites to allow remote signals from all directions access to the antenna. The yagi or directional antenna is one direction only. This antenna focuses the radio energy in one direction and will broadcast further than an omni of the same signal strength.

Signal Strength

To understand the dynamics of signal strength it requires the 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.

Antenna Gain: The broadcast power of an antenna is measured in "dBm" often referred to as "db". Antennas are ordered from the manufacturer for the amount of "Gain" or signal amplification they produce. Typical antennas used in gas measurement are 3dBm, 6dBm and 10 dBm.

Line Loss or Cable Loss: There are several types of cable that are used in gas measurement. The type used is determined by the distance the signal will have to travel over the cable. For short distances (10 to 30 feet) it is common to use a ½ inch 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. Another commonly used type is LMR-240. If your antenna is located more than 30 feet from the radio you may want to use 7/8 coax cable, which has 1dBm of loss per 50 feet.

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

Example of output power calculation:

Output Power	1 Watt or 30 dBm
Line Loss	Minus 1dBm for 25 feet of cable
Antenna Gain	Plus 6 dBm for the antenna

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

Filters

There are several types of filters available for radio systems. Notch filters block out a specific frequency. Band Pass filters allow signal over a band, or range of frequencies, but block out-of-band transmissions. It is important to 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 the noise or interference is reduced more than the signal.

Antenna Masts/Towers

There are commercial towers in almost all geographic locations. Space on these towers is 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 is charged by the height on the tower where you wish to have your antenna located (e.g. an antenna at 100 feet is less expensive than an antenna at 200 feet). The tower owner can often place the antenna or he will have contact information on a licensed tower climber. Most commercial towers are several hundred feet in height. It is 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 feet vertically separation to insure the antennas do not interfere with one another. Where ever possible antennas should have both horizontal and vertical separation of 10 feet. Private towers are available from many communication wholesalers such as Hutton and Tessco. These come in two types: guided and freestanding. The guided towers have guy wires that run from anchors in the ground up to the tower at two or more locations, to secure the tower. Guided towers are less expensive but a draw back is the guy wires take up a lot of ground space and some locations cannot accommodate the additional space.

Freestanding towers take less space but require more work to install and have deep cement foundations (6 foot by 6 foot with 6 feet depth for a 100 foot tower). The greatest expense in buying towers is often not the hardware but the labor to install them. A recent quote was $9,000.00 for a 100 foot guided tower and $12,000.00 for a freestanding 100-foot tower.

CONCLUSION

To design a communication system for SCADA applications you must first understand the objectives for the system. How much data is to be moved, how often is it to be moved, from where is it coming, and to where is it going are all important factors. Matching the "Best Fit" technology to the application is essential. In gas measurement this is most often a radio system, and in some cases, it is a hybrid radio system that ties to a microwave or phone backbone for the long distance distribution of the data.

Any time radio is to be deployed it is critical to the success of the project to do a preliminary path study and system design. When this phase of the project is properly done the installers will have all of the information needed to: order the hardware required, "Kit up" equipment for each location prior to deployment (put kits with antennas cables, and accessories together for each location) and even preprogram the radios for each specific location. The installation crews will know where repeater are to be located. The user can determine whether to use commercial towers or erect his own. The end user should be able to accurately forecast the coverage area and the cost of the system.

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

In addition to allowing the user access to near-real time data acquisition for gas measurement, a properly designed communication system will allow the user to accept alarms as "Cry-out-by-exception" alarms. The most important feature to look for to enable this function is a radio that has an over the air data speed that is significantly faster than that of the flow computers. This will allow the open air time that is required to let alarms slip through the system 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 and higher gas prices make that an easier decision than ever before.