Regional SCADA Communications Backhaul

Effective operation and monitoring of water and wastewater facilities

Client:
Regional Municipality of Wood Buffalo
Prime Consultant:
Associated Engineering
Contractor:
Westcan ACS

Associated Engineering | GLOBAL PERSPECTIVE. LOCAL FOCUS.

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Executive Summary

The Regional Municipality of Wood Buffalo has experienced significant growth in the past decade. To service this growth, the Municipality has expanded its water and wastewater infrastructure, which includes more than 40 facilities, many located in remote areas. Operating and maintaining these facilities had become a challenge for the Municipality's staff. The Municipality wanted the capability to operate and monitor all facilities remotely, and retained Associated Engineering to design and implement a Supervisory Control and Data Acquisition (SCADA) communication system to suit this purpose. The SCADA system had to be secure, robust, flexible and expandable for new facilities.

The design team developed a system architecture comprising of six strategically located high bandwidth radio towers, from which a distributed communication system was built linking to sub-nodes. The system is configured as interconnected nodes fed by clustered sub-nodes, facilitating back-up and expansion. Remote sites use point-to-multipoint licensed frequencies to connect to the backbone and maximize radio reach.

The SCADA system was delivered as a design-build project, reducing risk to the Municipality and fast-tracking implementation. The backhaul segment is now complete and performing above the Municipality's expectations. The new SCADA communications system provides operators with access to real-time data, video, audio, and full, remote site control from central locations. For the first time in the history of the Municipality, all water and wastewater sites spanning a geographical distance of 275 km will be visible and manageable from centralized locations over a high-speed network with greater through-put than most offices; the most advanced municipal radio system in northern Alberta.

The Need for Modern Communications

Located in northeastern Alberta, the Regional Municipality of Wood Buffalo is home to one of the world's largest oil resources, making it an economic hub in the province. The region's 70,000 people, plus its large transient workforce, are spread geographically across this region which occupies an area of 68,454 square kilometres.

To service the population, the Municipality owns and operates a large network of water and wastewater infrastructure, including pipelines, sewage lift stations, water reservoirs, water pump houses, and water and wastewater treatment plants. Since the early 1980's, the water and wastewater infrastructure in the region's urban centre, Fort McMurray, and the surrounding towns and hamlets depended mostly on operators who visit remote sites twice daily to operate simple manual controls, complete checks of the equipment, gather test samples, and ensure the sites were in good order. If problems or issues arose at facilities that negatively affected operations, hours could elapse before operations staff became aware of the issues.

As the Municipality grew and new water and wastewater facilities were constructed, the operational systems became more advanced and complex. Programmable Logic Controllers replaced traditional relay control systems, computer-based Human Machine Interfaces were added to allow operators to control facilities from a single point within the structure, and facilities became interdependent on each other for daily operations.

In order to cope with the new interdependency, the Municipality installed a combination of leased telephone lines and simple radio structures at several key locations, which typically provided telemetry data from Municipal reservoirs and several key sewage lift stations. Data was collected and displayed at the Water Treatment Plant, and operators could view live status at the facilities. These controls facilitated operations, allowing processes to run more smoothly and operators to deal with issues in a timelier manner. The result was some cost savings to the Municipality.

However, the installed radio system, while reliable, was very busy, fairly slow and inflexible, and had limited expandability. This was inherent to the existing architecture, as licensed serial radios are capable of long distances, but lack the bandwidth required by heavy data traffic.

The geographical area of the Municipality and physical interfaces in the system limited expansion to within the Fort McMurray boundary with outlying communities, such as Janvier and Anzac, completely in the dark. Remote areas, such as Fort Chipewyan, had limited communications and relied on telephone dial-up access for remote monitoring and system maintenance.

Eventually, as more and more systems were brought on line, retrieving “live data” updates stretched from 30 seconds to 60 seconds, and remote operational control was severely limited. By 2010 the technology was starting to show its age and its limitations in coping with emerging protocols such as Ethernet.

Recognizing the limitations of the existing system and with more than 35 sites remaining to be brought online, the Municipality decided to upgrade it and retained Associated Engineering to act as Owner’s Engineer to aid in updating the system. The new system had to be expandable and adaptable, reach all areas of the Municipality, and allow monitoring and operations of all facilities from two main sites: the Water Treatment Plant and the Wastewater Treatment Plant, located in Fort McMurray along the banks of the Athabasca River.

Starting in 2011, the project consisted of four phases:

1. A conceptual study to best determine the overall architecture and topology of the new system;
2. A feasibility study to ensure that the concept was viable, and explore options determined by the conceptual phase;
3. A master planning phase to solidify the overall performance requirements, topology and architecture, and;
4. An implementation phase that saw the construction and commissioning of the new system delivered by utilizing an alternate delivery design-build style.

The engineering team decided that the new system required the creation of two SCADA (Supervisory Control and Data Acquisition) communications “spheres” – one for the potable water facilities and one for the wastewater facilities. The two master nodes (the Water Treatment Plant and Wastewater Treatment Plant) would be linked together so that they could operate independently, but allow for secure remote control over the other system, as need arises. This arrangement created operator back up as well as cross-training opportunities. Certain remote locations, such as Fort Chipewyan, would require a merging of the Water and

Wastewater SCADA systems to create an economy of scale for higher speed communications through a common communications portal.)

To achieve these goals, the new system needed to be Ethernet-based and be interconnected to allow secure remote connections from one location in the SCADA to another. In essence, a secured Wide Area Network (WAN) would need to be created to carry all of the data traffic required by the Environmental Services division of the Municipality. High speed Ethernet connectivity would leverage emerging technologies.

Strategic Communications Architecture

The components of the Water SCADA system comprised of licensed 400 MHz serial point-to-multipoint radios and some leased telephone lines linking back to a central controller at the Water Treatment Plant (WTP). Wastewater remote SCADA routed back to the WTP through the same network, but was monitored by the WTP.

The conceptual study concluded that the existing and traditional topology of a single hub and spoke design was not flexible enough to meet the needs of an expanding system with multiple nodes. A new distributed system using multiple hubs would provide the coverage and flexibility for the future. The new system would forego the older style, low bandwidth radio systems, in favour of strategically placed, high-bandwidth radio towers that would form a SCADA Backbone upon which all 40+ facilities would link to.

Location, Location, Location

With the basic architecture in mind, a feasibility study was launched to assess different alternatives and recommend an overall SCADA system framework able to incorporate the Water Treatment Plant (WTP) and Wastewater Treatment Plant (WWTP) systems and improve remote access to all new and existing sites. The overall goal was to design a new system architecture that would increase communication speeds and be able to add new sub-nodes as the new facilities were constructed.

The project team explored several ideas for a medium that would accomplish the project objectives including the use of both direct connections (e.g. fiber optic, dial-up, leased line, high-speed internet) and wireless connections (Ethernet Radio, Cellular, Satellite).

The key findings and conclusions based on the assessment of the work were that:

- Design parameters indicate that an Ethernet-based Wide Area Network is the preferred mechanism for the upgraded SCADA system.
- A high-speed Ethernet radio backbone could be implemented in the urban area of Fort McMurray. Remote sites would use point-to-multipoint licensed frequencies to connect to the backbone to maximize radio reach.
- The Water and Wastewater SCADA networks would be separated into different radio frequencies where practical to improve speed.
- High speed wireless internet connections (where available) and virtual private network (VPN) routers would be used to link the remote sites of Fort McKay, Fort Chipewyan, Janvier, and Conklin to the SCADA system as these sites are too far to economically reach via conventional radios.

With the communications medium decided upon, the next course of action was to choose the optimum locations for the backbone radio tower locations. After reviewing the 40+ existing sites, we concluded that the ideal locations had to meet the following criteria:

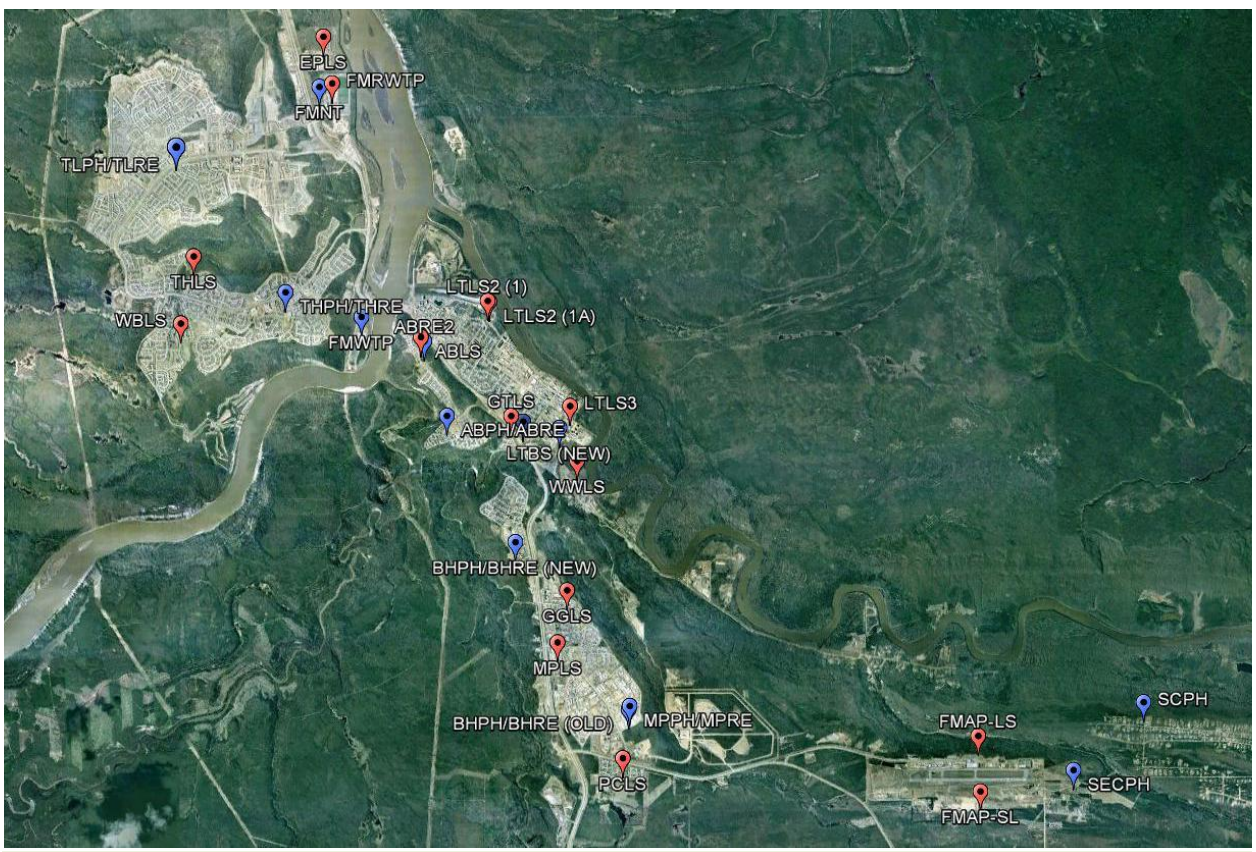
- Major upgrades completed so that future construction would not affect the network;
- Space was readily available;
- Located where existing radios could be swapped out as soon as the network was active;
- Available back-up power generation in the event of prolonged outages occurred; and
- Maximum radio reach to the remote communities.

Management of Risk

Backbone Radio Tower locations were selected using multiple criteria designed to reduce risk of system downtime.

With these criteria, the optimum sites for the backbone radio tower were identified as the WWTP, WTP, Abasand Pump House, MacKenzie Pump House, Saprae Creek Pump House and Highway 881 Booster Station.

Because of their geographical locations, sites such as Fort Chipewyan, Janvier, Conklin and Fort McKay would need to operate in their own radio "spheres". All remote sites in these regions would go back to one central location. For example all water and wastewater facilities within Fort Chipewyan would connect back to one main facility: the WTP located within the hamlet. From there, a high-speed Internet Service Provider (ISP, or Cellular) connection would be used to establish a Virtual Private Network (VPN) link between the remote site and Fort McMurray WTP.



Google Earth screen capture of the backhaul site locations

Master Planning & Network Realization

The Master Plan outlined the software and hardware requirements of each site, provided a suggested equipment list, gave a detailed structure for network segmentation and recommended solutions for each of the six backhaul node locations. The plan also suggested a phased implementation and provided details on the approach.

881 Booster Station

The primary recommendation was to establish a high speed (>20 Mbps) communications backhaul network within Fort McMurray linking the WTP, WWTP, Abasand Pump House, Mackenzie Pump House, Saprae Creek Pump House, and the Highway 881 Booster Station. It was essential to use point-to-point 5.8 GHz radios and routers, the best fit technology available.

After a thorough review, the engineering team, together with the Municipality, established 29 remote site connections for the use of new Motorola PMP 430 Ethernet radios at all SCADA sites. All urban radio locations (water and wastewater) in Fort McMurray would link into the closest backhaul node, and the signal traffic would be directed by routers to either the WTP or WWTP.

Remote locations (Fort Chipewyan, Fort McKay, Janvier, and Conklin) would each use 5.8 GHz Ethernet radios linking all water and wastewater sites together to the local WTP or pump house acting as a concentrator node. The local concentrator node would then use an internet connection with a VPN router and an encrypted link back to the high speed backhaul network.

The Master Plan recommended proceeding with completing a traditional project delivery approach. However, after the discussions with the Municipality, the team agreed that an alternate delivery approach utilizing a design-build template would be more suited to this project due to its specialized nature, existing marketplace and the vested interest that a design-build type delivery system fosters.

Management of Risk

Using a design-build delivery strategy reduced project technology risks to the Municipality and fast-tracked implementation.

In late 2014, the Municipality retained Associated Engineering to complete the Request for Proposals document and act as the Owner's Engineer through the construction process. The contract was awarded to Westcan ACS in late 2014 with construction commencing in early March 2015 and commissioning in September 2015.

The selection process for the construction award was not based solely on lowest bid price, but rather on a holistic approach to help reduce the risk to the Municipality. Associated Engineering developed the selection criteria based on content, technical solution, past experience, customer service, innovation, value added alternatives, and cost. While the successful proponent was not the lowest bidder, the project was completed under budget, with no major incidents occurring during the construction process.

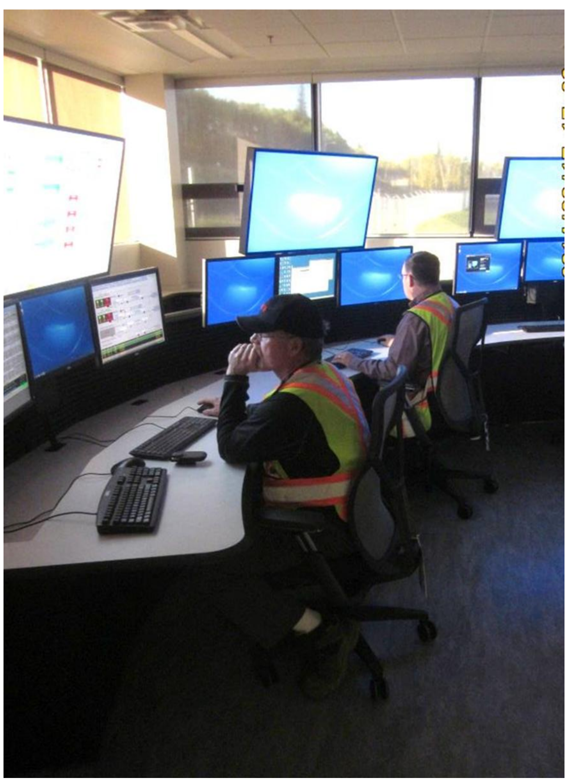
The decision to go with an alternate delivery strategy and ranking criteria paid dividends when, during the tender processes, Industry Canada opened up new licensed frequency bands with higher data rates. Based on that, Associated Engineering called for a change to the radios and frequencies to be used. The contractor worked closely with Associated Engineering and the Municipality to implement the new radios and frequency strategy without impacting costs.

Leveraging Geography & Multiple Facilities

The Regional Municipality of Wood Buffalo's region-wide, water and wastewater communications system supports data connections to its 40+ facilities and is the fastest, most technologically advanced municipal system in northern Alberta.

Innovation & Advancement of Technology
Point-to-multi-point clustered architecture with backhaul nodes takes advantage of the Municipality's size and numerous facilities to resolve speed drop over long distances.

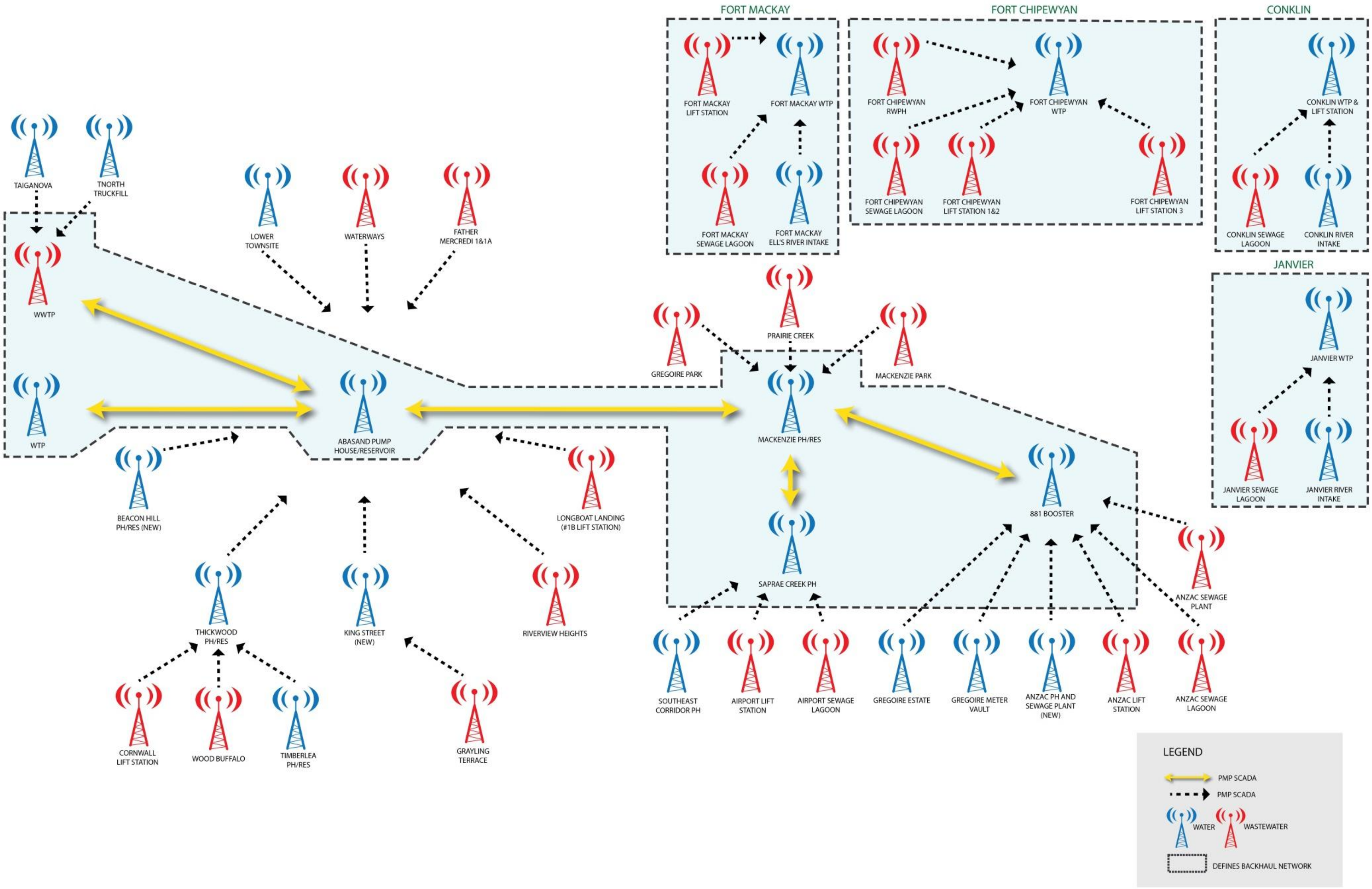
Typically, these systems are unlicensed 900 MHz radio systems or licensed 400 MHz radios that transfer relatively small amounts of data and connect several facilities back to a centralized location. The RMWB system utilizes 3.65 GHz point-to-multipoint and 18 GHz point-to-point licensed Ethernet radios that have been verified at data rates of 100 Mbps with the option to push the system to 200 Mbps; up to 1000 times faster than traditional radio systems. While this type of radio system has a more limited range compared to their slower counterparts, utilizing point-to-multipoint "clustered" architecture with strategically placed "backhaul nodes" solved that issue. In short, the system leverages and exploits the Municipality's size and numerous facilities to solve the problem of speed drop-off over large distances.



SCADA Water Treatment Plant Operator Node

Mackenzie Pump House new 18GHz Radio Tower

Network Block Diagram



Technical Excellence

Early on in the project Associated Engineering recognized that the communication system would need to be durable, expandable, and flexible in order to support the infrastructure over the next two decades. The methodology to achieve this goal was simple: maintain a high standard of excellence and look where the Municipality and industry is heading.

Technical Excellence
Tower design and location developed to provide the Municipality with a high speed, durable, expandable and flexible communication system.

The designed heights of the main towers used at the “Backhaul Node” sites were intentionally kept above 15 m, forcing the design-build team to ensure that the towers conform to CSA-S37. This design criterion ensures the builder conforms to the known set of stringent standards, and the public safety and interest are inherently upheld, and the Municipality’s liability is greatly reduced. Forcing the tower height above 15 m also made it easier to widen the gaps between “Backhaul Nodes” to minimize their numbers and minimize the overall costs.

Abasand Pump House Radio Tower

With the remote nature of some of the Municipality’s sites, co-sharing of the “Backhaul Node” towers was also forefront in the design. This would allow for expanded use of the towers to support other radio infrastructure, such as two-way radio relays, allowing operators and maintenance staff to keep communications even with central locations that have no cellular technology available. The requirement to use CSA-rated towers ensures that this expanded use would not diminish the safety to the public and increase Municipal liability as the towers can be recertified when expansions are completed.

Expandability of the towers is not enough for meeting the municipal needs over the next few decades. The radios systems chosen needed to be as robust, flexible, and expandable as possible to ensure that new facilities can be brought on line without having to redesign the entire system. To meet this, Associated Engineering designed the node-based approach that can be split into two separate Ethernet radio systems.

For Backhaul Node-to-Backhaul Node communications, the radios were chosen to be 18 GHz licenced point-to-point radios set to operate at a throughput of 100 Mbps. This rate is enough to maintain the data exchange rate traffic for all facilities currently operating within the Municipal boundary as of 2015. However, should the requirements change or demand for bandwidth grow, the radios software can be upgraded to support four times the amount of data traffic. This would place end-to-end data rates at approximately 512 Mbps. *Putting this in perspective, most offices in a wired environment experience speeds of 10 to 100 Mbps; 5 to 50 times slower than the potential speeds of this new wireless network.*

Communications network box

While the radio licencing does add overhead costs to the system, it gives the Municipality ownership of the system and allows them to add additional nodes as they grow, expand and develop. It also ensures that the Municipality has recourse and are able to take action should other private networks cause radio interference with the SCADA network. This adds piece of mind that other private networks will not be able to "muscle in" on the available bandwidth.

Portable Network Analyzer

A similar philosophy was used for the sub-node sites where other facilities would couple on to the master nodes. The sub-nodes used point to multipoint licenced radios running at 3.65 GHz providing a data rate of 13 Mbps. These are connected to receivers on the master node towers and are responsible for routing traffic on to the communications backbone. As with the master node radios, the sub-node radios are software upgradable to 98 Mbps and licenced, which gives the Municipality full control.

Lastly, since the system is configured as a collection of interconnected backhaul nodes fed by clustered sub-nodes, the Municipality can easily duplicate a backhaul node site at a new location and expand the network's reach.

Management of Risk

Radio licencing gives Municipality ownership of the system, reducing risk of private networks taking control of available bandwidth.

Resource Management

With the radio system backbone currently up and running, the Municipality is starting to bring the first of its facilities online. This will start to pay dividends in early 2016 as operations starts to see less of a strain on resources. There are several immediate benefits that will be the direct result of implementation of this high-speed system.

The largest such benefit is the reduced strain caused by facility downtime. Prior to facilities being connected, it wasn't always easy to discover the problems in a timely fashion, operators could recognize them only by observing their indirect impact on the processes.

Benefits to Society & Environmental Value

The new radio backhaul network provides remote operation and monitoring, increasing security, reducing the need for travel, and saving valuable resources time and effort.

The use of the SCADA system to monitor, not only real-time data from the facility, but to also have the ability to use video, audio and occupancy available prior to dispatching operational and maintenance staff will:

- Greatly reduce the risk of personal injury to Municipal employees by allowing for disaster avoidance;
- Reduce the risk to Municipal employees by being able to reasonably ensure the stations are clear of intruders;
- Allow for troubleshooting and correction planning as operations and maintenance staff are on their way to address the problems and;
- Reduce the potential of environmental impacts due to equipment malfunction by being able to remotely operate the system.

Degree of Difficulty

The challenges of this project split into two categories, stakeholder buy-in and system architecture.

During the first two phases of the project, stakeholder input was sought from multiple individuals who then changed positions requiring further consultation. Existing technology and emerging technology needed to be balanced to provide a useable system today, with the ability to accommodate new technologies as the Municipality and industry adopted them.

System architecture was a thought-out, iterative process involving multiple sites and creation of geographic and topographic maps to determine the relative location in 3D space of all sites from one another and then selection of the best locations. The maps eventually yielded the conclusion that the infrastructure was in clusters and a multi-node approach was the solution that would work the best. Using these maps, the Backhaul nodes were chosen based on geographic location, topographic reach and amenities such as backup power and recent PLC upgrade at the selected nodes.

Degree of Difficulty & Added Value

Stakeholder consultation throughout the process fostered buy-in.

System architecture had to consider current technology and future needs.

CONCLUDING REMARKS

- ✔ Associated Engineering worked closely with the Regional Municipality of Wood Buffalo to push the boundaries of “normal” technological employment to develop a new SCADA Communications System that will meet the Municipality’s requirements for the next decade and beyond.
- ✔ Technical hurdles that would be considered detrimental to a long distance network were leveraged to increase system performance.
- ✔ The alternate delivery approach reduced Municipality’s risk, provided flexibility in the design without sacrificing cost and performance, and fast-tracked implementation.
- ✔ Associated Engineering is continuing to work with the Municipality to integrate the remaining 33 facilities into the network with scheduled completion for late 2016.
- ✔ For the first time in the history of the Municipality, all water and wastewater sites spanning a geographical distance of 275 km will be visible and manageable from centralized locations over a high-speed network with greater through-put than most offices; the most advanced municipal radio system in northern Alberta.
- ✔ The communications system architecture is a model for similar municipalities which have many remote sites over a large area.