New Wireless Solutions to Meet Smart Grid Communications Requirements

Utilities are often already in the process of deploying Smart Grid applications such as advanced metering infrastructure (AMI) and distribution automation (DA) when they find that their existing communications infrastructure does not have the bandwidth or reliability to support the additional throughput those applications require. To avoid this costly surprise, a higher speed wired or wireless communications backhaul network must be implemented *prior* to deploying AMI or DA. Ultimately, the success of AMI and DA programs depends to a large extent on having selected the most appropriate backhaul communications technology to begin with.

While the need for speed is obvious, determining your throughput and latency requirement can seem complicated. However, knowing your requirements can help you match the best technology to your needs.

How Much Throughput Do You Need?

The first step in determining backhaul throughput and latency requirements is to determine which applications should be included. For example, if DA implementation starts next year, but AMI will not be deployed for at least five years, should AMI be included? Our recommendation is *yes*: incorporating all applications planned for the lifetime of the backhaul network helps you understand the impact of your technology selection further down the line. For example, you might weigh the option of deploying a slower backhaul technology now to accommodate DA at a significantly lower cost, and either replace the backhaul network with a faster one to accommodate the addition of AMI in five years or use a different backhaul media for AMI such as cellular.

Once you have a list of the applications you'll be including in your analysis, the next step is to determine the throughput requirements for each application. To determine the requirement for DA, for example, the amount of data per message (ranging from less than 100 bytes to multiple kilobytes), scan rates, requirements for round-trip latency, and device density must all be measured.

Note that devices such as remote terminal units (RTUs), switches, capacitor bank controllers, and voltage regulators may be polled cyclically with polling cycles (scan rates) that vary depending on the type of message and its priority. When DA device polling is unsolicited report-by-exception (RBX), throughput requirements during normal operations are significantly reduced versus throughput requirements during cyclic polling. In this case, bandwidth sizing is instead accomplished by determining the probable number of devices that will communicate through backhaul nodes during an outage, demand response, or other event. As the devices on an affected feeder may report exceptions in rapid succession, the ability to handle message collisions is important, particularly for slower communications technologies.

Similar throughput analysis should be completed for AMI, SCADA, mobile workforce, video security, and any other applications on your list. Then, the throughput for each application is aggregated to determine the overall throughput and latency requirement for each backhaul node. The results may be verified by field and lab testing for existing and future applications.

Due to the large number of DA devices (several thousand locations) and AMI meters, geographic information systems (GIS) are a valuable tool to aid in bandwidth sizing. Substation, DA device, meter, and other assets' geographic positions are typically part of the geodatabase. Communications assets such as towers and poles at substations can be readily added. For higher frequency wireless technologies that require line-of-sight, viewshed analysis can be used to determine how many DA devices can be "seen" by an antenna at a given height above ground level to determine device density at backhaul nodes. The addition of foliage layers from sources such as light detection and ranging (LIDAR) improves accuracy compared to bare earth models commonly used in radio frequency (RF) path study software. Meter densities are also readily calculated for input into bandwidth sizing algorithms.

Nearest neighbor analysis may also be performed using GIS tools to rapidly determine the potential number of feasible communications paths for each node in a wireless mesh network. For wired technologies, buffer analysis may be used to calculate the distances of backhaul nodes from existing utility owned or carrier fiber optic or copper coax.

Which Communications Technologies Meet Your Needs?

Once throughput and latency requirements are known, a shortlist of backhaul technologies may be identified. Options include:

- Wired media such as utility owned optical ground wire (OPGW) or all-dielectric self-supporting (ADSS) fiber or leased circuits from carriers
- High-speed licensed or unlicensed point-to-point microwave
- Unlicensed point-to-multipoint wireless
- Unlicensed, longer range mesh solutions
- Licensed point-to-multipoint solutions including new wider band options
- WiMax in the "pseudo-licensed" 3.65 GHz band
- Cellular data including 3G and 4G WiMax (2.5-2.7 GHz) and long-term evolution (LTE)
- Satellite
- Also, watch for new products based on the "white-space frequency" being introduced later in 2011

Depending on terrain and device density, multiple technologies may be required. While there is much debate on the relative merits of utility owned versus carrier options, the decision boils down to network availability and recovery time in the event of a communications network outage. Mission-critical applications require availability of at least 99.999% with restoration times of a few hours. While a wired connection to every DA device or AMI collector would be ideal, the extension of utility or telco networks to reach many of the nodes may be prohibitive until infrastructure is built out to support fiber to the node (FTTN) and fiber to the home (FTTH) initiatives.

A Note on Wireless Technology Throughput and Propagation

For wireless technologies, understanding the difference between the RF data rate (the "marketing" spec) and actual data throughput is crucial to determining whether a wireless technology will meet your throughput and latency requirements. For example, a product with a stated data rate of 100 Kbps may only yield 20 or 30 Kbps of actual data throughput due to factors including hardware and software delays, RF packet overhead, communications protocol overhead, half-duplex data transmission, network contention, retries, and many other factors. It is recommended to test the throughput of the shortlisted technologies both in a controlled lab environment and in the field using planned antennas, antenna height, etc. Front-end processors (FEPs) may be used to help lower-capacity technologies manage rapid polling or numerous unsolicited messages during events.

What New and Emerging Wireless Solutions are Available for DA and AMI Backhaul?

The list of wireless technologies that can meet both DA and AMI backhaul throughput and latency requirements *and* work with terrain, foliage, and structure challenges typical of DA and AMI sites without sinking the respective business cases due to cost of additional base stations or repeaters may be very short, if it exists at all with today's technology. While 3G/4G cellular can meet many of the needs, there may still be critical asset locations where cellular coverage does not exist, and these coverage "holes" are often random. While the speed of higher frequency products is very attractive, those products can only operate over shorter distances and require a line-of-sight path. Fortunately, new technologies such as wider channel licensed narrowband point-to-multipoint, broadband licensed point-to-multipoint, and improved wireless mesh solutions are emerging to meet these challenges. New spectrum options in the VHF and UHF bands, such as television white space (TVWS), should lead to faster offerings at frequencies with more favorable propagation.

- **New Licensed Narrowband Point-to-Multipoint Solutions**
  Vendors such as CalAmp and GE Digital Energy–MDS are introducing VHF and UHF licensed narrowband point-to-multipoint licensed wireless solutions supporting faster RF data rates of over 100 Kbps, enabling them to transport IP-based smart grid applications. The increase in data rates is due to wider channel bandwidths of 50 KHz and improved data compression (higher modulation methods). Assuming enough contiguous spectrum is available to support a 50 KHz channel reuse plan that provides enough bandwidth and limits RF self-interference, these new solutions offer enough bandwidth to support IP/Ethernet communications for DA and AMI backhaul. Even with full-duplex throughput at 25 percent of the RF data rate, with appropriate bandwidth planning and FEPs, superior propagation, and exclusivity of use within a geographic area make these solutions a good alternative versus higher frequency unlicensed technologies.

- **New Licensed Broadband Point-to-Multipoint Solutions**
  Emerging licensed point-to-multipoint solutions such as software-defined radios (SDR) from Full Spectrum Inc. extend WiMax 802.16e technology into VHF and UHF bands by allowing channel sizes down to 200 KHz. Using WiMax adaptive modulation and wider channels, application data throughput can be 100s of Kbps to multiple Mbps. If 200 KHz blocks of spectrum are available, the need for fewer base stations due to the higher throughput can offset channel reuse challenges. TVWS spectrum in multiple MHz size channels offers promise, but does not provide the interference protection of licensed spectrum. Future support of non-contiguous frequencies will help users in dense urban areas whose spectrum is fragmented by incumbents.

- **Wide Area Wireless Mesh Solutions**
  Wireless mesh networking is a proven means to overcome obstacles such as hills, buildings, and foliage by providing multiple paths around the obstacle. Mesh technology is very scalable through the addition of takeout points to high-speed wireless or wired backbone. Wireless mesh is one of the leading technologies for AMI neighborhood area meter networks. Mesh wide area networks (MWAN) have been used for intelligent control of switches and capacitor banks for years. While a number of vendors have MWAN products, few have been developed to meet the challenges and protocols of electric utility applications. The better propagation of lower frequency MWAN makes it preferred for applications such as DA as antenna height is typically limited to the communications space of distribution poles. An example of a new, higher speed MWAN solution operating in the 900 MHz unlicensed band is SpeedNet from S&C Electric. It has a RF data rate of 650 Kbps and low latency to support smart grid applications such as DA and AMI backhaul. In addition to factors

previously listed, user throughput and latency will also be negatively affected as the depth of the mesh increases; i.e. how many hops must be made before a mesh takeout node is reached.

Conclusion

The data throughput and latency requirement of smart grid applications such as AMI and DA represent a challenge above the usual challenges such as terrain, and further limits the technology options for data backhaul. Rigorously determining the required data throughput and latency and validating technology candidates via field testing will help ensure that your requirements are met and that your smart grid programs are successful. New and emerging wireless technologies should be considered as they will not only enable smart grid applications but also offer the potential for multiple applications to share wireless backhaul networks to reduce initial investment and lower operation and maintenance costs.

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