The “Mid-Grid” Communications Network:

A Hybrid Commercial/Private Communications Architecture Approach

By Rick Schmidt

Utilities often struggle with determining which backhaul communications media is better for distribution automation (DA) and advanced metering infrastructure (AMI). Deciding between commercial (cellular/satellite) or private may seem like a simple task, but it is often complicated. One or the other may be right for you, but you might not expect that a combination of both could be even better.

The mid-grid involves communications backhaul for applications often located down line from substations such as DA—cap banks, voltage regulators, switches, fault indicators—and AMI take-out points. A consistent challenge of communications with mid-grid applications involves both coverage (due to line-of-site issues) and bandwidth capacity (due to a large number of sites).

Selecting the backhaul communications technology for AMI and DA starts with understanding:

- The number of sites requiring backhaul communications,
- The location of those sites,
- The characteristics of the terrain,
- The bandwidth or round-trip latency requirement, and
- The existing communication assets that may be utilized, such as broadband backbone, towers, fiber/microwave to substations, etc.

The Right Mid-Grid Backhaul Technology May Surprise You

Power System Engineering, Inc. (PSE) has assessed backhaul communications technology for many electric utilities. We have found that although a utility may have a strong preference for private backhaul, for example, there is often not enough private frequency or capacity to handle all of the utility’s sites. Or, unlicensed radios fail to deliver line-of-sight coverage for many of the utility’s sites (both urban and rural) due to challenging terrain and heavy tree foliage. Given the lack of private frequency and cost-effective private communications alternatives to cover all areas of their service territory, these utilities elect to use cellular where private capacity constraints exist or when the costs exceed a defined threshold.

Similarly, although some utilities may prefer cellular, this technology comes with limitations, such as cellular coverage holes. Thus, these utilities may elect to build private backhaul in some areas to mitigate the lack of cellular coverage. Also, while cellular may be preferred, some AMI take-out points may be located on or near existing private broadband nodes, such as those at substations or offices where robust backhaul bandwidth already exists. With even a small amount of land available at substations and offices, utilities can install poles to mount antennas for AMI or DA collection points, which can raise the height of AMI collection points and both reduce the number of take-out points and improve coverage.

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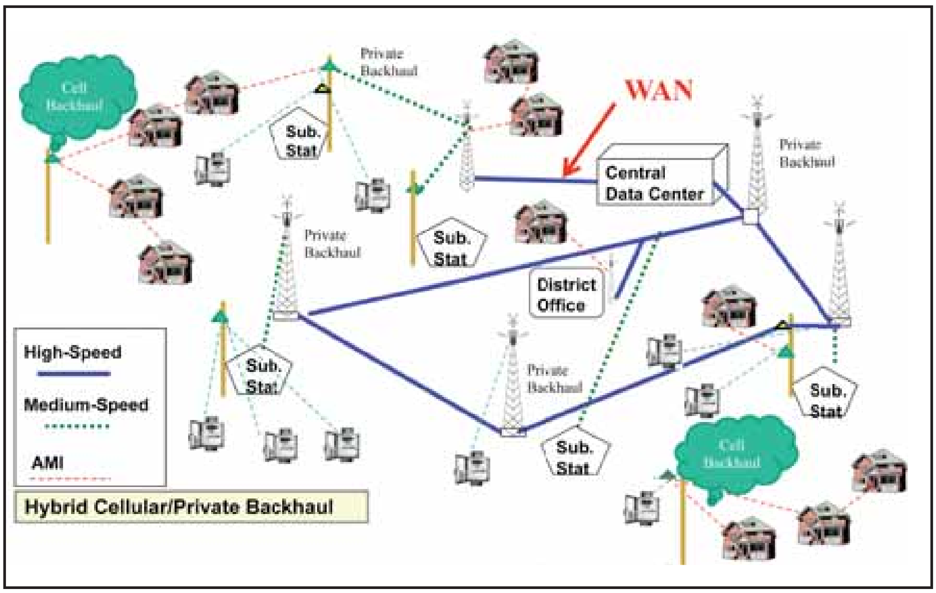

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Thus, utilities shouldn't feel that they must select only one backhaul technology. In fact, a *hybrid* approach can offer the best of both worlds. The diagram on page 29 reflects a hybrid approach where substations and tower sites are used as private communication data collection points, some locations on the feeders use private communications, and other locations use cellular.

Does a hybrid approach for mid-grid communications make sense for your utility?

	Question	Yes	No	If yes, then…
1	Does your utility have fairly robust private backhaul communications in place at substations, district offices and tower sites?	❐	❐	Taking advantage of private infrastructure can save operational recurring fees.
2	Do you own your towers and have control of what types of antennas are located on your towers?	❐	❐	This provides more control of possible unlicensed interference and can better mitigate interference than situations where your utility leases commercial tower sites and many unlicensed antennas may already exist or can be added on the same tower in the future.
3	Is there a shortage of licensed frequency to handle all the capacity?	❐	❐	Spreading some of the sites to cellular or unlicensed frequency really helps balance the bandwidth availability.
4	Are there areas within your service territory where private backhaul would be very expensive?	❐	❐	Cellular, and new forms of satellite technology, may allow for a cost savings approach for these hard to reach locations.
5	Does your wholesale power provider or other third-party fiber network owner/ operator have fiber within a couple of miles of your substations, offices, or communications towers?	❐	❐	Meet with the third-party fiber owner/ operator to determine if there is an opportunity for long-term dark fiber lease or additional wavelengths on lit fiber.

How to Make a Backhaul Technology Decision

So the best backhaul communications technology may not be what you initially expected, and a hybrid architecture that combines both private and public networks may work best for your utility. But how can you make the right decision?

It's important to start thinking about backhaul *before* you select your AMI and DA vendors. In regard to AMI, for example, the number of take-out points varies greatly from vendor to vendor, significantly impacting the associated backhaul costs in forecasting the total cost of ownership. Understand the backhaul requirements for each vendor's solution during the procurement process, and match your backhaul technology accordingly.

What are some typical backhaul requirements for AMI and DA?

	DA Requirement	AMI Requirement
Assumptions	100 DA field points tied to a single master radio point. Assuming no more than 25 DA points will have an event at the same time.	**1.** 5,000 meters **2.** 15 minute interval data sent every 15 minutes **3.** 25% of customers subscribe to a demand site management (DSM) program. **4.** Some bandwidth allocation for outage investigation and other AMI operational applications.
Data Acquisition Method	Unsolicited report by exception	Metering data sent every 15 minutes from collection point to AMI master. DSM commands sent four times per day.
Latency	Four seconds round trip: Field device to Master to field device	Twenty seconds: Take-out point to AMI Master
Bandwidth	~ 50 kbps1*	~ 900 kbps
Interface	Ethernet	Ethernet
Protocol	DNP/IP	TCP/IP
Reliability Target**	99.9% to 99.999%.	99.99% to 99.999%

* The bandwidth challenge for DA occurs when addressing the possible collisions at the master radio sites when several dozen remotes are being polled or for unsolicited report by exception when several remotes communicate at the same time. The bandwidth allocation assumes the latency requirement will be met 100% of the time and occasionally metering data, DSM events, and other operational AMI applications event data will be sent simultaneously to the same master radio. If willing to compromise on the latency, then much less bandwidth will be required.

** A single site may have a target of 99.9%. A node most often has a target of 99.999%.

How much throughput do you need?

While the need for speed is obvious, determining throughput and latency requirements can get complicated, especially when there is some uncertainty forecasting the amount of simultaneous data transfers to the same master radio location. Deploying from distribution poles, whose low heights often make for challenging radio frequency (RF) paths, sometimes causing data re-transmissions, can greatly impact the latency. However, knowing the system requirements can help you match the best technology to your needs.

Users can tolerate more latency in AMI backhaul since it is usually the meter data management (MDM) system, rather than a utility employee, that is waiting for the data to be delivered. However, there is less latency tolerance for DA control events. Rarely will more than 25 percent of the DA points from any common master radio node be triggered at the same time during an event, but splitting some of the DA points in urban high-density areas between cellular and private mitigates contention at a common private master radio node. Various factors including hardware and software delays, RF packet overhead, communications protocol overhead, half-duplex data transmission, network contention, re-tries, and packet file sizes impact throughout.

Forecasting the mid-grid system throughput requirements, or specifically the data throughput for DA, is much different than forecasting wide-area network (WAN) data traffic over a backbone. When a packet file size of 100 bytes is sent versus one of 50,000 bytes, nearly all radios will deliver significantly less throughput, and often far less than advertised in the product brochure. For example, a 900 ISM spread spectrum radio that achieves 500 kbps when sending a 50,000-byte file in a lab may achieve only 300 kbps or less when file sizes of 100 bytes are being sent from a DA pole in the field. Likewise, 3G cellular has been field-tested with actual throughput results less than half the throughput versus what is advertised by the cellular vendors when sending these small DA files on a round-trip basis from the field to the SCADA master and back. Note that devices such as remote terminal units (RTUs), switches, capacitor bank control-

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lers, 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 (URBX), throughput requirements during normal operations are significantly reduced versus throughput requirements during cyclic polling. In this case, throughput is instead forecast by determining the probable number of devices that will communicate through backhaul nodes during an outage, often competing with heavy traffic from other applications in a shared private architecture. As the DA devices on an affected feeder report exceptions in rapid succession, the ability to handle message collisions is important, particularly for slower communications technologies.

Which Communications Technologies Meet Your Needs?

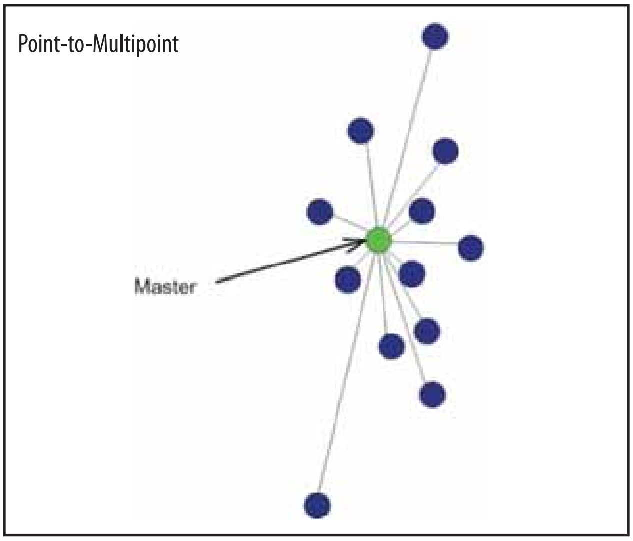
If we assume that mid-grid backhaul is defined by field locations where AMI collectors and DA points are located on distribution poles, the utility is most often faced with the selection of wireless backhaul technologies. (It is not common at all to use fiber to communicate with distribution pole mounted equipment.) The wireless backhaul choices most commonly selected include:

- Unlicensed 900 MHz and 2.4 GHz point-to-multipoint wireless;
- Unlicensed 900 MHz, 2.4 GHz, and 5.8 GHz mesh solutions;
- Licensed 150 MHz to 900 MHz 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);
- New satellite services; and
- New products based on the "white-space frequency" being introduced in 2012.

While there is much debate on the relative merits of private versus cellular and licensed versus unlicensed, 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 percent with restoration times of a few hours. While newer cellular services provide high throughput and are easier to maintain than private technologies, many cell sites do not have generator power backup, as most utilities have at their privately owned tower sites. Will the proliferation of smart phones and the use of cellular for consumer broadband purposes negatively impact the utilities use of the same cellular infrastructure? Can the utility "beef up" security when it uses cellular? These are critical questions to answer in your mid-grid communications strategy plan as your select your different technologies.

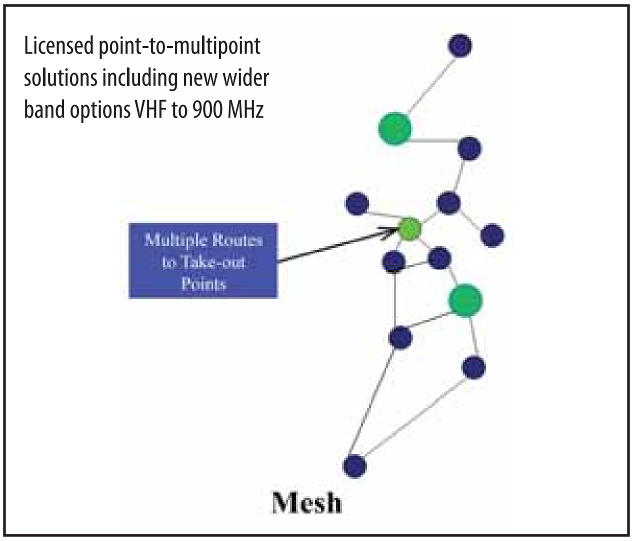
Unlicensed 900 MHz and 2.4 GHz point-to-multipoint wireless

Overall, the products and vendors in this class are mature and proven. Unlicensed point-to-multipoint provides a typical outdoor range of 15 to 25 miles and requires path and line-of-sight (LOS), which makes this technology challenging in heavy foliage areas. It is internet protocol based (IP), and functionality may differ among vendors; for example, repeater capability, QoS, propagation, environment, interface, etc. This technology offers data rates of ~256 kbps to ~10 MB and includes some risk for spectrum "overuse" interference at 900 MHz and 2.4 GHz.



Unlicensed 900 MHz, 2.4 GHz, and 5.8 GHz mesh solutions

Wireless mesh is appropriately one of the leading technologies for AMI neighborhood area meter networks. It is a proven means to overcome obstacles such as hills, buildings, and foliage by providing multiple paths around the obstacle. From a communications backhaul perspective, mesh-based communications technology is very viable for mid-grid applications. Mesh technology is very scalable through the addition of takeout points to high-speed wireless or wired backbone. The higher the den-



sity of mesh backhaul radios greatly improves the backhaul coverage. However, it is important to keep in mind that user throughput and latency are negatively affected as the depth of the mesh increases; i.e., the more hops are required to reach a takeout node.

Two examples of new, higher-speed metropolitan area network (MAN) solutions are SpeedNet from S&C Electric (operating in the 900 MHz unlicensed band) and Tropos Networks' mesh products (at 2.4 GHz/5.8 GHz).

Vendors such as CalAmp and GE Digital Energy-MDS have introduced new products in late 2010 with VHF to 900 MHz licensed point-to-multipoint solutions supporting RF data rates of 50 to 100 Kbps, enabling them to transport IP-based mid-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.

There is also an emerging vendor named Full Spectrum, Inc. in this licensed class that offers Software Defined Radio (SDR) WiMAX based VHF to

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900 MHz point-to-multipoint solutions that can be configured with 500 KHz of spectrum offering data rates above 500 kbps with non-line-of-sight propagation similar to Land Mobile Radio technology and is suitable for DA, AMI backhaul, and mobile data.

WiMAX in the "pseudo-licensed" 3.65 GHz band

Several vendors have product lines available using the 3.65 GHz band with the common platform being WiMAX. The bandwidth is very significant (over 10 Mbps) with this class of product, but it is a line-of-sight technology, making it more difficult in challenging terrain areas. However, it is very suitable for large AMI take-out point nodes, especially when pole/tower infrastructure exists.

Cellular data including 3G and 4G WiMAX (2.5-2.7 GHz) and long-term evolution (LTE)

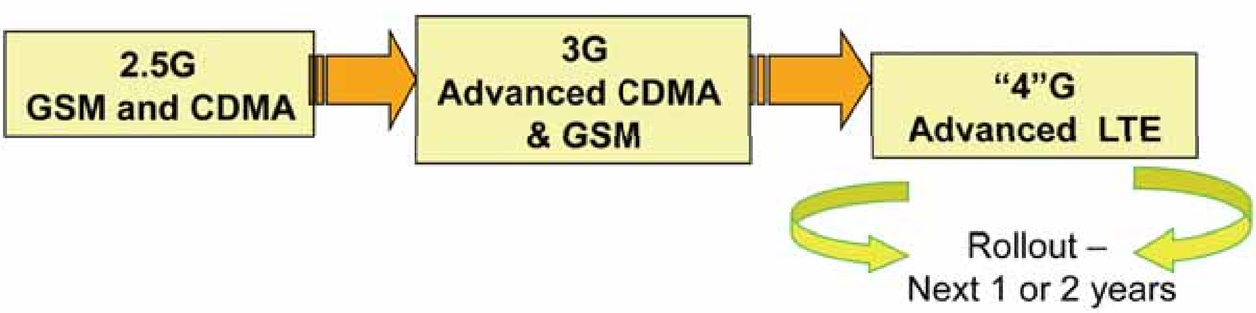
Cellular fits very well as a gap filler for mid-grid applications. Cellular services for low byte-count applications will cost less than $5 per month. For high byte-count AMI take-out points, cost may range from around $20 to $40 per month per site, with a digital cellular data throughput from around 60 to 300 kbps to possibly several dozen Mbps in 4G areas with light network congestion. The next generation wireless service provides faster data peak rates than the previous generation of products.

New satellite services

Most satellite vendors market their services through value-added resellers such as Stratos and Spacenet, two of the leading providers of satellite services for the utility market. Hughes is an example of a tier 1 provider. A GEO VSAT satellite, such as that offered by Stratos and Spacenet, are good technology choices for hard-to-reach substation sites where SCADA communications are needed. VSAT is now as affordable as other technologies that transmit data in excess of 100 kbps.

A good product option with a small footprint for hard-to-reach mid-grid sites, such as distribution automation and AMI field sites, is the Hughes 9201 M2M Satellite Terminal (pictured). It operates over the Inmarsat Broadband Global Area Network (BGAN) satellite network with data costs of ~$100/month/terminal for 8 MB of data. It is an "always-on" technology that charges only for data sent and received. Data rates are up to 400 kbps with latency specified at 1.2 seconds. BGAN operates in the "L" Band with terminal receiving frequencies of 1525.0 to 1559.0 MHz and transmitting frequencies of 1626.5 to 1660.5 MHz, so it has low susceptibility to degradation during precipitation, resulting in higher availability than Ku- or Ka-band satellite technology. What is attractive about this technology is that the radio fits into a square box without the use of

Generation	Mobile Data Rates
2.5G	25 Kbps – 80 Kbps
3G	Up to 1,250 Kbps
"4"G	Up to 10 Mbps (WiMAX, LTE)
4G	100 Mbps (LTE-Advanced, WiMAX-2)



a round VSAT dish. One can mount it on or near the pole, and it looks similar to other electric equipment that belongs to the utility.

Hughes 9201 M2M Satellite IP SCADA Terminal

New TV white space spectrum products

TV White Space (TVWS) spectrum will be coming soon—in 2012—with multiple 6 MHz-wide channels and offering some promise for higher bandwidth and strong propagation coming from frequency in the VHF/UHF band. However, the TVWS frequency does not provide the interference protection of licensed spectrum, but does provide more flexibility than the unlicensed bands. Future support of non-contiguous frequencies will help users in dense urban areas whose spectrum is fragmented by incumbents. Watch for product announcements and press releases for new products using TVWS.

Conclusion

The data throughput and latency requirement for mid-grid applications such as AMI and DA represent a challenge above those posed by substations and backbone networks. Challenging terrain and the low heights of the DA and AMI take-out points combined with sometimes dozens to hundreds of sites further limit the technology options and often justify hybrid technologies and a combination of cellular, satellite, and private media choices. Rigorously determining the required data throughput and latency and validating technology candidates via field testing will help ensure that your requirements and challenges are met. Always start new projects with a mind toward leveraging all current communication assets such as existing backbone networks, substation communications, and tower assets.

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