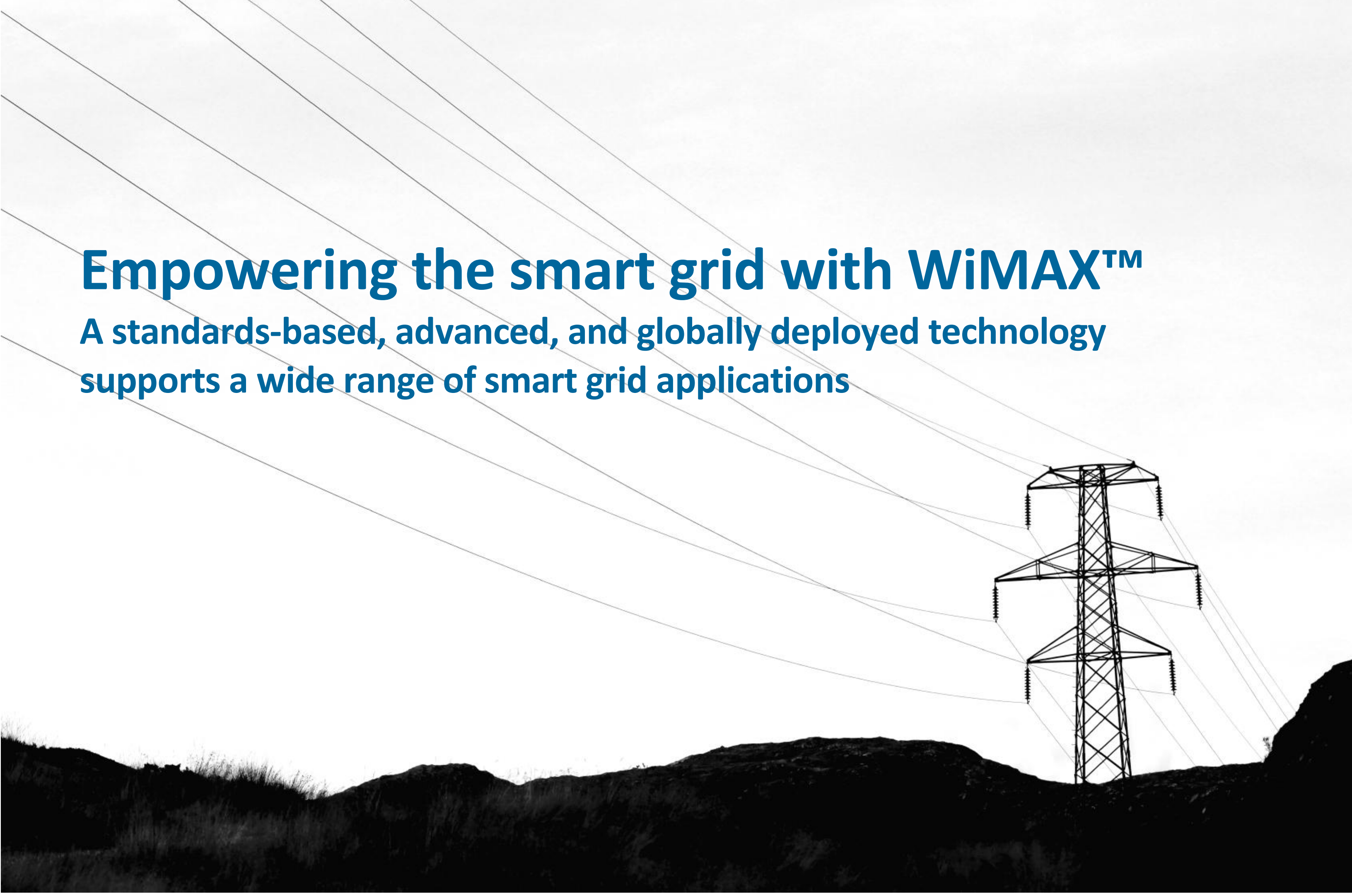

# Empowering the smart grid with WiMAX™

## A standards-based, advanced, and globally deployed technology supports a wide range of smart grid applications

- Fourth generation (4G) wireless technologies like WiMAX are crucial to successful, cost-effective smart grid applications.
- Security and control over infrastructure are top priorities for utilities. Ownership of the wireless network is often the best way to meet these priorities.
- WiMAX can support a wide range of applications that include smart metering, asset management and surveillance, mobile workforce and fleet connectivity, and emergency communications.
- Successful rollout of a WiMAX network requires a careful assessment of specific requirements, territory covered and spectrum availability, as well as a solid long-term business model, and a careful selection of vendors and system integrator.

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Electric utilities are reliable, ubiquitous providers of essential services, but have often been seen as resistant to change and innovation. Smart grid initiatives are rapidly reversing this perception, as utilities take a leading role in technological innovation and the efficient use of natural resources.

With smart grid applications, utilities can increase operational efficiencies, improve service quality, and save on costs. To make these achievements possible, utilities need to transform the way they operate their business—how they generate power, and how they deliver it to the end customer.

To take full advantage of smart grid applications, utilities' commitment has to extend beyond the initial capex. In particular, smart grid applications require a powerful, reliable, and secure telecom infrastructure to transport crucial information across all the utilities' assets. A growing number of utilities realize they need to become full-fledged telecom operators, managing networks that integrate a variety of wireline and wireless technologies in order to extract full benefits from the smart grid.

Utilities are under heavy pressure to move forward quickly and to select cost-effective, future-proof technologies that will generate a positive return on investment (ROI). The choice, however, can be difficult, because smart grid deployments break new ground, and utilities cannot rely solely on their previous experience. They need to chart new paths.

This paper focuses on how utilities can leverage 4G wireless broadband technologies like WiMAX to implement smart grid applications, using standards-based technologies that meet their unique performance, security, and reliability requirements.

We begin with an overview of the evolving role of telecoms and, specifically, wireless telecoms within utilities, and of the requirements involved in supporting smart grid applications. We continue with a discussion of the benefits of WiMAX, its business case proposition, and deployment considerations.

# Extending control over the telecom infrastructure

The smart grid will enable utilities to manage power generation and distribution by using sophisticated technologies and tools that rely on extensive and complex data networks. These data networks will become a core element of utilities' operations, replacing existing networks that play mostly a supporting role.

A big challenge for utilities will be the bidirectional transportation of this data across their entire network, to and from home residences and business locations, headquarters and remote locations, substations, distribution lines, and mobile field workers. At the same time, utilities do not want to depend, for the transport of sensitive core information on networks that are owned and operated by independent service providers, and that are shared with other customers.

As a result, utilities have started to deploy their own networks to get the level of control and reliability they need for smart grid applications. Many utilities are experienced at running telecommunications networks, but typically these are narrowband networks with limited functionality and, in many cases, supporting a single application—for example, emergency voice communications. With smart grid applications, utilities need to deploy and operate larger Internet Protocol (IP) networks that integrate multiple wireline and wireless technologies, and that support a large number of applications with a wide range of requirements.

Choosing the technologies and solutions best suited to their telecommunications infrastructure is one of the first steps, and a crucial one, toward implementing smart grid applications. Wireline technologies, such as fiber and broadband over power lines (BPL), are the ideal choice where they are available and meet performance requirements, and where utilities have cost-effective, reliable access to them.

For most utilities, though, wireline access is available in only part of the territory they cover. Where wireline technologies are not available or cost effective, wireless technologies allow utilities to reach their assets, employees, and customers. Even where wireline coverage is available, utilities increasingly find that wireless technologies provide better control and flexibility. Wireless technologies that support mobility, for instance, are better suited than wireline to communicating with field engineers repairing equipment, or driving to their next location.

# Do utilities need 4G wireless technologies?

The approach to smart grid initiatives is varied across utilities. Selected applications, priorities, requirements and preferences differ, driven by geography, funding availability and services offered. In nearly all cases, applications are rolled out in phases as resources become available and as utilities become ready to integrate them within the organization. By gradually adding new applications, utilities can incrementally extract more benefits from the smart grid, but they are still exploring different implementation paths as they learn more about what works best and which applications should have highest priority.

As a result, successful smart grid implementations rely on telecommunications networks that are scalable and future-proof, and that can easily accommodate the addition of new applications and upgrades to existing ones. This approach allows utilities to deploy new applications without facing expensive overlay network deployments.

**The utilities' perspective: The National Rural Telecommunications Cooperative (NRTC)**

NRTC is a member-owned, not-for-profit cooperative serving the advanced telecommunications needs of rural electric cooperatives and rural telephone companies. NRTC has over 1,500 members, of which more than 800 are rural electric utilities that cover 18 million US households and an impressive 70% of the US land area. The challenge that NRTC members face is how to serve such a dispersed customer base cost-effectively.

NRTC members are developing and implementing smart grid initiatives, frequently with the support of NRTC. In many rural areas, the population density is too low to justify the deployment of a communications network that would support only smart grid applications. To address this issue, NRTC developed a wider business model for WiMAX solutions. "Our approach is to encourage members to combine smart grid applications with broadband connectivity to homes and businesses in their coverage areas. Members can leverage their wireless broadband network to provide residential services to generate additional revenues. This additional service helps them to justify the cost of the wireless broadband deployment," says Kurt Schaubach, Vice President of Broadband Technologies at NRTC.

NRTC is working with GridNet and GE to test home smart meters with built-in WiMAX modules, which will allow utilities to have a two-way—uplink and downlink—channel to the home. This in turn will enable the development of more advanced real-time applications, such as demand response and time-of-day pricing. In addition, NRTC offers mobile workforce and remote surveillance and security applications that can utilize the communications capabilities of a WiMAX network.

For the wireless infrastructure component, 4G technologies like WiMAX can host the entire set of smart grid applications that utilities want to implement. Other technologies, such as narrowband proprietary wireless networks, second generation (2G) or third generation (3G) cellular networks, or Wi-Fi networks can support some applications, but not all.

For instance, narrowband or cellular networks provide good coverage and sufficient throughput to transport metering data, but are insufficient for remote surveillance, because their uplink capacity is severely constrained. Wi-Fi networks can support remote surveillance in some environments, but typically lack the ubiquitous coverage needed to support metering or mobile workforce access and have limited quality of service (QoS) functionality.

Because they combine high throughput, low latency, and wider coverage, 4G technologies can host and integrate all smart grid applications, and also act as the unifying platform that provides backhaul connectivity for other wireless networks using BPL, ZigBee (Institute of Electrical and Electronics Engineers [IEEE] 802.15.4), Wi-Fi (IEEE 802.11), or license-exempt wireless technologies. For utilities, a single wireless technology like WiMAX that is widely deployed within their territory means lower costs, less complexity, improved control over applications, and better overall performance.

# Applications and requirements

One of the challenges—but also a main benefit—of the smart grid is that energy generation, distribution, and consumption are managed throughout it, using different tools in different locations but within a unified network core. To do this, multiple applications must run in parallel and coexist on the same network (Figure 1), and each must be assigned to the appropriate priority level.

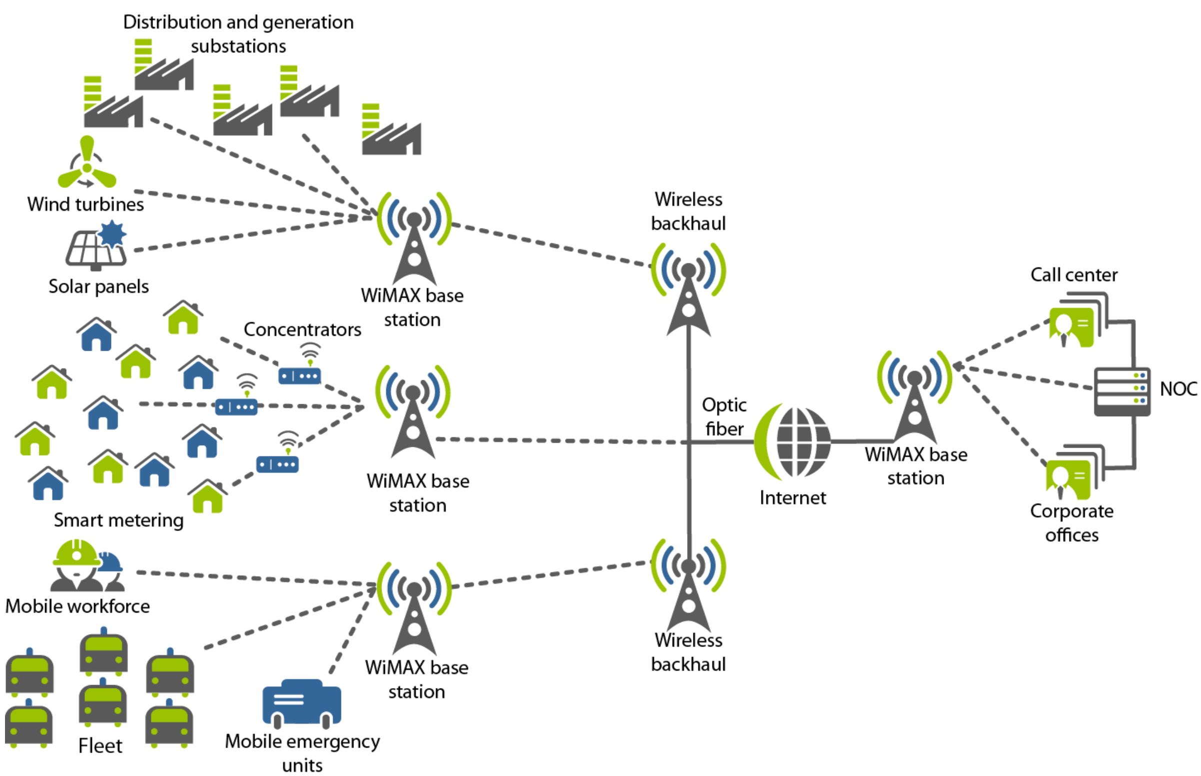


**Figure 1. Smart grid connectivity supported by WiMAX**

**The utilities' perspective: Sioux Valley Energy (SVE)**

In planning its smart grid initiatives, SVE finds itself in an enviable position: it has 2.5 GHz of spectrum, which it inherited from discontinued wireless TV services, and which can be used to offer wireless broadband access. SVE plans to leverage the existing infrastructure, and to expand the utility's wireless broadband network to add smart grid applications.

"For us, control over network access and security are paramount—this is why we want to own and operate the network," says Joel Brick, Wireless Technical Director at SVE. With technologies like WiMAX, Brick will have the tools to implement security protocols that protect sensitive data, introduce QoS and traffic prioritization to allocate traffic among applications, and have sufficient bandwidth to deploy all required applications concurrently.

SVE plans to develop partnerships with municipalities and to continue working with WiMAX operator Digital Bridge to expand this model beyond the areas SVE now covers. This will achieve economies of scale that will further strengthen SVE's business model.

For instance, metering data can receive lower priority than emergency communications or, in most cases, surveillance data. A voice over Internet Protocol (VoIP) call from a field engineer trying to fix a problem can have priority over the download of a blueprint or a map that another engineer will need later in the day. The ability to control and actively manage traffic enables utilities to cope with a complex mix of requirements driven by multiple applications by operational requirements.

Utilities are increasingly moving to deploy and manage their wireless networks in ways that meet the challenging demands of smart grid traffic. As they do so, they need to choose technologies that give them the flexibility to use their wireless network capacity effectively—advanced traffic management tools such as QoS, traffic prioritization, and policy management.

These tools are available in 4G networks, but they are typically not supported in cellular and Wi-Fi networks, which provide best-efforts data connections with high levels of contention.

If using a shared network, the cellular operator or service provider may use sophisticated traffic management tools, but utilities might have little or no visibility into or control of how this is done—or how it affects them. They certainly cannot dictate their own conditions on how to manage traffic.

The lack of control becomes a particularly sensitive issue during emergencies. Competition for network resources is likely to be highest at these times, and although not all traffic is equally crucial to resolving the emergency, in today's cellular networks, it's treated equally. In shared, best-efforts networks, utilities are not able to secure priority over other network customers—or even to have a guaranteed bandwidth—and end up competing for bandwidth with subscribers who are calling family and friends to let them know they are safe.

# WiMAX as a smart grid enabler

WiMAX is the first commercially available 4G technology. It is ideally suited to meeting both the requirements of smart grid applications and the needs of utilities to keep complexity under control without sacrificing security or reliability.

**Ecosystem.** Utilities have long operated proprietary networks, and know well that they often carry a hefty price tag, limit their ability to innovate and upgrade, and keep them tied to a vendor. WiMAX is not a technology specifically developed for utilities. It has wide appeal among network operators that provide services within public networks (e.g., Clear in the US, Yota in Russia, or P1 in Malaysia) or within enterprise or vertical networks (e.g., for utilities, transportation, or health care). WiMAX also has support from many infrastructure and terminal device vendors.

| Applications | Key requirements |
| --- | --- |
| Remote surveillance of generation, transmission, and distribution assets<br>Remote control capabilities | ▪ High uplink throughput for remote cameras<br>▪ Real-time connectivity with high availability and low latency<br>▪ QoS<br>▪ Secure connections |
| Remote real-time monitoring and control of generation, transmission, and distribution assets—e.g., with supervisory control and data acquisition (SCADA) systems and distributed control systems (DCS) | ▪ Real-time connectivity with high availability<br>▪ QoS<br>▪ Secure connections |
| Smart metering for residential and business locations | ▪ Support for a very large number of terminal devices<br>▪ QoS<br>▪ Secure connections |
| Connectivity to office and mobile workforce, including in-vehicle connectivity and fleet management, mobile access for field workers, and broadband connectivity from office locations | ▪ Support for mobility<br>▪ High throughput<br>▪ Virtual private network (VPN) support<br>▪ QoS<br>▪ Secure connections<br>▪ Low latency if using VoIP or video applications |
| Emergency connectivity through mobile base stations during emergencies | ▪ Support for mobility<br>▪ High throughput<br>▪ High availability<br>▪ QoS<br>▪ Low latency if using VoIP or video applications<br>▪ Secure connections |

With WiMAX, utilities can rely on a standards-based (IEEE 802.16) technology that keeps evolving, with the next major release, IEEE 802.16m—also referred to as WiMAX 2—promising higher throughput and better support for mobility and voice applications.

Because WiMAX equipment is interoperable, utilities can source it from multiple vendors, and select the best-of-breed gear for each application. For instance, utilities may choose one vendor for base stations and others for the terminal devices for meters and for the wireless units for cameras—or they may keep their current vendors while adding new ones for new equipment. In either case, they will be able to choose from multiple infrastructure and device vendors, which means more competitive pricing and wider selection.

**Environment.** Utilities have a presence throughout their territory. They need to reach every business and household, and they have assets in both urban and remote areas. The connectivity requirements—and challenges—differ wildly depending on location. In rural areas, coverage and backhaul availability are main issues. In urban areas, the more prominent issues are availability of spectrum and access point locations, the need for interference management, and the requirement for higher capacity. WiMAX, with its support for both multiple input, multiple output (MIMO) A and MIMO B, can operate in all environments, providing wide-area coverage in rural areas and high capacity in urban areas.

**Performance.** WiMAX has the right mix of features to support smart grid applications within a manageable carrier-class network:

- Uplink and downlink throughput is sufficient to host even the most demanding video surveillance applications. Uplink gain can be optimized with maximal-ratio receiver combining (MRRC).
- Low latency (< 100 ms round trip) enables support for real-time applications with video and voice components.

- Mobile workforce access and in-vehicle applications benefit from handover support.
- Utilities that are not interested in mobile access can deploy a streamlined version of WiMAX that supports only fixed applications, in which the terminal is at a fixed location, and nomadic applications, in which the terminal can be moved but needs to reconnect to the network after its location changes.
- As an IP-based technology, WiMAX supports QoS, traffic prioritization, policy management, and additional traffic management tools. With these, utilities can actively manage bandwidth and optimize the use of network resources.

**Security.** Security is a paramount concern for utilities, and it is likely to become an even more prominent one within a smart grid environment, where information on the entire grid is shared throughout the network. WiMAX provides secure communications and provides support for multiple security standards, including:

- 128-bit Advanced Encryption Standard (AES)
- Centralized authentication, authorization, and accounting (AAA)
- Access service network (ASN) gateway authentication
- EAP Tunneled Transport Layer Security (EAP-TTLS)

# The role of WiMAX within the smart grid

The role of WiMAX within different smart grid implementations will vary depending on the utility's requirements and existing infrastructure, the availability of wireline connectivity, and the overall environment in which the utility operates. WiMAX is a versatile technology that can be deployed in multiple roles:

- **Backhaul.** WiMAX can provide the backhaul link to the network operating center (NOC) or, more commonly, to the nearest or most cost-effective fiber connection. In this scenario, WiMAX can transport application data from and to terminal devices that use an intermediary wireline or wireless interface, such as BPL, ZigBee or Wi-Fi. This is likely to be the case for many smart meter applications, at least initially, with meters transmitting data to concentrators that in turn are connected with WiMAX base stations.
- **Last-mile connectivity.** WiMAX can also be directly connected to terminal devices. This is the most likely scenario for surveillance and remote monitoring of assets, especially for applications that require significant uplink bandwidth. As volumes grow and prices decrease, WiMAX will become widely used as a module to connect smart meters directly to the WiMAX network. This approach will enable the deployment of more-advanced applications that require real-time control and wider bandwidth channels. Initially, smart meters with WiMAX modules are more likely to be employed in rural, low-density areas, where WiMAX base stations can cover wide areas and may result in cost savings over the concentrator model.
- **Mobility.** A WiMAX network can also provide connectivity to the mobile workforce and to service vehicles, using the same network infrastructure that supports connectivity to fixed terminals and backhaul.
- **Emergency.** Mobile base stations and terminal devices can be moved to emergency areas to create temporary networks, which may use WiMAX, satellite, or other technologies for backhaul. In this case, the same devices used by the mobile workforce and in service vehicles and fixed locations (e.g., modules embedded in cameras or sensors) can be used to connect to the temporary base station.

# The business proposition

The most powerful advantage of WiMAX is perhaps the balance it strikes among cost, complexity, flexibility, and control. Until recently, carrier-grade performance and security required a large investment, complex networks, and dedicated spectrum. In most cases, these networks supported only narrowband connectivity, due to spectrum channel and wireless interface limitations. As an IP-based technology, WiMAX was designed with more than mobile operators in mind. It can be used by smaller operators, enterprises, transportation and safety agencies, municipalities, and, of course, utilities.

WiMAX's flat architecture gives utilities an unprecedented degree of flexibility and scalability. Multiple base station form factors are available, with multi-sector and single-sector macro base stations for wide-area coverage, and micro and pico base stations for dense areas. And WiMAX can use a wide range of frequencies, including licensed, lightly licensed (e.g., the 3.65 GHz band in the US), and license-exempt bands.[1] This level of flexibility and scalability enables utilities to add new applications, greater capacity, and wider coverage in a seamless, cost-effective way.

If using a public cellular network without QoS or traffic prioritization, utilities may still have to build a narrowband network for emergencies or for mission-critical data. Managing two networks and supporting two sets of terminal devices clearly results in higher costs and complexity. By deploying and managing their own broadband networks instead, utilities gain complete control over the wireless infrastructure. This enables them to manage applications as they see fit and to give priority to specific terminal devices, traffic flows, or applications as they deem appropriate. This greatly increases the value of the network to the utilities.

Public networks often have limited coverage in rural or other low-density areas. For instance, mobile operators might provide 2G but not 3G coverage, making it impossible to support most applications. Control over the wireless infrastructure allows utilities to extend coverage to rural and other low-density areas as needed and using the gear best suited for the environment.

Spectrum specifically reserved to utilities (e.g., the 1,830 MHz band in Canada) or available to utilities (e.g., the 3.65 GHz band in the US) is a strong incentive for utilities to deploy their own wireless networks. In many environments, however, especially outside urban areas, utilities are increasingly comfortable using license-exempt spectrum as well, as interference management tools become more effective and as WiMAX equipment becomes commercially available for these spectrum bands.

Utilities also require a long-term commitment to the technology they choose to deploy from their service provider or their vendor, to ensure that they are not forced to replace terminal devices or the network infrastructure ahead of their plans to do so. Mobile operators are often unable or unwilling to provide such a commitment, because they may have limited-time spectrum leases or because they may be forced to upgrade to new technology to meet their subscriber demand. Because cellular subscribers change their phones more often than utilities replace meters, mobile operators are more used to frequent upgrades than utilities are.

Finally, an independently owned network can bring substantial operating cost savings, because it does not have the recurrent charges per terminal device that are typically charged by mobile operators. Of course, building and operating an independent network does require an initial capex outlay and does impose

1 Only equipment that operates in selected licensed spectrum bands can be certified as WiMAX, as certification is available for only these bands. However, equipment that uses WiMAX-based technology can be used in lightly licensed and license-exempt bands, providing the same features and performance.

 

recurring network operating costs. But with equipment costs dropping and availability of free or inexpensive spectrum expanding, utilities are realizing that operating their own network can result in deep cost savings over the life of the network.

## Deploying the wireless infrastructure

As utilities move from proof-of-concept trials to planning and deployment of the wireless infrastructure in order to enable their smart grid initiatives, they face a wide array of decisions that will determine their long-term success. The smart grid will revolutionize the way they run their business—and perhaps it will change their business entirely. Electric utilities' focus is likely to shift from selling power to managing its production and consumption, with economic incentives to increase power efficiency in generation, distribution and consumption, rather than sales.

How can utilities choose the wireless infrastructure that is best suited to their current and future requirements? How can they pick the technology that will most smoothly evolve along with their smart grid applications?

The first step is to get a solid understanding of their overall requirements—initial ones and long-term ones. This might seem straightforward, but it can easily become challenging, since the requirements are dependent on new operational processes that have not been introduced yet. Utilities are bound to find that smart grid applications will, to some extent, work differently than anticipated, so they need some leeway to accommodate change.

**Tradeoffs:**
**Build your network or use available cellular networks**

| Build your own network | Use cellular networks |
|---|---|
| Capex intensive | Opex intensive |
| Complete control over network performance, traffic management, and resource allocation during both regular operations and emergencies | QoS currently not supported within cellular networks<br>Control over traffic management lies with the mobile operator<br>Transmission priority during emergencies may not be granted |
| More extensive planning and telecom expertise required, but IP-based core facilitates integration with rest of utilities network | Network already deployed, applications can be rolled out more quickly |
| Lower latency | Limited bandwidth, especially in the uplink |
| Choice of best-suited wireless interface | Choice of technology and pace of technology update dependent on mobile operator |
| Lightly licensed or license-exempt spectrum typically used, or licensed spectrum allocation required | Access to licensed spectrum through mobile operator |
| Commitment to support wireless infrastructure for the lifetime of the project | Long-term commitment may be problematic for mobile operators |
| Expensive to achieve ubiquitous coverage<br>Coverage extensions to rural areas are possible | Wide coverage already in place but may exclude some rural areas where utilities need it most |

The business model is another crucial choice for a utility that decides to roll out its own private network. In the previous pages we assumed that the utility would deploy and operate the network. In practice, the utility has another option: it can provide funding for the network, but rely on a third-party operator to install it and operate it on a day-to-day basis. In this scenario, utilities can keep their focus on generation, transmission, and distribution of power. They do not need to be involved in the daily running of the network, but they retain control over it.

The choice of vendors and a system integrator (if one is used) is fundamental to ensuring a successful implementation of smart grid initiatives. Most smart grid applications break new ground, and they require more extensive integration. Integrating a large set of applications with different requirements within a multi-technology platform is a challenging task. For most utilities, it will be more complex than rolling out the wireless infrastructure, for which deployment options are well understood.

Utilities should ensure that the vendors' equipment is the best suited to their specific performance and capability requirements, and that it offers solutions optimized for smart grid applications. Along with suitable equipment, it is best to choose vendors and a system integrator experienced at working with utilities and with requirements similar to those of smart grids. Because the wireless infrastructure will be tightly tied to the geographical environment, it is also advantageous to select vendors that have experience with the type of territory the utility intends to cover.

The vendor and integrator should have a commitment to both the wireless technologies supported and the utilities market. Even with technologies like WiMAX that support interoperability, a sudden or unanticipated change in vendors can be disruptive. The long-term ability of a vendor or system integrator to support future growth and facilitate technology upgrades will enable utilities to direct funding where it is most needed, which is conducive to a faster ROI.

Finally, vendor flexibility in the selection of spectrum bands can be a great advantage to utilities deploying smart grids, as new spectrum bands might become available and utilities may decide to transition to the new bands or to expand their existing network to include them. In this case, the ability to reuse the equipment makes the transition or expansion to a new band more affordable and less disruptive and protects the utilities' investment.

# Summary

Smart grid applications will profoundly change the way utilities operate, and will bring telecommunications to the core of their activities. Wireless will be a key part of the telecommunications infrastructure; it allows utilities to reach their subscribers, fixed assets, fleet, and staff in secure and cost-effective ways, using both fixed and mobile connections.

4G wireless broadband technologies and, in particular, WiMAX are optimally suited to the requirements of smart grid applications, because they provide low latency, high throughput, support for the most advanced security protocols, and traffic management tools, including QoS. These features allow utilities to run a wide range of applications concurrently over the same network, while maintaining full control over how network resources are allocated across applications with different priority levels.

Increasingly, utilities choose to build their own network instead of using the cellular infrastructure, because network ownership gives them the level of control and security they need. To ensure successful rollouts of wireless broadband technologies, utilities need to plan carefully; examine their requirements in detail; choose the best-suited technologies, vendors, and integrators; and assess spectrum availability.

Wireless broadband networks will enable utilities to deploy a wide range of applications, from smart metering to mobile workforce support, and from emergency communications to remote asset monitoring across all the territory they cover.

| What matters most to utilities |
|---|
| **Reliability, performance, and coverage.** The wireless infrastructure has to support utilities' core operations and, in many cases, improve the safety of their staff and customers, as well as protect their assets. |
| **Long-term vendor commitment to the technology.** Utilities need to ensure that the equipment they adopt will remain commercially available for the long term (10–20 years). |
| **Vendor support for multiple spectrum bands.** This makes it possible for the utility to reduce the complexity of the network by deploying a single solution across different bands, and to expand the spectrum bands used at a later stage is needed. |
| **Multiple form factors**. Utilities operate in a wide range of environments, from dense urban areas to the most remote rural areas, and they deploy a variety of applications that depend on a large set of terminal devices. So utilities require a high degree of flexibility in choosing the form factors best suited to each different environment. In the radio access network (RAN), a choice among macro, micro, and pico base stations allows utilities to deploy cost-effectively the wireless infrastructure at locations they have access to. |
| **Standards-based platform with interoperability across vendors.** This gives utilities a wider choice in sourcing best-of-breed equipment for different applications, and they eliminate the dependency on a single vendor and/or a proprietary solution. |

# About Senza Fili

Senza Fili provides advisory support on wireless data technologies and services. At Senza Fili we have in-depth expertise in financial modeling, market forecasts and research, white paper preparation, business plan support, RFP preparation and management, due diligence, and training. Our client base is international and spans the entire value chain: clients include wireline, fixed wireless and mobile operators, enterprises and other vertical players, vendors, system integrators, investors, regulators, and industry associations.

We provide a bridge between technologies and services, helping our clients assess established and emerging technologies, leverage these technologies to support new or existing services, and build solid, profitable business models. Independent advice, a strong quantitative orientation, and an international perspective are the hallmarks of our work. For additional information, visit www.senzafiliconsulting.com or contact us at info@senzafiliconsulting.com or +1 425 657 4991.

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