Telecom for Utilities
White Paper

Telecom Network Planning for Utilities

Designing networks for optimum performance (ready for growth/expansion)

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Overview

Utilities provide critical infrastructure for the nation and must heavily rely on telecommunications for monitoring and control of their assets. At present, this industry is transforming at a rapid pace as a result of new technologies, distributed generation, increased demand, and the changing needs and expectations of consumers.

Utilities rely on wireless communication infrastructure for vital operation systems, such as Supervisory Control and Data Acquisition (SCADA), Distributed Automation (DA), smart metering, and Field Area Network (FAN). To control the performance of this critical infrastructure, utilities can utilize both licensed and unlicensed Radio Frequency (RF) spectrum to meet the requirements of a variety of network devices.

Utilities are investing millions of dollars in communications as part of the effort to digitize their assets and enable two-way flow of information. They are combining telecommunications and Internet of Things (IoT) technologies to create an automated and widely distributed network.

In the case of electrical utilities, leaps in demand for broadband telecommunications capacity and computing power have translated into a sustained demand for even more abundant and reliable power supply. Modernization of electric utilities has made it clear that communications networks are critical to maintaining safe, reliable, and efficient delivery of services. Grid modernization has an increasingly rigorous set of requirements designed to support new, latency-sensitive, critical applications. Today's electric utilities have deployed communications based upon applications that provide network operators with the capability to monitor grid problems in real time. The evolving role of utilities in the integration of distributed energy resources is placing even greater demands on their communication networks, specifically when it comes to balancing inconsistent solar and wind energy resources with storage capacity. The same telecom network that delivers usage, outage notifications and power-quality measurements is also used to transmit demand-response and load-management messages, price alerts and green energy notifications, as well as to convey commands to optimize distribution equipment performance.

Currently, utilities are proficient at estimating their near-term communications needs, but future demands may be difficult to quantify because of the rapid pace of evolution in smart technologies and consumer demand.

Challenges of Design and Deployment

Addressing Multiple Types of Users

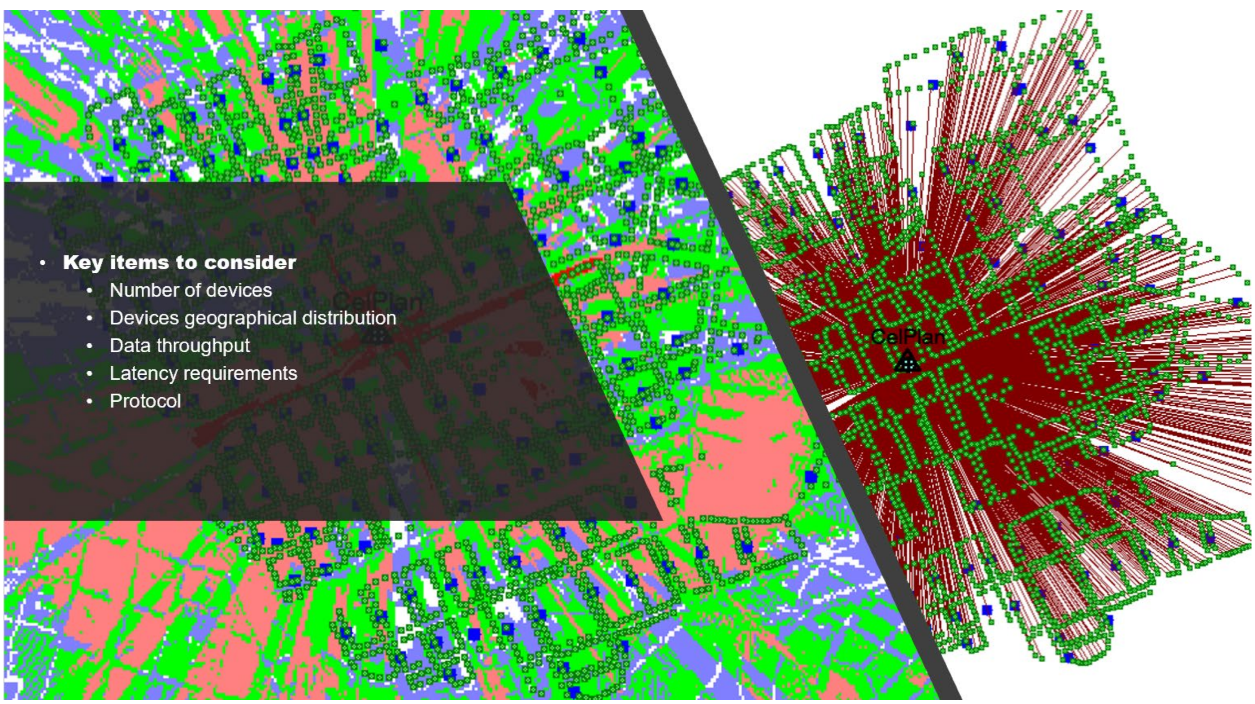
Cost of the telecommunications infrastructure represents a significant expenditure for utilities. As a result, planning and management of communication assets become very relevant. The large investment and required detailed planning of the telecom network is critical to control capital expenditure and reduce on-going operational costs.

Planning a reliable and secure telecommunications infrastructure with the capacity needed to carry increasing data traffic is a critical part of the utilities' modernization process. Integrated telecommunications allow real-time control and data exchange. When an integrated communications network is fully deployed across the utility footprint, it can optimize system reliability and asset utilization and increase security, including resistance to cyber-attacks. Utility operations leaders must plan and deploy the telecom technology needed to securely acquire and carry all this smart data. For instance, mesh radio networks require planning to provide optimal and cost-effective wireless access to thousands of endpoints in a service area while accounting for interference from other devices on the same band.

Utility telecommunication networks for today’s applications are complex, multi-tiered systems that can manage and integrate diverse technologies and facilitate the rapid, seamless flow of information within the whole network.

Utility wireless network infrastructure planning is challenging and complex because of the mix of technologies across multiple bands. The variety of network applications introduces requirements in terms of latency, speed, spectrum access, reliability, security, standards, and performance. This makes network design a complex task that demands advanced design tools along with engineering and business problem solvers. To add to the complexity, utility telecom engineers have the challenge of designing this complex network while maximizing the use of existing assets and planning for future growth.

The multiple devices connected to smart network might have different requirements in terms of data throughput, latency and protocols. It is important to have these clearly defined before planning so the network designer can properly dimension the actual coverage requirements of each site while keeping interference at bay.



The design of utility wireless telecom networks brings unique challenges, which cannot be properly addressed by using a “cookie-cutter” approach; proper network design has significant impact on the final performance and possible expansions of the network.

The Need for Constant Optimization

Over the past few decades, the utility industry has come to realize that communications networks, especially those designed to reach a variety of endpoints, need to be more than just a single tower covering the largest area possible. Different endpoints have distinct requirements in terms of traffic demand, latency, quality of service, and throughput. During the initial design, utilities may want to address all these and come up with a master plan that will indicate the direction they want to go. However, as deployment starts, new challenges may appear, new endpoints might be added, constraints not initially accounted for might introduce variations on the initial design. Thus, utilities need to be prepared to address these ongoing changes by testing the design and being prepared to adapt and modify the initial approach to accommodate new requirements. The optimization cycle should be constant during network deployment and expansion.

Key areas of ongoing system optimization include:

- Coverage and interference analysis to identify problem areas
- Drive tests to evaluate system performance (in certain areas, drive test might be required in both winter and summer)
- Traffic analysis to identify and alleviate traffic bottlenecks
- Reassessment of endpoints connection to servers
- Optimization of system parameters and resources (frequency and code planning)
- Redesigning to optimize existing investment and maximize performance
- Spectrum cleaning to free additional channels
- Final drive test to assess redesign work
- Technology transition planning and joint operation of technologies

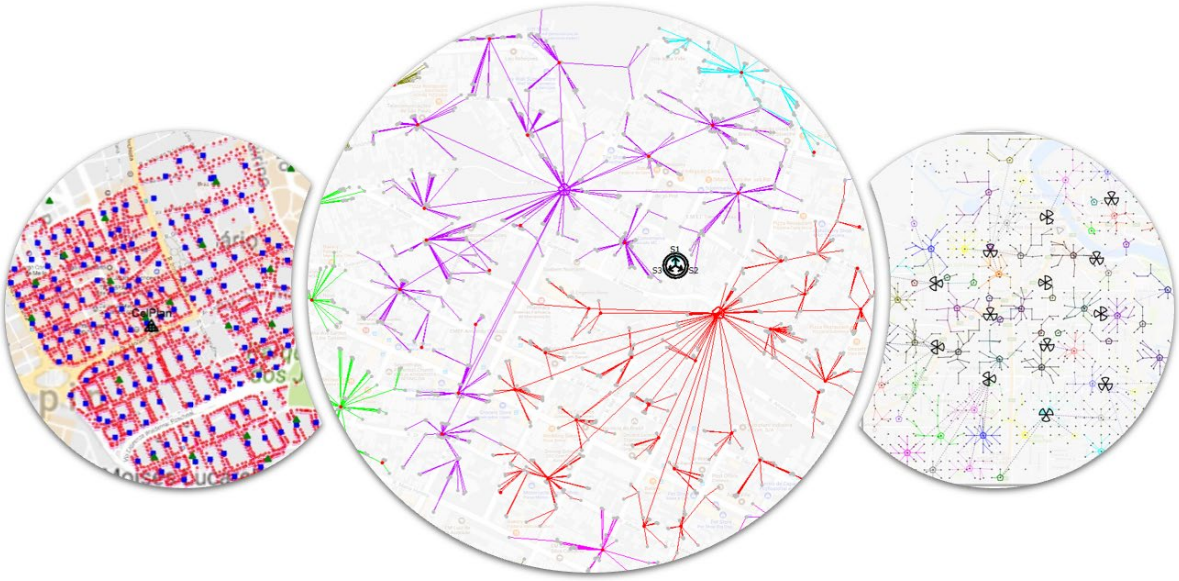
Why it matters

Designing a network with fixed endpoints may, at first, seem easier than designing for mobile users; however, the fact that fixed endpoints tend to be installed in high masts, the possibility of having areas with large concentration of devices, and the fact that they are capable of transmitting at power levels higher than most mobile units (e.g. higher gain antennas) are all factors that can be problematic when considering upstream interference, which is often overlooked during initial design.

Endpoints are often clustered in small areas within the AOI (Area of Interest) which makes load balance between sectors challenging for a site layout with fixed azimuths, i.e. the pre-defined orientation of the antennas may not provide a good distribution of users throughout the sectors.

This is where the so called cookie-cutter approach usually causes problems. By limiting the configuration of sites to one, fixed setting (i.e. specific height, azimuth, antenna type, etc) you are removing the variables that allow interference avoidance and mitigation. For example, lowering the height of a site is a very effective way of keeping the signal from that site from propagating too far, while still providing strong coverage for the devices nearby. This is a very good approach for areas dense with sites and devices, in which the target area of a site is usually within a couple of miles (or less) of the site itself.

Another frequent issue is the addition of new endpoints in areas already deployed; for example, in an urban setting that is experiencing a housing boom or industrial growth, a fixed network may have been designed for a certain number of endpoints, but now requires a partial redesign to avoid overloading the sector or increasing the network interference level.



Furthermore, the need to reuse existing assets usually introduces other problems to the design. Most existing assets come from legacy technologies previously used (or still in use) by utilities; the majority of which make use of high elevation sites ("umbrella" sites) to maximize coverage area. While this might sound interesting in terms of coverage area, this not necessarily translates into good network performance, given that the strong signal level coming from these elevated sites can cause interference in other sites in the service area. While this might sound interesting in terms of coverage area, this not necessarily translates into good network performance, given that the strong signal level coming from the tall sites can cause interference in other sites in your service area. Dealing with a limited number of frequency channels (or subcarriers and resource blocks) and having a few sites that overlap throughout the whole AOI might decrease the network performance due to an interference that could have been avoided in the first place.

The use of "umbrella" sites can be advantageous for connecting endpoints that cannot be otherwise reached; however, However, during the planning phase, these sites need to be carefully designed to use resources that will not be available for the other sites in the same AOI, thus avoiding interference.

Just the factors mentioned above are enough to justify spending time on a good initial design for the network, but, most importantly, they also pinpoint the need of continuous design work, to keep the network optimized. Network planners must remember that the technologies being used today in this type of network (e.g. 4G, 5G, narrowband, mesh) cannot be planned by simply looking at signal level coverage, both capacity and interference must be considered to properly dimension the system and analyze its performance.

For a proper design, it is essential to determine what devices will be served by the network and what are their requirements and have a general idea of where these devices are located. With this in mind, it is possible to create an initial layout of sites and adjust each site to best serve its target area.

Case Studies

CelPlan has designed several networks for utilities and smart-cities in the past few years, including AMI smart-lighting, distribution automation, field area networks, smart-metering and sensors. In each case, we spend time with customers to identify what is the goal of the network, what is the area to be served, what are the requirements for each type of device and what are the constraints of the network (for example, maximize use of existing assets). With this information, we help the customer determine what is the ideal balance of investment x performance that they want for the network.

In a recent study CelPlan performed, we helped a utility that serves over 12 million consumers in 805 municipalities in preparing a telecommunications investment plan for the next 15 years. This plan included multiple technologies and overlaid networks creating a telecom ecosystem that can support a variety of end users (from dispatch units all the way to meters and distribution automation).

CelPlan has also participated on the design of multiple networks in the upper 700 MHz A Block spectrum in the US. This spectrum comes with its unique challenges due to the narrow channel available for utility companies and the propagation characteristics of the band, which can be very helpful in terms of coverage area but, at the same time, presents a challenge when trying to curb interference. Once again, each of these networks need to rely on different techniques to limit this interference while still providing good service to endpoints. Different parts of the country have distinct clutter types: taller, dense trees in some areas; sparse vegetation in others; mountains and valleys in contrast with flat, arid expanses. The techniques to improve signal coverage while keeping interference in check cannot be the same.

On a pilot project for using mesh technology to collect information of over 60,000 meters, CelPlan showed the customer the importance of properly dimensioning the backhaul. Creating a good design for the last mile by providing mesh access to the aggregation points by itself is not enough, one needs to make sure the data gathered by the 5,000+ aggregation points could be backhauled to the office.

On a smart street-lighting project, using mesh technology to cover about 15,000 endpoints, CelPlan worked with the customer to correct issues with the pre-design, which had been done just by estimating the number of aggregation points required based on the final count of endpoints. When CelPlan did the actual network design it was clear that more aggregation points would be required to cover all endpoints; or more hops would be needed, which affects latency. We worked together with the customer to determine the cost-benefit ratio of each solution (more aggregators x more hops).

CelPlan really sees its relationship with the customer as a partnership. During the design of a private LTE network for a utility that covers over 800 municipalities and more than 9.6 million customers, CelPlan targeted the added challenge of designing a network meant to attend both mobile and fixed users. The difference in height and antenna gain of these users makes the service area provided by the sites quite different when analyzed from the perspective of the end devices. During the planning phase, CelPlan noticed that the customers initial requirements would imply in a significant over dimensioning of the network which might not actually be needed. CelPlan alerted the utility and helped them to realign the scope and requirements of the project, setting more appropriate and achievable goals for service requirements of mobile and fixed users. With the new scope in place, CelPlan was able to deliver a design that supported both mobile and fixed devices while still keeping the telecom investment at a reasonable level.

CelPlan's Suggested Approach

At CelPlan, we understand that utilities need to reuse existing assets as much as possible and have developed a methodology for designing a network that can use these to meet endpoints' requirements. Our tools support both standard-based and proprietary wireless technologies, includingNB-IoT, LTE, WiMAX, AEROMACS, WI-FI, LPWAN, 5G, 4G, 3G, 2G, LMR/PMR, Tetra, P25, trunking, and proprietary narrowband and wideband technologies. Our tools are also capable of automatically shaping cell footprints to simultaneously minimize interference (considering diversity effects), while optimizing coverage, and balancing traffic.

CelPlan RF engineers have work decades to perfect our design methodology which is usually divided in three phases:

- Phase I: Initial Design – this design considers all existing assets, targeted AOI, and location of endpoints (if available). Restrictions on cell configuration and parameters are addressed on this phase as well. This design includes a first run of optimization analysis to try to minimize any self-interference. On this initial design, endpoints are assigned to best server cells based on best SNIR available (according to predictions in the planning tool). This phase can be improved with spectrum sweeps and drive testing to improve predictions and identify potential issues.
- Phase II: Deployment Review – during this phase, the initial design should be reviewed to account for any exceptions on cell configuration (e.g. a site that cannot be downtilted as requested, an antenna installed at a different height due to unavailability of the planned height in the tower). The endpoints connections should also be reviewed at this stage to try to switch from best server to other secondary servers that may be close in terms of service and make more deployment sense (e.g. the boundary between two sectors might have endpoints pointing to either sector, to facilitate deployment, it might be better to group the endpoints in a certain area and point them to the same sector). After these updates are done, optimization of the network might have to be rerun, and interference and performance should be checked.
- Phase III: Design Maintenance: this phase should last for as long as the network is operational. The design should be often updated and kept current with any changes in the network (e.g. endpoints that may have switched to fiber connection, additional endpoints, disabled cells, changes in antennas, tilt, and power, etc.). It is important to keep up with these changes because they may affect network performance and they will be required for analyzing any network expansions (e.g. new areas, additional type of endpoint or throughput demand, additional spectrum). Phase III, ideally, should be done by the utilities themselves for cost-effective reasons. Usually this is accomplished by a transition from CelPlan to the utility FAN team, in which they are trained in the use of the planning tool with CelPlan mentoring on maintenance of the project and generation of analyses and reports.

Conclusion

Nearly every component of the intelligent grid relies on the next generation telecom network. Many utilities are completely revamping their telecom infrastructure, upgrading to an IP-based network that offers voice, data and control. The planning, design, inventory, optimization, and capacity management of the telecom network is of the highest priority.

Effective deployment and management of utility telecom infrastructure is critical to control capital expenditure, lower operating expenses, minimize network downtime, ensure optimal network performance, and deliver enough bandwidth and capacity to carry the increased network traffic.

Utility wireless telecommunications networks must:

- Support device-monitoring solutions
- Deliver real-time information about grid condition and performance
- Allow greater utilization of available network capacity
- Enable fast and efficient development of future network infrastructure

Whether you are looking to designing an RF network, identify design problems prior to deployment or during operations, correct potential sources of performance deficiency, or monitor the continuing expansion of your network - CelPlan can assist you with services and solutions that make a real difference in both operations and costs.