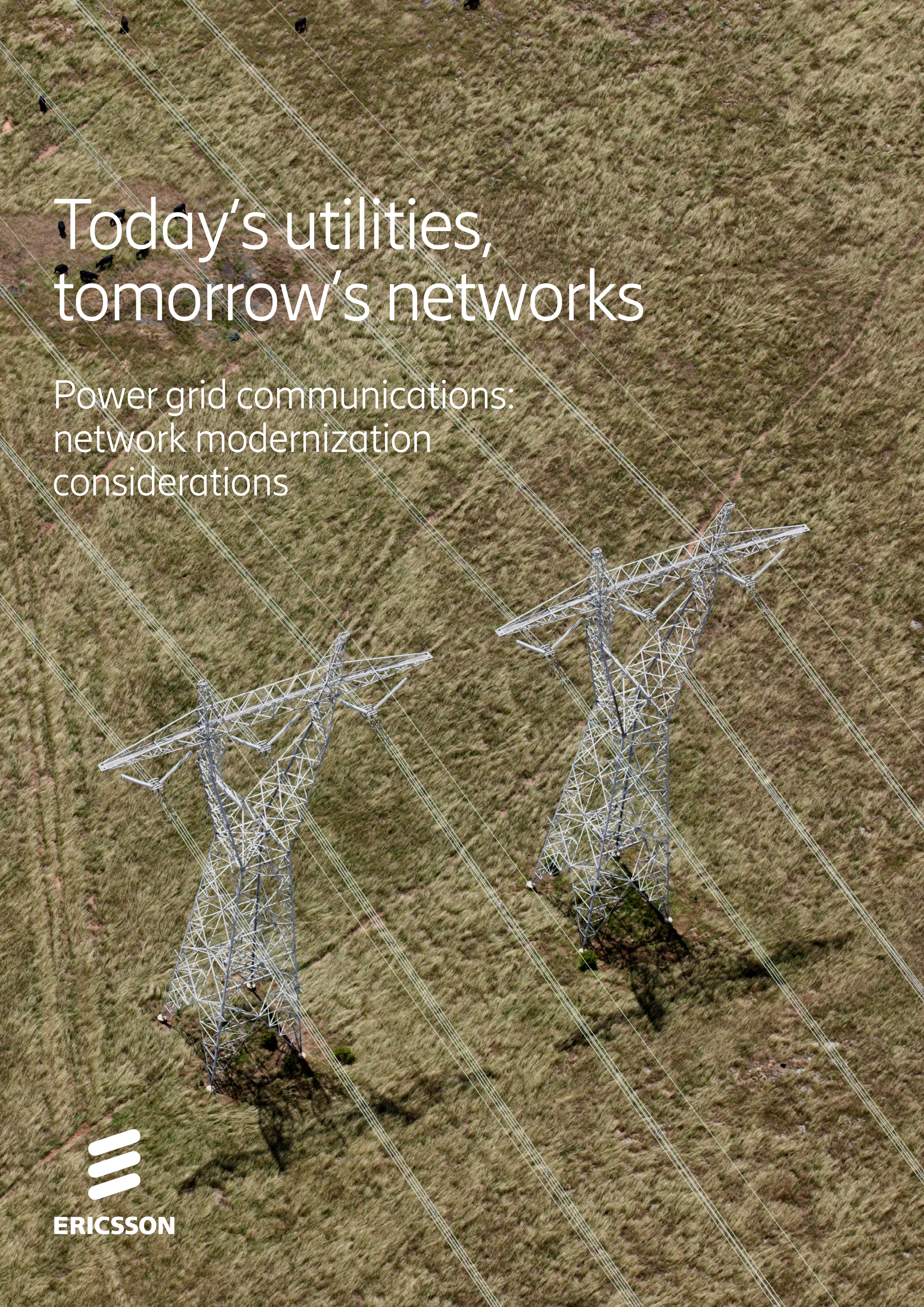
Today's utilities, tomorrow's networks

Power grid communications: network modernization considerations



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Contents

Executive summary

To address industry modernization and digitalization needs in the utilities sector, the use of 3GPP connectivity and LTE/5G-based cellular private networks on licensed and unlicensed spectrums is growing. US-based utilities believe they need secure, scalable and prioritized control of their infrastructure and can justify the ROI from private networks, encouraging them to seek out custom-built solutions, including spectrum and investment considerations. Availability of access to spectrum, in both the low-band (900MHz, 600MHz) and mid-band (CBRS), has accelerated the consideration for investments in private networks.

A number of these companies have run POCs on experimental/leased 900MHz and 600MHz licenses for private LTE networks:

- Ameren, a large electric utility company based in the US Midwest, has signed an LOI with Anterix (the owner of 900MHz spectrum assets), which is expected to result in the first signed commercial agreement.
- Southern Company, based in Atlanta, is one of the 10 largest US electric and gas utilities and the first to implement its own LTE network. It has deployed private LTE networks for utilities on the sub-1GHz spectrum.
- National Renewable Energy Laboratory, in Colorado, specializes in renewable and efficient energy research and development. Funded by the US Department of Energy, it has successfully demonstrated increased reliability of a distributed generation system on 900MHz.
- Exelon, the largest electric parent company in the US based on revenue, was granted an experimental 900MHz license in October 2019 and is initially piloting sites in Maryland.
- NYPA, the largest public power utility in the US, aims to be the one of the first digital utility companies and is looking to deploy private LTE for several use cases, including mobility and drones.

Many countries are considering offering spectrum specifically for utilities. In the US, as of February 2021, the FCC has cleared a 3x3 TDD block in the 900MHz band for private network communications. Such low-band spectrum is ideal for wider coverage, and therefore the best fit economically for private network buildout, supporting mission-critical applications.

Utilities have several options for deploying networks: partnering with CSPs, securing their own spectrum/assets, and taking a hybrid approach. While opex reduction is one of the primary drivers for US utilities, each business model poses different levels of benefit, risk, financial flexibility, reliability and control.

The economic analysis in this paper is based on multiple engagements with different-sized utilities in the US. The specific results referenced reflect a medium-sized, vertically integrated utility with generation, transmission and distribution facilities covering both electricity and gas in multiple US states. The model can accommodate smaller or larger utilities with different footprints, densities and operational parameters. For this analysis we assume a typical situation with an existing wireless network comprised of multiple technologies, many becoming obsolete. These technologies could include WiMAX and P25 LMR and be used for inter-substation transport, metering infrastructure and real-time communications. In combination with newly released CBRS spectrum, utilities can also offer Fixed and Mobile Broadband in a private network.

To address the challenges, Ericsson's business strategy and technology consulting division inCode Consulting analyzed the usage demand, network capacity requirements and economic aspects of building a private cellular network, including an investment and deployment roadmap and based on a portfolio of use cases. It was important to understand the data and bandwidth demands of traditional mission-critical systems, such as SCADA, DA, DER, tele-protection and mission-critical push-to-talk. Consideration was also given to mobile workforces of linespersons and engineers, who require sufficient bandwidth for their mobility needs and for smart meter rollout across service areas, as well as the need for a network able to support evolving and advanced use cases in the future, such as UAV and AR-based asset management.

The use case analysis was followed by an assessment of the spectrum options, where the feasibility of using 900MHz and CBRS bands to support the use cases was investigated. Each spectrum band comes with unique considerations of coverage, capacity, cost and availability. It is important to study the spectrum from these perspectives in order to develop a TCO model, outlining capital and operational expenses. As mentioned in the cited case study, the utility company has an existing infrastructure of communication towers, site leases, owned and leased fiber routes and microwave backhaul, which should be optimally reused to minimize capital and operating costs. Lastly, an ROI analysis justifies the spend and how private networks can offset existing capital and operating expenses.

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Key trends and business drivers

Leading utilities are looking to evolve to 3GPP-based communications and private mobile networks as part of their digital transformation, triggered by new demands such as micro energy generation and phasing out of legacy equipment. Major themes driving this change are:

Phasing out legacy equipment:
Existing narrowband mission-critical networks are reaching their end of life, as traditionally adopted technologies such as WiMAX and P25 LMR are becoming outdated with a shrinking ecosystem. Furthermore, decarbonization initiatives require updated communication models to monitor and manage the newer ecosystem.

Reduction of opex:
Regulated utilities prefer the stability of capex, which can be deterministically transferred to ratepayers, over fluctuating opex, such as connectivity services which charge based on data consumption and can eat into margins. The reduced operating costs make private networks affordable and well suited for utilities.

Security:
Multiple purpose-built and disparate communication networks that abound a large, regulated utility's infrastructure landscape also contribute to security vulnerability. High data security and control are needed to make critical assets unbreachable and to dynamically customize the network in challenging environments and situations.

Digitalization:
There are productivity gains with the move to Industry 4.0, through more flexible control and increased mobility, as well as value capture from enterprise connectivity. Data-heavy use cases for new applications incorporate AR, VR, high-definition video-based applications for remote inspection, monitoring, surveillance and control.

Operational visibility and prioritization:
Commercial networks offer a degree of reliability,[1] or service availability[2] in 3GPP terms, in that they can be enhanced to meet critical infrastructure industries' needs. Where outages are a significant liability to both customers and regulated industry players, a utility company can deploy and control resources at its discretion, prioritizing restoration of important services, which would rely more on private mission-critical networks.

Flexibility, control and innovation:
Utilities expect high-level control over the provisioning of new services and devices. They can secure greater flexibility through infrastructure decentralization, enhanced by 3GPP and 5G. Moreover, 3GPP technologies like LTE provide standardization, a vast ecosystem of devices and pathway to 5G, thus enabling utilities to deploy innovative use cases.

Reliability and Quality of Service:
The ability to limit network congestion by controlling contention and prioritizing access is important for utilities to guarantee different required service levels for various users and/or applications.

Upgrade cycle:
Commercial carriers tend to upgrade and move subscribers over quickly, but a utility company could control and plan for network upgrades in accordance with their UE/application support.

Ownership and coverage area:
The availability of private spectrum ownership, such as the aforementioned 900MHz band as well as CBRS spectrum, enable private networks to be built in line with the utility company's footprint, as opposed to the highway/byway/population density methodology used by commercial operators.

[1] Reliability is defined, in the context of network layer packet transmissions, as the percentage value of the amount of sent network layer packets successfully delivered to a given system entity within the time constraint required by the targeted service, divided by the total number of sent network layer packets (ETSI TS 122 261 V15.5.0)

[2] Communication service availability is defined as the percentage value of the amount of time in which the end-to-end communication service is delivered according to an agreed QoS, divided by the amount of time in which the system is expected to deliver the end-to-end service according to the specification in a specific area (ETSI TS 122 261 V15.5.0)

Private LTE benefits for utilities communications

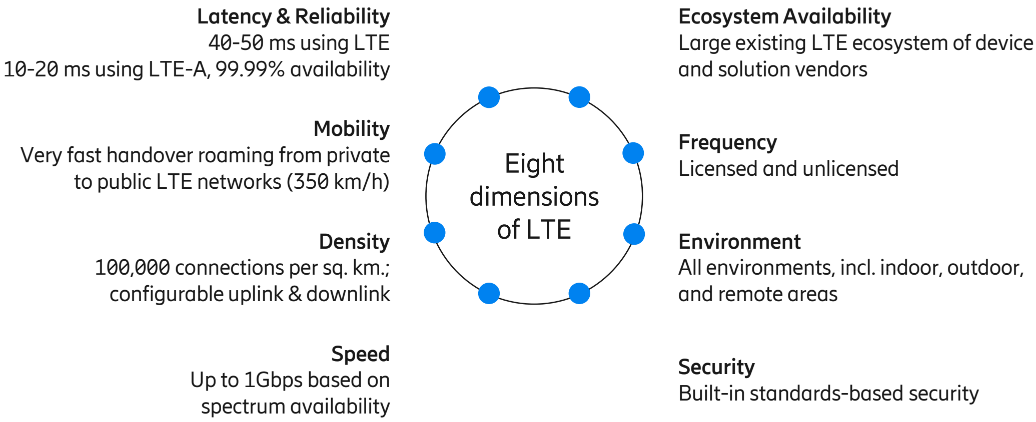

Figure 1: Eight dimensions of LTE

Source: Figures in the paper are by Ericsson inCode

Providing sufficient capacity, economical coverage, and indoor and outdoor mobility, LTE is a key enabler of the future. It brings a vast ecosystem of devices, infrastructure and solutions to a private cellular network deployed for utility substations, field personnel, smart meters and smart grids.

LTE is highly optimized, standardized and software upgradable[3] to 5G. It uses spectrum sharing, ensuring forward compatibility with future innovation. Unlike previous generational shifts, such as 2G to 3G and 3G to 4G/LTE, 5G is not a wholesale replacement of the previous generation, but an enhancement for future use cases, building on and leveraging existing 4G/LTE infrastructure.

With its high reliability, private LTE can address the aforementioned growth drivers, reduce opex and offer a path forward from legacy technologies. Keen emphasis on full-stack security prepares utilities communications infrastructure for increased productivity gains from industry digitalization use cases.

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[3] The latest generation of Ericsson LTE radios delivered since 2015 is software upgradable to 5G

Aligning use cases and digitalization strategy

Utilities have been progressing their digital transformation through a phased approach to the use cases and mission-critical aspects of their communications infrastructure. Use cases should be categorized and prioritized to align with the chosen digitalization strategy. They can also be grouped, based on client terminologies, into mission-critical (crucial for critical functions and business operations), quasi-mission-critical (secondary yet important to business operations), enterprise (unlocking operational efficiencies) and next-generation (emerging and future cases). Enterprise cases are further classified into low and high throughput use cases, based on their performance requirement characteristics. These use cases tie back to the business drivers that address line-of-business goals.

Business drivers	Opex reduction			
	Legacy replacement			
	Security	Reliability	Flexibility and control	Digitalization
Utilities perspectives	Mitigate threat vectors	Increased Quality of Service	High-level control of service and device provisioning	Accelerate digital transformation of the grid
Mission critical			DA: Volt / VAR Optimization Smart Metering	SCADA (E/G T/D) Push to Talk Smart Metering
Quasi mission critical			DA: CVR Demand Response Mgmt.	
Enterprise – low throughput		DER integration	DER integration	Fleet Telematics
Enterprise – high throughput	Video surveillance			Mobile Workforce – Tracking, Dispatching, GIS
Next-generation	Drone Monitoring Advanced Fleet Mgmt.		Autonomous Subst. Robots	Augmented Reality Workforce

Figure 2: Industry 4.0 use cases for utilities

Each use case is tied to several types of device with different data rates, polling frequencies and busy-hour requirements that can translate into network capacity demands. Some commonly used devices in the utilities industry are categorized as SCADA, DA, DER, VAR, FLISR and CVR.

Most mission-critical and quasi-mission-critical applications consume low bandwidth, and contribute little to the peak busy hour, as data transmission is only periodic; for example, smart meters transmit just 2.4 kilobytes every 4 hours. On the other hand, some enterprise use cases, such as video surveillance, and next-generation use cases, such as AR-based workforces, consume high bandwidth and capacity.

Our approach

To determine the ROI of multiple cellular network variants, Ericsson inCode has developed a model, which has been fine-tuned through strategic engagements with US-based utilities. The following sections of this paper outline the major factors considered within the model.

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Spectrum, capacity and coverage considerations

As part of the technical analysis, it is important to estimate how expansive the network buildout must/should/could be. Identifying the number of sites to be built for private networks will require understanding of the spectrum, coverage and capacity.

Given varying device densities and propagation characteristics of spectrum in different geographies, capacity and coverage analyses should be made separately for each geography. To account for regional cluster and distribution of buildings, customers, substations and devices, the footprint area can be broadly classified under three morphologies, based on population densities:

- Dense urban: a census tract with at least 5,000 people per sq. mile (~0.3 percent of the area)
- Urban/suburban: a census tract with between 200 and 5,000 people per sq. mile (~5.3 percent of the area)
- Rural: a census tract with, at most, 200 people per sq. mile (~94 percent of the area)

Substations and devices are more concentrated in urban and dense urban areas, making sufficient spectrum capacity crucial. In dense urban areas the device density is more than 6 times that of urban areas, which in turn is more than 25 times that of the rural device density.

Utilities globally are considering several spectrum frequency bands, with a growing emphasis in the US on 900MHz and CBRS spectrum options. For low-bandwidth use cases, including mission-critical, quasi-mission-critical and enterprise, the spectrum supply (3x3 for 900MHz) of the low-band could suffice. However, to serve high-bandwidth use cases and design the network for the decade ahead, mid-band spectrum would become imperative.

This poses a challenge, as mid-band spectrum, while possibly more economical, would require significantly more sites due to its limited propagation characteristics (link budget analysis shows a low band like 900MHz has approximately three times the cell radius of the power-limited CBRS band). To keep costs within a reasonable range, utilities should consider a multi-band spectrum strategy. This would involve initially deploying low-band spectrum to serve key use cases, with mid-band spectrum subsequently acquired and deployed when higher-bandwidth and next-generation use cases become a consideration. In addition, carrier aggregation can extend mid-band spectrum coverage when deployed along with 900MHz. This will provide a better ROI for a combined deployment model, especially when capacity needs are being considered along with coverage.

Factors influencing coverage and performance in different spectrum bands include cell edge speeds, morphology and tower height. Morphology comprises variables like terrain and clutter; that is, hills, valleys, buildings, trees and other elements that impact signal propagation. To determine the effects of these factors, link budget analysis is performed to calculate coverage and capacity limits, leading to an estimation of the number of sites required. This analysis is across spectrum bands, morphologies and tower height profiles.

Our findings show that a multi-band spectrum strategy is essential to economically support diverse use cases, based on regional availability and cost.

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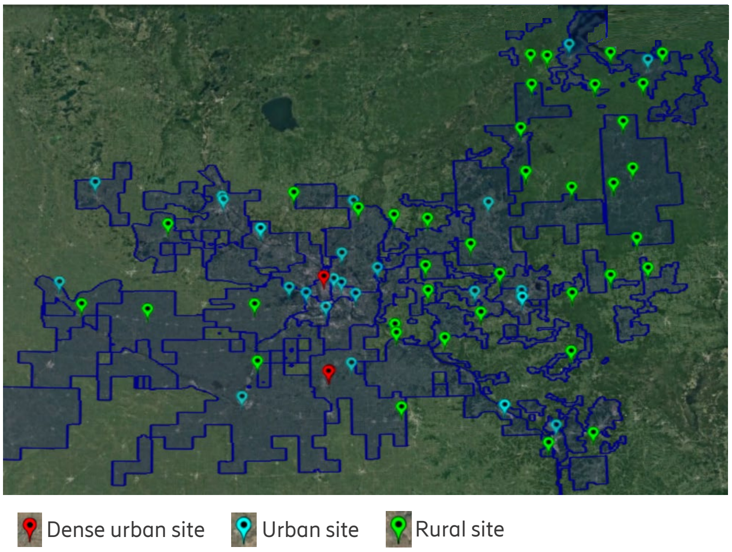
Existing asset reuse

Existing infrastructure is a critical piece of any investment analysis jigsaw. The location, condition and reuse of existing towers (built and leased), fiber rings and other infrastructures can impact costs substantially. Reuse, and termination where applicable, of these assets is imperative to reduce the cost of building and operating a next-generation private cellular network.

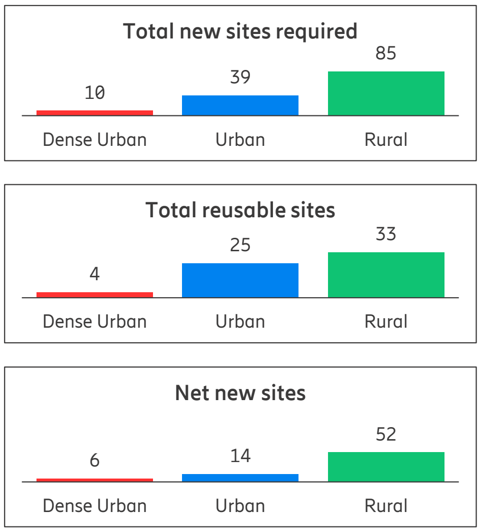
To achieve this, existing towers and sites are categorized, based on their height profiles and associated coverage characteristics across morphologies. Sites that fall within certain ranges are marked for reuse, while the rest are marked for site and/or backhaul termination. Reuse of shorter towers accounts for reduced coverage radii when calculating the new site builds.

Figure 3 indicates anonymized data on existing site distributions by morphology.

Overlay of reusable sites in service territory A



Sites analysis



All data in Figure 3 and Figure 5 has been anonymized for confidentiality purposes, but the relative scale has been maintained.

Figure 3: Reuse of existing site and backhaul assets

Economic analysis

The critical question posed by utilities is – do the cost savings achieved by migrating to LTE, mostly in the form of opex, justify investment in a private network?

As shown in Figure 4, building a capex and opex model for TCO is based on consideration of data usage, bandwidth demands and available spectrum.

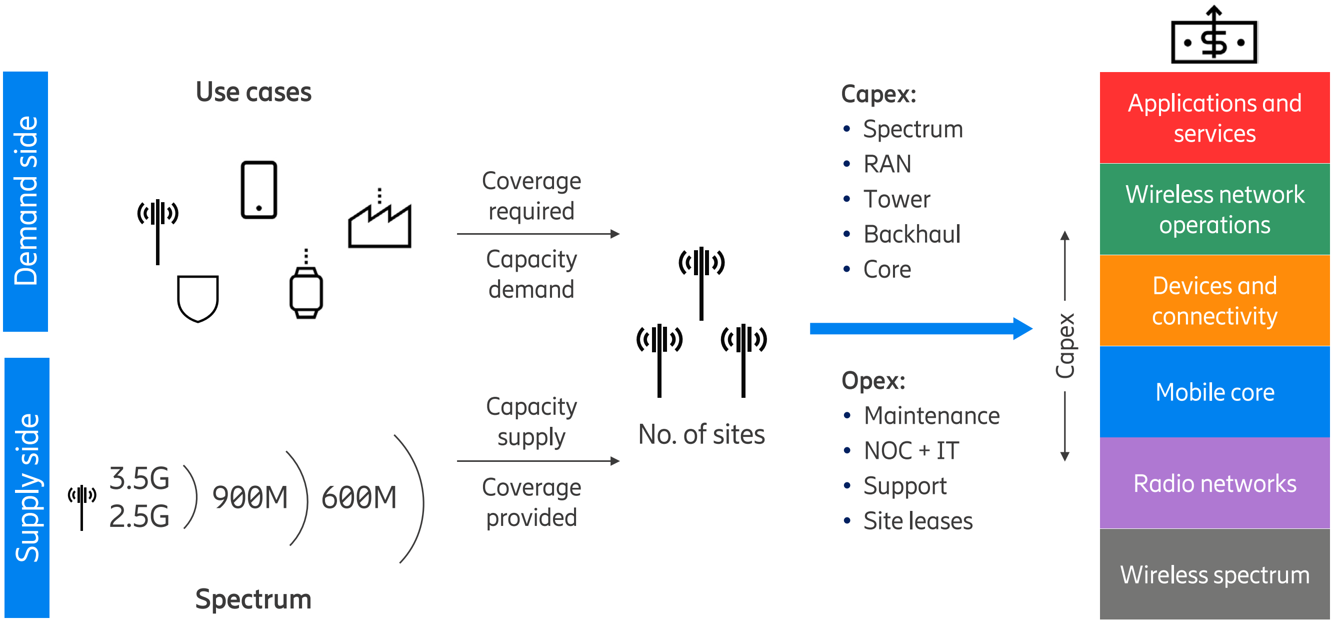
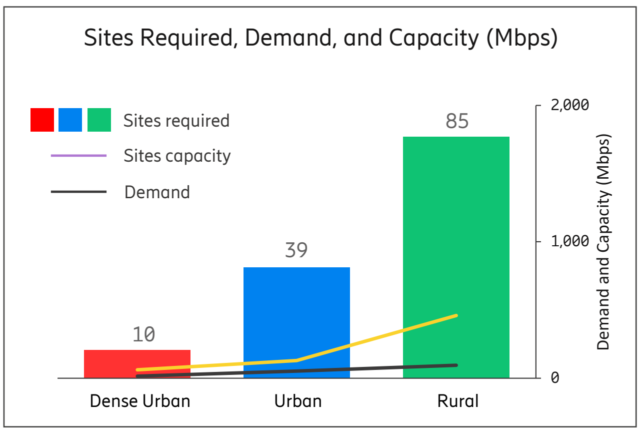


Figure 4: TCO model for private networks

The use cases are mapped to devices with bandwidth and peak usage requirements. Layering the devices across morphologies, we consider the capacity and throughput requirements of the sites and network.

Spectrum is the key supply-side enabler based on its coverage and capacity constraints. Using these requirements, as well as spectrum availability, we calculate the number of sites required in the three morphologies. Spectrum band coverage and capacity vary as device density decreases from dense urban to urban and rural morphologies.



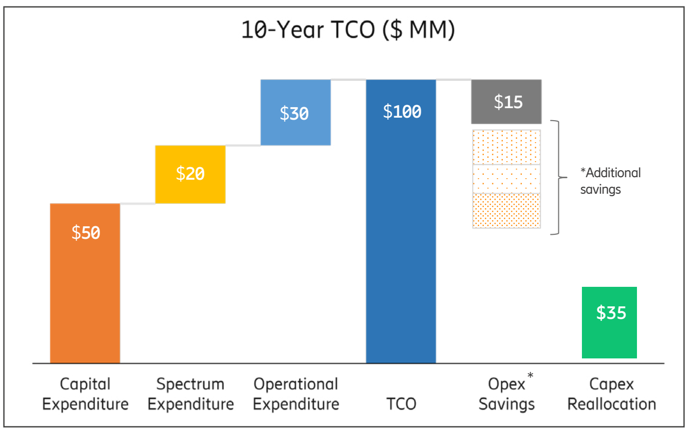


Figure 5: Site capacity and economic analysis – TCO and savings

* Additional Opex savings based on the number and category of use cases operating in the new Private Network environment

Figure 5 illustrates the number of sites required for building a private network across the footprint, as well as the demand and capacity across various morphologies. As there are fewer devices in rural areas but more sites due to expansive coverage, there is significant excess capacity available. The gap between demand and capacity is smaller in urban areas and further narrows in dense urban areas.

Capital costs for site buildout are influenced by spectrum, radio equipment, tower construction, fiber or microwave backhaul, core networks and IT. Costs for site construction, fiber and leases also vary across morphologies, while operating costs are influenced by network maintenance and support, NOC operations, IT maintenance and site and fiber leases.

For utilities, reducing opex is a key priority; most expect a TCO cycle of 10–15 years, with TCO the summation of capex and opex. Figure 5 illustrates the 10-year costs associated with capital, spectrum and operations. The opex is as low as 30 percent of TCO, which is in the range of utilities' priorities. The shaded area shows that there are many such expenses that could be reduced or eliminated, and which vary on a case-by-case basis. The capital cost reallocations are due to the negated planned buildouts of legacy networks.

Various factors contribute to capex and opex savings:

- Legacy network upgrade costs
- Spend on grid connectivity service
- Spend on metering connectivity
- Site visits and truck rolls
- Outage penalties
- Legacy network support costs

Performing an economic analysis based on use cases is essential to justify optimal investments in building a next-generation private network. A phased network rollout across morphologies and use cases will allow adaptation for the demand generation, based on deployment of devices and prevalence of asset locations.

Takeaways

Our study establishes some well-grounded conclusions, as listed below.

1. In the wave of digital transformation , the industry is moving to 3GPP-based communications networks with a focus on private networks.
   Key drivers propelling the industry towards private LTE include the need for reliability, opex reduction, flexibility and control, and security.
2. Use cases can be categorized and prioritized to align with the chosen digitalization strategy.
   Use cases vary within a company's operations and must be prioritized along with associated network demands, projected for the estimated lifetime of the network.
3. Multi-band spectrum strategy is essential for economically supporting varied use cases based on spectrum regional availability and cost.
   While low-band spectrum is valuable to both utilities and cellular network operators, availability and cost may vary regionally. Considering options such as unlicensed or lightly licensed spectrum like CBRS can help determine optimal investment.
4. Existing infrastructure reuse can substantially decrease costs.
   Existing assets such as fiber, backhaul and sites should be accounted for in building the business case.
5. Consider a phased rollout of networks across morphologies and use cases.
   The network must be built through a phased approach over several years and based on device and substation density in different morphologies where propagation characteristics differ. Similarly, support for various use cases can be phased for deployment across the network.
6. Performing an economic analysis based on use cases is essential to justify optimal investment in building a future-proof private network.
   Several capex and opex factors can be considered to determine further investment and savings areas.
7. Utilities and CSPs can work together. To reduce investment costs further, utilities could leverage common core and applications in the CSP's network and deploy radio access network components in a private network with interworking to common core and applications. CSPs could support utilities by:
   - offering spectrum, managed core, operations and managed services
   - offering devices through existing partnerships
   - helping to build utility-specific application ecosystems
   - reselling network equipment to build an end-to-end offering that also helps utilities capitalize costs

Explore further

For utilities, CSPs and other industry verticals like oil and gas and mining, investigating mission-critical private networks, key strategic questions need to be answered:

- Which use cases should be considered for optimal deployment?
- What are the spectrum options?
- What would it cost to build a private network, and would the investment be justified?
- What does the ecosystem look like? Which part of the value chain can or should we operate in?
- What technical, operational and organizational capabilities would be needed to build private networks?
- How do we monetize private networks?

Related offerings

If you are interested in learning more, please consider the related offerings below or contact Ericsson.

Ericsson inCode Consulting offerings

Ericsson Mission Critical Networks

Ericsson Private Networks

Glossary

2

2G
Second-generation cellular network ... 5

3

3G
Third-generation cellular network ... 5

3GPP
3rd Generation Partnership Project See also www.3gpp.org ... 3, 4, 11

4

4G
Fourth-generation cellular network ... 5

5

5G
Fifth-generation cellular network ... 3, 4, 5, 13

A

AR
Augmented reality ... 3, 4, 6

C

capex
Capital expenditure ... 4, 9, 10, 11

CBRS
Citizens Broadband Radio Service
See also https://cbrsalliance.org ... 3, 4, 7

CSPs
Communications service provider ... 3, 11, 12

CVR
Conservation voltage reduction ... 6

D

DA
Distribution automation ... 3, 6

DER
Distributed energy resources ... 3, 6

F

FCC
Federal Communications Commission ... 3

FLISR
Fault Location, Isolation, and Service Restoration ... 6

G

GHz
Gigahertz ... 3

I

inCode
inCodeConsulting, the Strategy Consulting division of Ericsson Inc.
See also www.incodeconsulting.com ... 3, 6, 12, 13

L

LMR
Land Mobile Radio ... 3, 4

LOI
Letter of intent ... 3

LTE
Long-Term Evolution ... 3, 4, 5, 9, 11, 13

M

MHz
Megahertz ... 3, 4, 7

O

opex
Operating expenditure ... 3, 4, 5, 9, 10, 11

P

P25 LMR
Project 25 Land Mobile Radio ... 3, 4

POC
Proof of Concept ... 3

Q

QoS
Quality of Service ... 4

R

ROI
Return on investment ... 3, 6, 7

S

SCADA
Supervisory control and data acquisition ... 3, 6

T

TCO
Total cost of ownership ... 3, 9, 10

TDD
Time division duplex ... 3

V

VAR
Voltage and reactive power ... 6

VR
Virtual reality ... 4

W

WiMAX
Worldwide Interoperability for Microwave Access ... 3, 4

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About Ericsson inCode

inCode Consulting supports investors, vendors, operators, enterprises and public sectors including industrials in economics and technology planning for private LTE/5G. With decades of expertise serving the telecom industry needs, inCode can help you answer wide-ranging questions on the applicability of private LTE/5G.

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