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Private Mobile Networks: The Role of Telecom Operators

A Heavy Reading white paper produced for Nokia

NOKIA

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PRIVATE LTE MOBILE NETWORKS

Private mobile networks (PMNs) are designed for the performance, coverage, and security requirements of enterprise users. They are attractive to a wide range of organizations seeking to redesign critical business processes and improve productivity. For example, PMNs can help an organization instrument and connect physical equipment, support Internet of Things (IoT) services, or simply optimize employee communication.

Private networks, by definition, represent a rupture with the public network model that has defined the mobile industry for decades. This rupture creates new requirements in terms of technology, operating processes, and business models. It also raises the question of how the ecosystem of technology suppliers, systems integrators, and network operators will interact to meet this new demand.

This white paper discusses how telecom operators—the classic users of mobile network technology—can apply their technical capabilities, network assets, and market reach to become leading providers of private LTE solutions to enterprises. The paper argues that public network operators are vital to the private network ecosystem. By working closely with partners, they will be influential in determining the shape and growth rate of this new market segment. For operators to succeed, however, they must "think and act enterprise" and not treat private networks simply as an add-on to the public network.

The focus of this paper is on LTE technology as a path to 5G private networks. It argues that, in the near term, LTE is appropriate for most businesses due to the well-developed ecosystem of equipment suppliers, devices, and integrators. It makes the case that, as part of the 3GPP family of technologies, LTE provides a migration path to private 5G networks.

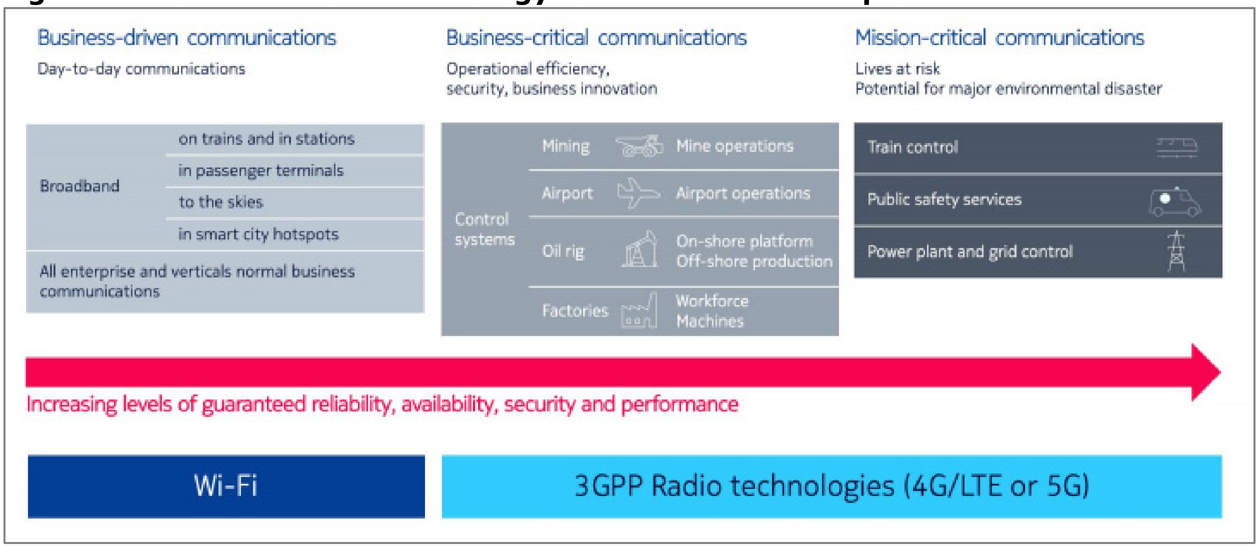
PMNs and operational technologies

Organizations decide to deploy PMNs when they have wireless connectivity needs for operational technology (OT) that cannot be met by the public mobile network or by Wi-Fi. There are three primary reasons why this might be the case:

- **The need for coverage:** Typically, where there is no (or insufficient) public network coverage. Classic examples are mines, oil & gas extraction, and utility grids, but may also include indoor and campus locations. In addition, some segments require the ability to rapidly or temporarily extend coverage (e.g., for exploration, to reach new facilities, and for field operations).
- **For need for control and security:** Companies across all sectors have proprietary operating data they prefer to retain within their perimeter and under their exclusive control. By controlling operation of the network, they maintain full control over critical aspects of their business operations.
- **Performance and reliability:** Private networks have 100% of their capacity dedicated to the enterprise customer's operations, providing predictability and confidence in performance. They can be configured according to the needs of the application (e.g., optimized for low latency, for maximum uplink performance, or for faster failover and fault recovery).

Mobile network technology is very capable of meeting the needs above. Public networks, however, are typically configured for mass-market broadband services. Wi-Fi, while also very capable, may not be sufficiently deterministic or able to adequately support mobility, high user densities, or coverage requirements. **Figure 1** shows that as the performance needs of applications become more demanding, the need for private networks, based on 3GPP mobile technologies, increases.

Figure 1: Mobile network technology for critical business processes



Source: Nokia

Operator contributions to private mobile networks

One of the arguments in favor of operators as lead providers of PMNs is that they already run mobile networks and have decades of experience operating them at scale. Many operators also have established business services divisions with long-term customer relationships and market presence. In principle, then, operators have assets, skills, and market reach to make useful, and in some cases unique, contributions to PMNs. These contributions are highlighted in **Figure 2**.

Figure 2: Operator contributions to private mobile networks

Asset	Contribution to private network value
Networking expertise	• Experienced in radio network design, planning, and operations • Able to maintain and upgrade networks over long lifecycles • Aware of upcoming technology/product/standards releases • Access to leading network equipment and device vendors
Spectrum	• Suitable spectrum is often controlled by licensed operators; operators can grant access to enterprise users • Licensed spectrum typically more dependable than unlicensed • Not all local/vertical licensed or unlicensed spectrum can support narrowband IoT (NB-IoT)/LTE-M; PMNs in these bands can be complemented with operators' spectrum

Asset	Contribution to private network value
Public mobile network	• Extending the public network is the first step to address coverage concerns • Interworking with public networks can be critical for certain sectors • Roaming is especially important to logistics and goods-in/ goods-out tracking • Public networks can be used to extend private networks' reach—for example, to connect utility meters (using LTE-M or NB-IoT) or to provide an extra layer of redundancy
Business services division	• Operators with business services have extensive preexisting relationships • Able to offer a wide range of associated enterprise services • Private networks likely to be part of the business services division
Market reach & influence	• Operators have national scale and reach deep into the economy • Often among the leading technology companies in national markets • Already have partnerships with device/equipment vendors and integrators

Source: Heavy Reading

Operators have not, however, always been successful in the enterprise market. At times, they have been unenthusiastic providers of on-premises managed services. To succeed in the high touch private networks market, operators will have to "think and act enterprise," commit resources to product development, and create dedicated go-to-market teams. Operators that view private networks as simply an extension of their public network will struggle to gain customer confidence.

Operators must also identify the sectors and customer types where their advantages can make the biggest contribution. For example, organizations with wide area mobility requirements in addition to the need for on-premises networks may be better prospects than those customers that require only isolated private networks. Similarly, operators with fixed line wide area connectivity services have advantages where multisite private networks are needed by the customer.

3GPP mobile technology for enterprise networks

In private mobile network terms, LTE is the technology of the moment and 5G is the technology of the near future. Both are standardized by the 3GPP and are part of a common ecosystem.

A robust supplier ecosystem has grown up around private LTE. This includes sector-specific integrators with deep knowledge of the requirements and operating models of the industries in question. It extends to specialist network equipment designed for enterprise scale, fast installation, and simple operations. Critically, these integrators now have a track record of long-term support, which is essential for many industrial users.

5G brings many new capabilities. For the first time, private networks (known in 3GPP terminology as "non-public networks") are being specified alongside public networks in the 3GPP standards process. Capabilities such as ultra-reliable low latency communication (URLLC) enable 5G to support the new wave of cyberphysical systems required to implement advanced Industry 4.0 applications. Private 5G will be deployed over the next two years but will tend to initially be used for smaller-scale pilots or "lighthouse" deployments for lead customers. It is likely to be 2023 before 5G becomes the mainstream, default deployment option for PMNs. 5G is a strategic decision for end-user organizations and will have a 10- to 20-year lifecycle.

Heavy Reading believes that, in many cases, private networks will be dual-mode 5G/LTE for an extended period. A strength of 3GPP technologies is backward and forward capability between generations. In the right circumstances, an existing LTE network can be tightly integrated with a new 5G network.

Characteristics of 3GPP mobile technologies that make LTE and 5G suitable for demanding private mobile network deployments include the following:

- **Mobility:** An undoubted strength of LTE and 5G. This includes intra-network mobility and inter-network roaming between the private and public network. LTE, and especially 5G, can support high speed mobility, which can be useful for vehicles, robots, drones, and so on.
- **Range and coverage:** LTE and 5G systems are developed with scheduled access and deployed with high specification radio hardware, both of which serve to extend the link budget considerably. As an approximate rule of thumb, one LTE small cell will cover about the same area as three Wi-Fi access points at more or less equivalent power output.
- **Spectral efficiency/capacity:** LTE and 5G are more spectrally efficient than Wi-Fi at the link level and MAC level thanks to mechanisms such as hybrid automatic repeat request (ARQ) with channel state information, more granular modulation, and adaptable coding schemes.
- **Multiservice quality of service (QoS):** 3GPP systems offer multiple layers of prioritization and can be engineered to provide low and predictable latencies for mission- and production-critical use cases.
- **Performance scaling:** LTE and 5G can scale to support applications from low power, low data rate services (e.g., NB-IoT) through to gigabit services such as 4K video and augmented reality (AR) on the same network.
- **Security:** 3GPP security frameworks are thoroughly tested and under continuous evaluation. Classic SIM-based as well as eSIM security can be used. Deployment flexibility allows for local credential management or centralized/remote credential management in roaming scenarios.

ARCHITECTURE AND DEPLOYMENT MODELS

There are many possible deployment architectures for PMNs. The decision about which to select is determined by the use case, the operating model, and spectrum preferences/ availability.

Spectrum for mobile network operator-provided private networks

Private networks need spectrum that is

- Available
- Supported by a product and integrator ecosystem
- Subject to stable regulations that allow for long-term planning

These are all important to enterprises making commitments to production-critical projects with long lifecycles. **Figure 3** summarizes four major spectrum options open to industrial companies looking to deploy private LTE/5G networks. In Heavy Reading's view, all these spectrum options are attractive, and all are likely to be used, national regulations permitting, extensively. In some cases, they will be used in combination, in the same network, as part of an integrated deployment.

Figure 3: Spectrum for Industrial IoT

Spectrum type	Description
Licensed spectrum owned by operators	• Continuation of the classic spectrum licensing model • Exclusive use is attractive to users with high availability requirements • Mechanisms to improve the subleasing of spectrum are in development
Dedicated enterprise spectrum	• Model being pursued in multiple markets for local area coverage • E.g., Germany to allocate 100MHz (3.7-3.8GHz) to industrial users; France to allocate 40MHz (2.6GHz) to industrial users • Attractive where available; however, some risk of niche ecosystems if not a "common" LTE/5G band
Unlicensed spectrum	• 5GHz is the lead band; US to open 6GHz, with Europe to follow • MulteFire LTE technology designed for 5GHz; NR-U (New Radio Unlicensed) for 5G unlicensed • Interference prone, hence less suitable in enterprise segments with public access (e.g., airports, etc.) • But large bandwidth (up to 400MHz) and ability to switch channel mean reliable operation is still possible • Can be a complement a private wireless network in a licensed band • Particularly suitable for temporary sites (construction, temporary sports and entertainment venues, tactical field operation, etc.)

Spectrum type	Description
Citizens Broadband Radio Service (CBRS) spectrum	• Unique to the US; offers lightly licensed and licensed spectrum • Strong technology and integrator ecosystem emerging for LTE; 5G to follow • Regulatory regime well-suited to private networks

Source: Heavy Reading

Operators prefer licensed spectrum and position this as a key advantage. The large majority of private LTE networks in operation today use licensed spectrum via an arrangement with a licensed operator. Enterprises, given the choice, also prefer licensed spectrum, especially where performance and reliability requirements are demanding. The licensed spectrum model works because the private network market, as it exists today, is specialist and high end. However, this model is hard to scale.

The emergence of local area enterprise licenses is a key enabler for the private network sector because it gives users the ability to act without operator permission. This increases the choice of deployment models and gives enterprises greater power when they specify solutions and negotiate with operator suppliers. This new option is injecting vitality into the ecosystem and is encouraging investment across the private network technology landscape—from silicon through to management software.

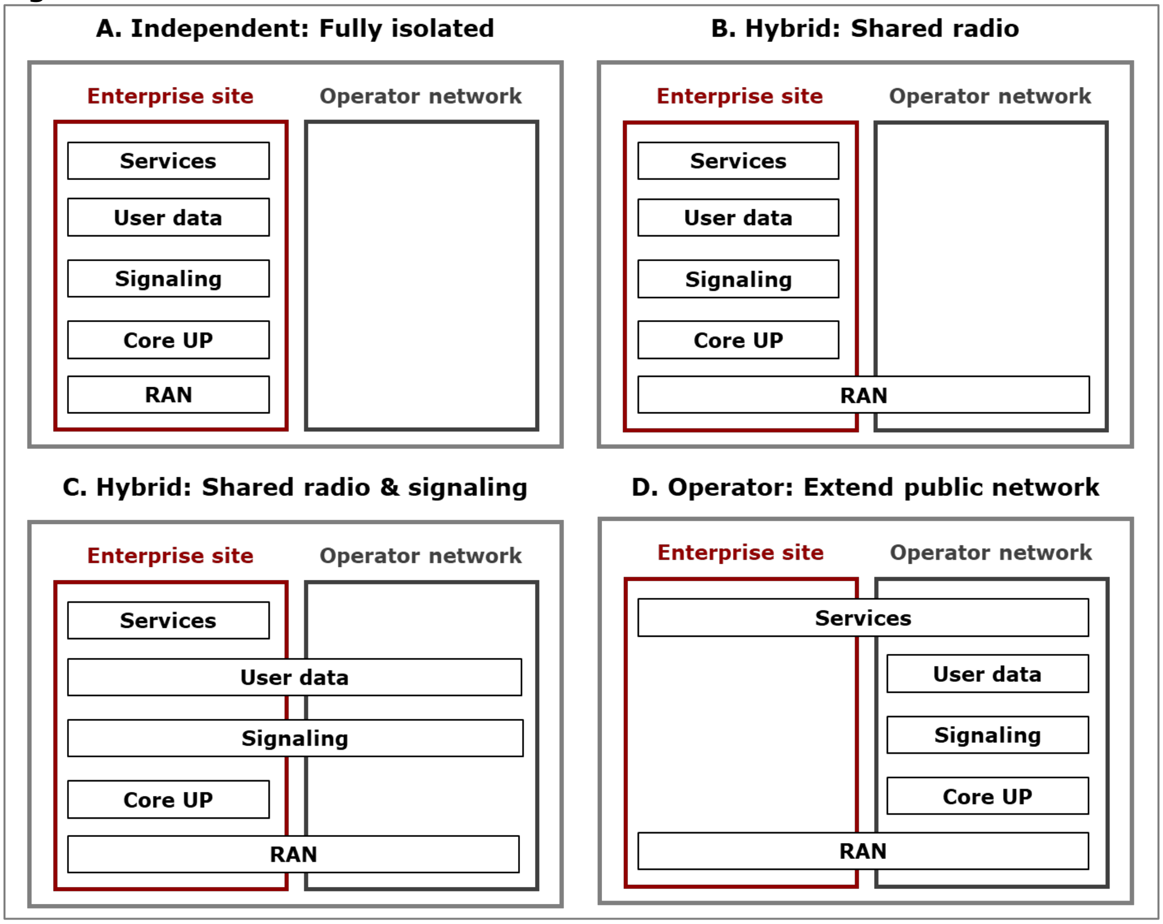
Spectrum for private networks is not an either/or decision. An interesting aspect of the market is that multiple spectrum types and bands can be used for different deployments or combined in the same solution. Operators are as free as any other party to make use of local area enterprise spectrum and unlicensed spectrum. They are also uniquely able to deploy it in combination with licensed spectrum to create competitive, integrated offers optimized according to network architecture and service type.

Operators can combine frequency-division duplexing (FDD) and time-division duplexing (TDD) spectrum to optimize performance by mapping services to the most appropriate frequency bands. For example, an LTE FDD layer may be deployed for critical voice communications and IoT devices (NB-IoT and LTE-M are not yet supported on TDD spectrum). Meanwhile, a 5G TDD layer could be deployed for high bandwidth applications such as video monitoring.

Private network architectures

There are many potential deployment architectures for PMNs. **Figure 4** below shows four options ranging from networks deployed on the enterprise site and fully isolated from the public network (Option A) through to an architecture where the public network is extended to cover the enterprise site (Option D). In between are various hybrid architectures (Options B and C). Options B, C, and D are uniquely available to licensed mobile operators. The selection of the appropriate architecture depends on performance requirements, cost, and the need for integration with the public network.

Figure 4: PMN architectures



Source: Heavy Reading

Option A. Independent: Fully isolated

This model is used in 70%+ of deployments and will likely remain the most common deployment model in the future. It is suitable where public network coverage is not available (e.g., in rural areas or remote locations such as mines or oil & gas production). It is also necessary where enterprises have a performance requirement or bespoke configuration that a public operator could not, or would not, support. This is the preferred model when enterprises want to be in full control of the network. As such, this architecture is used for higher end installations; however, it will work its way through the market tiers as spectrum options allow (e.g., via CBRS or local area enterprise spectrum). This architecture does not require integration with the public network, although there are options that enable devices to roam between private and public networks. Operators can resell or integrate such solutions and support this model by acting as managed services providers and, where appropriate, by permitting use of spectrum.

Option B. Hybrid: Shared radio

In this option, the core network, user data, and services are deployed only on the enterprise's site, isolated from the operator network. This approach retains application data onsite, which is helpful for the performance of local area applications, resiliency if the wide area network (WAN) link drops, and potentially, security. The radio access is deployed by the operator and can support both private and public users. This is useful particularly at locations where there is a mixture of private and public user types (e.g., at a business park, a campus, or a hospital). Operators are attracted to this model because it is way to play in private networks and simultaneously extend coverage of the public network. There may be concerns about how to prioritize private traffic over public traffic.

Option C. Hybrid: Shared radio & signaling

This is similar to Option B in that application data remains on-premises and is not routed to the operator network for performance and data security. Application data (user plane traffic) is separated at an edge gateway and processed on the on-premises edge cloud. In this model, however, subscriber identities and signaling are hosted in the operator's core network. This allows enterprises to benefit from operator core network capabilities such as IP Multimedia Subsystem (IMS) and voice services. It is also easier to implement roaming between private and public networks. This model is already used in LTE today with multi-access edge computing (MEC) gateways for local services. A drawback is that it requires connectivity to the operator core to be always-up; if that fails, devices can no longer register with the network.

Option D. Operator: Extend public network

Often the simplest network deployment, from the operator point of view, is to extend the existing public network to provide the required coverage (and capacity/performance) by deploying small cells onsite. Private network services are then provided using virtual private networks (VPNs) or, in the future, network slices. The main technical drawbacks include the following:

- Lesser ability to configure the network to the use case requirements
- Connectivity to the core network is a potential point of failure
- Less control of network operation and user data

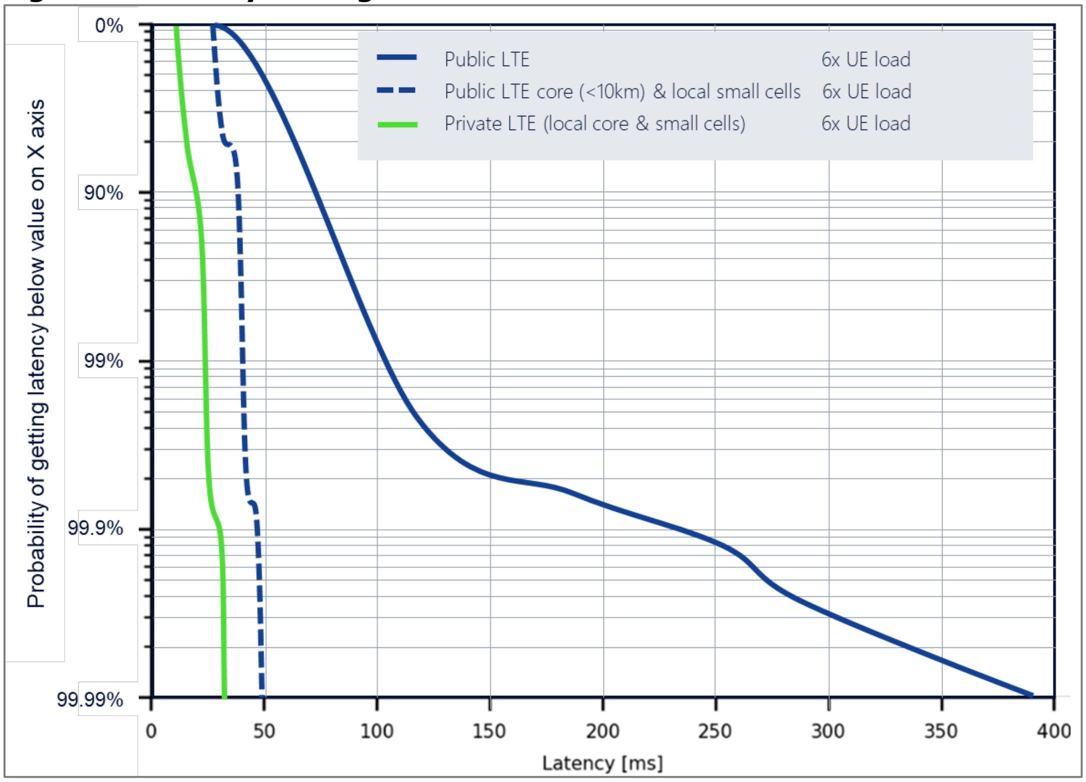
This model is most likely to be suitable for low touch locations such as branch offices or retail units where cost is the primary concern.

Importance of onsite, local area equipment

In the four architectures discussed above, equipment is physically deployed at the enterprise site. At a minimum, this includes the radio; ideally, it should include a gateway that supports breakout for local data processing. Deploying equipment at the same location as the application gives performance, security, and control advantages that a private network slice (or VPN service) on a macro network does not.

One way to look at this is in terms of latency. **Figure 5** below shows the results from testing the two-way latency of wireless connections in three different LTE network scenarios. The chart shows latency values on the x-axis plotted against the probability of achieving a latency value on the y-axis. A target of 4x9s availability of a given latency value (i.e., achievable 99.99% of the time) is appropriate for many of the applications that LTE private networks are typically designed to serve.

Figure 5: Latency testing in different LTE network scenarios



Source: Nokia

The three different LTE networks scenarios are shown as follows:

- The **solid blue line** shows the latency of a connection to device from a public outdoor cellular network using FDD. Latency is in the region of 100ms 99% of the time (i.e., with 2x9s availability); however, for the target 4x9s availability, latency would be in the range of 400ms.
- The **dashed blue line** shows an FDD small cell deployed onsite but connected to an offsite mobile operator core network. With the radio onsite, the availability of low latency improves markedly; 50ms is achievable 99.99% of the time.
- The **green line** shows a private LTE network deployed entirely onsite using a TDD small cell, but also with a local core network. In this case, there is the probability of getting 30ms performance 99.99% of the time. If this system had been using the same FDD spectrum as the blue lines, it is likely latency would be reduced by an extra 10ms to around 20ms.

The implication of this testing is that where an enterprise has production-critical processes with low latency requirements (e.g., cyberphysical processes, such as control of machinery or vehicles), then an onsite, local area deployment is the most suitable option. In other words, where performance is important, onsite deployments are better.

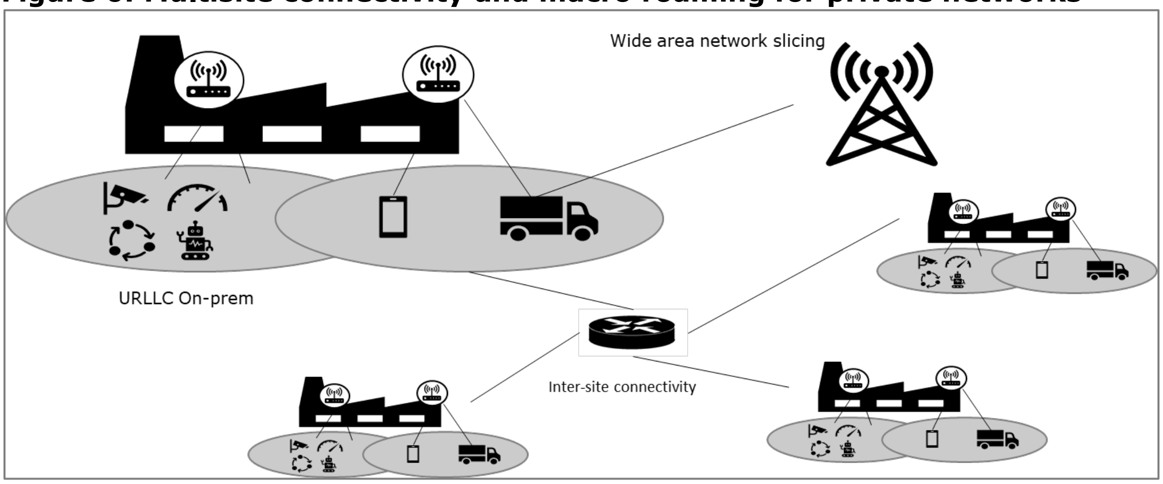
Integration with wide area public networks

Operators have two important and unique advantages linked to their WANs that can contribute to private networks:

- The ability to interwork with the wide area mobile network.
- Inter-site wireline connectivity to connect onsite networks to each other and to corporate data centers or cloud provider locations.

In almost all cases, private networks are part of a wider business process solution. Many organizations have multisite requirements and need solutions that can scale across their footprint, as shown in **Figure 6**. They move materials, goods, and equipment between locations, track vehicles and personnel, and work with external suppliers, distributors, and partners. A factory, for example, will need to receive inbound materials and track outbound shipments into the supply chain. A container port will need to support road, rail, and shipping hauliers and a distribution business will have to transport goods between automated warehouses, customers, and suppliers. In these examples, the operator can use the public network to provide an additional layer of redundancy to the onsite private network and to provide enterprise customers with nationwide reach.

Figure 6: Multisite connectivity and macro roaming for private networks



Sources: Heavy Reading, Qualcomm

Creating integrated solutions that allow devices to cross between wide area and local area private networks is undoubtedly a major systems integration task. However, it is of great value to many sectors and is an area where operators have unique assets and capabilities they can use to build a sustainable competitive advantage. Operator expertise in wide area networking comes to the fore in this scenario.

THINK ENTERPRISE, THINK PARTNERSHIPS

Operators are interested in PMNs because it is an opportunity to bridge the cyberphysical worlds and generate potentially large productivity gains for end-user companies and therefore new revenue for the operators themselves. To succeed in this market, they will need to collaborate and co-develop solutions with enterprises, OT suppliers, and sector-specific integrators.

Operators must “think and act enterprise”

Enterprises do not evaluate and purchase mobile network solutions according to the same criteria as public network operators. Rather than metrics relevant to public networks serving the consumer mass market (e.g., cost-per-gigabyte served), enterprises are focused on process outcomes to drive the business case. There are three key areas operators must address if they are to truly “think and act enterprise”:

- **Value-based pricing linked to key performance indicators and outcomes:** Value-based pricing is less familiar to the operators and vendors than the cost-based pricing models typically used in the mobile industry. This type of pricing requires deep understanding of the customer business, customization of the service offer, and risk-taking by the supplier of the private network solution. The opportunity is for the mobile network industry to share in the upside as customers are successful.
- **Create dedicated organizations:** Operators will need to set up specialist teams outside the regular enterprise sales structure to serve this market and be prepared to work through an investment phase while the market develops. Without adapting to customer needs (which are specific in each vertical segment), and without investing in customer-focused solutions, operators will cede the market to more traditional enterprise- and cloud-focused companies.
- **Customized technical solutions:** Private networks are different from public networks in many aspects. Dedicated enterprise designs are needed. Two areas that need attention are network operations (PMNs should be as easy to install and operate as Wi-Fi) and industry-specific network design templates that support production-critical use cases. For example, many enterprise use cases are more demanding on uplink than downlink (a reversal of the public network model) and many will need different, more reliable failover mechanisms.

Bringing these elements together to create integrated, end-to-end solutions is important. Operators should not expect to succeed by selling SIMs and airtime contracts or by reselling vendor equipment. There are many other organizations that can step in and take prime position if operators take a hands-off, low investment, low risk approach. Operators should focus on integrated propositions that leverage their strengths of market reach, expertise in mobile technologies, and customer relationships to create an “as a service” offer that can be adapted and enhanced through partnerships.

Tiered services: Gold, silver, bronze

To serve diverse customer types operators can use gold, silver, and bronze service tiers to differentiate offers. Service tiers expand the addressable market and can be linked to the deployment architectures discussed above to rightsize the investment by the customer:

- A **bronze** tier service would map to the "extend public network" option, perhaps with a small cell deployed on-premises. This may be suited to smaller companies or those with branch offices. For example, point-of-sale retail applications are business critical, but smaller locations often cannot justify the cost of a full onsite network. The opportunity for operators is to mirror the Wi-Fi model and simply ship small cell devices to the location for self-install and remote configuration.
- A **silver** service tier would likely use some form of hybrid deployment with radio deployed onsite to ensure coverage and performance with local data processing via a breakout gateway. Again, this would typically be configured and controlled remotely. This tier may also include public access services at the enterprise location.
- A **gold** service tier would be a fully private network, perhaps with integration to the operator network for certain users/devices that require wide area roaming. This would be appropriate for more advanced, technology-based enterprises investing in automation and process efficiency.

Meeting the requirements of the enterprise is important; however, operators should create a limited number of standardized offers that can be adapted to different industries across the tiers. Bespoke customizations for each customer engagement will compromise economies of scale and may lead to spiraling costs. It is important in the early phases of the market that operators create private mobile network architectures and processes that can be replicated and scaled.

Sector knowledge and practices

PMNs are interesting to enterprises in nearly all sectors of the economy. Operators need to identify which segments to focus on, understand how to develop specialist expertise in that sector, and partner to deliver the end-to-end solution. The key factors to consider are the following:

- **Key sectors should be identified:** Sector-specific solutions are important because different industries have common requirements, common OT suppliers, common regulations, and common customers. In countries strong in, say, manufacturing or primary industries (e.g., mining or oil production), the target sectors pick themselves. However, all decent sized economies have utilities, distributors, and so on. Identifying which ones are more likely to invest in private networks, and on what time cycle, is critical. This can be done only through close customer contact.
- **Operators should build sector practices:** Once identified, operators should build expert practices to capture requirements, inform product development, and stay close to the sector over the sales cycle. Developing and maintaining sector-specific expertise can be expensive because the practice may need to be maintained for a long period before the target sector is ready to invest. This is why identifying priority sectors, customers, and their timelines in the first step is important.

- **Partnerships are critical:** One way to spread the cost of a sector practice and gain additional expertise is through partnerships with industry specialists at consultancies, systems integrators, and OT companies. For telecom operators, which traditionally act as horizontal platforms, a close working relationship with industry specialists is essential.

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**on September 2020*