Maximising spectrum efficiency with private LTE

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Despite continuing growth in mobile network coverage, there are many areas where enterprise users suffer from no, or poor, connectivity. Manufacturing, agricultural and transport industries in these regions suffer from their remote locations, and they often find that their ability to benefit from Industry 4.0 – the automation through connected machines – is limited. This paper outlines how private LTE networks can help to overcome these issues, and the operating and regulatory frameworks needed for them to flourish.

The need for private LTE

Although regulators and governments have encouraged and obliged operators to improve mobile network coverage, this has usually been done on a 'population coverage' basis – that is, the networks have been designed to cover a certain proportion of where the population lives. Even where public mobile networks have covered rural areas, this is usually done using a low-frequency spectrum band with low bandwidth. The challenge now is not to connect people, but to connect things.

However, there is an increasing demand for high-quality connections in more remote areas, principally from industry who are looking to automate aspects of their production. These industries may have used other private mobile networks in the past, or rely on WiFi or even fibred data networks. In the absence of mobile operators covering their factories, farms and ports, firms have been forced to pay extra for a suboptimal service, which limits their ability to use the latest automation techniques. Even if mobile service is available, the quality of service may not be adequate to meet their needs.

From a mobile operator's viewpoint, the decision to not cover these premises is an easy one to make; there would be limited benefits in terms of revenues, and the costs of installing equipment would be high. However, this calculation is not the same for the factory owner – they stand to benefit greatly from the increased automation that LTE networks will allow, and the installation costs may be much lower given the limited range and locations to be installed. Therefore, a private LTE network may be financially feasible whereas a public network is not.

The feasibility of networks is further enhanced by the way they can be designed to meet specific needs for each site. The requirements of a network covering a large farm will be different to one covering a sports arena. When planning a national macro-level network, mobile operators must take account of the general demand and how devices are located and move, which means that specific needs, such as very low latency, or defined in-building use, cannot be met.

This is likely to be reinforced with 5G network evolution, where mm-wave technology may allow very high bandwidths and low latencies over small area networks. While this paper focuses on private LTE, its conclusions will remain valid for future technologies.

Network requirements

Not all applications specifically require a private LTE network. In fact, there are four types of network solution that can support industrial applications:

- The public cellular network provided by existing MNOs;
- A private LTE network customised to deliver specific applications over a closed network using dedicated licensed spectrum;
- Wireless networks that operate in a licence-exempt band but with some quality threshold; or
- Wireless networks that operate in a licence-exempt band under best-effort conditions.

Many connected industries currently rely on the third category of connections, but these have disadvantages in terms of the potential for interference and security issues. Some technologies may perform better than others; LTE-based technologies such as MuLTEfire could deliver a cellular quality performance over licence-exempt spectrum, for instance. However, the potential for interference would restrict firms from placing too much reliance on their networks and systems – again limiting the potential gains from the use of the technology.

Private LTE use cases

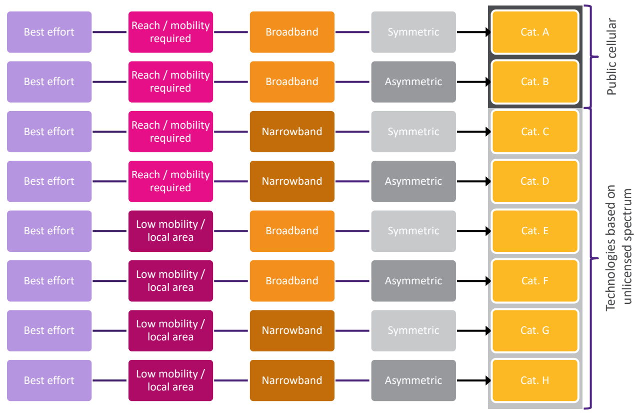
We have examined six main use cases for private LTE networks. These demonstrate the range of scenarios that these networks can accommodate – which would not be feasible for a national mobile operator.

- Indoor manufacturing – this could require a dense network (a high number of communication devices within a relatively small enclosed area). The nature of a factory could mean that while the area is contained (potentially mitigating interference effects) the radio environment could be complex because of internal partitioning and deployment of machinery.
- Outdoor processing – this may be spread out over a wide area and be sparser in terms of devices. There is more potential for interference with other spectrum users, and weather may affect network performance.
- Logistics operation – harbours and ports tend to be spread out over a wide area with busy communications. They can be dense areas for clutter and there is more potential for interference with other spectrum users. Devices may need to be tracked around the area
- Agricultural – these tend to be in remote locations, covering large land areas. The nature of these facilities means that they are usually low-density communication areas and while building clutter may be less of a problem than in some other environments, terrain and vegetation could present issues.
- Storage facility – these can vary from small-scale urban storage facilities for individuals to large-scale (rural) warehouse for storage of goods or other items
- Nomadic – video production and outside broadcast requires temporary high-bandwidth connections from one or more locations (which are possibly remote). There may also be remote production management, mixing and broadcast control facilities that require wireless support

Moving to a private LTE network which uses dedicated, licensed, spectrum is important for many users, but others may be content to continue on unlicensed bands using a best-efforts system. To consider which applications are best supported by the different types of network solution, it is necessary to characterise the applications by the properties of the network that are required to deliver them – unlike most spectrum policy questions, this must be done on a case-by-case basis rather than considering the entire ecosystem. The five key dimensions to consider are as follows.

1. Quality of service
2. Coverage level
3. Bandwidth
4. Symmetry
5. Security and privacy

Where best-efforts solutions are acceptable, there are clear cases for the use of public mobile and unlicensed spectrum.



However, the inability to guarantee service quality using these network solutions is problematic. Private LTE networks are crucial to encourage industry to invest in reliable and diverse networks.

Spectrum requirements

While the diversity of solutions offered by private LTE is a key benefit, it presents challenges in determining the spectrum needs for each network. Large-area networks, as would be required on a farm, will be best served using lower frequency spectrum such as the 800 MHz band; small-area plants such as a factory would be able to use the high bandwidths available when using bands such as 2600 MHz or above.

It is important, as well, to consider the equipment ecosystem. Designing a private LTE network based around any available spectrum is worthless if equipment does not exist that uses that spectrum. Analysis can therefore be restricted to defined licensed and licence-exempt LTE bands.

Access to spectrum

An essential requirement for delivering private LTE systems is access to suitable harmonised mobile spectrum that can support the necessary technical requirements for each application. As stated above, this includes the availability of an equipment ecosystem. With increasing global harmonisation, and more refined spectrum policies within regulators and governments, we find that more and more of the spectrum that can be used for private LTE networks is already held by mobile operators.

It is not feasible for private LTE network operators to bid for spectrum in a traditional auction. Even where auctions are held for regional licences, such as in Mexico or India, the regions are magnitudes larger than the areas required for the private LTE network. The fees required and the licencing conditions often imposed preclude industry from acquiring these spectrum bands.

Therefore, there are three main ways that spectrum may be acquired for private LTE networks.

- Regulators may choose to set aside dedicated spectrum for private LTE purposes, likely in higher frequency bands (3500 MHz or mm-wave bands). This would then be awarded on a first-come-first-served basis. For many use cases, there is unlikely to be excess demand for this spectrum given the small geographic footprints required, but for factories on industrial parks there may be some interference between sites.

- Private LTE operators may buy limited geographic rights from existing holders, where licences allow for such trading. This would give the private networks certainty over their operations, but would mean that mobile networks would not be able to use this spectrum in those regions. For mm-wave bands this is unlikely to be a deterrent, but for sub-1 GHz or even C-band spectrum this may prevent MNOs being willing to trade their rights.

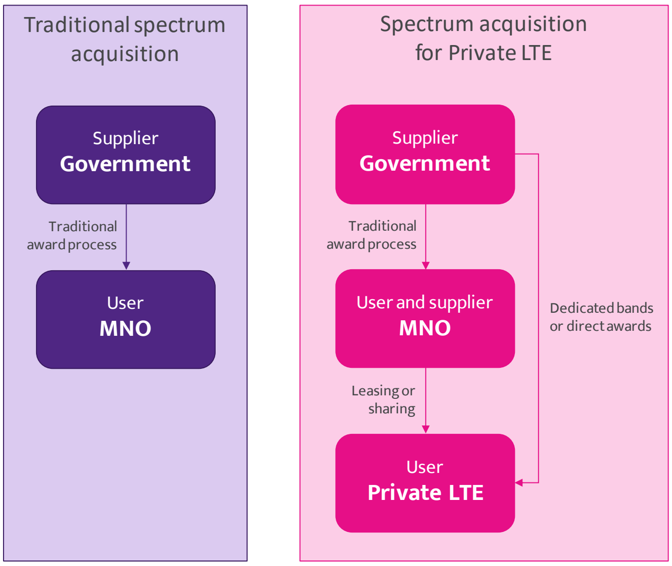
- An alternative to full trading is spectrum leasing or geographic sharing. This would mean that MNOs retain the option of using the spectrum in the future if they require additional capacity, but the private network operators would lose some certainty over their rights to use spectrum in the long term. This could be mitigated to some extent by including notice periods in any contract, or by guaranteeing capacity on the MNO network for the private operator if spectrum were reclaimed.

Recent developments around Dynamic Spectrum Access (DSA) and Licensed Shared Access (LSA) have provided more innovative possibilities for spectrum sharing. The shared use may be based on time, duration or geographic limitations and allow a higher degree of flexibility than classical sharing.

DSA typically involves the use of technologies such as geolocation databases, sensors and beacons, to determine if a particular frequency is in use at a specific location and whether transmitting at this frequency would result in interference to other users before access is granted. Examples of this approach include the use of TV white space in the UHF band and the proposed Citizen Broadband Radio Service (CBRS) in the 3.5 GHz band in the United States.

LSA is designed to allow a limited number of additional users into a band on a licensed basis. This might just be one other user in some cases. LSA is currently primarily foreseen as a mechanism to enable mobile broadband operators to access spectrum that has been harmonised in their region for mobile broadband use but where there are incumbents that are difficult to relocate. This approach is particularly useful where the incumbent is a government user such as the military or aeronautical sector. Frequency bands under consideration for LSA in some countries include the 2.3 GHz band.

The use of sharing mechanisms means that the usual chain of spectrum acquisition is different from the more traditional market.



This has significant implications on the way the spectrum is valued and paid for.

Valuing spectrum used for private LTE

Even with new developments in spectrum sharing as described above, we cannot expect mobile operators to invest additional resources into making sharing a possibility without some sort of incentive.

Although theoretically this incentive could come from the regulator – they could consider 'use it or lose it' requirements to prevent hoarding and encourage leasing – the effectiveness and enforceability of such measures have been questioned. Ofcom has argued that 'use it or lose it' provisions are unlikely to be effective at encouraging efficient use of spectrum as such conditions can be extremely difficult to monitor, not least due to the problem of identifying whether or not spectrum is actually being hoarded or used inefficiently.

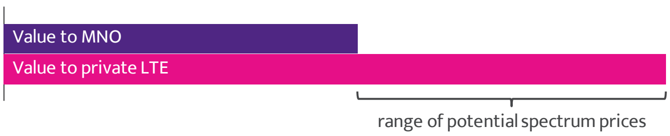
Equally, as private LTE networks will benefit their operators in some way, it is fair to expect that there should be some payment for the spectrum they use.

The key question is therefore what the appropriate fee should be – what is the value of spectrum to the private LTE operator? As with other spectrum valuation exercises, there is no single correct answer to this question, and there are a number of ways of estimating the value of the spectrum.

In its most basic definition, the value is a result of the benefits that could be generated from the use of the spectrum. For most industrial uses, there could be alternative communication networks that provide much of the same benefit, meaning the first of these areas will be key to understanding the value of the spectrum. From examination of case studies, it clear that while using private LTE can be beneficial to industry, the opportunity cost may be moderate due to the existence of these substitutes. This immediately restricts the price that private operators will be prepared to pay for spectrum.

Against this low valuation from the private networks, the value of the spectrum to MNOs is virtually zero, especially in non-congested locations. In most cases where sharing is possible, the mobile operators are not using the spectrum at all, and if there is a value it comes from an option value that would allow them to use the spectrum in the future. As discussed above, this can be allowed for in contracts. Therefore, there is a minimal opportunity cost to the mobile networks.

As long as the private LTE valuation is higher than the option value, there is a possibility for setting a price for the spectrum which would be acceptable.



If looking to maximise their profits, MNOs would want to price their spectrum at, or just under, the value to private LTE operators. However, the mobile operators will not be able to understand the actual value to the private LTE network without detailed business modelling and extensive research. Instead, MNOs should estimate their option value and administration costs, and charge fees just above this level – therefore pricing at their own opportunity cost, not at that of the private LTE operator. At this point, the MNO will be no worse off, and the private LTE operator will be better off – a Pareto improvement.

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Regulatory concerns

The low valuations we deal with here can cause their own issues, if bureaucracy and administration fees of tasks are overly burdensome. To facilitate the use of spectrum for private LTE, the administrative burden must be reduced as much as possible. This applies both to MNOs, who should formulate standard procedures for spectrum sharing and leasing, and to regulators who should ensure that MNO licenses allow for sharing with no disadvantages, and the registration or licencing procedure for private LTE networks is very light-touch.

Without support, these potentially beneficial uses of spectrum may not be realised. Governments and regulators should expand their view of the use of mobile systems to include provision of private network services – and must take account of these uses when defining spectrum licences and awards, while encouraging existing users to share spectrum.

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