FAST-TRACK CAPACITY WITH LICENSED SHARED ACCESS
Spectrum sharing opens opportunities for mobile operators to quickly unlock additional, currently underutilized, spectrum, with the Authorized/Licensed Shared Access approach showing great promise. In particular, Licensed Shared Access is a viable way to share spectrum with existing non-mobile incumbent users that exhibit low or localized utilization in their bands, and where it is undesirable to change the conditions of use within a reasonable time period.
INTRODUCTION

Spectrum is fundamental to the success of mobile wireless communications. Mobile operators have relied on the exclusive license as a key asset that provides investment certainty and helps to assure high service quality and reliability for the subscriber. Static assignments of dedicated and exclusive licenses over many years have dominated spectrum policy for mobile services, and – in light of a transition to the Networked Society that is increasingly dependent on reliable wireless connectivity anywhere and at any time – will continue to be the mainstay of the commercial wireless mobile industry.

The range of frequencies over which mobile communications networks can operate has increased significantly over time. During the past three decades, cellular systems have gained the ability to operate on frequencies of up to 5GHz and over increasing system bandwidths. This increase has been driven by an inexorable demand for spectrum that today still far exceeds that available for new exclusive licenses. The scarcity of spectrum has created a need for greater flexibility. It has led to significant interest among operators in the advancement of technology to enable the sharing of spectrum [1]. Many different approaches to spectrum sharing have been discussed, but these have generally failed to gain traction in large-scale carrier-grade mobile networks.

This paper illustrates how spectrum may be shared successfully by mobile operators – in other words, how the associated risks involved may be mitigated, and what prerequisites are necessary for spectrum to be shared effectively from both a technical and commercial point of view. Certain new developments in particular, such as the Authorized/Licensed Shared Access (ASA/LSA) approach [2], show great promise in making spectrum sharing attractive for mobile operators.

Shared spectrum may be used as a complement to dedicated licensed spectrum within commercial mobile networks to provide additional capacity. Spectrum sharing opens opportunities to quickly unlock additional, currently underutilized, spectrum for mobile broadband in cases where clearing that spectrum is not possible within reasonable time frames, or where incumbent or co-primary use does not diminish the value of that spectrum to the mobile operator. It is best suited for those parts of a mobile operator’s infrastructure that operate in higher frequency ranges.

ASA/LSA is the preferred approach to spectrum sharing for mobile broadband usage: it caters to controlled, coordinated binary use by either the operator or the incumbent; it provides predictability for investment security and QoS; and it protects the incumbent. Geo-location databases and appropriate policy control mechanisms are important technical enablers.
THE SPECTRUM SHARING CHALLENGE

The rapid adoption of smartphones and tablets and the huge increase in the capability of broadband technologies to provide wide area internet coverage have created a demand for additional radio spectrum [1][3][4]. Meeting this demand has been difficult, partly because of differences in terms of frequency assignments between various ITU regions, and partly because almost all additional spectrum that would be usable by today’s mobile broadband technologies is already designated for other diverse purposes unrelated to communications. Much of this spectrum was designated long ago based on policies that ensure exclusivity of access.

In public discourse today, one perception often shared is that increased uncoordinated spectrum sharing can solve many capacity problems. Yet, the world’s commercial broadband networks refute this largely false perception. Wide area cellular networks have enabled operators to manage shared access between millions of users, while ensuring seamless mobility and QoS. While uncoordinated sharing has created a convenient way of untethering users in local environments, it cannot enable the same level of spectrum utilization as a commercial broadband network deployed using licensed and purchased spectrum. It is essential to recognize that an efficient spectrum market benefits from a licensing policy that prices spectrum appropriately, and thereby provides the communications industry with the motivation to use the technology and innovation available to their full effect, as well as the benefits of doing so.

The mobile industry stands to benefit significantly from spectrum sharing. Expanded access to additional spectrum based on controlled licensed sharing is widely accepted as a key response to the mobile broadband capacity challenge [5]. In particular, the trend developing toward denser deployments enables use of higher frequency bands, and with that trend, spectrum sharing is made easier owing to more isolated deployments and lower transmit power, for example. The key questions in this context are: how shared spectrum should be regulated so that large-scale carrier-grade networks can successfully use it; and what technical enablers are needed in the networks in order to do so.
Regulating spectrum is not simple. There are many different aspects to it that need to be considered and weighed up together. These include the type of target deployment (wide area service, local area capacity boost), for example, as well as the predictability of the interference environment, how rights of use should be managed, whether there are societal service obligations (coverage, emergency, positioning), how incumbent users should be protected, the need for coordination and harmonization across countries and continents, and how flexible the regulations need to be to adapt to changing requirements.

This implies that there is no single approach to authorizing spectrum use. Regulators therefore need a toolbox including different authorization options so the right approach may be chosen for every given situation. For different parts of a mobile operator’s multi-RAT (radio-access technology) multilayer infrastructure, different authorization options can be used, depending on what requirements the intended network deployment is designed to fulfill.

This section describes three well-known tools: dedicated, licensed spectrum; license-exempt / unlicensed spectrum; and one new tool – LSA – for future policy (see Figure 1).

**DEDICATED, LICENSED SPECTRUM**

Mobile broadband networks are typically built using dedicated, licensed spectrum issued for 20 years or more. In most commercial cellular networks, spectrum bands are assigned to operators in dedicated blocks, often following competitive auctions. Operators are given the right to control access to spectrum in return for investing in access and transport infrastructure. Such spectrum ownership may be compared to a business entity that builds and manages a transportation network such as a railway, where the business needs to recover the cost of building and growing infrastructure to meet demand, while ensuring that access to scarce resources is controlled by charging users for those resources. The business model depends on incentives to innovate and improve telecommunications networks. A competitive market that can foster growth has been key to the generational improvement to mobile telecommunications networks.

Dedicated and licensed spectrum has therefore been a key instrument for operators and users; it enables mobility and wide-area coverage for large populations, gives dependable service quality over a wide range of system loads, and promotes investment security for large-scale deployments. Licensing policy provides an additional benefit to regulators by enabling proper valuation of scarce spectrum. Market valuation forces operators to invest in spectrum in return for ownership rights, and ensures that the regulator can place conditions on the purchase, usually in the form of coverage requirements. It is possible to conclude that more dedicated licensed spectrum will be needed in the future to ensure that the latest technology may be available to benefit the whole population. This will be made possible by enabling large up-front investments by network operators.

Licensed spectrum has the additional advantage of being identifiable and (typically) assigned to only a few license holders. Hence, it is possible to adapt regulations to changing needs and repurpose spectrum when licenses expire.

The demand for additional dedicated, licensed mobile broadband spectrum is currently being addressed by various regulatory jurisdictions, including in the preparatory work being carried out prior to the World Radiocommunication Conference 2015 (WRC-15) to ensure additional worldwide harmonized identification of IMT/mobile service spectrum.

In general, the coverage and capacity layer of an mobile broadband system is better deployed at lower frequency bands owing to the improved propagation environment. Subsequently, it is preferable as a guideline for regulators to maximize the amount of dedicated licensed spectrum at the lower frequency ranges under consideration (for example, below 2GHz), and to limit other forms of spectrum allocation for higher frequency ranges in general.
LICENSE-EXEMPT / UNLICENSED SPECTRUM

Rights of use for license-exempt / unlicensed equipment are typically based on certain specified technical conditions: for example, low maximum transmit power to handle uncoordinated interference potential.

The sharing conditions result in systems that work well for best-effort traffic, and are reliable at low system loads but less reliable at high loads. Rules for sharing sometimes follow an agreed or voluntarily assumed (by means of industry consensus or standardization) network etiquette. Contention resolution using Carrier Sense Multiple Access (CSMA) with associated Collision Avoidance (CSMA/CA) dominates accepted practice in many unlicensed standards including Wi-Fi. However, CSMA/CA performance declines in conditions of high traffic load involving many uncoordinated networks, causing throughput bottlenecks and reduced spectral efficiency. Hence, the perceived quality of an individual user depends rather more on overall system load when comparing a Wi-Fi system with commercial cellular networks.

Owing to the usual restrictions on maximum transmit power in unlicensed bands, building stand-alone contiguous coverage areas for mobility in unlicensed spectrum requires a very large number of sites. Unrestricted access to the bands also creates unpredictable interference conditions that typically lead to a decrease in accessible capacity when traffic levels are high. The result is high costs and intense operational complexity. License-exempt spectrum creates a low barrier to market entry. This has market advantages but also causes issues with controlling the numbers of users and operators, and in turn with controlling the quality of access and service. It is also difficult to repurpose license-exempt spectrum to adapt to changing regulatory needs, causing trouble in terms of long-term spectrum management.

Various grades of service are available with commercial cellular networks; service may be tailored to the particular use case. Such service provisioning would be tremendously difficult if not impossible to realize to the same extent using unlicensed spectrum. Yet, unlicensed bands have been very useful in enabling coverage extensions into private property, and have alleviated the effects of the rapid traffic increase in cellular networks by allowing offloading of cellular traffic. As mobile broadband usage becomes increasingly important to a productive society, unlicensed spectrum should rightly be viewed as a complement to dedicated, licensed spectrum. This development is already underway with the current 3GPP standardization efforts being made to ensure tighter Wi-Fi integration in mobile networks [6].

AUTHORIZED AND LICENSED SHARED ACCESS

ASA/LSA is a new approach to mobile spectrum that:

› is currently assigned to and used by an incumbent non-mobile user
› exhibits low or localized utilization
› is difficult to redistribute or repurpose to mobile/IMT within a reasonable time frame.

Typical examples are government and military spectrum subject to sparse use, either in terms of geographic coverage or temporal characteristics. Figure 2 shows an example situation in France for the 2.3-2.4GHz band (3GPP band 40) with very localized incumbent military telemetry use.

ASA/LSA assigns licenses that are similar in structure to dedicated, licensed spectrum with similar benefits to ASA/LSA licensees. An ASA/LSA spectrum usage right is binary: the spectrum is used by either the incumbent user or by the ASA/LSA licensee in any given place at any given time. The low or localized utilization by the incumbent makes it easier to characterize the rights of the incumbent, and provides scale and certainty to the ASA/LSA licensee.

A novel aspect of ASA/LSA licenses is that, in order to use the license, the licensee needs an agreement with the incumbent user, based on a sharing framework negotiated multilaterally between the parties and the regulator (see Figure 3). The

Figure 2: Example situation in France for 2.3-2.4GHz band with localized incumbent military telemetry use (usage zones are examples).
agreement outlines the terms of shared use, including the geographical areas included, technical conditions for protection, and how to vacate the spectrum if needed. Since ASA/LSA licensees are known and limited in number, the incumbent user can be certain of adequate protection. Harmonized ASA/LSA regulations will facilitate agreements with the incumbent user through well-defined processes and a standardized structure for the technical sharing conditions.

An important component of the ASA/LSA architecture is spectrum geo-location and policy databases (ASA/LSA repositories). In its simplest form, an ASA/LSA database is populated with information about incumbent usage, the technical sharing conditions, and any additional regulatory policies that may apply (in its domain of control). Based on location (and possibly other factors such as time), the database provides information on spectrum availability to the ASA/LSA licensee. Using standardized information elements, well-defined interfaces, and secure access protocols and policy mechanisms, the database ensures incumbent protection and enforcement of national regulatory policies and objectives, while minimizing restrictions to shared use by ASA/LSA licensees. Depending on national circumstances, the database may be operated by the regulator, the incumbent, or a trusted third party.

LSA is currently being developed through the European Commission’s Radio Spectrum Policy Group (RSPG), which will issue a report on LSA in November 2013 with recommendations to member countries. Ongoing work relating to the 2.3-2.4GHz band in Europe will benefit from LSA regulations (ECC FM 52). Standardization activities on LSA technical conditions and geo-location databases are ongoing at ETSI (the European Telecommunications Standards Institute), where they are being carried out by the Technical Committee on Reconfigurable Radio Systems (RRS). Shared access based on the ASA/LSA concept is being proposed for commercial use of 3.5GHz spectrum in the US.

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**Figure 3: Main LSA regulatory architecture.**
MOBILE NETWORKS

ADDING CAPACITY WITH ASA/LSA

Mobile broadband networks based on 3GPP specifications for Release 9 (dual band, dual carrier for HSPA) and Release 10 (carrier aggregation for LTE) and beyond have extensive and well integrated multi-RAT and multi-carrier functionalities. The integrated RATs include 3GPP accesses such as HSPA and LTE, and recently also Wi-Fi [6] integrated at radio network level for carrier-grade operator Wi-Fi service. The multi-carrier functionalities enable multiple standardized spectrum bands and band combinations to be used together for improved capacity and performance.

Figure 4 features a mobile network operator with licenses for three bands: two standard bands A and B and one ASA/LSA band C, which in this case has a geographic constraint on usage. The database interfaces reside within the operations and maintenance (O&M) system of the mobile network, which configures the radio network nodes accordingly. The radio network nodes use standardized procedures to manage all the configured bands on a device level. Channels for critical control signaling mobile broadband networks such as HSPA and LTE, and recently also Wi-Fi [6] integrated at radio network level for carrier-grade operator Wi-Fi service. The multi-carrier functionalities enable multiple standardized spectrum bands and band combinations to be used together for improved capacity and performance.

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Figure 5 shows examples of some standardized mechanisms and procedures for efficient band/carrier management on a device level. Reselection procedures [7] handle inter-band management for idle-mode devices, instructing a device to camp on a new band. Switching bands for connected mode devices is managed with inter-frequency handover procedures [8]. Finally, devices with carrier-aggregation capabilities (LTE R10 and beyond) can use carrier reconfiguration procedures [9][10] to include and remove an ASA/LSA band as needed.

Note that from a device perspective, the ASA/LSA band is just like any other band; regular multiband devices can be used without any additional changes (provided that radio frequency hardware for the given band is in place). Further, the fixed radio network is controlling the band usage of the mobile devices, which ensures that mobile devices do not use the ASA/LSA band when it is not permitted according to the terms of the ASA/LSA sharing conditions. This ensures the incumbent reliable protection.

The use of ASA/LSA is expected to create the means for greater global harmonization of spectrum bands. ASA/LSA is expected to be applied to bands that are dedicated to IMT use in large parts of the world, but where the same bands are allocated to other purposes in some parts. An example of this is provided by the 3.5GHz allocation in the US, which can be harmonized with 3GPP bands 42 and 43.

![Figure 4: Mobile network operator with multiple bands including an ASA/LSA band.](image-url)

![Figure 5: Procedures to manage ASA/LSA band use.](image-url)
When licensed shared (and unlicensed / license-exempt) spectrum carriers are integrated in mobile networks to enhance capacity, the system is able to use the mechanisms described above to compensate for temporary or geographical limitations on these carriers by relying on its dedicated, licensed carriers. This will create the benefits of dedicated, licensed spectrum, while embracing some of the flexibility that the other spectrum tools can provide.

SPECTRUM FOR FUTURE MOBILE NETWORKS

Dedicated, licensed spectrum for mobile broadband has so far been very successful in terms of societal benefits and spectrum use efficiency. Looking forward, the underlying success factors remain the same: it supports efficient mobility and wide-area coverage for large populations, dependable service quality at all system loads, and investment security and economies of scale for massive deployments. This means that dedicated, licensed spectrum should remain the main future spectrum management track for the mobile networks. The global average availability of such spectrum needs to increase to about 1.5-2.0GHz. Global, regional, and national efforts are already underway to secure progress toward this goal.

ASA/LSA is a viable way to share spectrum with existing non-mobile incumbent users that exhibit low or localized utilization in their bands, and where it is undesirable to change the conditions of use within a reasonable time period. Usage examples include military, radar and satellite. Even though the licensed, controlled sharing conditions will maximize the potential of shared use, there will be some geographical, time or transmit power limitations involved. These limitations have less impact on performance if the principle is applied to higher frequency bands.

The current alternatives of dedicated ownership versus unlicensed use lack mechanisms that allow ease of access to spectrum resources along with measurable and predictable interference protection in the presence of high traffic demand (such as in airports, sports stadiums and apartment complexes). The ASA/LSA concept allows for a balance between the conflicting needs of different users, where the access to spectrum is tempered by factoring in demand for resources. ASA/LSA also lowers the cost of spectrum in many such special situations, making it easier for operators, enterprises and individuals to improve service by investing in infrastructure for capacity wherever traffic demands are high. It is self-evident that ASA/LSA unlocks underutilized spectrum in a way that still allows the benefits of spectrum ownership in a robust market-oriented approach to regulatory policy.

ASA/LSA developments have momentum; such an approach regime could be considered for the 2.3-2.4GHz band in Europe and the 3.5GHz band in the US. ASA/LSA can rapidly unlock spectrum and provide complementary capacity of high quality to mobile broadband networks.

Figure 6: Spectrum complements for mobile broadband networks.
CONCLUSION

Availability of spectrum to mobile operators is a key enabler of the Networked Society. Spectrum needs to be coordinated and managed for coexistence and interference reasons, as well as to provide investment security and the ability to deliver ubiquitous coverage with a predictable level of service quality.

The prevailing method of providing dedicated licensed spectrum for mobile broadband has proven successful and will remain the main future spectrum management track. For certain parts of a future multi-RAT multiband network infrastructure, it will be complemented by ASA/LSA for mobile spectrum that cannot be released in reasonable time and where the conditions for ASA/LSA are fulfilled.

Building on already standardized mechanisms for multi-RAT, multi-carrier management, mobile broadband networks will use all spectrum resources (licensed dedicated, licensed shared and unlicensed) to provide capacity, mobility and predictable QoS in an efficient way.
## Glossary

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<tr>
<th>Abbreviation</th>
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<tr>
<td>ASA</td>
<td>Authorized Shared Access</td>
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<tr>
<td>CA</td>
<td>carrier aggregation</td>
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<tr>
<td>CA</td>
<td>Collision Avoidance</td>
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<td>CSMA</td>
<td>Carrier Sense Multiple Access</td>
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<tr>
<td>CSMA/CA</td>
<td>Carrier Sense Multiple Access with Collision Avoidance</td>
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<tr>
<td>ECC</td>
<td>Electronic Communications Committee of the European Conference of Postal and Telecommunications Administrations</td>
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<td>ETSI</td>
<td>European Telecommunications Standards Institute</td>
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<td>FM</td>
<td>frequency management</td>
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<td>IMT</td>
<td>International Mobile Telecommunications</td>
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<td>ITU</td>
<td>International Telecommunication Union</td>
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<td>LSA</td>
<td>Licensed Shared Access</td>
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<tr>
<td>O&amp;M</td>
<td>operations and maintenance</td>
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<td>RAT</td>
<td>radio-access technology</td>
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<td>RRM</td>
<td>Radio Resource Management</td>
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<td>RRS</td>
<td>Reconfigurable Radio Systems</td>
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<td>RSPG</td>
<td>Radio Spectrum Policy Group</td>
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<td>WRC</td>
<td>World Radiocommunication Conference</td>
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