# Review of efficiencies with Multi-Operator Core Network (MOCN) technology

**A Report by Plum Consulting**

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# Our Report

This Report provides an independent assessment of the efficiencies that may be associated with the deployment of Multi-Operator Core Network (MOCN) technology, as with commercial cellular radio systems.

We cannot guarantee that we have had sight of all relevant materials that may be in existence and that may be relevant to our purpose. Nevertheless, our review has included rigorous analysis of materials that we have gained access to and that we deem relevant at the time of preparation of this Report; such materials are referenced herein throughout.

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# Executive summary

## Introduction

This is the Report in our assessment of efficiencies that may result from the deployment of Multi-Operator Core Network (MOCN) in commercial cellular radio systems.

Our Report is informed by review of publically available materials, dialogue with equipment vendors and commercial operators offering MOCN based solutions, and our own experience in supporting clients in the telecommunications industry the world over.

## Study purpose and scope

Our purpose in the study has been to form an independent view on the economic potential that may be afforded with deployment of MOCN technology. Accordingly, we have undertaken a rigorous review of the technical capabilities afforded by the technology keeping in mind how it sits with alternatives.

Our study is guided by a focus towards deployments feasible in today's markets with network equipment that is generally available from network equipment vendors. As such, our Report considers the importance of flexible and efficient exploitation of the radio spectrum resource, which is essential as markets continue to evolve.

## What is MOCN technology?

- MOCN enables 'programmable' configuration of the radio communications resource across multiple commercial operators, as supported by one allocation of physical radio spectrum. With currently available equipment, such programmability is typically enabled via the network management system (NMS) which may be operated by one commercial operator in any commercial model, or jointly via a 'broker' based NMS network architecture. With current equipment releases, configuration of the radio resource is typically 'programmable' across the full network (e.g. to national or regional level), and with a level of flexibility consistent with managed usage at the NMS level.
- MOCN technology is established and commercially and economically proven; initial commercial deployments date back to 2001 (in Sweden).
- MOCN has some similarities with Multi-Operator Radio Access Network (MORAN) technology; both offer sharing of network elements across multiple commercial operators which can enable material cost efficiencies (across both investment and operational cost domains). Materiality in any such cost efficiencies will vary by specific deployment cases. However, and most importantly, MOCN also enables sharing of the physical radio spectrum resource across commercial operators, which is not possible with MORAN deployments. MOCN offers comparable levels of cost efficiency as with MORAN systems as a result of network element sharing, and a further incremental capability and efficiency as spectrum sharing. The materiality of benefits with this incremental capability may be substantial, dependent on deployment scenarios.

- Current commercial releases of MOCN equipment typically support spectrum sharing within each radio carrier and within one radio access technology type (e.g. multiple carriers with sharing on a 3G system, or multiple carriers with sharing in a 4G system). With developments towards 4.5G and 5G technologies, we expect that flexibility in spectrum sharing will increase; it may be possible in future to attain pooling of the radio resource across multiple radio access technologies.

## Key benefits available with MOCN system deployments

- MOCN can bring technical, commercial and economic benefits as a result of greater flexibilities in sharing that generally will not be afforded in other system deployments.
- 'Spectrum slicing' (i.e. flexible allocation of capacity across commercial operators, based on innovative technologies, supported by physical radio resources), as may be enabled by MOCN technology, and as is being actively considered in the development of 4.5G and 5G technologies, offers potential for substantially improved efficiency in the exploitation of the physical radio spectrum. The use of radio frequencies, as typical in today's markets, can give rise to inefficiencies in use.
- Cases that are likely to bring significant overall economic benefit are those where some imbalance exists in markets (e.g. in allocation of frequency bands, levels of capacity attainable, levels of market demand). Thus, MOCN can be seen as tool to enable competitive balance in markets in some cases, and as such is not only a mechanism for greater efficiency developed by operators, but it can also be a new important tool employed by regulators to enhance efficiency, competition and consumer benefits.

## Recommendations

- The use of MOCN technology should not be excluded via 'blanket' policies as is the case in some national jurisdictions; rather, MOCN should be considered as a viable, feasible, and proven technology that can offer significant benefits. Operators should be allowed to adopt this approach to enhance efficiencies. Regulators should also consider MOCN as a regulatory tool, just as they have in the past viewed resale, MVNO, and other approaches as remedies or safeguards on effective market operation.
- With significant ongoing growth in traffic demand in most markets, placing increasing demand on physical radio spectrum resources, technologies such as MOCN, and those under development (e.g. LWA[1], LSA[2], LAA[3], DSA[4]) will, no doubt, be actively examined by commercial operators. Regulators must also do the same to ensure economically efficient use of radio spectrum and to maximise benefits for users.

[1] LWA: LTE – WiFi Aggregation technology, under development towards 4.5G and 5G systems.

[2] LSA: Licensed Shared Access technology, under development towards 4.5G and 5G systems.

[3] LAA: Licensed Assisted Access technology, under development towards 4.5G and 5G systems.

[4] DSA: Dynamic Spectrum Access technology, under development towards 4.5G and 5G systems.

- Realisation of efficiencies and benefits possible with MOCN should not be inhibited or discouraged. In some cases this will require effective and proactive collaboration between commercial operators and governmental agencies.

# 1 Introduction

This is the Report in our review of the economic potential that may be associated with Multi-Operator Core Network (MOCN) technology, as may be deployed in the context of commercially operated cellular radio systems.

## 1.1 Purpose and scope of the study

The focus of our study has been to review the functional characteristics associated with MOCN technology, as available in current markets, as an enabler towards fully active network sharing (meaning sharing across both network and spectrum assets, over various commercial operators), to review commercial deployments across various selected country cases, and to provide independent review and comment on associated economic potential.

Principal elements in our review have included those as below.

- Background review of various forms of network sharing and inter-working, to enable clarification of any incremental economic benefits possible with MOCN systems.
- Review of the functional characteristics associated with MOCN technology.
- Country case (market) reviews and review of the regulatory stances and economic attributes relevant with MOCN deployments.
- Review of business models that may be enabled with MOCN systems.
- Overall assessment of economic potential associated with MOCN systems and comment on potential future applications and approaches.

Our scope and approach have been limited according to the following factors.

- Review of publically available materials.
- Dialogue with MOCN technology equipment vendors.
- Dialogue with commercial operators that have deployed MOCN based systems.
- Independent assessment of economic potential associated with MOCN based systems, as currently available in the market.

The primary purpose in our study has been to identify economic potential that may be associated with commercial deployment of currently available MOCN technology solutions.

The scope of our Report does not extend to quantitative assessment of commercial and economic benefits.

## 1.2 Background on network sharing and inter-working

The concept of network sharing in mobile telecommunications has been around for over a decade now[5], with initial commercial and regulatory interest driven by coverage requirements, development of

[5] Example: in 2001, Tele2 and Telia announced a joint venture company – Svenska UMTS-nät AB, to own and build a joint 3G network in Sweden.

competition in markets, or the need for reach to entirely new markets. Methods in the past have included resale and MVNO agreements (or regulatory fiats) to promote competition and economic benefits.

However, with strong growth in the demand for data services (e.g. video streaming), network and resource sharing is currently very topical in the industry, even mission critical, for infrastructure based players with urgent needs to control costs whilst continuing to innovate and meet market needs. Beyond the cost dimension, sharing of assets across multiple commercial operators can offer commercial and strategic advantage through realisation of complementary functions and synergies. For example, in a situation where one entity owns spectrum but has limited infrastructure, and a second entity has limited spectrum but established infrastructure, joint operations can yield clear benefits to both operators and consumers.

Early instances of network sharing involved so-called 'passive' measures with shared utilisation of assets such as radio sites, towers, masts, buildings and power equipment.

Collaborative operation of network resources across commercial operators has also been brought about via infrastructure inter-working which can be established through measures such as network roaming and MVNO[6] models.

Essentially, sharing refers to the situation where particular assets may be jointly deployed and used across multiple commercial operators. This is different from inter-working, i.e. interconnection across separately operated commercial infrastructures.

Until fairly recently, only limited deployment of 'active' sharing had occurred[7], where radio network equipment and potentially spectrum is shared directly across multiple commercial entities. Active multi-operator radio access network (MORAN) equipment[8], developed c. 2001, retains logical separation of different radio elements across commercial entities but enables cost savings via physical integration and sharing of equipment; MORAN systems maintain separated usage of spectrum across different operators.

At the broadest level, active network sharing may be defined as any arrangement in which multiple commercial operators share the functioning elements of a physical network.

Active sharing refers to the situation where network elements are shared and 'full' (or 'fully') active sharing describes the situation where both network elements and spectrum resource are shared, with key objectives as reduction of both capital investment and operating costs for each operator whilst meeting market needs, plus improvement in efficiency in use of resources, especially in cases where it may be difficult to attain effective returns on investments (e.g. regions with low population density, in cases where a large number of small cells must be deployed, or where it may be difficult to build capability due to limited resources). Sharing may include various forms of collaboration, including cases where capacity and spectrum may be effectively leased across operators.

The European regulatory body BEREC[9] defines spectrum sharing '*as the simultaneous usage of a specific radio frequency band in a specific geographical area by a number of independent entities,*

[6] MVNO: Mobile virtual network operator.

[7] Example: in 2007, T-Mobile (UK) Ltd and Hutchison 3G UK Ltd signed an agreement to combine their 3G radio access network build and operations under a joint venture company – Mobile Broadband Network Ltd (MBNL) to attain comprehensive coverage in the UK market.

[8] See: http://company.nokia.com/en/news/press-releases/2001/05/23/nokia-launches-multi-operator-radio-access-network-for-controlled-3g-network-sharing , accessed May 2016.

[9] BEREC: Body of European Regulators for Electronic Communications.

*leveraged through mechanisms other than traditional multiple- and random-access techniques, such as cognitive radio (use of white space). To put it simply, spectrum sharing consists in a common exploitation of frequencies among several operators: the end users of these operators can access the services of their respective MNO (Mobile Network Operator) through all the frequencies that are shared in the access network. Active infrastructure sharing can actually include spectrum sharing*'[10].

In 2012, the European Commission issued a report[11] entitled '*Promoting the shared use of radio spectrum resources in the internal market*', in which the case for increased levels of spectrum sharing was examined; the report highlighted ways in which innovations could be harnessed to enable spectrum sharing. Areas proposed for development included those as below.

- *Developing a common approach to identify beneficial opportunities to share spectrum in the internal market.*
- *Providing economic incentives and legal certainty for users to develop and deploy spectrum-sharing technologies, for example based on sharing contracts.*
- *Authorising shared spectrum access with 'guaranteed rights of use', as a tool for regulators to leverage economies of scale for wireless innovation.*
- *Monitoring and extending the harmonised licence-exempt internal market bands.*

However, within Europe and more widely, application of active sharing remains fragmented.

Active multi-operator core network (MOCN) solutions, developing commercially[12] pursuant to 3GPP Release 6 standards[13], covering GSM/EDGE, UMTS and LTE radio technologies, enable spectrum pooling – usage of a dedicated radio access technology (RAT) and radio frequency band across multiple commercial operators, with delineation of commercial operations amongst operators based on PLMN-ID code allocations[14].

The term 'MOCN' refers to the technology used, which can enable spectrum sharing. MOCN networks require the use of dedicated MOCN radio network equipment and this may require swapping out of non-MOCN equipment in legacy systems, or use of MOCN-enabled equipment in new builds.

The term 'spectrum sharing' broadly refers to the use of physical spectrum for multiple purposes across multiple commercial operators; this can be achieved via various methods and technologies. The term 'spectrum pooling' is more closely related to the use of MOCN technology; that is, physical spectrum is shared across multiple commercial operators, wherein each can be allocated some proportion of the overall quantum of spectrum, typically on a 'programmed' basis. There is some ambiguity across the terms 'spectrum pooling' and 'spectrum slicing'; however, slicing is more commonly used in association with ongoing technology research and development towards 5G systems. Slicing typically refers to the dynamic use of spectrum, and this may extend over multiple radio access technologies and networks.

During the technical set-up of communication links in cellular systems, system broadcast information is used to enable user devices to connect to the appropriate operator core network via the radio

[10] Joint BEREC/RSPG Report on infrastructure and spectrum sharing in mobile/wireless networks, 16 June 2011, http://rspg-spectrum.eu/_documents/documents/meeting/rspg25/rspg11-374_final_joint_rspg_berec_report.pdf

[11] See: https://ec.europa.eu/digital-single-market/en/promoting-shared-use-europes-radio-spectrum , accessed May 2016.

[12] See: http://crc.gov.mn/contents//raw/12/4/288/3._Operator_Infrastructure_Sharing.pdf , accessed May 2016.

[13] See: http://www.3gpp.org/specifications/releases , accessed May 2016.

[14] PLMN-ID code: public land mobile network ID codes are identifiers for separate commercial cellular networks, consisting of country code and operator code numbers.

access network (RAN). With MOCN systems, conveyance of services for commercially distinct operators essentially runs 'over the top' of the RAN radio system. MOCN sharing makes it possible for operators who lack the relevant licences, spectrum and network resources for entering certain technology markets to do so, subject to regulatory approvals; however, in such cases, operators may not necessarily maintain full control on their traffic quality and capacity – some items are not included in the standards such as quality of service and traffic management, network management and security management, meaning that careful business-technology design is required when deploying shared systems.

A deeper level of network integration is possible via gateway core network (GWCN) sharing – where core network elements may be shared in addition to the RAN. Commercial application of GWCN technology appears limited and its review is beyond our scope here.

With the potential for higher levels of cost efficiency and strategic advantage enabled via active network sharing, commercial interest continues to rise. However, the intersection of complex issues across technical, commercial and regulatory domains brings debate and challenge which must be carefully navigated. For example, in the march towards 4.5G and 5G technologies, numerous related concepts are being considered in the market such as Licence Assisted Access (LAA[15]) and LTE WiFi Aggregation (LWA[16]).

Thus, various cellular radio systems architectures and associated commercial models with and without sharing[17] have been developed in markets to date; we summarise these here as follows.

- Without sharing:
    - *'Traditional' infrastructure based mobile network operator (MNO) without sharing*: a commercial entity typically owning and operating its own network infrastructure with an owned spectrum licence for individual use; no sharing across multiple commercial operators of network equipment or spectrum resource is employed.
- Inter-working:
    - *MVNO*: an established approach in many markets, originally developed to accelerate competition, with various levels of ownership and operation, ranging from wholesale rebranding (e.g. white labelling) of infrastructure based operator services, through to separately operated core network operations typically involving BSS/OSS[18] systems (e.g. customer relationship management, CRM, systems and billing systems)[19]; no partitioning or sharing of spectrum resource exists and there is no sharing of network elements.
    - *Network roaming*: an established practice within mobile networks, where subscribers with a commercial relationship with an 'anchor' or home network operator may roam (e.g. geographically or logically, nationally or internationally) to other network

[15] LAA: use of unlicensed spectrum for cellular radio services, under development.

[16] LWA: integrated use of WiFi and cellular radio technology, under development.

[17] Whilst most network sharing agreements are voluntary, there are some cases (notably Colombia, France and the United States) where the regulator has imposed sharing to allow new entrants to enter the market and to increase coverage so that consumers may have more choice.

[18] BSS/OSS: Business and Operations Support systems.

[19] There is some similarity between MOCN and MVNO systems. MOCN solutions typically involve separate ownership and operations at the core network and BSS/OSS levels, whereas MVNO systems typically involve separate ownership and operations only at the BSS/OSS level.

operators whilst maintaining services via some commercial arrangements and potentially alternative tariffing structures; again, no sharing of network elements or spectrum resource is invoked; essentially, subscribers may ‘hop’ from one network operator and its network to another, depending on technical or business rules (e.g. quality of radio coverage, which may be measured via radio signal strength measurements with the system).

Whilst network roaming agreements enable support of subscribers across multiple commercial networks, roaming agreements have typically been established to enable coverage extension and ‘switching’ of users across networks has been designed on the basis of radio signal strength (i.e. coverage driven). Regulators have tended to view national roaming as anti-competitive, on grounds that infrastructure based competition may be diminished if networks are built out only in selected regions. In mature markets, this becomes less of an issue; once infrastructure-based competition is established across multiple operators, roaming may offer a means of utilising spare capacity. With roaming over common coverage, dual networks are required, and no major commercial advantage via equipment and site sharing can be realised.

- Passive sharing:
  - *Passive sharing*. Sharing of sites, masts and antennae is employed, but no sharing of network elements or spectrum is used.
- Active sharing:
  - *MORAN operator*: a commercial entity typically owning and operating core network and BSS/OSS infrastructure, with shared or partitioned ownership or operations[20] in the radio access part of the network; may include backhaul network sharing. Note: any sharing that does not include frequency sharing, including MORAN sharing, has the potential to require separate radio planning (as different frequency bands may be used); mobile network operators who have been allocated frequencies in higher frequency bands may need a higher number of sites, due to physical radio propagation characteristics. Therefore, commercial efficiencies are not ‘guaranteed’ with MORAN deployments. Further, MORAN based sharing may not yield optimal use of spectrum as frequency blocks have the potential to be under-utilised in some cases. With MORAN technology, no spectrum sharing is facilitated technically.
  - *MOCN operator*: a commercial entity typically owning and operating core network and BSS/OSS infrastructure, with shared or partitioned ownership or operations in the radio access part of the network and associated spectrum; may include backhaul network sharing. With MOCN sharing, participants may be forced to relinquish some level of control in management or traffic quality and systems (as technical standards may not cover these areas with sharing capabilities[21]). In MOCN systems, spectrum resource is effectively shared and may be partitioned between two or more operators (by virtue of PLMN-ID code allocations and radio system layer 2[22] control within the

[20] Commercially, this may be provided through a separate commercial entity, e.g. special purpose vehicle (SPV), or joint venture (JV), or other.

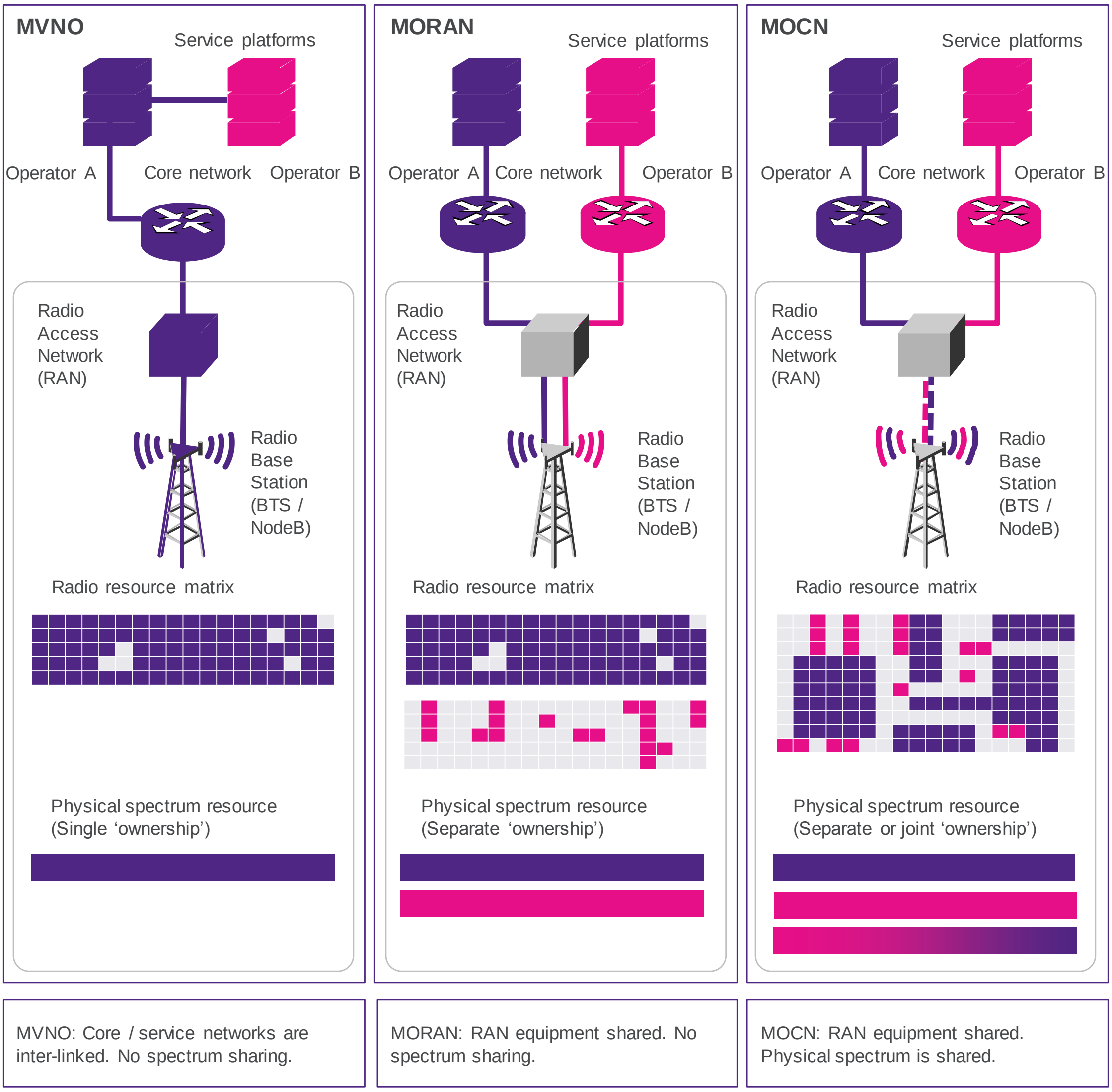
[21] Note that the number of MOCN solutions globally is limited. There are uncertainties associated with business cases and commercial operations, where for example, lack of clarity in quality and management control can lead some to be risk averse.

[22] Layer 2: a commonly used term in technical design in cellular systems, denoting a technical domain associated with radio system technical control and management.

network, with MNO selection enabled via user devices depending on user-MNO commercial contracts). Spectrum efficiency, at the system level, may be higher than with MORAN sharing, as the full allocation of spectrum across all commercial entities may be available to any one operator; in MORAN systems, if one MNO has low demand in a given allocation, the spectrum may lie 'idle' for some time. Capacity may be partitioned in MOCN systems according to commercial agreements (e.g. commercial contribution ratio, or agreed policies).

An overview of the architectural and functional characteristics across MVNO, MORAN, and MOCN systems is shown below.

**Figure 1-1: Overview of system architectures (MVNO. MORAN, MOCN)**




MOCN can be achieved by a simple commercial agreement for the sale of wholesale capacity, or via more strategic partnerships with commercial arrangements such as joint ventures (JVs) or special purpose vehicles (SPVs).

The following table (see Table 1-1) provides a summary of characteristics across alternative infrastructure models (national roaming, MVNO access, MORAN and MOCN).

**Table 1-1: Summary on selected characteristics across alternative infrastructure models**

| | Network cost efficiency | Spectrum access | Speed of rollout | Quality of service |
|---|---|---|---|---|
| **National roaming inter-working** | No active network sharing based cost advantage; requires both parties to have network infrastructure in place. | Requires both parties to hold licences (leasing deals could be negotiated). | If both parties have developed infrastructure, roaming may be established with limited incremental effort. | May offer improved coverage benefit for subscribers. |
| **MVNO inter-working** | Enables new entrants to build out services quickly, with limited investments, but MVNO players may be subject to 'high rental' costs. | MVNO players do not need spectrum, which may be 'in effect' leased from the infrastructure based 'host'. | Subject to commercial deals with 'hosts', MVNO services may be taken to market relatively quickly. | MVNO players without infrastructure will have very limited potential for service innovation and are reliant on the 'host' for quality of service. |
| **MORAN active sharing** | Active network sharing enables significant cost efficiency where joint network build out is implemented. (Legacy equipment will need to be retired). | Requires both parties to hold licences. (Two licences required for dual-MORAN network operation; spectrum 'leasing' deals could be negotiated). | May offer advantage in new joint build-out with leverage of common sites for dual network operation (subject to radio planning if alternative frequencies are used). | Without joint network operation, no service level advantage over single network case. (MORAN enables retention of full logical separation across networks). |
| **MOCN active sharing** | Active network sharing enables significant cost efficiency where joint network build out is implemented. (Legacy equipment will need to be retired). Further commercial and economic efficiencies may accrue in JV operations, where spectrum may be pooled and accessed with reduced administrative delays and challenges. Pooling of spectrum enables ' homogeneous' ('fair') access to frequency bands which may enable further economic efficiencies via radio and site planning across multiple frequency bands. | Shared network operation feasible with only one carrier (i.e. one licence) (but subject to capacity limitations). (Spectrum 'leasing' deals may be negotiated).<br><br>Carriers (with intra-carrier pooling) may be stacked across different bands. | May offer advantage in new joint build-out with leverage of common sites for dual network operation. | With a single RAN network 'opened' to multiple commercial operators, capacity allocated across the licensed carrier is pooled or shared across all operators. This may offer both technical advantage and disadvantage depending on traffic levels and sharing rules. |

*Source: Plum Consulting, 2016.*

# 2 Review of Multi-Operator Core Network (MOCN) technology

## 2.1 Technology development

As a technology enabling full active sharing, Multi-Operator Core Network (MOCN) technology was developed in 2004 via the 3GPP standards body under 3GPP's Technical Standard TS 23.251 (UMTS Release 6)[23], in recognition of the commercial importance in attaining improved cost efficiency in network deployments and operations.

MOCN technology enables multiple commercially distinct infrastructure based operators to share both radio access network equipment and radio frequency resources (i.e. spectrum) via standardised capability in a given radio network system to allocate user connections and sessions according to network codes[24] and radio resource control which allows subscribers across several commercially distinct networks to be pooled together under a single radio access network.

Prior to the development of MOCN technology, subscribers with a commercial relationship with one infrastructure based operator were able to attain service either via:

- Direct access to the infrastructure based operator's owned and operated network, wherein the subscriber has a direct commercial relationship with that same operator[25];
- Access to an alternative infrastructure based network via national[26] or international roaming (i.e. inter-working), where the subscriber's home service provider has a commercial relationship with the service provider wherein roaming is enabled[27]; or
- Access to an alternative infrastructure based network via a mobile virtual network operator (MVNO) arrangement, where the subscriber's home services provider has a commercial relationship with the service provider wherein MVNO interconnection is enabled[28].

[23] See: 'TS 23.251 Network sharing; Architecture and functional description', http://www.3gpp.org/DynaReport/23251.htm

[24] Such codes are referred to as PLMN-ID (Public Land Mobile Network Identification) codes.

[25] Note: this method of access may include the use of asset sharing via network equipment sharing with logical partitioning between distinct commercial network operations, as may be enabled via multi-operator radio access network (MORAN) based network sharing. Note that MORAN based network sharing does not enable any form of shared spectrum usage across separate commercial operators.

[26] Example, Pebble Network Limited, UK; see: https://pebblenetwork.ltd.uk/

[27] In the roaming case, depending on commercial agreements, home network subscribers may access services via a roamed (visited) network. In such a case, home subscriber services may traverse both access and core networks of a partner visited network. Services consumed will typically be billed to the subscriber via its home service provider, with call detail billing records (CDRs) passed back from the visited network to the home network. The home network will typically settle charges for its subscribers' usage of the visited network via wholesale charges derived from the CDR information, which may include the use of a clearing house operator. Home network subscribers may be billed by the home network service provider on the basis of the visited network CDRs, which may include re-rating or commercial mark-ups, according to the home network service provider's commercial roaming tariff policies. In this scenario, subscribers are able to use the resources of more than one network (i.e. with or without roaming); switching between service providers may be based on levels of coverage; essentially, subscribers are able to 'hop' across two 'traditional' radio networks, in the sense that each operator has distinct ownership on network infrastructure and spectrum resource. Roaming is not typically seen as network sharing in that the concept of two distinct physical networks remains; spectrum is only conceptually 'pooled', although separate spectrum licences are retained.

[28] In the MVNO case, depending on commercial arrangements and the extent of infrastructure operated by the 'virtual' operator party, 'virtual' network subscribers may access services via network infrastructure largely provided by a 'host' infrastructure based network operator. Typically, the 'host' operator will own and operate radio access and core network systems, and the

Whilst roaming and MVNO situations are not typically considered as network or spectrum sharing situations, there are some similarities with MOCN technology in that network resources across multiple operators are combined, although modes of combination are different in each case.

To enable understanding of potential commercial and economic benefits enabled with MOCN, it is important to understand technical operations of MOCN in some detail as below.

Since network asset sharing (though not spectrum sharing) is enabled with MORAN equipment, it is also important to understand what spectrum sharing means, in the context as enabled by MOCN capable equipment.

## 2.2 Functional characteristics

In a 'traditional' network architecture (i.e. without full active sharing), user terminals (or user equipments - UEs) are authenticated for network and service access to a commercially relevant network operator via a 'handshaking' procedure which entails the broadcasting of and response to particular system codes, referred to as PLMN-ID codes. Such codes include information uniquely identifying the relevant commercial operator and the country in which the UE is attempting network access. During this network log-on procedure, the UE 'scans' for available PLMN[29] networks at its location; it then refers to a list of allowable PLMN commercial operators, held in its SIM[30] or user account profile information. The UE then attempts to register itself with an allowable and available network, with priority which may be based on defined business rules.

In the case where the radio access network and UEs support the MOCN technology standard, a single radio system is designed to support propagation and recognition of PLMN-ID codes across different commercial operators. The system architecture is designed with a single physical radio access network (shared across multiple commercial operators), connected to multiple core network systems, each operated by a different commercial operator. This configuration allows UEs allocated to different commercial operators to co-exist with radio services provided by a single radio network; services at the core network and BSS/OSS levels (e.g. subscriber billing, mobility management) are provided and managed by each commercial operator, just as they would be in a network system without active sharing.

In the 'traditional' network case, UEs within a given radio system area (e.g. radio sector or cell) are allocated bandwidth over a given time slot according to a 'scheduler' algorithm that operates at the

'virtual' operator may operate subscriber billing systems. (In some cases, the 'virtual' operator may not operate any infrastructure, and may be entirely reliant on the 'host' for provision of all services to its subscribers, effectively 'white labelling' its services on the basis of a wholesale agreement with the 'host'). Billing for services may be accounted for based on the passage of CDR records from the 'host' operator to the 'virtual' party, wherein invoices from the 'virtual' party may be issued to its subscribers which may be identified according to CDR information. If the 'virtual' operator is fully 'white label' based, the 'host' may operate all of the 'virtual' operator's billing and invoicing and issue bills to subscribers on its behalf. In this scenario, only one access and core network system is used; the 'virtual' operator's subscribers are 'tagged' in the system according to their unique user billing information (e.g. phone numbers) via CDRs. There is no direct sharing of access network in this scenario and MVNO based operations are not typically referred to as shared networks. The 'host' network operator is at liberty to accept or deny as many 'virtual' network subscribers as it sees fit according to commercial conditions and any regulatory requirements. Spectrum is conceptually 'pooled', although only the 'host' provider operates the radio spectrum resource; the mix of 'host' and 'virtual' subscribers on one network is defined according to subscriber unique identifiers and CDR information.

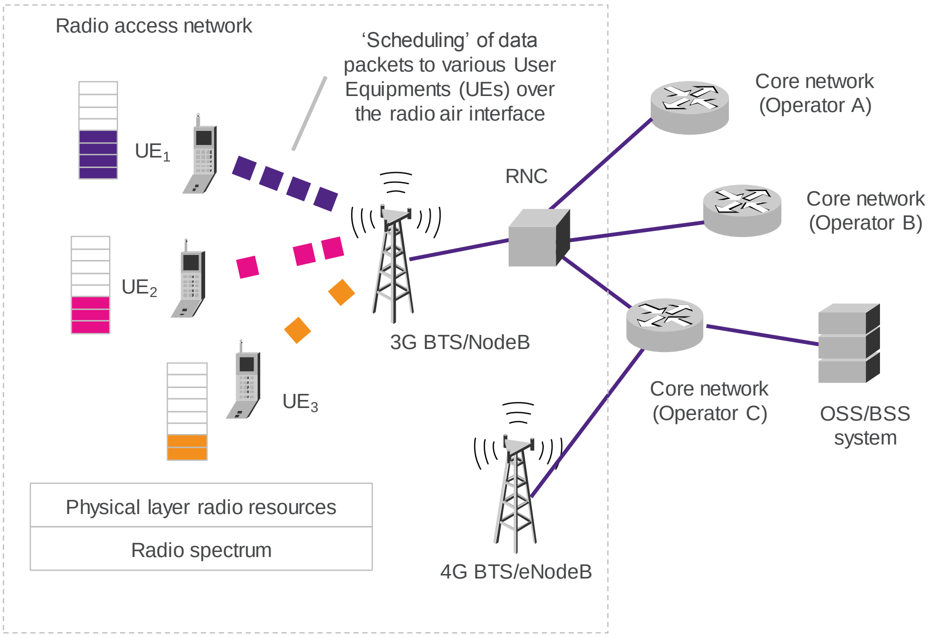
[29] PLMN: Public Land Mobile Network.

[30] SIM: Subscriber Identity Module.

‘layer 2’ level in the radio system[31] (see Figure 2-1). The scheduler is a critical technical element in a radio access system; it allocates physical layer radio resources[32] across the field of subscribers, according to technical and/or business rules, ensuring that all users in a system are able to access services to a required level of quality.

Whilst scheduler algorithms are typically proprietary (not subject to technical standardisation), many equipment vendors implement the so-called ‘proportional-fair’ (PF) method, which allocates bursts of data to users according to measured data rates for users across a given area; essentially, with this method, no one user is ‘allowed to be starved’ of data throughput and users attain similar average data throughput levels. Whilst the PF scheduling method is designed to allocate radio bandwidth with a degree of ‘fairness’ across all users, it is by no means a ‘perfect’ solution. Other methods for scheduling include the ‘opportunistic’ approach, where bandwidth is allocated to users under ‘best’ radio conditions (e.g. with low levels of interference) which can offer improved efficiency in use of spectrum, and methods which allocate bandwidth resource according to specific technical and/or business rules (e.g. ‘urgent’ access, for users requiring access to services with low latency needs such as video stream calling).

**Figure 2-1: Scheduling of data ‘packets’ to multiple users in a cellular radio system**




*Source: Plum Consulting, 2016.*

In a MOCN system, data packets can be scheduled not only across multiple users, but across multiple users over different commercial operators. This enables the radio resource to be used with improved flexibility. With full sharing, the radio access network becomes a pooled resource with programmable access; system resources can be managed across all commercial entities party to the shared system.

[31] Radio technologies are designed and defined according to various ‘layers’. At the ‘physical’ layer (layer 1), radio spectrum is used in accordance with radio modulation and coding schemes for conveyance of data streams over radio. Higher layers (e.g. layer 2) are used for control of data streams and provide important radio resource management in the system.

[32] In cellular radio systems, data is conveyed over a physical radio spectrum resource using a method which essentially consists of a grid of time slots and frequency bandwidth slots. The spectrum resource supports the conveyance of data via the radio equipment (collectively, the radio resource).

## 2.3 Equipment vendor support

Many vendors now support the MOCN standard across multiple cellular technologies (e.g. 2G, 3G, 4G) and spectrum bands[33]. Current commercial systems and standards typically support radio resource pooling across the RAN for up to 6 commercial operators across one radio carrier (e.g. LTE, up to 20 MHz per carrier); more than 6 commercial operators can be supported with MOCN technology over multiple carriers[34].

Further, with MOCN based systems, many vendors support varied use of the radio resource, with either full access to the shared resource for all commercial operators being possible (with scheduling, as above, across the full radio resource), or partitioned use – where blocks of capacity may be predefined for each commercial operator. In addition, hybrid schemes may be established as a mix of these two schemes.

Such resource partitioning is typically configurable across the whole RAN.

MOCN technology essentially enables programmable use of the radio resource, whether this is owned commercially by one or more operators; programmability is typically defined at the network management system (NMS) level in the network. This flexible and programmable exploitation of radio resources is referred to by many as ‘spectrum slicing’ (not to be confused to the concept of ‘network slicing’ which is being considered as an important technology in the development of 5G cellular systems, enabling flexible network configurations, according to varied use cases and business models, enabled with network function virtualisation (NFV) technology in the network).

With modern cellular radio systems exploiting the radio resource as a grid (matrix) across both time slots and frequency bandwidth, programmability enables flexible use of resource matrices, inclusive of resource scheduling, across multiple commercial operators (see Figure 2-2).

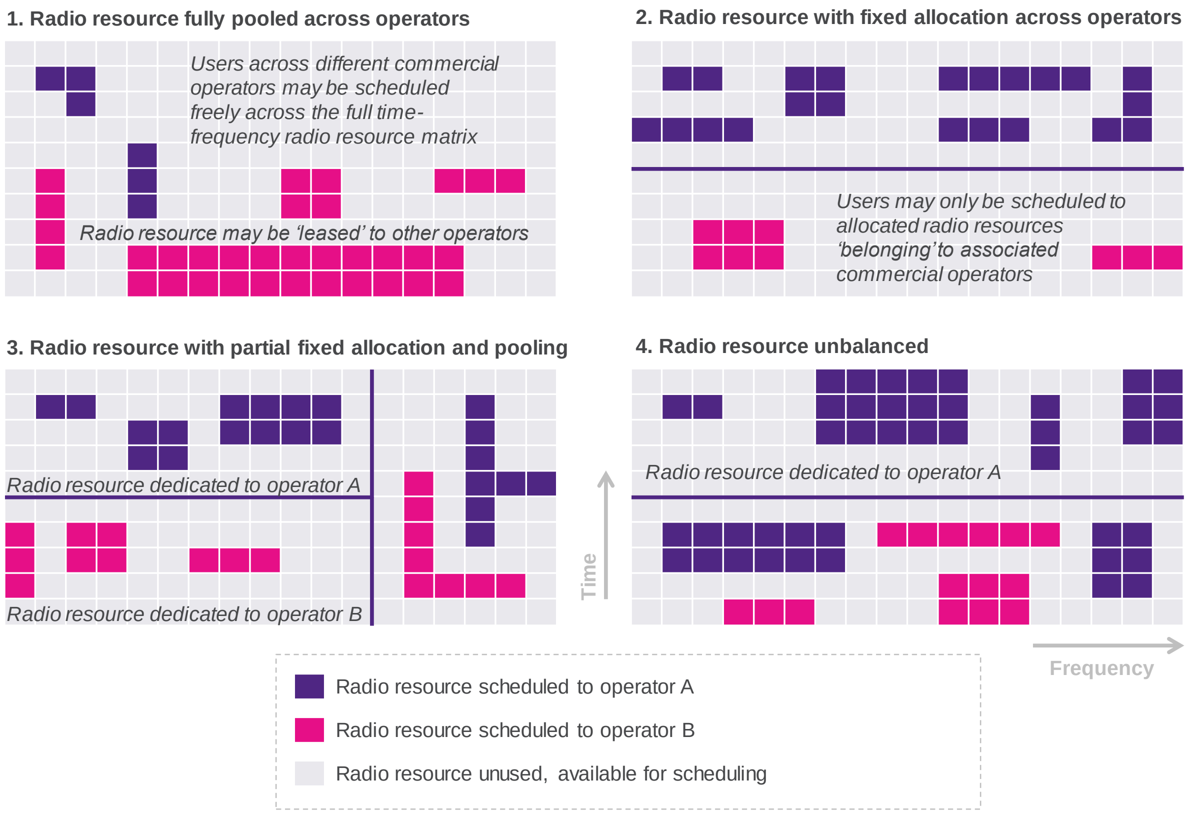
Full sharing is feasible within a given radio access network system and product-technology generation (e.g. 3G, 4G) with deployment of MOCN compliant radio network elements[35].

[33] We were advised by Huawei Technologies Co. Ltd. that the company supports MOCN technology across its 2G, 3G, and 4G products.

[34] E.g. Yota, Russia. See: http://www.yota.ru/

[35] Spectrum slicing is not feasible across different radio access technologies or carriers with current commercial systems (though this is being actively researched within the industry).

Figure 2-2: Flexible allocation of radio resource, various configurations, enabled via MOCN technology




*Source: Plum Consulting, 2016.*

## 2.4 Service quality issues

Where MOCN systems are deployed, radio resource allocation and service quality measures are defined via the collective NMS system. In a shared network configuration, network management systems may be operated in various configurations (e.g. as separate NMS systems, via a 'broker' NMS, or with one party operating a single NMS).

Since the management of parameters essential to the quality of the commercial services deployed is dependent upon the network management system and various element managers, the configuration of the overall NMS solution in a shared network can have bearing on the level of control that commercial operators are able to exercise.

The level of control afforded essentially depends on commercial models that may be developed (e.g. agreements on levels of access to NMS systems for MOCN 'programming').

Consequently, with MOCN based shared systems, the design of both shared architectures and commercial partnership deals is critical in ensuring that commercial parties attain levels of commercial and service control consistent with business requirements.

# 3 Potential benefits

We identify here key benefits that may be attainable with full sharing in radio networks via the use of MOCN compliant technology (depending on conditions of deployment).

## 3.1 Improved spectrum utilisation

With pooling of spectrum and radio resources across commercial operators, MOCN based systems offer incremental benefits (over MORAN based systems), bringing the potential for improved commercial and economic efficiencies as a result of enabling greater flexibility in allocation of spectrum resources across commercial entities. MOCN based pooling enables multiple commercial entities to simultaneously access one physical quantum of spectrum resource; this can prevent imbalance in allocation of spectrum resources across different bands to different market participants.

As cellular markets continue to develop, the availability of spectrum to meet market demand will become an increasing challenge. For example, with a typical growth in cellular data traffic at 50% CAGR (year on year), over the period 2016 to 2020, demanded traffic levels may grow by around a factor of five. Despite innovations across the industry and from equipment vendors to deliver higher levels of technical (spectrum) efficiency towards 5G systems, such innovations may not meet demand at acceptable price points, i.e. significant growth in traffic demand may require denser and more costly network infrastructure and greater allocations in spectrum.

A more flexible approach in the allocation and usage of spectrum may be required to support acceptable levels of competition. For example, in cases where spectrum resources are held across multiple commercial entities, pooling may enable effective joint operations, supporting market competition across a higher number of commercial operators than without.

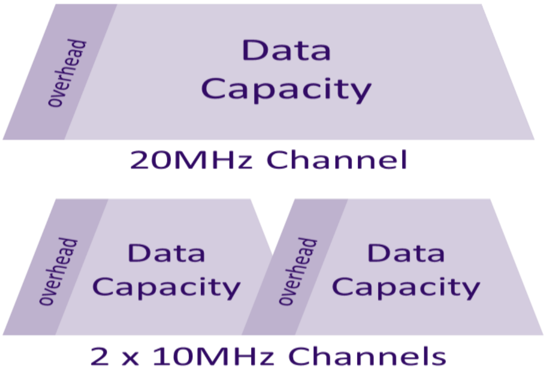
MOCN facilitates flexible spectrum pooling, meaning that radio resources across multiple commercial operators can be jointly used, according to business rules defined by operators via the NMS. Current commercially available products supporting the MOCN 3GPP technology standard enable radio resource pooling across a single radio carrier.

Referring further to Figure 2-2, it can be seen that in a shared network configuration, MOCN technology enables division or pooling of the radio resource, which may also include different methods of scheduling (e.g. via alternative business rules), according to commercial need.

In networks without full sharing, spectrum resources are necessarily tied to commercial operators via the established process of commercial auctions and band allocations. Whilst trading of licensed spectrum may be possible (subject to regulatory approval), operators may wish to utilise larger carriers by pooling, rather than dividing, spectrum bands.

The provision of high capacity data services on 4G and 5G networks requires large spectrum blocks. Larger spectrum blocks are proportionately more spectrally efficient than smaller spectrum blocks. For example, 20 MHz of spectrum provides more than 2 times the amount of capacity of 10 MHz of spectrum. There are three reasons for this: block edge mask is increased, signalling losses are incurred, and queueing inefficiency lowers the effective data carrying capacity of smaller channels compared to wider channels. Taken together, the overall data capacity of a single 20 MHz channel versus two 10 MHz channels can be up to 25% more. This is illustrated in the diagram below.

**Figure 3-1: Comparison on spectrum efficiency (overhead driven) across different size spectrum blocks**




Spectral efficiency is clearly of paramount importance commercially, with significant investments typically required to acquire licences[36].

Spectral efficiency may be examined in various ways and is seen as a key parameter in the design of new technologies and systems which may consume some level of spectrum resource, typically measured in bandwidth (Hertz), offering levels of data throughput typically measured in bits per second (Bps), against some costs associated with systems investment and operations.

A commercially tractable approach to the measurement of spectrum efficiency includes any such costs, with a useful metric as Bps per Hz per dollar (Bps/Hz/$). A detailed explanation of the intricacies of spectrum efficiency analysis is beyond our scope here; however, it is important to note that spectral efficiency, in the commercial assessment of cellular radio systems, is typically measured at a 'system level' (i.e. the full spectrum resource required for a given system is considered against the overall data throughput that may be attained for all customers supported on the network, and the cost required to deploy and sustain the system)[37]. Methods for improving spectral efficiency are not only of commercial interest to individual communications operators, but can contribute economic benefit to whole markets if a higher volume of services and service innovation are enabled for consumers.

Spectral efficiency can also be enhanced via pooling, as radio signalling (overhead) information is also effectively pooled across operators.

In a network with full sharing, radio resources across one or more commercial entities can be pooled and considered as a common radio resource. We consider below two scenarios:

[36] In the UK 3G spectrum auctions in the year 2000, the UK government raised c. £22.5bn from an auction of five licences for radio spectrum to support the then emerging 3G cellular systems. Bidders felt compelled to remain in the auction, driving up prices, on grounds that if they were to lose, they would be excluded from the industry for some years. Similar high levels were seen in the German auctions. With high risk and increasing debt levels, the stock market lost confidence, driving down the value of assets based on share price. With debt to asset ratios degraded, credit ratings suffered and the spiral with higher costs of capital contributed, many believe, to the 'crash' of the telecoms industry in the post-2000 era.

[37] Spectral efficiency varies across technologies; as new technologies are brought to market, new innovations can improve spectral efficiency, towards the point of physical bounds. Technologies that can improve spectral efficiency include higher order modulation schemes, and multiple input multiple output (MIMO) antenna systems. Absolute levels of spectral efficiency can vary instantaneously, with dynamically varying levels of electromagnetic noise in given systems.

i. ‘Traditional’ scenario (without spectrum pooling)[38]. Two infrastructure based cellular network operators; each operator has invested to acquire a spectrum licence with 2 x 10 MHz bands with indefeasible rights of use for a unique band of spectrum for a given term (e.g. 20 years).

ii. Fully shared scenario (with spectrum pooling, enabled via use of MOCN compliant radio access network equipment). Two infrastructure based cellular network operators; both operators have jointly invested to acquire a single spectrum licence with 2 x 20 MHz bands with indefeasible rights of use for a unique band of spectrum for a given term (e.g. 20 years), and have further negotiated with the regulator that rights of use in the licence shall be extended equitably across both operators. In regions where pooling is required, both operators have gone through a programme to replace legacy non-MOCN equipment with MOCN compliant network elements.

In the ‘traditional’ cellular situation, without full sharing, all commercial infrastructure based operators typically invest in both network equipment and ownership of physical spectrum. This means that individual operators (or any associated MVNO players) have access only to that limited spectrum to which they have licensed allowable access. In situations where spectrum resources across multiple operators are highly utilised, capacity across all market players may be limited and there would be no significant benefit for one operator in seeking additional radio resource within any given frequency band region. However, in ‘unbalanced’ situations where some blocks of spectrum may be more highly utilised than others, there may be benefit in spectrum pooling (see Figure 3-2).

The two scenarios illustrated in Figure 3-2 show that pooling can yield improved efficiency in the use of radio resources[39] (and hence physical spectrum) under certain conditions. With equivalent traffic loading situations across both scenarios, where traffic loads are unbalanced across both commercial operators, there is improved efficiency gained in the pooled scenario (ii); in scenario (i), a small increment in the traffic loading for operator A will tip the network into overload; users would experience consequent blocking of traffic and a reduction in perceived quality of service. In scenario (ii), the same increment in traffic for operator A will not result in blocking, since ‘spare’ capacity can be drawn from the underused resources in the pooled resource block. In scenario (i), these would be left ‘idle’ and in effect operator B would be wasting part of its investment in the spectrum licence over the term of any underusage (which could fluctuate rapidly or more slowly).

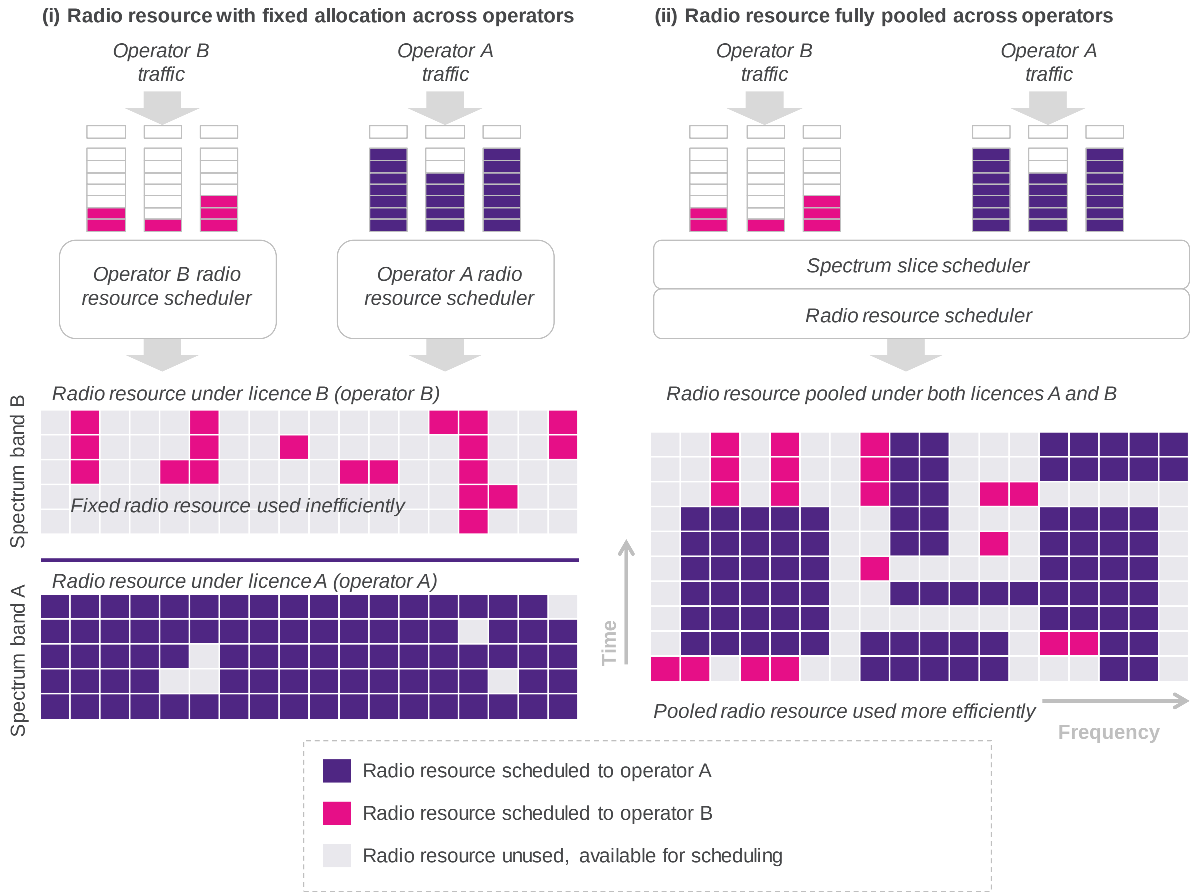
Thus, MOCN technology offers the potential for dynamic, flexible and ‘programmable’ use of the radio resource, which can offer spectrum efficiency improvements (depending on traffic loading conditions) and alternative commercial models (e.g. joint use of a common spectrum resource).

In practice, with current commercial MOCN systems and commercial models, the ‘rate’ of programmability in the radio resource is likely to be limited according to operational factors and technical factors associated with the NMS. Regulatory factors will also be key. In commercial deployments with MOCN technology, radio resource partitioning is typically set in alignment with commercial terms (e.g. 50:50 radio resource partitioning across commercial operators, aligned with 50:50 equity investments in a joint venture commercial deal).

[38] Note: A scenario with fixed allocation may also be ‘configured’ in a fully shared system via spectrum slicing (see Figure 2-2) (subject to regulatory approvals).

[39] We refer to radio resources meaning the available capacity enabled by various network technologies to support the conveyance of data services. In cellular systems, radio resources are supported by the availability of licensed spectrum bands.

Figure 3-2: Illustration of radio resource usage across two scenarios: (i) 'traditional' situation without full sharing, and (ii) 'pooled' situation with full sharing




*Source: Plum Consulting, 2016.*

For illustration on potential benefits, we consider the following example cases.

- Two separate commercial operators own separate national licences; operator A owns a licence allowing a 4G downlink at 20 MHz bandwidth centred on a carrier frequency at 1 GHz; operator B owns a licence also allowing a 4G downlink at 20 MHz, though centred on a carrier frequency at 4 GHz. Operator A is reaching full capacity on its existing 4G network in dense urban (city) regions. Operator B is newer to market, having fewer subscribers than operator A, and operator B faces a challenge to build out a national system with radio spectrum that will require denser radio network infrastructure by virtue of the higher carrier frequency (4 GHz) at which it is licensed to operate. Therefore, a competitive imbalance exists in the market in that the two operators are faced with different cost structures in their businesses to (in effect) seek to operate similar businesses (although such imbalance may have been addressed to some extent in the different costs associated with the licences). With capacity problems in its city networks, operator A could build out more sites as a single operator or acquire a new spectrum licence, at some cost and cash flow impact, also with time to market delays. Alternatively, it could do a deal with operator B to access some of operator B's spectrum in city regions in return for allowing operator B to access some of A's spectrum in rural areas, essentially cross-licensing spectrum, improving cash flow for the accounting period at a 'cost' of reducing A's capacity capability in rural areas, but this does not pose a problem for operator

A as its national licence offers more capacity than it needs for its rural operations. The deal may require regulatory and anti-competitive authority approvals, but offers both operators, A and B, commercial benefits. Economic benefits are gained as competition is increased in both city and rural areas. Cross-licensing for joint operations on the same radio carriers would not be possible with MORAN technology.

- Two operators C and D are under regulatory pressure to meet a universal service obligation (USO) ruling, calling for both operators to provide mobile radio services at a given minimum data rate to users, incrementally, to rural areas. Failure to meet the obligation will result in significant fines, damaging cash flow for both operators. The situation represents an instance of market failure, as both operators have considered build-out in the affected areas, but the investment cases are poor (at a regional level). Operator D has a national licence to operate 4G services at 4 GHz, whereas operator C has a national licence to operate 4G services at 700 MHz. Radio coverage per site will be much better with a carrier at 700 MHz frequency and therefore, operator C is in a much better situation to meet the USO (whilst both investment cases are poor, C's is less poor than D's). Subject to regulatory approval, operator D decides to strike a deal with operator C to deploy a MOCN RAN system across the rural areas, with radio carriers only deployed in the 700 MHz band. The MOCN system allows both operators to meet the USO with manageable levels of jointly developed investment and operational cost. Operator D is granted access to the MOCN deal by C, in return for a commercial agreement (e.g. shared access to advertising facilities) with C which may be less immediately impacting to D's cash flows. Both operators are able to derive commercial benefits and economic benefits accrue to rural users who are able to access mobile data services with competitive service choice across two operators. Again, joint operations on the same radio carriers would not be possible with MORAN technology.

## 3.2 Improved cost efficiency

MOCN facilitates active sharing of network elements in the radio access network, meaning that cellular base stations and sites[40] can be implemented and operated jointly across multiple commercial operators (subject to radio planning). Such active sharing requires installation of active sharing compliant equipment and may yield significant savings in both investment and operational costs, which may be attractive in radio areas or deployments which offer weak returns on investment (e.g. rural or low traffic demand areas, or dense networks requiring many small cells).

Active sharing of network elements in the radio access network may include the use of shared backhaul facilities which may yield additional cost savings through either economies of scale in leasing of circuits or in network build-out. (Sharing of radio network elements and sites is also attainable with multi-operator radio access network (MORAN) technology).

[40] Other radio elements may also be shared (e.g. 3G Radio Node Controllers, RNCs). The level of sharing attainable will depend upon specific commercial conditions, for example, in many cases, multiple operators may choose to operate combinations on shared and non-shared networks.

Whilst MVNO models enable support of subscribers from multiple retail providers on a single infrastructure-based network, MVNO operators can struggle to secure commercially attractive wholesale pricing rates and levels of access and control of network functions (e.g. quality of billing and customer operations services, ability to innovate in new services, ability to monitor quality and fault levels).

Active sharing in the RAN (as may be enabled with both MORAN or MOCN compliant equipment) provides a means for cost efficient build-out and operation of a part of the network which typically accounts for a high proportion of overall network related costs, whilst enabling commercial operators to retain control over important network functions that enable service control and innovation.

Fully active sharing in the RAN (as may be enabled with MOCN compliant equipment) provides the incremental capability[41] in pooling of radio resources over a given quantum[42] of spectrum which can enable more efficient use of such spectrum in cases of unbalanced loading across separate commercial operators.

## 3.3 Potential for new business models

Full active sharing may enable various new innovative business models[43]. Feasibility of such models, both technically and commercially will require investigation on case by case bases.

MOCN compliant systems may also enable new innovative business models such as on-demand leasing of capacity, RAN capacity wholesaling, and dedicated capacity reservations for third party services providers.

Further, in cases where different commercial operators own various network and radio resources, fully active sharing can provide a basis for the development of commercial operations for both operators with mutual advantage. In the case of two commercial operators A and B, A owning a spectrum licence and core network facilities though with no radio access network facilities, B having no spectrum licence though with established RAN facilities (see Figure 3-3), MOCN based fully active network sharing enables combination of complementary assets to enable business operations. In this case, subject to regulatory approval, UEs across both operators are scheduled, with carrier sharing, over spectrum owned by Operator A. The essential point here is that, with fully active sharing, UEs across both operators, can be supported technically on one radio carrier.

If MORAN technology were considered, per the same case scenario above, two radio carriers would be required, which could be both technically and commercially inefficient (depending on traffic loading conditions). However, with appropriate regulatory approvals on spectrum usage, it would still be feasible to develop a commercial scenario with complementary asset ownership (e.g. Operator A acquires a licence for two radio carriers and has established core network facilities, and gains regulatory approval for one of the carriers to be used by Operator B; Operators A and B negotiate commercial terms to build out MORAN equipment with shared costs; Operators A and B then operate their logically separate networks, serving UEs across a common coverage area).

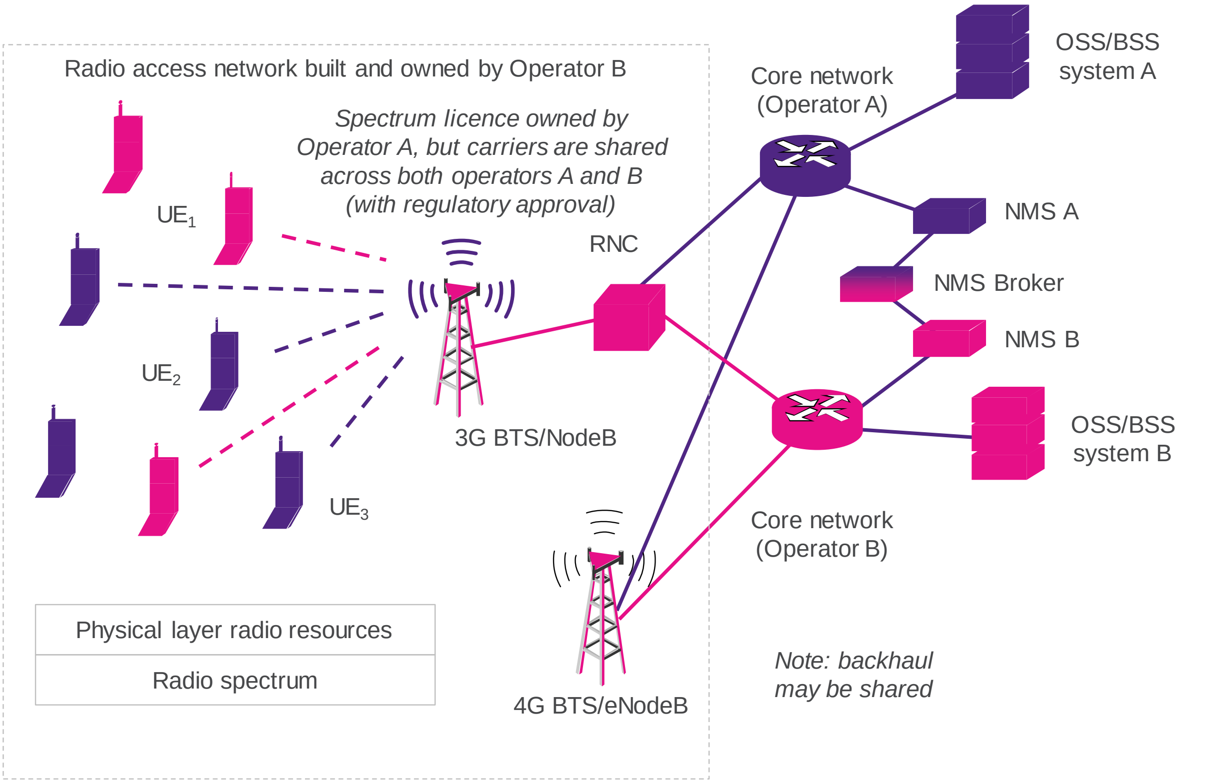
[41] That is, incremental capability over that enabled with MORAN compliant equipment.

[42] That is, with current commercial systems and standards, a single radio carrier within a particular technology (e.g. LTE).

[43] See also: 3GPP Technical Report TR 22.852, http://www.3gpp.org/DynaReport/22852.htm

In a case where two or more operators seek joint access across multiple spectrum bands, MOCN technology can be advantageous, allowing pooling of commercial operations across all bands.

**Figure 3-3: Shared network (illustrative) based on use of complementary network and spectrum resources (two commercial operators, A and B)**




*Source: Plum Consulting, 2016.*

Thus, shared carrier technology, such as MOCN, may offer some efficiency and flexibility gains in the usage of a quantum of spectrum across multiple commercial operators, over the case where spectrum may be physically allocated to such operators on an independently licensed basis.

## 3.4 Potential for new market entry

With any finite availability and allocation of spectrum within any given market situation, MOCN based spectrum sharing can provide a potential for increased competition via reduction of barriers to market entry. For example, in a market with 'N' spectrum licences allocated to 'N' infrastructure based carriers, competition may be increased in 'traditional' markets via the award of further licences, assuming availability of spectrum resource. MOCN based carrier sharing does not, in itself, make available more spectrum resource, but it enables existing underused resources to be shared amongst a greater number of commercial operators – several commercial operators are able to quite literally share a common band of spectrum. This can be advantageous in markets where 'spare' capacity exists.

Since MOCN technology enables abstraction of the radio access network, treating it as a resource which can be operated (and if necessary owned) distinctly from core networks, MOCN technology offers a means by which commercial operators with limited or no ownership of radio resource (e.g. spectrum and/or radio access network infrastructure) can offer services in competition with infrastructure based operators with ownership of radio resources. Consequently, the technology can be seen as an enabler for enhanced competition, allowing market participants such as new entrants to offer services based on developing technologies with equivalent levels of quality and innovation to those developed by incumbent infrastructure based operators.

This concept can be, and has been, advanced further, with development of operators which operate the radio access network as a wholesale business, effectively leasing its use to other network operators who may own insufficient radio access network resources. Whilst this approach may attract regulatory attention from the perspective of an argument based around potential limitations on infrastructure based competition and technology innovation, it may be countered with the premise that network infrastructure in today's global markets is typically offered at very competitive prices and margins in bitstream services are under pressure at many infrastructure based operators[44].

[44] Many competitive infrastructure based players (e.g. Interoute Communications Limited, Amazon Web Services Inc., Alphabet Inc. (Google)) derive significantly more margin from the provisioning of advanced services (such as hosted computing and data centre services) than they do from network infrastructure services, which are increasingly being seen as a necessary element in the provisioning of more commercially attractive services.

# 4 Positioning of regulatory authorities

In 2012, in a statement on spectrum sharing, the European Commission[45] noted that:

> '*Shared use of licensed or licence-exempt wireless broadband frequencies enables cost savings for mobile network operators, affordable internet connectivity and infrastructure sharing possibilities'.*

In its recent Communication entitled '5G for Europe: An Action Plan', the European Commission stated that:

> *'The potential for spectrum sharing … should be maximised as it generally supports innovation and market entry.'*

There is no clear overall European regulatory stance on network sharing and interworking; in practice stances vary by jurisdictions and on a case by case basis, with some significant variations in policies.

Licences pertaining to the use of radio spectrum are typically non-transferable and require regulatory approval in any change of use.

In cases where MOCN technology is deployed, national regulatory authorities (NRAs) appear to favour the granting of licences to joint ventures (as opposed to individual commercial operators), seeking to avoid excessive pooling of existing allocations which could result in unbalanced allocations within the market as a whole. Alternatively, regulators may seek to require concessions in any cases where pooling is permitted (e.g. conditions of non-participation in future spectrum auctions, mandatory disposal of blocks of spectrum held).

National regulators typically take a case by case approach to the review of requests for sharing agreements; it is important to reflect on country case situations to distil points for consideration, whilst applying any such considerations to the market in question.

Some jurisdictions (e.g. Spain, Romania) currently prohibit spectrum sharing. In France, ARCEP[46] recently has gained powers to change network sharing and inter-working agreements. Under these powers it has published (in May 2016) updated and generally more restrictive network sharing and interworking guidelines[47].

In Germany, BNETZA[48] published sharing guidelines in 2010[49] which permit sharing of sites, site support cabinets and logically separate base stations, so long as each operator retains independence as a competitor. This principle of independence is thought to be compromised if spectrum is shared. The guidelines indicate that if sharing promotes the German government's broadband strategy (e.g.

[45] See: 'Promoting the shared use of radio spectrum resources in the internal market' https://ec.europa.eu/digital-single-market/en/promoting-shared-use-europes-radio-spectrum , accessed May 2016.

[46] ARCEP: the French communications regulatory authority.

[47] See: http://www.arcep.fr/index.php?id=8571&no_cache=1&L=1&tx_gsactualite_pi1%5Buid%5D=1861&tx_gsactualite_pi1%5Bannee%5D=&tx_gsactualite_pi1%5Btheme%5D=&tx_gsactualite_pi1%5Bmotscle%5D=&tx_gsactualite_pi1%5BbackID%5D=26&cHash=5adae9e95469d2991951b0681b55dce1, accessed August 2016.

[48] BNETZA: the German communications regulatory authority.

[49] See: 'Shared use of wireless infrastructures and spectrum resources', published in the Bundesnetzagentur Official Gazette of 11 August 2010, No 15/2010, Communication 485/2010), http://www.bundesnetzagentur.de/EN/Areas/Telecommunications/Companies/FrequencyManagement/InfrastructureSharing/InfrastructureSharing_node.html , accessed August 2016.

rural broadband roll-out) it might be permissible if time limited. In any event the guidelines indicate that a case by case analysis would be required by the anti-trust authorities[50].

In the UK, spectrum sharing between mobile network operators through MOCN is not yet established[51], though MORAN arrangements, including active RAN sharing, are well established. Ofcom published a statement[52] in April 2016 in which demand for spectrum sharing is recognised and a framework is set out to inform on potential sharing decisions though this does not address the issue of spectrum sharing between two mobile operators. In the statement, Ofcom recognises that the framework may evolve over time, consistent with market and technology developments and seeks responses from interested parties.

In summary, some regulators and competition authorities have been reluctant to permit active network sharing (including full sharing as may be enabled by MOCN technology). However, many regulatory authorities, such as those in Canada, Hong Kong and Scandinavia, do permit spectrum sharing – as illustrated in the country case studies set out in the Appendix.

Essentially, regulators look to the impact on markets in competition and economic benefits; any granting of rights associated with active sharing, which may bring commercial and economic efficiencies for operators, may be offset by the imposition of remedies by authorities, deemed necessary to preserve market characteristics.

Any case based analysis may include assessment over:

- Whether sharing agreements are unilateral (one operator agrees to provide access to another), bilateral (two operators agree to provide mutual access) or multilateral (several operators agree on terms on which they will provide access to each other).
- The geographic scope of the sharing agreement – rural areas or rural and urban areas.
- The impact on the competitive situation in the concerned markets before and after the sharing agreement (does the agreement affect important competition parameters such as coverage, prices and network quality?) Reduction in the scale of competition amongst infrastructure based operators has the potential to lessen the ability of MVNOs to negotiate competitive deals impacting on retail competition and consumers.
- Whether the operators are enabled to conclude similar agreements with other parties (no exclusivity clauses).
- Whether the exchange of information between the parties is limited to what is strictly necessary for the purpose of the sharing agreement and does not extend to the exchange of confidential business information.
- Whether the operators retain the ability (technically and operationally) to differentiate themselves in terms of prices and quality and variety of services (e.g. by keeping control over the radio planning and having the freedom to add sites).
- Whether a reduction in spare capacity in networks will reduce capacity for MVNOs.

[50] Under German law, national roaming is exempted from competition rules.

[51] In the UK, there is a considerable amount of static sharing between applications but more active and dynamic sharing solutions such as dynamic spectrum access, DSA and LSA are not mature. MORAN based solutions have been deployed commercially in the UK.

[52] See: http://stakeholders.ofcom.org.uk/binaries/consultations/spectrum-sharing-framework/statement/statement.pdf , accessed May 2016.

- Whether the independence of a network operator is prejudiced either directly or indirectly such that there is an increased risk of tacit collusion.

# 5 Overall assessment and recommendations

MOCN technology offers the potential for material benefits, with incremental efficiencies feasible (over MORAN based systems) across both commercial and economic domains.

Commercial and economic benefits can arise particularly in those cases where assets may be ‘cross traded’ across multiple operators.

MOCN technology should be considered and appropriated in cases where such benefits can be realised.

Realisation of efficiencies and benefits possible with MOCN, spectrum slicing, and spectrum sharing methods will require effective and proactive collaboration between commercial operators and governmental agencies.

Requirements must be reviewed on a case by case basis; we recommend that tailored case analysis is developed for unique situations, inclusive of quantitative commercial modelling, with quantitative reporting on commercial and economic benefits, together with assessment on any remedies, with effective dialogue across commercial entities and governmental agencies.

# Appendix A: Country case reviews

In the EU, we present case reviews for MOCN deployments in Denmark, Finland, Hungary and Sweden. We also present case reviews for deployments beyond Europe in Canada, Hong Kong and Israel.  Details of these case reviews are provided in Appendix A. Further, MOCN deployments have also been developed in USA, Russia, Thailand, Malaysia, Iceland, India and Azerbaijan.

Regulatory positioning on sharing is still emerging in some jurisdictions. To illustrate how the balance of competitive and other impacts of MOCN based sharing has been addressed by regulators and competition authorities we have collected evidence from a number of countries where MOCN systems have been deployed.

Key features of the case reviews are summarised in Table 5-1.  In all cases, the RAN and spectrum is shared and core networks of the parties to the agreements are kept separate.

The main motivations for operators to seek MOCN arrangements have been to provide low cost coverage for 3G and 4G services in rural areas (Canada, Finland, Hungary, Sweden), to accelerate roll-out of 4G services (all countries) and to support service provision by a new entrant in circumstances where spectrum is in short supply (Hong Kong and Israel).

Competition issues have arisen in four of the seven case review countries. In these cases similar remedies were applied to ensure competition was maintained in wholesale and retail markets and to limit the opportunities for tacit collusion between the parties to the agreements. Specifically, the parties were obliged to:

- continue to offer fair and non-discriminatory access to their sites, masts and wholesale networks;
- there were controls on future spectrum purchases, and
- controls were imposed to ensure the independence of the ventures to prevent passing of information between commercial operators.
- In Israel there is also a requirement for mechanisms to ensure that the shared network entities continue to invest in new technologies.

In developing MOCN based sharing ventures, parties will have judged the 'cost' of any resulting competitive limitations imposed by regulators to be lower than the 'cost' benefits attainable with development of such ventures[53].

[53] Note that 'cost' savings may include intangible benefits (e.g. synergies in capabilities or brand value).

Table 5-1: Summary of MOCN case reviews

| Country (number of MOCN deals) | Commercial model[54] | Scope of deal | Motivation | Number of competing networks after the deal | Competition remedies applied |
|---|---|---|---|---|---|
| Denmark (1) | Joint venture | 2G/3G/4G in all of Denmark | Low cost coverage | 3 on a national basis | Yes, specific commitments |
| Finland (1) | Joint venture | Initially 800 MHz band for 4G in rural Finland – extending to 2G and 3G | Low cost 4G (and later 2G and 3G) coverage | 3 in the most populated parts of Finland<br>2 or 3 elsewhere | Yes, specific commitments |
| Hungary (1) | Spectrum lease and contract | 800 MHz for 4G in all of Hungary except the Budapest region | Enhance 4G capacity and rollout | 4 in Budapest region<br>Elsewhere, 3 for 4G (one new entrant), 3 for 2G and 3G | Under review |
| Sweden (3) | Joint ventures | 3G and 4G in all of Sweden | Low cost coverage, very high coverage obligations | 2 for 3G<br>3 for 2G and 4G | No |
| Canada (1) | Contract | 3G and 4G in parts of Canada | Low cost coverage | 2-4 depending on location | No |
| Hong Kong (3) | Joint venture and through contract | Variously 2G, 3G and 4G in all of Hong Kong | Lack of spectrum, strengthen new entrant (in one case) | 4 | No |
| Israel (4) | Joint ventures and contract | 2G, 3G and 4G for most of the country | Lack of spectrum, strengthen new entrants | Minimum 3 required | Yes, principles which must be met (incl. preservation of technology innovations) |

*Source: Plum Consulting, 2016.*

[54] Commercial models are reviewed under Chapter 4.

# A.1 Denmark

## A.1.1 Overview

In 2011, a RAN and spectrum sharing agreement was developed between Telia Denmark and Telenor for all mobile technologies (2G, 3G, LTE) covering the entire Danish territory.

In 2012, the agreement was approved by the Danish Competition Council (DCC), subject to binding commitments given by the parties that addressed the DCC's competition concerns. The commitments involved:

- Accepting all requests from wholesale customers to buy mobile telephony and mobile broadband on customary and market conditions.
- Paying the commonly owned joint venture for its supply of radio access capacity according to a tariff structure that at all times reflects the underlying cost structure of the radio access network.
- Buying frequency licences in common (through the joint venture).
- Selling or letting the antenna sites that prove to be superfluous to any interested player on the market.
- Restrictions regarding the appointment of the members of the board of the joint venture, the employment of the management and employees of the joint venture, the information that may be exchanged within the joint venture and between the joint venture and the parties.

More recently, Telia Denmark and Telenor applied to the European DG Comp to merge their Danish operations. Their application was rejected in September 2015[55].

## A.1.2 Sharing arrangements

In 2011, Telia Denmark and Telenor announced that they planned to implement a network sharing agreement via a joint venture, Newco, which they would jointly own[56]. Newco would control and develop the RAN infrastructure needed for the owners' respective businesses. The agreement involved network and frequency sharing but core networks were not shared. The network sharing agreement involved all mobile frequency bands and technologies (2G, 3G, LTE) covering the entire Danish territory. The purpose of the agreement was to deliver efficiency gains (e.g. cost reductions) and to create a 'better' network in terms of improved coverage and technology access, so that Telia and Telenor could compete more effectively with TDC.

TDC is the leading player in the retail mobile market with Telenor second, Telia third and Hi3G ('3') fourth. Telenor is the main wholesale provider followed by TDC, then Telia.

Telenor has reported that network sharing projects with Telia resulted in the sharing of 4G/LTE networks in 2013, the sharing of 3G network Q1 2014 and the sharing of 2G network in Q4 2014[57].

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[55] See: https://www.telegeography.com/products/commsupdate/articles/2015/09/11/teliasonera-telenor-withdraw-danish-merger-bid/

[56] https://www.telegeography.com/products/commsupdate/articles/2011/06/14/telia-and-telenor-share-danish-networks/;

[57] https://www.telenor.com/investors/company-facts/business-description/telenor-denmark/

The intention was that Telia Denmark and Telenor would remain separate mobile operators in both the wholesale and retail markets.

The sharing arrangements were submitted to the Danish Competition Council (DCC) for approval.

### A.1.3 Regulatory positioning

The DCC found that the network sharing agreement may infringe Article 101 of the Treaty on the Functioning of the European Union (TFEU) and section 6 of the Danish Competition Act; i.e. may prevent, restrict or distort competition.

In particular, the DCC concluded that the sharing agreement may have an anti-competitive impact on the market for access to sites (for mobile antennas), the wholesale market for mobile telephony and mobile broadband, the retail market for mobile telephony and mobile broadband and the market for purchase of frequency licences.

The DCC identified the following anti-competitive concerns:

1. The agreement may increase the risk of a collusive outcome on the wholesale market for mobile telephony and mobile broadband in Denmark.
2. The tariff structure initially chosen to recover the joint venture's costs from the parties may change the underlying cost structure of the RAN compared to the situation before the agreement in a way that converts fixed costs into variable costs. This could reduce the parties' incentives to compete and attract new customers.
3. The parties may obtain a joint amount of frequency resources that in the long term significantly exceeds that of the competing operators.
4. The parties will reduce the number of antennas and masts in their common RAN, which may create coverage problems for competitors that rent antenna positions on the parties' masts.
5. The agreement increases the risk of exchange of commercially strategic information that exceeds the sharing of data necessary for the joint production of the goods subject to the network sharing agreement.
6. The agreement reduces competition on significant parameters such as coverage and the development and spread of new technology (LTE, LTE-Advanced), as these parameters are solely defined in the RAN.

The parties submitted commitments which addressed the first five concerns. The commitments were as follows:

- Concern no. 1: The parties will accept all requests from wholesale customers to buy mobile telephony and mobile broadband on customary and market conditions.
- Concern no. 2: The parties will pay the commonly owned joint venture for its supply of radio access capacity according to a tariff structure that at all times reflects the underlying cost structure of the radio access network.
- Concern no. 3: In the future the parties are obliged to buy frequency licences in common (through the joint venture). This secures against a situation where the parties buy spectrum separately and afterwards pool the obtained frequency resources in the joint venture, thus gaining access to an overall larger amount of spectrum.

- Concern no.4: The parties are obliged to sell or let the antenna sites that prove to be superfluous to any interested player on the market.
- Concern no. 5: The parties will adopt a set of restrictions regarding the appointment of the members of the board of the joint venture, the employment of the management and employees of the joint venture, the information that may be exchanged within the joint venture and between the joint venture and the parties.

The DCC judged that the parties provided sufficient proof that the agreement would offer benefits to consumers in terms of improved coverage and technology enhancements to address the sixth concern.

## A.2 Finland

### A.2.1 Overview

The MOCN venture initially involves network and 800 MHz spectrum sharing in low density areas of Finland (north and eastern areas) – it will be extended to 2G and 3G services in other bands in this geographic area. The motivation for the agreement was to reduce costs of mobile service delivery in rural areas and to speed up 4G rollout in the northern and eastern areas of Finland. The vehicle for the shared network is a joint venture company. The parties to the transaction (Sonera and DNA) between them account for over 50% of mobile subscribers in Finland.

The Finnish competition authority had concerns about the competitive impact of the arrangements. To address these concerns the parties made binding commitments concerning:

- Mast sharing.
- Wholesale access.
- The extent of spectrum sharing.
- Information exchange between the parties.
- Independent provision of competitive network features through the joint venture.

### A.2.2 Sharing arrangements

In August 2014, TeliaSonera Finland (Sonera) and DNA announced that they intended to share a RAN covering northern and eastern Finland – core networks would remain separate. Geographically, the new network would cover approximately 50% of Finland's territory and around 15% of the population. Sonera and DNA proposed to combine their spectrum in the 800 MHz band to enable higher speeds and capacity in the regions covered by the shared RAN, with DNA stating that the network co-operation would contribute significantly to enhancing the technical quality of network services in sparsely populated areas.

The network would be sourced, implemented and managed by their jointly owned company Suomen Yhteisverkko Oy (Yhteisverkko). Sonera took a 51% stake in the Yhteisverkko joint venture, with DNA holding 49%. In future, all 2G, 3G and 4G mobile traffic would be carried by a common network in the joint venture´s operating area. Both operators would continue to compete independently with regard to products and pricing models in the areas covered by the shared RAN.

Sonera and DNA are respectively Finland's second and third largest mobile operators by subscribers, and both offer quadruple-play fixed line, broadband, mobile and pay-TV services. DNA is also Finland's largest cable TV operator[58]. Sonera and DNA together account for around 55% of all mobile subscribers in Finland with Elisa accounting for around a further 30%[59]. Finnet and other operators serve the remaining 15% of subscribers.

The parties sought the approval of the Finnish competition authority (FCCA) for the joint venture.

### A.2.3 Regulatory positioning

In April 2015, the FCCA expressed the preliminary opinion that the network partnership between DNA and Sonera would restrict competition in the mobile communications market. According to the FCCA, the network partnership would have harmonised DNA´s and Sonera´s mobile networks in eastern and northern Finland and reduced national network competition between the operators. Moreover, the partnership might have enabled the operators to reach a tacit understanding that they would align their competitive behaviour in a manner detrimental to consumers.

In November 2015, the FCCA announced that DNA and Sonera had made five commitments that would change their network partnership concerning eastern and northern Finland to ensure that consumers benefit from a more efficient network. The commitments concerned the following aspects of the partnership:

- Wholesale access: DNA and Sonera offered the FCCA a commitment that they would offer virtual and service operators access to their national networks and rent out mast and equipment location sites to competitors. By international comparison, few virtual and service operators compete in the Finnish mobile market. More competition could emerge in the future if new operators are able to offer services through DNA´s and Sonera´s networks.
- Spectrum sharing: Spectrum acquired by the operators would not, as a matter of course, be shared through the joint venture.
- Network features: The operators will be able to bring their preferred network features or additional capacity to the joint network. This will ensure that they can also offer independently competing services and products for their customers within the area of the joint network.
- Masts: The parties undertake that they will not dismantle masts not used by the joint venture in the shared network area. Underused or unused masts must be offered to third parties for rent at market rates.
- Information exchange and staffing: DNA and Sonera also undertook to restrict information exchange to within the sphere of the joint venture, as well as restricting other links through the board of directors and staff of the joint venture and the two operators.

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[58] See: https://www.telegeography.com/products/commsupdate/articles/2014/11/28/teliasonera-dna-contract-omnitele-to-design-shared-northern-eastern-network/; http://www.mobileworldlive.com/featured-content/home-banner/sonera-dna-form-network-sharing-jv-expand-rural-coverage-finland/

[59] See: https://www.viestintavirasto.fi/en/statisticsandreports/reviewsandarticles/2016/changesinmarketsharesin2015.html

## A.3 Hungary

### A.3.1 Overview

The agreement involves Telenor and Magyar Telekom leasing 800 MHz spectrum bands to each other on a regional basis, so that each operator has access to 20 MHz blocks of 800 MHz spectrum. Telenor will build and operate an 800 MHz network in the west of the country and Magyar Telekom will build and operate an 800 MHz network in the east; both networks exclude the Budapest region.

The parties to the agreement are Telenor and Magyar Telekom which have national market shares (by subscriber numbers) of 30% and 23% respectively. T-Mobile accounts for almost all the remaining 47% of subscribers, though there is a recent new entrant Digi Telecoms.

The agreement has been approved by the telecoms regulator NMHH. It is under investigation by the national competition authority.

### A.3.2 Sharing arrangements

In 2014, Magyar Telekom and Telenor won spectrum licences for the 800 MHz band. Later that year they entered into a co-operation agreement for the joint development and operation of their 4G networks in the 800 MHz spectrum band in all parts of Hungary except Budapest. The main goal of the agreement was to provide Telekom and Telenor customers living in rural areas with 4G coverage and access to 4G based mobile internet services as early as possible. The co-operation is also intended to improve service quality and availability in many areas already covered by the 4G network, such as urban areas (excluding Budapest), as a result of operator access to a 20 MHz frequency block versus a 10 MHz block at 800 MHz.

Also, it was claimed by the parties to the agreement that those living in the affected areas may benefit from 4G technology and improved coverage up to a year earlier than would otherwise be the case. As a result of the co-operation, Telekom expected to increase its nationwide outdoor 4G coverage to 97% instead of the earlier announced 93%, while Telenor planned reach to a nationwide outdoor 4G coverage of 95% by the end of 2015.

Telenor would implement and operate the 800 MHz LTE network in the Transdanubian region (i.e. western Hungary), while Telekom would implement and operate the 800MHz LTE network in the rest of Hungary, except Budapest[60]. Under the agreement, Telenor would lease its 800 MHz frequency blocks to Telekom in the part of the country Telekom serves (and vice versa).

As at 31 March 2015, Telenor had an estimated market share of 30%; the market leader, T-Mobile, had an estimated market share of 47%, and Magyar Telekom had an estimated market share of 23%. There is also a fourth operator Digi Telecoms that won 2 x 5 MHz blocks at 1800 MHz at auction in 2015.

[60] The Transdanubian regions account for around 30% of the population; Budapest accounts for a further 30% and the remaining regions account for around 40%. See: https://en.wikipedia.org/wiki/List_of_regions_of_Hungary

### A.3.3 Regulatory positioning

The spectrum lease contract has been approved by the National Media and Info communications Authority (NMHH[61]). NMHH's role was to check that the terms of the agreement, and in particular the spectrum lease, complied with the technical and other relevant conditions of the spectrum licences held by Telenor and Magyar Telekom.

On 24 February 2015, NMHH approved the execution of the contract on the above secondary trading. The lease agreement on the frequency band signed by the mobile operators expires in 2029 (5 years before the respective spectrum licences expire). Competition aspects are addressed by the national competition authority.

The Hungarian Competition Authority (GVH) has initiated supervisory proceedings against Magyar Telekom and Telenor, following notification of the agreement by both the undertakings and the NMHH.

The GVH launched the investigation in order to determine whether the agreement conforms with the provisions of the Hungarian Competition Act and Article 101 of the Treaty on the Functioning of the European Union[62].

The investigation would take account of the market power of the parties, the nature of the services they provide and also the number of potentially affected consumers. The investigation has not yet been concluded.

## A.4 Sweden

### A.4.1 Overview

Sweden has a long history of network sharing. The drivers for this are historical: in 2000, 3G licences were awarded through a comparative selection process ('beauty contest') based on a scoring system basically based on two main criteria: rapid rollout and nationwide coverage. The main mobile operator Telia (with around a 50% market share) was not successful in gaining a licence for 3G spectrum[63]. Instead, Tele2 and Telenor were joined by Hi3G (owned by Hutchison (60%) and Investor (40%)) and Orange as the successful applicants. All four applicants had pledged that their networks would reach 99.98% of the Swedish population by the end of 2003[64]. The Telia situation and high coverage obligations of the other operators were felt to give strong incentives for network and spectrum sharing.

A survey of Swedish municipalities found that the responding municipalities had received a large number of requests (approximately 6,000) for building permits regarding masts for radio transmission during 2001 and 2002. As a consequence of opposition to mast building from the general public, municipal planning authorities sought to encourage operators to share mast facilities whenever

[61] See: http://english.nmhh.hu/cikk/165946/NMHH_Approves_Interconnection_of_Magyar_Telekom_and_Telenor_Networks

[62] See: case number: VJ/18/2015, Budapest, 25 February 2015; http://www.gvh.hu/en/press_room/press_releases/press_releases_2015/gvh_investigating_cooperation_between_telekom_and_.html

[63] See: 3G Mobile Policy: Sweden Case study, ITU. https://www.itu.int/osg/spu/ni/3G/casestudies/sweden/Sweden_fin3.pdf

[64] The extensive coverage pledged is estimated to have required the construction of some 8,000 to 10,000 new masts for radio transmitters.

feasible. Gaining planning approvals took time and the regulator - PTS also observed operators were reluctant to share masts[65].

Despite a relatively wide range of shared network resources that might affect the incentives for different players to compete on the retail market, the available evidence suggests that the Swedish mobile market has retained a healthy degree of competition with four major operators competing on the retail market. The OECD Digital Communications Outlook 2015[66] recorded that mobile consumers in Sweden enjoy competitive prices across a range of baskets relative to peers in other countries. For example, in 2015 with mobile broadband consumption of 2 GB of data per month, Sweden had the eighth least expensive offer in the OECD area[67].

An issue facing the SUNAB joint venture (and potentially others) concerns its future as 3G services are eventually phased out. Will the spectrum used by SUNAB be used to migrate to an alternative technology or will the company be shut down? A technology migration path has not been anticipated in the arrangements.

In summary, the Swedish case (currently with four MNOs) suggests that healthy competition can be maintained with network sharing frameworks, even if they cover wide geographical areas and involve sharing spectrum bandwidth that has been originally allocated to individual operators.

### A.4.2 Sharing arrangements

The following two network sharing agreements were put in place following the award of 3G licences[68].

- SUNAB – a joint venture between Telia and Tele2 to build and operate a national 3G network and to share the 2100 MHz spectrum awarded to Tele2 (which was subsequently transferred to a holding company owned by SUNAB). Both operators continued to run their own 2G networks. This enabled Tele2 to take advantage of Telia's historically accumulated network assets as well as backhaul. By sharing 3G facilities newly built on those assets with a rival, Tele2 was able to significantly reduce the amount of investment and operational cost required for national 3G coverage. At the same time, network sharing was also beneficial for Telia, as it could provide 3G service without a spectrum licence and without the substantial costs that would have been necessary if it had built the infrastructures itself. Under the arrangement, passive infrastructures and the RAN including spectrum and backhaul are shared via a MOCN network approach. SUNAB outsourced the building of the 3G network to the two operators Tele2 and Telia. Each operator is responsible for building and operating the network in a defined part of the country[69] and there are defined fixed and variable charges for use of the network. The latter had to be approved by the competition authority.

[65] See: https://www.pts.se/upload/Faktablad/En/Factsheet_3G_Sweden.pdf and http://www.twobirds.com/en/news/articles/2004/infrastructure-sharing-mobile-networks-sweden

[66] See: http://ec.europa.eu/eurostat/documents/42577/3222224/Digital+economy+outlook+2015/dbdec3c6-ca38-432c-82f2-1e330d9d6a24

[67] See: OECD Communications Outlook 2013, which reports a wider range of wireless broadband price comparisons and also shows prices in Sweden are low compared with other OECD countries.

[68] See: http://www.impgroup.org/uploads/dissertations/dissertion_53.pdf http://www.twobirds.com/en/news/articles/2004/infrastructure-sharing-mobile-networks-sweden

[69] The country was split into four areas and each company developed operations over two areas.

- 3GIS – a joint venture between Three (Hi3G) and Telenor (formerly Europolitan) to build and operate a 3G network[70]. The two operators also deployed separate 3G networks serving part of the country. Under the scheme, shared components included passive infrastructures such as masts and sites and active elements such as backhaul and spectrum resources. The venture has been particularly beneficial for Hi3G as it was a new entrant at the time of 3G licensing, and had to rely on existing networks to swiftly expand coverage. 3GIS operates as a rural network outside the main cities and Karlskrona and has a separate organisation.

Tele2 and Telenor developed a third network sharing arrangement for their investments in 4G through a joint venture called Net4Mobility, with a similar set up as to that for SUNAB. To supply 4G services Net4Mobility has its own 800 MHz and 1800 MHz spectrum licences which it won at auction in 2011[71]. This went further than previous arrangements, because the two competitors bought 4G spectrum jointly and also brought existing licences in the 900 MHz, 1800 MHz and 2600 MHz bands into the venture; this involved a spectrum trade as it transferred spectrum from the two owners to the joint venture[72].

Net4Mobility outsourced the building and operation of the RAN network to its two owners – each taking half the country and sharing the network built and operated by the other partner company. This national network has, like predecessors, made extensive use of existing municipal fibre networks for backhaul to attain coverage objectives. In November 2010, the network entered service at a time when very few operators elsewhere in the world had commenced 4G networks.

### A.4.3 Regulatory positioning

In 2001 PTS, the telecommunications regulator, published a study setting out issues around network sharing and noted that:

- *'In countries with a low population density like Sweden it makes sense for operators to aim for a far-reaching network sharing agreement. In effect they would build a single network operator in sparsely populated areas where the traffic density is low[73]'.*

PTS has been positive towards network sharing as it has contributed to greater geographical coverage than might otherwise be expected[74], while retaining competition. For example, in the case of the Tele2 and Telenor joint venture this was seen as having the advantage of strengthening the competition between the largest and second and third largest competitors in the market. There was also reason to believe there can be an increased focus on rural coverage as a competitive advantage, as TeliaSonera had been a clear market leader in rural coverage[75]. PTS also believed that the arrangements have other benefits[76]: as the network sharing agreements are commonly very detailed and involve substantial financial commitments, they enable the regulator to establish a transparent and predictable regulatory framework. Until March 2011, no more than 70% of a network could be

[70] Orange was originally part of the joint venture. Orange withdrew its licence and exited from the Swedish market in 2003 without commencing service.
[71] Telia and 3 also won 800 MHz licences and Telia won an 1800 MHz licence for 4G services.
[72] See: 'Wireless Market Structures and Network Sharing', OECD Digital Economy Paper no.243, 2014.
[73] See: http://www.pts.se/en-GB/Documents/Reports/Telephony/2001/Network-Sharing-Study/
[74] See: https://www.itu.int/en/ITU-D/Conferences/GSR/Documents/GSR2014/Discussion%20papers%20and%20presentations%20-%20GSR14/Session%202%20GSR14%20-%20Discussion%20paper%20-%20Competition.pdf
[75] See: RSPG Report on 'Efficient Awards and Efficient Use of Spectrum', Brussels, 24 February 2016, RSPG16-004 FINAL.
[76] See: 'Wireless Market Structures and Network Sharing', OECD Digital Economy Paper No.243, 2014.

shared by a joint venture formed by multiple licensees; however, this limitation has since been removed.

All three sharing arrangements were approved by the Swedish Competition Authority Konkurrentsverket (KKV). KKV has not required any specific commitments from the relevant parties because it has judged that there is sufficient competition in the market[77]. For example, in an investigation into the sharing arrangements through Net4Mobility KKV stated that:

- *'… the potential remains for the two operators to continue competing aggressively on the end-customer market …';* and
- *'… the joint venture concerns a relatively small share of each operator's total costs for the supply of mobile phone and broadband services'. It also notes that rapid technological development in the mobile market makes it difficult for companies to enter into and sustain anti-competitive collaboration. Consequently, the Competition Authority has decided to close the investigation.*

The Swedish regulator did a competition assessment similar to that which the competition authorities would have had to do if Tele2 and Telenor had decided to merge. The assessment is of course specific for the competitive situation at a certain moment in time, but if competitive problems or distortions should arise there are tools to address this: e.g. spectrum caps, exclusion in future awards, competitive analysis of future trading, and significant market power (SMP) analysis of mobile origination.

## A.5 Canada

MNOs in Canada have entered into a range of network and spectrum sharing agreements to reduce costs of providing nationwide coverage and facilitate faster roll out of next generation wireless networks. The communications regulator (CRTC) regulates aspects of these arrangements; there are mandatory requirements to provide roaming, and wholesale mobile roaming rates for the three main operators (Bell, Telus and Rogers)[78] are regulated. The regulator also has powers to require operators to provide site and tower access if competition concerns arise. The main objective behind these initiatives has been to stimulate competition in the Canadian mobile market and to ensure competitive service provision outside a small number of major cities[79].

Bell and Telus (the second and third operators respectively[80]) have deployed a MOCN for a national HSPA network in 2009, an HSPA+ network in 2010 and an LTE network in 2011, in order to compete more effectively (in terms of cost, coverage and technology) with the leading operator – Rogers. In addition, they have entered into a network sharing agreement with regional incumbent Sasktel in Saskatchewan. Bell and Telus' national HSPA build ended Rogers' GSM monopoly.

[77] See: http://www.tele2.com/media/press-releases/2002/tele2-and-telia-umts-network-cooperation-accepted-by-the-swedish-competition-authority/; http://www.konkurrensverket.se/en/news/investigation-into-mobile-market-regarding-network-sharing-closed/

[78] Regulatory Framework for Wholesale Mobile Wireless services, TRP CRTC 2015-177. 5 May 2015. http://www.crtc.gc.ca/eng/archive/2015/2015-177.pdf

[79] See: http://www.iedm.org/files/cahier0215_en.pdf

[80] See: http://www.cwta.ca/wp-content/uploads/2016/05/SubscribersStats_en_2016_Q1.pdf

In 2009, Rogers partnered with regional incumbent MTS to jointly deploy an HSPA+ network in Manitoba, and in 2013 it partnered with regional cable operator Videotron to build and share an LTE network in Québec and part of Ontario.

## A.6 Hong Kong

### A.6.1 Overview

There are three MOCN network sharing arrangements in operation in Hong Kong.

The first two of these arrangements arose through commercial negotiations and did not raise competition concerns because of vigorous competition in wholesale and retail mobile markets. In both cases spectrum scarcity appears to have been a key factor motivating the sharing arrangements.

The third MOCN arrangement between HKT and CSL has been put in place as a means of facilitating the recent merger between the two companies. One condition of the merger was the continued operation of the commercially negotiated MOCN between HKT and CMHK.

### A.6.2 Sharing arrangements

Genius Brand Limited (GBL) was set up as a 50:50 joint venture between Hong Kong Telecommunications Limited (HKT), and Hutchison Telephone Company Limited (HTCL). It was established to deploy 4G LTE MOCN technology using 2.5/2.6 GHz frequencies. A key motivation for the GBL JV was to gain access to 2.5/2.6 GHz spectrum that was offered at auction by the regulator OFCA in 2009[81] and again in 2012[82,83]. The collaboration reduced the risk to the joint venture partners of being left without 2.5/2.6 GHz spectrum and arguably reduced the auction spectrum price. In addition, there were benefits of reduced opex and capex and fewer difficulties in gaining site access which is particularly problematic in congested areas of Hong Kong (given that more sites are required at 2.6 GHz than at lower frequencies held by the operators).

The GBL network uses the 2600 MHz band to deliver 4G services, and HTCL and HKT retain separate and additional RANs across the 900 – 2100 MHz, 1800 MHz, and 2300 MHz bands. HTCL and HKT have divided geographic responsibility for network build and operation and maintenance in Hong Kong.

HKT and China Mobile Hong Kong (CMHK) have operated a MOCN network sharing agreement on 3G services since 2013 using 2100 MHz spectrum. At the time of the deal CMHK did not have any 2100 MHz spectrum although in 2015 CMHK won 2 x 10 MHz in the band at auction[84].

[81] See: http://www.dailywireless.org/2009/01/23/hong-kong-25-ghz-auction-winners/

[82] See: http://www.ofca.gov.hk/en/industry_focus/radio_spectrum/auctions/2_5_spec_auctions_details/index.html

[83] See: http://www.ofca.gov.hk/filemanager/ofca/en/content_810/20130506.pdf

[84] See: http://www.ofca.gov.hk/filemanager/ofca/en/content_921/1.9-2.2_GHz_Band_Auction_Successful_Bidder_Notice.pdf

### A.6.3 Regulatory positioning

In May 2014, the Communications Authority (CA) of Hong Kong announced its decision to give consent, with conditions imposed, to HKT's proposed acquisition of CSL New World Mobility Limited (CSL). The CA found that the proposed acquisition would substantially lessen competition, and so consent to the merger was only granted on recognition of appropriate remedies. In summary, the remedies identified by CA were as follows:

- HKT and CSL were to divest an amount of spectrum held, via a competitive bidding process for assignment to other MNOs and/or new entrants, reducing spectrum concentration.
- HKT and CSL were to abstain from participation in spectrum auctions for a period of five years from the date of CA's direction.
- HKT and CSL were to notify the Office of the Communications Authority (OFCA) (CA's executive branch) and all other MNOs of any plan for closure of base station sites for a period of five years from the date of CA's direction, effectively supporting other market players to allow them to acquire any relinquished sites.
- HKT and CSL were to continue to provide wholesale network access to MVNOs based on existing agreements for a period of three years from the date of CA's direction.
- HKT was to continue its existing 3G network capacity sharing agreement with CMHK despite a reduction in its 2100 MHz spectrum holding at the time when these licences expired and were variously renewed or auctioned in 2013[85].

Thus, in this situation, CA required the (MOCN) network sharing agreement (operational since 2013) between HKT and CMHK to continue to sustain competition between operators.

Since 2014, MOCN technology has also been applied to joint network operations across both HKT and CSL to achieve coverage and capacity enhancements; in this case, MOCN technology has enabled the legacy RANs of both MNOs to be combined into a single network.

## A.7 Israel

### A.7.1 Overview

Policy on network sharing in Israel has been developed by the Ministry of Communications (MOC) in response to specific sharing requests from all five mobile network operators. The MOC first commissioned an Expert's Report[86] and then used this to develop sharing policy guidelines[87].

In May 2014, the MOC published a policy statement on sharing in wideband access networks[88] together with the Expert Report noting that:

[85] See: http://www.ofca.gov.hk/en/industry_focus/radio_spectrum/auctions/1_9_2_2_ghz_band_licensing/index.html , accessed October 2016.

[86] 'Economic Expert Opinion Regarding Sharing of the Radio Networks in the Cellular Phone Market in Israel', Ministry of Communications, May 2014. http://www.moc.gov.il/sip_storage/FILES/8/3728.pdf

[87] 'Policy for Sharing in a Wideband Access Network of a Holder of a General Permit as a Radio-Telephone Service Provider', Ministry of Communications, May 2014. http://www.moc.gov.il/sip_storage/FILES/0/3740.pdf

- *'… the Ministry sees advantages in MOCN-type active sharing, compared to MORAN-type active sharing, in light of the current need to optimize the frequency spectrum …'.*

The Ministry set out guideline principles for evaluation of any sharing agreement. Key points included:

- *MOCN sharing is only permitted where one of the sharers has a partially deployed 3G network.*
- *Three independent wireless networks must be operating in every region after the sharing agreement has been concluded.*
- *New sharers must be permitted to join in future under similar terms and conditions.*
- *MVNO access must be maintained by each sharer.*
- *An independent corporation to manage the access network is to be established with joint ownership by the sharers.*
- *Information is only to be transferred between sharers and the independent corporation.*
- *A mechanism for ensuring technological development of the network will be set out in the sharing agreement.*
- *Various mechanisms for ensuring sharer independence and for undoing the sharing agreement if required (shall be established).*

In May 2014, the four sharing agreements proposed by the operators were approved by Israel's Anti-trust Commissioner subject to the conditions above[89]. The network sharing arrangement between Partner and HOT Mobile was approved by the MOC in 2015[90].

### A.7.2 Sharing arrangements

In 2014, there were five network operators in Israel[91]. Three operators (Cellcom, Partner and Pelephone) each with national mobile networks accounted for service coverage to the majority of subscribers, with coverage split roughly equally between them. The two other operators (HOT/Mirs and Golan) each have networks with sub-national coverage. Since starting operations in 2012, HOT/Mirs and Golan have achieved around a 7% market share each[92]. They have had a positive impact on stimulating competition – new service packages were offered and average market prices have dropped[93].

In 2014, the five operators variously sought MOC approval for four sharing arrangements, namely:

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[88] See: http://www.moc.gov.il/sip_storage/FILES/0/3740.pdf During the period 2013 to 2014, the Ministry of Communications (MOC) of Israel conducted numerous meetings to assess the issue of sharing in radio networks in the cellular 'phone market in Israel. The Ministry conducted dialogue with regulatory bodies across the world.

[89] See: http://www.businesswire.com/news/home/20140522006001/en/Partner-Communications-Announces-Receipt-Antitrust-Commissioner-Approval

[90] See; http://www.businesswire.com/news/home/20150420005762/en/Partner-Communications-Announces-Receipt-Ministry-Communications-Approval

[91] There are now potentially six operators. A tender for 4G service in the 1800 MHz band was published in July 2014. Six winners were announced in January 2015, including all five existing operators and a new entrant, 018 Xfone.

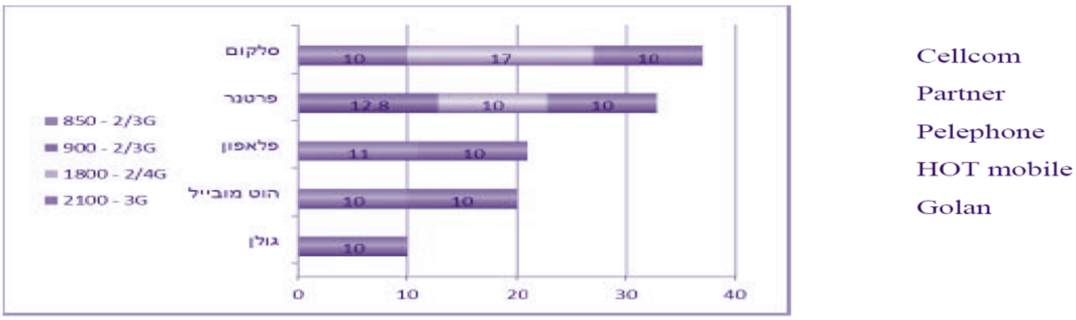
[92] http://www.moc.gov.il/sip_storage/FILES/8/3728.pdf

[93] The operators had a strong financial incentive to reach this market share as it resulted in payment of reduced licence fees. See Expert Report (2014).

- A network sharing agreement involving MOCN active sharing under a 50:50 joint venture between Partner Communications Company Limited (Partner) and HOT Mobile Limited (HOT).
- Three sharing agreements between the operators Celcom, Golan and Pelephone which included:
  i. MOCN frequency sharing between the three operators for 4G.
  ii. Access by Golan to Celcom's 2G and 3G RAN and frequencies.
  iii. A joint venture between Cellcom and Pelephone to establish a company to build and manage a 2G/3G network for each of the operators separately.

Figure A-1 summarises the access to frequencies and technologies used by the five network operators in 2014[94]. In addition, intra-country roaming agreements were negotiated between HOT/Mirs and Partner and between Golan and Cellcom.

**Figure A-1: Frequencies and technologies used by each operator[95]**




*Source: 'Economic Expert Opinion Regarding Sharing of the Radio Networks in the Cellular Phone Market in Israel', Ministry of Communications, 2014.*

A key issue facing all operators, and the two new entrants in particular, was limited access to spectrum. Frequencies not available to mobile operators included: 2 x 10 MHz at 1800 MHz (in early 2014, 2 x 45 MHz was not available, but 2 x 35 MHz was auctioned in early 2015), 2 x 10 MHz at 2100 MHz, all of the 2600 MHz band, and 2 x 10 MHz at 1800 MHz.

Also, below 1 GHz, a mix of Region 1 and 2 technologies was deployed and this significantly limited availability of spectrum at 900 MHz for GSM/3G and at 700 MHz / 800 MHz for 4G. There is non-standard use of 800 MHz for iDen and at 850 MHz only Pelephone has a network deployed.

The Expert Report stated that:

*'There are not enough frequencies for the existence of 5 independent 4G radio networks'.*

While this issue was partly addressed in 2015 by an auction of unallocated spectrum at 1800MHz[96], the lack of spectrum will either increase the costs of building 4G networks (because more infrastructure is required than would otherwise be the case) and/or reduce the quality of service that

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[94] See Expert Report (2014).

[95] Cellcom sought to replace the 850 MHz TDMA frequencies with 900 MHz GSM frequencies but Pelephone and Partner (formerly known as Orange) petitioned the Ministry of Communications to deny this for technical reasons. This put Cellcom at a disadvantage since though most of its users had converted to GSM, they were not able to make use of the lower frequency's better in-building penetration and greater cell reach.

[96] See: http://www.moc.gov.il/sip_storage/FILES/9/4089.pdf

can be provided (as a result of congestion in networks). In addition, the lack of frequencies below 1 GHz increases costs for operators with little or no useful spectrum in this frequency range.

In addition to the shortage of spectrum, the following issues have motivated operators to seek MOCN sharing.

- Difficulties in obtaining base station sites because of local opposition.
- Lack of capacity at some sites to increase the number of passive sharers.
- National roaming does not allow the two new entrants to differentiate their services technically and compete for customers on cost grounds. Furthermore, national roaming introduces up to a 17 second delay in making connections.

### A.7.3 Regulatory positioning

The Expert Report analysed the potential benefits and costs of MOCN versus other forms of network sharing. The key factors considered were as follows:

- Impact on competition:
    i. Number of access infrastructures.
    ii. Number of service providers (MNOs and MVNOs).
    iii. Exposure of technological and commercial information between sharers and its potential impact on market competition.
    iv. Potential exit barriers, including potential capacity of sharers to maintain quality of service after dissolution of sharing arrangements.
    v. Potential for tacit collusion or strategic co-ordination of sharers' market activities.
    vi. Potential cost savings – operating and capital expenditures.
    vii. The operator motivations for using cost savings to reduce tariffs, increase investment and/or increase dividend payments.
- Impact on investment and innovation, in particular the risk of one sharer 'free-riding' on investment by another so that no investment occurs.
- Efficiency of spectrum use:
    i. Availability of spectrum to each MNO and accepted requirements for bandwidth.
    ii. Impact of sharing at the radio performance level.
    iii. Demand for frequencies from other entities or for additional uses.
- Survivability and redundancy of the networks at national level.
- Sustainability of communications services over time, including ability to invest in new technologies.

In reaching its recommendations, the Expert's Report was guided by the desire to achieve a balance between maintaining competition and the incentives of all parties in the market to compete, and to bring about fast-as-possible technological development that would lead to provision of 4G services for the Israeli public in accordance with accepted global standards. In doing this it had particular regard to the spectrum constraints and issues of site access that apply in Israel.

Of the sharing alternatives available, the Expert Report concluded that active sharing including MOCN frequency sharing provided a practical solution to the issue of the existence of limited frequencies for 4G, and would allow the five existing operators to continue providing advanced cellular communications services over radio networks in their possession. The Expert Report discusses competitive concerns with a MOCN approach and recommends MOCN sharing is approved only where it is necessary in order to preserve existing cellular operators in the future market and that a number of restrictive conditions are applied, intended to ensure future investment in radio networks, independent decision-making for a cellular operator regarding hosting of MVNOs, and the enabling of future entry of cellular operators through MOCN sharing.

The implications of the Expert Report recommendations are that:

- Passive site sharing should be allowed wherever it can be implemented, with no need to establish a company owned by the partners for purposes of management of the shared sites.
- MOCN sharing between two market players that own independent, fully-deployed 3G mobile networks would not be permitted.
- MOCN sharing for 3G and 4G frequencies involving arrangements with the two small operators that used national roaming may be permitted subject to suitable competitive safeguards being implemented.

This analysis has informed the MOC's regulatory principles for MOCN sharing.