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Investment strategies for different actors in indoor mobile market: "In view of the emerging spectrum authorization schemes"

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INVESTMENT STRATEGIES FOR DIFFERENT ACTORS IN INDOOR MOBILE MARKET

"IN VIEW OF THE EMERGING SPECTRUM AUTHORIZATION SCHEMES"

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Abstract

The regulatory landscape is changing towards more flexible spectrum management schemes. Such schemes are expected to make additional spectrum resources available and lower the spectrum access barriers. Emerging spectrum authorization schemes such as secondary access (TV White Space) and Licensed Shared Access (LSA) are expected to open doors for new actors rather than traditional MNOs to access licensed spectrum resources at reasonable costs. These schemes will allow actors such as Facility Owners (FO), Mobile Virtual Network Operators (MVNO) and Internet Service Providers (ISPs) to invest in indoor mobile network infrastructure. These actors can act as Local Network Operators (LNO) and build their business models around provisioning of mobile services in locations where there seems to be a "hole" or lack of service coverage in a particular area within the mobile network operators (MNOs) service footprint.

This paper highlights the differences between indoor deployment and outdoor deployment in the light of the available spectrum bands to be used and the possible business models for MNOs and LNOs. In short, the possible investment strategies for provisioning indoor mobile services vary between MNOs and LNOs cases due to economic and regulatory aspects surrounding them. The main finding in this study indicates that the willingness of MNOs to invest in dedicated indoor solutions is driven by the balance between the potential revenues and the deployment cost. Moreover MNOs have more spectrum and investment options compared to LNOs who must bond their investment strategies to the available spectrum resources (i.e. the regulations of spectrum access).

Keywords— *Cost and capacity analysis, Investment Strategies, Licensed and unlicensed spectrum, Outdoor and indoor network deployment, Mobile broadband, Spectrum access, spectrum authorization schemes*

1 Introduction

The demand for mobile broadband access has increased dramatically in recent years in terms of mobile connection numbers and traffic volume. Further on; most of the data traffic in mobile networks originates from indoor locations such as office buildings and shopping malls. The main challenge facing mobile operators nowadays is how to extend their wireless coverage inside buildings to deliver better coverage and higher capacity. This challenge cannot be overcome easily by outdoor mobile networks due to the attenuation of the radio signals within buildings. This problem is more exacerbated for wireless service providers that use higher frequency bands for their transmission medium since high frequency radio signals attenuate more rapidly inside concrete or steel structures. Higher data rates are dependent on the level of received radio signal at the end user's terminal; therefore it is important to extend the network coverage capabilities of the macro-network into more confined radio environments.

WiFi and femtocell are gradually becoming potential technologies for provisioning mobile services within indoor locations due to technology maturity and reasonable deployment costs. In spite of the attractiveness of the use of the unlicensed spectrum solution (namely Wi-Fi), studies as in (Kang, et al., 2012) highlight the possible negative impacts on the network capacity resulting from network densification coupled with the lack of good interference coordination mechanisms. Moreover, the lack of seamless handover solutions between Wi-Fi and cellular systems may lead to lower user experiences. Deployment of femtocell networks could be a solution that mitigates the interference problem and enhances the user experience as it operates in the same licensed spectrum bands of the outdoor macro-cell networks. Furthermore, in femtocells' case the mobile operators can assure customers the required quality of service through the efficient spectrum use (Kang, et al., 2012).

Securing the licensed spectrum for indoor femtocell deployment is always a challenge for MNOs. However the use of TV white space and radar bands based on secondary access schemes and the emerging LSA scheme have presently attracted more attention these days. Moreover changes in the views and practices of prominent National Regulatory Authorities (NRA) that had been treating femtocell deployments similar to the outdoor mobile deployment are noticed in the last few years. For example OFCOM, the UK's telecom regulator is discussing the possibility of allocating portion of the 2.6-GHz band for exclusive femtocells deployment. Moreover in Sweden, the Swedish telecom regulator (PTS) is planning to allocate 5 MHz in 1.8 GHz (IMT band) for unlicensed use by first quarter of 2014.

Many publications that address the technical and business issues of the use spectrum resources exist in literature. The principle objective behind such practices had been to explore the optimum ways for securing the future spectrum demand for high capacity wireless networks, with special focus on indoor deployments. The use

of secondary access spectrum option by incorporating cognitive elements in deployed femtocells (cognitive sharing for licensed spectrum) has been discussed in (Matthias Barrie, 2012). In the same context, two spectrum schemes (i.e. split spectrum and common spectrum) for the femtocells deployment in a 4G network have also been addressed in (Bai, et al., 2009). A simple decision model that examines the possible choices for a potential secondary spectrum entrant considering cost and revenue components have been introduced in (Weiss & Cui, 2012). Moreover, some studies discuss the different spectrum value in the context of outdoor deployment and its impact on the firm's strategic position in the market (Mölleryd, et al., 2010). While in (Chiras, 2012.), deployment of femtocells by utilizing the TV white space has been studied in relation to different scenarios available to the involved actors; namely the Mobile Network Operator, Facility Owner, Wi-Fi operator and only a TV White Space operator. Similarly, a techno-economic evaluation of the LTE-femtocell deployment in TV White Space versus the use of licensed spectrum has been performed in (Karonis, 2012).

The aim of this paper is to discuss the perceived differences in the spectrum value between wide and local mobile network deployments. The discussion has been complemented by exploring the investment decisions of different actors in indoor mobile markets focusing on the available schemes to access the spectrum resources. Authorization schemes such as licensed, unlicensed, shared access (secondary access) and licensed shared access (LSA) has been used in this discussion and analysis aiming to answer the following questions:-

RQ1: How the value of the spectrum resources varies between the outdoor deployment and indoor deployment scenarios?

RQ3: What is the impact of the different spectrum authorization options on the actor's investment strategies?

2 Methodology and Scenarios

A dual quantitative and qualitative research study is chosen to perform the work in this paper. The quantitative part of the study is devoted to discuss the differences between macrocell and femtocell deployments focusing on deployment cost and spectrum demands. The qualitative part is intended to enrich the discussion by identify the different actors in the indoor mobile market context and their associated investment decision in view of the available spectrum access options. Towards this end, representatives from industry and regulatory authorities had been interviewed during the period 2010-2013.

2.1 Description of the Quantitative Study

2.1.1 Users Demand

To perform the quantitative part of the study, the deployment of a mobile network infrastructure in a densely-populated business district in an area of one square kilometres has been considered. Ten thousands mobile subscribers are assumed to be uniformly distributed in ten (10) five-floors buildings within the aforementioned business district. The expected demand and capacity requirement in this business district can be estimated based on the statistics periodically released by the Swedish regulatory body (PTS) on the monthly subscriber demand in the country. Guided by PTS forecasts, 5 GB and 20 GB per month and subscriber are assumed in low and high demand levels respectively.

The deployment cost incurred to satisfy the subscribers demand within the concerned area using either macrocells or femtocell deployment solution depends on the number of base stations that need to be deployed. In order to estimate the number of base stations in each deployment solution (i.e. macrocells and femtocells), the coverage and capacity characteristics of the used radio base stations (RBSs) need to be specified. The achieved capacity per RBS varies according to the used radio access technology (RAT) and bandwidth. We consider a radio access technology with spectral efficiency of 1,67 bps/Hz; this number can represents the average spectral efficiency in a typical LTE macrocell. However in the femtocell case, an average spectral efficiency of 2 bps per Hz is assumed due to the expectation of better coverage (i.e. high Signal to Interference and Noise ratio (SINR)). Beside the RBS capacity, the cell-size of the used radio base station affects the required number RBS as well. By using the same methodology as in (Markendahl & Mäkitalo, 2010), cell radius of 3 Km and 20m could be estimate for macrocell and femtocell respectively.

2.1.2 Cost Structure

The components of total investment cost to be borne by operators to deploy a mobile network to satisfy the anticipated users demands as previously described, includes the radio site build-out cost (i.e. civil works, radio equipment and backhaul solution, auxiliary systems etc.) in addition to the spectrum license fee. In Sweden, The cost of deploying one macrocell ranges between k€ 50 and k€ 200, for the purpose of this paper, the cost of deploying a new macrocell site is taken to be around k€ 100. While the deployment cost per base station in in the femtocell deployment case is estimated to be in order of k€1.

2.2 Description of the Qualitative Study

The primary data for enabling the conducted qualitative analysis was collected via a semi-structured data collection method where representatives from industry and regulatory authority have been interviewed. A first round of interviews was conducted in year 2010. Here Swedish mobile operators TeliaSonera, Tele2 and

Telenor and telecom manufacturers Ericsson, Huawei and Nokia Siemens Networks (NSN) were interviewed about drivers and obstacles of network sharing in general. Interviews were also made about indoor deployment solutions and business models. In addition to the actors mentioned above, interviews were made with the Swedish and UK regulators (PTS, Ofcom), with equipment providers and system integrators (Absolute Mobile, MIC Nordic and Powerwave), with the Swedish real estate company “Jernhusen” and with big organizations using indoor solutions (the Swedish parliament and Uppsala University).

In year 2012 a second round of interviews was done with focus on indoor deployment, shared solutions and the role of third party actors. In addition to telecom manufacturers (Commscope, Ericsson and NEC) we interviewed companies with focus on local network solutions and services (Cloudberry, Icomera and MIC Nordic) and on management of networks of other actors (Ericsson Global Services and 3GNS). Valuable inputs were gathered from train companies in the UK and in Sweden (Keolis, SJ, SL and Transitio) as well.

3 Spectrum Authorization Schemes

Providing more frequency spectrum is one important means of meeting the rapidly increasing demand for wireless data in a cost-efficient way. As the demand for high data rate wireless services continues to increase, the spectrum availability becoming an issue; the Frequency Allocation Tables for many countries might give the impression that the RF spectrum is over-used and congested. But measurements of actual spectrum usage show that depending on location, frequency, and time of day, large amounts of spectrum are being underutilized (FCC, 2013) (International Telecommunication Union, 2012) (BEREC/RSPG, 2011). This waste is caused by inefficiencies in the fixed legacy approach to spectrum licensing where a single licensee is allocated a specific frequency band, and is bound by particular technology constraints within that band. This licensing approach overlooks the fact that the licensee may not be using that spectrum all of the time or in all locations.

To resolve inefficiencies of the traditional spectrum management schemes, regulators have looked at more flexible and dynamic ways of licensing spectrum. For example, the European Commission (EC), following the footsteps of the US regulator, wants to create a framework for scarce radio spectrum to be shared by multiple technologies and players. Today the EU took a step towards formalizing that, with the introduction of a proposal for spectrum sharing Announced by Neelie Kroes, VP for the European Commission. The EU proposal highlights the importance of paving the way for forms of sharing the radio frequencies; as well as the need to create incentives and legal certainty for innovators (Commissioner, 2013).

Taking into account the emerging and historical evolution of the spectrum authorization schemes, two main practices for allocating and authorizing the use the radio spectrum resources could be identified; namely the Individual Authorization and General Authorization, as shown in Figure.1. However as will be illustrated in

the following subsections, many practices and the authorization options are continuously emerging from these two broad options in view of the technological advances and regulations harmonization activities at the continental and the international levels (METIS2020, 2013).

3.1 Individual Authorization (Licensed)

In the individual authorization practice, the right to use a specific spectrum band is exclusively granted by the National Regulatory Authority (NRA), to specific actor for certain period of time and within specific geographical region. Two schemes of spectrum access authorization exist within the individual authorization based on the concepts of primary usage and secondary usage as shown in Figure.1.

In the authorized primary license, the licensee will have an exclusive access right to use the assigned spectrum and enjoy protection from harmful interference caused by secondary users. However, other primary license holders with equal access rights could exist in the same spectrum band, this scheme known as co-primary sharing (or shared primary access), e.g. mobile service (IMT) and Fixed Satellite Services (FSS) co-existence in 3.5 GHz band.

In the authorized secondary scheme the aim is to allow other users to use the spectrum (or part of the spectrum) that has already been allocated to one or more primary users by applying appropriate sharing rules that protect the services of the primary users and provide a certain level of QoS for the services of other licensees. Fig.2, gives a good illustration of the emerging and the evolving concept known as Licensed/Authorized Shared Access (LSA/ASA) which is a framework or arrangement to share spectrum between a limited numbers of users. Under the LSA framework a primary license holder (incumbent) will be allowed to grant spectrum access rights to one or more other users who can use the band in accordance with a set of pre-defined conditions and regulations (METIS2020, 2013) (Zander & MÄHÖNEN, 2013) (Forge, et al., 2012) (Parcu, et al., 2011).

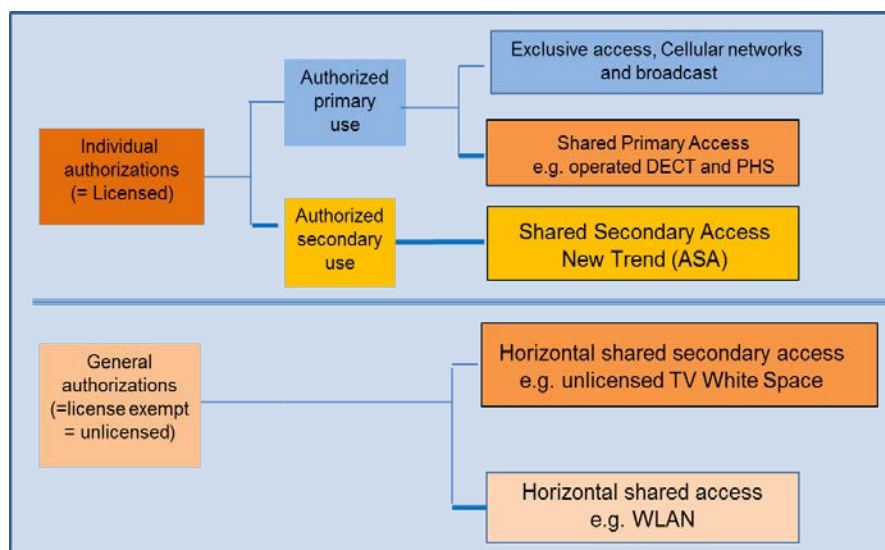


FIGURE 1: SPECTRUM AUTHORIZATION OPTIONS

3.2 General Authorization (Unlicensed or License exempt)

In the general authorization practice, the access right to use the spectrum is granted without any license fee to all actors if certain technical and regulation conditions are met. These unlicensed bands are shared between different systems without any guarantee of any sort of interference protection, which may jeopardize the QoS. As illustrated in Figure.2, two types of General Authorization could be seen; namely unlicensed shared access (also known as Horizontal Shared Access) and the secondary horizontal shared access. In the Horizontal shared Access, users share the band horizontally without protection rights against each other (the most common example is the ISM band at 2.4 GHz). While in the Secondary Horizontal Shared Access, there is a condition to protect the service of users with higher priority (primary users). The secondary access in the VHF/UHF TV band, often referred to as TV white space (TVWS), could stand as good example of the Secondary Horizontal Shared Access (Simic, et al., 2012) (Forge, et al., 2012).

3.3 Light-licensing

Light-licensing is another spectrum access scheme that mixes the aspects of individual authorization and general authorization schemes as shown in Figure-2. Light-licensing is typically applied in situations where there is no or little immediate concern about interference. However it will be desirable from NRAs spectrum management perspective to perform a check if the planned usage is likely to cause problems to other already existing usages; and accordingly a record about the spectrum use will be required through automated self-service licensing, e.g. user self-registration of radio devices in an online database with automated interference check (METIS2020, 2013).

Individual authorisation (Individual rights of use)		General authorisation (No individual rights of use)	
Individual licence	Light-licensing		Licence-exempt
Individual frequency planning / coordination	Individual frequency planning / coordination	No individual frequency planning / coordination	No individual frequency planning / coordination
Traditional procedure for issuing licences	Simplified procedure compared to individual licensing	Registration and/or notification	No registration nor notification
	With limitations in the number of users	No limitations in the number of users nor need for coordination	
Source: CEPT ECC Report 132			

FIGURE 2: LIGHT –LICENSING SCHEME

3.4 Spectrum for Femtocell: Licensing and legislative framework

Several national and international regulatory bodies have taken specific steps to clarify issues of policy and regulation relating to femtocells. As a new technology, femtocells do raise numerous questions about the modifications that may be necessary on the existing regulation framework. In this regard issues such as the impact of femtocells on spectrum licensing, public health concerns (power levels for femtocells operation), security and privacy concerns beside the ownership of femtocells need to be addressed. To answer the main regulator concerns about how to allocate spectrum resources for femtocells deployment, two possible operation types for femtocell should be considered; i.e. WiFi-like operation (unlicensed spectrum) and cellular system like operation.

Regulators mostly prefer not to allocate exclusive frequency band for femtocell deployment. In Europe, Radio Spectrum Committee (RSC) state that "femtocells operate as part of the operator's existing network (using the same frequencies) and that the operator remains in control of the femtocell at all times, it is reasonable therefore to assume that femtocells will comply with the existing technical licensing conditions in each specific case" (Samllcell-Forum, March 2011). Similar approach is adopted in the ASIA-PACIFIC TELECOMMUNITY (APT) as can be found in the published questionnaire in September 2011 (APT, September 2011). APT regulators are convinced that although Femtocell Access point (FAP) may be installed in user premises, a key feature of its operation are monitored and controlled by the host network. Apart from this view, in which the Femtocells operate in licensed or regulated spectrum (Unlike Wi-Fi), some regulator bodies are discussing the possibility of allocating portion of the 2.6-GHz band for exclusive femtocells deployment (such as OFCOM) or using part from the unlicensed 1800 MHz in Europe and USA, that traditionally allocated to the DECTS for femtocell deployment.

An international agreement and harmonized spectrum allocations may be required to enable private individuals and local operators (i.e. such as facility users) to deploy and use femtocells without being tied to the radio regulation in specific country (Wi-Fi like operation).

4 Spectrum Value and Deployment Strategies

The use of low frequency bands for outdoor deployment (wide area coverage) are of significant benefits due to their good propagation properties such as long range and the low wall penetration losses. On the other hand, wide bandwidth is beneficial not only in provision of high data rates and capacity but also from a cost perspective. In general, the value of additional spectrum in the outdoor deployment can be figured out by knowing the additional costs incurred if the additional spectrum needed was not acquired. Analysis using this so called engineering value is presented by many researchers (Plum Consulting, 2011) (Australian Communications and Media Authority, 2009) (Mölleryd & Markendahl, 2013). In many cases the engineering

value showed great variations due the assumptions made and the engineering value relation to auction prices it may vary greatly as well.

In essence, more spectrum bandwidth in outdoor deployment means that less number of base stations will be required to satisfy a given demand; which consequently means considerable cost savings as can be seen from Figure-3. In Sweden the mobile operators have spectrum allocations in the 800, 900, 1800, 2100 and 2600 MHz bands. In the three upper bands the operators have up to 60MHz. However, with network sharing and spectrum pooling cooperating operators can have well above 100MHz. These benefits are evident when compared to the benefits of operators with less amount of bandwidth as can be extracted from Figure 3. Moreover, in outdoor deployments, licensed shared access (LSA) is beneficial as it gives the operators extra exclusive usage rights and can be added to their licensed spectrum which move their deployment cost to the right in Figure 3. Other types of spectrum access are of less interest for outdoor deployment since other users may have access to them as well. In contrast, the deployment of indoor wireless access implies the presence of short range communications in spotty locations. The positive impact of wall penetration losses lead to the reduction of interference from neighbouring cells especially when higher frequency bands are utilized. The small coverage area of dedicated indoor nodes is the main enabler for re-using the spectrum resources many times. Moreover, in indoor deployment scenarios, the use of more spectrum bandwidth do not necessarily lead to less number of radio base stations, this is due to the coverage bottleneck where specific number of femtocells will be required to cover each floor any way as shown in Figure-3.

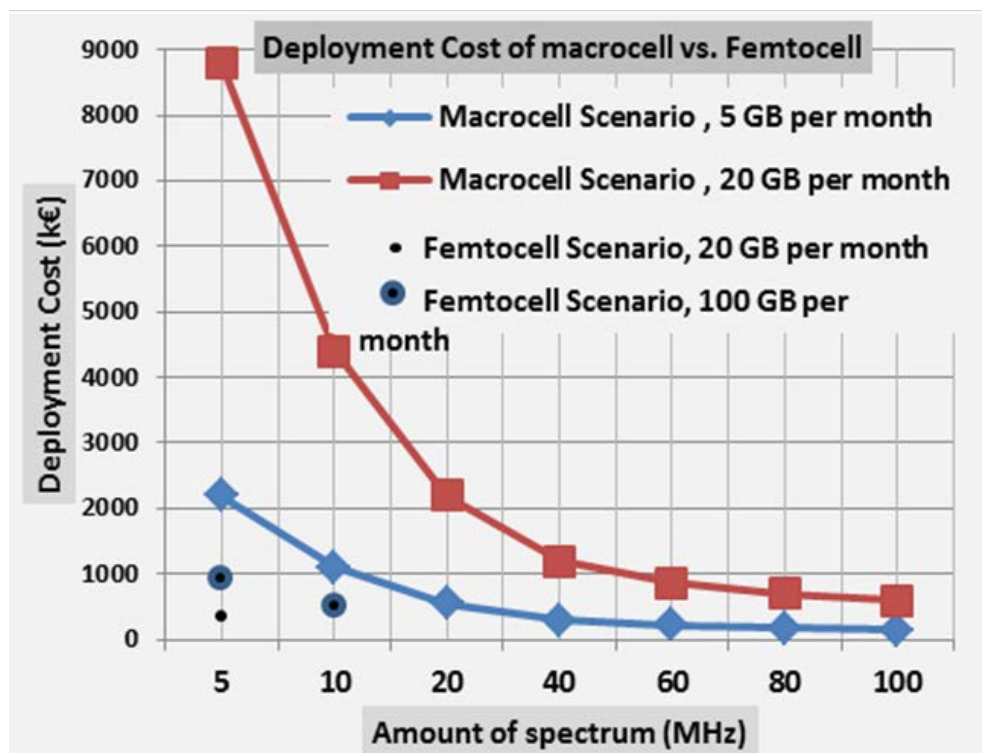


FIGURE 3: DEPLOYMENT COST: MARCOCELL VS.

5 Actors in indoor mobile Broadband Market

Traditionally, investments in mobile network infrastructure made by mobile network operators (MNOs) have been motivated by the long-term licensing policy that gives MNOs the right to utilize spectrum blocks exclusively and hence, the ability to keep new competitors out of the market. Mobile network operators, such as Vodafone, Orange and T-Mobile, employed dedicated armies of network engineers to build and manage industry infrastructure. Nowadays this vertically integrated value chain, in which all business roles are handled by the MNO, is changing toward Horizontal unbundling approach where mobile network operators started outsourcing network construction and operations to service providers, typically the equipment suppliers. Such shift in value chain are pushed by changes in customers' demands, technological advances and regulations pressures. Moreover, cooperation strategies between networks operators are taking place. The joint-ventures to deploy a denser 3G and 4G networks in Sweden can be a good example of cooperation strategies between MNOs. In this regard, during the last decade TeliaSonera has offered mobile broadband services using a shared network together with Tele2 and then entered into joint venture Net4Mobility with Telenor. It seems that Tele2 found a lot of benefits in network sharing that overcome the drawbacks of being less independent (Chambers, 2013). In forthcoming subsections, four types of actors/companies will be introduced along with their possible roles in the indoor mobile ecosystem that includes network operators (i.e. MNOs and MVNOs), Equipment Vendors and solution providers, internet service providers (ISPs) and Facility owners shown in Figure-4 will be covered.

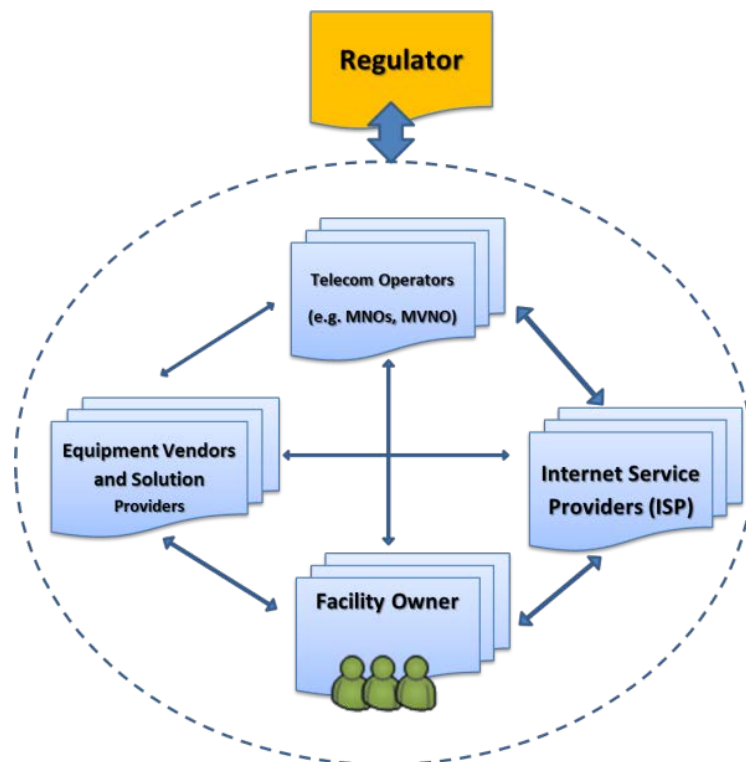


Figure 4: Actors in Mobile Ecosystem

5.1 Mobile Networks Operators (MNOs)

Mobile Networks Operators (MNOs) are traditional stakeholders dominating the mobile business domain. MNOs typically deploy dense outdoor cellular networks (i.e. macro, micro and Pico base stations) which enable national and regional level coverage. MNOs rely on outdoor cellular sites for the provisioning of good Quality of Service (QoS) and for sustaining competitive advantage in the market when availability of a stable and guaranteed access to spectrum resources i.e. (License Protected frequency bands) is maintained. As the licensing spectrum strategy bears high-volume capital expenses, MNOs always favor business activities that leverage their costly investments in spectrum licensing. Based on the foregoing discussion in section 4, the addition of more spectrums can lead to overall reduction in cost as long as the spectrum price remains low compared to the network infrastructure cost: a condition that is challenging to indoor deployments. This explains why MNOs are reluctant to use their licensed spectrum bands for indoor deployment, even at the expense of QoS. Moreover, deploying an indoor mobile network brings extra activities and overhead to MNOs, normally together with the need to establish relations with a number of facility owners; a matter which is not within the scope of the MNO core business. However, the motivation for undertaking wide-scale indoor deployment may be attributed to the phenomenon that around 80% of the mobile traffic comes from indoor locations as per Cisco forecast and hence from the pressing need for good indoor coverage and high capacity. Benefits open to MNOs include, among others, decreased customer churn, increased customer loyalty, delivery of location enabled services and bundled offerings, proliferation of customer lifetime value.

In response to the data traffic explosion, MNOs consider using solutions such as offloading the mobile traffic into the widely adopted wireless local networks. The problem facing the use of this approach is the fact that Wi-Fi network has not been designed as a mobile technology; i.e. the mobile subscribers cannot seamlessly move between Wi-Fi networks and outdoor cellular network sites. That is why more attention is given nowadays to indoor smallcell deployments (i.e. femtocell) which are perceived as a means that allow network operators to have better control on the provided QoS compared with case of WiFi deployments. The question here is there a need to furnish dedicated spectrum resources for femtocell deployments or not. If the same macrocells frequency bands are used for femtocell deployments, problems of co-existence and interference may arise. On the other hand, mobile network operators are usually not willing to allocate part of their licensed spectrum for dedicated femtocell deployment as mentioned early. The solution may be furnished by the recent advances in WiFi standards and by the new trends in the manufacturing and deploying integrated Femto-WiFi (IFW) access points that may, hopefully eliminate such shortcomings. IFW will allow MNOs to exploit both cellular and Wi-Fi coverage while delivering a seamless communication experience to the end users. Even though, the IFW access points still need to use the licensed bands of MNOs.

5.2 Mobile Virtual Network Operators (MVNO)

According to the International Telecommunications Union (ITU), MVNOs are “operators who provide mobile communication services to users without their own airtime and government-issued licenses”. Mobile Virtual Network Operators (MVNO) normally depends on the infrastructure of the MNOs to provide their services without having mobile networks of their own. This dependency may vary from leasing the radio transmission capacity (where the MVNO is known as a full MVNO) to extreme form in which the MVNO provides its contents or services on top of the MNO network (where the MVNO is called a service provider (SP) or a thin MVNO). The SpringMobil case, in Sweden, indicates that MVNO could own its indoor mobile network infrastructure and enter into different roaming agreement with a hosting MNO. Here, Spring Mobil provides indoor coverage for voice services at the company premises whereas nationwide outdoor coverage is provided by the partner Tele2 (which recently acquired Spring Mobil).

5.2.1 Internet Service Provider (ISP)

The Internet Service Provider (ISP) is known to be an actor that provides Internet connectivity. The ISP usually concludes a long term-contract with each of its end customers, whether residential or enterprise, to offer the customer Internet access through different connection means such as copper wires, fiber optic or fixed wireless access network. ISPs can also provide Wi-Fi hotspots in public places for their nomadic broadband customers. In this case, ISPs are referred to as Wireless Internet Service Providers (WISPs). WISPs have been established in the mobile market as providers of local area broadband access using the unlicensed band of the Wi-Fi technology. WISPs enjoy competitive advantages as they have their own backhaul solutions. Locations targeted by WISPs are the highly crowded public venues such as airports, hotels, restaurants, pubs, touristic places, etc. WISPs reap or obtain their income according to the venue served and the business model adopted. For instance, in open public places like airports or railway stations, the end user might pay a monthly or single-time access fee to the WISP network. However, in places like hotels or pubs, the venue owner might offer free internet access to its residents as an added service for differentiation and improved customer satisfaction as per an agreement or a contract signed between the venue owner and the WISP.

Vodafone Greece and HOL (Hellas Online) stand as a noteworthy WISP example. The two operators jointly deployed on the 1st of April 2013 the first public combined 3G Femto-Wi-Fi service for the customers of more than 150 restaurants and fast-foods across Greece. By using the service provided, which is called “Free 3G Hotspot”, the customers of two restaurant chains, Flocafe and Goody’s, can connect freely to the Internet using either the 3G Vodafone network via an indoor femtocell or using HOL Wi-Fi service. When a Vodafone mobile subscriber enters the “free” area, hand-over to the smallcell is achieved. After a five minutes delay the customer receives an SMS announcement about the free-surfing area. When the

mobile device is registered to the indoor cell, the generated traffic is free of charge for Vodafone's customers only being part of the monthly data allowance.

5.3 Facility Owner

Facility Owners (FOs) who have direct interaction with customers find themselves gradually involved in the mobile business. Facility Owners are always keen to provide high quality mobile broadband in their premises to enhance increase their customer satisfaction. The end-users in the FO's indoor mobile network could be customers of the FOs core business (e.g. hotel) or passers-by the site location (e.g. mall). FOs can deploy and operate their own indoor mobile network infrastructure or authorize a third party to deploy indoor network infrastructure within their premises. Due to their major assets, i.e. site operation and their customer base, FOs have strong bargaining position with actors willing to enter the indoor mobile broadband business.

5.4 Network Vendors and the Solution Providers

Nowadays network vendors such Ericsson and Huawei play an additional role in the mobile ecosystem by offering fully outsourced network management services to their clients. Vendors playing such a role are known as managed service providers (MSPs). This role is not restricted to network vendors, but small companies can play it as well. Cloudberry, a company that supplies smallcells to consumers and enterprises in Norway, stands as a notable MSP example. It owns smallcells network, and offers its services to big enterprises and mobile operators. The business model of Cloudberry Mobile centers around offering a new type of service called SCaaS (i.e. Small Cells as a Service) by deploying and operating small cell networks that both major and smaller mobile operators can use. The motivation behind Cloudberry business model is the ability to provide mobile coverage and capacity where it is needed by the customers; especially in places hard to be covered by the outdoor cellular networks.

5.5 Spectrum Options and actors business relations

As stated in the previous sections, the indoor mobile market comprises many players, e.g. MNOs, LNOs, Internet Service Providers, Real Estate companies, Hotel as shown in Figure 4. Different levels of cooperation between these actors exist depending on their business models and the available spectrum access options.

5.5.1 Managed Service Providers (MSP)

MNOs perceive the use of secondary access, unlicensed bands or LSA as additions to the existing licensed bands of MNO's that can provides them with flexibility to expand their networks coverage and capacity to indoor locations. The advantage of using dedicated frequency bands or LSA, for indoor deployment will enable MNOs to have better network planning capabilities in terms of avoiding possible interference between indoor and outdoor cellular networks, assuring QoS levels and imposing security measures as illustrated in Figure-5. Although MNOs

may be looking into alternative/additional spectrum bands using schemes like unlicensed, licensed shared access or dedicated licensed bands (local licenses) for indoor mobile deployment as shown in Figure-5, they are not really keen or willing to deploy indoor mobile network infrastructure. Furthermore, they tend to outsource their operation and maintenance activities as well. Such situation avails an opportunity for managed service providers (MSP) businesses to emerge and flourish. MSPs may utilize part of the MNO's spectrum resources to deploy the indoor mobile network infrastructure as shown in figure-4. Ultimately this business strategy option depends on the extent to which the MNO aims to save costs and take the risk to utilize part of his licensed spectrum for indoor deployment.

5.5.2 Local Network Operators

Actors such as WISPs may opt for an independent business strategy where they invest, deploy and operate indoor mobile network infrastructure and act as LNOs who's their business models concentrates on the provision of mobile services within spotty locations characterized by high subscribers demand such as office buildings and shopping malls. The drivers behind the necessity to deploy dedicated indoor systems can be the need to avoid or eliminate the inherent problems of wall penetration losses arising from the use of outdoor base stations and/or the desire of users in the concerned locations to enjoy dedicated and guaranteed capacity.

For LNO, spectrum resources could be secured via different spectrum access options as shown in Figure-5. One option is to use more licensed spectrum which is costly and hard to secure. Hence, actors such as WISPs may prefer to act as virtual operators rather than LNO and use other actor infrastructure, namely MNOs. A second option is to use more unlicensed spectrum bands made available by recent allocations in IMT/IMT-advanced: i.e. the 5 MHz allocated in 1800 MHz. This option is cost-effective and enables seamless operation and interoperability with the existing cellular systems when compared with the use of WiFi. A third option is to exploit spectrum bands allocated for other non-communication systems using the Horizontal Shared Secondary Access authorization scheme (e.g. Broadcasting (TVWS) and aeronautical bands as shown in Figure-5). The key obstacles for cognitive radio and Horizontal Shared Secondary Access authorization scheme are the availability of spectrum, network cost and end-user equipment. In this connection, the use of LSA scheme could provide long-term and stable conditions that may prompt or induce manufacture support for investing in user and network equipment.

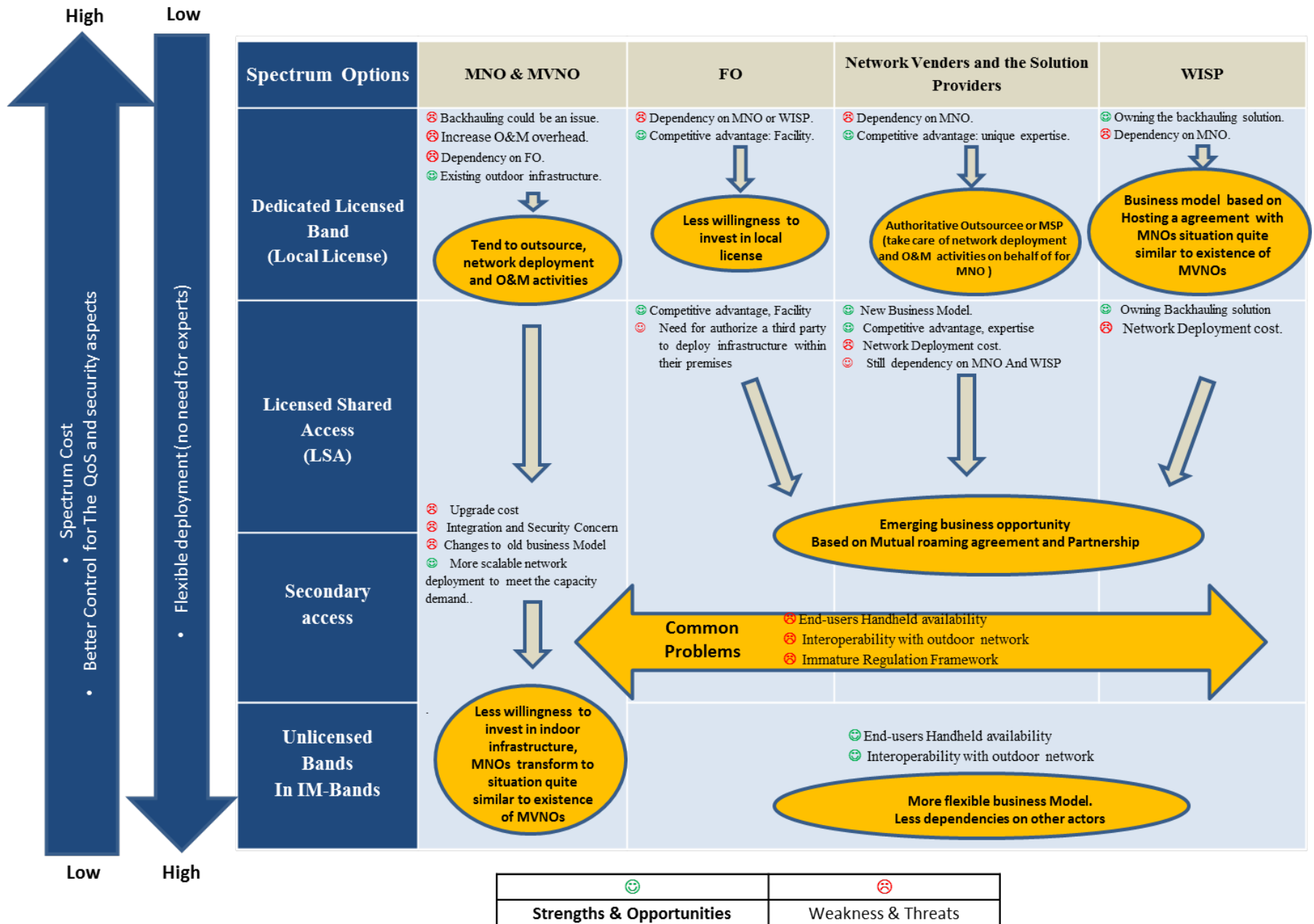


FIGURE 5 ACTORS INVESTMENT STRATEGY AND SPECTRUM ACCESS OPTIONS

6 Conclusion

The worldwide mobile market has witnessed evolutionary changes and significant growth in the past few years. However, the mobile environment has always been mainly challenged, to keep up with this growth and cope with the expanding consumers demand, by the high investment costs of the build-up of mobile network infrastructure and by the limitations on the radio spectrum access and its high acquisition costs. The high spectrum fees levied usually lead to the existence of a limited number of competitors holding long-term (exclusive) licenses. Such an exclusive license protects its owner from the advent of new entrants and encourages him to provide high quality services to be able to sustain a competitive edge in the market. However such exclusive licenses may prompt the formation of powerful oligarchies in national mobile markets as well.

As a consequence of the technological advances in the mobile industry and in response to the exponential growth in wireless data traffic and the increasing importance of wireless connectivity in the economy, the regulatory landscape is changing and heading towards more flexible spectrum management schemes and advanced spectrum access technologies. Furthermore, the use of technical innovations such as the low-cost low-power indoor smallcell to meet the demand for high capacity and the emerging spectrum access options (e.g. secondary access and LSA) may reduce or eliminate the traditional entry barriers to the mobile market (i.e. high spectrum fees and costly network infrastructure). The challenge for a mobile network operator remains to be how to adapt and stay abreast of his fellow competitors.

The issues of frequency bands of interest and the value of using more spectrum bandwidth per radio site in wide and local areas network deployments have been examined. The main findings indicate that the use of more spectrum resources in existing macrocell base stations means that network operators can deploy less number of new sites and exploit their existing infrastructure investments. Moreover in outdoor deployment, exclusive access over long time to frequencies with good coverage and propagation properties (e.g. "low frequency bands") is essential for the network strategic position in the market. Having frequency bands with favorable propagation characteristic enable network operators to provide services of better quality services (i.e. better QoS) in indoor and outdoor locations compared to other operators.

On other hand, the indoor mobile network is characterized by the short-range communication services of indoor mobile networks can be accommodated in the spectrum frequencies having short range propagation characteristic ("high frequency bands"). Moreover, indoor smallcells networks such as Femtocell Access Points (FAPs) are coverage-limited and have two salient merits: firstly, the frequencies can be re-used in more efficient manners and secondly, the use of more frequency bandwidth per smallcell results in overprovisioning of network capacity without significant cost reduction.

The possible investment business strategies of the players in the mobile industry ecosystem in the market of indoor mobile communications have been examined in view of the available spectrum access options. The ensuing results revealed that MNOs, with their long-term licensed businesses in the market of outdoor mobile communications, seek more spectrum to be able expand their mobile network infrastructures into indoor locations in the most cost-effective way. MNOs are reluctant to permit the use of their dedicated licensed bands for indoor deployments, even if it leads better QoS due to the differences in the engineering value of the spectrum resources between indoor and outdoor deployments. On other hand Local network Operators (LNOs), with no licensed spectrum of their own, can only provide mobile services by utilizing unlicensed spectrum resources. However, the possibility to possess spectrum resources at reasonable cost by virtue of the emerging authorization options, such as LSA, will open new business opportunities for LNOs. Furthermore, unlicensed spectrum resources in IMT-Bands and the secondary access (TVWS) could be highly appealing spectrum options for indoor deployments. Moreover, in view of the techniques for assuring quality of service in license-exempt spectrum, and the developments in the policies and regulations worldwide, the usage of LSA and secondary access authorizations could soon become an enabler for MNO's indoor business as well. In this regard, the harmonization of spectrum use for LSA and secondary access network across multiple countries will lead to economies of scale in the equipment production and in encouraging more equipment vendors to provide products built around a common set of frequencies and standards suitable for all regions and countries.

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