The Shared Spectrum Service, Technology and Network Provision in Mobile Communication

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Abstract. This text describes some developments of an explosive growth in mobile traffic demand. The growth has led to market driven approaches and need for more effective spectrum access and management. Regulatory, technology and economic issues have led to innovative strategic approaches and policies for more effective spectrum usages. This text seeks factors and possibilities to influence spectrum sharing and use of additional spectrum in mobile communication. Wireless network architecture defines functionalities, which impact on mobile subscriber's behavior both technically and economically. If telecommunication services fit together, interfaces between elements and services are the key. Economic assets form a new shared spectrum access, which means ubiquitous technical functionality, new service architectures and interfaces between different radio networks in the value-added chains. The modern radio networks form bit-pipes for added value services. For different stakeholders there are technology environment, economic environment and content wish environment in search for additional spectrum utility.

Keywords: Spectrum sharing and management · Additional spectrum · Cognitive radio · Mobile service · Technology and network provision

1 Introduction

Growth of mobile broadband will be significant in future. Mobile access, development of broadband networks, is increased especially in urban (U) and dense urban (DU) areas [1]. Planning of mobile needs requires efficient network planning, counting of engineering and strategic values. Communication markets are based on information technology (IT), cloud technology, big data handling and social communication technologies. The mobile communication changes customers' behavior: The questions are how to understand changes in mobile communication, how different operators are challenging it, and how subscribers challenge mobility possibilities. Current core competences, which are needed or should be mastered, mean features, which may become critical in future. Some of the competencies should be hold and some should be outsourced. Facilities of mobile telecommunication consist of mastering the

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technology, management all the services, logical chains and subscribers' wishes. Subscribers of mobile communication buy mobile products to solve their communication problems, regulators to serve nationwide needs and operators to make communication network and services profitable. Mobile system coverage, capacity, applications and modern devices facilitate demands for private and enterprise usages as well as in rural and metropolitan areas. Additional spectrum availability and agreement may fulfil coverage and capacity needs, if all quality issues (Quality of Services, QoS) are fulfilled [2].

Spectrum is an important asset and resource for mobile network operators (MNOs) and additional spectrum could provide significant business opportunities. The spectrum sharing concept has been understood in many international discussions meaning the idea of where MNOs could share spectrum from another type of spectrum users (incumbent) under the permission of the (national) spectrum regulator. On regulator point of view spectrum resourcing requires good management [3]. European RSPG (Radio Spectrum Policy group) search activities how to use spectrum more actively. RSPG make definitions and recommendations how collective use of spectrum could be possible. Those rules and instructions are listed in the document ECC Report 205 [4]. The report defines frequency allocation and authorization processes to harmonize the spectrum use in Europe and the report defines:

- individual rights of use
- national authorization

On business point of view the issue is linked to functional architecture, value network and financial model. The value of shared additional spectrum has to be defined. One might guess that local mobile sharing requires a reasonable large subscriber base and well defined network launch and management. More over introduction of growth in business of a MNO has to create new innovative services in creation of additional growth. Performance is still a challenge in spectrum use, because it requires flexibility, capabilities to learn radio environment and control of unpredictable operation in radio environments.

In USA the PCAST report [5] indicates that in the coming years, access to spectrum will be an increasingly important foundation for America's economic growth and technological leadership. In US the study covers the technical requirements, architecture and operational parameters of the proposal Spectrum Access System (SAS) for the 3550–3650 MHz band and not the band 2300–2400 MHz as in Europe. Also to launch the 4G LTE sharing additional technology additional tests will be required. The mobile communication changes the way of behavior and following question could be asked:

- What are spectrum management principles for broadband wireless, content services and applications in sharing?
- What are the technical solutions?
- How the value of shared spectrum could be defined and how it emerges with the mobile broadband in macro and small cell environments?

The rest of this paper is organized as follows. The mobile service provision is presented in Sect. 2. The mobile technology provision in Sect. 3 and the mobile network value provision in Sect. 4. Conclusions are drawn in Sect. 5.

2 Mobile Service Provision

Mobile communication business is characterized by political or governmental interest, cross-border work between countries, operators and services. Mobile communication subscribers can stream audio and video data to the network or load live events from the network. Loading can be done intelligently as the network bandwidth changes, but in real time traffic (like video-on demand, VoD) radio interface capabilities must be continuous. This includes also hand-over (HO) in case a subscriber is moving or is in a bad spectrum field. According to Cisco document [6] real time secondary distribution services requirement for standard definition (SD) video bit rates are 2–4 Mbps and for high definition video (HD) 8–20 Mbps. So the network provider has to manage and ensure the real time service distribution according to service level agreement (SLA). Generally, one could ask what does this mean for mobile telecommunication operators in terms of strategic and network planning. Network infrastructures must be designed for best-effort delivery to meet the exact requirements of next-generation communication services. This includes the real-time video, storage services, servers of internet service providers' networks, which are part of networking (Fig. 1).

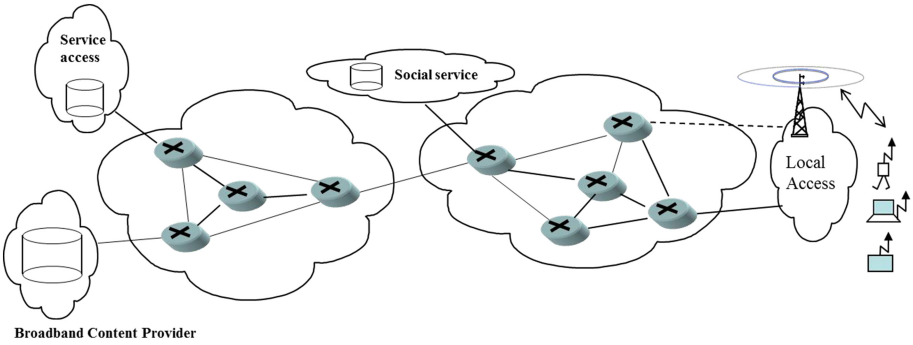

Fig. 1. Communication whenever, where ever: social media, entertainment, cloud computing, banking, Google web etc.

Mobile communication is in front of changes: widespread adoption of new technologies, development of business environment and the way to understand subscribers' behavior in getting new services. In other words it is an opportunity challenge to build new roles for value creation and capturing entrepreneurship [7]. The stakeholders such as spectrum regulators, mobile operators (dominating, incumbent or challenger MNO), subscribers, content-providers and device vendors have different needs in this challenge. Spectrum regulator in a country (National Regulatory Administration, NRA) wants to emphasize innovation and competitive landscape and ensure at the same time equal treatment to all involved stakeholders in spectrum usage cases. Internet players form a source of opportunities, and in some cases internet may be also a threat to nominal pure MNOs. As a whole, content service developers expect MNOs to be

operator bit-pipes in information services. To widen MNOs' operations in some cases MNOs are strongly involved in the background of mobile service provisions. The use of radio systems depend on regulation, wireless business and technology development. Ubiquitous communication because of internet is in front of strategy considerations: mobile services, voice and data are challenged by disruptive alternatives of internet. As MNOs take care of the last mile connection new business opportunities are opened in internet world and subscriber requirement with new technologies open new killer applications.

Additional spectrum can bring some benefits for MNOs, but certain regulatory and operational restrictions must be taken into considerations as well as measurements before network launch. As the smart mobile devices and terminals handle internet connectivity in a native way today, the impact of these internet implementations are changing subscribers' behavior. Spectrum management between cellular, additive (cognitive) radio and/or Wi-Fi (see the Fig. 2) networks has to have technical maturity to handle interaction performance between primary and secondary systems and as well has to have a flexible connection to the public internet.

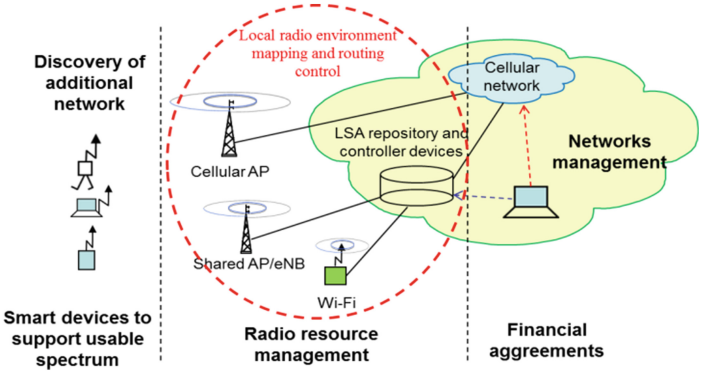

Fig. 2. Shared spectrum management [9]

Communication between networks requires elastic handover processes. In case of connection is from cognitive or Wi-Fi network to internet for capacity reasons, there is no added value of majority of the web traffic to route the data through the operator's core and cellular network. In this case the two networks are in practice totally separate. Management is depicted in the Fig. 2. In modern mobile communication uplink/downlink usage depends on an application. Some of the spectrum has remained unused for the past decade, which means that future candidate applications like terrestrial broadcasting, mobile broadband, mobile supplemental uplink or downlink, etc. application of spectrum requirements are to be defined. Quality requirement of spectrum handover scheme detects link failure and switches the connection to a new spectrum and system. Radio network resource of the MNO network handles access control, load control, power control and hand-over between systems [8].

Changes in mobile communications are sum of widespread adoption of new technologies, development of business environment and understanding how subscribers behave in getting new services. The stakeholders within the use of spectrum mean involvement of spectrum regulator, incumbent spectrum users like dominating MNO and challenger or incumbent MNO and subscribers. Spectrum regulator (NRA) wants to emphasize innovation and competitive landscape and ensure at the same time equal treatment to all involved stakeholders in spectrum usage cases. Internet players form a source of opportunities, and in some cases internet may be also a threat to nominal pure MNOs. As a whole, content service developers expect MNOs to be operator bit-pipes in information services. To widen MNOs' operations in some cases MNOs are strongly involved in the background of mobile service provisions. According to Ofcom report [10] price and speed are driving web-based communication. People at the age of 16–24 are more likely to use their mobile phone than computer in social networking and more and more adults are regular multi-users. Internet browsing is very common activity even when watching television.

The use of radio systems and communication interactors depend on regulation, wireless business and technology development. Ubiquitous communication, because of internet, is in front of strategy considerations: mobile services, voice and data are challenged by disruptive alternatives of internet. As MNOs take care of the last mile connection and networking new business opportunities are opened in internet world. Subscriber requirements and new technologies may open new killer applications.

3 Mobile Technology Provision

LTE FDD has been a mainstream for cellular mobile radio networks. There are references, which show that LTE TDD offers the potential advantages especially for small cell applications. Examples are presented in the documents [11, 12] and according to the documents LTE TDD is well suited to DL/UL traffic asymmetry, using only half of the band compared to FDD. This is the reason why regulators and industry are adopting combination of FDD and small cell TDD to better match the traffic asymmetry of data services and take full advantage of spectrum availability. LTE TDD was specified by the 3GPP already in release 8 for the use of mobile broadband radio access. LTE TDD shares its technical basis with LTE FDD, and LTE TDD is used in many countries already.

Requirement to support local and remote IP access is necessity, which should allow packet data traffic offload via used networks, is it home or corporate network to the public internet. Nowadays internet is a necessity in mobile value provision it is to tackle to the questions - What are the technical solutions – the ITU specification M.1225 [13] defines the combination of technical choices, concepts and a layered structure of radio interface: multiple access technology, modulation technology, channel coding and interleaving, RF-channel parameters such as bandwidth, allocation and channel spacing, duplexing technology, frame structure and physical channel structure and multiplexing.

The performance of shared spectrum is very challenging job for MNOs, device vendors and even local NRAs as regulating body. The interworking requires convincing

use of certain services, the broad technical characteristics that may impact the economics and performance of the system. The sharing receiver should have knowledge of the spectrum availability and usability and what kind of communication needs are (as seen in the Fig. 3). Software is currently large portion of the network and device technical usability. With the increased intelligence by Nielsen [14] internet is a future playground. In OSI model [15] different communication technologies with similar functions are grouped into different logical layers of this model. Quality of software engineering product standards is ISO/IEC 9126 [16], where the usability measures are effectiveness, efficiency and satisfaction. Effectivity, efficiency, safety, utility, learnability and memorability are usability goals of interactions by Preece et al. [17].

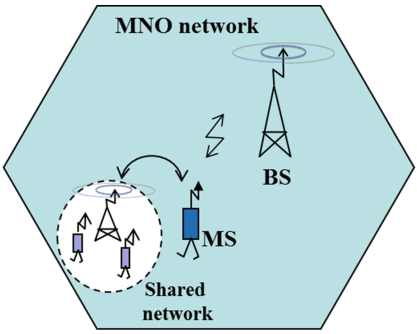

Fig. 3. Communication transfer between MNO macro network and a cognitive small cell

4 Mobile Network Value Provision

Mobile stakeholders have different operational concepts in business activities and in usability of radio network productivity. Productivity concept by Saari [18] defines relation to profitability, economic growth, efficiency, surplus value, quality, performance, partial productivity, need, etc. Model has objectives to exploit a business opportunity and to create value for the telecommunication stakeholders and to fulfill different stakeholders' needs and to create surplus [19].

As internet connection is a necessity in mobile value provision, one could ask: "How the value of shared spectrum could be defined and how it emerges with the mobile broadband in macro and small cell environments"? This approach contributes a more positive perspective for further developments in the mobile communication markets. MNOs and service providers can increase their profits significantly, if they have lucrative killer applications with which the whole market potential will be realized. The competitive advantages and the business models of the key ecosystem players have to count how those emerge in the mobile broadband business. According to Ballon [20] existing mobile business models have to be reconsidered with regard to:

- *value proposition,*
- *revenue model, and*
- *architecture for value provisioning*

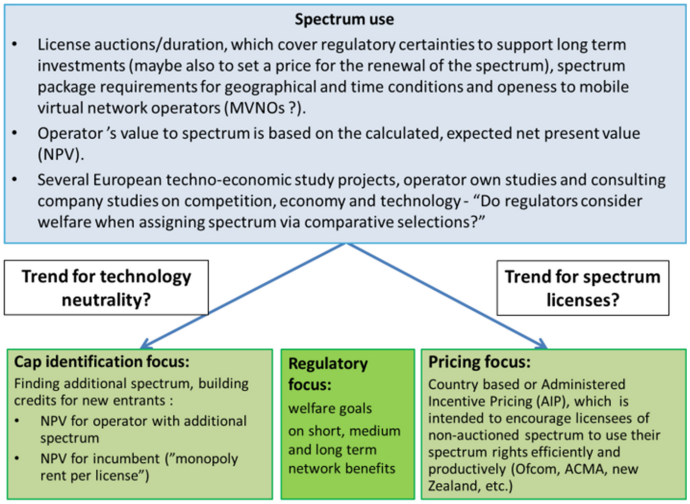

Fig. 4. Spectrum use: ideas from article of Gary Madden and Thien Tran: "Do regulators consider welfare when assigning spectrum via comparative selection?" [21].

Radio spectrum is a valuable and scarce resource, which makes a major contribution to economic and social development, and is necessary in ensuring national and civil security [21]. One view of spectrum use is seen in Fig. 4.

Broadband studies [22] show that economic impact is stronger in the regions of higher level of penetration. The economic goal of the radio spectrum is to maximize the net benefits to society. Spectrum values can also help to get significant revenues for the government. Spectrum value is defined by auctions, spectrum trading or leasing or by administrative means and spectrum management costs are based on authority or regulators rules of a country. Radio spectrum and broadband technology have been found to contribute to economic and business growth at several levels [23]. More efficient business processes like outsourcing services, virtual call centrums, adding virtual working methods, accelerating innovative service solutions and application of new commerce and financial services adopt spectrum efficiency. Mobile broadband telecommunication can be viewed as a methodology, which enables subscribers, society and companies to change their business processes and supply chains in introducing new products and services.

A. Network Sharing, Mobile Virtual Operation (MVNO) and Roaming

Proposals for sharing have been discussed for a long time and the report [24] lists management of sharing cases:

- *Sharing of sites and passive elements*
- *Sharing of antennas*
- *Sharing of base stations*

The passive network element sharing, site sharing and backhaul network of the leasing operator is a joint venture between two mobile operators.

If the MNO has spare capacity, MVNO existence at the markets is possible. The virtual network sharing has effect on capacity at wholesale level. The network capacity is determined on the basis of the MNO's frequency spectrum and the number of sites (capacity/area, subscriber grouping).

The international roaming is typical and supported by the majority of MNOs. The Body of European Regulators for Electronic Communications has launched a public set of regulation proposals, which will bring fundamental change to the structure of the European roaming market. The regulation would require European mobile network operators (MNOs) to open their networks to providers of voice and data roaming services acting as MVNOs, starting in July 2014 [25]. On business point of view is this threat to European MNOs' roaming revenues e.g. will new companies enter the market with compelling prices, brands and service propositions that can compete effectively with European operators? On European level there are guidelines which define some provisions for inadvertent roaming, addressing customer protection measures that operators can consider in roaming cases. In Europe BEREC's proposal for guidelines on roaming regulation is described in [26]. The new European digital market strategy concept is defied in the document [27].

B. Cellular Networks with Femto- and Macro cells

Femto cell is a small cellular base station (BS) designed to be located inside a building and using either DSL or cellular connection to backhaul traffic. The indoor environment is probably the most difficult in which to propagate radio signals. One-third of all mobile voice traffic is generated in the home or office [28]. Femto cells offer network carriers the opportunity to offload a lot of the traffic from their network assets to subscriber home-based cells that are backhauled through the IP core. A small cell base station (BS) is a typically low cost cellular BS with backhaul provided typically by broadband access network. Small cellular cells are offered to subscribers to allow the cellular home operations to improve indoor service coverage with small additional cost to subscribers. Interference management and capacity requirements associate challenges for small cells. As macro cells BS are operator-owned and maintained, small cells may be customer-bought. If there are several small cells in some area with coverage zone of the operator macro cells the operator has to address optimal resource allocation between macro and small cells. Such a deployment may make interference scenarios complicated. The MNO needs coordination between operator's own macro cells and surrounding small cells. In some cases self-configuration can be utilized to avoid severe interferences to maintain the SLA (mobile service level agreement) at adequate level to the small cell subscribers [29, 30].

The introduction of small cells creates a new architecture for mobile operators. The small cell architecture is one component in the networks and operators are looking solutions for addressing the fast-growing wireless data usage demands to provide

higher data rates and better quality of experience to the end-users [31]. According to Qualcom unlicensed LTE can give advances in spectrum efficiency and it provides better range than carrier Wi-Fi [32]. Even though LTE is expected to be the biggest driver for future small cells to deploy for coverage and capacity in high traffic areas, mobile network operators seek tighter integration between cellular and non-cellular.

Multifunction subscriber devices support also other radio systems, like Wi-Fi etc. The load of cellular spectrum environments is freed and home networks can widen with help of DHCP (Dynamic Host Configuration Protocol), where TCP/IP networking parameters are automatically distributed from the DHCP server to computers or smart devices. A network administrator needs are reduced, and user network configurations are set. In home network address translation (NAT, network address translation) provides a method to modify network address information and home network has only one IP address.

One example of small cells is the Japanese government aims to license 120 MHz of the 3.5 GHz band for 3 LTE-TDD operators with the 40 MHz block for each successful bidder with the requirement of commercial network plan in 2016 [33].

C. **Cognitive Spectrum use**

The MNO can use an additional cognitive spectrum for capacity reasons either constantly or for timely basis most probably in dense urban environments. In both of the cases the MNO has to negotiate with local NRA to get permission for the extra use of spectrum and find the proper incumbent and spectrum gap to start sharing joint venture discussions. For the purpose the MNO has to have reasonable subscriber base to make this additional cognitive radio lucrative. Another thing is, are there any other obligations to cover.

In Europe additive spectrum discussions covers the 2.3–2.4 GHz band. The rules and instructions are listed in the ECC Report 205 [4], where frequency allocation and authorization processes are defined. As there are several users in different European countries the interference free use requires high cooperation and time. This is an additional radio spectrum and subscriber has to have this spectrum hole supporting devices. The MNO has to have a repository system (see Fig. 2) to control the traffic balancing and control HO cases. In heavy load use subscriber's device finds an additional spectrum and recognizes spectrum opportunities and channel selection decisions are made. This sharing spectrum usage has to learn how subscribers of the MNO are exploiting the MNO spectrum, and then MNO can exploit the opportunity of sharing. Discovery of an empty local additive (cognitive) radio spectrum block with no additional spectrum incumbent users adds the MNO spectrum capacity. In US the additional spectrum study covers the technical requirements, architecture and operational parameters of the proposal Spectrum Access System (SAS) for the 3550–3650 MHz band [5].

Shared additional spectrum use is now based on network operators, MNO and incumbents, measured spectrum data. From potential users point of view it would be important to characterize how long shared communication channel blocks would be available. This means definitions of call durations and thresholds for changes. In case of increased activity of shared channel subscribers, the systems have to measure and estimate probabilities for a new channel block. Possibilities are either new free own

primary (MNO) resource block, and if those are assumed to be crowded, to discover a new spectrum block of shared access. The situation is more complex as behavior of PUs and SUs are independent random variables and how are usable resource blocks at shared spectrum available? If shared spectrum usage is based on measured shared channel data and expected behavior of PUs and SUs, the MNO and incumbent must or could make suitable connection algorithms for the acceptable use of the shared spectrum, which is sometimes settled case by case. The parameters needed are used broadband bandwidth, type of communication (RT or NRT), various power levels, modulation used, possible neighboring channel blocks, HO procedures etc. Shared channel activities and complexity of communication depend on call durations, which may be based on traffic load distributions and MNO and incumbent network owner statistic and measurements.

5 Conclusions

Mobile telecommunication service architecture requires interfaces between different radio networks in the value-added chains. The modern radio networks form bit-pipes for added value services. For stakeholders additional spectrum mean technology environment, economic environment and content wish environment. Firstly mobile operators need lucrative additional spectrum possibilities, secondly regulators have to have clear procedures for spectrum sharing and thirdly future technologies have to support the additional spectrum sharing. For mobile network operator there are mathematic modelling tools to calculate net presenting values. The main value of this business reasoning is that it requires reasonable good subscriber base to be profitable. Spectrum sharing need also radio environment mapping and routing control to manage network hand-overs and continuous mobile communication.

The discussions of the shared mobile communication form a question can additional spectrum provide significant business opportunities? On business point of view the issue is linked to network functional architecture, value networks and finance models. Performance is still a challenge in spectrum sharing and this requires flexibility, capabilities to learn radio environments and control of unpredictable occasions in the radio environment. Possible use of additional spectrum requires support of wireless devices and a network provider must combine and manage last mile connection and meet transport technologies to serve intended service level agreement needs. Mobile broadband will take a significant telecommunication market share and assumption is that the IT industry's growth, cloud technology, big data handling, social technologies using mobile are changing customer behavior.

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