Micro Operators Accelerating 5G Deployment

(Invited paper)

Marja Matinmikko-Blue and Matti Latva-aho
Centre for Wireless Communications (CWC)
University of Oulu
Oulu, Finland
marja.matinmikko@oulu.fi; matti.latva-aho@oulu.fi

***Abstract*—5G networks will address a variety of location specific deployment scenarios with stringent requirements for end-to-end service quality. This paper reviews the recent market and technology related trends in 5G deployments. To accelerate 5G deployment serving location specific needs arising in specific high-demand areas, the concept of 5G micro operators was recently proposed to open the mobile market for new entry. The micro operator concept allows different stakeholders to take a local operator role to deploy and operate small cell networks in specific premises and offer context related services and content. The local 5G micro operators can operate a closed network to serve its own customers, an open network for mobile network operators' (MNO) customers or a mix of both. This paper expands the recent micro operator concept by identifying and addressing key regulatory elements related its introduction to the mobile communication market. These elements include the role of operator with rights and obligations, spectrum authorization for obtaining quality guaranteed spectrum, access rights to infrastructure, and building of indoor networks.**

Keywords—5G; mobile network operator; regulation; small cell; spectrum sharing;

I. INTRODUCTION

Widespread deployment and timely take-up of new very high capacity networks are seen as the key enablers for realizing full economic and social benefits of the digital transformation for industries and the entire society [1]. The new generation of mobile communication networks known as 5G is expected to play an increasingly important role to revolutionize the traditional mobile communication market and serve increasingly stringent requirements for service quality that arise from the different vertical sectors' needs to connect billions of devices [2].

The on-going 5G development is largely based on local dense small cell network deployments planned for higher carrier frequencies as well as network function virtualization for improving implementation flexibility [3]-[4]. The operations in the higher frequency bands in the millimeter wave range (mm-wave) inherently limits the network coverage to local areas, which calls for new efficient deployment models and spectrum authorization models for ultra-dense small cell networks especially inside buildings [5]. Network function virtualization [6] further allows the separation of different network functions under the administrative domains of several stakeholders and aims at integrating services into the networks, which changes the traditional roles of mobile network operators (MNOs), service and application providers, and infrastructure vendors.

The recent 5G developments aim to address the needs of specific high-demand areas such as factories, campuses, malls, arenas, and hospitals with versatile service requirements [2]. Efficient serving of these areas will require domain specific knowledge for specialized service delivery, which could be in the possession of other stakeholders than the traditional MNOs and calls for the integration of various service providers into the future 5G networks. The increasing need for locally tailored and context specific service delivery has initiated research on new operator roles in the deployment of 5G networks that can open the mobile market for new entrants, see e.g. [5], [7]-[8]. For example, the facility owner is seen to play an increasingly important role in the deployment of local wireless networks in [5], where the local facility owner's network is suggested to serve its own customer set as well as to be opened for serving MNOs customers within the specific building. Following the local network deployment path by allowing MNOs and different non-MNO stakeholders to deploy their networks, the concept of micro operators [8] has recently emerged to speed up 5G deployment. The micro operator concept allows the different stakeholders to take a local operator role, deploy and operate local 5G small cell networks, and offer context related content and services in the given area.

The envisaged changes in the operator roles in the mobile communication market are highly dependent on the underlying regulatory framework [9]-[10]. Ultimately, the regulations define who can be an operator, gain access to the radio spectrum and what rules and conditions will need to be followed. The regulatory implications of the new micro operator concept were preliminary addressed in [11] where regulations for 5G were reviewed. The regulatory analysis in [11] focused on spectrum authorization and proposed a new spectrum micro licensing model to allow micro operators to gain local access rights to the radio spectrum.

This paper extends the work of [11] in examining how the recently proposed micro operator concept fits within the overall regulatory framework. This paper describes the key regulatory elements for the introduction of the new micro operator concept including the operator role, spectrum authorization decisions, access rights to the infrastructure, and building of indoor networks. The rest of this paper is organized as follows.

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Section II outlines the trends in the development of 5G networks including changing operator roles in the mobile market, and 5G technical developments. The micro operator concept is presented in Section III. The regulations related to the introduction of the micro operator concept are discussed in Section IV. Finally, conclusions are drawn in Section V.

II. Trends in 5G Deployments

5G deployments include both market and technology related trends which are discussed in the following next.

A. Changing Mobile Communication Market

Today's cellular mobile connectivity market is characterized with a small number of MNOs whose strong market position is based on high infrastructure investments and long-term spectrum licenses [11]-[12]. The spectrum access rights to deploy mobile communication networks are typically country-wide exclusive licenses that are auctioned which often results in high prices paid for licenses and high infrastructure investments. This further strengthens the status quo and limits the potential new market entry as presented in see Fig. 1. A future trend is the increasing demand for location specific services as the digitalization proceeds across different vertical sectors [1]-[2]. This results in a growing demand for mobile connectivity to support various services in specific locations, such as campuses, malls, factories, arenas and hospitals. Especially, the serving of high-quality indoor usage becomes a bottleneck and calls for ultra-dense indoor network deployments in specific buildings.

Recently, alternative network deployment models to serve the underserved and open the market have gained increasing interest in the research literature, see e.g. [5] and [7]-[8]. Authors in [7] identify four types of alternative networks including community networks, shared infrastructure, wireless internet service providers, and crowdshared approaches. The changing stakeholder roles are even more evident in the indoor ultra-dense small cell deployments whose techno-economics were discussed in [5]. The trend towards networks deployed by facility owners in the unlicensed spectrum was identified in [5] in order to find scalable and economically feasible solutions.

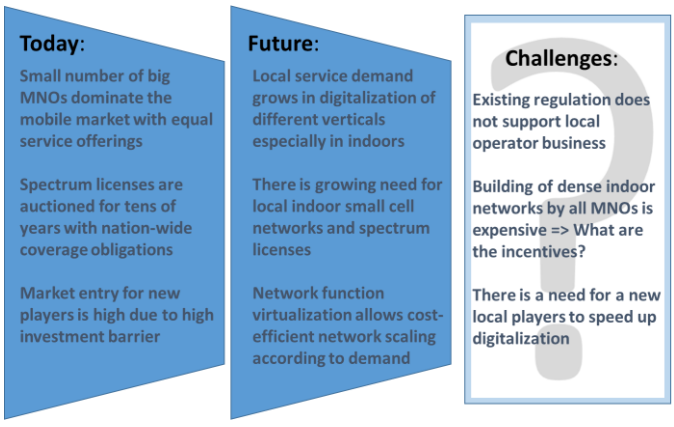

Fig. 1. Trends of mobile market change and related challenges.

The recent micro operator concept discussed in [8] and [11] is an example of locally deployed networks to respond to the location specific demands and speed up 5G deployment. The micro operator role can be taken by various stakeholders to deploy and operate local networks and offer context related services and content for its own customers or MNOs' customers or a mix of both [13]. New operator roles for providing low latency 5G applications and Internet of Things (IoT) services were further discussed in [14] and [15] where several different operator roles were identified going beyond the traditional MNO dominance. These roles include consumers buying equipment and handling connectivity themselves, local connectivity provided by an IoT operator, and shared networks between multiple operators.

5G developments with network function virtualization are expected to make it easier for mobile virtual network operators (MVNO) and over the top (OTT) service providers to lease network slices on demand from infrastructure providers including MNOs and infrastructure vendors [16]-[17]. The network slice broker function [16] and network slicing as a service [17] allow MNOs and vendors to offer customized end-to-end cellular networks as a service to the various service providers. This kind of multi-operator service provisioning needs to consider economic incentives for information sharing between stakeholders across the multi-actor value chain [18].

B. 5G Technology Developments

The envisaged changes in the mobile communication market with 5G can only take place if the technology solutions support them. The on-going 5G technical developments [3]-[4] focus on the new radio and evolution of LTE with the aim of meeting the increasingly stringent key performance indicators (KPIs) in terms of e.g. data rate, spectral efficiency, and latency. Three fundamental trends in the future of mobile identified in [19] include orders of magnitude increase in the system KPIs, small cells to support high data rates, and the use of complementary strengths of 3GPP and IEEE technologies.

Sharing is an inherent trend in 5G technology development including sharing of both wireless resources and the infrastructure [20]. Network infrastructure sharing will take new forms with the developments of virtualization and slicing techniques [16]-[17]. Architectural developments in 5G address the support of a highly reconfigurable network with versatile radio access technologies [21]. Moreover, the opening of interfaces for third parties is important for realizing the benefits of 5G, for allowing multi-tenancy for different service providers and other operators [22].

5G spectrum discussions are considering the use of higher frequency bands (24-86 GHz) as well as gradually upgrading existing mobile communication bands to support 5G. The role of small cells and particularly indoor networks becomes increasingly important in the higher carrier frequencies for 5G, which is no longer the traditional MNOs' core competence area and can also involve other stakeholders. Radio propagation from predominantly outdoor located cellular networks into the receivers often located inside the buildings is no longer feasible in the higher frequency bands due to increasing signal attenuation. Moreover, there are high variations in the

propagation losses caused by the building walls depending on the construction materials and building type, which further impacts the achievable network coverage and resulting interference distances [23].

In 5G a large numbers of small cells in specific indoor locations are needed to create high quality service delivery as there are highly preferable propagation conditions between the base station and the mobile terminal. Therefore, the serving of the higher user densities of both humans and machines through network densification is critical especially in the mm-wave frequency bands and its deployment should be low cost. In fact, indoor deployments makes the spectrum reuse more efficient as also the interference distances remain within the building when going to higher frequencies [5].

III. 5G Micro Operators for Local Network Deployment

The concept of micro operators aims at boosting local service delivery in 5G through locally deployed small cell networks in specific locations [8]. The three basic elements of the micro operator concept identified in [13] include 1) planning and building of local small cell infrastructure; 2) operation and maintenance of the network infrastructure; and 3) provisioning of tailored services within the specific location. Fig. 2 provides an overview of the micro operator concept. The concept aims to respond to the trends of change in the 5G deployments where location specific services, indoor networks and sharing of infrastructure become increasingly important. Micro operators are built on top of the technical features of dense indoor small cell networks, operation in higher carrier frequencies, and the opening of network architecture to support multi-tenancy and network slicing for serving multiple serviced providers customers. Regarding customers, the micro operator can operate a closed network to serve its own human or machine type of customers that are not served by MNOs such as in a factory [13]. Alternatively, the micro operator can act as a neutral host for other MNOs by serving their customers in the specific location, such as in a campus. A hybrid is also possible where the micro operator serves both MNOs' customers and its own customers, such as in a mall. The role and level of involvement of the micro operator is highly dependent on the specific use case and can differ across the different verticals.

A key challenge for the introduction of the new micro operator concept is the underlying regulatory framework. Changes are needed to create a sustainable environment for new entrants to the mobile communication market while maintaining the investment certainty of existing MNO based infrastructure deployment models. The key regulatory elements impacting 5G micro operators were preliminary identified in [11] to be access regulation, pricing regulation, competition, data and security, and authorization of networks and services. Within these elements in this paper we will further study the operator role, spectrum authorization decisions, access to the infrastructure, and building of indoor networks as listed in Fig. 2. For the spectrum authorization for micro operators, an initial interference analysis between two micro operator small cell deployments in co-channel and adjacent channel scenarios was presented in [23]. Furthermore, for access to the infrastructure, a technical architecture with support for multi-tenancy was provided in [22].

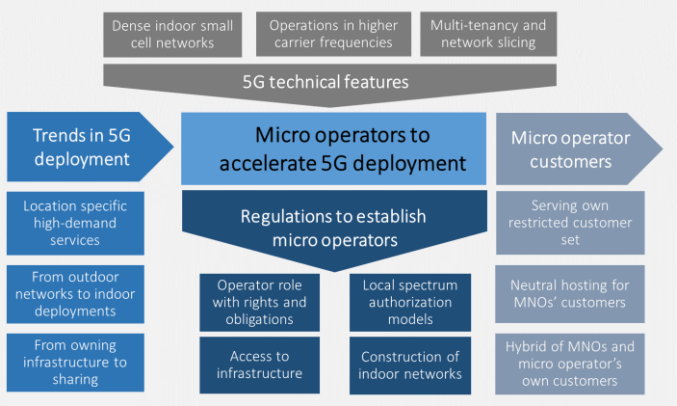

Fig. 2. Overview of micro operator concept

IV. Regulations to Establish 5G Micro Operators

Regulations governing the mobile communication market play a key role in shaping the ways that the future 5G networks can be deployed and operated. There are different levels of regulation including national, regional, and international levels and significant variations between countries. In Europe, the member countries of the European Union follow a common regulatory framework which is currently being revised into a new European Electronic Communications Code (EECA), see [9]-[10]. In the following we discuss the key regulatory elements for the introduction of micro operators in 5G.

The overall goals of regulating the mobile communication market continues to include promoting investment in new technology, competition by opening the market for entrants, and efficient use of spectrum [1][9]. Existing regulations are primarily designed for building country-wide outdoor mobile connectivity and they do not properly address the specificities of indoor deployments. In fact, construction of indoor networks within the same building premises by all MNOs is not cost efficient but calls for sharing based approaches to accelerate 5G small cell deployments. There is common consensus that the existing mechanisms need revisions for the new 5G bands, whose characteristics significantly differ from existing bands. The introduction of new local operator models including micro operators into the regulatory framework to promote innovation requires revisions to the current logic. Regulations for 5G were initially addressed in [11] where the focus was on proposing a local spectrum micro licensing model for micro operators. In the following the key regulatory elements are discussed in more detail including operator role, spectrum authorization, access to infrastructure, and building of indoor networks.

A. *Operator role*

The role of being a telecommunications operator brings a set of rights and obligations, which are defined by the national regulators. The changing operator roles with 5G networks complicate the defining of an operator as infrastructure sharing and offering network as a service are foreseen to become more common. For example, the Finnish setting defines a telecommunication operator depending on whether it participates in transmitting messages and serves an unrestricted

set of customers. Thus, the micro operator can have a different set of rights and obligations depending on the role it takes. The telecommunication service provider role depends on whether the micro operator is providing multi-tenancy for MNOs or it serves a restricted customer set, which results in different rights and obligations to follow. At the same time, the facility owners in the Finnish setup cannot restrict other MNOs from placing their networks within the same premises. Overall, it is important to note that the role of an operator is highly dependent on the national situation.

B. Spectrum authorization

Spectrum authorization decisions are in the key position to shape the mobile communication market by controlling who is permitted to enter the market and transmit in the given frequency band. In Europe the 5G spectrum discussions focus on the frequency range 24-86 GHz as well as in the lower frequency bands with existing allocations for the mobile service including the 3.4-3.8 GHz and 700 MHz bands. Traditional exclusive licensing and license-exempt spectrum authorization models are not optimized for 5G small cell deployment in the higher frequency bands. In fact, spectrum sharing solutions are critical in making new spectrum available for mobile communications while protecting the incumbent spectrum users' rights and allowing different 5G networks to coexist. The US regulator FCC:n has introduced a three-tier sharing model [24] in the 3.55-3.70 GHz band that enables market entry for different players with local access rights. In Europe, the Licensed Shared Access (LSA) concept [25] was standardized and trialed in the 2.3-2.4 GHz band to enable local mobile network deployments and is extended to 3.4-4.2 GHz. These sharing-based spectrum authorization model developments inherently include local operational area as they need to protect the potential incumbent spectrum users, which results in local service areas for the entrant 5G networks.

The introduction of the new micro operator concept is highly dependent on the availability of high quality spectrum for micro operators. To develop spectrum authorization models for 5G networks that take into account the specificities of the network deployments and 5G bands, it is important to define how the access rights of use should be granted among those requesting them. Moreover, the rights and obligations in terms of the level of protection from harmful interference and the associated interference coordination mechanisms need to be defined for 5G bands. These and other elements of spectrum authorization are discussed in more detail [26]. A new micro licensing model has been recently proposed for 5G local licensing to allow micro operator deployments especially in higher frequency bands [8][11]. The micro licenses are local access rights with a predefined level of protection from harmful interference to establish local 5G networks. Micro licensing uses horizontal spectrum sharing to protect micro licensees from harmful interference within their license area. Vertical spectrum sharing is used to protect incumbents from harmful interference from the micro operators. This results in the need to define the rules and methods to interference coordination between the small cell networks, which is critical to establish the local networks [26], see [23] for an initial interference analysis between micro operators. In fact the micro operator model is not feasible in the lower frequency bands due to potential harmful interference between different micro operators.

C. Access to infrastructure

Competition and market regulation are important in ensuring the proper functioning of the mobile communication market. Regulations on significant market power (SMP) aim to ensure that those holding significant position in the market cannot use their dominant position to limit and distort competition. This is evaluated nationally and additional sector specific regulation can be issued in the case of some player holding significant market power.

A micro operator's network coverage is typically restricted to a specific local area, which restricts its operational area. To provide services for end users outside this area, interconnection to other networks becomes critical. Therefore, for the introduction of the micro operator concept, the ways to ensure that the micro operators can gain access to the infrastructure are important. They could make commercial agreements with MNOs on national roaming by which the micro operator customers could be served by MNO networks outside the micro operator network coverage.

D. Building of indoor networks

Today's cellular network deployments are suffering from indoor connectivity problems as the outdoor based network faces significant signal attenuations when received in indoors. Especially new buildings with strict energy efficiency requirements have resulted in significant problems in the indoor connectivity. While the building of indoor network deployments could solve the connectivity problems, there are no licensed bands available for such deployments but the MNOs would have to deploy the indoor networks in the same bands as their existing networks, which restricts the performance of both indoor and outdoor networks.

The majority of indoor mobile traffic continues to be carried through wireless local area networks (WLAN) in the unlicensed bands. Business cases for MNOs to build indoor connectivity have remained limited and they differs from the mainstream outdoor coverage construction. While in some cases the existing license conditions can even include obligations for providing indoor connectivity, the defining of proper measures for it is not straight-forward.

Future 5G deployments are specifically aiming to serve indoor areas in specific locations, such as hospitals, arenas, malls, factories, and campuses. While the indoor connectivity has become a bottleneck for traditional cellular mobile communications as the building entry losses significantly restrict the indoor reception, the operations in higher 5G frequency bands with indoor networks will help the situation. To speed up 5G deployment, the building of indoor networks needs to be made simple. The rights of MNOs to place base stations inside buildings vary depending on national regulatory conditions. In Finland, the building owner cannot monopolize the property but has to let MNOs in. Also multi-operator support is required for the operator networks.

The newly proposed micro operator concept specifically addresses the indoor connectivity problems through offering their communications infrastructure to also serve MNOs' customers in addition to micro operator's own customers. Thus, regulations promoting new models for infrastructure ownership and shared access for the indoor network deployment case can change the traditional roles of stakeholders including building owner, building constructor, mobile network operator, micro operator and network constructor.

V. Conclusion

This paper has further developed the recently proposed micro operator concept to accelerate 5G deployment via establishment of locally operated small cell networks in specific high service demand areas. The new micro operator concept allows different stakeholders to undertake a local operator role to deploy and operate local small cell networks for context specific content and service delivery. We have reviewed the relevant regulatory elements for the introduction of the micro operator concept including defining of the operator role, spectrum authorization, access to infrastructure, and building of indoor networks.

Future work is needed to create a regulatory framework for the wide-spread adoption of the micro operator concept. Especially the integration of the micro operator concept into the 5G development path by developing the capabilities to integrate locally operated small cell deployments into the larger mobile communication infrastructure is needed to provide service continuity for micro operator customers, which calls for changes in the current regulations. Also interference coordination techniques between the micro operators and potential incumbents need to be investigated in detail.

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