Before the
Federal Communications Commission
Washington, D.C. 20554

In the Matter of	)	
	)	
Use of Spectrum Bands Above 24 GHz for Mobile Radio Services	)	GN Docket No. 14-177
	)	
Amendment of the Commission's Rules Regarding the 37.0-38.6 GHz and 38.6-40.0 GHz Bands	)	ET Docket No. 95-183 (Terminated)
	)	
Implementation of Section 309(j) of the Communications Act – Competitive Bidding, 37.0-38.6 GHz and 38.6-40.0 GHz Bands	)	PP Docket No. 93-253 (Terminated)
	)	
Petition for Rulemaking of the Fixed Wireless Communications Coalition to Create Service Rules for the 42-43.5 GHz Band	)	RM-11664

COMMENTS OF ALCATEL-LUCENT

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Alcatel-Lucent submits these comments in response to the Notice of Inquiry ("NOI") issued in the above-captioned proceedings exploring the potential for the provision of mobile radio services in bands above 24 GHz.

I. SUMMARY

Alcatel-Lucent considers 5G to be a major step forward for mobile communications as we strive to offer higher and higher bitrates for a mass market mobile broadband service. With the evolution to 5G, mass market services will become more targeted offerings with network capabilities used to match the individual end user's actual requirements and individual circumstances.

Our vision to realize this objective of building a flexible mobile network, offering support for a wide range of 5G use cases, is described below. After providing an overview of our 5G vision, these comments discuss how LTE technologies provide the foundation for the 5G evolution. Then, we discuss what we term "federated radio access" – the many ways diverse air interfaces and high and low spectrum bands will be used in concert for 5G. Alcatel-Lucent further sees networking technologies as key to 5G, such as network function virtualization (NFV) and software defined networking (SDN).

Alcatel-Lucent urges the Commission to consider the importance of fixed wireless services in high frequency bands even as technology innovations unlock these bands for mobile uses. Among other things, wireless backhaul is becoming increasingly important and must be given due consideration in this exploration of high spectrum bands.

II. ALCATEL-LUCENT'S 5G VISION

Alcatel-Lucent is the leading IP networking, ultra-broadband access and cloud technology specialist. We are dedicated to making global communications more innovative, sustainable and accessible for people, businesses and governments worldwide. Alcatel-Lucent's mission is to invent and deliver trusted networks to help our customers unleash their value.

Underpinning Alcatel-Lucent's leadership in driving transformation from voice telephony to high-speed digital delivery of data, video and cloud services is Bell Labs, one of the world's foremost technology research institutes, responsible for countless breakthroughs that have shaped the networking and communications industry. These innovations have resulted in 7 Nobel Prizes, a Turing Award, an Emmy, a Grammy and an Oscar. Alcatel-Lucent has been recognized by Thomson Reuters as a Top 100 Global Innovator, as well as being named by MIT Technology Review as amongst 2012's Top 50 "World's Most Innovative Companies." Alcatel-Lucent has also been recognized for innovation in sustainability, being named Industry Group Leader in the Technology Hardware & Equipment sector in the 2013 Dow Jones Sustainability Indices review, for making global communications more sustainable, affordable and accessible, all in pursuit of our mission to realize the potential of a connected world.

The following products represent some of Alcatel-Lucent's recent technological breakthroughs:

- Mobile cloud – A comprehensive set of network functions that are being virtualized allowing mobile networks to embrace the cloud: virtualized IP Multimedia Subsystem (vIMS), virtualized Evolved Packet Core (vECP), and virtualized radio access network (vRAN).

- 100G-400G optical transmission – The world's first 100G and then 400G coherent optical transmission for next generation optical backbones.

- Vectoring – Noise cancelling technology that enables gigabit speeds over copper access infrastructure.

- 400G Packet Processing – Application Specific Integrated Circuits (ASICs) supporting 400 Gbps simultaneously in both directions, equivalent to 70,000 users each watching a high-definition (HD) video simultaneously.

- A new Core IP Router – 5X density of alternative solutions; meets core routing, multiprotocol label switching (MPLS), data center interconnection and infrastructure service needs with maximum efficiency and lowest total cost of ownership.

As a leader in wireline and wireless, legacy and cutting edge cloud infrastructures, and with the long history of Bell Labs in defining the future of communications technology, Alcatel-Lucent is in a unique position to address the evolution of mobile technologies to the 5G network of the future.

Alcatel-Lucent believes that emerging 5G technologies will allow provision of services with higher and more consistent bitrates, lower end-to-end latency, higher connection densities to support both personal and machine-type communications devices, improved battery life and higher reliability. However, there is no known 5G use case at this time that requires all of these service attributes at the same time, to the same device. Therefore, 5G services will be driven by the need to match a wide variety of distinct application requirements, terminal capabilities, radio environments and local network loads (as well as the value chain), to build a flexible set of customizable services.

With this approach to 5G evolution, mobile operators will be able to construct unique service offerings for mobile broadband, ultra dense machine-type communication, mission-critical support for national roaming of public safety officers and many other use cases, customized to optimal investment in radio access and network infrastructure.

Alcatel-Lucent believes that this goal of flexible, customized networks and use cases can be achieved economically for the mass market mobile network. To meet this goal, end user services will need to be realized using a highly efficient 5G radio access system providing massive capacity coupled with a policy-centric 5G network, where knowledge of application requirements, terminal capabilities, radio environment and local network load is used to optimize the behavior of mobile devices, wireless access and networking systems. In this vision of 5G, end-user devices would no longer need complex user interfaces to control network settings.

The 5G service concept is therefore surprisingly simple: end users, applications and/or third party content providers announce what is required and a policy framework matches device, access and network resources to realize the service within the applicable economic constraints inherent in the value chain. In most cases, this will all occur seamlessly, without the end-user even being aware of these processes.

As discussed in greater detail below, 5G services will start with the parallel deployment of a new 5G carrier on macro cells to offer improved quality of service and the opening of wideband carriers in new higher bands above 20 GHz on small cells to offer peak capacity. Existing LTE capacity on both macro and small cells will remain in place and combined with the new 5G radio access technology using carrier aggregation. 5G will also depend on introduction of a new networking approach based on extensive use of network policy to guide devices, wireless services and networking along with the generalization of SDN and NFV technologies to offer a flexible and programmable network.

A. 5G – A Major Shift, But Built on the Foundation of LTE Technologies

LTE will continue to evolve over the next 10 years at least, as industry completes and implements existing and anticipated work items in 3GPP, including a number of very useful features that will allow support of many "5G" requirements and introduce a number of technologies that may be re-used by native 5G access.

Key LTE evolution technologies include:

- HetNets built using macro and small cells working together to offer high capacity radio access.
- Interworking between LTE and WLAN access to provide seamless service continuity and network policy based solutions to hide access selection management from end users.
- Further enhancements to MIMO to allow elevation beamforming with up to 16 antennae and beyond, offering higher peak and cell edge bitrates.
- Extensions to Inter-Cell Interference Coordination to improve capacity and cell edge performance for HetNets.
- Carrier aggregation (CA) to combine up to 32 carriers for higher peak bitrates and capacity.
- Dual-connectivity (DC) solutions to combine multiple cell sites (e.g. macro and small cell sites) for high peak bitrates and capacity along with reduced risk of call drops during handover.
- Coordinated MultiPoint (CoMP) operation to combine multiple cell sites (i.e. neighbouring macro cell sites or macro and small cell sites) for high peak and cell edge bitrates and capacity.
- Enhanced support for Machine Type Communications (MTC) to offer in band support for lower cost devices with improved coverage.
- Device-to-device (D2D) transmission mode for both public safety and commercial applications including "off net" services for devices outside LTE coverage.
- Multimedia Broadcast/Multicast Service (MBMS) enhancements to support more efficient content provision to multiple users.
- vRAN introducing a new "city node" hosting centralized baseband processing, local IP breakout, local applications and RAN optimization features.

B. Federated Radio Access

5G radio access will be based on the federation[1] of 5G radio technologies optimized for use in bands below 6 GHz and new spectrum for very high capacity access (>20 GHz), combined with 4G LTE and WLAN radio carriers.

Macro cells would exploit low band, and potentially high band, 5G and 4G carriers tied together using an extension of the LTE carrier aggregation or dual connectivity technology to allow 5G capable devices to use an available 5G carrier as both primary and connectionless service bearer while using other 5G carriers and all 4G carriers as secondary resources for connection oriented services. Legacy 4G devices on the other hand would use LTE as both primary and secondary carriers.

A similar arrangement would be used on the small cell layer with 5G capable devices using a mixture of low and high band 5G carriers, 4G carriers and WLAN for both connection oriented and connectionless based services. The main difference will be that, when the macro cell layer is also available, most devices will remain connected to the macro layer and hence use a combination of carrier aggregation with dual- and multi- connectivity technologies to combine 5G, 4G and WLAN carriers on macro and small cell layers.

The 5G low band carriers are likely to be based on an extension of the Orthogonal Frequency Division Multiplexing (OFDM) technology used by LTE. One leading candidate is UF-OFDM (Universal Filter OFDM), which uses an additional variable filter stage in the transmitter to offer improved spectrum emission shaping and a flexible guard space between symbols. Working together, these two features can offer higher performance than LTE, especially for narrow bandwidth transmissions typical of short-burst

[1] The word "federated" is used here instead of aggregated to also encompass carrier aggregation, dual-connectivity, cellular plus WLAN load sharing and other mechanisms offering sharing of radio capacity for other purposes (e.g., public safety/MVNO), and to provide a hedge against less efficient spectrum sharing approaches.

transactions for use by both Internet of Things (IoT) services and messaging plus signaling for all devices including smart phones.

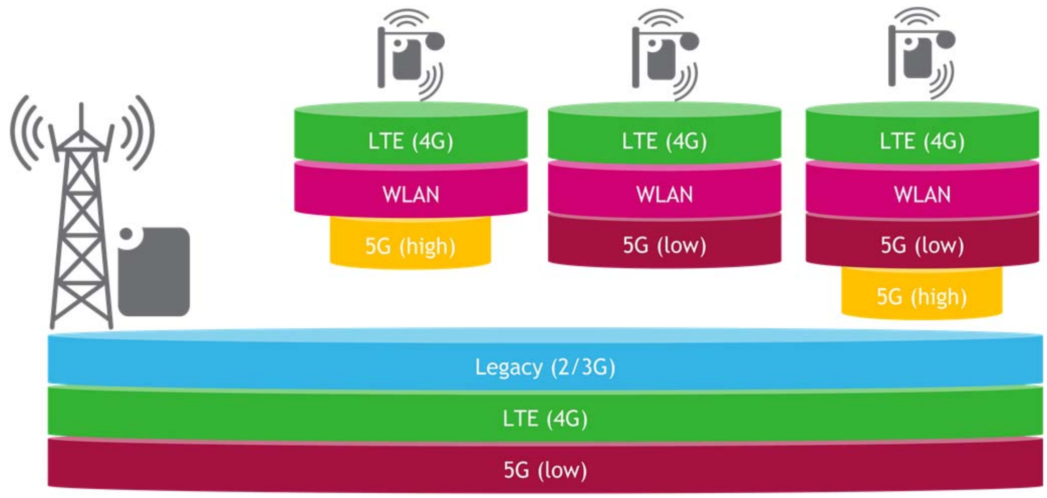
The waveform of the 5G high band solution will depend on the exact band adopted and the associated propagation conditions. One option is to adopt the same scalable OFDM based technology as the low band solution but with a wider sub-carrier spacing and corresponding shorter sub-frame timing to offer native support for lower latency services and adapt to the lower mobility and propagation delay spread that would be expected for an access solution that is optimized for small cell applications. Common upper layer procedures for both low and high band parts of the 5G standard should be adopted to ensure federated usage of the low and high bands, between macro and small cell layers and between 5G, 4G and WLAN access.

New deployment models which include RAN sharing will be needed in 5G systems to be able to allow joint deployment of 5G cost effectively while maintaining the ability for our customers to compete. RAN sharing already exists to some degree in common use of towers and backhaul for macro deployments and shared DAS indoors. This sharing can be extended to include shared radios and perhaps even shared spectrum. This will be a significant benefit for extending our networks indoors where site acquisition is a particular problem which needs to be overcome as a growing fraction of wireless traffic is from indoors.

Today, in all but a few indoor locations wireless traffic is carried (with varying quality) by WiFi. 5G will need to be architected to serve such a RAN sharing model in order to provide high levels of wireless quality indoors as well as outdoors. The alternate possibility is the emergence of "in-building operators" that specialize in providing multi-operator connectivity within buildings through appropriate roaming and spectrum sharing relationships with traditional MNOs. In this case, air-interface resource sharing features of

RAN sharing will likely still be needed and could be enabled by the ubiquitous 5G control layer.

Figure 1: 5G radio access vision showing low (< 6GHz) and high (>20 GHz) band 5G carriers deployed across macro and small cells and combined with LTE and WLAN to offer a federated access solution



C. Networking

5G networking is being designed with the principles of NFV and SDN in mind to allow the packet core and controllers for mobility (e.g. Mobility Management Entity MME in 4G) and policy (Policy and Charging Resource Function (PCRF) and Access Network Discovery and Selection Function (ANDSF)) to evolve into a truly flexible and configurable solution that allows mobile operators to rapidly deploy new and innovative services and network solutions optimized to specific service use case, environments, device types and end user needs. Such technologies will enable the re-distribution of core network functions (EPC, HSS and IMS) from central data centers, offering the potential to build customized networks to suit different subscription classes (i.e. MTC devices with limited mobility could locally handled within a short distance from the cell sites).

Key elements of this networking concept include a policy-based service management framework establishing per user and per flow policies for charging, mobility, security, quality of service, network control and optimization functions. Most of the wireless access functionality contained with the base station, which is likely to be built using a distributed implementation based on vRAN principles, splitting functionality between the antenna sites and new centralized sites serving a local area. Inter-site and inter-technology mobility functionality including mobility anchor points and radio interface selection on mobile devices will be part of 5G.

Combining these concepts, new services and configurations would be defined using a set of network policies that are applied on a need basis to command both wireless and networking functionality to create independent service- and device-specific networking solutions.

Using this solution, an IoT/Machine-to-Machine (M2M) device may be handled by a dedicated realization of the mobile network using connectionless services, which have low signaling overhead and low peak bitrate and distributed mobility anchors. At the same time, a high priority and high mobility mission critical device may be assigned dedicated radio and networking resources to realize a low latency, high reliability and high mobility service. In each case the network is configured as needed based on pre-defined network policies, with resources being released when no longer required.

III. HIGH-BAND SPECTRUM CHALLENGES THAT MUST BE OVERCOME

One of the challenges of mobile communications in the higher bands for outdoor access will be to overcome the expected propagation conditions. The most obvious obstacle will be the higher path loss of the bands above 6 GHz relative to traditional cellular bands. Just looking at free-space path loss, the expected loss will be:

$$L_P = 92.4 + 20\log f + 20\log d$$

where f is the frequency in GHz and d is the distance in kilometers between transmitter and receiver. For example, an additional 22.9 dB and 30.9 dB of losses are expected to result in the ranges from 2 GHz to 28 GHz and 70 GHz respectively which will need to be compensated by some means, for example, larger antenna array sizes with higher antenna gains and MIMO technologies.

A second major impediment to using high frequencies is the fact that at these frequencies wave propagation is characterized by little refraction around objects. Hence, in addition to the path loss, there will be significant loss because of various obstructions, which will be difficult to overcome. For example, body penetration loss in excess of 30 dB has been observed in measurements at 60 GHz. Communication in higher bands thus has to be primarily through line-of-sight links or reflections. In dense urban areas, reflections increase the potential for communication.

The third major impediment is the costs of radio frequency components, especially for high transmit powers, commonly used in macro cells. This essentially limits the maximum output power in millimeter wave frequencies.

Compensating for the 30 dB of path loss will require extremely narrow beams and a combination of beamforming at both the transmitter and receiver. Coupled with blocking effects, one can expect the connectivity to be rather intermittent with frequent searches for new beam directions required to maintain the link.

Because of the above considerations Alcatel-Lucent believes that higher bands will be used only in small cell configurations as an addition to a 5G macrocell layer in lower bands. Furthermore, we expect the use of spectrum above 24 GHz to be in dual connectivity and/or in carrier aggregation mode in which the device is simultaneously connected to a high band carrier and a below 6 GHz low band carrier either from the same site or from different cell sites.

Today, the majority of cellular traffic originates indoors. While large buildings use specialized indoor systems such as Distributed Antenna Systems (DAS) or indoor small cell systems, indoor coverage for many small buildings is provided by deployment of cells outdoors, which is more convenient for operators. However, because of excessive penetration loss in the case of frequencies above 24 GHz (for example, measurements reported in 28 GHz suggest the penetration loss through tinted glass is 24.3 dB and through brick is 28 dB)[2] providing indoor coverage from outdoor cells may not be feasible at high frequencies. It is thus expected that separate high frequency small cells will be deployed both indoors and outdoors in areas of high traffic demand.

IV. FIXED WIRELESS WILL CONTINUE TO NEED ACCESS TO SPECTRUM ABOVE 24 GHZ

While the new capabilities available with 5G mobile services have great potential, the Commission must ensure that technologies that enable these capabilities, such as fixed wireless, also receive appropriate attention. The primary use of microwave links currently is for mobile infrastructure backhauling. Wireless backhauling will be even more strongly associated in 5G. As mentioned above, small cells are expected to be widely deployed to support 5G. These small cells will all require backhaul, and a significant percentage will require high-quality licensed fixed service connections, possibly in the 24 GHz and above frequency range. As we look to provide needed spectrum to support new mobile services, we must also ensure that the underpinnings on which these services are built are protected.

Apart from 5G, fixed wireless continues to make up a growing part of the network. Applying new technologies to the higher bands may make it possible to achieve backhaul capacities approaching 10 Gbps and 40 Gbps. These very high-capacity links can provide a viable alternative to deploying fiber optics, not only in rural areas, but also in high-

[2] Hang Zhao, Rimma Mayzus, Shu Sun, Mathew Samimi, Jocelyn K. Schulz, Yaniv Azar, Kevin Wang, George N. Wong, Felix Gutierrez, Jr., Theodore S. Rappaport, "28 GHz Millimeter Wave Cellular Communication Measurements for Reflection and Penetration Loss in and around Buildings in New York City," *Proceedings of the IEEE ICC*, 2013

density urban areas where it would be not physically or economically feasible to deploy wired infrastructure.

V. CONCLUSION

Alcatel-Lucent applauds the Commission's efforts to explore spectrum bands above 24 GHz and requests that the Commission consider these Comments as it moves forward.

Respectfully submitted,

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/s/

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