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Research Challenges of Millimeter Wave Technology in 5G Cellular System

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Abstract— The continuously increasing the demand of Mobile phones & use of data growth in wireless technology are creating challenges for cellular service providers. In Mobile communication system, wireless spectrum is limited and thus strictly regulated for various wireless communication systems. Any wireless network can only operate using a finite bandwidth. This paper presented how millimeter wave band can be used for 5G cellular system. Millimeter-wave communication is a promising platform for further development and research towards fifth generation mobile broadband communication systems. Also paper shows the propagation characteristics and device technology challenges associated with this band as well as its unique advantages for mobile communication.

Keywords- MIMO Antenna, 5G Network, Millimeter wave generator, Heterogeneous network.

I. INTRODUCTION

With rapidly use of smart devices with increase in mobile communication system, data traffic has also continuously increased in mobile communication networks.[1] Qualcomm, especially, expects that the volume of mobile traffic in 2020 will increase 1000 times more than that of the current traffic [2], 10 times the spectral efficiency, energy efficiency and data rate (i.e., peak data rate of 10 Gb/s for low mobility and peak data rate of 1 Gb/s for high mobility), and 25 times the average cell throughput. To accommodate the data traffic, current fourth generation (4G) mobile communication systems will use the technology like long term evolution-advanced (LTE-A) and worldwide interoperability for microwave access networks (WiMAX) in which various advanced technologies such as multiple input and multiple output (MIMO), multicarrier transmission, and carrier aggregation [3,4]. Out of these technologies, frequency bands below 3GHz used in the current mobile communication systems are expected to be crowded due to the increasing demand in mobile data traffic. Therefore, in order to enlarge the frequency band to accommodate the emerging data traffic, a new type of frequency band should be considered in 5th generation (5G) mobile communication systems.

Mm-Wave is a new technology for future 5G cellular systems. Since limited amount of spectrum is available for commercial cellular systems, most research has focused on increasing spectral efficiency by using OFDM, MIMO, efficient channel coding, and interference coordination. The millimeter-wave band in the 30–300GHz range is being considered as a good framework for new radio bands for 5G mobile communication systems [6,9]. Since most of the millimeter-wave band is underutilized, 5G mobile communication systems are expected to utilize wide and continuous bands for radio access networks (RANs). By using the vast amounts of radio resources in the millimeter wave band, system capacity of the 5G mobile communication systems can be improved and mobile devices served by the system can experience better service environments with high-speed transmission and low latency compared to those of the current mobile communication systems. Therefore, a mobile communication system using the millimeter-wave band is expected to provide novel multimedia services with exacting service requirements.

The advantage of large continuous spectrum in mm-wave range, cellular type of communication with mm-wave technology has been considered as challenging. Mainly, this is due to unfavorable channel characteristics of mm-wave spectrum, i.e. large path loss, as well as impact of atmospheric absorption CO2, O2, and rain/fog/snow attenuation which are expected to reduce a service coverage significantly compared to existing broadband mobile systems. Additionally, mobility support has been limited. Traditionally, due to aforementioned reasons, potential deployment scenarios of mm-wave technology have been thought to be limited to a short range point-to-point communication in a line-of-sight (LOS) condition with low mobility.

II. REQUIREMENTS OF 5G

Uniform user experience for all users across a 5G network:

I. Data rates of several tens of Mb/s should be supported for tens of thousands of users.- minimum 1Gbit/s data rate anywhere.

II. Up to Several 100,000's simultaneous connections to be supported for massive sensor deployments

III. Support for ultra-high data rates up to 5 and 50 Gbit/s for high mobility and pedestrian users. Support for real-time services; e.g. UHD/3D video streaming, tactile network, augmented reality, leading to stringent latency requirements, i.e. round-trip-time requirement to be 1 ms.

IV. Coverage should be improved.

V. Signaling efficiency enhanced.

VI. Support for cloud based services.

By looking at above drivers, mm-wave communication looks a promising technology ground for further development and research in the framework of 5G networks

III. 5G VISION

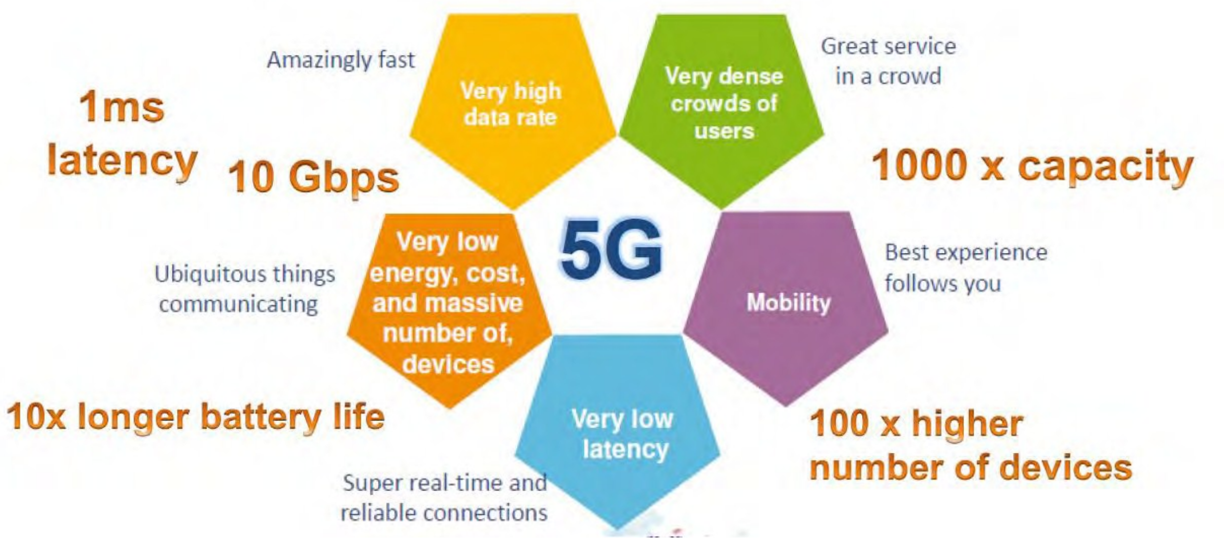

Figure 1. Fifth Generation System

IV. INTRODUCTION OF MILLIMETER WAVE

The use of a millimeter-wave band defined as a 30–300GHz range is used for improving performance of 5th generation (5G) mobile communication systems.[9] However, since the millimeter-wave signal has propagation characteristics especially toward non-line-of-sight regions, the system architecture and antenna structure for 5G mobile communications should be designed to overcome these propagation limitations. For realization of the 5G mobile communications, electronics and telecommunications research institute (ETRI) is developing central network applying various massive antenna structures with beam forming.

Several researches and projects for the 5G mobile communications have been conducted in recent years [9,10]. At the University of Texas, the characteristics of the millimeter wave band at 38GHz for outdoor cellular communication channels have been evaluated based on experimentally measured received signal strength (RSS) in a real campus environment [9]. In the Dallas Technology Laboratory of Samsung Electronics, an adaptive antenna array structure is proposed for beam forming in the millimeter-wave band [8]. In addition, new radio frame structure and network architecture are introduced for a mobile broadband system operating in the millimeter-wave band. Despite the merit of large contiguous spectrum in mm-wave range, cellular type of communication with mm-wave technology has been considered as challenging. Mainly, this is due to unfavorable channel characteristics of mm-wave spectrum, i.e. large path loss, as well as impact of atmospheric absorption CO_2, O_2, and rain/fog/snow attenuation which are expected to reduce a service coverage significantly compared to existing broadband mobile systems. Additionally, mobility support has been limited. Traditionally, due to aforementioned reasons, potential deployment scenarios of mm-wave technology have been thought to be limited to a short range point-to-point communication in a line-of-sight (LOS) condition with low mobility. However, recent results demonstrate that the mmwave communication at 28 GHz band has been proven to be viable technology for a outdoor cellular communication.

4.1 Spectrum Aspects

Beyond the traditional sweet spot of spectrum for wireless communications which ends at around 6 GHz, there is an additional 200 GHz of spectrum in the so-called mm-Wave frequency range that today is mainly under-utilized. This spectrum band has channel sizes capable of supporting wireless data speeds of 10-50 Gbps.[1]. A significant proportion of this enormous radio spectrum could be unlocked within the next 5 years for 5G cellular and WiFi communications. For the field of 5G research, the target is above 6 GHz, [1] and the research in this field should look to electro magnetic field (EMF) aspects, link budgets, propagation issues, and channel model description. a low millimeter band and high millimeter bands within the range of 20 to 90 GHz are briefly discussed. The low millimeter bands of interest in the 20-50 GHz range along with their currently allocated usage. As can be seen, a contiguous bandwidth up to 2 GHz can be found in this frequency range. It is worth noting that an ITU co-primary service band for mobile systems has been marked with green color.

Currently, ITU co primary mobile bands 20-50 GHz range have been used also for other services, e.g. fixed satellite services and navigation. Therefore, the co-existence of mm-wave communication with other existing systems needs to be carefully considered. For higher part of mm-wave band, there is also 7GHz unlicensed spectrum surrounding 60GHz. Additionally, ITU has allocated lightly licensed 5GHz bandwidths for both 71- 76 GHz and 81-86 GHz bands for establishing high bandwidth wireless links. Similarly, the band 92-95GHz has been allocated for high bandwidth wireless links.

mm-Wave Signals

Property	Microwave	mm-Wave	IR/Visible Light
Generation	Electronic	Electronic	Optics
Spatial resolution	~cm - m	~mm - cm	um
Antenna size	PCB	Package	Package
Cost, area, power	Low	High	Low

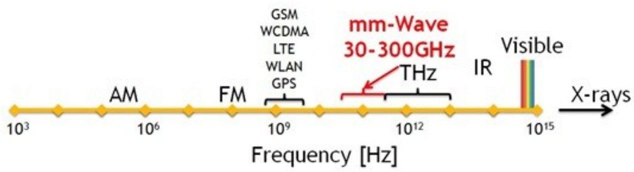

Figure 2. Millimeter wave frequency spectrum

4.2 Propagation characteristics

Signals at lower frequency bands can propagate for many miles and penetrate more easily through buildings, millimeter wave signals can travel only a few miles or less and do not penetrate solid materials very well. However, these characteristics of millimeter wave propagation are not necessarily disadvantageous. Millimeter waves can permit more densely packed communications links, thus providing very efficient spectrum utilization, and they can increase security of communication transmissions. This paper reviews characteristics of millimeter wave propagation, including free space propagation and the effects of various physical factors on propagation. Millimeter waves travel by line-of-sight, and are blocked by building walls and attenuated by foliage. The high free space loss and atmospheric absorption limits propagation to a few kilometers. Thus they are useful for densely packed communications networks such as personal area networks that improve spectrum utilization through frequency reuse.

They show "optical" propagation characteristics and can be reflected and focused by small metal surfaces around 1 ft. diameter, and diffracted by building edges. At millimeter wavelengths, surfaces appear rougher so diffuse reflection increases. Multipath propagation, particularly reflection from indoor walls and surfaces, causes serious fading.

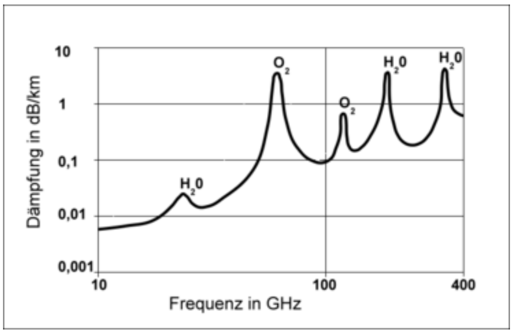

Figure 3: Atmospheric attenuation in dB/km as a function of frequency over the EHF band. Peaks in absorption at specific frequencies are a problem, due to atmosphere constituents such as water vapor (H2O) and carbon dioxide (CO2).

Doppler shift of frequency can be significant even at pedestrian speeds. In portable devices shadowing due to the human body is a problem. Since they penetrate clothing and their small wavelength allows them to reflect from small metal objects they are used in millimeter wave scanners for airport security scanning.

4.3 Heterogeneous Networks

One of the main challenges of Heterogeneous Network is planning and managing multilayer, dense networks with high traffic loads. The tools used today for network planning, interference management and network optimization require too much manual intervention and are not scalable enough for advanced Heterogeneous Networks. Self-organizing networks (SON) enables operators to automatically manage operational aspects and optimize performance in their networks, and to avoid squandering staff resources to micromanage their radio access networks. In denser networks, atomization reduces the potential for errors, and frees up precious resources to focus on more important activities of network design, management and operation. . Mobile networks continue to become faster and capable of transporting more traffic, thanks to the increased efficiency and wider deployment of 3G, 4G technologies now and 5G in future.

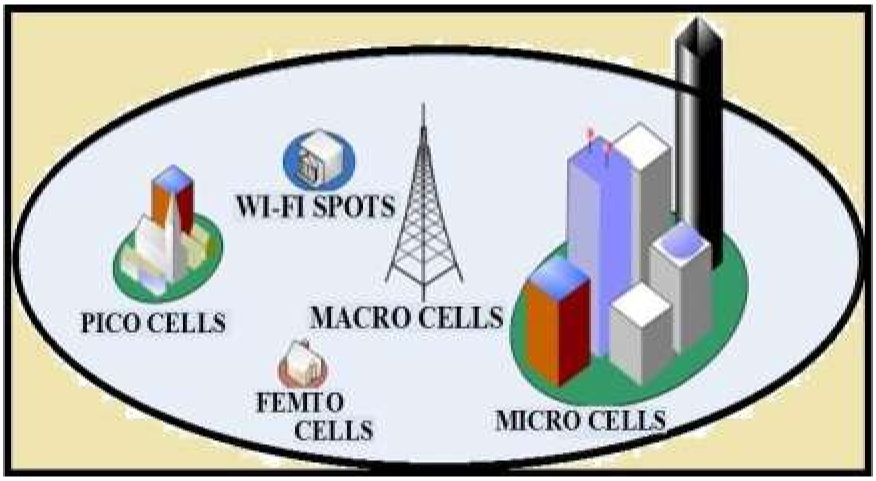

Figure 4. A typical heterogeneous network

4.4 Advanced Multi-Antenna Transceivers

To overcome unfavorable channel conditions in a cellular communication, i.e. pathloss in LOS/NLOS, signal blockage, by achieving high array gains, advanced beam forming techniques with large antenna arrays are required in mm-wave communications at both transmitter and receiver sides. By large antenna array, we mean that the number of antenna elements can be very large potentially up to hundreds. One of the benefits for mm-wave technology is that large number of antenna elements can be packed into a small physical size leading a larger aperture and achieving to high antenna array gains.

4.5 Energy Efficiency and Cost Aspects

Recently, the large volume of research and development efforts in academia and industry have been dedicated for a green wireless communication in the fourth generation (4G) networks. Clearly, in the context of 5G networks, the importance of green communication will become even more important with respect to existing systems. From a mm-wave communication perspective, novel energy efficient and cost-efficient multi-antenna transceiver architectures and mechanism to access large continuous chunks of spectrum are under interest. Additionally, the minimizations of installation and operation costs of wireless backhaul are under high interests while deploying of scalable ultra-dense mm-wave small cell networks.

V. CONCLUSION

This paper, Shows that new research challenges and future scope of mm-wave communication for 5G mobile broadband networks. More specifically, various challenges aspects like, service requirements, spectrum, propagation channel, cost and energy efficient aspects, heterogeneous networks from the perspective of mm-wave communication have been discussed. Based on provided overview, it can be concluded that mm-wave communication is a promising platform for further development and research towards next generation mobile broadband communication systems, particularly for 5G systems.

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