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Road Towards Mili Meter Wave Communication For 5G Network: A Technological Overview

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ABSTRACT

For future broadband cellular communication networks wireless carriers has motivated the exploration of the under-utilized millimeter (mm-wave) frequency spectrum. The cellular mm wave propagation is densely populated in the world. It is vital for the design and operation of future fifth generation cellular networks that use the mm-wave spectrum. This paper provides the overview of the recent world-wide activities for beyond 4G and 5G wireless standardization and technological aspects for millimeter wave communications. A complete characterization of the mm-wave link for next generation 5G mobile broadband remains elusive. The coverage, directionality and reliability of mm-wave communications will require new innovations in system design and communication technologies that are far from trivial. The transmission range and spatial selectivity's in the mm-wave bands especially in non line of sight channels can be increased by system design. So it require highly direction antennas and steerable antenna beams to compensate for the high propagation loss.

Keywords: Millimeter wave, 4G, 5G, Spectrum

1 INTRODUCTION

The millimeter wave wireless technology for 5G will play a very serious role as an augmentation of cellular infrastructure. To overcome a global bandwidth shortage for wireless service providers, now a days cellular providers come forward to deliver low latency and high quality video. [3]It also provide multimedia application for wireless devices. The millimeter waves technological capacity are still unknown to many developing countries. Its capability to respond to future communication demand of the society is not appreciated and the necessity to invest in further studies in the field is carefully neglected.

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The highly increase of wireless data growth creates challenges for wireless companies to suppress worldwide bandwidth shortage. For today's world of communication network wireless providers steps towards to provide very high quality, zero or low latency and many more multimedia applications. But they are highly limited to carrier frequency spectrum ranging from 700MHz to 2.6GHz.

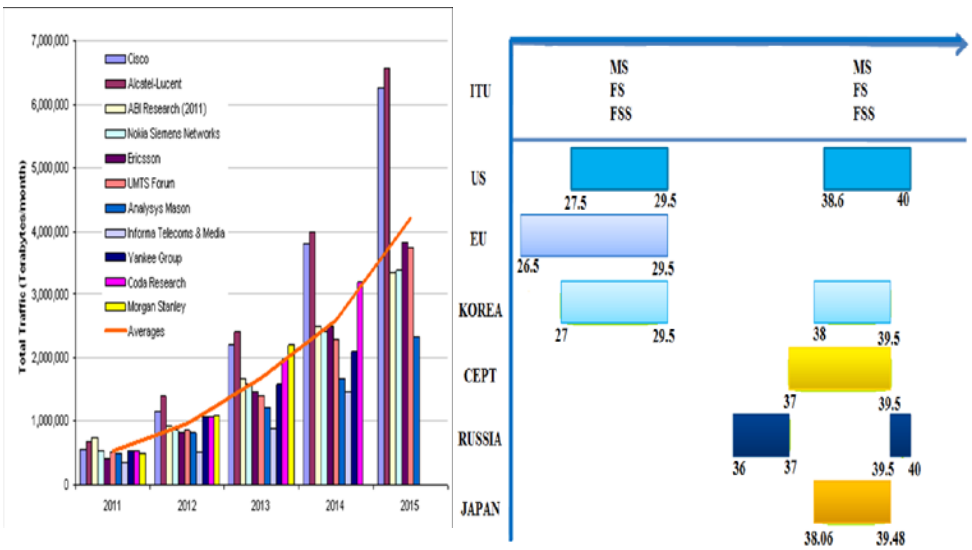
- To get new spectrum a several mm-wave 5G opportunities and challenges to face, they are
- The lower mm-wave bands must be allocated to other services like mobile backhaul and satellite.
- In the field of feasibility of sharing need to be researched.
- Cognitive radio technologies, databases interference cancelation like sharing mechanism will be required.
- For both backhaul and access there must be opportunity to develop shared use of mm waves, as a recent enabling fast spectrum release.

Now a days there are 4 generations of wireless communication systems adopted in USA in every 10 years since 1980:first FM cellular systems in 1981;second Digital technology in 1992;3G in 2001 and in 2011 4G LTE-A. The evolution from 1G to 4G is described in the Table 1 and Fig1 (a) shows year verses different companies forecast the rapid growth of total traffic demand (b) Possible Frequency for mm wave communication for 5G

Table-1: Evolution of wireless generations with their respective access technologies and features

GENERATION	ACCESS TECHNOLOGY	FEATURES
1G Wireless	• Advanced Mobile Phone Service(AMPS)	Analog voice service No data service
2G Wireless	• Code Division Mobile Access • Global System For Mobile Communication(GSM) • Personal Digital Cellular(PDC)	Digital voice service 9.6K-14.4Kbits/sec. CDMA, TDMA, PDC offers One way data transmissions only Enhanced calling features like caller ID No always ON-data connection
3G Wireless	• Wide-Band Code Division Multiple Access(WCDMA) • Based On The Interim Standard-95 CDMA Standard(CDMA2000) • Time Division Synchronous Code-Division Multiple-Access(TD_SDMA)	Superior voice quality and data always add-on Up to 2 Mbits/sec. Always on data Broadband data services like video and multimedia. Enhanced roaming Circuit & Packet switched networks.

4G Wireless	• Orthogonal Frequency Division Multiplexing(OFDM) • Multi Carrier CDMA(MC_CDMA) • LAS-CDMA	Coverage data and voice over IP Entirely packet switched networks. All network elements are digital Higher bandwidth to provide multimedia services at lower cost(100 Mbits/sec)



(a) (b)

Figure 1: (a) Plot shows year verses different companies forecast the rapid growth of total traffic demand

(b) Possible Frequency for mm wave communication for 5G

2 FUTURE ROAD MAP DESIGNERS

2.1 Nokia Siemens Network (NSN)

The NSN declares their motivational view on mobile communication evolution for 5G mm-wave beyond 2020 includes larger traffic volume, higher data rates, lower latency, more connected devices increased reliance on connectivity, new use cases, energy efficiency and lowest TCO.

The main anticipated technology enables mm- waves for 5G vision includes increasing spectrum availability both below and above 6GHz, improves spectral efficiency by MIMO, advanced transceivers and interference coordination and HetNet with high focus on small cells using mm-wave spectrum for 5G telecommunication MM-wave have higher propagation losses than bands below 6Ghz, the losses can be overcome through the one of antenna arrays with many elements. By using a massive number of antennas, the constructive interference of all the antennas should enable a significant increase in range while maintaining an acceptable transmits power. [5]NSN believes that 5G systems should provide peak rate greater than

10Gbps and a round –trip time of less than 1ms. To meet these requirements a large amount of additional spectrum both above and below 6Hz will be needed beyond 2020.

On the basis of mm waves communications major advantage over the current LTE standard NSN notes that '' Some aspects of user experience in a mm wave Enhanced local Area(ELA) system may be at least 20 times greater than that experienced with LTE.[10] This is possible since mm waves uses 50x the bandwidth compared to LTE''. There were some challenges like difficult propagation conditions, difficulties with the manufacture of small elements and inadequate chip processing power.[12] But now progress in chip and antenna technologies have moved mm wave for cellular- type communications much closer to reality.

The four key aspects to ensuring spectrum scarcity of Nokia Simens networks are additional harmonized spectrum must be allocated and used, 100Mhz of additional spectrum below 1Ghz will provide improved rural broadband, 500 MHz of additional spectrum between 1 and 5 GHZ will provide capacity for and spectrum shall be dedicated to mobile broadband on a technology neural basis. It's research targets flexible spectrum usage and spectrum sharing methods like spectrum harmonization and novel spectrum authorization as well looks in to propagation conditions in high frequency bands and different use cases for 5G local area systems operated in the millimeter wave region

2.2 Intel

Millimeter wave standards in Intel's mobile and wireless group defined a specification for 60 GHz as a local-area network.[14] The team is researching 28Ghz and 39 GHz as access links to mobile devices, targeting a throughput of 1Gbit/s or more at distances of at least 200m. Intel says that 5G cellular systems will need to use millimeter wave links to meet rising numbers of subscribers using more mobile data.

2.3 Samsung

As per Samsung ''39Ghz is more suitable for rule modification' because satellite services use portions of the 38Ghz band. By contrast, 39Ghz has significantly more than 1GHz available for use. [16]The 39 GHz band allows smaller antennas and thus could pack more of them in to that space than a 28 GHz link. Also 39 GHz offers 3-5dB signal improvement over 60 GHz. The 28 GHz band offers a benefit of only about 1.5dB over 39GHz.

Samsung stated it's new mm wave communication for 5G technology which will provide transmission rates of several hundred times faster than 4G. Samsung's test achieved that transmissions in the millimeter wave band do not pass through building walls, attenuated even by trees, easily absorbed by rain drops and humidity has significant impact. Also this test achieved that transmissions in the millimeter band are typically used in line-of-sight applications because they do not bend or reflect well.

The Samsung technology realizes on 28-giga hertz frequencies –also known as millimeter wave which are roughly on order of magnitude higher than the cellular frequencies used today and, as such, can carry commensurately more data.

The millimeter wave frequencies Samsung uses can be blocked by buildings, rain and other obstructions, a problem Samsung gets around using 64 antennas in both the transmitter and receiver and rapidly switching which transmitter and receiver beams carry data depending on which can get the clearest signal.

Recently Samsung's article states, 5G mm wave technology will sit at the core of 5G mobile communications, and it will allow for speeds several hundred times faster than current 4G networks. Samsung predicts 5G mm-wave wireless technology will be consumer-ready network capacities would have to grow well beyond 100X compared with today's capacities. To support future networks and growing video demands, 1000X growth could be needed. The industry is currently looking at interim solutions for more spectrum, but there is simply not enough spectrum being discussed to provide more than 10X growth. The article also mentions that they achieve up to a 2 km distance using a 64-element antenna.[1] While there are occlusions where 2km links are useful, 5G mm-wave deployments would likely focus on urban and hot-spot deployments where only a few hundred meters are needed. These cell densities are becoming common place under current 4G deployments and mm-wave will later provide an upgrade in throughput at these small-cell locations.

Samsung's designed are always operating at or near millimeter wave frequencies that is 3 to 300 gigahertz. So array of 64 antennas elements connected to build signal processing components. This trans-receiver generates a beam just 10 degree wide by dynamically varying the signal phase at each antenna. As a result it can switch rapidly in any direction. To connect with one another a base station named mobile radio would continuously sweep their beams to search for the strongest connection, getting around obstructions by taking advantage of reflections. As per the Samsung R/D center '' the transmitter and receiver work together to find the best beam path. According to Samsung's outdoor experiment, a prototype transmitter was able to send data at more than 1 GB/s to two receivers moving up to 8 kilometers per hour, which is the approximation speed of a Fast Jog. The collaboration between NYU and Samsung has achieved very similar results for crowded urban spaces in New York city and Austin, Texas.

In resent experiments Theodore Rappaport and his students simulated beam-forming arrays using megaphone like horn antennas to steer signals. They found signal coverage of up to 200 meters. They measured path losses between two horn transceivers installed at various places and conclude that a base station operating at 28 or 38 GHz continuously provide the above signal coverage.[20] But millimeters wave transceivers may not the perfect replacement for current wireless base stations. The current base stations covers up to a kilometer. T. Rappaport suggests that in the future, many base stations will likely be much smaller than today's. To expand data capacity in congested urban areas, already carriers are using compact base stations which is widely known as ‘’small cells’’. Also it provide a simple inexpensive alternative to backhaul cables which link mobile base stations to operators’ core networks’.

2.4 South Korea

Recently Korea has carried out a series of R/D activities toward beyond 4G evolution. It aims to establish ‘’Giga Korea’’ during 2013 to 2020 for hyper connected IT infrastructure deployment. Those activities include the acquision of wider spectrum, green networks and millimeter wave communication. South Korean farm hoped devices based on the technology could be brought to market by 2020, offering mobile data transfers up to several hundred times faster than today’s 4G tech. As a result, Subscribers will be able to enjoy a wide range of services such as 3D movies and games, real-time streaming of ultra-high-definition (UHD) content and remote medical; service

3 MILLIMETER WAVE SOLUTION FOR 5G CELLULAR NETWORKS

Despite industrial research efforts to deploy the most efficient wireless technologies the industry always faces overwhelming capacity for wireless technologies. It emergence the new customer handsets and use cases to access internet. Around 2020 the wireless network will face congestion and need to implement new technologies of carriers and customers. The life span of every generation cellular technology is a decade or less. This occur due to the natural evolution of computer and communication. By the help of the recent studies it shows that mm-wave frequencies could be used to augment the saturated 700MHZ to 2.6GHz radio spectrum bands. The CMOS technology can be operate well into mm-wave frequency bands and high-gains, steerable antenna at the mobile ,base station. The carrier frequencies of mm-wave allow larger bandwidth allocations which convert to higher data transfer rates.MM-wave allow the service provider to expand channel bandwidth beyond the present 20MHz channel by 4G customer. The data capacity is greatly increased due to increasing RF channel bandwidth and latency of digital traffic greatly decreased.[21] Due to smaller wavelength of mm-wave it exploit polarization and new spatial processing such as MIMO and adaptive beam forming. As mm-wave has significant jump in bandwidth and new capabilities offered by mm-waves the base station will be able to handle much greater capacity in 4G.The operator reduce cell coverage area to exploit spatial reuse and implement new cooperative MIMO, relays and interference mitigation between the base station. The cost per base station will drop as they become more plentiful distributed in urban areas for flexibility, quick deployment and reduced ongoing operating costs. Many cellular operators coverage cells sites widely over three octaves of frequency between 700MHz and 2.6GHz.The mm wave will have spectral allocations closer together making propagation characteristics of different mm waves bands much more comparable and homogenous. The 28GHz and38GHz are currently available with spectrum allocation over 1 GHz of bandwidth.

4 TEN TECHNOLOGICAL ASPECTS OF MM-WAVE COMMUNICATION FOR 5G NETWORK

4.1 Practicability of mm Wave system .

To obtain the low real-time latency, a frame structure is used with 100 microsecond slots to enable rapid retransmissions. To obtain peak data rates in excess of 10Gbps, the high bandwidths available at mm Wave are exploited along with the use of two stream MIMO enabled with polarization diversity, giving in excess of 10 Gbps without the need for more complex techniques. The main mode of operation for the wireless network at mm Wave will be dynamic time division duplexing (TDD).[22] TDD is attractive because the downlink and uplink traffic will be dynamic in the future and the transceiver will be simple and easy to build. A key element of the 5G mm Wave system solution is the use of mm Wave radio frequency integrated circuits (RFICs) that provide the core radio technology for the system. RFICs provide highly integrated solutions with benefits of reduced size, power consumption and cost.

4.2 Millimeter Wave Small-cells in 5G Heterogeneous Wireless Networks

Millimeter-wave (mm Wave) small-cell technology can provide sustainable and low radiation multi-gigabit-per-second data rates to mobile users in future 5G wireless networks, leading to unprecedented access to contents, applications and cloud services. Providing broadband wireless mobile communications to connect peoples, contents, clouds and things through the future Internet is a major objective of the Digital Agenda for Europe at the horizon of 2020. The current growth of the mobile data traffic of portable devices dramatically challenges the 4G cellular networks currently under deployment. There are critical technical problems that need to be addressed for the successful deployment and operation of future 5G heterogeneous wireless networks including (i) wireless access rates which are today significantly lower than those of fixed access; (ii) taking advantage of wide unlicensed or light-licensed frequency bands available at mm Wave frequencies to allow flexible spectrum usage as well as peak capacities above 10 Gbit/s aggregated throughput, well beyond the LTE-Advanced system. (iii) Communication networks energy consumption is growing rapidly, especially in the radio part of mobile networks; (iv) to reduce the total human exposure without compromising the user's perceived quality in the large panel of envisioned frequency band for 5G.

4.3 5G phones may be riding on the Millimeter Wave communication

By the end of this decade, analysts say, 50 billion things such as these will connect to mobile networks. They'll consume 1000 times as much data as today's mobile gadgets, at rates 10 to 100 times as fast as existing networks can support. So as carriers rush to roll out 4G equipment, engineers are already beginning to define a fifth generation of wireless standards. What will these "5G" technologies look like? It's too early to know for sure, but engineers at Samsung and at New York University say they're onto a promising solution. The South Korea–based electronics giant generated some buzz when it announced a new 5G beam-forming antenna that could send and receive mobile data faster than 1 gigabit per second over distances as great as 2 kilometers.[23] Although the 5G label is premature, the technology could help pave the road to more-advanced mobile applications and faster data transfers. Samsung's technology is appealing because it's designed to operate at or near "millimeter-wave" frequencies (3 to 300 gigahertz). Cellular networks have always occupied bands lower on the spectrum; where carrier waves tens of centimeters long (hundreds of megahertz) pass easily around obstacles and through the air. But this coveted spectrum is heavily used, making it difficult for operators to acquire more of it. Meanwhile, 4G networks have just about reached the theoretical limit on how many bits they can squeeze into a given amount of spectrum. So some engineers have begun looking toward higher frequencies, where radio use is lighter. Engineers at Samsung estimate that government regulators could free as much as 100 GHz of millimeter-wave spectrum for mobile communications—about 200 times what mobile networks use today. This glut of spectrum would allow for larger bandwidth channels and greater data speeds. Wireless products that use millimeter waves already exist for fixed, line-of-sight transmissions. And a new indoor wireless standard known as WiGig will soon allow multi gigabit data transfers between devices in the same room. But there are reasons engineers have long avoided millimeter waves for broader mobile coverage.

4.4 Global Strategic Business Report 2013-2018: MM Waves to Power 5G Networks

This report analyzes the worldwide markets for Millimeter Wave Equipment in US$ Thousands. The report provides separate comprehensive analytics for the US, Canada, Japan, Europe, Asia-Pacific, and Rest of World. Annual estimates and forecasts are provided for the period 2009 through 2018. Market strategies of different companies are summarized in Table 3.

Table-3: Market strategic report from 2013 to 2018 of different companies

Companies	**Executive Summary**	**Market**	**Competitive Landscape**
Aviat Networks	Industry Overview	The United States	The United States (23)
BridgeWave Communications	Technology Overview	Canada	Canada (1)
DragonWave,	Applications Of Mm-Wave Technology	Japan	Japan (8)
E-Band Communications Corporation	Peek Into Regulatory Scenario	Europe	Europe (8)
ELVA-1	Recent Industry Activity	Asia-Pacific	France (1)
INTRACOM TELECOM	Product Innovations/Introductions	Rest Of World	The United Kingdom (3)
NEC Corp	Focus On Select Key Players		Rest of Europe (4)
Siklu Communication Ltd	Global Market Perspective		Middle East (1)

4.5 Erik Vrielink 5G Beam Scheme

Steerable millimeter-wave beams could enable multi gigabit mobile connections. Phones at the edge of a 4G cell could use the beams to route signals around obstacles. Because the beams wouldn't overlap, phones could use the same frequencies without interference. Phones near the 4G tower could connect directly to it . For one thing, these waves don't penetrate solid materials very well.[24] They also tend to lose more energy than do lower frequencies over long distances, because they are readily absorbed or scattered by gases, rain, and foliage. And because a single millimeter-wave antenna has a small aperture, it needs more power to send and receive data than is practical for cellular systems. Samsung's engineers say their technology can overcome these challenges by using an array of multiple antennas to concentrate radio energy in a narrow, directional beam, thereby increasing gain without upping transmission power. Such beam-forming arrays, long used for radar and space communications, are now being used in more diverse ways. The Intellectual Ventures spin-off Kymeta, for instance, is developing met materials-based arrays in an effort to bring high-speed satellite broadband to remote or mobile locations such as airplanes.

4.6 Full filling The Future Needs:

This will take a total combination of exclusive spectrum and shared solutions to achieve the requirements of cellular network operators to 2020. During the upcoming 10 years these two sensitive approaches must increase the total amount of spectrum resources below 6 GHz up to a total of 1.5 GHz. Beyond this spectrum the cellular industry must look forward for resources above 6GHz.The availability of a large bandwidth such as 13GHz in the 70-80GHz band which coupled with large antenna arrays at both the transmitter and receiver can make this spectral band attractive for using high capacity 5G local area network based on mm-wave technology.

The 4 key aspects to ensuring spectrum scarcity does not impede growth :

- Additional harmonized spectrum must be allocated and used.
- 100MHz of additional spectrum below 1 GHz will provide rural broadband.
- 500MHz of additional spectrum between 1 and 5 GHz will provide capacity of data.
- Spectrum shall be dedicated to mobile broadband on a technology-neutral basis.

4.7 Challenges of mm-wave

4.7.1 5G LTE or 5G mm-wave or both

Much work has been done to make LTE more efficient with techniques such as carrier aggregation, single-user and multi-user MIMO, coordinated multi-point, interference management and heterogeneous networks (HetNets).However, the large amount of mm Wave bandwidth available gives it an advantage over LTE and exploiting this may ultimately prove to be effective. Some aspects of user experience in a mm Wave enhanced Local Area (eLA) system may be at least 20 times greater than that experienced with LTE. This is possible since mm Wave uses 50x the bandwidth compared to LTE. In cell edge spectral efficiency, LTE-A can be approximately 2.5 times better than the basic mm Wave system, though mm Wave has the potential to match or exceed.

4.7.2 Networks to get for denser

A practical 5G system will be based on very dense networks of small cells, working with a high frequency macro network using 3G and 4G, including LTE-Advanced. In addition NSN believes that 5G systems should provide more than 10Gbps peak rate and a normal trip time of less than 1 msec. A large amount of additional spectrum, both below and above 6GHz will be needed to meet the capacity target beyond 2020. However, the available spectrum below 6GHz is limited and there are practical limits to how much cells can shrink to efficiently use the limited spectrum.

4.8 Unlocking Mm-Wave Spectrum For 5G

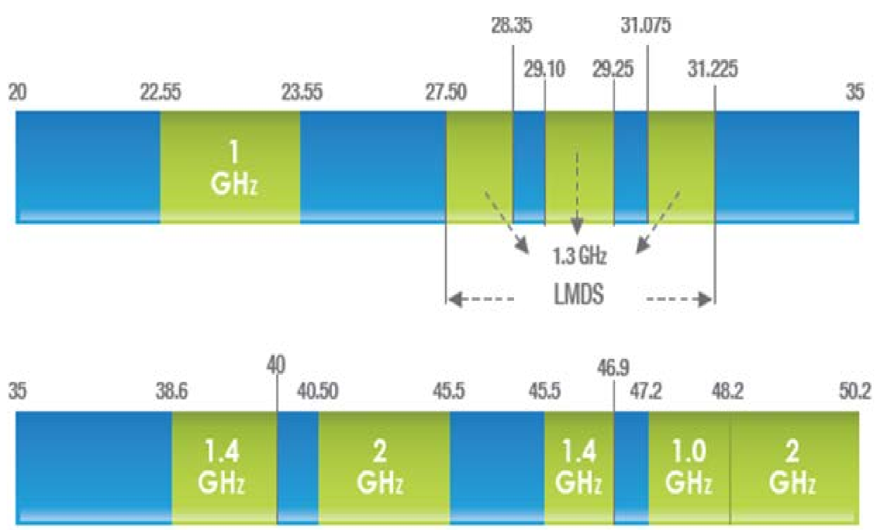


Fig 2: Spectrum of Unlocking mm wave for 5G

- mm-wave provides 25 times more spectrum than available in 4G
- Very large blocks of contiguous spectrums are used to support the future application.
- Use of large antenna arrays for adaptive beam forming can be possible due to its small wavelength.
- Beam forming is maintained between base station (BS) and terminal propagation exponent which is very similar to spectrum below 7GHz.

4.9 Mm wave communication for 5G networking in support of future internet services

Millimeter communication 5G networks need to support unprecedented requirements for the wireless access connection. At the same time a dramatic paradigm shift is found in internet usage with multimedia traffic .So far the discussed innovations alone will not be able to support such services requirements to fast moving mobile users. Hence the network infrastructure characteristics and architecture need to fundamentally change. A shift in frequencies will require a very small size cell compared to the 4G ones and hence a significantly larger scale deployment of wireless base station sites would be necessary. The very small size and the very high cell throughput will boost dramatically the requirements from the front/back-hauling networks which is based on optical fiber networks. Conventional solutions like CPRI back-hauling networks would not be efficient and hence solutions like analogue mm-wave radio over fiber solutions might become prominent. Operators are struggling now a days to satisfy the requirements of the 4G wireless access networks using advanced front/back hauling techniques. Their the first approach was to keep existing wire line and wireless architecture as much as possible.[2] Wireless base stations have been connected to the core network via IP. Hence back-hauling network requires to provision for tunnels for transporting S1 and X2 packets. The second approach is the CRAN concept which is a hot topic a couple of years ago, where fully centralized versions for embedding the wireless subsystem in to wire line network. Since the impact of metro cell within a macro cell are highly enhanced while less gains are achieved when coordinating cells are far apart from each other. Hence a very high degree of centralization is not really required.

4.10 Attenuation Issues

The millimeter-wave bands ranging from 3mm to 30mm in wavelength are also practically unused for commercial wireless communication because absorption by rainfall climbs rapidly from 2GHZ to 100GHZ, making this region of the spectrum unattractive for long-distance radio communication. Prof Rappaport says that rainfall and oxygen absorption will attenuate these frequencies too much. He also suggest that if you restrict the use of 20GHZ- plus signals to relatively short distances, some of the problems can be avoided. Higher frequency transmission are highly directional and work best where the handset has a clear line of sight to the base station. But prof Rappaport’s found the waves bounce off building s providing multiple paths to a user even if they cannot see the transmitter. To steer radio transmissions towards a receiver, Prof Rappaport suggest the use of beam-forming with multiple antennas.

5 CONCLUSION

Despite this significant progress, a complete characterization of the mm-wave link for next generation 5G mobile broadband remains elusive. In particular coverage, directionality and reliability of mm-wave communications will require new innovations in system design and communication technologies that are far from trivial. System designers must increase the transmission range and spatial selectivity in the mm-wave bands, especially in Non-line-of-sight channels. This necessities highly directional antennas and steerable antenna beams to compensate for the high propagation loss.

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