5G WIRELESS COMMUNICATION USING MILLIMETER WAVE

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***Abstract* – The rapid increase of mobile data growth and the use of smart phones are creating unprecedented challenges for wireless service providers to overcome a global bandwidth shortage. As today's cellular providers attempt to deliver high quality, low latency video and multimedia applications for wireless devices, they are limited to a carrier frequency spectrum ranging between 700 MHz and 2.6 GHz. The global bandwidth shortage facing wireless carriers has motivated the exploration of the underutilized millimeter wave (mm-wave) frequency spectrum for future broadband cellular communication networks. There is, however, little knowledge about cellular mm-wave propagation in densely populated indoor and outdoor environments. We will be simulating the integration of mm-wave using Wi-Fi network and cooperation between base station to achieve the increase in bandwidth and decrease in path loss.**

Keywords: 5G, millimeter wave, bandwidth, bit rate.

1. Introduction

First generation cellular networks were basic analog systems designed for voice communications. A move to early data services and improved spectral efficiency was realized in 2G systems through the use of digital modulations and time division or code division multiple access. 3G introduced high-speed Internet access, highly improved video and audio streaming capabilities by using technologies such as Wideband Code Division Multiple Access (W-CDMA) and High Speed Packet Access (HSPA). As a key technology in supporting high data rates in 4G systems, Multiple-Input Multiple-Output (MIMO) enables multi-stream transmission for high spectrum efficiency, improved link quality, and adaptation of radiation patterns for signal gain and interference mitigation via adaptive beam forming using antenna arrays. As the demand for capacity in mobile broadband communications increases dramatically every year, wireless carriers must be prepared to support up to a thousand fold increase in total mobile traffic by 2020, requiring researchers to seek greater capacity and to find new wireless spectrum beyond the 4G standard.

LTE-Advanced supports heterogeneous networks with co-existing large macro, micro, and picocells and Wi-Fi access points. Low cost deployment will be realized by self-organizing features and repeaters/relays. As fifth generation (5G) is developed and implemented, we believe the main differences compared to 4G will be the use of much greater spectrum allocations at untapped millimeter wave frequency bands, highly directional beam forming antennas at both the mobile device and base station, longer battery life, lower outage probability, much higher bit rates in larger portions of the coverage area, lower infrastructure costs, and higher aggregate capacity for many simultaneous users in both licensed and unlicensed spectrum (e.g. the convergence of Wi-Fi and cellular).

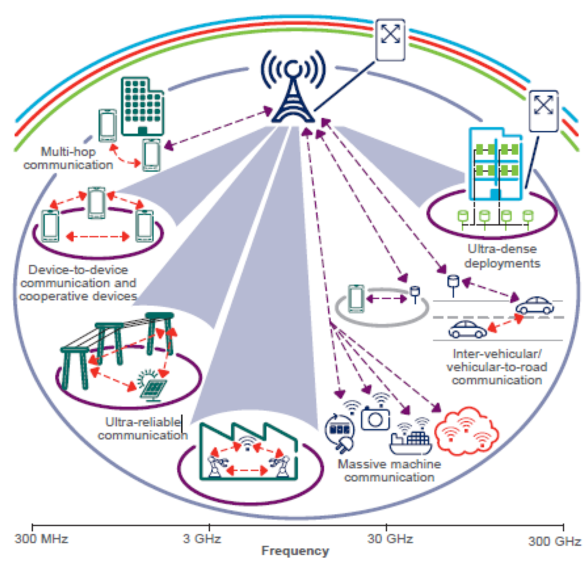


Fig 1: Scope of 5G Radio Access Technology © Ericsson

The backbone networks of 5G will move from copper and fiber to mm-wave wireless connections, allowing rapid deployment and mesh-like connectivity with cooperation between base stations.

Millimeter waves occupy the frequency spectrum from 30 GHz to 300 GHz. They are found in the spectrum between microwaves (1 GHz to 30 GHz) and infrared (IR) waves, which is sometimes known as extremely high frequency (EHF). The wavelength (λ) is in the 1-mm to 10-mm range. At one time this part of the spectrum was essentially unused simply because few if any electronic components could generate or receive millimeter waves.

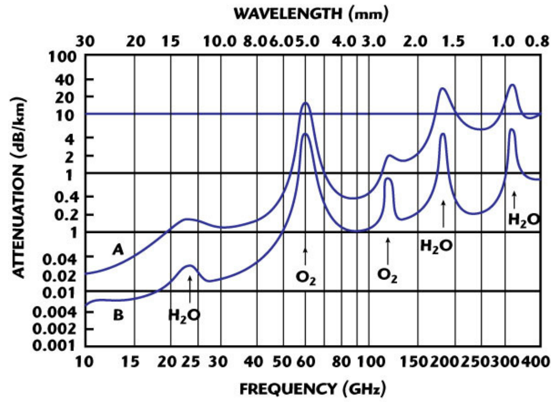
In July 2013, India and Israel have agreed to work jointly on development of fifth generation (5G) telecom technologies.

Samsung Electronics recently announced it had made a breakthrough in wireless network technology, calling it "5G". Samsung said that its researchers "successfully developed the world's first adaptive array transceiver technology operating in the millimeter-wave Ka bands for Cellular communications". The transmissions used in the test were made at the ultra high 28GHz frequency, which offers far more bandwidth than the frequencies used for 4G networks. High frequencies can carry more data, but have the disadvantage that they generally can be blocked by buildings and lose intensity over longer distances. Samsung said its adaptive array transceiver technology, using 64 antenna elements, can be a viable solution for overcoming the weaker propagation characteristics of millimeter-wave bands, which are much higher in frequency than conventional wireless spectrum.

METIS (Mobile and Wireless Communications Enablers for the Twenty-twenty (2020) Information Society) METIS is an EU-funded, Ericsson-led, consortium of 29 organizations with a 27 million Euro budget and more coming from the European Commission is aimed at replicating Europe's worldwide success with GSM and subsequent technologies. It will "develop a system concept that delivers the necessary efficiency, versatility and scalability, investigate key technology components supporting the system and evaluate and demonstrate key functionalities."

2. Characteristics of millimeter wave

Rain, fog, and any moisture in the air make signal attenuation very high, reducing transmission distances. Oxygen (O_2) absorption is especially high at 60 GHz. Water (H_2O) absorption is responsible for the other peaks. Selecting frequencies within the curve valleys minimizes the loss. Additionally, high-gain antenna arrays can boost the effective radiated power (ERP), significantly increasing range.



Average atmospheric absorption of MMWs: (A) Sea Level: T = 20°C, P = 760mm, H_2O = 7.5 g/m³ (B) 4 km altitude: T = 0°C H_2O = 1 g/m³

Fig 2: Attenuation due to Atmospheric gases © Wiley IEEE Press

Samsung's current prototype is a matchbook-size array of 64 antenna elements connected to custom built signal processing components. By dynamically varying the signal phase at each antenna, this transceiver generates a beam just 10 degrees wide that it can switch rapidly in any direction, as if it were a hyperactive searchlight. To connect with one another, a base station and mobile radio would continually sweep their beams to search for the strongest connection, getting around obstructions by taking advantage of reflections.

In fact, the short range can be a benefit. For example, it cuts down on interference from other nearby radios. The high-gain antennas, which are highly directional, also mitigate interference. Such narrow beam antennas increase power and range as well. And, they provide security that prevents signals from being intercepted. Small size is another major advantage of millimeter-wave equipment. While ICs keep the circuitry small, the high frequency makes very small antennas necessary and possible. Another challenge is making circuitry that works at millimeter-wave frequencies. With semiconductor materials like silicon germanium (SiGe), gallium arsenide (GaAs), indium phosphide (InP), and gallium nitride (GaN) and new processes, though transistors built at submicron sizes like 40 nm or less that work at these frequencies are possible.

The Silicon Image Ultra Gig 6400 60-GHz transceiver is small enough to fit in the modern smart phone for video connectivity.

3. Challenges of 5G

The future mobile-broadband user should experience radio access with "unlimited" performance data should be accessible instantaneously and the delivery of services should not be hampered by waiting times or unreliable access. The overall traffic volume in wireless communication systems has grown tremendously in recent years, fueled primarily by the uptake in mobile broadband. This trend is expected to continue into the future. There are more than 5 billion wirelessly connected mobile devices in service today, most of which are handheld terminals or mobile broadband devices in portable computers and tablets. In the future, such human-centric connected devices are expected to be surpassed between 10- and 100-fold by communicating machines including surveillance cameras, smart-city, smart-home and smart-grid devices, and connected sensors. The transition from five to 50 or perhaps even 500 billion connected devices will present a formidable challenge. Problems are also faced by service providers.

Applications relating to the control of critical infrastructure (such as electrical grids), industrial control or vital societal functions, such as traffic, e-health and smart-city management, require very high levels of network reliability higher than what present networks typically offer. Mobile-broadband services such as video streaming, data sharing and cloud services will remain, and will continue to drive a demand for higher consumer data rates. Reliably achievable multi gigabytes per second data rates should be available in special scenarios, such as office spaces or dense urban outdoor environments these rates will support applications such as synchronization of device, local storage to cloud drives, network hard drives, ultra-high-resolution video, and virtual and augmented reality. In the present technologies there is congestion in system due to low bandwidth and low channel capacity so more interference occurs. Due to large number of mobile users, call drop probability is fairly high. Duty cycle of present system is very high. Radio coverage is also less.

4. System Design

Aim of our simulation is to enhance the capacity of 5G wireless network. Millimeter wave can be multiplexed using the derived technique to improvements in the channel capacity.

If we let the number of users be N, and the transmitted power from each user to be S, the received signal will consists of the received signal power for the desired user (S) and the interference from N-1 other users, thus the signal to noise ratio will be:

$$SNR = \frac{S}{(N-1)S} = \frac{1}{N-1}$$

Since the noise in the channel is reduced by the process gain during demodulation, the noise on each data bit seen after demodulation will be less. The process gain is the ratio of the total bandwidth (W) to the base band information bit rate (R). Thus the received energy bit to noise ratio (Eb/No) is:

$$\frac{E_b}{N_o} = \frac{W}{R}\frac{1}{(N-1)}$$

The above equation does not take into account thermal noise. The thermal noise simply increases the effective amount of noise. Let the thermal noise be n. Thus, the Eb/No becomes

$$\frac{E_b}{N_o} = \frac{W}{R}\frac{1}{(N-1)+n/S}$$

In order to achieve an increased capacity, the interference from users needs to be reduced. This can be achieved by monitoring the voice activity so that the transmitter is switched off during periods of no voice activity. This reduces the effective interference level by the reduced duty cycle of the transmitted signal.

The interference can also be reduced by using further antenna sectorization.

If we let d be the duty cycle of the voice activity, and G is the cell sectorization then equation becomes

$$\frac{\boldsymbol{Eb}}{\boldsymbol{No}} = \frac{\boldsymbol{W}}{\boldsymbol{R}\,[\,(\boldsymbol{N}-\boldsymbol{1})\frac{\boldsymbol{d}}{\boldsymbol{G}} + \boldsymbol{n/S}\,]}$$

thus the capacity of a single cell system would be

$$\boldsymbol{N} = \frac{\boldsymbol{G}}{\boldsymbol{d}}\left(\frac{\boldsymbol{No}}{\boldsymbol{Eb}}\frac{\boldsymbol{W}}{\boldsymbol{R}} - \frac{\boldsymbol{n}}{\boldsymbol{S}}\right) + \boldsymbol{1}$$

G is the antenna sectorization,
d is the voice duty cycle,
Eb/No is the energy bit to noise ratio,
W is the total transmission bandwidth,
R is the base band bit rate,
n/S is the ratio of received thermal noise to user signal power.

The above expression will be fine tuned to get the desired result for possible best cell capacity, The BER increases as number of user increases, reaching a peak value, and then decreasing as number of user increasing further.

5. Proposed Solution

Sectorization is increased by deploying more directional antennas to increase channel capacity and large number of mobile users can be served. Overall energy of the system i.e. bandwidth will also be increased.

Convergence of all technologies i.e. 2G, 3G, RF, Wi-Fi will be done in 5G so vertical handoff between various technologies can be done so call drop probability reduces and latency issue can also be solved. Duty cycle can be reduced so low power consumption. Thermal noise can be reduced.

Bit error rate can be improved so co-channel interference within the cell is reduced and we get higher data rate.

5G will be able to provide ultra high traffic capacity and data rates.

The combination of cost-effective CMOS

technology that can now operate well into the mm-wave frequency bands, and high-gain, steerable antennas at the mobile and base station, strengthens the viability of mm-wave wireless communications. Further, mm-wave carrier frequencies allow for larger bandwidth allocations, which translate directly to higher data transfer rates. Mm-wave spectrum would allow service providers to significantly expand the channel bandwidths far beyond the present 20 MHz channels used by customers

By increasing the RF channel bandwidth for mobile radio channels, the data capacity is greatly increased, while the latency for digital traffic is greatly decreased, thus supporting much better internet based access and applications that require minimal latency. Millimeter wave frequencies, due to the much smaller wavelength, may exploit polarization and new spatial processing techniques, such as massive MIMO and adaptive beam forming.

Millimeter waves also permit high digital data rates. Wireless data rates in microwave frequencies and below are now limited to about 1Gbit/s. In the millimeter-wave range, data rates can reach 10Gbits/s and more.

6. Results

Considering bandwidth of 500 MHz and onwards up to 7Ghz, at working frequencies between 28Ghz to 60GHz. As duty cycle is reduced in this system, considering Duty cycle of 0.5% we can achieve minimum energy usage.

Although Thermal noise increases with increase in frequency approximate value in consideration is 174dBm/ MHz but in millimeter range using optical fiber can make transmission independent of Thermal noise.

Doubling number of sectors per site doubles the throughput, hence it is essential to increase sectoriztion to 8 or 12. While increasing sectorization beamwidth should be reduced accordingly. With increased frequency reuse Cell radius is reduced to 300m.

In our simulation we have varied the input of transmitter and receiver power, as well as antenna height, and calculated Process Gain, Single Cell Capacity, Signal to noise Ratio. The process gain increases with increase in number of users, SNR reduces with increase in number of users and capacity increases with increased number of users.

1. Bandwidth

5G wireless networks will support 1000-fold gain in capacity, connection of at least 100 billion devices. Bandwidth of the proposed system i.e. 5G will be more compared to existing system as shown in the below graph.

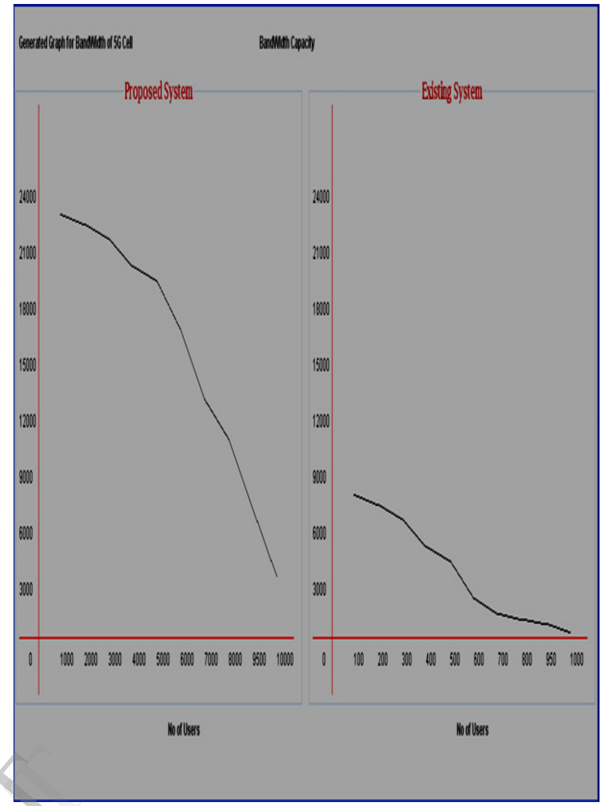


Fig 3: This graph that shows comparison between bandwidth of proposed system and existing system.

The graph shows that in the proposed system 5G as the number of users increases more bandwidth are allocated as per the requirement results in increased channel capacity and enhanced system performance. System utilization in 5G would be more as it is convergence of existing wireless technologies and complementary new technologies. Call drop probability in 5G will be reduced compared to existing system by maintaining higher bandwidth utilization or lower blocking rates for new calls in system.

2. Bit rate

From the Fig 4 it can be concluded that bit rate of the proposed system i.e.5G would be 1Gbps compared to existing technology i.e.3G where the bit rate is only 2Mbps.

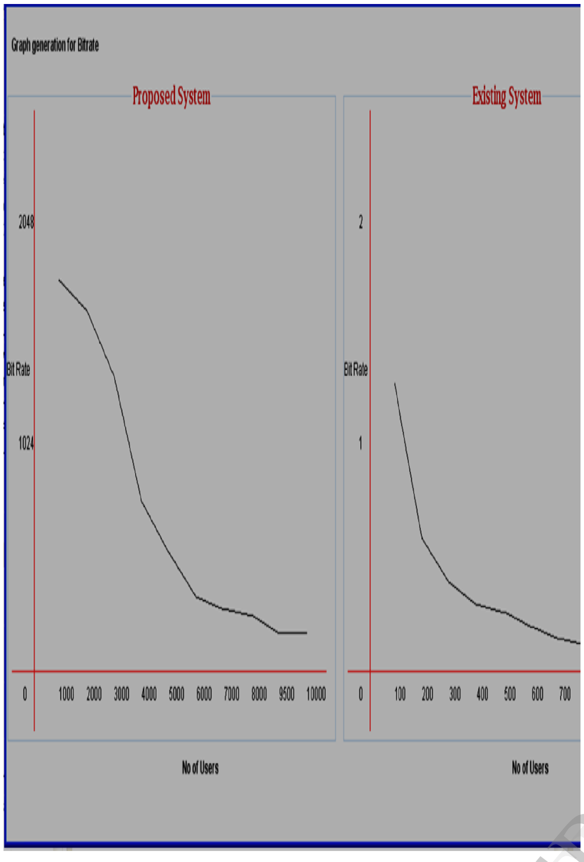


Fig 4: This graph shows comparison between bit rate of proposed system and existing system.

Energy- per- bit usage in the proposed i.e.5G will be reduced to improve connected device battery life.

7. Conclusion

The 5G system for 2020 and beyond will meet our long-term vision of unlimited access to information and sharing of data available anywhere and anytime to anyone and anything.

To do this, it is clear that a much wider variety of devices services and challenges than those accommodated by today's mobile-broadband systems will have to be addressed. Due to this diversity, the 5G system will not be a single technology but rather a combination of integrated RATs (radio access technologies), including evolved versions of LTE and HSPA, as well as specialized RATs for specific use cases, which will jointly fulfill the requirements of the future. It can Support IPv6, Support Flat IP, multihoming, Mobile cloud computing support, High Altitude stratospheric Platform Station Systems, etc. 5G will provide foundational infrastructure for smart cities, m-health would emerge as one the biggest application of new 5G network as wearable device use increases, it will lead to new type of 'sentient' health devices that are aware of real time changes in your health and capable of relaying that information to health providers

This project proposes a channel enhancement capacity technique, which depends on Bit error rate. The spectrum of mm wave can be multiplexed with various techniques like CDMA, OFDM using the proposed equation to increase the channel capacity.

The new 5G network would be faster, smarter and hyper connected to everything. 5G network will provide massive capacity and connectivity to support Internet of things (IoT) applications. Low latency and extremely high reliability will be the important feature of 5G network.

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