EXPLORING THE ROAD TO 6G -

Foundation for Intelligent Mobile Networks

A Seminar Report

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CERTIFICATE

This is to certify that the report entitled **Exploring the Road to 6G - Foundation for Intelligent Mobile Networks** submitted by **Vipin Chandran M** (TVE17EC061), to the APJ Abdul Kalam Technological University in partial fulfillment of the B.Tech. degree in Electronics and Communication Engineering is a bonafide record of the seminar work carried out by him under our guidance and supervision. This report in any form has not been submitted to any other University or Institute for any purpose.

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DECLARATION

I Vipin Chandran M hereby declare that the seminar report **Exploring the Road to 6G - Foundation for Intelligent Mobile Networks** , submitted for partial fulfillment of the requirements for the award of degree of Bachelor of Technology of the APJ Abdul Kalam Technological University, Kerala is a bonafide work done by me under supervision of Prof. Jijina N

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Abstract

The 5th generation (5G) mobile networks has been put into services across a number of markets, which aims at providing subscribers with high bit rates, low latency, high capacity, many new services and vertical applications. 6G is not only about moving data around – it will become a framework of services, including communication services where all user-specific computation and intelligence may move to the edge cloud. The integration of sensing, imaging and highly accurate positioning capabilities with mobility will open a myriad of new applications in 6G.

To meet these challenging demands, research is focusing on 6G wireless communications enabling different technologies and emerging new applications. In this seminar report, the latest research work on 6G technologies like Terahertz Band ,Cell Free Massive MIMO, Radio Stripes and applications is summarized, and the associated research challenges are outlined.

Acknowledgement

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Vipin Chandran M

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NOMA : Non-orthogonal multiple access

GSM : Global System for Mobile Communications

UMTS : Universal Mobile Telecommunications Service

LTE : Long-Term Evolution

NLOS : Non-line-of-sight

OFDMA : Orthogonal frequency-division multiple access

SIC : Successive Interference Cancellation

mm Millimeter

Hz Hertz

Kbps Kilobits per second

Mbps Megabits per second

Mbps Gigabits per second

Chapter 1

Introduction

1.1 Evolutions of G's–

The last few years have witnessed a phenomenal growth in wireless inidustry, both in terms of mobile technology and its subscribers. There has been a clear shift from fixed to mobile cellular telephony. With all the technologicsl advances and simultaneous existence of 2G, 2.5G and 3G networks efficiency have become even more critical. The first generation(1G) has fullfilled the basic voice, while second generation(2G) has introduced capacity and coverage, followed by third (3G) which has quest for data at higher speeds to open gates for true experience followed by the path to advanced communications in 4G and further.

1.2 1G vs 2G vs 3G vs 4G

Features	***1G***	***2G***	***3G***	***4G***
Technology Based	Analog	GSM	UMTS	LTE, WiMax
BandWidth	2 Kbps	14.4 - 64Kbps	2Mbps	Upto 1Gbps
Access System	FDMA	TDMA	CDMA	OFDMA
Carrier Frequency	30 KHZ	200 KHz	5 MHz	15 MHz
Operating Frequency	800 MHz	1800MHz	2100 MHz	850 MHz, 1800 MHz
Band Frequency Type	Narrow band	Narrow band	Wide band	Ultra Wide Band

1.3 WHY and WHEN 6G ?

One of the goals of the 6G Internet will be to support one micro-second latency communications, representing 1,000 times faster – or 1/1000th the latency – than one millisecond throughput.The 6G technology market is expected to facilitate large improvements in the areas of imaging, presence technology and location awareness.Additionally, whereas the addition of mobile edge computing (MEC) is a point of consideration as an addition to 5G networks, MEC will be built into all 6G networks.The University of Oulu in Finland is committed to a 6G research initiative referred to as 6Genesis.The United States is planning to open up 6G frequency for RD purposes pending approval from the Federal Communications Commission (FCC) for frequencies over 95 gigahertz (GHz) to 3 THz. 6G is expected to launch commercially in 2030. The usage of smart devices is increasingly growing each year and the data traffic usage will be exponentially increasing as shown in Fig. 1.1 given below (including and excluding M2M data), which puts constraints on the 5G communication network.

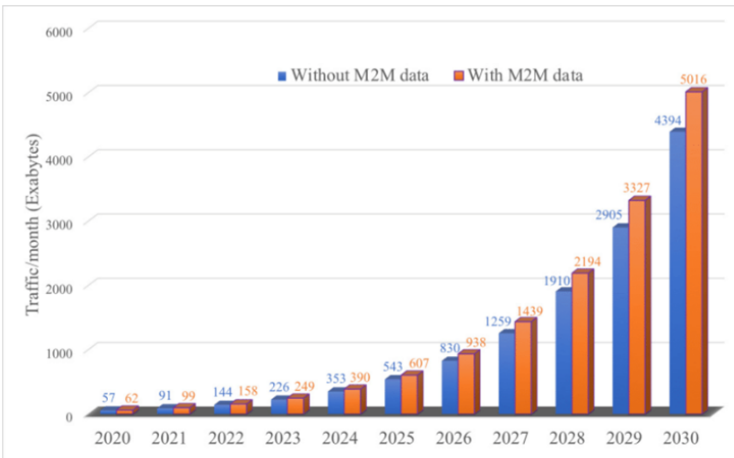

Figure 1.1: ITU Global Mobile Data Traffic Prediction [1]

Chapter 2

Literature Review

To provide a foundation for the discussion of 6G services, 5G core services of enhanced mobile broadband (eMBB), ultra-reliable low latency communications (URLLC), and massive machine type communications (mMTC) are first reviewed. Three basic performance requirements for 5G services are high data rate, low transmission latency, and massive connectivity, which address the most urgent wireless communication issues for present demand [2].

Numerous studies have explored the effects of various 5G technologies such as orthogonal frequency division multiple access (OFDMA), polar code, massive multiple input multiple output (MIMO), millimeter wave (mmWave), and software defined network (SDN) on the basic requirements. Various additional techniques for supporting 5G performances include full duplex, non-orthogonal multiple access (NOMA), and mobile edge computing (MEC). From this perspective, B5G can be considered as an evolution to further enhance 5G performance. Despite 5G advancements toward more efficient network setups, the heterogeneity of future network applications and the need for 3D coverage calls for new cell-less architectural paradigms, based on the tight integration of different communication technologies, for both access and backhaul, and on the disaggregation and virtualization of the networking equipment [1].

Although standardization bodies are promoting study items that are oriented toward the investigation of terahertz and VLC solutions for future wireless systems (i.e., IEEE 802.15.3d and 802.15.7, respectively), these technologies have not yet been included in a cellular network standard, and will be targeting beyond 5G use cases.

Moreover, additional research is still required to enable 6G mobile users to operate in the terahertz and VLC spectra, including hardware and algorithms for flexible multi-beam acquisition and tracking in non-line-of-sight (NLoS) environments. Besides the new spectrum, 6G will also transform wireless networks by leveraging a set of technologies that have been enabled by recent physical layer and circuit research, but are not part of 5G. Many of the Key Performance Indicators (KPIs) used for developing current and emerging 5G technologies are valid also for 6G. Some of the essential KPIs are depicted in the fig 2.1 shown below [5].

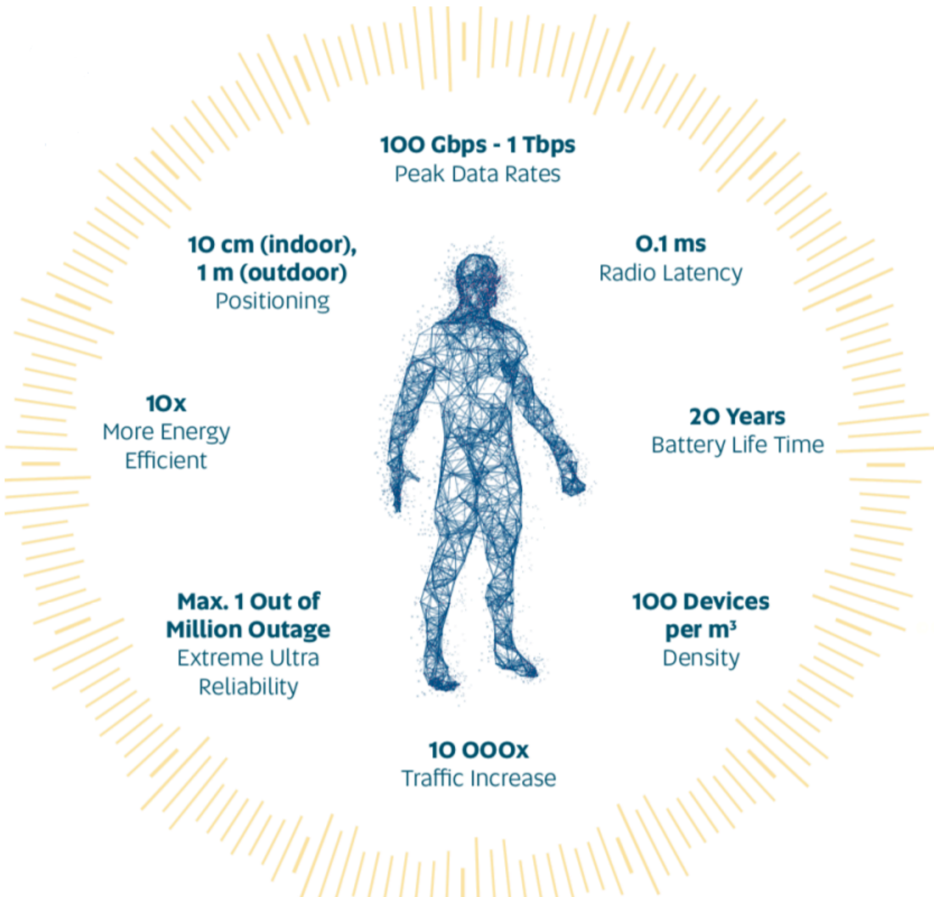

Figure 2.1: Revolutionising 6G

Chapter 3

5G Revolution-Technologies

3.1 Millimeter Waves

Millimeter wave spectrum is the band of spectrum between 30 GHz and 300 GHz. Wedged between microwave and infrared waves, this spectrum can be used for high-speed wireless communications as seen with the latest 802.11ad Wi-Fi standard (operating at 60 GHz). The extremely short wavelengths of mm wave signals make it feasible for very small antennas to concentrate signals into highly focused beams with enough gain to overcome propagation losses.The short wavelengths of mm wave signals also make it possible to build multi-element, dynamic beam-forming antennas that will be small enough to fit into handsets.

3.2 Massive MIMO

At higher frequencies and with more antenna elements, new forms of transmissions should be considered for improved efficiency. By coherently combining transmission from and reception at multiple points the signal can be locally shaped according to each user's location and service requirements. This constitutes a new frontier for massive MIMO development. Joint transmissions to and from multiple devices that cooperate is a related technique that can help improve network efficiency. By forming an effective array together, the coverage of the devices can be extended, which is especially useful at higher bands.

3.3 Beam Forming and Small Cell

Beam forming is the application of multiple radiating elements transmitting the same signal at an identical wavelength and phase, which combine to create a single antenna with a longer, more targeted stream which is formed by reinforcing the waves in a specific direction. While digital beam-forming at the base-band processor is most commonly used today, analog beam-forming in the RF domain can provide antenna gains that mitigate the lossy nature of 5G millimeter waves. To enhance beam-forming, several other techniques will be added, these include beam steering, beam switching, and MIMO. Beam steering is achieved by changing the phase of the input signal on all radiating elements. Phase shifting allows the signal to be targeted at a specific receiver.

3.4 NOMA Technology

NOMA is fundamentally different from the other multiple access schemes which provide orthogonal access to the users either in time, frequency, code or space. In NOMA, each user operates in the same band and at the same time where they are distinguished by their power levels. NOMA uses superposition coding at the transmitter such that the successive interference cancellation (SIC) receiver can separate the users both in the up-link and in the down link channels.In NOMA downlink, the base station superimposes the information waveform for its serviced users. Each user equipment (UE) employs SIC to detect their own signals. Fig 3.1 given below depicts the NOMA technology wherein multiple users can accommodate one resource block of variable powers.

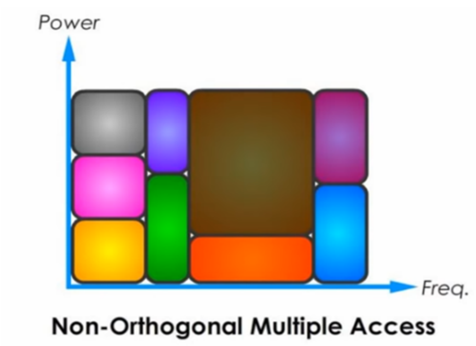

Figure 3.1: Resource Allocation in NOMA

Chapter 4

6G - Network With The Sixth Sense

4.1 Research Directions to 6G

A new generation is ultimately characterized by the number of novel, essential technologies that shape the communication system. Truly fundamental new technologies typically take a decade or more to become realized in practice. In view of this, the truly novel technologies forming 6G must be research concepts today. Keeping with the theme of “six” for 6G, we have identified six new potential technology transformation that we expect to be part of shaping the 6G system

4.1.1 Cognitive Spectrum Use

Low-frequency spectrum will continue to be of paramount importance for wide-area coverage due to the superior propagation properties in NLOS compared to higher-frequency bands.Thus, in the timeframe of 6G, new spectrum-use methods will be required even within the licensed spectrum regime to allow better local access to the spectrum and coexistence with other users. Operators may need to share spectrum among themselves and with other private dedicated networks. And even within a single operator, multiple generations of technologies will coexist and share spectrum. Allowing various forms of coexistence among cognitive sharing systems that will be highly beneficial.

4.1.2 Cell-Free Massive MIMO Networks

The combination between cell-free structure and massive MIMO technology yields the new concept: Cell-Free Massive MIMO. It is a system where a massive number access points distributed over a large area coherently serve a massive number of user terminals in the same time/frequency band. By contrast, in Cell-Free Massive MIMO there are no cells. All service antennas coherently serve all user terminals.Connection to Cloud RAN, Reinforcing the Radiations, Coherent Reception and Transmission are some of its usefull features.

4.1.3 Radio Stripes

The pWave Chain seems to contain small access points that are connected with network cables to a cloud RAN that does all the processing, while in the radio stripes the RF components are printed electronics on tape and the processing is done sequentially inside the cable. Each Antenna at 3.5GHz band and can be increased by adding more dual polarized elements at Antenna Processing Unit(APU). Invisible Installation, Scalable nature, Cost Effective are its main features. Concept of SOC for APU's has been implanted from mobile chipsets.

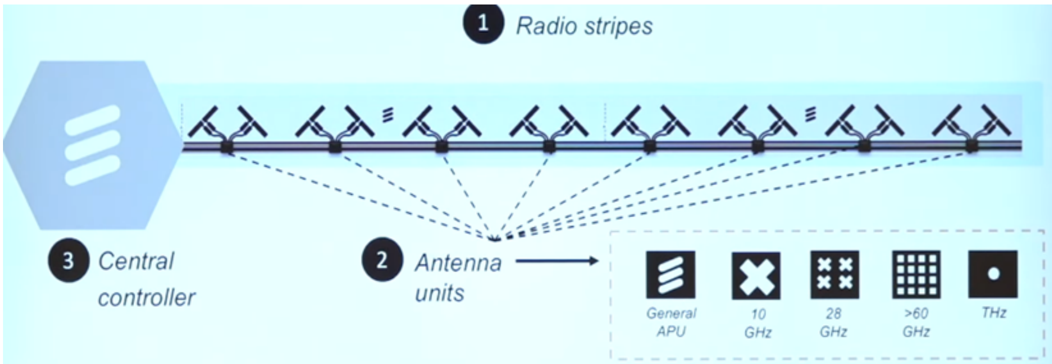

Figure 4.1: Electronic Print View of a Radio Stripes

4.1.4 RAN-CORE Convergence

In 5G, the base station has been compartmentalized into the distributed unit (DU) and centralized unit (CU). The DU includes the lower layers of the user and control plane protocol stack, namely the physical Layer 1 and real-time Layer 2, while the CU includes the non-real-time Layer 2 and Layer 3 functions.With increasing centralization of the higher-layer RAN functions and the distribution of the core functions, simplification can be achieved by combining some of the RAN and core functions into single entities.Thus, in the timeframe of 6G, we expect a reduced set of functional blocks implementing a combination of 5G RAN and core, resulting in a coreless RAN, especially on the user plane.

4.1.5 Terahertz Band and Beyond

Terahertz waves (despite what the name implies) occupy the 300 gigahertz to 3 terahertz band of spectrum. This means the frequencies are higher than the highest frequencies that will be used by 5G, which are known as millimeter waves, and fall between 30 and 300 GHz.This band has many advantages for wireless communications, but there are also many challenges. The benefits include hugebandwidths (more than 50 GHz) available to support the Tbps links,higher frequency (short wavelength) with spatial resolution,and short pulse (picoseconds) with high resolution in time domain,which can be used for super-resolution sensing and high-precision positioning.Up Conversion or Down Conversion due to its position in spectrum is also a region of research.

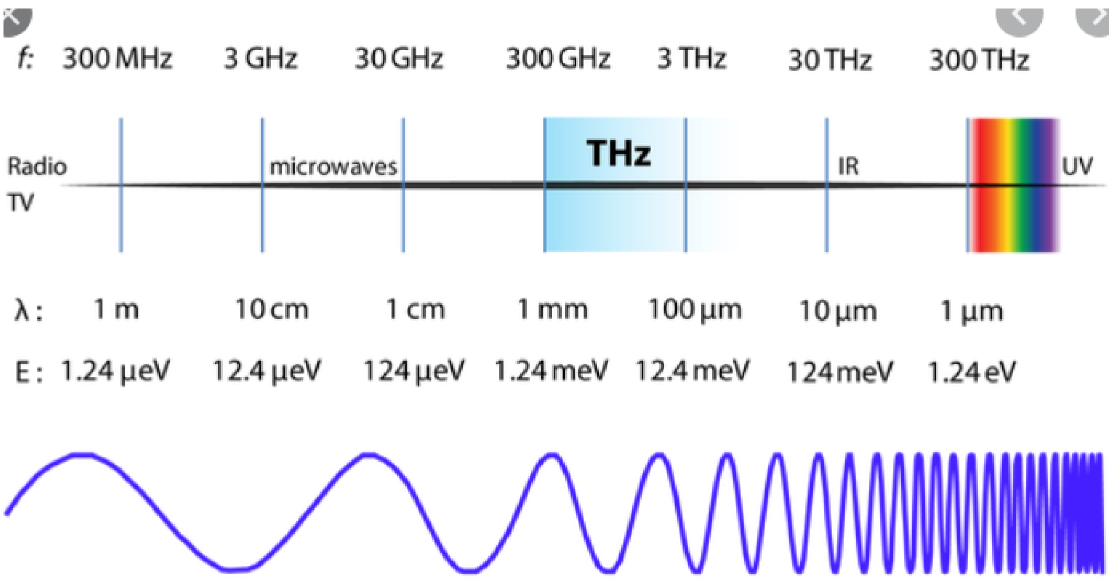

Figure 4.2: THz Band and Beyond in Electromagnetic Spectrum

Chapter 5

Expected Emerging 6G Applications

5.1 WIET Technology

Wireless energy transfer will be involved in 6G, providing suitable power to the batteries in devices such as; smartphones and sensors. The base stations in 6G will be used for transferring power as Wireless Information and Energy Transfer (WIET) uses the same fields and waves used in communication systems. WIET is an innovative technology that will allow the development of batteryless smart devices, charging wireless networks and saving the battery life-time of other devices.

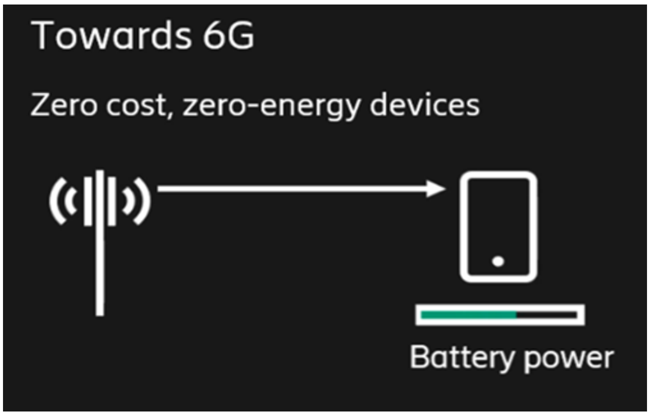

Figure 5.1: Wireless Power Transfer

5.2 Industry 4.0

6G will fully realize the Industry 4.0 revolution started with 5G, i.e., the digital trans-formation of manufacturing through cyber physical systemsand IoT services.

Overcoming the boundaries between the real factory and the cyber computational space will enable Internet-based diagnostics, maintenance, operation, and directmachine communications in a cost-effective, flexible and effi-cient way . Automation comes with its own set of require-ments in terms of reliable and isochronous communication, which 6G is positioned to address through the disruptive set of technologies. For example, industrial control requires real-time operations with guaranteed s delay jitter, and Gbps peak data rates for AR/VR industrialapplications (e.g., for training, inspection).

5.3 Wireless BCI Applications

Recently wearable devices are increasingly used, some of them are brain-computer interface (BCI) applications. Using BCI technologies, the brain will easily communicate with external discrete devices which will be responsible for analyzing brain signals and translating them. BCI also will involve affective computing technologies, in which devices will function differently depending on the user's mood. BCI applications were limited because they require more spectrum resources, high bit rate, very low latency and high reliability.

5.4 E-Health

The lack of electronic healthcare in other wireless communication technology was because of low data rate and time delay. 6G will provide secure communication, high performance, ultra-low latency, high data rate and high reliability enabling the full existence of remote surgeries through XR, robotics, automation and AI. Also, the small wavelength due to the THz band supports the communication and the development of nanosensors allowing developing new nanosized devices to operate inside the human body.

Chapter 6

6G-Open Problems and Challenges

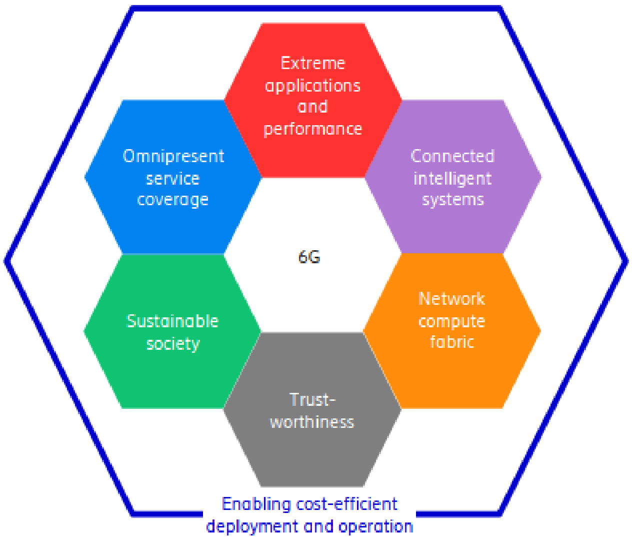

Figure 6.1: Main challenge areas for 6G

Device Capabilities with the Terahertz Band, Increased Radiation Health Hazards, Complex Transceiver and Antenna Design, Development of Improved mm Efficient Control Systems, Need of protocols that can learn and adapt to the environment, Development of new channel coding techniques are a few of challenges which are yet to be tackled.The security approaches used in 5G will not be sufficient in 6G, and hence new security techniques with innovative cryptographic methods should be considered including the physical layer security techniques and integrated network security techniques with low cost, low complexity and very high security.

Chapter 7

Conclusion

Reliable data connectivity is vital for the ever increasingly intelligent, automated, and ubiquitous digital world. 5G Telecommunication Technology that will be launched within few years will not fulfil the increasingly growing demands in 2030 or even before. Therefore researches in 6G are being conducted to be able to reach its goals by 2030. In this seminar, new features in 6G and the possible applications and technologies that will be deployed in 6G like millimeter waves, Cognitive spectrum usage, RAN Core Convergence, Radio Stripes, Distributed Serial Massive MIMO are provided. At the same time, it will enable new use cases that we cannot yet imagine or describe in detail. Potential challenges in the development of 6G technology are then discussed and possible solutions are proposed. Finally, opportunities for exploring 6G are analyzed in order to guide future research, for example the support for Terahertz and visible light spectra, cell-less and aerial architectures ,and massive distributed intelligence, are some among them.

6G is not only about moving data around – it will become a framework of services, including communication services where all user-specific computation and intelligence may move to the edge cloud. The integration of sensing, imaging and highly accurate positioning capabilities with mobility will open a myriad of new applications in 6G. Above all concluding in a statement **”5G will Enable but 6G will make it Happen!”**.

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