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5G Network from Space

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***Abstract*— The new generation of Mobile communication systems known as "5G" has evolved, and new equipment is currently being installed in densely populated areas across the world. In many cases, the demand for 5G capacity is demanding infrastructure improvements, especially in thinly populated areas that are difficult to access. For years, satellite communication has remained standalone technology, rather than of mobile networking. Now with the subsequent generation of satellites - built from 5G architecture - they are going to connect with networks to manage connectivity to cars, airplanes, and other IoTdevices in remote and rural areas.5G provides the opportunity for the satellite industry to break out of its niche and for service providers to supply anenormous range of services. Soon, 5G signals will beam down from space and support our 'terrestrial' 5G infrastructure on Earth. The result is a new space race for satellites - promising to supply customers a seamless wireless experience across the entire globe.**

***Index Terms*—5G, networking,satellite communications, signaling,IoT**

1. INTRODUCTION

Mobile and wireless networks have made an exceptional development in the last 50 years. The systems have evolved through a progression known as "Generations" started from Analog communication(1G) in the 1980s which is upgraded to GSM(2G) in 1991 where many mobile service providers enabled to send the text message between two cellular networks which delighted the world. In 1997 world proceeded on the CDMA2000(3G), which helped in the liberation of making phone calls, sending text messages, and browse the internet with superb speed. In the 2010s LTE(4G) is introduced which enhanced many capabilities that were made possible in the third generation. People could browse the web at rapid speed, send text messages and make video calls and they can download and upload large files without any problems and hustle free. In recent years many mobile network providers added LTE which helped for long-term evolution to 4G connectivity 5G enables machine to communicate without human intervention in an IoT capable to drive a near-endless array of services. From the lower power, sensor driving machines to conference video calls 5G enables richer, smarter and more convenient living and working. According to GSMA [2], it is expected that commercial 5G networks to be widely deployed in post 2020 period. According to it there will be over 5 billion mobile internet users with 1.35 billion 5G connections with different machines by 2025. Another key driver for 5G is exposure of IoT and their vision of billions of connections to the internet.

and it started competing with the technologies like WIMAX in the market. LTE made the 4G technology even faster and set down the foundation of 5G. Satellite Communication is used in many fields like media broadcasting, back hauling, etc. But nowadays, the evolution in IoT-based applications, satellites Communication are going through a transformation phase refocusing the system design. The 5G is the integration of wired and wireless technologies. Networks and the satellite ISI are to integrated as these two key components of the future communication. Since 5G began to deploy worldwide in 2019, satellite plays an important role to get the seamless network. In this paper, we conducted a survey on the integration of satellite into 5G mobile networks. In Section 2, we explored the development of mobile networks, and then we discussed in section 3 basic characteristics of satellite communication and vital role of satellite in 5G section 4. In section 5 we had gone through research areas covering latency delay, spectrum aspect and path loss. We surveyed proposed architectures in the literature, classified terrestrial mobile networks. In section 6, we went through. We conclude our work in Section VII.

2. THE 5G ERA

The Era of 5G is commencing in full from 2020, creating a wide range of opportunities for consumers, operators, vendors, and all stakeholders. To deliver their promises, the mobile industry has some clear goals in 5G like to provide seamless connectivity to all, delivering sustainable network innovation, transforming the mobile broadband experience, etc. 5G is just an evolutionary step to a new generation of technology.5G will evolve from existing LTE(4G) networks but will mark an inflection point in the future of communications. It is designed in such a way that users want to live and provide a platform on which new digital services and business models can grow as well.

This enables for development of 'smart cities' and 'smart environments' and emergence of 'Big Data' applications. This implies the handling large quantities of low communications efficiently covering widespread networks and M2M connections. The important issue is to reduce energy. By 2025 the target is to reduce 85% of today's total energy at no reduction of performance and no increase in cost. Thus 5G network designs becomes a complex task involving link and area spectral efficiency together with energy efficiency.

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3. SATELLITE COMMUNICATION

Mobile network providers provide network services to air, sea, and remote areas through GEO operators like Inmarsat, Thuraya, and non-GEO operators like Iridium, Globalstar etc. These operate in I, S, and Ka bands, to both handheld and vehicle mounted as well as some fixed terminals. Geo satellites are appear to be fixed over one spot above earth. Receiving and transmitting antennas used on earth don't need to trace satellite. These antennas are cheaper than tracking antenna. These satellites are traditional communication satellites and have been orbit for past 50 years. These satellites weigh more than 1000kg and operates 36,000 km above earth.

In contrast, Low Earth Orbit (LEO) satellites are miniaturized, orbiting versions that operate between 500 to 2000 kilometers above Earth's surface and weigh under 500 kg. Due to its low orbit, latency is significantly reduced as satellite is better positioned to quickly receive and transmit data. Unfortunately, this will create a small coverage area so LEO satellites continuously hand off communication signals and traffic across a constellation of satellites. This will ensure a seamless, wide-scale coverage over large geographical areas [3].

The 5G communication is expected to transform in three major factors: Enhanced Mobile Broadband (eMBB), Ultra- Reliable and Low-Latency Communication (URLLC), and Massive Machine-Type Communication (mMTC). Satellite has to play a vital role in these areas.

I. Satellite uses for eMBB:
The author in [5] come up with some points of satellite-based 5G use cases for Enhanced Mobile Broadband (eMBB) services
- Backhauling and tower feed (BATF): In this use case the satellite gives a complementary role by backhauling the network load from towers to broadcasting the popular feature to an edge, hence optimizing the 5G networks.
- Trunking and headend feed (THEF): In this case satellite brings broadband connectivity where it is difficult to deploy terrestrial connections in remote area across a vast geographic region and in rural areas. It will be covered by satellites.
- Hybrid multiplays (HYMP): In this use case satellites allow 5G services to home/office in an underserved area through hybrid terrestrial-satellite connections.
- Communications on the move (COOM): In this use case satellite will provide broadband connectivity to UEs on the move such as airplanes, trains, vehicles or maritime vessels.

II. Satellite uses in Ultra-Reliable and Low-Latency Communications (URLLC):
The second use case of 5G is URLLC applications that are particularly to support where the delay in the communication link is extremely low (less than 1ms) and the reliability means minimal packet loss (1 packet loss in 10^5 packets). Some practical applications are autonomous driving, industrial automation, remote diagnosis, remote surgery, smart energy, etc. Most efficient way for scheduling for URLLC services is proposed by scheduling unit smaller than a slot, known as mini-slot. Mini-slot transmission leads for immediate transmission of resources requiring low latency. The ongoing transmission will be handled by Hybrid Automatic Repeat reQuest (HARQ). In 5G transmission, HARQ allow to transmit only single code block interrupted. The Low-Density Parity Check (LDPC) adopts for the fast turnaround HARQ to their parallelized decoding process. It is understandable that the satellite, without of the pick out orbit attitude. For example in autonomous cars when latency is quite low. To operate successfully, autonomous cars need to communicate each other and their environment also known as vehicle-to-everything within nanoseconds. The distribution if data should be faster if it doesn't be routed to core network.
It is known that satellite (GEO, LEO, MEO) can't provide such latency. It should be provided within the car's network system though software updates like media streaming and OTT platforms.

III. Satellite uses in Massive Machine-Type Communication (mMTC):
The third use case of 5G is mMTC for mobile to mobile connections or basically IoT devices and sensors instrument. IoT devices and sensors instruments have to do communication with low complexity and affordable devices that are able to produce and exchange information between devices. Even these are very small devices but create a huge impact on network. These devices will increase the traffic load of network providers. The satellites will help to minimize the traffic load

Several private companies like SpaceX launched its fifth batch of 60 Starlink satellites to orbit in February to deliver high-speed internet service to markets and their customers. This will bring around 300 Starlink satellites currently in orbit with a goal of around 12000 satellites by mid-2020 [4].

We are more focusing on Medium Earth Orbit [MEO] where a group of 20 satellites (O3B) has been placed in a circular orbit around the earth at the altitude of 8100 km. Each satellite consists of twelve mechanically dirigible antennas to tracking and handover the terminals. The next generation of these satellites is planned to use active antenna which can produce thousands of beams along with an on-board digital transparent processor. It will manage to reduce the latency and constellation size [4].

Satellite and terrestrial system integration is already a trend and this will continue the development of interoperability standards to allow two sectors to interconnect efficiently both at network level and the IP levels. In addition mobility management integration will evolve across the larger satellite and smaller terrestrial cells.

4. USE CASES OF SATELLITE IN 5G

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by backhauling, or generate continuous service where terrestrial network cannot reach. This group of use case mainly divided into two parts according to their application, IoT sensors, and IoT uses.

- Wide area IoT services: This use case is application based group of IoT devices which are located over a wide area for reporting data or to be controlled by central server or main server. For example like collecting data of train status or aircraft management, Inspection on farming, and many more.
- Local area IoT services: This use case is also application based group devices which are located over a small area and to by control by local server. Some examples are home automation, smart on-board moving platforms, many more.[4]

The architecture of 5G needs to expand over a large scale that will help to connecting and backhauling data from billions of IoT devices and sensors present inside the homes and urban architecture, as it will helps us for building smart cities all around the world in coming years. So, in order to minimize the impact of these IoT devices on network system, it is a golden opportunity for satellite for backhauling non-latency data from these devices.

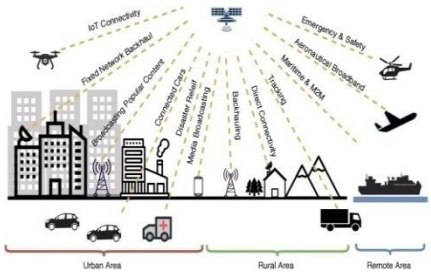

Fig 2. The use case of satellites [1]

5. CHALLENGES FOR SATELLITE COMMUNICATION

In the vision of 5G, and the role of satellite in it, reveals some of challenges. These challenges need to be tackled to obtain required performance. So, in this section we will get to know the major challenges that need to tackle in coming future.

I. Path loss

Link budget is an aspect for linking the satellites, it is affected by many factors like Signal-to-Noise Ratio (SNR), power availability, and sensitivity of communication at both ends. According to author of [6][7], power at the receiver defined as factor of source power, distance, antenna characteristics and free space attenuation L_{bf}'1'.

$$L_{bf} = 20\log_{10}(4\,\pi d/\lambda) \qquad (1)$$

To tackle this problem beamforming are introduced into satellite-terrestrial mobile networks to improve coverage and serve multiply users.

Beam management is the operation of beamformed wireless cellular systems widely used as 5G New Radio (NR) networks. It is focusing on the energy that is radiated from mobile terminals by increasing the number of beams per cell as to increase signal power and decrease the distortion of networks.

The Beam management is nothing but a procedure with set of phases like Beam sweeping, Beam measurements, Beam determination, Beam reporting and Beam failure recovery.[13]

II. Spectrum

Satellite communication runs on the Extremely High Frequency (EHF) band, ranging between 1-50 GHz. Different frequency bands are suitable for different climate regions, type of service required and type of end user. For the simplicity of frequency band used in satellites these are identified by letters.

i. L-Band

It consists of frequency range from 1-2 GHz. The L means long wave. The wavelength is around 30-15 cm.

It is mainly used in Mobile Satellite Services (MSS), and Radio-Navigation Satellite Service.

i. S-Band

It consists of frequency range from 2-4 GHz. The S means short wave. The wavelength is around 15-7.5 cm. It is mainly used in Radars, MSS, Broadcasting, and Space Research.

ii. C-Band

It consists of frequency range from 3.4-7 GHz. The C means Compromise between S and X wave. The wavelength is around 7.5-3.75 cm. It is mainly used in Fixed Satellite Service (FSS), VSATs, and Direct-To-Home (DTH).

iii. X-Band

It consists of frequency range from 7-10 GHz. The X means cross wave. The wavelength is around 3.75-2.4 cm. It is mainly used in Radars, Satellite Imaging, and Space Research.

iv. Ku-Band

It consists of frequency range from 10-15 GHz. The Ku means Kurz-under wave. The wavelength is around 2.4-1.7 cm. It is mainly used in FSS, VSATs, Broadcasting, and MSS.

v. Ka-Band

It consists of frequency range from 17.7-21.2, 27.5-31 GHz. The Ka means Kurz-above wave. The wavelength is around 1.1-0.75 cm. It is mainly used in FSS"Broadband", Inter-Satellite Links, MSS.[]

In the World Radio Communication conference 2019 (WRC-19), it has been accepted on the use of frequency bands (24.25-27.5 GHz, 37-43.5 GHz, 45.5-47 GHz 47.2-48GHz) for the 5G

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network throughout the world. This is basically based on Ka bands.[13]

III. Latency delay

Latency has been a major problem in mobile satellites, because of large distance from earth. If the α is indirect factor in overall delay then

$(d+r_E\sin(\alpha))^2= r_E \sin^2(\alpha)+H^2 +2Hr_E\sin(\alpha)$

The below table is propagation delay in orbit.[12]

orbit	Average altitude of Orbit	Uplink Delay	Round trip delay
LEO	800 Km	2.7 ms	10.8 ms
MEO	10,355 Km	34.5 ms	138 ms
GEO	35,786 Km	119.3 ms	480 ms = ½ Second

Table 1

We can clearly see that by using LEO satellites we can decrease the latency as compared to MEO and GEO satellites. This is because of shorter distance from earth as compared to other two satellites. However we can decrease the latency by protocol stacks.

6. THE COVERAGE MANAGEMENT

I. Literature Review on Coverage System

The satellites have been used for the past four decades, mainly used for scientific purpose but now satellites are emerging for mobile networks. As LEO satellites are visible only for few minutes, it is difficult to provide constant network to consumers. Therefore frequency handover should take place to achieve this. Satellites can provide the wide coverage to complement and to extend the deep, dense cells, which is in the line with the coverage meant to attain an achieved by the 5G network. They will not able to match the area of spectral efficiently of 5G boundaries but to provide larger area that can be used in emergency services of signaling and of management in the software runned network.

The wide ranging of demand of wireless telecommunication and data transfer through wireless devices has been a major importance in antenna designing. 5G is going to be most efficient and powerful technology in its coming future due to its immediate and wide coverage with the help of LEO satellites.[15]

II. Our Proposed System

To reduce the impact of frequent re-selections in satellites network, we propose some different types handover to increase the coverage

- From where the mobile terminal will get the broadcasting, the TAC broadcasted will receive same during satellite coverage. This will ensure the reducing of signals overhead and amount of signal will receive by other mobile network.
- When the requested service matched, a satellite layers needs to be preformed.
- In the case when satellite and terrestrial networks are connected to two different core networks, it will ensure the mobile network providers to extend their coverage across the worldwide.
- Satellite beams should be designed for Satellite Fixed Cell (SFC) and Earth Fixed Cell (EFC).[8][9] The number of spot-beams should be increased so to achieve efficient frequency noise to increase the coverage area.
- To guarantee a smooth network system, the no. of satellites increases so that they will cover a large part of earth for the seamless connection.
- The internetworking of terrestrial and satellite RANs would be get to a desired architectures in the coming future. So in this case, Each RAN will have a alone interface with the core network under the guidance of PLMN Global ID. Author in [14] has listed relevant simulations and emulation platforms. Author of [16] has provided some ideas to increase in mobility of satellites which would help to increase the network of 5G from space.

7. CONCLUSION

Satellite communication has gone in for a crucial phase of evolution, mainly motivated to IoT applications and mobile networks because of increasing demand of IoT and its services. It demands high speed, very low latency and ultra reliable. So, this paper illustrated and illuminated the important areas in which satellite will play an important part in the 5G networks and applications, We will also highlighted the various challenges to attain our presented architecture. This paper also illustrates a summary of use of satellite in 5G and their applications.

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