Taming Existing Satellite and 5G Systems to Next Generation Networks

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Abstract: To update any existing wireless or cellular network, the operators must exchange old fashion equipment by the new developed one. This problem arises when operators have to modify or release new generation. This paper proposes a new integrated satellite and 5G systems for the next generation network (NGN). The paper proposes a system that utilizes 5G wireless cellular integrated with satellite communication systems. Many downlink channels of the satellite link are trained to manage the new 6G system. With the terrestrial's satellite, the satellite receivers will be directed to the LEO-system which are communicated to the 5G systems or base stations. The new system will be able to support all user services and applications. Moreover, the system will help monitor and track all objects, rockets, airplanes, vehicles, and flying drones. The monitoring and tracking of vehicles will be very simple as the system will integrate the satellite and the 5G mobile systems using the high definition cameras and wireless sensor networks (WSNs) to view and track the vehicles. With the dependency of this future proposal, 6G will integrate 5G with the satellite system for global internet and mobile coverage.

Keywords: 5G, 6G, Channel, mmWave, Taming, Satellite.

1. INTRODUCTION

5G wireless network services provided by operators are deployed as very small cells, compared to the previous, long term evolution (LTE) and group service mobile (GSM), and cellular generation [1]. All the 5G user's equipment (UE)s in a cell communicate by the base station (BS) distributed in the coverage area, over wireless channels allocated by the shared resource of subcarriers reused into adjacent cells [2]. 5G system uses millimeter waves for their developed systems. Millimeter-wave (mmWave) has a shorter range than the microwave, so the cells are divided into smaller sizes. The waves suffer from low penetration to pass through different building walls, as the transmitted frequency increases [3]. The recent array antenna scheme utilized for a huge increased bit-rate is the massive multiple-input multiple-output (MIMO) [2].

All BSs have a massive number of antennas communicating to users by assigning beam to each UE [2]. Along with the massive MIMO, another technique called beamforming, which permits the BS beam former to determine the shortest route for the beams to reach each UE to organize multiple antennas together as phased arrays to create beams of mmWaves to reach the UE [4]. European Telecommunications Standards Institute (ETSI) released a standard 5G schemes defining the key requirements for technology assigning the planned peak bit-rate and is expected to be about 20 Gbps at the downlink and 10Gbps at the uplink [5].

Recent hybrid 5G cellular terrestrial communications are expected to support modified scheduling for both machine type communication (MTC), been a fast development for developing satellite communication. Satellite mobile communication, that yield some unique features, such as large coverage and support for reliable emergency communication, must satisfy all requirement for the convergence between the terrestrial cellular communications and satellite mobile communication for future broadband communication [6][7]. These techniques presented an introduction to a typical application scenario of futuristic cognitive radio-broadband hybrid communication systems toward 5G. Also, an end-to-end

hybrid-satellite terrestrial network (HSTN) was proposed, during that the performance requirements and metrics; spectral efficiency (SE), analyzed in ultra-dense networks [7].

The architecture for any integrated nanosatellite (nSAT)-5G network operating in mmWave band is understood assuming a delay-tolerant networking (DTN) approach permitting end user to adopt standard UEs.

At the ground terrestrial uplink, the coded random access (CRA) is active to realize a very high-capacity interface for the typically irregular traffic of 5G UEs, while, at the satellite uplink, the DTN architecture is joint with the contention diversity (CD) slotted Aloha (SA) protocol to match the new update of the DVB-RCS2 standard [8].

The objectives of this paper are:

a. Proposed novel architecture that integrates many existing systems, the satellite, and 5G systems. The proposed scheme for the 6G system, considered novel compared to the existing systems, in that the proposed architecture makes use of recent and existing systems to produce a novel architecture for future global communication systems.

b. Then, the main objective is the taming of numerous channels in the existing systems to produce the new 6G system.

The rest of this article is ordered as follows. In section 2, the 6G future visions will be presented and speculate on the requirement. In section 3, the existing architectures will be explained in some details. Section 4 explains the details of the proposed integrated 6G scheme. Section 5 presents the 6G vision architecture. Finally, the paper concludes in Section 6.

2. FUTURE VISION

Each 5G system starts the arrangement stage, in the meantime, another persistent discussion for 6G development starts. Some research centers think that it is early to define 6G, and any such argument is more or less a proposal or assumption. In this section, the paper expects a visionary developed and the proposed 6G vision, by explaining some promising trends and directions. Enhancing the 5G visions, 6G will continually enable modern capitals and cities to be wholly smarter as connected to the excess of autonomous applications and services for smartphones, internet of things (IoT) adapters, unmanned or driverless vehicles [8]. Capital cities will witness flying long buses, now in a limited-dimension operation in modern towns [8]. Monitoring, tracking and controlling the over-limit cars and vehicles on high-way will be the most familiar services utilized with the 6G. The ability to do that was previously mentioned by many kinds of research that used the 4G Long Term Evolution (LTE) systems [9].

The monitoring, and tracking of vehicles will be very simple as the system will integrate the satellite and the 5G mobile systems using the video cameras and wireless sensor networks (WSNs) to view and track the vehicles [10].

One certainty of 6G is that it must be energized by the modern artificial intelligence (AI) in all stages and levels, including network management, instrumentation, coding and high-level digital signal processing (DSP) at the receiver's device, operation of advanced assemblies, and huge data embedded at the UE and network-level for UE service-based context-aware wireless communications [11].

In 6G, the networks expect to witness operative AI with distributed training at the UEs and small-coverage base stations (SBSs) is still a continuous challenge. There is also the sight of achievements in other evolving fields that are not yet making an impact in the previous cellular or wireless systems might become realistic in 6G [11]. The promising techniques including optical wireless communication or Li-Fi, wireless power transfer radio frequency (RF) energy harvesting, and Ultra-reliable low-latency communications (URLLC), a main key parameter in new radio (NR), will yet again become an affecting key in 6G system approximating the limits further to reduce latency to be about 1ms.

Based on the demand that 5G can meet and the development trend of other related fields, 6G vision can be summarized into four keywords:

a) Intelligent Connectivity;

b) Deep Connectivity;

c) Holographic Connectivity; and

d) Ubiquitous Connectivity.

The above four keywords together establish the 6G overall vision of everything that follows your heart. It emphasizes information exchange, and that everything can be connected, besides the connecting objects are concentrated in a limited space of 10 km above the land.

3. EXISTING SYSTEM ARCHITECTURES

A. Satellite System Architecture

There are many types of satellite communications systems classified according to their service, altitude, design, and architecture. Some satellite systems are for fixed satellite services while others are mobile satellite services. The satellite classification according to the altitude is as follows:

- Low Earth orbit (LEO): A Geocentric orbits elevation from (180– 2,000) km. The propagation delay is 1-15 msec. [12];

- Medium Earth Orbit (MEO): Geocentric orbits elevation from (2,000 – 35,786) km [12];

- A Geosynchronous Orbit (GEO): A circular orbit with an elevation of 35,786 km.

  The speed is approximately 3,000 m/s. The propagation delay is 120-140 msec. [12]; and

- High Earth orbit (HEO): Geocentric orbits above the altitude of geosynchronous orbit 35,786 km [12].

It is very important to mention that the very long-distance between the earth station and the GEO satellite causes, to the RF carrier, a power attenuation about 200 dB on both downlink and uplink [13].

Another type, very small aperture terminals (VSAT)s are aligned and visible from the satellite, while RF carriers can be relayed via the satellite from nearest VSAT to any other VSAT at the ground networks [13]. Regarding meshed VSAT networks, the following limitations must be taken into consideration;

- Typically, about 201 dB RF carrier power attenuation at downlink and uplink caused by the distance to and from a GEO satellite [13];

- The satellite transponder RF power is limited by a few watts [13]; and

- The small size of the VSAT, that confines its receiving sensitivity and transmitted power [13].

As a result, it may well be that the detected signal at the receiving VSATs do not provide the quality of service (QoS) demanded by the UEs [13].

This paper proposes to utilize the existing LEO W-band satellite system at the downlink transmissions. In figure 1, the deployment of W-band satellite system is presented, which shows the ground cell communications to the LEO
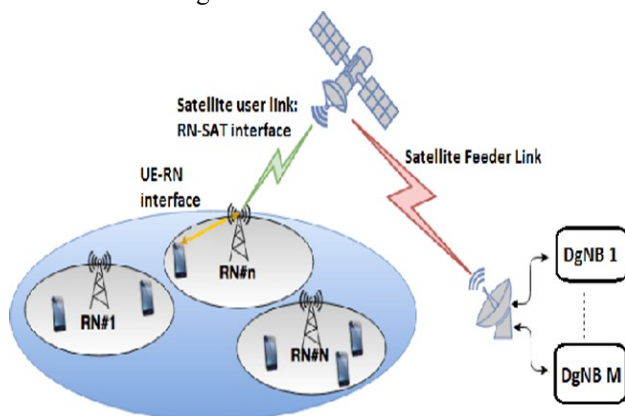
satellite [14]. W-band with its broad bandwidth with a frequency range for high data rate transmission via satellite supports massive connectivity required at the future

wireless systems. The standard and specification of the W-band link is shown in Table I.

Figure 1.   LEO Satellite system

Due to the advances of the LEO satellite, space technologies are becoming closer, smaller, and cheaper, which stimulating space industries by providing different new services such as earth monitoring [14]. These services of small satellites stimulate the top tier operators and companies such as SpaceX, Google, and Facebook to investigate the utilization of such systems at a low cost instead of utilizing the conventional satellites, to provide earth observation and immediate connectivity to the internet of everything (IoET) devices in remote areas [14].

TABLE I. MAIN PATH BUDGET PARAMETERS OF THE W-BAND UPLINK [14].

Parameters	Numerical datum
Link distance	932 Km
Link elevation angle	36º
Maximum LEO field of view	45º
Frequency	80GHz
Available RF power	16 dB
Tx Gain	52.18 dB
Tx terminal EIRP	69 dBW
Free space Loss	189.8 dB
Additional atmospheric attenuation	11.22 dB
Rx terminal Gain	41 dB
Required BER	10^{-6}
Receiver bandwidth	200MHz
Channel data rate	800Mbps

B. LTE Network Architecture

4G LTE and LTE-A systems have been developed to provide packet-switched services. LTE system is a set of additional architectures to provide continuous IP connectivity of packet data network (PDN) and UEs without any interruption to the end-user's application through its mobility [14]. The System Architecture Evolution (SAE) standards are defined in 3rd Generation Partnership Project (3GPP) Rel. 8 specifications. The main key parameter provided by SAE is the Evolved Packet
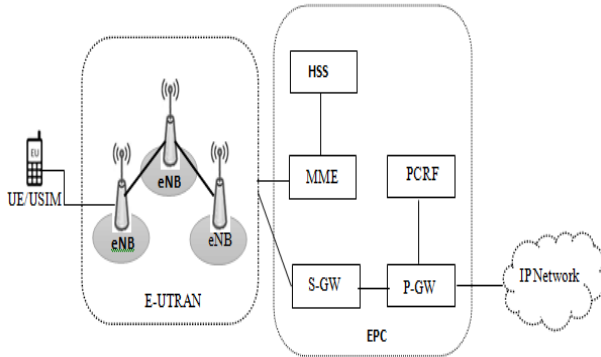
System (EPS), which is composed as LTE and SAE that comprises the EPS which provides the UE with continuous IP connectivity to a PDN to access the Internet, as well as to support many applications such as video streaming.
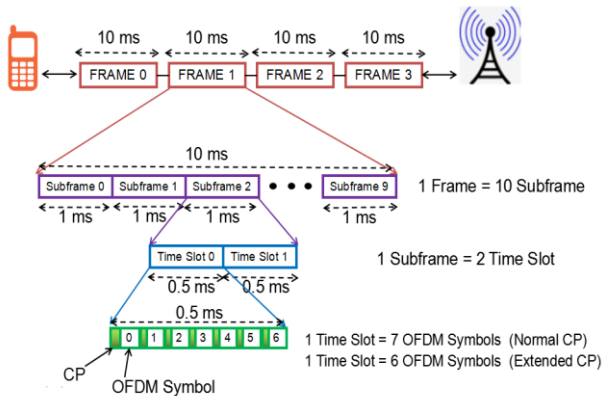

Figure 2 indicates the LTE network architecture. LTE frame structure is presented in Figure 3.

Figure 2.   LTE Network Architecture

Figure 3.   LTE Frame Format

C. 5G System Technologies

5G is a recent wireless technology that has a wide deployment since the early days in 2019. 5G wireless cellular networks use six technologies:

1)Massive MIMO: each BS has massive multiple antennas communicating with the UEs to increase the received data. Massive MIMO is a multi-user MIMO scheme that provides uniformly good service to UEs in high-mobility environments. The key idea is to equip each BS with an array of a huge number of antennas, each antenna is directed to every UE simultaneously [2];

2)Small cell deployment: very low-power short-range, radio access BSs that have a range of hundred meters compared to previous LTE system macro-cell.

In 5G, the new macro-cell sites are divided into smaller cells as an important method to increase network capacity with a growing focus using LTE-A [15].

3)Beamforming: is a technique which permits the BS to form multiple arrays to operate as phased-arrays to form many beams to communicate with the UEs. A Beamforming technique is a digital signal processing technique utilized in sensor arrays for directional signal reception which are accomplished by uniting many elements in an antenna array in such a method that signals at specific angles suffering constructive interference [16];

4)mmWaves: 5G system uses millimeter waves, which are shorter, in range, than microwaves. Consequently, each cell is limited to less coverage to reduce the transmitted power and to overcome the wave penetration problems due to building walls and obstacles [17];

5)Non-orthogonal multiple access (NOMA): its concept facilitates supporting multiple UEs in the power domain. In more details, compared to the conventional Multiple Access techniques, NOMA uses a new dimension to perform multiplexing within one of the classic time/ frequency domains [18]; and

6)Mobile-edge computing (MEC): is a network architecture perception that enables cloud computing abilities at the cell edge [19]. The idea involving MEC is that by running any application and performing the related dealing out tasks very close to the UE or client, packet collision will be reduced. MEC technology was developed to be applied at the cellular BSs, and enables network flexibility and swift deployment of new applications for UEs [19].

The 5G system, UEs and devices, also, support LTE services, as the new network uses LTE for creating a connection with the cell, as well as in locations where 5G access is not enabled [5].

The international telecommunication union (ITU-R) has been defined, also, as three utilizations for 5G system. The utilizations are:

- Enhanced Mobile Broadband (eMBB), which exploits the 5G as an evolution from LTE broadband services, with higher capacity, and enhanced throughput [2].
- Ultra-Reliable Low Latency Communication (URLLC), which denote to use the network for mission-critical services and applications that require un-interruption [2].
- and Massive Machine Type Communication (mMTC), which would be utilized to communicate with a large number of low power devices [2].
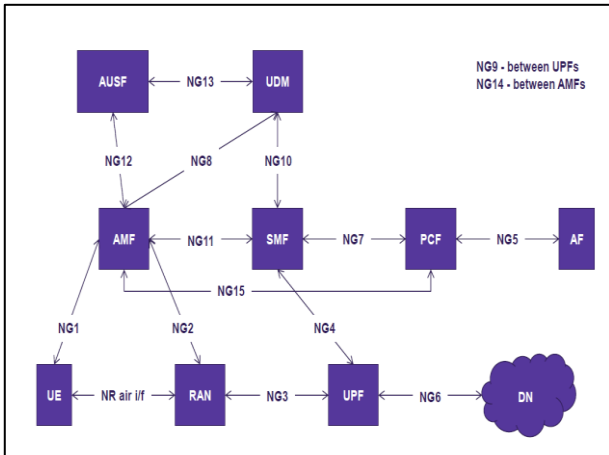
The frame structure for 5G is presented in Figure 5.

The existing systems, the cellular and the satellite systems, cannot provide the integrated demands individually as well providing the full coverage as the proposed architecture as well the wider channel by taming many satellite channels.
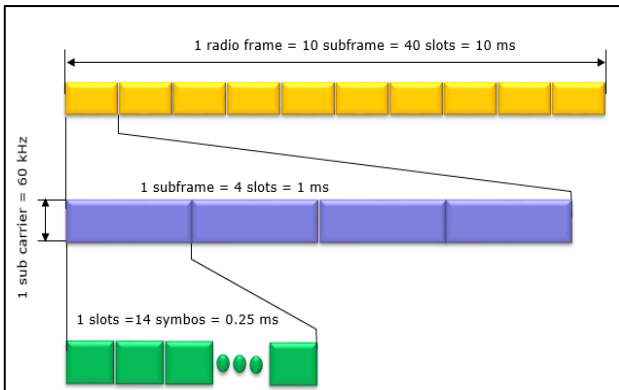
Figure 4.   5G Network Architecture

Figure 5.   5G Frame Format

4. INTEGRATION OF SATELLITE AND 5G SYSTEM

The Most interesting research area is the combination of two or more existing systems. In this paper, integration of the LEO satellite communication system with the next-generation of wireless or cellular networks is the core of the proposed system. The proposed system integrated many communication systems into new system to provide all users the demanded services.

The proposed new system will be composed of the exist systems, as indicated in Figure 6, which shows that LEO satellite receives signals from the sky. These distributers have the link, at each, to communicate to the 5G system. Also, Figure 6 shows the LEO controller, which manages the channels.

Figure 6. The proposed 6G vision architecture

A. The Cellular Communications System

This paper presented the existing wireless communications systems, LTE and 5G systems. The proposed architecture to utilize the LTE-A system as it is the most famous system nowadays. This will make the proposed system easier to integrate with LEO system as there will be no interference.

B. The Satellite Communication System

This paper presented the most existing satellite communications systems. This paper has proposed to utilize the low earth orbital (LEO) because of their low latency communications [20].
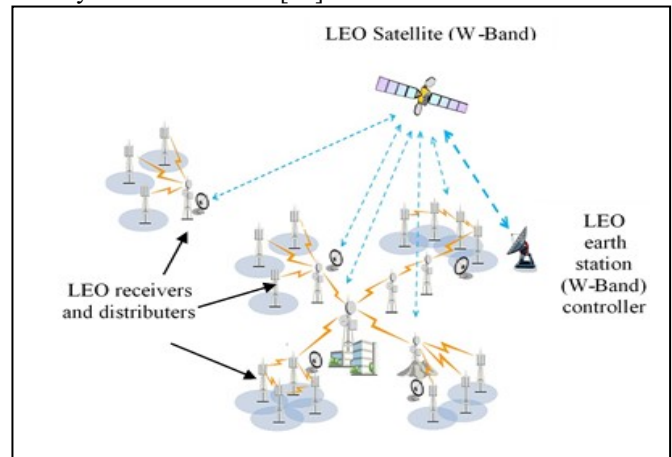
C. Taming Many Adjacent Downlink Channels

Getting a wide range new channels at the downlink will provide a high bit-rate to support the demanded users. In my previous article, the consolidation of adjacent beams at vacant traffic provided a throughput enhancement. This idea will be utilized in this paper [21].
Consolidating or taming many channels will produce a new wider channel that can support higher bit-rate.

D. Air and wireless Interface

5G air interfaces have the challenges of integrating a wide range of diverse traffic modes from very high-definition (HD) video, according to recent user's

demanded, to the very low-rate IoT new application and services with a range of delay requirement. The integration of cellular 5G and satellite is vital to evaluate many mutual benefits of both systems. The satellite channels are differing from channels in the 5G signal to noise ratio (SNR) is abundant lower, multipath are not so important while the channels are non-linear and suffer from more delay constraining adaption, depending on the satellite types and orbits.

For this consideration, it is needed to adopt a flexible waveform and wireless interface, which can be tuned depending on the channels they have to face. Multi-polarization massive MIMO, as a technique that involves low channel state information (CSI) appropriate for satellite and context-aware multi-user (MU) detection as a means to introduce quality of experience (QoE) requirement. A Frequency reuse (FR) technique joint with MU-MIMO technique can improve the system throughput. Filter bank Multicarrier (FBMC) schemes or enhanced Orthogonal Frequency Division Multiplexing (OFDM) schemes with suitable modulation schemes offer optimal spectral efficiency (SE) is being explored in wireless but also have unity to satellite system. Recently, there is a spectrum limiting for cellular and it is needed to utilize the spectrum effectively. Therefore, frequency allocation or sharing between satellite and cellular is one component that can donate for solving the above problems. At the moment the frequency bands are sliced but this is wasteful and it is needed to allocate available resources dynamically on the crises of demands.

A. the 6G Vision Architecture

The proposed architecture integrates the two mentioned architectures, 5G, and the W-band satellite systems. In section III, it yields new future generations. Each cell or sector will be equipped with a link to the LEO W-band satellite through a wide bandwidth composed of many channels at the downlink. From table I, the W-band receiver channel bandwidth is 200 MHz and the channel data rate are 800 Mbps. To tame the downlink to provide a wider channel, the proposed scheme will combine two or more of adjacent channels. The channel's format is indicated in Figure 7. The taming of downlink channels is shown as sub-channels, each 200MHz. As shown in Figure 7, the total bandwidth is 5000MHz. This bandwidth can be considered as a single channel or multiple sub-channels. To be considered a single channel, 5GHz, it can verify the ITU standard for 5G and beyond. Each LEO satellite will communicate to all 5G BS within the LEO coverage. Each BS relays the communication among the small base stations.
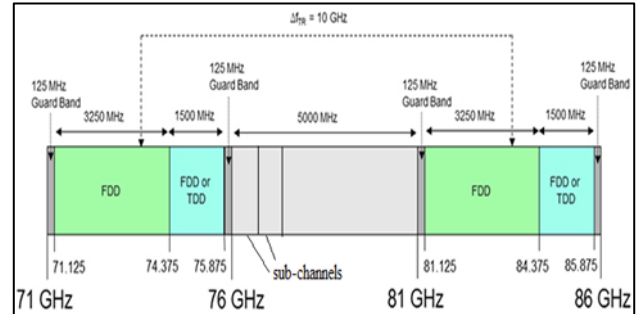

Figure 7. The channels and sub-channels for the proposed system

5. TAMING EVALUATION AND VALIDATION

The proposed system based on the integrated 5G Cellular and satellite networks can be simulated in order to be implemented and tested efficiently. It can be a modified 5G and satellite systems to yield a new 6G system that supports a very high bitrate for user's demands and high-capacity. The proposed architecture schemes or models, operating at mmWave, will provide a wide radio channel better than the existing systems individually, the cellular and the satellite systems, which cannot provide the integrated operative services and application individually as well providing the full coverage as the proposed architecture will do.

CONCLUSION

This paper presented a new integrated system proposed for the future 6G system. The proposed system utilized the existing 5G wireless cellular integrated with satellite communications systems by taming many downlink channels of the satellite link to manage the new 6 G system with the massive MIMO terrestrial mmWave 5G system. With the terrestrial's satellite, the satellite receivers will be directed to the LEO-system which are communicated to the 5G systems or base stations to produce the new system. The proposal uses the 5G, recently implemented and existing satellite system to yield the novel proposed 6G system. The proposed system will be able to support all user services and applications. Also, the proposed system will help to monitor and track all objects, rockets, airplanes, vehicles, and flying drones. The monitoring and tracking of vehicles will be very simple as the system will integrate the satellite and 5G mobile systems using

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