6G Networks for Next Generation of Digital TV Beyond 2030

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Abstract

This paper proposed a novel 6G QoS over the future 6G wireless architecture to offer excellent Quality of Service (QoS) for the next generation of digital TV beyond 2030. During the last 20 years, the way society used to watch and consume TV and Cinema has changed radically. The creation of the Over The Top content platforms based on Cloud Services followed by its commercial video consumption model, offering flexibility for subscribers such as n Video on Demand. Besides the new business model created, the network infrastructure and wireless technologies also permitted the streaming of high-quality TV and film formats such as High Definition, followed by the latest widespread TV standardization Ultra-High-Definition TV. Mobile Broadband services onset the possibility for consumers to watch TV or Video content anywhere at any time. However, the network infrastructure needs continuous improvement, primarily when crises, like the coronavirus disease (COVID-19) and the worldwide pandemic, creates immense network traffic congestions. The outcome of that congestion was the decrease of QoS for such multimedia services, impacting the user's experience. More power-hungry video applications are commencing to test the networks' resilience and future roadmap of 5G and Beyond 5G (B5G). For this, 6G architecture planning must be focused on offering the ultimate QoS for prosumers beyond 2030.

Keywords 6G · 4K · 8K · B5G · Broadcasting · Holographic communications · Live TV · NextGen TV · Multicasting · OTT · UHD TV · QoS · QoE · Prosumers · Satellite TV · Quantum computing · Quantum machine learning

1 Introduction

Since the invention of motion pictures in the 19th Century and TV's creation in the 20th Century, humanity has seen a drastic change in how TV and film content has been delivered and consumed in the past 20 years [1]. A considerable part of this began after the

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Third Industrial Revolution, which enabled the popularization of PCs (Personal Computers) and the Internet [2]. Another process that contributed further to the change of the traditional TV and film landscape was the technological transformation delivered in the telecommunications industry, which occurred in the past decades, allowing evolved fixed and wireless technologies to combine synergies enabling multimedia services to advance. The evolution of telecommunication systems created the home broadband and mobile Internet, which presented a new possibility of delivering video content, especially over the Internet and the cellular network. The outcome of such technological innovation was creating new multimedia services, including a new business model for broadcasting TV, which transitioned to IPTV for multicasting content for consumers utilizing the Content Delivery Networks (CDNs). The third and fourth generations of cellular communications (3G) and 4G enabled the new TV concept, known as the TV Everywhere, which became a reality using unicasting or multicasting communications over the Internet. The TV Everywhere model changed the consumer's landscape to increase and control their viewers' choices. This model established the Over The Top (OTT) content platforms based on Cloud Services, followed by its commercial model of video on demand (VoD) consumption, offering flexibility for subscribers based on Subscription Video on Demand (SVoD) and Transaction Video on Demand (TVOD). Besides the new business proposition created, the infrastructure of the Internet and cellular technologies also permitted the streaming of high-quality TV attending different film formats such as HD TV (High Definition), followed by the latest widespread TV standardization, the UHD TV (Ultra High Definition) and 4K cinematic format, and the Cinema 3D [3]. However, 4G Network was a game-changer that boosted the market penetrability of the TV Everywhere concept with the release of Long-Term Evolution-Broadcasting (LTE-B) [4] and the Multiple Input Multiple Output (MIMO) antenna array technologies. Moreover, the progress made in wireless communication networks offering IP communication end-to-end in the cellular network. It also enabled the popularization of other video formats such as video conferencing calls, offering a good quality of services (QoS). 4G positively impacted the business world, reshaping the way of handling business meetings, remote learning (e-learning), and ultimately supporting the reduction of carbon emissions. Nevertheless, there is more to do to improve the network infrastructure response to attend high demand, as revealed especially by the worldwide spread of COVID-19 and the pandemic situation it created [5]. For example, high traffic on video conferencing platforms created issues for fixed and mobile networks in handling the Quality of Service (QoS) and the Quality of experience (QoE) on both audio and video for users, particularly during business hours. Ultimately, and due to limitations of the network infrastructure, these led to heavy network congestions. In the entertainment industry, the side effects weren't much different. OTT platforms were obliged to deal with the unprecedented growth of video streaming consumption and live IP multicasting TV streaming, especially during the airing primetime. Also, the Content Delivery Networks (CDNs) responsible for caching and distribution of content were operating on their limits, while many times, they were not able to cope with the high traffic demand. To cope with the high demand for video IP traffic, some popular OTT services had to downgrade [6] the video quality of their streaming services from UHD to HD and consequently to Standard Definition (SD) keep attending to subscribers' demands and UX. The dawn of the 5G era and the advancements of its newer versions, Release 17 and Release 18, both to be launched in 2021, will enable better video traffic consumption across the Internet. According to CISCO reports, video traffic is expected to represent 82 On the other hand, to provide continual service improvement for video services and other formats of video, including holographic communications and all varieties of Augmented Reality (AR), Virtual Reality (VR), and

Cross Reality (CR), a new network model must be proposed. This paper will investigate the future generation wireless network (FGWN), the 6G, which is scheduled to debut on the world stage in 2030. The presented article will focus on the 6G Network structure and set of knowledge performance index (KPIs) to allow such evolution of multimedia services and the next generation of digital TV beyond 5G (NextGen DTV B5G). This paper is organized in presenting first the TV evolution from Analog TV to Digital. The importance of satellite broadcasting, cable, and IPTV is also presented, followed by the Mobile Broadband's contributions to multimedia streaming. Finally, the paper will present 6G QoS proposals based on the orchestration of technologies at the edge of 6G Cloud-RAN.

2 From Analog Linear TV to Digital TV

This section presents a highlight of TV evolution from analog to digital. Additionally, it also shows the different ways of distributing TV content from Terrestrial to Satellite.

2.1 The Development of Television Systems and Challenges

TV creation was a collective of different scientists and engineers' efforts dating back to the end of the 19th Century to the middle of the 20th Century with the standardization of color TV by the National Television Systems Committee in 1952 [9]. The establishment of TV owes credits to many researchers, like the British physicist Sir William Crookes (1832–1919), who developed the first cathode ray tube (CRT) [10], which was an evolved version of Heinrich Geissler primitive CRT. The CRT consisted of a tube hosting an anode and a cathode in its extremities separated by a filament. Once an electrical discharge was applied, it freed the existing electrons inside the tube, which emitted photons and produced the phenomenon of cathodoluminescence [11]. In 1900, the Russian scientist Constantin Dmitrievich Perskyi coined the word television at the International Congress of Electricity in Paris [12], France. Perskyi proposed a method representing the image of an object utilizing electricity. However, it was only in 1925 that a public demonstration of a figure in motion took place in the city of London [13]. The mass production of the electronic CRT TV started with the black and white standard. The black and white TV standard was created by the Russian American scientist Vladimir Kosmich Zworykin, who teamed up with Radio Corporation of America (RCA) to advance the research to develop a commercial and viable TV [14]. According to the historian Mitchell Stephens [15], between 1946 and 1955, half of the US homes had a black and white TV installed, which symbolized a successful technological deployment. This was also a success for the several Broadcasting TV companies spread on the North American soil, producing content. Based on the scientific advancements made by Columbia Broadcasting Systems (CBS) and thanks to the chief engineer Peter Carl Goldmark [16], they created the colored TV. In 1958, NBC broadcasted the first colored TV program entitled "An Evening with Fred Astaire" [17]. The colored TV was also based on CRT technologies, and it ruled the media entertainment industry until the beginning of the 21st Century. In the meantime, while the TV was being commercialized to households worldwide, the TV Broadcasting Industry and government regulated bodies had to standardize the methodology of improving the transmission and reception of the TV, as far as the broadcasting radio signal could travel. For this, several radiofrequency spectrum and broadcasting standards were created, licensed, and

adopted. The analog TV was utilizing different video format standards for broadcasting its content. The National Television Standards Committee (NTSC) initially created the major TV standards for black and white TV. It was followed later by Phase Alternate Line (PAL), and Séquentiel couleur avec mémoire (SECAM), both for standardized colored TV [18], and all standards were running interlaced video technique. The frequency carriers used for modulating analog TV were the very high frequency (VHF) bands, varying from 54Mhz to 216Mhz and ultra-high frequency (UHF), varying from 470Mhz to 806Mhz, both were having 6Mhz bandwidth allocated for each TV Channel [19]. The terrestrial analog TV had its challenges due to the nature of its architecture. The drawbacks of analog TV were embedded in the nature of the analog radio frequency (RF) signals, which were sensitive to external signal interference causing ghost appearances and snow, the latter caused by an electromagnetic noise absorbed by the receiving antenna. Also, it efficiently degraded with the increase of the distance of the transmission source from the receiver. Furthermore, the quality of the image was low in comparison with modern digital TV. The image quality restriction was due to the bandwidth's size allocated to analog TV [20]. Figure 1 illustrates an example of terrestrial analog TV architecture. In order to resolve the problem regarding low-resolution images, known as Standard Definition (SD) format new format was proposed. Thus, the high-Definition Multiplex Analog Components TV (HD-MAC) format over analog signal was planned in 1995 [21], offering the double number of screen pixels horizontally and vertically. HDTV had the concept of compressing the video signal, but the project was commercially widely used on digital terrestrial TV (DTTV). Figure 2 shows the CRT technology for colored TV, in which the Red, Green, and Blue (RGB) colors were utilized to compose the colored image. Figure 3 shows the signal transmission through a linear system, which is also utilized for the analog TV. The system presented below in Fig. 3 represents the transformed $G(w)$ known as the transfer function, which demonstrates that the interference of any frequency w will have phase and amplitude shifts. This system serves the purpose of helping anyone know the system's response to any source signal.

Fig. 1 Analog terrestrial TV architecture

Fig. 2 CRT RGB system for colored TV **Fig. 3** Signal transmission through linear system

2.2 Digital TV

Digital Terrestrial TV (DTV) started with the standardization proposed by the Advanced Television System Committee (ATSC) in the USA and Europe by the Digital Video Broadcasting (DVB) consortium in the early 1990s. The advancement made was that the TV content was transmitted using a digital signal, which was not sensitive to either distance or interference. Additionally, the digital signal allowed the successful implementation of the HDTV format right from its first versions. With digital technology embedded into TV, several new applications were added to it warranted by a wider bandwidth for broadcasting TV signals via the air. The Digital TV enabled digital Interactivity with image, surround audio, and text over the TV ecosystem and also paved the way for the SmartTVs and innovative full suite of multimedia services. HDTV operating over the DTV started using the IP multicasting technology to efficiently use the digital channel to transmit the data packet from a point to a multipoint without increasing bandwidth [22]. All of this was possible using IP multicast routing protocols. This methodology became known as point-to-multipoint communications (PMP). The distinction between broadcasting and multicasting is that broadcasting is designed to be sending a data stream to all sources available in the network. In the case of multicast, its protocol is intended to send a data stream via one source to multiple sources that are labeled as authorized receivers [23]. Multicast protocols interact with the media access control (MAC) located at Layer 2—Data Link in the Open System Interconnection (OSI) model. This new format influenced the IPTV, the digital cable TV utilizing

a CDN to orchestrate the Live TV and VoD content distribution over the Set-Top-Box (STB). The opposite version of broadcasting and multicasting is unicast. Unicast routing protocol allows the single source to send a data stream to a single authorized destination only, and it is widely used for streaming Live TV over the Internet.

2.3 Satellite Broadcasting from Analog to Digital

In order to tackle the issue regarding the weaknesses of the analog TV signal and make Terrestrial TV reaching households as far as possible, including remote and rural areas and areas, the satellite broadcasting system was envisioned. The satellite concept was first conceived by Sir Arthur Charles Clarke [24], a British writer and inventor who proposed it in October of 1945 [25]. However, it was only at the beginning of the 80s that Direct Broadcast Satellite (DBS) or Direct-to-Home (DTH) satellite systems started gaining commercial traction worldwide [26]. The first DBS satellites were based on analog satellite systems. In order to guarantee a good signal reception, a big dish had to be installed at the TV receptor along with a Low Noise Block (LNB) receiver, which is an RF signal amplifier. The C-Band was less susceptible to rain interference, and it could cover a vast geographic area. On the other hand, the C-Band satellite lacked encryption, which was offered by cabling TV to challenge the DBS commercial status quo. However, C-Band satellite communications are still operating, not just for commercial communications but also for disaster recovery purposes. For instance, in the US, the C-bands frequencies allocated for downlink are 3.4 Ghz to 4.2GhZ, and the uplink starts from 5.85 Ghz to 6.425 Ghz. One can see that 5G frequency bands might create interference [27] in the C-bands signals. Therefore, a site survey and correct planning are required while deploying 5G in these regions to mitigate the interference. The digital satellites started operating in the early 90s. The DTH digital offered a smaller dish for users by comparison with the analog satellite systems [28]. Additionally, it increased the number of TV channels available and enabled better audio and video quality, allowing the distribution of HDTV for consumers. Digital satellites for Broadcasting communications are still evolving and nowadays include Satellite Radio. Currently, Digital DTH offers consumers hybrid services that include pay-per-view, VoD, local free channels, HDTV, and digital video recorder (DVR). The analog and digital satellites bands for broadcasting TV are described below, in Table 1: Satellite Broadcasting TV paved the way to spread the TV reach to consumers, where the traditional terrestrial TV failed to do so. DTH is still important, especially where there is a lack of terrestrial TV coverage or non-available IPTV or Cable TV infrastructure to cover specific geographic regions.

Table 1 Satellite TV broadcasting frequency band

Satellite broad-casting system	Direct to Home (DTH)	
	Frequency range	System type
C-Band	3.7–8 GHz	Analog
Ku-Band	11.7–12.2 GHz and 12.2–12.7 GHz	Digital
Ka-Band	18.3–18.8 GHz and 19.720.2 GHz	Digital

2.4 From Standard Definition CRT to Flatscreen TV

Not only the digital TV changed the quality of the image in the TV, but it also changed physically how the TV set was built, retiring the CRT technology to Liquid Crystal Display (LCD), Light Emitting Diode (LED), Organic Light Emitting Diode (OLED), and Quantum-dot Light Emitting Diode (QLED). The TV became flat rather than squared and prolonged at the back. With this new design, the TV could be fitted on any wall. The LCD display was not a new invention. The first patent was registered by electrical engineer George H. Heilmeier [29] from RCA in the 1960s. But LCD only started being commercially adopted for TV in the early 2000s competing with Plasma TV. Some studies have also compared the human ability to retain temporal images once offset from the CRT and LCD screens. The results have shown that LCD is better to maintain the temporal memory of an offset image in the human brain than CRT [30]. The Flatscreen TV brought the new enhanced quality of the Ultra-High-Definition TV (UHD TV) image and the 4K format. UHD TV has a wider color gamut close to the spectrum of light captured by the human eyes. It also embedded immersive audio and High Dynamic Range (HDR) in its ecosystem as an additional feature to improve the image's quality and the user's experience (UX). UHD TV and 4K's primary difference is that the UHD TV format builds an interlaced image. On the other hand, the 4K is the cinematic format. The 4K image is totally scanned to compose the frames of the motion picture. After all efforts TV technologies progressed, the time arrived for cutting the cord of TV and going wirelessly with the support of 3G and 4G inaugurating the concept of mobile TV (MTV), also known as TV Everywhere.

3 Mobile Generations and Next Generation TV

Section 3 here presented describes mobile broadband generations' importance in creating the new concept of TV Everywhere. Moreover, it explains the core mobile entities that enabled the multimedia data to flow over the cellular network from 3G to 4G, allowing OTT platforms' evolution. Finally explains the advancements being done in the 5G Architecture for video streaming and the future challenges that 6G will need to tackle.

3.1 Mobile Broadband Services Architecture for Multimedia Applications

Mobile broadband connectivity, also known as mobile Internet, initiated the multimedia revolution, changing how mobile subscribers and Internet consumers used to navigate and interact with multimedia services. The consumers of Universal Mobile Telecommunications Services (UMTS), 3G, had experienced the first video calling applications over the mobile handset having some QoS controls. Additionally, consumers enjoyed the ability to navigate thru the Internet everywhere at any time. The 3G architecture was created to be a cellular network to handle multimedia applications. For instance, 3G network architecture added the Packaging Switch (PS) Core to establish data sessions within the 3G ecosystem. Furthermore, 3G added an IP Multimedia Subsystem (IMS) [31] core entity to enable the exchange of voice, text, video, and audio across the cellular network. 3G utilizing the IMS paved the way for TV Everywhere, the concept of watching video content over the wireless medium. 3G also added the Session Initiation (SIP) Protocol [32]. SIP protocol enables users to access the Internet offering the process to initiate, control, and terminate

an Internet session. This feature was so vital for multimedia applications and any mobile application software (APP). The hierarchical correlation and management between Content Providers/TV Broadcasters and subscribers' resource entitlements were also a product of the 3G architecture based on the implementation of Virtual Home Environment (VHE) and Personal Service Environment (PSE) [33]. The VHE permitted the VoD over mobile networks to exist. The UX based on videos just changed completely, and it allowed users to watch video content on Smartphones with qualities varying from SD to HD video format. 4G brought the era of producer/consumer (prosumers) into Reality. Prosumer is the term created by the north American writer Alvin Toffler [34], and this term means the person who consumes and also produces goods. It is the new consumer of the 21st Century based on the digital economy. This is well noticed as mobile subscribers can utilize their mobile handset to create video content, for instance, or set up a business over the mobile Apps offering peer-to-peer services. In other words, 4G inaugurated the Mobile Economy [35]. However, one of the notorious advancements provided by 4G to media broadcasting services was the LTE-Broadcasting (LTE-B) [36] releases. LTE-B allowed Broadcasters or Content Providers to send content for multiple users utilizing multicast and unicast technologies. As presented previously in this paper, multicast has the advantage of saving bandwidth while transmitting a data stream to multiple authorized users. The technology enabler for LTE-B was the evolved Multimedia Broadcast Multicast Service (eMBMs) associated with Multiple Input Multiple Output Antenna (MIMO) technologies. With 4G technologies, it was possible to broadcast, multicast, and unicast UHD TV over consumers' cellular networks. 5G will deliver a continual evolution for multimedia services and to the TV and Cinema industry. The 5G architecture key enablers for the next generation of TV is located on the 5G New Radio (NR) Releases presented in Table 2: The table shows that the 5G release will deliver essential features to offer QoS for multimedia services over the 5G architecture. Additionally, the deployment of a new protocol, Service Data Adaptation Protocol (SDAP) [37], will label the media data packets with QoS. Furthermore, 5G Release 17 has the enhanced Multimedia Priority Services (eMPS) embedded within the enhanced Mobile Broadband (eMBB) core entity. eMPS will be responsible for traffic prioritization within the 5G NR. These features combined with Network Slicing and 5G QoS flow will permit the new class of services and QoS priority to improve multimedia services' quality. Video traffic will receive a new apparatus to support its evolution and also will pave the way to (Cross Reality) XR and Augmented Reality (AR) applications with the future implementation of 5G XR Radio [38]. Current research shows [39] the need for an advanced wireless network to handle new multimedia applications that probably 5G cannot cope. These new eligible multimedia services will require wider bandwidth and near-zero latency together with an advanced QoS feature to deliver the expected QoE for users. Some of these applications are already on the radar of researchers and engineers for 8K TV, Holographic Communications [40], and 3D video. Therefore, it is worthy of

Table 2 5G NR release features

Release	5G NR features Technology
Release 16	Unicast Point-2Point, SDAP
Release 17	eMBB, mMTC, URLLC, network slicing, and 5G QoS Flow
Release 18	QoS for multicast Services

investigating the continual evolution of the cellular network architecture beyond 5G. To better comprehend the set of principles already envisaged in 6G, it is fundamentally important to look at the 5G goals and understand them. 5G will be responsible for establishing the foundations of the Fourth Industrial Revolution (4IR). The technological expression of 4IR, also known as, Industry 4.0 will be the Industrial Internet of Things (IIoT). IIoT will be massively employed to the robotization across all industry verticals. 5G Release 17 will serve IIoT via its core entities, massive Machine Type Communications (mMTC) and Ultra-Reliable Low Latency Communications (URLLC). Innovative multimedia applications such as Holographic Type Communications and 3D Video Callings are potential candidates to benefit from 6G networks. Analyzing these multimedia services will be based on unicast protocols. These services will become critical services as their application varies from serving medical industries to day-to-day commercial applications based on real-time video streaming. Observing this previous statement, it is clear that the next generation of the mobile network must focus on human needs rather than solely on industrial applications. Precisely 6G will need to encompass this principle of the human-centric network.

4 6G Service orchestration for the Future Multimedia Services

Despite the advancements made in the 5G ecosystem to support multimedia applications, more is needed to support the state of the art of future video use cases. They will require extremely low latency and broader bandwidth for handling upcoming multimedia services. Therefore, this section presents the 6G QoS and 6G architecture to address such critical services.

4.1 6G Attributes and Architecture for Multimedia Services

The planning and investigation of defining and standardizing the future wireless network have been initiated. Several institutions and organizations are getting together to research the pre-requisites of 6G. It is known that 6G must sustain a hyperconnected society and offer total convergence between the physical and cybernetic realm [41]. As mentioned previously, the 6G research and development (R&D) are in the early stages of investigations. Nevertheless, it is essential to describe its future attributes to understand better what 6G would look like in 2030. Figure 4 shows the main drivers that will shape the 6G architecture from the technological and societal perspective. Evaluating the main drivers that will shape 6G Networks' future architecture, further explanation is given along with its principles. Omnipresent and Superfast is a quality that is expected in the 6G attributes. To reach such qualities, 6G is envisioned to operate in Terahertz radio frequency and to increase spectrum gain Ultra-Massive MIMO antennas (UM-MIMO), and Holographic Radio will be used. Both technologies will enable data throughput in Terabits/s. Visible Light Spectrum is being investigated as an option to increasing 6G signal coverage. An example of Visible Light communication is Optical Wireless Communications (OWC). The human-centric aspect of 6G is regarding the need for a network to assist humans and be the cornerstone of Society 5.0, Knowledge Human Bond Communications Beyond 2050 (Knowledge Home) [42] and the integration of Communication, Navigation, Sensing and Services (CONASENSE) [43]. Intelligence is another attribute of 6G, in which the core and the edge of the novel network will need to be knowledgeable of how to improve traffic. Artificial Intelligence (AI) and

Fig. 4 6G main drivers

its derivative Machine Learning (ML) are pre-requisites for 6G. AI and ML will be pivotal to grant an intelligent network handling Big Data near real-time to optimize network traffic prioritization based on Network Slicing and other specific KPIs. Therefore, the capacity of learning and adapting the Service Level Agreements (SLAs) for different QoS for multimedia services will be of utmost. Quantum Computing (QC) is a technology to be added to 6G Networks' Edge to provide enough processing power and speed based on the challenges created by Big Data. Quantum computing would be useful if science and technology managed to make it mature enough to be employed on a large scale within the next ten years. QC's computer power is immense compared to the traditional computational power based on classical computers utilizing Binary Language. Quantum technologies are based on Quantum mechanics. Different from the current state of the art for classic computers, there are only two possibilities of state 1 or 0. In quantum mechanics, the atomic and subatomic particles demonstrate that they can have more than one state at once unless the particle collapsed to a single state. This means that a particle can be either 0, 1, or in between the two values. It is a phenomenon also known as "coherence" or "superposition". In QC, this possibility is translated to Qubits [44]. The QC can have more than several values simultaneously expressed in Qubits, which is advantageous against classic computing, and it creates a robust computational process. Based on Peter Shor's algorithm [45], which is responsible for processing QC, Quantum computers will solve complex and intricate tasks. Quantum Computing is still under R&D, and there are many international initiatives to foster QC and Quantum Communications within this decade [46]. QC will be combined with Machine Learning to create a new core entity entitled Quantum Machine Learning (QML) [47]. This is a reason to apply QML to speed up the learning of all activities being traded at the edge of the 6G Network to adjust the network's resources automatically. The reason for using QML is that 6G will be a decentralized network with an urge for faster computational

Table 3 2D video format

2D TV format	Pixels	Bitrate	Latency
HD	2,073,600	12 Mbs	≤ 250 ms
UHD and 4K	8,294,400	20–25 Mbs	15–35 ms
8K	33,177,600	100 Mbs	15–35 ms

power to handle all the heavy data traffic predicted to flow in the network. Table 3 below show the KPIs for multimedia services that can benefit from QML.

The evolution of 4K will be 8K video streaming, which requires four times the amount of bitrate of the current video format as it is set to deliver four times better quality of the image. The bitrate degradation can directly influence the quality of the video image at the destination if it suffers attenuation. For video streaming different from 2D video format, the bitrate is even higher. In summary, the processing power available in QML will easily cope with the future increase of video traffic and heterogeneous data. QML's role is to optimize the traffic for the applications highlighted above. Additional attention to take on Quantum Computing technologies is the security threat already predicted if QC is wrongly used or in the hands of criminals. If this happens, Quantum computing attacks will be able to create world instability in case no advanced security solution is planned. Several scientific types of research are being done to counter-protect future networks [48] from QC attacks. Furthermore, an additional component to be added is the Multi-Access Edge Computing (MEC). MEC is a core entity located at the cellular network edge that allows Telecom Operators to share network resources and traffic optimization via Cloud Services to Third Party applications. The benefits of MEC are huge for consumers and to the third-party application services that require optimized traffic with SLA control. Utilizing this type of technology allow Telecom operators to offer a new service portfolio for vertical industries.

4.2 6G QoS

The main factors impacting the quality of experience for video services are in general described as jitter, rebuffering, resolution degradation, video playback failures, to name just a few. Therefore, a 6G QoS for future multimedia applications must be studied and proposed to guarantee the excellent QoE for 6G consumers. The 6G QoS proposed in this article aims to combine innovative core entities at the Edge of the 6G network, specifically connected to the 6G Cloud-Radio Access Network (6G C-RAN). The 6G QoS will be the fingerprint of the 6G intelligent network. With this architecture, a specific network data header would be added to mission-critical communications. The 6G C-RAN and 6G Multi-Access Edge Computing (6G NextGen-MEC) will handle all multimedia traffic flowing thru these core entities. This architecture will also assure the SLA to be met to guarantee QoS and QoE for consumers in the 6G ecosystem. In summary, 6G will be an intelligent wireless network powered by Artificial Intelligence and Machine Learning and probably supported by quantum computing at its core and at the network's edge. Thus, the future wireless network, 6G, will need to offer a better Knowledge Performance Index (KPI) [49] by comparison with 5G. Some of them are already discussed and commonly agreed across the scientific community, such as presented in Table 4.

Figure 5 below shows the proposed architecture for providing Quantum Machine Learning and the 6G NextGen-MEC to offer High QoS and QoE for multimedia services over 6G.

Table 4 6G KPIs

KPIs	6G Future KPIs/Technologies Performance description
Latency	0,1 mS
Data throughput	1 T bps
Energy efficiency	1J/bit
Geopositioning	centimeters
High-speed connectivity	1000 KM/h

Fig. 5 6G QoS for Multimedia Services

Many possible multimedia services will necessitate having such ultra-low latency. One of them is the Holographic Type Communications (HTC), 8K TV streaming, and 3D video streaming. On the other hand, these types of multimedia services have a high bitrate, even with encoding techniques for data compression. Therefore, large network bandwidth and high speed are required to cope with these applications' data traffic.

5 Conclusions and Future Scope

6G networks infrastructure will require a long period of dedicated investigation for all possible technological innovations to achieve the ambitious objectives of providing a hyper-connected society by 2030. Thus, future wireless technology will affect and change all segments of our society. Planning for such a network starts with the technical evaluation of the obstacles needed to overcome by 2030, combined with the study on trendsetting multimedia applications' characteristics with advanced functionalities requirements. Forecasting potential future requirements for critical multimedia wireless data services and defining the ideal conditions based on their set of KPIs will be the next step. It is then imperative to start looking at the 6G QoS to guarantee QoE for the future 6G prosumers. Consequently, to respond to those demands, planning for the evolved 6G NextGen-MEC underpinned by

AI and QML will be crucial for a successful QoE for the advanced video and image applications. Furthermore, all 6G users' equipment for 6G networks will require an embedded QoS probe to send feedback about the QoE health status (UX) to the intelligent 6G C-RAN for adjusting the user's experience near to real-time [50]. Further investigation in this field, it's been carried out at the 6G Home Lab at Aarhus University in Denmark, and future papers based on this topic will be published.

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