6G Technology in Mobile-Health Multimedia

Subjects: Telecommunications

Contributor: Moustafa M. Nasralla , Sohaib Bin Altaf Khattak , Ikram Ur Rehman , Muddesar Iqbal

Mobile-health (m-health) is described as the application of medical sensors and mobile computing to the healthcare provision. While 5G networks can support a variety of m-health services, applications such as telesurgery, holographic communications, and augmented/virtual reality are already emphasizing their limitations. These limitations apply to both the Quality of Service (QoS) and the Quality of Experience (QoE). However, 6G mobile networks are predicted to proliferate in order to solve these limitations, enabling high QoS and QoE.

e-health healthcare internet of things m-health quality of experience 6G multimedia

1. Introduction

The healthcare industry has constantly adopted the latest technologies with the goal of improving the overall healthcare of the global population. The use of technology has significantly changed the way in which healthcare is provided [1], and it has had far-reaching impacts on delivering healthcare facilities to the general population, including those living in remote locations and in underdeveloped countries [2]. The advancements in technology have enabled the diagnosis of complicated diseases, and currently, sophisticated medical treatments are carried out easily. For instance, advancements in medical imaging technology have led to an increased understanding of the internals of human physiology, and this technology has become an important tool for diagnosing patient diseases, and conditions [3]. One of the most important applied technologies in healthcare is communications technology. The use of network and communication technologies has, over the decades, providing numerous benefits to healthcare. The earlier communication technologies, such as wired telephone lines, fax technology and networking technologies, supported quick and easy communication lines for the exchange of simple diagnostic information such as patient reports, treatment options, prescriptions, etc. The advent of wireless communication and the advancements in internet and satellite communication technologies have provided a significant boost to the delivery of healthcare [4]. They are necessary to revitalize primary healthcare since they contribute to the personalized monitoring of chronic diseases, increase access to healthcare for rural populations, and optimize data measurement and management. Patients must have to visit hospitals; it is generally a time-consuming and labor-intensive process that involves the participation of both the patient and healthcare workers. It often requires the management of several different healthcare aspects, making this process even more confusing and overwhelming. Hence, researchers turned towards smart healthcare using technologies such as wearable sensors enabled technologies, artificial intelligence (AI), and the Internet of Things (IoT) [1][5][6][7]. Moreover, the authors in [8] conducted a comprehensive review of E-Health Practices and Technologies from 2014 to 2019. E-Health refers to a range of technologies that utilize the internet to enhance the provision of healthcare services and improve the overall quality of life.

2. m-Health (Mobile-health)

The rapid increase in mobile phone penetration across the globe has led to the advent of applications that deliver services in different areas, including healthcare. Several nations across the globe are adopting mobile-based technologies for healthcare. The World Health Organization (WHO), in their report on mobile-based technologies for healthcare, declared that over 80 percent of their member nations had made efforts towards the adoption and implementation of mobile technologies for health in their countries [9]. These technologies are popularly referred to as m-health technologies, where medical sensors and mobile computing for healthcare were the original definitions of mobile health (m-health) [10]. m-health works on the concept of any-time, anywhere access, exploiting the best connection features of emerging wireless communications and network technologies in a heterogeneous environment. Hence, it provides an alternative to the traditional healthcare delivery system and assists this system by bridging the gap between terrestrial boundaries and rural and urban areas. However, it is largely driven by successful business and market sectors. It still aims to reach the tipping point for clinical adoption and healthcare delivery efficiency. The three technology pillars of m-health, including telecommunications, computing, and medical sensing, drive this growing popularity. A massive number of smartphones and devices connected to a large number of mobile health applications are used worldwide by both patients and healthcare professionals. These services continuously generate structured and unstructured datasets, revealing new healthcare insights, but also creating some challenges. Today's m-health apps are increasingly coupled to wearable sensors and Internet of Things (IoT) devices [6]. These applications are becoming common in everyday health, wellness, and clinical applications, including chronic disease tracking and management, remote patient data collection and monitoring, diagnostics and treatment, healthcare resource management, patients' education and awareness as well as healthcare professionals' training [11].

3. Multimedia Communications in m-Health

The different types of data transmitted via m-health applications could include text, image, and video data. In recent years, there has been a significant increase in medical imaging/videos for diagnostic purposes. Medical imaging technology advancements have resulted in portable scanning machines that have made producing medical images and videos easier. Subsequently, medical images and videos are also becoming an important part of the data transmitted via m-health applications [12]. Many use cases directly touch our lives and are now more complete and intuitive using multimedia technologies. Systems and services have been developed to use the benefits of multimedia technology, e.g., medical images and videos can be supplied to remote clinicians for consultation, and they can also be disseminated for educational and awareness purposes. As an added convenience in emergency situations, ambulances may be outfitted with portable scanners that capture and transmit diagnostic information to hospitals. Tele-consultation via video conferencing and remote patient monitoring sharing medical data can make individuals with chronic diseases see their doctors regularly and lessen the requirement for patient–physician visits. Gesture recognition and speech recognition are two technologies that are frequently used in conjunction with telemedicine in the smart medical home. Informing patients about diagnosis, surgery, and treatment is critical to their understanding of medical processes. Many patients are being educated using visual, audio, interactive, and internet content to supplement traditional paper-based information. As a result, medical video streaming is becoming an increasingly important component of m-health applications.

Multimedia services are time-sensitive, where efficient network systems are required to ensure service quality [13]. Due to the potential loss in quality in the video between the source and the destination, the quality of video transmission in m-health applications must be maintained at high levels so that the change in quality remains imperceptible. Further, medical videos carry sensitive data that determine patient diagnosis, and at times a loss in quality may impact the diagnostic understanding that can be gleaned from the medical videos. Thus, it is crucial that the quality of video transmission from source to destination is maintained at high levels in m-health applications.

4. QoE of Multimedia Communications in m-Health

To ensure that the quality of video transmission is maintained, a quality assessment needs to be carried out at the destination. Quality assessment is a process that employs methods to measure the quality of the video received at the destination compared to that of the video at the original source. There are two approaches to quality assessment; one is measuring the Quality of Service (QoS), and the other is Quality of Experience (QoE) [14]. In networking and communication applications, the QoS is a method of assessing the service quality that the network provides [15]. It is a network-centric measure that measures the quality of the data transmission provided by the communication network. The QoS measurement includes metrics that measure the key performance indicators (KPIs) of a communication system. These KPIs include metrics such as the percentage of data transmitted, the amount of data lost during transmission, channel throughput, speed of data transfer, system fairness, etc. On the other hand, QoE is a user-centric evaluation approach that reflects the degree of delight or annoyance of the user with the service used [16]. In the case of video transmission, the QoE of a user is the perception of the video quality by the end-user [17][18]. The QoE puts the focus of quality assessment on the user's perspective and typically considers many factors surrounding the context of the application [19]. There are two broad categories of QoE evaluation: subjective and objective evaluations. Subjective evaluation methods are based on the Human Visual System (HVS), which largely depends on observation by human subjects. The subjective evaluation method uses an evaluation score known as the Mean Opinion Score (MOS), a mean score of the users' opinions about their perception of the video's quality. On the other hand, objective evaluation methods use mathematical models that act as quality metrics to measure the audio or video received quality, such as Peak Signal to Noise Ratio (PSNR), Mean Square Error (MSE), etc. A list of subjective and objective QoE assessment metrics are listed in **Table 1** and **Table 2**, where more details and explanations about all these metrics can be found in [20][21]. Given that QoS primarily focuses on the technical elements, whereas QoE is centered around customer service and satisfaction, it is plausible to include QoS as an inherent component within the definition of QoE.

Table 1. Subjective assessment metrics for multimedia quality evaluation.

Metrics	Description
Mean Opinion Score (MOS)	A widely used metric that evaluates the overall quality of multimedia content by asking users to rate it on a scale from 1 to 5 or 1 to 10.
Differential Mean Opinion Score (DMOS)	Measures the difference between the user's rating of the quality of two versions of multimedia content.
Single stimulus (SS) or Absolute category rating (ACR)	The most basic method of subjective assessment, where the viewer rates the quality of a stimulus on a predefined scale.
Absolute category rating-hidden reference (ACR-HR)	A variant of SS/ACR method where the reference is hidden from the viewer.
Degradation category rating (DCR) or Double stimulus impairment scale (DSIS)	The viewer is presented with two stimuli—the original and the degraded version, and the viewer is asked to rate the quality of the degraded stimulus.
Double stimulus continuous quality scale (DSCQS)	Similar to DCR/DSIS method, but the viewer is presented with a continuous scale to rate the quality of the stimulus.
Pair comparison method (PC)	The viewer is presented with two stimuli, and the viewer is asked to select the stimulus with better quality.
Subjective assessment methodology for video quality (SAMVIQ)	A standardized subjective assessment methodology for video quality evaluation that involves multiple test conditions and scales.
Single stimulus continuous quality evaluation (SSCQE)	The viewer is presented with a stimulus and asked to continuously rate the quality on a scale.
Simultaneous double stimulus for continuous evaluation (SDSCE)	The viewer is presented with two stimuli, and the viewer is asked to continuously rate the quality of both stimuli.

Table 2. Objective assessment metrics for multimedia quality evaluation.

Metrics	Description
Peak signal-to-noise ratio (PSNR)	Measures the difference between the original and the compressed multimedia content.
Structural similarity index (SSIM)	Measures the similarity between two images or video frames.
Multiscale-SSIM (MS-SSIM)	An extension of SSIM that considers the structural information of images at multiple scales.
Moving picture quality measure (MPQM)	Measures the quality of the compressed video based on the perceptual quality of individual frames.
Video quality metric (VQM)	Measures the quality of the compressed video based on the distortion of individual frames.
Visual information fidelity (VIF)	Measures the visual similarity between two images.
Visual signal-to-noise ratio (VSNR)	Measures the difference between the original and the compressed multimedia content based on the perceptual quality of individual frames.
Motion-based video integrity evaluation (MOVIE)	Measures the quality of the compressed video based on the amount of motion.
Video multimethod assessment fusion (VMAF)	A perceptual video quality metric that combines several objective metrics to predict the subjective quality of the video.
Spatio-temporal reduced-reference entropic (STRRED)	A reduced-reference metric that measures the quality of the compressed video based on the spatiotemporal distribution of entropy.
STRREDopt	It is a computationally efficient variant of STRRED.

Metrics	Description
Spatial efficient entropic differencing for quality assessment (SpEED-QA)	A reduced-reference metric that measures the quality of the compressed video based on the spatial distribution of entropy.
No reference bitstream (NR-P)	A no-reference metric that measures the quality of the compressed video based on the statistical properties of the bitstream.
Pixel-based no-reference (NR-B)	A no-reference metric that measures the quality of the compressed video based on the statistical properties of the pixels.
Blind/referenceless image spatial quality evaluator (BRISQUE)	A no-reference metric that measures the quality of images based on the statistical properties of the pixels.
The natural image quality evaluator (NIQE)	A no-reference metric that measures the quality of images based on natural scene statistics.
Psychovisual-based image quality evaluator (PIQE)	A no-reference metric that measures the quality of images based on the human visual system. [22]

Recently, ... tures that ... fessionals include bandwidth, packet delay, jitter and packet loss tolerance, quality of the image, frame rate of the video received, real-time streaming when required, the direction of flow (uplink/downlink), mobility, etc. [23]. Measuring QoE can be complex, as several factors need to be considered that influence the end user's QoE. The authors in [24] term these factors as "Influence Factors" (IF) and define them as: "Any characteristic of a user, system, service, application, or context whose actual state or setting may have an influence on the Quality of Experience for the user". The m-QoE is the concept of traditional QoE seen from the perspective of healthcare applications. It is defined as the overall acceptability of m-health applications as perceived by end-users, where the end-users are the patients and healthcare professionals [25]. The m-QoE perceived in m-health systems is generally influenced by the system, context, and human influence factors (IFs).

5. The Role of 6G towards Multimedia Communications

Smart healthcare must be able to monitor health, diagnose diseases, and treat patients remotely with services such as Hospital-to-Home (H2H) services, emergency services, ambulance services, Intelligent Wearable Devices (IWD), etc. These services send the patient data remotely over the internet and then analyze them at data centers. Healthcare networks must provide mobility, high capacity, low latency (1 ms), green communication for patient safety, and continuous connectivity availability with high reliability. For these requirements, the sixth generation of wireless communication (6G) is regarded as the ideal solution for hosting healthcare networks [26][27]. **Figure 1** depicts the healthcare network architecture in 6G; this diagram depicts the network's key deployment tiers, including intelligent sensing, intelligent access, and intelligent cloud. This 6G architecture will enable many processes, such as security, flexibility, and intelligent resource management. This figure displays the slicing architecture of 6G networks, where different network slices enable different applications. The devices in the sensing layer gather data and deliver it to the next level. At this level, the nodes, users and devices connect to the radio access networks technologies such as massive MIMO, small cells, and advanced modulation techniques are implemented. Lastly, in the cloud layer, intelligent resource allocation, network management and optimization are performed. These different layers provide flexibility to the system on different levels, and a wide range of applications benefit from the network. This figure envisions such a scenario, demonstrating all layers and their key technologies.

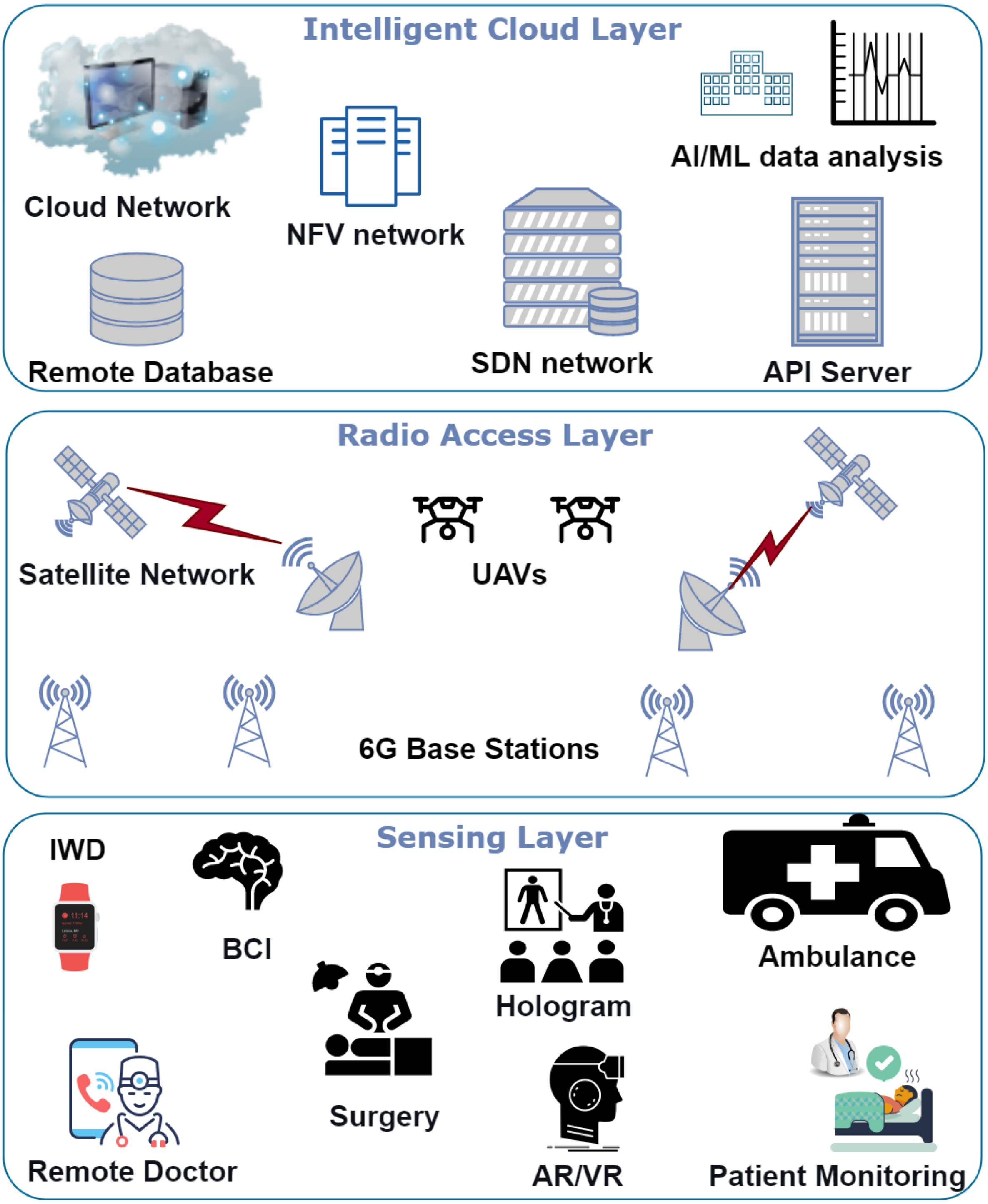

Figure 1. The 6G healthcare network layers.

The development of 6G communication technologies addresses some of the issues discussed in previous subsections, particularly in connectivity, data rates, network compatibility, and guaranteeing high levels of QoS and QoE for m-health applications [28][29][30]. A high data rate of at least 1 Tbps, extremely reliable, further-enhanced mobile broadband (FeMBB), ultra-reliable low-latency communication (URLLC), long-distance and high mobility communications (LDHMC), ultra-massive machine-type communications (umMTC), and extremely low-power communications (ELPC) are all features of 6G technology. QoS also incorporates parameters such as mobile broad bandwidth and low latency (mBBLL), and massive low latency machine type (mLLMT), revolutionizing many applications. The 6G technology must execute all desired characteristics to achieve good QoE. Thus, 6G technology will be groundbreaking in many fields as providing high QoS and QoE will enable new applications such as telesurgery, holographic communications, augmented and virtual reality, five-sense communications, and tactile internet. QoE will also play a vital role in intelligent transportation services and autonomous vehicles such as intelligent cars, drones, and ambulances [31].

References

1. Stefanova-Pavlova, M.; Andonov, V.; Tasseva, V.; Gateva, A.; Stefanova, E. Generalized nets in medicine: An example of telemedicine for people with diabetes. In Imprecision and Uncertainty in Information Representation and Processing: New Tools Based on Intuitionistic Fuzzy Sets and Generalized Nets; Springer Publishing: Berlin, Germany, 2016; pp. 327–357.
2. Taleb, H.; Nasser, A.; Andrieux, G.; Charara, N.; Motta Cruz, E. Wireless technologies, medical applications and future challenges in WBAN: A survey. Wirel. Netw. 2021, 27, 5271–5295.
3. Smith-Bindman, R.; Miglioretti, D.L.; Johnson, E.; Lee, C.; Feigelson, H.S.; Flynn, M.; Greenlee, R.T.; Kruger, R.L.; Hornbrook, M.C.; Roblin, D.; et al. Use of diagnostic imaging studies and associated radiation exposure for patients enrolled in large integrated health care systems, 1996–2010. JAMA 2012, 307, 2400–2409.
4. Stefanova-Pavlova, M.; Andonov, V.; Stoyanov, T.; Angelova, M.; Cook, G.; Klein, B.; Vassilev, P.; Stefanova, E. Modeling telehealth services with generalized nets. In Recent Contributions in Intelligent Systems; Springer: Cham, Switzerland, 2017; pp. 279–290.
5. Kashani, M.H.; Madanipour, M.; Nikravan, M.; Asghari, P.; Mahdipour, E. A systematic review of IoT in healthcare: Applications, techniques, and trends. J. Netw. Comput. Appl. 2021, 192, 103164.
6. Bhuiyan, M.N.; Rahman, M.M.; Billah, M.M.; Saha, D. Internet of things (IoT): A review of its enabling technologies in healthcare applications, standards protocols, security, and market opportunities. IEEE Internet Things J. 2021, 8, 10474–10498.
7. Aghdam, Z.N.; Rahmani, A.M.; Hosseinzadeh, M. The role of the Internet of Things in healthcare: Future trends and challenges. Comput. Methods Progr. Biomed. 2021, 199, 105903.
8. Da Fonseca, M.H.; Kovaleski, F.; Picinin, C.T.; Pedroso, B.; Rubbo, P. E-health practices and technologies: A systematic review from 2014 to 2019. Healthcare 2021, 9, 1192.
9. World Health Organization. Telemedicine: Opportunities and Developments in Member States. Report on the Second Global Survey on eHealth; World Health Organization: Geneva, Switzerland, 2010.

10. Istepanian, R.S.; Al-Anzi, T. m-Health 2.0: New perspectives on mobile health, machine learning and big data analytics. Methods 2018, 151, 34–40.
11. Istepanaian, R.S.; Zhang, Y.T. Guest editorial introduction to the special section: 4G health—The long-term evolution of m-health. IEEE Trans. Inf. Technol. Biomed. 2012, 16, 1–5.
12. Kim, J.; Wang, Z.; Cai, T.W.; Feng, D.D. Multimedia for Future Health—Smart Medical Home. In Biomedical Information Technology; Elsevier: San Diego, CA, USA, 2008; pp. 497–512.
13. Mancas, C.; Mocanu, M. Enhancing QoS/QoE in multimedia networks. In Proceedings of the 2013 IEEE International Conference on Communications Workshops (ICC), Budapest, Hungary, 9–13 June 2013; pp. 637–641.
14. ITU. Vocabulary for Performance, Quality of Service and Quality Of Experience. 2017. Available online: https://www.itu.int/rec/T-REC-P.10-201711-I/en (accessed on 5 June 2023).
15. ITU. Guidelines on Regulatory Aspects of Quality of Service. 2021. Available online: https://www.itu.int/rec/T-REC-E.800SerSup9-202110-I/en (accessed on 5 June 2023).
16. ETSI Technical Report 102643 V1.0.2. Human Factors (HF); Quality of Experience (QoE) Requirements for Real-Time Communication Services. 2010. Available online: https://www.etsi.org/deliver/etsi_tr/102600_102699/102643/01.00.02_60/tr_102643v010002p.pdf (accessed on 5 June 2023).
17. ITU. GSTR-5GQoE—Quality of Experience (QoE) Requirements for Real-Time Multimedia Services over 5G Networks. 2022. Available online: https://www.itu.int/pub/T-TUT-QOS-2022-1 (accessed on 5 June 2023).
18. Martini, M.G.; Nasrall, M.M.; Ognenoski, O. QoE control, monitoring, and management strategies. In Multimedia Quality of Experience (QoE): Current Status and Future Requirements; Wiley: Hoboken, NJ, USA, 2016; pp. 149–167.
19. Zhao, T.; Liu, Q.; Chen, C.W. QoE in video transmission: A user experience-driven strategy. IEEE Commun. Surv. Tutor. 2016, 19, 285–302.
20. Kougioumtzidis, G.; Poulkov, V.; Zaharis, Z.D.; Lazaridis, P.I. A Survey on Multimedia Services QoE Assessment and Machine Learning-Based Prediction. IEEE Access 2022, 10, 19507–19538.
21. QoE-Driven IoT Architecture: A Comprehensive Review on System and Resource Management. IEEE Access 2022, 10, 84579–84621.
22. Ruan, J.; Xie, D. A survey on QoE-oriented VR video streaming: Some research issues and challenges. Electronics 2021, 10, 2155.
23. Martini, M.G. Wireless broadband multimedia health services: Current status and emerging concepts. In Proceedings of the 2008 IEEE 19th International Symposium on Personal, Indoor and Mobile Radio Communications, Cannes, France, 15–18 September 2008; pp. 1–6.

24. Brunnström, K.; Beker, S.; de Moor, K.; Dooms, A.; Egger, S.; Garcia, M.-N.; Hossfeld, T.; Jumisko-Pyykkö, S.; Keimel, C.; Larabi, M.-C.; et al. Qualinet White Paper on Definitions of Quality of Experience. 2013. Available online: https://hal.archives-ouvertes.fr/hal-00977812/ (accessed on 5 June 2023).
25. Istepanian, R.S.; Alinejad, A.; Philip, N.Y. Medical quality of service (m-QoS) and quality of experience (m-QoE) for 4G-health systems. In Multimedia Networking and Coding; IGI Global: Pennsylvania, PA, USA, 2013; pp. 359–376.
26. Kaiser, M.S.; Zenia, N.; Tabassum, F.; Mamun, S.A.; Rahman, M.A.; Islam, M.; Mahmud, M. 6G access network for intelligent internet of healthcare things: Opportunity, challenges, and research directions. In Proceedings of the International Conference on Trends in Computational and Cognitive Engineering, Batu Pahat, Johor, Malaysia, 21–22 October 2021; pp. 317–328.
27. Padhi, P.K.; Charrua-Santos, F. 6G enabled tactile internet and cognitive internet of healthcare everything: Towards a theoretical framework. Appl. Syst. Innov. 2021, 4, 66.
28. Hakeem, S.A.A.; Hussein, H.H.; Kim, H. Vision and research directions of 6G technologies and applications. J. King Saud Univ.-Comput. Inf. Sci. 2022, 34, 2419–2442.
29. Imoize, A.L.; Adedeji, O.; Tandiya, N.; Shetty, S. 6G enabled smart infrastructure for sustainable society: Opportunities, challenges, and research roadmap. Sensors 2021, 21, 1709.
30. Alraih, S.; Shayea, I.; Behjati, M.; Nordin, R.; Abdullah, N.F.; Abu-Samah, A.; Nandi, D. Revolution or evolution? Technical requirements and considerations towards 6G mobile communications. Sensors 2022, 22, 762.
31. Damaj, I.W.; Serhal, D.K.; Hamandi, L.A.; Zantout, R.N.; Mouftah, H.T. Connected and autonomous electric vehicles: Quality of experience survey and taxonomy. Veh. Commun. 2021, 28, 100312.