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A Review of 6G: Towards The Future

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Abstract – *The first wireless communication signal was transmitted across the Atlantic by Marconi in the early 1900s. The world has been revolutionized by mobile communication since the 1980s. The internet has transformed all aspects of people's lives. As a result, communication and sharing of information have greatly improved. As 5G opens up endless possibilities, technology companies begin to wonder what 6G will bring. A 6G network will provide more than just communication in a new generation of mobile devices communications. An era of true intelligence in everything will begin when the physical, biological, and cyber worlds are connected by neurons. It will continue to evolve as connected people and things develop connected intelligence. Ultimately, it will bring intelligence to every individual, home, and business. A holistic view of 6G is presented in this article, the study highlights the most promising lines of research in the recent literature that support this vision. A key contribution of the paper is the exploration of 6G communications' critical issues and key features, including: The vision and key features of the organization; the challenges and possible solutions; and the research activities. For a specific, concrete, and concise conclusion to be reached, these controversial topics were critically examined in relation to their various sub-domains of motivation. This article will help researchers learn more about a topic so they can continue investigating it.*

Keywords: 5G, LTE, 6G, Wireless Communication, 6G Mobile Communication, enhanced mobile broadband (eMBB+), mMTC+, URLLC+, AI, Sensing.

1.INTRODUCTION

People and things (e.g., places, devices) rely on this Internet infrastructure to communicate, connect, and interact across physical and virtual spaces. Having this foundation sets the stage for a smarter era dominated by robots and artificial intelligence [1]. With an ever-increasing exchange of information, communication technology will continue to evolve rapidly to connect people with machines and things. Currently, 6G technology is utilized to the fundamental infrastructure of various industries and is supporting everything from smart factories to vehicle-to-vehicle communication. A next-generation connectivity technology called ultra-wideband (UWB), which can accurately and safely measure distances, is also emerging to connect devices and provide location-based services. Ahead of any other technology, communication technology is evolving to prepare for the future. Globally, major countries are already working on 6G research and introducing it to fierce leadership competitions due to the rapid change in mobile communication technology every 10 years [2]. To strengthen 5G competitiveness, prepare core technologies for the 6G era a decade later, and lead global standards based on them, technology companies will continue to focus on advanced communication research.

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2.METHODOLOGY

The purpose of this technical report is to introduce the technologies offered in the new generation of 6G and summarize the article so that the reader can reach the desired references more easily and quickly. How can 6G networks compete with 5G cellular mobile wireless communications networks? Then what are the missing units from LTE and 5G that must be integrated into 6G? Various academic, industrial, and research communities have established research modalities on the formulation, definition, design, and identification of important core technologies driving "beyond 5G" or "beyond 6G." In this study, the "Keyword Research Methodology" was applied as the methodology. Keyword research is the best way to find online content that has already been indexed. So, the goal of this study is to find 6G keyword-related content on web services by using the essentials of keyword research methodology to find keyword-related content. In order to conduct this research, Google was used to search for the keywords "6G," "6G Future," and "6G mobile communication," and all articles up to today were filtered. Only 30 popular news stories were used in the study. Duplicates and sources that couldn't be trusted were taken out. This section will talk about a wide range of ideas that have been discussed in recent books and articles about the future of 6G communications and its most important features. Firstly, this section begins by providing a brief overview of the applications that will be supported by 6G communications in order to identify the key features that will be required. This work does not contain any personal opinions. Also, the order of the references has been kept, except for the reference number, which has been replaced by the basic article. This way, if the reader needs to, they can find the relevant reference in the basic article.

3.MEGA-TRENDS AND 3 KEY DRIVERS ARE LEADING MOBILE COMMUNICAITONS TO A NEW ERA OF CONNECTED INTELLIGENCE

New generations of mobile communications systems come out every 10 years, but it takes two generations or more for new services and applications that use new frequency bands to become popular [3]. To create a connected society, it took almost four generations for people to be able to connect anywhere and anytime. With the rapid global commercialization of 5G starting around 2020, society will not only be better connected with enhanced communication capabilities, but more devices in all kinds of business scenarios will be connected, leading to a connected society [4]. Taking advantage of the trend of a smart society, 6G is expected to continue the transition from connected people and things to connected intelligence. Besides the three usage scenarios initiated in 5G, AI and sensing will also become two new scenarios in 6G, as shown in Figure 1. There are three key drivers driving mobile communications toward a new era of connected intelligence.

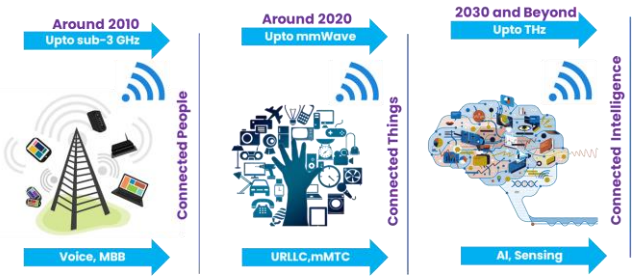

Fig -1: Mega-trends and drivers are leading mobile communication to a new era of connected intelligence toward 2030 and beyond

4. 6G NETWORK DESIGN CHALLENGES- BIG DATA AND IoT APPLICATIONS

4.1 Driver 1: Developing new applications and establishing new businesses

More applications will emerge in the 6G era. In human-centric applications, extended reality cloud

services, haptic feedback, and holographic displays are likely to become mainstream [4]. In terms of the massive capacity required, the exponential growth in traffic demand per device, combined with strict latency and reliability requirements, will make 6G network design challenging. While the amount of IoT devices grows and wireless sensing becomes more capable, AI will become an engine for all kinds of automation based on big data. Consequently, big data will drive a massive increase in 6G network throughput. Furthermore, high-performance industrial IoT applications will require deterministic latency and jitter, as well as availability and reliability guarantees [5]. In addition, these use cases will contribute to 6G's extreme and diverse performance.

4.2 Driver 2: Spread of Intelligence

There has been a deep impact on people's lives, and the mobile industry has contributed to alleviating the digital divide as well as contributing significantly to society's productivity and economic growth. In 2030 and beyond, this trend will continue. It is anticipated that the following four critical factors, as shown in Figure 2, will drive paradigm shifts in radio technology and network architecture in the future, as pervasive intelligence is enabled by massive machine learning (ML), brute-force computing, as well as big data analytics.

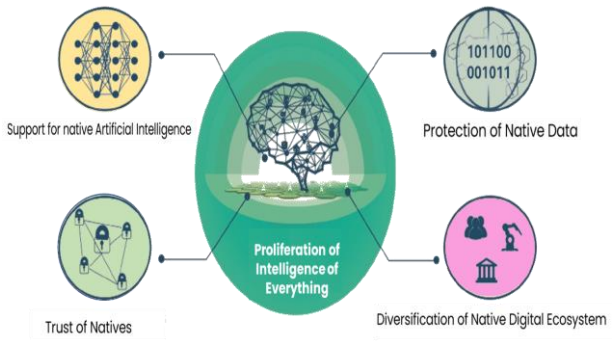

Fig -2: Proliferation of intelligence drives 6G features

Support for native Artificial Intelligence

During 6G development, end-to-end (E2E) mobile communications systems will be designed with optimal support for AI and ML not only as a basic functionality, but also for efficiency. Data ownership concerns can be addressed by running distributed AI at the edge as part of a distributed architecture. In the future, pervasive intelligence will be combined with deeply converged ICT systems that feature diverse connectivity, computing, and storage resources. As 6G networks become natively AI-enabled, they will create "Networked AI," moving away from centralized "Cloud AI."

Protection of Native Data

There will be a need for privacy protection at every level of 6G networks and data. As data owners, users—whether people or machines—will have control and operation rights over their data. While ensuring privacy, protecting data subjects' rights, enabling data control and processing, and supporting policies such as the General Data Protection Regulation (GDPR), the design of 6G should establish fundamental guidelines for technology use and design in the future.

Trust of Natives

It is essential to have customized, verifiable, and measurable trustworthiness in order to support a variety of use cases and markets. It will be essential to develop a multilateral trust model, rather than a unilateral one, for the ownership and operation of today's nomothetic networks. As well as being future-oriented, the trustworthiness architecture should incorporate security, privacy, resiliency, safety, and reliability.

Diversification of Native Digital Ecosystem

In the 2020s, the vertical wireless market is likely to increase with 5G capabilities gradually expanding. A universal ICT framework, able to offer an overarching perspective for all industries, would be extremely helpful for accelerating collaboration and convergence between ICT and OT sectors as we approach 6G. It is expected that 6G will boost both

the consumer and vertical markets during the first wave of commercial use.

4.3 Driver 3: How 6 G will bring a commitment to sustainability as well as social responsibility

There is a high demand for sustainable 6G innovations in light of multiple generations of technologies and spectrum deployments in mobile systems. The deployment, operation, monitoring, and management of 6G networks and services should be cost- and energy-efficient, easy, and automated [7]. Moreover, 6G should facilitate society's achievement of sustainable development goals (SDGs).

5.OVERALALL VISION AND CAPABILITIES OF 6G

Next-generation mobile communications, or 6G, will go far beyond just communication. Technology breakthroughs will be fueled by the rise of massive AI and the creation of massive digital twins over the next decade in addition to continuous wireless innovations. Creating a 6G network will change both the economy and society - it will lay the groundwork for the future Intelligence of Everything.

It is expected that 6G will enable the transition from connected things and people to connected intelligence within the next few years. A significant improvement will be realized in terms of key performance indicators (KPIs) with 6G compared to its predecessor [8]. Moreover, it will help all vertical businesses achieve full-scale digital transformation. The 6G network will be an integrated sensor, communication, and computing system, enabling distributed neural networks to function. It will bring about a world where everything is sensed, connected, and intelligent, fusing the physical, biological, and cyber worlds.

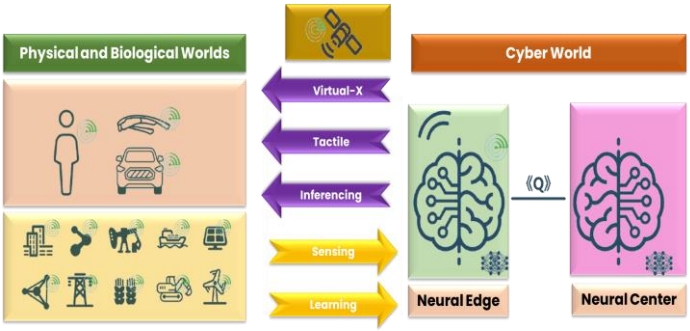

Fig -3: A fusion of the physical, biological, and cyber worlds

An overview of 6G's role as a fabric of converged physical and cyber worlds can be found in Figure 3. A typical downlink channel between the virtual and physical worlds will be all kinds of XR, which, enhanced by tactile interaction and an enhanced human-machine interface, creates an immersive experience when interacting with a computer. In the meantime, continuous deep learning serves as an AI engine for the physical world, providing real-time inferences to help make decisions [9]. With such high throughput and ultra-low latency requirements, designing the radio interface is extremely challenging. In addition, the primary purpose of this uplink channel is sensing and the collection of big data for machine learning. ML poses a new challenge when it comes to compressing and transmitting huge amounts of data [10]. As data centers become neural centers, and ML tasks spread from neural centers to deep neural edges of the network, 6G will be a network of sensors and artificial intelligence (AI).(e.g., base stations, mobile devices.)

6.A LIFECYCLE OF 6G- THE FUTURE OF WIRELESS COMMUNICAITONS

Many people overestimate the amount of work they can do in 10 years but underestimate the amount of work they can do in two years. In the 6G lifecycle, innovative technologies will help improve many aspects of people's daily lives, including ultra-fast

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and highly reliable wireless connections, core AI and advanced sensing capabilities. This study has identified five key use cases based on the key features you need. The use cases identified in 5G have been extended and integrated into eMBB+, URLLC+ and mMTC+, and the use cases identified in 6G will thrive in sensing and artificial intelligence. Detailed explanations of these classifications are provided in the following sections, along with use cases and requirements as show Fig-4.

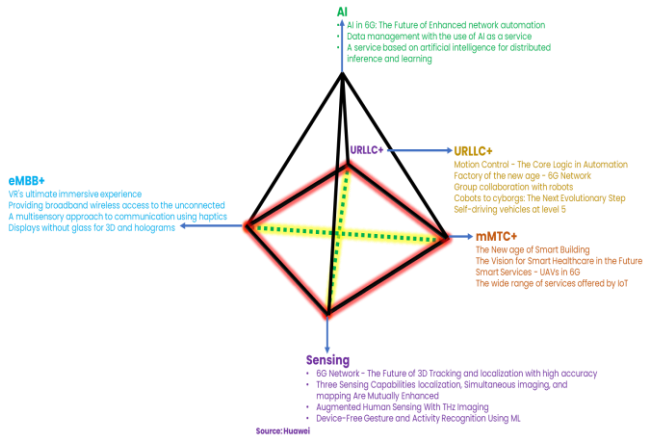

Fig -4: A Lifecycle of 6G - The Future of Wireless Communications

6.1 The Human-Centric Communication Use Cases of Enhanced Mobile Broadband (eMBB+)

For human-centric communication use cases, enhanced mobile broadband (eMBB+) is continuously evolving. This technology will allow for augmented reality, virtual reality, mixed reality and telepresence which are XR applications. In order to achieve eMBB+, higher top data rates will be required, along with low E2E latency, large system capacity, and a high throughput [11]. Moreover, it will transform the ways we live, learn, work, and travel, enabling use cases in entertainment, education, manufacturing, and navigation. It is necessary to have a good user experience inside and outside along the entire route between target activity areas, regardless of how mobile people are [12]. It is essential to maintain high-quality connections in remote areas, on planes, and on ships. These use cases are discussed below.

VR's ultimate immersive experience

In terms of resolution and frame rate, 360 degree immersive XR offers even higher resolution and frame rates than current XR services. With its extremely low interactive latency, it delivers the best immersive visual experience. In addition, people will be able to view live football matches from the referee's point of view, so they can play football virtually with their friends wherever and whenever they want. For cloud VR to be suitable for extended periods of use without making users dizzy, motion sickness must be considered. In terms of motion-to-photon (MTP) latency, the target is approximately 10 ms, which is half the requirement of current VR. Furthermore, ultimate VR will require more than a 100-fold increase in raw data rate in addition to extreme video resolution and color depth. Additionally, devices with limited computing capabilities are more likely to benefit from an architecture that enables pure remote rendering. Power and weight are often strict constraints on user devices. This requires a low transmission latency (no more than 2 ms RTT) and a high data rate.

Providing broadband wireless access to the unconnected

In today's world, about 40% of people lack access to mobile networks. A significant goal of the 6G era is to enhance financial and social inclusion in sparsely populated areas through the integration of terrestrial and non-terrestrial networks. Non-terrestrial networks can provide relay links between terrestrial base stations and remote, unconnected areas or ships. To ensure seamless switching between different access services, connecting non-terrestrial networks directly to mobile phones is an attractive prospect. People on the move, for example, should have access to broadband. As a result of the unified 6G system, people on cars, trains, planes, and ships would be able to receive

optimal, scenario-specific MBB coverage. With terrestrial as well as non-terrestrial networks integrated, 6G will be resilient to natural disasters, ensuring continuity of service.

A multisensory approach to communication using haptics

Surface, touch, actuation, motion, vibration, and force are all types of haptic information that can be exchanged in real-time through haptic communication. Along with audiovisual data, this information is transmitted over the network[13]. The wearer can experience the texture, weight, and pressure of a virtual ball with haptic clothing, or receive a virtual hug from a family member who is far away with haptic clothing. One of the toughest haptic applications is teleoperation in highly dynamic environments (such as telesurgery, telediagnosis, and telemotion control). As a result, haptic feedback is critical for stimulating the brain and for adjusting the users' operating time, stress levels, gestures, and so on. The RTT requirement for air interface transmission is as low as 0.1 ms for this type of interactive teleoperation. Additionally, teleoperation has strict requirements on the transmission latency between audio, video, and haptic information, as well as on reliability and throughput.

Displays without glass for 3D and holograms

Whether the displayed object is close or far away, wearers of VR devices always focus on the screen. This may cause dizziness or other unwanted effects since it affects users' ability to perceive depth correctly. Light field and holographic displays are expected to be the next game-changing technology in glass-free 3D displays. An immersive and true-to-life experience could be delivered by such displays, enabling users to see far-away family members up close without the need for glasses. The 6G mobile system is needed to enable users to experience this anywhere and at any time. Several new applications, such as mobile 3D navigation, will require the transmission of 3D images over mobile networks, which will raise network bandwidth requirements significantly. Depending on image size, resolution, color, and so on, raw data rates vary from sub-1 Tbit/s to a few hundred Tbit/s [14]. Compression techniques that reduce bandwidth consumption are being researched.

6.2 URLLC+ : 6G will help vertical industries make a complete digital transformation.

6G will accelerate the digital transformation of industries. It shows how URLLC is changing in Industry 4.0 and beyond [15]. It applies to manufacturing and public service in addition to other areas. The requirements on latency as well as reliability may be strict in first-order statistics, like the mean number of errors per period, but controllable in distributions or higher-order statistics, like the distribution of errors per period.

Motion Control - The Core Logic in Automation

Aside from being a challenging use case, motion control is an essential part of automation. Controlling every aspect of a machine's movement is its responsibility. Wired technologies, such as industrial Ethernet, are already used to accomplish this type of operation in modern manufacturing. Communication must be transformed from wired to wireless - for example, 6G - in order to realize a truly flexible production line. An elevated level of reliability (e.g., greater than 99.9999%) and low latency (e.g., less than 1 second) are required., sub-ms or even μs) of deterministic communication capability so that precise and reliable control can be achieved.

Factory of the new age - 6G Network

As opposed to traditional assembly lines, a factory of the new age will have full automation and flexibility, meeting the demands of mass customization. The 6G network will play a key role in enabling this revolution. As a precondition to instantly assembling a customized assembly line, modules need to be able to move freely, which can be achieved using ultra-high-performance radio links. With AI and digital twins, machines and robots will be able to gain and share manufacturing

knowledge, which will help optimize manufacturing. The factory of the future could also benefit from 6G in many other ways. In the production environment, a ubiquitous RF sensing system would enable proactive maintenance. Moreover, lights-out manufacturing would reduce OPEX and carbon footprint significantly since it does not require humans onsite.

Group collaboration with robots

Most of the major work will be performed by robots instead of humans in the factory of the future. Many types of robots will be used during production, including automated guided vehicles (AGVs) and drones. In collaborative carrying, multiple robots work together to transport large or heavy parts. Cyber-physical control applications will be used to coordinate and control the movement of these robots in order to achieve safe and efficient cooperation [16]. As an example, rigid and fragile parts require precise coordination, whereas flexible or elastic parts allow greater freedom of movement. In order to accomplish complex collaborative tasks, 6G networks will provide latency, synchronization, and localization accuracy capabilities. There may be a need for a localization accuracy of 1 cm, an E2E latency of approximately 1 ms, and reliability above 99.9999% in this case.

Cobots to cyborgs: The Next Evolutionary Step

Manufacturing companies have recently begun to use collaborative robots, or cobots. Unlike traditional robots operating in separate and restricted areas, cobots are capable of collaborating and interacting with people in close proximity [17]. In addition to being intelligent (allowing them to comprehend the dynamic environment), they should be cautious regarding human safety and proactive when dealing with risks and actions, and they must be reliable as regards to functionality. All of this can only be accomplished through the integration of AI, ICT, and OT [18]. Cobots' mobility and interaction with humans are enhanced by the high-performance sensing and communication technologies of 6G. An evolutionary step beyond cobots, cyborgs were first proposed in 1960. It is a cybernetic organism - a human enhanced with a machine. A cyborg could help someone overcome physical disabilities and could enhance their strength or senses. As neuroscience develops, 6G will be the key to the interconnection of cyborgs.

Self-driving vehicles at level 5

The most challenging use case from a technical requirement perspective for smart transportation is autonomous driving. Human pilots and teleoperation are required to operate initial self-guided vehicles. It will change how passengers travel if Level 5 vehicles are used. Passengers could enjoy a relaxing, enjoyable, productive experience while retaining their privacy on journeys in self-drive vehicles. In order to deal with unforeseen situations, it will be essential to have ultra-low latency, high reliability, and precise localization capabilities provided by 6G.

6.3 6G to Connect Everything : massive Machine type of communication (mMTC+)

Despite 5G's promise of connecting everything, 6G will do so with new devices, new displays, higher connectivity density, and native trustworthiness. In smart cities, healthcare, buildings, transportation, manufacturing, and agriculture, mMTC+ involves highly connected, sporadic devices. A packet's arrival time can range from a day to several milliseconds, depending on the data rate. Having a long lifetime is a key requirement for sensors, but their energy harvesting capability may impact this significantly [19]. Depending on the application, passive IoT devices that utilize zero-power backscattering may also be an option for establishing extremely low-cost connections.

The New age of Smart Building

Electronic products, smart materials, control systems, and users are all part of a smart building that is managed and controlled seamlessly. To make a building smart, integration is the first step. There are many subsystems within one building, including surveillance cameras, elevator control, air

conditioning, and electricity. By utilizing 6G in the smart building industry, a common infrastructure of high efficiency and intelligence can be built. Moreover, since smart buildings have an abundance of sensors, they must also support large-scale connectivity and low energy consumption [20]. Interconnecting buildings is the second step. Trustworthiness will be built on mobile communication infrastructure in the future.

The Vision for Smart Healthcare in the Future

Smart healthcare will provide ubiquitous and customized healthcare services that are not restricted by geographical boundaries. The development of mobile communications technology will enable a variety of new use cases, including dynamic monitoring of personal health, telediagnosis and pathology inference, and holographic medical training and recovery. Real-time analysis of patient data could be extremely beneficial with 6G's new sensing and AI capabilities. Additionally, tele-diagnosis and telesurgery will significantly reduce the pressure in an aging society, especially in regions lacking adequate medical resources.

Smart Services - UAVs in 6G

Drones are small, lightweight UAVs that are used in many different fields. In mining and exploration, unmanned aerial vehicles are used for unmanned inspection, and aerial filming is used for entertainment and media. With 6G's advanced communication, sensing, and AI capabilities, UAV applications are expected to become more ubiquitous in our daily lives. 6G UAVs can function as mobile base stations that can provide on-demand, high-capacity coverage for live streaming of XR services and high-accuracy positioning. With autonomous driving capabilities, massive UAVs may be utilized in future logistics to deliver packages long distances. A UAV could land on top of a car or bus during a long-distance delivery to recharge.

The wide range of services offered by IoT

Wide-range IoT services will also benefit significantly from 6G's global, seamless coverage. The 6G technology can help report container status during ocean transportation or forecast and prevent natural disasters through the use of buoys in the oceans or sensors in forests and deserts. The Internet of Things will be extended to such unconnected locations to better protect the world.

6.4 Networked Sensing - A New Usage Scenario Beyond Communication

New usage scenarios are possible because of the new sense of networks. There are many ways to use this technology, such as localizing for both device-based and even deviceless targets, imaging, reconstruction, and monitoring the environment, and recognizing gestures and activities. The new performance dimensions include detection probability, sensor resolution, and accuracy. It depends on the application. Ultra-high resolution will be required for certain applications in the future, whereas high sensor accuracy and resolution will be essential. The main priority for gesture and activity recognition is finding out how likely it is to be detected.

6G Network - The Future of 3D Tracking and localization with high accuracy

It will be possible for the 6G network to provide positioning services for device-free objects, similar to radar use cases. Coordinates, orientation velocity, and other geometric information can be obtained from scattered and reflected wireless signals. It is possible to link cyber information with the locations of physical entities by using high-accuracy 3D tracking. This will make a lot of different applications possible, such as factories, warehouses, hospitals, retail shops, agriculture, and mining. This could allow robots in a factory to easily get parts from a warehouse shelf and put them in place. High requirements on relative localization are posed by applications such as automatic docking and multi-robot cooperation. The location of each robot or drone in a swarm of them is critical for it to determine its location with respect to other people. Future systems could also provide context awareness and dynamic address resolution. This

would allow restaurants to use robots. A robot could deliver a glass of wine to a customer sitting by the window without the need for a human to coordinate it.

Three Sensing Capabilities localization, Simultaneous imaging, and mapping Are Mutually Enhanced

Three sensing capabilities are enhanced when imaging, mapping, and localization are conducted simultaneously. Image capture and localization functions provide information about the surroundings. This map is then used by the mapping function to improve the localization function's ability to infer locations based on the images. The simultaneous localization and mapping [SLAM][21] of unknown environments is possible through sensors in the mm wave or THz bands. The sensing devices in 6G could be 6G base stations or terminals, including cars, drones, and robots. In comparison to traditional lidar and optical camera systems, SLAM via 6G wireless signals enables autonomous vehicles to obtain ultrahigh resolution and accuracy in all weather conditions. Robots and AGVs can move around freely in crowded environments using similar functions for indoor scenarios.

Augmented Human Sensing With THz Imaging

In addition to providing superior vision to the human eye, augmented human senses aim to provide safe, precise, and low-power sensing capabilities. Such capabilities can be integrated into portable devices, wearable devices, or even implants with THz ISAC technology that leverages the mm Wave band. It is possible to carry out contactless flaw detection as well as quality control in smart factories by applying "seeing beyond eyes" technology - enabled by ultrahigh resolution imaging - in everyday life. The invisible can also be made visible with this concept. On portable devices or even smartphones, electromagnetic waves can be used to perform security scans on packages and detect wires in the walls. Utilizing larger radio frequency range of 6G, it will be possible to see through skin, subcutaneous fat, suitcases, and even furniture. This concept also incorporates spectrogram recognition, which detects electromagnetic and photonic characteristics of targets using spectrograms. By analyzing THz signals, different materials can be characterized according to their unique absorption characteristics. Food calorie detection and PM2.5 analysis are typical applications. During the EuCNC2021 virtual booth (virtual.eucnc.eu), one of our prototypes demonstrated how THz imaging can be implemented on a tabletop device. With mm-level resolution, this prototype senses and images hidden objects using communication waveforms.

Device-Free Gesture and Activity Recognition Using ML

Machine learning will be used in the future to recognize gestures and activity. Users are able to easily interact with their devices with gestures and actions. Micro and macro are the two types of recognition. The recognition of body movements is referred to as macro recognition. Future smart hospitals may be able to detect falls or monitor rehabilitation exercises, for example. ISAC is better than traditional camera surveillance at protecting privacy[22]. Micro recognition is the opportunity to recognize small details, such as gestures, finger movements, or facial expressions. The ability to hear music and see pictures at the same time is possible with the use of XR. At any time with this technology, art can be created.

6.5 Distributed Intelligent Agents for Real-Time Artificial Intelligence

The goal of this use case is to connect intelligent agents in different places in a smart way so that AI can be widely used in all fields on a large scale. The transmission of data and model parameters among large numbers of intelligent agents must be spectrally efficient, high-capacity, and low-latency. This usage scenario is enabled by native trustworthiness, native security, and local data privacy.

AI in 6G: The Future of Enhanced network automation

For network operation, administration, & maintenance (OA&M), mobile networks require large workforces. Artificial intelligence holds great potential to alleviate this major financial and labor burden. Network configurations and functions could be implemented, operated, and managed by the network system itself. Passive OA&M will be replaced by zero-touch proactive OA&M, for example, using predictive network analytic services and E2E system OA&M. Adaptability and optimization of communication and computing resources will be key characteristics of AI in 6G solutions.

Data management with the use of AI as a service

In future mobile communication networks, vast quantities of data will be generated, collected, and exchanged. Data such as this will be used for network operations and management tasks (such as configuration management, fault management, and service level agreement assurance). The knowledge derived from raw data can also be shared with other systems or business sectors in order to generate a broader range of benefits. A valuable asset for AI is data, but not all raw data is useful. It is therefore necessary to support efficient data processing while reducing computational complexity and energy consumption. Using AIaaS, vast amounts of raw data could be processed into high-quality data.

A service based on artificial intelligence for distributed inference and learning

The 6G era will see software generation change from Software 1.0 (human coding) to Software 2.0 (data coding), where massive data is provided to deep learning algorithms to generate deep neural network (DNN) models. In 10 years, AI model providers will be field-specific OTTs or carriers, while AI inference capabilities will be delivered by operators and public service providers to individuals and vertical industries. A mobile communications system that provides AIaaS for distributed learning and inference applications will be the key to meeting the real-time and large-scale learning and inference requirements of society and vertical industries in the future. Mobile communication networks are not simply a big pipe for transmitting bits and bytes. They are platforms with integrated connectivity and computing capabilities that provide optimal resource scheduling in order to support learning tasks and achieve fast learning convergence in distributed learning and inference services. While meeting local privacy requirements, this will also result in superior performance (e.g., ultra-low latency) by bringing AI services closer to end users.

7. CONCLUSIONS

The shift from the Internet of Things to the Internet of Intelligence will be enabled by the next generation of information and communication systems, referred to as 6G. The global digital economy will be affected by 6G. It is expected to be secure by design and be AI-native and prosumer centric. It will also support a variety of new usage scenarios and, as a result, be more stringent than earlier mobile communication systems. This will make it ten times better, or more, in terms of the following metrics: Supported spectrum and bandwidth, coverage, reliability, latency, density of endpoints, synchronization of multiple flows to and from multiple collaborative devices, location and position tracking, and energy and resource consumption, among other performance indicators. New security control measures, security assurance schemes, and privacy preservation approaches will form a core part of 6G.

Investments in R&I provide a fascinating prospect for our future, as many 6G initiatives are ongoing globally. Billions of dollars have already been invested by the public and private sectors in Australia, the UK, China, the US, South Korea and Japan to tackle technology requirements for 6G. To make the vision of 6G wireless in this work come true, everyone who is involved, worldwide, must work

together more than ever before. This includes satellite groups and vertical alliances, such as the 3GPP, which sets the technical standards for 6G wireless. Additionally, it requires a multidisciplinary approach in the form of a multi-player ecosystem and a multidisciplinary approach to ensure: For security authorization in the country where the system is deployed, all assets that make up 6G systems must be interoperable and conform to standardized security evaluation criteria, such as GSMA/3GPP NESAS GSMA, 2020. In addition, every end-to-end supply chain asset supports the minimal set of requirements for security, safety, and privacy, including even the smallest and most insignificant ones.

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