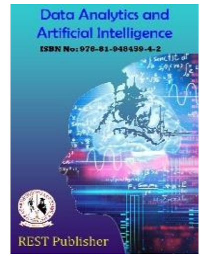
Data Analytics and Artificial Intelligence
Vol: 3(7), 2023
REST Publisher; ISBN: 978-81-948459-4-2
Website: http://restpublisher.com/book-series/daai/



A Review in Prophecy of 6G Wireless Systems: Applications, Trends, Skills

P. Usha
M.G.R. Colleger, Hosur, Tamilnadu, India.
*Corresponding Author Email: ushaselvam@gmail.com

Abstract: *The ongoing deployment of 5G cellular systems is continuously exposing the inherent limitations of this system, compared to its original premise as an enabler for Internet of Everything applications. These 5G drawbacks are spurring worldwide activities focused on defining the next-generation 6G wireless system that can truly integrate far-reaching applications ranging from autonomous systems to extended reality. In this article, we present a holistic, forward-looking vision that defines the tenets of a 6G system. We opine that 6G will not be a mere exploration of more spectrum at high-frequency bands, but it will rather be a convergence of upcoming technological trends driven by exciting, underlying services using machine learning. In this regard, we first identify the primary drivers of 6G systems, in terms of applications and accompanying technological trends. Then, we propose a new set of service classes and expose their target 6G performance requirements. We then identify the enabling technologies for the introduced 6G services and outline a comprehensive research agenda that leverages those technologies.*
Keywords *-6G networks, Cellular System, Spectrum, New Technologies, Privacy, Security, Internet communications, Machine Learning.*

1. INTRODUCTION

After successfully commercializing 5G NR communication technologies, both industry and academy establish a foundation for the next generation networks, namely B5G and 6G. It typically takes a decade to standardize and do the research for the next generation (Dang S., 2020). Highlights on wireless communication history and future trends are outlined in Fig. 1. In the 1980s, analog wireless networks, known as 1G, started to appear to allow voice communication over the air. In the early 1990s, it was replaced by the digital version of cellular networks, 2G, which also gave a boost for new services. Notably, that is the time when digital encryption and short message service (SMS) were born. Further, in the 2000s, 3G took advantage of WCDMA and CDMA2000 technologies to bring new data services such as internet access, video calls, and mobile television. Those applications have boosted the development of digital devices, smartphones, etc. After another decade, in the 2010s, 4G/Long-Term Evolution (LTE) has brought great Quality-of-Experience and Quality-of-Service (QoS and QoE) by providing broad coverage and high-speed mobile data transmission. Following this trend, 5G NR is launched in 2020, bringing even higher data rates and enhanced lowlatency and ultra-reliable connections. Moreover, since spectral efficiency is reachingits limits, millimeter-Wave (mmWave) came into play to provide additional bandwidth and therefore increasing the data rate. Regardless of current progress, forthcoming applications are imposing more challenges and higher QoS/QoE requirements, which creates a high demand for further development and new solutions, which will form the core of 6G. Hence, the wireless communication community has initiated studies in this direction.Although these IoT-enabled applications will bring convenience to human life, it is an extremely daunting task for 5G to support these applications. First, these IoT-enabled applications require superior performances in terms of data rate, latency, coverage, localization, and so on. Second, they are more data-intensive and computation-intensive, which far exceeds the range of ultra-reliable low latency communications (uRLLC) and massive machine-type communication (mMTC) of 5G [2]. Third, it is hard to efficiently manage massive IoT devices in this case. Fourth, with massive data generated, serious security issues are accompanying [3]. With IoT evolving, 5G will gradually reach its limitations and be unable to provide support to most of these advanced applications, which can be predicted from the history of previous generations. So there is a strong motivation for the sixth generation networks (6G), to extend 5G capabilities to a higher level to enable massive IoT.

2. VISIONS OF 6G

Inspired by the robust requirements of the future IoTenabled applications and the limitations of 5G, 6G, as an evolutionary generation, will expand and upgrade based on 5G from every aspect, which revolutionizes not only human life but also society. First, network performance of 6G will upgrade to a superior level, e.g., higher data rate (up to Tbps), lower latency (sub-ms), three dimensional (3D)-ubiquitous coverage (into space, sea, and even the undersea), more accurate localization (up to cm-level), more stringent privacy and security, and so on. Second, use cases in 6G will be more multitudinous and complex, resulting in different and even conflicting requirements in different use cases. Third, several trends about 6G have started to emerge, summarized as follows: More bits and spectrum, and denser networks Convergence of various communication systems, Convergence of communication, caching, computing, control, sensing, and localization (4CSL),From network softwarization to network intelligentization, From centralization to distribution As a result, 6G maintains the ability to connect millions of devices and applications seamlessly with performance guaranteed. Thus, 6G plays a major role in supporting massive interconnectivity in IoT with highly diverse service requirements. To enable massive IoT, 6G will provide a new network architecture and breakthrough technologies to meet their demands.

2.1. New Network Architectures for Massive IoT: With human activities expanding to the extreme environment, e.g., higher altitudes, outer space, oceans, and deep under the sea, a ubiquitous (covering earth, sea, sky, and space), everything-connected (IoE), omniscient (with various sensors), and omnipotent (4CSL) network should be built to truly realize the connection anytime and anywhere with diverse requirements. To achieve this goal, a four-tier network architecture enhanced by edge computing is provided by 6G, i.e., space-air-ground-underwater/sea networks. The space tier contains various types of satellites, which aims to provide Internet connections for some extreme environment, e.g., rural areas, mountains, and so on. In this tier, the very low earth orbit (VLEO) satellites are promising to provide high data rates, low round trip latency, and accurate localization with the lowest orbit [4], [5]. The air tier consists of UAVs, airships, and balloons, which are aerial mobile systems to complement the terrestrial networks with its flexibility. For example, UAVs could move closer proximity to the ground IoT devices to collect data or acting as a computing hub, achieving higher throughput rates and conserving the energy of less-capable IoT devices [6], [7]. As the main way to acquire services for most IoT-enabled applications, the ground tier refers to the legacy wireless networks, e.g., cellular networks, wireless local area networks, VLC, and so on, where terahertz communications are promising to achieve the ambitious goals of 6G [8].

2.2. Breakthrough Technologies: As an omnipotent network, 6G is enhanced by a number of breakthrough technologies, including machine learning and blockchain. As one of the most powerful intelligence enabling technologies, machine learning has been widely used for different aspects of the IoT-enabled applications, ranging from the application layer and the network layer to the perception layer. In the application layer, machine learning is widely used for task offloading and resource allocation. In turn, edge computing in the application layer provides storage and computation capability to enable edge intelligence. In the network layer, network intelligentization and automation are the primary goals of the IoT systems in 6G. Machine learning is recently being adopted in wireless systems to address the related challenges and to pave the way for future massive IoT communications. Toward the future IoT networking in 6G, machine learning algorithms are widely used for multiple resource allocation, power allocation, transmit scheduling, traffic offloading, and so on. In the perception layer, machine learning is used for autonomous control for different IoT scenarios, e.g., movement control for autonomous robots (e.g., tactile Internet, smart factory, and remote surgery), driving aid for autonomous driving, intelligent management for smart grid.

3. CONTRIBUTIONS

In this paper, we present a comprehensive survey of massive IoT enabled by 6G. We mainly identify four aspects, on which we focus, drivers and requirements, visions of 6G, network architecture, and breakthrough technologies. The main contributions of this paper are summarized as follows. • Compared with the other survey papers related to this topic, we provide a comprehensive survey on massive IoT enabled by 6G, where the challenges of future massive IoT are reviewed and the roles of 6G for massive IoT are presented from the perspectives of network architecture and breakthrough technologies. The visions of 6G are presented, including core technical requirements, use cases, and trends of 6G. The technical requirements in terms of data rate, latency, etc. are summarized, along with use cases of 6G. Several trends associated with 6G are presented, encompassing more bits and spectrum, and denser networks, convergence of various communication systems, convergence of communication, caching, computing, control, sensing, and localization (4CSL), from network softwarization to network intelligentization, and from centralization to distribution. A new four-tier network architecture enhanced by edge computing for massive IoT is reviewed. The promising technologies in each tier are presented, including VLEO satellites, UAVs, terahertz communications, VLC, and optical communications. The breakthrough technologies in 6G for massive IoT are reviewed, e.g., machine learning and blockchain, which provide intelligence and distribution, respectively. The applications and open issues are also summarized.

3.1. IoT-enabled Applications and Corresponding Requirements: Instead of only exchanges of voice, image, or video in the earlier and current generations, people are exploring new forms of IoT-enabled interactions in the future, including holographic communications, five-sense communications, and WBCI, which can lead to a true immersion into a distant environment. Powered by near-real-time and true-immersive experiences in personal communication using holograms and five senses and autonomously operating machinery in the industry as new fundamental media-objects, new verticals emerge, including smart healthcare, smart education/training, industry Internet, fully autonomous driving, and super smart city/home.

3.2. Holographic communications: The first new form of interactions refers to holographic communications, which is capable of projecting full-motion 3D images in real time. This technology captures images of people and/or objects, presents in reality or at a remote location, and transmits these images and related sounds to the receiver. In this way, it makes objects or people along with the real-time audio information present at a different location and appear right in front of the users, resulting in a closer-to-reality experience than VR and AR. Holographic type communications will have a big part to play in the industry, agriculture, education, entertainment, and in many other fields.

3.3Five-sense communications: Despite tactile transmission and traditional human interaction in terms of the exchange of voice, images, and videos, researchers also state the trend of new forms of remote human interactions [8], the socalled immersive five-sense or five-dimension (5D) communications. The five-sense media will integrate all human sense information, including sight, hearing, touch, smell, and taste. This technology detects sensations from the human body and the environment and integrates sensations by using the neurological process. Then the information is transferred to the receiver at a remote location, leading to a truer immersion into a distant environment. Such multi-sensory applications (e.g., a remote surgery), combined with VR/AR or holographic communications, will constitute truly immersive services for 6G.

3.4. Wireless brain-computer interfaces (WBCI): Another potential form of interactions refers to WBCI, also known as wireless mind-machine interfaces (WMMI), which are interfaces that use human thoughts to interact with machines and/or the environments. This technology first reads the neural signals generated in the human's mind with a certain number of electrodes, then translates these acquired signals into commands that a machine can understand , thus achieving control or other functions, e.g., turn on a light. WBCI is a communication pathway between the brain and the external peripheral devices, which is a promising approach to control the appliances that are used daily in smart cities, homes, and medical systems in a more simple and intelligent way. Beyond healthcare and smart cities/home scenarios, the recent advent of WBCI revolutionizes this field and introduces new use-case scenarios, ranging from brain-controlled movies to fully-fledged multi-brain-controlled cinemas.

3.5. Smart education/training: Smart education/training will benefit from 6G wireless systems because innovations, e.g., holographic communications, five-sense communications, high-quality VR/AR, mobile edge computing, and AI, will help build smart education/training systems

3.6. Smart healthcare: 6G can help build smart healthcare systems, where a reliable remote monitoring system, remote diagnosis, remote guidance, and even remote surgery can be facilitated by 6G. 6G with high data rate, low latency, accurate localization, and ultra reliability will help to quickly and reliably transport huge volumes of medical five-sense data, which can improve both the access to care and the quality of care. Cooperated with artificial intelligence (AI), the data can be better analyzed by doctors to make accurate diagnoses. With blockchain, personal data can be privately and safely shared among the world to contribute to the development of medicine.

3.7. Super-smart city/home: The superior features of 6G will lead to significant improvement of life quality, intelligent monitoring, and automation to accelerate the building of supersmart cities and homes. A city is considered to be smart when it can run intelligently and autonomously by collecting and analyzing mass quantities of data from a wide variety of industries, from urban planning to garbage collection, which can make better use of the public resources, increase the quality of the services offered to the citizens, as well as reduce the operational costs of the public administrations.

3.8. Analysis of recent studies and publications: A noticeable number of researchers have presented their views (Viswanathan, H., 2020; Ericsson, 2020; Samsung Research, 2020; Brown, G., 2016; Huawei Technologies Co. Ltd.; Docomo NTT; Nakamura, T., 2020; Saad, W., 2019) on the future of wireless technologies. Mainly, leading industrial vendors, such as Nokia Bell Labs (Viswanathan H., 2020), Ericsson (Ericsson), Samsung (Samsung Research, 2020), Qualcomm (Brown, G., 2016), Huawei (Huawei Technologies Co. Ltd.), and DOCOMO (Docomo NTT., 2020; Nakamura, T., 2020) have published white papers, both marked the 2030s as a target for launching 6G. In there, authors agree upon key enabling technologies, such as Artificial Intelligence (AI) and Machine Learning (ML), dynamic network deployment (cell-free), energy harvesting, exploiting terahertz (THz) spectrum bands, usage of Intelligent Reflecting Surfaces (IRS), new security, privacy and trust paradigms (trustworthy networks). However, all of those visions are diverse in terms of projected applications and services. Notably, (Viswanathan, H., 2020) suggests an expansion of the technology in the biological world, while (Ericsson, 2020) and (Brown, G., 2016) predict AI's growth embedded in a wireless network. Samsung Research projects the primary trend to be hyper-connectivity involving humans and everything. Huawei Technologies Co. Ltd. stresses the security enhancements and proposes novel safety architectures. The technologies and applications mentioned above will be discussed in detail in the rest of the paper. Next, we will show that it creates a suitable framework for machines becoming the primary user, i.e., machine-centric network.

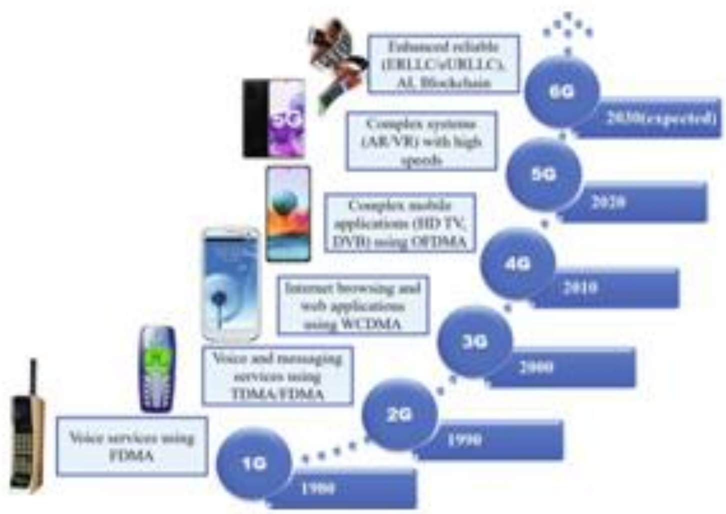


FIGURE 1. 1G to 6G Evolution, representing the trend of new generation per decade

What is 5G so far? Currently, at the first stage of implementation of 5G networks, both base station (gNB) and User (UE) manufacturers follow 3rd Generation Partnership Project 5G NR specifications for dense urban areas (3GPP TS 38.300). First, changes in the network architecture took place using network slicing. It allows mobile and service operators to create virtual networks over the physical infrastructure, to distribute virtual network resources for specific service needs. This gives the ability to tailor wireless systems according to the applications or even reconfigure the whole network without replacing hardware.

4. REVIEW OF ML TECHNIQUES

Machine learning (ML) models are computational systems that are used to learn the discriminative features about a system that cannot be represented by a mathematical model. These models are commonly used in tasks such as regression, classification, and interactions between an intelligent agent and an environment. Once a model is trained on the given data, then this model can effectively takes the decision on unknown data and also performs the tasks based on arithmetic calculations. This will allows ML modeling for mobility, availability, accessibility, management of network communication based on 6G data, and improve and automate network performance management in order to keep current Key Performance Indicators (KPIs) within predefined thresholds. ML also allows the management of 6G mobile networks with smart adaptive cells. This will improve beam management, power-saving, fault management, maintenance, operation, power control, network configuration, QoS prediction, throughput and performance of coverage. Following Figure shows ML enhancing 6G network performance management aspects. ML covers three paradigms which are known as

4.1. Supervised learning: where the learning of the model is to be carried out by using input samples and their corresponding outputs,

4.2. Unsupervised learning: in which the model learns to distinguish the input samples without any output labels and, and,

4.3. Reinforcement learning: where an agent communicates with an environment and learns to map any input to an action.

ML is backbone of 6G wireless networks as it model the systems that can't be represented mathematically. Moreover, certain ML methods are already being used to substitute brute-force or heuristic algorithms to find optimal solutions for network problems. As ML makes its stride in 6G networks, it will be possible for real-time monitoring and automated zero contact operation and control. Moreover, ML predictions can be made by mobile devices and reported to the network for use in resource management, making mobile devices an integral part of the infrastructure. ML agents for 6G networks will be responsible for various roles including orchestration, network management, adaptive beam forming strategies and optimization of the radio interface. ML will play a key role in 5G and 6G wireless networks. We envision that every traditional component of a wireless communication system will use ML techniques in their design. Therefore, it is important for wireless researchers to start thinking possible ways of integrating ML techniques in the wireless systems.

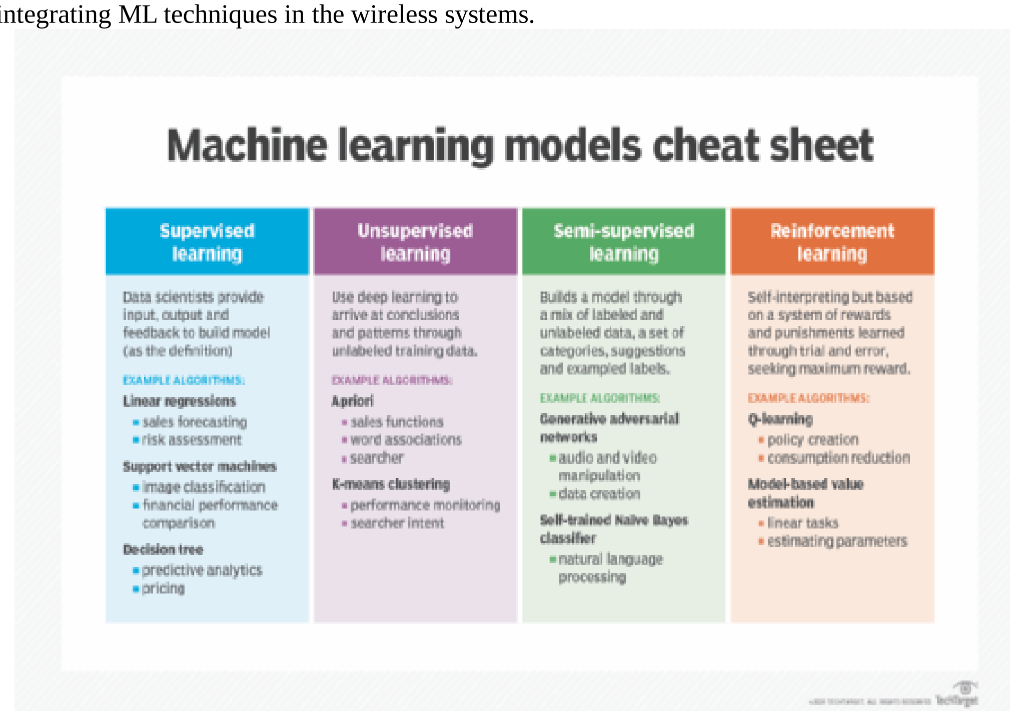


FIGURE 2. An example of Un-supervised ML model

5. ML AT INFRASTRUCTURE LEVEL

At the infrastructure level, ML has begun to penetrate the field of wireless communication. The infrastructure level of traditional wireless communication is generally designed based on client-server interactions, mathematical models, where several major modules are modeled and optimized separately. The main contributions of ML techniques at infrastructure level are:

5.1Power allocation*:* At infrastructure level, supervised ML is where true joint distribution of output and input parameters in client-server architecture.

5.2Training system: In the area of semi-supervised learning, annotated training data in small amount is available with most of the unlabeled data but in the area of unsupervised learning, no such data is available.

In unsupervised learning, the collection of available input data samples is exploited to train the system without any systems prior information.

5.3Unsubstantiated learning: Unsupervised learning is applied for various kinds of tasks for example, clustering, sample generation, distribution specific and features classification. However, at infrastructure level, when there are high dynamic scenarios, the coherence is less which further limits the availability of data and time required for supervising clients and servers.

5.4Learning requirements and capability*:* ML algorithm model can be determined on the basis of nature and amount of data in progression. Batch-learning algorithms can be used at infrastructure level for applications where large amount of prior data is available. These algorithms search space for every possible structure of knowledge with the unlimited time of computing. These kinds of methods where data is obtained manually, batch-processed and labelled is having a constraint of limited data.

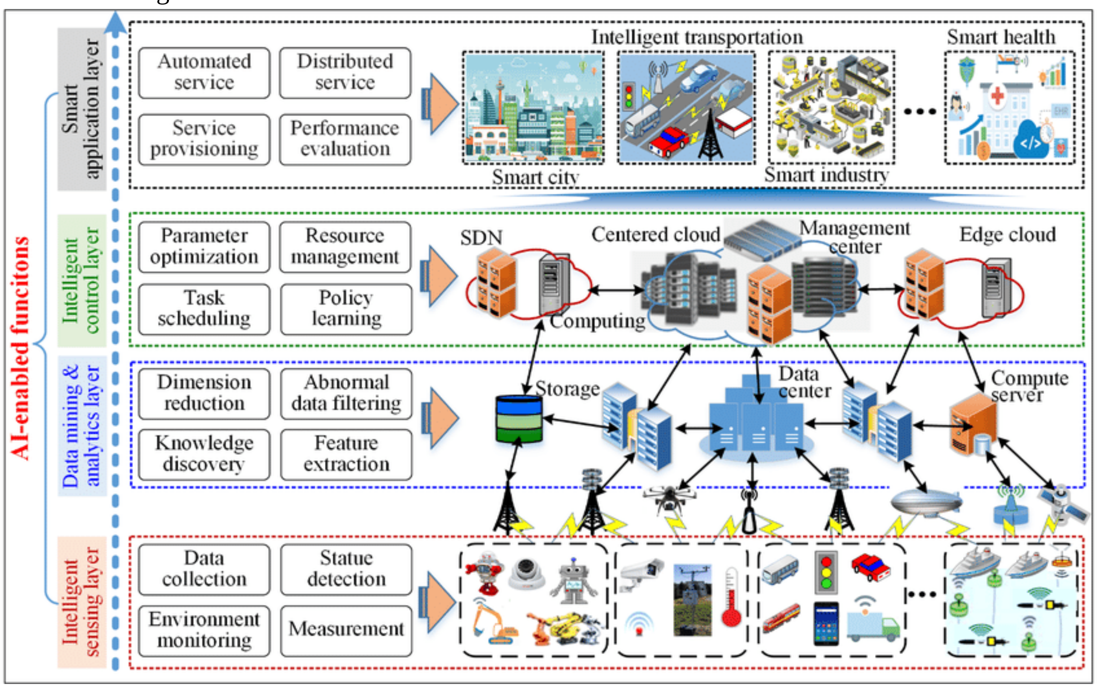


FIGURE 3. ML techniques for 6G at application and infrastructure levels

6. CONCLUSION

Future Vision of 6G and Current Technologies:

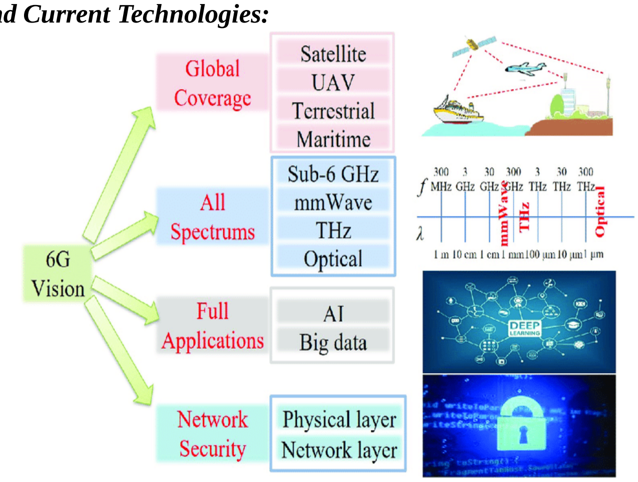


FIGURE 4. ML techniques for 6G at application and infrastructure level

The need for next-generation mobile communication systems is arising due to the scalable deployment of 5G wireless networks. Many pieces of research are focusing on the future of 5G that leads to 6G. The authors future vision of 6G with disruptive techniques, cell-less networks, intelligent connectivity, seamless coverage, distributed antenna system.

REFERENCES

[1]. H. Zhou, W. Xu, J. Chen, and W. Wang, "Evolutionary V2X technologies toward the Internet of Vehicles: Challenges and opportunities," Proc. IEEE, vol. 108, no. 2, pp. 308–323, Feb. 2020.

[2]. Ma, X, Gao, H, Xu, H, Bian, M: An IoT-based task scheduling optimization scheme considering the deadline and cost-aware scientific workflow for cloud computing. vol. 2019, issue 1, pp. 249. EURASIP J WirelCommunNetw (2019). doi: 10.1186/s13638-019-1557-3

[3]. W. Saad, M. Bennis, and M. Chen, ''A vision of 6G wireless systems: Applications, trends, technologies, and open research problems,'' IEEE Netw., vol. 34, no. 3, pp. 134–142, May 2020

[4]. N. Crisp, P. Roberts, S. Livadiotti, V. Oiko, S. Edmondson, S. Haigh, C.Huyton, L. Sinpetru, K. Smith, S. Worrall, and et al., "The benefits of very low earth orbit for earth observation missions," Progress in Aerospace Sciences, vol. 117, pp. 1–23, 2020. [Online]. Available: http://dx.doi.org/10.1016/j.paerosci.2020.100619

[5]. S. M. Dakka, "VLEO satellites: A new earth observation space systems commercial and business model," in Proc. 36th International Communications Satellite Systems Conference (ICSSC 2018), 2018, pp. 1–11.

[6]. M. Samir, S. Sharafeddine, C. M. Assi, T. M. Nguyen, and A. Ghrayeb, "UAV trajectory planning for data collection from time-constrained IoT devices," IEEE Trans. Wireless Comm., vol. 19, no. 1, pp. 34–46, 2020.

[7]. Z. Na, Y. Liu, J. Shi, C. Liu, and Z. Gao, "UAV-supported clustered NOMA for 6G-enabled Internet of things: Trajectory planning and resource allocation," IEEE Internet of Things Journal, pp. 1–1, 2020.

[8]. L. Yan, C. Han, and J. Yuan, "Hybrid precoding for 6G terahertz communications: Performance evaluation and open problems," in Proc. 2020 2nd 6G Wireless Summit (6G SUMMIT), 2020, pp. 1–5.

[9]. D. Pompili and I. F. Akyildiz, "Overview of networking protocols for underwater wireless communications," IEEE Comm. Magazine, vol. 47, no. 1, pp. 97–102, 2009

[10]. E. O'Dwyer, I. Pan, S. Acha, and N. Shah, ''Smart energy systems for sustainable smart cities: Current developments, trends and future directions,'' Appl. Energy, vol. 237, pp. 581–597, Mar. 2019.

[11]. Y. Liu, C. Yang, L. Jiang, S. Xie, and Y. Zhang, ''Intelligent edge computing for IoT-based energy management in smart cities,'' IEEE Netw., vol. 33, no. 2, pp. 111–117, Mar. 2019.

[12]. R. Petrolo, V. Loscrì, and N. Mitton, ''Towards a smart city based on cloud of things, a survey on the smart city vision and paradigms,'' Trans. Emerg. Telecommun. Technol., vol. 28, no. 1, p. e2931, Jan. 2017.