From 5G network to the advent of 6G network: Requirement & challenges

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Dr. Bharat Batham

Assistant professor Computer science & Application department Atal Bihari Vajpayee Hindi Vishwavidyalaya, Bhopal

Abstract

Rapid advancements in wireless communication systems over the last several decades have led to various positive social and economic outcomes. To facilitate "connected things," the 5G system shifts away from the "communication-oriented architecture" (COA) of previous generations and instead uses a "service-based architecture" (SBA). The shift in emphasis from "connected things" to "connected intelligence" is what will distinguish 6G from prior generations of wireless technology. Fifth-generation communications standardization efforts are complete, and rollout has begun throughout the world. This paper discusses how to keep wireless networks competitive by introducing the next generation of wireless communication systems (specifically, 6G) that will serve as a basis for the stratification of future communication requirements.

Keyword: Telecommunication; 5G; 6G; Network Technologies;6G Network; 5G Challenges.

1. INTRODUCTION

Since the introduction of 2G mobile radio network technologies in the early 1990s, there have been significant advancements in the worldwide communication infrastructure. Without a shadow of a doubt, the advent of second-generation network heralded the beginning of a new age in the digital communications on a global scale. Given the exponential growth of user-to-user contact through SMS messages and phone conversations towards the tail end of the past century, the aforementioned should come as no surprise. New business models might emerge because of a global paradigm change during the period, affecting everyone from individual consumers to multinational conglomerates. Since then, efforts have focused on making connections quicker and accommodating more users.

Third-generation (3G) systems emerged in early 2000s with the new innovations, the most important being the "Universal Mobile Telecommunications System" (UMTS), which is based on the "wideband code division multiple access", to address the connectivity issues which arise when many users attempt to access the network simultaneously and provide a better experience. However, 3G's time in the spotlight was brief for several reasons. Regulatory and technological concerns were cited by numerous experts as reasons why many network operators were removing support for 3G. On the other hand, 4G, the successor to 3G, which was released in 2010, has received universal acclaim from the media and has proven to be the most successful generation following 2G. Until recently, it was believed that current network services and applications could make use of theoretical speeds of 1 Gb/s & beyond that fourth-generation network, depending on the "orthogonal frequency division multiplexing" (OFDM) and "multiple-input, multiple-output" (MIMO) systems, offers.

Many new applications and network requirements today call for bandwidth and network infrastructures that go well beyond what 4G can provide. Recently launched 5G networks are typically portrayed as a unified solution to the problems that 4G networks have in meeting modern network requirements like ultra-high communication rates and extremely low-link latency. However, a new line of inquiry has lately begun, exploring 5G's competitors and potential successors. In the next part, we'll go further into the motivations for this shift in strategy. In essence, 5G is unlikely to be sufficient to meet the demands of future networks. Moreover, some difficulties are still unresolved or overlooked in current 5G standards, such as managing efficient network administration under increasingly complex networks or coping with the inevitable increase in the signal propagation loss that comes with using higher frequencies (beyond 20 GHz).

Fifth-Generation Network's concerns

As 5G continues to expand into new areas throughout the world, this section assesses the technology's anticipated performance. Before discussing the future of 5G, it is necessary to look at the technologies that are now driving it. The massive rollout of tiny cells is a crucial component of the 5G's network densification. Despite the obvious

advantages of this deployment—improved coverage and faster data transfer rates—the large rise in infrastructure cost means that there will eventually be diminishing returns as more and more tiny cells are installed. Carrier aggregation is another method that uses many carriers to increase bandwidth for end customers.

However, this necessitates end-user-facing technology that can accommodate many frequency bands. To go around the restrictions of endpoint technology, 5G will rely heavily on cloud radio access network (C-RAN). As the scale of networks, however, increases exponentially, it becomes clear that cloud-only computing is insufficient and that additional resources, such as fog & edge node computations, are required. The primary 5G technologies, including "software-defined networks" (SDNs), lack the means to verify trust between the management applications and the controller, making it impossible to implement such systems on a massive scale with adequate security. "Network function virtualization" (NFV) is the other example, since it is vulnerable to attacks which target software-level components like the "virtual infrastructure manager" and produce false logs that make NFV less effective.

One of the primary benefits of 5G is its support for "ultra-reliable, low-latency communication" (URLLC). However, it only works at network's periphery, with no true integration into the network as a whole. Furthermore, 5G technologies centre on the idea of heterogeneous networks (HetNets), although this kind of network integration is now only possible in the terrestrial networks. If we want this to operate in three dimensions, we'll need to add mesh networks in the sky and out in space to the existing infrastructure. DoS attacks and other risks that might jeopardise 5G's availability should also be taken into account. Considering the exponential growth of networks into the billions of nodes, it is critical that this be enhanced in the future networks.

- **Speed**

The 5G network is said to handle "massive machine-type communication" (mMTC) and provide "enhanced mobile broadband" (eMBB) at rates of up to 20 Gbps. This, however, will not be sufficient to meet future needs, since 5G is predicted to approach its limitations by the year 2030. In less than 10 years, data transmission rates will need to significantly increase to go far over 1 Tbps (up to 10 Tbps), since this is what the need for faster communication speeds requires. Exploring technologies that can provide such speeds is thus part of thinking beyond 5G.

- **Scalability**

High data rates are necessary because of kind of services which are just becoming popular or are likely to become popular in near future. In the near future, we may expect to see widespread implementation of services like human nano-chip implants, augmented reality (AR), networked robots, autonomous systems, and tele-medicine. Furthermore, it is predicted that there would be hundreds of billions of devices linked to the Internet as a result of the anticipated development in the M2M communications. As a result, the optimal performance trade-offs for 5G are only anticipated at scales of up to a billion devices.

- **Reliability**

The stability of the link, quantified by "bit error rate" (BER) or frame error rate, should also be discussed. Factory automation, "vehicle-to-everything" (V2X) connectivity, and railway system management are just a few examples of the numerous mission-critical applications that need ultra-reliable connections to assure low incident rates. The "frame error rate" reliability of certain applications in Industry 4.0 is said to be as high as 109, although 5G only claims to handle up to 105. Therefore, the connection's dependability must be increased by many orders of magnitude to completely implement the notion of smart cities and totally trustworthy machine operations, like remote surgery. In order to effectively allocate resources, B5G systems must be able to provide improved levels of dependability at a variety of service levels.

- **Link Latency**

Many emerging real-time services today will be permanent fixtures of the network for decades to come. These services may vary from assisting in the development of autonomous cars and industries in the building of smart cities to the discovery of novel methods of interacting with the environment via the use of technologies like virtual reality (VR) and exoskeletons or prosthetic limbs. Most real-time services are the time-sensitive, necessitating a low latency of 10 milliseconds or less for optimal performance.

Furthermore, several technological aspects may induce latency deterioration, such the length of a cyclic prefix (CP) in the OFDM systems or the usage of specialized channels for the machine communications, which need continual dynamic scheduling owing to their intermittent nature. Many applications in the current industrial revolution, known as Industry 4.0, need concurrent support for URLLC to reach complete autonomy without human oversight or intervention. This has been taken into account in the most recent version of the 5G standards, however support is still capped at 1 ms latency for the basic motion control. The needed latency is sub-ms (0.1-1 ms) in numerous applications, including aero plane or vehicle control as well as the intra-vehicle communication for the suspension and the engine management.

Sixth-Generation Network's Facets

Sixth-generation (6G) wireless systems, the next iteration of the industry, are expected to include several new features, needs, and applications. We analysed 6G from several perspectives using the following taxonomy: Communications are covered broadly from a social, technological, and economic perspective at highest level. At this level, crucial information regarding the network's needs is presented, including the most important technologies, services, and research challenges.

- **Social Impact**

When it comes to modern communication systems, there are a number of neglected areas. Access rights to personal data by users, subscription plans by operators, and community and individual users' understanding of the value of sharing data are only a few examples. These considerations are of great societal relevance, since they may significantly sway public opinion on delicate issues.

Technical Impact

The exponential growth of technological advancements over last 30 years has made the digital future appear brighter than ever, and it shows no indications of slowing down. The sixth-generation network will supposedly have the most cutting-edge features available. Quantum physics will pave the way for a new kind of bit used in computers; the Q-bit. In its simplest form, this idea proposes inspecting the state of electrons in wires in order to decode information encoded by a transmitter.

Such computing has the potential to radically alter the digital landscape by allowing for hitherto impossible levels of performance and the introduction of novel network services. Integrating AI into global network is another interesting case to consider. By introducing various ideas, like network self-sustainability or management and autonomous systems in the factories, cars, and many other configurations, AI is altering how end devices view communication networks. Many 6G services as well as technologies will reportedly be built on AI, and they are expected to be so sophisticated that people won't need to touch the network's operations at all. To improve the user experience in the increasingly common human-bot chats, AI at its highest levels may be able to analyse human sentiments for a variety of purposes, like better selection of online content as well as advertisements to be delivered to individual users centred on their facial feedback.

- **Economic and Environmental Impact**

Especially hazardous waste from electronics, the economic and the environmental effect of communication networks is often overlooked. For example, batteries contain toxic substances that would be bad for the environment if they were simply dumped. Therefore, the debut of 6G is anticipated to usher in new developments, such as the widespread use of energy harvesting using radio waves or laser beams to realise battery-free gadgets. Furthermore, the yearly rise in electronic waste is due in part to exponential growth of Internet-connected gadgets.

2. LITERATURE REVIEW

(Arulappan et al., 2022) Through the use of an NFVI architecture, "Network Function Virtualization" (NFV) unifies "automated network service management" with virtualized network functions. Due to the possible negative influence on performance and operational expenditure cost, the placement of the "Virtual Network Function Manager" (VNFM) in the "large-scale distributed NFV deployment" is a tough undertaking. Using effective placement methods, the VNFM allocates "Virtual Network Functions" (VNFs) depending on the needs of the network and ensures reliable performance. Declining performance and skyrocketing capital and operational costs pointed to this anarchic issue. In order to efficiently allocate VNFs to each node in the element management systems, this article developed a technique for the VNFM placement using information on a resources in every node's Element Manager (EM). Furthermore, this article presented an OEM technique for examining suitable EMs for the installation of VNF through the periodic information on the available resources. It also solves issues with latency and VNF workload volatility in edge computing and dispersed cloud environments. Linear programming & tabu search methods, among others, are used in the calculations used to evaluate performance. By combining VTS with OpenStack, a novel BGP-EVPN service provisioning paradigm for VXLAN becomes a reality. Numerical results reveal that, on average, the OEM method provided here is just 8% off from the best answer

(Salameh & El Tarhuni, 2022) Wireless researchers are already plotting the next generation of the "mobile radio networks" as the rollout of 5G networks accelerates throughout the world. In this article, we discuss the limitations of 5G when it comes to supporting low-latency, ultra-reliable applications that need large amounts of data. Using a hierarchical framework that incorporates social, economic, and technical factors, we then explore the most notable features of 6G network. We also go through some of the main technologies that will underpin the shift to 6G. Finally, we give a potential schedule for 6G activities after conducting a thorough search of publications & research organisations to quantify and summarise the research activity linked to beyond 5G and 6G networks.

(Al-jawad et al., 2022) “Smart value-based care strategies” are being adopted by healthcare organisations on a massive scale, with a focus on delivering better care at much lower costs without sacrificing QoS. Fifth-generation (5G) mobile service offers several advantages over earlier generations such as 3G and 4G for these reasons. 5G is expected to bring new difficulties, as is the case with most innovations, and this has prompted the community to consider what comes next. The purpose of this study was to investigate the most up-to-date smart 5G applications and the associated healthcare sector solutions. Finally, the study explains how the next-generation 6G technology may revolutionise the healthcare industry even more than the existing 5G technologies have thus far.

(Oinas-Kukkonen et al., 2021) "Fifth-generation broadband cellular network technologies", which are just now making their way to markets, and "6th-generation broadband cellular network technologies", which are still in the research as well as development phase, are two of the most promising information technologies with the potential to profoundly alter our modern way of life. Lower latency for delivering consumers feedback on their behaviour is a central promise of these next-generation technologies, opening up new avenues for influencing people in their natural environments. This opinion piece aims to analyze the potential effects of these openings on persuasive design & research in the field of information technology before the year 2030. The potential of 5G and 6G networks will also be discussed, along with the obstacles that must be overcome. Only if people have access to the internet and other forms of communication technology can they use it to their advantage in their efforts to alter their behaviour. As an example, this article will discuss strategies for reducing the digital gap between rural & urban regions, which poses a serious threat to social cohesion.

(Liyanaarachchi et al., 2021) —It is anticipated that the fifth-generation (5G) networks would heavily use "joint communication and sensing" (JCAS), a new technique for effectively utilising the limited radio frequency (RF) spectrum. To achieve OFDM waveform optimisation, we take into account a JCAS system in which full-duplex radar transceiver and also communication transmitter are implemented on a single chip, and we seek to simultaneously minimise the lower limits of latency and the Doppler estimation. This is accomplished by redistributing some of the power from the communication subcarriers to the non-communication subcarriers, thereby controlling the balance between the two functions, and filling the remaining vacant subcarriers in OFDM frame with optimised samples. In order to handle radar signals, both the communication and the filled radar subcarriers are utilised. An method that can be run on modern computers is provided, and the optimal sample values are calculated analytically. We also discuss how to regulate and reduce the "waveform's peak-to-average power ratio" during optimisation. The numerical evaluation of the findings in context of the 5G New Radio (NR) network reveals the trade-off between the minimising of the lower limits and other network objectives. The radar image's range as well as velocity profiles are examined, as well as its main-lobe width and "peak side-lobe level" (PSL). It is possible to simultaneously minimise main-lobe width and lower bounds, and there is an inverse relationship between lower limits and the PSLs. An examination of the sensing-communication trade-off reveals that tighter boundaries may be achieved at the expense of the communication capacity. The PSL enhancement in range profile is verified in the outdoor mapping situation using air-to-air RF measurements using both unoptimized and optimised 5G NR waveforms in 28 GHz mm-wave band, demonstrating a significant performance boost.

(Ali et al., 2021) Researchers are shifting their attention to next generation of the wireless communication as commercial deployments of 5G networks have begun in various parts of the globe. The goal of this study is to examine the factors that must be taken into account to ensure a swift launch of the 6G wireless communication's theoretical & practical measures. This paper's goal is to lay out the current state of research on 6G from a variety of angles, and then use that information to set a course for the future. Then, the 4 forms of connectedness that underpin the 6G vision are summed up in the phrase "Wherever you think, everything follows your heart." Different characteristics of 6G which render it a viable successor are addressed to bridge the gap between market demands after a decade and the restricted capabilities of 5G. There is also an examination of the several candidate technologies that have the ability to realise the 6G communication, followed by a discussion of the various difficulties in this realisation and the prospective research avenues that may be pursued to overcome these difficulties. This study seeks to summarise the broad 6G architecture by discussing the future vision, its definition, and important candidate technologies. The purpose of this study is to direct researchers in the right direction and pique their curiosity about the difficulties inherent in bringing 6G to fruition.

(Dogra et al., 2020) Currently, 5G is in the early stages of its commercial rollout. The 5G network, with its superior capabilities and cutting-edge features, will completely replace the current wireless system. The "3rd Generation Partnership Project",(3GPP) is currently working on the worldwide standardizations of 5G, known as "5G New Radio" (5G NR), which can operate on a broad variety of frequency bands, from below 6GHz to mauve (100GHz). Ultra-Reliable & Low-Latency Communication (3GPP's primary emphasis), "Massive Machine Type Communication" (2GPP's primary focus), and "Enhanced Mobile Broadband" (3GPP's secondary focus) are the three primary use cases of 5G New Radio (5G NR). 5G NR adds many elements to LTE networks in order to achieve its goals. These include flexible spectrum, scalable numerology, forward compatibility, and ultra-lean architecture. This document provides a high-level introduction to the new capabilities and KPIs of 5G NR. This study does a good job of addressing the problems of inter-RAT handover synchronisation and the adoption of higher modulation schemes. A new "wireless communication architecture" is developed with these difficulties in mind. The architecture serves as the foundation for upgrading to next-generation 5G and 6G networks. This study also provides an outline of the technology and uses of 6G networks. Services centred on edge computing, artificial intelligence (AI), optical wireless communication, quantum computing, hybrid access, and haptic technologies will all be a part of the 6G network. A 6G architecture based on network slicing, which is virtualization, is suggested to provide these various services. Many current initiatives involving 6G and its associated technologies are also detailed here.

(Akyildiz et al., 2020) 6G and beyond will deliver universal wireless connection to satisfy the needs of a fully connected world. The need for supporting a rapidly expanding number of the intelligent devices and services is anticipated to be driven by disruptive solutions. Connectivity goals within 6G can be accomplished with the help of several significant technological advances, including (i) the network operating at THz band with several wider spectrum resources, (ii) intelligent communication environments which enable the wireless propagation environment with the active signal transmission as well as reception, (iii) pervasive artificial intelligence, (iv) the large-scale net- work automation, (v) the all-spectrum reconfigurable front-end for the dynamic spectrum access, and (vi) amb Use examples for these enabling approaches are emphasised, together with recent breakthroughs on relevant issues, open difficulties and proposed solutions, and a development timetable describing the global efforts in the realisation of 6G. Beyond 6G, intriguing early-stage technologies have been covered at length in this study, including Internet of BioNanoThings, Internet of NanoThings, and quantum communications, all of which are likely to have a significant influence on the wireless communications.

(Chowdhury et al., 2020) Over the last several decades, there has been a meteoric rise in the number of people wanting to connect wirelessly. Soon, people all around the globe will have access to fifth-generation (5G) communications, which provide a plethora of advantages over their predecessors. Between 2027 and 2030, the sixth-generation (6G) system—a new paradigm in wireless communication that will be backed by complete artificial intelligence—is scheduled to be fully deployed. System capacity, data throughput, security, latency, and quality of service (QoS) improvements beyond those of the 5G system are among the most pressing concerns that must be addressed. The goals and network design of the future 6G wireless communication are presented in this study. Artificial intelligence, wireless optical technology, terahertz communications, blockchain, free-space optical network, quantum communications, three-dimensional networking, cell-free communications, unmanned aerial vehicles, integrated sensing and communication, integration of wireless information and energy transfer, dynamic network slicing, integrated access- backhaul networks, holographic beamforming, & backscatter diffraction are just some of the emerging technologies discussed in this article. Additionally, potential technologies and anticipated uses that would need 6G communications are outlined. We also detail some of the obstacles and future research that might help us get there.

(Tomkos et al., 2020) Telecommunications connection infrastructures of the future will include cutting-edge technologies and innovations. Fifth-generation (5G) mobile networks and internet of things (IoT) technologies are discussed in this article as a precursor to the forthcoming smart sixth-generation (6G) networks that will use artificial intelligence (AI) to optimise and automate their operation.

(Alsharif et al., 2020) Fifth-generation communications standardisation efforts are complete, and rollout has begun throughout the world. Industrial and academic cooperation have started conceptualising sixth-generation (6G) wireless communication systems to establish the groundwork for the stratification of the communication demands in the 2030s, ensuring the continued viability of the wireless networks. In light of this goal, this research summarises the most potential areas of study in the current literature that go in a similar direction to the 6G initiative. Its primary contribution is an analysis of the vision and essential aspects, difficulties and possible solutions, and research efforts of the 6G communications. In order to arrive at a clear and unambiguous conclusion on these contentious areas of study, a thorough examination of the motivations behind their many sub-domains was conducted. As a result, this publication will play a pivotal role in illuminating novel avenues for future study.

(Ramírez-Arroyo et al., 2020) The usage of mobile devices and the number of people who rely on them, together with the speed at which they expect to receive the services they need, are both on the rise. Fifth-generation (5G) cellular networks have been the subject of significant development and implementation efforts in recent years. However, new, extremely demanding applications are developing and will need network performance that beyond what 5G can provide. However, energy consumption of communication networks must be seriously considered since the Earth no longer permits us to grow the carbon imprint. Therefore, it is necessary to use a multi-goal strategy to solving these problems. In order to optimise the many competing goals, this study creates a cellular network architecture that allows for the assessment of system parameters across varying traffic patterns. The innovation lies in the fact that the optimisation process incorporates key performance indicators from various parts of network, specifically radio and network layers, in an effort to find solutions that take into account base station power consumption, the total capacity provided to the mobile users, and signalling cost generated by handovers. There is also a need for novel measurements with which to compare potential remedies. Three new merit factors are suggested to characterise network performance, expanding on the "well-known energy efficiency merit factor" (bits/Joule) by considering other network properties. These metrics reveal the optimum operating condition, from which a network's operational centre may be designed. These states of operation include minimal signalling load, moderate power load, and high capacity.

(Alghamdi et al., 2020a) There has been a dramatic increase in the number of individuals who depend on their mobile devices, as well as their expectations for the speed with which they can get the services they need. Recent years have seen intensive work on development and deployment of 5th-generation (5G) cellular networks. However, as time goes on, more and more complex applications will emerge, pushing the limits of what 5G can provide in terms of network performance. The Earth no longer allows us to increase our carbon footprint, thus we must give significant thought to the energy usage of communication networks. In order to effectively address these issues, a multi-target approach is required. This research establishes a cellular network structure that permits the evaluation of system characteristics across different traffic patterns, which is essential for optimising the numerous conflicting objectives. In order to find solutions which account for the total capacity provided to mobile users, base station power consumption, and signalling cost produced by handovers, the optimisation procedure includes key performance indicators from multiple facets of network, specifically the radio and the network layers. There is also the need for alternative metrics by which treatments might be evaluated. In addition to the "well-known energy efficiency merit factor" (bits/Joule), the 3 new merit factors are proposed to describe network performance by taking into account other network features. These measurements expose the optimal working state, from which the nerve centre of a network might be fashioned. Low signaling load, medium power load, & high capacity are all examples of these modes of operation.

(Alghamdi et al., 2020b) Sixth-generation (6G) wireless physical platforms are emerging as promising possibilities, and this study covers optimization frameworks and performance analysis approaches for the "large intelligent surfaces" (LIS). LIS have shown useful qualities in enhancing the spectral efficiency of the wireless networks by manipulating phase shifts of reflections to modify the behavior of interacting the electromagnetic (EM)waves. Researchers have been delving into LIS technology as a technique to create virtualized, programmable, and distributed wireless network architectures in this setting. LIS have also been shown to be an inexpensive, environmentally friendly, long-term, and energy-efficient answer for 6G systems at the system level. This study presents a novel synthesis of principles of the operation of LIS with methods for optimizing and evaluating their performance. The article begins with a brief overview of LIS technology and its physical operation. The paper then proposes a number of optimization strategies designed to maximize energy efficiency, secrecy-rate, sum-rate, and coverage. After introducing the topic of performance analysis, the article proceeds to address a number of related studies, such as capacity analysis, the effect of the hardware impairments on capacity, uplink or downlink data rate analysis, and the likelihood of outages. The implications of using LIS technology for positioning purposes are also presented in this research. Finally, we highlight several interesting unanswered questions for LIS-enhanced 6G wireless networks, such as resource allocation issues, the "hybrid RF-VLC systems", health concerns, and localization.

(Directions et al., n.d.) Industry and academics have begun to look beyond 5G at 6G communications as the 5G networks are being rolled out globally. It is widely expected that 6G networks would be built on pervasive AI to enable data-driven ML solutions in distributed and large-scale environments. However, growing privacy concerns are slowing widespread use of classical ML methods, which need centralised data gathering and processing by a single server. Because of its dispersed and privacy-preserving nature, federated learning is gaining traction as a promising avenue towards the realisation of ubiquitous AI in sixth-generation (6G) wireless networks. First, we present an overview of 6G and federated learning and then discuss some of the ways in which 6G might be used in conjunction with federated learning. We then detail the most pressing technological issues, the solutions provided by federated learning, and the gaps in knowledge that need for further study in the field of the 6G communications.

3. CONCLUSION

Research on 6G has already been launched to meet the rising demand for the wireless services as well as applications, even though 5G has begun initial deployment throughout the globe and promises many new capabilities. In this study, we discussed the problems with 5G and how 6G could be able to solve them. Network operators will have a lot of leeway in allocating speed, coverage, and capacity for different use cases in the next 5G and 6G networks. now than manually configuring their networks, operators must now write programmes to accommodate the rollout of new services. When it comes to ensuring a consistent state transition for the "storage-based distributed systems", flexibility is a crucial feature for end users in the face of varying demands. The rapid rollout of 5G/6G networks has coincided with a surge in worldwide data traffic. Although the service providers have started virtualizing their packet core networks, the true benefits of 5G or 6G are realised with the horizontal breaking of the NFV silos in the telco cloud to achieve efficiency in deploying the new services with the mobile edge computing and the network slicing capabilities for the end-to-end orchestration of services for the 5G mobile system.

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