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ORIGINAL RESEARCH ARTICLE

Digital twins approach proposition for 5G/6G

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ABSTRACT

In order to step toward the next decade with steady pace in terms of mobile networks we need to admit that the advanced technologies enabled in the last decade by 5G mobile networks produced more dimensions for totally new high-performance technologies for the next generation. Truly immersive extended Reality XR, high fidelity mobile hologram and digital replica. The usage of such technologies cannot be achieved only by actual 5G mobile networks. This is because of various problems such as capacity and data rates, but most importantly network coverage, which is one of the challenges mobile networks will be facing in the next few years. In this paper, we will discuss specifically coverage challenges in mobile networks, in addition to the digital twin concept as an important concept in 6G mobile networks, and we will finally propose an approach to deal with network coverage problems based on the 6G service digital twin.

Keywords: digital twin DT; coverage; 6G

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1. Introduction

One of the most challenges in mobile networks is coverage. It is unlike other problems such as data rates, and capacity, that most researchers are interested in. Coverage is the less mentioned and treated challenge in dealing with mobile network challenges. When it is the most important thing that the network should prioritize. On the other hand, new IT advancements are currently enabling the production of digital twins (DTs). DTs have become a popular study topic because they provide a better way to coordinate proactive tasks with the virtual world. Digital reproduction will be taken to a new level in 6G by accurately recreating verifiable elements into a sophisticated circle using modern sensors, AI, and correspondence advances. This might then be stretched onto a holographic show or placed in a virtual world. This technology can help resolve various problems in different domains such as healthcare, manufacturing and so on. It can also help create self-mobile network management as we will see in our paper.

2. 5G/6G deployment challenges

2.1. 5G/6G exigence

Through the deployment of a sizable number of low-power sensor networks in cities and rural areas, 5G now can accelerate the development of smart cities and the Internet of Things when the 6G is anticipated to come with the thing-to-thing aspect which means brand new dimensions of data rate and the need of huge coverage.

Fifth-generation (5G) and sixth-generation (6G) mobile technologies creates intelligent networked communication environments that connect people, things, data, applications, transportation systems, and cities. With the help of networks, it should be feasible to process massive amounts of data quickly, link a big number of devices, and transmit enormous amounts of data more quickly[1].

The low latency and safety features of 5G are beneficial for the development of intelligent transportation systems, enabling communication between smart vehicles and opening up possibilities for linked, autonomous automobiles and trucks. For instance, a cloud-based autonomous driving system must enable an autonomous vehicle (AV) to stop, accelerate, or turn when instructed to do so. There could be disastrous repercussions if there is network latency or a reduction in signal coverage that prevents the message from being delivered[2]. Such challenges make the world increasingly need new solutions for mobile networks, we are meaning here the sixth generation of mobile networks.

The problems with data throughput, effectiveness, and capacity that the current crop of mobile broadband applications presents. This is anticipated to be improved even more by the current 5G technology roadmap, which is projected to change to accommodate the unique needs of MIoT deployments and MCS use cases.

One of the biggest challenges in mobile networks is the network coverage in different types of areas. As we mentioned in our previous work about the need of 6G and how the communication jumps from people to thing, to thing to thing. We will present in through this paper one of the most important aspects of the applications of 6G and how we can use it to propose a solution to the network coverage problem.

2.2. Self organized network

One of the concepts for improving mobile networks is the self-organized network presented by Jiang et al.[3]. A self-organized network is already adopted by 4G networks, the concept is precisely about make 4G Long-Term Evolution (LTE) networks capable of auto-configuration, auto-healing and auto-optimization which Ean a self-management, after that the concept was mentioned by Jiang et al.[3] in order to find a solution to the heterogeneous 5G network management problem. However, because of the dynamic nature of 5G networks the 4G SON concept was not suitable to use. This is why it was a necessity to work on a new version suitable for 5G.

3. Network coverage challenge

3.1. The coverage challenge in mobile networks

Future cellular networks must have seamless and widespread coverage. Since coverage quality has such a significant impact on system performance and end-user experience, network coverage continues to be a significant problem.

It is projected that the growing interference from base stations and user terminals will have a negative influence on network coverage. Additionally, the "ubiquitous coverage" use cases, such as those in remote and rural locations, pose a serious obstacle for mobile communication technology.

In addition, the main current deployments and improvements that are anticipated to increase network coverage in order to satisfy the needs of the coming systems are outlined, along with any implementation difficulties.

3.2. The coverage challenge in 5G/6G

However, these technologies come with built-in implementation difficulties. Densification has the potential to drastically raise the energy consumption of the network[4], higher frequencies are vulnerable to severe attenuation due to increasing path loss and channel intermittency, and centralization necessitates a massive amount of computational processing power[5]. Parallel to this, network coverage issues become one of the primary worries with regard to cellular networks in the future. Without supplying good quality signals, it will be impossible to fully realize the throughput and capacity benefits of future mobile telecommunication technologies. Additionally, one of these technologies' limitations is coverage.

Deep indoor coverage, which is crucial for the massive machine-type communications (mMTC) use case, nevertheless poses a significant problem. In those areas, it's critical to offer connectivity as well as improved network performance. With the standards surrounding the universal coverage concept, coverage in rural areas also plays a significant role[6].

Furthermore, a crucial challenge for design in 5G/6G networks is coverage analysis. In fact, signal-to-noise plus interference ratio (SINR), which differs from environment to environment, has a substantial relationship with coverage probability[6]. Noting that the 5G network uses a variety of base station types, including macro base stations (MBS), micro base stations (mBS), and femtocells, to build a heterogeneous network (HetNet)[7].

4. Digital twin concept

4.1. Digital twin concept

The idea of a digital twin begins from Michael Grieves' 2003 introduction of item life-cycle as shown in **Figure 1**.

If we want to define digital twin today, one of the most direct and clear definitions is the one of IBM—A virtual presentation of a physical object. This object is furnished with different sensors connected with imperative areas of usefulness. These sensors produce information about various parts of the actual item's presentation, for example, energy yield, temperature, weather patterns and that's just the beginning. This information is then handed-off to a handling framework and applied to the computerized duplicate.

Once such data is sent, the virtual model starts using it by running simulations, concentrating on execution issues and producing potential enhancements, all determined to create beneficial knowledge which can be executed to its corresponding physical object[8], we schematized this process in the **Figure 2**.

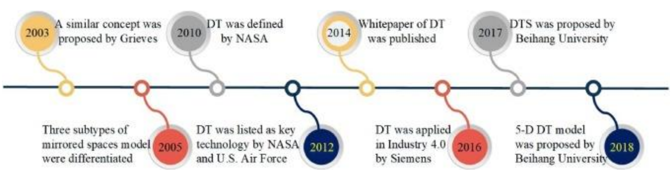

Figure 1. Digital concept timeline.

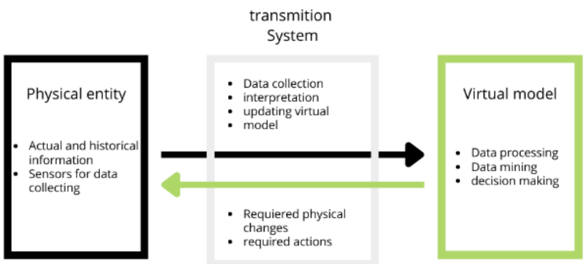

Figure 1. Illustration of digital twin concept.

A DT means coordinating Multiphysics, multiscale, probabilistic recreation of an as-fabricated vehicle or framework that utilizes the most ideal that anyone could hope to find actual models, sensor refreshes, armada history, and so on, to reflect the existence of its relating flying twin[9]. In addition, it is an idea related to cyber-physical combination. A DT makes high-constancy virtual models of actual items in virtual space to reproduce their ways of behaving in reality and give response[10].

A DT mirrors a bi-directional unique planning process; it breaks the boundaries in the item life-cycle and gives a total computerized trace of items[11]. The perception for DTs is to give a far reaching physical and utilitarian depiction of a part, item, or framework[12].

The first and most significant step is to make high-constancy virtual models to practically repeat the calculations, actual properties, ways of behaving, and rules of the actual world[13]. These virtual models are not just exceptionally steady with the actual parts concerning calculation and design, yet in addition are ready to mimic their spatiotemporal status, ways of behaving, capabilities, and more[14]. As a result, the virtual models and actual elements have a comparative appearance, similar to twins, and similar ways of behaving, similar to a perfect representation. What's more, the models in the advanced climate can straightforwardly upgrade the activities and change the actual cycle through criticism[15]. Utilizing bi-directional unique planning, the actual substances and virtual models co-develop. In this way, the planning connection between the physical and computerized universes of a DT gives a balanced correspondence. A virtual model, which incorporates calculation, structure, conduct, rules, and useful properties, addresses a particular actual item[16].

4.2. Need of DT

Digital twins are of most use when an item is changing over the long run, accordingly making the underlying model of the article invalid, and when estimation information that can be connected with this change can be caught. These changes could be unfortunate, for example wear in course or weakness in metal parts, or they could be nonpartisan yet significant, for example varieties in provided material properties. In the event that an item doesn't change a lot after some time, or on the other hand on the off chance that information related with that change can't be caught, then a computerized twin isn't probably going to be valuable. One explanation that the computerized twin idea is so significant in assembling is that it considers improvement of individual models of individual articles inside a unified system that makes model turn of events, approval, and refreshing straightforward[17].

5. Use cases of DT

5.1. Digital twins in livestock farming

The livestock farming domain is going through a big transformation and revolution by involving digital twin technology. Digital twins can possibly drastically move livestock farming from cultivating based on climate and additionally cost estimates, the farmer experience, and human perceptions, to real-time information, controlled by AI examinations, which can then fuel better business choices, work on the animal wellbeing and prosperity, and boost the return from agricultural assets[18].

DT would help in various areas in this context such as mental states of animals, sicknesses control and expectation, accuracy livestock farming, animals energy management, observing the movement of grazing livestock, dairy animals growth observation and development.

5.2. Manufacturing and industry

One of the most important works for DT on the manufacturing domain is the research of Zhou et al.[19] that proposes a framework for knowledge-driven digital twin manufacturing cells (KDTMC) that includes DT as its key enabling technology of its construction.

DT helps to overcome any barrier between physical space and computerized space of KDTMC by connecting virtual space and physical space with an iterative pattern of correspondence, calculation and control. Aside from the customary creation capacities, the physical space could likewise see the assembling information connected with humans, gadgets, materials, climate, and so forth[19].

5.3. Healthcare

Healthcare is a high potential domain for DT application, because it has various variables and circumstances especially for patients' health. One of the most interesting future applications is a digital twin of a human, giving a constant investigation of the body. Such investigation can help in reproducing the impacts of specific medications such as drugs[20]. Also, DT can help for arranging and carrying out surgeries, for observing patients with chronic diseases, even cancer care and detection. This can be achieved by giving the ability to doctors to investigate and manage the patient body and identify issues remotely through DT.

In order to give quick, exact and productive clinical benefits utilizing DT innovation with Multiscience, multi-physical science and multi-scale models, an approach for clinical action and framework is proposed by Zhou et al.[21] called digital twin healthcare (DTH) in order to project the power of DT for elderly healthcare.

In actual fact, the utilization of numerical models for higher volumes handling of 'biodata' empowers compelling clinical mediations. A few early models of computerized twins were acknowledged which utilizing a cloud-based programming application and multi-layered information alongside a data model were fabricated[22].

By perusing patients' tactile information, we can mention that a 'virtual patient' can be made. In this manner, the digital twin can be a platform for exposing engineering solutions in healthcare. In addition, DT can be used also to predict maintenance for medical material.

DT will have a major impact on healthcare from now on. because it works on the combination of human healthcare and hospital management simultaneously.

6. Implementing digital twins

6.1. Implementation steps

In this section we will discuss the key knowledge and steps to digital twin implementation.

First step for DT implementation, because the goal is to create a virtual model of the physical entity, it is important to focus on the physical first, we need to gather actual and historical[23] information about the object, about its environment and understand its process goals, then gathering real-time data with the help of IOT so the virtual model will be an exact complete model of the original entity.

Second step, in this stage, will move from the physical to the virtual model. We are obligated to utilize the most recent advances in data management, big data and cloud servers. This is important because the virtual model here will need to get, store and cycle enormous amounts of data continuously in real-time. In addition, the collected and stored data need to be processed to generate relationships in between and to determine beneficial and non-beneficial data. This can be done by artificial intelligence (AI) and machine learning (ML) algorithms.

Third and final step, because the most essential goal of all this technology is to improve the work of the physical entity, the virtual model needs to be trained multiple times by simulations, such as scenarios of 'what-if' and analysis of sensitivity[24]. This implies that ML calculations should be prepared under unambiguous conditions to learn, try and advance the most ideal action-plan for the physical entity.

6.2. Data management

The process of data management in digital twins is very complicated and critical. It incorporates information collection, transmission, capacity, handling, combination and representation (**Figure 3**). So, in order to simplify the process, we can divide it into 6 parts:

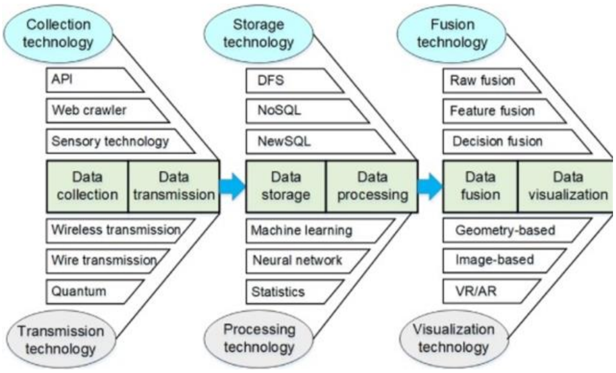

Figure 2. Enabling technologies for data management in DT[25].

The first is data source that contains hardware, software and network[24] The static characteristic information and dynamic status information define the hardware part. Such as IoT technologies, cameras, sensors, barcodes and QR codes that help in the process of data collection from all parts of the environment.

Secondly, data transmission technologies, this part includes wire and remote transmissions that rely upon transmission conventions, access strategies, multi-access plans, channel multiplex balance and coding, and multi-user detection advancements.

Next is data storage, as its name implies it is about storing data in the most optimal way in order to use it in the next processing stages. Because of the huge amount of data resulting from DT, we are talking about heterogeneous data. This is the reason why we need to call advanced data storage technologies; we mean here big data technologies such as NoSQL database, NewSQL database, cloud storage and distributed file storage (DFS).

After granting the data storage, the next step is absolutely processing it. In this stage we need to mention that it is divided into two parts, the preprocessing and the processing. The first one is the preparation of the data, we mean here filtering and clearing it from all noises and incomplete and incorrect data. We can use in this stage various methods such as classification algorithms, mission values imputation and dimensionality reduction. The second step is finally processing the data through statistical methods, neural network methods. The step needs huge analyses so we can detect which data to filter, process in the base of its final goal.

The next step of DT management data is data fusion. This step is about starting to integrate data resulting from previous steps to provide more relevant and useful information. This can be done using artificial intelligence methods and even random methods such as classical reasoning, weighted average method, Kalman filtering, Bayesian estimation, and Dempster-Shafer evidence reasoning[25].

Information perception effectively presents information examination results in a clear, natural, and intuitive way. As a rule, a technique planned to express the hidden standards, regulations, and rationales contained in information through illustrations is called information representation. Information perception appears in different ways, for example, histogram, pie diagram, line outline, map, bubble graph, tree graph, dashboards, and so on. As indicated by the standard of its perception, these techniques can be partitioned into math-based innovations, pixel-situated advancements, symbol-based advances, layer-based advancements, picture-based advancements, and so on.

7. Proposition of a DT approach to deal with network coverage problem

7.1. Approach proposition

Based on the aspect of thing to thing that 6G brings, and the digital twin concept, we will present in this section (**Figure 4**) our proposition of self-management coverage network due to DT. We thought of using the concept of digital twin in order to create an autonomy network. more precisely we propose the creation of a digital twin of the physical antennas in order to prevent coverage equipment and connections from having any issues. With this approach we assume that all work, data processing, Problem detection, prediction, resolution and maintenance will be executed on the virtual model, so that only the best and successful solutions will apply to the physical antennas.

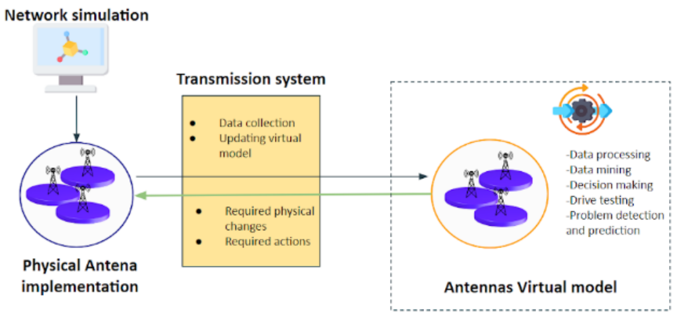

Figure 3. Self-management coverage network due to DT approach for 6G.

The implementation of this approach would contain 3 principal steps: The first one is data collection where we need to gather actual and historical information about the antenna, about its environment and understand its process goals, then gathering real-time data with the help of IOT so the virtual model will be an exact complete model of the original entity. This can be done by getting hardware and software data sources, listing all important and essential factors and measures for antennas functionality and getting dynamic data sources using sensors.

Second step is virtual antenna creation. We can use the most recent advances in data management, big data and cloud servers. This is important because the virtual antenna here will need to get, store and cycle enormous amounts of data continuously in real-time. Also, we need to determine beneficial and non-beneficial data using artificial intelligence (AI) and machine learning (ML) algorithms.

Third step is training. This step is very important where the virtual antenna will be trained multiple times by simulations, such as scenarios of 'what-if' and analysis of sensitivity.

7.2. Opportunities

This approach of self-management coverage problems using DT will creates a powerful auto management antenna with high performance and power. on the one hand, it will shorten time of coverage interruptions and gives problems prediction before they even happen. On the other hand, it will guarantee applying solutions of each problem faced by the antenna including its inside and outside environment variables. This power is essentially coming from the virtual twin processing, because, all potential solutions will be applied on the virtual model and only the successful one will be sent to the physical one.

8. Conclusion

In this paper, we deeply discussed two important aspects, the first was the challenges of 5G/6G and more specifically the coverage problem. The second was the digital twin concept as a 6G trend that will bring so many opportunities in the near future. In addition, we proposed an approach based on digital twin, to deal with antenna coverage problem. Next works from now on is to define details of implementation of each step of the approach in addition to all technologies that will be used to achieve such a goal.

Author contributions

Conceptualization, OER; methodology, OER; writing—original draft preparation, OER; writing—review and editing, OER; visualization, TM; supervision, TM. All authors have read and agreed to the published version of the manuscript.

Conflict of interest

The authors declare no conflict of interest.

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