Role of Cyber Twin Mobile Networks in Digital Communication

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Abstract

Due to the unprecedented increase in the utilization of Internet of Things (IoT) technology, there is a huge increase in network/internet traffic due to which the existing network architectures are facing number of challenges in terms of reliability, availability, scalability, portability and expandability. In order to deal with the challenges, the cyber-twin technology has been recently proposed to assist in establishing a strong communication network in terms of digital asset management, network data maintenance etc. Recently, cyber-twin has become a well-established environment for real-world applications ranging from manufacturing, healthcare to smart city applications. The proposed study reviews the concept of cyber-twin mobile networks along with a representation and efficient utilization of cyber-twin networks and its impact in the digital world. Further, different state-of-the-art cyber-twin architectures are compared to show how these architectures outperform the traditional peer-to-peer networks in order to make the futuristic networks safer, secured, adaptable, portable and reliable.

Keywords: Cyber Twin, Internet of Things (IoT), Network security, Artificial Intelligence (AI)

1. Introduction

The cyber twins are realistic representations of physical components that contains the behaviour of physical component. As a result, cyber twin functions similarly to the physical component. The physical twin consists of the real component, which is expanded by the additional sensors. With the help of the sensor, the data is collected and sent to the cyber twin. Cyber twins collect information from all the stages of the product life and analyse the impact in real time. The cyber twins create an algorithm to modify the operation of physical

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component. Furthermore, by using the simulation technique, the functions of the physical twin as well as present and forthcoming situations can be predicted. Cyber twin is the complete collection of tools used for creating a user friendly virtual and augmented reality experiences that are fully integrated with existing operational and Information technology systems in real world. Modern smart factories are made possible by cyber twin.

The unique characteristics of cyber twin makes the network to be flexible, secure, reliable and scalable. They have characteristics such as including the connected network, frequently exchange the data, interconnecting the communication between all of the system's object. The main benefits of cyber twin are the reduction of dependability factor, which will significantly extend the lifetime of all industrial components. The cyber twins help to analyse the power distributor and predict the power network under various operating conditions. The quality and reliability of future components can also be increased. The cyber twin enables the connection of real environments in future developments. The cyber twin can also help to increase the sustainability of the product. The behaviour of the product is optimised to reduce the energy consumption. The cyber twin has collected a large amount of data from all the network communications, and the data stored can be used to create a better systems. Cyber twin improves both the system performance and accuracy. Thus, the cyber twin network enables the traffic mobility as per the user convenience. Cyber twin enables users to assess the performance of the physical systems in real time remote monitoring process.

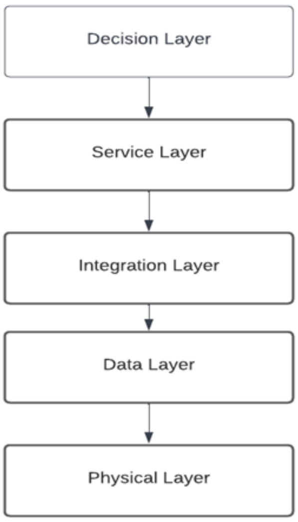

Figure 1. Cyber Twin Layered Architecture

In the recent years, research efforts have been made to examine the latest technological developments to improve the data driven applications, including the cloud computing, big data, Artificial Intelligence (AI), Virtual Reality (VR), Augmented Reality

(AR), Industry 4.0 and Internet of things (IoT). The concept of cyber twin is applied in various applications like healthcare, transportation, smart cities, Industry 4.0, etc. The most important application of cyber twin is healthcare. The implementation of cyber twin enables the rapid sharing of a large amount of data collected in IoT devices. IoT and cyber twin technologies are used to create an analytical report of patient to monitor and predict the potential threats. Cyber twin is also used in manufacturing industry to check the performance and reliability of measuring the product developments. It also helps to automate the processing function. The cyber twin is also used in smart city applications. By utilising the AI techniques, the cyber twin helps to simulate the smart building and perform traffic management and smart farming operations.

Cyber twins are considered as the recent technological advancement used for developing a service oriented, dependable, or sustainable product. Fig.1 shows the overview of the cyber twin layered architecture. Each layer has a specific purpose. The physical layer shows how the system or process is physically described to users. The data layer displays the various systems- related details. The integration layer provides the integration interlayers with support and security. The service layer provides a tool to control, monitor and manage the system. The last layer, decision layer displays the centralised information about the process.

2. Related Work

Table 1. Comparison of Different Techniques of Cyber Twin

Reference	Technique	Application	Outcome	Advantage
Yu et al [1]	Cyber twin based next generation network architecture	Cloud Network Operating System	- efficient and trusted authentication methods developed - protected the data privacy and security	- flexible - scalable - reliable - secure, Availability
Hou et al [2]	Multi-agent Deep Deterministic Policy Gradient (MADDPG)	Deep reinforcement learning (RL), Federated Learning (FL), edge computing	- improved processing efficiency - protected end devices' data privacy	- Faster, - lower latency, - ensuring privacy - security
Chai et al [3]	Block chain framework, Diffused	Internet-of-Vehicles (IoVs)	- Reduced cost - enhance the authentication efficiency	- improving the efficiency - data integrity - reduce consensus

	Practical Byzantine Fault Tolerance (DPBFT)		- reduce the authentication delay	latency
Yin et al [4]	Space Air Ground Integrated Networks (SAGIN)	6G network	- improved networking efficiency and service experience - increased model accuracy	- High power and safe - High changing efficiency
Syed et al [5]	FNN Resource Allocation	6G wireless communication	- Increased success rate on average - more efficient use of resources - improved network throughput	- Reduction of storage and computation costs - higher scalability
KUBO et al [6]	DT-assisted CPSs, Networked Control Systems (NCSs)	Communication quality estimation observer (CQEO)	- Effectively Haptic communication systems - Best communication quality	- Increase system reconfigurability, - Enhance resource utilization and reliability - High-transparency haptic communication
Manoharan et al [7]	Cyber twin technology and blockchain technology	Artificial intelligence (AI), Support Vector Machine (SVM)	- collected data analysis and management process, - outperforms rate of 72%, - decreased the menace of traffic, - Increasing the scalable routes	- decrease weighted loss function - usage in a high-dimensional space - provided exact distances between various sensors.
Keshmiri Neghab et al [8]	Digital Twin of a Medical Microrobot	Machine Learning (ML)	- current, position, and velocity were simulated - Minimizes noise and accurately checks the reference	- reliable approach for trajectory tracking - contactless mobility
Javed et al [9]	Intelligent reflecting surface (IRS)	6G vehicular network	- Increased reliability - Improved percentage of LoS links by 60%	- enhances the security - improved localization - removal of obstructions
Yi et al [10]	Artificial Neural networks & Musculoskeletal models	6G, Internet of Everything	- better combination method - improved generalization ability	- Easier - Effectiveness

Table 1 summarizes the comparison of different techniques of cyber twin. Yu et al [1] introduced the Cyber twin based next generation network architecture, which helps to improve the efficiency. This approach provides a solution to overcome and manage the resources to the end users in order to achieve more safe and scalable architecture, and also to develop a trusted authentication, protect the data privacy and security.

Hou et al [2] describe the cyber twin based multiagent deep deterministic policy gradient to perform task offloading resource allocation, which helps to increase the system efficiency and task completion ratio. By utilising the multiagent deep deterministic policy gradient, the goal is achieved by implementing a faster task processing, dynamic real-time allocation, and achieve lower overhead to protect the data privacy and system security. It also improves the processing efficiency.

Chai et al [3] discussed about the cyber twin empowered blockchain for authentication in Internet of Vehicles, which is used to reduce the storage cost and communication while maintaining the system efficiency. The proposed cyber twin-based framework protects the privacy of vehicle and increases the authentication performance and efficiency. Furthermore, a DPBET mechanism is used to reduce the authentication delay.

Yin et al [4] suggested the cyber twin enabled SAGIN architecture, which enables to improve the network efficiency and service experience. The suggested method of cyber twin enabled 6G architecture displays the model accuracy. In addition, two open issues in the SAGIN that supports the cyber twin are discussed. The FL and AL based approaches have pointed out the potential solution in the appropriate directions.

Syed et al [5] presented the FNN wireless healthcare model used in resource allocation of cyber twin technology, which helps to reduce the storage cost and computation cost. The simulation results show how the efficient resource allocation and management is better than the standard methods. In comparison to the existing method, the proposed method uses more resources and has a greater success rate. In addition, it also improves the network throughput.

KUBO et al [6] developed the DT assisted CPSs based on the communication quality estimation observer, which provides the best communication quality. The proposed technique is utilized with two different types of NCSs with haptic communication system and remote motor control system. The outcome of the simulation result showed the potency of the CQEO based network control technique for the haptic communication system.

Manoharan et al [7] explained that the system model is combined with the SVM algorithm to provide an effective performance. By utilizing a sensor prototype and simulation, the effectiveness of proposed model is evaluated. When compared to existing methodologies, the predicted model performs better in more than 72% of the cases.

Keshmiri Neghab et al [8] proposed the digital twin of a medical microrobot, which is controlled by stochastic model predictive controller empowered by machine learning based system identification. The identification method helps the controller to understand the dynamic robot. The results demonstrated that the proposed controller will work effectively without any error and reduces the noise.

Javed et al [9] explored the 6G vehicular network powered by cyber twins must have the Intelligent Reflecting Surface which is enhance the security. The effort aims mainly to improve the reliability for 6G networks. The result show to IRS can increasing the percentage of LoS links in urban and highway road network by 60% and 25% respectively, which will significantly improve the cyber twin IOV connectivity.

Yi et al [10] Investigated the Muscular human cyber twin for internet of everything, which helps to improve the data efficiency. The proposed method combines the Artificial Neural Networks (ANN) & Musculoskeletal Models (MSM) and the result shows the effectiveness and a better combination method. The outcomes show that the running out algorithm is more feasible. With enough training data, the proposed technique achieves accuracy comparable to ANN and it achieves accuracy nearly 30% better than MSM.

Table 2. Different Types of Cyber Twin Benefits and Issues

Reference	**Types**	**Methodologies**	**Advantages**	**Challenges**
Duo et al [11]	Cyber physical system	Cyber attacks	✓Good detection performance ✓Increase the attention	✓Limited users ✓Economic loss ✓Worse outcome ✓Difficult to access the all methodologies
Bocklisch et al [12]	Cyber physical system	Multidimensional Fuzzy pattern	✓High resolution voltage ✓Better Indicator	✓Complex information pattern ✓Dynamic and autonomous behavior ✓Lack of knowledge
Botín-Sanabria et al [13]	Digital Twin	Manufacturing and Smart cites	✓Improve reliability ✓Reduce the future risks ✓Productivity	✓Lack of standards ✓Limited accessibility ✓Cost ✓Maintenance

Qamsane et al [14]	Digital Twin	Open Process Automation, Health monitoring approach and Industry 4.0	✓Performance Maintenance ✓Energy consumption ✓Improve the efficiency	✓Costly ✓Development investments
Emara et al [15]	Digital Twinning	Mobile Robot	✓Performance measured ✓Validated the performance	✓Load capacity ✓Safety risk ✓Not navigate over obstacles

3. METHODS

3.1 Cyber Physical Systems

Table 2 summarizes the comparison of different types of cyber twinadvantages and challenges. Cyber physical system (CPS) is a computer system in which the entities are interconnected by using wired and wireless technologies. It consists of a combination of embedded system technologies based on hardware and software components. CPS examples include, a smart grid, smart city, segway shooter, IOT, self-driving cars, and intelligent transportation systems connect new data devices and new applications. Some characteristics of Cyber Physical Systems (CPSs) are user friendliness, capability, dynamical reorganisation and reconfiguration, and high degrees of automation. The growth of CPS innovation depends on the needed to support and maintain the contributions of many other disciplines. It has the power to transform, enhance, and address different critical issues. By analysing and evaluating the data collected, cyber physical systems can perform certain tasks.

Duo et al [11] describe the cyber-attacks on cyber physical systems, which helps to improve the attention of various cyber-attacks. This approach provides a solution to overcome the defects and achieve better performance. Some challenges and practical issues are follows as: It will be accessed by limited users. Complex problem has only received a minimum attention.

Bocklisch et al [12] introduced the multidimensional fuzzy pattern by using cyber physical system, which is used to classify the thermal spring. Here, two multidimensional fuzzy pattern classification models are developed. The proposed approach describes how the human psychological and technological perspectives can be combined in the HCPS concept with the suitable measurement techniques to collect and process the data in the cogent FPC framework.

3.2 Digital Twin

One of the most trending technologies in recent years is Digital Twin (DT). Digital twin is a digital representation of the real-world entity and system. The digital system is a combination of data and intelligence that represents a structure, context, and behaviour of physical system of any type, which allows to understand the past and present operation and are used to predict the future operation. Each system has a digital twin developed with the physical product. Digital twin consists of three components, they are physical twin, digital twin and linking mechanism. The examples of digital twins are: wind farm, healthcare, robotics, and 3D printers. The main advantages of digital twin are the time and location independent simulation of the behaviour of a real product. Botín-Sanabria et al [13] explained the application and challenges of digital twin, which helps the smart cities and manufacturing industry to increase the reliability and productivity. The proposed strategy provides a thorough analysis of digital twin technology, as well as its implementation of difficulties and limits in the most important engineering areas and applications. The limitations and challenges of the digital twin include the cost, maintenance, lack of standards, information complexity and the issues related to cyber security.

Qamsane et al [14] discussed about the health monitoring approach and industry 4.0, which uses digital twin and open process automation to improve the performance, efficiency and the safety of manufacturing systems. The goal of the digital twin framework is to offer the guidelines to develop, test and evaluate a new system with wide DT solution without interfering with production processes or requiring expensive R&D investments. The cost and investment of developments is a major issue in digital twin. Emara et al [15] proposed the digital twining model for a three-wheel omnidirectional mobile robot, which is useful for measuring and validating the performance. This digital twin model approach can be applied to related projects, and it is also important to note that it can be applied to large-scale projects. The challenges and issues are as follows: safety risk, loading capacity, and inability to navigate over obstacles.

4. Conclusion

This study reviews the concept of cyber twin to increase the authentication effectiveness. In this study, the concept and definition of cyber twins are discussed along with an analysis of various advantages. The connection of physical world and virtual world helps to enable a new understanding and better awareness on digital interactions. The primary challenges like dependability, availability, and scalability are addressed in this study by providing suitable solutions. In order to show the value of the cyber twin, the crucial characteristics are highlighted. There are still certain research difficulties that need to be resolved in order to provide a safer and more scalable architecture. Future studies will examine how cyber twins interact and how their relationships affect certain industries like healthcare.

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