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Concepts of Digital Twin Network
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Abstract

Digital twin technology is becoming a hot technology in industry 4.0. The application of digital twin technology in network field helps to realize efficient and intelligent management and network innovation. This document presents an overview of the concepts of Digital Twin Network (DTN), provides the definition and DTN, and then describes the benefits and key challenges of DTN.

Requirements Language

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Table of Contents

1.	Introduction	2
2.	Definition of Digital Twin Network	3
3.	Benefits of Digital Twin Network	4
3.1.	Lower the cost of network optimization	4
3.2.	More intelligent for network decision making	5
3.3.	High efficient for network innovation	5
3.4.	Privacy and Regulatory Compliance	6
3.5.	Customize Network Operation Training	6
4.	Reference Architecture of Digital Twin Network	6
5.	Challenges to build Digital Twin Network	9
6.	Summary	10
7.	Security Considerations	10
8.	IANA Considerations	10
9.	References	10
9.1.	Normative References	10
9.2.	Informative References	10
	Authors' Addresses	10

[1.](#) Introduction

With the advent of 5G, Internet of Things and Cloud Computing, the scale of network is expanding constantly. Accordingly, the network operation and maintenance are becoming more complex due to higher complexity of network; and innovations on network will be more and more difficult due to the higher risk of network failure and higher trial cost.

Digital twin is the real-time representation of physical entities in the digital world. It has the characteristics of virtual-reality integration and real-time interaction, iterative operation and optimization, as well as full life-cycle, and full business data-

driven. At present, it has been successfully applied in the fields of intelligent manufacturing, smart city, complex system operation and maintenance [[Tao2019](#)].

A digital twin network platform can be built by applying digital twin technology to network and creating virtual image of physical network facilities. Through the real-time data interaction between physical network and twin network, the digital twin network platform can help the network to achieve more intelligent, efficient, safe and full life-cycle operation and maintenance.

2. Definition of Digital Twin Network

So far, there is no standard definition of digital twin network in networking industry or SDOs. This document attempts to define Digital Twin Network (DTN) as a virtual representation of the physical network, analyzing, diagnosing, simulating and controlling the physical network based on data, model and interface, so as to achieve the real-time interactive mapping between physical network and virtual twin network. According to the definition, DTN contains five key elements: data, mapping, model, interface and orchestration stack, as shown in Figure 1.

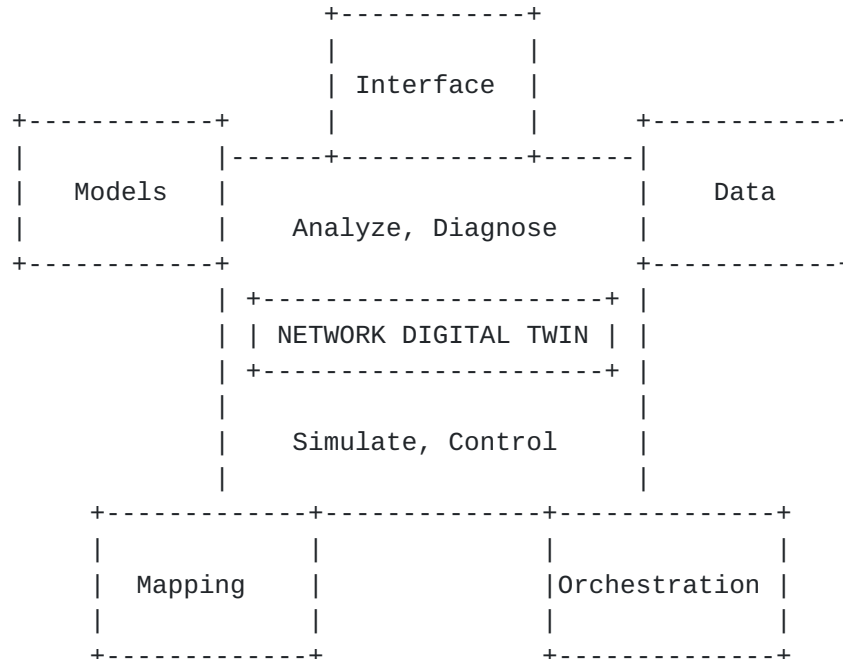


Figure 1: Key Elements of Digital Twin Network

- o Data is cornerstone for constructing a DTN system, in which unified data repository can be the single source of the truth and provide timely and accurate data support.

- o Real-time interactive mapping between physical network and virtual twin network is the most typical feature that DTN is different from network simulation system.
- o Data model is the ability source of DTN. Various data models can be designed and flexibly combined to serve various network applications.
- o Standardized interface is the key technique enabler, which can effectively ensure the compatibility and scalability of DTN system.
- o The orchestration stack controls the flows of data and control actions. It relies on the dynamic lifecycle management of network models and elements to provide repeatability (the capacity to replicate network conditions on demand) and reproducibility (the ability to replay successions of events, possibly under controlled variations).

3. Benefits of Digital Twin Network

DTN can help enable closed-loop network management across the entire lifecycle, from digital deployment and simulation, to visualized assessment, physical deployment, and continuous verification. In doing so, customers are able to achieve network-wide insights, precise planning, and rapid deployment in multiple areas, including networks, services, users, and applications. All the benefits of DTN can be categorized into three major types: low cost of network optimization, intelligent network decision making, and high efficient network innovation. The following sections describe the three types of benefits respectively.

3.1. Lower the cost of network optimization

With extremely large scale, network is becoming more and more complex and difficult to operate. Since there is no effective platform for simulation, traditional network optimization has to be tried on real network directly with long time cost and high service impact running on real network. This also greatly increases network operator's OpEX.

With DTN platform, network operators can well simulate the candidate optimization solutions before finally deploy them to real network. Compared with traditional methods, this is of quite low risk and will bring much less impact on real network. In addition, the operator's OpEX will be greatly decreased accordingly.

3.2. More intelligent for network decision making

Traditional network operation and management mainly focus on deploying and managing current services, while lacking of handling past data and predicting future status. This kind of passive and protective maintenance is difficult to adapt to large-scale network scenarios.

DTN can combine data acquisition, big data processing and AI modeling to achieve the assessment of current status, diagnosis of past problems, as well as prediction of future trends, then give the results of analysis, simulate various possibilities, and provide more comprehensive decision support. This will help network achieve predictive maintenance from current protective maintenance. The network behavioral repeatability and reproducibility properties in the DTN allow to evaluate different conditions and controlled variations of them, exploring choice as many times as needed to apply the better emulation and decision procedures.

3.3. High efficient for network innovation

Due to higher trial risk, real network environment is normally unavailable to network researcher when they explore innovation techniques. Instead, researchers have to use some offline simulation platforms. This greatly impacts the real effectiveness of the innovation, and greatly slow down the speed of network innovation. Moreover, risk-averse network operators naturally reluctant to try new technologies due to higher failure risk as well as the higher failure cost.

DTN can generate virtual twin entity of the real network. This helps researches explore network innovation (e.g. new network protocols, network AI/ML applications, etc.) efficiently, and helps network operators deploy new technologies quickly with lower risks. Take AI/ML application as example, it is a conflict between the continuous high reliability requirement (i.e. 99.999%) of network and the slow learning speed or phase-in learning steps of AI/ML algorithms. With DTN platform, AI/ML can fully complete the leaning and training with the sufficient data before deploy the model to the real network. This will greatly encourage more network AI innovations in future network.

Implementing Intent-Based Networking (IBN) via DTN can be another example to show how DTN improves the efficiency of deploying network innovation. IBN is an innovative technology for life-cycle network management. Future network will be possibly Intent-based, which means that users can input their abstract 'intent' to the network, instead of detailed policies or configurations on the network

devices. [[I-D.irtf-nmrg-ibn-concepts-definitions](#)] clarifies the concept of "Intent" and provides an overview of IBN functionalities. The key character of an IBN system is that user's intent can be assured automatically via continuously adjusting the policies and validating the real-time situation. To lower the impact on real network, several rounds of adjustment and validation can be simulated on the DTN platform instead of directly on physical network. Therefore, DTN can be an important enabler platform to implement IBN system and speed up the deployment of IBN in customer's network.

3.4. Privacy and Regulatory Compliance

The requirements on data confidentiality and privacy on network service providers increase the complexity of network management, as intelligent decision engines depend on data flows. As a result, the improvement of data-enabled management requires complementary techniques providing strict control and security mechanisms to guarantee data privacy protection and regulatory compliance in these aspects. Some examples of these techniques can include payload inspection, including de-encryption user explicit consents, or data anonymization mechanisms.

Given DTN works with mapped traffic or services from real networks, but using traffic simulations, including automated tools for synthetic user activity. The lack of personal data permits to lower the privacy requirements and simplify privacy-preserving techniques, as the data is not coming from real users. As a result, DTN allows to focus on management improvements, without other concerns. Additionally, logging and auditing the DTN experiments and synthetic user activities provide additional information for further design and planning, without the need of traffic inspection.

3.5. Customize Network Operation Training

Networks architectures can be complex, and their operation and management require expert personnel and the learning curve can be steep in most cases. DTN offers an opportunity to train staff for customized networks and specific user needs. Several areas can benefit with the use of it. Two salient examples are the application of new network architectures and protocols, or the use of cyber-ranges to train security experts in threat detection and mitigation.

4. Reference Architecture of Digital Twin Network

So far, there is no reference or standard architecture for Digital Twin Network in network domain. Based on the definition of key elements of DTN described in [section 2](#), reference architecture with

three layers of Digital Twin Network can be designed as below, shown in Figure 2.

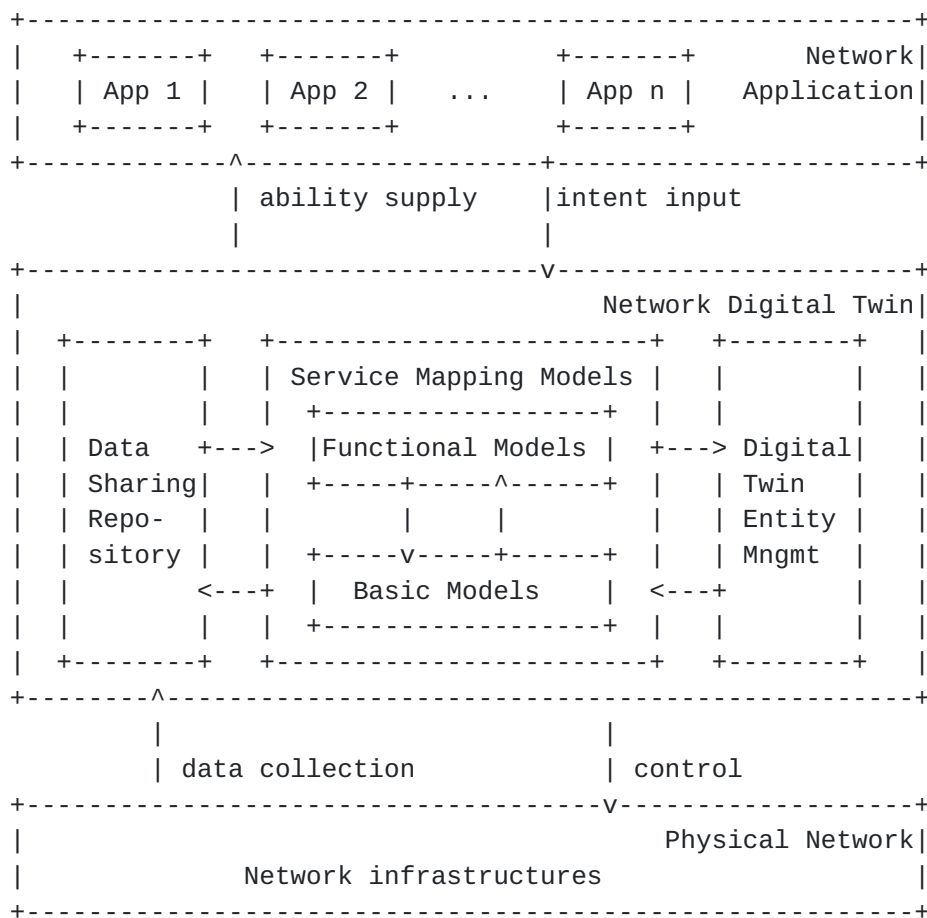


Figure 2: Reference Architecutre of Digital Twin Network

1. Bottom layer is Physical Network. All network elements in physical network exchange massive network data and control with network digital twin entity, via southbound interfaces. Physical network can be either telecommunication operator network, or data center network, campus network, industrial Internet of things or other network types.
2. Middle layer is Network Digital Twin Entity, which is the core of DTN system. This layer includes three key subsystems: Data Sharing Repository, Service Mapping Models and Digital Twin Entity Management.

* Data Sharing Repository provides accurate and complete information for building various service models by collecting and updating the real-time operational data of various network elements through the southbound interface. In addition to

data storage, Data Sharing Repository is also responsible to provide data services for the Service Mapping Models subsystem, including fast retrieval, concurrent conflict, batch service, unified interface, etc.

- * Service Mapping Models completes data-based modelling, provides data model instances for various network applications, and maximizes the agility and programmability of network services. The data models include two major types: basic models and functional models.
 - + Basic Model refers to the network element model and network topology model of the network digital twin entity based on the basic configuration, environment information, operational state, link topology and other information of the network element, to complete the real-time accurate description of the physical network.
 - + Functional model refers to various data models such as network analysis, simulation, diagnosis, prediction, assurance, etc. The functional models can be constructed and expanded by multiple dimensions: by network type, there can be models serving for single network domain or multi network domain; by function type, it can be divided into state monitoring, traffic analysis, security drill, fault diagnosis, quality assurance and other models; by generality, it can be divided into general model and special-purpose model. Specifically, multiple dimensions can be combined to create a data model for more specific application scenario.
 - * Digital Twin Entity Management completes the management function of digital twin network, records the life-cycle of the entity, visualizes and controls various elements of network digital twin, including topology management, model management and security management.
3. Top layer is Network Application. Various applications (e.g. Network intelligent O&M, IBN, etc.) can effectively run against Digital Twin Network platform to implement either conventional or innovative network operations, with low cost and less service impact on real network. Network application provide requirements to network digital twin entity via northbound interface; then the service is simulated by various service model instances; after fully verified, the change control can be deployed safely to physical network.

5. Challenges to build Digital Twin Network

As mentioned in above section, DTN can bring many benefits to network management as well as network innovation. However, it is still challenging to build an effective and efficient DTN system. The following are the major challenges and problems.

- o Large scale challenge: The digital twin entity of large-scale network will significantly increase the complexity of data acquisition and storage, the design and implementation of model. And the requirements of software and hardware of the system will be very high.
- o Compatibility issue: It is difficult to establish a unified digital twin platform with unified data model in the whole network domain due to the inconsistency of technical implementation and supporting functionalities of different manufacturers' devices in the network.
- o Data modeling difficulties: Based on large-scale network data, data modeling should not only focus on ensuring the richness of model functions, but also need to consider the flexibility and scalability of the model. These requirements further increase the difficulty of building efficient and hierarchical functional data models.
- o Real-time requirement: For services with high real-time requirements, the processing of model simulation and verification through DTN system will increase the service delay, so the function and process of the data model need to increase the processing mechanism under various network application scenarios; at the same time, the real-time requirements will further increase the system software and hardware performance requirements.
- o Security risks: Network digital twin entity synchronizes all the data of physical network in real time, which will increase the security risk of user data, such as information leakage or more vulnerable to attack.

To solve the above problems and challenges, Digital Twin Network needs continuous optimization and breakthrough on key enabling technologies including data acquisition, data storage, data modeling, network visualization, interface standardization, and security assurance, so as to meet the requirements of compatibility, reliability, real-time and security under large-scale network.

6. Summary

The research and application of Digital Twin Network is just beginning. This document presents an overview of the concepts and definition of DTN. Looking forward, further researches on DTN usage scenarios, requirements, architecture and key enabling technologies should be promoted by the industry, so as to accelerate the implementation and deployment of DTN in real network.

7. Security Considerations

TBD.

8. IANA Considerations

This document has no requests to IANA.

9. References

9.1. Normative References

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