Network Management Research Group
Internet-Draft
Intended status: Informational
Expires: January 13, 2021
C. Zhou
H. Yang
X. Duan
China Mobile
July 12, 2020

Concepts of Digital Twin Network
draft-zhou-nmrg-digitaltwin-network-concepts-00

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

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in RFC 2119 [RFC2119].

Table of Contents

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 Digitla 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 four key elements: data, mapping, model and interface, as shown in Figure 1.

```
                              +--------------+
                              |              |
                              |  Interface   |
                              |              |
                        +-----+--------------+-----+
                        |                          |
                        |    Analyze, Diagnose     |
           +------------+                          +------------+
           |            | +----------------------+ |            |
           |   Models   | | NETWORK DIGITAL TWIN | |    Data    |
           |            | +----------------------+ |            |
           +------------+                          +------------+
                        |    Simulate, Control     |
                        |                          |
                        +-----+--------------+-----+
                              |              |
                              |   Mappping   |
                              |              |
                              +--------------+
```

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.

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.

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 netowrk. Therefore, DTN can be an important enabler platform to implement IBN system and speed up the deployment of IBN in customer's network.

4. 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.

- 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.

- 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.

- 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.

- 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.

5. 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.

6. Security Considerations

TBD.

7. IANA Considerations

This document has no requests to IANA.

8. References

8.1. Normative References

[RFC2119] Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels", BCP 14, RFC 2119, DOI 10.17487/RFC2119, March 1997, <https://www.rfc-editor.org/info/rfc2119>.

8.2. Informative References

[I-D.irtf-nmrg-ibn-concepts-definitions] Clemm, A., Ciavaglia, L., Granville, L., and J. Tantsura, "Intent-Based Networking - Concepts and Definitions", draft-irtf-nmrg-ibn-concepts-definitions-01 (work in progress), March 2020.

[Tao2019] Tao, F., Zhang, H., Liu, A., and A. Nee, "Digital Twin in Industry: State-of-the-Art. IEEE Transactions on Industrial Informatics, vol. 15, no. 4.", April 2019.

Authors' Addresses

Cheng Zhou
China Mobile
Beijing 100053
China

Email: zhouchengyjy@chinamobile.com

Hongwei Yang
China Mobile
Beijing 100053
China

Email: yanghongwei@chinamobile.com

Xiaodong Duan
China Mobile
Beijing 100053
China

Email: duanxiaodong@chinamobile.com