GISC 2024

Global ICT Standards Conference 2024

2024. 11. 4.(MON) ~6.(WED)

ELTOWER GRACE Hall 6F

(세션2) 디지털 콘텐츠: 포용성장을 위한 디지털 콘텐츠 표준의 미래

가상과 현실의 연결: 네트워크 디지털 트윈 표준 최신 동향과 AI의 역할

한연희 교수, 한국기술교육대학교

ICT Standards and Intellectual Property : Inclusive Innovation

주최 과학기술정보통신부 특허청 주관 국립전파연구원 TTA IITP KEA kisto ETRI

Index

네트워크 디지털 트윈의 개념 및 필요성

01. 디지털 트윈 – History & Definition

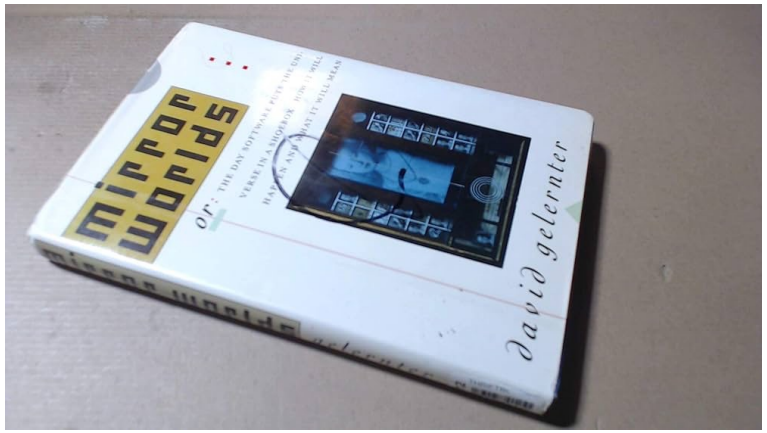
Wikipedia

"Digital twins were anticipated by David Gelernter's 1991 book Mirror Worlds."

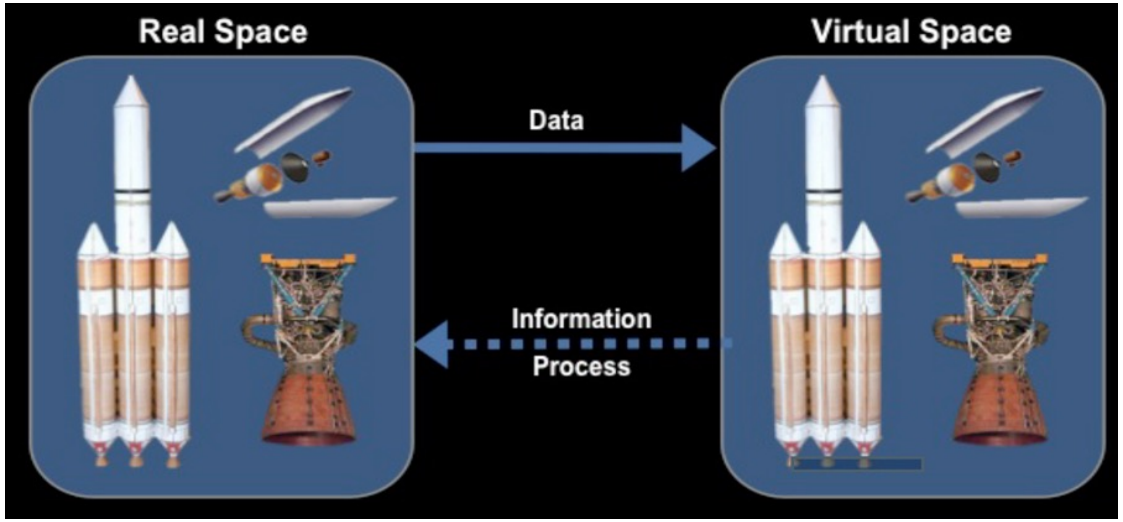
"… the first practical definition of a digital twin originated from NASA in an attempt to improve the physical-model simulation of spacecraft (or rocket) in 2010 …"

"… called the 'digital twin' by John Vickers of NASA …"

[source] https://en.wikipedia.org/wiki/Digital_twin



David Hillel Gelernter (Oct. 1991)



An Early Digital Twin Concept

01. 디지털 트윈 – History & Definition

IBM

"A digital twin is a virtual representation of an object or system that spans its lifecycle, is updated from real-time data, and uses simulation, machine learning, and reasoning to help decision-making."

IBM

"디지털 트윈은 객체 또는 시스템의 가상 표현으로, 생애주기 동안 실시간 데이터로 업데이트되며, 시뮬레이션, 기계 학습, 추론을 사용하여 의사 결정을 돕는다."

HPE (Hewlett Packard Enterprise)

"A Digital Twin is a virtual copy of a physical asset that incorporates real-time data captured via sensors. By integrating a multiphysics simulation model, IoT, and machine learning, a Digital Twin can enhance the product."

HPE (Hewlett Packard Enterprise)

"디지털 트윈은 물리적 자산의 가상 복사본으로, 센서를 통해 수집된 실시간 데이터를 통합한다. 다중 물리학 시뮬레이션 모델, IoT, 기계 학습을 통합하여 제품을 향상시킬 수 있다."

Wikipedia

"A digital twin is a digital model of an intended or actual real-world physical product, system, or process (a physical twin) that serves as the effectively indistinguishable digital counterpart of it for practical purposes, such as simulation, integration, testing, monitoring, and maintenance."

Wikipedia

"디지털 트윈은 실제 세계의 물리적 제품, 시스템, 또는 프로세스(물리적 트윈)의 디지털 모델로, 시뮬레이션, 통합, 테스트, 모니터링, 유지 보수 등의 실용적인 목적을 위해 물리적 자산과 구분이 되지 않는 디지털 대응체로 기능한다."

02. 자동화 (Automation)

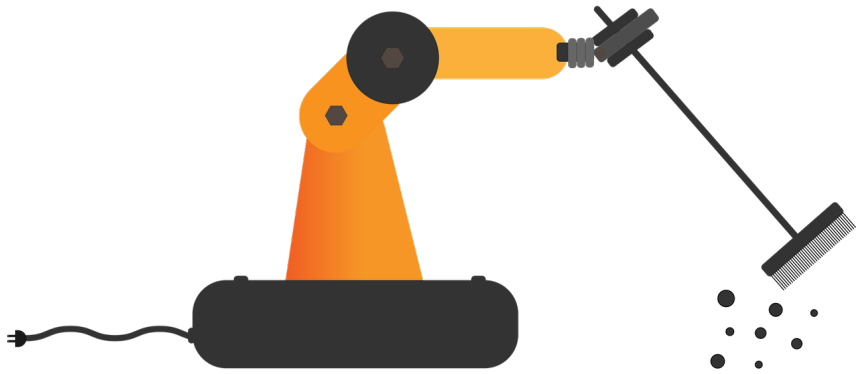
1. Enhancing Human Capability

[source] http://www.allcsn.co.kr/news/view.html?section=116&no=3246&category=117

02. 자동화 (Automation)

2. Reducing Human Error

- Several significant human errors have occurred in the past year
- This is not a new phenomenon.
- How many incidents go unreported?



PROS

- Automation performs tasks:
  - Faster
  - More reliably
  - With fewer errors

CONS

- Automation can amplify the consequences of an error, potentially increasing the damage.

- **Key Questions**:
  - Can automation detect errors?
  - Can automation effectively fix issues?
  - Does automation solve the problems?

03. 테스팅 (Testing)

1. Testing's Role

- We can't prove that automation is correct and error-free
- But, testing can reduce common cause and thus the probability of error

2. Types of Testing

Functional Tests

Regression Tests

Generally done on a laptop
or on a small laboratory network

Scaling Tests

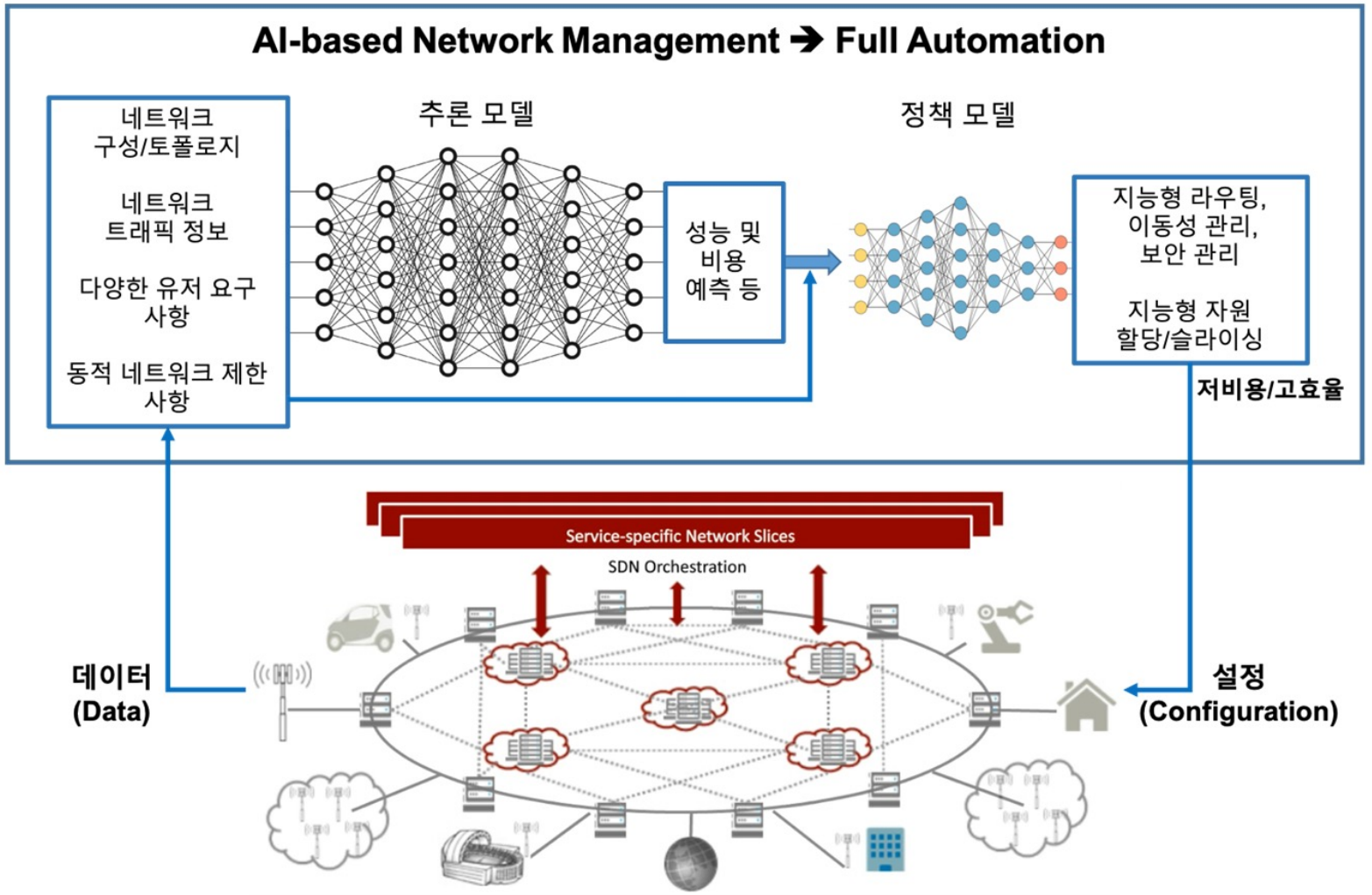
Real-world Tests

These tests find the most bugs,
corner cases, and weird behaviors

04. 인공지능 (AI)

1. AI's Role

- Aggregates critical data for analyzing the root causes of network failures, anomalies, vulnerabilities, etc.
- Suggest (or execute) remedial action!



04. 인공지능 (AI)

2. Limitation of AI's Role

Scaling Tests

Real-world Tests

These tests find the most bugs, corner cases, and weird behaviors

"테스트하는 동안 네트워크는 얼마나 자주 중단되나요?"

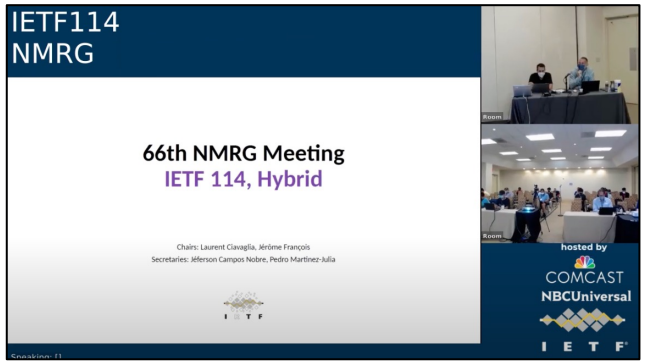
"테스트를 위하여 필요한 네트워크 상태 (Controlled Situation)는 어떻게 마련하나요?"

"AI 모델 훈련을 위한 대규모의 다양한 데이터는 어떻게 마련하나요?"

"실제 네트워크에서 발생하는 장애나 변동성에 적응하는 AI 모델 능력은 어떻게 향상시킬 수 있나요?"

네트워크 디지털 트윈 표준 (IETF NMRG)

01. IETF NMRG (Network Management Research Group)



1. Goal: 네트워크 관리 및 운영에 관련된 연구를 촉진하고, 새로운 기술 및 방법론을 탐구하여 네트워크 관리의 효율성 향상

2. Creation: March 14, 1999

3. Chairs

- Jérôme François (University of Luxembourg and Inria)
- Laurent Ciavaglia (Nokia)

4. Charters

- Autonomic Networking (**자율 네트워킹**)
- Intent-Based Networking (IBN, **의도 기반 네트워킹**)
- Coupling between AI and Network Management (**AI와 네트워크 관리**)
- Network Digital Twin (**네트워크 디지털 트윈**)

01. IETF NMRG (Network Management Research Group)

1. Documents

RFCs (6 hits)

RFC 9315 **Intent-Based Networking - Concepts and Definitions**	23 pages	2022-10	Informational RFC
RFC 9316 **Intent Classification** Errata	35 pages	2022-10	Informational RFC
RFC 8316 **Autonomic Networking Use Case for Distributed Detection of Service Level Agreement (SLA) Violations**	16 pages	2018-02	Informational RFC
RFC 7575 **Autonomic Networking: Definitions and Design Goals**	16 pages	2015-06	Informational RFC
RFC 7576 **General Gap Analysis for Autonomic Networking**	17 pages	2015-06	Informational RFC
RFC 5345 **Simple Network Management Protocol (SNMP) Traffic Measurements and Trace Exchange Formats** Errata	23 pages	2008-10	Informational RFC

Active Internet-Drafts (2 hits)

draft-irtf-nmrg-network-digital-twin-arch-07 **Network Digital Twin: Concepts and Reference Architecture**	34 pages	2024-09-26	I-D Exists Active RG Document : Informational
draft-irtf-nmrg-green-ps-03 **Challenges and Opportunities in Management for Green Networking**	34 pages	2024-06-28	I-D Exists IRSG Review : Informational

2. Meetings

Future Meetings

Meeting	Date	Materials
IETF 121	2024-11-07 22:00-00:00 KST	Agenda Minutes Materials
IETF 121	2024-11-09 00:30-02:00 KST	Agenda Minutes Materials

Past Meetings (within the last four years)

Search

Meeting	Date	Materials
interim-2024-nmrg-03	2024-10-08 19:00-21:00 KST	Agenda Minutes Materials
IETF 120	2024-07-26 05:00-06:30 KST	Agenda Minutes Materials
IETF 120	2024-07-23 07:30-09:00 KST	Agenda Minutes Materials
interim-2024-nmrg-02	2024-06-25 19:00-20:00 KST	Agenda Minutes Materials
IETF 119	2024-03-22 08:30-10:30 KST	Agenda Minutes Materials
interim-2024-nmrg-01	2024-02-06 20:00-21:30 KST	Agenda Minutes Materials
IETF 118	2023-11-10 21:00-23:00 KST	Agenda Minutes Materials
interim-2023-nmrg-02	2023-10-20 21:00-23:00 KST	Agenda Minutes Materials
IETF 117	2023-07-28 09:00-10:00 KST	Agenda Minutes Materials
IETF 117	2023-07-26 09:00-10:00 KST	Agenda Minutes Materials
interim-2023-nmrg-01	2023-05-10 06:30-07:30 KST	Agenda Minutes Materials
IETF 116	2023-03-29 15:30-17:00 KST	Agenda Minutes Materials

02. Digital Twin Network: Concepts and Reference Architecture

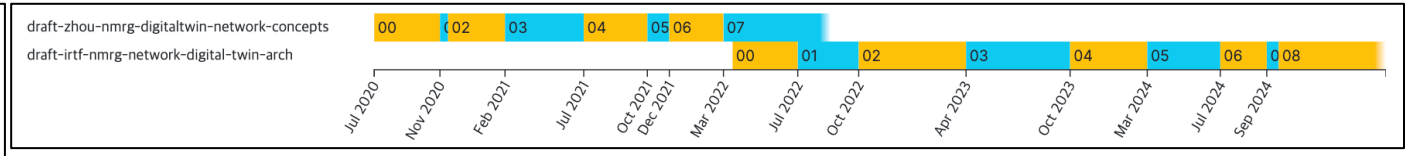
Network Management — C. Zhou
Internet-Draft — H. Yang
Intended status: Informational — X. Duan
Expires: 19 April 2025 — China Mobile
D. Lopez
A. Pastor
Telefonica I+D
Q. Wu
Huawei
M. Boucadair
C. Jacquenet
Orange
16 October 2024

Network Digital Twin: Concepts and Reference Architecture
draft-irtf-nmrg-network-digital-twin-arch-08

Abstract

Digital Twin technology has been seen as a rapid adoption technology in Industry 4.0. The application of Digital Twin technology in the networking field is meant to develop various rich network applications, realize efficient and cost-effective data-driven network management, and accelerate network innovation.

This document presents an overview of the concepts of Digital Twin Network, provides the basic definitions and a reference architecture, lists a set of application scenarios, and discusses such technology's benefits and key challenges.



中国移动 China Mobile

Telefónica

HUAWEI

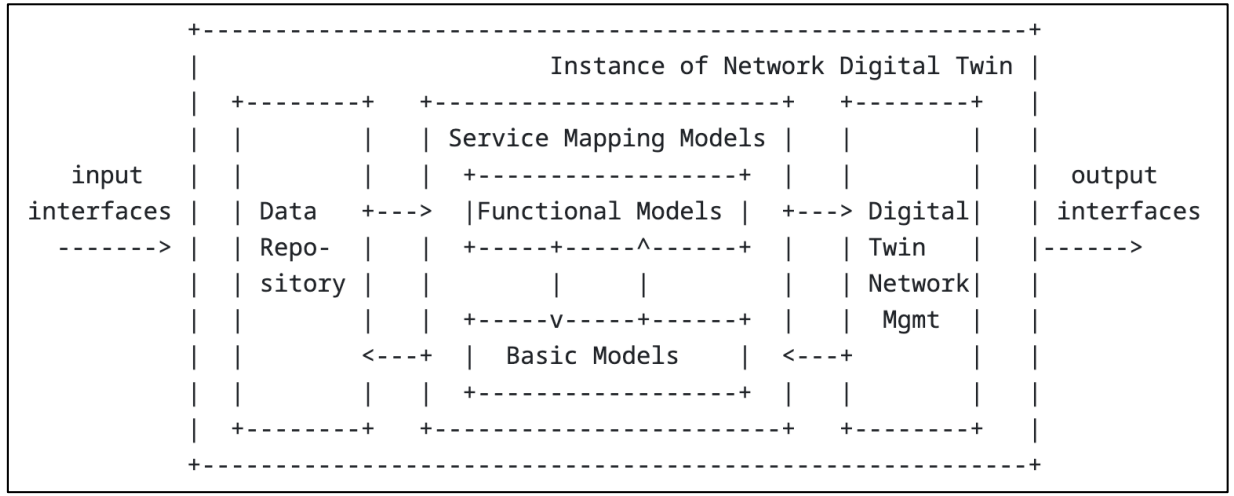
02. Digital Twin Network: Concepts and Reference Architecture

1. Network Digital Twin (NDT)

- A digital twin for networks can be created by applying Digital Twin technologies to networks, resulting in a virtual replica of real network facilities (emulation).

- A Network Digital Twin (NDT) is **an advanced platform for network emulation**, serving as a tool for scenario planning, impact analysis, and change management.

- Unlike conventional network simulation, it features an **interactive virtual-real mapping and a data-driven approach to establish closed-loop network automation**.



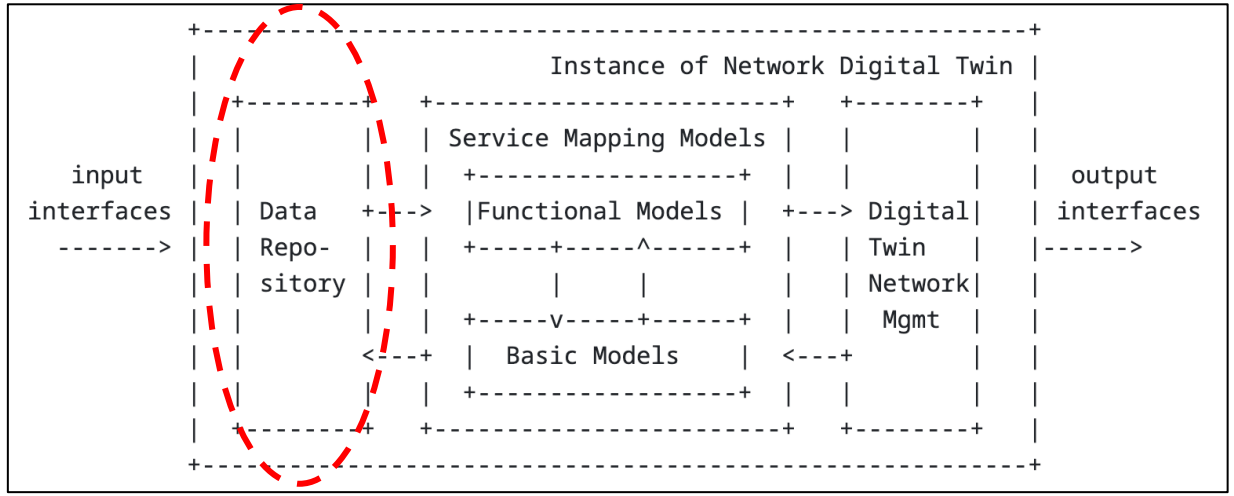
Reference Architecture of Network Digital Twin

02. Digital Twin Network: Concepts and Reference Architecture

2. NDT Reference Architecture

Data Repository

- **Operational Data**
  - **네트워크 대역폭 사용량**
  - **패킷 전송 및 수신량**
  - **사용자 세션의 수와 지속 시간**
  - **시스템 가동 시간(uptime)**
  - **처리 속도와 성능**
- **Instrumentation Data**
  - **CPU 사용률, 메모리 사용량**
  - **시스템 온도, 전력 소비량**
  - **장비의 동작 상태, 로그 데이터, 오류 발생률**
  - **시스템 내부에서 발생하는 이벤트, 트랜잭션**
- **Data services to a Service Mapping Models**
  - fast retrieval, concurrent conflict handling
  - batch service



Reference Architecture of Network Digital Twin

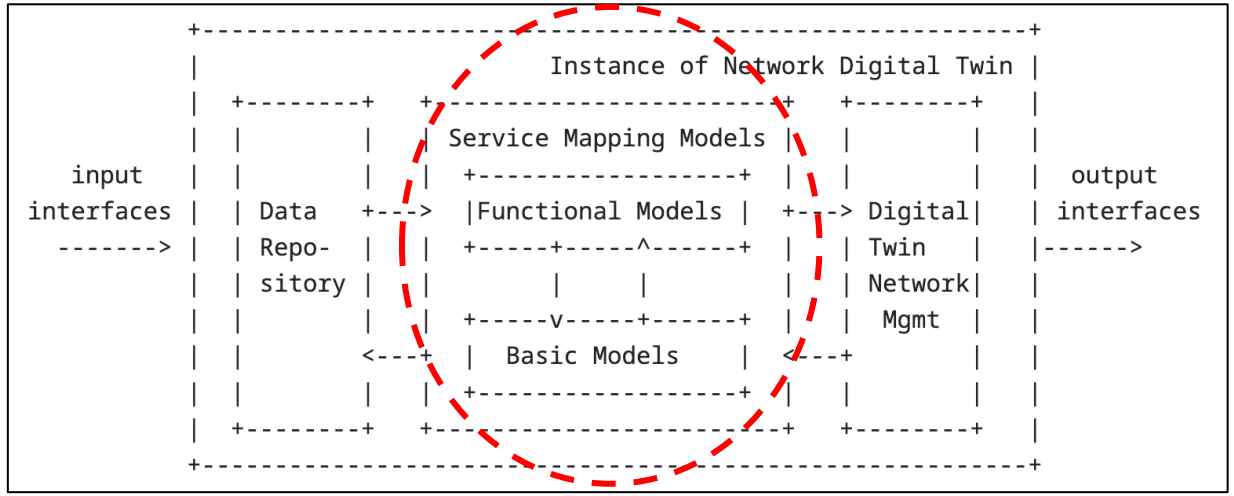
02. Digital Twin Network: Concepts and Reference Architecture

2. NDT Reference Architecture

Service Mapping Models

- **Functional Models**
  - models related to state monitoring, traffic analysis, security, fault diagnosis, quality assurance, planning, construction, maintenance, optimization and operation.
  - used to generate information supporting network analysis, emulation, diagnosis, prediction, assurance, etc

- **Basic Models**
  - network elements & network topology
  - used to reflect the basic configuration, environment information, operational state, link topology, etc. of the network and its elements



Reference Architecture of Network Digital Twin

02. Digital Twin Network: Concepts and Reference Architecture

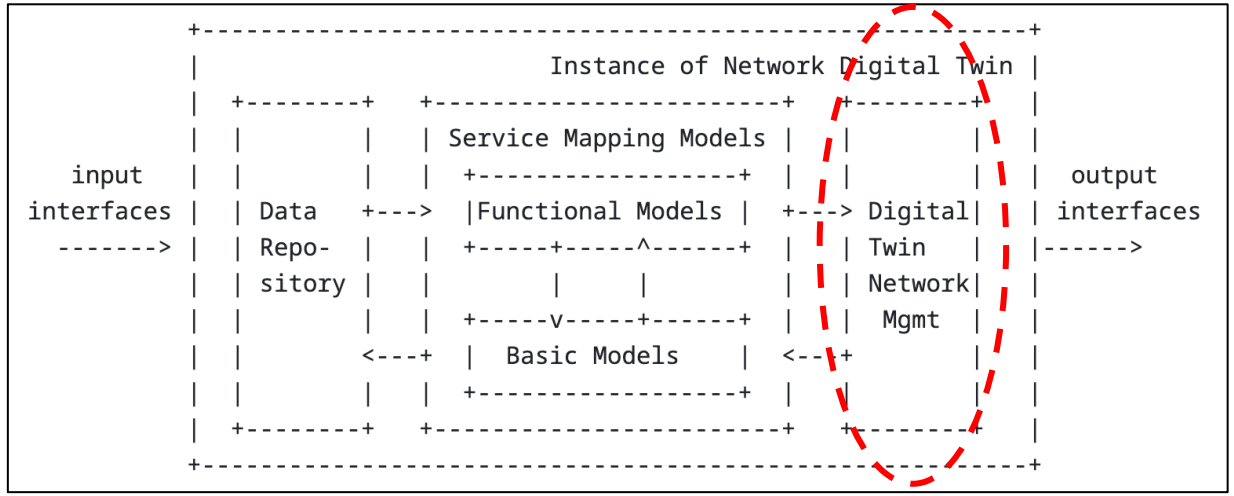
2. NDT Reference Architecture

Digital Twin Network Management

- It manages the session-based operation of the NDT, managing the life-cycle of these operations under the direction of associated applications

- It monitors the performance and resource consumption of the NDT (including individual models)

- It controls various operational aspects of the NDT,
  - configuration management
  - performance management
  - ecurity management.



Reference Architecture of Network Digital Twin

02. Digital Twin Network: Concepts and Reference Arch

3. NDT Use Case

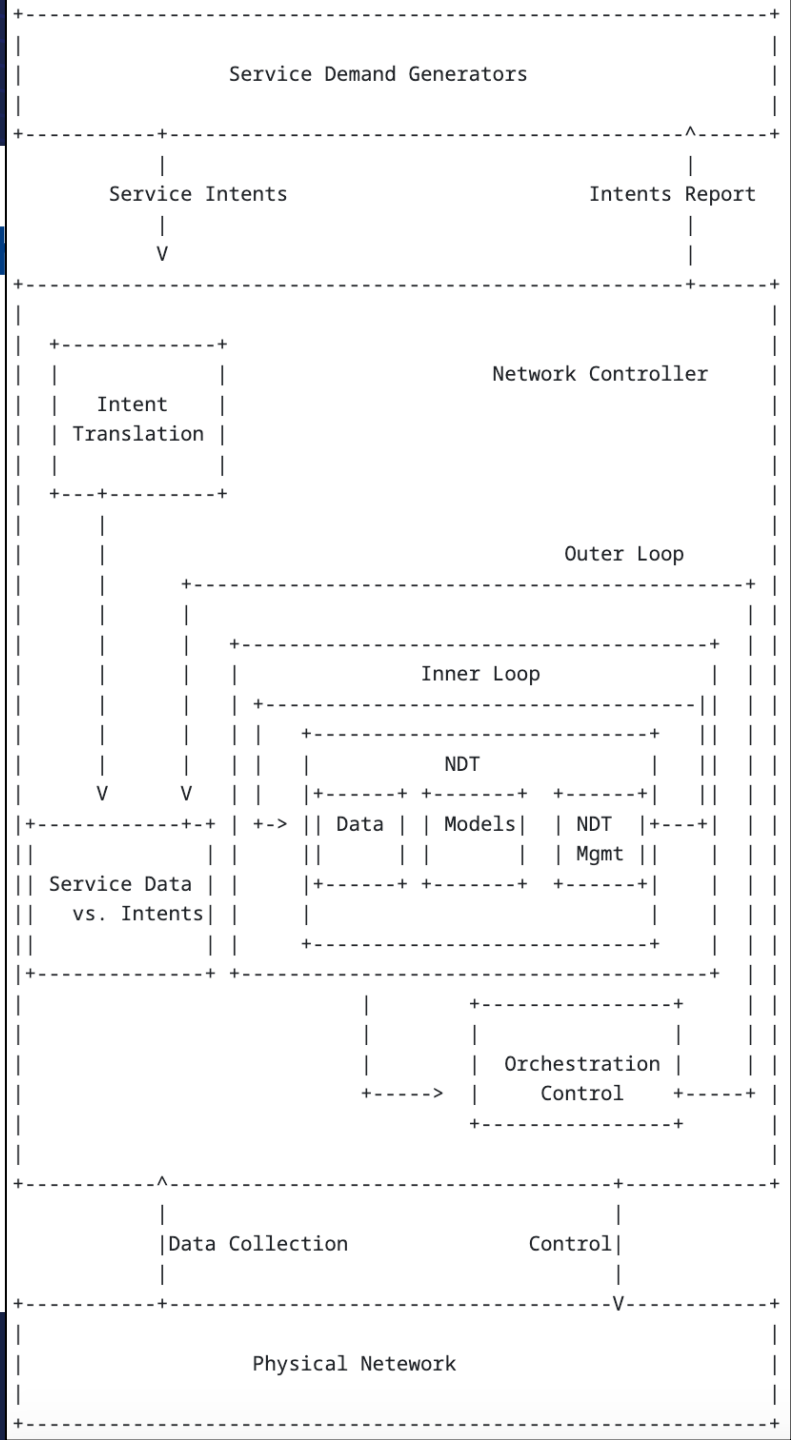
인텐트 기반 NDT 응용

- “외부” 루프는 인텐트로 설정된 목표 서비스와 실제로 관찰된 서비스 특성 간의 격차를 감지하고, 관찰된 편차를 완화하기 위한 후보 해결책을 제안하고, 또한, 그 해결책을 네트워크에 적용하는 과정을 요청

- NDT 내에서 이러한 해결책을 찾는 과정은 “내부” 루프에 의존하며, 여기서 NDT는 가상 공간에서 “샌드박스” 역할을 하여 잠재적 해결책을 제안하고 그 해결책이 서비스에 미치는 영향을 평가

- 이 과정은 만족스러운 해결책이 나올 때까지 반복될 수 으며, 여러 반복 이후 선택된 해결책은 외부 루프에 전달되어 실행.

NDT를 사용하여 가상 공간에서 최적화 기준에 따른 해결책을 반복적으로 찾고, 그 해결책은 운영 시스템의 다른 활성화된 구성 요소에 제공

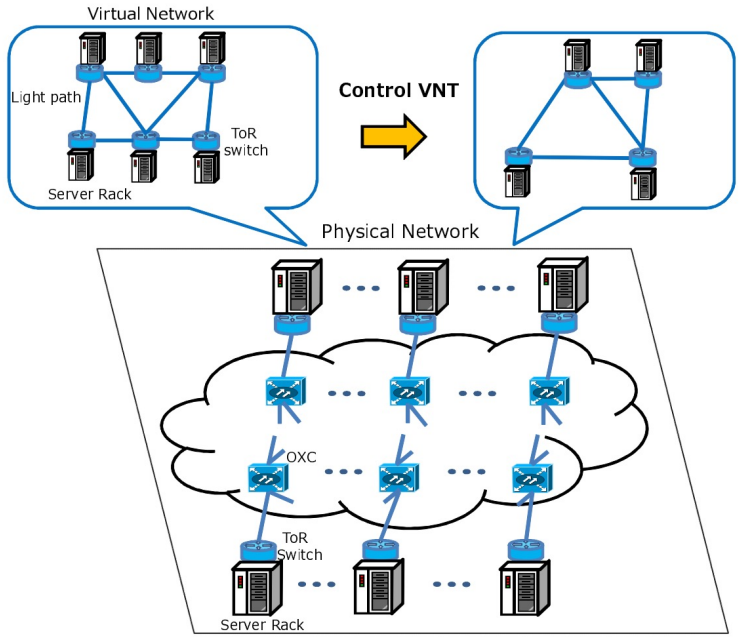


네트워크 디지털 트윈과 AI의 역할

01. NDT Application Scenarios

- Human Training (Education)
- Machine Learning Training & Inference (Prediction)
- DevOps-Oriented Certification
- Network Fuzzing (Experiment)
- Network Inventory Management
- Data Generation

02. NDT + AI + Testing



Nodes, Links, Traffic in an NDT

1. **The nodes and links in the NDT are virtual**
   - A node in the NDT runs the same OS, control plane and management plane as a “real” node
   - A link in the NDT is a virtual link that generally represents a “logical interface”

2. **Traffic in an NDT is artificially created, typically by traffic generators**

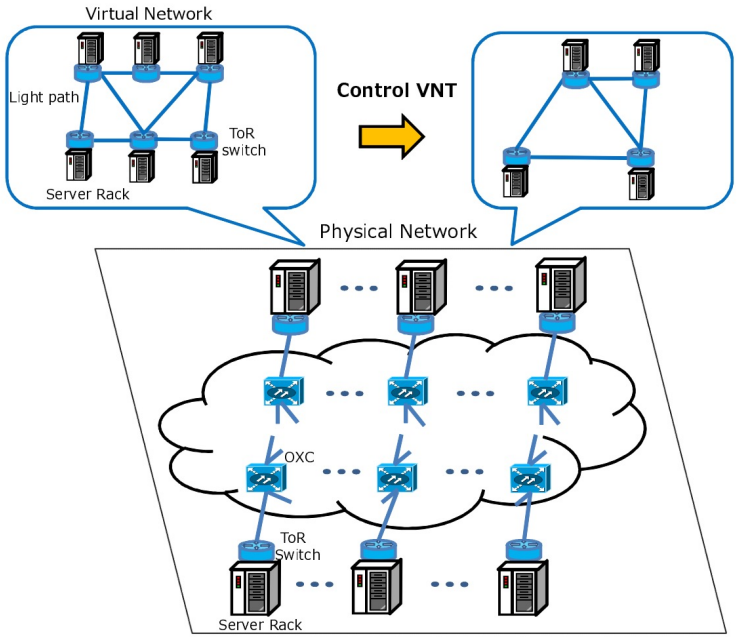
NDT allows you to clone a network for …

… recreating a problem, and trying out fixes

… looking at the past, the present, the probable, the possible, the never-to-be

[source] https://www.researchgate.net/figure/Data-center-network-using-OCSs-and-ToR-switches_fig1_266255576

02. NDT + AI + Testing



The environment is under your control in a Digital Twin!

1. On a digital twin, you can simulate many faults under various conditions and learn
2. You can also run simulations faster to get behavior trends, thus start predicting
3. “What happened” analysis & “What if” scenarios

[source] https://www.researchgate.net/figure/Data-center-network-using-OCSs-and-ToR-switches_fig1_266255576

03. Fidelity

A digital twin's utility increases dramatically as its fidelity to real systems increases

Whether one is interested in …

Human Training (Education)

Machine Learning Training & Inference (Prediction)

DevOps-Oriented Certification

Network Fuzzing (Experiment)

Network Inventory Management

Data Generation

The results will better reflect actual behavior, the more faithful the digital twin is

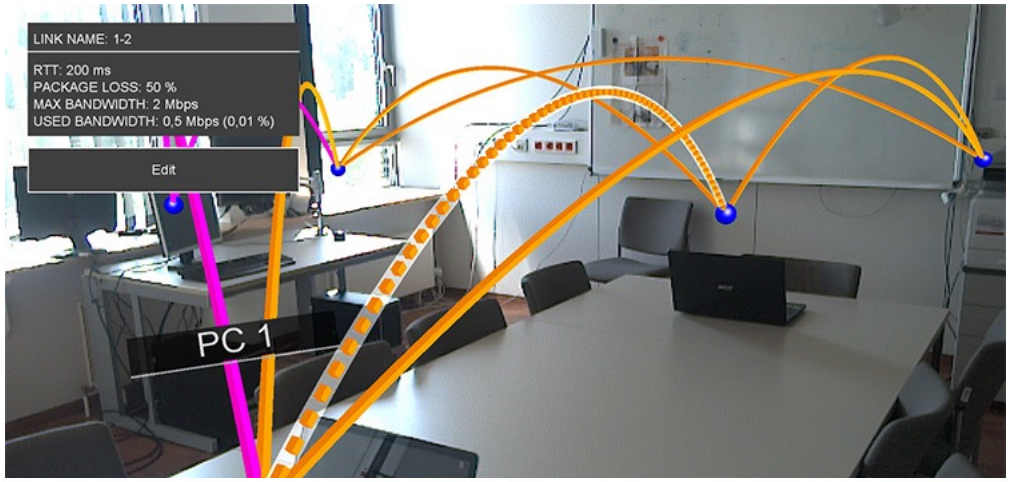
However, fidelity comes at a cost

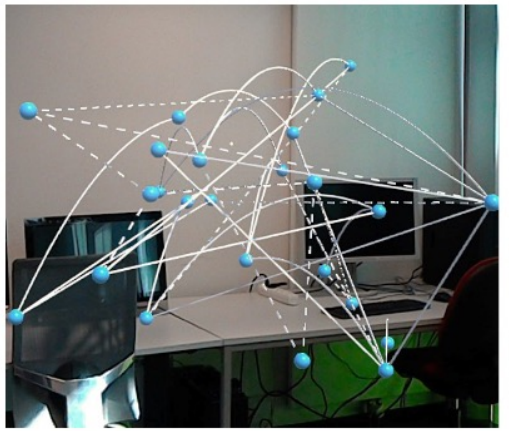
- One must target fidelity based on desired and potential use cases

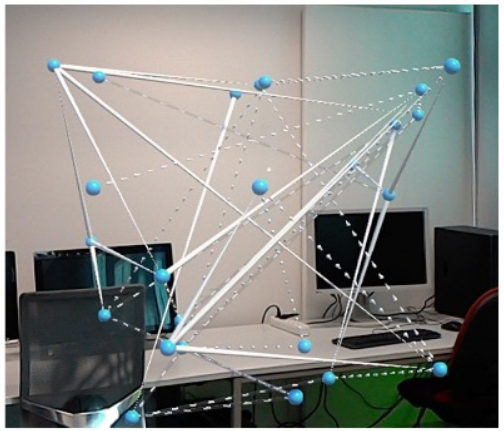
04. Network Visualization

- Help users better understand the internal structure of the network, and mine valuable information hidden in the network
  - Network topology visualization
  - Modelling visualization
    - ➢ Increase the interpretability of AI models.

- Interaction methods
  - The data query technology such as SPARQL to express queries across diverse data sources
  - Visual dynamic interaction: direct interaction, focus plus context interaction, relevance interaction and immersive simulation; XR (AR, VR and MR) etc.





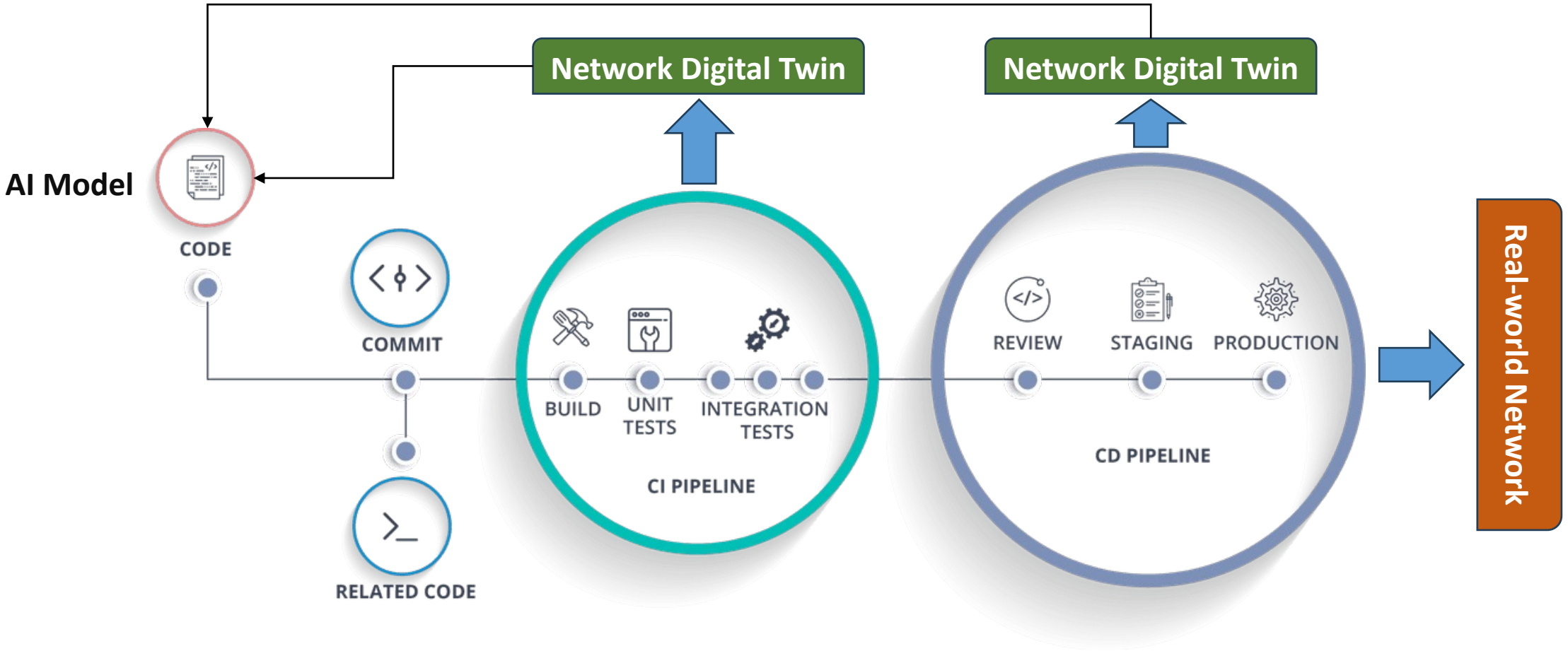


Augmented Reality Graph Visualizations

[source] https://imld.de/en/research/research-projects/ar-graph-vis/

CI/CD: Continuous Integration/Continuous Deployment

05. Testing: "CI/CD" like Pipeline



[source] https://solidstudio.io/blog/ci-cd-pipelines

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감사합니다.

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