IOWN-GF
Network Digital Twin

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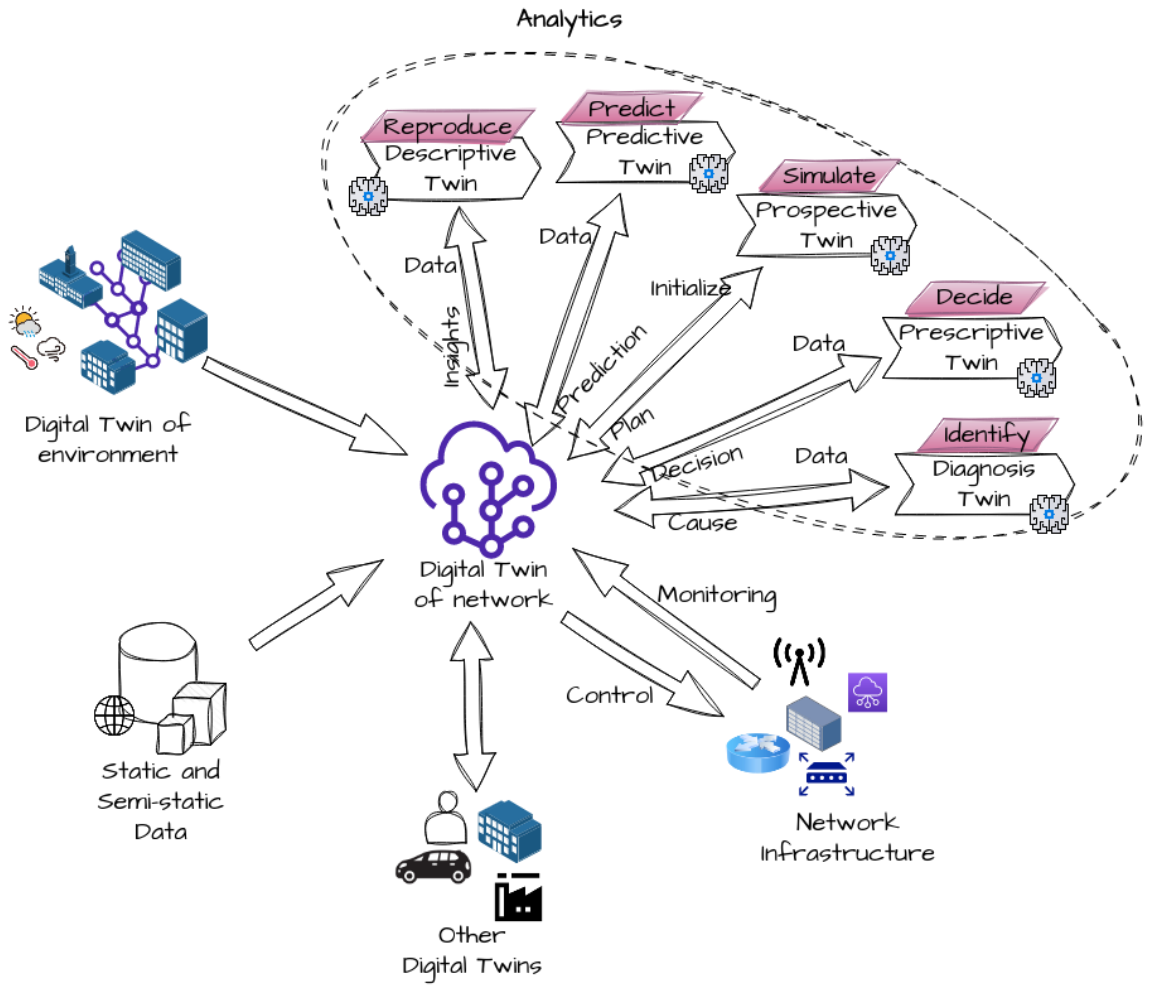
Network Digital Twin concept



ETSI ISG CIM [1] defines different capabilities for the Digital Twin

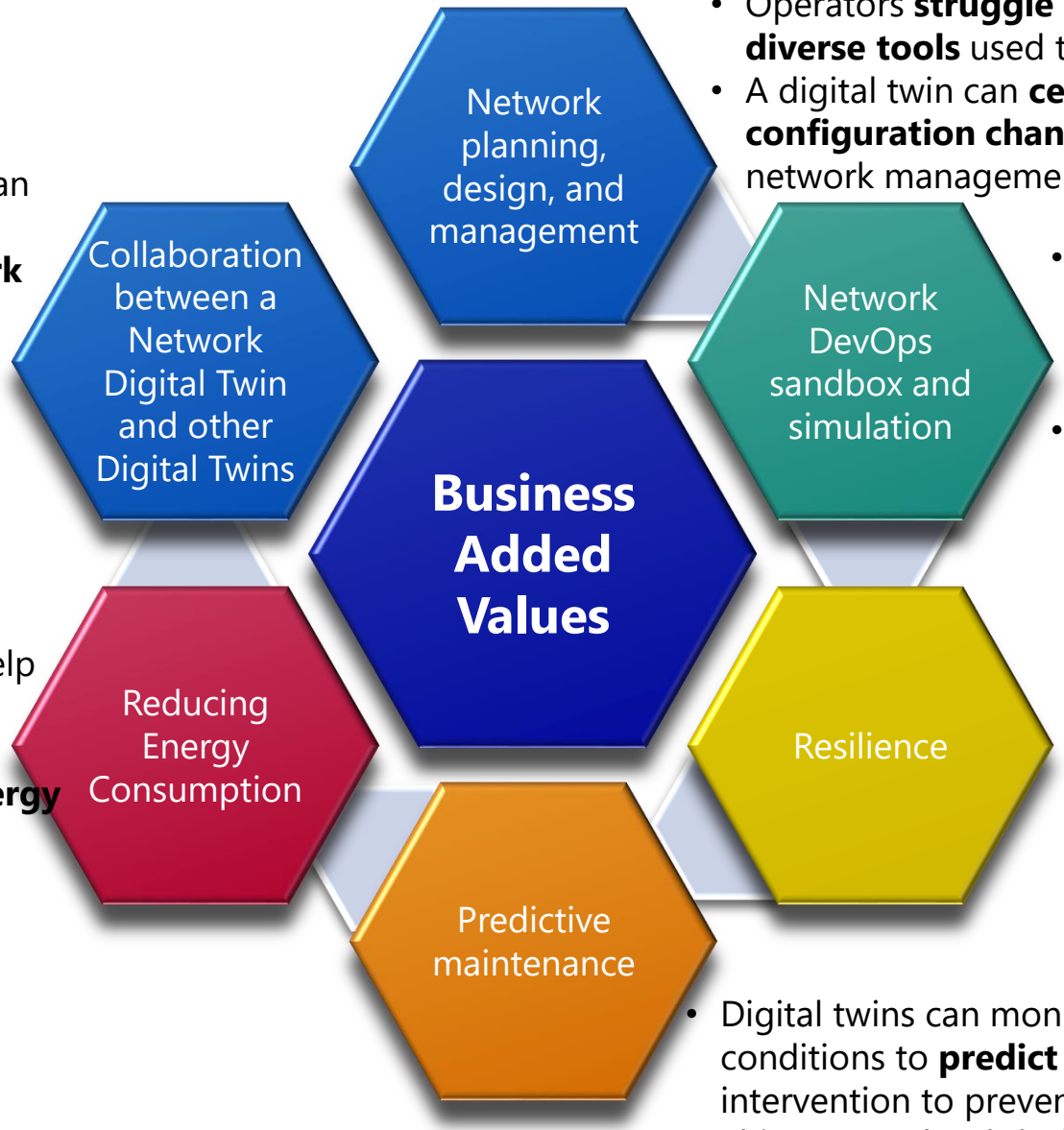
- Descriptive Twin*:* **current status** of the digital twin that includes:
  - observations
  - inferred insights not directly observed through monitoring (e.g., anomaly detection or pattern recognition)
  - from different stakeholders and administrative domains
- Predictive Twin: **predicts future status** of the network given the current status and the past recorded behaviours (e.g., foreseen failure in the network)
- Prospective Twin*:* **simulate hypothetical** (“**what-if**”) **scenarios** given the current understanding of the network comprising of the descriptive (monitoring and insight inference) and predictive modules.
- Prescriptive Twin*:* functions to **decide upon actions** aiming at having the network in a target state.
- Diagnosis Twin*:* **understand the causes** of a detected situation into the network.

[1] Context Information Management (CIM); Feasibility of NGSI-LD for Digital Twins. https://www.etsi.org/deliver/etsi_gr/CIM/001_099/017/01.01.01_60/gr_CIM017v010101p.pdf

Business Added Values

- Digital twins of networks and cities can collaborate to manage events, **optimizing both traffic and network resources**.

- By **analyzing network waste and configuration impact**, digital twins help optimize energy usage.
- Decisions based on real-time data to **dynamically reduce unnecessary energy expenditure**.



- Operators **struggle to manage network** knowledge due to **diverse tools** used throughout the network lifecycle.
- A digital twin can **centralize network inventory and configuration changes**, improving team collaboration and network management.

- A digital twin allows **services to be simulated and tested before deployment**, ensuring interoperability between devices.
- It also supports **large-scale scenario simulations** like DDoS attack mitigation.

- As networks become critical, ensuring **resilience** through **robustness** and **quick recovery** is essential.
- Digital twins can optimize **preventive maintenance** to enhance system robustness and recovery speed.

- Digital twins can monitor network devices and external conditions to **predict failures**, enabling timely intervention to prevent disruptions.
- This approach **minimizes unexpected service interruptions**.

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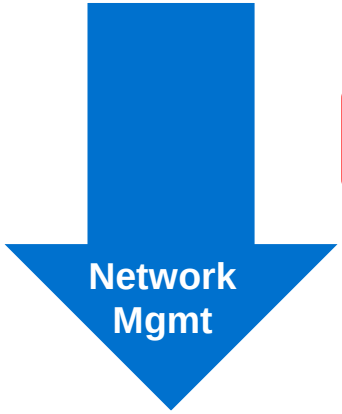
Network Digital Twin use cases

Network Digital Twin for vertical applications

- Green Twin
- Radio Communication Environment
- Metaverse Event



Network Digital Twin for network management

- CPS Network Infrastructure Management
- Optical Network Infrastructure Management
  - ➢Failure detection and route selection for service restoration in multi-layer networks
  - ➢QoT estimation and its application to NW resource optimization
- Time Variable Routing (TVR) predictions
- Security Traffic Analysis
- Gen AI-Powered Digital Twin for Autonomous Operation

Technical work
planned for CY2025

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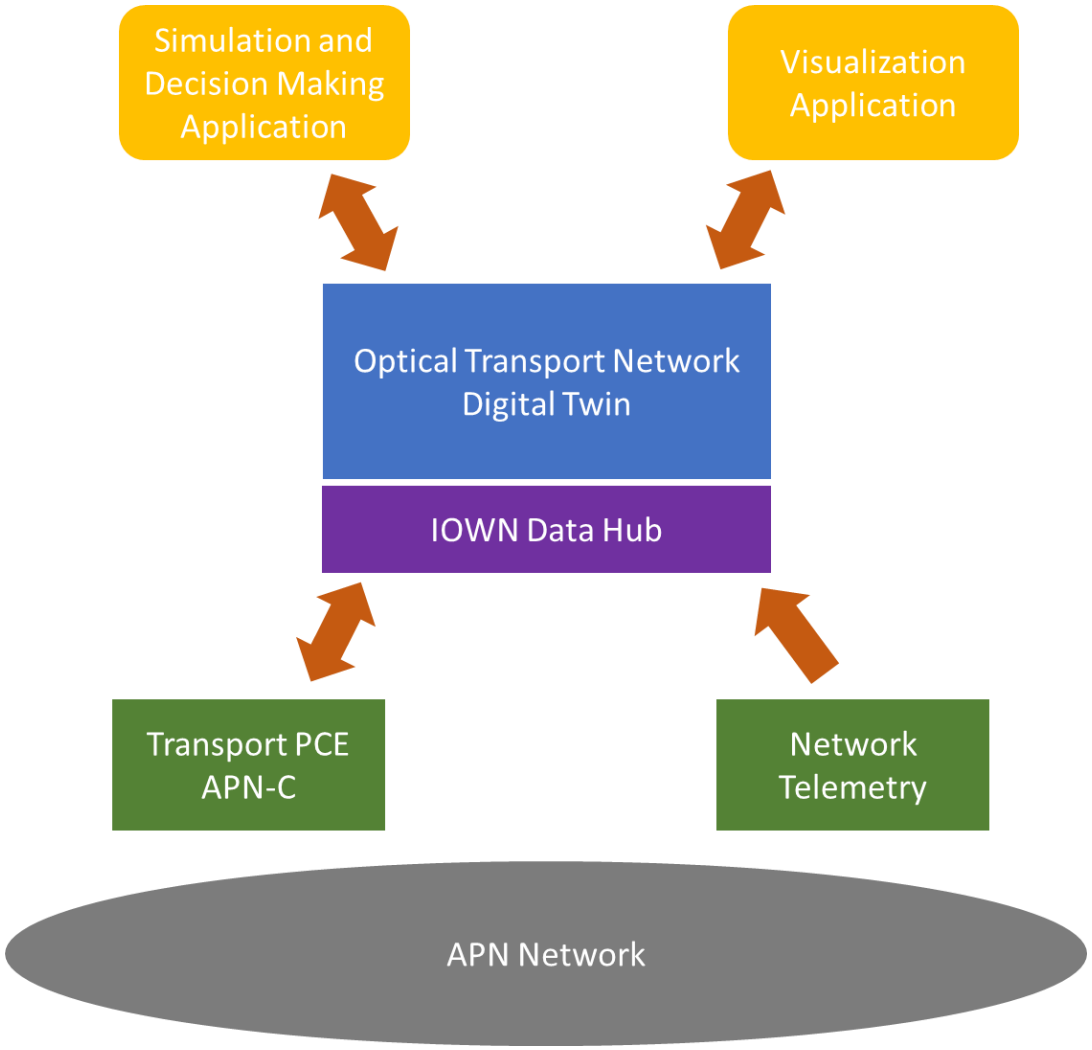
Optical Network Infrastructure Management

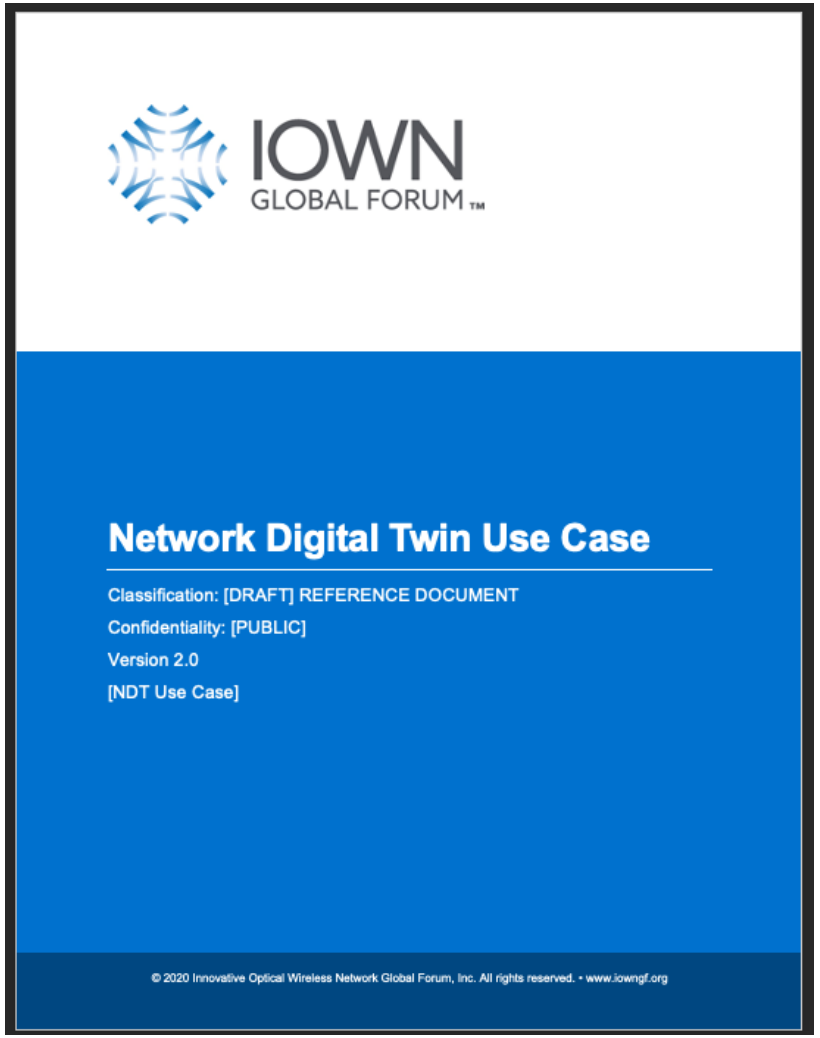


- **Visualization of network topology and state**:
  Digital Twins provide unified 2D/3D visualizations across network layers for better visibility and tool compatibility.
- **Real-time monitoring**:
  A Digital Twin allows real-time monitoring of network performance to quickly detect and resolve issues.
- **Performance prediction**:
  Simulations using the Digital Twin help predict network performance under varying conditions for better planning.
- **Resource Optimization**:
  The Digital Twin enables optimization of network resources by identifying bottlenecks and improving efficiency.
- **Troubleshooting and problem solving**:
  Digital Twins help compare current and expected network states to quickly locate and resolve issues.
- **Maintenance Scheduling**:
  Operators can proactively schedule maintenance by simulating its impact, minimizing disruptions.

Network Digital Twin Use Case

- **Network Digital Twin Use Case**

  - Focuses on Digital Twin use-cases for network management to reduce operation costs, increase resilience, and avoid disruption.



These Use Cases are available for download from the following URL: https://iowngf.org/use-cases/

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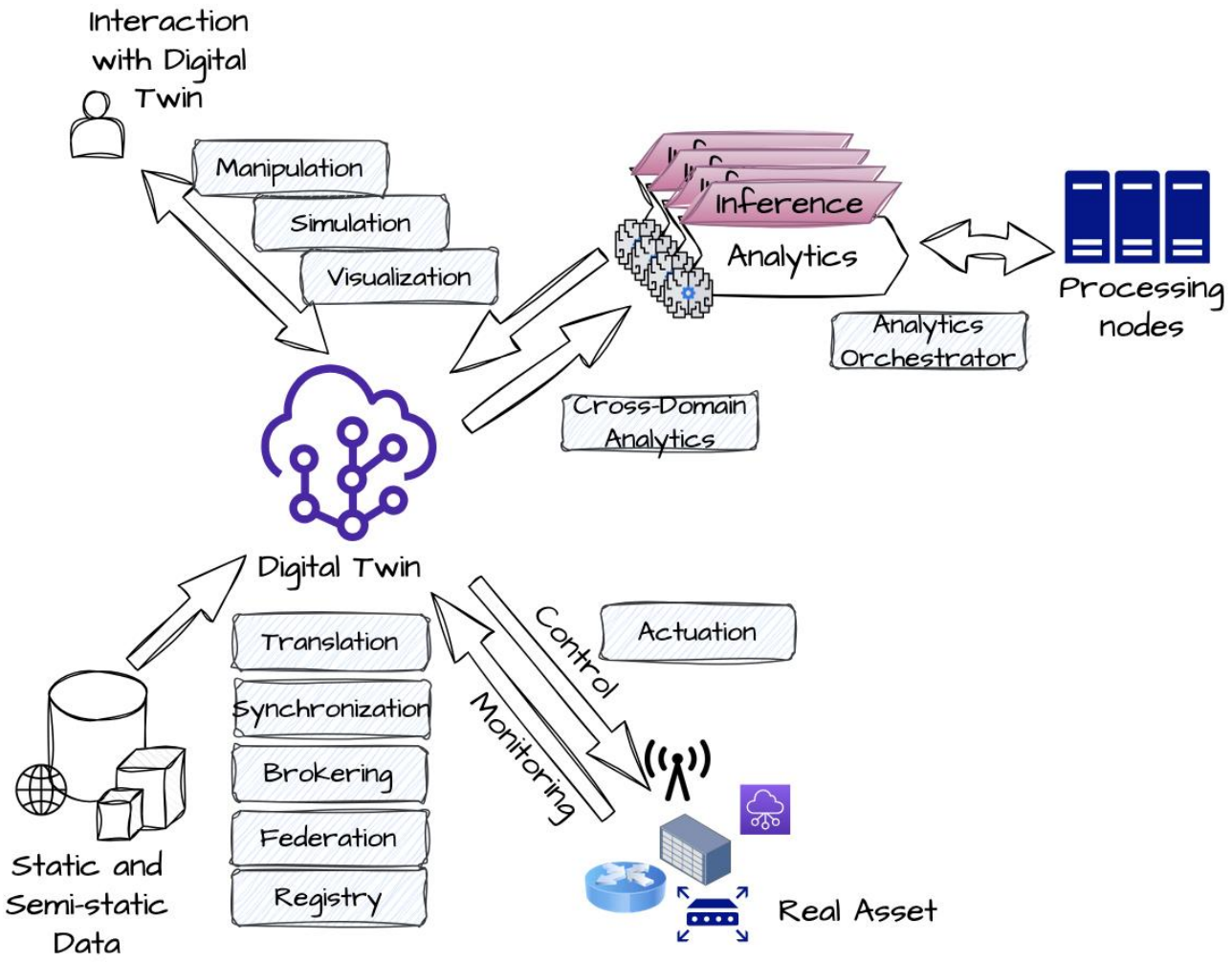
Functional Requirements

	CPS Network Infrastructure Management	Optical Network Infrastructure Management	Time Variable Routing (TVR) predictions	Gen AI-Powered Digital Twin for Autonomous Operation	Green Twin	Radio Communication Environment	Metaverse Event
Data Collection		✓	✓			✓	
Data storage and exchange		✓			✓	✓	✓
Interoperability	✓	✓		✓	✓		✓
Interfaces and data models		✓		✓	✓		✓
Efficient use of data	✓						
Data Analytics orchestration					✓		
Reliable data analytics					✓	✓	
Optimization	✓						
Digital Twin management							✓
Actuation	✓	✓	✓				✓
Visualization		✓					
Simulation		✓					✓
Data Security					✓	✓	

Digital Twin overview

- **Static and semi-static** data such a real asset description and specifications
- **monitored status** of the real asset such as through an IoT deployment
- Information about the **environment** of the digital twin such as spatial information or weather forecasts.
- **Other digital twins** of heterogeneous types.



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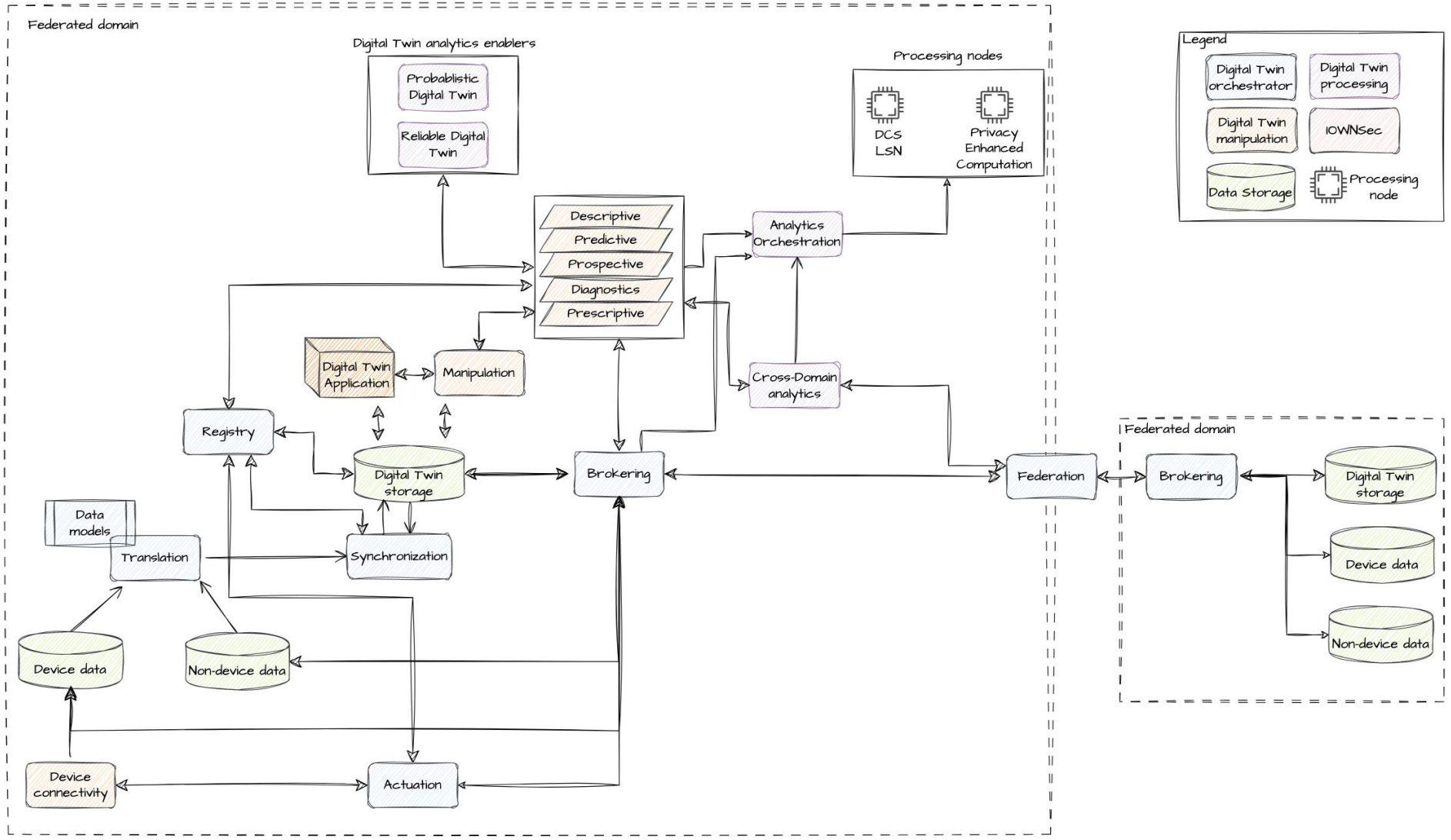
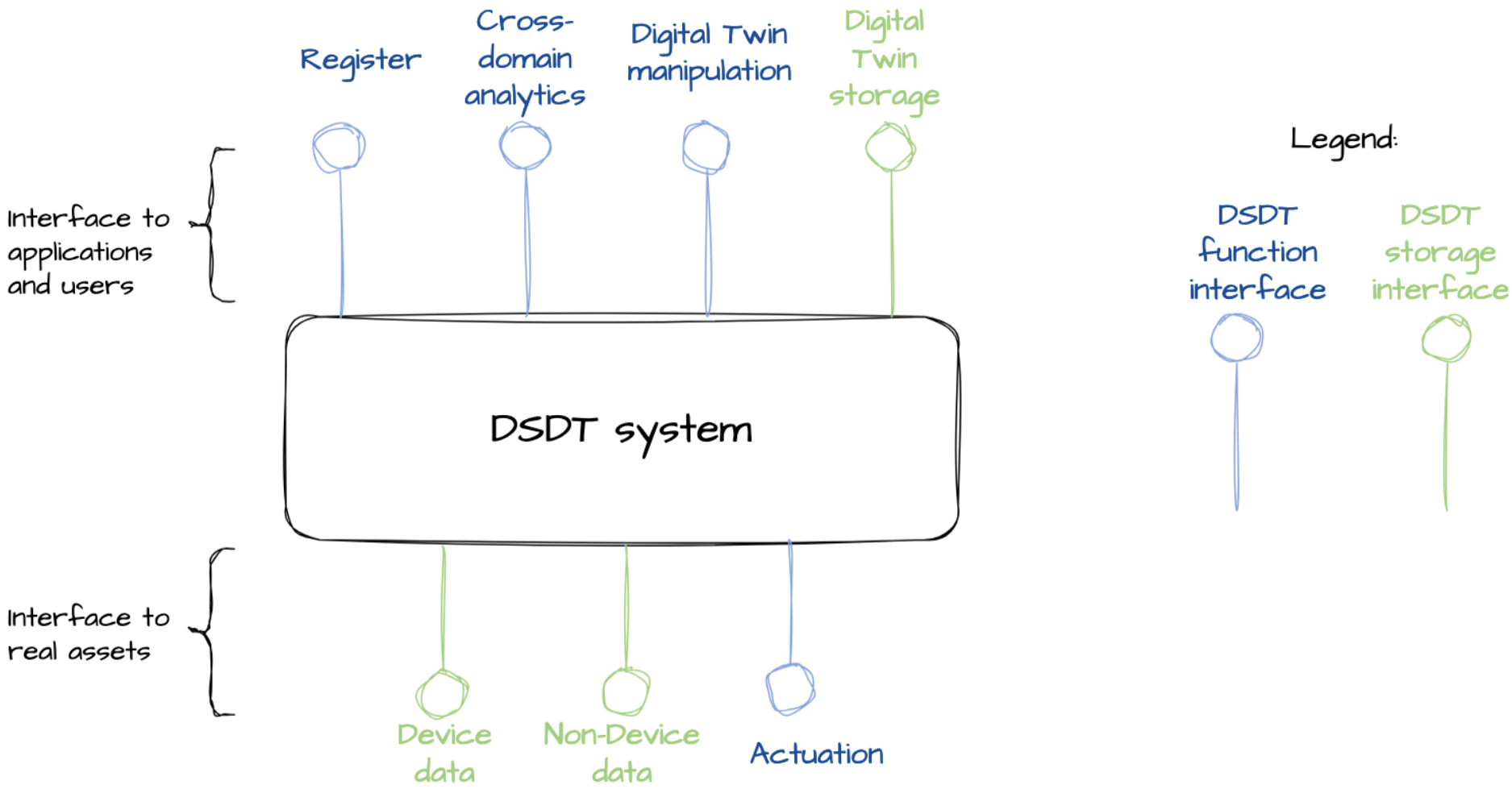
Digital Twin architecture



The functional overview for enabling the DSDT can be grouped in the following:

- **Digital Twin data handling** targets information sharing and interaction among heterogeneous stakeholders, each of them managing a different version of the same digital twin or other digital twins.
- **Digital Twin analytics** comprises functions to handles data analytics services in the data space across multiple stakeholders and in distributed and disaggregated processing nodes.
- **Digital Twin manipulation** comprises functions that enables the user to interact with the Digital Twin. Simulation and visualization offer opportunity to the users to have immediate view of the digital twin, manipulate it and see the effects, thus actuating the real world assets.

Interaction with external systems and users



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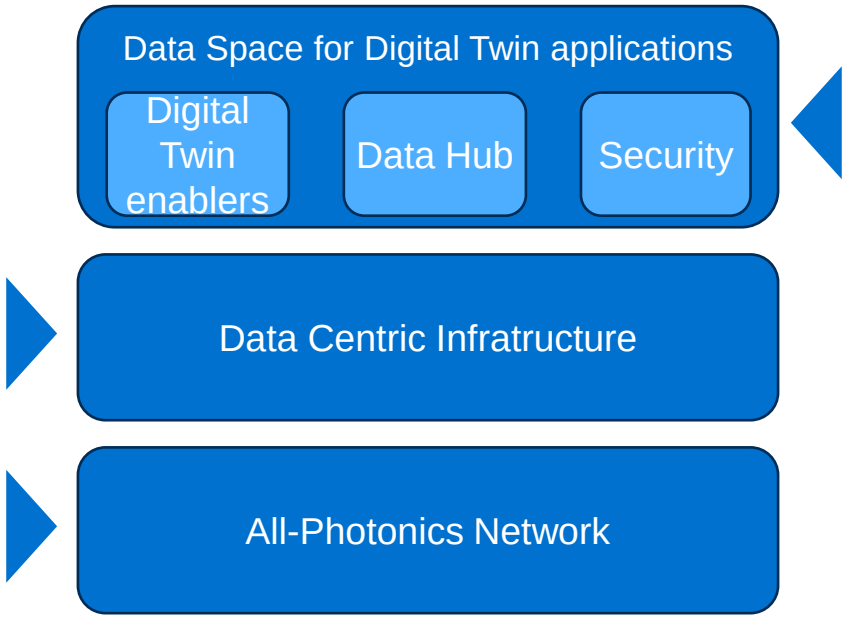
Data Space for Digital Twin applications (DSDT)

DSDT is the IOWN holistic approach to realize the Digital Twin leveraging the integrated IOWN optical and processing infrastructure

Data Centric Infrastructure (DCI)
- Network-wide Disaggregated Computing
- Computing Resource Pooling and Sharing
- Advanced DCIaaS features for composing Logical Service Nodes (LSN) from resource pools, HW/SW

Open All-Photonic-Network (Open APN)
- Disaggregated Open Network
- Extended dynamics, granularity, bandwidth, services (incl Fiber Sensing)
- Functional building blocks: APN-Interchange, APN-Gateway, APN-Transceiver, APN-FlexBridge



Digital Twin Enablers
- Data interoperability for analytics and simulation
- Digital twin orchestration
- Federation between data centers sites
- Analytics enablers for robustness

IOWN Data Hub
- Disaggregated Data/Stream Hub
- Distributed RDB, KVS, Graph Store, Message Broker, Object Storage, Compute-and-storage decoupling for the Block Storage

IOWN Security
- Data in motion: Privacy Enhancing Technologies (e.g., Trusted Execution Environment)
- Data in use: Multi-Factor Security (MFS) to achieve End-to-End post-quantum cryptographic communications
- Data at rest: access control

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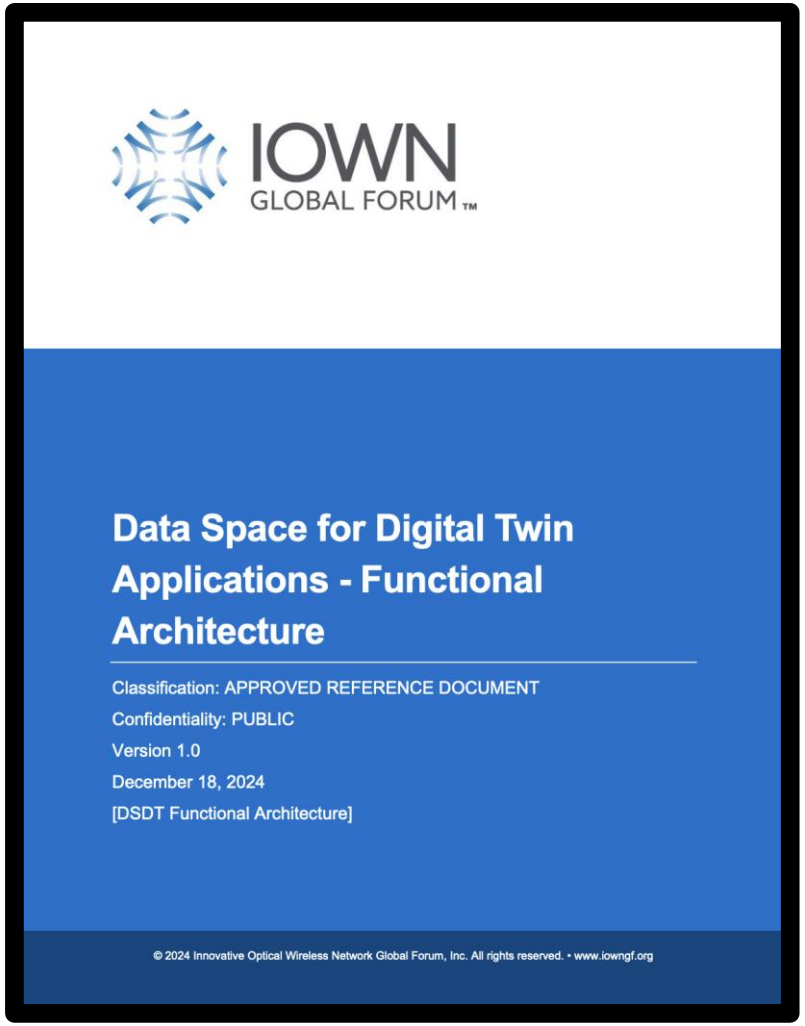
Data Space for Digital Twin applications Functional Architecture

- Concept
- Functional architecture comprising 3 function groups
  - Digital Twin data handling functions
  - Data Analytics
  - Digital Twin manipulation
- Interaction with IOWN infrastructure
  - IOWN Data Hub
  - IOWN security
  - Data Centric Infrastructure system
- Interaction with external systems and users



Functional architecture available in the technology page of IOWN:
https://iowngf.org/technology/

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Other Digital Twin Use Cases

The use case documents describe key feature sets and requirements that would leverage the contemplated next generation optical network in different vertical industries.

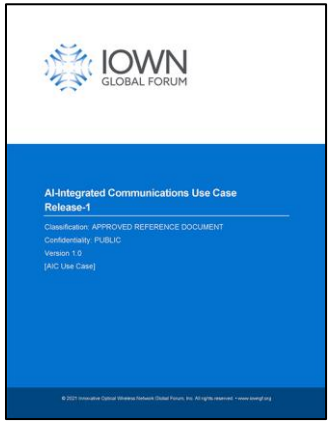
- **AI-Integrated Communications Use Case [AIC Use Case]**
  - Focuses on human-centric applications like entertainment, remote operation, navigation using XR technology and human augmentation.

- **Cyber-Physical Systems Use Case [CPS Use Case]**
  - Focuses on beyond-human applications enabling prediction and autonomy.

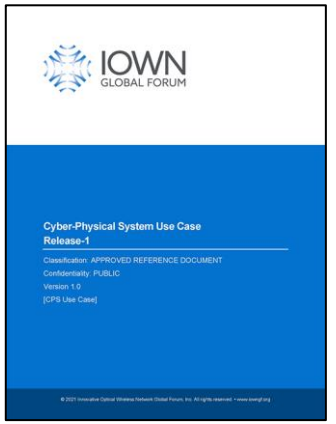
- **Metaverse Use Case [MV Use Case]**
  - Focuses on Metaverse use-cases which enable communication, interaction, and immersive experiences to take place in the virtual space.

- **Digital Twin Framework Analysis Report [DTF AR]**
  - Provides an analysis for understanding the use cases of digital twins defined by IOWN Global Forum.

AIC Use Case

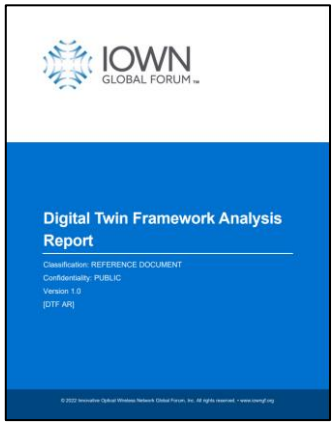


CPS Use Case



Metaverse Use Case

Digital Twin Framework Analysis Report



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