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Digital Twin Networks for AI-Driven Control

ITU-T Standardization Progress toward Autonomous Network Control

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Overview of DTN related work in ITU-T SG13

This presentation reviews ITU-T SG13's standardization work on Digital Twin Networks, from foundational architecture to autonomous network control.

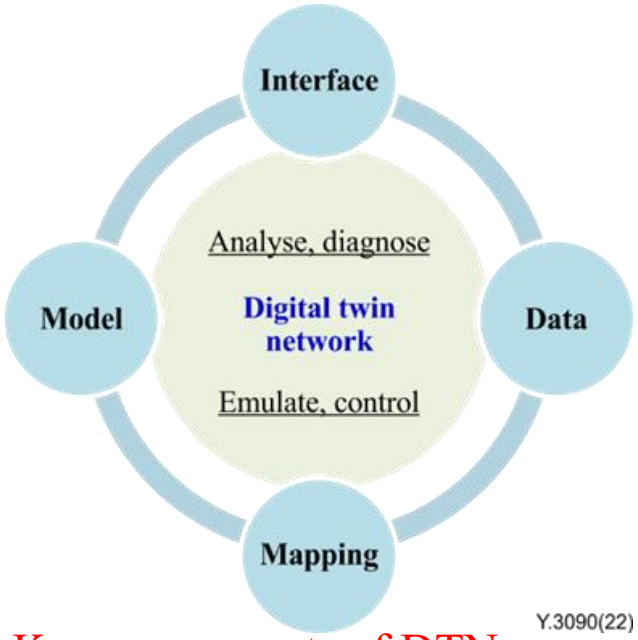
Overviewing the following ITU-T Recommendations on DTN:

- Y.3090 (2022) : Fundamental reference architecture
- Y.3091 (2023) : Capability levels and evaluation methods
- Y.3092 (2024) : Integration in management and orchestration
- Y.3093 (2025) : Data domain framework
- Y.3094 (2026) : Model domain framework
- Work-in progress drafts (3 active)

ITU-T Y.3090 (2022): DTN requirements and architecture (1/2)

Definition and scope:

- A digital twin network (DTN) definition: a virtual representation of a physical network.
  - *It is useful for analysing, diagnosing, emulating, and controlling the physical network based on data, model, and interface, to achieve a real-time interactive mapping between physical networks and digital twin networks.*
- Scope
  - Functional and service requirements
  - Reference architecture



Key components of DTN

Functional requirements	Service requirements
• Efficient data collection • Unified data repository • Unified data models • Open interfaces • Efficient management	• Compatibility • Scalability • Reliability • Security • Privacy • Flexibility • Visualization • Synchronization

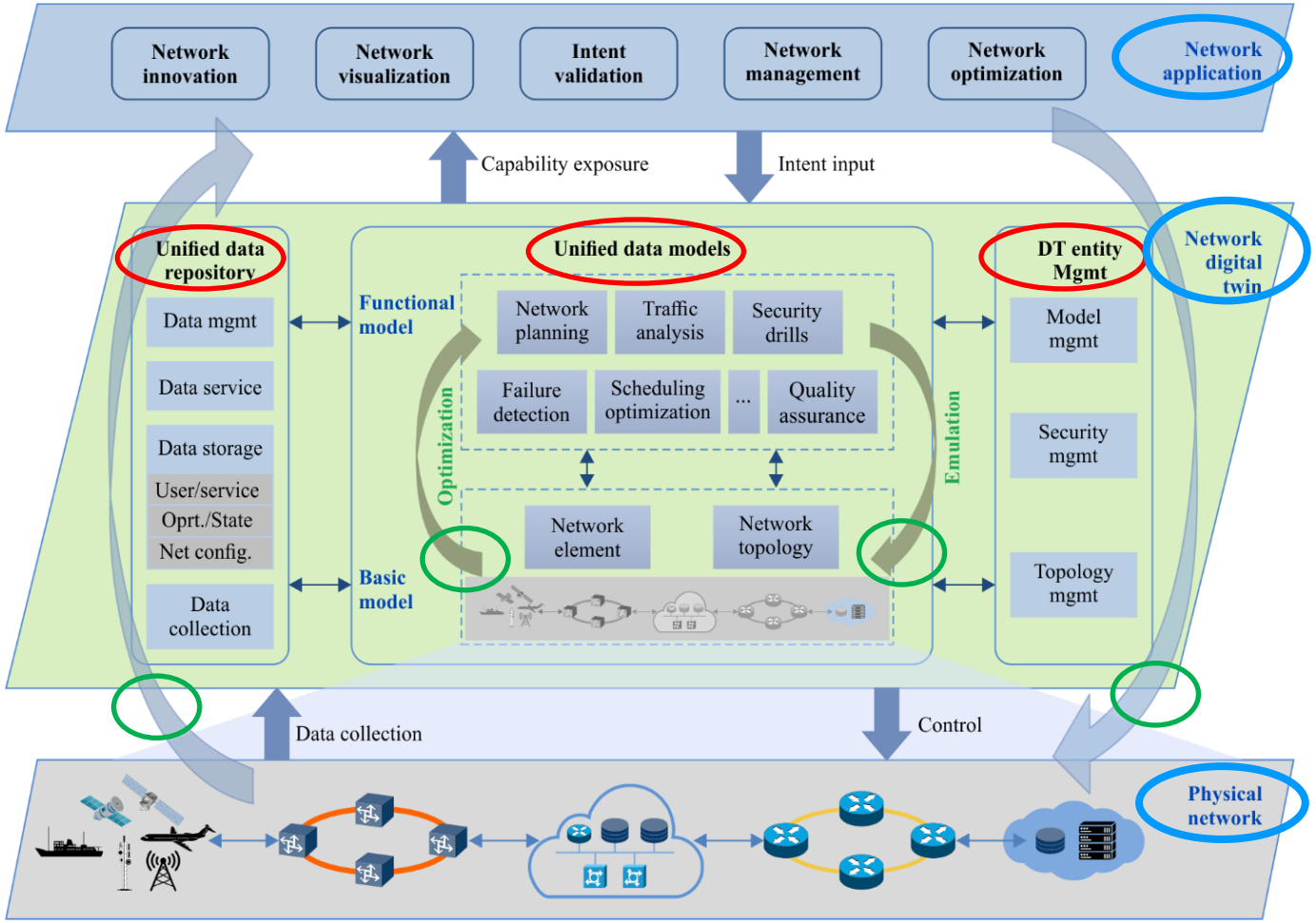
ITU-T Y.3090 (2022): DTN Requirements and architecture (2/2)

Architecture of Digital Twin Network

- **Three layers**
  1. Physical network
  2. Network digital twin
  3. Network application

- **Three domains**
  1. Unified data repository (*data domain*)
  2. Unified data models (*model domain*)
  3. DT entity management (*mgmt. domain*)

- **Double closed-loops**
  1. Inner closed-loop *for fast, automated control within DTN*
  2. Outer closed loop *for longer-cycle optimization via network applications*



Digital twin network – reference architecture

All subsequent Recommendations elaborate on specific components of this reference architecture.

*ITU-T Y.3091 (2023): DTN - Capability levels and evaluation methods (1/3)

Scope:

- Definitions of DTN capability levels
- Dimensions and indicators of DTN capability levels
- Evaluation methods for DTN capability levels

Definitions of DTN capability levels

Level	Name	Definition
L1	Representative level	Virtual twin can represent states and behaviors of physical network (1-way mapping)
L2	Interactive level	Virtual twin can be used to control physical network (2-way interaction)
L3	Prediction level	Virtual twin can be used to assess states and predict performance of physical network (performance and trend prediction)
L4	Optimization level	Virtual twin can use intelligent algorithms for decision-making, optimization and control of physical network (intelligent control)
L5	Autonomy level	Virtual twin and physical network live in symbiosis; perceive and recognize each other's states and behaviours in real time and autonomously, dynamically reconfigure themselves (autonomous twin)

**Based on ITU-T Y.3173 "Framework for evaluating intelligence levels of future networks"*

ITU-T Y.3091 (2023): DTN - Capability levels and evaluation methods (2/3)

Evaluation dimensions

Seq.	Dimension	Dimension definitions
A	Data service	Provides high-precision network data collection, multi-source heterogeneous database construction, and a unified data service interface
B	Digital twin modeling	Basic model = (corresponds to) network element model Topology model = physical network Functional model = network perception, analysis, simulation, reasoning, decision-making, and other models established for specific applications.
C	Interactive mapping	Provides virtual and physical synchronization services to collect data, represent or control physical network
D	Intelligence	Provides services for analysis, decision-making, control, and other intelligent capabilities
E	User experience	Provides users with the ability to interact with digital twin network and visualize its data.
F	Trustworthiness	Provides security, privacy, reliability, resilience, and other trustworthiness capabilities.

ITU-T Y.3091 (2023): DTN - Capability levels and evaluation methods (3/3)

Evaluation indicators for each dimension

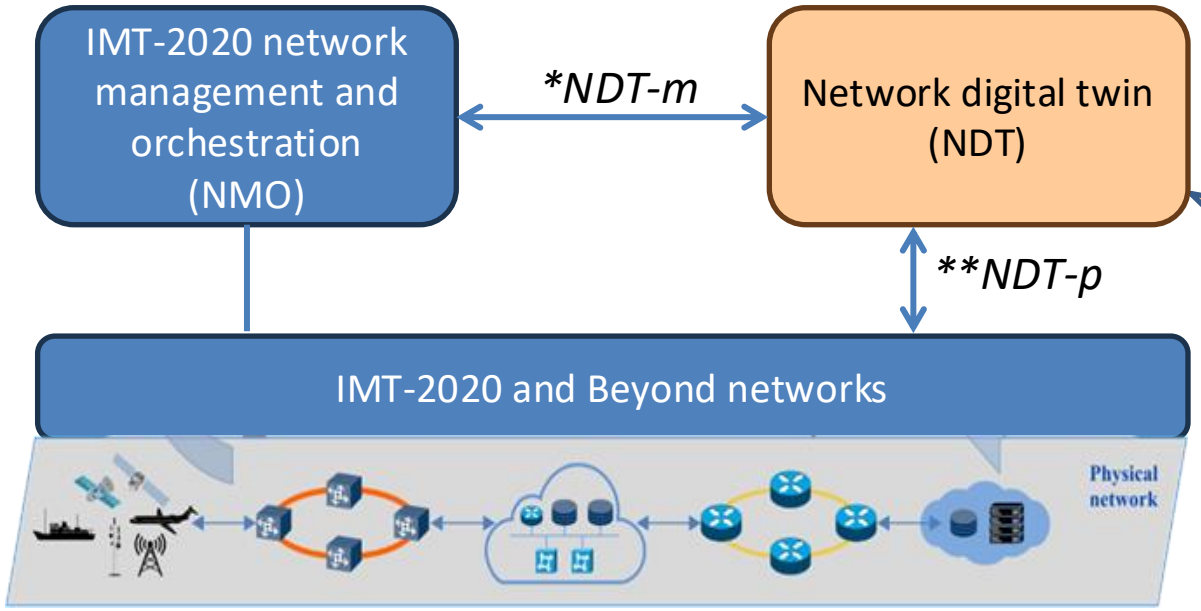
Dimension	Evaluation indicators
A. Data service	Data richness
	Update frequency
	Compatibility
	Data quality
	Data service interface
	Efficiency
B. Digital twin modelling	Basic model integrity
	Functional model integrity
	Standardization
	Interfaces
	Update frequency
	Flexibility, efficiency
C. Interactive mapping	Mapping mode
	Real to virtual mapping
	Virtual to real mapping
	Interface richness
	Interaction quality

Dimension	Evaluation indicators
D. Intelligence	Orchestration
	Analysis
	Decision-making
	Instruction execution
	AI/ML model training and inference
	Model quality
	AI/ML model explainability
E. User experience	Visualization scope
	Data visualization mode
	Entity visualization mode
	Interaction
F. Trustworthiness	Security
	Privacy
	Reliability
	Resilience

ITU-T Y.3092 (2024): DTN for management and orchestration of networks

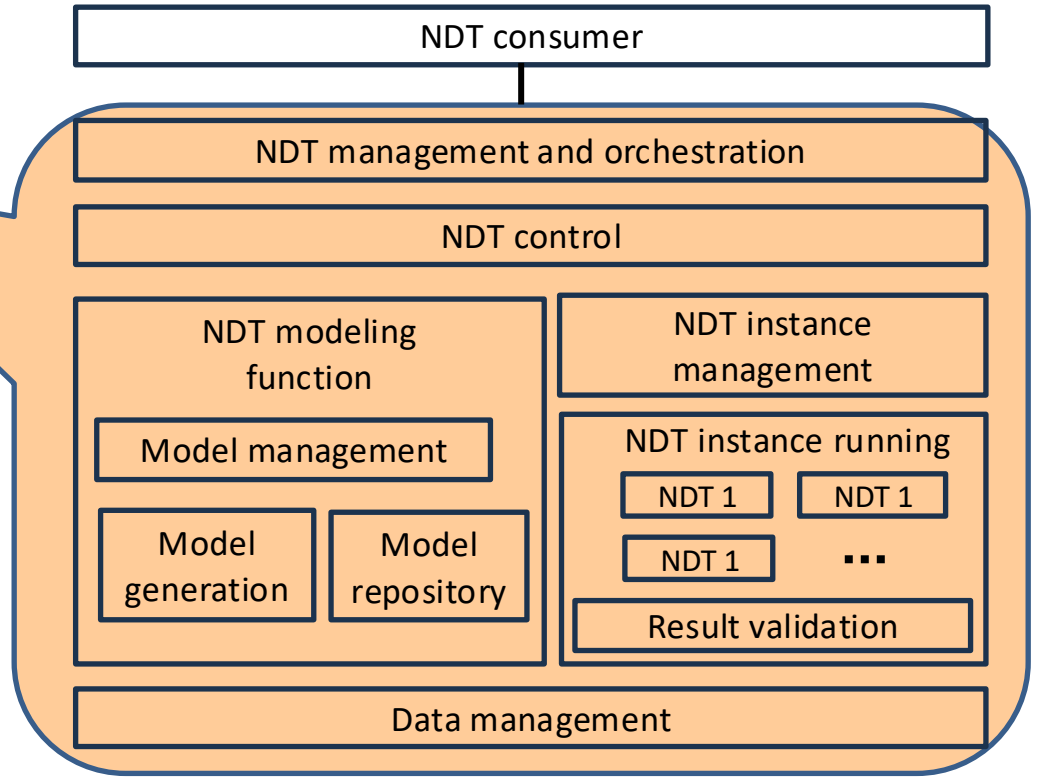
Scope:

- Requirements for DTN based management and orchestration (general and data security)
- Framework, interfaces, data collection methods



NMO and NDT relationship

Y.3092 defines how the digital twin layer integrates with existing network management systems without requiring a full replacement.



Functional framework of network digital twin

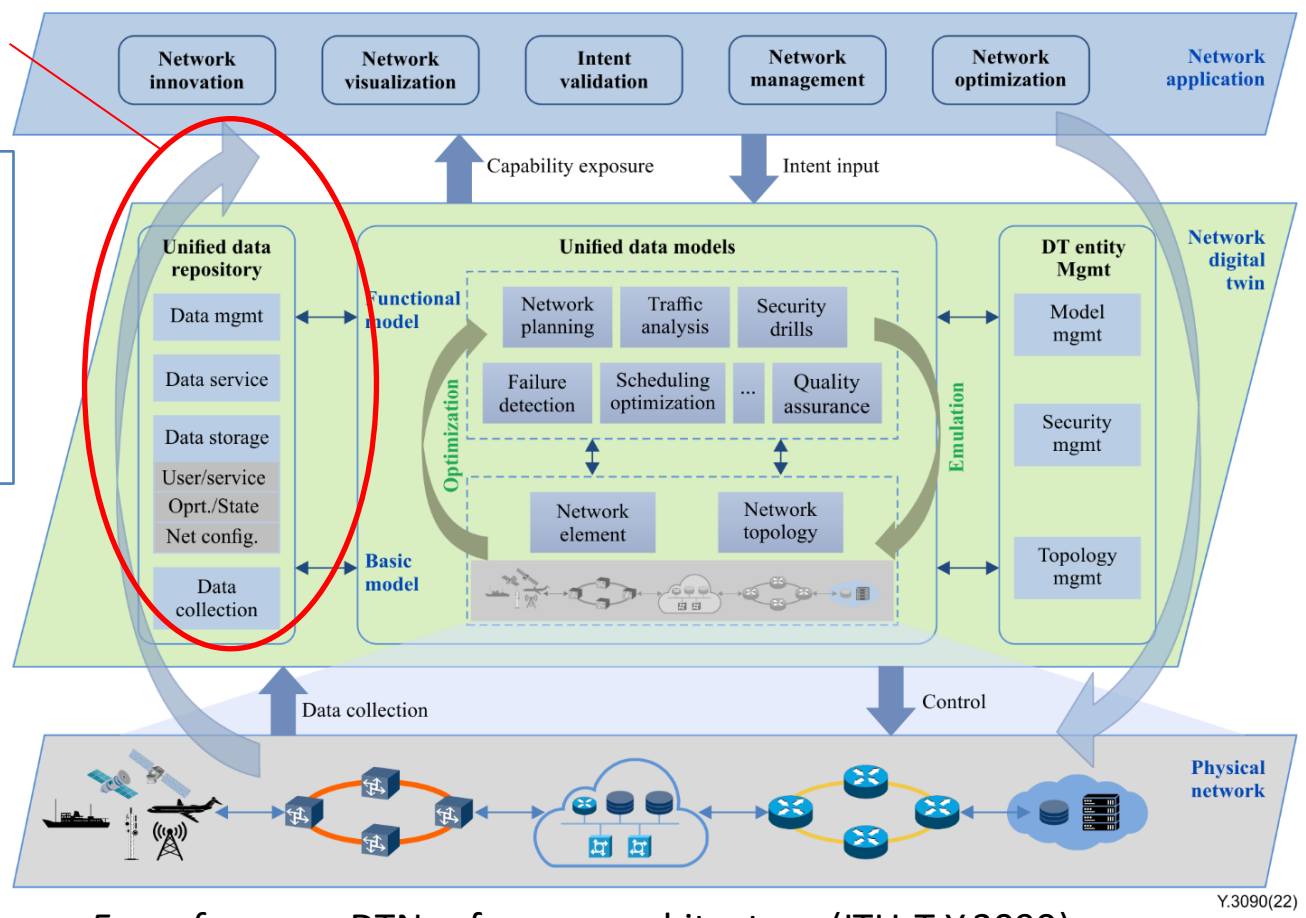
*NDT-m: Interface to exchange management data
**NDT-p: Interface to collect network status data

ITU-T Y.3093 (2025): DTN – Framework and functional requirements of data domain (1/2)

Scope:

- Data scope and types
- Framework
- Functional requirements
- Unified interfaces requirements
- Compatibility requirements

Y.3093 standardizes what data the DTN collects, how it is structured, and how it is exchanged — enabling interoperability across vendors and operators.



For reference - DTN reference architecture (ITU-T Y.3090)

ITU-T Y.3093 (2025): DTN – Framework and functional requirements of the data domain (2/2)

Data types

(1) Physical attributes
(2) Configuration data
(3) Status data
(4) Event data
(5) Topological data
(6) Performance data, and
(7) Service status data

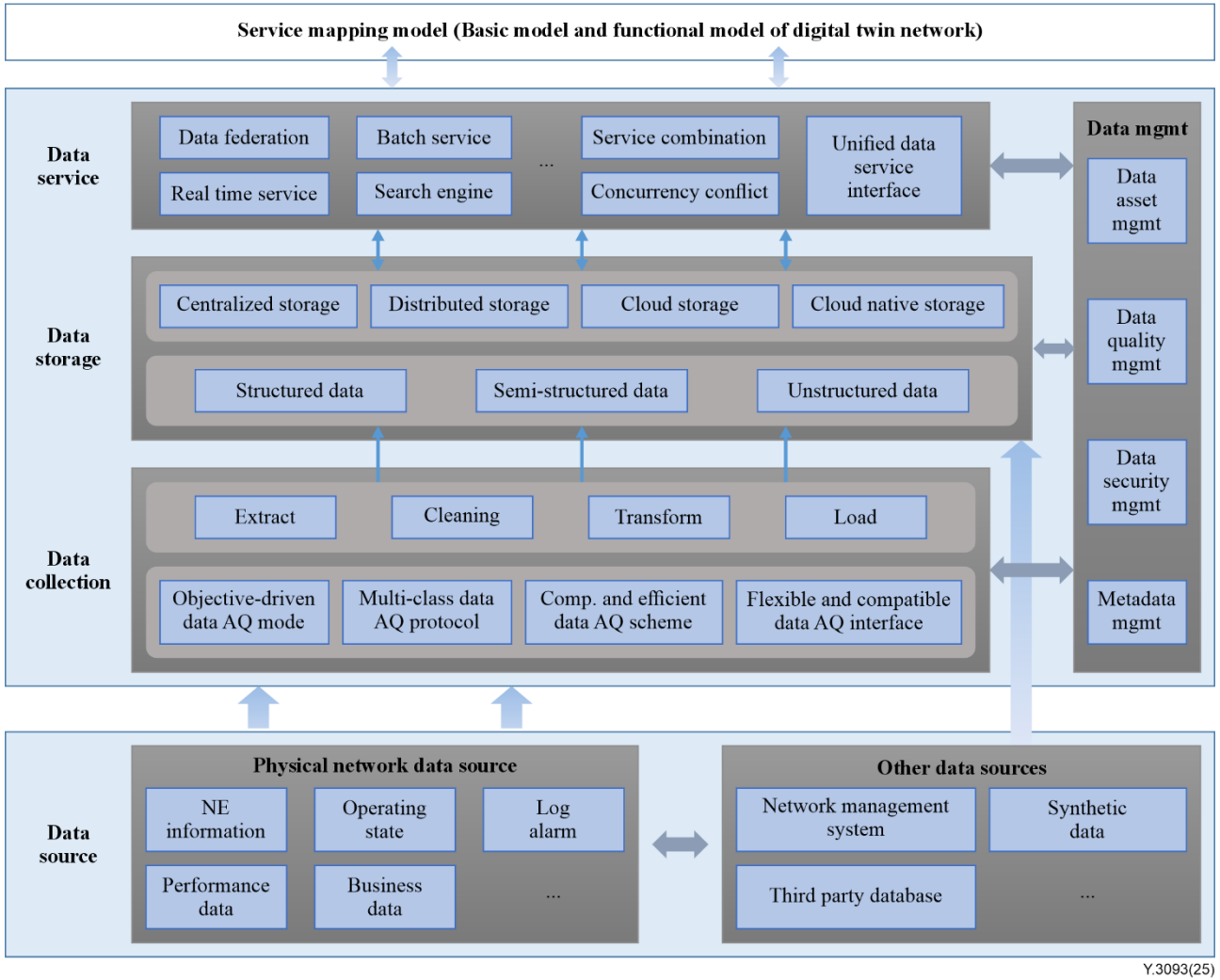
Data sources

Physical network entities:

Network entities, operating states, log alarms, performance data, service/business data, systems and third-party repository

Others:

Network management systems and third-party repository



DTN data domain framework

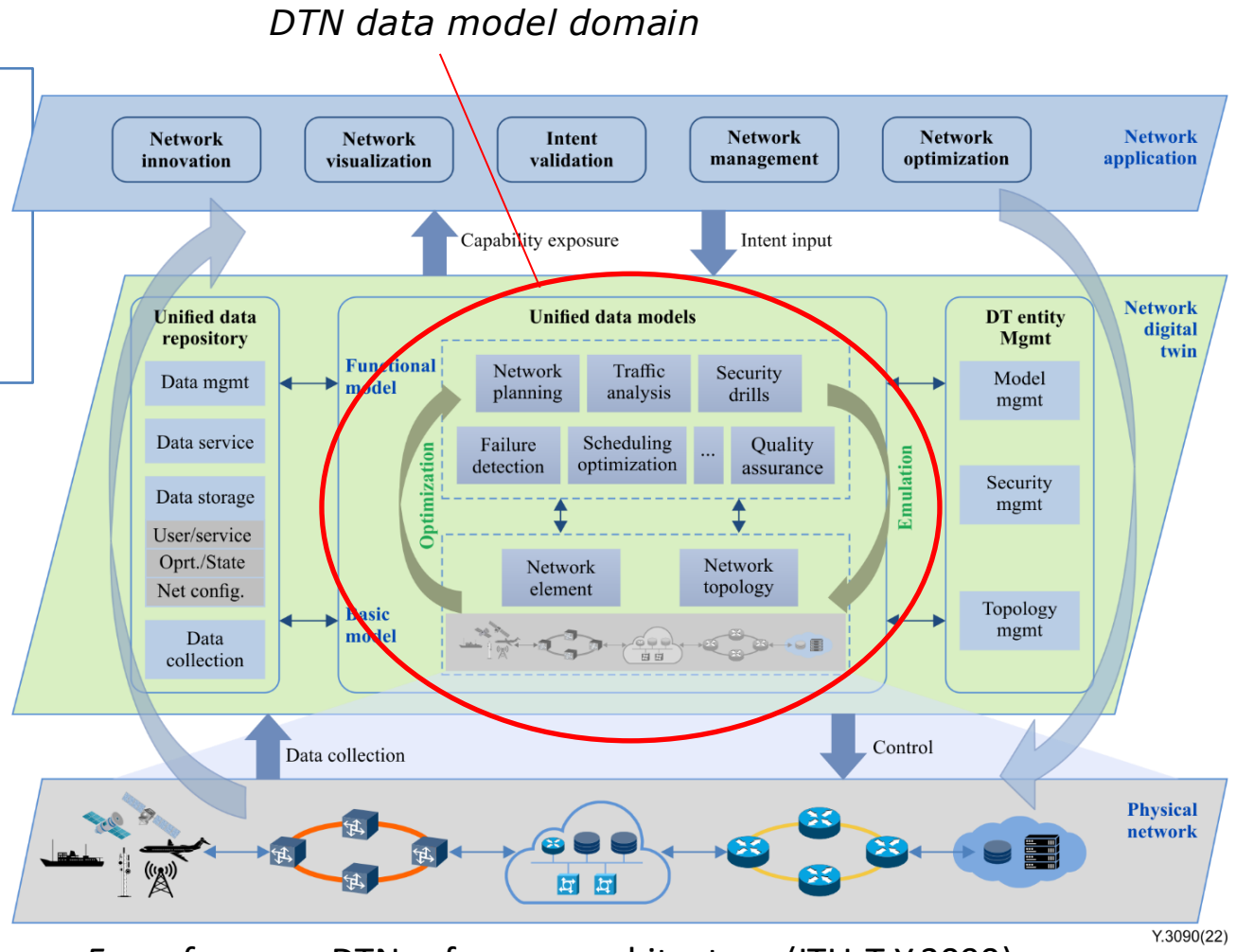
Separating physical network data sources from third-party repositories enables flexible, federated data ingestion into the DTN.

ITU-T Y.3094 (2026): DTN - Requirements of DTN data model domain (1/2)

Scope:

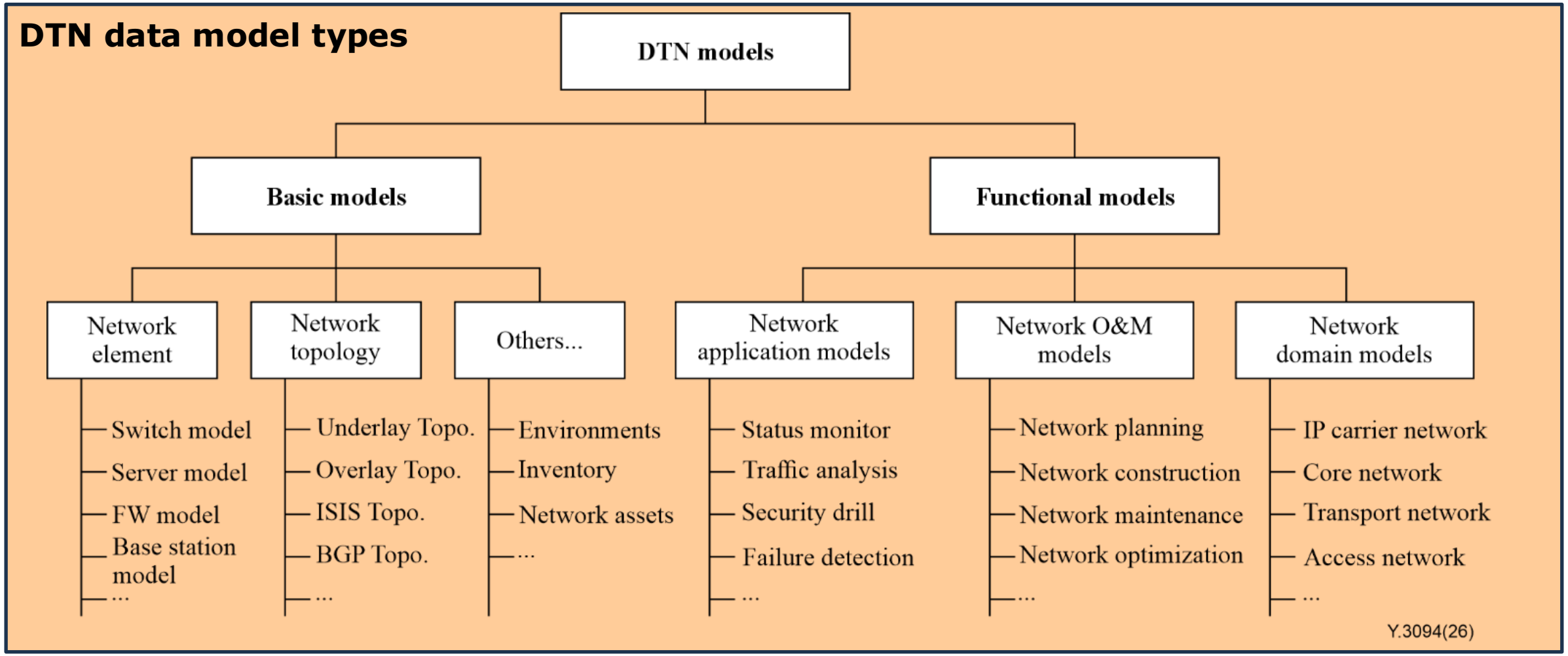
- Data model types and functionalities
- Requirements for model orchestration and management, as well as interfaces

Y.3094 defines the model layer — what the DTN 'thinks with' — building on the data layer defined in Y.3093.



For reference - DTN reference architecture (ITU-T Y.3090)

ITU-T Y.3094 (2026): Requirements of DTN data model domain (2/2)



Functional models (right branch) are where AI/ML capabilities are embedded — enabling DTN to perform network planning, optimization, and failure detection autonomously.

Work-in progress drafts on DTN

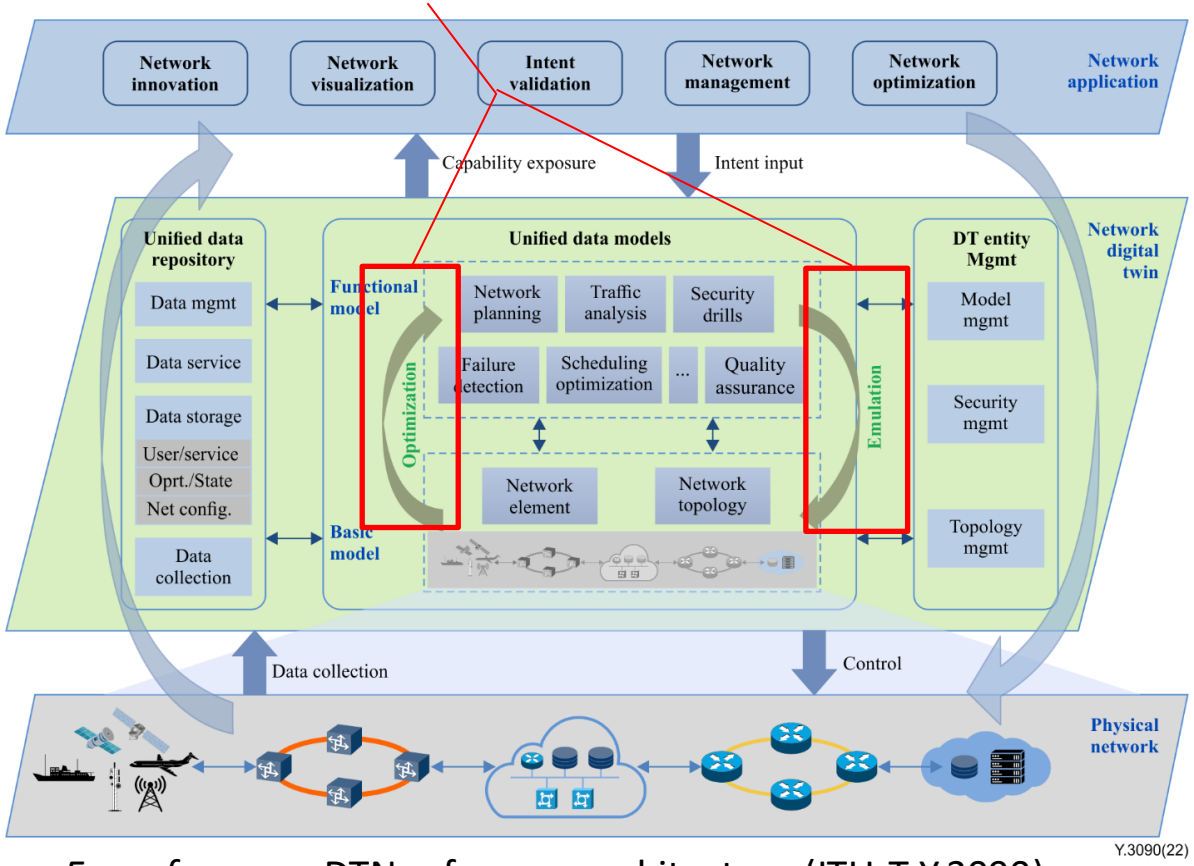
These drafts extend DTN standards to emerging use cases including private 5G/6G networks and formal AI-driven network verification.

- Y.DTN-NPNsp
  - DTN – Functional requirements and architecture of service platform for non-public networks
- Y.DTN-NDMfr
  - DTN – Functional requirements for network data models
- Y.DTN-NetVerificaiton
  - Requirements of network verification for DTN

Y.DTN-NetVerificaiton: Requirements of network verification for DTN

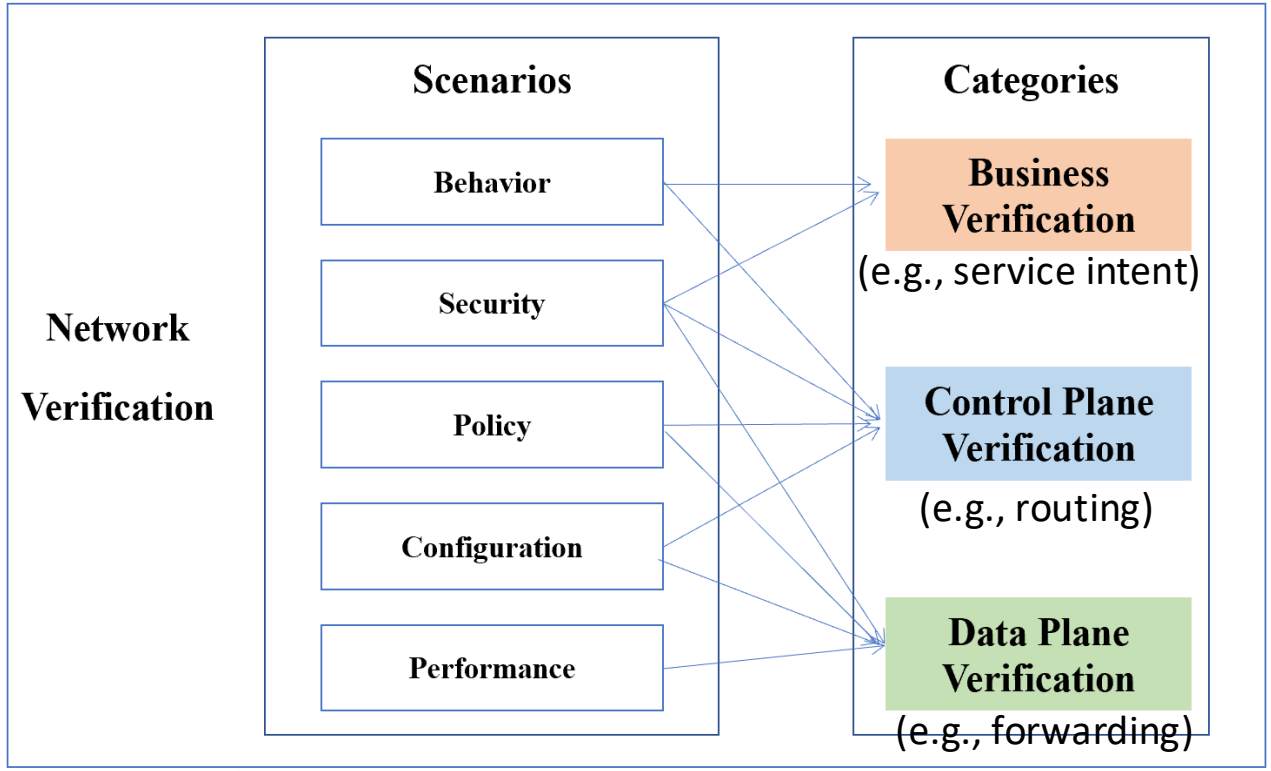
Scope: Categories, capabilities and requirements of network verification for digital twin network

Scope of network verification



For reference - DTN reference architecture (ITU-T Y.3090)

As networks become increasingly AI-controlled, formal verification becomes essential to ensure correctness, security, and trustworthiness of autonomous decisions.



Scenarios and categories of network verification

Summary

- ITU-T SG13 has established a comprehensive DTN framework.
- DTN enables AI-driven, closed-loop network control.
- ITU-T's DTN standards provide a globally harmonized foundation.
- ITU-T SG13 welcomes contributions and collaboration from AI for Good partners to accelerate DTN standardization toward trustworthy autonomous networks.

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