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J. Zhao, Ed.
R. Pang, Ed.
S. Zhang, Ed.
China Unicom
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AI Agent Architecture for DTN Digital Twin Network
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Abstract

This document proposes an AI agent architecture for Digital Twin Network (DTN) that integrates AI agents with digital twin technology. The architecture extends the traditional DTN architecture by incorporating autonomous AI agents at each component level, enabling more intelligent and adaptive network management capabilities.

Status of This Memo

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1. Introduction

Digital twins have emerged as a powerful paradigm for network management, providing virtual representations of physical networks that enable simulation, analysis, and optimization. However, traditional digital twin architectures often lack the autonomous decision-making capabilities needed for modern network environments. This document proposes a architecture that combines digital twin concepts with intelligent AI agents, creating a more dynamic and responsive network management system.

The architecture is designed to be compatible with existing digital twin architectures. This approach enables distributed decision-making, adaptive behavior, and enhanced collaboration between digital twin components.

2. AI Agent Architecture for Digital Twin Network

Based on the concept of the Network Management Agent (NMA) [I-D.zhao-nmop-network-management-agent], we propose an AI Agent architecture for Digital Twin Networks (DTN) [I-D.irtf-nmrg-network-digital-twin-arch]. This architecture extends the traditional digital twin network by integrating AI agents into each core component. While preserving the fundamental structure of digital twins, the architecture introduces enhanced autonomous capabilities and intelligent decision-making across the network management lifecycle.

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   |                                             Digital Twin Network Management Agent
                                        |
   |                                        - Resource Monitor
                                        |
   |                                        - Lifecycle Management (DTN Instantiation)
                                        |
   |                                        - Intent Translation & Policy Derivation
                                        |
   |                                        - Virtual-Physical Synchronization Control
                                        |
   +-------------------------------------------------------------------------------------------------------------------------+
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   +------------------------------------------------------------------+    +----------------------------------------------------------+
   |                    Functional Model Agent                        |    |
          Data Repository Agent                         |
   |                                                                  |    |
                                                        |
   |                                                                  |<-->|
      - Real-time Data Collection                       |
   | - Service Model Optimization                                     |    |
                                                        |
   | - Scenario-specific Model Creation                               |    |
      - Historical Data Intelligence Management         |
   +------------------------------------------------------------------+    |
                                                        |
                                   |                                       |
      - Adaptive Data Services                          |
   +------------------------------------------------------------------+    |
                                                        |
   |                     Basic Model Agent                            |<-->|
                                                        |
   |                                                                  |    +----------------------------------------------------------+
   | - Network Element Models (Config, State, Environment)            |
   | - Topology Models (Connectivity, Link Relationships)             |
   +------------------------------------------------------------------+
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Figure 1: AI Agent Architecture for Digital Twin Network

TBD.

3. Architecture Components

3.1. Digital Twin Network Management AI Agent

The Digital Twin Network Management Agent serves as the central coordination and management component in the architecture, providing the following key functionalities:

* Resource Monitoring: Continuously tracks and monitors the status, performance metrics, and operational health of all resources within the digital twin environment.

* Lifecycle Management: Governs the complete lifecycle of Digital Twin Network instances, encompassing instantiation, configuration, state synchronization, maintenance, and termination.

* Session Control: Manages and orchestrates communication sessions and interactions among the various AI agents within the architecture to ensure coherent operation.

* Intent Translation & Policy Derivation: Translates high-level business or operational intents from users into specific, executable policies and configuration models for the digital twin and its physical counterpart.

* Virtual-Physical Synchronization Control: Manages the bidirectional data flow and state synchronization between the digital twin and the physical network to ensure accurate representation and control.

3.2. Functional Model AI Agent

The Functional Model Agent is responsible for advanced service modeling and optimization capabilities, it can autonomously invoke the required functional models based on validation policies, while continuously optimizing models through the analysis of historical data. Additionally, it develops specialized models tailored to specific operational scenarios, use cases, and network conditions.

* Service Model Optimization: Continuously refines and optimizes service models through performance analysis and adaptive learning algorithms.

* Scenario-specific Model Creation.

TBD.

3.3. Basic Model AI Agent

The Basic Model Agent maintains fundamental network element and topology representations, capable of updating itself in real-time based on changes in the physical network to ensure the accuracy of validation.

3.4. Data Repository AI Agent

The Data Repository AI Agent serves as the intelligent data governance and provisioning component, enabling data-driven operations across the digital twin ecosystem. It autonomously manages data lifecycle with the following AI-enhanced capabilities:

* Real-time Data Collection: Implementing multi-protocol ingestion for streaming network telemetry and performance metrics, while autonomously detecting and flagging data anomalies or inconsistencies.

* Historical Data Intelligence Management: Building structured data and integrates intelligent analytics capabilities to support trend analysis and pattern mining, providing data foundation for model training and proactive optimization.

* Adaptive Data Services: Providing context-aware data retrieval with intelligent caching, pre-processing, and conflict resolution, dynamically prioritizing datasets for critical tasks such as simulation or root cause analysis.

4. Agent Interactions

The architecture employs bidirectional Agent-to-Agent (A2A) communication to ensure seamless operation: the Functional and Basic Model Agents interact with the Data Repository Agent for data access and synchronization, while the Digital Twin Network Management Agent centrally orchestrates these interactions and manages inter-agent dependencies to maintain a coherent workflow across the entire system.

5. Intelligent Use Case Realization

5.1. Simulation Scenario Construction

S1: The Digital Twin Network Management Agent receives user instructions, performs intent translation, and generates simulation strategies.

S2: The Functional Model Agent constructs functional models or coordinates existing models based on the strategies.

S3: The Basic Model Agent provides real-time configuration models and topological relationships for the migration scenario.

S4: The Data Repository Agent injects real-time traffic information.

All agents collaborate to create a simulation sandbox consistent with the actual physical network, within which the Functional Model Agent simulates the complete migration process.

5.2. Simulation Execution

S1: The Functional Model Agent continuously evaluates network performance indicators.

S2: If KPIs fail to meet standards or risks are detected, a rollback mechanism is immediately triggered. The agent coordinates with the Basic Model Agent to develop and execute a rollback plan.

S3: After analyzing and optimizing the solution, the simulation restarts and cycles iteratively until a compliant migration plan is generated.

S4: Upon simulation completion, the Functional Model Agent leverages historical data to optimize existing service models.

6. Security Considerations

TBD.

7. IANA Considerations

TBD.

8. Informative References

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[I-D.zhao-nmop-network-management-agent]
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Authors' Addresses

Jing Zhao (editor)
China Unicom
Beijing
China
Email: zhaoj501@chinaunicom.cn

Ran Pang (editor)
China Unicom
Beijing
China
Email: pangran@chinaunicom.cn

Shuai Zhang (editor)
China Unicom
Beijing
China
Email: zhangs366@chinaunicom.cn