Digital Twin Network: Concepts and Reference Architecture

draft-irtf-nmrg-network-digital-twin-arch-01

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Change Log

- **RG Adoption:**
  - draft-irtf-nmrg-network-digital-twin-arch-00, adopted, Mar, 2022

- **Major changes in -01**
  - Add new section of ‘Enabling Technologies to Build Digital Twin Network’
    
    7. Enabling Technologies to Build Digital Twin Network . . . . . . . 16
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  - Closed several open issues and made some editorial changes.
Data Collection and Data Management

• **Data types**
  − Configurations, running status, and service data.
  − Data plane, control plane, and management plane.

• **Data collection**
  − Target-driven and on-demand
  − Diversified tools for various types of data
    • Legacy and current tools: SNMP, NETCONF, IPFIX, Telemetry, INT, etc.
    • Innovative tools: sketch-based measurement, iFIT (In-situ Flow Information Telemetry)/iOAM, IFL (Inband Flow Learning), etc.
  − Light-weight with high-efficiency

• **Data management**
  − Data warehouse techs
  − Data services: fast search, batch-data handling, conflict avoidance
  − Unified interfaces for data exchange
# Network Modeling

## Comparisons between networking modeling methods

<table>
<thead>
<tr>
<th>Modeling Types</th>
<th>Examples</th>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simulation/Emulation</td>
<td>NS-2, NS-3, OPNET, MiniNET/EVE-NG, GNS-3</td>
<td>• Event/packet driven,</td>
<td>• High computation cost,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Easy to deploy for small scale network,</td>
<td>• Not suitable for large scale network,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Easy for functional evaluation</td>
<td>• Hard for performance evaluation</td>
</tr>
<tr>
<td>Virtualization Technologies</td>
<td>MS’s CrystalNet, Arista’s CVP (Cloud Vision</td>
<td>• Quick construction for full twin network,</td>
<td>• Needs virtual OS (low availability of virtual NE system);</td>
</tr>
<tr>
<td>(NFV, Containers, etc.)</td>
<td>Portal)</td>
<td>• Easy for functional evaluation</td>
<td>• Hard for performance simulation;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• High-fidelity</td>
<td>• Huge resource consumption</td>
</tr>
<tr>
<td>Mathematical Modeling</td>
<td>Formal methods</td>
<td>• Low resource cost</td>
<td>• Limited extensibility</td>
</tr>
<tr>
<td></td>
<td>Veriflow, Batfish, DNA, etc.</td>
<td>• Fast calculation</td>
<td>• Hard for performance evaluation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• More suitable for data plane/control plane evaluation</td>
<td></td>
</tr>
<tr>
<td>Theory of bottleneck structures</td>
<td>[G2-SIGCOMM]</td>
<td>• Low resource cost</td>
<td>• Limited extensibility</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Fast calculation</td>
<td>• Hard for functional/protocol evaluation</td>
</tr>
<tr>
<td>Data Driven - AI/ML Algorithms</td>
<td>[RouteNet], [MimicNet], [xNET], [xWeaver],</td>
<td>• High efficiency,</td>
<td>• Hard to validate new protocols,</td>
</tr>
<tr>
<td></td>
<td>[DeepComNet], etc.</td>
<td>• High accuracy on performance evaluation</td>
<td>• Data are ‘expensive’ to acquire,</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Low interpretability of AI models</td>
</tr>
</tbody>
</table>

*Notes: YANG modeling can be a common method to describing a network equipment with simple structured language*

**Recommendation:** Multiple methods can be in combination to build a comprehensive DTN system.

NMRG IETF 114 meeting
For "What-if" performance evaluation, data-driven methods are most promising, comparing with simulation and analytical approaches.

Three requirements (fidelity, efficiency, and flexibility) for performance evaluation.

Present a comparison of selected data-driven methods and investigate their potential trends in data, models, and applications.

Digital Twin for Networking: A Data-driven Performance Modeling Perspective

Network Visualization

Help users better understand the internal structure of the network, and mine valuable information hidden in the network.

• Network topology visuability
  − Acquire topology data using solutions provided in [RFC8345], [RFC8346], [RFC8944]
  − Hierarchical layout, heuristic layout or force-oriented layout

• Modelling visuability
  − Increase the interpretability of AI models.
  − Present the creation of model instances, data loading, simulation process, and verification results of the 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.
## Interfaces

- Candidate options for three types of Interfaces on building DTN system

<table>
<thead>
<tr>
<th>Types</th>
<th>Requirements</th>
<th>Candidate options</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northbound</td>
<td>Open, Standardized, Extensible</td>
<td>RESTFul, RESTCONF</td>
</tr>
<tr>
<td>Internal</td>
<td>Open, Standardized, Fast and efficient</td>
<td>XMPP (RFC7622), and HTTP/3.0</td>
</tr>
<tr>
<td>Southbound</td>
<td>Open, Standardized, Light weighted</td>
<td>SNMP, NetConf</td>
</tr>
</tbody>
</table>

[Diagram of Digital Twin Network and Related Concepts]
Next Steps

• To dig deep on each enabling technology
• To build a digital twin network system on trial network, and validate the gains against specific use cases.
• We also welcome proposals to enhance the document.

• Your comments are always welcome!