ETSI GS ZSM 018 V1.1.1 (2024-12)

Zero-touch network and Service Management (ZSM); Network Digital Twin for enhanced zero-touch network and service management

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Foreword

This Group Specification (GS) has been produced by ETSI Industry Specification Group (ISG) Zero-touch network and Service Management (ZSM).

Modal verbs terminology

In the present document "**shall**", "**shall not**", "**should**", "**should not**", "**may**", "**need not**", "**will**", "**will not**", "**can**" and "**cannot**" are to be interpreted as described in clause 3.2 of the ETSI Drafting Rules (Verbal forms for the expression of provisions).

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1 Scope

The present document specifies extensions and new capabilities to support and integrate digital twin technologies with the ZSM framework reference architecture in order to enhance end to end zero-touch network and service management and automation.

The present document defines use cases related to Network Digital Twins (NDTs) to derive specific requirements. It also documents important NDT principles.

The present normative document is based on the ZSM reference architecture and refers to available standards and open source works where appropriate. ETSI GR ZSM 015 [i.1] provides background relevant to the present document and should be read as a companion document.

2 References

2.1 Normative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

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The following referenced documents are necessary for the application of the present document.

[1] ETSI GS ZSM 002: "Zero-touch network and Service Management (ZSM); Reference Architecture".

[2] ETSI GS ZSM 003: "Zero-touch network and Service Management (ZSM); End-to-end management and orchestration of network slicing".

[3] ETSI GS ZSM 016: "Zero-touch network and Service Management (ZSM); Intent-driven Closed Loops".

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The following referenced documents are not necessary for the application of the present document but they assist the user with regard to a particular subject area.

[i.1] ETSI GR ZSM 015: "Zero-touch network and Service Management (ZSM); Network Digital Twin".

[i.2] ETSI GS ZSM 007: "Zero-touch network and Service Management (ZSM); Terminology for concepts in ZSM".

3 Definition of terms, symbols and abbreviations

3.1 Terms

For the purposes of the present document, the terms given in ETSI GS ZSM 007 [i.2] and the following apply:

Digital Twin (DT): digital counterpart of the physical twin that captures its attributes, behaviour and interactions

Network Digital Twin (NDT): virtual replica of a communications network or part of one

NOTE: Communications network can for example include equipment, systems, processes, software or environments of physical network elements and components, virtualised network functions, services and traffic.

physical twin: equipment, system, process, software or environment that the digital twin is designed to replicate and represent virtually

3.2 Symbols

Void.

3.3 Abbreviations

For the purposes of the present document, the abbreviations given in ETSI GS ZSM 007 [i.2] and the following apply:

NRT	Non-Real Time
RT	Real Time

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4 Concept and Principles of Network Digital Twin for Enhanced Zero-Touch Network and Service Management

4.1 Concept

As discussed in clause 4.1 of ETSI GR ZSM 015 [i.1] a Digital Twin (DT) is a virtual replica of a real-world system. That replica may model the composition, state, attributes, behaviours and other aspects of the physical twin. A Network Digital Twin (NDT) is a DT whose physical counterpart is a real-world communications network, or some part of one.

There have been different views expressed in the industry over time concerning the extent and nature of functions encompassed by an NDT. But all NDT use cases that have been considered are based fundamentally upon modelling to determine the expected outcomes, impacts and effects of prospective operations, processes or changes. Such modelling is thus the essential function of NDTs. An NDT management service reflecting this is defined in clause 8.

Information about the outcomes and effects of prospective operations, actions or changes - determined by NDT-based modelling - may be used to guide operational decision-making, including within automation-supporting closed loops. The precise nature and context of such decision-making, and in general the precise role of an NDT, vary among NDT use cases. Use case-dependent detailed functional architectures may be represented by "composing" NDT management services with other management services, per the ZSM architectural principles of flexible modularity and composability ETSI GS ZSM 002 [1], clauses 4.2.1 and 4.2.9. This is illustrated in Annex A.

The use - or at least, the potential use - of NDT-generated information within automated operations systems, is what distinguishes NDTs from other simulations and modelling. Such use depends on data and information flow between the NDT and other elements of the operations environment. This includes:

a) data and information flow to the NDT, to support accurate modelling of the physical network and its use; and

b) information flow from the NDT to other components of operations systems.

NOTE: In this context, the term "operations" encompasses any or all of the meanings traditionally encompassed by the terms control & orchestration, management and planning.

4.2 Principles

1) NDT should be use case specific

The NDT, including the input and output as well as the data on which the NDT depends should be use case-specific. NDT may use data from various sources and this data should be at right level of granularity and abstraction. Additionally, data should meet the requirements for quality, quantity and other characteristics suggested by the use case.

2) Different actions in NDT may be executed concurrently

NDT can be executed concurrently and independently, instead of sequentially, to greatly boost the processing efficiency.

Depending on the scenario requirements (e.g. risk prediction, fault analysis, configuration verification), it may be necessary to trigger multiple NDT modelling sessions in order to perform multiple evaluations of the scenario. The execution of multiple NDT modelling sessions could require coordination among them. Examples include:

- The NDT management service for signalling storm analysis will perform several NDT modelling sessions, predicting the amount of signalling traffic based on the current number of users and then evaluating the impact of the predicted signalling traffic has on the current network.

- During the intent negotiation phase, when an intent handler is required to respond to a Best operation query (Best operation is defined in ETSI GS ZSM 016 [3], clause 6.2.4.3) from an intent owner. In this case, the NDT management service can be requested to explore several possible solutions for the evaluation for the best possible outcomes that could be achieved by the intent handler. It is also possible to use the NDT management service to find out the optimal combination of values for intent parameters, which are best aligned with the intent handler's capabilities.

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In order to efficiently fulfil these requirements, it should be possible to start multiple NDT modelling sessions concurrently, and then report the best possible proposal after evaluation. Therefore, a management function may be used to initiate multiple concurrent modelling sessions. In addition, this management function may coordinate among the multiple modelling sessions, including identifying and addressing the different types of relationships such as cooperation, conflict or dependency.

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3) Separation of Concerns in NDTs

In order to support the separation of concerns in management, described in principle 8 from ETSI GS ZSM 002 [1], clause 4.2.8, the ZSM framework supports the same separation of concerns in NDTs as follows:

- E2ES MD NDT: Provide Management Services (MnS) and capabilities which support the management of end-to-end managed services that span multiple management domains.

- MD NDT: Provide Management Services (MnS) and capabilities which support the management of management domain entities.

4) NDT enables improved decision-making through its dynamic behaviour modelling capability

NDT's dynamic behaviour modelling capabilities like simulation, emulation and prediction enable network and service management to have improved decision-making capabilities compared to traditional methods without any adverse impact on the physical twin.

5) NDT is aware of the dynamic changes of the physical twin environment

The NDT is environment-aware based on information received from telemetry data, sensors, anomaly detection, failure prediction etc. The dynamic behaviour models of the NDT should consider the dynamic changes in the physical twin and its environment.

6) **NDTs should accommodate variations in physical twin composition**

Real networks vary and evolve in a number of ways, for example network size, equipment types involved, supported processes, diverse data sources and types. These variations of the physical twin affect the performance of the NDT. An NDT shall accommodate such variations in order to generate the best quality outputs from the NDT models.

NOTE: The variations an NDT can accommodate is implementation dependent.

5 Use cases

5.1 Introduction

The present clause describes the use cases related to Network Digital Twins (NDTs) that have been used to derive specific requirements listed in clause 6. For a more extensive set of use cases refer to ETSI GR ZSM 015 [i.1].

5.2 Network Slicing risk prediction

5.2.1 Description

As described in clause 7.1 of ETSI GS ZSM 003 [2], the required attribute values for the network slice SLA/SLS are translated and used as input for the attributes of Service profile or intent expectations of the E2E Service MD, which in turn are further translated into attributes or intent expectations for the network slice profiles of each MD (normally CN domain, AN domain and TN domain). In the ZSM framework the NDT MnS may be utilized to identify the risks of SLA/SLS not being met due to changing traffic and network conditions (e.g. a MD not being able to provide the network slice latency it committed for) and the NDT supports the ZSM framework to take actions before these risks materialize and therefore before the committed SLA/SLS are broken.

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5.2.2 Use case details

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A precondition of this use case is that the network slice is established and running in the network and the target of the use case is to ensure the network slice SLA/SLS is not broken.

The present clause describes the sequence how the NDT MnS may be used for the prediction of risks in network slicing with the following steps from Figure 5.2.2-1:

1) Data collected from the physical twin is used by the NDT at the required frequency.

2) A MD MnS consumer requests the NDT MnS to perform predictions on slice parameters values.

3) The NDT MnS returns the predicted values.

4) MD MnSs use the predicted slice parameter values to identify the risks of SLS being outside of the expected range for these parameters. Once a risk is identified the MD tries to find domain level solutions to avoid or mitigate the risk.

5) If the MD can find a solution to avoid the risk within the MD, and no other dependencies are affected or broken by the new solution, it implements it by executing domain level actions.

6) If it cannot find a solution it reports the risk to the subscribed MnS(s) in the E2ES MD using a domain analytics service as described in clause 6.5.3.2.1 of ETSI GS ZSM 002 [1].

7) Using the risks information reported by the prediction service, as well as other performance measurements collected from the different MDs, the E2ES MD identifies possible solutions.

8) The E2ES MD requests one or multiple predictions from the E2E NDT MnS in order to identify a valid solution that would avoid or mitigate the reported risk.

9) The E2E NDT MnS returns the predicted values.

10) Once the E2ES MD identifies a valid solution it communicates it to the appropriate MD using a domain orchestration service as described in clause 6.5.5.2.1 of ETSI GS ZSM 002 [1].

11) The MDs implement domain level actions.

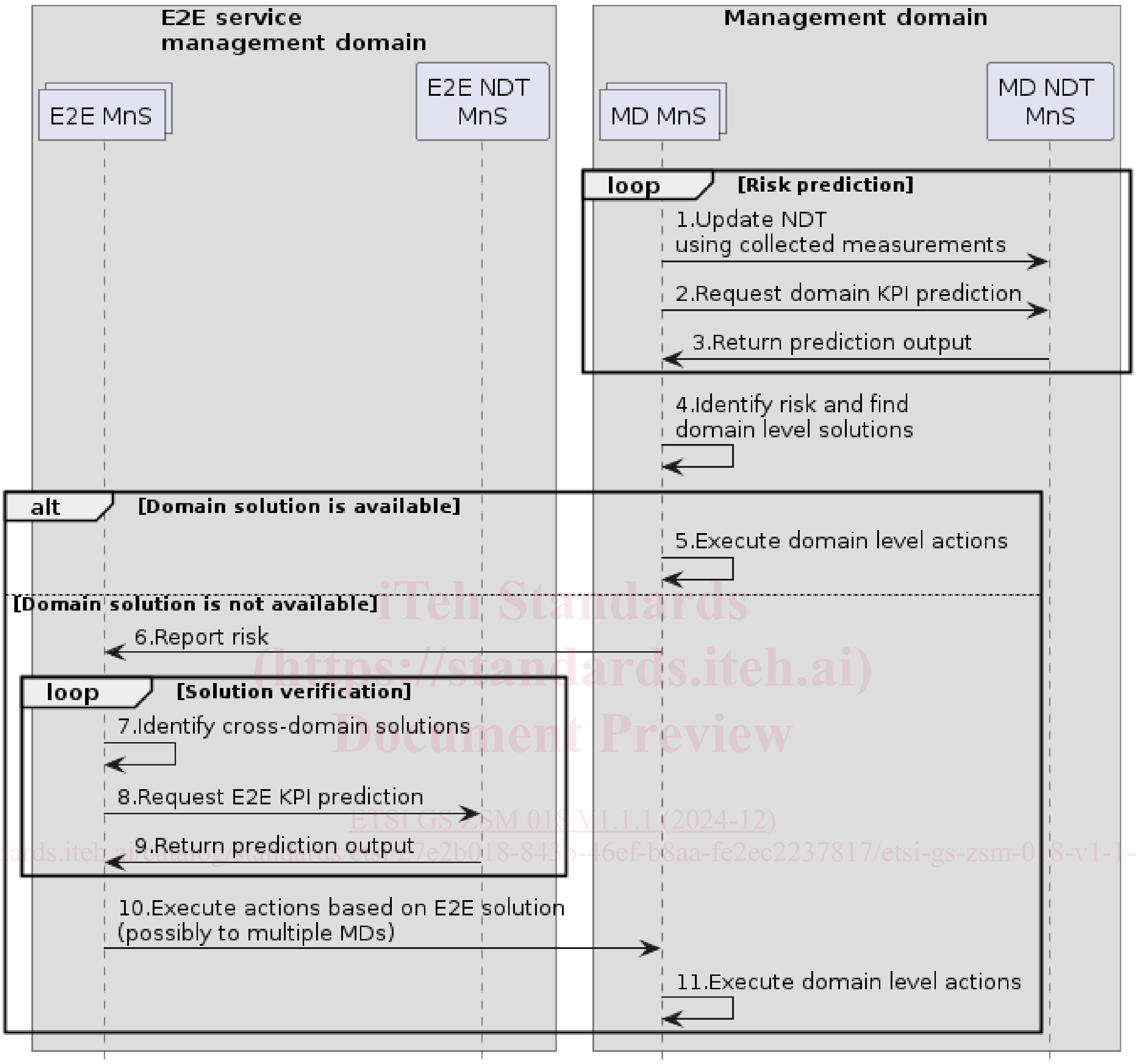

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Figure 5.2.2-1: Example of simplified sequence diagram of network slice risk prediction and healing

NOTE: E2ES MD could also be doing the risk prediction. However, in this use case the focus is the MD doing the risk prediction.

5.3 Visualization of network

5.3.1 Description

The visualization of the network is helpful for the network operators. As an NDT can be time basis modelling (e.g. current time, historical time, future time), the visualization of the network can show not only the current information (e.g. running status, health status), but also the historical information or future predictions of the network.

For example, based on the definition in clauses 6.5.5.2.7 and 6.6.5.2.7 of ETSI GS ZSM 002 [1], by querying the topology information from topology information service producer, the visualization of network topology can be available and help in understanding the current status of the network. On the other hand, the traffic data can be collected from the physical twin, and used for network performance analysis, fault prediction, etc. based on its variation. With the help of NDT which can model the correlation of different models and data (e.g. topology model and traffic data), it is possible to get a complete view relevant to the specified time (e.g. a specified point of time or a specified time frame). This view represents the physical twin by combining topology visualization with traffic information, and it can show how traffic flows across network topology in a specified time, and help to quickly detect abnormal traffic and root cause of a fault.

5.4 Synthetic data

5.4.1 Description

An essential part of the NDT is the usage of different types of data, e.g. current data including performance data, operational data, and historical data. The current data that can be collected from the physical twin are expected to be up-to-date to build and update the network digital twin. Therefore, the data collection characteristics such as type, frequency (e.g. minute-level, 10-second level, second-level), on demand mode, etc. shall be configured to meet the requirements of NDT.

In some cases, the collected data for the NDT is not sufficient on the quality and/or quantity, and therefore some additional data may be needed. For example, an NDT can be used to evaluate the mitigation effect on the signalling storm, the current signalling data is collected at current time T based on the configured data collection frequency, and the signalling data at future time T + 1 is required for identifying whether signalling storm will happen and verifying whether the mitigation measures will be effective in the future. In this case, the signalling data at time T + 1 cannot be collected currently. A possible mechanism for obtaining the additional data may be synthetic data generation based on data interpolation, data extrapolation, data inference, data generated by another NDT, etc. The synthetic data can be used by the NDT, for example for creating or updating NDT models. Furthermore, in this signalling storm mitigation evaluation case, when current time is T + 1, the signalling data can be collected and used to verify the accuracy of the synthetic data generation mechanism by comparing it with the synthetic data.

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5.4.2 Use case details

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In this use case, the synthetic data generator is introduced for managing the generation of synthetic data that is required to create or update NDT models. Generally, the synthetic data generator may be part of an NDT, it means the synthetic data producer and consumer belong to the same NDT. In some scenarios, an NDT can have the capability to provide synthetic data for another NDT, for example, the output data of one NDT is the synthetic data which can be used as the input of another NDT.

As a prerequisite, the synthetic data generator used for the NDT is deployed and available in the ZSM framework.

Following steps show an example of the NDT workflow with synthetic data generator:

1) Based on the requirements of specific use case, the collected data obtained by configuring the collection frequency, collection method, data storage, etc. can be provided to the NDT.

2) NDT MnS producer can ascertain whether the data is sufficient, and then trigger the synthetic data generator to generate synthetic data for the current NDT solution if required.

3) NDT MnS producer may validate the synthetic data using different approaches (e.g. comparing to the real data), and then will request the synthetic data generator producer to trigger subsequent optimizations if needed. For example, optimize the algorithm (e.g. interpolation algorithm) or model (e.g. GAN) for synthetic data generation with the up-to-date collected data if the accuracy of the synthetic data is degraded.