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Network Digital Twin for enhanced zero-touch network and service management**

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650 Route des Lucioles
F-06921 Sophia Antipolis Cedex - FRANCE

Tel.: +33 4 92 94 42 00 Fax: +33 4 93 65 47 16

Siret N° 348 623 562 00017 - APE 7112B
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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".

2.2 Informative 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 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

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.

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.

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.

5.2.2 Use case details

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.

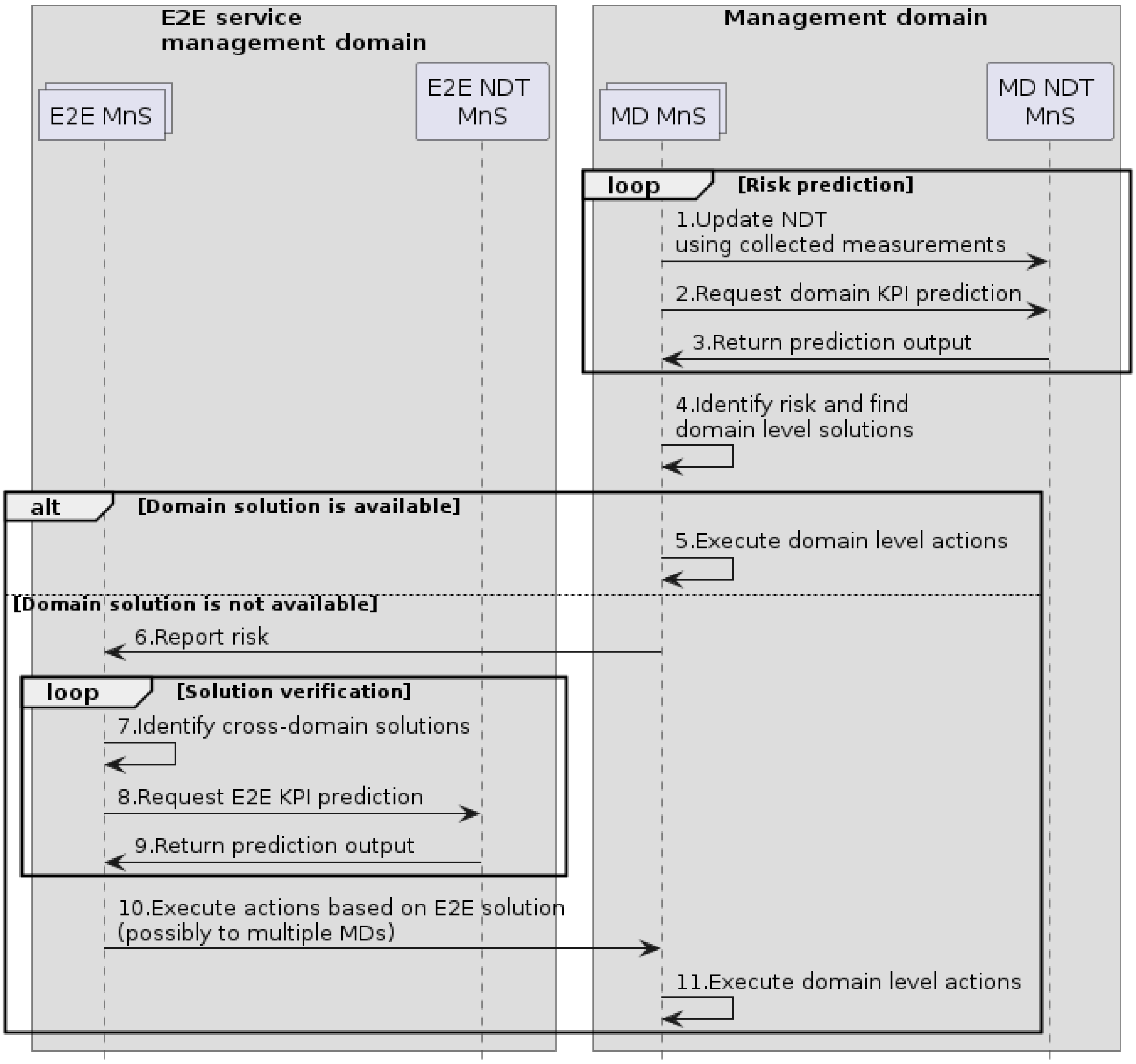

Figure 5.2.2-1: Example of simplified sequence diagram of network slice risk prediction and healing

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.

5.4.2 Use case details

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.

5.5 Historical incident analysis

5.5.1 Description

A post-incident analysis (or incident post-mortem) is a structured review process conducted after an adverse event or incident happens in a communications network. Its purpose is to analyse what happened, why it happened, and how similar incidents can be prevented in the future. It involves gathering information about the incident, identifying contributing factors, assessing the impact of the incident, and generating recommendations or action items in order to avoid or minimize the likelihood of similar incidents occurring again.

An NDT capable of performing historical "what-if" analysis is a great asset for this historical incident analysis as it can be used to evaluate what were the contributing factors for the incident to happen. In this case the NDT supports the exploration of different scenarios and the assessment of the outcomes if certain changes or decisions had been made at the time. It involves leveraging variations of the historical data (i.e. different network configurations to the ones operating during the past event) in order to explore alternative courses of action and evaluate their potential impact in the communications network.

5.5.2 Use case details

An authorized ZSM consumer or MnS may wish to perform an incident post-mortem analysis on a historical event and evaluate what different courses of actions could have been taken. The steps for the use case are as follows:

1) As part of a post-incident analysis (or incident post-mortem) an authorized consumer requests the NDT to perform analytics about past events.

2) NDT has access to MD/E2ES MD historical data for the time when the event happened in the network.

3) NDT has access to the specification of scenario for modelling. This target scenario represents the "what-if" scenario that should be modelled by the NDT.

4) The NDT produces the results of scenario-based modelling execution which can be consumed by authorized consumers in order to analyse these results.

5.6 Data transfer between physical twin and NDT

5.6.1 Description

In order to build and keep condition of NDT to be the same as physical twin, the latest data including configuration data of the physical twin is required to be transferred to the NDT. In addition, data may need to be transferred to the NDT for simulation or evaluation. In short, the capabilities enabling to transfer data between physical twin and NDT are needed.

NOTE: The RT/NRT data transfers are use case specific and are not define in the present clause.

5.6.2 Use case details

Some use cases of transferring data between physical twin and NDT extracted from ETSI GR ZSM 015 [i.1] are shown below:

- **Verification in NDT in CI-CD process:** In CI-CD process, the NDT MnS producer verifies in the NDT whether the introduction or update of software is appropriate and returns the verification results to the NDT MnS consumer.

- **Risk prediction by simulation in NDT:** NDT MnS producer analyse risks (e.g. related to specific service) by simulation and evaluation in NDT and returns the prediction results to the NDT MnS consumer.

- **Replay historical data in NDT:** The NDT MnS producer plays back the past network condition in the NDT by using historical data. This allows them to gain visibility of the performance, availability, and reliability of the communications network in the past, analyse the sequence of events leading up to a particular issue or network outage, and assess the outcomes if certain changes or decisions had been made at the time.

- **Machine learning training in NDT:** When the NDT MnS producer is instructed to train and deploy an ML model, the NDT MnS producer trains the ML model in NDT using synthetic data (refer to clause 5.3), evaluate whether the ML model meets the requirements from the NDT MnS consumer until the ML model is ready to be deployed.

5.7 Cloud workload placement

5.7.1 Description

Workload placement in a cloud is a complex task that involves deciding where to allocate workloads or network virtual functions/components within the cloud infrastructure. This complexity arises from the need to balance several technical, operational, and business considerations, including some of the following:

- **Resource Optimization:** Different workloads have varying requirements for CPU, memory, storage, and other resources and efficient placement requires matching these requirements with available resources across servers.
- **Workload Verification:** Many workloads have **interdependencies**, relying on data or services provided by other workloads. Placement should consider these dependencies to minimize communication overhead and latency.
- **Energy Efficiency:** Workload placement should consider energy efficiency to minimize the overall power usage.

An NDT can be used to model all the above factors enabling the exploration of multiple options that can support the process of optimizing the workload placements on a telco cloud.

5.7.2 Use case details

An authorized ZSM consumer may wish to optimize the workload placement on a telco cloud in order to efficiently consume the existing resources while minimizing energy consumption and communication overhead and latency between interdependent workloads. The steps for the use case are as follows:

1) An authorized consumer provides the specification of scenario for modelling (target workloads and interdependencies) to an NDT.
2) The NDT has access to the current state of the target cloud (workloads being executed and the interdependencies between then).
3) The NDT produces the results of scenario-based modelling execution which can be consumed by authorized consumers in order to analyse these results.

NOTE: Examples of results produced by the NDT may be capacity verification or workload dependency verification.

4) Steps 1 to 3 are executed multiple times until an optimum configuration is identified.

6 Requirements for Network Digital Twin

The following requirements have been extracted from the use cases described in clause 5:

- NDT-Gen-1: The ZSM framework shall support capabilities to integrate the NDT MnS in the management domain and/or E2E service management domain.
- NDT-Gen-2: The ZSM framework shall support capabilities for NDT MnS to register services and capabilities.
- NDT-Gen-3: The ZSM framework shall support capabilities for NDT MnS consumers to discover the NDT management services and capabilities.

- NDT-Gen-4: The ZSM framework shall support the capability to allow an authorized MnS consumer to request an NDT to provide predictions.

NOTE 1: Examples of predictions may be network performance, network behaviour or capacity optimization predictions.

- NDT-Gen-5: The ZSM framework shall support the capability to allow the NDT MnS producer to report the predictions results to the authorized MnS consumer.
- NDT-Gen-6: The ZSM framework shall support the capability for an authorized consumer to request the NDT MnS to support the visualization of the network based on the specified time.

NOTE 2: The specified time here refers to a specified point of time or a specified time frame.

- NDT-Gen-7: The ZSM framework shall expose NDT management service end points to authorized MnS consumers.
- NDT-Gen-8: ZSM framework shall support transfer of data from the physical twin to the NDT.
- NDT-Gen-9: The ZSM framework shall support the composition of NDT together with other management services to provide recommendations for the optimal combination of intent parameters during intent negotiation.
- NDT-Gen-10: The ZSM framework shall support the coordination of NDT modelling sessions when they need to be run concurrently or sequentially.
- NDT-Gen-11: The ZSM framework shall support the handling of different types of relationships between NDT modelling sessions such as coordination, cooperation, conflict or dependency.
- NDT-Data-1: The ZSM framework should support the capability to allow an NDT MnS to trigger synthetic data generation based on the specified data requirements.

NOTE 3: Data requirements can include data sources, data type, data criteria, etc.

- NDT-Data-2: The ZSM framework should support the capability to allow the synthetic data and other collected data to be used by the NDT MnS.
- NDT-Data-3: The ZSM framework should support the capability to allow NDT MnS producer to trigger the validation of the synthetic data.

NOTE 4: Validation of the synthetic data aims to check whether the synthetic data generation mechanism needs to be optimized.

- NDT-Historical-1: The ZSM framework shall support the capability to enable an authorized MnS consumer to request analysis of what-if scenarios based on variations of the historical data (i.e. different network configurations to the ones operating during the past event).
- NDT- Historical-2: The ZSM framework shall support the capability to enable the NDT MnS producer to provide the results of a what-if scenarios based on variations of the historical data (i.e. different network configurations to the ones operating during the past event).

7 Network Digital Twin Architecture based on ZSM Framework Management Services

In ZSM framework architectural terms, an NDT is a management service. Specifically, it is a type of analytics service, per the descriptions of such services in ETSI GS ZSM 002 [1], clauses 6.5.3.2.1 (domain analytics services) and 6.6.3.2.1 (E2E analytics services). Analytics services generate, from data and information, "actionable intelligence" - that is, information that is useful in operational decision-making. From ETSI GS ZSM 002 [1], clause 6.5.3.2.1:

- *"Various analytics services can generate aggregated data and derive insights from the collected data, possibly considering additional information such as topology."*

This is a good high-level description of an NDT, which uses modelling to determine e.g. state, behaviour, condition, and/or performance of the network or services, given data and information reflecting specific circumstances. Such data and information may relate to e.g. the state, condition, use and performance of the network or of network elements, services or traffic, including e.g. network topology, service topology, resource identifiers, instrumentation data.

The standard capabilities of NDT management services are defined as follows. They represent specific, detailed instances of the service capabilities defined in ETSI GS ZSM 002 [1] for generic analytics services and each is described in detail below, along with the concept of modelling sessions.

- **Manage NDT service connections:** Used by authorized MnS consumers to drive NDT modelling sessions and/or to access NDT output.
- **Configure NDT modelling sessions:** Authorized MnS consumers can configure NDT modelling sessions, including specification of scenarios for NDT modelling, of time bases for modelling, and of session life cycle information and triggers.
- **Provide NDT output:** Used by the NDT MnS producer to provide results of scenario-based NDT modelling, along with appropriate notifications to authorized MnS consumers.

An NDT modelling session is, in effect, a modelling exercise instance that is driven by a management service appropriately connected to the NDT. Each session reflects a particular scenario and has a particular time basis, duration and life cycle (see below). All of these aspects may differ among sessions.

The "manage NDT service connections" capability is an adaptation of the "manage subscriptions" service capability defined in ETSI GS ZSM 002 [1] for generic analytics services. It provides a mechanism by which functional connections are created between an NDT management service and other management services. Other management services may "connect" in either or both of two different capacities: as able to configure NDT modelling sessions, and/or as able to receive NDT outputs. These functional capacities persist, in respect of a given management service, as long as the service connection with the NDT is maintained. Multiple, concurrent and successive modelling sessions may be requested over the lifetime of every such service connection. Each NDT modelling session is associated with a particular connected management service or services: connected management services that receive NDT outputs do so only in respect of appropriately associated modelling sessions.

The configuration of an NDT modelling session involves specification of:

a) **Scenario for modelling:** the target scenario might simply be the state and condition of the network as it is, or as it was at some point in the past. But it may also represent some variation of such a state and condition, or even an entirely hypothetical state and condition: i.e. it may represent a "what-if" scenario.

b) **Time basis for modelling:** determines the real-world time or time interval (instantaneous, finite time interval, or ongoing/continuous) to be represented by a modelling session: current time, historical time, future or arbitrary time, etc.

c) **Modelling session life cycle information and triggers:** coordinates scenario specification and time basis inputs, as well as provision of modelling results, using e.g. appropriate start, stop, continue or similar triggers.

An NDT management service is responsible for appropriate handling of the various tasks and concerns described in ETSI GR ZSM 015 [i.1], including: maintaining an appropriate inventory of primary (i.e. element, component or partial functional) models; generating appropriately connected sets of primary models as dictated by session-based scenario requirements; and parallel execution of concurrent modelling sessions, including appropriate handling of per-scenario data instances and modelling execution life cycles, etc.

Architectural representation of NDT use cases, based on NDT management services, is illustrated in Annex A.

8 Management Services for Network Digital Twins in the ZSM Framework

8.1 NDT Management

As defined in clause 7, the specialized NDT management service capabilities are the following:

Table 8.1-1: Service capabilities of a Network Digital Twin (NDT)

Service name		Network Digital Twin (NDT)
Service type		Analytics service (domain or E2E)
External visibility		OPTIONAL
Service capabilities		
	Manage NDT service connections (M)	Connected management services are able to drive NDT modelling sessions and/or to access NDT output.
	Configure NDT modelling sessions (M)	Configure NDT modelling sessions, including specification of scenarios for NDT modelling, of time bases for modelling, and of session life cycle information and triggers.
	Provide NDT output (M)	Provide results of scenario-based NDT modelling, along with appropriate notifications.

8.2 NDT Feasibility Check Service

As described in ETSI GS ZSM 002 [1], clauses 6.5.5.2.2 and 6.6.5.2.2 the feasibility check service provides a generic service to check whether the service is deployable at proposed service level. The NDT feasibility check service has the same capability as the generic service and performs feasibility checks of NDT specific aspects and is used in NDT specific use cases.

Examples of NDT specific feasibility checks are:

- NDT modelling performance requirements (e.g. require to perform a Network Slicing risk prediction).

Table 8.2-1: NDT feasibility check MnS definition

Service name		NDT Feasibility Check Service
External visibility		OPTIONAL
Service capabilities		
	Check NDT modelling performance feasibility (O)	Check whether the NDT modelling performance requirements can be supported by the E2E service management domain or management domain.

Annex A (informative): Usage of NDTs: Compound Management Services

In the ZSM framework, management services may be "composed" by flexible association of more granular management services, per the modularity and service composability principles described in ETSI GS ZSM 002 [1], clauses 4.2.1 and 4.2.9. Use cases of NDTs are thus represented architecturally by appropriate compositions - combinations - of NDT and other management services.

Such compositions are more easily drawn as collections of management functions than as collections of management services. Per ETSI GS ZSM 002 [1], clause 6.1.2.2, management functions are entities that consume and/or produce management services. This annex uses the iconography introduced in ETSI GS ZSM 002 [1], Annex C to depict relationships among management services comprising closed loops: see Figure A.1. A management function is represented as implementing the service capabilities of its corresponding management service. The "management function end-points" represent sources or sinks of data, information, control or orchestration commands or triggers, etc. that are associated with particular management service capabilities. Arrows inter-connecting such management function end-points among icons are used to represent directional flows of data, information, control or orchestration commands or triggers, etc., among management functions and services.

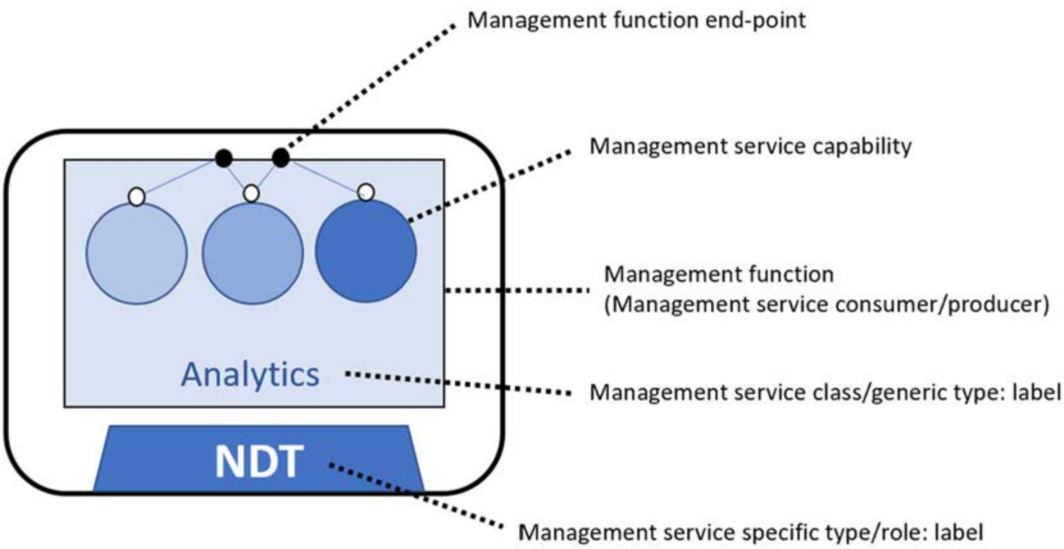

Figure A.1: Iconography for depicting management services and their corresponding management functions

An important functional architectural building block that uses an NDT is an optimization closed loop, see Figure A.2. Such a closed loop is typically used in so-called "sandbox" exercises, wherein an optimal or acceptable e.g. network or service configuration or state - optimal or acceptable with respect to some particular criterion or criteria - is sought through an iterative evaluation that takes place in "virtual space" using an NDT, rather than through "experimentation" on the real network.

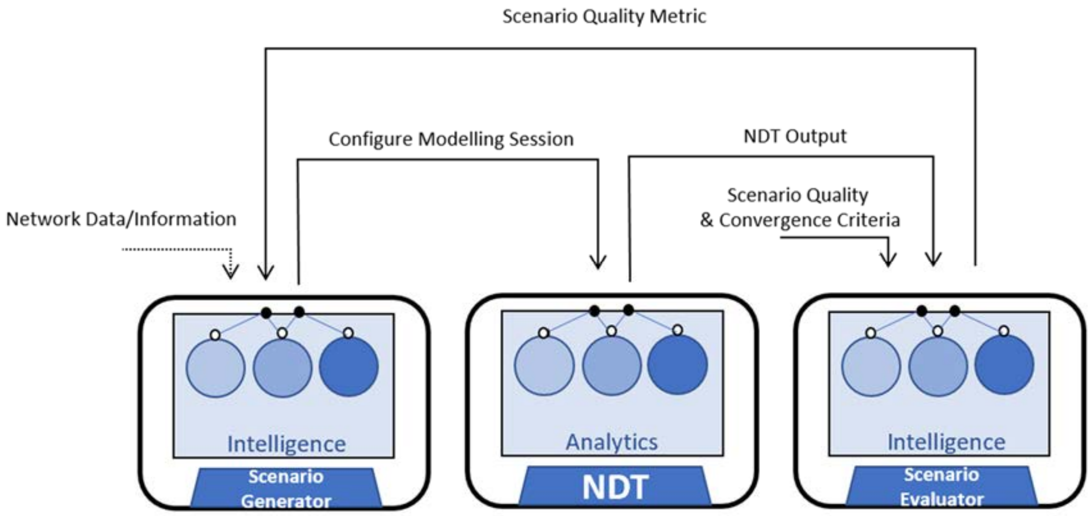

Figure A.2: Schematic representation of an NDT-based optimization closed loop

The NDT-based optimization closed loop involves three components: in generic terms, a scenario generator, an NDT, and a scenario evaluator. The scenario generator is responsible for driving scenarios for modelling evaluation into the NDT: to facilitate this task, the scenario generator may consume data services, per ETSI GS ZSM 002 [1], clauses 6.4, 6.5.2 and 6.6.2, that collectively reflect the current and/or historical state, status and condition of the network, services, etc. The scenario evaluator assesses the NDT output based on some optimization solution quality criterion or criteria, generating a scenario "quality metric" or similar information which is returned to the scenario generator. The scenario generator uses this information to adjust the scenario it presents to the NDT, closing the loop. When a scenario is evaluated to meet particular optimization/quality targets, the closed loop is exited, and the determined scenario is made available for use by other management services/functions. The scenario generator and evaluator are reflected in Figure A.2 as instances or specific types of intelligence services, which are categorized in ETSI GS ZSM 002 [1], clause 6.5.4.1 and 6.6.4.1 as decision-supporting, decision-making or action-planning services. They also correspond, effectively, to the "data" and "decision/action" components, respectively, of closed loops (the decision-contingent action is simply to exit the closed loop).

The NDT-based optimization closed loop as a whole may itself be represented as a management service. This is illustrated in Figure A.3, which depicts use of an NDT-based optimization closed loop - i.e. the entirety of Figure A.2 - within an intent assurance closed loop (NDT-based optimization is an "inner closed loop" while intent assurance is an "outer closed loop").

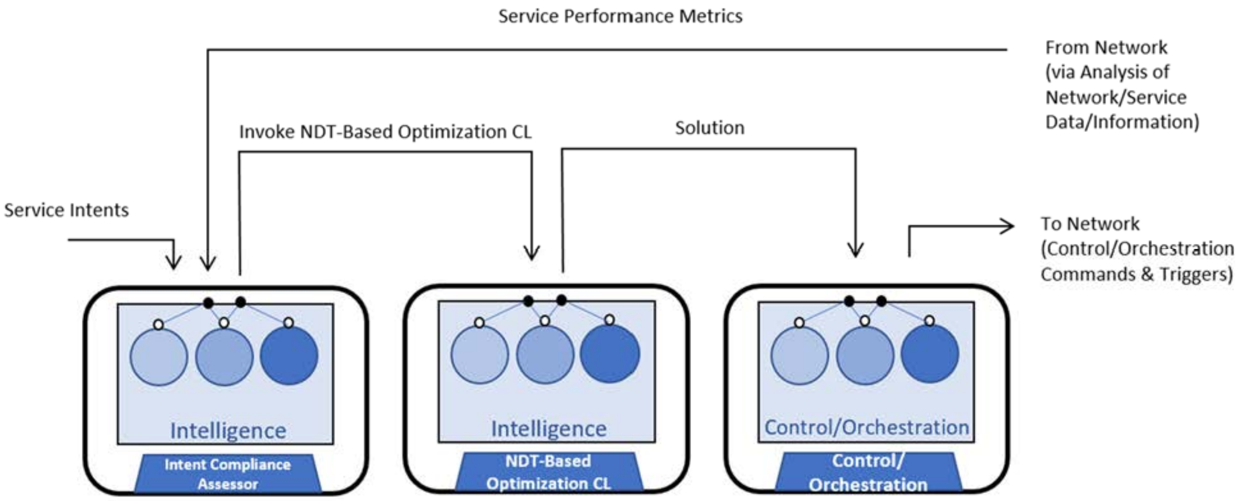

Figure A.3: Schematic representation of an intent assurance closed loop, containing an NDT-based optimization closed loop

A management service checks intent compliance by comparing e.g. service performance information, obtained as (or by analysis of) real network and service data/information, to the intent-defined performance targets or constraints for the various services. If and when gaps appear between target and actual service performances, an NDT-based optimization closed loop is activated. The objective of that closed loop is to find network or other configurations, settings etc. that would bring service performances back into alignment with their intent-defined targets. When the optimization closed loop finds such configurations, settings, etc., they are provided to control or orchestration or management services - per ETSI GS ZSM 002 [1], clauses 6.5.5, 6.5.6 and 6.6.5 - which activate the solution on the real network. The intent compliance assessor continues to monitor the resulting services to identify any newly emerging gaps between actual and targeted performance criteria, effectively closing the loop. In this case, the intent compliance checker and NDT-enabled optimization closed loop are both reflected as instances or specific types of intelligence services, as each is categorizable as a decision-supporting, decision-making or action-planning service.

These are examples of NDT-based use case architectural representations that are consistent with ZSM architectural concepts and conventions, and which use the ZSM management service definition of clause 8. Other NDT-based use cases may be represented following similar principles and procedures, invoking the appropriate combination and permutation of management services.

Annex B (informative): Change history

Date	Version	Information about changes
March 2024	V0.0.1	Initial skeleton approved Incorporated contributions: • ZSM(24)000059r2_ZSM018_Network_Digital_Twin_Terms • ZSM(24)000060r2_Add_Principles_for_Network_Digital_Twin • ZSM(24)000062r2_ZSM018_Add_requirements_for_NDT
June 2024	V0.0.2	Incorporated contributions: • ZSM(24)000078r3_ZSM018_Add_Terms • ZSM(24)000079r4_Add_Principles_for_Network_Digital_Twin • ZSM(24)000080r4_ZSM018_Add_Network_Slicing_risk_prediction_use_case • ZSM(24)000114r6_ZSM018_Add_visualisation_use_case • ZSM(24)000115r4_ZSM018_Add_data_generation_use_case
September 2024	V0.0.3	Incorporated contributions: • ZSM(24)000024r3_ZSM018_-_Clause_4_1_NDT_Concept • ZSM(24)000063r1_ZSM_018__Requirement_for_Network_Digital_Twin • ZSM(24)000098r3_ZSM018_Data_transfer_between_physical_twin_and_NDT • ZSM(24)000116r3_ZSM018_Add_Network_Historical_Playback_use_case • ZSM(24)000147r2_ZSM_018_Clause_8_0_Network_Digital_Twin_Architecture_Based_o • ZSM(24)000150r2_Network_Digital_Twin_modelling_session • ZSM(24)000153r2_ZSM018_NDT_model_session_requirements • ZSM(24)000154r3_ZSM018_NDT_workload_placement • ZSM(24)000156_ZSM018_NDT_Feasibility_Check_Service
October 2024	V0.0.4	Incorporated contributions: • ZSM(24)000184_ZSM018_Changes_in_references • ZSM(24)000187_ZSM018_Updating_and_Removing_Clauses • ZSM(24)000188_ZSM018_Annex_Removal
November 2024	V0.0.5	Incorporated editorial comments from ZSM support
November 2024	V0.0.6	Incorporated contributions: • ZSM(24)000199r1_ZSM018_Update text in clause 4.2 principle 1 • ZSM(24)000200r1_ZSM018_Removal_of_figure_in_clause_5_6 • ZSM(24)000201r2_ZSM018_Removal_of_editors_notes • ZSM(24)000202_ZSM018_Change of annex title
December 2024	V1.1.1	First published version

History

Document history		
V1.1.1	December 2024	Publication