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**Group REPORT**

Zero Touch Network and Service Management (ZSM);

Network Digital Twin

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# Foreword

This Group Specification (GS) has been produced by ETSI Industry Specification Group 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](https://portal.etsi.org/Services/editHelp%21/Howtostart/ETSIDraftingRules.aspx) (Verbal forms for the expression of provisions).

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# 1 Scope

This report will describe the Network Digital Twin concept, investigate its applicability for automation of zero-touch network and service management and introduce existing, emerging and future scenarios that can benefit from it.

Principles and functionality needed to support and utilize the Network Digital Twin for zero-touch network and service management will be introduced, considering also state of the art.

The report will outline recommendations of additional capabilities needed in the ZSM framework to support Network Digital Twins.

The report will identify existing specifications and solutions (both ETSI and external ones) that can be leveraged to maximize synergies. Collaboration with other SDOs (e.g. in IRTF NMRG, ITU-T SG13) will be recommended when appropriate.

Editor’s note: TODO: update scope description as document matures.

# 2 References

## 2.1 Normative references

Normative references are not applicable in the present document.

## 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.

NOTE: While any hyperlinks included in this clause were valid at the time of publication, ETSI cannot guarantee their long term validity.

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] A. M. Madni, C. C. Madni and S. D. Lucero, “Leveraging digital twin technology in model-based systems engineering,” MDPI Systems, vol. 7, no. 7; doi:10.3390/systems7010007, 2019.

[i.2] Y. Wu, K. Zhang and Y. Zhang, “Digital Twin Networks: A Survey,” IEEE Internet of Things J., vol. 8, no. 18, pp. 13789-13804, Sept. 2021.

[i.3] C. Zhou, H. Yang, D. Lopez, A. Pastor, Q. Wu, M. Boucadair, C. Jacquenet, “Digital Twin Network: Concepts and Architecture,” draft-irtf-nmrg-network-digital-twin-arch-02, Oct. 2022.

[i.4] ETSI GS ZSM 007: “Zero-touch network and Service Management (ZSM); Terminology for concepts in ZSM”

[i.5] ETSI GS ZSM 003: “Zero-touch network and Service Management (ZSM); End-to-end management and orchestration of network slicing”

[i.6] ETSI GS ZSM 002: “Zero-touch network and Service Management (ZSM); Reference Architecture”

# 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.4] and the following apply:

Editor’s note: TODO: where needed, provide definition of terms aligned with terminology used in industry and literature.

## 3.2 Symbols

For the purposes of the present document, the [following] symbols [given in ... and the following] apply:

## 3.3 Abbreviations

For the purposes of the present document, the abbreviations given in ETSI GS ZSM 007 [i.4] and the following apply:

NDT Network Digital Twin

REC Recommendation

# 4 Introduction of Network Digital Twin

## 4.1 Concept of Network Digital Twin

Digital Twins (DTs) are an increasingly examined technology relevant to system automation. A DT is a virtual replica of a real-world system - a “physical” system - on which operations can be performed [i.1]. The observed outcomes and effects of such operations constitute information that can be used e.g. to inform operational decision-making, including within automation-supporting closed loops.

A Network Digital Twin (NDT) is a DT whose physical counterpart is a communications network, or some part of one [i.2]. The communications network can include e.g. physical network elements and components, virtualized network functions (VNFs - i.e., network functional elements instantiated as software-based entities), the physical hosts for such VNFs, services and traffic, etc.

In [i.3], it is proposed that an NDT encompasses four components: data, models, interfaces and mapping (referring to between digital entities and their real-world counterparts). Data and models constitute the functional core of an NDT.

“Data” can include information about the network, its use, and its environment; e.g.:

* physical and virtual equipment types, functions and capabilities;
* network topology and configuration;
* services or traffic;
* network element, or network element component, health and status (e.g. fault management data);
* service or network element performance data;
* network environmental data;
* interface-related information, including interface operations;
* histories of any or all of the above;
* etc.

Specific data consumed by an NDT is determined by the requirements of targeted use cases.

“Models” can include information and data models used to represent e.g. network or service topology or configuration, and also behavioural models used to compute the physical network, service or other behaviours expected in postulated scenarios. Specifics of required models, including the required accuracies of behavioural models, are determined by the requirements of targeted use cases.

The functional perimeter of an NDT can be viewed as limited to the information-generating function: an “type-1 NDT”. Alternatively, it can be viewed as also encompassing other functions, such as additional closed loop stages, that are needed to drive actions on the physical system: a “type-2 NDT”.

Editor’s note: Type-1 and Type-2 are provisional names.

A type-1 NDT can be used to determine the expected behavioural impacts of changes to network, traffic, service, environmental or other conditions, or of prospective operational actions. A type-2 NDT additionally can make operational decisions based on such assessments and drive those decisions forward into actuation on the physical network.

Achieving highly accurate behavioural predictions requires that behavioural models have access to as much current data as possible, representing in detail the “twinned” physical network, services, traffic, environment etc.. The use by NDTs of copious and current data specific to the physical networks they represent lies at the heart of the notion of “twinning” and distinguishes NDTs from generic behavioural simulations and their uses. However, in many cases, NDTs are used to predict behaviours that would occur in scenarios – circumstances, actions, etc. – that are at least partly hypothetical or prospective, rather than strictly representing the actual state of the physical network. In such cases, current network data may be modified or complemented for use by the NDT in order to specify scenarios for which

## 4.2 Generic benefits of Network Digital Twin

The following benefits can be obtained from network digital twins:

* A network digital twin may have access to real-time data, which facilitates accurate verification of network and service configurations, deployments, etc., before their application on the counterpart physical network. This reduces operational risks and unintended adverse impacts.
* A network digital twin may have access to historical as well as current data, so that it can “replay” a historical status, for example to analyze past network and services issues (e. g. failures, network congestions, etc.). In addition, data analysis can be used to predict potential network and service issues in the future.
* A network digital twin may have access to additional contextual data (e.g., environmental data, etc.), which allows verification, simulation, etc. in a realistic environment.
* Network digital twins facilitate data sharing and organizational collaboration. For example, in the case of a natural disaster forecast, the autonomous network can be informed of potential issues and it can make automatic adjustments based on this.

Editor’s note: additional advantages that fit in terms of network digital twin is FFS.

## 4.3 Industry progress of Network Digital Twin

Editor’s Note: This clause describes the state of the art in NDT.

# 5 Examples of use cases using NDT

## 5.1 Radio network energy saving

### 5.1.1 Description

The objective of energy saving is to lower OPEX for mobile operators, through the reduction of power consumption in the mobile networks that is becoming more urgent and challenging. One typical scenario of energy saving is to reduce (or switch-off) radio resources when the traffic demand is low, and re-activate them on a need basis. But, as we know, the energy saving actions may deteriorate the service experience (e.g. throughput, coverage), and it is not straightforward to evaluate the influence on service experience of energy saving actions beforehand. NDT provides a further way for verification of energy saving actions.

### 5.1.2 Use case details

This clause describes the detailed steps that the NDT may be used for the intent-based closed loop.

1. When receiving an intent related to radio network energy saving from an Intent Owner, the Intent Management Function translates the intent and derives the energy saving actions to satisfy the intent.
2. The Intent Management Function applies these derived actions on the NDT for verification. Typically, examples of these actions include “switch on some energy saving algorithms in the cell”, “configure the cell overlaid relations” etc. By performing these actions, the NDT sends the relevant performance metrics (e.g. energy consumption, throughput, weak coverage ratio, and maximum UE number) to Intent Management Function for evaluation.

The interactions between Intent Management Function and NDT may be performed multiple times to compare among different sets/configurations of energy saving actions. Following the default behaviour of an intent-based system, the intent-based system will perform the closed-loop automation to satisfy the intent.

## 5.2 Network Slicing risk prediction

### 5.2.1 Description

As described in clause 7.1 of ETSI GS ZSM 003 [i.5] the required SLA for a network slice is translated into a set of service profile parameters which in turn are further translated into configurable parameters or intent expectations for the network slice profiles of each MD (normally CN domain, AN domain and TN domain). Using the NDT to predict risks, the ZSM framework can identify risks of specific service or network slice profile parameters 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.

Editor’s note: For this use case existing capabilities of the ZSM framework may not be enough and requirements for new services will be identified in clause 6.

### 5.2.2 Use case details

A precondition of this use case is that the network slice is established and running in the network.

This clause describes the sequence how the NDT may be used for the prediction of risks in network slicing.

1. (Step 1-4 of figure 5.2.2-1) The managed entity provides performance measurements. These measurements are constantly used by the NDT to perform simulations and to identify possible risks for network slice parameters to be outside of the expected range for these parameters in the near future.
2. (Step 5-7 of figure 5.2.2-1) When the prediction results indicate that the simulated parameters will be outside of the expected ranges it will attempt to identify a solution for the risk. If it can find a solution to avoid the risk within the MD, it will implement it by configuring the managed entities. If it cannot find a solution it will report the risk to the subscribed MnF(s) in the E2E SMD using a domain analytics service as described in clause 6.5.3.2.1 of ETSI ZSM GS 002 [i.6].
3. (Step 8-10 of figure 5.2.2-1) Using the risks information reported by the prediction service, as well as other performance measurements collected from the different MDs, the E2E SMD MnF will request one or multiple simulations from the E2E NDT in order to identify a valid solution that would avoid the risk for materializing and the SLA/SLS of the network slice being broken.
4. (Step 11-12 of figure 5.2.2-1) Once the E2E SMD MnF identifies the valid solution it will communicate it to the appropriate MD MnFs using a domain orchestration service as described in clause 6.5.5.2.1 of ETSI ZSM GS 002 [i.6].

 

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

## 5.3 Signalling storm simulation and analysis

### 5.3.1 Description

During mobile network service disruption, terminal users will repeatedly attempt to establish connections until they are reconnected. The explosion in the volume of reconnect signals in such scenarios might overload network processing capacity in the core network. This might in turn lead to a signalling storm, eventually causing serious impacts on network performance.

### 5.3.2 Use case details

The adoption of the NDT can predict the amount of signalling traffic based on the number of users, and to analyze the impact of optimization actions derived by management services (e.g. domain intelligence services). While handling signalling traffic, the network digital twin provides the capabilities as described below:

1. The NDT could predict terminal reconnection growth in the physical network. To do so, it could utilize data such as the number of current subscribers, signalling traffic collected in recent and historical periods, predicted or estimated recovery durations, and any other relevant data to predict maximum terminal reconnection growth. This predicted information may be consumed by management services (e.g. a proactive network optimization service as defined in clause 6.5.3.2.1 of ETSI GS ZSM 002 [i.6]) for optimization analysis.
2. Based on the predicted maximum terminal reconnection growth, optimization (e.g. set the maximum rate of traffic received at a network node) is triggered, and the NDT can be used to validate the impact of the optimization actions.

# 6 NDT for zero-touch Network and Service management

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## 6.1 Principles

Editor’s note: Principles and functionality needed to support and utilize the Network Digital Twin for zero-touch network and service management will be introduced in this section

## 6.2 Adopting NDT based on ZSM architecture

Editor’s note: This clause describes requirements and recommendations needed on the NDT in order to be used by the ZSM architecture

## 6.3 Potential new ZSM Capabilities to support the NDT

REC-1: It is recommended that the ZSM framework provides capabilities to integrate the NDT in the MD/E2ESMD.

Annex A (informative):

Editor’s Note: The report will identify existing specifications and solutions (both ETSI and external ones) that can be leveraged to maximize synergies. Collaboration with other SDOs (e.g. in IRTF NMRG, ITU-T SG13) will be recommended when appropriate.

Annex (informative):
Change History

| Date | Version | Information about changes |
| --- | --- | --- |
| May 2022 | 0.0.1 | Initial skeleton for approval |
| June 2022 | 0.0.2 | Skeleton approved during ZSM Tech Call #19e |
| February 2022 | 0.0.3 | Incorporated contributions:* ZSM(22)000391r5\_ZSM015\_Add NDT scenario signalling storm
* ZSM(23)000019r1\_ZSM015\_Adding requirements to verification scenario
* ZSM(22)000271r10\_ZSM015\_Add\_benefit of network digital twin
* ZSM(22)000388r3\_ZSM015\_Section 4.1 Concept of Digital Twin
* ZSM(23)000013\_ZSM015 - editing terms and abbreviations
* ZSM(22)000361r4\_ZSM015\_Add scenario related to risk prediction for network slicing using NDT
* ZSM(22)000305r4\_ZSM015\_Add scenario related to verification using NDT
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