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**SmartM2M;**
**Digital Twins communication support in oneM2M**

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# Foreword

This Technical Report (TR) has been produced by ETSI Technical Committee Smart Machine-to-Machine communications (SmartM2M).

# Modal verbs terminology

In the present document "**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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# Executive summary

The present document builds on previous STF 628 work ETSI TR 103 844 [i.9], ETSI TS 103 845 [i.10], ETSI TS 103 846 [i.11] to guide the implementation of Digital Twins (DTs) within the oneM2M framework. It outlines the key oneM2M features that meet specific requirements and demonstrates how oneM2M can support DTs across various scenarios.

Key highlights include:

- Emphasis on modularity and adaptability to ensure interoperability across different platforms and technologies.
- Practical examples illustrating oneM2M's capabilities in meeting Digital Twin requirements.
- Critical analysis identifying potential gaps in oneM2M, offering insights for future enhancements.

The present document aims to provide a comprehensive guide for effectively integrating Digital Twins into the oneM2M ecosystem, promoting seamless IoT communication and functionality.

# Introduction

The present document explores the insights and architectural foundations from ETSI TR 103 844 [i.9], ETSI TS 103 845 [i.10] and ETSI TS 103 846 [i.11] and compares them to the features and capabilities offered by oneM2M. It provides a guide for mapping Digital Twins (DTs) communication requirements to the oneM2M framework.

The present document emphasizes modularity and adaptability for communication, ensuring interoperability across installations and platforms. It uses oneM2M's features to keep elements and information technology-agnostic, minimizing the impact of evolving communication frameworks on DT information. The present document shows the mapping of DT requirements to oneM2M features in clauses 4,5 and 6.

Additionally in clause 8, it provides practical examples of Digital Twins within the oneM2M context. These examples show how oneM2M meets specific requirements, bridging the gap between concepts and real-world applications. This helps stakeholders understand the proposed solutions.

The present document also identifies potential gaps in the oneM2M framework, in clause 7, that may hinder the defined requirements. ETSI TS 103 845 [i.10] analyses these areas, suggesting enhancements to better accommodate Digital Twins communication. This aims to offer valuable insights for future developments, promoting effective integration of Digital Twins into the IoT communication landscape.

# 1 Scope

The purpose of the present document is to capture the requirements defined in ETSI TS 103 845 [i.10] and demonstrate the ways in which these requirements can be implemented using the oneM2M standard:

- List the architectural, communication, description and discovery requirements for DTs.
- Description of the oneM2M features that can be used to implement each requirement.
- Identification of any existing gaps within the oneM2M architecture with respect to implementation of requirements.

# 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 nonspecific. 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] ETSI TS 118 112 (V2.0.0): "oneM2M; Base Ontology (oneM2M TS-0012 version 2.0.0 Release 2)".

[i.2] ETSI TS 118 125 (V2.0.0): "Definition of product profiles (oneM2M TS-0025 version 2.0.0 Release 2A)".

[i.3] ETSI TS 118 123 (V2.0.0): "oneM2M; Home Appliances Information Model and Mapping (oneM2M TS-0023 version 2.0.0 Release 2)".

[i.4] ETSI TS 118 103 (V1.0.0): "oneM2M Security solutions (oneM2M TS-0003)".

[i.5] oneM2M TS-0034: "Semantic Support".

[i.6] ETSI TR 118 524 (V2.0.0): "oneM2M; 3GPP Interworking (oneM2M TR-0024)".

[i.7] ETSI TS 118 133 (V4.0.1): "Interworking Framework (oneM2M TS-0033 v4.0.1 Release 4)".

[i.8] ETSI TS 118 101 (V1.0.0): "Functional Architecture (oneM2M TS-0001)".

[i.9] ETSI TR 103 844 (V1.1.1): "SmartM2M; Digital Twins and Standardization Opportunities in ETSI".

[i.10] ETSI TS 103 845 (V1.1.1): "SmartM2M; Digital Twins Communication Requirements".

[i.11] ETSI TS 103 846 (V1.1.1): "SmartM2M; Digital Twins: Functionalities and communication Reference Architecture".

[i.12] oneM2M TR-0073: "Developer Guide: Deploying Semantics".

# 3 Definition of terms, symbols and abbreviations

## 3.1 Terms

For the purposes of the present document, the following terms apply:

**Application Entity (AE):** application process that performs specific functions or services in an M2M (Machine-to-Machine) or IoT (Internet of Things) system

NOTE: An AE contains the application logic and processes required to perform specific tasks or provide services within the M2M/IoT environment. An AE can represent a physical or an application.

**Common Services Entity (CSE):** fundamental component within the oneM2M architecture

NOTE: It represents a set of "common service functions" essential for M2M (Machine-to-Machine) and IoT (Internet of Things) environments. The CSE acts as a middleware layer, facilitating communication and management tasks between various Application Entities (AEs) and the underlying network services.

**data sharing resource:** oneM2M resources whose main purpose is to share data between a physical device or data source and applications

EXAMPLE: oneM2M data sharing resources are <contentInstance>, <timeSeriesInstance>, <flexContainer>. Other resources may have data that is shared, but they are generally considered meta-data or service parameters, e.g. subscription attributes.

**Digital Communication Adapter (DCA):** modular component within the Digital Communication Channel (DCC) that handles the specifics of communicating with external digital entities

NOTE: Each DCA is responsible for managing a specific protocol or interaction pattern, translating the DT's internal data into a format that can be understood by the target digital system and vice versa.

**Digital Communication Channel (DCC):** core component that enables the digital twin to communicate and interact with external digital entities, such as applications, services, and other digital twins

NOTE: It acts as the bridge between the DT's core and the external digital world, ensuring seamless and effective exchange of data, commands and interactions.

**Digital Twin (DT):** comprehensive software representation of an individual Physical Object

NOTE: It includes the properties, conditions, and behavior(s) of the real-life object through models and data. A Digital Twin is a set of realistic models that can digitalize and simulate an object's behavior in the deployed environment. The Digital Twin represents and reflects its physical twin and remains its virtual counterpart across the object's entire lifecycle [i.1].

**Digital Twin Description (DTD):** detailed representation of a physical entity or system in a digital format

NOTE: This description encompasses the physical characteristics, operational states, behavioral models, and interactions of the physical entity, allowing for real-time monitoring, analysis, and simulation. DTD is essential for creating an accurate and functional digital twin, which is a virtual counterpart of a physical object or system.

**Interworking Proxy Entity (IPE):** component within the oneM2M architecture designed to facilitate the integration and interoperability of non-oneM2M systems and protocols with the oneM2M framework

NOTE: The IPE acts as a bridge, enabling communication and data exchange between oneM2M-compliant devices and external systems that use different protocols or standards. The IPE is a special purpose AE.

**Physical Communication Adapter (PCA):** modular component within the Physical Communication Channel (PCC) designed to interface with various physical assets, such as sensors, devices and machinery

NOTE: The PCA enables communication between the DT and these physical assets by translating the physical characteristics, protocols, and data formats into a standardized format that the DT can understand and process.

**Physical Communication Channel (PCC):** fundamental component designed to facilitate seamless interaction between digital twins and their physical counterparts

NOTE: It serves as a conduit for communication, ensuring that DTs can effectively interact with various physical entities, such as sensors, devices and machinery.

## 3.2 Symbols

Void.

## 3.3 Abbreviations

For the purposes of the present document, the following abbreviations apply:

| | |
|---|---|
| ADN | Application Dedicated Node |
| AE | Application Entity |
| API | Application Program Interface |
| ASN | Application Service Node |

NOTE: Contains one Common Services Entity and contains at least one Application Entity.

| | |
|---|---|
| CDT | Composed Digital Twin |
| CMDH | Communication Management and Delivery Handling |
| CoAP | Constrained Application Protocol |
| CSE | Common Service Entity |

NOTE: Represents an instantiation of a set of Common Service Functions of the M2M environments. Such service functions are exposed to other entities through reference points.

| | |
|---|---|
| DCA | Digital Communication Adapter |
| DCC | Digital Communication Channel |
| DT | Digital Twin |
| DTD | Digital Twin Description |
| HTTP | Hyper Text Transfer Protocol |
| IoT | Internet of Things |
| IPE | Interworking Proxy application Entity |
| JSON | Java Script Notation Object |
| MN | Middle Node |

NOTE: Contains one Common Services Entity and contains zero or more Application Entities.

| | |
|---|---|
| MQTT | Message Queue Telemetry Transport |
| NoDN | Non-oneM2M Device Node |
| OPC-UA | Open Platform Communications Unified Architecture |
| PCA | Physical Communication Adapter |
| PCC | Physical Communication Channel |
| PT | Physical Twin |
| PTD | Physical Twin Description |
| QoS | Quality of Service |
| RDM | Requirements and Domain Models |
| SDT | Smart Device Template |
| WoT | Web of Things |
| XML | eXtensible Mark-up Language |

# 4 Architecture Requirements

## 4.1 Introduction

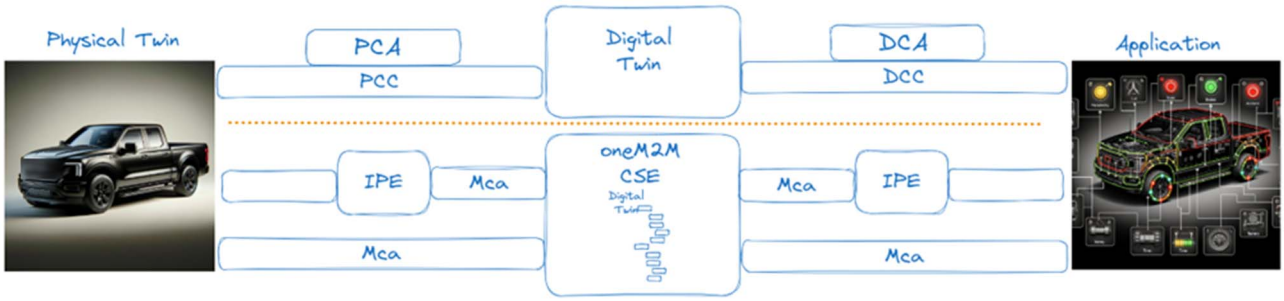


**Figure 4.1-1: Architecture of a Digital Twin**

A basic architecture of a digital twin system is shown in the top portion of Figure 4.1-1. It starts with the Physical Twin, an automobile, that can communicate with a Digital Twin through a PCA and PCC. There is also an application or service, a display shows status of vehicle systems, that communicates with the Digital Twin though a DCA and DCC. The same system, in the bottom of Figure 4.1-1, shows using a oneM2M system that has a device AE (on the left) that communicates through the Mca interface to the CSE, where the Digital Twin resides in the form of a resource tree. Applications or services also communicate to the CSE using the Mca interface. In a oneM2M deployment where the physical twin or the application does not use native oneM2M APIs, an IPE can be deployed to provide protocol and data model translation so that they can communicate with the oneM2M CSE.

The architectural description of a digital twin is readily implemented using a oneM2M solution. The present document uses the following mapping of architectural terms between the digital twin architecture and the oneM2M architecture.

**Table 4.1-1: Mapping of Digital Twin Components to oneM2M Components**

| ETSI TS 103 845 [i.10] Digital Twin Architectural Components | oneM2M Architectural Components |
|---|---|
| **Physical Twin** | ADN-AE |
| **PCA** | IPE AE |
| **PCC** | Mca |
| **Digital Twin Core** | ASN-CSE, MN-CSE, IN-CSE |
| **DCC** | Mca |
| **DCA** | IPE AE |
| **Digital Applications or services** | IN-AE |

## 4.2 Digital Twin Architecture Requirements

**Table 4.2-1: Digital Twin Architecture Requirements**

| Requirement ID | Digital Twin Requirement | Mapping to oneM2M |
|---|---|---|
| REQ_4.2_001 | A DT shall include an implementation of a PCC. A PCC allows communication between the Physical device and a Digital Twin. | The Mca reference point allows communication between the CSE and the device AEs.<br><br>See Deployment Scenario #1. |
| REQ_4.2_002 | The DT Core shall serve as the epicentre of the twin, housing its fundamental behaviors, properties, events, relationships, and actions. | A Common Services Entity (CSE) is crucial in the oneM2M architecture, providing essential middleware services that enable efficient, secure, and scalable communication and management of IoT devices and applications. It supports interoperability, modularity, and adaptability, making it a foundational component in M2M and IoT systems.<br><br>See Deployment Scenario #1. |

| Requirement ID | Digital Twin Requirement | Mapping to oneM2M |
|---|---|---|
| REQ_4.2_003 | Composition shall allow for the creation of hierarchical structures, enabling a parent DT to oversee and coordinate multiple child DTs. | In the oneM2M framework, resources can be composed to model a hierarchical structure where a parent Digital Twin (DT) organizes multiple child Digital Twins. This composition leverages the hierarchical nature of oneM2M resources and the ability to nest resources within containers and groups.<br><br>Smart Devices Template models, defined in ETSI TS 118 123 [i.3], have examples of composition using <flexContainer> resources.<br>Physical Twins should use <flexContainer> resources.<br><br>See Deployment Scenario #2. |
| REQ_4.2_004 | Composition shall integrate with the DCC of DTs, ensuring that digital interactions with external entities extend to the entire hierarchy. | To access a Digital Twin (DT) data model in a oneM2M framework, an application follows a structured process leveraging the oneM2M resource architecture and APIs. The process includes discovering the relevant resources, retrieving data, and potentially subscribing to updates.<br><br>See Deployment Scenario #3. |
| REQ_4.2_005 | Composition shall provide a unified description of the parent DT and its child DTs, including their relationships, properties, events, and actions. | In the oneM2M framework, the <semanticDescriptor> resource is used to provide semantic descriptions of other resources. This allows for a richer, more meaningful representation of data by adding context and relationships that can be understood by machines. For a Digital Twin (DT) data model, <semanticDescriptor> can be utilized to describe the structure, attributes, and relationships of the DT in a way that enhances interoperability and understanding across different systems and applications.<br><br>Semantic descriptions of the DT shall be provided in <semanticDescription> resources. Semantic descriptions SHOULD use SAREF and oneM2M Base ontologies and MAY use other ontologies.<br><br>See oneM2M TS-0034 [i.5] and ETSI TS 118 112 [i.1]. |
| REQ_4.2_006 | Composition shall facilitate collaboration between DTs from different domains or application scenarios. | The announceTo feature in oneM2M can be leveraged to share resources across different CSEs (Common Services Entities) or domains, facilitating the creation and management of a hierarchical parent-child Digital Twin (DT) structure. This feature allows resources to be "announced" to other CSEs, making them accessible in multiple locations.<br><br>Composition shall be realized using announceTo functionality.<br><br>Composition shall be realized using <flexContainer> resources.<br><br>See Deployment Scenario #3. |
| REQ_4.2_007 | Composition shall provide management interfaces that allow administrators and operators to control and configure the behavior of hierarchical DT structures. | For data models that allow control of the physical device, subscription and notifications shall be used.<br><br>See Deployment Scenario #2. |
| REQ_4.2_008 | DTs shall implement robust security measures to protect against unauthorized access, data breaches, and cyber-physical attacks. | oneM2M defines security and access control in ETSI TS 118 103 [i.4].<br><br>Digital Twins shall implement <accessControlPolicy> resources. |

| Requirement ID | Digital Twin Requirement | Mapping to oneM2M |
|---|---|---|
| REQ_4.2_009 | Cross-Domain DTs shall implement robust security measures to protect data and interactions when bridging different domains. | oneM2M defines security and access control in ETSI TS 118 103 [i.4].<br><br>Digital Twins shall implement <accessControlPolicy> resources.<br><br>Digital Twins shall implement authentication. |
| REQ_4.2_010 | Access control mechanisms shall be in place to ensure that only authorized entities can interact with the DTs, preventing unauthorized access or malicious actions. | oneM2M defines security and access control in ETSI TS 118 103 [i.4].<br><br>See ETSI TR 118 524 [i.6].<br><br>Digital Twins shall implement <accessControlPolicy> resources.<br><br>Digital Twins shall implement authentication. |
| REQ_4.2_011 | Cross-Domain DTs shall be capable of transforming and normalizing data from various domains. | oneM2M can semantically describe data, but has no ability to transform or normalize data. RDM Gap.<br><br>See clause 7.3. |
| REQ_4.2_012 | Cross-Domain DTs shall be adaptable and customizable to meet the specific requirements of each domain they interact with. | The announceTo feature in oneM2M can be leveraged to share resources across different CSEs (Common Services Entities) or domains, facilitating the creation and management of a hierarchical parent-child Digital Twin (DT) structure. This feature allows resources to be "announced" to other CSEs, making them accessible in multiple locations.<br><br>Cross-Domain Composition shall be realized using announceTo functionality.<br><br>Cross-Domain Composition shall be realized using <flexContainer> resources.<br><br>See Deployment Scenario #3. |
| REQ_4.2_013 | DTs shall support replication strategies that enable them to create digital replicas and distribute them across edge nodes allowing replicas to effectively communicate without limitations associated to their architectural deployment on the edge or in the cloud. | The announceTo feature in oneM2M can be leveraged to share resources across different CSEs (Common Services Entities) or domains, facilitating the creation and management of a replica Digital Twin (DT) structure. This feature allows resources to be "announced" to other CSEs, making them accessible in multiple locations.<br><br>Cross-Domain Composition shall be realized using announceTo functionality.<br><br>Cross-Domain Composition shall be realized using <flexContainer> resources.<br><br>See Deployment Scenario #3. |
| REQ_4.2_014 | Edge and Cloud DTs shall allow for customization and configuration to meet the specific requirements of various edge environments and cloud infrastructures. | This is a platform requirement. |
| REQ_4.2_015 | Both Edge and Cloud DTs shall address unique communication requirements. | This is a platform requirement. |

| Requirement ID | Digital Twin Requirement | Mapping to oneM2M |
|---|---|---|
| REQ_4.2_016 | Both Edge and Cloud DTs shall provide robust support for composition and orchestration management. | The announceTo feature in oneM2M can be leveraged to share resources across different CSEs (Common Services Entities) or domains, facilitating the creation and management of a replica Digital Twin (DT) structure. This feature allows resources to be "announced" to other CSEs, making them accessible in multiple locations.<br><br>Cross-Domain Composition shall be realized using announceTo functionality.<br><br>Cross-Domain Composition shall be realized using <flexContainer> resources.<br><br>See Deployment Scenario #3. |
| REQ_4.2_017 | They (Edge DT) shall support a wide range of communication protocols, data formats, and interaction patterns to facilitate seamless integration with edge devices, sensors, and cloud services. | A oneM2M CSE (DT) supports http, websocket, mqtt, coap communication protocols.<br><br>A oneM2M CSE (DT) supports xml, json, cbor data formats.<br><br>A oneM2M CSE can communicate bidirectionally with other CSEs using the Mcc reference point. |
| REQ_4.2_018 | Edge DTs shall possess data processing and analytics capabilities to extract meaningful insights from local data sources. | This is a platform requirement. |
| REQ_4.2_019 | Cloud DTs, on the other hand, shall offer extensive data processing and storage resources to perform advanced analytics and support data-intensive applications. | This is a platform requirement. |
| REQ_4.2_020 | The DTD's primary role shall be to encapsulate the essential attributes and characteristics of a DT, effectively serving as a digital representation of the physical entity. | Semantic descriptions of the DT shall be provided in <semanticDescription> resources. Semantic descriptions SHOULD use SAREF and oneM2M Base ontologies and MAY use other ontologies.<br><br>Data from the physical twin shall be stored in attributes of the data sharing resources.<br><br>See oneM2M Dev Guide for semantic interop. |
| REQ_4.2_021 | Each DT shall be globally uniquely identified, and its identifier should be reported in the DTD to provide an immediate reference to the target twin. | In oneM2M each resource is uniquely identified.<br><br>The oneM2M base ontology shall be used to describe the resource identifier of the parent digital twin.<br><br>The identifier of child digital twins may be described using the oneM2M base ontology.<br><br>See oneM2M Dev Guide for semantic interop. |
| REQ_4.2_022 | DTDs shall include identifiers of the associated PTs, type, description, and the potential associated metadata. | The oneM2M base ontology shall be used to describe the resource identifier of the parent digital twin. |
| REQ_4.2_023 | DTDs shall introduce information about how an external application can monitor the DT discovering and observing available and exposed metrics and events generated by the DT, enhancing overall accountability and the awareness on both the cyber-physical relationship between DT and PT and their evolution during their lifecycle. | Semantic descriptions of the DT shall be provided in <semanticDescription> resources.<br><br>Semantic descriptions should use the SAREF ontologies to describe the digital twin.<br><br>Semantic descriptions of the DT shall use oneM2M Base ontologies.<br><br>Semantic descriptions of the DT may use other ontologies.<br><br>See oneM2M Dev Guide for semantic interop. |

| Requirement ID | Digital Twin Requirement | Mapping to oneM2M |
|---|---|---|
| REQ_4.2_024 | Each DT shall have a unique and standardized identifier, making it addressable in a software space. | In oneM2M each resource is uniquely identified. |
| REQ_4.2_025 | DTDs shall include comprehensive metadata about DTs, including their type, description, associated PTs, and relevant contextual information. Metadata enhances the understanding and context of DTs. | Semantic descriptions of the DT shall be provided in <semanticDescription> resources.<br><br>Semantic descriptions should use the SAREF ontologies to describe the digital twin.<br><br>Semantic descriptions of the DT shall use oneM2M Base ontologies.<br><br>Semantic descriptions of the DT may use other ontologies.<br><br>See oneM2M Dev Guide for semantic interop. |
| REQ_4.2_026 | DTs shall provide resource descriptors that outline their properties, relationships, events, and behaviors/actions. These descriptors should be structured, standardized, and machine-readable. | Semantic descriptions of the DT shall be provided in <semanticDescription> resources.<br><br>Semantic descriptions should use the SAREF ontologies to describe the digital twin.<br><br>Semantic descriptions of the DT shall use oneM2M Base ontologies.<br><br>Semantic descriptions of the DT may use other ontologies.<br><br>See oneM2M Dev Guide for semantic interop. |
| REQ_4.2_027 | DTDs shall be represented in a standardized format or data model to facilitate interoperability across different platforms, systems, and implementations. | Semantic descriptions of the DT shall be provided in <semanticDescription> resources.<br><br>Semantic descriptions should use the SAREF ontologies to describe the digital twin.<br><br>Semantic descriptions of the DT shall use oneM2M Base ontologies.<br><br>Semantic descriptions of the DT may use other ontologies.<br><br>See oneM2M Dev Guide for semantic interop. |
| REQ_4.2_028 | For scenarios where a centralized directory service is appropriate, DTDs shall provide information necessary for directory services to maintain up-to-date listings of available DTs. | Advanced Semantic Discovery (Rel 5) provides federated discovery capabilities.<br><br>See oneM2M TS-0034 [i.5]. |
| REQ_4.2_029 | DT shall enable versioning and change tracking for DTDs to manage updates and modifications over time. | *Change tracking* for <semanticDescriptor> resources is not supported. Implementation of versioning and change tracking for DTDs can be achieved using existing oneM2M capabilities in a non-standard manner.<br><br>See clause 7.4. |
| REQ_4.2_030 | DT shall allow for integration with other existing standards and description formats, such as WoT or oneM2M, to promote compatibility and alignment with established IoT and cyber-physical system ecosystems. | oneM2M has specific interworking guidelines for popular IoT standards, such as OPC UA. There is also an interworking framework specification the describes how custom interworking can be realized with IoT protocols that have not been formally adopted in oneM2M.<br><br>See ETSI TS 118 133 [i.7]. |
| REQ_4.2_031 | DT shall implement resource and service indexing to facilitate efficient querying and discovery of specific DT capabilities or services within a DT ecosystem. | Advance Semantic Discovery (Release 5) provides federated discovery capabilities.<br><br>See oneM2M TS-0034 [i.5]. |

| Requirement ID | Digital Twin Requirement | Mapping to oneM2M |
|---|---|---|
| REQ_4.2_032 | DT shall enable query and search mechanisms for DTDs, supporting advanced search criteria based on properties, relationships, and other contextual information. | Advance Semantic Discovery (Release 5) provides federated discovery capabilities.<br><br>See oneM2M TS-0034 [i.5]. |

## 4.3 Physical Interface Requirements

**Table 4.3-1: Physical Interface Requirements**

| Requirement ID | Digital Twin Requirement | Mapping to oneM2M |
|---|---|---|
| REQ_4.3_001 | A PCC shall support multiple PCAs. A PCA supports device protocols that may be different from the DT protocol. | An IPE is used to convert data from a non-oneM2M device (nodn) to a oneM2M data model. In oneM2M an IPE is implemented as an AE. A CSE can support multiple IPE-AEs.<br><br>The IPE is responsible for all data conversion between the nodn and the CSE. |
| REQ_4.3_002 | A PCA shall convert the native data model of the physical device to the data model format used by the DT. | An IPE is used to convert data from a non-oneM2M device (NODN) to a oneM2M data model. |

## 4.4 Digital Interface Requirements

**Table 4.4-1: Digital Interface Requirements**

| Requirement ID | Digital Twin Requirement | Mapping to oneM2M |
|---|---|---|
| REQ_4.3_001 | The DT shall support one or more DCCs, enabling adaptive functionality, isolating the core data model from the custom needs of the application and services. | The Mca reference point, used between the CSE and the application AEs, is equivalent to the DCC.<br><br>See Deployment Scenario #1. |

# 5 Communication Requirements

## 5.1 Introduction

The requirements expressed in this clause are targeted at the communication requirements of Digital Twins.

## 5.2 Communication Support Requirements

**Table 5.2-1: Communication Support Requirements**

| Requirement ID | Digital Twin Requirement | Mapping to oneM2M |
|---|---|---|
| REQ_5.2_001 | Cross-domain communication in DT ecosystems is a pivotal capability that shall be implemented to enable interoperability and collaboration between DTs belonging to different domains or application scenarios. | A oneM2M CSE can communicate bidirectionally with other CSEs using the Mcc reference point. |
| REQ_5.2_002 | It is fundamental that the PCC shall support multiple communication protocols (PCAs) concurrently. | An IPE is used to convert data from a non-oneM2M device (nodn) to a oneM2M data model. In oneM2M an IPE is implemented as an AE. A CSE can support multiple IPE-AEs. The IPE is responsible for all data conversion between the nodn and the CSE. |

| Requirement ID | Digital Twin Requirement | Mapping to oneM2M |
|---|---|---|
| REQ_5.2_003 | The PCA shall support and use security based protocols. | oneM2M defines security and access control in ETSI TS 118 103 [i.4].<br><br>See ETSI TR 118 524 [i.6].<br><br>Digital Twins shall implement <accessControlPolicy> resources.<br><br>Digital Twins shall implement authentication. |
| REQ_5.2_004 | The PCC shall facilitate bidirectional communication between the DT and the physical twin. | For data models that allow control of the physical device, subscription and notifications shall be used.<br><br>See Deployment Scenario #2. |
| REQ_5.2_005 | The PCC/PCA shall use standardized protocols | A oneM2M CSE (DT) supports http, websocket, mqtt, coap communication protocols. |
| REQ_5.2_006 | The DT shall offer the flexibility for customization and configuration of communication patterns and protocols to align with specific use cases and the unique requirements of individual physical assets. | oneM2M CMDH allows for customization and configuration of communication channels, schedules, and rates.<br><br>See ETSI TS 118 101 [i.8]. |
| REQ_5.2_007 | Bidirectional communication shall be facilitated by the PCC, empowering the DT to not only passively observe but actively influence its physical environment in real-time. | For data models that allow control of the physical device, subscription and notifications shall be used.<br><br>See Deployment Scenario #2. |
| REQ_5.2_008 | To support seamless interoperability, the DCC shall exhibit a high degree of flexibility in translating the DT's internal data into various formats and protocols commonly used in the digital world. This includes widely recognized standards such as JSON, XML, or even protocol-specific representations like MQTT or RESTful APIs. | A oneM2M CSE (DT) supports http, websocket, mqtt, coap communication protocols.<br><br>A oneM2M CSE (DT) supports xml, json, cbor data formats. |
| REQ_5.2_009 | To ensure data security and privacy, the DCC and its DCAs shall support encryption protocols and secure communication channels, safeguarding sensitive information during transmission. | oneM2M defines security and access control in ETSI TS 118 103 [i.4].<br><br>Digital Twins shall implement <accessControlPolicy> resources.<br><br>Digital Twins shall implement authentication. |
| REQ_5.2_010 | The DCC through its DCAs shall support multiple protocols and interaction patterns, such as Publish/Subscribe through MQTT, RESTful APIs with HTTP and CoAP, WebSocket, and more. | A oneM2M CSE (DT) supports http, websocket, mqtt, coap communication protocols. |
| REQ_5.2_011 | Composition capabilities shall be protocol-agnostic, allowing the use of multiple communication protocols and patterns both for physical and digital communications. This flexibility accommodates diverse environments where different protocols may be prevalent. | To access a Digital Twin (DT) data model in a oneM2M framework, an application follows a structured process leveraging the oneM2M resource architecture and APIs. The process includes discovering the relevant resources, retrieving data, and potentially subscribing to updates. Parent Digital Twins, Child Digital Twins, Digital Twin hosting CSEs, and applications all have the flexibility to use any supported oneM2M protocol.<br><br>See Deployment Scenario #3. |
| REQ_5.2_012 | DTs shall be adaptable to scenarios ranging from disconnected DTs with no direct connection to strong, direct connections between the DT and its PT. | oneM2M CMDH allows for customization and configuration of communication channels, schedules, and rates.<br><br>See ETSI TS 118 101 [i.8]. |
| REQ_5.2_013 | DTs shall support a spectrum of communication timeliness, from non-real-time scenarios with delayed updates to hard real-time communication requiring instantaneous data transmission. | oneM2M CMDH allows for customization and configuration of communication channels, schedules, and rates.<br><br>See ETSI TS 118 101 [i.8]. |

| Requirement ID | Digital Twin Requirement | Mapping to oneM2M |
|---|---|---|
| REQ_5.2_014 | DTs shall support instantaneous data exchange with their Physical Twins (PTs) to facilitate immediate control and monitoring, making them suitable for applications requiring rapid responses and decision-making. | oneM2M CMDH allows for customization and configuration of communication channels, schedules, and rates.<br><br>See ETSI TS 118 101 [i.8]. |
| REQ_5.2_015 | Cross-Domain DTs shall be compatible with various replication strategies, such as one-to-one and one-to-many, to facilitate the creation of digital replicas that can operate seamlessly across different domains. | The one-to-many replication strategy can be implemented using announceTo functionality.<br><br>One-to-one replication strategy is not supported by the oneM2M architecture. There is no recommendation to support one-to-one replication strategy in oneM2M.<br><br>See Deployment Scenario #3. |
| REQ_5.2_016 | Cross-Domain DTs shall offer flexible composition capabilities to create hierarchical structures where a parent DT oversees the coordination of child DTs from different domains. | The announceTo feature in oneM2M can be leveraged to share resources across different CSEs (Common Services Entities) or domains, facilitating the creation and management of a hierarchical parent-child Digital Twin (DT) structure. This feature allows resources to be "announced" to other CSEs, making them accessible in multiple locations.<br><br>Composition shall be realized using announceTo functionality.<br><br>Composition shall be realized using <flexContainer> resources.<br><br>See Deployment Scenario #3. |
| REQ_5.2_017 | They (DT) shall be aware of the dynamic and ever-changing nature of the relationship between digital and physical entities, considering factors like connectivity, promptness, and association. | oneM2M resources can be subscribed so that notifications of changing conditions or states are generated. oneM2M has multiple resources and attributes that represent the state of connectivity, timeliness of data from physical devices and new associations (through subscriptions and announcements). |
| REQ_5.2_018 | DTDs shall specify the communication protocols and data formats supported by DTs, both for the digital and physical communication layers. This information aids in selecting appropriate interaction patterns. | Semantic descriptions of the DT shall be provided in <semanticDescription> resources.<br><br>Semantic descriptions should use the SAREF ontologies to describe the digital twin.<br><br>Semantic descriptions of the DT shall use oneM2M Base ontologies.<br><br>Semantic descriptions of the DT may use other ontologies.<br><br>See oneM2M TR-0073 [i.12].<br><br>Data from the physical twin shall be stored in attributes of the data sharing resources. |

## 5.3 Communication Interoperability Requirements

**Table 5.3-1: Communication Interoperability Requirements**

| Requirement ID | Digital Twin Requirement | Mapping to oneM2M |
|---|---|---|
| REQ_5.3_001 | The DT shall provide a representation of the physical device that is usable by external systems. | In the oneM2M framework, resources can be composed to model a hierarchical structure where a parent Digital Twin (DT) organizes multiple child Digital Twins. This composition leverages the hierarchical nature of oneM2M resources and the ability to nest resources within containers and groups.<br><br>Smart Devices Template models, defined in ETSI TS 118 123 [i.3], have examples of composition using <flexContainer> resources.<br><br>Physical Twins should use <flexContainer> resources.<br><br>See Deployment Scenario #2. |
| REQ_5.3_002 | The DCC shall provide a homogeneous representation of DTs to external digital entities. | A oneM2M CSE (DT) supports xml, json, cbor data formats.<br><br>When an application retrieves data from the CSE the resource representation is in the format specified by the application.<br><br>See Deployment Scenario #3. |
| REQ_5.3_003 | The DT's DCC shall abstract raw data and information from its core model, providing a simplified representation of the DT's state (properties, events, action and relationships), capabilities and actions to external digital entities through the representation through one or multiple format of a Digital Twin Description (DTD). | A oneM2M CSE (DT) supports xml, json, cbor data formats.<br><br>When an application retrieves data from the CSE the resource representation is in the format specified by the application.<br><br>See Deployment Scenario #2.<br><br>An IPE is used to convert data from a non-oneM2M service (nodn) to a oneM2M data model. In oneM2M an IPE is implemented as an AE. A CSE can support multiple IPE-AEs. The IPE is responsible for all data conversion between the nodn and the CSE. The IPE can simplify the information from the CSE to a format consumable for custom applications.<br><br>Native Digital composition in oneM2M requires allowing attributes from multiple resources to be announced (or combined) to a single resource.<br><br>See clause 7.2 for recommended feature support. |
| REQ_5.3_004 | To support interoperability, the layer shall be capable of translating the DT's internal data into various formats and protocols commonly used in the digital world and enable the call of actions available on the PT and replicated on the DT. | A oneM2M CSE (DT) supports xml, json, cbor data formats.<br><br>When an application retrieves data from the CSE the resource representation is in the format specified by the application.<br><br>See Deployment Scenario #2. |

## 5.4 Communication Services Requirements

**Table 5.4-1: Communication Services Requirements**

| Requirement ID | Digital Twin Requirement | Mapping to oneM2M |
|---|---|---|
| REQ_5.4_001 | The DCC shall support the reception, management and forwarding of incoming commands targeting the DT instance and coming from external digital application and/or other twins. | A request primitive sent to the CSE will be forwarded to one or more DTs, based on the content of the primitive.<br><br>See Deployment Scenario #3. |
| REQ_5.4_002 | When external digital entities request specific actions to be performed by the DT, the DCC shall update the DT's properties, triggering events, or invoking relationships with other entities. | The SDT model shows examples of resource hierarchies that support monitoring and control of modelled physical devices.<br><br>See Deployment Scenario #2. |
| REQ_5.4_003 | The DCC component acts as an intermediary, receiving these action requests and forwarding them to the DT Core for validation and adaptation. The DT core shall process these actions to ensure they align with the digital twin's behavior and context. | The SDT model shows examples of resource hierarchies that support monitoring and control of modelled physical devices.<br><br>See Deployment Scenario #2. |
| REQ_5.4_004 | The DCC shall receive and process the incoming request on the associated DCA and if necessary, apply required transformation or enrichment in the data format to forward to effective action request. | An IPE is used to convert data from a non-oneM2M service (nodn) to a oneM2M data model. In oneM2M an IPE is implemented as an AE. A CSE can support multiple IPE-AEs. The IPE is responsible for all data conversion between the nodn and the CSE. The IPE can transform and enhance the information sent to the CSE. |
| REQ_5.4_005 | The digital action shall be received by the DT's core that validates accordingly to its internal model and forwards the request to the PCC and the associated PCA responsible of handling the target exposed action. | The SDT model shows examples of resource hierarchies that support monitoring and control of modelled physical devices.<br><br>See Deployment Scenario #2. |
| REQ_5.4_006 | The PCA shall send the actual action request to the associated PT adopting the protocol and the data format required by the specific target action and the specifications of the physical counterpart. | An IPE is used to convert data from a non-oneM2M device (nodn) to a oneM2M data model. In oneM2M an IPE is implemented as an AE. A CSE can support multiple IPE-AEs. The IPE is responsible for all data conversion between the nodn and the CSE. |
| REQ_5.4_007 | The PCC, through the target PCA, shall forward the notification associated to the variation of the PT to notify the DT's core. | The Mca reference point allows communication between the CSE and the device AEs.<br><br>See Deployment Scenario #1. |
| REQ_5.4_008 | The DCC shall ensure that actions requested by external digital entities are validated, adapted, and then, if applicable, sent to the physical interface using the appropriate physical adapter for execution on the corresponding physical twin. | A request primitive sent to the CSE will be forwarded to one or more DTs, based on the content of the primitive.<br><br>See Deployment Scenario #2. |
| REQ_5.4_009 | A DT shall support at least one of either the One-to-One or One-to-Many synchronization patterns. | The one-to-many replication strategy can be implemented using announceTo functionality.<br><br>See Deployment Scenario #2. |
| REQ_5.4_010 | The PCC shall ensure that every alteration in the physical world is promptly captured and conveyed, aligning with the chosen synchronization model. | A request primitive sent to the CSE will be forwarded to one or more DTs, based on the content of the primitive.<br><br>See Deployment Scenario #3. |

| Requirement ID | Digital Twin Requirement | Mapping to oneM2M |
|---|---|---|
| REQ_5.4_011 | DT shall support physical composition and/or digital composition. | Physical composition in oneM2M requires allowing multiple PT to write to a single resource, such as a flexContainer. This is possible but users need to take care of overwrite scenarios.<br><br>See Deployment Scenario #2.<br><br>Digital composition in oneM2M requires allowing attributes from multiple resources to be announced to a single resource.<br><br>See clause 7.2. |
| REQ_5.4_012 | The one-to-many pattern designates one DT as the primary that shall synchronize with its physical twin and manage all connected replicas. | The announceTo feature in oneM2M can be leveraged to share resources across different CSEs (Common Services Entities) or domains, facilitating the creation and management of a hierarchical parent-child Digital Twin (DT) structure. This feature allows resources to be "announced" to other CSEs, making them accessible in multiple locations.<br><br>The one-to-many pattern shall be realized using announceTo functionality.<br><br>See Deployment Scenario #2. |
| REQ_5.4_013 | The DCC shall enable external applications to access and consume DT data, including properties, telemetry, events, and other relevant information as reported through its adapter base structure. | The Mca reference point, used between the CSE and the application AEs, is equivalent to the DCC.<br><br>See Deployment Scenario #1. |
| REQ_5.4_014 | the layer shall support bidirectional communication by allowing external applications to trigger actions within the DT, affecting its behavior and physical counterpart if necessary. | For data models that allow control of the physical device, subscription and notifications shall be used.<br><br>See Deployment Scenario #2. |
| REQ_5.4_015 | Access control mechanisms, including user authentication and authorization, shall be in place to regulate external entities' interactions with the DT, preventing unauthorized access. | oneM2M defines security and access control in ETSI TS 118 103 [i.4].<br><br>Digital Twins shall implement <accessControlPolicy> resources.<br><br>Digital Twins shall implement authentication. |
| REQ_5.4_016 | The layer shall be adaptive, capable of reconfiguring its communication parameters, data formats, and protocols according to the specific requirements of the DT's deployment scenario. | oneM2M CMDH allows for customization and configuration of communication channels, schedules, and rates.<br><br>See ETSI TS 118 101 [i.8].<br><br>A oneM2M CSE (DT) supports xml, json, cbor data formats.<br><br>When an application or physical twin sends or receives data from the CSE the resource representation is in the format specified by the application or physical twin.<br><br>See Deployment Scenario #1. |
| REQ_5.4_017 | DT shall be able to efficiently re-configure and manage the DCC together with the available DCAs to align with evolving operational needs, ensuring seamless integration and communication. | oneM2M CMDH allows for customization and configuration of communication channels, schedules, and rates.<br><br>See ETSI TS 118 101 [i.8]. |
| REQ_5.4_018 | The layer shall provide interfaces for DT management, allowing authorized entities to control and configure the DT's behavior, including the execution of communication modules and/or adapt model behaviors and digital replication parameters. | oneM2M defines security and access control in ETSI TS 118 103 [i.4].<br><br>Digital Twins shall implement <accessControlPolicy> resources.<br><br>Digital Twins shall implement authentication. |

| Requirement ID | Digital Twin Requirement | Mapping to oneM2M |
|---|---|---|
| REQ_5.4_019 | The DCC shall incorporate error handling mechanisms to address communication failures gracefully, ensuring the DT's stability and resilience. | oneM2M CMDH allows for specification of multiple communication channels and conditions for the selection of which communication channel to use.<br><br>See ETSI TS 118 101 [i.8]. |
| REQ_5.4_020 | Composition shall enable seamless communication and data sharing within the hierarchical structure. | In the oneM2M framework, resources can be composed to model a hierarchical structure where a parent Digital Twin (DT) organizes multiple child Digital Twins. This composition leverages the hierarchical nature of oneM2M resources and the ability to nest resources within containers and groups.<br><br>Smart Devices Template models, defined in ETSI TS 118 123 [i.3], has examples of composition using <flexContainer> resources. |
| REQ_5.4_021 | Composition shall support bidirectional communication flows between parent and child DTs within the hierarchy. | A oneM2M CSE can communicate bidirectionally with other CSEs using the Mcc reference point.<br><br>For data models that allow control of the physical device, subscription and notifications shall be used.<br><br>Composition shall be realized using announceTo functionality.<br><br>See Deployment Scenario #3. |
| REQ_5.4_022 | Composition shall support the scalability of DT hierarchies, allowing for the addition of new child DTs and the adjustment of existing structures to accommodate evolving requirements. | The announceTo feature in oneM2M can be leveraged to share resources across different CSEs (Common Services Entities) or domains, facilitating the creation and management of a hierarchical parent-child Digital Twin (DT) structure. This feature allows resources to be "announced" to other CSEs, making them accessible in multiple locations.<br><br>Composition shall be realized using announceTo functionality.<br>Composition shall be realized using <flexContainer> resources.<br><br>See Deployment Scenario #3. |
| REQ_5.4_023 | DTs shall be capable of both monitoring and controlling the PT in bi-directional associations, allowing for versatile interaction patterns. | A oneM2M CSE can communicate bidirectionally with other CSEs using the Mcc reference point.<br>For data models that allow control of the physical device, subscription and notifications shall be used.<br><br>See Deployment Scenario #3. |
| REQ_5.4_024 | DTs shall be equipped with data buffering and storage capabilities to capture and store data when communication with PTs is temporarily interrupted. | Messages directed towards a PT can be stored in a Polling Channel.<br><br>oneM2M CMDH allows for customization and configuration of communication channels, schedules, and rates. |
| REQ_5.4_025 | DTs shall synchronize their digital representation with the PT once communication is reestablished, ensuring that the digital model accurately reflects the physical state. | When a PT has established communications with the CSE, it updates relevant states.<br><br>Using CMDH at DT can handle communication failures and recovery services.<br><br>A Digital Twin with that requires communication recovery capabilities shall implement CMDH. |

| Requirement ID | Digital Twin Requirement | Mapping to oneM2M |
|---|---|---|
| REQ_5.4_026 | When live and low-latency communication is not possible, DTs shall transition into a mode that focuses on data storage, analysis, and preparation for future actions. | An application specific node CSE (ASN-CSE) allows for customized features and interfaces to a CSE. When the CSE communicates with other CSE, it shall use the Mcc interface. A profile for digital twin ASN-CSE would include specific definitions for "analysis" and "preparation for future actions" and perhaps generic oneM2M features to add an "analysis" function or a "future action" function.<br><br>See clause 7.5. |

## 5.5 Communication Performance and Monitoring Requirements

The oneM2M framework offers several resources and mechanisms to monitor the communication performance of an Application Entity (AE):

- Network Monitoring Request Resource (<nwMonitoringReq>): This resource allows an AE to request network status information, such as congestion status and the number of devices in a specific geographic area. It includes attributes like monitorEnable (type of network monitoring request), monitorStatus (response status from the network), and failureReason (reason for any failure response).
- End-to-End Quality of Service Session (<e2eQosSession>): This resource manages the end-to-end quality of service for communication sessions. It includes attributes like e2eQosStatus (status of the QoS session) and e2eQosRequirements (requirements for the QoS session), allowing actions based on the session status.
- Statistics Configuration (<statsConfig>): This resource stores policies for collecting and managing statistics related to AEs. It includes eventConfig to configure events for statistics collection and allows subscription to changes or updates in statistical data.
- Communication Management and Delivery Handling (CMDH): This resource manages communication delivery, handling network disconnections, and buffering requests for future delivery. Its capabilities include selecting appropriate communication paths, detecting and managing disconnections and reconnections, and buffering requests for store-and-forward processing.

By leveraging these resources, AEs can effectively track network status, manage QoS requirements, handle asynchronous communication, collect performance statistics, and ensure reliable data delivery within the oneM2M framework.

**Table 5.5-1: Communication Performance and Monitoring Requirements**

| Requirement ID | Digital Twin Requirement | Mapping to oneM2M |
|---|---|---|
| REQ_5.5_001 | The DT shall provide a representation of the physical device that is usable by external systems. | An IN-AE can request resource serialization in each request, specifying XML, json or cbor.<br><br>Custom representations of data elements cannot be specified. Custom representations of data elements in oneM2M requires allowing attributes from multiple resources to be announced (or combined) to a single resource.<br><br>See clause 7.2 for recommended feature support. |
| REQ_5.5_002 | The DCC shall provide a homogeneous representation of DTs to external digital entities. | A oneM2M CSE (DT) supports xml, json, cbor data formats.<br><br>When an application retrieves data from the CSE the resource representation is in the format specified by the application.<br><br>See Deployment Scenario #3. |
| REQ_5.5_003 | Tailored to the specific application requirements, the PCC together with the implemented and active PCAs shall incorporate mechanisms for real-time performance monitoring, management, and control of communication parameters such as latency, packet loss, and other pertinent metrics. | The <statsCollect> is designed to collect and manage statistics related to various aspects of the system. This resource is used to monitor performance, track usage, and gather data for analysis. It works with other resources to provide a full view of the system's operational metrics. |
| REQ_5.5_004 | PCC shall provide comprehensive techniques for monitoring the health and performance of physical communication according to the nature of the supported communication protocols and interaction patterns. | The <statsCollect> is designed to collect and manage statistics related to various aspects of the system. This resource is used to monitor performance, track usage, and gather data for analysis. It works with other resources to provide a full view of the system's operational metrics. |
| REQ_5.5_005 | Furthermore, external applications shall be empowered with the capability to gauge the quality of the cyber-physical connection and its potential variations over time. | External application can subscribe to the relevant resources to be notified of changes, or it can read the appropriate resource as needed. |
| REQ_5.5_006 | Ensuring reliable communication with physical entities is paramount. According to the context and the nature of DTs the PCC shall incorporate mechanisms for redundancy, failover, and error handling to maintain consistent communication, especially in mission-critical applications. | The oneM2M CMDH features support management of multiple communication channels and criteria for selection of the channel to use. For example, an expensive cellular channel may be used only when Wi-Fi® is not working and storage buffers are full. |
| REQ_5.5_007 | Comprehensive logging and reporting capabilities shall be available to record communication-related events, aiding in troubleshooting and performance optimization. | The <statsCollect> is designed to collect and manage statistics related to various aspects of the system. This resource is used to monitor performance, track usage, and gather data for analysis. It works in conjunction with other resources to provide a comprehensive view of the system's operational metrics. |
| REQ_5.5_008 | The DCC shall generate detailed logs of communication-related events, capturing information such as error types, timestamps, and affected components. | The <statsCollect> is designed to collect and manage statistics related to various aspects of the system. This resource is used to monitor performance, track usage, and gather data for analysis. It works in conjunction with other resources to provide a comprehensive view of the system's operational metrics. |
| REQ_5.5_009 | DTs shall be able to implement physical communication that are aware of their performance over time through monitoring metrics in order to support a high level of entanglement awareness in particular in scenarios where the optimization and support for live and fresh data exchange and reliability are required. | oneM2M CMDH allows for customization and configuration of communication channels, schedules, and rates.<br><br>See ETSI TS 118 101 [i.8]. |

# 6 Description and Discovery Requirements

## 6.1 Introduction

The oneM2M framework provides robust features for describing and discovering resources, ensuring efficient and scalable management of IoT and M2M systems. Discovery can be based on specific attributes of resources as well as label attributes that each resource has. However, the oneM2M semantic features support a much more powerful description and discovery capability. Resources can be described using standardized ontologies, like the recommended SAREF ontologies, or customized ontologies. The oneM2M Advance Semantic Discovery feature (Release 5) supports advertisement and discovery across a federated network of oneM2M CSEs.

While it may be possible to implement some of the discovery features for digital twins using labels, the present document specifies that the semantics features of oneM2M are to be used.

## 6.2 Description Requirements (SAREF)

**Table 6.2-1: Description Requirements (SAREF)**

| Requirement ID | Digital Twin Requirement | Mapping to oneM2M |
|---|---|---|
| REQ_6.2_001 | The DT shall have a description of Connection, speed, and direction characteristics. | Semantic descriptions of the DT shall be provided in <semanticDescription> resources.<br><br>Semantic descriptions should use the SAREF ontologies to describe the digital twin.<br><br>Semantic descriptions of the DT shall use oneM2M Base ontologies.<br><br>Semantic descriptions of the DT may use other ontologies. |
| REQ_6.2_002 | The PCC through the deployed PCAs shall provide the DT core and model with a structured and standardized description of the associated physical twin that can be denoted as Physical Twin Description (PTD). | Semantic descriptions of the DT shall be provided in <semanticDescription> resources.<br><br>Semantic descriptions should use the SAREF ontologies to describe the digital twin.<br><br>Semantic descriptions of the DT shall use oneM2M Base ontologies.<br><br>Semantic descriptions of the DT may use other ontologies.<br><br>See oneM2M Dev Guide for semantic interop.<br><br>Data from the physical twin shall be stored in attributes of the data sharing resources.<br><br>See oneM2M Dev Guide for semantic interop. |

| Requirement ID | Digital Twin Requirement | Mapping to oneM2M |
|---|---|---|
| REQ_6.2_003 | This description shall encompass details about the physical asset's characteristics, properties, events, actions, and relationships. | Semantic descriptions of the DT shall be provided in <semanticDescription> resources.<br><br>Semantic descriptions should use the SAREF ontologies to describe the digital twin.<br><br>Semantic descriptions of the DT shall use oneM2M Base ontologies.<br><br>Semantic descriptions of the DT may use other ontologies.<br><br>See oneM2M Dev Guide for semantic interop.<br><br>Data from the physical twin shall be stored in attributes of the data sharing resources.<br><br>See oneM2M Dev Guide for semantic interop. |
| REQ_6.2_004 | DTD shall encapsulate various characteristics and attributes that are instrumental in comprehensively describing a DT, enabling seamless interaction, monitoring, and interoperability across diverse application domains. | Semantic descriptions of the DT shall be provided in <semanticDescription> resources.<br><br>Semantic descriptions should use the SAREF ontologies to describe the digital twin.<br><br>Semantic descriptions of the DT shall use oneM2M Base ontologies.<br><br>Semantic descriptions of the DT may use other ontologies.<br><br>See oneM2M Dev Guide for semantic interop.<br><br>Data from the physical twin shall be stored in attributes of the data sharing resources.<br><br>See oneM2M Dev Guide for semantic interop. |
| REQ_6.2_005 | DTDs shall include management-related specifications, allowing external application to discover the capabilities and functionalities of the DT's software instance that can be managed and how it can be done. | Semantic descriptions of the DT shall be provided in <semanticDescription> resources.<br><br>Semantic descriptions should use the SAREF ontologies to describe the digital twin.<br><br>Semantic descriptions of the DT shall use oneM2M Base ontologies.<br><br>Semantic descriptions of the DT may use other ontologies.<br><br>See oneM2M Dev Guide for semantic interop.<br><br>Data from the physical twin shall be stored in attributes of the data sharing resources.<br><br>See oneM2M Dev Guide for semantic interop. |

| Requirement ID | Digital Twin Requirement | Mapping to oneM2M |
|---|---|---|
| REQ_6.2_006 | DTs shall offer detailed descriptions of their resources, capabilities and entanglement monitoring allowing applications and digital services to explore and understand their functionalities and being aware of their performance and cyber-physical quality over their life cycle. | Semantic descriptions of the DT shall be provided in <semanticDescription> resources.<br><br>Semantic descriptions should use the SAREF ontologies to describe the digital twin.<br><br>Semantic descriptions of the DT shall use oneM2M Base ontologies.<br><br>Semantic descriptions of the DT may use other ontologies.<br><br>See oneM2M Dev Guide for semantic interop.<br><br>Data from the physical twin shall be stored in attributes of the data sharing resources.<br><br>See oneM2M Dev Guide for semantic interop. |
| REQ_6.2_007 | DTs shall enable external digital applications to be aware and evaluate their suitability for specific applications based on the level of entanglement. | Semantic descriptions of the DT shall be provided in <semanticDescription> resources.<br><br>Semantic descriptions should use the SAREF ontologies to describe the digital twin.<br><br>Semantic descriptions of the DT shall use oneM2M Base ontologies.<br><br>Semantic descriptions of the DT may use other ontologies.<br><br>See oneM2M Dev Guide for semantic interop.<br><br>Data from the physical twin shall be stored in attributes of the data sharing resources.<br><br>See oneM2M Dev Guide for semantic interop.<br><br>Advanced Semantic Discovery (Rel 5) provides federated discovery capabilities.<br><br>See oneM2M TS-0034 [i.5]. |

# 7 Proposed new requirements for oneM2M

## 7.1 Introduction

Many of the feature and requirements for digital twins can be met with the existing functionality of oneM2M. However, there are some requirements that are not fully supported in oneM2M or warrant an investigation into a modification or enhancement to existing oneM2M features. The following clauses describe the functionalities that can improve support of digital twins in oneM2M. These feature are being considered in the oneM2M plenary meetings.

## 7.2 Composite Digital Twin

A digital composition of a digital twin entails a custom definition of a data model that can be composed from other digital twins.

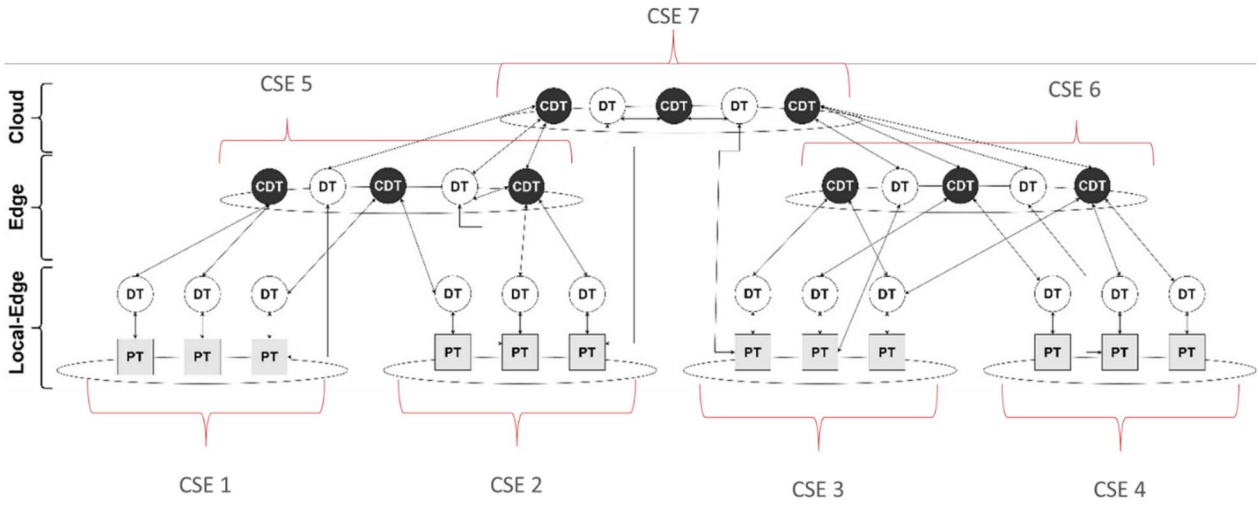


**Figure 7.2-1: Composite Digital Twin**

Some constraints for the candidate solutions to this requirement in oneM2M is that the device AE cannot be responsible for sending device data to more than one location. Some potential solutions to this problem are:

- FlexContainer:
  - Offers the custom attributes that can be used for the CDT.
  - Lacks Bi-directional synchronization.
- AnnounceTo:
  - Offers Bi-directional synchronization.
  - Lacks custom definition (subset of existing resource can be announced).
  - Lacks support for multiple data sources.
- Aggregator AEs:
  - Subscribes to data elements and then creates new composite resources.
  - Bi-directional synchronization can be challenging.
  - New composite DT requires new AE.
- <Group> DT resources to realize CDT.

## 7.3 Digital Twin Data Transformation and Normalization

A key strength of oneM2M is the ability to model data from a physical device using a format for the data that is suitable to the device manufacturer. This simplifies the device development process, improves the ability to integrate legacy devices into oneM2M, and recognizes that there is no single universal representation of data from many devices. However, when it is attempted to integrate multiple device sensors to create a single composite digital twin, this heterogeneity of data creates challenges that need to be addressed. To describe this with a simple example that relates to the scenario shown in Figure 4.1-1, consider a sensor that monitors the water temperature of the vehicle engine cooling system that reports the temperature in degrees Celsius. Also consider another temperature sensor for the passenger compartment of the vehicle that reports the temperature in degrees Fahrenheit. Displaying these two temperatures values on the application requires, first knowing that the formats are different and then converting the formats prior to displaying them.

In oneM2M, using <semanticDescriptor> resources, the format of the data can be described, which addresses the first problem. Using the <semanticDescriptor> information the application can add logic to convert the data prior to displaying it. This results in the responsibility for each application developer to write the code to read the format and convert each data element to the desired format.

As a service that maintains the data from the physical devices and offers mechanisms to combine data sources to create larger digital twins, oneM2M is in a key position to offer a feature to convert the data for the benefit of application developers. This service should leverage the data format description provided in the <semanticDescriptor> resource of a source of information and support the conversion to a different format.

This service could be made available in multiple manners:

1) A request primitive could contain an indication of the desired format of the data. The oneM2M CSE would check the existing format of the data target and convert the data to the desired format.

2) A resource that is announced another location, either in a different CSE or the same CSE, could convert the data so that it is stored in a different format at the other location.

3) A resource could have a <semanticDescriptor> resource that describes the data format that comes from the source, and the data format that should be used when storing the data. In this case the CSE would convert the data upon arrival (CREATE or UPDATE) and only store the desired data.

## 7.4 Digital Twin Change Tracking

The data model of a digital twin can evolve over time creating the need for additional complexity it applications that use the digital twin. For example, adding or changing sensors in the digital twin of the vehicle shown in Figure 4.1-1, might require the application to develop logic detect or manage these changes, if they can be foreseen.

As a service that maintains the data from the physical devices and offers mechanisms to combine data sources to create larger digital twins, oneM2M is in a key position to offer a feature to indicate a user defined version of the digital twin.

This feature could leverage the capabilities of the *label* attribute, or some other mechanism. By describing the supported functionality in normative language oneM2M would be able to offer an interoperable solution that application developers can leverage.

## 7.5 Digital Twin Application Specific Functions

The oneM2M architecture defines an Application Specific Node CSE, ASN-CSE, that performs functions that use a CSE for some functions, but also allows for customization of interfaces and functionality. There is little definition of how the customization occurs or how that can be achieved with an existing CSE implementation. Essentially, it requires the customization of a CSE implementation.

A oneM2M feature that would support customization is one that allows a new service to be inserted into the process flow of a primitive at select steps of primitive handling. For example, a service could be added to allow a custom operation to be performed prior to storing a new resource in the resource tree. This feature could add customization points at various key points in the CSE primitive processing steps. These customization points could support the definition of a policy that would determine if the custom functionality would be executed. For example, a custom service for analysis might only execute if the data is in a certain format. Policy creation and the data sent to the service could be standardized in oneM2M such that the service could work with multiple CSE implementations.

## 7.6 SAREF Ontology Alignment for Digital Twins

A key aspect of a digital twin that can be combined with other digital twins and reused to create comprehensive models that meet the needs of application developers and efficient analysis of the digital twin operation is the discovery of the digital. There are many requirements that are supported by the oneM2M Semantic Support. However oneM2M does not define domain based ontologies. The SAREF ontologies are developed with the expectation to be used by oneM2M. An analysis of the existing SAREF ontologies to see how well they capture the Digital Twin Description requirements is proposed. The intention is to be able to describe the digital twin capabilities as defined in the requirements in clause 6.

# 8 Digital Twin implementation using oneM2M

## 8.1 Introduction

This clause provides exemplary DT scenario(s) that show how digital twins can be implemented using oneM2M. The first scenario shows the call flows that would be executed to implement the digital twin described. The remaining scenarios do not show the call flows, but focus on a description of the features. The goal is to use this content to define a oneM2M work item for the creation of Developer Guides that demonstrate these scenarios. This may be one or multiple developer guides. These are not complete descriptions, but contain enough information for a developer proficient in oneM2M to implement digital twins that meet the requirements of the present document.

## 8.2 oneM2M Deployment Scenario #1

This is a basic scenario that includes the deployment of a smart outlet that has presence sensing to automatically turn on when a person enters the room. The items plugged into the outlet can also be remotely monitored and controlled.

The physical device can use mqtt/xml over a Wi-Fi® connection. The smartphone application might use http/json while the dashboard application uses mqtt/cbor.

The call flow below shows that all the AEs register to the oneM2M CSE. Physical twin and applications are represented and registered in oneM2M as an "AE". Once registered, all AEs perform some basic setup of the data model that they use. In the case of the smart outlet, this includes creating data sharing resources, such as <container> resources, to send status of the device. Also, since the smart outlet can be remotely controlled, the smart outlet would set up subscriptions as well. Then depending on how the smart outlet receives messages, either a server or polling, additional resources might be created. The application AEs do the same thing; however, they would typically also perform discovery operations to locate the physical twins that they are controlling or monitoring. Finally, in steady state operations the outlet sends status changes to the CSE and receives commands from the applications. Likewise, the applications listen for status changes and send commands.

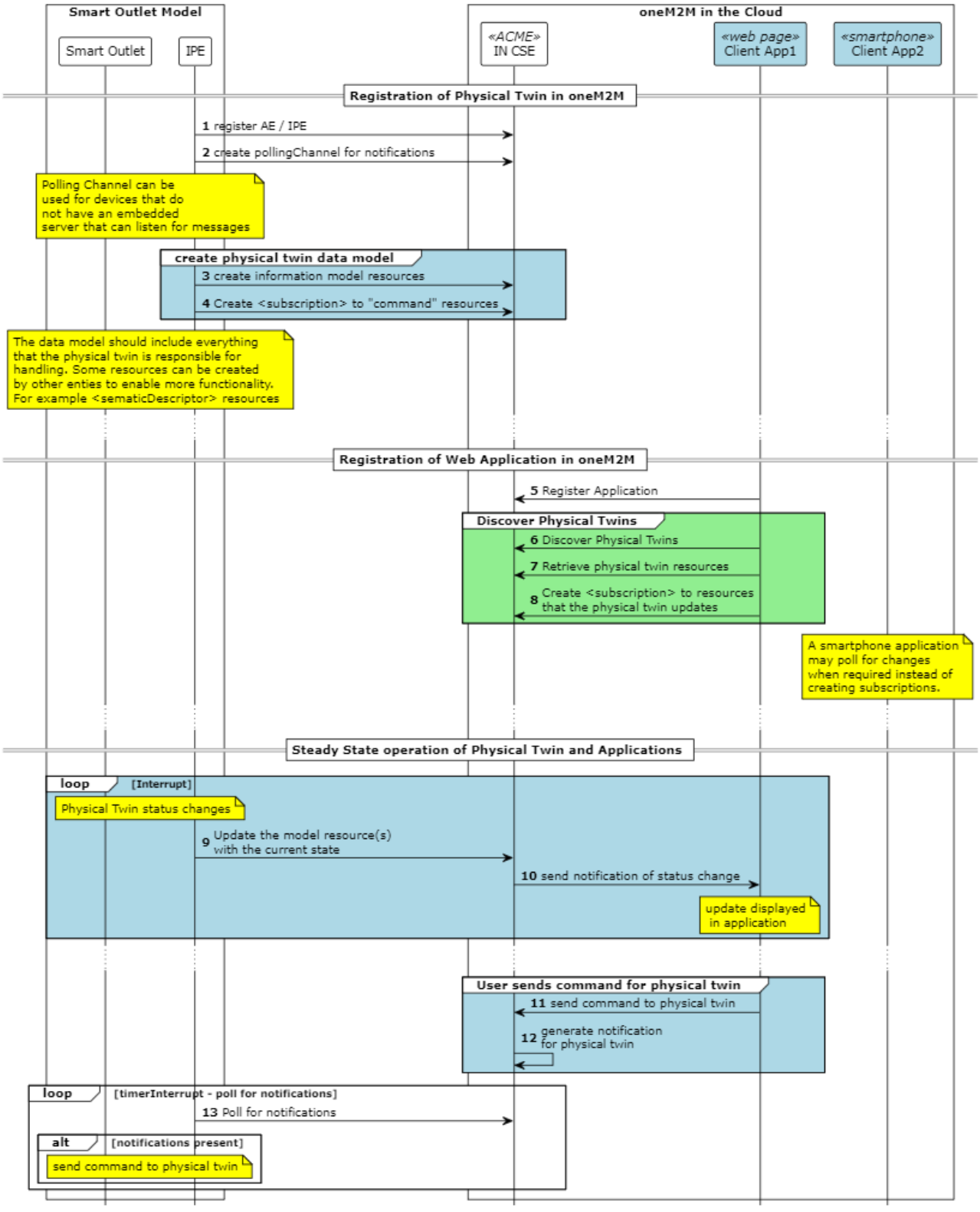


**Figure 8.2-1: Message sequence for digital twin using oneM2M**

## 8.3 oneM2M Deployment Scenario #2

In oneM2M physical composition of digital twins is standardized in ETSI TS 118 123 [i.3]. In ETSI TS 118 123 [i.3] there are information models for a variety of vertical industries that create standardized data models for common physical twins. Some of the information models also demonstrate composition of multiple physical twins into a single composite digital twin.

In Figure 8.3-1, the ETSI TS 118 123 [i.3] data model for a Smart Plug is shown. This expands upon the previous deployment by showing three separate outlets that are aggregated into a single Smart Plug data model.

In this deployment, each outlet is a separate physical device that maintains its own digital twin data. Each physical twin is configured to send it digital twin data to the parent digital twin as the target resource. The integrity of the data is maintained by the proper use of <accessControlPolicy> resources that grant access only to the device or application that needs it. For example, the *energyConsumption* attribute of 'outlet1' can only be set by the associated physical twin. Other attempts to set that value will be rejected. In this deployment 'outlet3' is shown as a legacy device that uses a different protocol than oneM2M, such as a Bluetooth profile. In this case an IPE, which is equivalent to a PCA, translates the data between the Bluetooth protocol and the oneM2M protocol.

On the application side of the deployment, even though each of the three outlets may use different protocols, the application uses the protocol that is most suitable for its development, such as http and json. When the application sends commands to the outlets, for example to turn them all off, the command is sent from the application using http/json. But when the oneM2M CSE sends the commands to each outlet, the commands will be received in the protocol that each outlet expects.

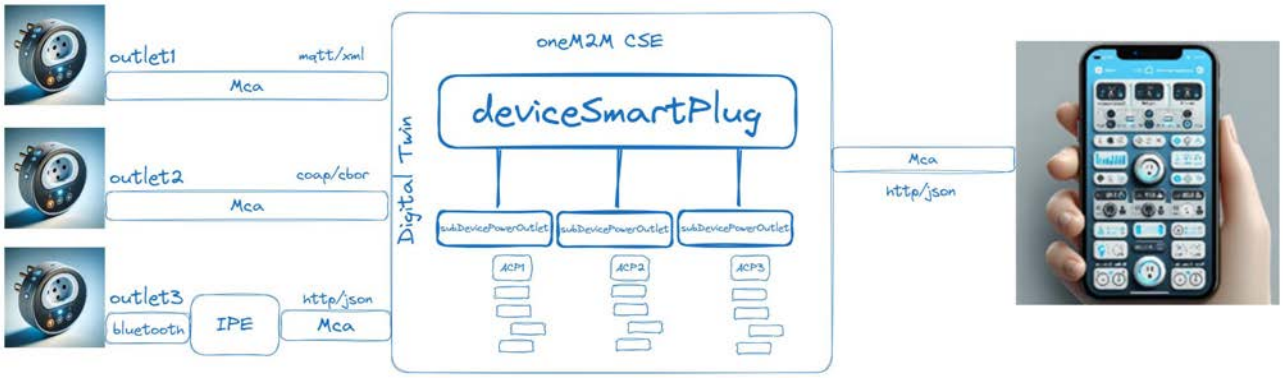


**Figure 8.3-1: Architecture for an interoperable system of digital twins in oneM2M**

## 8.4 oneM2M Deployment Scenario #3

Another example of digital twin composition across different CSEs can be realized using announceTo functionality.

This scenario shows a digital twin of a Multi dwelling apartment, where each tenant has a CSE to manage their smart devices, but the landlord also has some sensors to monitor the condition of the apartments, such as energy consumption of specific appliances such as a water heater. The landlord can monitor the water heater, but not other sensors in the apartment. Landlord has a separate CSE (but has some access privileges on all CSEs).

The devices that the landlord installed and configured in the individual apartments have complete digital twin models, using SDT, on the local CSEs. Each tenant can also install other devices in their apartment. The landlord has to manage multiple apartments and wants to avoid having to look at each individual CSE separately. The parts of the individual digital twins of interest are configured to announce resources to the remote CSE. When all the individual resources are announced to the remote CSE, the landlord has access to a new custom digital twin that supports monitoring the entire multi-dwelling facility. The configuration of the announce functionality is not done by the physical device that generally is not aware of how its data is used. The configuration occurs through separate configuration giving the flexibility to create any kind of composite digital twin.

Using the oneM2M announce procedures, when a physical device sends an update to its digital twin, the oneM2M CSE will forward the data to a configured remote CSE. The application used the data in the composite digital twin hosted on the remote CSE. If the application makes a change to composite digital twin data hosted on the remote CSE, the change will be forwarded to the digital twin hosting CSE, where it may further be forwarded to the physical twin.

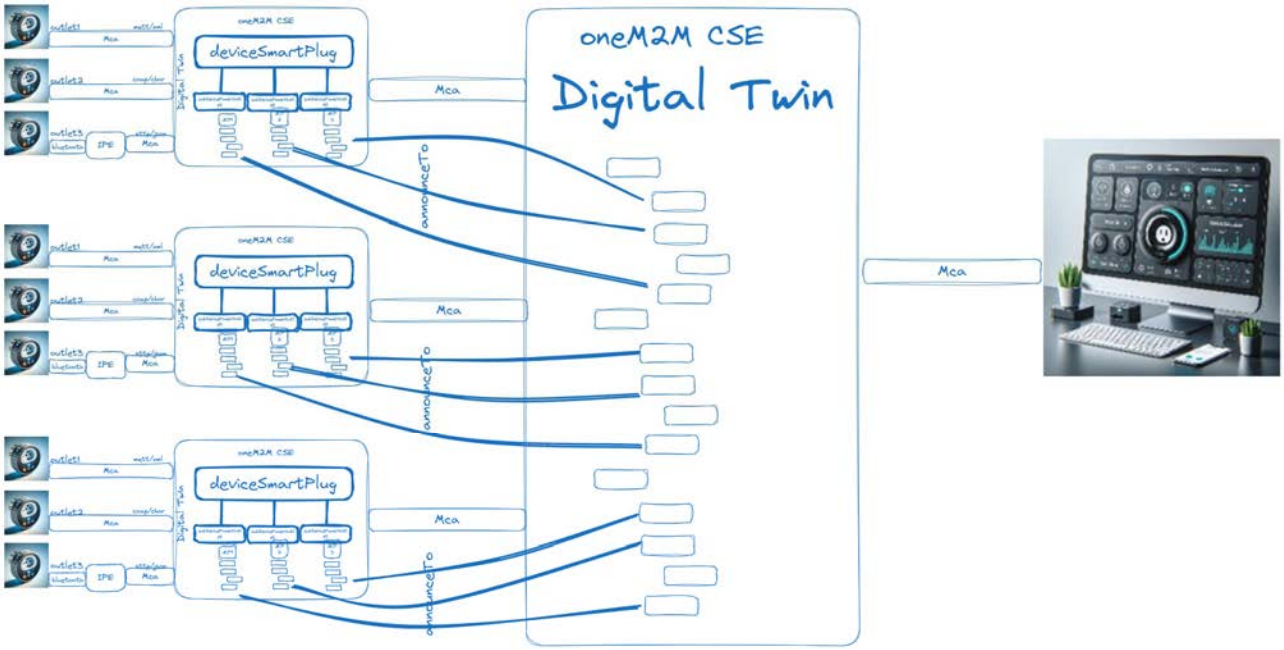


**Figure 8.4-1: Digital Twin composition using oneM2M**

# 9 Digital Twin Profiles in oneM2M

## 9.1 Introduction

This clause lists which requirements are required to certify oneM2M components as a digital twin. Certification as a digital twin may require several oneM2M entities to have specified functionality. For example, REQ_5.3_001 6.2 has functionality that has to be implemented by both an AE and a CSE to work properly. The present clause 9 is intended to be used as the basis for developing specific digital twin profiles in oneM2M that will be interoperable when certification of the AE and CSE is done according to the specified list of requirements. The requirements listed here should guide the selection of the specific test cases developed in oneM2M. A digital twin profile is defined for each of the deployment scenarios described in clause 8. It should be noted that these profiles are defined in a manner that assures support for earlier profiles, i.e. if a CSE can support profile #3, then it can also support profile #1 and #2.

## 9.2 Digital Twin Profile for Scenario #1

This scenario can be used to define a profile for a oneM2M AE that implements Physical Twin communications as well as a oneM2M CSE. This is a common scenario in most oneM2M deployments. The AE can be based on the primary AE sensor profile in ETSI TS 118 125 [i.2]. Additionally, if the AE has actuator capabilities or configurable properties, the actuator profile should be used. An application specific ASN-CSE can be defined that supports a subset of the oneM2M features:

- Mca interface (including protocols and binding support).
- <accessControlPolicy> resource.
- Data sharing resources (container/contentInstance, timeSeries/timeSeriesInstance, flexContainer/flexContainerInstance).
- Node resource (for device management which is best practice for any IoT device).

## 9.3 Digital Twin Profile for Scenario #2

This scenario has all the same requirements for a profile as Scenario #1. Additionally, since the SDT models defined in ETSI TS 118 123 [i.3] are normative, a profile for this scenario would include requirements related to proper implementation of the SDT model. While there may be multiple ways to implement some of the call flows described in ETSI TS 118 123 [i.3], for the purpose of interoperability it is recommended that a profile define a specific implementation approach:

- Mca interface (including protocols and binding support).
- <accessControlPolicy> resource.
- Data sharing resources (container/contentInstance, timeSeries/timeSeriesInstance, flexContainer/flexContainerInstance).
- Node resource (for device management which is best practice for any IoT device).
- SDT model from ETSI TS 118 123 [i.3].

## 9.4 Digital Twin Profile for Scenario #3

This scenario demonstrates composite digital twin implementation. This profile adds announce functionality to the earlier defined profiles, i.e. if using an SDT model based digital twin, this profile adds announce functionality to that list of features. Otherwise, if the basic profile described in scenario #1 is used, then adding announce functionality to that profile is required:

- Mca interface (including protocols and binding support).
- Mcc interface.
- <accessControlPolicy> resource.
- Data sharing resources (container/contentInstance, timeSeries/timeSeriesInstance, flexContainer/flexContainerInstance).
- Node resource (for device management which is best practice for any IoT device).
- SDT model from ETSI TS 118 123 [i.3].
- Announce functionality.

# History

| Document history | | |
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| V1.1.1 | September 2024 | Publication |
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