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Reference model for the metaverse based on a digital twin enabling integration of virtual and physical worlds

Working Group 4: Virtual/Real World Integration

PREPUBLISHED

Version

Technical Specification ITU FGMV-29

Reference model for the metaverse based on a digital twin enabling integration of virtual and physical worlds

Summary

This Technical Specification provides the reference model for the metaverse based on digital twins enabling the integration of virtual and physical worlds. In order to realize this integration of the virtual and physical worlds, a reference model for interaction is necessary, with digital twins serving as a key component of this model. This Technical Specification aims to establish the reference model for the metaverse based on digital twins, enabling the seamless integration of virtual and physical worlds.

Keywords

Digital twin, integration, reference model, integration enabler

Note

This is an informative ITU-T publication. Mandatory provisions, such as those found in ITU-T Recommendations, are outside the scope of this publication. This publication should only be referenced bibliographically in ITU-T Recommendations.

Change Log

This document contains the ITU-T Technical Specification on "*Reference model for the metaverse based on a digital twin enabling integration of virtual and physical worlds*", approved at the 5th meeting of ITU Focus Group on metaverse (ITU FG-MV), held on 5-8 March 2024 in Queretaro, Mexico.

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Additional information and materials relating to this Technical Specification can be found at: https://www.itu.int/go/fgmv. If you would like to provide any additional information, please contact Cristina Bueti at tsbfgmv@itu.int.

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Table of Contents

Technical Specification ITU FGMV-29

Reference model for the metaverse based on a digital twin enabling integration of virtual and physical worlds

1 Scope

This Technical Specification provides reference model for the metaverse based on digital twins enabling the integration of virtual and physical worlds. The scope of this Technical Specification includes the following:

- Reference model to integrate the metaverse based on digital twins to physical world applications;
- Functional entities of the reference model for the metaverse based on digital twins.

2 References

None.

3 Definitions

3.1 Terms defined elsewhere

3.1.1 physical object [b-ISO/IEC 18039]: Object that exists in the real world.

3.1.2 virtual object [b-ITU-T FGMV-28]: A computer-generated entity that is designated for a virtual world.

NOTE – a virtual object may associate with a physical object, which becomes a digital twin.

3.2 Terms defined in these Technical Specification

None.

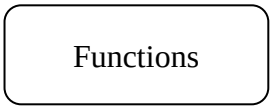
4 Abbreviations and acronyms

This Technical Specification uses the following abbreviations and acronyms:

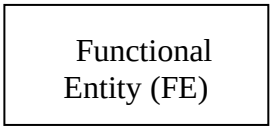
DTAC	Digital Twin Access Control
DTDA	Digital Twin Data Acquisition
DTIA	Digital Twin Information Acquisition
DTIF	Digital Twin Integration Functions
DTS	Digital Twin Synchronization
DTSD	Digital Twin System Discovery
DTSR	Digital Twin System Registration
SDC	System & Data Collaboration
SIF	Systems Integration Functions
TPSAA	3rd Party System Authentication & Authorization
TPSD	3rd Party System Discovery
TPSR	3rd Party System Registration
TSI	3rd Party System Interaction

5 Conventions

In this Technical Specification, the keyword "functions" is defined as a collection of functionalities. It is represented by the following symbol in this Technical Specification:



The keyword "functional entity" (FE) is defined as a representation of functionality that has not been further subdivided at the level of detail described in this Technical Specification. It is represented by the following symbol in this Technical Specification:



NOTE – In the future, other groups or other Technical Specification may possibly further subdivide these FEs.

6 Overview

The concept presented in Figure 1 illustrates the metaverse, which is built upon the integration of virtual and physical worlds through digital twins. The metaverse represents a vast virtual space composed of various virtual worlds, each with its distinct purpose and characteristics. Just as our universe consists of different planets and countries, the metaverse comprises diverse virtual environments like homes, towns, classrooms, and playgrounds. Within these virtual worlds, users create avatars to represent themselves. They can engage with digital objects and other avatars in numerous ways.

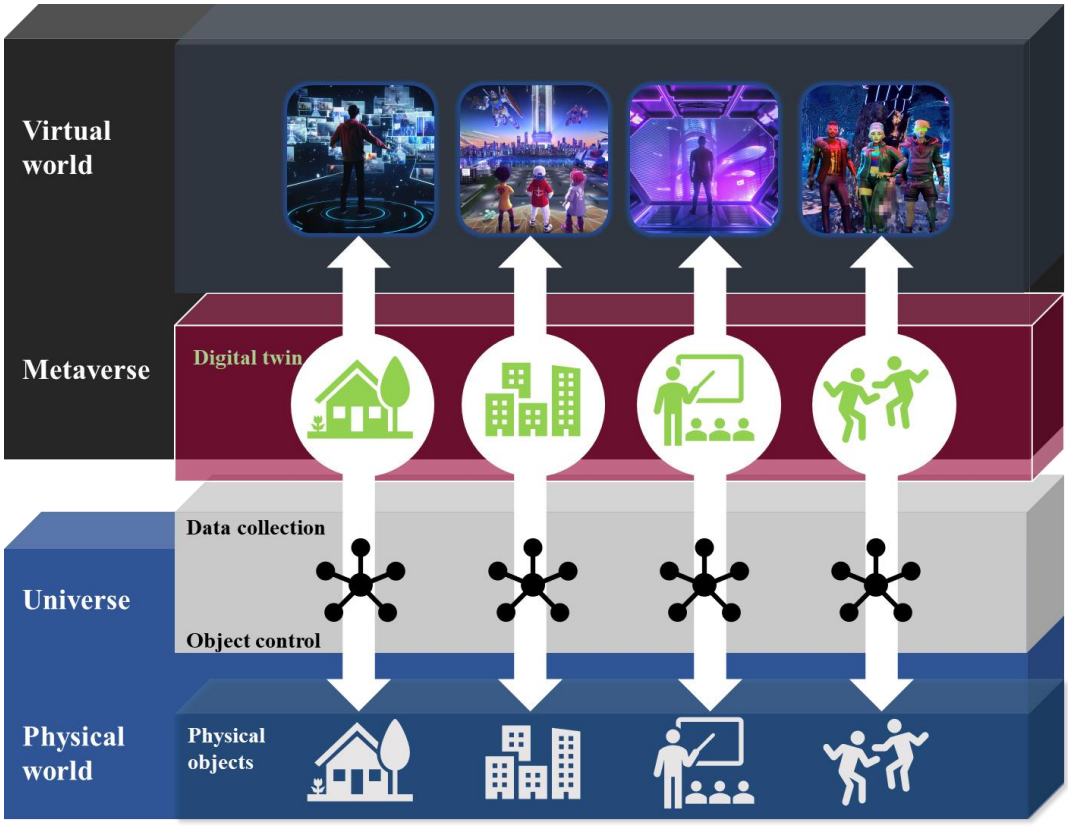


Figure 1 – Concept of the digital twin-based integration between virtual and physical worlds

NOTE 1 – Interoperability in terms of cross-platform metaverses is out of the scope of this Technical Specification, while the integration enablers specified in this Technical Specification can be used for improving interoperability of cross-platform scenarios.

Digital twin serves as a key component for integrating the virtual and physical worlds, allowing users to extend their experience beyond the confines of the virtual environment. As digital representation of physical objects, digital twins comprise the virtual worlds. Avatars representing users can be an example of digital twin in the virtual worlds. For the integration of virtual and physical worlds, the digital twin is an interface between them. For example, as an avatar, the digital twin of a user can mirror the facial expression captured by the user equipment. Digital goods are another example of digital twin integrating the worlds. Users can watch digital goods like pictures or clothes. In virtual worlds, the users can even dress up their avatars. If a user purchases any digital good in the virtual world, the physical objects corresponding to the digital good will be delivered to the user. Virtual world for engineering can also be integrated with physical world. Avatars of geographically dispersed engineers may meet together and design a machine using the digital twins of the real component of a product. After finalizing the design, the machine can be built in the physical world according to the design made in the virtual world.

To realize this integration of the virtual and physical worlds, a reference model for interaction is necessary, with digital twins serving as a key component of this model. This Technical Specification aims to establish the reference model for the metaverse based on digital twins, enabling the seamless integration of virtual and physical worlds.

7 Reference Model

7.1 General

Figure 2 shows a reference model for the metaverse based on a digital twin enabling integration of virtual and physical worlds.

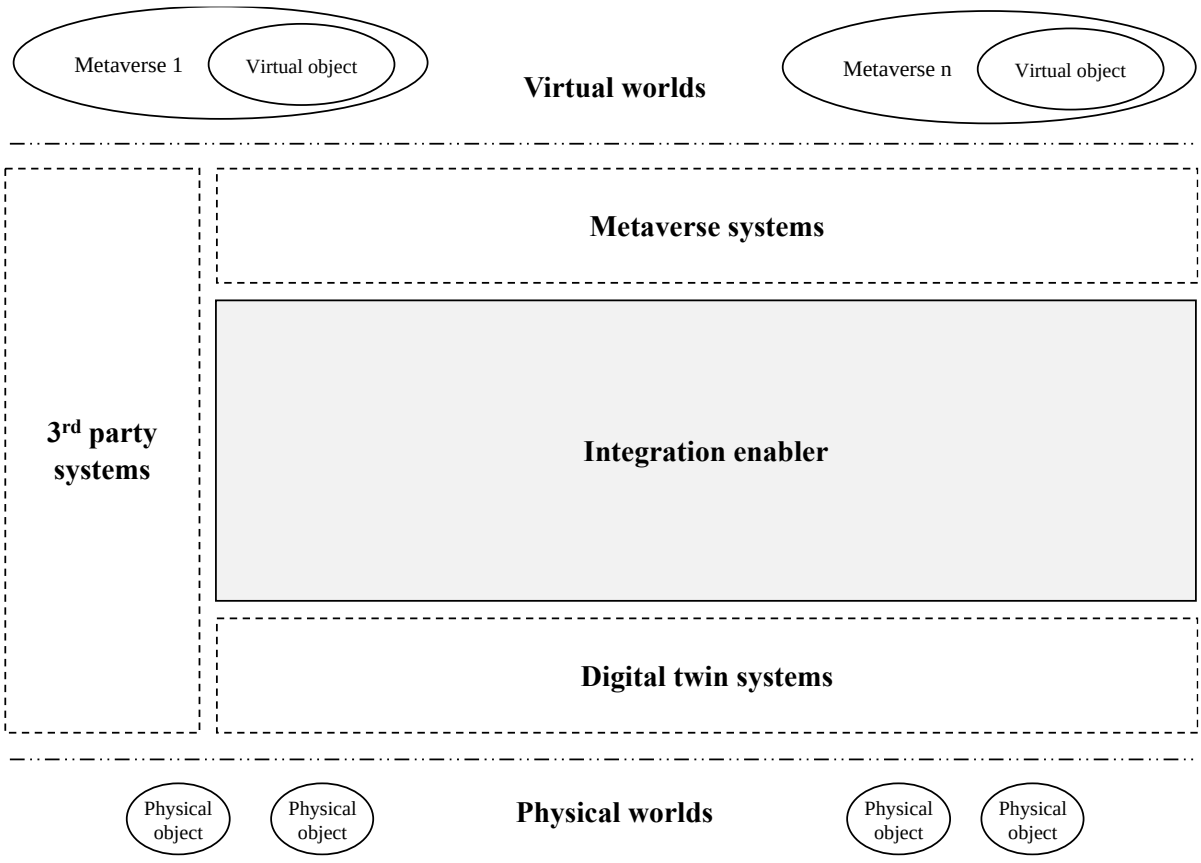


Figure 2 – Reference model for the metaverse based on a digital twin enabling integration of virtual and physical worlds

NOTE 2 – Integration enabler is not a system but a set of functionalities which can be within metaverse system, digital twin system, and/or 3rd party system.

NOTE 3 – A digital twin can be corresponding to a physical object, while another digital twin is not.

NOTE 4 – 3rd party system in this Technical Specification does not consider another metaverse system and digital twin system that are related to interoperable metaverse services.

This reference model defines the integration enabler to facilitate the integration of digital twins and the metaverse. The integration enabler serves as a management system to incorporate digital twin objects into the metaverse, building interrelated operations and interworking with external 3rd party systems.

The 3rd party systems, metaverse systems and digital twin systems are outside the scope of this Technical Specification, but are depicted in order to support the understanding of the reference model.

8 Integration enabler

8.1 General

Figure 3 shows functional entities of the integration enabler in the reference model of the metaverse, which is built upon digital twin technology to enable the integration of virtual and physical worlds. The integration enabler comprises two main components: systems integration functions and digital twin integration functions.

The systems integration functions are responsible for facilitating the integration of the virtual world with external 3rd party systems. The digital twin integration functions are designed to support the integration of one or multiple digital twin systems, allowing for the creation of a unified virtual world.

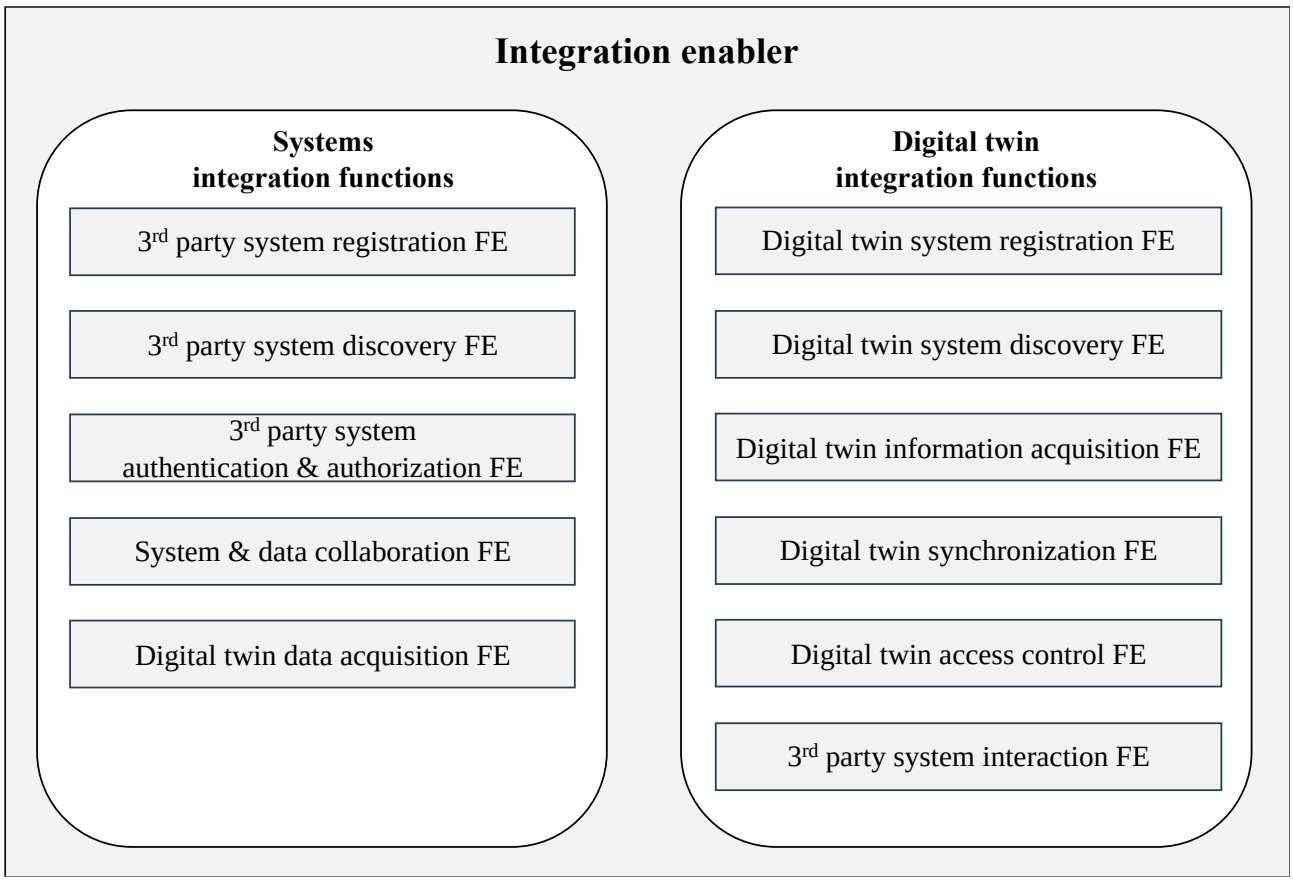


Figure 3 – Functional entities of integration enabler for reference model–

NOTE – Integration enabler is a set of functionalities while it is represented as the shape of a functional entity defined in clause 5.

8.2 Systems integration functions

The systems integration functions (SIF) supports integration with external 3rd party systems.

8.2.1 3rd party system registration FE

The 3rd party system registration (TPSR) FE provides functionality for external systems to integrate with the metaverse system by registering their own information. Additionally, it offers a monitoring feature for the registered external systems' statuses and performance. This FE collects information such as system type, system ID, system properties, service charge, service level, and APIs, during the registration process.

8.2.2 3rd party system discovery FE

The 3rd party system discovery (TPSD) FE provides functionality to search for registered system information through the registration process, enabling the metaverse system to identify systems that meet the conditions from metaverse systems.

8.2.3 3rd party system authentication & authorization FE

The 3rd party system authentication & authorization (TPSAA) FE provides functionality for user information management for system access and access permission to interact with the system and use its resources.

8.2.4 System & data collaboration FE

The system & data collaboration (SDC) FE provides functionality for service execution and necessary data sharing among multiple 3rd party systems. It includes data processing, transformation, and API conversion for seamless service and data collaboration.

8.2.5 Digital twin data acquisition FE

The digital twin data acquisition (DTAC) FE provides functionality for 3rd party system to directly request digital twin information from the digital twin integration functions. It works with the 3rd system interaction FE of DTIF.

8.3 Digital twin integration functions

The digital twin integration functions (DTIF) provides the capability to map multiple digital twin systems into a single virtual world.

8.3.1 Digital twin system registration FE

The digital twin system registration (DTSR) FE provides functionality for digital twin systems to integrate with the metaverse system by registering their own information. Additionally, it offers a monitoring feature for the statuses and performance of the registered digital twin systems. This FE collects information such as digital twin system type, digital twin system ID, and digital twin system properties during the registration process.

8.3.2 Digital twin system discovery FE

The digital twin system discovery (DTSD) FE provides functionality to search for registered digital twin system information through the registration process, enabling the metaverse system to identify digital twin systems that meet the conditions from metaverse systems.

8.3.3 Digital twin information acquisition FE

The digital twin information acquisition (DTIA) FE provides functionality for the integration enabler to retrieve information of digital twin from the selected digital twin system.

8.3.4 Digital twin synchronization FE

The digital twin synchronization (DTS) FE provides functionality for synchronization between virtual and physical objects.

NOTE – The synchronization targets include the state, location, behaviour, and other attributes of an object.

8.3.5 Digital twin access control FE

The digital twin access control (DTAC) FE provides management functionality for controlling access to each digital twin and specifying the characteristics including behaviour that each object can perform.

8.3.6 3rd party system interaction FE

The 3rd party system interaction (TSI) FE provides functionality for collecting digital twin's information upon request from a 3rd party system. It works with the digital twin data acquisition FE of SIF.

9 Operational Flow

9.1 Operational procedures of integrating 3rd party systems

Figure 4 shows the operation procedures of integrating 3rd party systems.

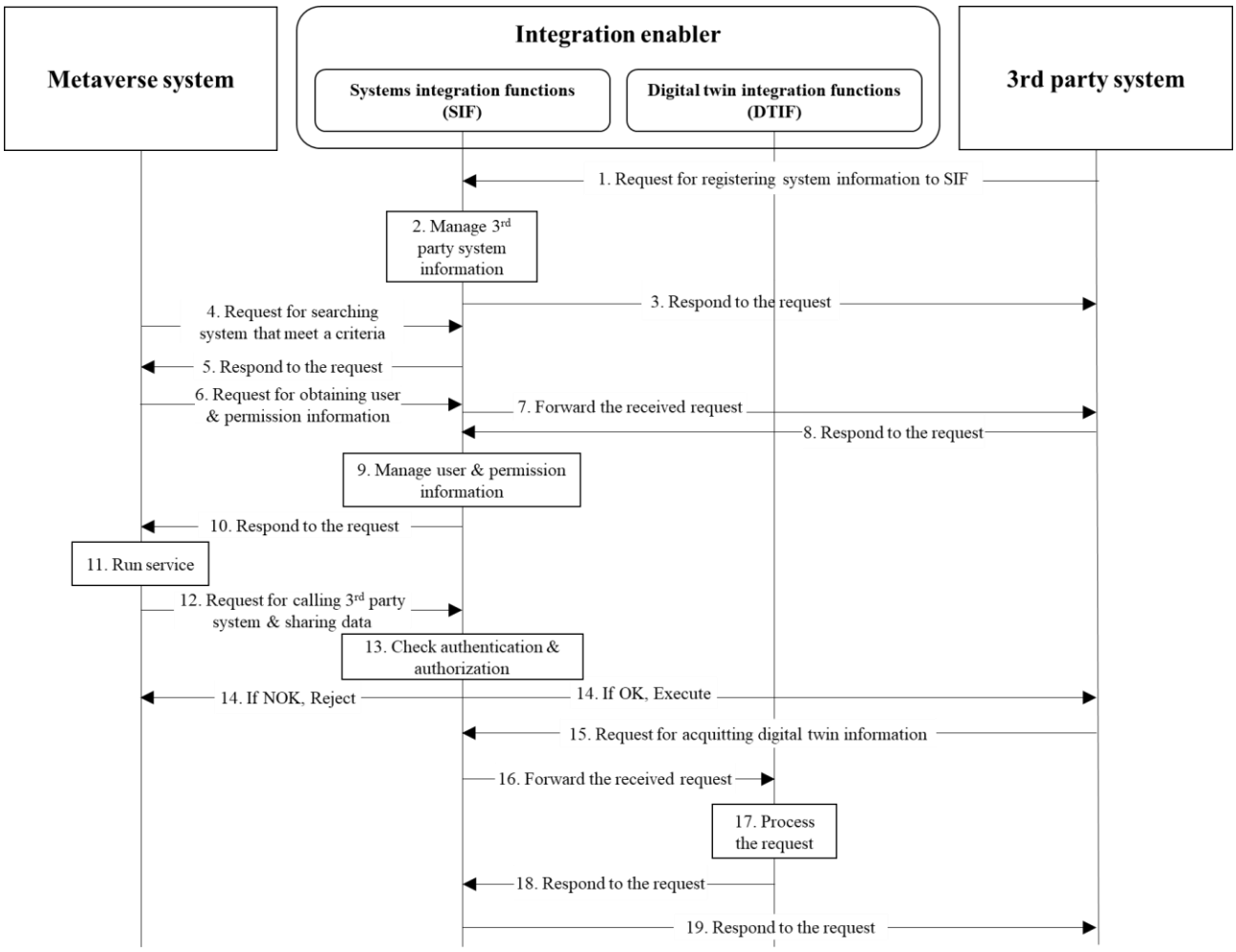


Figure 4 – Operational procedures of integrating 3rd party systems

The description about each step of the operational procedures is as follows:

1. The 3rd party system registers its information to the SIF of integration enabler;
2. The SIF manages registered 3rd party system information;
3. The SIF responds to the registering request;
4. The metaverse system searches for 3rd party systems that meet the criteria in the SIF;
5. The SIF responds to the searching request;
6. The metaverse system requests user authentication and authorization from 3rd party system;
7. The SIF forwards the received request to 3rd party system;
8. The 3rd party system responds with user and permission information;
9. The SIF manages user and permission information for accessing the 3rd party system;
10. The SIF responds to the request from the metaverse system;
11. The metaverse system runs the service using the selected 3rd party systems;
12. The metaverse system initiates a request to utilize 3rd party systems or share data;
13. The SIF verifies user authentication and authorization for accessing 3rd party systems;
14. If the request is valid, the SIF forwards it to the 3rd party system for execution. If the request is invalid, the SIF rejects it;
15. If the 3rd party system requires digital twin information, it can request the information from the SIF;
16. The SIF forwards the received request to the DTIF;
17. The DTIF processes the request for digital twin's information;
18. The DTIF responds to the acquisition request;
19. The SIF responds to the request from the 3rd party system.

NOTE – The 3rd party system receives information about the digital twin through the metaverse system. If it needs to collect additional information, it can request to collect the information directly through the integration enabler.

9.2 Operational procedures of integrating digital twin systems

Figure 5 shows the operation procedures of integrating digital twin systems.

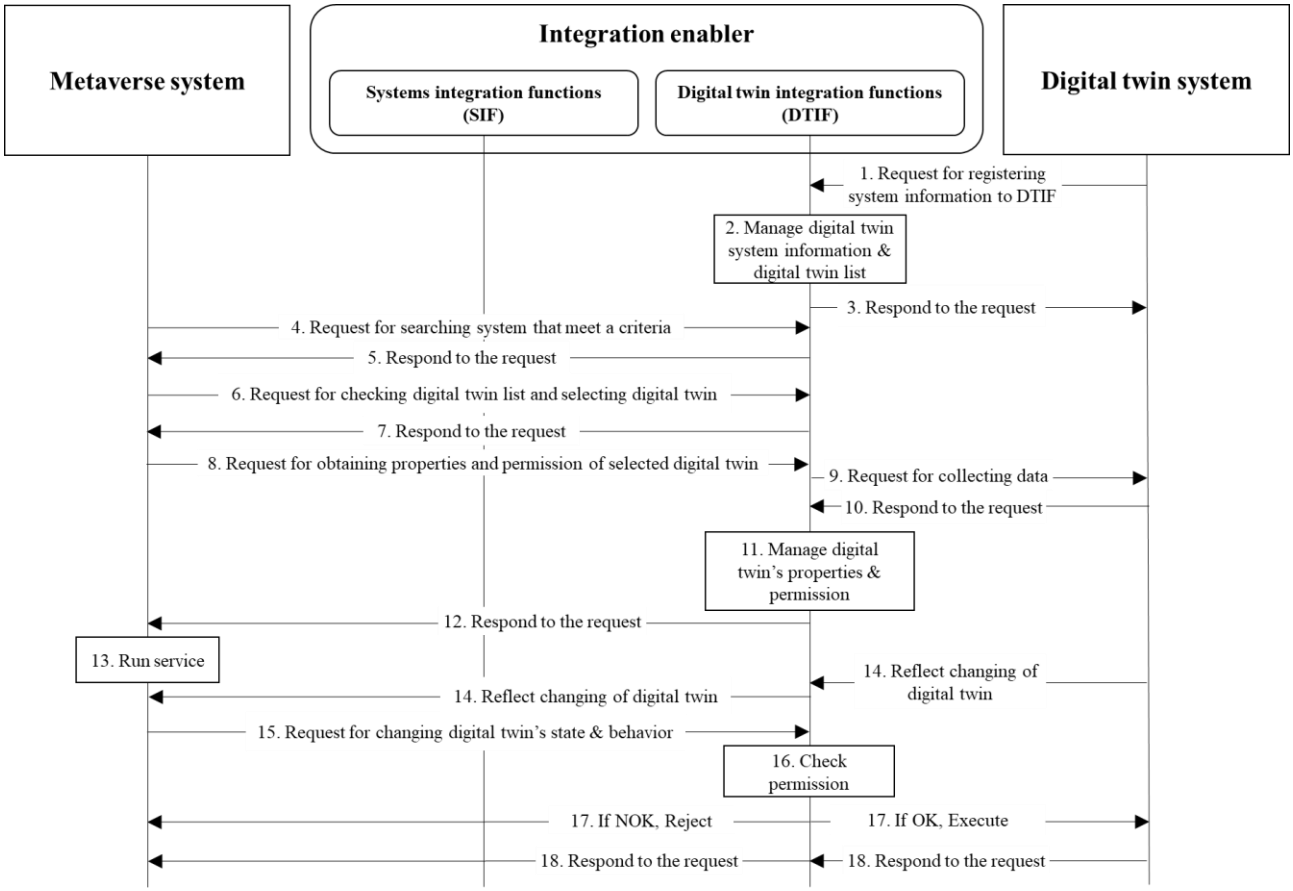


Figure 5 – Operational procedures of integrating digital twin systems

The description about each step of the operational procedures is as follows:

1. The digital twin system registers its information to the DTIF of integration enabler;
2. The DTIF manages registered digital twin system information and digital twin list;
3. The DTIF responds to the registering request;
4. The metaverse system searches for digital twin systems that meet the criteria in the DTIF;
5. The DTIF responds to the searching request;
6. The metaverse system checks the digital twin information list and selects the digital twins it wants to use;
7. The DTIF responds to the request from the metaverse system;
8. The metaverse system requests the DTIF to obtain properties and permission of selected digital twin;
9. The DTIF forwards the metaverse system's request to digital twin system;
10. The digital twin system responds to the request from the DTIF;
11. The DTIF manages the digital twin's properties and permission;
12. The DTIF responds to the request from the metaverse system;
13. The metaverse system runs the service;
14. The changing of physical object is reflected in the metaverse system through the DTIF;
15. The metaverse system requests the DTIF to change the state or behaviour of the object;
16. The DTIF verifies permissions to ensure that the change request can be applied;

17. If the request is valid, the DTIF forwards it to the digital twin system for execution. If the request is invalid, the DTIF rejects it;
18. The digital twin system responds to the request from the DTIF.

NOTE – The digital twin system does not interact with other digital twin systems; instead, it interacts with the metaverse system and 3rd party systems.

Bibliography

[b-ISO/IEC 18039] ISO/IEC 18039:2019, *Information technology — Computer graphics, image processing and environmental data representation — Mixed and augmented reality (MAR) reference model*.

[b-ITU-T FGMV-28] Technical Specification ITU FGMV-28, *Requirements for the metaverse based on digital twins enabling integration of virtual and physical worlds*.