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Automation systems and integration — Digital Twin framework for manufacturing — Part 2: Reference architecture

DIS stage

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Contents

Foreword iv
Introduction v
1 Scope 1
2 Normative references 1
3 Terms and definitions 1
4 Digital Twin reference architecture for manufacturing goals and objectives 3
5 Digital Twin reference models for manufacturing 4
5.1 Domain-based reference model 4
5.1.1 Domains of Digital Twin for manufacturing 4
5.1.2 Observable manufacturing domain 5
5.1.3 Data collection and device control domain 5
5.1.4 Digital Twin domain 5
5.1.5 User domain 5
5.2 Entity-based reference model 5
5.2.1 Entities of Digital Twin for manufacturing 5
5.2.2 Observable manufacturing element 6
5.2.3 Data collection and device control entity 6
5.2.4 Digital Twin entity 7
5.2.5 Digital Twin user entity 7
5.2.6 Cross-system entity 7
5.3 Domain-entity mixed reference model 8
6 Digital Twin reference architectural views for manufacturing 9
6.1 General 9
6.2 Functional view 9
6.2.1 Functional reference architecture 9
6.2.2 Functional entity of observable manufacturing element 9
6.2.3 Functional entity of data collection and device control entity 9
6.2.4 Functional entity in Digital Twin entity 10
6.2.5 Functional entity in Digital Twin user entity 11
6.2.6 Functional entity in cross-system entity 11
6.3 Networking view 12
6.3.1 Networking reference architecture 12
6.3.2 Transmission network 12
6.3.3 Service network (optional) 13
6.3.4 User network 13
Bibliography 14

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Foreword

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This document was prepared by Technical Committee ISO/TC 184, *Automation systems and integration*, Subcommittee SC 4, *Industrial Data*.

A list of all parts in the ISO 23247 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

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Introduction

ISO 23247 series defines a framework to support the creation of Digital Twins of observable manufacturing elements including personnel, equipment, materials, processes, facilities, environment, and products.

The scope of the four parts of this series are defined below:

– Part 1: Overview and general principles

  Provides an overview of Digital Twin for manufacturing, describes general principles, and provides requirements and guidance for developing a Digital Twin framework for manufacturing;

– Part 2: Reference architecture

  Provides a reference architecture goals and objectives, reference model, and reference architectural views for a Digital Twin framework for manufacturing

– Part 3: Digital representation of manufacturing elements

  Identifies manufacturing elements of the Digital Twin framework for manufacturing that shall be represented in digital models;

– Part 4: Information exchange

  Identifies technical requirements for information synchronization and information exchange within the Digital Twin framework for manufacturing.

The types of manufacturing that can be supported by an implementation of the framework will depend on the technologies selected to implement its functional elements.

Use cases for Digital Twin framework for manufacturing will be detailed in a series of technical reports attached to this series.

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Automation systems and integration — Digital Twin framework for manufacturing — Part 2: Reference architecture

1 Scope

This part of ISO 23247 provides a reference architecture of Digital Twin for manufacturing.

ISO 23247 series defines a framework to support the creation of Digital Twins of observable manufacturing elements including personnel, equipment, materials, processes, facilities, environment, and products.

The following are within the scope of this part of ISO 23247;

- reference architecture goals and objectives,
- reference model, and
- reference architectural views

The following are described in other parts of ISO 23247;

- overview and general principles (Part 1)
- digital representation of manufacturing elements of the Digital Twin framework for manufacturing (Part 3);
- information exchange of the Digital Twin framework for manufacturing (Part 4);
- use cases of the Digital Twin framework for manufacturing are to be detailed in technical reports.

The following are outside of the scope of ISO 23247;

- selection of the implementation methods and technologies for a Digital Twin for manufacturing;
- selection of the communication protocols for a Digital Twin for manufacturing;
- selection of the manufacturing devices and other resources to be represented by a Digital Twin;
- selection of the manufacturing processes to be represented by a Digital Twin;
- selection of the manufacturing products to be represented by a Digital Twin;
- design and process planning, and other non-manufacturing stages of the product lifecycle.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 23247-1, *Automation systems and integration — Digital Twin for manufacturing framework — Part 1: Overview and general principles*

ISO/IEC 30141, *Internet of Things (IoT) — Reference architecture*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 23247-1 and the following apply.

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3.1
observable manufacturing domain
spatial/logical/functional area of the observable manufacturing resources

EXAMPLE Spatial/logical/functional area of machine tool is an example of observable manufacturing domain.

3.2
data collection and device control domain
data collection & device control domain
spatial/logical/functional area of monitoring and collecting data from observable manufacturing domain, and controlling devices in observable manufacturing domain

EXAMPLE Spatial/logical/functional area of machine tool controller is an example of data collection and device control domain.

3.3
data collection and device control entity
data collection & device control entity
(a set of) system(s) or device(s) providing data collection and device control in data collection and device control domain

3.4
Digital Twin domain
spatial/logical/functional area of overall operation and management of Digital Twin including provisioning, managing, monitoring, and optimization

EXAMPLE Spatial/logical/functional area of Digital Twin server implementing Digital Twin management, simulation, and authentication and authorization is an are example of Digital Twin domain.

3.5
Digital Twin entity
set of systems providing management of Digital Twins and additional functionalities such as synchronization and simulation, and etc

Note 1 to entry: Digital Twin entity is not Digital Twin of physical element itself.

3.6
user domain
spatial/logical/functional area of using applications and services provided by Digital Twin domain

EXAMPLE Spatial/logical/functional area of a human who uses Digital Twin for manufacturing an example of use domain.

3.7
Digital Twin user entity
human or (a set of) system(s) that uses application and services provided by Digital Twin entity

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— IEC Electropedia: available at http://www.electropedia.org/

— ISO Online browsing platform: available at https://www.iso.org/obp

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4 Digital Twin reference architecture for manufacturing goals and objectives

Digital Twin reference architecture for manufacturing defines reference models and architectural views.

Digital Twin reference architecture for manufacturing outlines what the overall structured approach for the construction of D0igital Twin for manufacturing should be. In other words, Digital Twin reference architecture for manufacturing provides guidance for developing Digital Twin for manufacturing and aims to give a better understanding of Digital Twin for manufacturing to the stakeholders of such systems, including device manufacturers, application developers, users, etc.

Digital Twin encompasses Internet of Things (IoT) as its data collecting and controlling technology as well as conceptual background. ISO/IEC 30141 defines IoT reference models including domain-based reference model and entity-based reference model, and also defines reference architecture by providing several reference architectural views including functional view, system deployment view, networking view, and usage view.

By reference to ISO/IEC 30141, this document has the following descriptions:

- Digital Twin reference models for manufacturing, describing structure of the domains and structure of the entities;
- a set of relevant architectures in terms of functional and networking views

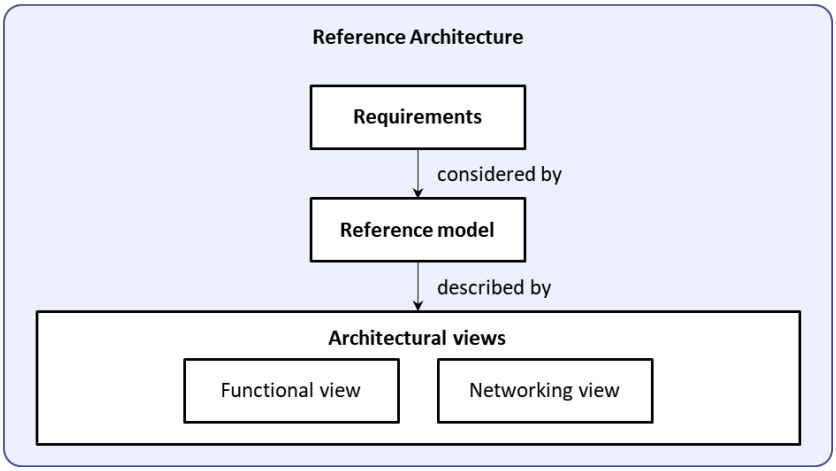

Figure 1 – Outline of Digital Twin reference architecture for manufacturing

Figure 1 shows outline of Digital Twin reference architecture for manufacturing to define relevant reference models and architectural views derived from requirements specified in ISO 23247-1.

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5 Digital Twin reference models for manufacturing

5.1 Domain-based reference model

5.1.1 Domains of Digital Twin for manufacturing

Figure 2 shows a domain-based reference model of Digital Twin for manufacturing. Domain-based reference model is useful to describe various tasks that have to be performed in separate areas, by allowing a logical and sometimes physical subdivision. In other words, domains are used to sort functions into areas of responsibility.

In Digital Twin for manufacturing, domains are classified into four categories as follows:

- user domain
- Digital Twin domain
- data collection and device control domain
- observable manufacturing domain

Observable manufacturing domain is out of scope of Digital Twin for manufacturing, however, this document describes observable manufacturing domain to enhance understanding of Digital Twin for manufacturing.

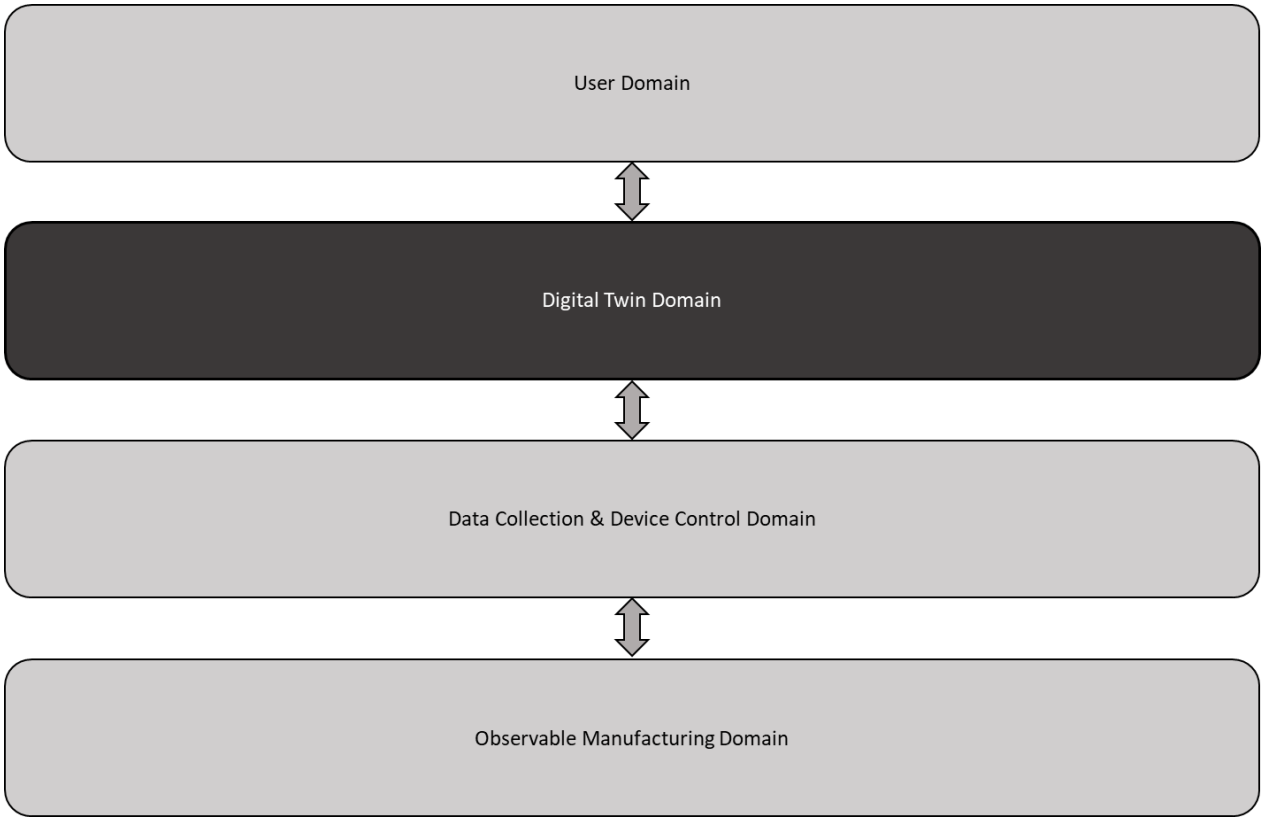

Figure 2 – Domain-based Digital Twin reference model for manufacturing

This classification is a logical grouping of tasks and functions, which are performed by functional entities (FE) explained in 6.2 in detail. Entities in domain interact with other entities by means of a set of networks described in 6.3.

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5.1.2 Observable manufacturing domain

Observable manufacturing domain consists of the physical manufacturing resources such as personnel, equipment, material, process, facility, and environment. Observable manufacturing domain shall be monitored and sensed for data collection and device control in Digital Twin for manufacturing.

5.1.3 Data collection and device control domain

Data collection and device control domain monitors and collects data from sensory devices in observable manufacturing domain, and control and actuate devices in observable manufacturing domain. Data collection and device control domain links observable manufacturing elements and digital entities for synchronization.

5.1.4 Digital Twin domain

Digital Twin domain is responsible for overall operation and management of Digital Twin for manufacturing including provisioning, managing, monitoring, and optimization. In detail, digital modeling, presentation, and synchronization of observable manufacturing element are done in Digital Twin domain.

Digital Twin applications and services are hosted in Digital Twin domain such as simulation, analysis, etc. In addition, Digital Twin domain provides access to entities of Digital Twin for manufacturing and interaction with external entities such as peer Digital Twin domain by guaranteeing interoperability.

5.1.5 User domain

In Digital Twin for manufacturing, a user can be a human, a device, or a system who uses applications and services provided by Digital Twin domain. Even if a user is a human, the user shall interact with Digital Twin domain through some device.

5.2 Entity-based reference model

5.2.1 Entities of Digital Twin for manufacturing

Entity-based reference model breaks down Digital Twin for manufacturing into system level in conjunction with the domain concept, which helps to understand system composition of Digital Twin for manufacturing.

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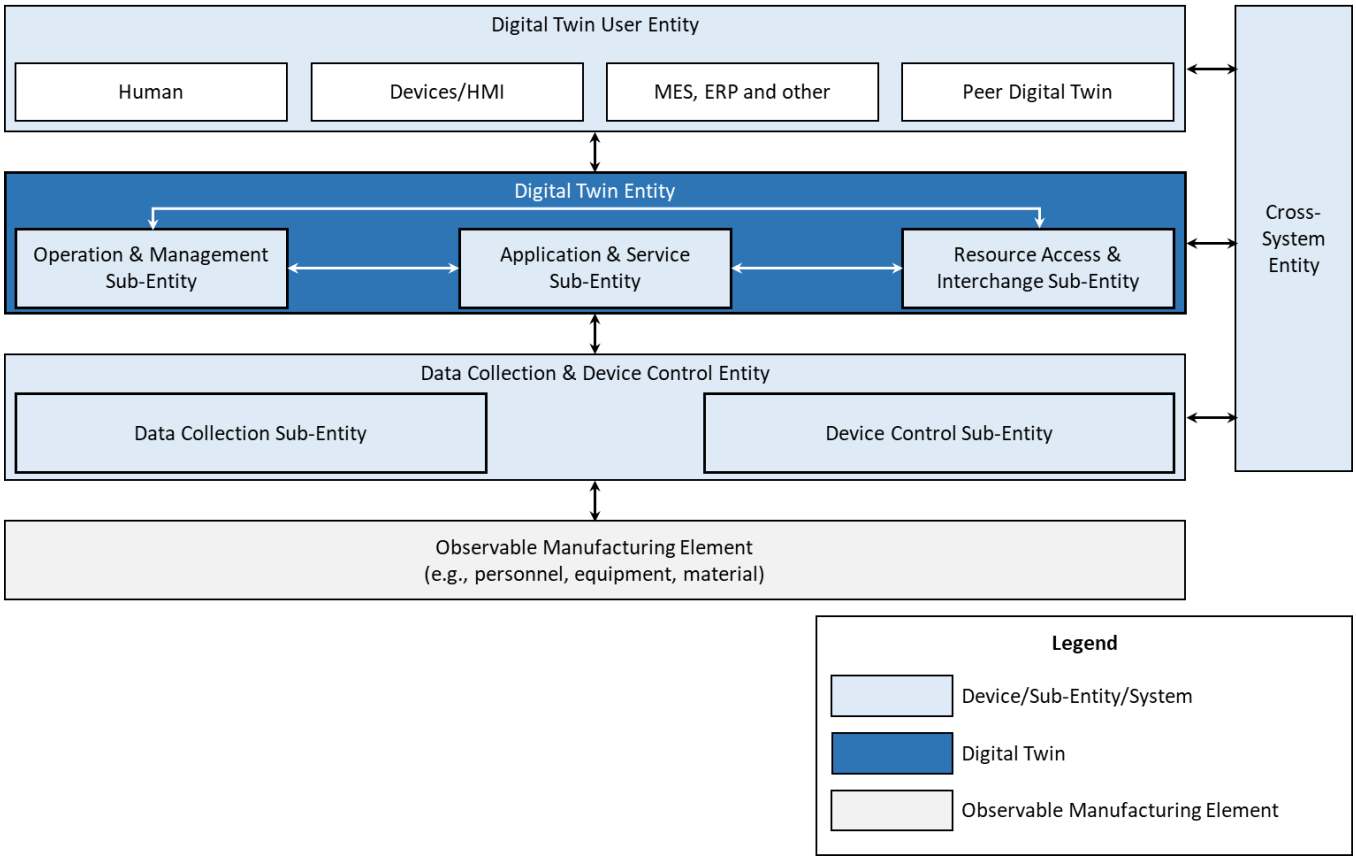

Figure 3 – Entity-based Digital Twin reference model for manufacturing

Figure 3 shows an entity-based Digital Twin reference model for manufacturing. A set of operation and management sub-entity, application and service sub-entity, and resource access and interchange sub-entity digitally represents observable manufacturing elements as Digital Twins, and maintains the Digital Twins, therefore it is called Digital Twin entity.

5.2.2 Observable manufacturing element

Observable manufacturing element shall be monitored and sensed, and may be actuated and controlled by data collection and device control entity. It includes personnel, equipment, material, process, etc.

5.2.3 Data collection and device control entity

5.2.3.1 General

Digital Twin for manufacturing shall have one or more data collection and device control entity, because Digital Twin for manufacturing consists of one or more observable manufacturing elements that shall be controlled.

5.2.3.2 Data collection sub-entity

Data collection sub-entity interacts with the observable manufacturing element by monitoring and sensing for data collection, therefore may include sensors and other data collecting devices.

Data collection sub-entity communicates with Digital Twin entities, i.e., operation and management sub-entity, application and service sub-entity and resource access and interchange sub-entity, for support of generating, synchronizing, and managing Digital Twins, exactly speaking, digital entities of observable manufacturing elements. Therefore, data collection sub-entity may include executables in the form of a program or agent.

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5.2.3.3 Device control sub-entity

Device control sub-entity interacts with the observable manufacturing element by controlling and actuating for device control, therefore may include controller and other actuating devices. Like data collection sub-entity, device control sub-entity may include executables in the form of a program or agent.

5.2.4 Digital Twin entity

5.2.4.1 Operation and management sub-entity

Operation and management sub-entity operates and manages Digital Twin entity. Operation and management sub-entity shall maintain information of observable manufacturing element both in production and in design, including digital modeling, presentation, and synchronization. In addition, operation and management sub-entity supports capabilities related to operation and management of overall Digital Twin entity such as providing administration functionality to Digital Twin user entity.

5.2.4.2 Application and service sub-entity

Digital Twin entity provides various kinds of application and services including simulation of manufacturing system, analysis of data captured from observable manufacturing element, reporting of action such as production, etc. Application and service sub-entity provides functionalities related to applications and services, and support.

5.2.4.3 Resource access and interchange sub-entity

Resource access and interchange sub-entity provides access to functionalities of Digital Twin entity to Digital Twin user entity with controlled interfaces for application and service functionalities, administration functionalities, and business functionalities in support of interoperability. Access and interchange control functions may vary depending on the type of Digital Twin user entity requiring authentication, authorization and other necessary actions.

5.2.5 Digital Twin user entity

As shown in Figure 3, Digital Twin user entity can be any entity that can utilize Digital Twin for manufacturing such as human, a device, manufacturing execution system (MES)/enterprise resource planning (ERP) systems, or even peer Digital Twin entity. Appropriate interface shall be offered to Digital Twin user entity, where application specific capabilities are supplied by an underlying application that interacts with Digital Twin entity by means of APIs controlled by Resource access and interchange sub-entity.

5.2.6 Cross-system entity

Cross-system entity is an entity that resides across domains to provide common functionalities such as information exchange, data assurance, security support, etc.

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5.3 Domain-entity mixed reference model

Figure 4 shows a domain-entity mixed reference model. This is a reference model, therefore both domains and entities can be extended, merged, or added depending on practical use cases.

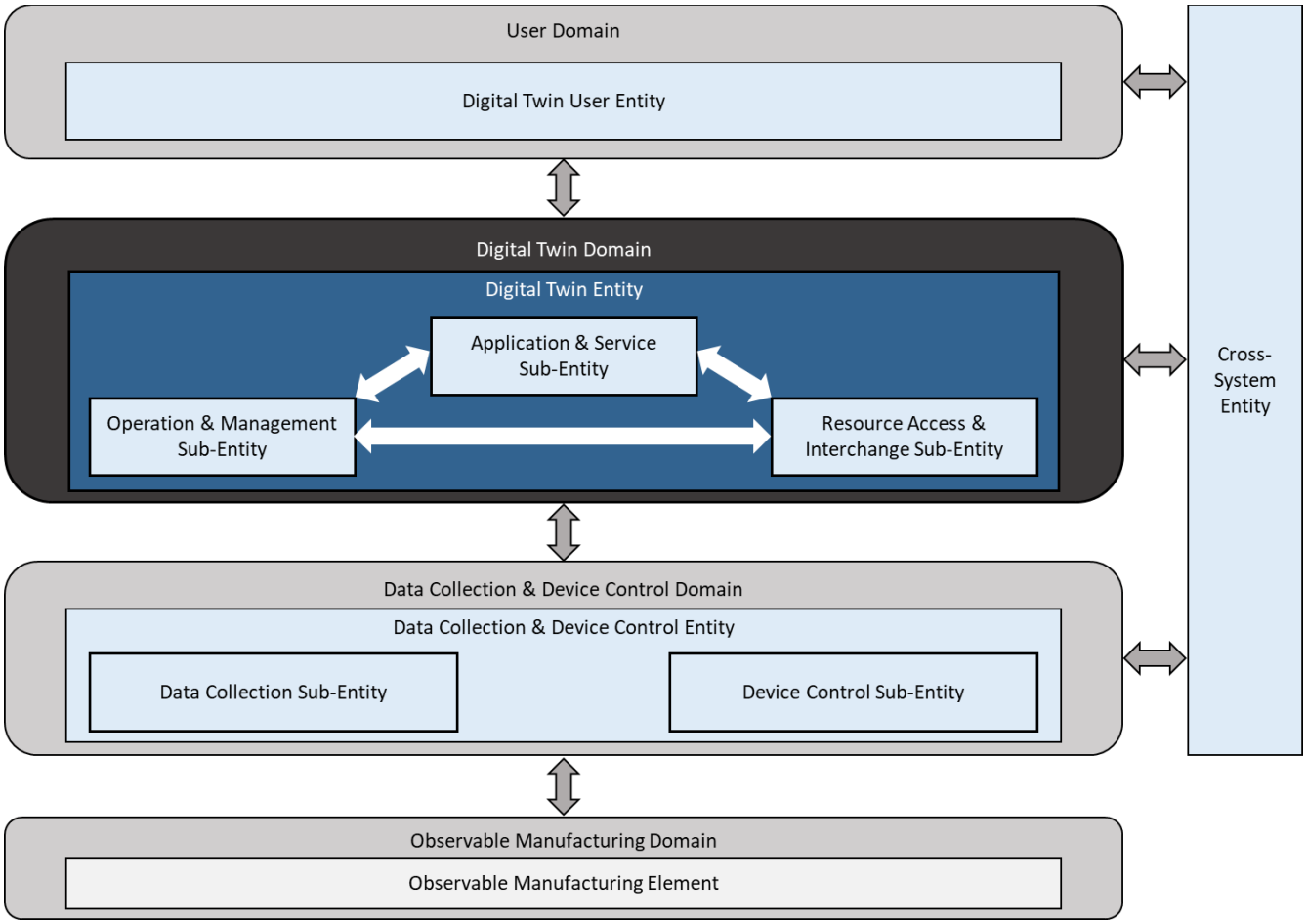

Figure 4 – Domain-entity mixed Digital Twin reference model for manufacturing

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6 Digital Twin reference architectural views for manufacturing

6.1 General

This clause defines functional view and networking view of Digital Twin reference architecture for manufacturing based on IoT reference architecture defined in ISO/IEC 30141.

6.2 Functional view

6.2.1 Functional reference architecture

Digital Twin reference architecture for manufacturing provides an infrastructure to support a large number of Digital Twins. Figure 5 shows a functional reference architecture to support requirements defined in ISO 23247-1.

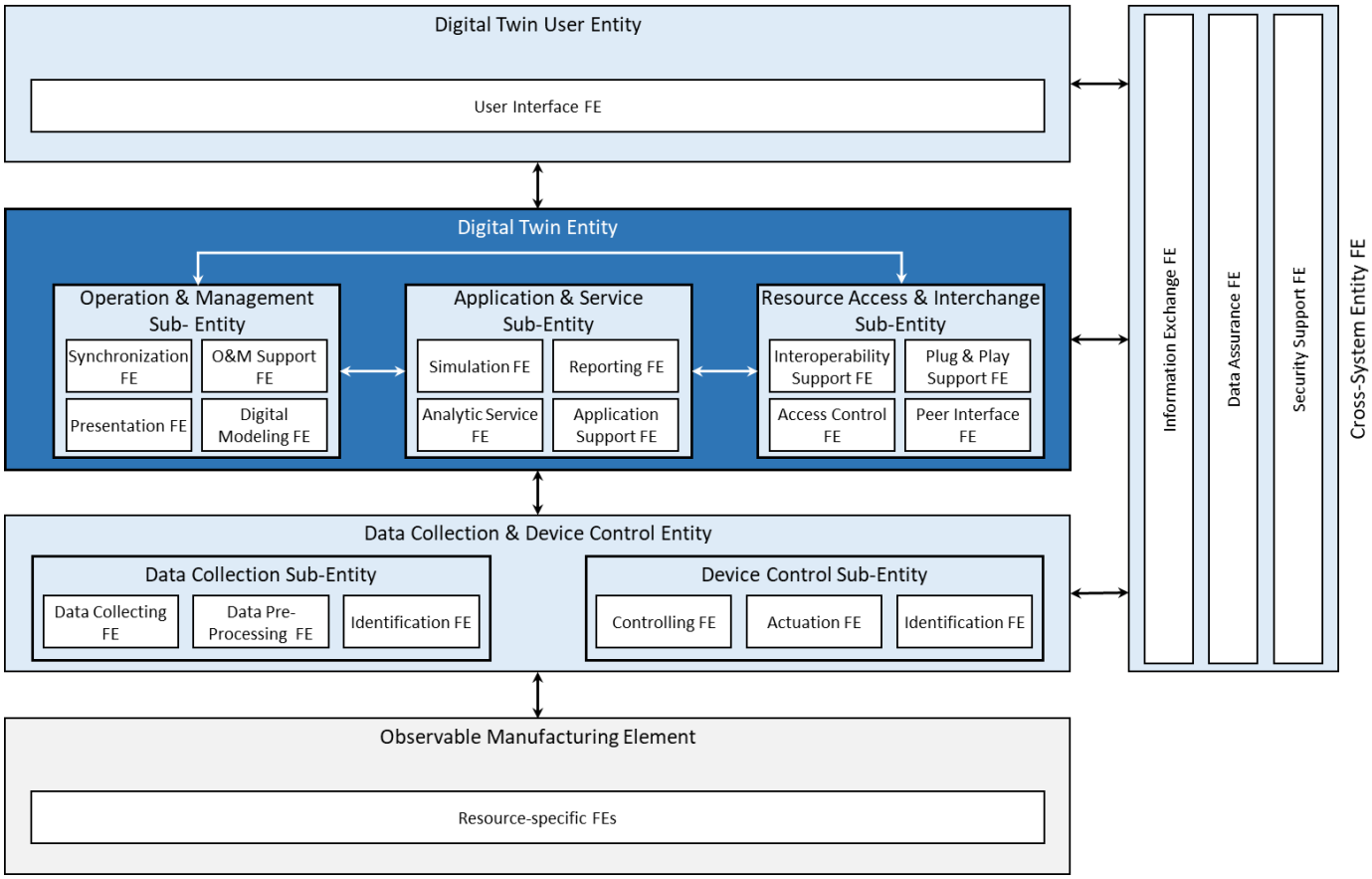

Figure 5 – Functional reference architecture of Digital Twin for manufacturing – decomposition of functional entities (FEs)

6.2.2 Functional entity of observable manufacturing element

Resource-specific FE is a functional entity of an observable manufacturing element. It shall be digitally modelled to be utilized by entities in Digital Twin for manufacturing.

6.2.3 Functional entity of data collection and device control entity

6.2.3.1 Data collecting FE in data collection sub-entity

Data collecting FE provides data collection functionality from observable manufacturing element.

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6.2.3.2 Data pre-processing FE in data collection sub-entity

Data pre-processing FE provides pre-processing functionality for collected data, for example filtering and aggregation.

6.2.3.3 Controlling FE in device control sub-entity

Controlling FE provides functionality of controlling observable manufacturing element by the request from Digital Twin entity.

6.2.3.4 Actuation FE in device control sub-entity

Actuation FE provides functionality of actuating observable manufacturing element by the request from Digital Twin entity, similarly with controlling FE.

6.2.3.5 Identification FE in data collection sub-entity and device control sub-entity

Identification FE provides functionality of identifying observable manufacturing element and its data to be collected and controlled uniquely and unambiguously.

6.2.4 Functional entity in Digital Twin entity

6.2.4.1 Functional entity in operation and management sub-entity

6.2.4.1.1 Synchronization FE

Synchronization FE provides functionality of synchronizing the status of the visualized digital entity with the status of the observable manufacturing element, or vice versa.

6.2.4.1.2 Presentation FE

Presentation FE provides functionality of presenting observable manufacturing element as digital entity in conjunction with digital modeling FE.

6.2.4.1.3 Digital modeling FE

Digital modeling FE provides functionality of interpreting information of observable manufacturing element to understand its physical properties, status, etc.

6.2.4.1.4 O&M support FE

O&M support FE provides functionalities of operating and managing Digital Twin entity.

6.2.4.2 Functional entity in application and service sub-entity

6.2.4.2.1 Simulation FE

Simulation FE provides functionalities of simulation.

6.2.4.2.2 Analytic service FE

Analytic service FE provides functionality of analysing data collected from observable manufacturing element and the result of simulation.

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6.2.4.2.3 Reporting FE

Reporting FE provides functionality of generating report of production result, analysis on simulation, etc.

6.2.4.2.4 Application support FE

Application support FE provides functionality of hosting platform for implementing predictive and reactive, open and closed loop applications.

6.2.4.3 Functional entity in resource access and interchange sub-entity

6.2.4.3.1 Interoperability support FE

Interoperability support FE provides functionality of interworking with other Digital Twin entity in conjunction with peer interface FE.

6.2.4.3.2 Access control FE

Access control FE provides functionality of controlling access of Digital Twin user entity to observable manufacturing element in conjunction with security support FE.

6.2.4.3.3 Plug & play support FE

Plug & play support FE provides functionality of dynamic involvement of observable manufacturing element, i.e., joining and leaving Digital Twin for manufacturing in run time, in conjunction with O&M support FE.

6.2.4.3.4 Peer interface FE

Peer interface FE provides functionality of interfacing to other Digital Twin entities in conjunction with interoperability support FE.

6.2.5 Functional entity in Digital Twin user entity

6.2.5.1 User interface FE

User interface FE provides Digital Twin user entity with functionality of interfacing to Digital Twin entity.

6.2.6 Functional entity in cross-system entity

6.2.6.1 Information exchange FE

Information exchange FE provides functionality of exchanging information among entities of Digital Twin for manufacturing by appropriate networking protocols.

6.2.6.2 Data assurance FE

Data assurance FE provides accuracy and integrity of data in conjunction with security support FE.

6.2.6.3 Security support FE

Security support FE provides functionality of securing Digital Twin for manufacturing including authentication, authorization, confidentiality, integrity, etc.

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6.3 Networking view

6.3.1 Networking reference architecture

Networking reference architecture describes communication network which are involved in Digital Twin for manufacturing.

Figure 6 shows three principal communication networks in terms of domain-entity mixture reference model (see 5.3) in Digital Twin for manufacturing. Main role of communication network provides means to exchange information between entities across the different domains.

However, data collection and device control entity is physically attached or integrated into observable manufacturing element, therefore communication network between these two entities is not considered in this document.

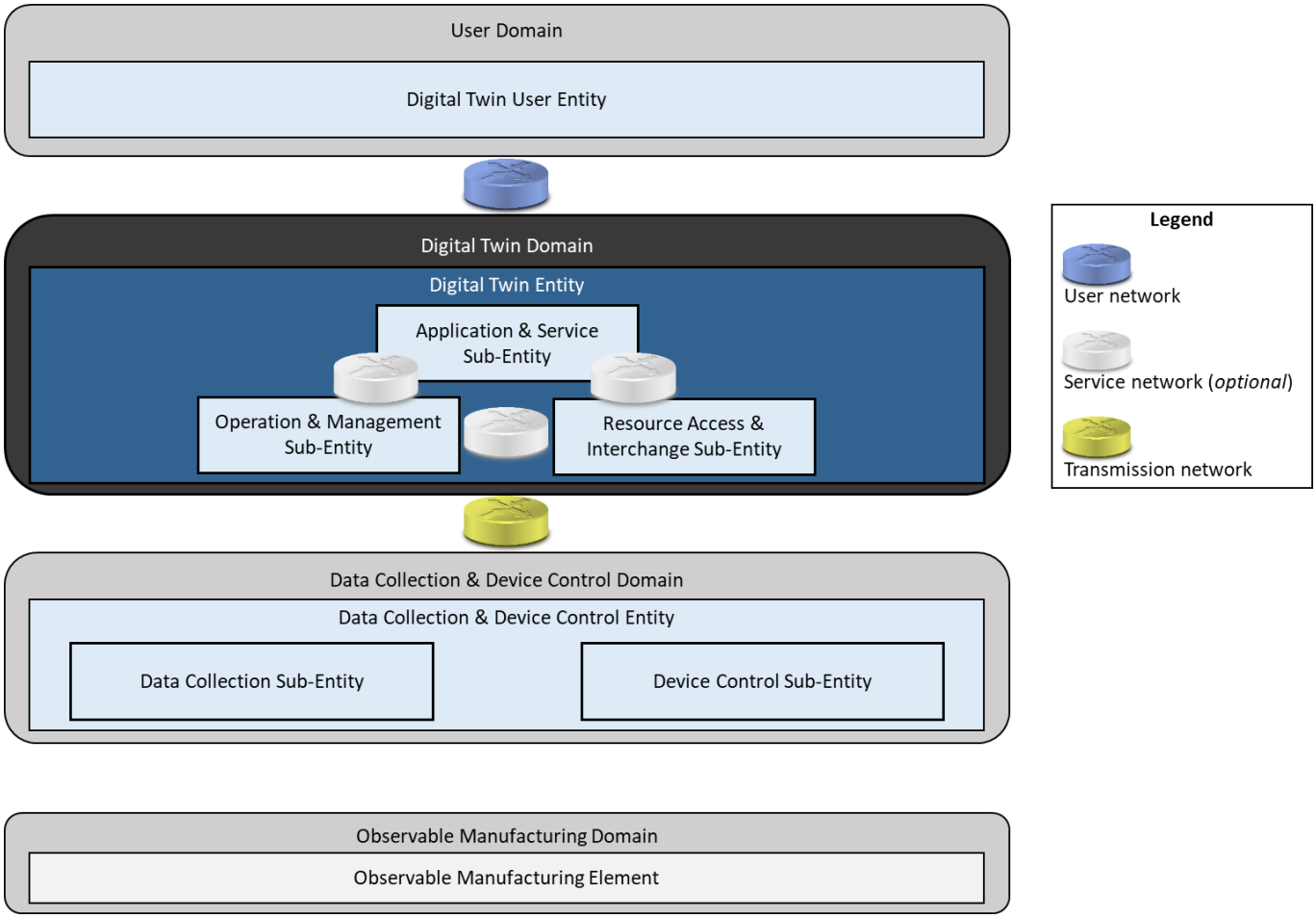

Figure 6 – Networking view of Digital Twin reference architecture for manufacturing

6.3.2 Transmission network

Transmission network connects data collection and device control entity to Digital Twin entity, i.e., operation and management sub-entity, application and service sub-entity, and resource access and interchange sub-entity. Through this network, data collection sub-entity transmits collected data from observable manufacturing element to the target entities of Digital Twin entity. In addition, control information for observable manufacturing element is delivered to device control sub-entity from entities of Digital Twin entity.

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Typical examples of transmission network can be wired communication such as LAN, and wireless communication such as WLAN and mobile (cellular) network, which generally adopt IP-based communication protocols regardless of communication type.

Information exchange between data collection and device control entity and Digital Twin entity over transmission network is supported by appropriate communication protocol. For example, MTConnect and OPC-UA can be used as information exchange protocol. ISO 23247-4 defines information exchange over transmission network. However, if data collection and device control entity and Digital Twin entity are implemented in one system, it might not be necessary to have transmission network.

6.3.3 Service network (optional)

Service network connects operation management sub-entity, application and service sub-entity, and resource access and interchange entity with each other, which are typically wired networks running IP-based protocols.

Service network can include both typical Internet and also (private) Intranet in case that Digital Twin entity is implemented in a single private domain, even a single system. In this case, a service network is not needed and dedicated connections can be applied to a single private domain connecting different entities as well as internal communication within a single system. ISO 23247-4 defines information exchange over service network.

6.3.4 User network

User network connects Digital Twin user entity with Digital Twin entity. In case that Digital Twin user entity is one of MES, ERP, other manufacturing management system, and even other Digital Twin entity, this type of Digital Twin user entity is connected to resource access and interchange sub-entity over user network.

User network is typically based on Internet and uses IP. Such networks can use any of the technologies commonly used to exchange information. ISO 23247-4 defines information exchange over user network.

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Bibliography

[1] The Structure of the Administration Shell: TRILATERAL PERSPECTIVES from France, Italy and Germany, International Paper, Platform Industrie 4.0, 2018

[2] IEC 62264-1 (2013), Enterprise-control system integration — Part 1: Models and terminology

[3] ISO 23247-4, Automation systems and integration — Digital Twin framework for manufacturing — Part 4: Information exchange

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