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Recommendation

ITU-T Y.4224 (11/2023)

SERIES Y: Global information infrastructure, Internet protocol aspects, next-generation networks, Internet of Things and smart cities

Internet of things and smart cities and communities – Requirements and use cases

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Requirements for digital twin federation in smart cities and communities

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Global information infrastructure, Internet protocol aspects, next-generation networks, Internet of Things and smart cities

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Recommendation ITU-T Y.4224

Requirements for digital twin federation in smart cities and communities

Summary

A digital twin is the digital representation of an object of interest with data connections that enable convergence between the physical and digital states at an appropriate rate of synchronization. Also, a digital twin has the capabilities of connection, integration, analysis, simulation, visualization, optimization and provides an integrated view throughout the life-cycle of the objects of interest. The digital twin can provide real-time monitoring and proactive control, predictive maintenance by data analytics, cost and downtime reduction, and so on. Due to these benefits, various industries have adopted the digital twin technology.

The smart cities and communities may have many kinds of cross domain problems, such as manufacturing, transportation, energy and safety, and it is difficult to resolve these problems by individual digital twins. To solve them, the digital twins in various domains can be federated.

The federated digital twins collect and analyse the information from various domains, provide the solution for the problems, and simulate the effects. For this, some components and functions are needed to support for digital twin federation. First, registration of information for each digital twin is performed. And the discovery, connection, and utilization for the adequate digital twins are carried out for digital twin federation.

Recommendation ITU-T Y.4224 defines the requirements for digital twin federation.

History *

Edition	Recommendation	Approval	Study Group	Unique ID
1.0	ITU-T Y.4224	2023-11-29	20	11.1002/1000/15682

Keywords

Digital transformation, digital twin, federation, object of interest, observable object, smart sustainable cities and communities.

* To access the Recommendation, type the URL https://handle.itu.int/ in the address field of your web browser, followed by the Recommendation's unique ID.

FOREWORD

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The World Telecommunication Standardization Assembly (WTSA), which meets every four years, establishes the topics for study by the ITU-T study groups which, in turn, produce Recommendations on these topics.

The approval of ITU-T Recommendations is covered by the procedure laid down in WTSA Resolution 1.

In some areas of information technology which fall within ITU-T's purview, the necessary standards are prepared on a collaborative basis with ISO and IEC.

NOTE

In this Recommendation, the expression "Administration" is used for conciseness to indicate both a telecommunication administration and a recognized operating agency.

Compliance with this Recommendation is voluntary. However, the Recommendation may contain certain mandatory provisions (to ensure, e.g., interoperability or applicability) and compliance with the Recommendation is achieved when all of these mandatory provisions are met. The words "shall" or some other obligatory language such as "must" and the negative equivalents are used to express requirements. The use of such words does not suggest that compliance with the Recommendation is required of any party.

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Requirements for digital twin federation in smart cities and communities

1 Scope

This Recommendation provides the concept and service scenarios of digital twin federation and defines requirements for digital twin federation in smart cities and communities. The scope of this Recommendation includes the following:

– Concept of digital twin federation;

– Service scenario of digital twin federation;

– Requirements for digital twin federation.

2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

None.

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following term defined elsewhere:

3.1.1 digital twin [b-ITU-T Y.4600]: A digital representation of an object of interest.

NOTE – A digital twin may require different capabilities (e.g., synchronization, real-time support) according to the specific domain of application.

3.2 Terms defined in this Recommendation

This Recommendation defines the following terms:

3.2.1 candidate digital twin: A set of digital twins which can be the participating digital twin.

3.2.2 connection information: Information used for establishing a connection between digital twins.

NOTE – Example components of connection information are protocols, Uniform Resource Identifiers (URIs), IP address and port number.

3.2.3 digital twin federation: Sharing data and functions for collaboration across different digital twins.

3.2.4 federated digital twin: A digital twin created as a result of digital twin federation.

NOTE – A federated digital twin is an extension of the initiating digital twin.

3.2.5 feature information: Description of digital twin including the data and functions which can be provided, the access rights to the data and functions, semantic information for each data and function, and connection information for the digital twin.

3.2.6 initiating digital twin: A digital twin that initiates digital twin federation.

3.2.7 participating digital twin: A digital twin that participates in digital twin federation according to the request from an initiating digital twin.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

CM-REQ Connection Management Requirements for digital twin federation

FI-REQ Feature Information Requirements for a digital twin

FS-REQ Digital twin Requirements for federation support

IP Internet Protocol

SE-REQ Security Requirements for digital twin federation

URI Uniform Resource Identifier

5 Conventions

In this Recommendation:

The keywords "is required" indicates a requirement that must be strictly followed and from which no deviation is permitted if conformance to this Recommendation is to be claimed.

6 Concept of digital twin federation

A digital twin can be defined as a digital representation of an object of interest which may require different capabilities according to the specific domain of application, and can be used to predict future situations that could occur in the real world. The object of interest refers to an observable object.

The digital twins are developed for their specific purposes and dedicated requirements in each domain, such as manufacturing, transportation, energy and safety. However, a functional expansion is required to provide cross-domain services for smart sustainable cities and communities. Since the smart sustainable cities and communities include multiple domains and stakeholders, mentioned above, and they may suffer from conflicts of interest. These problems can be solved by pre-simulating various complex situations through sharing data and functions for collaboration across different digital twins. This collaboration is defined as digital twin federation.

Among the cross-domain problems in smart cities and communities, the greenhouse gas emission is one of the major problems. To solve the problem, the digital twins in various domains, such as manufacturing, transportation and energy, that emit pollutants can be federated to manage and reduce the overall greenhouse gas emission in smart sustainable cities and communities.

The spread of infectious diseases is another cross-domain social problem to be solved in smart cities and communities. To respond the infectious disease, digital twin federation among transportation, manufacturing and medical domain is needed for medical transport, procurement of quarantine goods and patient treatment, respectively. This digital twin federation enables to simulate and respond to a variety of situations, including manufacturing medical resources, transporting patients and preparing patient beds as the number of patients is increased.

To provide this kind of services, digital twin federation is formed according to the procedures such as discovering and collaborating with the related digital twins. The digital twin federation is an operation to share data and functions for collaboration across different digital twins.

Digital twin federation can provide the following valuable benefits for smart cities and communities:

– Support identifying and responding to cross domain problems;

– Support integrated simulation to provide predictive services across multiple domains;
– Support multi-faceted decision making among various stakeholders;
– Support identifying co-relations and mutual side-effects occurring across domains.

The concept of digital twin federation is shown in Figure 1. The digital twins A, B, C and D are domain-specific digital twins and provide the specific services for their purposes and dedicated requirements. Each digital twin consists of the data, which are collected, managed and utilized, and functions, which are provided. The federated digital twin 1 is an example of digital twin federation, which is federating data A1, data A2, function A1 and function A2 in digital twin A and the data B1 in digital twin B to provide the new services that the digital twin A cannot provide.

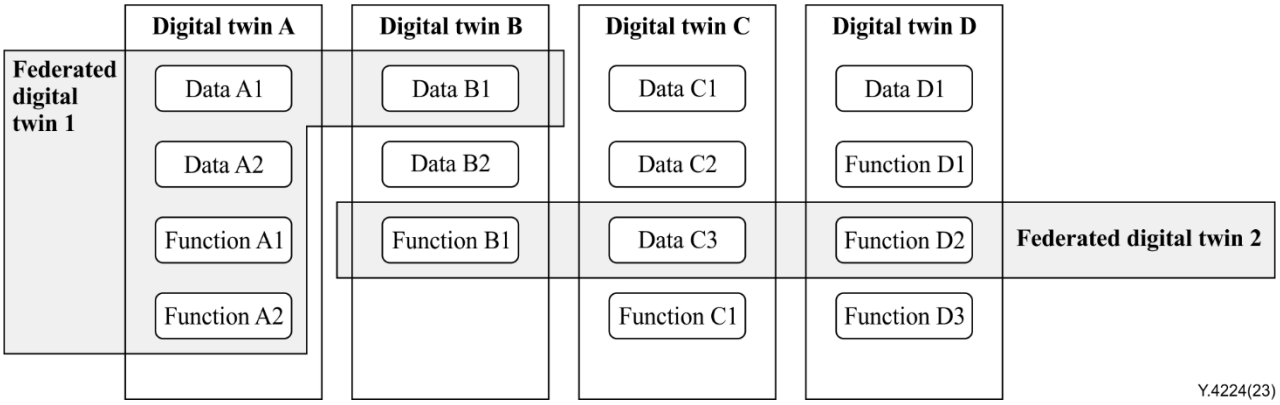

Figure 1 – A concept of digital twin federation

7 Service scenario of digital twin federation

Figure 2 shows an example of federated digital twin for emergency response by sharing the data and functions between a digital twin for emergency medical care and a digital twin for traffic. For sharing, the data and functions in the digital twin for traffic have to be preregistered or known to each other.

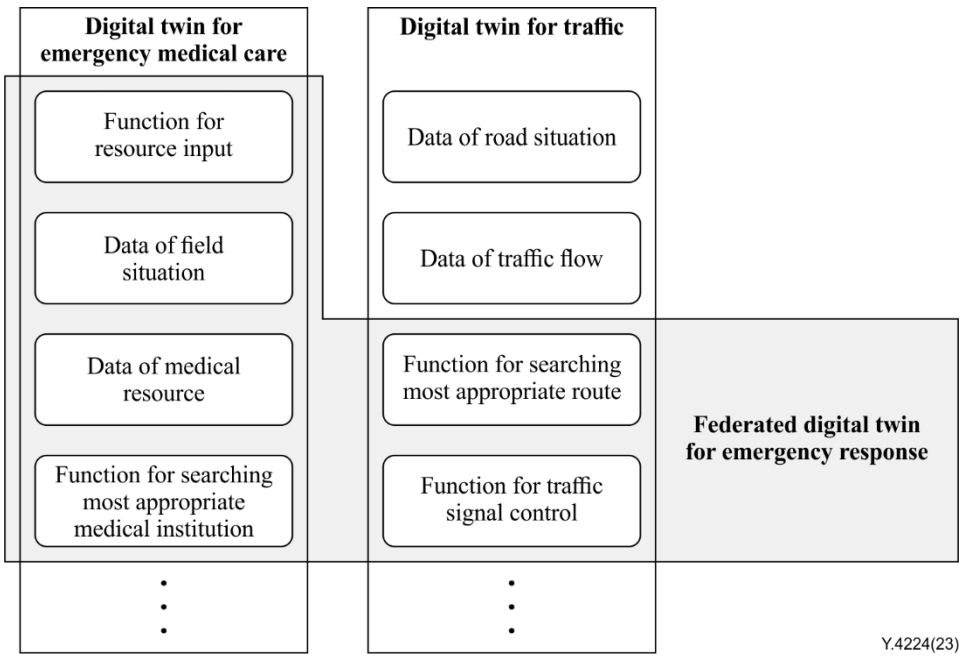

Figure 2 – An example of digital twin federation for emergency response

Figure 3 describes a service scenario of digital twin federation for emergency response in Figure 2. For rapid and effective patient transport, the digital twin for emergency medical care uses the data and functions of the digital twin for traffic as follows:

– Step 1) The digital twin for emergency medical care and the digital twin for traffic register their respective feature information;

– Step 2) The digital twin for emergency medical care sends emergency resources such as emergency vehicles, rescuers, etc. to the field;

– Step 3) The digital twin for emergency medical care obtains the information of emergency situation;

– Step 4) The digital twin for emergency medical care searches for the most appropriate medical institution based on information from the field, such as the number and the status of the patients, etc.;

– Step 5) The digital twin for emergency medical care discovers and selects the required data and functions in other digital twins;

– Step 6) The digital twin for emergency medical care sends the request to the digital twin for traffic for searching the most appropriate route to the medical institution;

– Steps 7-8) The digital twin for traffic searches for the most appropriate route, and sends the response with the searched route;

– Steps 9-11) For rapid and effective transferring patients, the digital twin for emergency medical care requests the digital twin for traffic to control the traffic lights according to the location of the emergency vehicle.

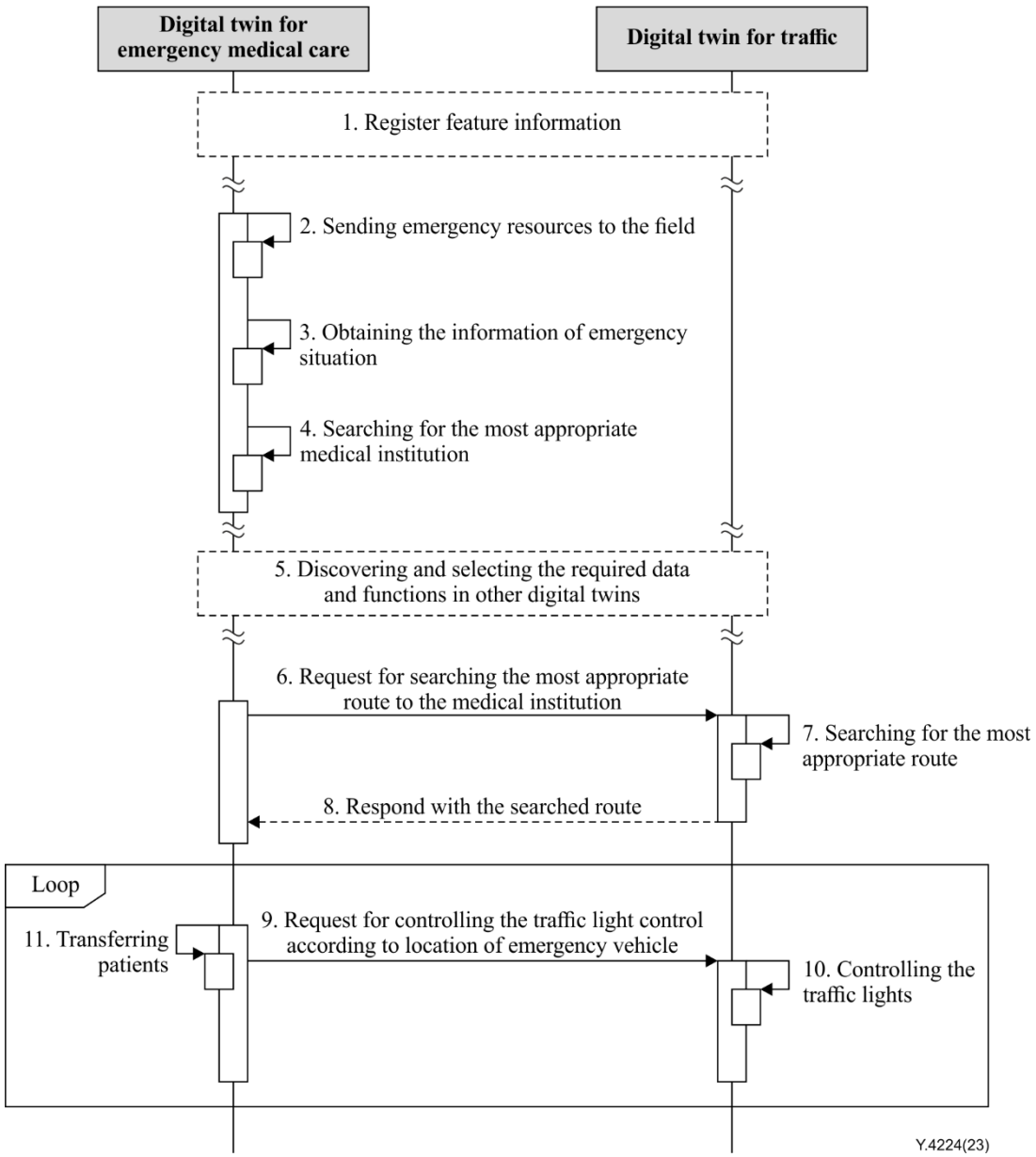

Figure 3 – Service scenario of digital twin federation for emergency response

In Figure 3, the digital twin for emergency medical care searches for other digital twins that can provide a function for most appropriate route search and a function for traffic light control. The description of the data and functions which the digital twins can provide and the access rights and semantic information for each data and function are called feature information, where the access rights to the data and functions are set in advance. In addition, the feature information shall include connection information used for establishing a connection between digital twins. The connection information consists of required protocols, URI, IP address and port number, etc.

8 Requirements for digital twin federation

8.1 Digital twin requirements for federation support (FS-REQ)

The following are the digital twin requirements for federation support:

– FS-REQ-01: It is required that a digital twin be uniquely identified;

– FS-REQ-02: It is required that a digital twin provides the feature information;

– FS-REQ-03: It is required that a digital twin establishes and manages connections with one or more digital twins to be federated;
– FS-REQ-04: It is required that a digital twin utilizes the data and functions in other digital twins that have the data and functions needed;
– FS-REQ-05: It is required that a digital twin sets access rights to its relevant data and functions.

8.2 Feature information requirements for a digital twin (FI-REQ)

The following are the feature information requirements for a digital twin:

– FI-REQ-01: It is required that the feature information includes a description of the data and functions available;
– FI-REQ-02: It is required that the feature information includes information on access rights to relevant data and functions available;
– FI-REQ-03: It is required that the feature information includes connection information such as protocol, IP address, port number, URI, etc;
– FI-REQ-04: It is required that the feature information includes semantic information;
– FI-REQ-05: It is required that the feature information is registered or shared, and can be updated and deleted;
– FI-REQ-06: It is required that the feature information be searchable.

8.3 Connection management requirements for digital twin federation (CM-REQ)

The following is the connection management requirement for digital twin federation:

– CM-REQ-01: It is required that indirect connections are established and managed between the digital twins to be federated, if direct connections cannot be established due to some reasons such as unsupported protocol, data format mismatch, security policies, etc.

8.4 Security requirements for digital twin federation (SE-REQ)

The following are the security requirements for digital twin federation:

– SE-REQ-01: It is required that authentication and authorization be previously performed when searching, registering, sharing, updating, and deleting the feature information of a digital twin;
– SE-REQ-02: It is required that authentication and authorization be previously performed when accessing data and functions of the digital twins to be federated.

Bibliography

[b-ITU-T Y.4600] Recommendation ITU-T Y.4600 (2022), *Requirements and capabilities of a digital twin system for smart cities.*

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