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ITU-T Y.4605 (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 – Services, applications, computation and data processing

Information exchange model for digital twin federation in smart cities and communities

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Recommendation ITU-T Y.4605

Information exchange model for digital twin federation in smart cities and communities

Summary

A digital twin is the digital representation of an object of interest with data connection that enables convergence between the physical state and digital state at an appropriate rate of synchronization. The digital twin has been applied in various industry domains including manufacturing, transportation, energy, firefighting, medical and safety. Digital twin federation is the act of sharing data and functions among two or more digital twins to solve the problems related to multiple domains.

Recommendation ITU-T Y.4489 defines the reference architecture of digital twin federation. The information exchange model among the components, which are the digital twins, the registry and the communication adaptor, is required to define digital twin federation based on the reference architecture. The exchangeable information is the data and functions used for digital twin federation. The information exchange model provides the overview and defines the message structure with actions and objects. Actions are performed on objects through information exchange among the components.

Recommendation ITU-T Y.4605 addresses an information exchange model for digital twin federation in smart cities and communities.

History *

Edition	Recommendation	Approval	Study Group	Unique ID
1.0	ITU-T Y.4605	2023-11-29	20	11.1002/1000/15690

Keywords

Digital twin federation, information exchange, 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.

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Recommendation ITU-T Y.4605

Information exchange model for digital twin federation in smart cities and communities

1 Scope

This Recommendation provides the information exchange model for digital twin federation in smart cities and communities. The scope of this Recommendation includes the following:

– Overview of information exchange models;

– Message structure for information exchange;

– Actions and objects 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.

[ITU-T Y.4224] Recommendation ITU-T Y.4224 (2023), *Requirements for digital twin federation in smart cities and communities*.

[ITU-T Y.4489] Recommendation ITU-T Y.4489 (2023), *Reference architecture of digital twin federation in smart cities and communities*.

[ISO 8601-1] ISO 8601-1:2019, *Date and time – Representations for information interchange. Part 1: Basic rules*.

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms 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.

3.1.2 digital twin federation [ITU-T Y.4224]: Sharing data and functions for collaboration across different digital twins.

3.1.3 feature information [ITU-T Y.4224]: 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.

3.1.4 initiating digital twin [ITU-T Y.4224]: A digital twin that initiates digital twin federation.

3.1.5 participating digital twin [ITU-T Y.4224]: A digital twin that participates in digital twin federation according to the request from an initiating digital twin.

3.2 Terms defined in this Recommendation

None.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

ID Identifier

IP Internet Protocol

URI Uniform Resource Identifier

URL Uniform Resource Locator

URN Universal Resource Name

UUID Universally Unique Identifier

UTC Universal Time Coordinated

5 Conventions

None.

6 Overview of information exchange model

Digital twin federation is sharing data and functions for collaboration across different digital twins to solve cross-domain problems. New services for cross-domain can be provided as a result of digital twin federation.

The three main components, including the digital twins, the registry and the communication adaptor are identified in [ITU-T Y.4489] based on the requirements defined in [ITU-T Y.4224]. The basic operations between the components are defined in [ITU-T Y.4489] as follows:

a) **Feature information registration between a digital twin and a registry**: This operation is performed between a digital twin and a registry to register feature information of the digital twin;

b) **Feature information registration between digital twins without registry**: This operation is performed between digital twins to share their feature information;

c) **Candidate digital twin discovery**: This operation is performed between an initiating digital twin and a registry to find appropriate candidate digital twins for digital twin federation;

NOTE – The candidate member discovery is not needed for case b);

d) **Direct communication establishment**: This operation is performed between digital twins to establish direct communication between them when they use the same communication protocol, the same data format and the common semantics;

e) **Indirect communication establishment**: This operation is performed between digital twins via a communication adaptor to establish indirect communication between the digital twins, when they use the different communication protocols or the different data formats or the different semantics;

f) **Direct information exchange**: This operation is performed between digital twins to exchange information directly;

g) **Indirect information exchange**: This operation is performed between digital twins via a communication adaptor to exchange information indirectly.

Figure 1 shows the possible information exchange models between the components of digital twin federation.

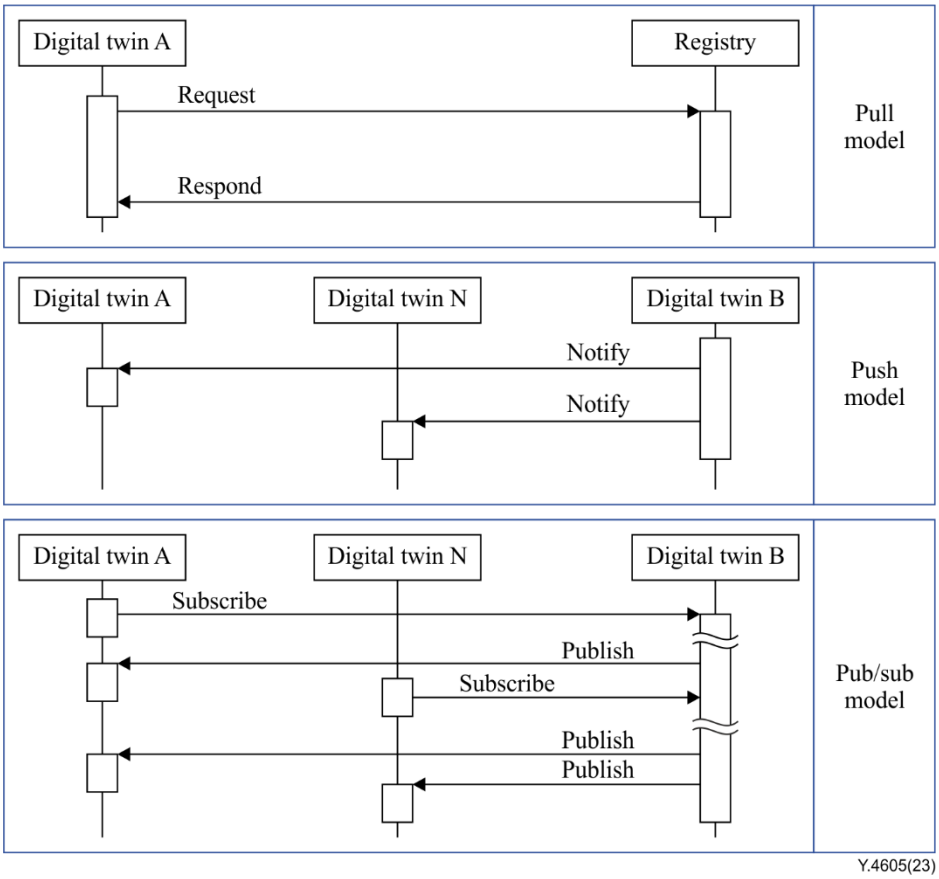

Figure 1 – Information exchange models between the components of digital twin federation

The components for digital twin federation may take on multiple roles, such as the sender and the receiver, in information exchange models, as follows:

– Pull model: The sender requests the receiver to send information, and the receiver responds by sending the requested information. In the pull model in Figure 1, the digital twin A requests the registry to send information, and the registry responds;

– Push model: The sender notifies the new or changed information to the receivers without request or subscription. In the push model in Figure 1, the digital twin B notifies its changes to the digital twins A and N without request or subscription from them;

– Pub/sub model: After subscription procedure, the publisher sends the subscribed information to the subscribers. In the pub/sub model in Figure 1, after subscription procedure, the digital twin B publishes the subscribed information to the digital twins A and N.

The use of the above three operation models are implementation dependent. The operations from a) to e) can be implemented using the pull model. Operations f) and g) can be implemented using the pull, push or pub/sub model. Detailed implementation examples are given in Appendix I.

7 Message structure for information exchange

7.1 Overview

The message structure for information exchange consists of a header area and a data area as shown in Figure 2. The header area contains the information for communication and the data area contains an action field and an object field.

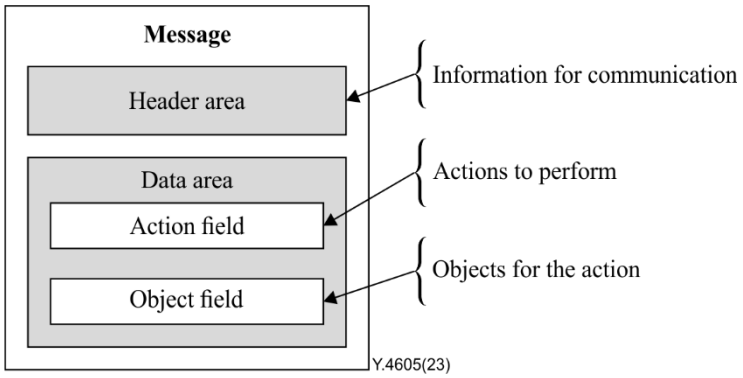

Figure 2 – Message structure

7.2 Header area

The header area consists of the sender, the receiver and the time fields.

7.2.1 Sender field

The sender field shall contain the sender ID that requests a receiver to perform an action. Table 1 shows the attributes for the sender ID.

Table 1 – Attributes for sender ID

Attribute	Description	Examples
Sender ID	A value used to uniquely identify a sender, e.g., uniform resource identifier (URI) or mapping of internet protocol (IP) address and port number.	– telnet://192.0.2.17:80/ – 192.168.10.21:2231

7.2.2 Receiver field

The receiver field shall contain the receiver ID that receives an action request from the sender. Table 2 shows the attributes for the receiver ID.

Table 2 – Attributes for receiver ID

Attribute	Description	Examples
Receiver ID	A value used to uniquely identify a receiver, e.g., URI or mapping of IP address and port number.	– mailto:John.Doe@example.com – 192.168.10.25:2242

7.2.3 Time field

The time field shall contain the timestamp that indicates the time a message was created. It is presented according to [ISO 8601-1]. Once assigned, the time should not be changed during the life of the message.

Table 3 – Attributes for time

Attribute	Description	Examples
Timestamp	A value of creation time of a message, e.g., date and time in universal time coordinated (UTC), or date.	– 2022-10-20T03:22:04+00:00 2022-10-20T03:22:04Z 20221020T032204Z – 2022-10-20

NOTE – The timestamp is written according to [ISO 8601-1], which is the internationally accepted way to represent dates and times.

7.3 Data area

The data area consists of the action field and the object field.

7.3.1 Action field

The action field shall contain an operation or a response that is performed by a component including the digital twins, the registry and the communication adaptor. The types of attributes for an object are not limited to those listed in Table 4.

Table 4 – Attributes of the action field

Attribute	Description	Examples
Action	A value used to uniquely identify one of the actions listed in Table 5	– Action = GET
Result	Values for the RESPOND action that contains the result (OK or NOK) and the number of objects in object field	– Result = (OK, 1)

The actions to be performed or responded by the digital twins, the registry and the communication adaptor are listed in Table 5.

Table 5 – List of actions

Action name	Description
CHANGE	Request sent to a receiver for it to change the existing data
CONNECT	Request sent to a receiver for it to connect for digital twin federation
DELETE	Request sent to a receiver for it to delete existing data
GET	Request sent to a receiver for it to share data. – Used among a digital twin, a registry and a communication adaptor
PROCESS	Request set to a receiver for it to process a function – Used to between the digital twins
REGISTER	Request sent to a receiver for it to register data
RESPOND	Response to an action which contains the result (OK or NOK) and the number of objects in the object field
SYNC	Request sent by information owners to subscribers for them to publish new information or changes in existing information. – It is required for the Pub/sub procedure to have already been performed.

7.3.2 Object field

The object field shall include one or more objects that are the targets of the action. The types of attributes for an object are not limited to those listed in Table 6.

Table 6 – Attributes for the object field

Attribute	Description	Examples
Object	The object name for the action	– digital twin for traffic – digital twin for emergency medical care – registry A – communication adaptor B
ID	A value used to uniquely identify an object, e.g., universally unique identifier (UUID), uniform resource locator (URL), and universal resource name (URN)	– UUID: 45256ed6-dd58-47af-b185-13e8055640ab – URL: https://url.kr/e5j79b – URN: tel: +82-18-123-4567
Description	Explanation of the digital twin, the registry and the communication adaptor	– The digital twin for traffic provides the functions to find the optimal route and to control traffic signal. – The digital twin for emergency medical care provides the function to find the optimal medical institution based on the number and the status of the patients.
Data format	Notation formation for an object	– application/xml – application/json – text/plain
Function property	A list of properties for each function provided by a digital twin including function identifier, description, parameter and example of function.	– Identifier: Func001 – Description: find the best route – Parameter: start, destination – Example: Func001(A building, B hospital)
Data property	A list of properties for each data provided by the digital twin, e.g., the data identifier, the description, the synonyms, the contents with a value and value unit of measures.	– Identifier: ABC Hospital – Description: general hospital – Synonyms: clinic, infirmary, a doctor's office – Data: value = "5" value unit of measure = "number" – Example: value = ResultFunc050(start, destination)
Connection information	A list of value used to access the object, e.g., URL.	– URL: https://url.kr/5dksr4

Appendix I

Examples of information exchange for digital twin federation

(This appendix does not form an integral part of this Recommendation.)

Appendix I describes the examples of information exchange for digital twin federation as shown in Annex A of [ITU-T Y.4489].

I.1 Feature information registration between a digital twin and a registry

Figure I.1 describes an example of feature information registration between a digital twin and the registry. Also, other digital twins can be also registered in the same way as the digital twin A (DT-001).

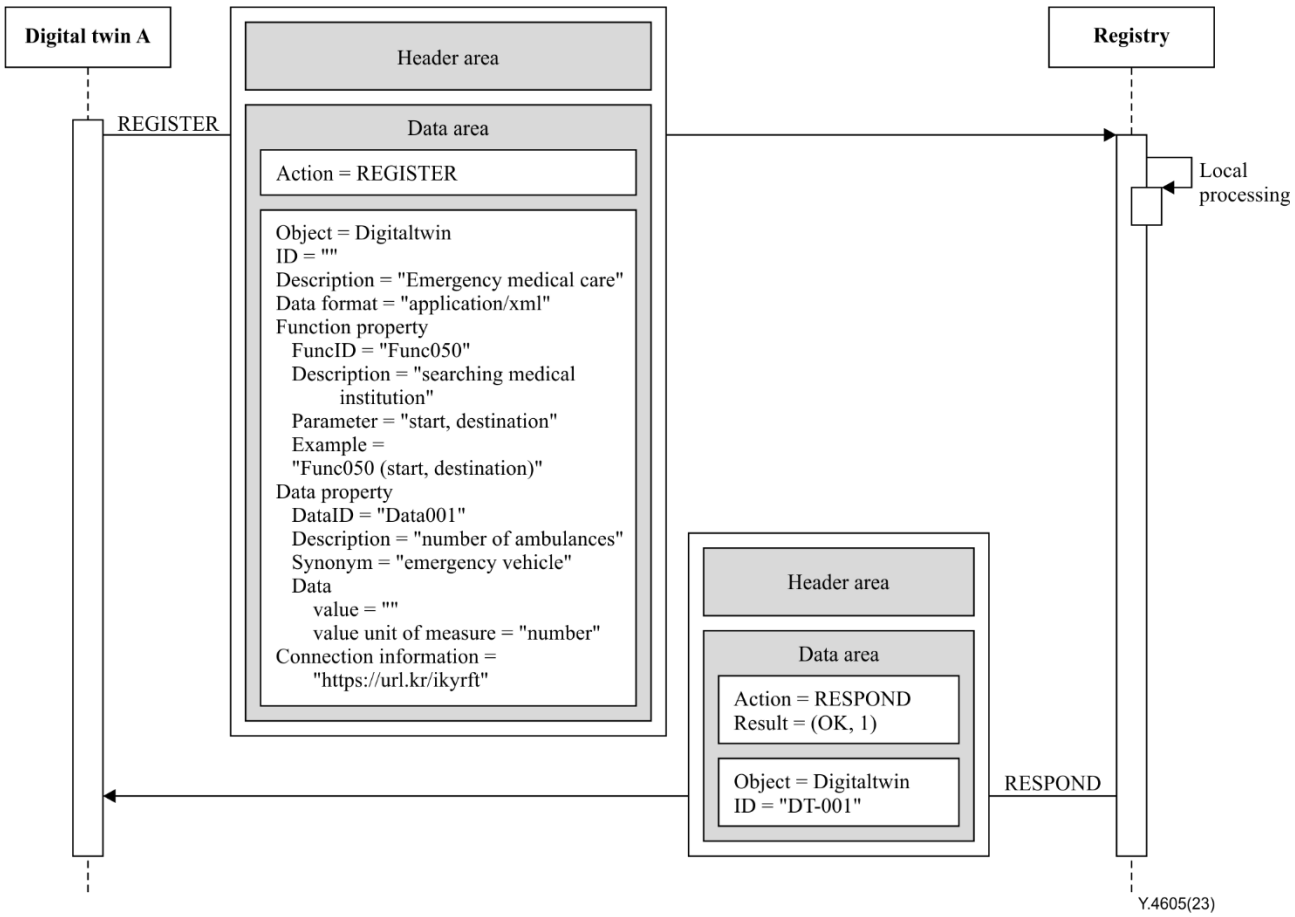

Figure I.1 – An example of feature information registration between a digital twin and a registry

I.2 Feature information registration between digital twins

Figure I.2 describes an example of feature information registration between digital twins. Here, Digital twin B (DT-002) registers its feature information to digital twin A (DT-001).

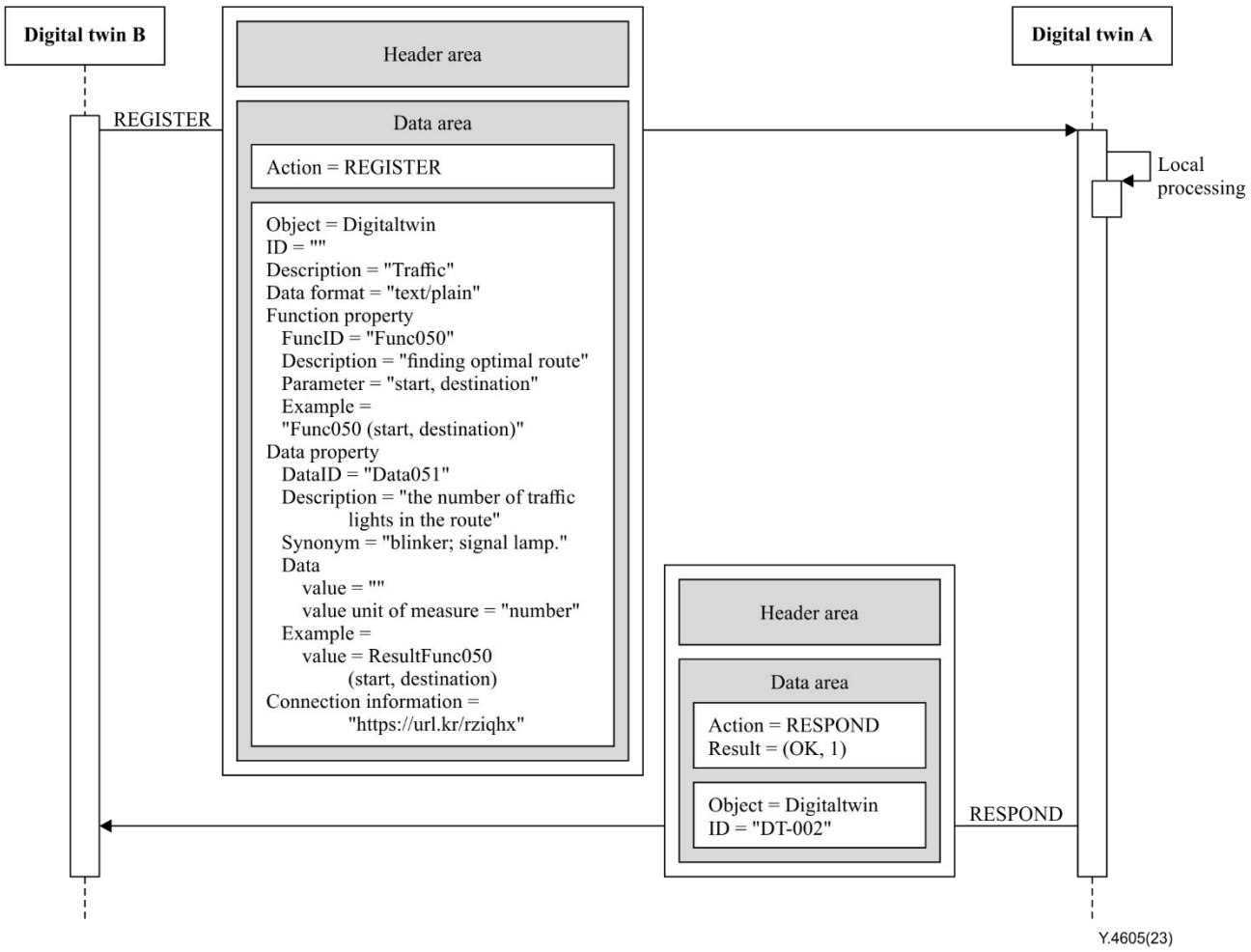

Figure I.2 – An example of feature information registration between digital twins

I.3 Candidate digital twin discovery

Figure I.3 describes an example of candidate digital twin discovery. Digital twin A looks for adequate digital twins with the function of "*route*" in a registry, and the result is "Digital twin B" (DT-002).

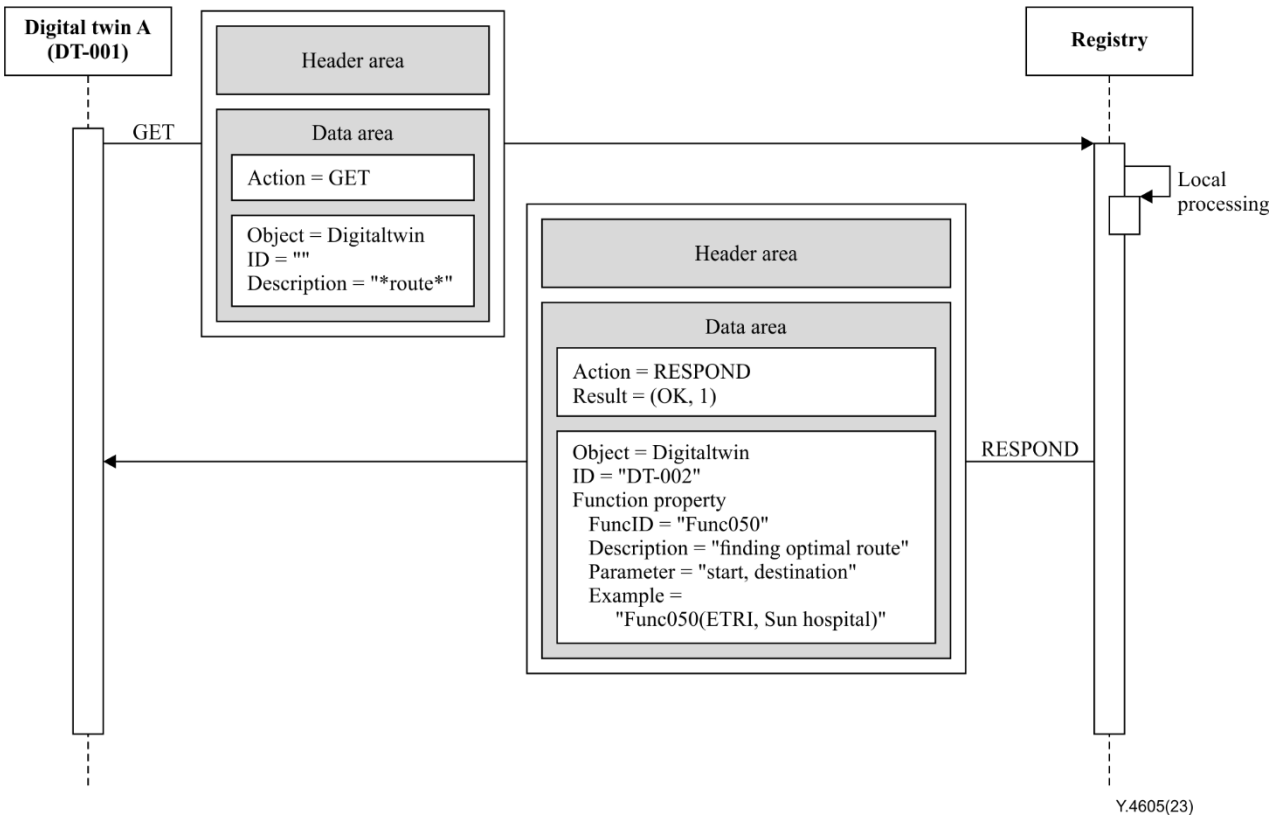

Figure I.3 – An example of candidate digital twin discovery

I.4 Direct communication establishment

Figure I.4 describes an example of direct communication establishment between digital twin A (DT-001) and digital twin B (DT-002).

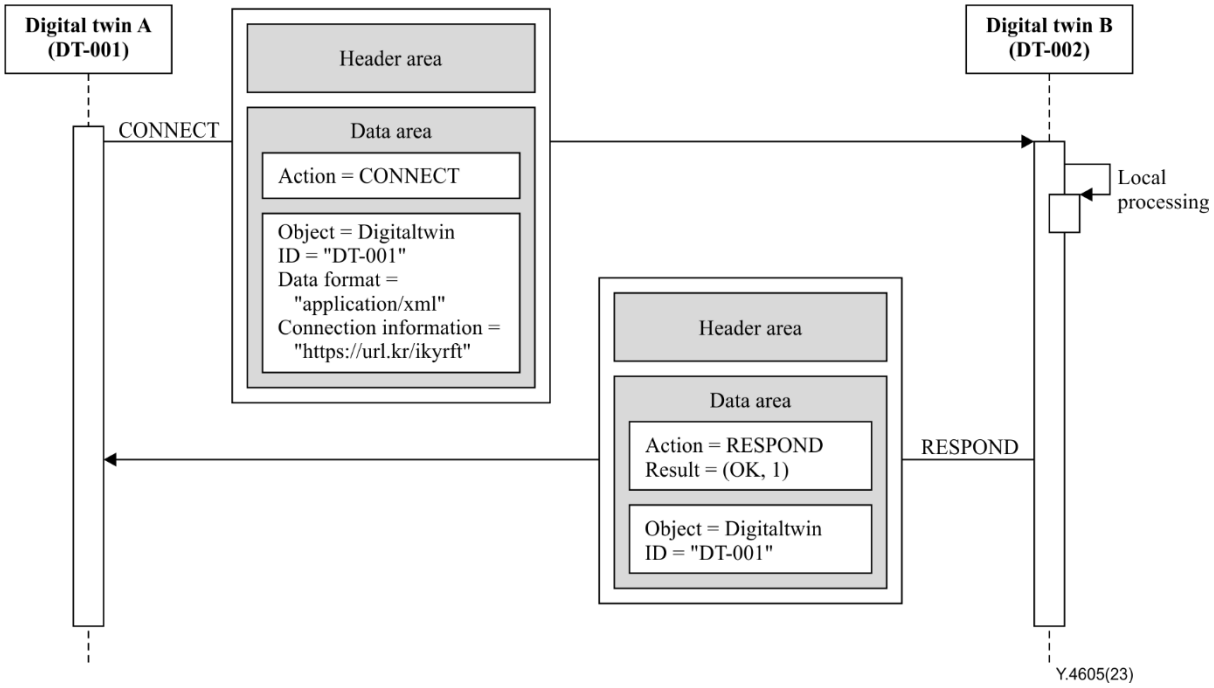

Figure I.4 – An example of direct communication establishment

I.5 Indirect communication establishment

Figure I.5 describes an example of indirect communication establishment for the cases where direct communication between digital twins is impossible.

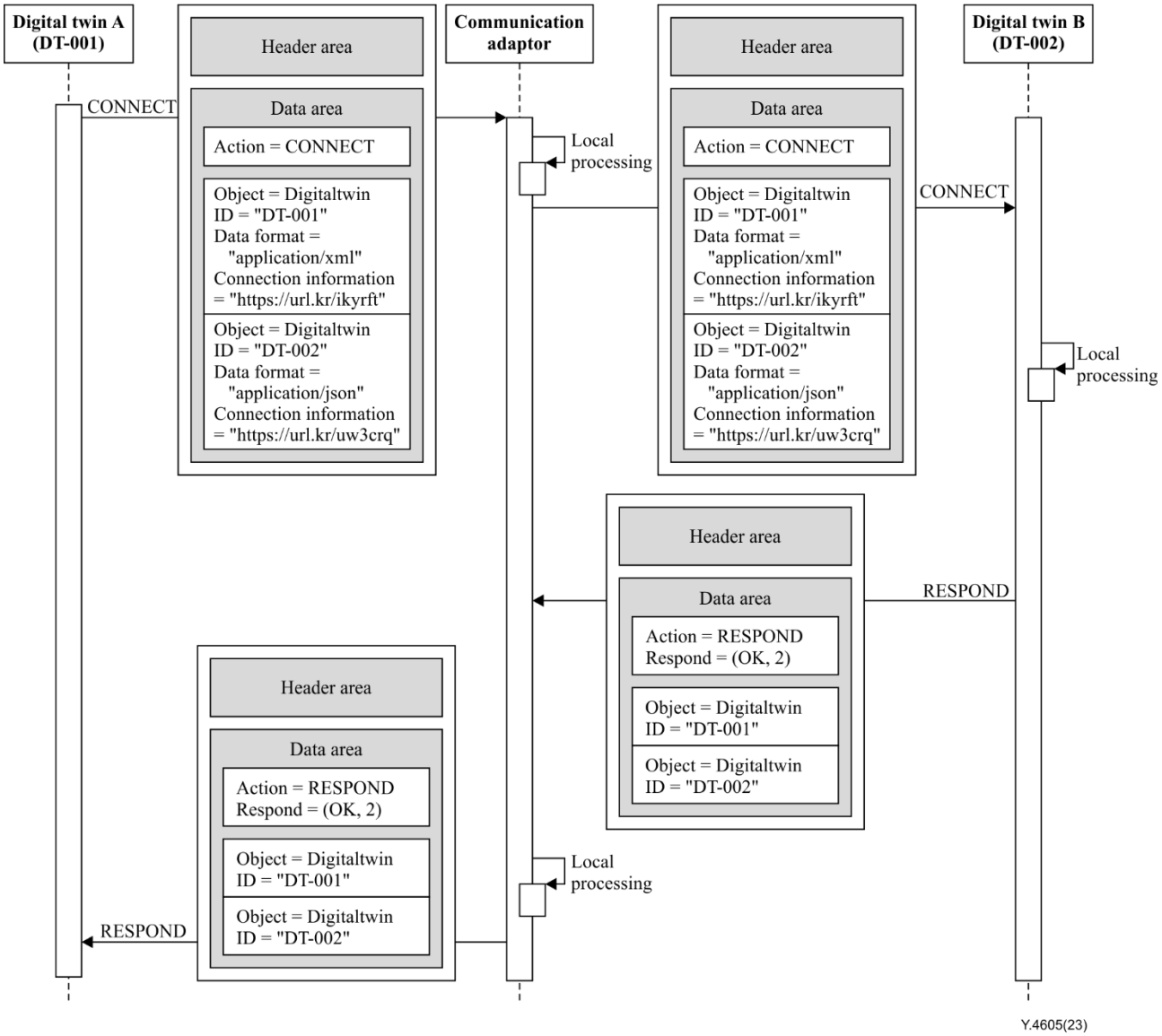

Figure I.5 – An example of indirect communication establishment

I.6 Direct information exchange

Figure I.6 describes an example of direct information exchange to notify the changed data from digital twin B (DT-002) to digital twins A (DT-001) and N (DT-00N).

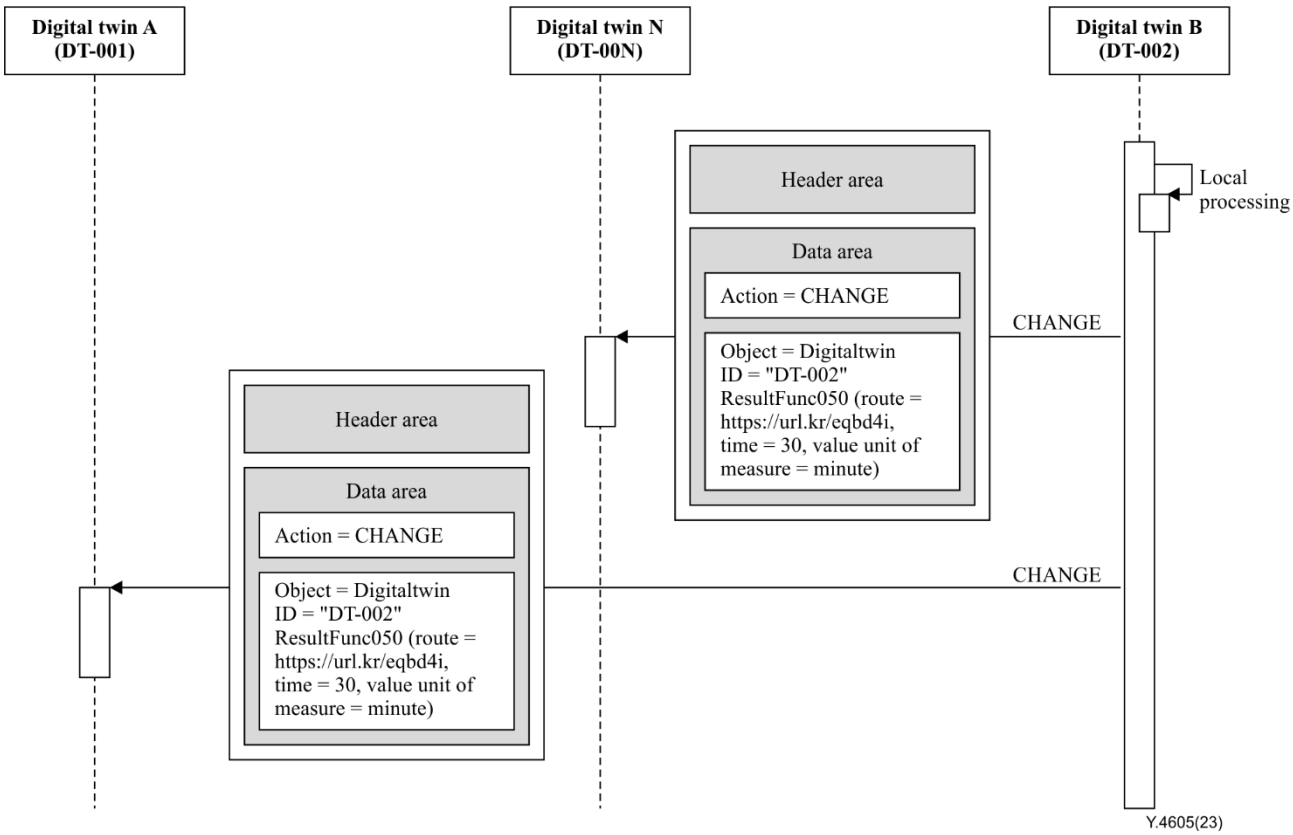

Figure I.6 – An example of direct information exchange

Appendix II

Example XML schema of message structure

(This appendix does not form an integral part of this Recommendation.)

Appendix II describes an example XML schema of message structure. Figure II.1 and Figure II.2 show the XML schema diagram and XML schema, respectively.

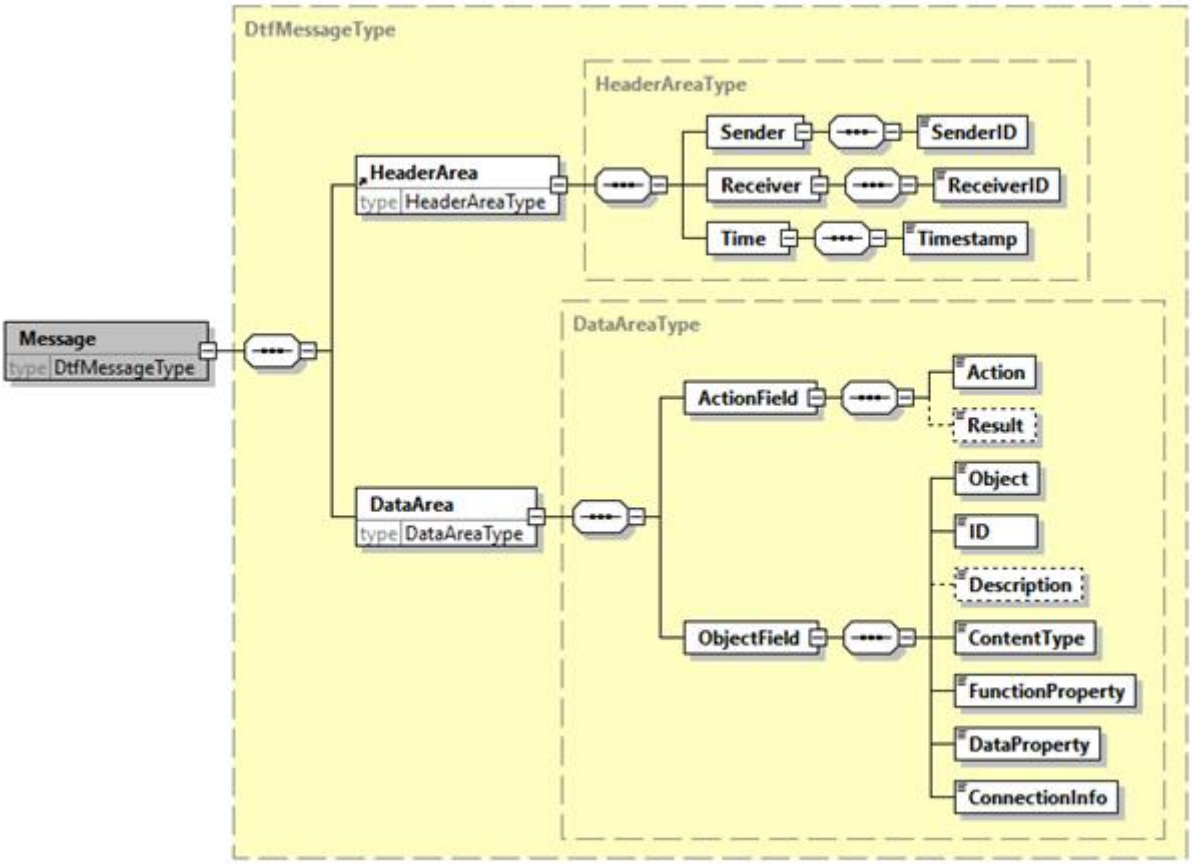

Figure II.1 – XML schema diagram of message structure

```
<?xml version="1.0" encoding="UTF-8"?>
<xs:schema xmlns:xs="http://www.w3.org/2001/XMLSchema" xmlns:vc="http://www.w3.org/2007/XMLSchema-versioning"
elementFormDefault="qualified" attributeFormDefault="unqualified" vc:minVersion="1.1">
        <xs:element name="Message" type="DtfMessageType"/>
        <xs:complexType name="HeaderAreaType">
            <xs:sequence>
                <xs:element name="Sender">
                    <xs:complexType>
                      <xs:sequence>
                            <xs:element name="SenderID"/>
                      </xs:sequence>
                    </xs:complexType>
                </xs:element>
                <xs:element name="Receiver">
                    <xs:complexType>
                      <xs:sequence>
                            <xs:element name="ReceiverID"/>
                      </xs:sequence>
                    </xs:complexType>
                </xs:element>
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                    <xs:complexType>
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                      </xs:sequence>
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            </xs:sequence>
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                    </xs:complexType>
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                      <xs:sequence>
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                            <xs:element name="ConnectionInfo"/>
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                </xs:element>
            </xs:sequence>
        </xs:complexType>
        <xs:complexType name="DtfMessageType">
            <xs:sequence>
                <xs:element ref="HeaderArea"/>
                <xs:element name="DataArea" type="DataAreaType"/>
            </xs:sequence>
        </xs:complexType>
        <xs:element name="HeaderArea" type="HeaderAreaType"/>
</xs:schema>
```

Figure II.2 – XML schema of message structure

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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