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Internet of things and smart cities and communities – Services, applications, computation and data processing

SERIES Y: GLOBAL INFORMATION INFRASTRUCTURE, INTERNET PROTOCOL ASPECTS AND NEXT-GENERATION NETWORKS, INTERNET OF THINGS AND SMART CITIES

Next Generation Networks – Frameworks and functional architecture models

Application support models of the Internet of things

Recommendation ITU-T Y.4552/Y.2078

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Recommendation ITU-T Y.4552/Y.2078

Application support models of the Internet of Things

Summary

Recommendation ITU-T Y.4552/Y.2078 provides application support models of the Internet of things (IoT). This Recommendation describes the basis of IoT application support models: the configurable application support model, the adaptable application support model and the reliable application support model. These three application support models are described in functional view, implementation view and deployment view, in order to identify, respectively, the configurable capabilities, the adaptable capabilities and the reliable capabilities for support of IoT applications having some characteristic requirements.

This Recommendation describes the IoT configurable capabilities that extend the IoT basic capabilities specified in Recommendation ITU-T Y.4401/Y.2068 in order to enable the IoT applications to configure the IoT capabilities based on their characteristic requirements.

This Recommendation describes the IoT adaptable capabilities that extend the IoT basic capabilities specified in Recommendation ITU-T Y.4401/Y.2068 in order to enable the IoT applications to adapt to the IoT capabilities based on their characteristic requirements.

This Recommendation describes the IoT reliable capabilities that extend the IoT basic capabilities specified in Recommendation ITU-T Y.4401/Y.2068 in order to support the IoT applications by the IoT capabilities with required degrees of reliability for fulfilling their characteristic requirements.

Use cases from the smart home environment provide examples about the usage of the IoT application support models.

History

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Recommendation ITU-T Y.4552/Y.2078

Application support models of the Internet of Things

1 Scope

This Recommendation describes basis of application support models of the Internet of things (IoT) and specifies three application support models of the IoT: the configurable application support model, the adaptable application support model and the reliable application support model.

The three application support models are specified in functional view, implementation view and deployment view respectively.

The configurable capabilities, adaptable capabilities and reliable capabilities related, respectively, to each of the three models, are also identified and described.

The scope of this Recommendation includes:

- The basis of application support models;
- The functional view, the implementation view and the deployment view of the configurable application support model and related configurable capabilities that extend the IoT basic capabilities specified in [ITU-T Y.4401] to enable the IoT applications to configure the IoT capabilities based on their characteristic requirements;
- The functional view, the implementation view and the deployment view of the adaptable application support model and related adaptable capabilities that extend the IoT basic capabilities specified in [ITU-T Y.4401] to enable the IoT applications to adapt to the IoT capabilities based on their characteristic requirements;
- The functional view, the implementation view and the deployment view of the reliable application support model and related reliable capabilities that extend the IoT basic capabilities specified in [ITU-T Y.4401] to support the IoT applications by the IoT capabilities with required degrees of reliability for fulfilling their characteristic requirements.

All capabilities identified and specified in this Recommendation are numbered and summarized in the annexes.

Appendix I shows three use cases of the IoT application support models from the smart home environment.

NOTE – Only three IoT application support models are described and specified in this Recommendation. The specification of other application support models is outside the scope of this Recommendation and for further consideration.

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.4000] Recommendation ITU-T Y.4000/Y.2060 (2012), *Overview of the Internet of things*.

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[ITU-T Y.4100] Recommendation ITU-T Y.4100/Y.2066 (2014), *Common requirements of the Internet of things*.

[ITU-T Y.4401] Recommendation ITU-T Y.4401/Y.2068 (2015), *Functional framework and capabilities of the Internet of things*.

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 application [b-ITU-T Y.2091]: A structured set of capabilities, which provide value-added functionality supported by one or more services, which may be supported by an API interface.

3.1.2 application domain [ITU-T Y.4100]: An area of knowledge or activity applied for one specific economic, commercial, social or administrative scope.

NOTE – Transport application domain, health application domain and government application domain are examples of application domains.

3.1.3 device [ITU-T Y.4000]: With regard to the Internet of things, this is a piece of equipment with the mandatory capabilities of communication and the optional capabilities of sensing, actuation, data capture, data storage and data processing.

3.1.4 functional entity [b-ITU-T Y.2012]: An entity that comprises an indivisible set of specific functions. Functional entities are logical concepts, while groupings of functional entities are used to describe practical, physical implementations.

3.1.5 Internet of things (IoT) [ITU-T Y.4000]: A global infrastructure for the information society, enabling advanced services by interconnecting (physical and virtual) things based on existing and evolving interoperable information and communication technologies.

NOTE 1 – Through the exploitation of identification, data capture, processing and communication capabilities, the IoT makes full use of things to offer services to all kinds of applications, whilst ensuring that security and privacy requirements are fulfilled.

NOTE 2 – From a broader perspective, the IoT can be perceived as a vision with technological and societal implications.

3.1.6 thing [ITU-T Y.4000]: With regard to the Internet of things, this is an object of the physical world (physical things) or the information world (virtual things), which is capable of being identified and integrated into communication networks.

3.2 Terms defined in this Recommendation

None.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

IoT Internet of Things

M2M Machine-to-Machine

QoS Quality of Service

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5 Conventions

In this Recommendation:

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

The keywords "is recommended" indicate a requirement which is recommended but which is not absolutely required. Thus this requirement need not be present to claim conformance.

The keywords "can optionally" and "may" indicate an optional requirement which is permissible, without implying any sense of being recommended. These terms are not intended to imply that the vendor's implementation must provide the option and the feature can be optionally enabled by the network operator/service provider. Rather, it means the vendor may optionally provide the feature and still claim conformance with the specification.

6 Basis of IoT application support models

6.1 Concepts and purpose of IoT application support models

The IoT application support models refer to different sets of the IoT capabilities, including their relations, which can support IoT applications with some characteristic requirements, such as application adaptability, reliability and manageability.

NOTE 1 – The application characteristic requirements, as named in this Recommendation, are part of the common requirements as specified in [ITU-T Y.4100]. The application characteristic requirements refer to requirements related with some characteristics of IoT applications, such as the adaptability of M2M applications, the reliability of e-health applications and the configurability of smart city applications.

The IoT application support models are used to guide the design, implementation and deployment of the IoT capabilities to fulfil application characteristic requirements, in order to establish a common service platform [ITU-T Y.4401] for support of IoT applications across different application domains.

NOTE 2 – The service platform established by implementing and deploying capabilities of the IoT application support models may be used to shorten the time period and reduce the cost of developing the IoT applications with characteristic requirements, such as configurable, adaptable, or reliable requirements, by making usage of the capabilities of the service platform. Appendix I describes some use cases from the smart home environment showing examples about the usage of the IoT application support models.

In particular, the purposes of the IoT application support models are as follows: the first one is to specify groups of IoT capabilities in order to facilitate the selection of IoT capabilities [ITU-T Y.4401] for the support of IoT applications with some characteristic requirements; the second one is to derive, based on the selected IoT capabilities, other IoT capabilities, not explicitly identified in [ITU-T Y.4401], as necessary in order to facilitate the design, implementation and deployment of the IoT capabilities for support of IoT applications with some characteristic requirements.

In this Recommendation, the framework of the IoT application support models and three specific application support models: the adaptable application support model, the reliable application support model and the configurable application support model, are specified. Clause 6.2 provides the rationale for this classification of the IoT application support models.

NOTE 3 –This Recommendation specifies only three application support models. Because of different IoT application characteristic requirements, different IoT application support models could be specified. Other application support models are for further consideration with respect to other relevant characteristic requirements of IoT applications.

The configurable application support model refers to the set of IoT capabilities, including their relations, to support the IoT applications with the characteristic requirement of configurability. The

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configurable application support model includes the IoT capabilities that can be configured by IoT applications, such as some service capabilities and communication capabilities that are related with the IoT applications.

The reliable application support model refers to the set of IoT capabilities, including their relations, to support the IoT applications with the required degrees of reliability. The reliable application support model includes the IoT capabilities that can enhance the reliability of IoT applications, such as reliable data communication capability.

The adaptable application support model refers to the set of IoT capabilities, including their relations, to support the IoT applications with the characteristic requirement of adaptability. The adaptable application support model includes the IoT capabilities that are adaptable to different application contexts, such as content awareness capability and context awareness capability.

6.2 Rationale for the selection of the IoT applications support models

Regarding the possible diverse classifications that can be considered for IoT applications, different classes for a given classification may require different application support models.

One possible classification of IoT applications is based on the characteristics of things, characteristics of IoT users and other functional characteristics of IoT.

The characteristics of things may include mobility, intelligent ability, etc. The characteristics of IoT users may include mobility, non-human operated, etc. Other functional characteristics of IoT may include content awareness, context awareness, etc.

NOTE 1 – For example, the IoT applications in support of things with mobility belong to the category of mobile thing applications of IoT; the IoT applications in support of things with intelligent ability belong to the category of smart thing applications of IoT; the IoT applications in support of non-human operated users of IoT belong to the category of IoT applications with non-human operators.

This classification of IoT applications may be too diverse to derive common application support models usable across different application domains. So this classification of IoT applications is not suitable as the basis to describe the IoT application support models.

Another classification of IoT applications is based on the non-functional requirements of IoT applications as specified in [ITU-T Y.4100], such as reliability, availability, manageability and adaptability. Based on this classification, IoT applications can be classified into reliable applications, manageable applications, adaptable applications, etc. Even if there are some differences among these non-functional requirements across different application domains, these differences consist in the absence of certain requirements in given application domain(s), or in the different strengths of certain requirements to be satisfied at the implementation and deployment level. So the application support models derived from this IoT application classification can be used across different application domains. This classification of IoT applications is suitable as the basis to describe the three IoT application support models specified in this Recommendation.

NOTE 2 – The three IoT application support models are related with several practical IoT applications, such as M2M applications, e-health applications and smart city applications. The configurable application support model specified in this Recommendation may be used to support smart city applications because these applications may address different application domains and require different configurations in these different domains. The adaptable application support model specified in this Recommendation may be used to support M2M applications because these applications usually require being able to adapt to different networking or application environments. The reliable application support model specified in this Recommendation may be used to support e-health applications because the e-health applications usually require high reliable networking and service provisioning.

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6.3 The three views of IoT application support models

The three views of an IoT application support model consists of the functional view, the implementation view and the deployment view for support of the identified IoT applications with some characteristic requirements.

The functional view consists of the functional groups, including their relations, which support the identified applications.

NOTE 1 – This functional view is based on the functional view of the IoT framework that is specified in [ITU-T Y.4401].

The implementation view consists of the functional entities, including their relations, which support the identified applications.

NOTE 2 – This implementation view is based on the implementation view of the IoT framework that is specified in [ITU-T Y.4401].

The deployment view consists of the functional components, including their relations, which support the identified applications.

NOTE 3 – This deployment view is based on the deployment view of the IoT framework that is specified in [ITU-T Y.4401].

NOTE 4 – Based on the three views of the IoT application support models, some IoT application support capabilities can be derived for support of the IoT applications with some characteristic requirements.

NOTE 5 – The IoT application support capabilities derived from the three views of the IoT application support models are aligned with and extend the IoT capabilities specified in [ITU-T Y.4401] in order to fulfill some characteristic requirements of the IoT applications. The three views of the IoT application support models can identify the IoT application support capabilities required in the stages of designing, implementing and deploying the IoT applications.

7 The configurable application support model

The configurable application support model consists of the functional view, implementation view and deployment view and related capabilities.

NOTE – The three views of application support model can be used to derive and validate the capabilities for support of configurable applications of the IoT.

7.1 The description of the configurable application support model

7.1.1 The functional view of the configurable application support model

The functional view of the configurable application support model consists of a configurable management group, a configurable security and privacy protection group, a configurable data management group, a configurable service provision, a configurable communication group, a configurable connectivity group and a configurable application support group and the interactions among these groups as illustrated in Figure 7-1. Each functional group contains related capabilities for support of the IoT configurable applications.

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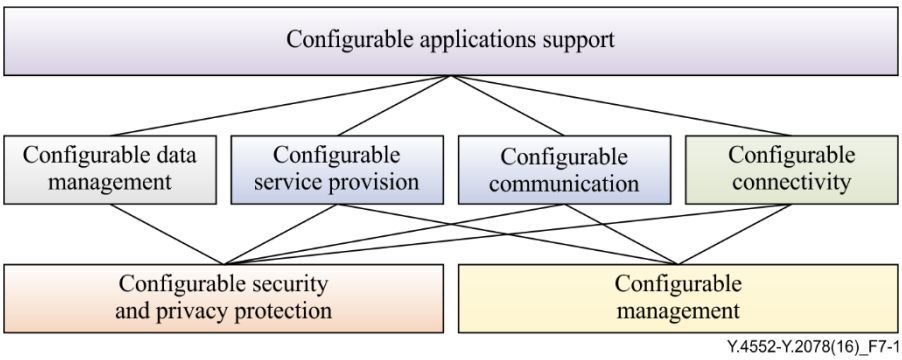

Figure 7-1 – The functional view of the configurable application support model

The configurable security and privacy protection group is related to the configurable data management group, the configurable service provision group, the configurable communication group and the configurable connectivity group, which refer to the fact that the other functional groups rely on the security and privacy protection capabilities specified in this functional group to protect their configurable capabilities for support of IoT applications.

The configurable management group is related to the configurable service provision group, the configurable communication group and the configurable connectivity group to provide required management capabilities.

The data management group has its own management capabilities, because configurable data management capabilities depend on data models. By ensuring the management of the data models by the data management group's own management capabilities, configuration management can be simplified.

The security and privacy protection group also has its own configurable management capabilities in order to prevent any possible intrusion or attack from external configuration management.

The configurable application support group is related to the configurable data management group, the configurable service provision group, the configurable communication group and the configurable connectivity group to allow the exposure of the configurable capabilities contained in these functional groups to IoT applications.

NOTE 1 – The functional view of the configurable application support model can be used to identify the functional groups related to the configurable capabilities for support of IoT applications.

NOTE 2 – In the functional view of the configurable application support model, there is no interaction among the configurable data management group, the configurable service provision group, the configurable communication group and the configurable connectivity group, because each of these functional groups does not need to interact with others to provide configurable capabilities.

7.1.2 The implementation view of the configurable application support model

The implementation view of the configurable application support model consists of a configurable management and identity management entity, a configurable IoT security and privacy protection entity, a configurable IoT gateway entity, a configurable end-user device entity, a configurable transport control entity, a configurable IoT transport control entity, a configurable service control entity, a configurable IoT service control entity, a configurable IoT data management entity and a configurable application support entity and the interactions among these entities as illustrated in Figure 7-2.

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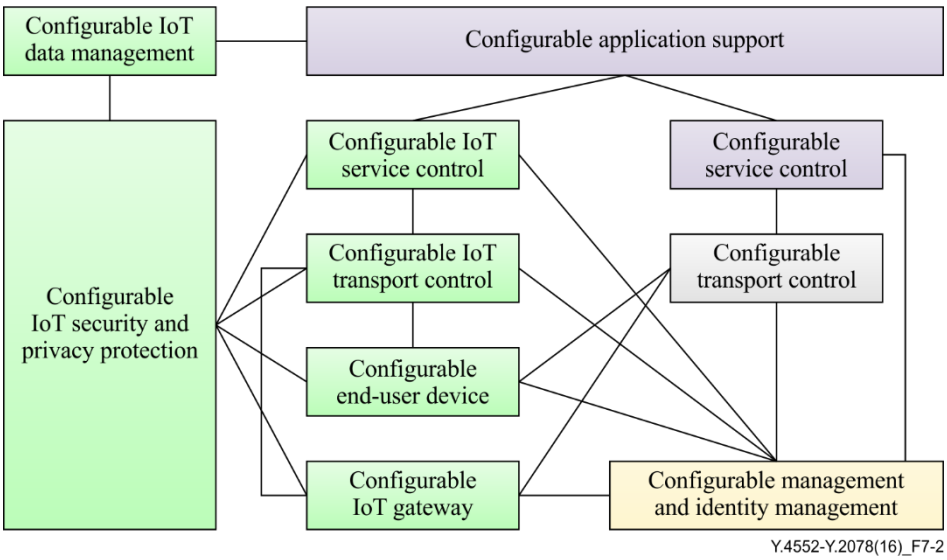

Figure 7-2 – The implementation view of the configurable application support model

The configurable management and identity management entity is related to the configurable IoT gateway entity, the configurable end-user device entity, the configurable transport control entity, the configurable IoT transport control entity, the configurable service control entity and the configurable IoT service control entity, in order to provide the required management capabilities for these functional entities.

The IoT security and privacy protection entity is related to the configurable IoT gateway entity, the configurable end-user device entity, the configurable IoT transport control entity, the configurable IoT service control entity and the configurable IoT data management entity, in order to provide the required IoT related security and privacy protection capabilities for these functional entities.

The configurable transport control entity is related to the configurable IoT gateway entity and the configurable end-user device entity in order to provide configurable transport capabilities for these functional entities. The configurable IoT transport control entity is related to the configurable IoT gateway entity and the configurable end-user device entity in order to provide configurable IoT related transport capabilities for these functional entities.

The configurable service control entity is related to the configurable transport control entity in order to expose the configurable transport control capabilities in the configurable service control entity. The configurable IoT service control entity is related to the configurable IoT transport control entity in order to allow the exposure of the configurable IoT related transport control capabilities in the configurable IoT service control entity.

The configurable application support entity is related to the configurable IoT data management entity, the configurable IoT service control entity and the configurable service control entity, in order to allow the exposure of all configurable capabilities specified in clause 7.2 by the application support entity specified in [ITU-T Y.4401].

7.1.3 The deployment view of the configurable application support model

The deployment view of the configurable application support model consists of the configurable device manager component, the configurable IoT gateway component, the configurable end-user device component, the configurable network manager component, the configurable IoT network controller component, the configurable service manager component, the configurable IoT service controller component, the configurable IoT data server component and the configurable service platform component and the interactions among these components as illustrated in Figure 7-3.

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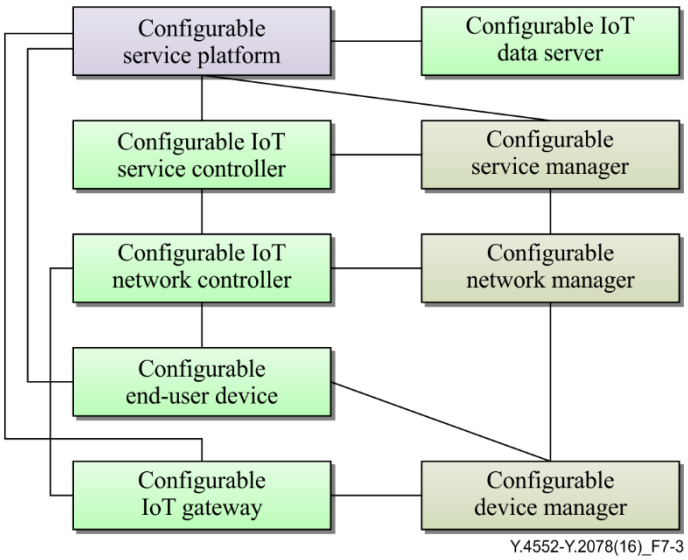

Figure 7-3 – The deployment view of the configurable application support model

The configurable service platform component is related to the configurable IoT data server component to enable the configurable capabilities for support of the IoT applications to be configured with different requirements on data of things. The configurable service platform component interacts with the configurable service manager component and the configurable IoT service controller component to enable the configurable capabilities for support of the IoT applications with different requirements of service provisioning, such as service creation or service customization.

The configurable service platform component is related to the configurable end-user device to enable the configurable capabilities for support of the IoT applications to be configured with different requirements of end-users. The configurable service platform component is related to the configurable IoT gateway component to enable the configurable capabilities for support of the IoT applications to be configured with different requirements of IoT devices, such as different ways of capturing and transferring data of things.

The configurable IoT network controller component is related to the configurable end-user device component and the configurable IoT gateway component to enable the configurable capabilities for support of the IoT applications with different network requirements.

The configurable network manager component is related to the configurable service manager component and the configurable device manager component to enable the configurable capabilities for support of the IoT applications to be configured across all functional layers of IoT, such capturing, buffering, transferring and analysing the data of things.

7.2 The capabilities of the configurable application support model

Based on the categories of the IoT basic capabilities specified in [ITU-T Y.4401] and the description of the configurable application support model specified in clause 7.1, the capabilities of the configurable application support model can be classified into the following groups: the configurable service provision capabilities, the configurable communication capabilities, the configurable data management capabilities, the configurable connectivity capabilities, the configurable management capabilities, the configurable application support capabilities and the configurable security and privacy protection capabilities.

The capabilities of the configurable application support model are specified from the perspective of configurable application support components as described in the deployment view of the

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configurable application support model in clause 7.1.3 because these capabilities are implemented, deployed and used in these configurable application support components.

The following clauses describe, respectively, these capabilities of the configurable application support model. These same capabilities are numbered and summarized in Annex A.

NOTE – In the following clauses, the capability numbers, as shown in Annex A, are put between square brackets "[ ]" and inserted at the end of the description of the corresponding capability.

7.2.1 Configurable service provision capabilities

The configurable service provision capabilities extend the service provision capabilities of the IoT basic capabilities specified in [ITU-T Y.4401], in order to enable IoT applications to configure the IoT service provision capabilities based on their requirements.

The configurable service provision capabilities include the configurable service prioritization capability, the configurable service composition capability and the configurable location based and context-aware service capability.

The configurable service prioritization capability enables the IoT applications to configure services with different priorities, in order to provide differentiated services based on their requirements [A-1-1].

The configurable service composition capability enables the IoT applications to configure service creation or service customization based on their requirements [A-1-2].

The configurable location based and context-aware service capability enables the IoT applications to configure services that are provided both on the location information and related context and on the predefined rules or policies, in order to fulfil their requirements [A-1-3].

7.2.2 Configurable communication capabilities

The configurable communication capabilities extend the communication capabilities of the IoT basic capabilities specified in [ITU-T Y.4401], in order to enable IoT applications to configure the IoT communication capabilities based on their requirements.

The configurable communication capabilities include the configurable event-based communication capability, the configurable periodic communication capability, the configurable communication mode capability, the configurable quality of service (QoS) communication capability, the configurable content-aware communication capability and the configurable location based communication capability.

The configurable event-based communication capability enables the IoT applications to configure different events in order to initiate communication based on the requirements of the IoT applications [A-2-1].

The configurable periodic communication capability enables the IoT applications to configure the rules in order to periodically initiate communication based on the requirements of the IoT applications [A-2-2].

The configurable communication mode capability enables the IoT applications to configure different modes of communications in the transport network in order to transfer data from the source(s) to the destination(s) based on the requirements of the IoT applications [A-2-3].

The configurable quality of service communication capability enables the IoT applications to configure the related mechanisms in order to guarantee the QoS required for the delivery and processing of data (e.g., time-sensible data) based on the requirements of the IoT applications [A-2-4].

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The configurable content-aware communication capability enables the IoT applications to configure the parameters related to the content and selected path for routing or blocking data transfer based on the requirements of the IoT applications [A-2-5].

The configurable location based communication capability enables the IoT applications to configure the parameters related to the locations and predefined rules in order to initiate communication based on the requirements of the IoT applications [A-2-6].

7.2.3 Configurable data management capabilities

The configurable data management capabilities extend configurable capabilities to the data management capabilities of the IoT basic capabilities specified in [ITU-T Y.4401], in order to enable IoT applications to configure the IoT data management capabilities based on their requirements.

The configurable data management capabilities include the configurable data storage capability, the configurable data processing capability, the configurable information exchange capability, the configurable semantic data operation capability and the configurable autonomic data operation capability.

The configurable data storage capability enables the IoT applications to configure the rules or the policies for storing data based on the requirements of the IoT applications [A-3-1].

The configurable data processing capability enables the IoT applications to configure the rules or the policies for processing data based on the requirements of the IoT applications [A-3-2].

The configurable information exchange capability enables the IoT applications to configure the parameters for sending data to or receiving data from external data sources, e.g., data centres and data servers outside the IoT based on the requirements of the IoT applications [A-3-3].

The configurable semantic data operation capability enables the IoT applications to configure the parameters for semantic annotating, semantic discovering, semantic storing and semantic composition of data of things based on the requirements of the IoT applications [A-3-4].

The configurable autonomic data operation capability enables IoT applications to configure the parameters for automatically collecting, aggregating, transferring, storing, analyzing data of things, as well as automatically managing these data operations based on the requirements of the IoT applications [A-3-5].

7.2.4 Configurable connectivity capabilities

The configurable connectivity capabilities extend the connectivity capabilities of the IoT basic capabilities specified in [ITU-T Y.4401], in order to enable IoT applications to configure the IoT communication capabilities based on their requirements.

The configurable connectivity capabilities include the configurable identification based connectivity capability, the configurable things' status notification capability, the configurable device mobility capability and the configurable and adaptable connectivity capability.

The configurable identification based connectivity capability enables the IoT applications to configure the parameters for connectivity establishment based on the identification of things and the requirements of the IoT applications [A-4-1].

The configurable things' status notification capability enables the IoT applications to configure the rules of automatic notification of the status of things and its changes based on the requirements of the IoT applications [A-4-2].

The configurable device mobility capability enables the IoT applications to configure the parameters for maintaining the connectivity with the IoT when end-user devices or IoT gateways are moving, based on the requirements of the IoT applications [A-4-3].

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The configurable and adaptable connectivity capability enables the IoT applications to configure the parameters for extending connectivity configurations in order to connect with different types of devices of the IoT based on the requirements of the IoT applications, in order to be adaptable to different technologies in devices of IoT [A-4-4].

7.2.5 Configurable security and privacy protection capabilities

The configurable security and privacy protection capabilities extend the security and privacy protection capabilities of the IoT basic capabilities specified in [ITU-T Y.4401], in order to enable IoT applications to configure the IoT security and privacy protection capabilities based on their requirements.

The configurable security and privacy protection capabilities include the configurable communication security capability, the configurable data management security capability, the configurable service provision security capability, the configurable security integration capability and the configurable mutual authentication and authorization capability.

The configurable communication security capability enables IoT applications to configure the rules and policies for supporting secure, trusted and privacy protected communication based on the requirements of IoT applications [A-5-1].

The configurable data management security capability enables the IoT applications to configure the rules and policies for providing secure, trusted and privacy protected data management based on the requirements of the IoT applications [A-5-2].

The configurable service provision security capability enables the IoT applications to configure the rules and policies for providing secure, trusted and privacy protected service provision based on the requirements of the IoT applications [A-5-3].

The configurable security integration capability enables the IoT applications to configure the rules and policies for enabling integration of different security policies and techniques related to the IoT functional components based on the requirements of the IoT applications [A-5-4].

The configurable mutual authentication and authorization capability enables the IoT applications to configure the rules and policies for authenticating and authorizing IoT applications and devices before a device accesses IoT based on the requirements of the IoT applications [A-5-5].

7.2.6 Configurable application support capabilities

The configurable application support capabilities extend the application support capabilities of the IoT basic capabilities specified in [ITU-T Y.4401], in order to enable IoT applications to configure the IoT application support capabilities based on their requirements.

The configurable application support capabilities include the configurable group management capability, the configurable time synchronization capability, the configurable orchestration capability and the configurable application support operation acknowledgement capability.

The configurable group management capability enables the IoT applications to configure the parameters for creating, modifying, deleting and querying IoT groups, as well as adding, modifying, deleting and querying IoT group members, based on the requirements of the IoT applications [A-6-1].

The configurable time synchronization capability enables the IoT applications to configure the parameters for synchronizing the time among related functional components with different degrees of reliability, in order to support global or local time stamping for applications based on the different QoS requirements of the IoT applications [A-6-2].

The configurable orchestration capability enables the IoT applications to configure the parameters for automatic coordination of service provisioning or device operations based on the requirements of the IoT applications [A-6-3].

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