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

Future networks

Requirements and capabilities of information-centric networking routing and forwarding based on control and user plane separation in IMT-2020

Recommendation ITU-T Y.3075

International Telecommunication Union

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Recommendation ITU-T Y.3075

Requirements and capabilities of information-centric networking routing and forwarding based on control and user plane separation in IMT-2020

Summary

Recommendation ITU-T Y.3075 specifies service requirements and functional requirements of information-centric networking (ICN) routing and forwarding based on control and user plane separation (CUPS) in IMT-2020. In addition, the capabilities of ICN routing and forwarding in control plane and data plane are described with consideration of various scenarios. Finally, the security consideration is discussed.

History

Edition	Recommendation	Approval	Study Group	Unique ID*
1.0	ITU-T Y.3075	2020-09-29	13	11.1002/1000/14394

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Control and user plane separation, control plane, data plan, ICN routing and forwarding, IMT-2020.

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Recommendation ITU-T Y.3075

Requirements and capabilities of information-centric networking routing and forwarding based on control and user plane separation in IMT-2020

1 Scope

This Recommendation describes the service requirements and functional requirements of information-centric networking (ICN) routing and forwarding based on control and user plane separation (CUPS) in IMT-2020, and also explains the capabilities of ICN routing and forwarding in consideration of various scenarios, including mobility, multi-homing, multicast and caching.

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.3032] Recommendation ITU-T Y.3032 (2014), *Configuration of node identifiers and their mapping with locators in future networks*.

[ITU-T Y.3071] Recommendation ITU-T Y.3071 (2017), *Data aware networking (information centric networking) – Requirements and capabilities*.

[ITU-T Y.3072] Recommendation ITU-T Y.3072 (2019), *Requirements and capabilities of name mapping and resolution for information-centric networking in IMT-2020.*

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 control plane [b-ITU-T Y.2011]: The set of functions that controls the operation of entities in the stratum or layer under consideration, plus the functions required to support this control.

3.1.2 data plane [b-ITU-T Y.2011]: The set of functions used to transfer data in the stratum or layer under consideration.

3.1.3 identifier (ID) [b-ITU-T Y.2091]: A series of digits, characters and symbols or any other form of data used to identify subscriber(s), user(s), network element(s), function(s), network entity(ies) providing services/applications, or other entities.

3.1.4 information-centric networking (ICN) [b-ITU-T Y.Sup.48]: A new approach to networking where named objects (not only devices) are the principal components for the network. Named data objects can be stored in network nodes (with caching capability) distributed throughout the network. Data objects are transmitted by using names to requesting consumers from any network node that can provide requested data. Locations of the nodes that store data objects in their caches are irrelevant to consumers because they send their requests for data objects by using names (not the data object locations).

3.1.5 IMT-2020 [b-ITU-T Y.3100]: Systems, system components, and related technologies that provide far more enhanced capabilities than those described in Recommendation [b-ITU-R M.1645].

NOTE – [b-ITU-R M.1645] defines the framework and overall objectives of the future development of IMT-2000 and systems beyond IMT-2000 for the radio access network.

3.1.6 name [b-ITU-T Y.2091]: The identifier of an entity (e.g., subscriber, network element, physical or logical objects) that may be resolved/translated into an address.

3.1.7 named data object (NDO) [b-ITU-T Y.Sup.35]: A data object that is identifiable by a name.

3.1.8 user plane [b-ITU-T Y.2011]: A synonym for data plane.

3.1.9 name mapping [ITU-T Y.3072]: A service that builds one-to-one or one-to-many relationships between an identifier of an object and addresses of the object, where the addresses can be IP addresses.

3.1.10 name resolution [ITU-T Y.3072]: A service that provides the translation between an identifier and address(es) of the object based on the relationship built by name mapping.

3.2 Terms defined in this Recommendation

This Recommendation defines the following terms:

3.2.1 named object (NO): An object that is identifiable by a name. The object can be a data object, a device, a service, etc.

3.2.2 name-based ICN: A type of information-centric networking (ICN) wherein a named data object (NDO) is routed and forwarded based on its name.

3.2.3 ID/IP integrated ICN: A type of information centric networking (ICN) wherein a named data object (NDO) is routed and forwarded based on joint ID and IP address.

3.2.4 name mapping and resolution system: A system that supports name mapping and resolution services, and in which a registration process is also included. It contains naming, mapping, registering, resolving and managing functionalities.

3.2.5 identifier protocol (IDP): A set of rules and regulations that specifies how the locator(s) of a data packet is/are manipulated based on ID in the network layer under the ID/locator separation of information-centric networking (ICN).

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

AN Access Network

ARP Address Resolution Protocol

CN Core Network

CP Control Plane

CUPS Control and User Plane Separation

DAN Data Aware Networking

DDoS Distributed Denial-of-Service

GNMRS Global Name Mapping and Resolution System

HDD Hard Disk Drive

ICN	Information-Centric Networking
ID	Identifier
IDP	Identifier Protocol
IMT-2020	International Mobile Telecommunications 2020
IP	Internet Protocol
LNMRS	Local Name Mapping and Resolution System
NDO	Named Data Object
NDP	Neighbour Discovery Protocol
NO	Named Object
RF	Radio Frequency
SDN	Software Defined Networking
SSD	Solid State Disk
UE	User Equipment
UP	User Plane
UPF	User Plane Function

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 Recommendation is to be claimed.

The keywords "is prohibited from" 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 "is not recommended" indicate a requirement which is not recommended but which is not specifically prohibited. Thus, conformance with this specification can still be claimed even if this requirement is present.

The keywords "can optionally" indicate an optional requirement which is permissible, without implying any sense of being recommended. This term is 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 this Recommendation.

6 Introduction

Information-centric networking (ICN) has been considered as an emerging technology for the IMT-2020 network to achieve its performance goals. [ITU-T Y.3071] gives a functional view of data aware networking (DAN) which is also called ICN, capabilities with separated control capability and data capability. Control and user plane separation (CUPS) has been set as a key feature of the core network (CN) for the IMT-2020 network, which allows enabling of software defined networking (SDN) to deliver the user plane data more flexibly. As fundamental functions of ICN, the ICN routing and forwarding should follow the same mechanism of CUPS in IMT-2020. In ICN, unique ID is used to label data/devices, and the ID-locator pairs are usually maintained. Currently, the Internet has a locator-based infrastructure, such as IP. When using ICN technology to

build IMT-2020 network, it is required to give consideration on how to inter-operate with the existing locator-based network infrastructure. Under the mechanism of ID/locator separation, using IP as a locator is a reasonable option for ICN in IMT-2020. Considering the IMT-2020 scenarios and the previous studies of DAN in [ITU-T Y.3071], this Recommendation intends to specify the requirements and capabilities for ICN routing and forwarding based on CUPS in IMT-2020.

Capabilities in the control plane and data plane for ICN routing and forwarding based on CUPS in IMT-2020 are separated. The routing controlling and forwarding information maintaining are responsibilities of the control plane. The packet classification, packet reconstruction and name-based/IP-based forwarding are all processed in the data plane, and the locator(s) or address(es) of a data packet can be manipulated based on its ID, which are instructed by the controlling information sent by the control plane. Meanwhile, some actions or process logics are also executed in the node of the data plane, such as local computing and local storage. In addition, both control plane and data plane have the interface to interact with the global name mapping and resolution system (GNMRS), and local name mapping and resolution system (LNMRS) [ITU-T Y.3032], [ITU-T Y.3071], [ITU-T Y.3072], in which the ID-locator mappings are maintained globally and locally separately. GNMRS and LNMRS can help name-based forwarding to retrieve its corresponding IP address based on its ID. Usually, GNMRS maintains global ID-locator pairs, and LNMRS maintains local ID-locator pairs.

NOTE – The terms "data plane" and "user plane" are synonyms in this Recommendation. In the context of routing and forwarding, the data plane is commonly used instead of user plane.

7 Requirements of ICN routing and forwarding

Requirements of ICN routing and forwarding are described in this clause.

7.1 Service requirements

1 It is required to implement the separation of control plane and data plane for ICN routing and forwarding based on CUPS in IMT-2020.

2 It is required to have the capability to interact with the global or local name mapping and resolution system.

- It is required to have the capability for the control plane to interact with the GNMRS or LNMRS.
- It is required to have the capability for the data plane to interact with the GNMRS or LNMRS, and to obtain the ID and IP mapping information. Usually, LNMRS is located near the user, which may bring more efficient or onsite service for users.

3 It is required to have the capability for the data plane to receive the flow table from the control plane, and the data plane creates, forwards, modifies or duplicates packets based on the received flow table.

4 It is required to have the capability to configure or load the routing and forwarding strategies dynamically to meet service requirements elastically. Meanwhile:

- It is required to have the capability to configure the routing and forwarding algorithm manually.
- It is recommended to have the capability to update the routing and forwarding strategies in the run time.

5 It is required to have the capability for the network layer to provide an ID based service interface for the transport layer.

6 It is required to have the capability to support the hybrid networking schema of IP and ICN based on control and user plane separation in IMT-2020.

7.2 Functional requirements

1 It is required that the control plane has the capability to support different kinds of routing.

- It is required to have the capability to get the network topology and status information for routing.
- It is required to have the capability to route based on the joint of ID and IP address.
- It is required to have the capability to route based on name.
- It is required to have the capability to route based on IP address.

2 It is required to have the capability to support the intermediate network node to store or cache data for highly efficient or nearby forwarding in the data plane. Meanwhile, it is required to have the capability to support the intermediate network node to store or cache the forwarded data.

3 It is required to have the capability to maintain more information for elastic caching or storing in the data plane. For example, the information about intermediate network node and its nearby nodes are maintained, including load status, storage status, service status and input/output (IO) status, which can be used for collaborative caching and storing among different nodes.

4 It is required to have the capability to support querying and measuring the network status in the data plane, including:

- It is required to support querying and measuring the network status in real-time, such as the load of ports and available bandwidth.
- It is recommended to support analysing and predicting the network status.

5 It is required that the data plane has the capability to forward, create, modify and duplicate packets, including:

- It is required to have the capability to differentiate and forward different kinds of packets, including IP packets, ID/IP integrated ICN packets and other packets.
- It is required to have the capability for a node in data plane to construct a new packet according to the information from control plane or local function of the node. For example, construct specific packets for the name mapping and resolution purpose.
- It is required to have the capability to elastically select proper address(es) and modify the address field for a packet during the forwarding process. For example, in a multi-homing scenario, a user equipment (UE) may have a candidate address set which may contain more than one address. The proper address(es) should be selected from the candidate address set during the forwarding. The corresponding address field in the packet may be modified (e.g., added, deleted or changed) based on the selected address(es) accordingly.
- It is required to have the capability to change the destination address during the forwarding process. For example, in a mobility scenario, if a UE changes its location and so is its IP address. Therefore, the destination address in the packets which are forwarded to the UE should be modified to the new address during the forwarding process.

6 It is recommended to have the capability of computing in the data plane, which can execute some actions or network protocols, such as network measuring and neighbour discovery protocol (NDP)/address resolution protocol (ARP).

7 It is recommended to have the capability to acquire the network status information from the data plane by the control plane for routing.

8 It is required to have the capability to calculate the forwarding path based on the hybrid routing schema of IP and ICN in the control plane.

8 Capabilities of ICN routing and forwarding

Capabilities of ICN routing and forwarding based on CUPS in IMT-2020, as shown in Figure 8-1, are divided into the capabilities in the control plane and the data plane. Figure 8-1 also illustrates the functionalities that support the capabilities of ICN routing and forwarding. Capabilities in the two planes are depicted in clauses 8.1 and 8.2 respectively.

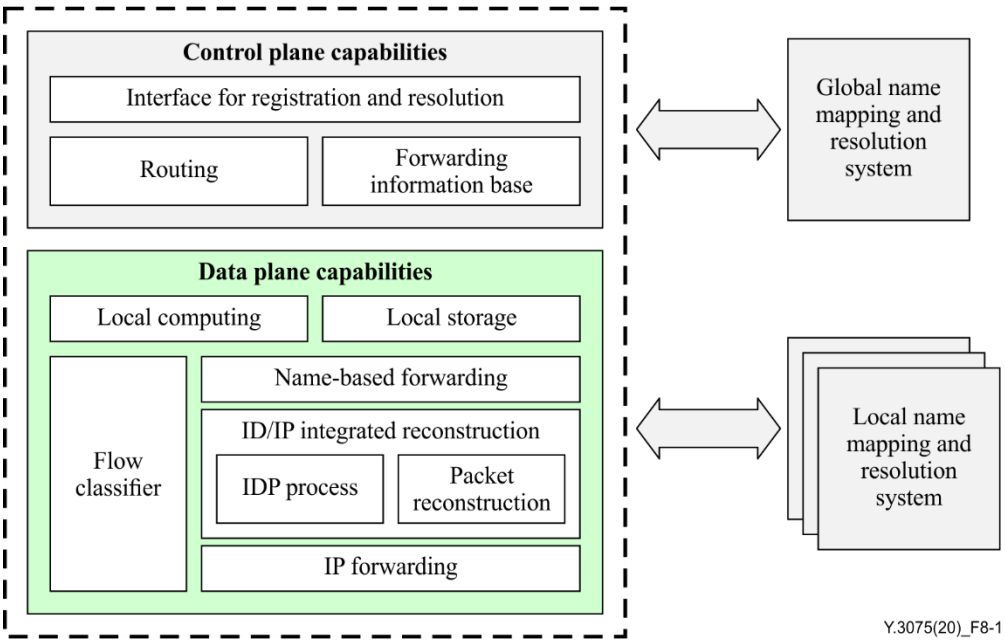

Figure 8-1 Capabilities of ICN routing and forwarding based on CUPS in IMT-2020

8.1 Capabilities in the control plane

Capabilities in the control plane have three major functionalities, including routing, forwarding information base and name mapping and resolution. The functionalities are described as follows:

Routing: Collect and analyse the network topology and status information reported from the data plane; calculate the transmission path based on specific routing algorithms including algorithms for name-based routing, ID/IP integrated routing and IP routing. Routing can support different scenarios such as mobility, multi-homing and multicast.

Interface for name mapping and resolution: Provide the interface to GNMRS and LNMRS. Usually, GNMRS maintains the global information. LNMRS contains the information that is related to the nearby users, and LNMRS is located at the edge of network. In general, it is more efficient for end users to look up in LNMRS than in GNMRS. The control plane and the data plane maintain the entrance of GNMRS or LNMRS, sending the mapping or resolution messages to GNMRS or LNMRS and receiving the address information from them.

Forwarding information base: It is the storage to hold information to determine the direction of a packet to be forwarded to, and **forwarding information base** is to be used by the forwarding function. The forwarding information is derived from the routing function.

8.2 Capabilities in the data plane

Capabilities in the data plane have six major functionalities, which are described as follows:

Flow classifier: Recognizes different kinds of packets including ID/IP integrated ICN packets, IP packets and other specified packets.

IP forwarding: Forward IP packets according to the forwarding information base.

Name-based ICN forwarding: Forwards the ICN packet by name according to the forwarding information base, which is totally different from IP forwarding.

ID/IP integrated ICN reconstruction: Contains the IDP process module and packet reconstruction module. The IDP process module is responsible for asking GNMRS or LNMRS for address(es), maintaining the rules and regulations about how to process the address/es in the packet and modifying the address field in the packet based on the aforementioned rules or regulations, for example, deleting some addresses from the address field, or changing the destination address. In order to get the corresponding address(es) based on a unique ID, the IDP process module uses the interface to query GNMRS or LNMRS. Under the consideration of the elastic and onsite service, LNMRS is normally first queried. The address field of a packet may be modified based on the queried address/es through the IDP process module. After that, a new ID/IP integrated ICN packet will be reconstructed by the packet reconstruction module, which will finally be forwarded by the IP forwarding module.

This process includes the following capabilities, which can correspond to various scenarios.

- In a multicast scenario, a data packet can be duplicated and forwarded to more than one port. The destination IP addresses of the duplicated packets can be modified by the identifier protocol (IDP) process module accordingly.
- In a multi-homing scenario, an ID may correspond to multiple IPs. Selection of the suitable address as the destination address is based on the network status information and the forwarding strategies. The address field in the packet may be modified by the IDP process module during the forwarding process.
- In a mobility scenario, when a UE changes its position, its IP address may also be changed. It implies that the IP address in the packet should be modified by the IDP process module dynamically.
- In a caching scenario, the same content may have multiple replicas cached at different intermediate network nodes. In order to achieve better data service, the address of the proper data replica may be selected as the destination address based on some strategies by the IDP process module.

Local computing: Executes some actions or process logics in a node of the data plane, which may be valuable to provide elastic resources for some services, especially in the resource autonomous network. Some computing functions in the control plane can also be executed by this module, such as measuring network status and maintaining status information. It may improve the processing efficiency of the data plane to satisfy the requirements on high efficiency or onsite process for some time-sensitive services.

Local storage: Provides storage medium in the node of the data plane, such as solid state disk (SSD) or hard disk drive (HDD). It can be used by the local computing function to read/write data.

9 Security consideration

To support the capabilities of radio frequency (RF), different kinds of security threats should be considered.

The availability of RF is dependent on the interaction between RF and GNMRS or LNMRS. In order to avoid the potential risks caused by the interaction with outside systems, some security mechanisms should be considered to ensure the interacting process is safe enough, for example, authentication and authorization to avoid illegal users, and malicious information detection against unexpected messages.

In RF, the data plane has the capability of storage, which implies some intermediate nodes are data providers and become the destination of user packets. Distributed denial-of-service (DDoS) attack caused by node address leakage may be the risk in this stage. To alleviate this risk, address

translation can be executed at the network boundary, and the real addresses of intermediate nodes are shielded for end users. In addition, some approaches for IP network devices defence can also be borrowed, such as a firewall.

For SDN, many mechanisms are applied to secure the network, for example, encryption and authentication for data and users, examining programs thoroughly before their installation to networks, verifying the communication channel between the controller and network resources, and shaping secure data traffic, which can guarantee the security of RF with the aforementioned approaches simultaneously.

Bibliography

[b-ITU-T Y.2011] Recommendation ITU-T Y.2011 (2004), *General principles and general reference model for Next Generation Networks*.

[b-ITU-T Y.2091] Recommendation ITU-T Y.2091 (2011), *Terms and definitions for next generation networks*.

[b-ITU-T Y.3100] Recommendation ITU-T Y.3100 (2017), *Terms and definitions for IMT-2020 network*.

[b-ITU-T Y.3033] Recommendation ITU-T Y.3033 (2014), *Framework of data aware networking for future networks*.

[b-ITU-T Y.Sup.35] ITU-T Y-series Recommendations – Supplement 35 (2016), *Data aware networking – Scenarios and use cases*.

[b-ITU-T Y.Sup.48] ITU-T Y-series Recommendations – Supplement 48 (2018), *Proof-of-concept for data service using information centric networking in IMT-2020*.

[b-ITU-R M.1645] Recommendation ITU-R M.1645 (2003), *Framework and overall objectives of the future development of IMT-2000 and systems beyond IMT-2000*.

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