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

Future networks

Architecture of ICN-enabled edge network in IMT-2020

Recommendation ITU-T Y.3076

International Telecommunication Union

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Recommendation ITU-T Y.3076

Architecture of ICN-enabled edge network in IMT-2020

Summary

Recommendation ITU-T Y.3076 specifies the requirements and architecture for ICN-enabled edge network in IMT-2020. From the service and network operation point of view, it discusses detailed requirements of ICN-enabled edge network in IMT-2020. It provides architecture of ICN-enabled edge network and it describes the key functions and interfaces to satisfy the requirements of ICN-enabled edge network.

History

Edition	Recommendation	Approval	Study Group	Unique ID*
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Edge data network, ICN, ICN-enabled edge network, IMT-2020, information-centric networking, MEC, mobile/multi-access edge computing.

* To access the Recommendation, type the URL http://handle.itu.int/ in the address field of your web browser, followed by the Recommendation's unique ID. For example, http://handle.itu.int/11.1002/1000/11830-en.

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Architecture of ICN-enabled edge network in IMT-2020

1 Scope

This Recommendation describes requirements, architecture, and key functions of ICN-enabled edge network in IMT-2020, to meet the high and ultra-performances of enhanced mobile broadband (eMBB) based services, massive machine type communications (mMTC) based services and ultra-reliable low latency communications (uRLLC) based services in IMT-2020.

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; all 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.3101] Recommendation ITU-T Y.3101 (2018), *Requirements of IMT-2020 network.*

[ITU-T Y.3102] Recommendation ITU-T Y.3102 (2018), *Framework of the IMT-2020 network.*

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 address [b-ITU-T Y.2091]: An address is the identifier for a specific termination point and is used for routing to this termination point.

3.1.2 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.

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

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

3.1.5 mobility [b-ITU-R M.2083]: Mobility is the maximum speed (e.g., in km/h) as a performance target at which a defined quality of service (QoS) and seamless transfer can be achieved between radio nodes, which may belong to different layers and/or radio access technologies (RAT).

3.1.6 network function [b-ITU-T Y.3100]: In the context of IMT-2020, a processing function in a network.

3.2 Terms defined in this Recommendation

This Recommendation defines the following terms:

3.2.1 edge data network: A data network that is accessible by the user equipment (UE) and access network (AN) only in specific network edge locations.

3.2.2 identifier: An identifier is 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.

NOTE – Definition adapted from [b-ITU-T Y.2091].

3.2.3 identifier/locator separation: Identifier/locator separation is decoupling the semantic of IP address into the semantics of node identifiers and locators. Distinct namespaces are used for node identifiers and locators so that they can evolve independently. Locators are associated with the IP layer whereas node identifiers are associated with upper layers in such a way that ongoing communication sessions or services shall not be broken by changing locators due to mobility and multi-homing.

NOTE – Definition adapted from [b-ITU-T Y.2015].

3.2.4 name: A name is the identifier of an entity (e.g., subscriber, network element, physical or logical objects) that may be resolved/translated into address.

NOTE – Definition adapted from [b-ITU-T Y.2091].

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

AF	Application Function
AN	Access Network
ASF	Authentication Server Function
CEF	Capability Exposure Function
CMF	Cache Management Function
CN	Core Network
CP	Control Plane
CSF	Computing Services Function
DN	Data Network
E2E	End-to-End
eMBB	Enhanced Mobile Broadband
FIB	Forwarding Information Base
ICN	Information-Centric Networking
ICN-edge	ICN-enabled Edge Network
ID	Identifier
IMT-2020	International Mobile Telecommunication 2020
IoT	Internet of Things
IP	Internet Protocol
MEC	Mobile/Multi-Access Edge Computing
mMTC	massive Machine Type Communications
NACF	Network Access Control Function
NF	Network Function

NFR Network Function Repository

NFV Network Functions Virtualization

NSMF Name Services Management Function

NSSF Network Slice Selection Function

PCF Policy Control Function

PDU Protocol Data Unit

RAN Radio Access Network

RMF Routing Management Function

SDN Software-Defined Networking

SMF Session Management Function

UE User Equipment

UP User Plane

UPF User Plane Function

USM Unified Subscription Management

uRLLC Ultra Reliable Low Latency Communications

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

Edge computing enables operators and third-party services to be hosted close to a user equipment's (UE) access point of attachment, so as to achieve an efficient service delivery through the reduced end-to-end (E2E) latency and load on the transport network.

In line with the key features and the requirements identified in [ITU-T Y.3101], the distributed network architecture of IMT-2020 is expected to bring a significant reduction of backhaul and core network traffic by enabling the placement of content servers closer to the end user devices and also to be beneficial in terms of service latency.

The IMT-2020 network support concurrent access to edge and centralized services. To support low latency services and access to edge data networks, user plane function (UPF) can be deployed close to the access network (AN) and UE. In [ITU-T Y.3102], an UE may establish multiple protocol data unit (PDU) sessions to the different data networks (DN) and served by different UPF terminating RP-ud. Therefore, the IMT-2020 core network can select a UPF close to the AN and execute the traffic steering from the UPF to the edge data network via a RP-ud interface, as shown in Figure 6-1.

However, the existing IP-based architecture infrastructure, in which IP addresses are used as both identifiers (IDs) and locators, would not be capable to meet the above IMT-2020 requirements, since the location-dependent model has its inherent limitations in supporting mobility, scalability, etc. Research has shown that information-centric networking (ICN) has been identified as one of the most effective ways to overcome the above limitations.

The IMT-2020 core network will take advantage of the network slicing function to instantiate heterogeneous slices, and the same framework can be extended to create ICN slices as well. This concept offers a wide range of architectural discussions and proposals on enabling slices and managing multiple PDU sessions with edge data networks having mobile/multi-access edge computing (MEC) and its associated architectural support (in the service, control and data planes) and procedures within the context of a core network.

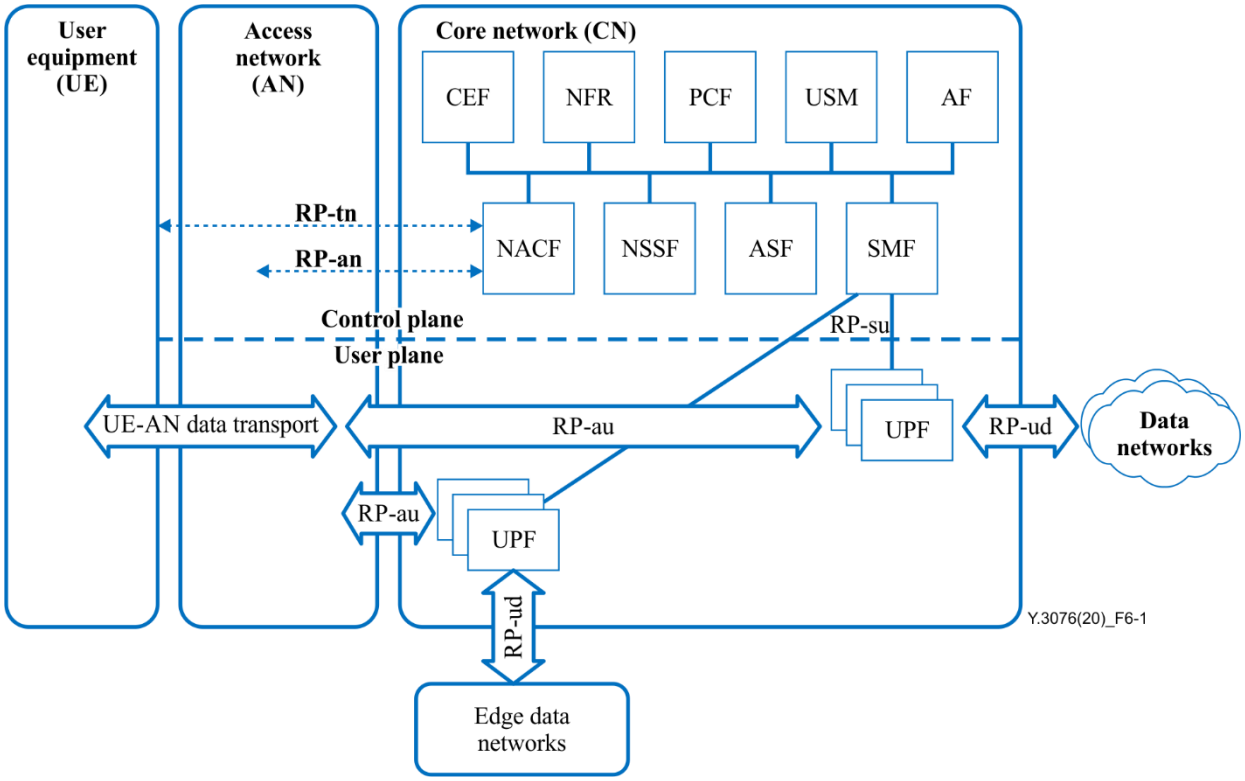

Figure 6-1 – Position of edge data networks in the IMT-2020 network architecture

Based on the existing architecture of IMT-2020, it supports two programming methods for ICN.

1) The ICN architecture is expected to be deployed in the edge data networks. As shown in Figure 6-2, business applications have already been deployed in this way on the ICN-edge node. By cooperating with an IP-enabled core network, the high and ultra-performances of IMT-2020 can be achieved. In addition it can bring a significant reduction in backhaul and core network control costs and traffic.

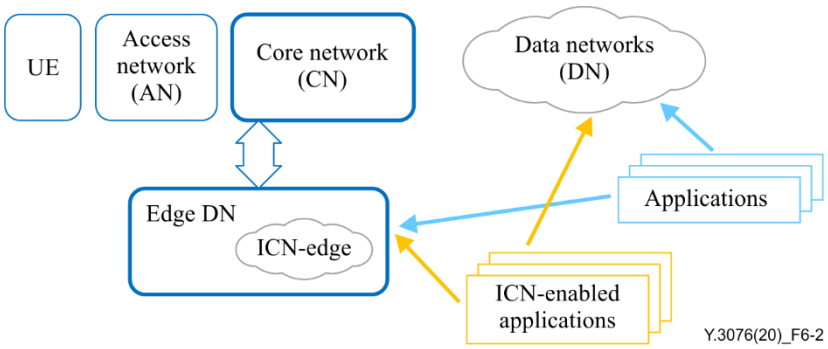

Figure 6-2 – ICN-enabled edge network in the IMT-2020 network architecture

2) The ICN architecture is expected to be deployed in both the edge network and core network. As shown in Figure 6-3, in this way the ICN-enabled core network cannot deploy business applications. Business applications are still deployed on the edge DN and DN.

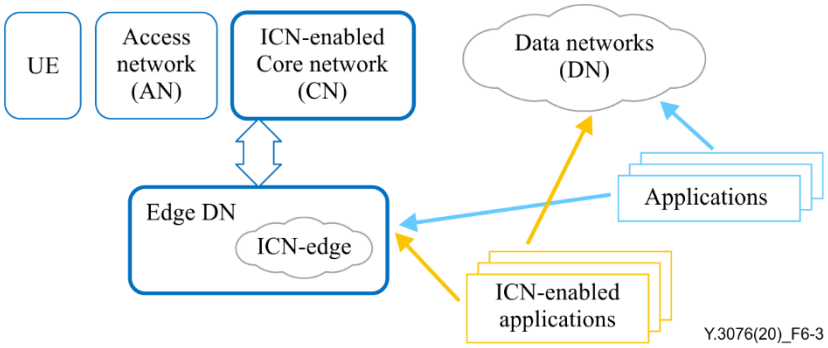

Figure 6-3 – ICN-enabled edge network and core network in the IMT-2020 network architecture

This Recommendation describes requirements, architecture and functionalities of ICN-enabled edge network in IMT-2020 and also describes the interfaces between ICN-enabled edge network and core network. The architecture of ICN-enabled core network is beyond the scope of this Recommendation.

7 Requirements of ICN-enabled edge network in IMT-2020

7.1 Principle requirements

The IMT-2020 network will enable a variety of services, including enhanced mobile broadband (eMBB) based services, massive machine type communications (mMTC) based services and ultra-reliable low latency communications (uRLLC) based services [ITU-T Y.3101], on an infrastructure of network and computing resources.

In line with the key features and the requirements identified in [ITU-T Y.3101], ICN-edge in IMT-2020 network is required to be a more efficient, personalized, intelligent, reliable and flexible network.

– From the service point of view, ICN-edge is required to support capabilities to cope with the explosion in mobile data traffic, and provide mechanisms to support consistent E2E QoS and minimize traffic congestion situations for a massive number of MTC devices, and support ultra-low latency communications-based services with high-reliability and real-time constraints.

– From the network operation point of view, ICN-edge is required to be scalable and distributed, with network functions in the user plane (UP) and control plane (CP) which can be flexibly deployed as required and enhanced programmability and scalability.

In order to satisfy the future requirements from the services and network operation, ICN-edge is requested to have both the CP and UP capability to provide services that meet the high and ultra-performances of IMT-2020.

7.2 Requirements of ICN-edge in eMBB

ICN-edge in the IMT-2020 network is required to support capabilities to cope with the explosion in mobile data traffic, and ultra-high bandwidth services.

– It is recommended to support local offloading in an efficient manner.

NOTE 1 – The ICN-edge application function (AF) describes the in-network content publishing and subscribing and in-network caching/storage strategy, which is designed for any specific services and applications. The data plane is also requested to have the capability to provide cache.

– It is required to have ability to support the ultra-high bandwidth transmission.

NOTE 2 – The ICN-edge AF describes the new ICN-edge routing strategy. The ability of the high efficient packet processing and transferring in data plane is also required.

7.3 Requirements of ICN-edge in mMTC

ICN-edge in the IMT-2020 network needs to provide mechanisms to support consistent E2E QoS and minimize traffic congestion situations for a massive number of MTC devices.

– It is required to support a massive number of MTC devices in an efficient way.

NOTE 1 – The ICN-edge AF describes the traffic patterns including short and massive burst traffic, delay sensitive and non-sensitive traffic, and communication types including unicast, multicast and broadcast communications, which are designed for any specific services and applications.

– It is required to minimize traffic congestion that can be caused by a massive number of MTC devices.

NOTE 2 – Enhanced capabilities for consideration include simplified session or bearer management mechanisms, data processing using in-network computing, infrequent and frequent small data delivery using control signalling channel and efficient multicast methods.

– It is required to support consistent E2E QoS even in the presence of a large number of concurrent connections.

7.4 Requirements of ICN-edge in uRLLC

ICN-edge in the IMT-2020 network needs to provide mechanisms to support services with high-reliability and real-time constraints.

– It is required to provide enhanced service performance by reducing E2E latency according to service requirements.

NOTE 1 – ICN is a natural platform to deliver mobility services by separating the names and location components. ICN-edge is required to provide efficient name management, high-speed name resolution and resolution-based routing which can be used to lower E2E latency.

– It is required to support increased service reliability according to service requirements.

NOTE 2 – Considerations for increased service reliability include the ability to replicate and cache contents in ICN-edge nodes, and provide redundant ICN routing.

8 Architecture of ICN-enabled edge network in IMT-2020

8.1 Overview

As shown in Figure 8-1, [ITU-T Y.3102] specifies the IMT-2020 network framework, including the high-level description of network functions and basic network services.

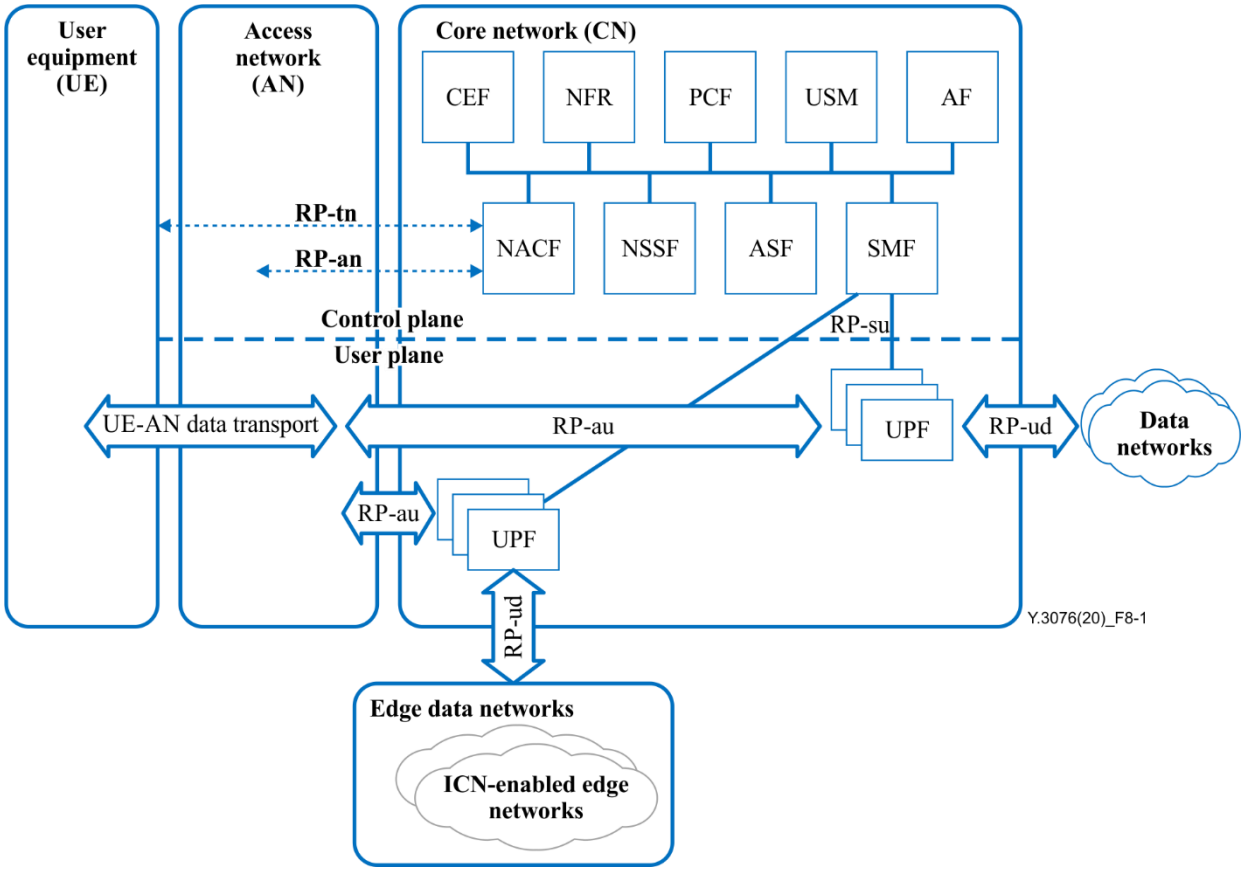

Figure 8-1 – Position of ICN-edge in the IMT-2020 network architecture

Based on the existing architecture of IMT-2020, the high-level architecture of ICN-based edge network will be introduced in IMT-2020. These edge-service realizations can be located in the edge data networks enabling edge instantiation of ICN services to consumers.

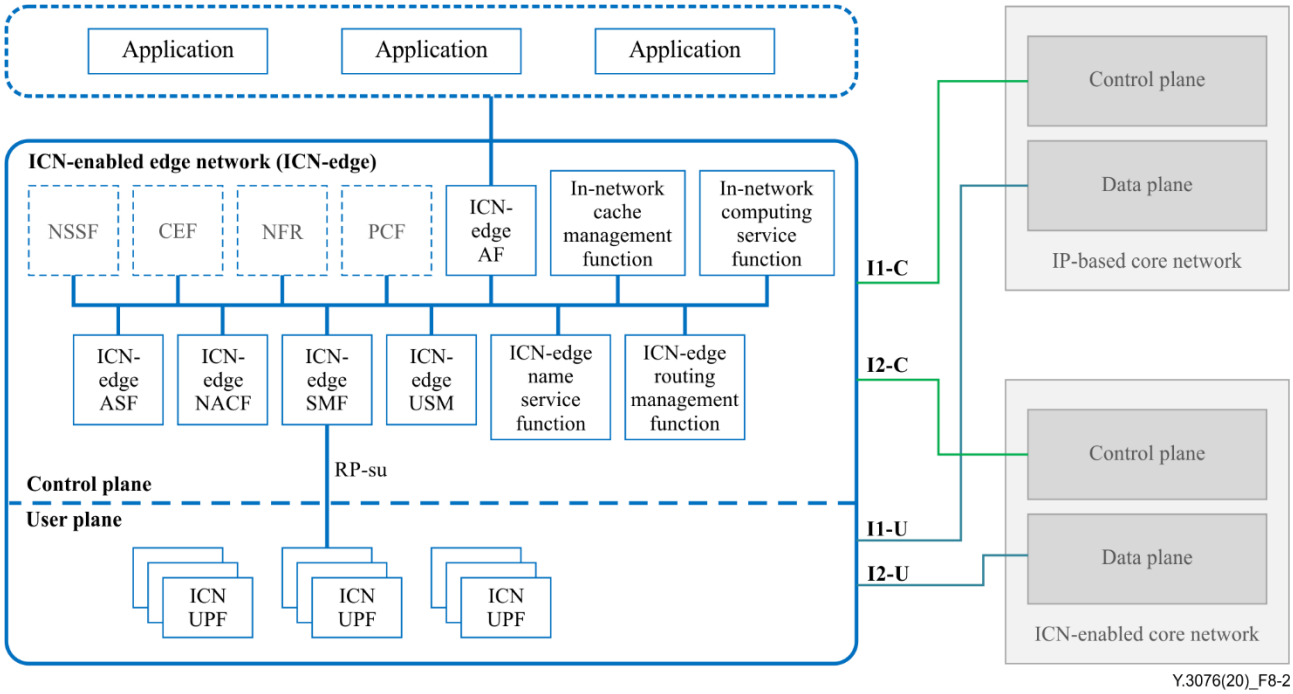

Figure 8-2 – High-level architecture of ICN-enabled edge network

The architecture and interface of ICN-enabled networks are as shown in Figure 8-2.

For IMT-2020, the ICN architecture is expected to be based on distributed network functions in the user plane (UP) and control plane (CP). We focus on control and user plane enhancements required to enable ICN within edge network of IMT-2020. The functional components and interfaces that require extensions to enable ICN-edge as a service in IMT-2020 can be identified in the figure with an 'ICN-edge' symbol. We next summarize the control, user plane and normative interface extensions that help with the formal ICN-edge support.

In the user plane, the ICN-enabled edge network should be support to the user plane function (UPF) of IMT-2020, flow classifier, ICN-gateway, ICN-forwarding, and cache which is a key function to supporting data services.

In the control plane, the ICN-enabled edge network should provide the new functionalities including ICN-edge name services management function (NSMF), in-network cache management function (CMF), in-network computing services function (CSF), ICN-edge routing management function (RMF), and the enhancements functionalities including ICN-edge AF, ICN-edge network access control function (NACF), ICN-edge authentication server function (ASF), ICN-edge session management function (SMF), ICN-edge unified subscription management (USM).

For the diversified requirements of eMBB, mMTC and uRLLC in IMT-2020 network, ICN-enabled edge networks and core network need to cooperate to provide services. The communication between the ICN-enabled edge network and the core network is critical.

8.2 Key functions in control plane

The enhanced control functions are designed as the control plane extensions to orchestrate ICN-edge services in coordination with the core network's control components. In addition the new ICN-edge control functions are designed as the key part that help with the formal ICN-edge support.

8.2.1 The enhanced control functions

The enhanced control functions consist of ICN-edge AF, ICN-edge NACF, ICN-edge ASF, ICN-edge SMF, and ICN-edge USM. AF, NACF, ASF, SMF, and USM had been defined in IMT-2020

network framework [ITU-T Y.3102]. The functions defined in this part are also to enhance these existing functions based on ICN-edge.

- **ICN-edge NACF (Network access control function)**

ICN applications in the UEs have to be authorized to access ICN-DN. For this purpose, as a network service, ICN-UE should also be subscribed to it and this is imposed using the ICN-edge policy control function (ICN-edge PCF) and ICN-edge unified subscription management function (ICN-edge USM), which may interface with the ICN-edge application function (ICN-edge AF) for subscription and session policy management of ICN sessions.

Therefore, NACF should have the following enhanced capabilities for ICN-edge:

- The UE communicates with ICN-edge NSMF through NACF for the registration, location update, etc.,
- authenticating UE's attach request for ICN resources in ICN-enabled edge network,
- supporting ICN specific bootstrapping (such as naming and security) and forwarding functions to configure the UE's ICN layer,
- allowing an UE to request authentication to ICN-enabled edge network either in ICN, IP or dual-stack (IP and ICN) modes,
- optimizing attach procedures so that an ICN capable UE can be bootstrapped by minimizing the number of control plane messages,
- offering name-based control plane messaging and security which one can leverage during the UE attach procedures.

- **ICN-edge SMF (Session management function)**

Once an UE is authenticated to access an ICN service in an ICN-enabled edge network, the SMF manages to connect the UE's ICN sessions to the ICN-DN.

This extension supports control functions such as naming, addressing, mobility, and tunnel management for ICN sessions to interact with ICN-edge SMF and ICN-edge NACF. ICN-edge SMF interfaces with ICN-edge NACF to enable ICN specific user plane functions, which include tunnel configuration and traffic filter policy to inter-connect the UE with the appropriate radio and the edge network slice. Furthermore, ICN-edge NACF sets the appropriate state in the RAN and the UE that directs ICN flows to the chosen ICN-edge uplink classifier, and towards the right UE in the downlink.

SMF should have the following enhanced capabilities for ICN-edge:

- managing both IP, ICN or dual stack UE with IP or ICN capabilities,
- creating appropriate session policies in the UPF to support ICN sessions,
- providing ICN session management information for the creation, modification and deletion,
- interacting with ICN-edge RMF to create the appropriate forwarding state in ICN UPF using the forwarding information base (FIB) to enable ICN flows over appropriate tunnel interfaces,
- signalling resource management rules to share compute, bandwidth, storage/cache resources among multiple slice instances co-located in the ICN UPF,
- simplified session or bearer management mechanisms for infrequent and frequent small data delivery,

- **ICN-edge AF (Application function)**

Based on ICN service requirements, ICN-edge AF represents the application controller function that interfaces with ICN-edge SMF, ICN-edge PCF/USM, ICN-edge CMF/CSF/RMF functions. It should have the following enhanced capabilities for ICN-edge:

- transferring ICN forwarding rules to ICN-edge SMF,
- interfacing with ICN-edge PCF/USM/CMF/CSF to transfer user profile and subscription policies along with session management requirement to UE's ICN session in the ICN-enabled edge network,
- influencing ICN-edge SMF to steer traffic based on ICN service requirements,
- interacting with the IMT-2020 operator's service functions, such as capability exposure function (CEF) that exposes network capabilities, for e.g., edge based services, that can be used by ICN-edge AF for proactive ICN session and slice management and offers additional capabilities to the ICN-enabled edge network.

- **ICN-edge ASF (Authentication server function)**

Since identity is used to authenticate an entity (e.g., device, user, service, etc.), ICN-edge ASF interacts with ICN-edge NACF to provide the identifiers-based access authentication function.

- The identifiers based on the proposed naming can be optionally self-certifying, and provide data traceability and integrity verification,
- The identifiers mapping is recommended to be accompanied by security functions for ensuring reliability in network operations and communication services.

- **ICN-edge USM (Unified subscription management function)**

Unlike IP addresses, ICN-edge USM should support obtaining meta-data of an entity using an entity's identifier.

8.2.2 The new ICN-edge control functions

The new ICN-edge control functions consist of ICN-edge NSMF, in-network CMF, in-network CSF, and ICN-edge RMF, which defined in the Recommendation to specially support ICN-edge.

- **ICN-edge NSMF (Name services management function)**

The main functionalities provided by ICN-edge NSMF are efficient name management and resolution for ICN-enabled edge network.

- managing the information of all named entities in an ICN-enabled edge network,
- providing efficient, real-time name resolution service to support mobility and scalable routing in ICN-enabled edge network,
- high-speed name resolution. For instance, a locally enhanced function of name mapping and resolution to achieve high performance of deterministic latency and scalability for a massive number of named objects for information-centric networking.

- **In-network CMF (Cache management function)**

In-network caching is the inherent capability of ICN, which allows intermediate network nodes, such as switches and routers with storage resources, to store data for a period so that the data can be efficiently delivered to users in a distributed manner.

In-network CMF should generate the in-network caching/storage strategy, which is designed for any specific services and applications.

- **In-network CSF (Computing services function)**

In-network CSF should provide the computing ability for network transmission. Therefore, the capabilities of in-network CSF for consideration include cache scheduling, transcoding, data fusion and so on.

- **ICN-edge RMF (Routing management function)**

ICN-edge RMF generates the ICN-edge routing strategy, which is designed for any specific services and applications.

- supporting the ultra-high bandwidth transmission,
- providing redundant ICN routing for increased service reliability,
- providing resolution-based routing for lower E2E latency,
- efficient unicast, multicast and broadcast methods.

8.3 Key functions in data plane

In the data plane, an ICN-enabled edge network should support UPF of IMT-2020, and enhanced UPF functions which include four sub-functions, flow classifier, ICN-gateway, ICN-forwarding and ICN-caching.

The interconnection of a UE to an ICN-DN comprises of two segments, one from the radio access network (RAN) to the flow classifier and the other from the flow classifier to the ICN-gateway.

Therefore, ICN-edge UPF should have the following enhanced capabilities for an ICN-enabled edge network:

- providing an uplink flow classifier function which re-routes the flow to an edge data network and checks the source or destination address to direct traffic to an appropriate ICN-gateway,
- providing an ICN-gateway function which can host services or cache content enabled through the ICN architecture and manage multiple tunnel interfaces enabling the relay of ICN flows to appropriate flow classifier instances in the downlink,
- providing a set of ICN nodes used for ICN networking and with heterogeneous service resources such as storage and computing points,
- providing cache which is a key function to supporting data services,
- providing software-defined network (SDN) forwarding nodes function and a logically centralized path computation entity, where the path computation entity is used to determine suitable forwarding identifiers being used for the path-based forwarding in the SDN-based transport network,
- re-using/extending the existing ones to manage the new user plane realizations, for instance, using advanced data plane programmability or enhanced SDN data plane for IMT-2020.

9 Reference points for ICN-enabled edge network in IMT-2020

As shown in Figure 8-2, the interfaces between ICN-enabled edge network and core network include:

I1-C: the control plane interfaces between ICN-enabled edge network and IP-enabled core network.

I2-C: the control plane interfaces between ICN-enabled edge network and ICN-enabled core network.

I1-U: the user plane interfaces between ICN-enabled edge network and IP-enabled core network.

I2-U: the user plane interfaces between ICN-enabled edge network and ICN-enabled core network.

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