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Information-centric networking – Overview, standardization gaps and proof-of-concept

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Supplement 47 to ITU-T Y-series Recommendations

Information-centric networking – Overview, standardization gaps and proof-of-concept

Summary

Supplement 47 to ITU-T Y-series Recommendations provides the overview of information-centric networking (ICN) and describes the fifteen standardization gaps and five proof-of-concept technologies investigated by the ITU-T Focus Group on IMT-2020 (FG IMT-2020) during 2015-2016. It is based on the ICN related contents of the two final output documents of FG IMT-2020 [b-FG IMT-2020 Gaps] and [b-FG IMT-2020 ICN PoC].

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Supplement 47 to ITU-T Y-series Recommendations

Information-centric networking – Overview, standardization gaps and proof-of-concept

1 Scope

This Supplement describes fifteen standardization gaps and five proof-of-concept technologies investigated by the ITU-T Focus Group on IMT-2020 during 2015-2016.

2 References

None.

3 Definitions

3.1 Terms defined elsewhere

This Supplement uses the following terms defined elsewhere:

3.1.1 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].

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.

3.1.2 latency [b-ITU-R M.2083-0]: the contribution by the network to the difference in time (in ms) between when the source sends a packet and when the destination receives it.

3.1.3 mobility [b-ITU-R M.2083-0]: from a performance target point of view, mobility is the maximum speed (in km/h) at which a defined QoS and seamless transfer can be achieved between radio nodes, which may belong to different layers and/or radio access technologies (multi-layer/-RAT).

3.1.4 future network (FN) [b-ITU-T Y.3001]: A network able to provide services, capabilities, and facilities difficult to provide using existing network technologies. A future network is either:

- a) A new component network or an enhanced version of an existing one, or,
- b) A heterogeneous collection of new component networks or of new and existing component networks that is operated as a single network.

NOTE – The plural form "Future Networks" (FNs) is used to show that there may be more than one network that fits the definition of a future network.

3.1.5 network virtualization [b-ITU-T Y.3011]: A technology that enables the creation of logically isolated network partitions over shared physical networks so that heterogeneous collection of multiple virtual networks can simultaneously coexist over the shared networks. This includes the aggregation of multiple resources in a provider and appearing as a single resource.

3.1.6 software-defined networking [b-ITU-T Y.3300]: A set of techniques that enables to directly program, orchestrate, control and manage network resources, which facilitates the design, delivery and operation of network services in a dynamic and scalable manner.

3.1.7 identifier [b-ITU-T Y.2091]: 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 (e.g., physical or logical objects). Identifiers can be used for registration or authorization. They can be either public to all networks, shared between a limited number of networks or private to a specific network (private IDs are normally not disclosed to third parties).

3.1.8 locator (LOC) [b-ITU-T Y.2015]: A locator is the network layer topological name for an interface or a set of interfaces. LOCs are carried in the IP address fields as packets that traverse the network.

NOTE – In [b-ITU-T Y.2015], locators are also referred to as location IDs.

3.1.9 node ID [b-ITU-T Y.2015]: A node ID is an identifier used at the transport and higher layers to identify the node as well as the endpoint of a communication session. A node ID is independent of the node location as well as the network to which the node is attached so that the node ID is not required to change even when the node changes its network connectivity by physically moving or simply activating another interface. The node IDs should be used at the transport and higher layers for replacing the conventional use of IP addresses at these layers. A node may have more than one node ID in use.

NOTE – [b-ITU-T Y.2015] specifies a node ID structure.

3.1.10 name [b-ITU-T Y.2091]: A name is the identifier of an entity (e.g., subscriber, network element) that may be resolved/translated into address.

3.2 Terms defined in this Supplement

None.

4 Abbreviations and acronyms

This Supplement uses the following abbreviations and acronyms:

5G	Fifth generation mobile network
AAA	Authentication, Authorization, Accounting
APN	Access Point Name
BGP	Border Gateway Protocol
BH	Backhaul
BRAS	Broadband Remote Access Server
CCN	Content-Centric Networking
CDN	Content Delivery Network
CN	Core Network
COTS	Commercial Off-The-Shelf
C-RAN	Cloud Radio Access Network
CS	Content Store
D2D	Device-to-Device
D2N	Device-to-Network
DASH	Dynamic Adaptive Stream over HTTP
DDD	Directional Division Duplex
DNS	Domain Name System
DRM	Digital Rights Management
E2E	End-to-End
EMS	Element Management System
eNodeB	Evolved Node B

EPC	Evolved Packet Core
FDD	Frequency Division Duplex
FIB	Forwarding Information Base
FID	Forwarding Identifier
FQDN	Fully Qualified Domain Name
GTP	Generic Tunnelling Protocol
GTP-C	GTP Control
GW	Gateway
HTTP	Hyper Text Transfer Protocol
ICN	Information Centric Networking
ICNRG	Information Centric Networking Research Group
IDC	Internet Data Centre
IMEI	International Mobile Equipment Identity
IMT	International Mobile Telecommunications
IoT	Internet of Things
IP	Internet Protocol
KPI	Key Performance Index
LAN	Local Area Network
LINP	Logically Isolated Network Partitions
LISP	Location/Identity Separation Protocol
LTE	Long Term Evolution
M2M	Machine to Machine
MAC	Medium Access Control
MEC	Mobile Edge Computing
MIMO	Multiple-Input and Multiple-Output
MLDR	Mobility Loss Detection and Recovery
MME	Mobility Management Entity
mmWave	Millimetre Wave
MNO	Mobile Network Operator
MTC	Machine Type Communication
NAP	Network Access Point
NDN	Named Data Networking
NFV	Network Function Virtualization
NP	Network Performance
OAM	Operation, Administration and Management
ONOS	Open Network Operating System
PCE	Path Computation Element



PDCP	Packet Data Convergence Protocol
PDN	Packet Data Network
PDU	Protocol Data Unit
P-GW	Packet data network Gateway
PIF	Protocol Independent Forwarding
PIT	Pending Interest Table
PoC	Proof of Concept
POF	Protocol Oblivious Forwarding
PTN	Packet Transport Network
QCI	QoS Class Identifier
QoE	Quality of Experience
QoS	Quality of Service
RAN	Radio Access Network
RAT	Radio Access Technologies
RoF	Radio over Fibre
ROHC	Robust Header Compression
RTP	Real-time Transport Protocol
SAE-GW	System Architecture Evolution - Gateway
SAP	Service Access Point
SDN	Software Defined Networking
SDO	Standard Development Organization
S-GW	Serving Gateway
SIP	Session Initiation Protocol
sNAP	Source Network Attachment Point
SON	Self Organizing Network
SR	Segment Routing
TCP	Transmission Control Protocol
TDD	Time Division Duplex
TMN	Technology Management Network
UDP	User Datagram Protocol
UE	User Equipment
UHD	Ultra-High Definition
UMTS	Universal Mobile Telecommunication System
UNI	User Network Interface
URI	Uniform Resource Identifier
VLAN	Virtual LAN
VM	Virtual Machine

VNF	Virtual Network Function
VoLTE	Voice over LTE
VPN	Virtual Private Network
VSER	Virtual Service Edge Router
WLDR	Wireless Loss Detection and Recovery

5 Conventions

None.

6 ICN overview

6.1 Background

Information centric networking (ICN) was studied in FG IMT-2020 as an example of emerging network technologies. FG IMT-2020 produced two output documents on the description of ICN related standardization gaps and proof-of-concept technologies [b-FG IMT-2020 Gaps] [b-FG IMT-2020 ICN PoC].

ICN has been considered useful to satisfy the network requirements of IMT-2020 to support enhanced mobile broadband, massive machine-type communications and ultra-reliable low-latency communications. Research shows that ICN is a promising technology that can provide benefits for IMT-2020 networks supporting very large-scale heterogeneous devices, Internet of things (IoT) applications, new mobility models, edge computing and end device self-configuration.

ICN offers a different approach to addressing and framing data to today's Internet Protocol (IP) semantics. In IP, a source and destination addresses are used to identify the two endpoints of packet communication. The destination is almost always a unicast address and in a small number of cases an anycast address; the use of IP multicast is very limited. Inside the network, the payload of an IP packet is usually an arbitrarily framed byte stream such as transmission control protocol (TCP) or datagrams (UDP). TCP/IP assigns an ephemeral name to each packet: source IP, source port, destination IP, destination port, byte offset, byte length. These names are not reusable, nor cacheable beyond use for retransmission of lost packets. ICN's approach is to assign a re-usable name to each packet or small group of packets. This allows object re-use and peer-to-peer messaging via name without needing to resolve endpoint identifiers beforehand. ICN also bundles object authenticity with the network packets.

There are several ICN architectures being proposed to use today. The most widely known is content-centric networking (CCN) and its offshoot named data networking (NDN). NDN forked from CCN around 2012. While there are several important protocol differences between NDN and CCN, they are close enough in function so that only CCN will be described here.

Because ICN does not require resolving endpoint identifiers into locators before using a name, it opens new possibilities in machine-to-machine and IoT applications. Today, IP-based applications must use specialized rendezvous mechanisms, such as link broadcast, multicast, dynamic domain name system (DNS), multicast DNS, or session initiation protocol (SIP). This is because they must resolve an IP address for a desired name. ICN technologies remove the IP abstraction so the network can operate at the name level. This can make the network more responsive to application demands with less infrastructure.

Within an IMT-2020/5G radio access network (RAN), ICN could serve as the object transport for intra-RAN data. For example, the state of a network slice could be stored and transported as ICN data objects, so as services move between evolved Node B (eNodeB) sites its state follows in the named ICN objects.

In the ICN technology CCN, the name combines both a locator and identifier into one routable hierarchical structure. It could be thought of as routing on uniform resource identifiers (URIs), where each name segment can be arbitrary binary data not restricted to the URI syntax. At one end of the spectrum are pre-generated content names, such as for a movie. A movie service could name content with a prefix like */movie_service/superman/h264/768kbps/32kbps/English* to indicate a codec and encoding rate. Names can identify things beyond static content. A simple example would be a dynamic web service, such as */book_store/home/<encrypted_account_idenfier>*, where the *<encrypted_account_idenfier>* is a blob that the book store server can understand and use to generate a custom homepage. Names could also indicate a type of calculation, for example */calc/4/2/times* could return a content object with the value "8". In all these examples, ASCII names were used, but in practice name segments can be binary values, not necessarily human-readable.

6.2 Elements of ICN

ICN is usually made up of content producers, content publishers, content replicas and content consumers. A producer generates a piece of content, such as a document, photo, movie, or web page. It may have its own digital rights management (DRM) attached by the producer. A publisher packages a piece of content for use in the network. This may include pre-encoding the content to certain formats and names and signing them with a network identity. A replica distributes content from a publisher. A consumer fetches content via network names from replicas. The download process at a consumer understands the inherent security offered by the ICN, which usually allows authenticating every packet via direct signature or implicit hash chain from the publisher. This is different from today's security model, where authenticity derives from a secure connection to a replica. In the simplest configuration, one entity is a producer, a publisher and a replica for its content.

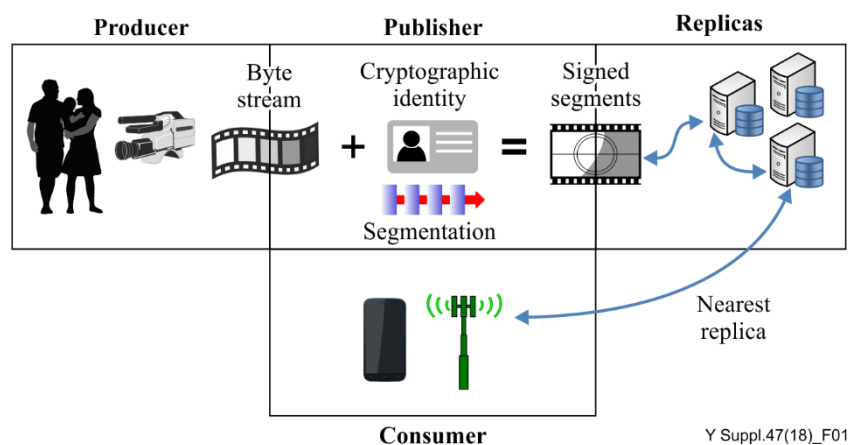


Figure 1 – Typical ICN architecture

Figure 1 illustrates the typical ICN architecture, which is referred to here to describe how an actual instance of CCN would handle these activities. This is an example of a family video service created at home, such as a video of their baby. The video camera produces video stream (e.g., MP4 byte stream). The publisher function, which may reside on the camera, home gateway, or other device, segments the byte stream to CCN content objects. For a live stream like this, the publisher would segment it to a certain number of video frames in a number of network packets (i.e., content objects). A CCN manifest tree incorporates those content objects by hashing into a single signed manifest representing the whole video segment. The video segment is stored on a first replica point, such as a home gateway. The publisher updates the movie catalogue to include the new segment, then repeats for the next segment. A consumer queries its nearest replica for the movie catalogue and segments. If the nearest replica does not have it, the request is forwarded towards the publisher until satisfied. The content travels to the consumer and is optionally cached in intermediate replicas.