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

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# Proof-of-concept for data service using information centric networking in IMT-2020

ITU-T Y-series Recommendations – Supplement 48

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## Supplement 48 to ITU-T Y-series Recommendations

# Proof-of-concept for data service using information centric networking in IMT-2020


### Summary

Supplement 48 to ITU-T Y-series Recommendations specifies a proof-of-concept for a service that provides named data such as Internet of things (IoT) named data by information centric networking in IMT-2020. In this Supplement, an enhanced name resolution system is implemented based on distance-constrained containers to resolve from names to addresses more efficiently.


### History

| Edition | Recommendation | Approval | Study Group | Unique ID* |
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### Keywords

IMT-2020, ICN, data service, naming, name resolution.


* 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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# Proof-of-concept for data service using information centric networking in IMT-2020

## 1 Scope

This Supplement describes a proof-of-concept for data service using information centric networking in IMT-2020 to fulfil four standardization gaps investigated by the ITU-T Focus Group on IMT-2020 during 2015-2016. It demonstrates the feasibility and benefits of an enhanced name resolution system based on distance-constrained containers by use cases such as real-time video streaming and temperature-humidity monitoring.

## 2 References

[ITU-T Y.3011] Recommendation ITU-T Y.3011 (2012), *Framework of network virtualization for future networks*.

[ITU-T Y.3031] Recommendation ITU-T Y.3031 (2012), *Identification framework in future networks*.

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

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

## 3 Definitions

### 3.1 Terms defined elsewhere

This Supplement 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 gateway** [b-ITU-T Y.2261]: A gateway is a unit that interconnects different networks and performs the necessary translation between the protocols used in these networks.

**3.1.3 identifier (ID)** [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).

**3.1.4 identifier/locator separation** [b-ITU-T Y.2015]: 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.

**3.1.5 IMT-2020** [b-ITU-R M.2083]: IMT-2020 is systems, system components, and related aspects that support to provide far more enhanced capabilities than those described in [b-ITU-R M.1645].

**3.1.6 latency** [b-ITU-R M.2083]: Latency is the contribution by the network to the difference in time (e.g., in ms) between when the source sends a packet and when the destination receives it.

**3.1.7 locator** [b-ITU-T Y.2015]: A locator is the network-layer topological name for an interface or a set of interfaces. Locators are carried in the IP-address fields as packets traverse the network.

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

**3.1.8 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).

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

**3.1.10 service** [ITU-T Y.3031]: Service is a set of functions and facilities offered to a user by a provider.

## 3.2 Terms defined in this Supplement

**3.2.1 distance-constrained container (DCC)**: Distance-constrained container is a service space/area within which the end-to-end QoS such as latency can be guaranteed, where the service space/area can be dynamically adjusted based on network measurement to satisfy some distance-related constraints.

**3.2.2 human-readable name**: Human readable name is a name that identifies an entity such as data and service to be easily understood by humans. A human readable name usually contains semantic information.

**3.2.3 information centric networking (ICN)**: Information centric networking is 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).

**3.2.4 ICN data service**: ICN data service is a service that provides globally unique ICN named data such as Internet of things (IoT) data.

# 4 Abbreviations and acronyms

This Supplement uses the following abbreviations and acronyms:

| | |
|---|---|
| CM | Container Management |
| DCC | Distance-Constrained Container |
| DS | Data Service |
| EID | Entity Identifier |
| eMBB | Enhanced Mobile Broadband |
| GN | Global Naming |
| GW | Gateway |
| HDD | Hard Disk Drive |
| HRN | Human-Readable Name |
| ICN | Information Centric Networking |

| | |
|---|---|
| ID | Identifier |
| IMT | International Mobile Telecommunications |
| IoT | Internet of Things |
| IP | Internet Protocol |
| LID | Local Identifier |
| LOC | Locator |
| MAC | Medium Access Control |
| MME | Mobility Management Entity |
| mMTC | Massive Machine Type Communication |
| MoD | Mobility on Demand |
| MTU | Maximum Transmission Unit |
| NA | Network Address |
| NAP | Network Access Point |
| NNRS | Naming and Name Resolution System |
| NRS | Name Resolution System |
| OAM | Operation, Administration and Maintenance |
| P-GW | Public data Network Gateway |
| PKI | Public Key Infrastructure |
| PoA | Point of Attachment |
| PoC | Proof-of-Concept |
| QoS | Quality of Service |
| RAT | Radio Access Technology |
| ROHC | Robust Header Compression |
| S-GW | Serving Gateway |
| SDN | Software Defined Networking |
| SON | Self-Organizing Network |
| SSD | Solid State Drive |
| SSHD | Solid State Hybrid Drive |
| TCP | Transmission Control Protocol |
| UDP | User Datagram Protocol |
| UE | User Equipment |
| URI | Uniform Resource Identifier |
| URLLC | Ultra-Reliable Low-Latency Communications |
| WSN | Wireless Sensor Network |

## 5 Conventions

In this Supplement:

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" 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 document.

## 6 Relevant standardization gaps

**Table 1 – Comparison with the related PoCs and the relevant standardization gaps identified by FG IMT-2020**

| Standardization gaps | | ICN enhanced mobile video | Functional chaining system in ICN | End-to-end ICN service orchestration | IP services over ICN | ICN transport in mm wave networks | Data service using ICN |
|---|---|---|---|---|---|---|---|
| E.1 | ICN in IMT-2020 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| E.2 | ROHC | | | | | | |
| E.3 | ICN S-GW | | | | | | |
| E.4 | ICN MME | | | | | | |
| E.5 | ICN P-GW | | | | | | |
| E.6 | ICN Slice | ✓ | | | | | |
| E.7 | Lawful intercept | | | | | | |
| E.8 | Mobility and routing | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| E.9 | UE provision | ✓ | | | | | ✓ |
| E.10 | ICN management SON | | | | | | |
| E.11 | OAM | | | | | | |
| E.12 | SDN and OpenFlow | | | ✓ | ✓ | | |
| E.13 | Authentication and encrypt | | ✓ | | ✓ | | ✓ |
| E.14 | Encryption | | | | | | |
| E.15 | QoS | | | | | | |

This proof-of-concept (PoC) provides the description and demonstration to show how it fulfils four of the fifteen information centric networking (ICN) related standardization gaps [b-ITU-T D 208-2015], [b-ITU-T Y-Sup.47] defined by FG IMT-2020, as shown in Table 1.

For Gap E.1, ICN protocol is considered in this PoC for IMT-2020. Each entity is assigned a globally unique name with at least one locator to obtain the requested service. To provide DS efficiently, the data can optionally be propagated to nodes that are located as close as possible to users. The data can exist in backhaul, core, or access networks. Data consumers from anywhere can directly access data in IMT-2020. Therefore, the public data network gateway (P-GW) is not always required for data access, even if IP is used as the locator.

For Gap E.8, this PoC refers to ICN mobility and routing to solve the architectural problems by separating the identifier from the locator. The dynamic binding between the identifier and the locator is used to solve the mobility issue by an enhanced name resolution system (NRS). The PoC supports mobility for both consumer and provider. The locator information can optionally include IP address to improve the compatibility with IP-based infrastructures.

For Gap E.9, this PoC considers ICN user equipment (UE) provisioning to support the data transmission and service delivery under heterogeneous access technologies using the connectionless communication model. The PoC supports the provisioning of entities by assigning a name and other ICN parameters. Since ICN entities are recommended to include UEs, data and services, the provisioning of data with diverse forms such as file-based data and in-memory data should be considered. In addition, the metadata are adopted to describe the characteristics of data service (DS).

For Gap E.13, this PoC applies an authentication system that allocates fixed-length globally unique names to network entities. It supports self-certifying and several existing certifying techniques such as public key infrastructure (PKI) and block chain. The privacy, integrity and consistency of data and metadata can be realized for a distributed system.

Furthermore, the issues or topics to be addressed by future work items include scalability, security, architecture of naming and name resolution, on-site elastic autonomous service [b-Wang-2015] and mobile edge intelligence-enabled networking [b-Sheng-2018]. For the scalability, the number of ICN names for entities keeps increasing to reach $10^{12}$, $10^{15}$ or even more in future. The trade-off between the scalability and the aggregation should be considered. In addition, it would be recommended to deal with the privacy risks and to consider the global situation under the environment of network virtualization [ITU-T Y.3011].

## 7 Background

IoT is one of the most important topic areas for typical IMT-2020 scenarios such as ultra-reliable low-latency communications (URLLC) and massive machine type communication (mMTC). Service-oriented IoT data sharing [b-Chen-2016] and mobility support for IoT data are two big challenges that have to be faced in IMT-2020. It is inefficient for the current techniques to directly share IoT data for the increasingly diverse vertical IoT applications due to the hardness of cross-application interoperability without a global naming system. ICN or data aware networking [ITU-T Y.3033], [ITU-T Y.3071] is an emerging technology with the ability of global naming to sharing of IoT data on the network layer. According to the Report on Standards Gap Analysis [b-FG IMT-2020 Gaps], a scalable NRS is required for interconnecting numerous IoT entities and establishing reachability to them by considering dynamic factors such as service replication and in-network caching. The objective of the ICN-IoT research on naming and name resolution is to achieve scalable name resolution handling for both static and dynamic ICN entities with low complexity and control overhead. The existing techniques fail to handle mobility for IoT data in a scalable and flexible way due to the challenges of large-scale mobile networks, while the topology-independent nature of ICN with the identifier-locator separation [b-ITU-T Y.2057], global naming and name resolution gives the opportunity to define a new solution to tackle the flexible mobility problem for IoT data as well as IoT networks.

# 8 Overview

This PoC demonstrates the feasibility and benefits of ICN in IMT-2020 by providing DS through various use cases [b-ITU-T Y-Sup.35] such as real-time video streaming and temperature-humidity monitoring. Since ICN naturally supports identifier-locator separation and dynamical binding between globally unique names and their mapped addresses, the PoC offers the flexibility of the entities to move between different administrative domains. It shows the performance of ICN DS on supporting mobility on demand. This PoC implements an enhanced NRS based on nested distance-constrained containers (DCCs) to resolve the bindings of names to their addresses more efficiently. The enhanced NRS consists of a series of nested DCCs on the network layer. The name registration and query requests can be forwarded to the most appropriate DCCs to ensure that users can get low-latency responses regardless of their positions and moving speeds. It is beneficial to mobility on demand (MoD) and service continuity. As a result, a safe, quick and accurate service response can be achieved.

# 9 Technical details

## 9.1 Architecture

The ICN naming mechanism for each entity is designed as follows. Each entity has a fixed-length globally unique identifier, i.e., an entity identifier (EID) and the name certification should be used to map from a human-readable name (HRN) to an EID. The HRN for a data entity could be described by uniform resource identifier (URI). A long globally unique name is required for each entity, while a short flat name is recommended in the local wireless sensor network (WSN) due to the limitation of IoT resources. As a result, the mapping [ITU-T Y.3032] between the local short name and the global long name is one of the basic functions for IoT GWs. As typical IoT scenarios, restricted temperature-humidity sensor data and live streaming camera data are used to show how the above naming mechanism works. Temperature-humidity data are received and stored in an IoT GW with a series of data files as named entities, while live streaming data are stored in the camera itself with a dynamic refreshed file as a named entity.

The architecture of PoC for IoT DS using ICN in IMT-2020 is shown in Figure 1. An enhanced naming and name resolution system (NNRS) is used to get EIDs from HRNs and network addresses (NAs) from EIDs, e.g. A50E… for a video streaming data entity, E12C… for a temperature-humidity data entity and 7EB5… for a UE entity. The enhanced technique for name resolution is based on nested DCCs which are constructed by the existing conditions such as physical partitions, tracking areas or network measurement. An entity should be registered in the enhanced NNRS as the binding between EIDS and NAs for the sake of being accessible for other entities. The IoT devices in a WSN are connected with IoT GW based on private routing. The IoT GW and the UE such as a camera or a mobile phone are connected with a point of attachment (PoA) for public routing over IP.

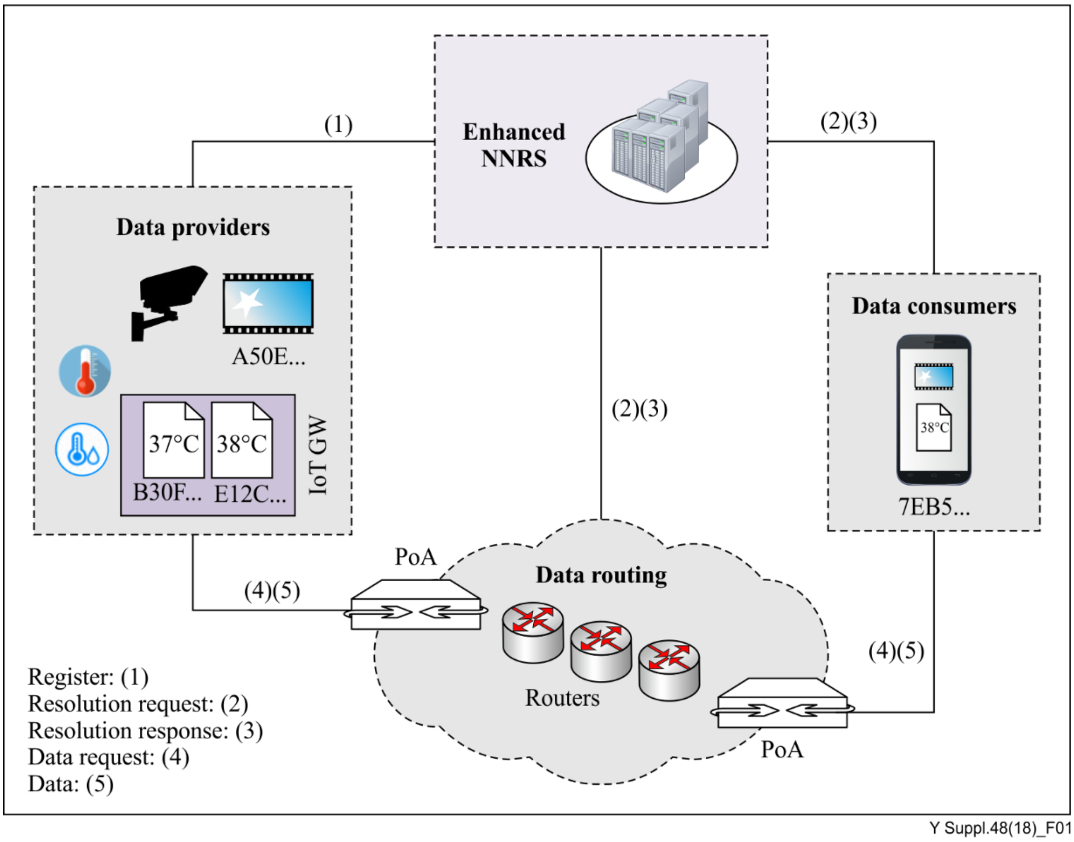


**Figure 1 – PoC architecture for IoT DS using ICN in IMT-2020**

As shown in Figure 1, a registration request (1) from data providers would be propagated to the enhanced NNRS, so that an EID and its NAs are recorded in the system for sharing the registered data globally. A resolution request (2) from data consumers would be propagated to the enhanced NNRS to get NAs as the resolution response (3) for any registered data with EIDs. A data request (4) from data consumers could be propagated to a router via a PoA, the router would forward the data request to other routers hop by hop till reaching one of the resolved NAs for the data providers. The requested data (5) would be propagated from the data providers to the data consumer. In practice, any network elements such as PoAs or routers could send a resolution request (2) to the enhanced NNRS, so that at least one NA is returned to the requested elements as the result of name resolution (3) during data routing.

## 9.2 Implementation

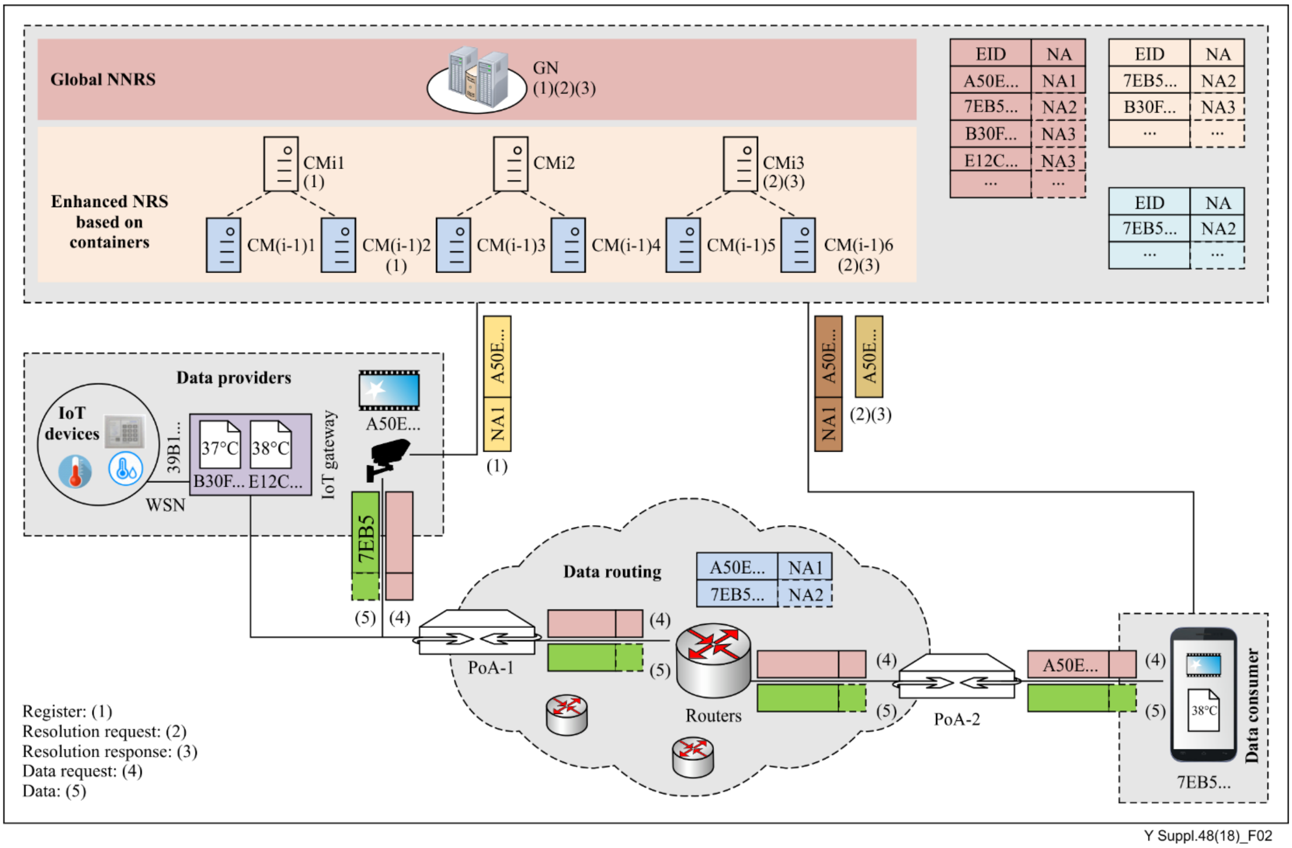


**Figure 2 – PoC implementation for IoT DS using ICN in IMT-2020**

As shown in Figure 2, the enhanced NNRS includes the global NNRS and the enhanced NRS based on DCCs. A registration request (1) from a data provider is propagated to the enhanced NNRS, so that a new binding for an entity is recorded in the DCCs and/or the global NNRS. The registration request (1) could be from IoT GW, IoT devices or a video camera. When an IoT data entity is registered in the enhanced NNRS to save the binding between EIDs and their NAs, e.g., A50E… with NA1, the registration request could be directly or indirectly propagated to the DCCs and/or the global NNRS. When a resolution request (2) is from a data consumer for a certain requested entity, e.g., A50E…, it would be propagated to the enhanced NNRS so that at least one NA is returned to the consumer as a name resolution response (3), e.g., A50E… with NA1. If a data request (4) from a consumer is propagated to a PoA or a router, the PoA or router could send a resolution request (2), e.g., A50E… and 7EB5…, to the enhanced NNRS so that at least one NA is returned to the PoA or router as the result of name resolution (3), e.g., A50E… with NA1 and 7EB5… with NA2. Next, the router keeps forwarding the data request (4) to other routers hop by hop till reaching the returned NA of the provider. Then, the requested data (5) would be propagated to the data consumer.

Inside the enhanced NRS, the DCCs are nested with multiple levels such as the enhanced (i-1)-th level and the enhanced i-th level. The enhanced (i-1)-th level DCCs include several network elements and their container management nodes respectively marked as CM(i-1)1, CM(i-1)2, … and CM(i-1)6 in Figure 2. The enhanced i-th level DCCs include several enhanced (i-1)-th level DCCs and their container management nodes respectively marked as CMi1, CMi2 and CMi3. The global NNRS is denoted by GN in Figure 2. The GN is with an identifier-locator mapping, e.g., from A50E...to NA1, from 7EB5...to NA2, from B30F...to NA3 and from E12C...to NA3. The topology of the nested DCCs is a tree or forest with bidirectional communication. In the topology, the CMi1 is the father of CM(i-1)1 and CM(i-1)2 in Figure 2.

## 9.3 Mobility support

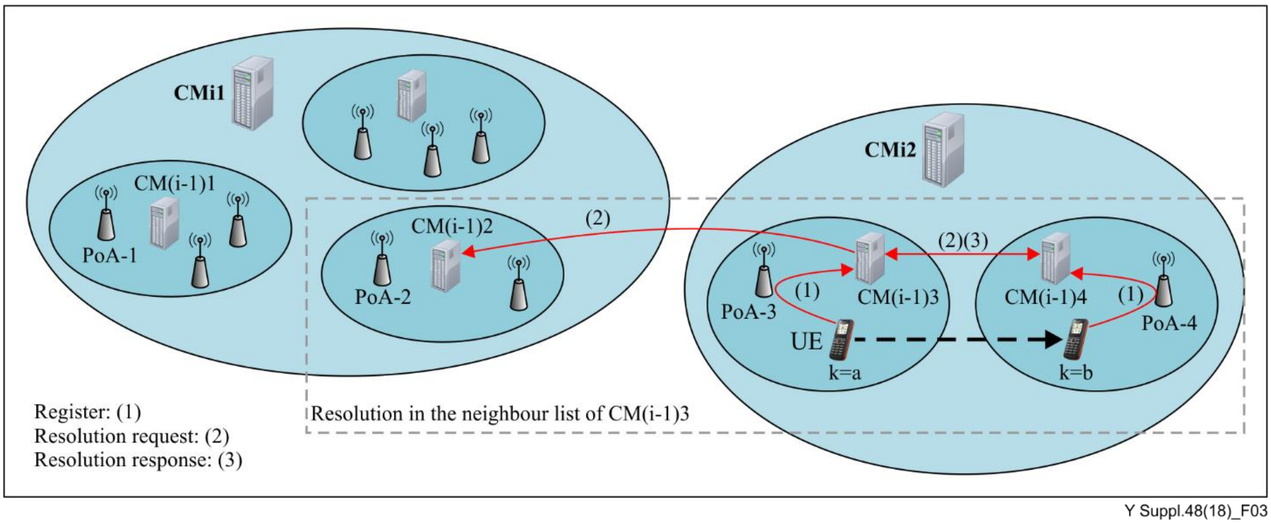


**Figure 3 – Mobility support for IoT DS using ICN in IMT-2020**

As shown in Figure 3, the mobility support for IoT DS is implemented by using ICN in IMT-2020. We assume the DCCs are nested with two levels. The DCCs Ci1 and Ci2 are on the enhanced i-th level, where CMi1 and CMi2 are their management nodes. The DCC Ci2 includes C(i-1)3 and C(i-1)4 on the enhanced (i-1)-th level, while the DCC Ci1 includes C(i-1)1, C(i-1)2, etc. The PoA-3 and the UE located at k=a are network elements in the DCC C(i-1)3, and CM(i-1)3 is its management node. Any network element such as a UE can join the enhanced NRS based on DCCs through a management node of its DCC which the network element is located in.

It is assumed that a UE is moving from k=a to k=b, where k is the current locator of the UE. The registration request (1) sent by the UE located at k=a is propagated to CM(i-1)3. After UE moving to the position k=b, it sends a new registration request to CM(i-1)4 to bind its new NA in the enhanced NRS. When a resolution request (2) is propagated to CM(i-1)3, the CM(i-1)3 propagates this request to its neighbours CM(i-1)2 and CM(i-1)4 in the enhanced NRS. The CM(i-1)4 sends a resolution response (3) with the new NA back to CM(i-1)3.

# 10 Standardization gaps addressed in PoC

With this PoC implementation, the concept of IoT DS using ICN in IMT-2020 has been demonstrated. Furthermore, this PoC shows the evaluation of effectiveness of IoT DS for supporting mobility on demand. In particular, this PoC used the ICN naming and name resolution to achieve IoT data sharing for IoT DS in IMT-2020.

This PoC covers the following four standardization gaps identified by the Focus Group on IMT-2020: Gap E.1 Considering ICN as a protocol for IMT-2020, Gap E.8 ICN mobility and routing, Gap E.9 ICN UE provisioning, and Gap E.13 ICN security.

– *Gap E.1 Considering ICN as a protocol for IMT-2020*

This PoC shows the feasibility of DS by using the mechanism of naming and name resolution in ICN for a typical IMT-2020 scenario with the deployment over IP. DS was demonstrated by the use cases of real-time video streaming and temperature-humidity monitoring. It opens new possibilities in IoT applications by considering ICN as a protocol, which assigns a globally unique name to each data entity. The endpoint NAs could be resolved to obtain the required data service. The compatibility with IP over ICN has been considered in this PoC. Related ICN transmission protocol over IP was designed to transport the names and data. The IoT GW played the role of protocol conversion, which allowed the usage of private IoT routing protocols such as Zigbee, WiFi, and

BLE. In addition, the feasibilities to handle mobility and continuity of services are demonstrated by the binding between EIDs and NAs. Even if a device with the requested service has moved, UE would get access to the service and the generated data by querying the enhanced NRS with the service and data EIDs to get the latest NAs.

– *Gap E.8 ICN mobility and routing*

It is required to consider IMT-2020 mobility as comprising more demanding requirements, such as the support of in-session user experience at different speeds such as 100 km/h, 200 km/h, 500 km/h or even higher. The current IP-based mobility comes with high network cost, high complexity and low flexibility of network deployment and management. ICN addresses the architectural issue of mobility and routing in IP by allowing entities to bind to names and its resolution to a location through a NRS. In this PoC, data entities with short flat names in a private network were transformed to globally unique names by IoT GWs. In this way, every data entity has its globally unique name and can be registered with its NA in the enhanced NRS. By utilizing the transformation between short names and long names, consumers can pass through different administrative domains to visit target data entities without the need of anchor nodes [b-Augé-2015]. As a result, the routing between public networks and private networks becomes easier. Furthermore, traffic generated from mobile users is prone to losses due to connection through unreliable wireless channels or to mobility events. The enhanced name resolution, which allows the deployment of distributed in-network controllers by DCCs, is designed to take full advantage of the ICN naming, name resolution and routing. The hierarchical structure of the enhanced NRS based on DCCs provides the flexibility to demarcate different managing scopes based on end-to-end latency and spatial location. When registering or querying in the NRS, UE requests are assigned to an appropriate DCC level to ensure that UE obtains low-latency response at different moving speeds. The requirements of seamless communication [b-Azgin-2016] have the ability to be fulfilled. Moreover, this PoC is used to detect and recover traffic losses caused by mobility events. Target DCCs broadcast the requests to neighbour DCCs to recover losses.

– *Gap E.9 ICN UE provisioning*

Heterogeneous access technologies are expected to be simultaneously used for diverse ICN UEs in IMT-2020. This PoC considers the provisioning of ICN UEs such as IoT devices, personal computers and mobile phones to interface with different radio access technologies (RATs) such as BLE and WiFi. UE does not need to maintain the parameters required to establish IP connections in ICN. Consumers get the NA of requested data by using EID queries in the NRS. In this PoC, the IoT GW implements the function of bidirectional protocols translation, by abstracting the EIDs of requests and keeping the EID, consumers request different data from different providers in different fields.

Furthermore, this PoC allows the provisioning of diverse entities such as devices, data and services, based on naming and name resolution using IP as locator information and ICN for service delivery. The data provisioning is with diverse forms such as streams, files and databases in different storages such as in memory, hard disk drive (HDD), solid state drive (SSD) and solid state hybrid drive (SSHD). In order to achieve mobility support, the PoC is used to configure the UEs in the enhanced NRS. The mobility configuration of UEs guarantees the continuity and seamless mobility of services.

– *Gap E.13 ICN security*

ICN security is mainly demonstrated from two aspects in this PoC. For one aspect, this PoC demonstrates the use of the enhanced NRS for ICN naming, name certification and name resolution with secure self-certifying by an authentication system that allocates a long fixed-length globally unique identifier for each entity, i.e., EID. The EIDs are randomly selected, since their length ensures that the probability of a collision is small. The authenticity of the data is guaranteed by using self-certifying names and the risks of naming forgery are avoided. Furthermore, the EIDs are self-certifying hashes of information entities, thus allowing information integrity verification, which is advantageous for reducing mistakes in transit. In another aspect, the separation of identifiers and locators means that some security threats that were ubiquitous in IP networks would no longer exist in ICN. For instance attacks on host-based connections are naturally avoided.

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