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

Future networks

Information centric networking for IMT-2020 and beyond – Requirements and capabilities of data object segmentation

Recommendation ITU-T Y.3078

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Recommendation ITU-T Y.3078

Information centric networking for IMT-2020 and beyond – Requirements and capabilities of data object segmentation

Summary

Recommendation ITU-T Y.3078 starts with an introduction to data object segmentation in information centric networking (ICN) for IMT-2020 and beyond. It specifies the service and functional requirements and capabilities of data object segmentation to achieve high efficiency of caching and forwarding in ICN.

History

Edition	Recommendation	Approval	Study Group	Unique ID*
1.0	ITU-T Y.3078	2022-02-13	13	11.1002/1000/14851

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ICN, IMT-2020, manifest, named data chunk, named data object.

* 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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Information centric networking for IMT-2020 and beyond – Requirements and capabilities of data object segmentation

1 Scope

This Recommendation specifies the requirements and capabilities of data object segmentation to achieve high efficiency of caching and forwarding in information centric networking (ICN) for IMT-2020 and beyond. Its scope specifically includes the following items:

– Introduction to data object segmentation in ICN for IMT-2020 and beyond,

– Service and functional requirements of data object segmentation,

– Capabilities of data object segmentation in ICN for IMT-2020 and beyond.

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.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 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 data object (DO) [ITU-T Y.3033]: An individually identifiable unit of information created by individuals, institutions and technology to benefit audiences in contexts that they value.

3.1.3 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).

3.1.4 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].

3.1.5 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.

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

3.1.7 name mapping [b-ITU-T Y.3072]: Name mapping is 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.

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

3.1.9 service [b-ITU-T Y.3031]: A set of functions and facilities offered to a user by a provider.

3.2 Terms defined in this Recommendation

This Recommendation defines the following terms:

3.2.1 data chunk (DC): A part of a data object which is segmented with specific size.

3.2.2 DO metadata: Structural information describing the data object's attributes such as times of last change, access, and modification, as well as owner and permission data, which may be modified during its lifecycle and may be as a special data object.

3.2.3 DO segmentation: A process, which comprises segmenting data objects into data chunks, labelling data chunks as labelled data chunks, generating the relationship between data objects and labelled data chunks, and reassembling the data object based on labelled data chunks and the relationship between the data object and labelled data chunks.

3.2.4 labelled data chunk (LDC): A data chunk with a unique label. The label is the identifier of a data chunk, and the name also can be used as a kind of identifier.

3.2.5 manifest: A description which describes the structural information between a data object and labelled data chunks.

3.2.6 name mapping and resolution system: A system that supports the name mapping and resolution services.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

DAN	Data Aware Networking
DC	Data Chunk
DO	Data Object
GNMRS	Global Name Mapping and Resolution System
ICN	Information Centric Networking
ID	Identifier
IMT-2020	International Mobile Telecommunications 2020
IP	Internet Protocol
LDC	Labelled Data Chunk
LNMRS	Local Name Mapping and Resolution System
NA	Network Address
NDO	Named Data Object
NMRS	Name Mapping and Resolution System
QoS	Quality of Service

TTL Time-To-Live

URI Uniform Resource Identifier

5 Conventions

In this Recommendation:

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

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

6 Introduction

Use of information centric networking (ICN) or data aware networking (DAN) as an emerging technology for the IMT-2020 network to achieve performance goals, provides a new network paradigm to deal with an enormous amount of data efficiently in a distributed environment, and enables users to access desired data safely, easily, quickly and accurately, regardless of data locations. [ITU-T Y.3033] notes that the essence of DAN lies in the name-based communication that routes a data object in the network by its name or identifier (ID). [b-ITU-T Y-Sup.35] presents a set of service scenarios and use cases supported by DAN. In these scenarios and use cases, all kinds of named data objects (NDOs) (e.g., videos, text files, measurement data, and executable programs, etc.) were collected, cached, and transmitted by DAN elements to achieve multiple benefits for service providers and users, network operators, and application developers etc. [b-ITU-T Y-Sup.48] describes a proof-of-concept for data service using ICN in IMT-2020, and demonstrates the feasibility and benefits of ICN by providing data service based on globally unique named data. In light of these service scenarios and use cases, [ITU-T Y.3071] specifies the requirements of DAN, including NDO cache and fragmentation function requirements. It is required that DAN elements are equipped with a cache that temporally holds NDOs, and that DAN elements fragment large NDOs into a series of smaller units for network transmission. Therefore, it is necessary to segment the large data object (DO) into a series of smaller units, also called data chunks (DCs), of specific size, which can benefit transmission and caching in ICN. Actually, this process involves complex operations in ICN, and some capabilities should be supported by the network, including segmenting DOs into labelled DCs (LDCs) and managing the relationship between DOs and LDCs (manifest), caching and transmitting LDCs in the ICN network, and reassembling DOs based on LDCs, manifest and certain strategies. However, no existing standard focuses on similar work. Some work in IETF refers to some of the technique points, such as designing the format of the manifest, but that is not the same issue as the DO segmentation process. Therefore, the purpose of this Recommendation is to discuss the requirements and capabilities of DO segmentation to achieve high efficiency of caching and forwarding for ICN. An overview of the DO segmentation process in ICN is introduced. Here, the smaller unit that is assigned a label is the labelled data chunk (LDC).

For a DO, when it is to be transmitted or cached in an ICN should be segmented into LDCs, and the relationship between the DO and LDCs should be created. Meanwhile, the replicas of LDCs should be cached and managed by the network; when a subscriber requests this DO, how to get the corresponding LDCs of this DO from the network, and how to select proper LDC replicas for reassembling the DO to respond the subscriber, should also be considered. The above process relates to complex operations of the network, and a series of capabilities should be provided by the network. There are three kinds of capabilities that the network should provide:

1) When a DO is transmitted and cached by the network, firstly, it should be segmented into a series of LDCs, and a manifest that contains the description of the relationship between the DO and LDCs should be generated. In order to process LDCs in ICN safely and efficiently,

the network should have some capabilities, including access control, integrity guarantees, safety processes and data chunk labelling. Meanwhile, the network can also register a data chunk in a name mapping and resolution system (NMRS) for further retrieval.

2) After the segmentation, LDC is used to cache and transmit in the network. Each LDC can be replicated and cached in different positions independently based on some strategies. All replicas of a LDC may be located in different positions in the network, and each replica should be registered in the NMRS. Meanwhile, the manifest of the DO is also published in the network.

3) If a subscriber requests a DO, the manifest should be returned first. Labels of LDCs and the structure of LDCs for reassembling the DO can be obtained. Then, the proper replica of each LDC will be chosen based on some strategies. The DO will be reconstructed based on the returned replicas of LDCs, and the reassembled DO is returned to the subscriber. In this process, some capabilities, such as the access control and integrity check, are also required.

The above stages support the ICN to provide capabilities for accepting any size of DO, caching, forwarding and publishing/subscribing data, which has not been referred to directly in existing standards and consequently Recommendation ITU-T Y.3078 is proposed resolve these issues.

7 Service and functional requirements of data object segmentation

Requirements of DO segmentation in the network for IMT-2020 and beyond, including service requirements and functional requirements, are described in clauses 7.1 and 7.2, respectively.

7.1 Service requirements

1) It is required to support the DO segmentation service, by which DOs can be segmented into LDCs and a manifest is generated, and all LDCs and the corresponding manifest can be published in the network for further transmission, caching and storing.

2) It is required to support providing DCs and the relationship between the DO and DCs for reconstructing the DO.

3) It is required to support caching replicas of LDCs based on specific caching strategies, or support storing LDCs based on storage requirements such as reliability or location.

4) It is required to support registering LDCs in the NMRS.

5) It is recommended to support choosing and obtaining the proper replica of an LDC based on some specific strategies.

6) It is recommended to separately store DOs and DO metadata based on different strategies, such as different reliability levels and different positions.

7) It is recommended to have interfaces which can be used to map data to objects to deal with different kinds of data, such as files, streaming, and DO metadata.

8) It is recommended to deliver DOs to applications in different ways, such as on demand or by subscription.

7.2 Functional requirements

1) It is required to have the capability to pre-process DOs.

   – It is required to support processing application-related preferences and mapping them to underlying transmission parameters which are carried in packet headers during the transmission process. The application-related preferences include storage QoS, specific storing positions, caching strategies, security strategies, multipath transmission, one-to-many transmission based on multicasting, etc.

2) It is required to have the capability to segment DOs.
   - It is required to support segmenting DOs into specific size DCs.
   - It is required to support assigning a unique label for each DC.
   - It is required to support registering the LDC and network address (NA) mapping in a NMRS.
   - It is required to support generating LDC's transmission parameters inherited from DO's transmission parameters or based on DO's preferences.
   - It is recommended to have the capability to generate integrity check information for LDCs.
3) It is required to have the capability to reassemble DOs.
   - It is required to support obtaining the manifest based on the DO.
   - It is required to support extracting LDCs from the underlying transported information.
   - It is required to support providing DCs and the relationship between DO and DCs for reconstructing a DO.
   - It is recommended to support the integrity check for DCs.
4) It is required to have the capability to process the manifest.
   - It is required to support creating the manifest when a DO is segmented to LDCs and publishing the manifest.
   - It is required to support retrieving the manifest of DOs and parsing the manifest structure.
   - It is required to have the capability to maintain the manifest for a DO with streaming data content whose manifest may be dynamically changed.
   - It is recommended to have the capability to store manifest with high reliability if it is stored in ICN and maintain structural information if it contains sub-manifests.
   - It is recommended to support deleting the manifest of a DO when the DO is deleted from the network.
5) It is required to have the capability to support the security functions.
   - It is required to support controlling access to LDCs and the manifest of a DO.
   - It is required to support LDC integrity validation and recovery from LDC corruption throughout its lifecycle.
6) It is required to have the capability to define different quality of service (QoS) levels and storing reliability levels for applications, which are associated to DO storing patterns, such as transmission priority, where to store the LDCs of DOs, or how many replicas of LDCs should be stored in the network.
7) It is required to have the capability to map different transmission strategies from applications to underlying transmission schemas, such as multipath transmission or multicasting.

8 Capabilities of data object segmentation

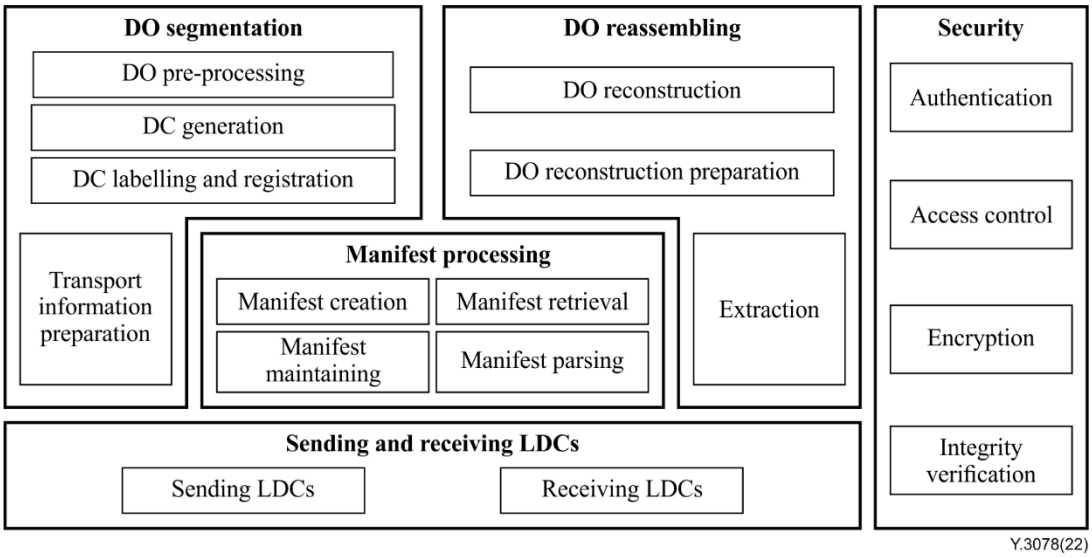

Figure 1 – Capabilities of data object segmentation in ICN for IMT-2020 and beyond

Capabilities of data object segmentation in ICN for IMT-2020 and beyond and the interaction between different parts are shown in Figure 1, containing: DO segmentation, DO reassembling, manifest processing, sending and receiving LDCs, and security.

8.1 DO segmentation

The DO segmentation is required to have the capabilities to segment a DO into DCs and assign a unique label for each DC. Then, all LDCs will be registered in the NMRS for the further querying. There are at least four functions to support the corresponding capabilities, including DO pre-processing, DC generation, DC labelling and registration, and transport information preparing. The description of each part is as follows:

– DO pre-processing: It is used to parse application-related preferences, map them to defined transmission parameters such as transmission priority, transmission or storage security level, how many replicas of LDCs, where to store the LDCs of a DO, or multicasting in the network.

– DC generation: It is used to receive the DO, segment the DO into DCs with the specific size, and generate the relationship between the DO and DCs for manifest creation.

– DC labelling and registration: It is used to assign a unique label to each DC. There are many methods to assign the label to a DC, such as the hierarchically human-readable naming method, self-certifying flat naming method, attribute-based naming method, hybrid method of multiple naming mechanism, etc. For example, the label can be composed by the hash value of the uniform resource identifier (URI) and the hash value of the DC. It can also get the NA of the network element where the DC is located, and register the label and the NA mapping to the NMRS.

– Transport information preparation: It is used to combine output from the modules above it, prepare the parameters or information that is necessary for the transport process, and build the LDC transport packet based on DC and some additional information, such as labels, structural information of the DC, integrity checking information, and replica placement strategies according to the specific packet structure. It may have the capability to store DOs and DO metadata based on specific strategies, such as different reliability levels, different positions and different lifecycles. It may also hint for transport path selection to steer DCs to different paths. Moreover, these strategies can assist in generating information for

collaboration between nodes. Meanwhile, it should manage and configure resource requirements of the transport process such as queue size and buffer size.

8.2 DO reassembling

The DO reassembling is required to have the capability to aggregate requests and replicate LDC for multiple applications and reconstruct the DO based on LDCs. The corresponding functions include:

– DO reconstruction: It is used to deliver the DO to applications on demand or by subscription. When a DO is requested on-demand, it is used to convert DO requests from multiple applications to corresponding LDCs requests according to the DO's manifest which should be obtained firstly, and construct responded LDCs into the DO based on the manifest of the DO. When the DO is obtained by subscription, it is recommended to utilize a more efficient underlying network service such as multicasting service to get the DO. It is responsible for allocating and configuring the temporary buffer space for DO reconstruction. It is recommended that this function may be executed in the application to enhance the performance.

– DO reconstruction preparation: It should aggregate simultaneous LDC requests based on the request related information, and maintain status information of requests such as the request identifier, request timestamp, request time-to-live (TTL), and buffer space address. It should also get the responded LDC from the extraction module below and replicate LDCs to corresponding buffer space based on the status information of requests.

– Extraction: It is used to extract the useful information from the transported information, such as LDCs. It should also maintain the mapping of the LDC request to the transport process, and allocate a queue for the received LDCs.

8.3 Manifest processing

The manifest processing is required to have the capability to create, retrieve, maintain and parse manifest, which includes several functions.

– Manifest creation: It is used to generate the manifest for DOs and publish the manifest in the network.

– Manifest retrieval: It can retrieve the manifest, including building an index of the manifest and responding to the retrieval request.

– Manifest maintaining: It can maintain the manifest in the network, such as storing, backup, updating or deleting the manifest. It guarantees that the manifest should be stored with high reliability in a proper network location. Meanwhile, it can be obtained based on the structural information which describes the sub-manifests.

– Manifest parsing: It is used to parse the content of the manifest and extract the needed information such as the relationship between the DO and LDCs from it.

8.4 Sending and receiving LDCs

Sending and receiving LDCs is to provide the interface to the transport layer for ICN, which includes two functions, sending LDCs and receiving LDCs.

– Sending LDCs: It is used to send the LDC and some necessary information to the protocol of the transport layer, and call the application programming interface (API) of the transport layer for data sending. It is recommended that the information should contain the identifier of the LDC to better support the identifier-based multipath scheme and in-network caching.

– Receiving LDCs: It can call the API of the transport layer for receiving the LDCs and their related information. It is recommended that the receiving API receives the LDCs based on the identifier to better support the identifier-based multipath scheme and in-network caching.

Sending and receiving LDCs is mainly responsible for maintaining the information that will be sent by the transport layer, or the information received from the transport layer, such as DC, manifest information, and transporting parameters. Moreover, the DC should be processed by the transport layer based on this information, such as duplicating replicas and multipath selection hints.

8.5 Security consideration

The security has the capability of authentication, access control, encryption and integrity verification.

– Authentication: The authentication capability is mainly used for authenticating the valid users, which can be further used for access control, encryption, etc.

– Access control: The access control capability is used for guaranteeing that all access and operations are correct and from authorized users.

– Encryption: The encryption capability can support the encryption of LDCs and manifest to ensure the data confidentiality. To satisfy the different requirements of security, it can support encryption with different security levels, which comes from the application-related preferences.

– Integrity verification: The integrity verification capability is used for examining and confirming the integrity of each LDC to ensure that the LDC has not been tampered with. It is recommended to achieve integrity through the naming method of LDCs. The label of the LDC is obtained from the hash value of the DC and the label can be further used to verify the integrity of the LDC.

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