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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 in networks beyond IMT-2020: Framework of locally enhanced name mapping and resolution

Recommendation ITU-T Y.3079

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Recommendation ITU-T Y.3079

Information-centric networking in networks beyond IMT-2020: Framework of locally enhanced name mapping and resolution

Summary

Recommendation ITU-T Y.3079 specifies a framework for locally enhanced 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 networks beyond IMT-2020.

History

Edition	Recommendation	Approval	Study Group	Unique ID*
1.0	ITU-T Y.3079	2022-09-29	13	11.1002/1000/15049

Keywords

ICN, IMT-2020, locally enhanced name mapping, locally enhanced 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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Information-centric networking in networks beyond IMT-2020: Framework of locally enhanced name mapping and resolution

1 Scope

This Recommendation specifies a framework for locally enhanced name mapping and resolution (NMR) function for information-centric networking (ICN) in networks beyond International Mobile Telecommunications-2020 (IMT-2020). This Recommendation specifically includes:

- detailed requirements for deterministic latency and scalability;
- key functions of locally enhanced NMR;
- architectural framework of locally enhanced NMR.

NOTE – The global frameworks of NMR for ICN in networks beyond IMT-2020 lie outside the scope of this Recommendation.

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

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

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 address [b-ITU-T Y.2091]: The identifier for a specific termination point used for routing to that termination point.

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

3.1.3 identifier/locator separation (ID/LOC separation) [b-ITU-T Y.2015]: Decoupling the semantic of an Internet protocol (IP) address into the semantics of node IDs and LOCs. Distinct namespaces are used for node IDs and LOCs so that they can evolve independently. LOCs are associated with the IP layer whereas node IDs 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 multihoming.

3.1.4 IMT-2020 [b-ITU-T Y.3100]: (based on [b-ITU-R M.2083]) 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.

3.1.5 latency [b-ITU-R M.2083]: 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.

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

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

3.1.7 mapping record [ITU-T Y.3072]: A basic information element of name mapping and resolution that contains the relationship between an identifier and address(es) of the object.

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

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

3.1.12 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 constrained neighbour structure: A structure consisting of name mapping and resolution node(s) where the transmission latency between any node and user in this structure is within a deterministic upper bound.

3.2.2 name mapping and resolution (NMR) node: A server on which a name mapping and resolution service is installed.

3.2.3 name mapping and resolution (NMR) user: Any element in a network that can access NMR services, such as a switch, router, server or user device.

3.2.4 record exchange: Interactive behaviour between different nodes to share records in distributed systems, improve the utilization of system resources and improve the response speed and availability of the system.

3.2.5 request redirection: A behaviour in a distributed system where a node automatically forwards a received user request to one or more other nodes for processing, e.g., when the node does not have corresponding service capabilities, scheduling policies, etc.

3.2.6 structure-related information exchange: A type of information exchange between nodes in a distributed system that is used for the autonomous management and maintenance of the local structure of a node to correctly support its functions and services.

NOTE – This information exchange can be performed periodically or is triggered by a structural change event.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

BRO Broker

FRM	Federal Relationship Maintenance
GNMRS	Global Name Mapping and Resolution System
ICN	Information-Centric Networking
ID	Identifier
IMT-2020	International Mobile Telecommunications-2020
IP	Internet Protocol
LNMRS	Locally enhanced Name Mapping and Resolution System
LOC	Locator
MF	Management Function
mMTC	Massive Machine Type Communication
NMR	Name Mapping and Resolution
OF	Operation Function
REQ	Requester
RNL	Resolution Node List
RP	Request Process
SF	Security Function

5 Conventions

In this Recommendation:

The phrase "is required to" indicates a requirement that must be strictly followed and from which no deviation is permitted, if conformity to this Recommendation is to be claimed.

The phrase "is prohibited from" indicates a requirement that must be strictly followed and from which no deviation is permitted if conformity to this Recommendation is to be claimed.

The phrase "is recommended" indicates a requirement that is recommended but which is not absolutely required. Thus, this requirement need not be present to claim conformity.

The phrase "is not recommended" indicates a requirement that is not recommended but which is not specifically prohibited. Thus, conformity with this specification can still be claimed even if this requirement is present.

The phrase "can optionally" indicates an optional requirement that 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 or service provider. Rather, it means the vendor may optionally provide the feature and still claim conformity with this Recommendation.

6 Introduction for locally enhanced name mapping and resolution

This Recommendation focuses on an enhanced framework of NMR for ICN in networks beyond IMT-2020. Research shows that ICN is a promising technique which could facilitate IMT-2020 to support large-scale heterogeneous objects, Internet of things applications, mobility models and device self-configuration [b-ITU-T Y-Suppl. 47]. According to [b-ITU-T Y-Suppl. 48], the proof of concept demonstrates the feasibility and necessity of local NMR service to support many application scenarios, such as ultra-reliable low latency communications and massive machine type communications (mMTCs), to satisfy the requirements of IMT-2020 and beyond [b-ITU-R M.2083].

Provision of an efficient service of translation between an ID and its addresses due to the ID/LOC separation [b-ITU-T Y.2057] is expected to handle enormous amounts of data objects for ICN or data aware networking [ITU-T Y.3071] and to enable users to access named data objects with deterministic latency by NMR [ITU-T Y.3072]. In fact, it is required that NMR be enhanced with the constraints of sub-domains or distances to support deterministic latency in IMT-2020. However, so far there is no such framework available for locally enhanced NMR based on the capabilities in [ITU-T Y.3072]. Therefore, a framework is necessary to realize locally enhanced NMR for ICN in networks beyond IMT-2020.

7 Detailed requirements of deterministic latency and scalability

7.1 Detailed requirements of deterministic latency

Latency for NMR service is composed of two basic parts. One is the query-processing latency on the NMR node; the other is the transmission latency from NMR node to the NMR user or an assigned network element by the NMR user.

1) It is required for the NMR node to have the capability to guarantee a deterministic maximum query-processing latency.

1.1) It is recommended to support scheduling on storage and computing resources to retrieve mapping records for a given name within a deterministic time deadline.

2) It is required for the NMR system to have the capability to guarantee multiple levels of deterministic maximum transmission latency.

2.1) It is required to maintain a series of constrained neighbour structures for a specific maximum transmission latency.

NOTE – A constrained neighbour structure consists of NMR node(s), and the transmission latency between any node and user in this structure is within a deterministic upper bound.

2.2) It is required that the NMR node be able to provide the resolved address; the transmission latency between the corresponding network element with this address to the NMR node has a deterministic upper bound.

2.3 It is required to maintain a hierarchical structure consisting of NMR nodes for multiple levels of maximum transmission latency.

3) It is recommended to maintain the entrance node list to help NMR users find the NMR node that can meet the requested level of transmission latency quickly.

3.1) It is recommended to retrieve NMR nodes at different levels of transmission latency for an NMR user when it accesses NMR for the first time, and the retrieved NMR nodes constitute the entrance node list for this NMR user.

3.2) It is recommended to update the entrance node list periodically based on the network measurement.

4) It is recommended to maintain a resolution node list (RNL) for a user or a group of users to get the appropriate service node quickly. In order to maintain the RNL, when a user joins the NMR system, latencies between this user and candidate NMR nodes are measured, and the nodes that meet the latency requirements are selected and maintained in the RNL. This RNL is recommended to be stored in a network access point-like device or user device.

7.2 Detailed requirements for scalability

1) It is required for the NMR node to have the capability to distribute storage or query-processing tasks to other NMR nodes on condition that the processing or transmission latency can be guaranteed.

2) It is required for the NMR node to have the capability to manage the lifecycle of records based on specified strategies.

3) It is required for the NMR system to support dynamic node joining in and quit with no impact or little impact on the other part of the system (including NMR nodes and NMR users).

4) It is required for the name mapping and NMR system to have the capability to maintain a federal relationship among different administration domains.

   NOTE – Different NMR systems can optionally be established by different organizations. If they collaborate together, the service performance of the NMR system can be enhanced, and this collaborated system is the federal system.

5) It is recommended for the NMR node to parse the registered or requested information and have the capability to execute some specific action based on it.

   NOTE – For example, publishing some content to a network, or notifying a network or another node of what is registered in the NMR node.

6) It is recommended for the NMR node to have the capability to adjust the logical connection relationship with other nodes, such as neighbours in a graph, and parents or child nodes in a tree structure.

7) The NMR node can be optionally deployed in a distributed mode, which means several nodes take on the entire work of a single NMR node together.

8 Locally enhanced name mapping and resolution

In order to satisfy the requirements in clause 7 for deterministic latency and scalability simultaneously, the key technology and functions of locally enhanced NMR are described.

8.1 Latency-based hierarchical network structure

In the example shown in Figure 1, the dotted circles indicate the fully covered sub-domains of network partitioning based on latency with no intersection between sub-domains. The dashed circles indicate the neighbourhood relationship among the sub-domains. The continuous lines indicate different service levels of sub-domains based on latency. A physical network can be divided into several logical sub-domains or domains that may contain one or more nodes for locally enhanced NMR. There are multiple levels, such as ith and $(i-1)$th levels to represent different latency limitations such as T_i and T_{i-1} in a nested structure. OF_{i1}, OF_{i2} and OF_{i3} represent the operation function (OF) modules on the ith level. $OF_{(i-1)1}$, $OF_{(i-1)2}$, $OF_{(i-1)3}$, $OF_{(i-1)4}$ and $OF_{(i-1)5}$ are the OF modules on the $(i-1)$th level. NMR nodes on $(i-1)$th and ith levels, and the interface-based connection with a nested structure between two levels, form a tree topology. On the ith level, the interface-based connection can be designed to form a neighbour relationship between OF_{i2} and OF_{i3}. On the $(i-1)$th level, the interface-based connection can be designed to form a neighbour relationship between $OF_{(i-1)1}$ and $OF_{(i-1)2}$ as well as between $OF_{(i-1)4}$ and $OF_{(i-1)5}$.

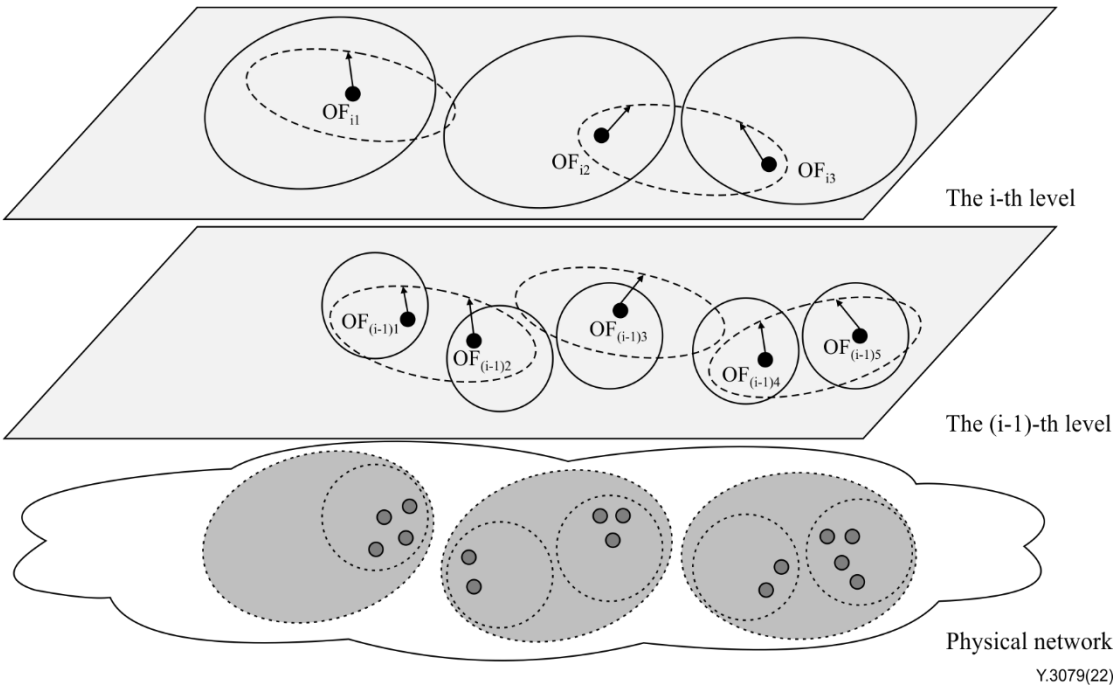

Figure 1 – The hierarchical/nested structure with neighbour relationship

8.2 Key functions of locally enhanced name mapping and resolution

Locally enhanced NMR mainly consists of three parts: OF, management function (MF) and security function (SF). An OF includes key functions related to name mapping and name resolution. An SF mainly deals with security aspects of the system. An MF mainly deals with management and visualization of the system. See Figure 2.

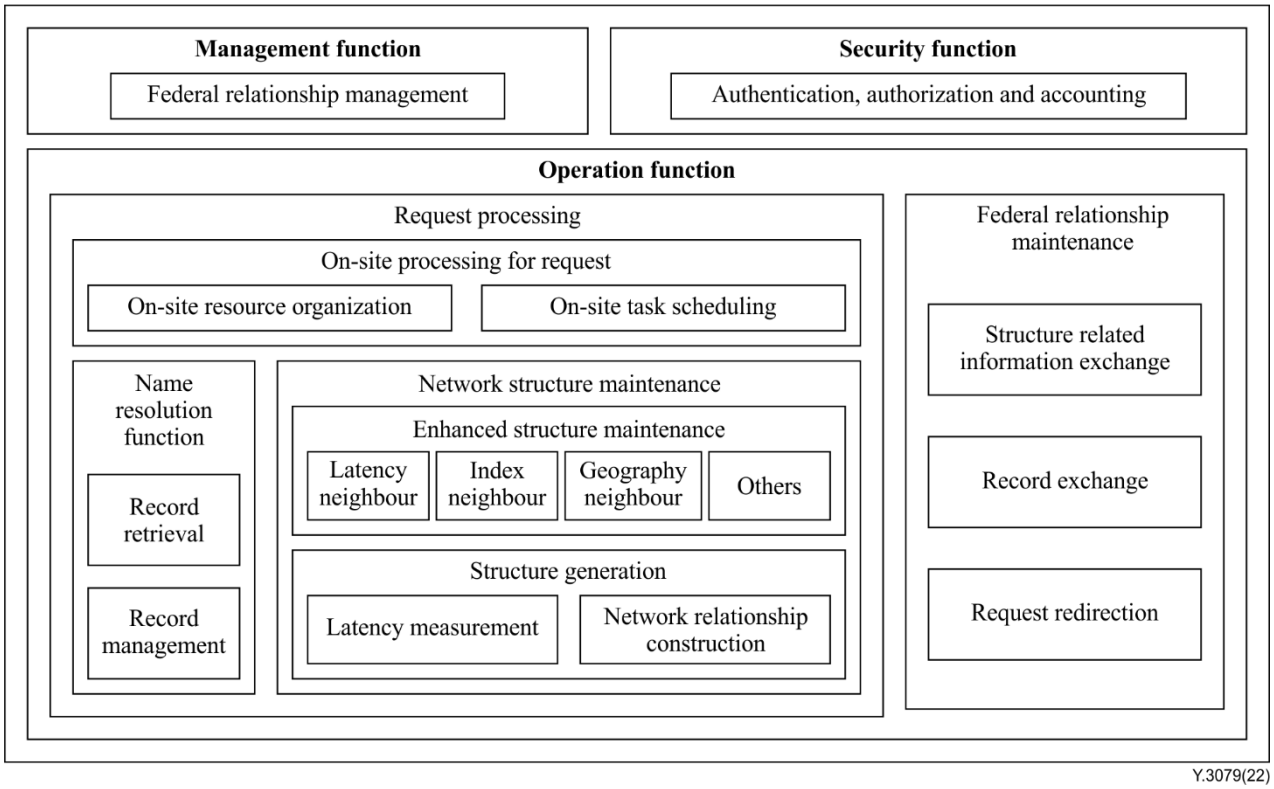

Figure 2 – Key functions of locally enhanced name mapping and resolution to satisfy the requirements of deterministic latency and scalability

Operation function

An OF includes an RP function and federal relationship maintenance (FRM) function. An RP function deals with NMR RP and hierarchical structure maintenance with other NMR nodes and users based on transmission latency. An FRM function deals with the cooperation of NMR nodes in different administration domains.

1) Request processing

In the RP function, there are three parts, including: name resolution function; network structure maintenance; and on-site processing for request.

The *name resolution function* is a module that manages mapping records stored in the NMR node and provides an interaction interface for retrieval. In this function, record management includes registration, expiry and deletion; record retrieval is used to guarantee that the retrieved record can be responded to in a deterministic latency, which should be realized by some strategies or algorithms.

Network structure maintenance is a function for constructing NMR nodes according to certain management structures, which are generated based on the transmission latency between nodes, and used to guarantee the network transmission latency of requests. The structure is helpful for users to locate the appropriate NMR node to provide the deterministic transmission latency.

– *Structure generation* is a module to manage all NMR nodes in a logical structure that is generated in advance based on the transmission latency between NMR nodes and registration relationships between NMR users and the corresponding NMR node. For example, a nested structure is applied, in which nodes at the same level of the structure can provide the same deterministic transmission latency for a group of users.
  - *Latency measurement* is a function for measuring network metrics between two NMR nodes or between an NMR user and an NMR node, which is mainly used to obtain the latency for constructing the network structure for NMR nodes.
  - *Network relationship construction* is a module that can construct all nodes in the network as a logical structure based on the measured latency.

– *Enhanced structure maintenance* is a module that generates and maintains some neighbour relationships based on the logical structure generated by a network structure maintenance module. The neighbour relationships can be used to provide cooperative service among NMR nodes.
  - *Latency neighbour*: Each NMR node maintains a latency neighbour set, and the latency between this NMR node and any node in this neighbour set is lower than a specified maximum latency bound. Meanwhile, all nodes in this neighbour set should provide the name resolution service within the same deterministic latency. For example, some requests can be sent to latency neighbours concurrently, which may enhance the reliability of the service performance.
  - *Geographic neighbour*: Each NMR node maintains a geographic neighbour set, which contains node(s) near to it. Similarly, all nodes in this neighbour set should provide the name resolution service within the same deterministic latency. For example, when a device moves, the new service node near the location the device moves to may be found quickly from the geographic neighbours.
  - *Index neighbour*: Each NMR node maintains an index neighbour set, in which all nodes should provide the name resolution service within a smaller deterministic latency than that provided by this NMR node. Meanwhile, at least some of the mapping records in this NMR node could be stored in its index neighbours. When the workload of this NMR node is too heavy, its index neighbours can undertake some requests and balance its workload.

- *Others*: Each NMR node may maintain other neighbour sets based on some strategies, e.g., the request context, which can be used to collaboratively serve users with the NMR node together to improve service performance.

On-site processing for request is a module to organize the resources from the structured neighbours, and schedule request from NMR users with the appropriate resources, which can guarantee the response obtained within a certain deterministic latency.

– *On-site resource organization*: Based on the request requirements, appropriate nodes that can provide the cooperative service and satisfy the latency requirements are chosen, and corresponding resources are organized for scheduling.

– *On-site task scheduling*: Received request(s) will be assigned to the appropriate node(s) to satisfy its or their latency requirements. An algorithm or strategies should be executed in this module.

2) Federal relationship maintenance

A set of NMR service providers is in a federal relationship if they can share their name records to extend the service coverage based on some specific interface. FRM is designed to alleviate the scalability problem caused by the increasing number of administration domains for NMR service nodes. The function of FRM consists of: request redirection; structure-related information exchange; and record exchange. Uniform mapping records would contribute to supporting the interaction among different administration domains in a federal manner.

Structure-related information exchange is used to support federal interaction between NMR systems with different administrations by reliably transferring network structure-related information about one NMR system to others, e.g., in the neighbour relationship of some NMR nodes.

Record exchange is used to support federal interaction between NMR systems with different administrations by safely exchanging record information.

Request redirection is used to support federal interaction among many administration domains by securely forwarding requests for NMR.

In addition, *federal relationship management* in the MF and authentication, as well as authorization and accounting in the SF, are designed to exchange information among different administration domains.

9 Architectural framework of locally enhanced name mapping and resolution

To realize the structures for deterministic latency and scalability described in clauses 7 and 8, the architectural framework of a locally enhanced name mapping and resolution system (LNMRS) is designed, as shown in Figure 3. A requester (REQ) of an LNMRS can be a network element such as a switch or piece of user equipment. A broker (BRO) is an entry executing the locally enhanced NMR service to a device for mobility in order to determine where the current mobile device is in the event of its location change. A global name mapping and resolution system (GNMRS) usually contains the mapping and resolution information of the entire network, and is deployed in the cloud or in the network. In addition, based on the key functions in clause 8, there are three functional modules in an LNMRS, including MF, SF and OF. An OF contains both RP and FRM functions.

I_Q is the interface between REQ and LNMRS, which is used to propose request to LNMRS.

I_B is the interface between BRO and LNMRS, by which BRO can obtain RNL from LNMRS.

I_R is an interface between LNMRS and GNMRS, which is used to exchange information between these two systems and update the local information stored in LNMRS to GNMRS.

I_E is an interface that connects to other LNMRSs to build a federal relationship to improve performance and extend service coverage.

When a request is proposed by REQ, it is first sent to the LNMRS. If the request can be processed by LNMRS, it responds to the REQ within the deterministic latency; otherwise, the request can be forwarded to GNMRS, and GNMRS responds to the REQ without a guarantee of deterministic latency.

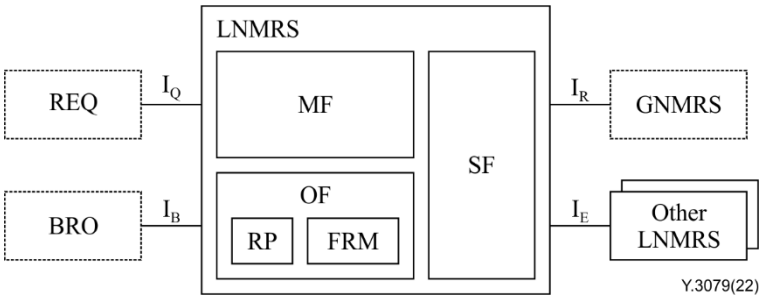

Figure 3 – The architectural framework of locally enhanced name mapping and resolution

10 Security considerations

To support the functionalities of NMR, different kinds of security threats should be considered.

System security: The NMR system is composed of NMR nodes, and a security management mechanism for NMR nodes is required. In order to prevent attacking the NMR system by connecting malicious or illegal nodes, authentication and authorization are required before communication and exchanging information among NMR nodes.

User security: It is necessary to have a mechanism of authentication, authorization and access control for NMR users to avoid illegal users. At the same time, it should have the capability to detect and resist the abnormal and attack behaviour of users. For example, if a user sends a large number of service requests to the same NMR node within a short period of time, the NMR node may provide services abnormally. Therefore, it needs to be able to detect and identify user attack behaviour, and have the capability to resist the attack to ensure normal service provision.

Mapping records security: When registering mapping records on LNMRS nodes, verification is required of both the authority of users and whether the user is in the resolution service domain of this LNMRS node. Only authorized users in the domain covered by the LNMRS node can register records in it. When deleting records, it is necessary to verify whether the user has the permission to delete them. The privileges of users or user groups should be managed. Only authorized users or user groups have the permission to delete mapping records. Meanwhile, encryption should be considered to protect the mapping records.

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