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SERIES X: DATA NETWORKS, OPEN SYSTEM COMMUNICATIONS AND SECURITY

OSI networking and system aspects – Networking

Managed peer-to-peer (P2P) communications: Functional architecture

Recommendation ITU-T X.609

International Telecommunication Union

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Recommendation ITU-T X.609

Managed peer-to-peer (P2P) communications: Functional architecture

Summary

Recommendation ITU-T X.609 describes the detailed functional architecture of managed P2P networking and the information flows for providing managed P2P-based services.

A peer-to-peer (P2P) network is composed of participants called peers that share their available resources such as processing power, storage or network resources that are available to other participants without central coordination. P2P networking characteristics include self-organization, high scalability and sharing of resources among many other participants. These characteristics mean that P2P technology can be used in various applications such as file distribution, distributed computing, VoIP, media streaming, etc. In spite of various advantages such as high scalability and high throughput, P2P networking may incur problems such as high churn, illegal distribution of content or absence of distribution control. Managed P2P networking aims to provide manageability features for P2P networking.

History

Edition	Recommendation	Approval	Study Group	Unique ID*
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FOREWORD

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In some areas of information technology which fall within ITU-T's purview, the necessary standards are prepared on a collaborative basis with ISO and IEC.

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In this Recommendation, the expression "Administration" is used for conciseness to indicate both a telecommunication administration and a recognized operating agency.

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As of the date of approval of this Recommendation, ITU had received notice of intellectual property, protected by patents, which may be required to implement this Recommendation. However, implementers are cautioned that this may not represent the latest information and are therefore strongly urged to consult the TSB patent database at http://www.itu.int/ITU-T/ipr/.

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Managed peer-to-peer (P2P) communications: Functional architecture

1 Scope

This Recommendation describes the functional architecture of managed P2P as follows:

– overview of managed P2P framework;

– functional architecture of managed P2P;

– reference points;

– information flows.

This Recommendation extends the framework of managed P2P defined in [ISO/IEC TR 20002] to describe in more detail functional entities for providing manageability features to P2P-based services.

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.

[ISO/IEC TR 20002] ISO/IEC TR 20002:2012, *Information technology – Telecommunications and information exchange between systems – Managed P2P: Framework*.

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 content delivery [b-ITU-T Y.2080]: In the context of the DSN functional architecture, the operation of sending and receiving content between the requested peer and the requesting peer or client.

NOTE – A client is a service consumer external to DSN. A peer is a node within DSN.

3.1.2 content distribution [b-ITU-T Y.2080]: In the context of the DSN functional architecture, the whole process of content sending from one or more content sources, and sharing among DSN nodes.

NOTE – During the content distribution process, content is often sent to appropriate intermediate nodes to enable subsequent delivery.

3.1.3 control plane [b-ITU-T G.8081]: The control plane performs the call control and connection control functions. Through signalling, the control plane sets up and releases connections, and may restore a connection in case of a failure. The control plane also performs other functions in support of call and connection control, such as routing information dissemination.

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

3.1.5 functional entity [b-ITU-T Y.2012]: An entity that comprises an indivisible set of specific functions. Functional entities are logical concepts, while groupings of functional entities are used to describe practical, physical implementations.

3.1.6 managed P2P [ISO/IEC TR 20002]: P2P with manageability features to manage the P2P-based service and P2P network by the P2P participants such as P2P service provider, ISP, and peer.

3.1.7 overlay network [b-ITU-T X.1162]: An overlay network is a virtual network that runs on top of another network. Like any other network, the overlay network comprises a set of nodes and links between them. Because the links are logical ones, they may correspond to many physical links of the underlying network.

3.1.8 peer [b-ITU-T X.1161]: Communication node on P2P network that functions simultaneously as both "client" and "server" to the other nodes on the network.

3.1.9 peer-to-peer (P2P) [b-ITU-T Y.2206]: A system is considered to be P2P if the nodes of the system share their resources in order to provide the service the system supports. The nodes in the system both provide services to other nodes and request services from other nodes.

NOTE – Peer is the node in a P2P system.

3.1.10 user profile [b-ITU-T Q.1741.4]: The set of information necessary to provide a user with a consistent, personalized service environment, irrespective of the user's location or the terminal used (within the limitations of the terminal and the serving network).

3.1.11 reference point [b-ITU-T Y.2012]: A conceptual point at the conjunction of two non-overlapping functional entities that can be used to identify the type of information passing between these functional entities.

3.2 Terms defined in this Recommendation

This Recommendation defines the following terms:

3.2.1 buffermap: A map showing the downloading status of fragments comprising a shared content.

3.2.2 delivery: The procedures and means employed to provide a user with the required archived material for reuse.

3.2.3 fragment: A piece of the shared content.

3.2.4 fragmentation: A process that divides the shared content into multiple fragments in order to share the content in a distributed manner.

3.2.5 metadata: The parts of Content which describe the Essence and other aspects of the program material.

3.2.6 peer status information: Both the dynamic and static status information of a peer. The dynamic status information describes the activity of a peer in the participating overlay network. The static status information describes a peer's activity configuration.

3.2.7 resource virtualization: Creation of virtual resources comprised of parts of resources or whole resources shared by the participating peers. The virtual resources can be utilized by peers for a certain purpose.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

BC Buffermap Comparison

BM Buffermap Management

CIM	Content Information Management
CMM	Content Meta-information Management
CP	Content Provider
CR	Content Reconstruction
CS	Cache Server
CSR	Cache Server Resource
CSRM	Cache Server Resource Management
DD	Data Delivery
DE	Data Exchange
DR	Data Relay
FE	Functional Entity
FW	Firewall
ISP	Internet Service Provider
IXS	Index Server
LBIM	Local Buffermap Information Management
LPM	Local Profile Management
MIC	Meta Information Management
MP2P	Managed Peer-to-Peer
NIP	Network Information Management
OIM	Overlay Information Management
OMS	Overlay Management Server
ONIM	Overlay Network Information Management
ONM	Overlay Network Management
ONMP	Overlay Network Management Peer
ONRIM	Overlay Network Resource Information Management
ORC	Overlay Resource Control
ORM	Overlay Resource Management
OSPF	Open Shortest Path First
P2P	Peer-to-Peer
P2PSP	P2P Service Provider
PAIM	Peer Activity Information Management
PAM	Peer Activity Management
PAMS	Peer Management Server
PC	Peer Communication
PDC	Peer Distance Calculation
PIA	Peer Information Analysing
PLM	Peer List Management

PLO Peer List Optimizing

PPIM Peer Profile Information Management

PPM Peer profile Management

PRM Peer Resource Management

RBIM Remote Buffermap Information Management

RIP Routing Information Protocol

RMIM Relay Mapping Information Management

RS Relay Server

RSM Resource Status Management

RSR Relay Server Resource

RSRM Relay Server Resource Management

RUIM Resource Usage Information Management

RV Resource Virtualization

UAL User Activity Logging

UIM User Information Management

UMS User Management Server

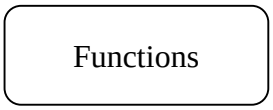
UNIS Underlying Network Information Server

VoIP Voice over IP

5 Conventions

In this Recommendation:

– The keyword "functions" is defined as a collection of functionalities and is represented by the following symbol:



– The keyword "functional entity" (FE) is defined as a group of functionalities that has not been further subdivided at the level of detail described. It is represented by the following symbol:

NOTE – In the future, other groups or other Recommendations may possibly further subdivide these functional blocks.

Frame borders of "functions" and a "functional entity" and relational lines among "functions" and a "functional entity" are drawn with solid lines or dashed lines. The solid lines represent required functionalities or relations. While the dashed lines represent the optional functionalities or relations.

6 Overview

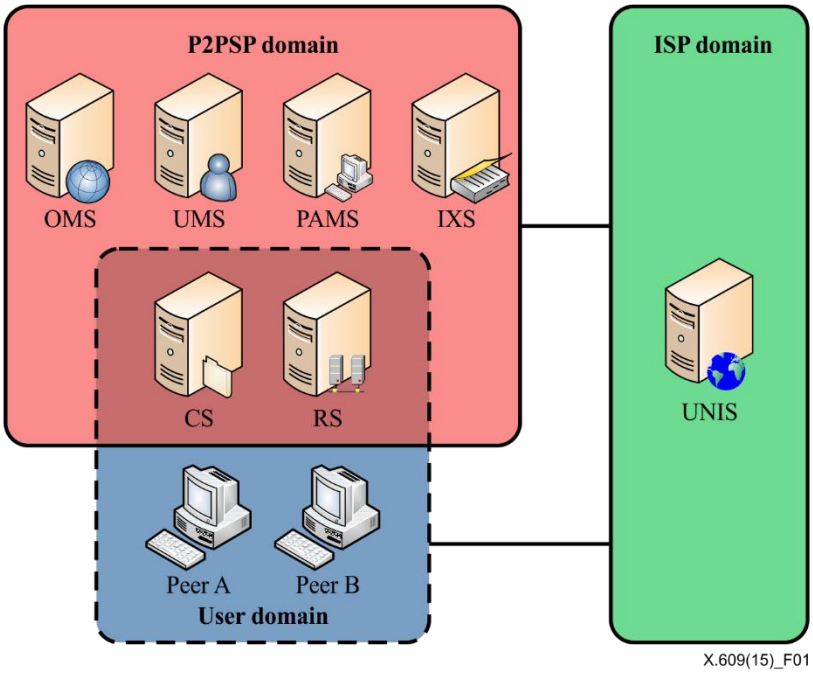
A peer-to-peer (P2P) network is a kind of decentralized communication model in which the participants (called peers) share their resources such as computing power and storage, or network

resources to be used by other participants in the P2P network. Unlike the client-server model, peers are equally privileged as both server and client in the P2P networks. The P2P network is a self-organized network composed of peers and is capable of adapting to the dynamics of peers without central coordination. The P2P network provides high scalability since each peer shares resources with other peers rather than requesting a designated server. P2P networking has been used in various applications such as file distribution, distributed computing, VoIP, multimedia streaming, etc.

In spite of its advantages, P2P networking has several problems such as conflicts with the ISP, unequal load distribution, high churn, no distribution control, illegal distribution of contents, etc. [ISO/IEC TR 20002], *Information technology – Telecommunications and information exchange between systems – Managed P2P: Framework*, addresses these problems and describes requirements and a framework of managed P2P that provides manageability features for P2P networks in order to solve or ease the problems. [ISO/IEC TR 20002] also addresses requirements and the framework of managed P2P.

6.1 MP2P framework defined in [ISO/IEC TR 20002]

The framework of the managed P2P (MP2P) network defined in [ISO/IEC TR 20002] is shown in Figure 1. The framework consists of various entities to provide manageability features to the P2P network.



UMS: user profile management server
OMS: overlay management server
PAMS: peer activity management server
RS: relay server
CS: cache server
IXS: index server
UNIS: underlying network information server

Figure 1 – Framework of MP2P

The framework of MP2P consists of three domains, i.e., the user domain, the P2P service provider (P2PSP) domain and the Internet service provider (ISP) domain. The following eight logical entities are defined:

– **Overlay management server (OMS)**: The OMS manages the MP2P network and assists peers joining the MP2P network. Through interaction with the underlying network information server (UNIS), the OMS can provide the optimum peer list to organize an optimal MP2P network.

– **User profile management server (UMS)**: The UMS maintains and provides user information in a service point of view for manageability features when the OMS requests information.

– **Peer activity management server (PAMS)**: The PAMS aggregates the status information of each peer in the MP2P network and sends the collected information to the OMS for management of the overlay network. Status information is reported by the participating peers when appropriate. This server can interact with the UMS to provide the peer activity information for charging or incentives.

– **Index server (IXS)**: The IXS provides service-specific information such as contents meta-information, the overlay network identifier and the OMS address. The information varies depending on the type of service on the MP2P network.

– **Cache server (CS)**: The CS provides caching of contents to stabilize the MP2P-based service.

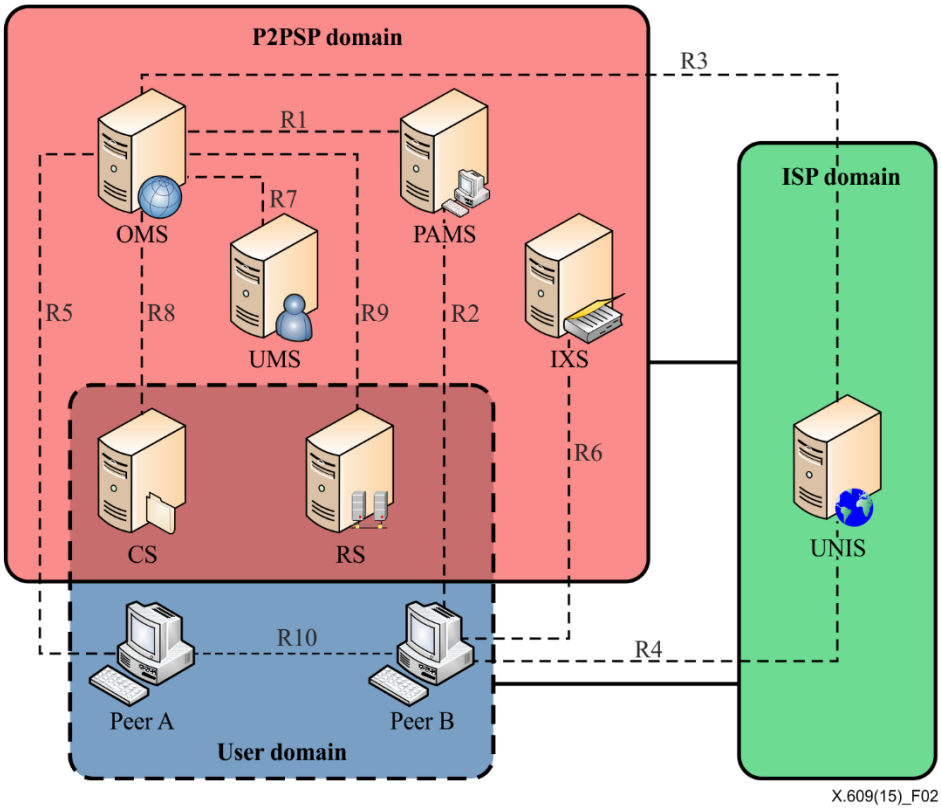
– **Relay server (RS)**: The RS is used to relay traffic to assist the peer behind the network address translator and/or firewall (NAT/FW) to properly join the P2P network.

– **Peer**: As a provider and a consumer of the MP2P-based service, the peer is an essential entity of an MP2P framework. Each peer shares its resources with other peers in the same overlay network.

– **Underlying network information server (UNIS)**: The UNIS is a dedicated server that belongs to the ISP and provides a set of network distance information among peers in the MP2P network. The UNIS can interact with both peers and the OMS.

7 Functional architecture of a managed P2P

This Recommendation defines the functional architecture for MP2P based on the MP2P framework and requirements identified in [ISO/IEC TR 20002]. The framework and reference points of MP2P are shown in Figure 2.



UMS: user profile management server
OMS: overlay management server
PAMS: peer activity management server
RS: relay server
CS: cache server
IXS: index server
UNIS: underlying network information server

Figure 2 – Framework and reference points of managed P2P

This clause defines the detailed functional architecture of each entity in the MP2P framework. The reference points are described in clause 8.

7.1 User management server (UMS)

The UMS manages user (subscribers) information such as user profile, preferences and the information related to the service activities. The information can be used for managing MP2P-based services, incentive mechanisms, billings, etc. The UMS is composed of user information management (UIM) functions as shown in Figure 3.

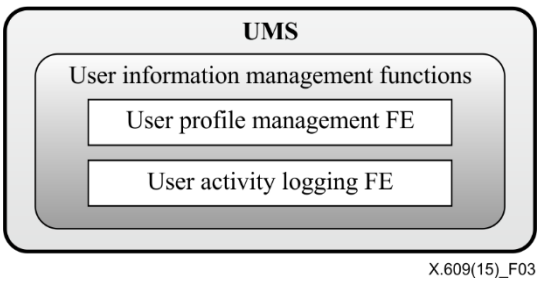


Figure 3 – Functional architecture of UMS

7.1.1 User information management (UIM) functions

The UIM functions manage user-related information that consists mainly of user-created information and activity information. User-created information includes user profiles and peer configurations; user profile is the information in a service perspective and peer configuration is the information in a P2P network perspective. The user-created information can be used to provide user specific services such as the granting of benefits to higher contributors. This can be accomplished through reputation

and incentive mechanisms. The UIM functions consist of user profile management (UPM) FE and user activity logging (UAL) FE.

7.1.1.1 User profile management (UPM) FE

The UPM FE maintains the information of the P2P-based service subscriber that pertains to a single user account. A user is distinguished from the "peer", since a single user can possess more than one peer. The UPM FE stores and manages the user profile which may contain the information related to an account such as user ID, user reputation, subscription, preference, registered devices, service area, etc. The UPM FE is responsible for responding to requests for user-related information.

7.1.1.2 User activity logging (UAL) FE

The UAL FE retrieves activity information of a peer from the PAMS and logs the peer activity to be used for accounting for the user. The logged data is the peer activity information that can be used for providing incentives or penalties to the pertaining user.

7.2 Peer activity management server (PAMS)

The PAMS aggregates the peer status information to be used for manageability. PAMS can analyse the aggregated information to understand the status of the MP2P network. The aggregated information is provided to the OMS to manage the MP2P network and to the UMS to manage the peer activity information. The PAMS consists of peer activity information management (PAIM) functions as shown in Figure 4.

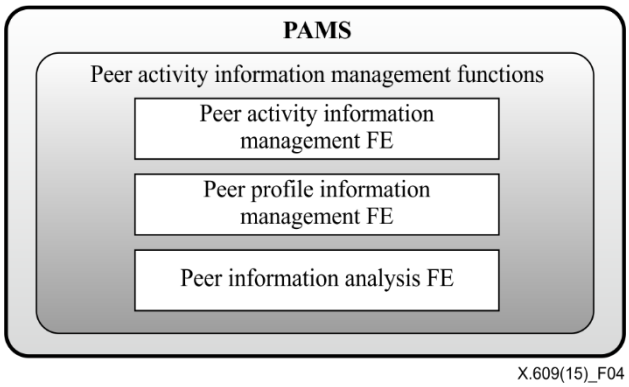


Figure 4 – Functional architecture of PAMS

7.2.1 Peer activity information management (PAIM) functions

PAIM functions keep track of both dynamic and static status information of peer. PAMS receives reports from peer directly and aggregates the received reports. PAMS can analyse the aggregated information and provides the analysis results to OMS/UMS upon the request from OMS/UMS. PAMS can send the analysis results without the request, if there is a predefined agreement for sending the results. PAIM functions consist of peer activity information management (PAIM) FE, peer profile information management (PPIM) FE and peer information analysis (PIA) FE.

7.2.1.1 Peer activity information management (PAIM) FE

Information used by the PAIM FE to keep track of a peer's dynamic information includes:

– physical network status information such as incoming bandwidth and outgoing bandwidth;

– overlay network status information such as failure of peer connection or the amount of data sending/receiving to/from other peers;

– system status information such as load status, storage status, etc.

In other words, the PAIM FE aggregates various types of dynamic information by receiving reports from peers. The reports from peers include the periodically generated report and the report on the

predefined event. The activity information received from peers tends to be changed as time flows. Since information from the past may be meaningless in the present, the reported information should be updated upon receiving the newly reported information.

7.2.1.2 Peer profile information management (PPIM) FE

The PPIM FE manages static peer information that includes peer profile information such as:

– configurations/preferences such as maximum upload/download capacity and maximum number of peer connections;

– behaviour policy of the peer, etc.

Note that the information maintained by the PPIM FE is not dynamic information, thus it does not change frequently.

7.2.1.3 Peer information analysis (PIA) FE

The PIA FE analyses both the static and dynamic information of peers; the OMS can utilize the analysis results to keep the overlay network up-to-date. The OMS may request the analysis results regarding every peer or selected peer(s).

7.3 Overlay management server (OMS)

The OMS manages overall overlay network information to provide a well-organized overlay network and to control resources within the overlay network. Each peer interacts with the OMS to join and leave the overlay network. In order to provide the optimal peer list to the peer joining a specific overlay network, the OMS can interact with the PAMS, the UNIS and the UMS. The OMS is composed of overlay network management (ONM) functions and overlay resource management (ORM) functions as shown in Figure 5.

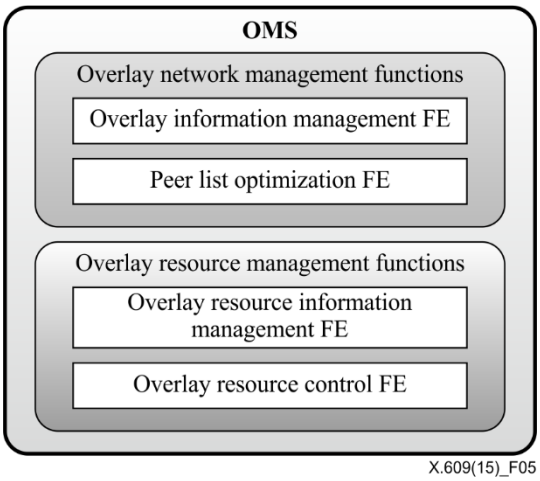


Figure 5 – Functional architecture of the OMS

7.3.1 Overlay network management (ONM) functions

The ONM functions keep track of overlay network information and peer information. ONM functions interact with peers regarding behaviour such as the creation/removal of the overlay network and the joining/leaving of peers. This function also interacts with the UNIS, PAMS and UMS in order to retrieve several parameters for peer list optimization. ONM functions consist of the overlay information management (OIM) FE and the peer list optimization (PLO) FE.

7.3.1.1 Overlay information management (OIM) FE

The OIM FE manages the information of overlay networks such as the overlay network ID, the number of peers, relay server information, cache server information, lifetime, etc. Peer information

includes the peer ID and network address used in communication. When the OMS receives the overlay network join request from a peer, the OIM FE determines whether the request is acceptable and then responds to the request. In addition, when a peer joins an overlay network, the OIM FE can recommend other overlay networks organized to share the related contents as described in clause 9.3. The OIM FE also supports a closed overlay network by using the membership control and can expel a specific peer from the overlay network if it decides the peer is not appropriate in participating in the overlay network. If a peer requests to allocate the overlay resources such as CS and RS, the OIM FE can allocate the requested resources by interacting with the overlay resource control (ORC) FE.

7.3.1.2 Peer list optimization (PLO) FE

The PLO FE creates an optimized peer list from the given peer list. The PLO FE can interact with the UNIS, PAMS and UMS to fetch the information for creating the optimized list.

7.3.2 Overlay resource management (ORM) functions

ORM functions take control of the overlay resources of the overlay network. It is possible to utilize the cache server (CS) and the relay server (RS) residing in the P2PSP domain to organize the overlay network to provide better performance and more stability. ORM functions interact with the CS and RS to manage the overlay resources. The ORM functions consist of overlay resource information management (ORIM) FE and overlay resource control (ORC) FE.

7.3.2.1 Overlay resource information management (ORIM) FE

The ORIM FE maintains the overlay resource information such as availability, usage, etc. of the CS/RS under the control of the OMS. However, it does not store nor maintain CS/RS usage history; the CS/RS maintains its own usage history. Upon reception of usage information from the CS/RS, the ORIM FE forwards the usage information to the UMS.

7.3.2.2 Overlay resource control (ORC) FE

The ORC FE controls the functionalities of the CS/RS by reserving their resources and then instructing the CS/RS to join the particular overlay network. Through this procedure, the ORC FE can allocate the resources of the CS/RS to be used for the overlay network; the allocated resources include up/downlink bandwidth, maximum number of connections, etc.

7.4 Underlying network information server (UNIS)

The UNIS is located in the ISP domain and provides physical network related information. The network information may include network status such as routing metrics or network distance between designated peers, etc. In general, the UNIS interacts with the OMS, but it is also able to interact with peers and the CS as well. Whether or not the UNIS provides the information to the entities located in the user domain depends upon the ISP's policy. The UNIS is composed of network information management (NIM) functions as shown in Figure 6.

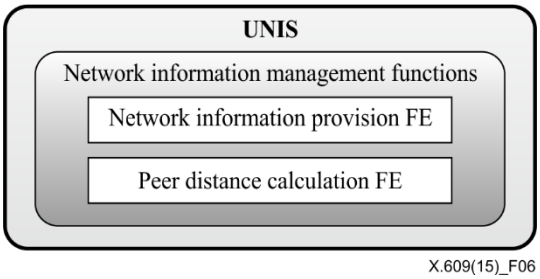


Figure 6 – Functional architecture of UNIS

7.4.1 Network information management (NIM) functions

NIM functions calculate distance and costs between two specific end-points by using metrics from routing protocols such as open shortest path first (OSPF) and routing information protocol (RIP). NIM functions may filter the information based on the predefined policy. NIM functions consist of the network information provision (NIP) FE and the peer distance calculation (PDC) FE.

7.4.1.1 Network information provision (NIP) FE

The NIP FE provides distance information to the requester, which can be a peer or an OMS, based on the network topology perspective and ISP preference.

7.4.1.2 Peer distance calculation (PDC) FE

The PDC FE performs a cost calculation between the two specific end-points using the network information provided by NIP FE. For a given two or more peers, the PDC FE can sort the peers by distance/cost from the network topology perspective.

7.5 Index server (IXS)

The IXS maintains meta-information related to a specific content. The IXS also maintains mapping information between content and the overlay network which is organized to share the content. The IXS is composed of content information management (CIM) functions as shown in Figure 7.

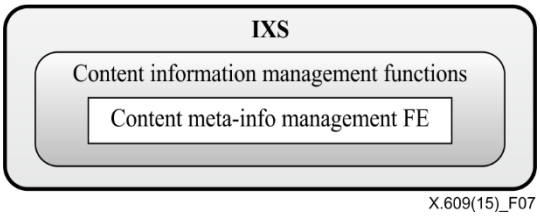


Figure 7 – Functional architecture of IXS

7.5.1 Content information management (CIM) functions

CIM functions register a specific content with a meta-information and it can provide the meta-information including the overlay network ID to other users; the overlay network ID is used as a key to join a specific overlay network. The CIM functions consist of content meta-information management (CMM) FE.

7.5.1.1 Content meta-information management (CMM) FE

The CMM FE stores, manages and extracts the meta-information for contents. A single content presented by a meta-information corresponds to an overlay network; therefore a user can discover either a specific content or a specific overlay network by using the meta-information. The meta-information is generated by the content owner.

When the IXS receives a request for meta-information regarding a specific content or specific overlay network, the CMM FE is responsible for responding to the request.

7.6 Peer

A peer can share its resource(s), such as content and computing power, with other peer(s) by exchanging messages. A peer can also act as a CS or RS based on the configuration, see Figure 8 for a description of the functional architecture of a peer.

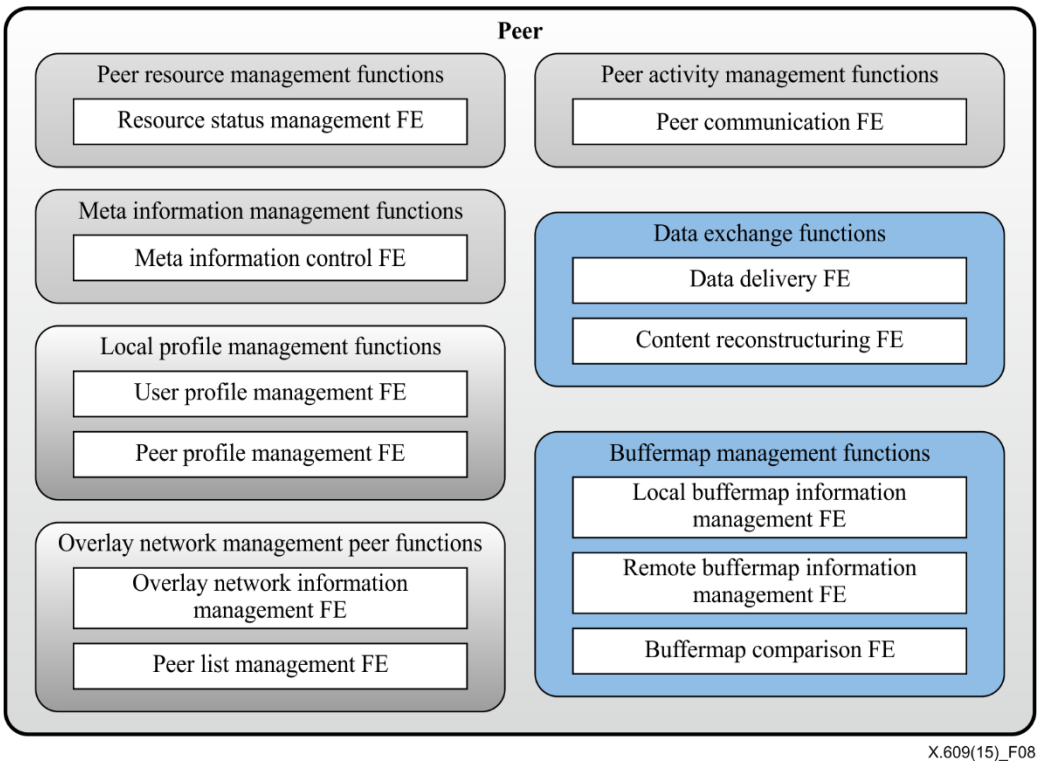


Figure 8 – Functional architecture of peer

The functions of the peer can be classified into two planes; control plane and data plane.

The functions in the control plane perform the connectivity management among the peer/CS/RS, the decision for participation in the overlay network and the report of activity status. The control plane consists of peer resource management (PRM) functions, meta-information management (MIM) functions, local profile management (LPM) functions, overlay network management peer (ONMP) functions and peer activity management (PAM) functions.

The functions residing in the data plane perform buffer management and data exchange with the peer/CS/RS. The data plane consists of data exchange (DE) functions and buffermap management (BM) functions.

7.6.1 Peer resource management (PRM) functions

The PRM functions manage the peer's resource status. Based on the resource status, the peer can decide whether to accept the other peer's resource request. The PRM functions consist of the resource status management (RSM) FE.

7.6.1.1 Resource status management (RSM) FE

The RSM FE manages the information of the resource shared for P2P services such as storage space, network capability, contents, etc. It can also manage the information on usage policy and/or usage statistics. The RSM FE is also used to report peer activity information to the PAMS.

7.6.2 Meta information management (MIM) functions

The MIM functions manage meta-information for resource sharing. The instances of this meta-information include information of the resource to be shared, the network address of the OMS, overlay network ID and fragmentation information. The fragmentation information includes the number of the fragment, fragment size and the hash value for integrity.

NOTE – The hash value of the resource information can be used as an overlay network ID.

The MIM functions consist of meta-information control (MIC) FE.

7.6.2.1 Meta information control (MIC) FE

The MIC FE creates and registers the meta-information to be registered in the IXS. The MIC FE can also search the meta-information registered in the IXS. A peer of a contents owner creates and registers the meta-information to the IXS, while the other peers can search for the contents using the keyword of the meta-information through this FE.

The MIC FE also generates fragment information for content by logically slicing the contents with fixed size to be distributed.

7.6.3 Local profile management (LPM) functions

The LPM functions manage profiles of peer activity. The managed profile can be classified into two types; the user profile for service level and the peer profile for overlay network level. The LPM functions consist of user profile management (UPM) FE and peer profile management (PPM) FE.

7.6.3.1 User profile management (UPM) FE

The UPM FE defines and manages user profiles in the service level which may include User ID, password, e-mail address, etc.

7.6.3.2 Peer profile management (PPM) FE

The PPM FE defines and manages peer profiles to be used for participation in the overlay network. The profile may include maximum uplink/downlink bandwidth, maximum number of peers allowed in connectivity, preference, peer behaviour policy, etc.

7.6.4 Overlay network management peer (ONMP) functions

The ONMP functions manage the information on the overlay network(s) in which the peer is participating and the information of the peer list for each overlay network. The ONMP functions consist of the overlay network information management (ONIM) FE and the peer list management (PLM) FE.

7.6.4.1 Overlay network information management (ONIM) FE

The ONIM FE manages the information of the overlay network that the peer is participating in. The information includes the overlay network ID, OMS information, etc. The ONIM FE can interact with the OIM FE in the OMS to participate in an overlay network. The content owner peer is the initial sender. It can create the distribution control policy and send the policy to the OMS for membership control. ONIM interacts with the OIM FE in the OMS to request overlay resources.

7.6.4.2 Peer list management (PLM) FE

The PLM FE manages the list of peers that are participating in the same overlay network. The peer list can be acquired from the OMS or other peers. The managed information includes peer ID, the network address for communication, networking cost, etc.

7.6.5 Peer activity management (PAM) functions

The PAM functions provide functionalities to communicate with other entities of MP2P functional architecture. Overlay network participation, meta-information registration/retrieval, and peer communication such as buffermap information and data exchange can be examples of peer activity. The PAM functions consist of peer communication (PC) FE.

7.6.5.1 Peer communication (PC) FE

The PC FE interacts with the PC FE within a remote entity in order to exchange messages or to control data exchange among peers.

7.6.6 Data exchange (DE) functions

The DE functions send and receive data. This indicates that other functions can send or receive data through the DE functions. The DE functions consist of the data delivery (DD) FE and the content reconstruction (CR) FE.

7.6.6.1 Data delivery (DD) FE

The DD FE interacts with the DD FE within a remote entity in order to send and receive data. The DD FE also reports delivery statistics to the PAMS.

7.6.6.2 Content reconstruction (CR) FE

The CR FE combines the received fragments into content. The CR FE needs meta-information from the MIM FE.

7.6.7 Buffermap management (BM) functions

The BM functions manage local buffermap and the buffermap of other neighbouring peer(s). In addition, BM functions can conduct comparisons between local buffermap and the buffermap of other neighbouring peer(s). The BM functions consist of local buffermap information management (LBIM) FE, remote buffermap information management (RBIM) FE and buffermap comparison (BC) FE.

7.6.7.1 Local buffermap information management (LBIM) FE

The LBIM FE creates, updates and manages the local buffermap based on the information received from the DD FE.

7.6.7.2 Remote buffermap information management (RBIM) FE

The RBIM FE creates, updates and manages the buffermap of other peers. The RBIM distinguishes each buffermap with a peer ID.

7.6.7.3 Buffermap comparison (BC) FE

The BC FE performs comparisons of the buffermaps of the LBIM with the buffermap of the RBIM. The peer can discover the needed data (i.e., content fragments) that can be provided by the pertaining peer.

7.7 Cache server (CS)

The cache server (CS) is a proxy for a peer that does not have enough resources to distribute or to download the content. The CS can participate in the overlay network on behalf of a peer that requests a proxy service and can conduct the requested operations such as content distribution or content download. In addition, the CS can be used to stabilize the overlay network by serving other peers in the same overlay network. The CS may be a dedicated server that P2PSP configures; it indicates that the CS may operate based on P2PSP's policy. See Figure 9 for a description of the functional architecture of a CS.

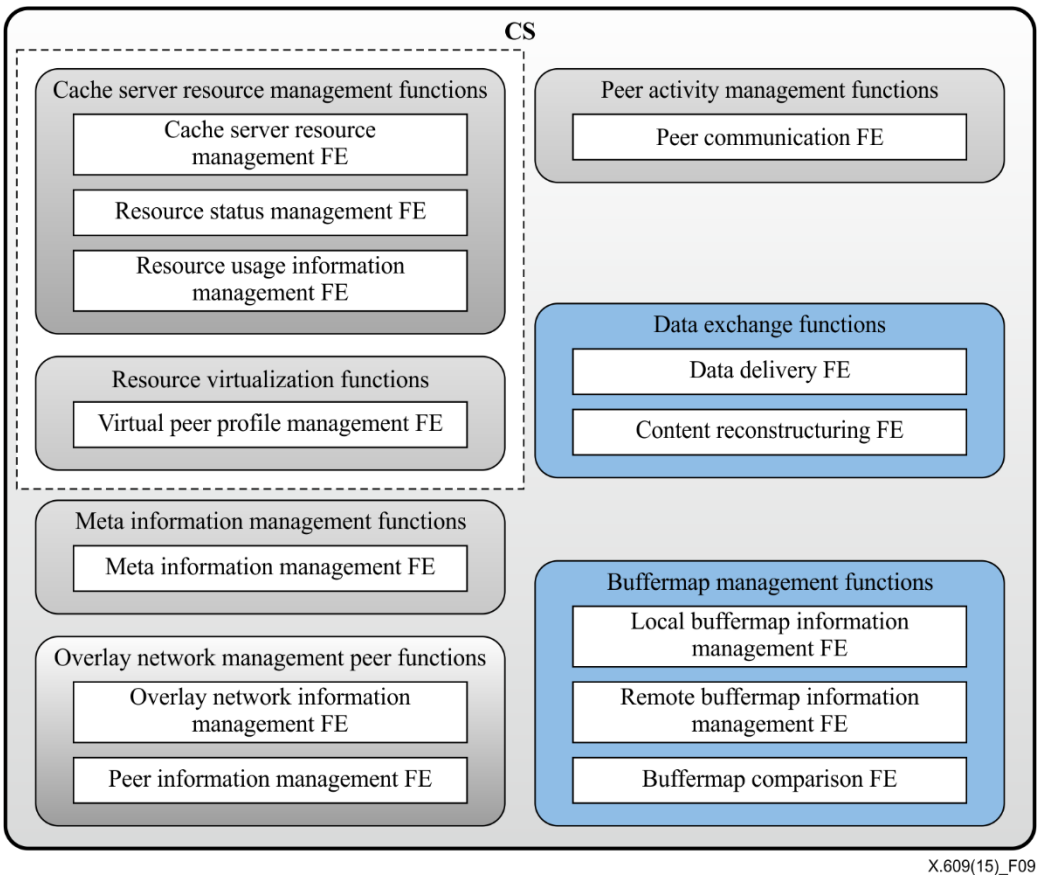


Figure 9 – Functional architecture of a CS

The functions of the CS can be classified into two planes; the control plane and the data plane. The control plane manages the connectivity with peers and CS/RS, the participation with the overlay network and the activity status to be reported. The functions in the control planes are the cache server resource management (CSRM) function, the meta-information management (MIM) function, the resource virtualization (RV) function, the overlay network management peer (ONMP) function and the peer activity management (PAM) function. The data plane conducts buffer management and data exchange with peers or with CS/RS. The functions in the data plane are data exchange (DE) functions and buffermap management (BM) functions.

NOTE – Functions except CSR functions and RV functions are equivalent to those in a peer.

7.7.1 Cache server resource (CSR) functions

The CSR functions control and manage CS resources. CSR functions maintain the status of the CS resources. Based on the status information, the CS can determine whether to accept a resource request. Since a peer can request the resource of a CS, the CS also maintains resource usage information per peer. The CSR functions consist of cache server resource management (CSRM) FE, resource status management (RSM) FE and resource usage information management (RUIM) FE.

7.7.1.1 Cache server resource management (CSRM) FE

The CSRM FE provides information on the available resources to the requestor and performs allocation of the requested resources. In order to allocate the requested resources, the CSRM FE needs to interact with the RSM FE and the RUIM FE.

7.7.1.2 Resource status management (RSM) FE

The RSM FE manages the information of the resources provided by the CS such as storage space, network capability, contents, etc.

7.7.1.3 Resource usage information management (RUIM) FE

The RUIM FE manages the resource usage status of each peer in order maintain usage statistics for each peer. This information will be delivered to the UMS, which manages the user information and activities, through the OMS.

7.7.2 Meta information management (MIM) functions

The functionalities are identical to the MIM functions of a peer, see clause 7.6.2.

7.7.3 Resource virtualization (RV) functions

The RV functions manage virtual peer profiles and service policy information for each requested resource. RV functions are needed, since a CS can be requested to operate as a peer for content download or content distribution. Thus a CS can make a virtual peer profile and service policy information when it allocates its resource for the requested service. The virtual peer profile is a peer profile for the overlay network corresponding to the requested service. Service policy information is the information of the service policy for service provision and termination. Both the virtual peer profile and service policy information are maintained until the allocated resource is released. The RV functions consist of virtual peer profile management (VPRM) FE.

7.7.3.1 Virtual peer profile management (VPPM) FE

The VPPM FE manages the virtual peer profile to act as a peer in the overlay network. The virtual peer profile is similar to the profile of an ordinary peer but the virtual peer profile may include service policy information such as service provision and service termination. Based on the virtual peer profile managed by VPPM FE, the CS can participate in the pre-specified overlay network and conducts the requested operations as a peer.

7.7.4 Overlay network management peer (ONMP) functions

The functionalities are identical to those of ONMP functions within a peer, see clause 7.6.4.

7.7.5 Peer activity management (PAM) functions

The functionalities are identical to those of PAM functions within a peer, see clause 7.6.5.

7.7.6 Data exchange (DE) functions

The functionalities are identical to those of DE functions within a peer, see clause 7.6.6.

7.7.7 Buffermap management (BM) functions

The functionalities are identical to those of BM functions within a peer, see clause 7.6.7.

7.8 Relay server (RS)

The relay server (RS) is used to relay contents to assist peers behind the NAT/FW. The RS maintains the connection with the peer behind NAT/FW to assist the peer in establishing a connection with other peers in the overlay network. An RS can be either a dedicated device (i.e., a dedicated RS) provided by the P2PSP or temporary contributing peer (i.e., a temporary RS). The dedicated RS is normally a trusted device that is controlled by the P2PSP, thus, if a problem occurs to this device, it is required to notify the OMS. The temporary RS is normally a peer that may stop the relay in anytime without notification. Thus, if a problem occurs to temporary RS, it is recommended to notify to OMS. See Figure 10 for a description of the functional architecture of an RS.

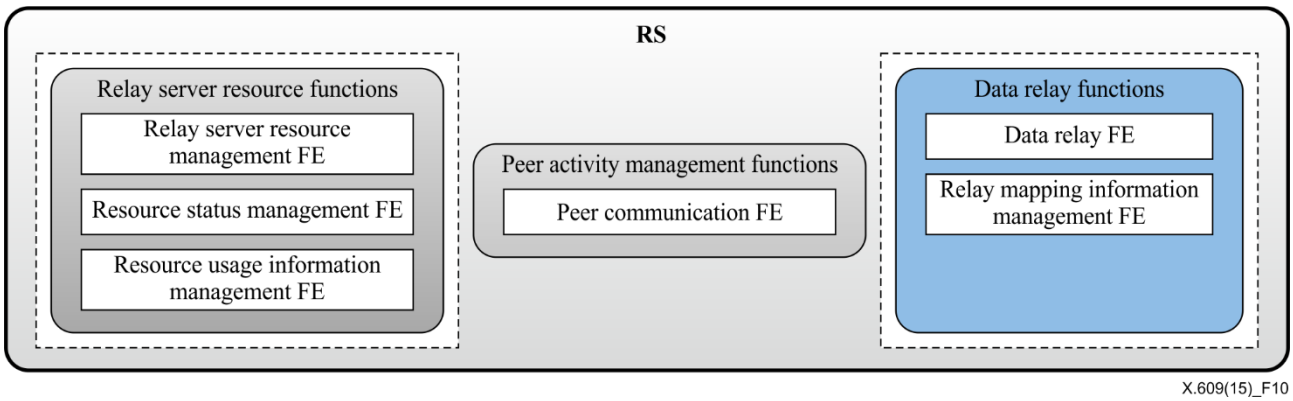


Figure 10 – Functional architecture of an RS

The functions of the RS can be separated into a control plane and a data plane. The control plane manages connectivity with peers (and CS/RS), subscription for a particular service, relay information and activity status to be used to report activity information. The functions in the control planes are relay server resource (RSR) functions and peer activity management (PAM) functions. The data plane manages local buffer, exchange data with other peers (or CS/RS) and data relay (DR) functions are located in the data plane.

NOTE – Functions except RSR functions and DR functions are equivalent to those in peer.

7.8.1 Relay server resource (RSR) functions

RSR functions control and manage RS resources. The RSR functions maintain the status of RS resources. Based on the status information, the RS can determine whether or not to accept a resource request. Since a peer requests resource of an RS, an RS also maintains resource usage information per peer. The RSR functions consist of relay server resource management (RSRM) FE, resource status management (RSM) FE and resource usage information management (RUIM) FE.

7.8.1.1 Relay server resource management (RSRM) FE

The RSRM FE provides information on the available resources to the requestor and performs allocation of the requested resources.

7.8.1.2 Resource status management (RSM) FE

The RSM FE manages information on the resources provided by the RS such as network capability, contents, etc. It is also possible to report the current status of the particular resources for receiving a request from the ORMS FE of the OMS. When a peer requests the resources of an RS through the OMS, the RSM FE checks the availabilities of the requested resources.

7.8.1.3 Resource usage information management (RUIM) FE

The RUIM FE manages the resource usage status by each peer to be used for usage statistics. This information will be delivered to the UMS, which manages the user information and activities, through the OMS.

7.8.2 Peer activity management (PAM) functions

The functionalities are identical to those of PAM functions within a peer, see clause 7.6.5.

7.8.3 Data relay (DR) functions

The DR functions forward the receive data with the control of the RSRM FE. The DR functions consist of data relay (DR) FE and relay mapping information management (RMIM) FE.

7.8.3.1 Data relay (DR) FE

The DR FE interacts with the DD FE or DR FE within a remote entity in order to relay data. The DR FE also reports delivery statistics to the PAMS.

7.8.3.2 Relay mapping information management (RMIM) FE

The RMIM FE manages the mapping between the RS and the peer using relay services.

8 Reference points

This clause provides descriptions of the reference points of the MP2P framework in Figure 2.

8.1 Reference point R1

Reference point R1 is defined between the OMS and the PAMS. It is used to exchange a peer's status information between the OMS and the PAMS. The OMS requests the PAMS to provide the peer's status in the form of {peer, status} mapping. The OMS can request information of single or multiple peers.

The protocol that can be used in this reference point is PAMP (specification under development in ITU-T).

8.2 Reference point R2

Reference point R2 is defined between the PAMS and peers. It is used to exchange a peer's activity information. The peer reports its activity status to the PAMS in the method requested by the PAMS. That is, it can report the activity status in a periodical manner, or at the end of a transaction with the other peer.

8.3 Reference point R3

Reference point R3 is defined between the OMS and the UNIS. It is used to retrieve the physical network status from the UNIS by the OMS. In an MP2P framework, the OMS provides a list of peers to be sorted according to the status of the physical network. The status in this reference point refers to the network distances, network interface status, networking policy, etc. The UNIS provides the same peer list, but sorted according to the status of the physical network. The IETF has defined the ALTO protocol [b-IETF-ALTO] which can be used in this reference point.

8.4 Reference point R4

Reference point R4 is defined between the peer and the UNIS. The peer can request the UNIS to select the most appropriate peer in terms of physical network status. The network service provider would not want to reveal the status of the physical network to the public. Therefore, the UNIS applies various logics in selecting an appropriate peer for the requesting peer.

The IETF has defined the ALTO protocol [b-IETF-ALTO] which can be used in this reference point.

8.5 Reference point R5

Reference point R5 is defined between the OMS and peers. Reference point R5 is used by the peer to exchange information of an overlay network, join an overlay network, apply distribution policy by the contents provider, allocation of overlay resources, exchange of peer lists, etc.

The most popular protocol that can be used in this reference point is 'tracker protocol'. In an MP2P framework, the functional extension is needed for manageability such as inclusion of user account, authentication, use of overlay resources, etc. There can be two kinds of approach; define a new MP2P tracker protocol or define stand-alone extensions that do not interfere with the existing P2P protocol.

8.6 Reference point R6

Reference point R6 is defined between peers and the IXS. It is used in the exchange of meta-information that is related to specific contents. This reference point can be realized in various ways such as web server and stand-alone protocols for exchanging meta-information. The meta-information may be composed of two kinds of information; content-meta information which provides description of the contents such as genre, title, rating, etc.; and overlay-meta information which provides descriptions of MP2P-based services such as chunk size, hash value, address of the OMS, etc. There is no protocol involved in this reference point.

8.7 Reference point R7

Reference point R7 is defined between the OMS and the UMS. It is used to retrieve user-related information from the UMS and it also probes the validity of the user. In an MP2P functional architecture, it is required to identify the user to provide differentiated service based on the user's contribution such as how much a user has contributed or consumed through some kind of reputation system.

8.8 Reference point R8

Reference point R8 is defined between the OMS and the CS. It is used to control the CS to improve service quality. The OMS reserves the resource of the CS to provide caching of contents on behalf of the contents owner to improve content distribution. When a peer requests the OMS to reserve the CS resources, the OMS interacts with and controls the CS to provide the cache service. The CS sends usage information to the OMS.

8.9 Reference point R9

Reference point R9 is defined between the OMS and the RS. It is used to control the RS to improve the service quality. The OMS reserves the resource of the RS to provide NAT/FW traversal or service relay to improve overall MP2P-based service quality. When a peer requests the OMS to reserve the RS resources, the OMS interacts with and controls the RS to provide the relay service. The RS sends usage information to the OMS.

8.10 Reference point R10

Reference point R10 is defined between peers. It is used to exchange buffermap information and contents between peers. This reference point is the basic reference point for P2P. There are no manageability issues involved in this reference point, so no new protocol needs to be defined.

9 Information flows

This clause describes the information flow of basic operations which might be happening in an MP2P network. Each information flow shows how FEs interact with each other for the corresponding operations.

9.1 Content distribution control

The content provider (CP) may have a policy regarding content distribution and it would want to control the distribution based on the policy. For example, a CP may want to expel a specific peer that does not have privileges to download the content or it may need to reorganize the overlay network comprised of peers with specific condition(s). Figures 11 and 12 show how content distribution can be controlled in an MP2P functional architecture. Figure 11 depicts the way to control the overlay network during the distribution and Figure 12 depicts the way to control the overlay network before distribution.

9.1.1 Overlay network access control

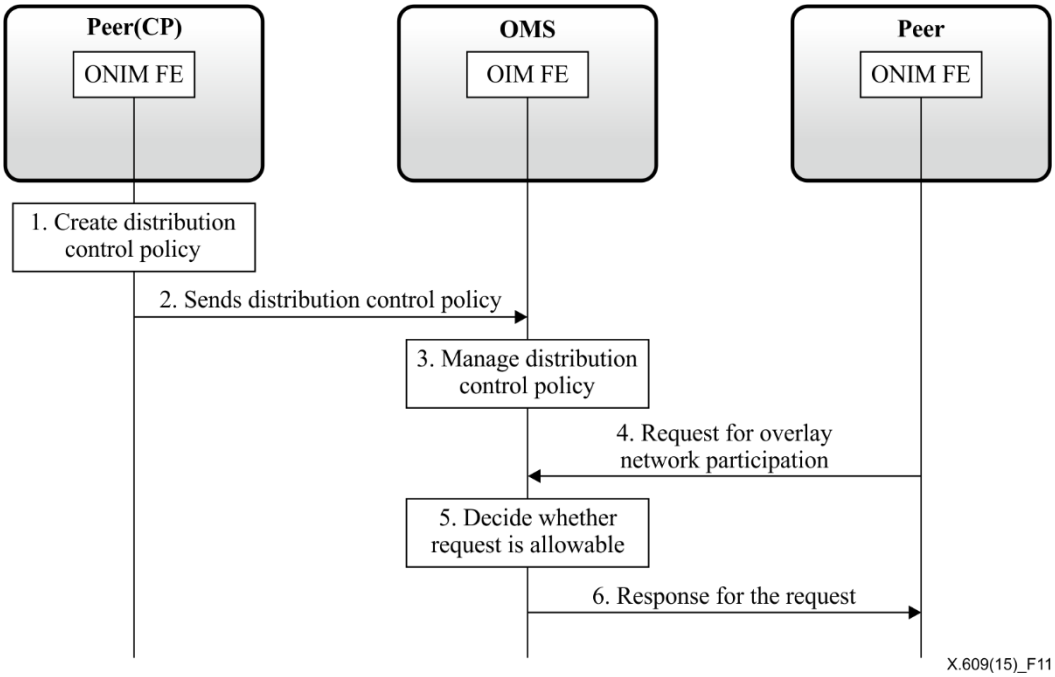


Figure 11 – Procedure for overlay network access control

1) A peer of the content provider creates a distribution control policy before content distribution. The policy contains the conditions for overlay network participation such as network capacity or membership status.

2) A peer of the content provider sends the distribution control policy to the OMS.

3) The OMS manages the received policy for participation requests to be received. The policy contains specific user identifiers if it wants to create a closed overlay network. It is also possible to add various constraints for joining the overlay network.

   NOTE 1 – One user identifier can be mapped to multiple peer identifiers, since a user can have multiple peer instances at the same time.

   NOTE 2 – Detailed information regarding distribution control policy is further study.

4) A peer requests to join an overlay network whose policy is managed by the OMS.

5) The OMS checks whether the peer can access this overlay network or not.

   NOTE 3 – If the distribution control policy contains underlying network-level conditions such as network capacity, the OMS needs to interact with the UNIS. If the policy contains overlay network-level conditions such as how much the peer contributes to other peers already, the OMS needs to interact with the PAMS.

6) Based on the decision, the OMS responds to the peer.

9.1.2 Overlay network membership control

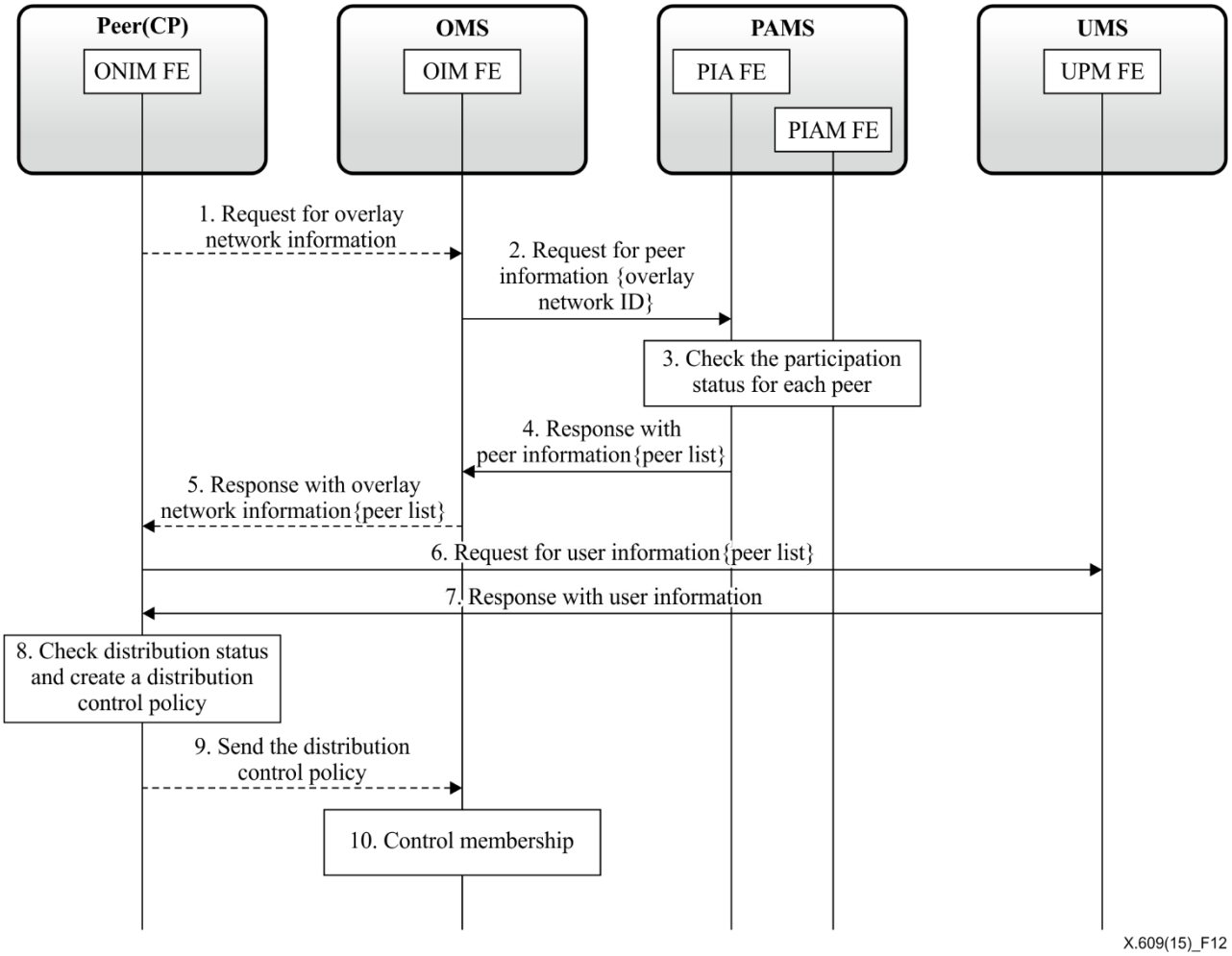


Figure 12 – Procedure for membership control

1) The ONIM FE of the content providing peer requests information from the overlay network which distributes its content.

2) The OMS interacts with the PAMS to get the status of peers.

3) The PAMS checks the status of peers participating in the given overlay network.

   NOTE 1 – For the participation status check, the PAMS may interact with peer(s).

   NOTE 2 – Detailed information and format for describing the status of peers are specified in the peer activity management protocol (the specification is under development in ITU-T).

4) The PAMS sends the list of peers participating in the given overlay network. The OMS may update the information on the corresponding overlay network based on the received information.

5) The OMS responds with the list of peer(s). The list should contain the peer ID of each peer.

6) The ONIM FE of the content providing peer requests the UMS to send user information corresponding to the given peer(s). The request needs to contain the peer ID because the UMS manages user information with the peer ID.

7) The UMS sends the user information of the given peer(s).

8) The ONIM FE of the content providing peer checks whether the peer is participating illegally. If there are any illegal users, the CP generates the distribution control policy to expel the user(s).

9) The ONIM FE of the content providing peer sends the distribution control policy to the OMS.

10) The OMS controls the overlay network participation based on the received policy.

9.2 Use of overlay resources

The MP2P framework includes a CS and an RS to provide more stable and sustainable services over the overlay network. This clause provides two information flows showing how to use those resources.

9.2.1 Content distribution using the CS

The CS can distribute content on behalf of a peer. If a peer needs to sustain the content distribution after leaving the overlay network or without participation in the overlay network, the peer can utilize the CS to distribute the content on its behalf. Figure 13 shows how the CS distributes content on the behalf of peer.

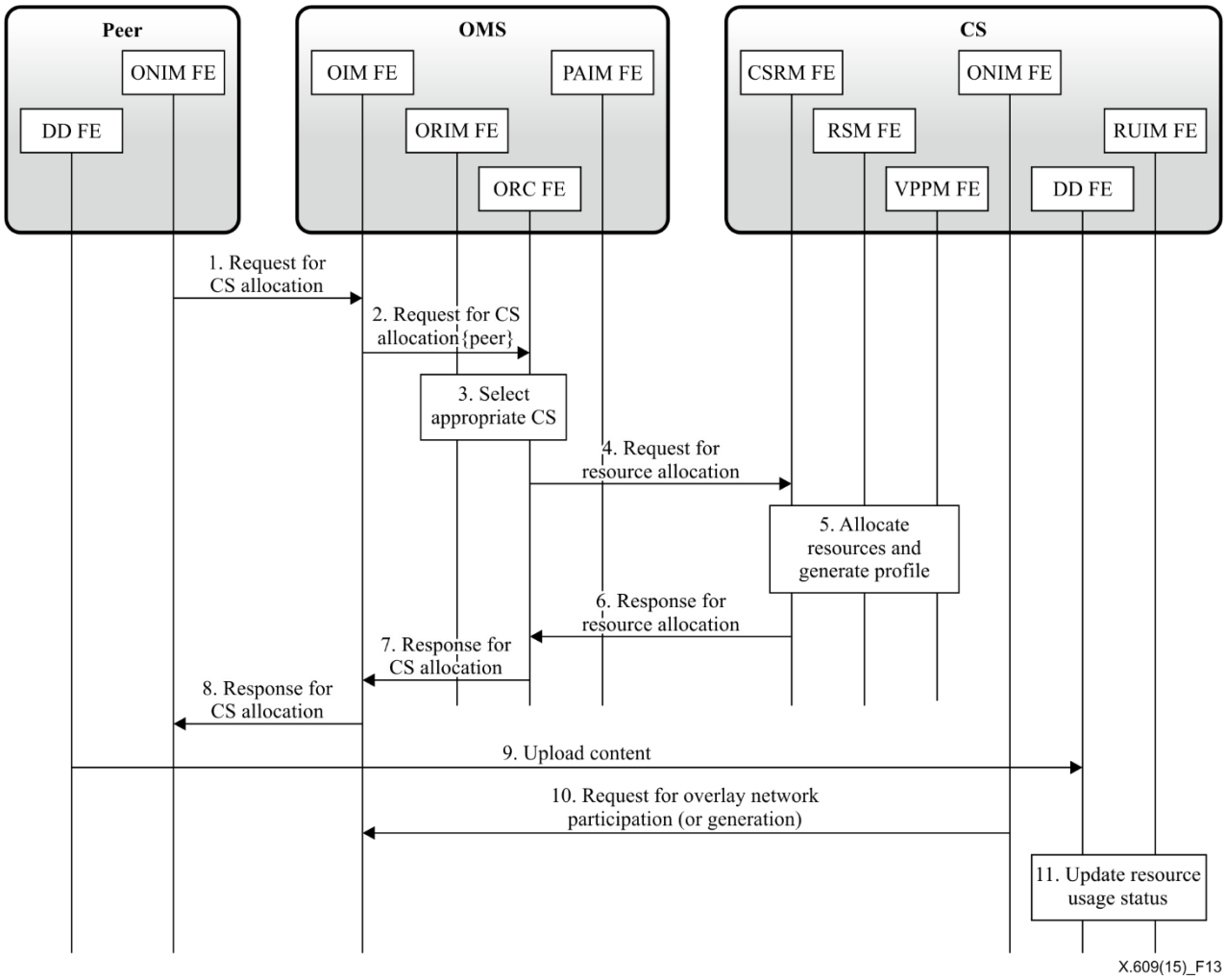


Figure 13 – Procedure for content distribution using the CS

1) When a peer needs to allocate a CS for content distribution, the ONIM FE of the peer requests the OMS to allocate a CS.
2) Upon receiving the request, the OIM FE requests the ORC FE to allocate a CS. In order to select the appropriate CS for the requesting peer, the OIM FE may give the requesting peer information for the ORC FE.
3) The ORC FE selects the appropriate CS for the requesting peer by interacting with the ORIM FE.
4) After CS selection, the ORC FE requests the selected CS to allocate resources.

5) Upon receiving the request, the CSRM FE allocates resources by interacting with the RSM FE. In addition, the CSRM FE interacts with the VPPM FE to generate the profile for content distribution operations.

6) After resource allocation, the CSRM FE responds to the resource allocation request.

7) Upon receiving the response, the ORC FE informs the OIM FE of the CS allocation.

8) The OIM FE informs the peer of the CS allocation.

9) The peer uploads the content to be distributed to the allocated CS.

10) In order to distribute the content, the CS needs to participate in the overlay network for the content.

11) During the distribution, the CS can update the status of resource usage for the requested content distribution. The usage information may be used for charging or other management purposes.

9.2.2 NAT/FW traversal using RS

If a peer is under NAT/FW, the P2PSP needs to provide MP2P-based services to the peer under NAT/FW traversal. The control flow for NAT/FW traversal is shown in Figure 14. The description of the flow is as follows. In Figure 14, it is assumed that peer A is behind the NAT (or FW) which is willing to join the MP2P network.

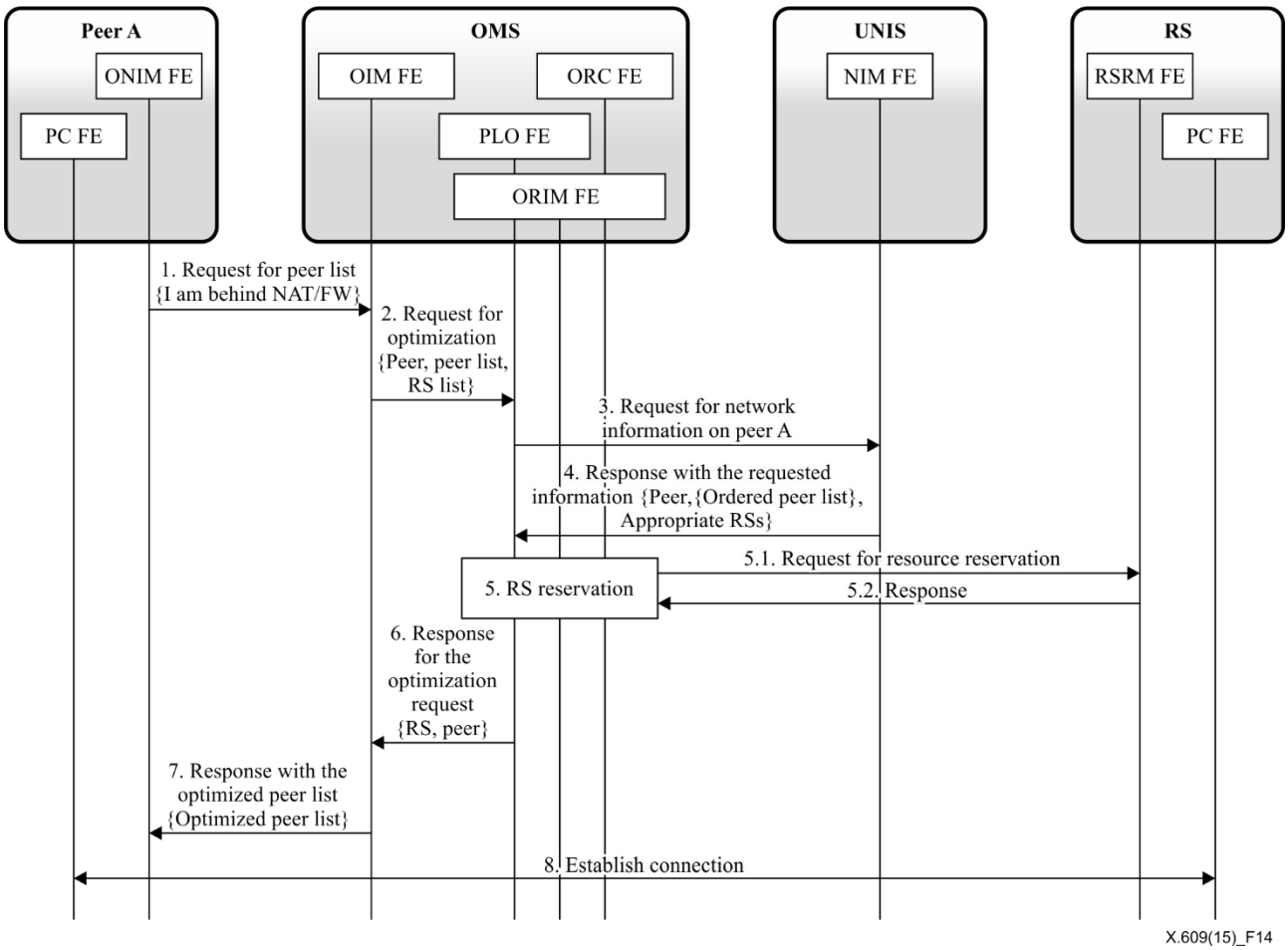


Figure 14 – Procedures for NAT/FW traversal using RS

1) The ONIM FE of peer A requests the OMS to send the peer list to be connected. The OIM FE in the OMS will handle the request. When peer A requests to join, it needs to mention that it is behind the NAT (or FW).

2) Upon receiving the request, the OIM FE requests the PLO FE to optimize the peer list for peer A. The request may contain the peer list which is managed by the OIM FE but not optimized.

3) The PLO FE may request the UNIS to sort the peer list for peer A. The NIM FE in the UNIS will handle the request and it will sort the peer list based on the underlying network information.

4) After sorting, the NIM FE responds with the sorted peer list. In addition to the sorted peer list, the response needs to contain the list of RSs which are appropriate for peer A.

5) The OMS requests resources for relay to the RS.

6) After optimization, the PLO FE gives the optimized peer list to the OIM FE.

7) The OIM FE sends the optimized peer list to peer A.

8) Peer A tries to establish a connection with the RS. After connection establishment, peer A can make connections with other peers in the peer list received from the OMS and all data flow will be relayed through the RS.

9.3 Recommending related contents

A user may want to see the list of contents that other users are receiving so that he/she can easily find contents of interest without searching for a specific keyword. In order to archive this, a peer can interact with the OMS and IXS. A peer interacts with the OMS to get the list of the peers joining the overlay network where the peer tries to join. Then the peer needs to interact with the IXS to get the information on content(s) shared in the corresponding overlay network. Figure 15 shows how a peer can gather the information on content(s). The way to provide the gathered information to the user is not covered by this Recommendation.

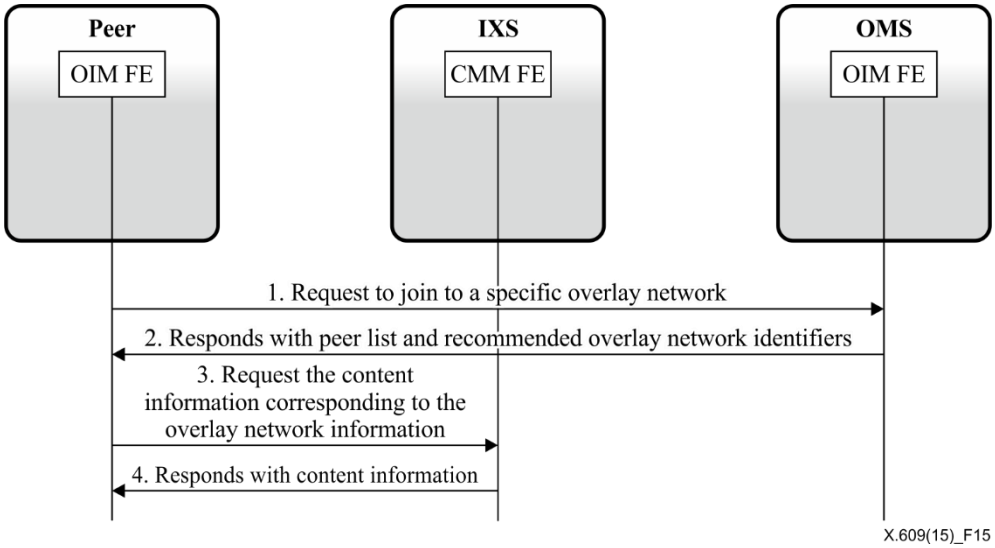


Figure 15 – Procedure for content information acquisition

1) A peer requests to join a specific overlay network.

2) The OMS replies with the information on the requested overlay network and it can also provide information on contextually adjacent overlay networks as a content recommendation service. The peer can also request the information on the overlay network where a specific peer joining the same overlay network is joining. The OMS can provide the requested information, if the peer is privileged to get the requested information according to the service provider's policy. For example, let us assume that peer A is joining overlay network 1 and peer B is joining both overlay network 1 and overlay network 2. Peer A can request which overlay network peer B is joining; peer A can recognize peer B because it receives the list of

peers from the OMS when it joins overlay network 1. The OMS will provide the information on overlay network 2, if peer A is privileged to gather the requested information.

NOTE 1 – In this step, additional security can be applied to prevent the malicious use of gathered information.

NOTE 2 – In a configuration, a peer can refuse to provide the information on an overlay network that it is joining. Then the OMS cannot provide the information on overlay network(s) which the refused peer is joining.

NOTE 3 – It is possible to find an adjacent overlay network by statistical analysis on other overlay networks that peers in a specific overlay network are participating in.

3) The peer requests the information on the content(s) corresponding to the received overlay network ID(s).

4) The IXS returns meta-information of the contents shared in the overlay network(s) corresponding to the requested overlay network ID(s). If a user wants to receive the recommended contents as well, it then goes to step 1 repeatedly.

9.4 Peer list optimization

The MP2P functional architecture provides functionality to keep track of the status of the overlay network and participating peer (s) through use of the PAMS and the UNIS. Each peer reports its status to the PAMS that aggregates and analyses the report. The UNIS provides the underlying network information such as the expected bandwidth between certain peers or the expected network cost among certain peers. When the OMS receives a request for a peer list from a certain peer, it can provide the optimized peer list by interacting with the UNIS and the PMS. Figure 16 shows how the OMS can optimize the peer list.

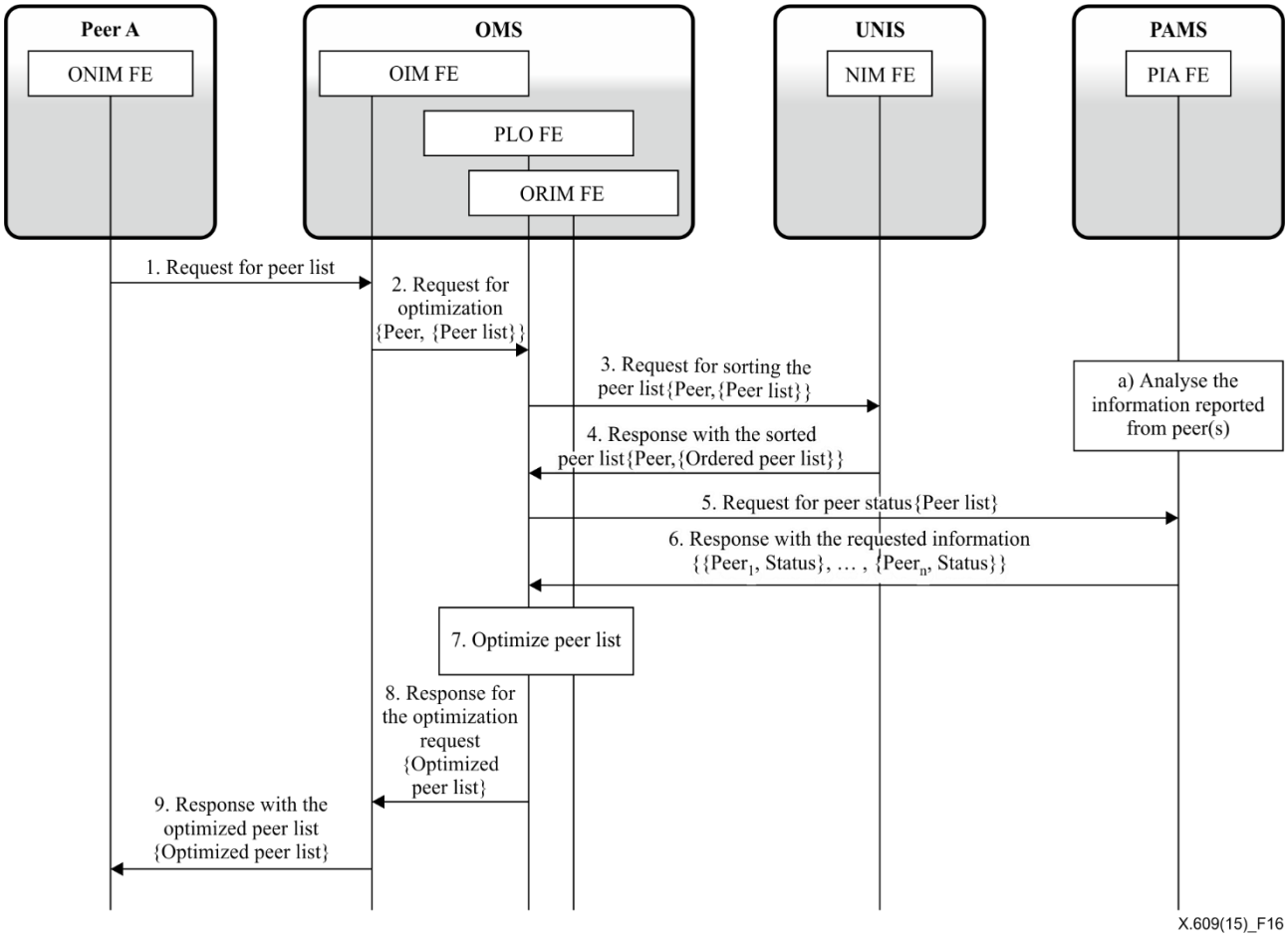


Figure 16 – Procedure for peer list optimization

a) The PAMS generates the peer list by analysing the information reported from the peer(s) or the OMS. For the analysis operation, the PIA FE can interact with the RSM FE and the DD FE in the PAMS.

1) Peer A requests the OMS to send the peer list to be connected. The OIM FE in the OMS will handle the request.

2) Upon receiving the request, the OIM FE requests the PLO FE to optimize the peer list for peer A. The request may contain the peer list which is managed by the OIM FE but not optimized.

3) The PLO FE may request the UNIS to sort the peer list for peer A. The NIM FE in the UNIS handles the request and it will sort the peer list based on the underlying network information.

4) After sorting, the NIM FE responds with the sorted peer list.

5) If needed, the PLO FE requests the PAMS to send the overlay network status information of peer(s) in the peer list. The PIA FE in the PAMS handles the request.

6) The PIA FE responds with the requested information. The response may have a form of {peer, status} mapping.

7) The PLO FE performs optimization. The optimization can be performed based on the gathered information by interaction with the UNIS and with the PAMS.

8) After optimization, the PLO FE gives the optimized peer list to the OIM FE.

9) The OIM FE sends the optimized peer list to peer A.

NOTE – Step a) can be carried out in the middle of steps 1) to 6); this is the reason why the alphabetic and numeric orders co-exist in the procedure.

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