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OSI networking and system aspects – Networking

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**Managed P2P communications: Multimedia  
streaming signalling requirements**

Recommendation ITU-T X.609.3

ITU-T



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## Recommendation ITU-T X.609.3

### Managed P2P communications: Multimedia streaming signalling requirements

#### Summary

Recommendation ITU-T X.609.3 specifies signalling requirements for distributed multimedia streaming over managed P2P architecture. This Recommendation lists requirements on all reference points that are defined in Recommendation ITU-T X.609 for providing multimedia streaming services. This Recommendation also describes high-level procedures for multimedia streaming services over managed P2P architecture, and the roles of managed P2P components.

In providing multimedia streaming service to a massive number of concurrent users by use of existing server-client model, there are limitations and problems such as bottleneck issues and burdens on network cost. If a massive number of users have access to a small number of servers, service providers may suffer from bottleneck problems, which signify additional network costs to service providers. The problem is worse in the case of ultra high definition (UHD) video streaming. In case of peer-to-peer (P2P)-based video streaming, each peer that is participating in the same session shares their resources to distribute stream data with each other. P2P-based streaming is much more scalable compared to the server-client model, and accommodates a massive number of concurrent users. This Recommendation addresses signalling requirements for providing managed P2P (MP2P)-based multimedia streaming services for further protocol specifications.

#### History

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

Managed P2P, requirements, signalling, streaming.

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# Recommendation ITU-T X.609.3

## Managed P2P communications: Multimedia streaming signalling requirements

### 1 Scope

This Recommendation describes signalling requirements and service architecture for providing multimedia streaming services based on managed peer-to-peer network. It also describes a service architecture for providing stable and scalable streaming services by defining additional functionalities and requirements of related components defined in [ITU-T X.609].

### 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 X.609] Recommendation ITU-T X.609 (2015), *Managed P2P communications: Functional architecture*.

[ITU-T X.609.1] Recommendation ITU-T X.609.1 (2016), *Managed P2P communications: Peer activity management protocol (PAMP)*.

[ITU-T X.609.2] Recommendation ITU-T X.609.2 (2016), *Managed P2P communications: Overlay resource control protocol (ORCP)*.

### 3 Definitions

#### 3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

**3.1.1 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.

**3.1.2 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.

**3.1.3 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.

**3.1.4 managed P2P** [b-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.

**3.1.5 buffermap** [ITU-T X.609]: A map showing downloading status of fragments comprising a shared content.

**3.1.6 resource virtualization** [ITU-T X.609]: Making virtual resources comprised of the part or whole resources shared by the participating peers. The virtual resources can be utilized by peer for a certain purpose.

**3.1.7 fragment** [ITU-T X.609]: A piece of the shared content.

**3.1.8 fragmentation** [ITU-T X.609]: A process that divides the shared content into multiple fragments for sharing the content in a distributed manner.

## **3.2 Terms defined in this Recommendation**

This Recommendation defines the following terms:

**3.2.1 source peer:** A peer that streams the multimedia contents to the overlay network. The peer only provides content data to other peers and does not receive it. This peer generates fragments using the multimedia data received from the contents source.

**3.2.2 client peer:** A peer that sends fragments received from other peers to other peers, and does not generate its own fragments.

## **4 Abbreviations and acronyms**

This Recommendation uses the following abbreviations and acronyms:

CS	Cache Server
FTP	File Transfer Protocol
FW	Firewall
HTTP	Hypertext Transport Protocol
ISP	Internet Service Provider
IXS	Index Server
MP2P	Managed peer-to-peer
NAT	Network Address Translation
NTP	Network Time Protocol
OMS	Overlay Management Server
PAMP	Peer Activity Management Protocol
PAMS	Peer Activity Management Server
RS	Relay Server
RTP	Real-time Transport Protocol
UHD	Ultra High Definition
UMS	User Management Server
UNIS	Underlying Network Information Server

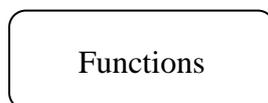
## **5 Conventions**

In this Recommendation:

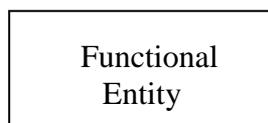
- The keywords "is required to" indicate a requirement which must be strictly followed and from which no deviation is permitted, if conformance to this Recommendation is to be claimed.
- The keywords "is recommended" indicate a requirement which is recommended but which is not absolutely required. Thus, this requirement need not be present to claim conformance.
- The keywords "can optionally" indicate an optional requirement which is permissible, without implying any sense of being recommended. This term is not intended to imply that

the vendor's implementation must provide the option, and the feature can be optionally enabled by the network operator/service provider. Rather, it means the vendor may optionally provide the feature and still claim conformance with this Recommendation.

- The keyword "functions" are defined as a collection of functionalities. It is represented by the following symbol in this Recommendation:



- The keyword "functional entity" is defined as a group of functionalities that has not been further subdivided at the level of the detail described in this Recommendation. It is represented by the following symbol in this Recommendation:

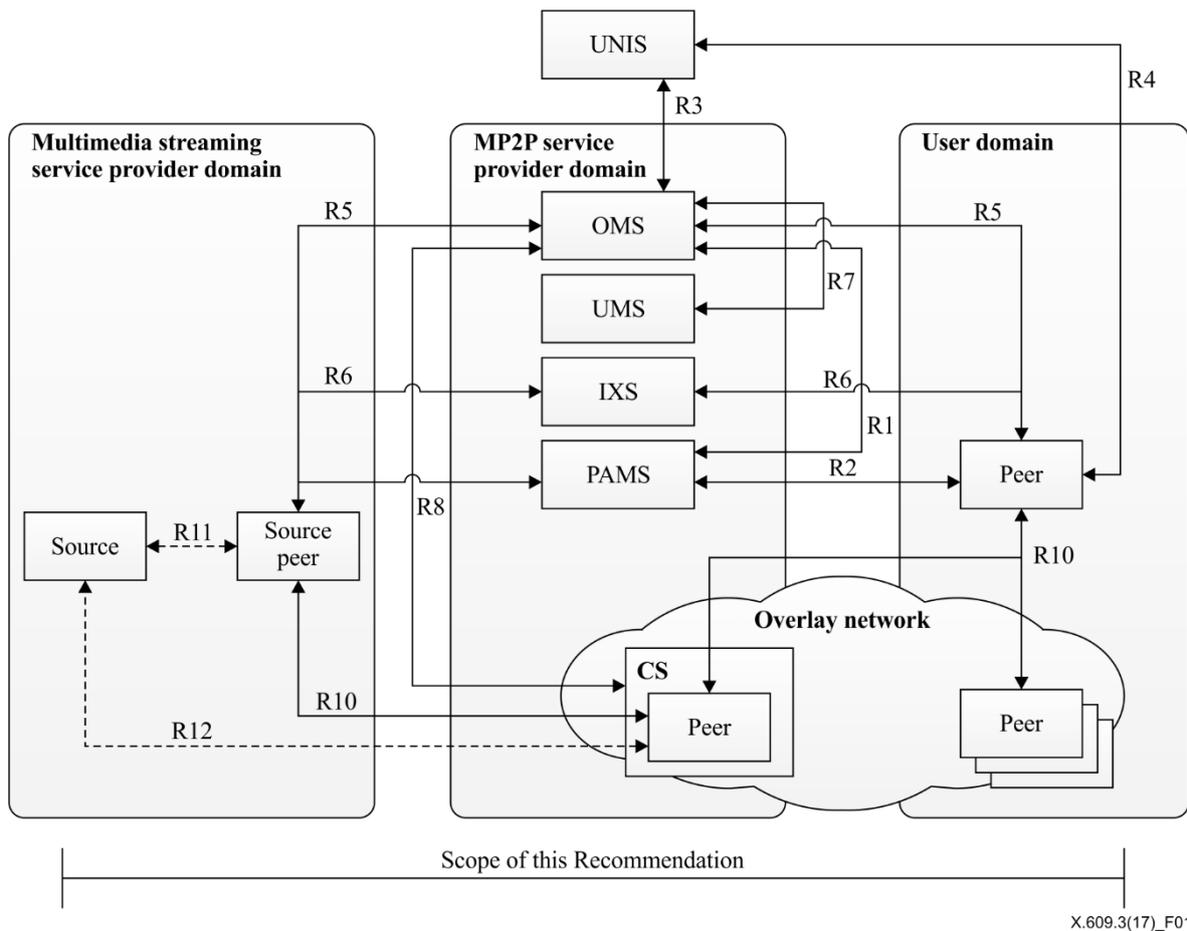


NOTE – In the future, other groups or other Recommendations may possibly further subdivide these functional blocks.

Frame borders of "functions" and "functional entity", and relational lines among "functions" and "functional entity" are drawn with solid lines or dashed lines. The solid lines mean required functionalities or relations. On the other hand, the dashed lines mean optional functionalities or relations.

## **6 Service architecture**

In providing multimedia streaming services, a source requests a source peer to prepare a streaming session. The source peer is a normal peer that is capable of interacting with the index server (IXS), the overlay management server (OMS), the peer activity management server (PAMS) and peers. It creates an overlay network to the OMS and register channel information to the IXS. On receiving streams from the source, the source peer slices the streams into multiple fragments. It is also possible to push the stream to the cache server (CS) directly, and the CS takes the role of slicing instead of that of a source peer. The protocol between source peer and the CS is the same as the peer protocol.



**Figure 1 – Architectural overview of multimedia streaming service on MP2P architecture**

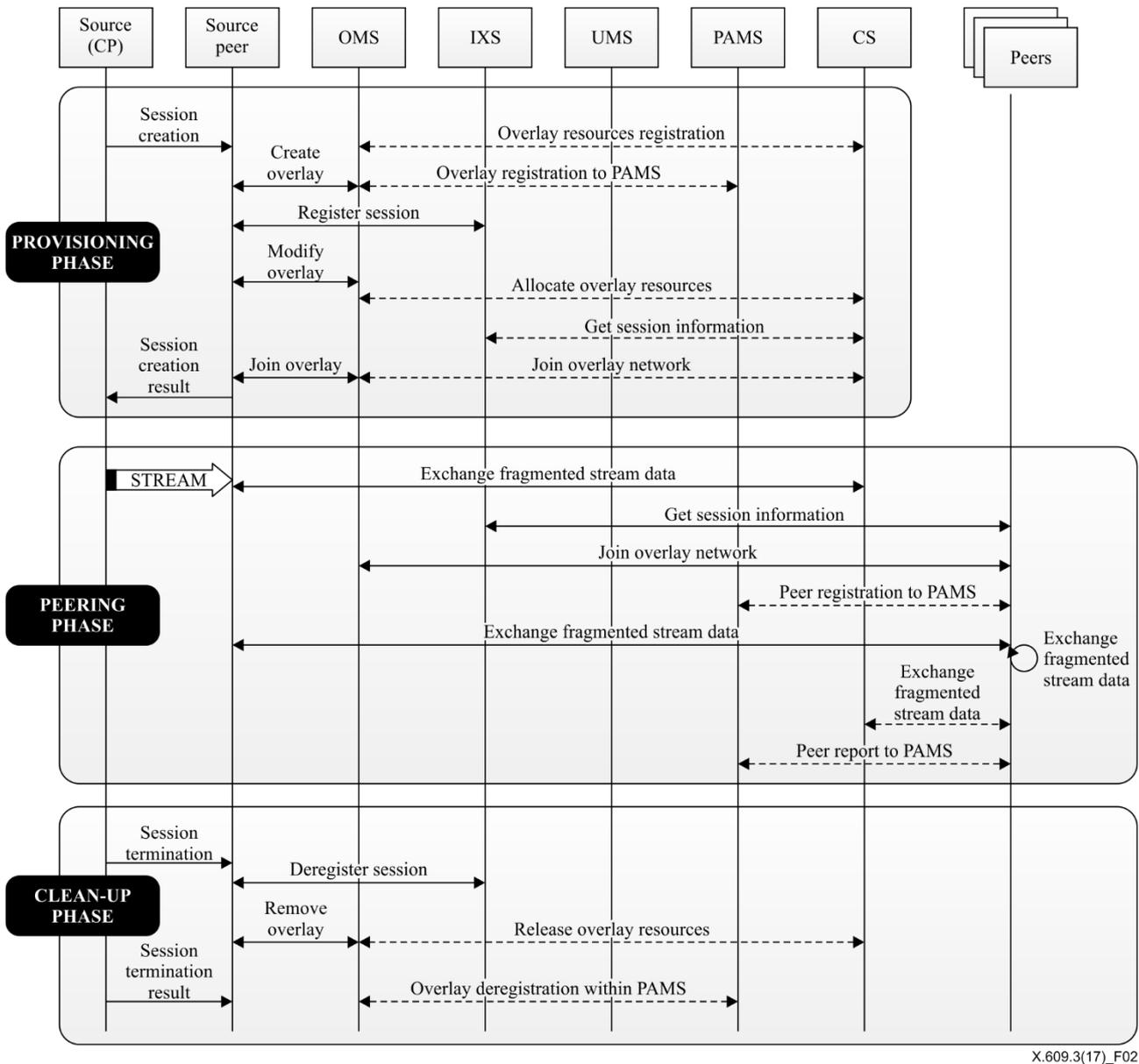
Figure 1 shows an architectural overview for multimedia streaming services over managed P2P networking infrastructure that is defined in [ITU-T X.609].

## 7 Multimedia streaming procedures and components

This clause outlines the steps to take in the managed peer-to-peer (MP2P)-based multimedia streaming service and briefly describes the role of each MP2P component.

### 7.1 Procedures for multimedia streaming services on MP2P architecture

This clause describes brief procedures for providing MP2P-based multimedia streaming services. Figure 2 shows an overview of the multimedia streaming service procedures based on MP2P. As shown in Figure 2, the streaming service is composed of three main phases; the provisioning phase, the peering phase and the clean-up phase.



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**Figure 2 – Overview of multimedia streaming service procedures on MP2P architecture**

### 7.1.1 Provisioning phase

In the provisioning phase, the MP2P service provider and the contents provider prepares for the streaming session. The MP2P service provider registers overlay resources that can be used to enhance the performance and load balancing, and the contents provider creates an overlay network by interacting with the OMS and registers the session information to the IXS. Meanwhile, the OMS may assign the overlay resources to a specific overlay network.

### 7.1.2 Peering phase

In the peering phase, the contents provider begins to push a multimedia stream to its source peer. The source peer slices the incoming stream data into multiple fragments with indexing. These fragments will be distributed to other peers and CSs. If necessary, each peer reports their activity to the PAMS to be used to get the status of the overall overlay network.

### 7.1.3 Clean-up phase

In the clean-up phase, the content provider asks the source peer to stop the session. The source peer deregisters the session information by interacting with the IXS, and removes the overlay network by sending a request to the OMS. Additionally, if a PAMS had been assigned to the overlay network,

the OMS will deregister it as well. A peer may leave at any time, but this does not interfere with the ongoing streaming services.

## **7.2 Roles of MP2P components for multimedia streaming**

This clause describes related components for multimedia streaming services on MP2P architecture.

### **7.2.1 Peers**

Peers exchange part of their received stream with each other. The source peer does not receive fragments from other peers and is responsible for distributing the sliced stream to other client peers.

### **7.2.2 CS**

The CS receives streams from the source peer and gives its resources to distribute the stream data into the overlay network, and the resources are managed and allocated by the OMS. If the OMS decides that the overlay network has enough peers for the overlay network, it orders the CS to get out of the overlay network. Accordingly, it is also possible to add CS resources to an existing overlay network.

### **7.2.3 IXS**

The IXS manages metadata for multimedia streaming session. The metadata includes mapping information to be used to indicate overlay network that is for a particular multimedia session.

### **7.2.4 OMS**

The OMS manages the overlay network information including the peer list containing network information for the participating peer. This information is used for peer-to-peer communication, and the OMS does not send or receive contents data itself. In multimedia streaming services, the OMS interacts with the underlying network information server (UNIS) and the PAMS to create a peer list optimized for multimedia services.

### **7.2.5 PAMS**

PAMS manages information related to the activity of a peer, and it also keeps track of exchange records between peers. Since the PAMS knows that the actual status of the overlay network consists of multiple peers, it is possible to ascertain the distribution status of fragments, peer's contribution ratio, etc. In multimedia streaming services, this provides an optimized peer list based on the status of peer on receiving the request from OMS.

### **7.2.6 UNIS**

The UNIS provides network information of the underlying network. It is also able to provide the network distance between peers if the Internet service provider (ISP) does not provide its network information for some reason (e.g., for network security).

## **8 Signalling requirements of each reference point**

This clause describes requirements to be considered in developing relevant protocols for providing a streaming service. This Recommendation assumes that any other existing protocols and its combinations can be used if they can meet the requirements that are listed in this clause.

### **8.1 Signalling requirements of reference point R1 (PAMS-OMS)**

Reference point R1 is used for exchanging the status of peers of the overlay network between the PAMS and the OMS. This clause describes signalling requirements of R1 in providing multimedia streaming services.

Through this reference point, the OMS figures out the overlay network status by requesting the peer status information from the PAMS. Unlike delay-tolerant services, such as file sharing, streaming services are subjected to time and performance constraints. It is necessary to avoid streaming

problems due to the limited sources that would have to satisfy a large number of client peers. In this case, classified and differentiated services will need to be provided based on the user's class. When the OMS uses the functionalities of the PAMS, it first needs to register the overlay network to the PAMS for further aggregation of peer's activity information. When a peer or the OMS requests an optimized list for a given peer list, the PAMS builds up the optimized list for the request.

- The PAMS is required to provide an available range of fragments for the listed peers, if so requested by the OMS.
- The OMS is recommended to notify the type of overlay network on registering the overlay network to the PAMS.
- The PAMS is recommended to provide an ordered peer list, optimized according to the type of overlay network.
- The PAMS is recommended to provide an interval or period of report in order to prevent concentration of reports from massive numbers of peers.
- The OMS is recommended to indicate the range of fragments that needs to be exchanged.
- The PAMS is recommended to provide peer's static and dynamic information.

## **8.2 Signalling requirements of reference point R2 (PAMS-Peer)**

Reference point R2 is used to gather peer's information from peers by the PAMS. This clause describes signalling requirements in providing multimedia streaming services. A peer sends reports on receiving/sending fragments from/to other peers to the PAMS. These reports will be used to analyse the status of the overlay network for streaming services, and can give incentives based on the contribution of each peer. It is also possible for the PAMS to probe peers to update the status of the overlay network. This is important as dead peers would degrade the quality of service, especially for streaming services. Refer to [ITU-T X.609.1].

- The CS and peer are required to register themselves to the PAMS prior to sending a report.
- The PAMS is recommended to indicate the required interval or frequency of the reports when the peer registers to the PAMS.
- The CS and peer are recommended to indicate their type on registration, that is, whether it is pure peer or virtual peer of the CS, along with the delegation identifier.
- A peer is recommended to notify its static status information, including maximum uplink/downlink bandwidth when it registers to the PAMS.
- A peer is recommended to provide the status of its activity to the PAMS by use of the peer activity management protocol (PAMP).
- The PAMS can optionally probe if a peer is alive by sending a ping packet. Non-responsive peers will be removed.
- The PAMS can optionally give the reputation of peers, such as their sharing ratio.

## **8.3 Signalling requirements of reference point R3 (OMS-UNIS)**

Reference point R3 is used by the OMS to retrieve the physical network status from the UNIS. This clause describes signalling requirements in providing multimedia streaming services.

In case of UHD streaming, it generates a massive volume of traffic, and this leads to the burdening of the ISP. Hence, it is important to localize the traffic by interacting with UNIS. The OMS gives the peer list information of the particular overlay network, and the UNIS will return a classified and ordered list for the overlay network based on the policy of the ISP. This event will occur when a new peer joins or with a renewal request from peers. However, the frequency of interaction with ISP needs to be limited in order to prevent a bottleneck or concentrated load on the UNIS by caching the result

of a query within the OMS. Also, the network distance information can be reused in another overlay network.

- The OMS is recommended to interact with the UNIS to ascertain the preferences of the ISP on selecting a peer list for a specific peer.
- The OMS is recommended to build a local cache of network distance information among peers to prevent frequent queries on the UNIS.
- The OMS is recommended to refresh the local cache of network distance information among peers by means of an expiration mechanism.
- The UNIS is recommended to give the expiration time for a given information.

#### **8.4 Signalling requirements of reference point R4 (UNIS-Peer)**

Reference point R4 is used by peers to retrieve the physical network status from the UNIS. This clause describes signalling requirements in providing multimedia streaming services.

- A peer is recommended to keep the local cache of network distance information with other peers to prevent frequent queries on UNIS.
- A peer is recommended not to request updates before expiration of the timeout.
- A peer can optionally set its preferences on calculating network distance between peers by the UNIS.
- The UNIS can optionally provide the expiration timeout value for the peer.

#### **8.5 Signalling requirements of reference point R5 (Peer-OMS)**

Reference point R5 is used by the peer for exchanging information of an overlay network, joining an overlay network, applying distribution policy by the content provider, allocation of an overlay resource, exchange of the peer lists, etc. This clause describes signalling requirements in providing multimedia streaming services.

When a source peer creates a streaming session, it creates an overlay network by interacting with the OMS. On successful creation, the OMS returns the overlay network identifier. If the overlay network is not publically open, it requests further credential with an appropriate error message. On constructing an optimized peer list, the OMS can gather information from the UNIS and the PAMS through reference points R1 and R3.

- The OMS is required to provide the address of the CS that is receiving the streaming data from the source, if it assigns the resources of the CS to the overlay network.
- The OMS is required to provide the overlay network identifier to a source peer on successful creation.
- The OMS is recommended to provide the expiration time for the overlay network identifier. If it expires, it removes the overlay network.
- A source peer is recommended to release the overlay network when there is no streaming data from the source for a particular time.

When a source peer creates a closed streaming session, it can specify the list of participants or common password for the session.

- A source peer is required to provide a peer list, if it creates a closed session with a pre-specified peer. The peer lists consist of a set of peer identifiers, and it include any necessary information as well.
- A source peer is required to provide the session credential information, if it creates a closed session with pre-specified credentials.

- The OMS is recommended to provide the digital signature of the source peer, if an integrity check of fragments is required.
- The OMS can optionally provide the session key to a client peer that joins a closed session after user validation check, and it is required to generate different session keys per peers.

When a source peer wants to keep track of the status of the overlay network, it requests the OMS to register the overlay network to the PAMS. Refer to clause 8.1.2.1 of [ITU-T X.609.1].

- A source peer is recommended to provide preference whether it needs the PAMS or not, when it creates or modifies an overlay network.

When a client peer joins an overlay network for a multimedia streaming session, the OMS can optionally provide a different peer list to support differentiated services based on the level/class of the user. Refer to clause 8.2.5 of [ITU-T X.609.1].

- The OMS can optionally provide the fragments list to the peers on responding to the peer list request from a peer.

## **8.6 Signalling requirements of reference point R6 (Peer-IXS)**

Reference point R6 is used to exchange meta-information related to a streaming session. This clause describes signalling requirements in providing multimedia streaming services.

After creation of an overlay network, it registers the overlay network to the IXS with additional meta-data that describes the attributes of the session, such as the title, genre, fragment size, video attributes, participants, etc.

- The IXS is required to provide the characteristics of the multimedia streaming session. It includes an overlay network identifier, address of the OMS, video codec, bitrate, resolution, public/private, etc.

## **8.7 Signalling requirements of reference point R7 (OMS-UMS)**

Reference point R7 is defined between the OMS and the user management server (UMS). It is used to retrieve the user-related information from the UMS, and it also probes the validity of the user. This clause describes signalling requirements in providing multimedia streaming services.

There will be various charging models for multimedia streaming services such as pay-per-view, subscription model, quota-based model, etc. The UMS will check the access rights to access a particular streaming session for a specific user, and this information needs to be passed to the OMS.

- The UMS is required to verify the access rights on an overlay network for a specific peer to the OMS, if requested by the OMS.
- The UMS is recommended to include the service access rights of the user that includes validity period, and the access level when sending the result of the authentication check of a particular user.

## **8.8 Signalling requirements of reference point R8 (OMS-CS)**

Reference point R8 is used to control the CS by the OMS. This clause describes signalling requirements for controlling the CS in providing multimedia streaming services.

- The OMS is recommended to allocate and release the resource of the CS dynamically according to the status of an overlay network for stable services or by operators.  
NOTE – If the number of peers in an overlay network is not enough for stable service, the OMS requests the CS to initiate a virtual peer instance.
- The OMS is recommended to provide information on the PAMS to the CS, if the overlay network is configured to use the PAMS.

- The OMS is recommended to provide priority information of the CS when it requests allocation of resources to the overlay network.

### 8.9 Signalling requirements of reference point R9 (OMS-RS)

Reference point R9 is used to control the relay server (RS) by the OMS. The RS is mainly used to traverse the network address translation/firewall (NAT/FW), and this is not quite related to multimedia services, since streaming data tends to go one way. Hence, there is no requirement for this reference point in the view of multimedia services.

- A peer that generates fragments is recommended to decide the size of the fragment automatically based on the characteristics of the stream from the source, if not specified. The size of the fragment affects the performance and quality of the streaming session.
- A peer that generates the fragments is recommended to put hop count and timestamp.
- A peer is recommended not to distribute a fragment that exceeds the limit of the hop count.

### 8.10 Signalling requirements of reference point R10 (Peer-Peer)

Reference point R10 is used to communicate between peers. Through this interface, each peer exchanges buffermap information and contents with other peers. This clause describes signalling requirements in providing multimedia streaming services.

In streaming services each peer requests recent fragments, and old fragments have a lower chance of being exchanged. Hence, a sliding window that represents the subset of buffermap is needed. The size of the sliding window will be different according to the quality or bitrate of streams, and would be specified by a source peer in creating an overlay network.

Even though a peer exchanges all the fragments with other peers, it is possible to keep their connections for further new fragments. Unlike file sharing services, a source peer keeps generating new fragments. Hence, it needs to keep the relationship for a certain time.

- A peer is recommended to probe the bandwidth between other peers. Since peers may leave without any notification, a peer needs to prepare candidate peers in case of failure of connection with a particular peer.
- A peer is recommended to send an explicit message to release the relationship with a neighbour peer or a partner peer.
- A peer is recommended to support the multimedia streaming services without any dependency on the multimedia codecs. This means that the peer protocol is not aware of codecs, and it only slices the incoming stream data from the source into fixed-size fragments.
- A peer is recommended to exchange the peer list of corresponding peer.
- A peer is recommended to provide the information to be used for synchronized presentation of the stream data.
- A peer is recommended to provide the information to be used for the scheduled presentation of the stream data.

NOTE 1 – As an example, the stream data with play schedule information should be presented on the screen according to the scheduled information regardless of the sequence of the received stream data.

- A peer is recommended to provide the information to be used for representing the nature of the delivered contents (e.g., normal content, expedited content, etc.) between peers.

NOTE 2 – As an example, the expedited content attribute may be used to deliver the emergency warning information for digital signage service, which needs to be played on the screen immediately prior to the normal digital signage content.

- A peer is recommended to check the integrity of the received fragment, and also to provide the information for the integrity check such as checksum and hash.

- A peer is recommended to support various transport methods. It means that the peer protocol is recommended not to be dependent on the underlying transport layer. A source peer is recommended to provide the information for verifying the integrity of received fragments from many corresponding peers. Each client peer makes use of the information to verify the integrity of the fragments received from other peer.
- A peer is recommended to provide a hop count that indicates how many peers the fragment has passed before arriving to the peer in question. This information is used to prevent an overall slowdown by preventing older fragments from being distributed continuously.
- A peer can optionally support codec-aware streaming service, and the size of the fragment can vary. In this case, it is required to inform the size of the fragment explicitly when sending the fragment.

When the OMS requests to allocate the overlay resource of the CS to a particular overlay network, the CS initiates a virtual peer acting like a peer within the overlay network. The virtual peer uses the same peer protocol with an ordinary peer for distributing stream contents. Since the virtual peer of the CS assumes the role of distributing the streaming contents on behalf of the source peer, it needs to have those contents prior to other ordinary peers. In addition, it needs to accord differentiated priority to the overlay resource, since those resources can be provided by multiple heterogeneous CS. Refer to clause 8.2.5 of [ITU-T X.609.2].

- A virtual peer is required not to expose its priority information to an ordinary peer or to virtual peers with lower priority.
- A virtual peer is required not to expose other virtual peer's priority information when exchanging peer list with other ordinary peers.
- A virtual peer is recommended to provide its priority information, if it has such information. When a peer acts as an overlay resource that provides its resources for enhancing a particular overlay network, it provides its priority information to be verified by a corresponding virtual peer.
- A virtual peer is recommended to figure out corresponding peer's priority without additional interaction with the OMS.
- A virtual peer is recommended to provide its priority information to corresponding virtual peers without modifications of the peer protocol. It means that virtual peers and ordinary peers make use of the same peer protocol, but virtual peers can figure out whether a corresponding peer is a virtual peer or an ordinary peer.

### **8.11 Signalling requirements of reference point R11 (Source-Peer)**

Reference point R11 is used to transfer multimedia stream data from the source to an overlay network. This clause describes signalling requirements in providing multimedia streaming services.

When a source peer successfully registers to the IXS for a new streaming session and creates an overlay network to the OMS, the source begins to push its streaming data to the CS. When the source peer receives streams from the source, it produces fragments to be shared among peers. The size of the fragments may be fixed or variable.

- A peer that generates fragments is recommended to decide the size of the fragment automatically based on the characteristics of the stream from the source, if not specified. The size of the fragment affects the performance and quality of the streaming session.
- A peer that generates fragments is recommended to put the hop count and a timestamp.
- A peer is recommended not to distribute a fragment that exceeds the limit of the hop count.
- A source that generates multimedia stream data can optionally provide time information within the stream data which can be used by the user domain peer to play received stream data according to the scheduled time or sequence of playing contents.

NOTE – This capability may be used for multimedia application such as a digital signage that requires scheduled playing of received contents at a specific time or sequence on the signage terminal device.

- A source can optionally provide the network time protocol (NTP)-based time synchronization information within the stream data to enable synchronization of the playing contents of the received stream data among the user domain peers.
- A source can optionally provide content attribute information within the stream data to represent the nature of the delivered contents (e.g., normal content, expedited content, etc.) to other peers.

## **8.12 Signalling requirements of reference point R12 (Source-CS)**

Reference point R12 is used to transmit multimedia contents from the source to the CS. This clause describes signalling requirements in providing multimedia streaming services.

The CS acts like a source peer except that it does not register new streaming sessions and does not create overlay networks.

- The CS is recommended to provide multiple methods to a source peer to receive multimedia streams such as FTP, HTTP and real-time transport protocol (RTP).
- A source can optionally support time information within the stream data which can be used by the user domain peer to play received stream data according to the scheduled time or sequence of the playing contents.
- A source can optionally provide the NTP-based time synchronization information within the stream data to enable synchronization of the playing contents of the received stream data among the user domain peers.
- A source can optionally provide content attribute information within the stream data to represent the nature of the delivered contents (e.g., normal content, expedited content, etc.) to other peers.

## Bibliography

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