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OSI networking and system aspects – Networking

Managed P2P communications: Content distribution signalling requirements

Recommendation ITU-T X.609.6

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Recommendation ITU-T X.609.6

Managed P2P communications: Content distribution signalling requirements

Summary

Recommendation ITU-T X.609.6 specifies signalling requirements for content distribution services over a managed peer-to-peer (P2P) overlay network that is specified in Recommendation ITU-T X.609. Content distribution over a managed P2P network provides flexible content management over existing overlay networks and also enables contents providers to control accessing of the overlay network. That is, the content provider can update the content to be distributed over an overlay network anytime and every update will be applied to all peers in the overlay network. This Recommendation lists requirements for the related reference points that are defined in Recommendation ITU-T X.609 for providing content distribution services and it also describes high-level procedures for a content distribution service over managed P2P architecture and roles of the managed P2P components for the service.

History

Edition	Recommendation	Approval	Study Group	Unique ID*
1.0	ITU-T X.609.6	2018-12-14	11	11.1002/1000/13801

Keywords

Content distribution, managed P2P, requirements, signalling.

* To access the Recommendation, type the URL http://handle.itu.int/ in the address field of your web browser, followed by the Recommendation's unique ID. For example, http://handle.itu.int/11.1002/1000/11830-en.

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 P2P communications: Content distribution signalling requirements

1 Scope

This Recommendation describes signalling requirements and service architecture to provide content distribution services over a managed peer-to-peer network. This Recommendation describes a service architecture to provide stable and manageable content distribution services by specifying additional functionalities and signalling requirements to related components defined in *Managed peer-to-peer (P2P) communications: Functional architecture* [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 peer-to-peer (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 fragment [ITU-T X.609]: A piece of the shared content.

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

3.1.8 source peer [b-ITU-T X.609.3]: 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 content source.

3.1.9 client peer [b-ITU-T X.609.3]: A peer that sends fragments received from other peers to other peers, and does not generate its own fragments.

3.2 Terms defined in this Recommendation

This Recommendation defines the following term:

3.2.1 index file: A file that describes the contents to be distributed over a peer-to-peer overlay network.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations:

CS Cache Server

ISP Internet Service Provider

IXS Index Server

MP2P Managed Peer-to-Peer

OMS Overlay Management Server

ORCP Overlay Resource Control Protocol

P2P Peer-to-Peer

PAMP Peer Activity Management Protocol

PAMS Peer Activity Management Server

TCP Transmission Control Protocol

UMS User profile Management Server

UNIS Underlying Network Information Server

WebRTC Web Real-Time Communications

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.

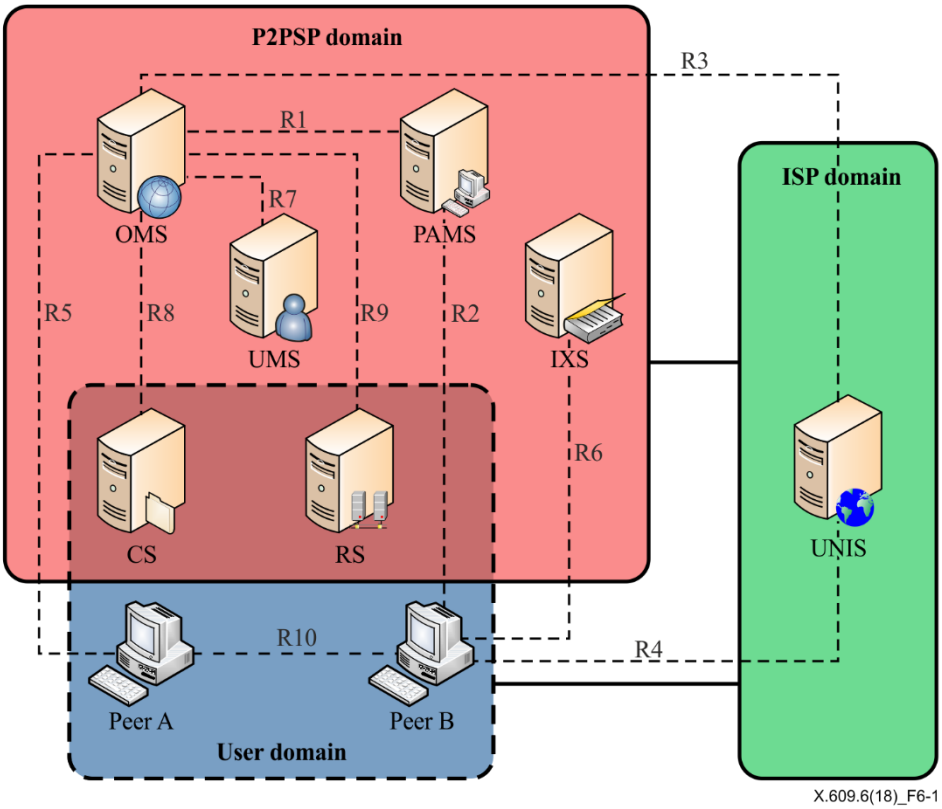
– The keywords "is recommended" indicate a requirement which is recommended but which is not absolutely required. Thus, this requirement need not be present to claim conformance.

– 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.

6 Service architecture

[ITU-T X.609] defines a functional architecture of managed peer-to-peer (MP2P) communications. Figure 6-1 shows several entities and reference points associated with the entities in MP2P architecture. For a content distribution service, a peer interacts with an overlay management server (OMS) through R5 to join or create an overlay network and R6 is used to retrieve and register an index file which describes contents to be distributed and the overlay network information corresponding to the contents. Peers within the same overlay network interact with each other through R10 to share the fragments. To support the content distribution service when a contents provider does not run a source peer, the MP2P service provider allocates one or more cache servers (CSs) which will operate as a source peer using overlay resource control protocol (ORCP) that is specified in [ITU-T X.609.2] for R8. In the case of aggregating the peer activity information on a specific overlay network, peer activity management protocol (PAMP) specified in [ITU-T X.609.1] is used for R2.



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 6-1 – Functional architecture of managed P2P communications [ITU-T X.609]

For a content distribution service, it is also necessary to support access control to designated peers for contents and to support contents updates at any time without disrupting the existing overlay network. This Recommendation extends the architecture of MP2P as shown in Figure 6-2. The reference point R11 is used to deliver contents from a content source to a source peer before distributing the contents and R12 is used to send contents from a content source to peers running on a specific CS. Reference point R13 is used to register the peer with the user profile management

server (UMS) and inform the newly registered peer of the list of distribution channels that the peer should participate in.

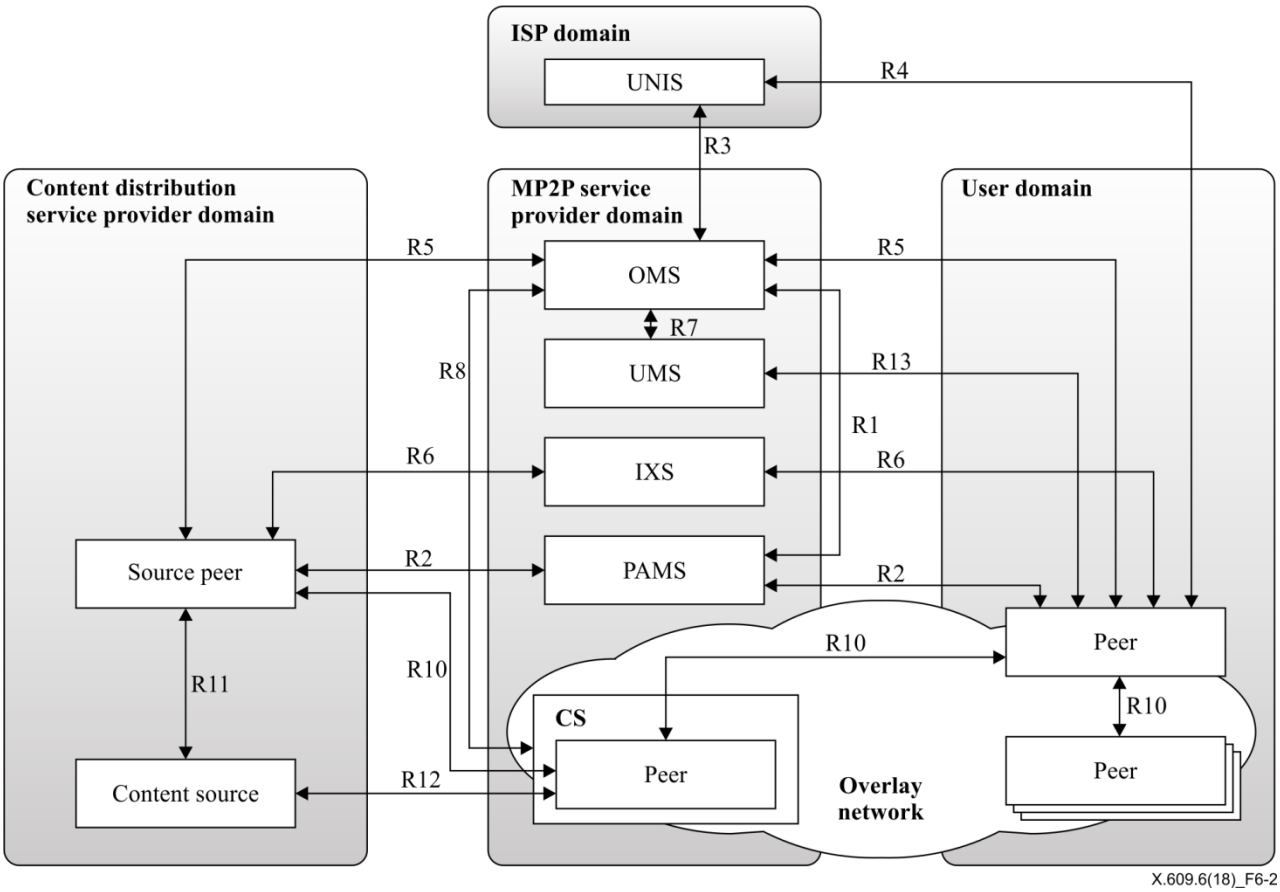


Figure 6-2 – Extended MP2P architecture for content distribution

This Recommendation specifies signalling requirements and high-level service procedures for distributing contents over the MP2P communications architecture defined in [ITU-T X.609].

7 Content distribution procedures and components

This clause describes the roles of MP2P components and the procedures of content distribution service over MP2P network.

7.1 Roles of MP2P components for content distribution service

This clause describes related components for content distribution services on MP2P architecture.

7.1.1 Peers

Peers exchange their possessed fragments with each other. The source peer makes fragments and an index file for their contents to be distributed. The source peer registers this index file to the index server (IXS) and then it can update at any time.

7.1.2 OMS

The OMS manages the overlay network information which includes the peer list and overlay network attribute information and then provides the information to other peers to share content among them. In content distribution service, the OMS interacts with the underlying network information server (UNIS) and the peer activity management server (PAMS) to create a peer list optimized for content distribution.

7.1.3 UMS

The UMS manages the peer/user information and enables specific peers to participate in pre-assigned content distribution channels. In a content distribution service, the source peer can specify the list of peers/users to control the access for the contents and each peer gets the list of distribution channels to join on its bootstrap.

7.1.4 IXS

The IXS manages information of content distribution channels. The source peer submits an index file containing the attributes of content distribution channel and then the IXS maintains and provides this file to other peers.

7.1.5 PAMS

The PAMS manages information related to the activity of peers and it also keeps track of exchange activity records among peers. Since the PAMS knows that the actual status of the overlay network consisting of multiple peers, it is possible to check the distribution status of fragments, peer's contribution ratio, etc. In content distribution services, the PAMS provides optimized peer lists and the status of content distribution channels.

7.1.6 UNIS

The UNIS provides network information of the underlying network. It also can provide the network distance between peers, in case the Internet service provider (ISP) does not provide its network information.

7.2 Procedures for content distribution services on MP2P architecture

This clause describes high-level procedures to provide MP2P-based content distribution service.

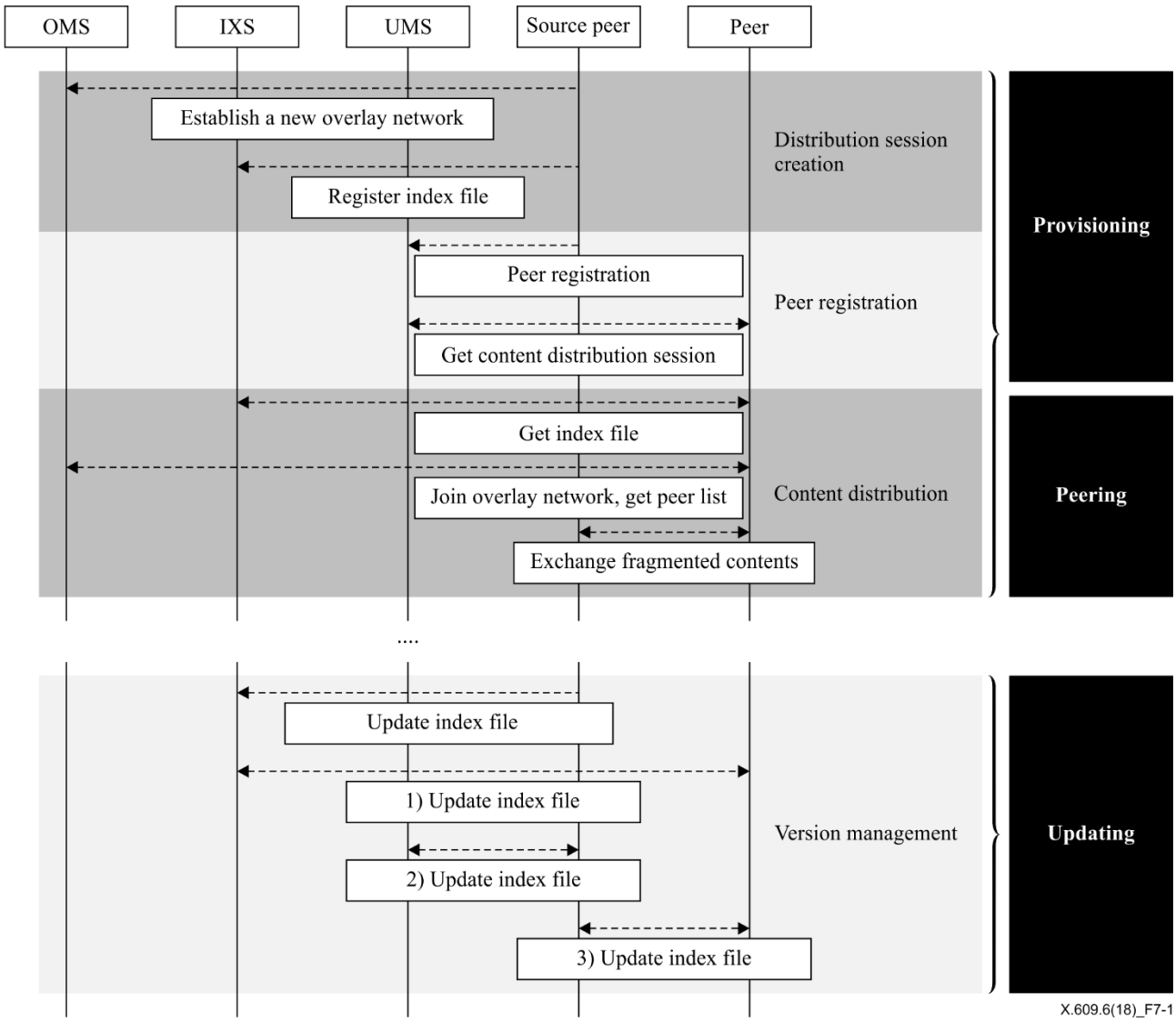


Figure 7-1 – High-level procedures for content distribution service

As shown in Figure 7-1, the content distribution service is composed of three main phases; the provisioning phase, the peering phase and updating phase.

– **Provisioning phase:**

  A source peer creates an overlay network in the OMS and registers an index file to the IXS and client peers register themselves to the UMS. In this phase, no fragment is exchanged.

– **Peering phase:**

  Each peer retrieves the index file from the IXS and the overlay network information from the OMS and then interacts with other peers to exchange fragments.

– **Updating phase:**

  Once a source peer updates the index file to the IXS and each peer, on detecting the modifications of the index file, then retrieves the latest fragments. As shown in the Figure 7-1, when it needs to update a list of contents to be distributed, a source peer updates the index file with an increased version number. A newly joining peer gets the up-to-date index file from the IXS which is the sequence (1) of Figure 7-1 and some peers can get the latest index file from other peers which is the sequence (2) of Figure 7-1, including the source peer which is the sequence (3) of Figure 7-1.

7.2.1 Provisioning phase

In this phase, the contents provider creates an overlay network by interacting with the OMS and registers the session information to the IXS.

7.2.1.1 Distribution session creation

A source peer creates a distribution session by interacting with the overlay management server (OMS) and registers its index file to the index server (IXS). In this phase, the source peer can designate the peers that have rights to receive the contents. A source peer can select one or more specific peers to request them to join a specific overlay network. In addition, it can request the peers to stop receiving specific contents and discard all the received fragments composing the contents and can control client peers to receive additional contents.

7.2.1.2 Peer registration

To support the managed content distribution, every peer needs to register its information to the UMS. A peer can register its preferred channel in order to get notification from the UMS on creation of a relevant distribution channel.

7.2.2 Peering phase

In the peering phase, the contents provider begins to push its contents to a source peer. The source peer slices the contents into multiple fragments with indexing. These fragments will be distributed to other peers. If necessary, each peer reports its activity information to the PAMS.

7.2.3 Updating phase

When the source peer that created the overlay network for this channel updates the list of contents to be distributed, the version of the index file is incremented and registered to the IXS. Each peer basically tries to exchange the latest index file from other peers; even though the index file has a different version, they continue to distribute contents. That is, distribution of the content and distribution of the changed index file are performed in parallel. Finally, all the peers have the same contents and the same index file. A source peer can modify the list of files to be distributed and this modification leads to updating of the index file. When a source peer updates the index file, it is required that all peers in the overlay network have the updated index file. This clause describes how to update the index file and how to distribute the updated index file to all peers. Figure 7-2 shows overall procedures to distribute the updated index file over an existing overlay network.

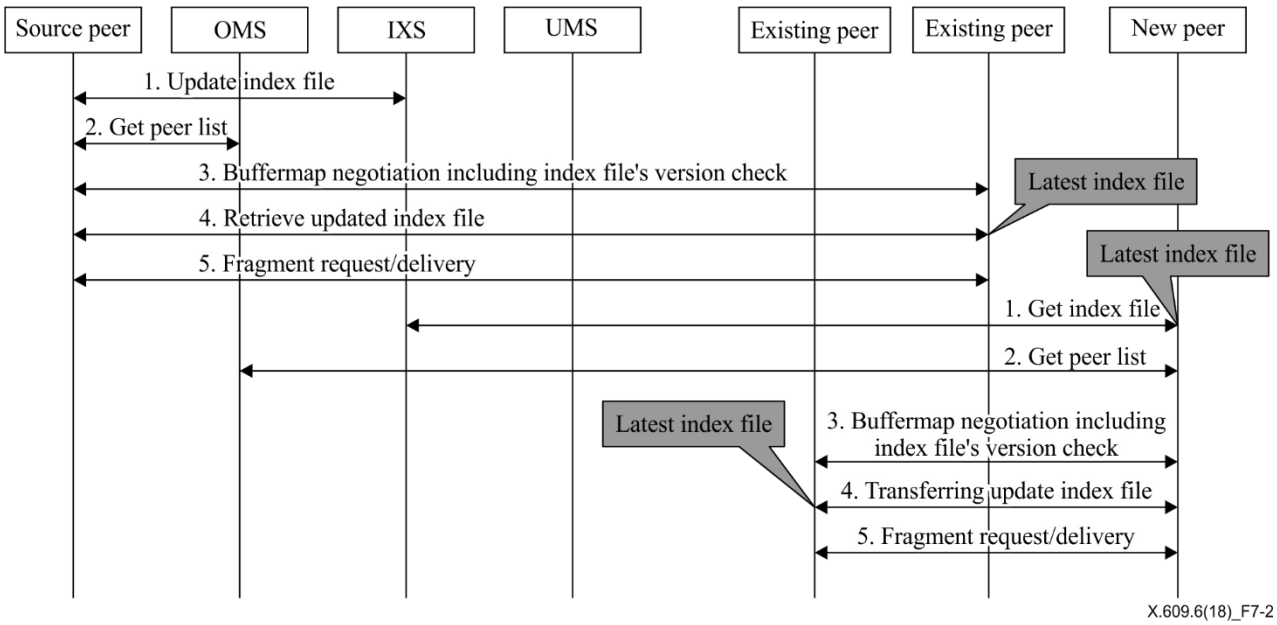


Figure 7-2 – Procedures for diffusing the updated index file

7.3 Updating procedures

This clause describes the procedure for updating contents over an existing overlay network in detail.

7.3.1 Updating index file

When a source peer updates an index file with fragmentation of newly added files, it sends the updated index file to index server (IXS). Prior to uploading of the updated index file, the source peer signs the file with its private key to prevent malicious forgery of the index file with a version increment.

7.3.2 Diffusion of updated index file

Since the buffermap of each peer is dependent of an index file, all peers need to have the same index file prior to the fragments exchange. Hence, it is required to spread the latest index file to all participating peers in the same overlay network.

The peer which newly joins the overlay network can retrieve the latest index file by contacting the IXS, since a source peer sends the latest index file to the IXS when it updates the index file. However, the peers which joined the overlay network before an index file is updated do not contact the IXS. Thus, the existing peers need to get the latest index file.

Figure 7-3 shows the procedures of diffusing the updated index file over the overlay network.

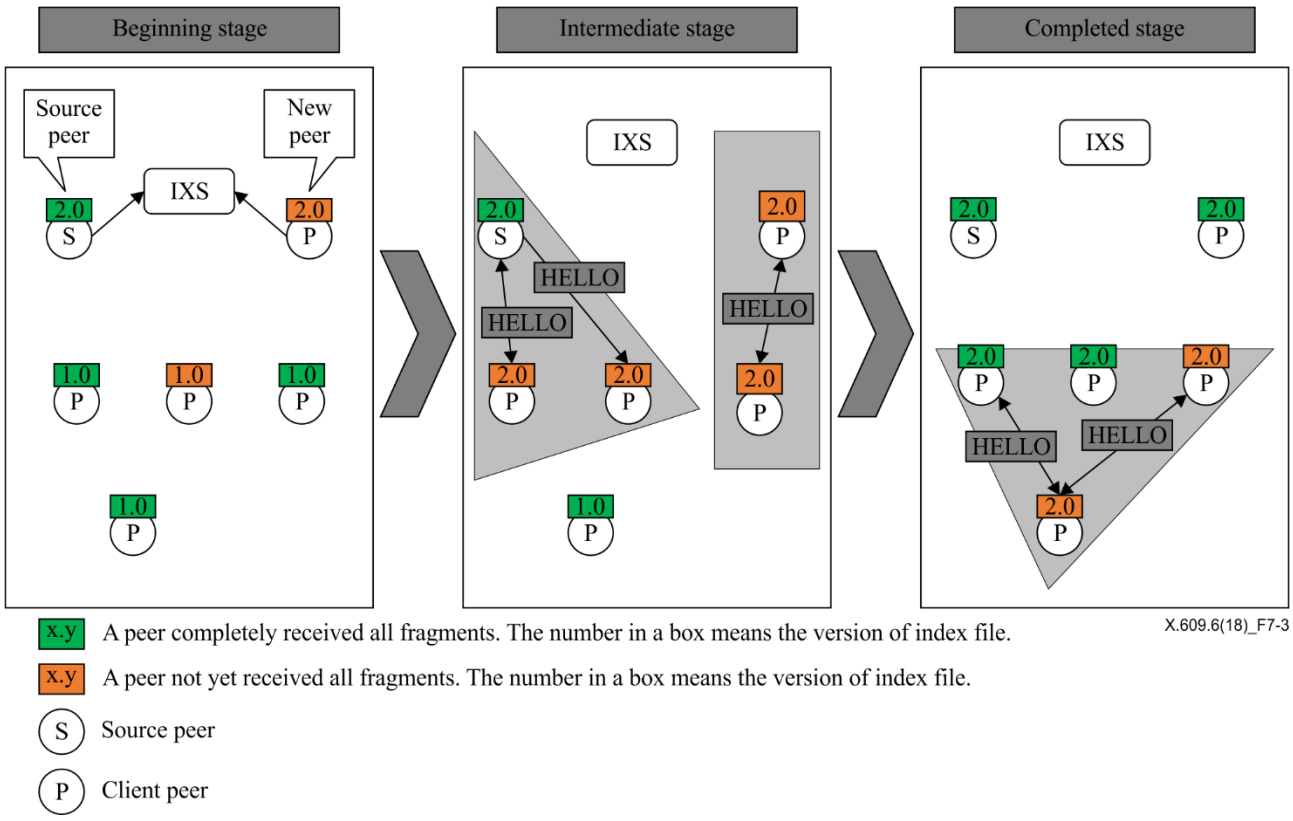


Figure 7-3 – Diffusion of updated index file

7.3.2.1 Diffusion by a source peer

Figure 7-4 shows the procedures for diffusion by a source peer. When a source peer uploads an updated index file to the IXS, it actively diffuses the updated index file to peers that are already in the overlay network. The source peer contacts the OMS and gets the peer list of the overlay network. Then the source peer begins a buffermap negotiation with other peers concurrently. During the buffermap negotiation, each peer checks the version of their index file and the existing peers get an updated index file from the source peer. For buffermap negotiation, the source peer sends a buffermap negotiation message to notify of the update to existing other peers. The peer that receives this message can figure out that it needs to update the index file and then sends a request message to get the updated index file. On receiving the request message for the updated index file, the source peer sends the latest index file to the requesting peer.

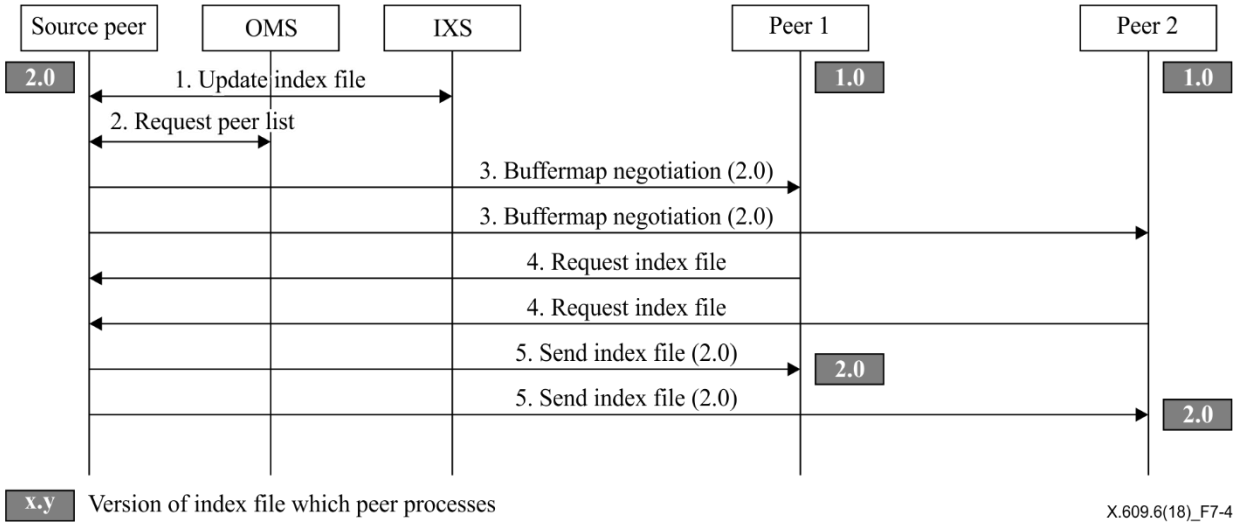


Figure 7-4 – Diffusion of an updated index file by a source peer

7.3.2.2 Diffusion by a newly joining peer

When a newly joining peer gets the latest index file from the IXS it tries to get the contents from existing peers.

Figure 7-5 shows procedures for diffusion of an updated index file by a newly joining peer. On buffermap negotiation with the newly joining peer, the existing peers can figure out that the index file has been updated. Then the existing peers try to get the latest index file from the newly joining peer. Each peer, which gets the updated index file, recalculates its own buffermap to reflect the updated index file. During the recalculation of buffermap, the peers can maintain the already received fragments, if the fragments are valid in the updated index file. If not, the peers discard the received fragments. If the corresponding peer does not send a buffermap negotiation message within a specific time, the newly joined peer releases the connection with the corresponding peer and finds other peers to receive fragments.

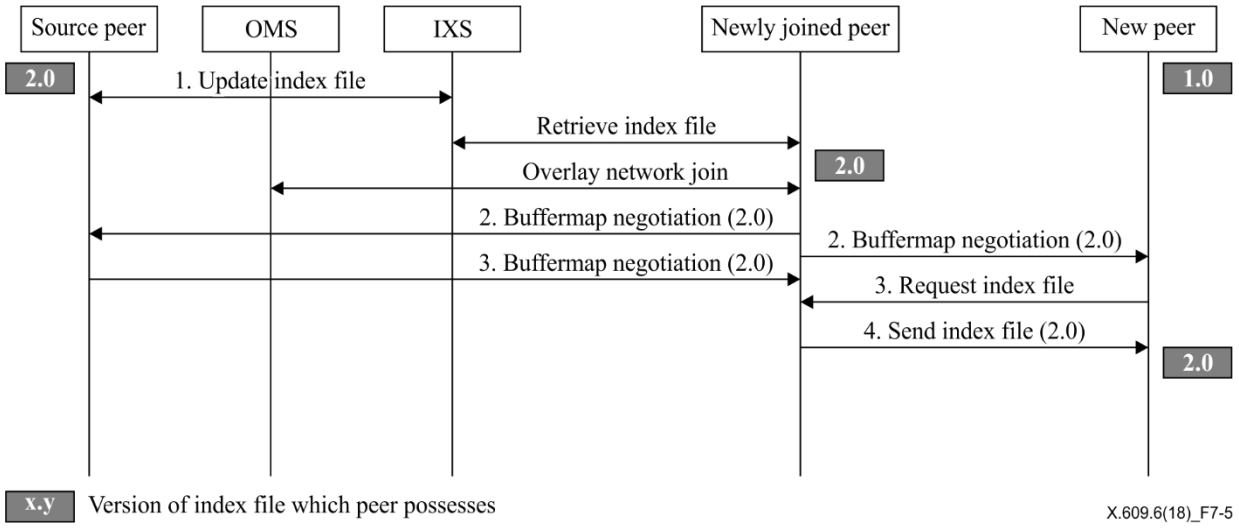


Figure 7-5 – Diffusion of updated index file by a newly joining peer

7.3.2.3 Diffusion by existing peers

When an existing peer gets the latest index file through the procedures described in clauses 7.3.2.1 and 7.3.2.2 it actively interacts with other peers to get the fragments newly appeared in the latest index file.

Figure 7-6 shows procedures for diffusion of an updated index file by an existing peer. Other peers that do not have latest index file can get the updated index file and this procedure will be operated iteratively. In the case that a peer does not have the latest version of the index file, the peer initiates buffermap negotiation with other peers with the latest index file, the peer that receives the buffermap negotiation message sends a message that contains the latest index file. On receiving this message, the peer recalculates its buffermap and then sends a buffermap negotiation message again.

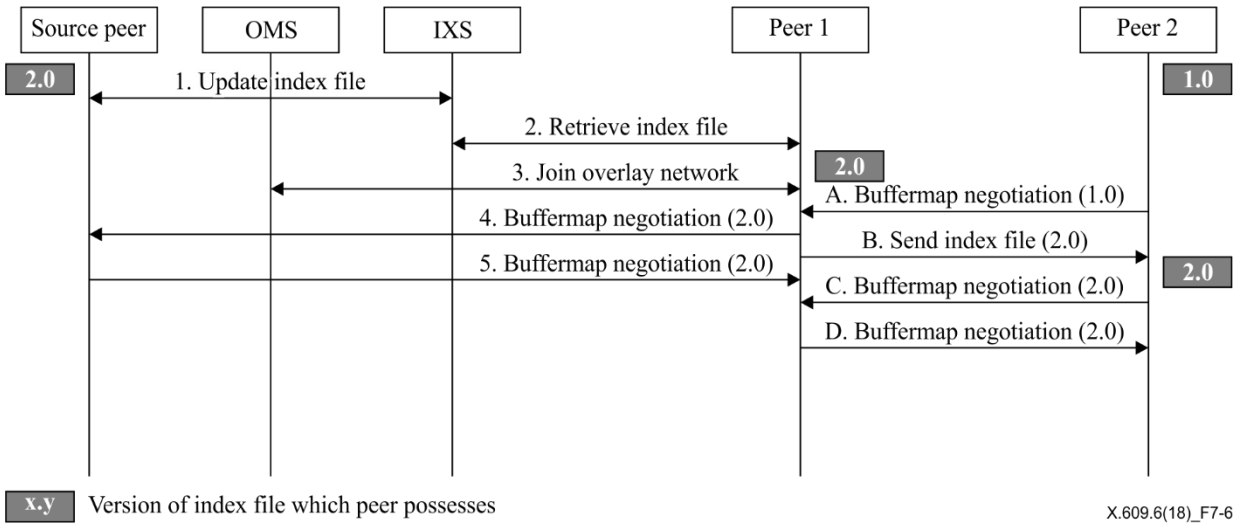


Figure 7-6 – Diffusion of updated index file by an existing peer

7.3.3 Recalculation of buffermap

Since all peers in an overlay network should have same buffermap constructed by use of an identical index file, they need to recalculate their buffermap whenever the index file is updated. Figure 7-7 shows an example of buffermap recalculation. According to the index file version 1.0, a peer can calculate buffermap for the files from file 1 to file 4. Upon receiving the index file version 2.0, the peer needs to recalculate the buffermap by removing buffer space for file 2 and to add a new buffer space for file 5. During the recalculation, the already received fragments of file 2, which do not exist in the index file version 2.0, are discarded.

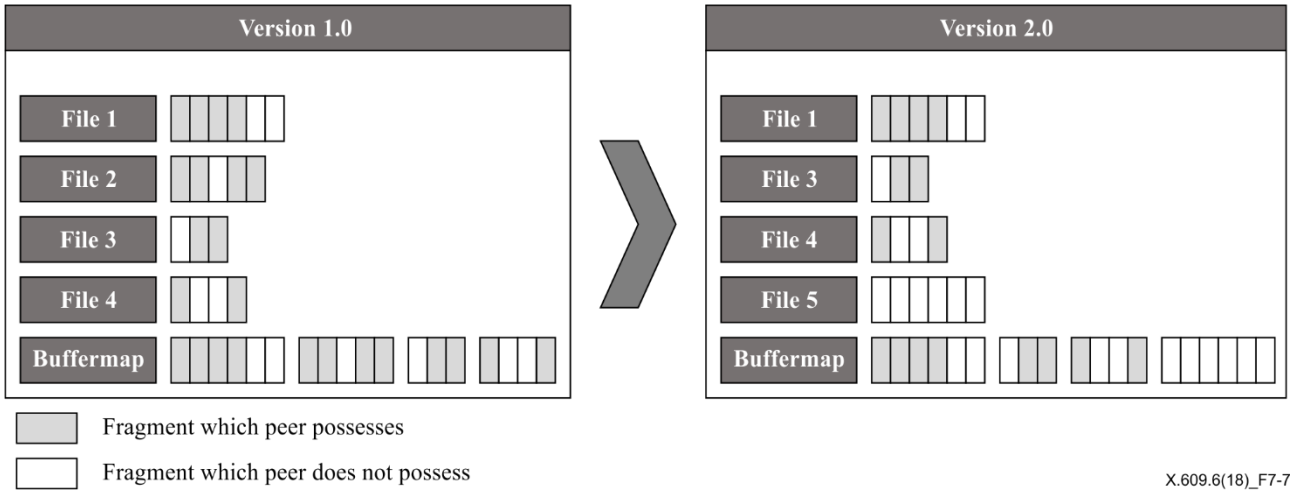


Figure 7-7 – Buffermap recalculation for updated index file

8 Protocol requirements of related interfaces for content distribution service

This clause describes the requirements of protocols for content distribution service over managed P2P communications.

8.1 Requirements of reference point R5 (peer-OMS)

In this reference point R5, peers interact with the OMS to join a particular overlay network and get the peer list of the overlay network.

When a source peer creates a content distribution channel, it creates an overlay network by interacting with the OMS. On successful creation, the OMS returns the overlay network identifier.

– The OMS is required to allow a source peer to create a distribution channel.

– 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 and it removes the overlay network after the expiration time.

– A source peer is recommended to refresh the expiration time periodically for keeping the distribution channel.

On creating a closed content distribution channel, the source peer can specify the peer list or common password for the distribution channel.

– A source peer is required to provide a peer list, if it creates a closed session with pre-specified peers. The peer lists consists of a set of peer identifiers and it includes any necessary information as well.

– A source peer is required to provide the channel credential information, if it creates a closed channel with pre-specified credentials.

When a client peer joins an overlay network for a content distribution channel, 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 peer list as well as a fragments list to the peers on responding to the peer list request from a peer.

When a source peer needs to distribute contents within a predefined time constraint, the OMS can organize an appropriate overlay network based on the information of peers.

– The OMS is recommended to be capable of organizing an appropriate overlay network in order to meet a predefined condition for contents distribution;

– The OMS is recommended to be capable of providing a list of peers to each peer so that the peer can organize the overlay network as OMS configured.

8.2 Requirements of reference point R6 (peer-IXS)

In this reference point R6, a peer interacts with the IXS to create and modify the index file that contains information regarding contents to be distributed over a particular overlay network.

– A source peer is required to register the index file to the IXS before initiating a distribution channel and the index file is required to include the following:
  - version of the index file;
  - digital signature signed by the source peer;
  - structures of directory;
  - fragment ranges for each file;
  - overlay network identifier;
  - address of the OMS;
  - hash values of each fragment.

– The IXS is required to provide a new distribution channel identifier on successful registration of the index file.

– A source peer is required to increment the version of the index file whenever the file is modified.

– A source peer is required to update the index file that is registered into the IXS in order to apply the changes in the contents.
– A source peer is required to include signature into the index file in order to prevent malicious forging of the index file.
– The IXS is required to manage the version information of the index file that contains the information of contents to be distributed over each overlay network.
– The IXS is required to allow a source peer to manage a list of contents to be distributed over the overlay network.
– The IXS is required to support the update of a content list for an existing overlay network.
– The IXS is required to provide the up-to-date index file to peers.

8.3 Requirements of reference point R10 (Peer-Peer)

In this reference point R10, peers interact with each other to share fragmented contents. In addition, each peer can exchange the index file during the negotiation phase.

– A source peer is recommended to propagate the updated index file to other peers within the overlay network.
– A peer is required to check whether a corresponding peer has the same version of the index file during buffermap negotiation.
– A peer is required to request the latest index file from a corresponding peer, if it has a lower version of the index file compared to the corresponding peer.
– A peer is required to provide its latest index file to the requesting peers.
– A peer is required to verify the integrity of index file received from another peer before buffermap recalculation.
– A peer is required to get the latest index file from the IXS, in case it fails to get the index file from another peer within specified time.
– A peer is recommended to exchange the peer list of the corresponding peer.

When a peer interacts with other peers, various types of transport protocol can be used depending on the operating environment of the application service.

– A peer is required to support transmission control protocol (TCP) as a transport protocol.
– A peer can optionally support WebRTC to interact with a peer running as a web application within a web browser.

8.4 Requirements of reference point R13 (peer-UMS)

In this reference point R13, the peer interacts with the UMS to obtain their content distribution session information on its bootstrap and the source peer is able to specify the peer lists of the distribution channel for this.

– A source peer is recommended to specify the list of peers of the distribution channel during the registration of a content distribution channel.
– A source peer is required to provide the identifier of a content distribution channel issued by the IXS.
– A peer is required to obtain the list of distribution channels from the UMS on its bootstrap.
– The UMS is required to provide the list of distribution channels for the requesting peers.

Annex A

A method for content distribution within a predefined time constraint

(This annex forms an integral part of this Recommendation.)

A.1 Introduction

In a certain service scenario, contents are required to be distributed within a constrained time. Specific announcements such as emergency alerts, for example, should be distributed to specific target devices like digital signage and be played on the screen immediately. To achieve this goal in content distribution over MP2P communications, peers are required to organize an appropriate overlay network. The organization can be performed based on the goal which is time constraint specified by the service provider and the information on peers. This annex describes how the aforementioned overlay network is organized.

NOTE – The content distribution in this annex relies on the overlay network organized in tree topology.

A.2 Overview

The content distribution in MP2P communications can be achieved with a new overlay network or an existing overlay network. In the case of the distribution over an existing overlay network, the OMS and IXS may need to modify the information of the overlay network. Figure A.1 depicts the source-side procedure for the content distribution in MP2P communications.

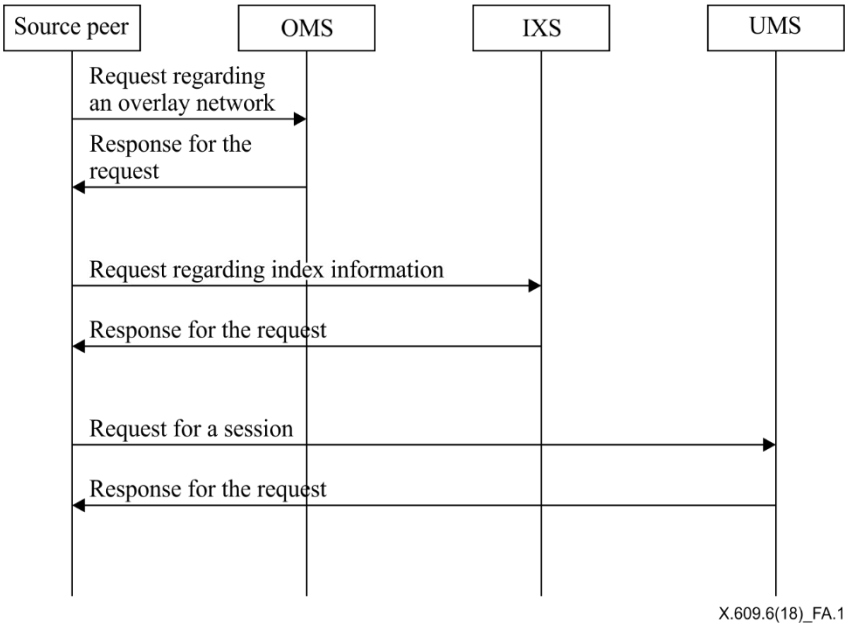


Figure A.1 – Source-side procedure of content distribution

A source, noted as 'Source peer' in Figure A.1, requests the OMS to establish a new overlay network for contents distribution. When the source wants to use an existing overlay network, it can request the OMS to modify the overlay network. The request from the source includes a list of target peers, authentication information, etc. As a response, the OMS sends confirmation. If the request was for establishing a new overlay network, the response includes the information of the newly established overlay network such as overlay ID. Then source interacts with the IXS in order to establish a new index information or to modify an existing index information. To ensure that the index information has the proper description about the content, the request includes the title of content, overlay ID, etc. After all preparation is done, the source requests the UMS to manage the corresponding channel.

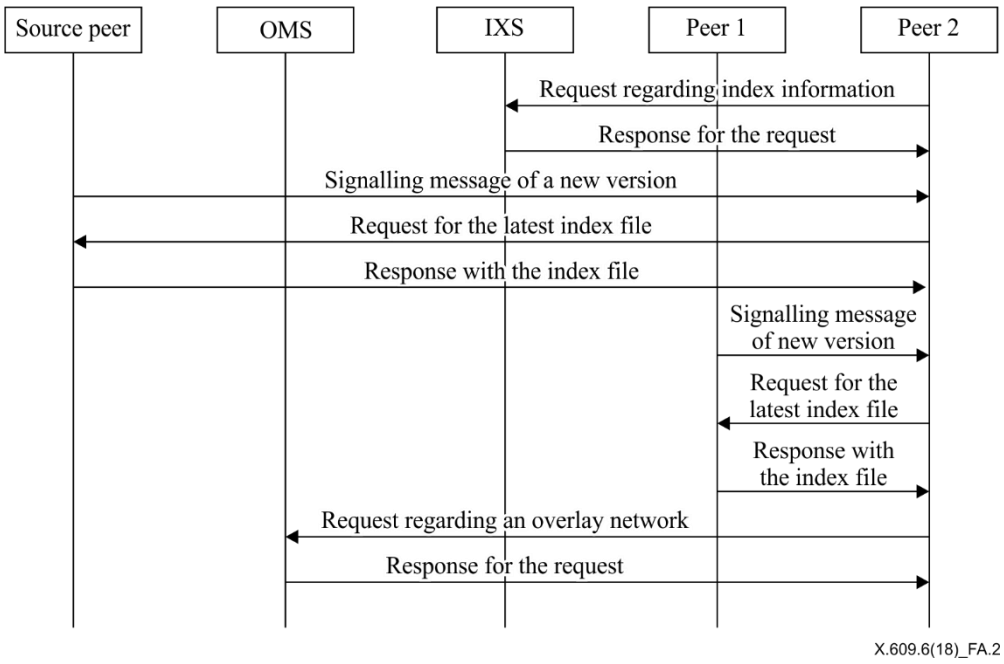


Figure A.2 – Peer-side procedure of content distribution

Figure A.2 shows the peer-side procedure of content distribution. The change of version can be notified by message exchange with a source peer or other peers. A source peer may send a signalling message indicating that the version has been changed. Peer 1 may also send a signalling message indicating a new version. Upon receiving the message, peer 2 sends a signalling message which requests the latest index file. Based on the latest index file, peer 2 interacts with the OMS to have the latest list of peers participating in the overlay network. With the information obtained from the OMS, the peer can interact with other peers for contents distribution.

A.3 Organization of overlay network

The previous clause describes how a source can initiate contents distribution and how peers can be notified of participating contents distribution. This clause describes the method for organization of the aforementioned overlay network which is formed to achieve content distribution among peers within a predefined time. Table A.1 lists notations used in this clause.

Table A.1 – Notation and definition

Notation	Definition
T_{CONST}	The predefined time constraint. All peers should receive the content within the time.
$T_{ELAPSED}$	The expected elapsed time for content delivery from source to the current peer.
N_{TOT}	The total number of peers participating in content distribution.
N_{1HOP}	The number of peers that receives fragments from source directly over the overlay network in tree topology.
U	The available uplink capacity of a peer.
S_{FRAG}	The size of a fragment.
$N_{TOTFRAG}$	The total number of fragments.
T_{SEND}	The required time for sending a fragment from a peer to a child peer. $T_{SEND}=S_{FRAG}/U$
N_{PFRAG}	The total number of fragment that a peer needs to send.

Table A.1 – Notation and definition

Notation	Definition
	$N_{PFRAG}=N_{TOTFRAG}/N_{1HOP}$
T_{TOT}	The total required time for sending N_{PFRAG} fragments from peer i to all children. $T_{TOT}=N_{PFRAG} * T_{SEND}$
$N_{CHILDREN}$	The total number of children that a peer can have. $N_{CHILDREN}=(T_{CONST}-T_{ELAPSED})/T_{TOT}$

When an overlay network is organized, only N_{1HOP} number of peers, which are selected by the OMS, will receive fragments of a specific content. Since each peer receives distinct fragments, all peers send the received fragments to all other peers in the overlay network so that every peer in the overlay network can merge all fragments into the content.

NOTE – In order to minimize the transmission delay, the number of hops for a relaying fragment is limited to two hops.

In order to organize the appropriate overlay network in tree topology, the OMS interacts with the PAMS to calculate N_{1HOP} and $N_{CHILDREN}$. To determine the two values, the OMS conducts the algorithm shown in Figure A.3. First, the OMS sorts all the peers in ascending order. The sorting criterion is the uplink capacity of each peer. Then the OMS calculates $N_{CHILDREN}$ of all peers. Based on the result of comparison between $N_{CHILDREN}$ and (N_{1HOP}-1), the OMS can decide whether it can increase N_{1HOP}. After determining N_{1HOP} and $N_{CHILDREN}$, the OMS organizes an overlay network in tree topology. The overlay network includes the top N_{1HOP} peers in the sorted list; the top N_{1HOP} peers are denoted as 1-HOP peers. If the lowest $N_{CHILDREN}$ value of the 1-HOP peers is larger than N_{1HOP} value, the overlay network additionally can include ($N_{CHILDREN}$-N_{1HOP}) number of peers. Consequently, the organized overlay network can accommodate at most $N_{CHILDREN}$ number of peers. Note that the additionally accommodated peers will not receive fragments from the source but they can get all fragments from the 1-HOP peers. The rest (N_{TOT}-$N_{CHILDREN}$) number of peers will get whole fragments from the source directly. In other words, peers outside of the overlay network in tree topology will get the content from the source directly.

- Sort all peers in descending order

```
prevN1HOP = 0;
N1HOP = 1;
findProperNumber = false;
do while (findProperNumber == true)
        if N1HOP == NTOT
                break;
        end if
        NPFRAG=NTOTFLAG/ N1HOP;
        select top N1HOP peers from the sorted list.
        for every peer in the selection
                Calculate NCHILDREN;
        end for
        if the lowest NCHILDREN >= N1HOP – 1
                prevN1HOP = N1HOP;
                N1HOP = N1HOP +1;
        else
                if prevN1HOP == 0
                        SRC covers all peers directly;
                else
                        N1HOP  = prevN1HOP;
                        Calculate NCHILDREN w.r.t N1HOP;
                        findProperNumber = true;
                end if
        end if
end do
Organize the overlay network in tree topology with the lowest NCHILDREN peers;
Organize client-server connection with (NTOT – NCHILDREN) peers;
```

Figure A.3 – Algorithm for determining N_{1HOP} and $N_{CHILDREN}$

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