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SERIES Q: SWITCHING AND SIGNALLING, AND ASSOCIATED MEASUREMENTS AND TESTS

Protocols and signalling for peer-to-peer communications

Hybrid peer-to-peer communications: Functional architecture

Recommendation ITU-T Q.4100

International Telecommunication Union

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Recommendation ITU-T Q.4100

Hybrid peer-to-peer communications: Functional architecture

Summary

The hybrid peer-to-peer (P2P) network can be composed of tree-based overlay network and mesh-based overlay network in order to utilize the advantages of each type of overlay network. The tree-based overlay network will be used for fast distribution of small data, and the mesh-based network will be used for distribution of relatively larger sized data. Recommendation ITU-T Q.4100 specifies the functional architecture and the reference points for the hybrid peer-to-peer networking with information flows.

History

Edition	Recommendation	Approval	Study Group	Unique ID*
1.0	ITU-T Q.4100	2020-09-29	11	11.1002/1000/14420

Keywords

Functional architecture, hybrid peer-to-peer, overlay network.

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* 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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Hybrid peer-to-peer communications: Functional architecture

1 Scope

This Recommendation describes the functional architecture of hybrid peer-to-peer communications as follows:

– concept of hybrid P2P networking,

– functional descriptions of hybrid P2P networking,

– reference points,

– information flows.

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.609.3] Recommendation ITU-T X.609.3 (2017), *Managed P2P communications: Multimedia streaming signalling requirements*.

[ITU-T X.609.4] Recommendation ITU-T X.609.4 (2018), *P2P communications: Multimedia streaming peer protocol*.

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 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 hybrid overlay network: A peer-to-peer overlay network that participating peers use to exchange data applying the pull and push method. The hybrid overlay network also provides a way to organize and maintain a tree-style path for pushing data to all peers without loops, as well as obtaining data from other peers simultaneously.

3.2.2 hybrid peer: A peer capable of exchanging data using the mesh-based and tree-based methods running over a hybrid overlay network.

4 Abbreviations and acronyms

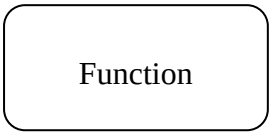
This Recommendation uses the following abbreviations and acronyms:

AI	Application Interface
CM	Cache Management
CPM	Candidate Path Management
DB	Data Broadcast
DR	Data Recovery
FE	Functional Entity
H-PEER	Hybrid Peer
HCI	HOMS Client Interface
HOMS	Hybrid Overlay Management Server
HP2P	Hybrid Peer-to-Peer
HPC	Hybrid Peer Communication
HPI	HOMS Peer Interface
IoT	Internet of Things
MP2P	Managed Peer-to-Peer
OIM	Overlay Information Management
OM	Overlay Management
OPM	Overlay Peer Management
OSM	Overlay Status Monitoring
P2P	Peer-to-Peer
PC	Peer Configuration
PIR	Peer Information Registrar
PLM	Peer List Management
POC	Peer operation control
PPM	Primary Path Management
PSM	Peer Status Monitoring
PSP	Path Status Probe

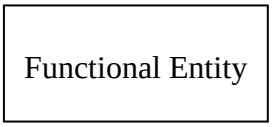
5 Conventions

In this Recommendation:

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



– The keyword "functional entity" 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 "function" and "functional entity", and relational lines among "function" and "functional entity" are drawn with solid lines or dashed lines. The solid lines mean required functionalities or relations. While the dashed lines represent the optional functionalities or relations.

6 Overview

The hybrid peer-to-peer network is capable of accommodating various kinds of data from any source. Figure 6-1 shows an overall conceptual view of the hybrid overlay network with the characteristics of the mesh-based overlay network and the tree-based one at the same time.

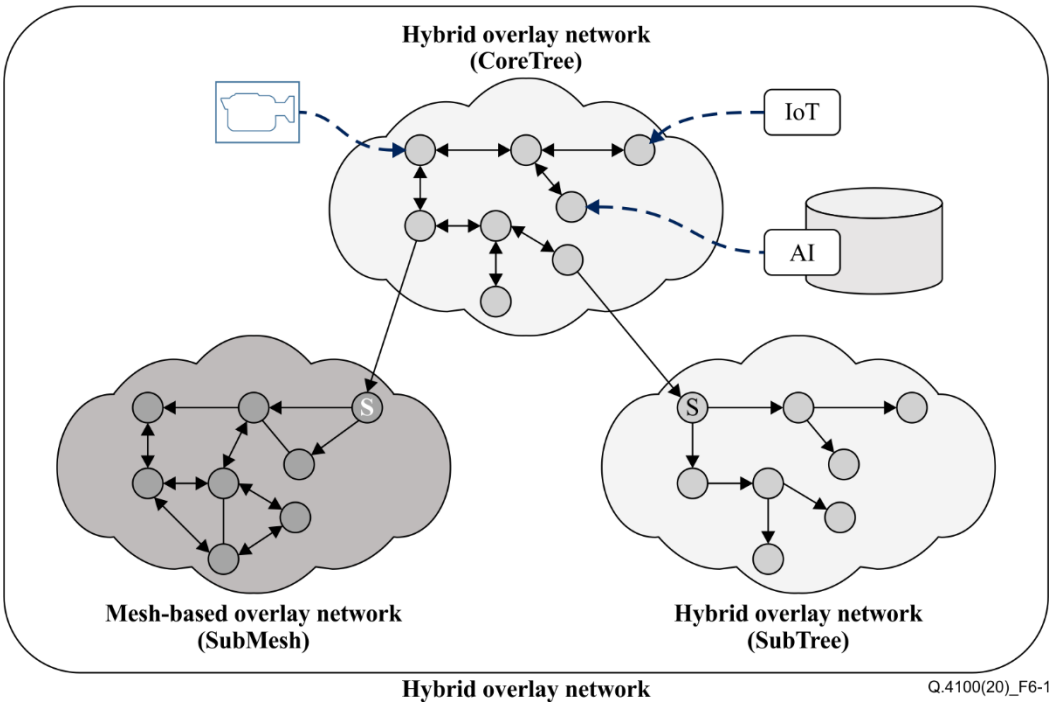


Figure 6-1 – Conceptual view of the hybrid overlay network

The types of an overlay network are classified according to the behaviours of peers as follows:

– CoreTree: The peers of this type of overlay network can broadcast their data at any time.
– SubTree: There is only one source peer within this overlay network, and the source peer gets data from one of the peers within a CoreTree network. The data is broadcasted using the tree hierarchy of the hybrid overlay network.
– SubMesh: There is only one source peer within this overlay network, and the source peer gets data from one of the peers within a CoreTree network. The data is shared among peers using the pull method in the mesh-based overlay network.

The paths between peers in a hybrid overlay network are classified as follows:

– Primary path: A peer within a hybrid overlay network has one or more primary paths for sending/receiving data from another peer. When a peer lost a primary path, it initiates a recovery procedure immediately.
– Candidate path: This is not used for data broadcast (DB) or relaying. This path remains established for rapid primary path recovery. When a peer detects a loss of a primary path, it switches one of the candidate paths to a primary path.

7 Functional architecture of hybrid P2P

This clause specifies the functional architecture of hybrid peer-to-peer networking by defining the relevant components and detailed functional architecture.

7.1 Functional architecture overview of hybrid P2P network

This clause specifies the architecture of the hybrid peer-to-peer network and describes the relevant components to be located within the overlay network.

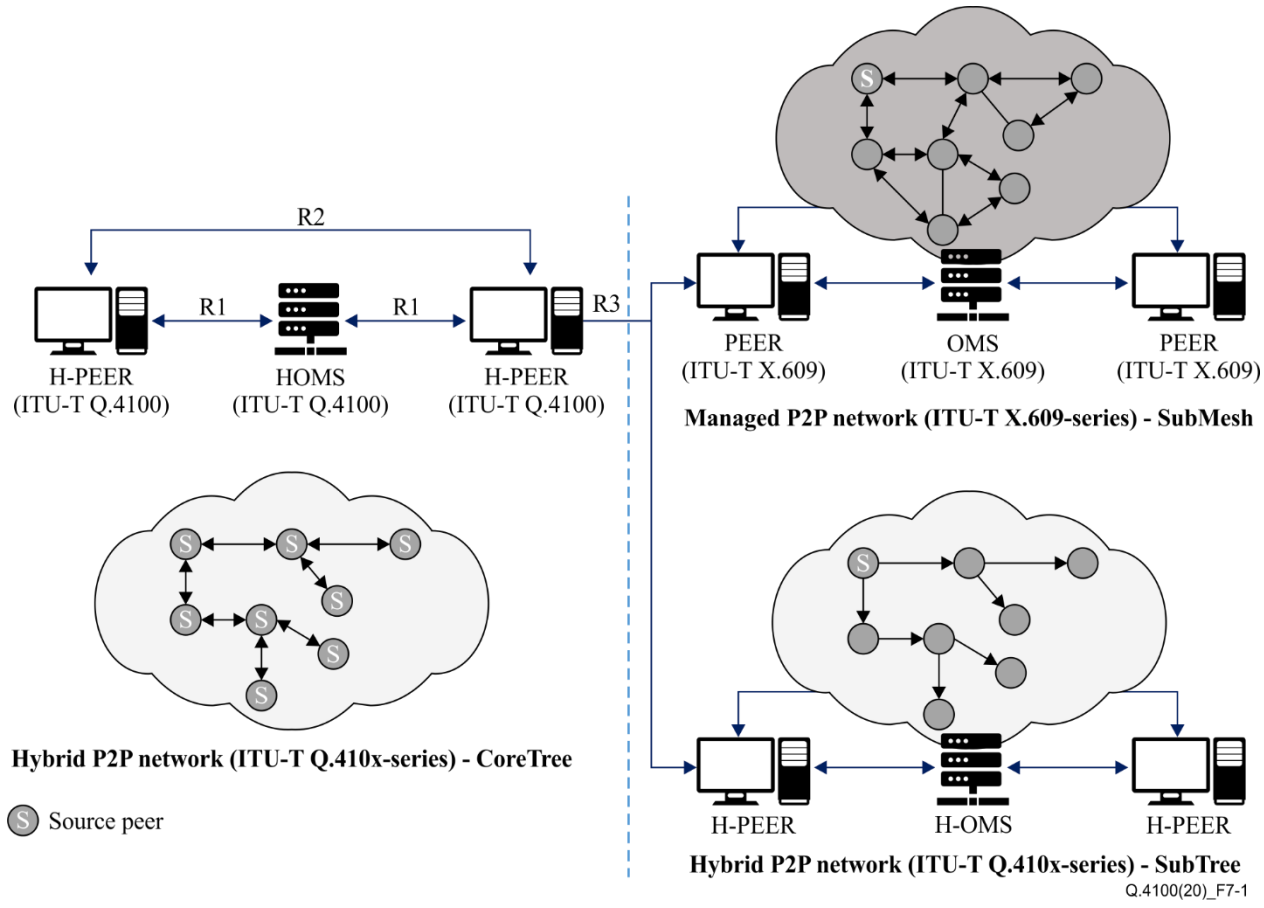


Figure 7-1 – Architectural overview and reference points of HP2P network

Figure 7-1 shows the architectural overview and reference points of the hybrid peer-to-peer (HP2P) network. As shown in the figure, the hybrid overlay management server (HOMS) manages the tree-based overlay network and the mesh-based overlay network. When a peer requests to join a mesh-based overlay network, it sends a request to HOMS and the HOMS forwards the request to the overlay status monitoring (OMS) through reference point R3.

7.2 Functional architecture of hybrid peer

The hybrid peer interacts with HOMS to create, modify, join, or leave an overlay network, and also communicates with other hybrid peers to establish connections for constructing an actual hybrid overlay network. Figure 7-2 shows a functional architecture of the hybrid peer.

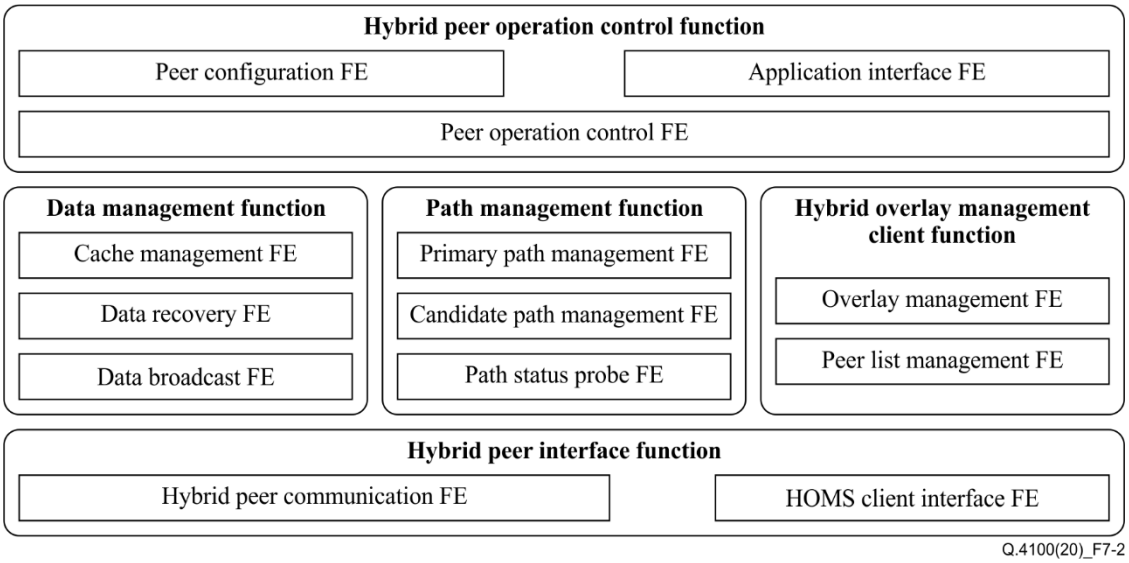


Figure 7-2 – Functional architecture of the hybrid peer

7.2.1 Hybrid peer operation control function

The hybrid peer operation control function manages configurations of the hybrid peer, and it controls behaviours of peers on behalf of requests from application by a user. This function consists of PC FE, AI FE and POC FE.

7.2.1.1 Peer configuration (PC) FE

The PC FE keeps configuration information regarding the operation of the hybrid peer, and is manipulated by a user. This information includes the peer identifier that would be used for identification of a hybrid peer within a hybrid overlay network and any policy that would affect the behaviour of the hybrid peer.

7.2.1.2 Application interface (AI) FE

The AI FE interacts with an application that makes use of a hybrid overlay network to send or receive data. This FE sends requests from an application to the POC FE. The application requests the POC FE to initiate a feeding of data or requests data from the hybrid overlay network.

7.2.1.3 Peer operation control (POC) FE

The POC FE controls the behaviour of a hybrid peer. This peer interacts with PC FE to get configurations that has been specified by a user and interacts with the data management function and hybrid overlay management client function to send/receive data to/from hybrid overlay network.

7.2.2 Path management function

The path management function manages primary paths and candidate paths that are established by the HPC FE of the hybrid peer interface function. This function also monitors the status of those paths to detect if they are alive.

7.2.2.1 Primary path management (PPM) FE

The PPM FE maintains peers having primary path with this peer. The HPC FE interacts with other peers for establishing a path, and the POC FE decides the type of path, primary and candidate. If it decides to set a specific path as primary, it notifies so to the PPM FE.

7.2.2.2 Candidate path management (CPM) FE

The CPM FE keeps peer information having a candidate path with this peer. This FE manages the incoming candidate path and outgoing candidate path separately since their operations are different from each other. When the number of outgoing candidate path goes below the pre-specified configuration from PC FE of the hybrid peer operation control function, this initiates procedures for establishing more outgoing candidate paths. In the case of an incoming candidate, it does not take any actions. However, if the number of incoming candidate path goes beyond the configuration, it does not accept any further connection from other peers until the number goes down.

7.2.2.3 Path status probe (PSP) FE

The PSP FE monitors primary and candidate paths to detect if they are alive using periodic heartbeat messages. Even though the peer uses transport control protocol for transport protocol, it does not guarantee that this peer detects the loss of connection. Hence, this FE should periodically check the connections to detect if they are alive and notify to the PPM FE and the CPM FE. If a primary path is lost, the POC FE initiates recovery procedures.

7.2.3 Data management function

The data management function exchanges data among peers over the hybrid overlay network as well as maintains data cache for the recovery of other peers. This function consists of CM FE, DR FE and DB FE.

7.2.3.1 Cache management (CM) FE

The CM FE manages internal caches before sending data to other peers over the hybrid overlay network. This FE overwrites cached data when the number of cached data exceeds the number configured by the PC FE. This FE also provides a buffermap to the HPC FE for exchanging with other peers for data recovery. When the HPC FE receives a request for data recovery, this FE provides the requested data to the HPC FE.

7.2.3.2 Data recovery (DR) FE

The DR FE recovers lost data due to hybrid overlay network reconstruction. When a peer is located in the middle of tree leaves, other peers that had primary path with the leaving peer need to recover their primary path. When the primary path is recovered, this FE tries to find any missing data during the tree reconstruction procedures and recovers the lost data by interacting with other peers by use of HPC FE.

7.2.3.3 Data broadcast (DB) FE

The DB FE sends data to the primary path of the peer. If an application of this peer generates a data to be broadcasted, it sends it to this FE which then sends the received data to all primary path. When the HPC FE receives data from other peers, it hands over the received data to this FE. The DB FE interacts with CM FE to cache the data and obtain primary connections from PPM FE to broadcast the received data with the exception of the path from which the data arrived.

7.2.4 Hybrid overlay management function

The hybrid overlay management function interacts with HOMS to manipulate or gain access to a hybrid overlay network.

7.2.4.1 Overlay management (OM) FE

The OM FE of a hybrid peer interacts with the HPI FE of HOMS through HCI FE to manage its own overlay network or to gain access to other overlay networks created by other peers. On receiving overlay information, this FE also internally keeps the information for later usage.

7.2.4.2 Peer list management (PLM) FE

The PLM FE interacts with the HPI FE of HOMS through HCI FE to get the list of peers of a specific hybrid overlay network and keeps the list. This FE tries to keep the number of peer large enough for robust hybrid overlay.

7.2.5 Hybrid peer interface function

The hybrid peer interface function is responsible for interaction with a HOMS and hybrid peers. This function consists of HPC FE and HCI FE.

7.2.5.1 Hybrid peer communication (HPC) FE

The HPC FE communicates with other peers for the establishment of tree, data broadcasting and recovery, etc.

7.2.5.2 HOMS client interface (HCI) FE

The HCI FE interacts with the HPI FE of the HOMS for the operations of OM FE of the hybrid peer.

7.3 Functional architecture of HOMS

The HOMS manages the overlay network information created by a peer and keeps track of the status of the overlay network by receiving reports from peers. Figure 7-3 shows the functional architecture of a HOMS.

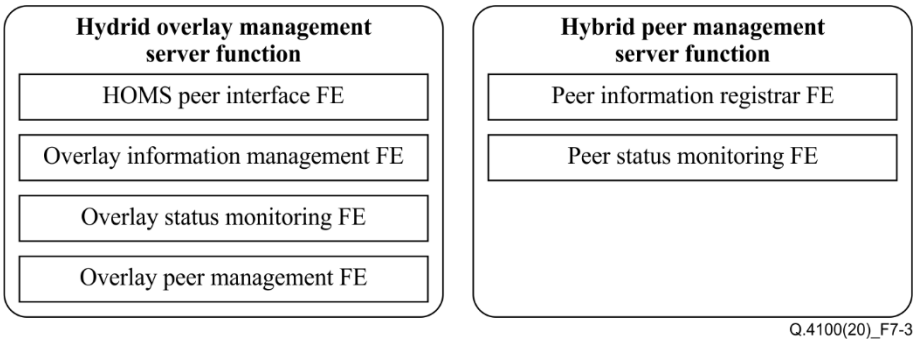


Figure 7-3 – Functional architecture of HOMS

7.3.1 Hybrid overlay management server function

The hybrid overlay management server function maintains the overlay network, status and peer list information that is gathered by peer's activities. This function consists of HPI FE, OIM FE, OSM FE and OPM FE.

7.3.1.1 HOMS peer interface (HPI) FE

The HPI FE interacts with peers for manipulating the overlay information and gathering status information. When a peer requests to create a new overlay network with the appropriate information, this FE interacts with OM FE to store the information after validation check. On receiving the query request for a particular overlay network from a peer, this FE interacts with OM FE and PIM FE to

retrieve the related information, and transfer the information to a requesting peer with the appropriate message format.

7.3.1.2 Overlay information management (OIM) FE

The OIM FE manages and provides the overlay network information on receiving requests from HCI FE.

7.3.1.3 Overlay status monitoring (OSM) FE

The OSM FE manages and provides the overlay status information on receiving requests from HCI FE. This FE also provides the information for operation, administration and monitoring to administrators.

7.3.1.4 Overlay peer management (OPM) FE

The OPM FE manages the peer list for each overlay network. When a peer sends a join request to HCI FE, the HCI FE sends peer and overlay information to this FE. This FE stores the information and provides them on receiving a query request from a requesting peer. In particular, when it provides the peer list for a particular overlay network, it provides an optimal list depending on the type of the overlay network. That is, this will provide random subset of peer list for a mesh-based overlay network and provide a list of peers to be connected for a tree-based overlay network.

7.3.2 Hybrid peer management server function

The hybrid peer management server function maintains peer information such as physical network information and peer preferences that were provided by a peer when joining. This function does not have any information related to a specific overlay network, but only manages peer related information. This function consists of PIR FE and PSM FE.

7.3.2.1 Peer information registrar (PIR) FE

The PIR FE manages peer information that is registered by a joining peer. When a peer joins a specific overlay network, it sends a message containing the peer information along with an overlay network information to the HCI FE of an overlay management function. The HCI FE hands over the information to this PIR FE.

7.3.2.2 Peer status monitoring (PSM) FE

The PSM FE monitors the status of peers by receiving report messages from peers. When a peer leaves unexpectedly without appropriate procedures, the other peer that detects the loss of the peer sends a report message to this FE through the HPI FE.

8 Reference points for hybrid P2P network

This clause specifies the reference points of the hybrid peer-to-peer networking.

8.1 Reference point R1 (Hybrid peer – HOMS)

Reference point R1 is used for interaction between a hybrid peer and HOMS. This reference point provides the following functionalities:

– Creation/removal/modification/query of overlay network,

– Join/leave of an overlay network,

– Reporting of peer activities regarding overlay construction and maintenance.

8.2 Reference point R2 (Hybrid peer – Hybrid peer)

Reference point R2 is used for communication between peers. Although the HOMS manages the overlay network, the shape of the tree is not controlled directly by the HOMS but is structured by interactions between peers. This reference point provides the following functionalities:

– Tree construction: On every joining of a new peer, the shape of tree will be restructured,

– Tree recovery: When a peer leaves from a hybrid overlay network, each peer communicates with each other to recover the tree,

– Probing: Each peer probes the status of other peers for better connectivity and checking the health of the hybrid network,

– Data broadcasting: Every peer within a core hybrid overlay network can generate and broadcast its own data, and all peer is responsible for relaying to its primary paths,

– Data recovery: If for any reason a peer loses some data, each peer communicates with each other to recover the lost data.

8.3 Reference point R3 (Hybrid peer – Managed peer)

Reference point R3 is used to exchange data between the core tree hybrid overlay network and the SubTree and SubMesh overlay networks. Hybrid overlay networks are specialized for real-time data distribution, and the managed P2P networks [ITU-T X.609] are advantageous for distributing large amounts of data that are resistant to latency. Thus, live data can be distributed over a hybrid network and data can be collected and stored within a managed P2P network. However, hybrid peers and managed peer-to-peer peers do not use the same protocol because interaction at the application level is sufficient. That is, data received from the hybrid overlay network is transmitted at the application level to the peers of the managed P2P network. The compositions of overlay networks are up to the application function.

9 High-level information flows for various application services

This clause describes high-level information flows of several services over the hybrid peer-to-peer network and shows how the function of each component interacts with each other. The information flows will be described on the level of components, and further detailed procedures will be specified in other Recommendations.

9.1 IoT data streaming service

This clause provides high-level information flows for Internet of things (IoT) data streaming service on top of hybrid peer-to-peer network. As shown in Figure 9-1, there may exist multiple sources within a hybrid overlay network. The sources are member of the CoreTree of the hybrid overlay network, and they can produce and broadcast their own data at any time.

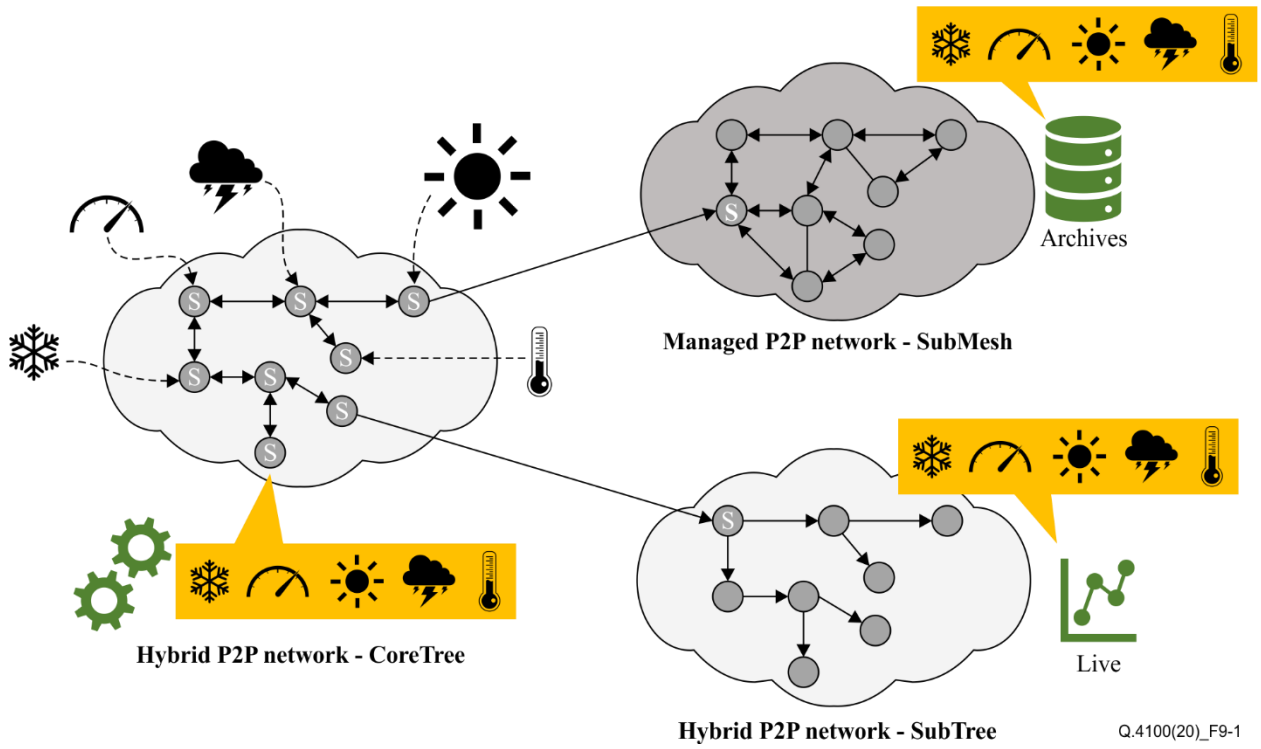


Figure 9-1 – Overall topology for IoT data streaming service

Data generated by the CoreTree can be delivered to a SubMesh or SubTree overlay network. The SubMesh overlay network will stack the received data for additional use, similar to a database, and the SubTree overlay network will be used to update the current state in real time without saving the data. However, this depends on the implementation of this service.

Figure 9-2 shows information flows for the IoT data streaming services. It is assumed that H-PEER B is configured to sending received data from the hybrid overlay network to the source peers of the SubMesh and the SubTree overlay network.

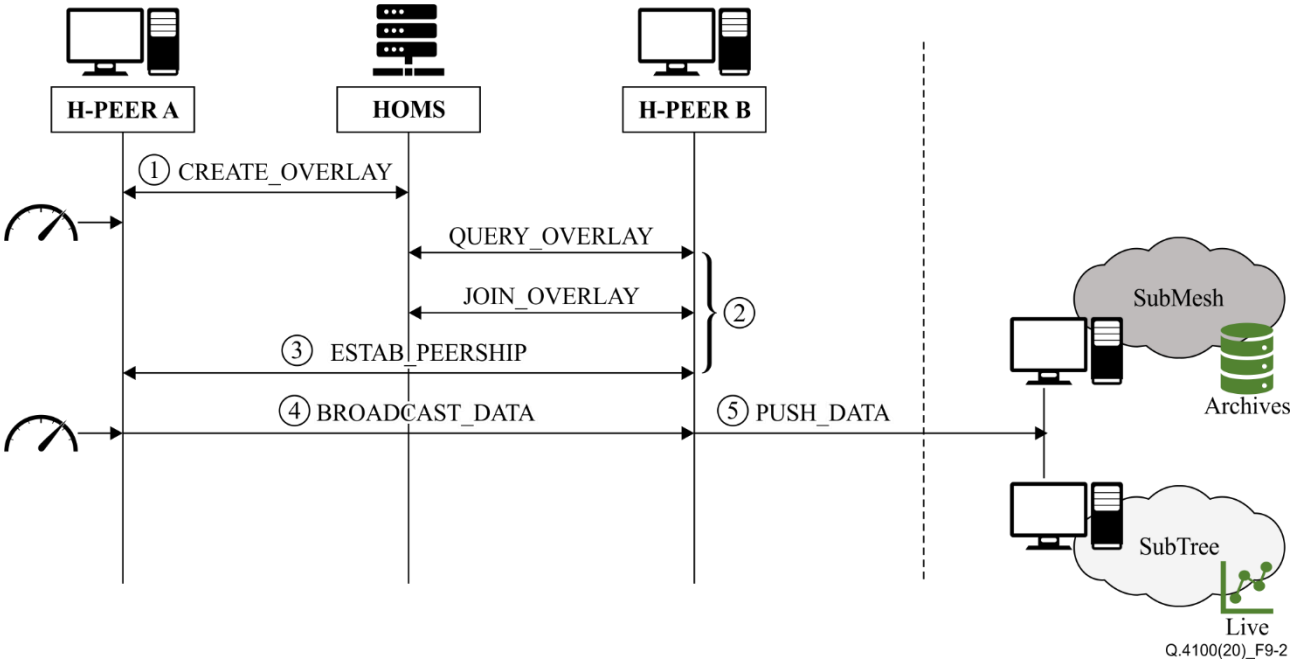


Figure 9-2 – Information flows for IoT data streaming service

1) H-PEER A creates a hybrid overlay network by interacting with HOMS.

2) H-PEER B joins the hybrid overlay network created by H-PEER A after querying to find an appropriate overlay network. This means that this peer will add its IoT data to the virtual data broadcast channel. During the joining procedures, H-PEER B receives a peer list that shows the participating peers including their network address.

3) H-PEER A and B establish a peer relationship by exchanging messages. If it satisfies some pre-conditions, the relationship will be switched to a primary path.

4) H-PEER A sends data to H-PEER B with the primary path when generating data from IoT devices such as sensors.

5) H-PEER B pushes the data of PEER-A for further distribution in the application level through reference point R3.

9.2 Blockchain service

This clause provides high-level information flows for blockchain service on top of hybrid peer-to-peer network. The transaction data which needs to be shared as soon as possible will be distributed over tree-based overlay network, and the blocks will be shared by using the mesh-based overlay network.

Figure 9-3 shows the overall topology for blockchain services. This figure assumes that the block producers will be a member of the CoreTree overlay network, and other blockchain nodes are members of the SubMesh overlay network.

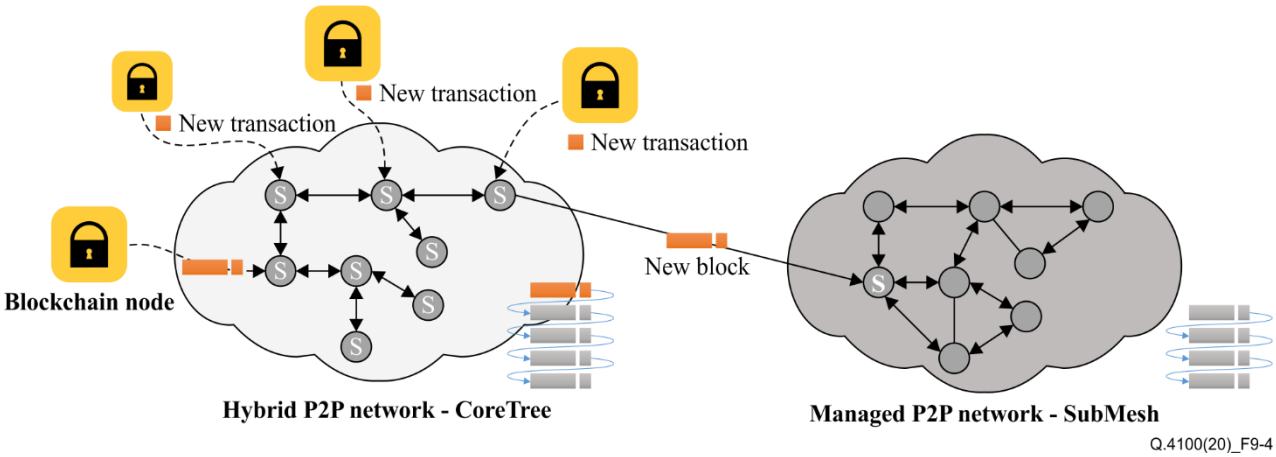


Figure 9-3 – Overall topology for blockchain service

The block producer nodes broadcast its transaction data whenever a new transaction is made, and it also broadcasts a new block when it finds one. If one of the peers of the CoreTree overlay network is the source of a SubMesh network, it pushes the new block to the SubMesh network. All peers within the SubMesh network exchange the newly generated data with each other.

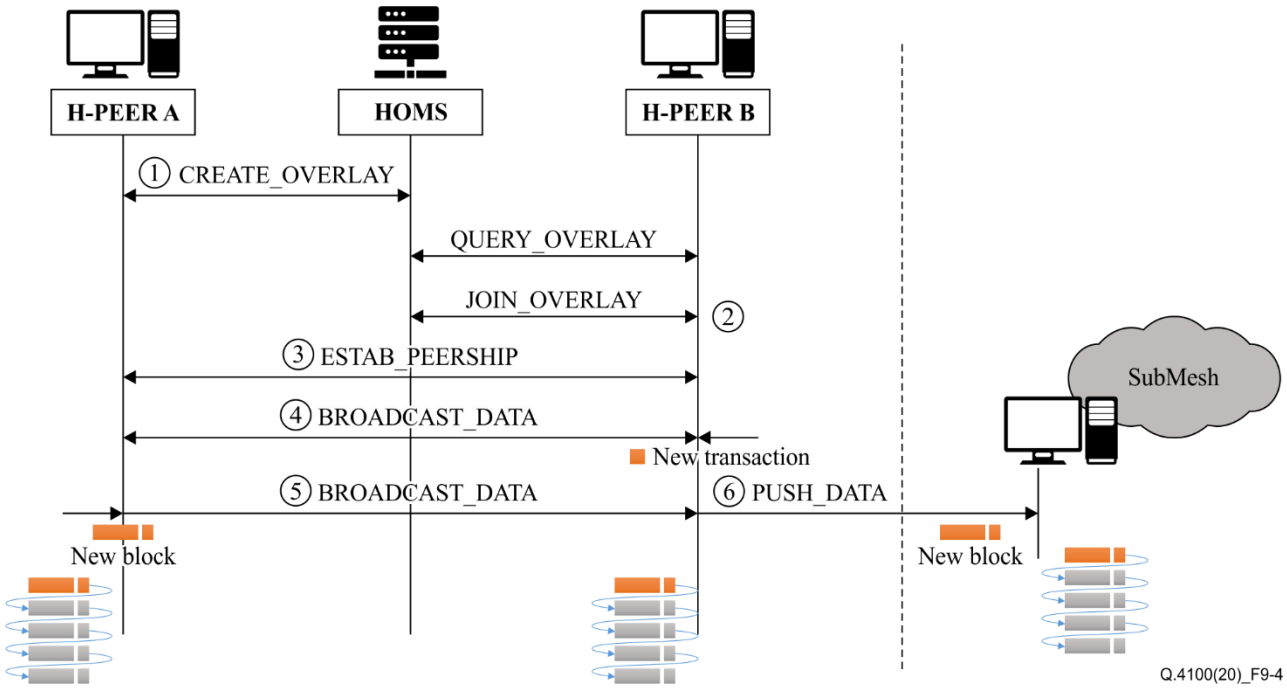


Figure 9-4 – Information flows for blockchain service

Figure 9-4 shows information flows for blockchain service, and it is assumed that block producing nodes are joining a CoreTree hybrid overlay network, and other full nodes are members of the SubMesh overlay network. It is also assumed that H-PEER B is transmitting transaction and block data to a source node of the SubMesh overlay network.

1) H-PEER A creates a hybrid overlay network by interacting with HOMS.

2) H-PEER B joins the hybrid overlay network created by H-PEER A after querying an overlay network for the blockchain. During the joining procedures, H-PEER B receives a peer list that shows the participating peers including their network address.

3) H-PEER A and B establish a peer relationship by exchanging messages. If it satisfies the conditions, the relationship will be switched to a primary path.

4) Any H-PEER sends transaction data to other peers whenever it generates a new transaction. In this case, H-PEER B sends to H-PEER A.

5) H-PEER A sends a block to H-PEER B when the blockchain application of this peer finds a new block.

6) H-PEER B pushes the newly created block to the SubMesh overlay network that is composed of blockchain nodes through reference point R3.

9.3 Multimedia live streaming service

This clause provides high-level information flows for live multimedia streaming such as video communications with an additional large number of observers (see Figure 9-5). However, this does not limit the type of services or media. Any kind of multimedia stream can be conveyed through the hybrid overlay network, depending on the application function.

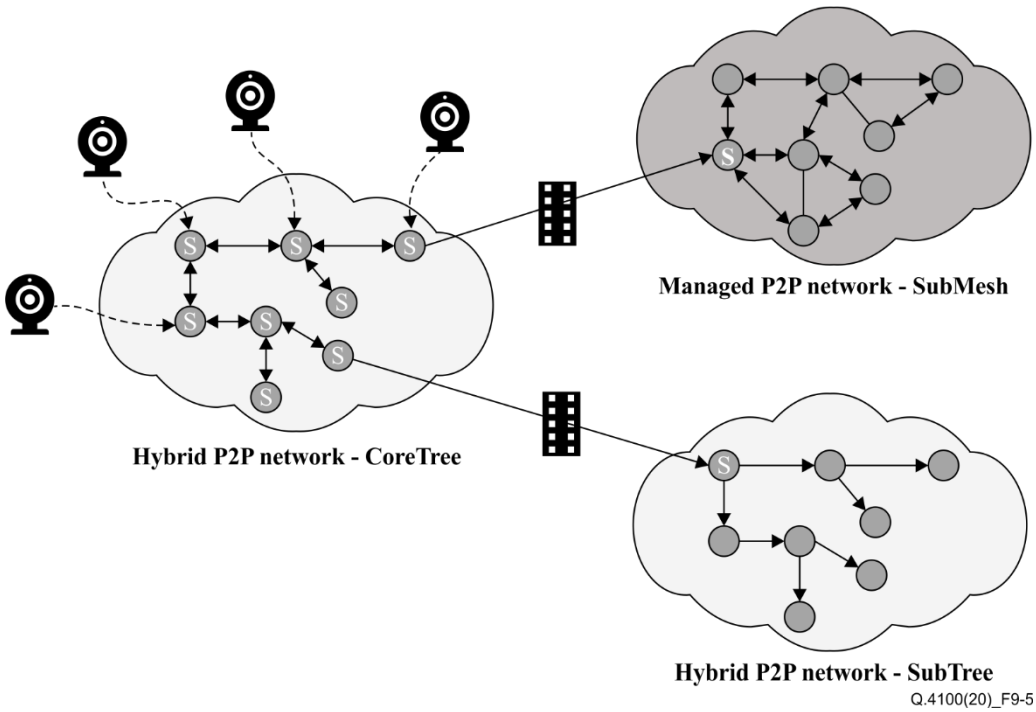


Figure 9-5 – Overall topology for multimedia live streaming service

The media from the hybrid overlay network is pushed to multiple other sub overlay networks. A user who wants to watch live media will be attached to a SubTree overlay network, and other users who want to save for later play back will be attached to a SubMesh overlay network. The topology shape of the overlay network composition depends on the application service provider. In the case of multimedia streaming over SubMesh, it uses a protocol specified in [ITU-T X.609.3] and [ITU-T X.609.4].

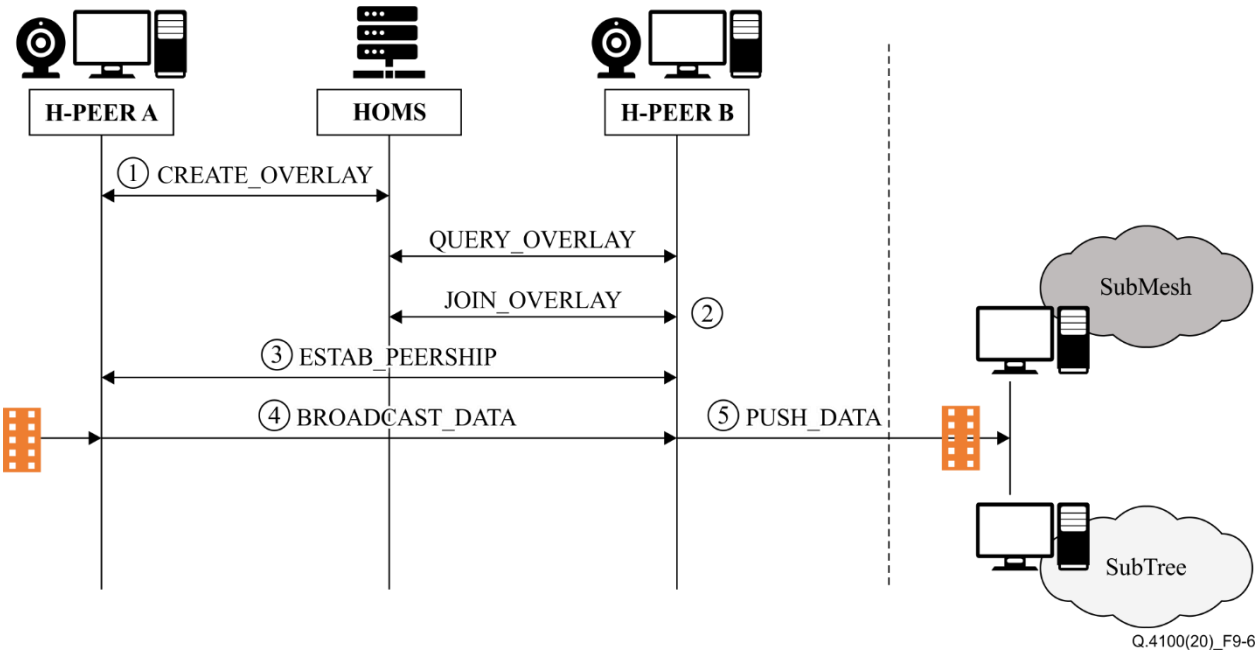


Figure 9-6 – Information flows for multimedia live streaming service

Figure 9-6 shows information flows for multimedia live streaming services. It is assumed that H-PEER B is configured to push data received from the hybrid overlay network to other sub overlay networks.

1) H-PEER A creates a hybrid overlay network by interacting with HOMS.

2) H-PEER B joins the hybrid overlay network that is created by H-PEER A. During the joining procedures, H-PEER B receives a peer list that shows the participating peers including their network address.

3) H-PEER A and B establish a peer relationship by exchanging messages. If it satisfies the conditions, the relationship will be switched to a primary path.

4) After the primary path is established, H-PEER B can receive multimedia stream from H-PEER A, and it is also possible to send at any time as well.

5) The application running on top of H-PEER B, pushes the media stream to the source peer of the sub overlay network through reference point R3. It is assumed that the sub overlay is already constructed, and the source peer is ready to receive data stream from H-PEER B.

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