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SERIES Y: GLOBAL INFORMATION INFRASTRUCTURE, INTERNET PROTOCOL ASPECTS AND NEXT-GENERATION NETWORKS

Internet protocol aspects – IPTV over NGN

Framework for multicast-based IPTV content delivery

Recommendation ITU-T Y.1902

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Recommendation ITU-T Y.1902

Framework for multicast-based IPTV content delivery

Summary

Recommendation ITU-T Y.1902 describes a framework for multicast-based IPTV content delivery based upon different content delivery functional models and their associated requirements. The content delivery functional models are defined according to different methods of multicast-based IPTV content delivery in terms of IPTV functional architecture described in Recommendation ITU-T Y.1910. Requirements for multicast capabilities specified in this Recommendation are based on the requirements provided in Recommendation ITU-T Y.1901.

History

Edition	Recommendation	Approval	Study Group
1.0	ITU-T Y.1902	2011-04-22	13

FOREWORD

The International Telecommunication Union (ITU) is the United Nations specialized agency in the field of telecommunications, information and communication technologies (ICTs). The ITU Telecommunication Standardization Sector (ITU-T) is a permanent organ of ITU. ITU-T is responsible for studying technical, operating and tariff questions and issuing Recommendations on them with a view to standardizing telecommunications on a worldwide basis.

The World Telecommunication Standardization Assembly (WTSA), which meets every four years, establishes the topics for study by the ITU-T study groups which, in turn, produce Recommendations on these topics.

The approval of ITU-T Recommendations is covered by the procedure laid down in WTSA Resolution 1.

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.

NOTE

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

Compliance with this Recommendation is voluntary. However, the Recommendation may contain certain mandatory provisions (to ensure, e.g., interoperability or applicability) and compliance with the Recommendation is achieved when all of these mandatory provisions are met. The words "shall" or some other obligatory language such as "must" and the negative equivalents are used to express requirements. The use of such words does not suggest that compliance with the Recommendation is required of any party.

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As of the date of approval of this Recommendation, ITU had not 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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Recommendation ITU-T Y.1902

Framework for multicast-based IPTV content delivery

1 Scope

This Recommendation provides a framework for multicast-based IPTV content delivery based upon different content delivery functional models and their associated requirements for delivery of IPTV content to multiple end users simultaneously.

The content delivery functional models are defined according to different methods of multicast-based IPTV content delivery in terms of the common functions of the IPTV functional architectural approaches (i.e., non-NGN, NGN-non-IMS, and NGN-IMS) described in [ITU-T Y.1910].

For each content delivery functional model, different roles for the functions of the IPTV architecture are identified according to the multicast capabilities defined in [ITU-T Y.2236].

For each multicast capability, the corresponding requirements for multicast-based IPTV content delivery are further identified based on the requirements to support IPTV services [ITU-T Y.1901].

2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

[ITU-T Y.1901] Recommendation ITU-T Y.1901 (2009), *Requirements for the support of IPTV services*.

[ITU-T Y.1910] Recommendation ITU-T Y.1910 (2008), *IPTV functional architecture*.

[ITU-T Y.2019] Recommendation ITU-T Y.2019 (2010), *Content delivery functional architecture in NGN*.

[ITU-T Y.2236] Recommendation ITU-T Y.2236 (2009), *Framework for NGN support of multicast-based services*.

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 channel changing [ITU-T Y.1901]: The act of changing from one channel to another.

3.1.2 cluster [ITU-T Y.2019]: Cluster is a grouping of content delivery processing entities with their related control entity. Such grouping allows the sharing of resources (e.g., storage capacity) based on the provider's policy (e.g., taking into account parameters such as user location).

3.1.3 content provider [ITU-T Y.1910]: The entity that owns or is licensed to sell content or content assets.

3.1.4 content segment [ITU-T Y.1901]: A continuous portion of a piece of content, for example, a single topic in a news programme.

3.1.5 delivery [ITU-T Y.1910]: In context of IPTV architecture, "delivery" is defined as sending contents to the end user.

3.1.6 distribution [ITU-T Y.1910]: In context of IPTV architecture, "distribution" is defined as sending the content to appropriate intermediate locations to enable subsequent delivery.

3.1.7 end user [ITU-T Y.1910]: The actual user of the products or services.

NOTE – The end user consumes the product or service. An end user can optionally be a subscriber.

3.1.8 linear TV [ITU-T Y.1910]: A television service in which a continuous stream flows in real time from the service provider to the terminal device and where the user cannot control the temporal order in which contents are viewed.

3.1.9 multicast [b-ITU-T X.603]: A data delivery scheme where the same data unit is transmitted from a single source to multiple destinations in a single invocation of service.

3.1.10 multicast group [b-ITU-T X.601]: A set of service users that abide by appropriate group-membership criteria, or a set of rules belonging to a group that enables multicast-based services and applications.

3.1.11 multicast connection [ITU-T Y.2236]: A transmission path used for data transfer among members of a multicast group.

3.1.12 network provider [ITU-T Y.1910]: The organization that maintains and operates the network components required for IPTV functionality.

NOTE 1 – A network provider can optionally also act as service provider.

NOTE 2 – Although considered as two separate entities, the service provider and the network provider can optionally be one organizational entity.

3.1.13 service provider [b-ITU-T M.1400]: A general reference to an operator that provides telecommunication services to customers and other users either on a tariff or contract basis. A service provider can optionally operate a network. A service provider can optionally be a customer of another service provider.

NOTE – Typically, the service provider acquires or licenses content from content providers and packages this into a service that is consumed by the end user.

3.2 Terms defined in this Recommendation

None.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

AAA Authentication, Authorization, Accounting

ALTO Application-Layer Traffic Optimization

CD&SF Content Delivery and Storage Functions

CDF Content Delivery Functions

CDN Content Delivery Network

CE Customer Edge

CS Content Source

DiffServ Differentiated Services

DNS Domain Name Services

DoS Denial of Service

DSN	Distributed Service Network
EUF	End-User Functions
IGMP	Internet Group Management Protocol
MDT	Multicast Distribution Tree
MLD	Multicast Listener Discovery
MN	Management Node
MPLS	Multiprotocol Label Switching
MTF	Multicast Transport Functions
mVPN	Multicast Virtual Private Network
NF	Network Functions
NP	Network Provider
p2p	Peer-to-Peer
PE	Provider Edge
PIM	Protocol Independent Multicast
QoE	Quality of Experience
QoS	Quality of Service
SCF	Service Control Functions
SNMP	Simple Network Management Protocol
SP	Service Provider
TOCF	Traffic Optimization Control Function
VPN	Virtual Private Network
VRF	Virtual Routing and Forwarding

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 document is to be claimed. These requirements are identified in the form of R <clause #>-#.

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. These requirements are identified in the form of RR <clause #>-#.

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 or service provider. Rather, it means the vendor may optionally provide the feature and still claim conformance with the specification. These requirements are identified in the form of OR <clause #>-#.

Requirements are identified using the convention for the requirements in [ITU-T Y.1901].

6 Overview

In the multicast-based IPTV content delivery, IPTV content is delivered to one or more end users simultaneously via the use of unicast or multicast mechanisms supported by network functions (NF) of the IPTV functional architecture.

To support the multicast-based IPTV content delivery, the functions of the IPTV architecture provide their own capabilities as defined in [ITU-T Y.1910].

Figure 6-1 depicts the IPTV architectural overview (as per Figure 9-1 in [ITU-T Y.1910]) and highlights the functional groups involved in multicast-based IPTV content delivery which are in the scope of the framework provided in this Recommendation, i.e., service control functions (SCF), content delivery functions (CDF), end-user functions (EUF), and NF as defined in [ITU-T Y.1910].

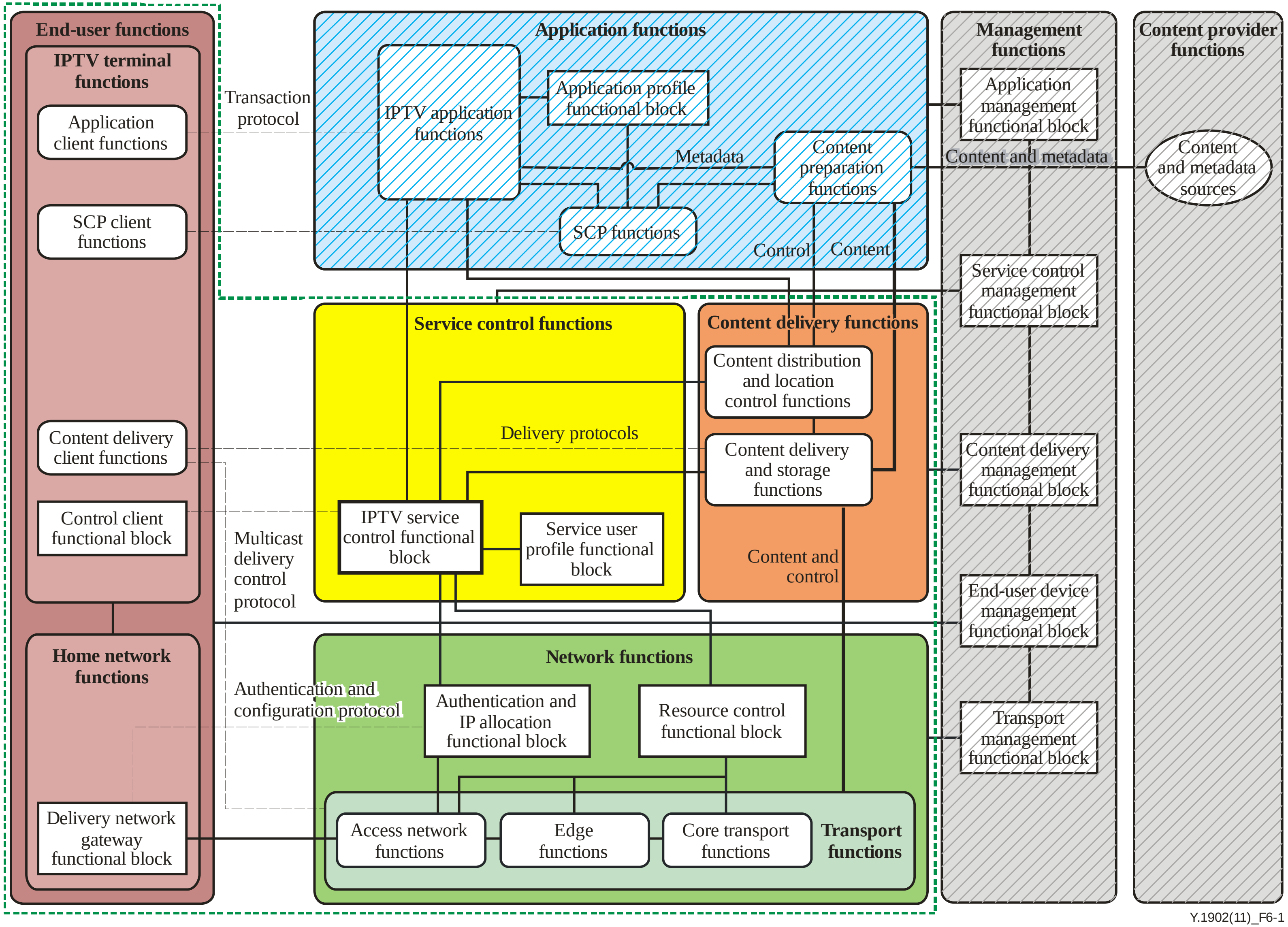

Figure 6-1 – IPTV functional architecture and the involved functions to multicast-based IPTV content delivery

The roles and use of the functions of the IPTV functional architecture [ITU-T Y.1910] may vary depending upon the business models in place, thus leading to different content delivery functional models.

In the following clauses, this Recommendation describes such different functional models for multicast-based IPTV content delivery. The involved functions of the IPTV functional architecture and their roles and use for each of the described models are shown. This Recommendation further describes the specific roles of the functions of IPTV functional architecture and the corresponding requirements for multicast-based IPTV content delivery based on the multicast capabilities defined in [ITU-T Y.2236].

NOTE 1 – In this Recommendation, unless explicitly indicated otherwise, the term "multicast-based IPTV content delivery" is used in general way to indicate a method of delivery of IPTV content to multiple end users simultaneously. In [ITU-T Y.1910], the term "multicast content delivery" or "multicast delivery" is used more specifically to indicate one of the IPTV content delivery methods by which CDF delivers IPTV content to EUF via multicast transport functions (MTF).

NOTE 2 – This Recommendation does not address interconnection issues related to multicast-based IPTV content delivery, e.g., interconnection between different service providers (SPs) supporting content delivery functions.

7 Functional models for multicast-based IPTV content delivery

This clause describes the functional models for multicast-based IPTV content delivery.

NOTE 1 – This Recommendation does not provide specific functional model for unicast content delivery. [ITU-T Y.1910] provides a description of the CDF that support unicast content delivery and which can be deployed in different ways depending of the delivery constraints. Starting from content delivery functions defined in [ITU-T Y.1910], [ITU-T Y. 2019] describes a further decomposed functional model called "hierarchical model" that can be used for unicast content delivery.

For each functional model, the description includes figures illustrating how relevant functions of the IPTV functional architecture are used for multicast-based content delivery.

In Figures 7-1 to 7-4, the boxes in dotted lines indicate the IPTV domains, which are defined in [ITU-T Y.1910], and solid lines indicate the content distribution paths. The solid lines with arrows indicate the forwarding of replicated data performed by the multicast capability. The small rounded boxes indicate the instances of relevant IPTV architecture functions for multicast-based IPTV content delivery in the considered model. The IPTV domains and functions which provide multicast capabilities in the considered model are highlighted.

NOTE 2 – In Figures 7-1 to 7-4, the control paths for multicast-based IPTV content delivery are omitted given that the functional models for content delivery are differentiated depending upon which functions perform the multicast-based delivery of IPTV content.

NOTE 3 – The figures in this clause depict some examples of content distribution paths. However, in the multicast-based IPTV content delivery, the way to construct a content distribution path (e.g., mesh-based, tree-based) and to distribute the content among the instances of functions in IPTV architecture (e.g., pull-based or push-based, multiple source-based or single source-based) may vary depending on implementation choices.

NOTE 4 – In the IPTV functional architecture [ITU-T Y.1910] there are other functional groups (such as content preparation functions, home network functions) which are related to multicast-based IPTV content delivery. Given that the roles of these functions do not vary in the different considered content delivery functional models, these functions are not mentioned, for simplicity reasons.

The following clauses describe four different functional models for multicast-based delivery of IPTV content.

These functional models differ mainly due to the roles and use of the functions which support the multicast capabilities for delivering IPTV content. In this Recommendation, the considered multicast capabilities described in [ITU-T Y.2236] consist of multicast group management, multicast service control, quality of service (QoS) control, security, mobility, accounting and charging, and multicast data delivery. Depending on the functional model, these capabilities are supported by different functions in the IPTV functional architecture.

More details about these functional models are provided in Appendix I.

7.1 Network multicast model

In this model, the multicast capabilities are supported by MTF provided in the network provider (NP) domain (i.e., by the telecommunication equipments operated and controlled by the network provider). Each instance of EUF registers itself to a specific multicast group by exchanging messages for joining (e.g., Internet group management protocol (IGMP) [b-IETF RFC 3376] messages) with an MTF instance. MTF instances construct multicast distribution paths and IPTV content is delivered from content sources (CSs) via the CDF to each EUF along the paths.

Figure 7-1 depicts how the IPTV content is delivered by the relevant functions in the network multicast model.

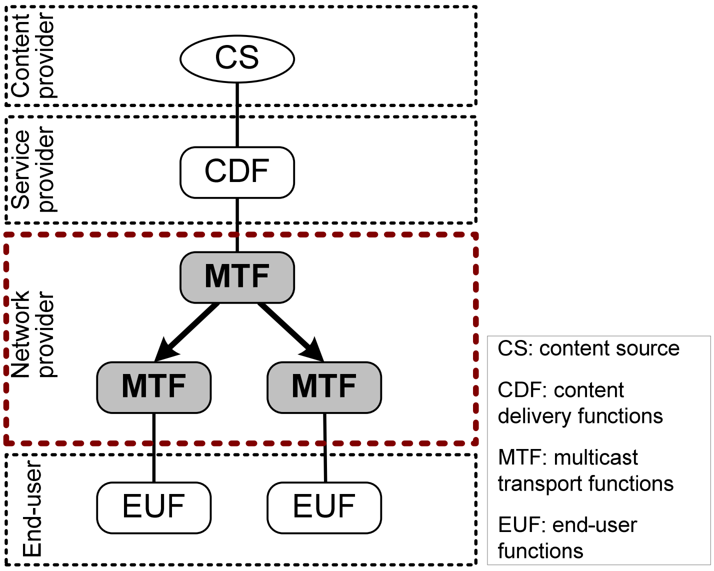

Figure 7-1 – Network multicast-based content delivery

In this model, a network provider provides, and manages the multicast capabilities for multicast-based IPTV content delivery. Performance of a network multicast-based IPTV content delivery is tightly related to the condition of NP's network.

Network multicast-based content delivery can be deployed using IP multicast or multicast virtual private network (mVPN) mechanisms. Refer to Appendix IV for specific details of mVPN. Details of IP multicast-based deployment are currently under study within ITU-T.

More details about the network multicast-based content delivery are provided in clause I.1 of Appendix I.

7.2 Cluster model

In this model, the multicast capabilities are supported by CDF which is provided in the service provider domain. Within CDF, clusters for content delivery (e.g., such as cluster instances [ITU-T Y.2019]) are placed in appropriate locations to distribute IPTV content.

Figure 7-2 depicts how the IPTV content is delivered by the relevant functions in the cluster model.

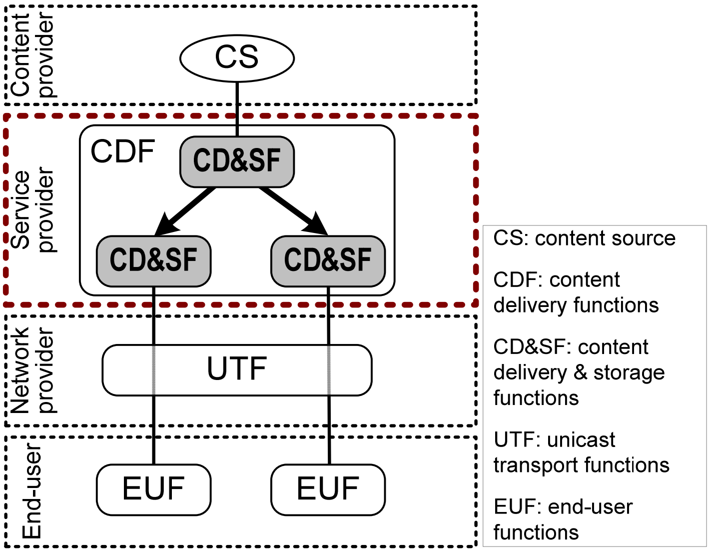

Figure 7-2 – Cluster-based content delivery

The cluster model uses functions provided in the service provider domain (i.e., by telecommunication equipment controlled and operated by the service provider). CDF is responsible for providing multicast capabilities.

This model has performance characteristics tightly related to the capacities of content delivery and storage functions (CD&SF) instances and to the number of CD&SF instances, due to the fact that a given CD&SF instance has to send IPTV content on a per end user basis (i.e., individually via the unicast connection between the CD&SF instance and each end user). The number of end users that can be served simultaneously depends on the CD&SF instances' capacities.

This model can be deployed using content delivery network (CDN) mechanisms described in [b-CDN] or [ITU-T Y.2019].

More details about the cluster-based content delivery are described in clause I.2.

7.3 Peer-to-peer model

In this model, the multicast capabilities are supported by EUF, which is provided in the end-user domain (i.e., by telecommunication equipments controlled and operated by the end user). Thus, an end user can distribute the IPTV content while receiving the IPTV content at the same time. To distribute the IPTV content, EUF instances construct multicast distribution paths with themselves. Along the paths, the end users distribute the content to the other end users via unicast transport.

Figure 7-3 depicts how the IPTV content is delivered by the relevant functions in the peer-to-peer (p2p) model.

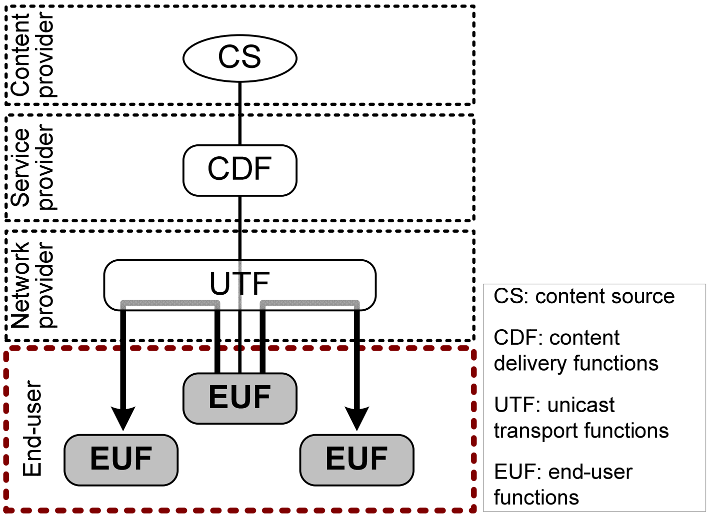

Figure 7-3 – p2p-based content delivery

In this model, EUF takes charge of multicast capabilities to distribute the IPTV content, multicast capabilities provided by network or service providers for content delivery not being required. This model makes the deployment easier and more resilient to failures during content distribution.

As the number of end users increases, more storage resources for IPTV content distribution are provided, which makes the deployment scalable.

However, managing the end users (e.g., for billing, presence and traffic management) is difficult because the p2p-based content delivery is not controlled by service providers nor network providers. For example, network providers may encounter difficulties regarding traffic management, which may result in performance degradation of content delivery due to traffic overload in the network.

Service providers and network providers may be involved in appropriate management functions of p2p-based content delivery in order to achieve manageable content distribution (examples of these functions are application-layer traffic optimization (ALTO) [b-IETF RFC 5693] and the traffic optimization control function (TOCF) of the distributed service network (DSN). In this way, the p2p-based content delivery can be tightly managed and related performance can be improved.

More details about p2p-based content delivery are provided in clause I.3, while details about managed p2p-based content delivery are provided in Appendix II.

7.4 Hybrid model of cluster and peer-to-peer

In this model, the multicast capabilities are supported by CDF in the service provider domain (i.e., provided by telecommunication equipments controlled and operated by a service provider) with assistance of EUF in the end-user domain (i.e., provided by telecommunication equipments controlled and operated by the end user). Multicast content distribution is mainly performed by CDF with the involvement of EUF making this model more scalable than the cluster model or the peer-to-peer model. A multicast distribution path is constructed by CD&SF instances and end users. Along this path, the IPTV content is delivered from a content source to each end user.

Figure 7-4 depicts how the IPTV content is delivered by the relevant functions in the hybrid model combining the peer-to-peer and cluster models for multicast-based IPTV content delivery.

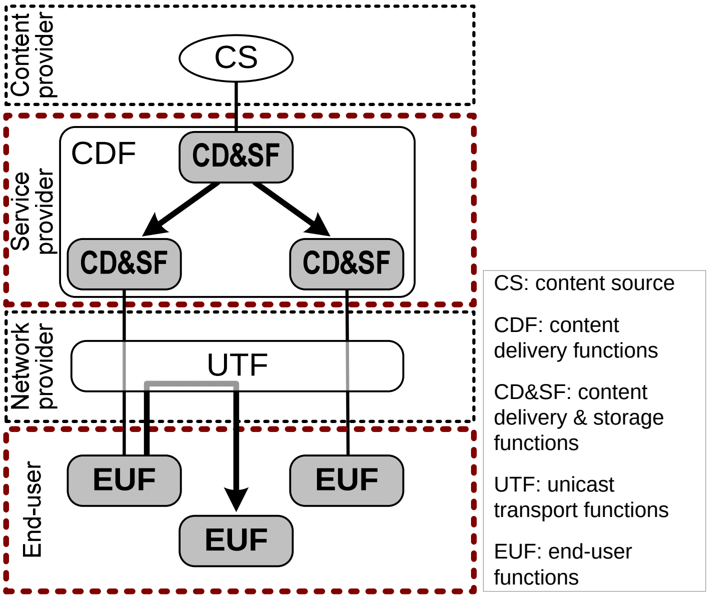

Figure 7-4 – Content delivery based on hybrid of peer-to-peer and cluster models

As this model is based on the cluster model, it has the same advantages as the cluster model (see clause 7.2). Considering that this model exploits EUF for further distribution of IPTV content in the end-user domain, it allows a better scaling than the cluster model. In addition, since content distribution is mainly controlled by CDF, traffic management issues resulting from content distribution by EUF in the end-user domain are less important than in the case of the peer-to-peer model.

More details about the hybrid of p2p and cluster-based content delivery models are described in clause I.4.

Additional hybrid models (e.g., hybrid model of p2p and network multicast as presented in Appendix III) are also possible.

8 Multicast capabilities for content delivery and distribution

8.1 General multicast capabilities

In order to provide multicast-based delivery of IPTV content, the IPTV functional architecture is required to support the multicast capabilities. The general multicast capabilities are described in [ITU-T Y.2236] and are categorized into seven parts: data delivery, group management, service control, QoS control, security, mobility, and accounting and charging.

– Data delivery: This capability deals with the delivery of data to the multicast group members. The essential function of multicast data delivery is data forwarding according to the group membership of users.

– Group management: This capability deals with membership management of a group involved in a multicast-based service. Its main functionalities include group or group member identification, group advertisement and discovery, group monitoring, and membership management.

– Service control: This capability deals with service control for multicast data delivery. Its main functionality is to manage the multicast connection between the multicast source and group members, which is used at service delivery. It includes connection establishment and maintenance, service admission control, service advertisement and discovery, and service monitoring.

– QoS control: This capability deals with QoS control support for multicast-based services. It defines the target QoS level of a multicast connection.

– Security: This capability deals with security support for multicast-based services. It provides user authentication and authorization, data confidentiality support, and data integrity support.

– Mobility: This capability deals with mobility support for multicast-based services. It provides maintenance support of a multicast connection while multicast senders or receivers roam.

– Accounting and charging: This capability deals with the charging and accounting of multicast-based services.

8.2 Multicast capabilities in IPTV functions

In the IPTV functional architecture [ITU-T Y.1910], MTF deals with the multicast capabilities. Specifically, the multicast control point functional block is responsible for control of multicast delivery, e.g., group and path management; the multicast replication functional block is responsible for delivery of multicast data, e.g., replication and forwarding of multicast data to the other MTF instances or EUFs.

As described in clause 7, however, multicast capabilities can be provided by functions of the IPTV architecture [ITU-T Y.1910] different from MTF, according to the functional models of multicast-based IPTV content delivery. The mapping of multicast capabilities to IPTV functions [ITU-T Y.1910] is classified under two groups:

– "*multicast control*" for group management, QoS control, security, mobility, and accounting and charging;

– "*multicast delivery*" for data delivery.

Note that service control capability for multicast-based IPTV content delivery is not classified under either of the two above groups since it is provided by IPTV service control functional block of SCF regardless of the functional model.

In the network multicast model, the mapping of multicast capabilities to IPTV functions is the same as in [ITU-T Y.1910]. That is, multicast control capability is provided by multicast control point functional block of MTF; and multicast delivery capability is provided by multicast replication functional block of MTF. All multicast capabilities are performed within NF provided by the network provider.

In the cluster model, CDF is responsible for the multicast capabilities: specifically, content distribution and location control functions of CDF for multicast control, and content delivery and storage functions of CDF for multicast delivery.

In the peer-to-peer model, content delivery client functions of EUF in the end-user domain is responsible for both of multicast control and multicast delivery because this model does not exploit any other IPTV functions provided by network or service provider.

In the hybrid model of p2p and cluster, both of CDF and EUF take a charge of multicast control and multicast delivery capabilities. In specific, multicast control is supported by content distribution and location control functions of CDF and content delivery client functions of EUF; multicast delivery is supported by content delivery and storage functions of CDF and content delivery client functions of EUF.

The following table summarizes the mapping between multicast capabilities and functions of the IPTV architecture [ITU-T Y.1910] according to the functional models for multicast-based IPTV content delivery.

Table 8-1 – Mapping between multicast capabilities and relevant functions of the IPTV architecture

Functional model	Multicast capability	
	Multicast control	**Multicast delivery**
Network multicast model	Multicast control point functional block of MTF	Multicast replication functional block of MTF
Cluster model	Content distribution and location control functions of CDF	Content delivery and storage functions of CDF
Peer-to-peer model	Content delivery client functions of EUF	Content delivery client functions of EUF
Hybrid model of cluster and p2p	Content distribution and location control functions of CDF; Content delivery client functions of EUF	Content delivery and storage functions of CDF; Content delivery client functions of EUF

More details about the roles of IPTV functions for multicast-based IPTV content delivery in functional models are described in Appendix I.

9 General requirements for IPTV content delivery

R 9-01: The IPTV architecture is required to support network multicast-based content delivery.

R 9-02: The IPTV architecture is required to support cluster-based content delivery.

R 9-03: The IPTV architecture is required to have means for multicast capabilities to be designed to mitigate unexpected attacks such as denial of service (DoS) attacks.

R 9-04: The IPTV architecture is required to support mechanisms to provide end users with high quality of experience (QoE) for multicast-based IPTV content delivery [ITU-T Y.1901].

R 9-05: The IPTV architecture is required to use, where applicable, standard multicast protocols (e.g., protocol independent multicast (PIM) [b-IETF RFC 4601], IGMP [b-IETF RFC 3376], multicast listener discovery (MLD) [b-IETF RFC 4604]).

RR 9-01: The IPTV architecture is recommended to support mechanisms through which multicast-based IPTV content delivery is provided in robust manners.

RR 9-02: The IPTV architecture is recommended to be fully redundant to prevent multicast-based IPTV content delivery from being affected by a single point of failure (e.g., redundancy of multicast capabilities such as MTF instances).

OR 9-01: The IPTV architecture can optionally support p2p-based content delivery.

OR 9-02: The IPTV architecture can optionally support content delivery based on hybrid of cluster and p2p.

10 Requirements for multicast data delivery

R 10-01: The IPTV architecture is required to support multicast data delivery.

RR 10-01: The IPTV architecture is recommended to support mechanisms to control distribution of multicast traffic in a load-balanced manner.

RR 10-02: The IPTV architecture is recommended to support distribution of the IPTV content sources to different multicast groups for load-balancing.

RR 10-03: The IPTV architecture is recommended to support content segmentation [ITU-T Y.2019].

RR 10-04: The IPTV architecture is recommended to support mechanisms to vary the size of content segmentation.

11 Requirements for multicast group management

R 11-01: The IPTV architecture is required to support multicast group management.

NOTE – The multicast group management capability creates or maintains multicast groups of end users. This also includes the managements of group size and rate of group membership change.

R 11-02: The IPTV architecture is required to support mechanisms to assign and manage multicast addresses within the service provider domain to ensure the deployment of IPTV services.

RR 11-01: The IPTV architecture is recommended to support mechanisms for multicast address mapping across different service provider domains for IPTV service interoperability purposes in case of multi-domain IPTV service deployment.

NOTE – The multicast address mapping policy may vary depending on deployment choices of IPTV service providers.

RR 11-02: The IPTV architecture is recommended to manage multicast address for delivery of user created contents.

RR 11-03: The IPTV architecture is recommended to support mechanisms to modify a multicast address if a conflict among multicast addresses used in different service provider domains is detected.

RR 11-04: The IPTV architecture is recommended to provide identification of multicast groups to EUF.

OR 11-01: The IPTV architecture can optionally support mechanisms to bind multicast addresses with the domain names of domain name services (DNS) [b-IETF RFC 1035].

NOTE – With this mechanism, service providers do not have to allocate a multicast address to each multicast channel of IPTV service directly, but register domain names of these channels, and bind multicast addresses with their domain names dynamically.

12 Requirements for multicast service control

R 12-01: The IPTV architecture is required to support multicast service control.

R 12-02: The IPTV architecture is required to support the control of multicast content delivery sessions.

NOTE – This includes functions for session establishment, session release, session modification, and session status monitoring.

RR 12-01: The IPTV architecture is recommended to support mechanisms to dynamically restore multicast distribution paths in the event of multicast distribution path failures.

RR 12-02: The IPTV architecture is recommended to support mechanisms to use multiple multicast distribution paths for a multicast content delivery session.

NOTE – Using multiple multicast distribution paths can be helpful in load balancing of CDandSF instances and robustness of a multicast content delivery session.

RR12-03: The content delivery functions, in such a way that if multiple multicast distribution paths are used, they are recommended to assign minimum number of child nodes to a CD&SF instance in a multicast distribution tree in order to minimize impact of CD&SF instances failures.

RR 12-04: The IPTV architecture is recommended to consider the resource availability or activity status of CD&SF instances when establishing multicast distribution paths.

NOTE – The CD&SF instances with higher resource availability, while not being overloaded for multicast-based IPTV content delivery, are more likely to be located at higher level of the multicast distribution trees.

RR 12-05: The IPTV architecture is recommended to support performance measurement of a multicast distribution path.

RR 12-06: The IPTV architecture is recommended to support resource management of a multicast content delivery session.

NOTE – A resource management capability performs resource (e.g., storage capacity of CD&SF instances) control and admission control in a multicast content delivery session in order to support QoS for IPTV services.

RR 12-07: The IPTV architecture is recommended to support policy control and management in multicast-based IPTV content delivery to filter IPTV content to be delivered.

NOTE – This mechanism allows parents to block viewing of certain programs by children. The policies may vary with the use of time limiting or content rating.

RR 12-08: The IPTV architecture is recommended to support service monitoring mechanisms to report the service status.

12.1 Requirements specific to functional models

R 12.1-01: The IPTV architecture, if network multicast-based content delivery is supported, is required to support mechanisms to dynamically build and maintain network multicast distribution paths based on the formation of network topology in the network provider domain.

RR 12.1-01: The IPTV architecture, if network multicast-based content delivery is supported, is recommended to support static configuration of a network multicast distribution path.

R 12.1-02: The IPTV architecture, if cluster-based content delivery is supported, is required to record and report performance statistics of the CD&SF instances in a cluster.

RR 12.1-02: The IPTV architecture, if cluster-based content delivery is supported, is recommended to support the centralized management of content locations.

NOTE – The centralized content location management is responsible for keeping track of the locations of all the content in the CD&SF instances. It maintains a record of network topology, a content location, and a content delivery session.

R 12.1-03: The IPTV architecture, if p2p-based content delivery is supported, is required to support control for setup of content delivery session among peers (i.e., end users).

R 12.1-04: The IPTV architecture, if p2p-based content delivery is supported, is required to associate every peer with a credit.

NOTE – As a response to a service resource request to a target peer, the requesting peer can obtain corresponding resource information and the credit of the target peer. If the credit meets the requirement that the requesting peer sets for the target peer in terms of requested resource, the requesting peer sets up connection with the target peer and gets the requested resource from the target peer.

R 12.1-05: The IPTV architecture, if p2p-based content delivery is supported, is required to support control of reliable multicast distribution path for multicast-based IPTV content delivery (e.g., for IPTV end-user join and leave).

NOTE – The multicast distribution path is constructed over unicast transport paths in p2p-based content delivery, and is used to forward data along the constructed transport path. Examples of the path management capability are path join and leave, path maintenance, loop detection and avoidance, partitioning detection and recovery, parent switching, and session status reporting functions.

RR 12.1-03: The IPTV architecture, if p2p-based content delivery is supported, is recommended to support peer management functions in order for service providers to achieve manageable p2p-based content delivery.

NOTE – Peer management functions include:

– registration and maintenance for peer capability and status management;

– priority setting in p2p messages such that peers can behave differently based on this priority information when receiving p2p messages;

– admission control to prevent peers from making the p2p network unstable by frequently joining and leaving.

More details are described in Appendix IV.

13 Requirements for QoS control

R 13-01: The IPTV architecture is required to support QoS control of multicast-based IPTV content delivery.

R 13-02: The IPTV architecture is required to support service admission control in a multicast connection based on available resources (e.g., bandwidth, storage capacity, processing capacity).

NOTE – When an end user requests IPTV content, SCF needs to perform service admission control to check if the current available resources (e.g., bandwidth, number of connections) are enough for a new connection for delivery of the requested content.

R 13-03: The IPTV architecture is required to support mechanisms to manage the priorities of IPTV traffic [ITU-T Y.1901].

R 13-04: The IPTV architecture is required to support congestion avoidance and congestion management mechanisms that provide higher prioritized delivery of multicast traffic.

NOTE – These mechanisms are used to prevent multicast traffic from being dropped over other traffic (e.g., unicast traffic).

RR 13-01: The IPTV architecture is recommended to support mechanisms for monitoring quality parameters of content delivery.

NOTE – These parameters may include content segment loss, delay or jitter.

RR 13-02: The IPTV architecture is recommended to support multicast QoS control function.

NOTE – This function performs collection and management of transport network resources (e.g., using differentiated services (DiffServ) [b-IETF RFC 2475]) via specified interfaces (e.g., using simple network management protocol (SNMP) [b-IETF RFC 3411]).

RR 13-03: The IPTV architecture is recommended to support handling of IPTV traffic according to the requested QoS [ITU-T Y.1901].

RR 13-04: The IPTV architecture is recommended to support mechanisms to handle IPTV traffic according to pre-assigned QoS class.

RR 13-05: The IPTV architecture is recommended to give the traffic for linear TV a higher priority than the other traffic, in order to guarantee linear TV's quality and service provisioning.

RR 13-06: The IPTV architecture is recommended to support capabilities for classifying channel priorities of linear TV.

NOTE – Those priorities can be classified based on bandwidth and multicast resources reserved for programmes.

RR 13-07: The IPTV architecture is recommended to support the means to provide channel changing capability with sufficient QoE when delivering IPTV channels using multicast [ITU-T Y.1901].

RR 13-08: The IPTV architecture is recommended to support QoS measurement and management.

NOTE – QoS is measured in terms of measurement data such as throughput, loss rate, delay, and jitter.

RR 13-09: The IPTV architecture is recommended to support mechanisms for IPTV service to obtain the periodical measurement of the IPTV service quality, including on a daily, weekly, monthly basis.

OR 13-01: The IPTV architecture can optionally support mechanisms for end-to-end resource reservation to match QoS requirements.

14 Requirements for security

R 14-01: The IPTV architecture is required to provide security support for multicast-based IPTV content delivery [ITU-T Y.1901] [ITU-T Y.2236].

OR 14-01: The IPTV architecture can optionally support configuration of end-users' multicast privileges according to their multicast group address [ITU-T Y.1910].

15 Requirements for mobility

RR 15-01: The IPTV architecture is required to comply with the requirements described in clause 6.4.3 of [ITU-T Y.1901] as far as multicast-based IPTV content delivery is concerned.

16 Requirements for accounting and charging

R 16-01: The IPTV architecture is required to provide with accounting and charging of multicast-based IPTV content delivery.

17 Security considerations

The security requirements of this Recommendation are provided in clause 14.

Appendix I

Examples of multicast-based IPTV content delivery scenarios

(This appendix does not form an integral part of this Recommendation.)

This appendix provides examples of multicast-based IPTV delivery scenarios by describing the procedural view of the functional groups and blocks of IPTV architecture which are defined in [ITU-T Y.1910].

I.1 Network multicast-based content delivery scenario

In network multicast-based content delivery, the network provider is in charge of replicating and delivering IPTV content to each end user. The role of MTF is to configure a multicast distribution tree that allows forwarding of replicated data along the configured multicast distribution tree. The network provided by NP includes access, edge, and core network functions.

Figure I.1 shows an example scenario of network multicast-based content delivery (see clause 7.1).

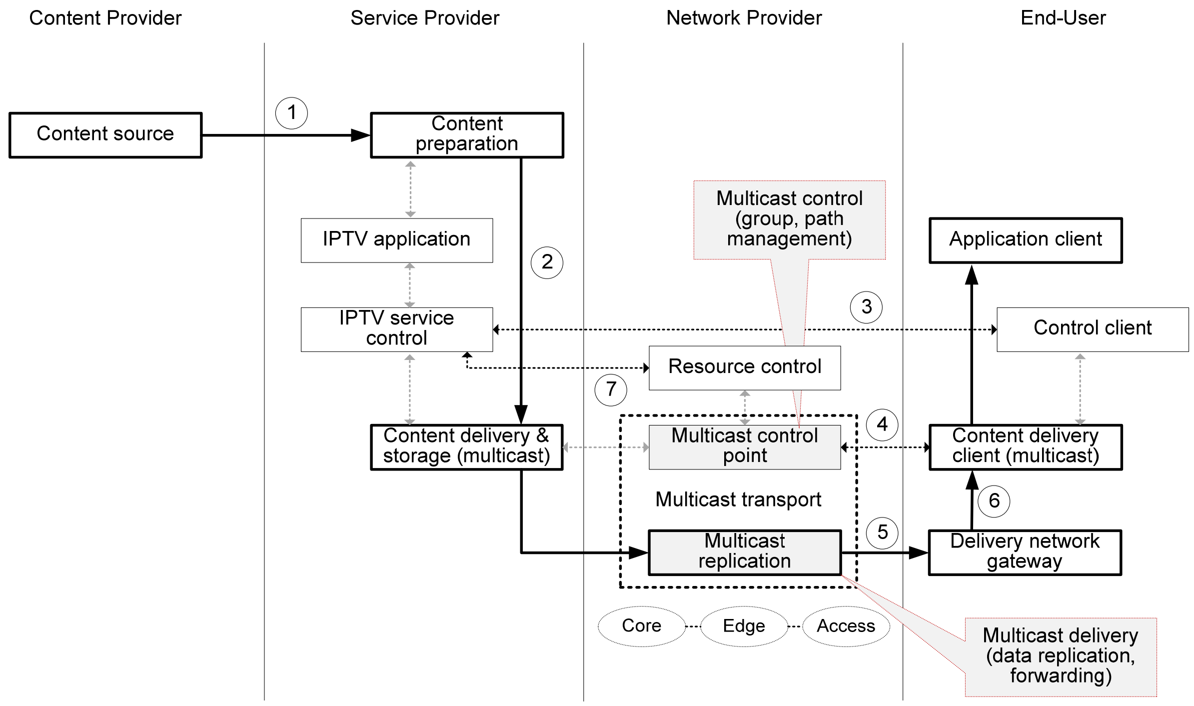

Figure I.1 – Network multicast-based content delivery scenario

Figure I.1 includes the following interactions:

1) The content provider asks the service provider (SP) to multicast IPTV content.

2) SP prepares the IPTV content for multicasting to the announce group.

3) The end user (i.e., control client functional block) exchanges signalling with SP's IPTV service control functional block for initiating IPTV service.

4) The end user can join a specific multicast group by exchanging messages for group management (e.g., IGMP [b-IETF RFC 3376], MLD [b-IETF RFC 2710]). At NP, a multicast distribution tree from SP to end users is configured by exchanging routing protocol messages.

5) Once the end user has successfully joined the multicast distribution tree, the content from SP can be delivered to the end user with help from multicast replication capabilities provided by NP.

6) The content reaches the end user's content delivery client functions via delivery network gateway functional block and is delivered to the application client functions.

7) In case QoS monitoring is necessary, the SP may gather information by asking experienced QoS reports to the control client functional block or by asking network statistics to NP.

I.2 Cluster-based content delivery scenario

Figure I.2 shows an example scenario of cluster-based content delivery (see clause 7.2).

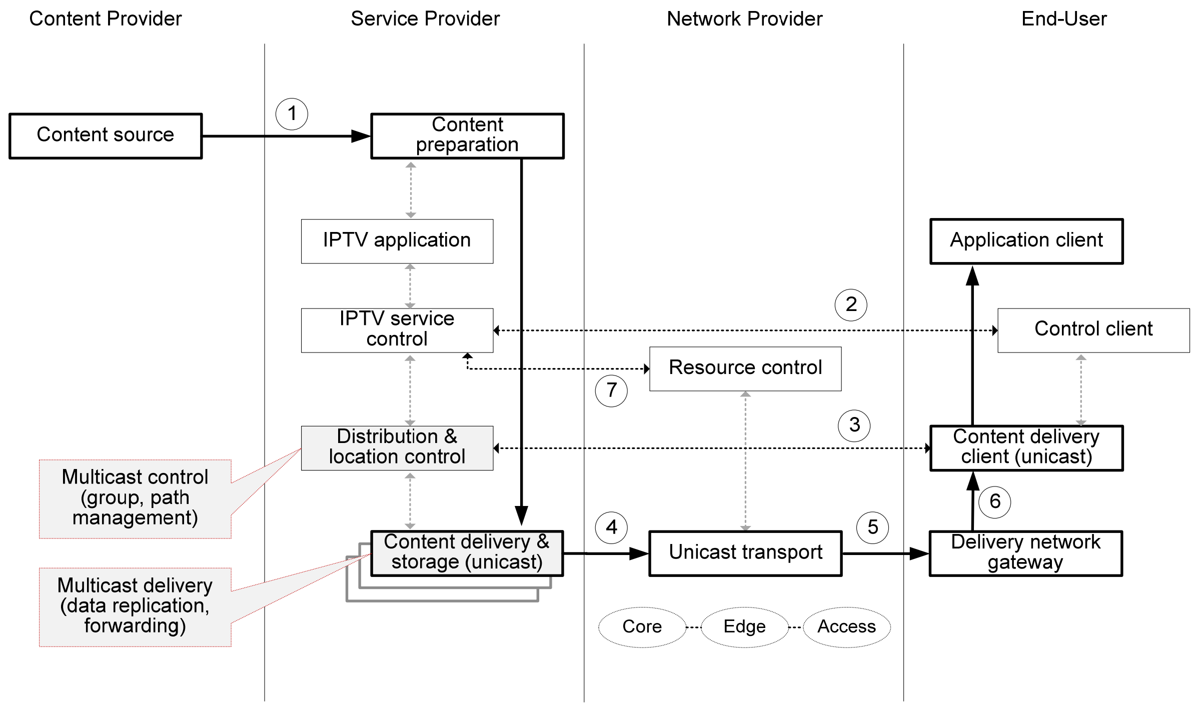

Figure I.2 – Cluster-based content delivery scenario

Figure I.2 includes the following interactions:

1) Content provider asks SP to deliver IPTV content. The SP converts the requested IPTV content into a suitable format for content delivery.

2) To receive IPTV content, the end user asks the SP for specific IPTV content.

3) SP gives information about available CD&SF instances for content delivery. The end user then tries to establish a content delivery session with the CD&SF instance.

4) The unicast mechanism is applied by the CD&SF instance to deliver the IPTV content to end users.

5) The NP delivers the IPTV content to the end user using unicast data delivery capabilities.

6) The content reaches the end user's content delivery client functions via the delivery network gateway functional block and is delivered to the application client functions.

7) When QoS monitoring is necessary, the SP may gather information by asking for detailed QoS reports from the control client functional block, or by asking for network statistics from the NP.

I.3 p2p-based content delivery scenario

In p2p-based content delivery, each end user constructs a multicast distribution path. Along the path, each end user can receive the IPTV content from its parent peer (i.e., end user) and can also relay the received content to its child peers; therefore it is required for each peer to know the location information of other participating peers.

Figure I.3 shows an example scenario of p2p-based content delivery (see clause 7.3).

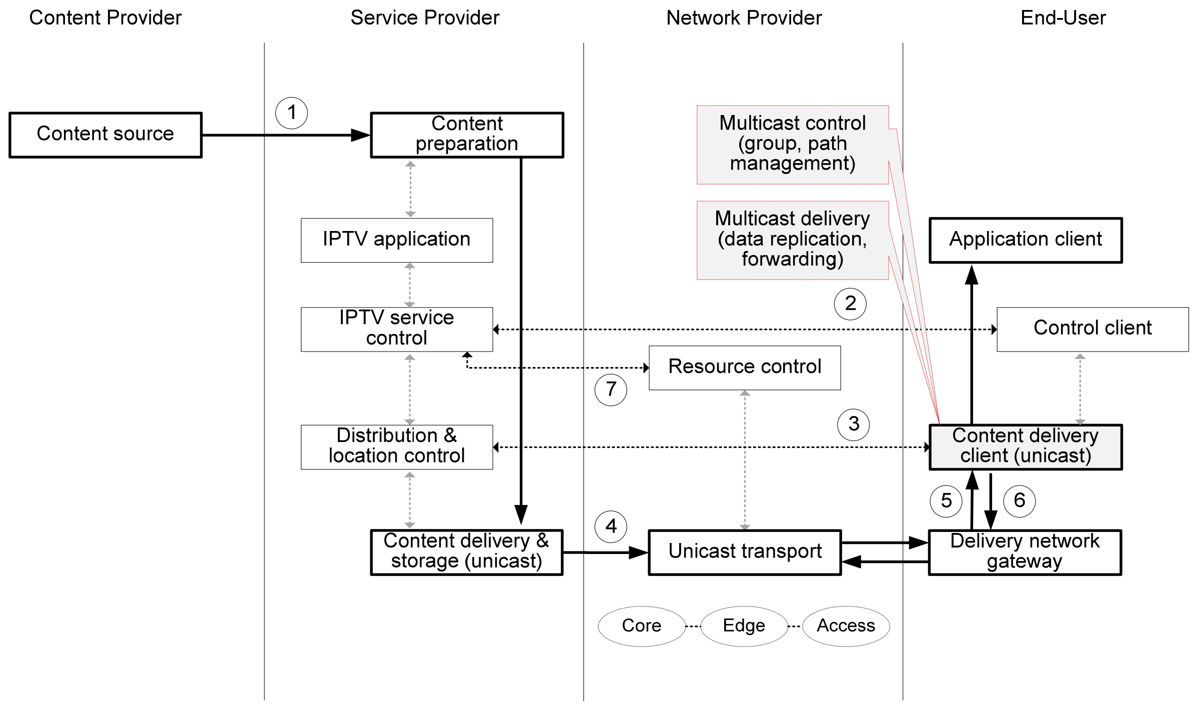

Figure I.3 – p2p-based content delivery scenario

Figure I.3 includes the following interactions:

1) The content provider asks the SP to deliver IPTV content and then the SP converts the requested content into a suitable format for content delivery.

2) The end user asks the SP to deliver IPTV content.

3) The end user interacts with the SP to acquire information about other participating end users.

4) The unicast mechanism is applied to deliver content; NP only needs to support unicast data delivery capabilities.

5) The content reaches the end user's content delivery client functions via the delivery network gateway functional block and is delivered to the application client functions.

6) The end user forwards the received IPTV content to its child peers through the network.

7) When QoS monitoring is necessary, the SP may gather information by asking for detailed QoS reports from the end user or by asking for network statistics from the NP.

I.4 Hybrid of p2p and cluster-based content delivery scenario

Figure I.4 shows an example scenario of the content delivery based on hybrid of peer-to-peer and cluster model (see clause 7.4).

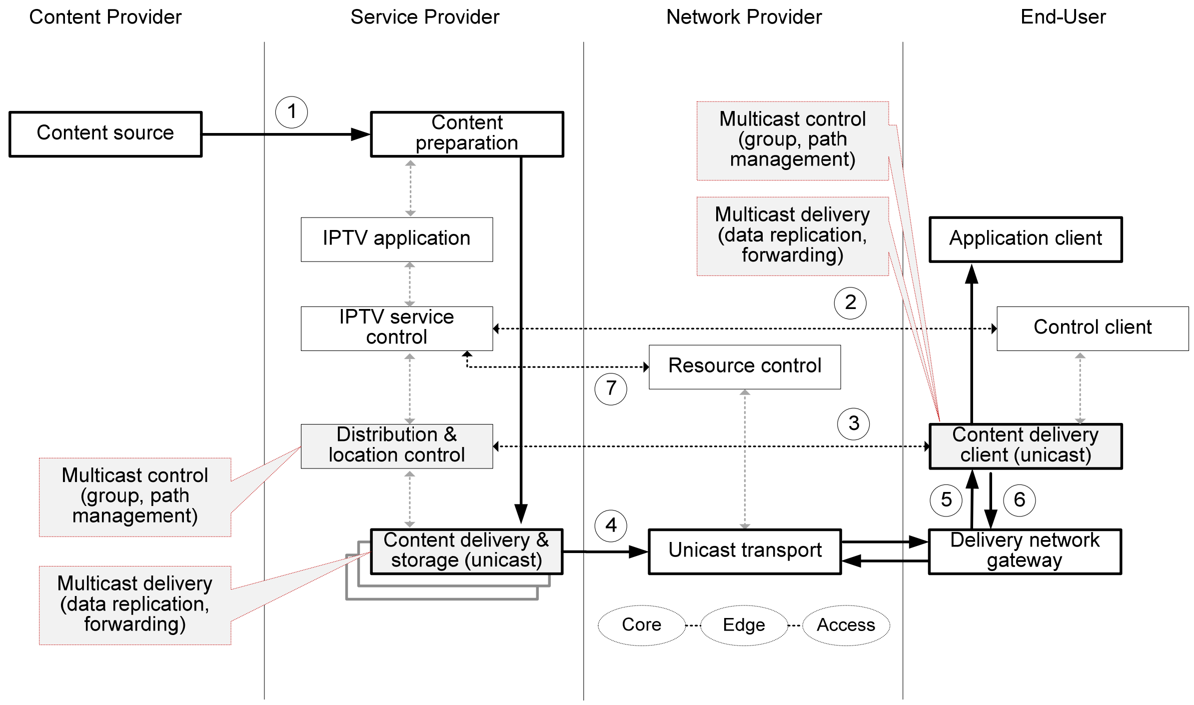

Figure I.4 – Hybrid of p2p and cluster-based content delivery scenario

Figure I.4 includes the following interactions:

1) The content provider asks SP to deliver content. The SP converts the requested IPTV content into a suitable format for content delivery.

2) To receive the IPTV content, the end user asks the SP for specific IPTV content.

3) SP gives information about available CD&SF instances for content delivery. The end user then tries to establish a content delivery session with the CD&SF instance.

4) The unicast mechanism is applied by the CD&SF instance to deliver content to end users.

5) The content reaches the end user's content delivery client functions via the delivery network gateway functional block and is delivered to the application client functions.

6) The end user forwards the received IPTV content to its child peers through the network.

7) When QoS monitoring is necessary, the SP may gather information by asking for detailed QoS reports from the control client functional block of or by asking for network statistics from the NP.

Appendix II

Using peer-to-peer mechanisms for content delivery

(This appendix does not form an integral part of this Recommendation.)

This appendix describes how peer-to-peer (p2p) mechanisms can be used to support multicast-based IPTV content delivery, in particular the peer-to-peer model described in clause 7.3.

II.1 Overlay networks for p2p-based content delivery

In p2p-based content delivery, an overlay network among the participating peers (i.e., end users) is used for control and distribution of IPTV content.

An overlay network for p2p-based content delivery consists of virtual network topologies on top of one or several networks, where an overlay node corresponds to an end user, and an overlay link corresponds to a network path between end users, as illustrated in Figure II.1.

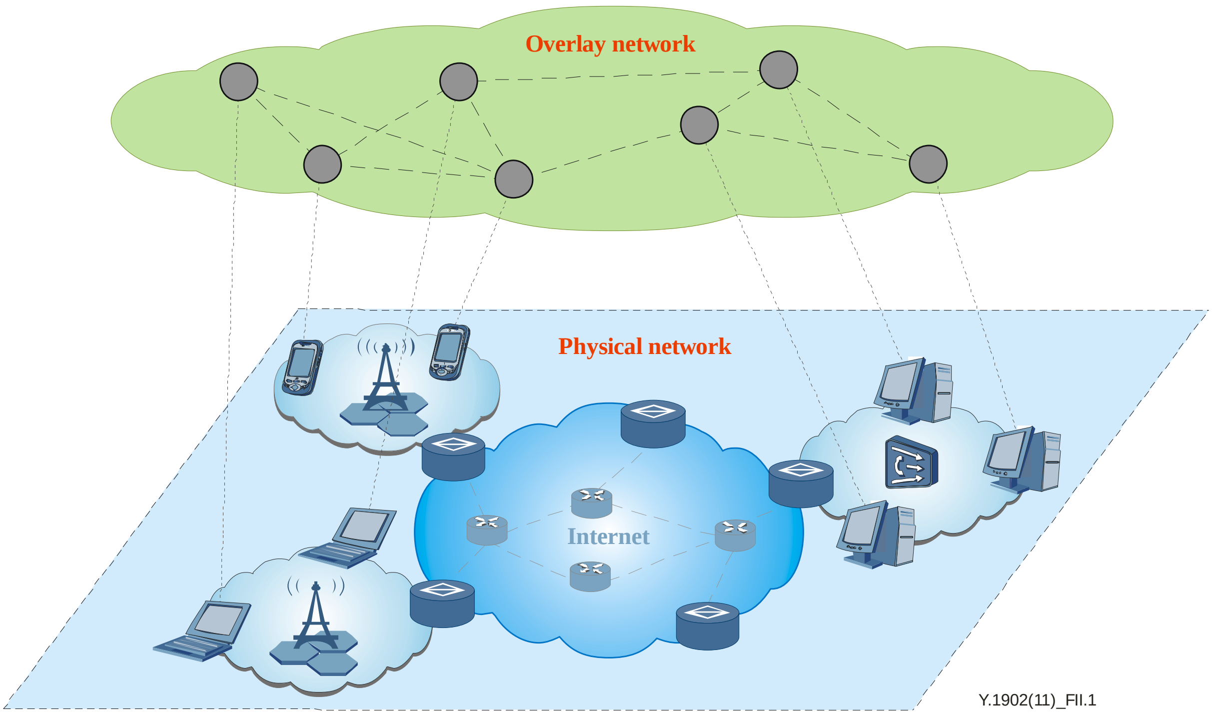

Figure II.1 – Overlay network for p2p-based content delivery

An important advantage of an overlay network is that it makes use of the end-user system capabilities such as computational resources and storage power. Moreover, due to its logical nature, overlay networks can quickly and flexibly build various service specific networks over current networks with limited need to change the underlying network infrastructure.

II.2 Managed overlay networks for p2p-based content delivery

II.2.1 Introduction

Since largely self-organized by end-user systems, overlay networks usually do not require any specifics from networks or service providers. For example, in most p2p file-sharing systems, the end-user systems use proprietary or open source protocols to communicate and transfer data with each other.

However, from the perspective of IPTV services, it is important that the IPTV service provider, while operating a network, tightly control the process of IPTV service and content delivery. If the IPTV service provider is not in the position of managing the overlay network, then critical problems in IPTV service provisioning may arise, such as breach of authentication, authorization, accounting (AAA), QoS, and security. Therefore, the concepts and principles of managed overlay networks are of great interest to IPTV service providers.

In order to achieve a managed overlay network, the IPTV service provider can play a key role by implementing management functions in the overlay network through management nodes (MNs). Figure II.2 provides an example of managed p2p overlay network, where:

– grey coloured ovals (see figure legend) in the overlay network represent peers corresponding to end users;

– blue coloured ovals represent MNs corresponding to network equipment deployed by IPTV service provider;

– yellow coloured oval in the overlay network represents IPTV content sources.

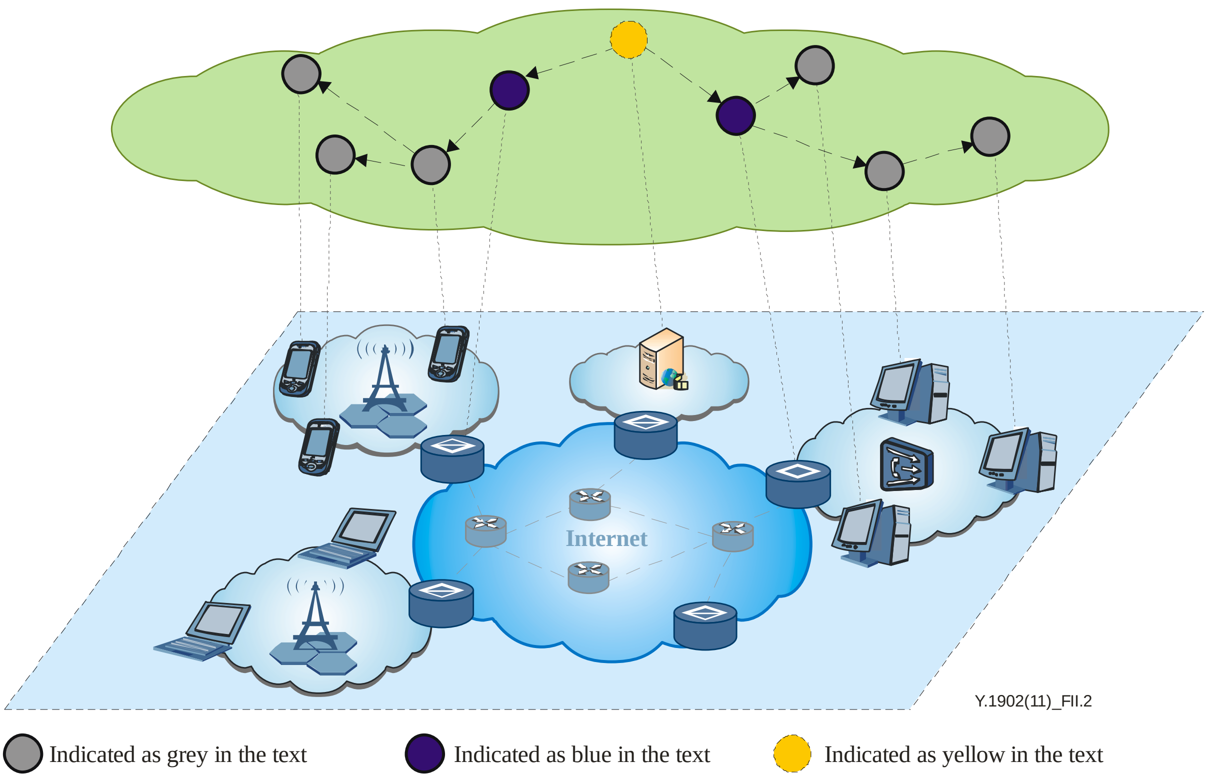

Figure II.2 – Managed overlay multicast network

II.2.2 Management node functions

Figure II.3 illustrates a managed p2p overlay network structure.

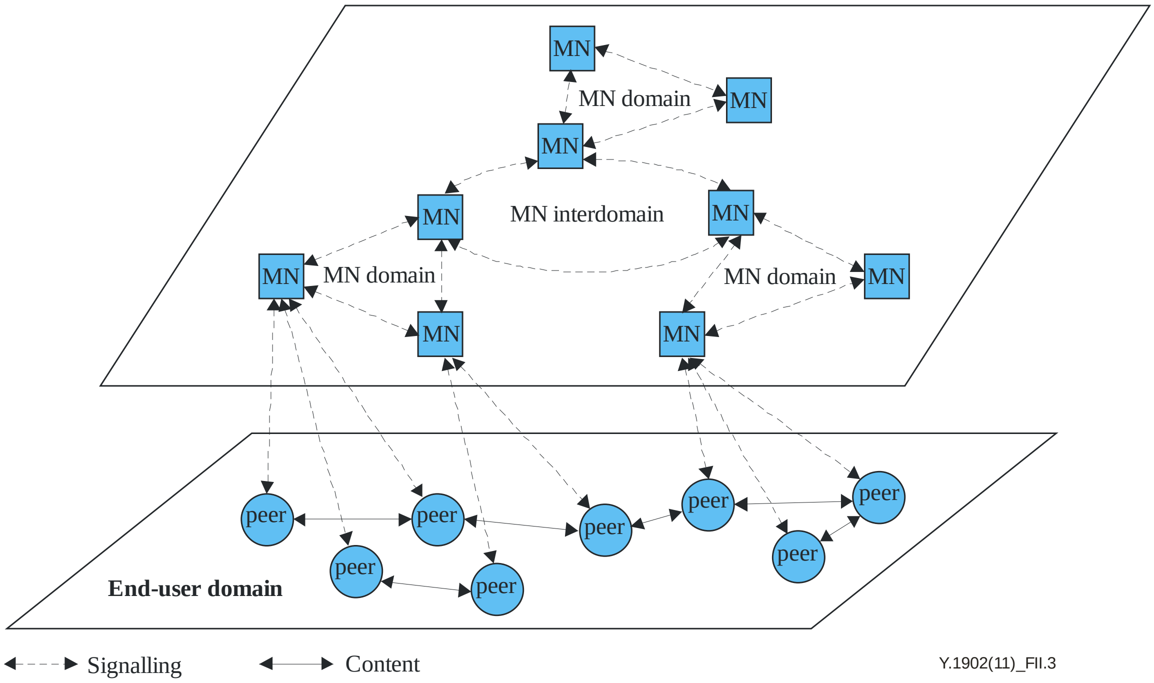

Figure II.3 – Managed p2p overlay network structure

As shown in Figure II.3, peers are classified into several groups, with each group having a management node (MN) deployed by an IPTV service provider. Peer classification can be done based on either content sharing criterion, or physical location criterion. In content sharing criterion, peers with common interest on a certain kind of content (e.g., movie, file) are classified into one group. In physical location criterion, peers with short distance (e.g., network distance, geography distant) are classified into one group.

In peer group, MN implements peers' management functions including the following:

– Peer registration: Peers register with MN describing its own capabilities, e.g., CPU, storage, or bandwidth.

– Peer maintenance: MN periodically collects status, e.g., link or capabilities from peers.

– Peer AAA: MN can authenticate and authorize a peer when it joins the group, and account for peer during service provisioning.

– Priority information provided by MN in p2p messages: Upon receiving p2p messages, peers can behave differently according to the priority information provided by the MN.

– Peer admission control: In order to prevent malicious peers from making the p2p network unstable by frequently joining and leaving the p2p network, MN can record the events of peer joining and leaving the peer group. Upon receiving a peer join request, MN can deny the request when deciding to disallow the peer join according to joining/leaving event records.

II.2.3 p2p proxy functions of MN

In peer group, MN performs p2p proxy for peers including:

– Peer content publication:

As shown in Figure II.4, peer A publishes its content ID to MN1, together with its contact address. As the p2p proxy of peer A, MN1 publishes the content ID and peer A address to responsible MN (MN3 in Figure II.4) in the MN domain which is responsible for the content ID, according to some p2p content publish mechanism.

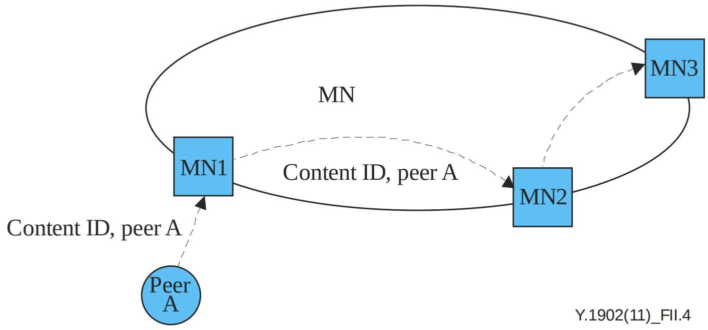

Figure II.4 – Peer content publication

– Peer content search in MN domain:

As shown in Figure II.5, peer B sends a content request (e.g., content ID) to MN4. As the p2p proxy of peer B, MN4 finds the responsible MN (MN3 in Figure II.5) in the MN domain which stores the content ID, according to some p2p content search mechanism. MN3 then returns the corresponding peer A address to peer B.

MN can collect peer information from its peer group. Upon receiving the request of searching content ID, MN locates the peer holding the content ID according to collected peer ID and content ID in the request, then directs the requesting peer to that peer.

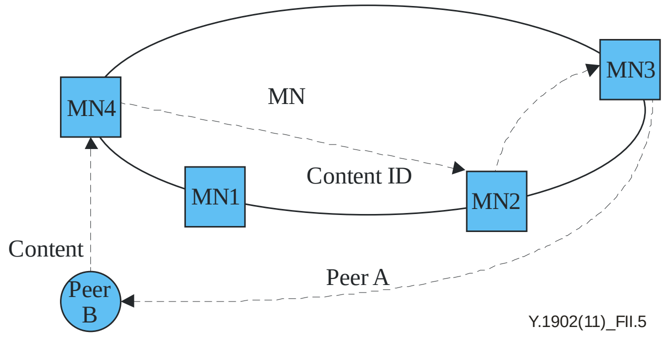

Figure II.5 – Peer content searching

– Peer content search in MN inter-domain:

If the requested content ID cannot be found in MN domain, MN could launch a search procedure in MN inter-domain. As shown in Figure II.6, when MN3 does not contain the requested content ID, it could forward the content request to MN5 in another MN domain through the MN inter-domain. MN5 then finds the responsible MN (MN6 in Figure II.6) in its MN domain which stores the content ID, according to some p2p content search mechanism. MN6 finally returns the corresponding peer C address to peer B.

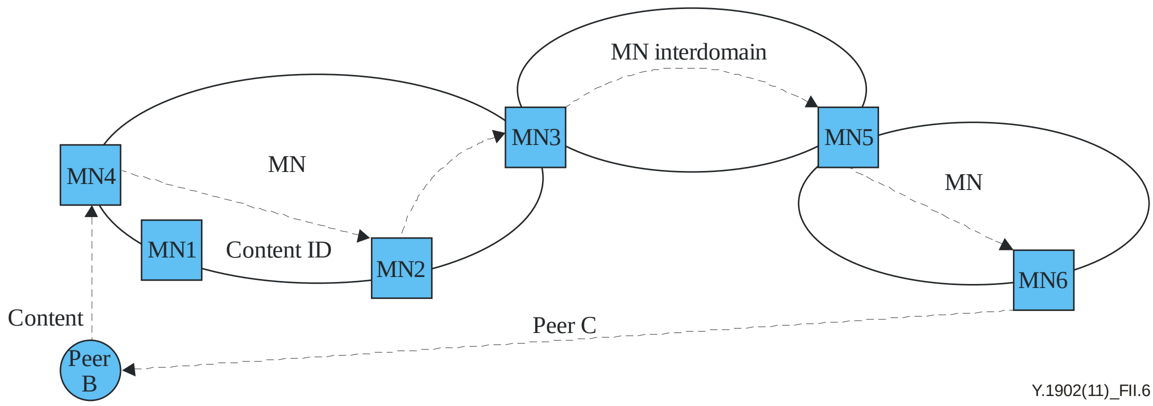

Figure II.6 – Peer content searching across MN domain

Appendix III

Hybrid model of peer-to-peer and network multicast

(This appendix does not form an integral part of this Recommendation.)

This appendix provides an example of p2p hybrid model for multicast-based IPTV content delivery.

In this model, IPTV content is delivered to end users via network multicast in the NP domain and p2p mechanisms are exploited for further distribution of the IPTV content in the end-user domain.

Figure III.1 shows the concept of hybrid model of p2p and network multicast.

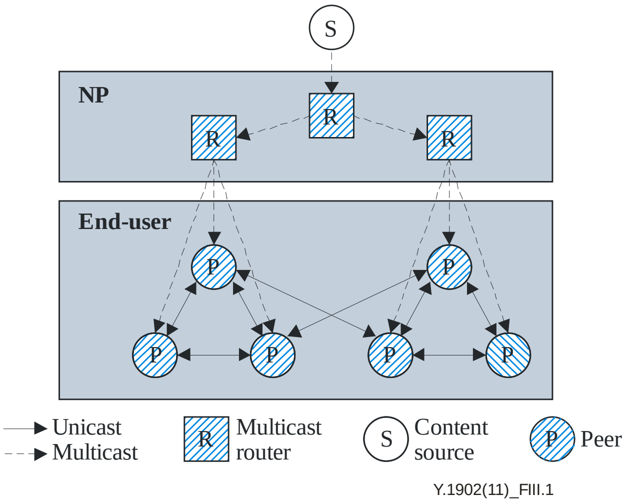

Figure III.1 – Concept of hybrid model of p2p and network multicast-based content delivery

In this model, end users join a multicast group. They then need to form a p2p group. The IPTV content is delivered via network multicast. When an end user finds out that it has lost some data, it sends a broadcast message to other peers to request the lost data. The end user then requests the first responding peer to send the lost data. This mechanism requires the peers to cache some data in case that the data needs to be retransmitted to other peers.

Figure III.2 depicts how the IPTV content is delivered by the relevant functions in the hybrid model combining the peer-to-peer and network multicast models for multicast-based IPTV content delivery.

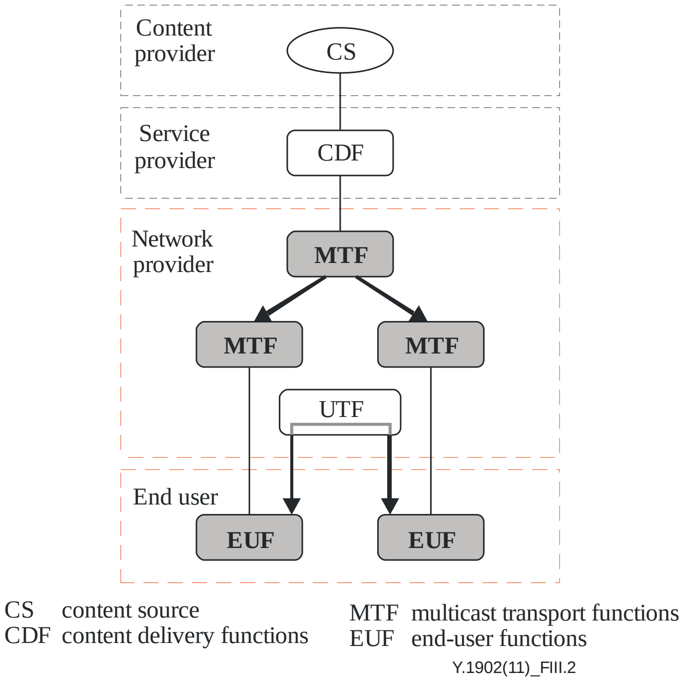

Figure III.2 – Content delivery based on hybrid of peer-to-peer and network multicast models

Appendix IV

Details of multicast VPN

(This appendix does not form an integral part of this Recommendation.)

Multicast VPN (mVPN) provides a method to separate private multicast traffic over a shared core network by establishing multicast tunnels among different VPN sites.

In this appendix, some details are provided about mVPN when multiprotocol label switching (MPLS) is used as the core network technology.

In a classic MPLS-enabled VPN environment, MPLS routers are not capable of MPLS label binding for multicast traffic. To transmit multicast traffic through such a MPLS-based VPN, it is necessary to implement mVPN technology, with the introduction of additional multicast tunnels (e.g., IP-in-IP tunnels) for the transmission of the multicast traffic. In mVPN, routing information is managed by the provider edge (PE) routers of the MPLS VPN backbone. Using the routing information, PE routers carry multicast data traffic from source to receivers via customer edge (CE) routers. When multicast data is forwarded by a CE router connected to the source to a PE router, the PE router forwards the multicast data packets to other PE routers via multicast tunnels and packet encapsulation. The receiving PE routers further forward the multicast data packets to the CE routers connected to the receivers.

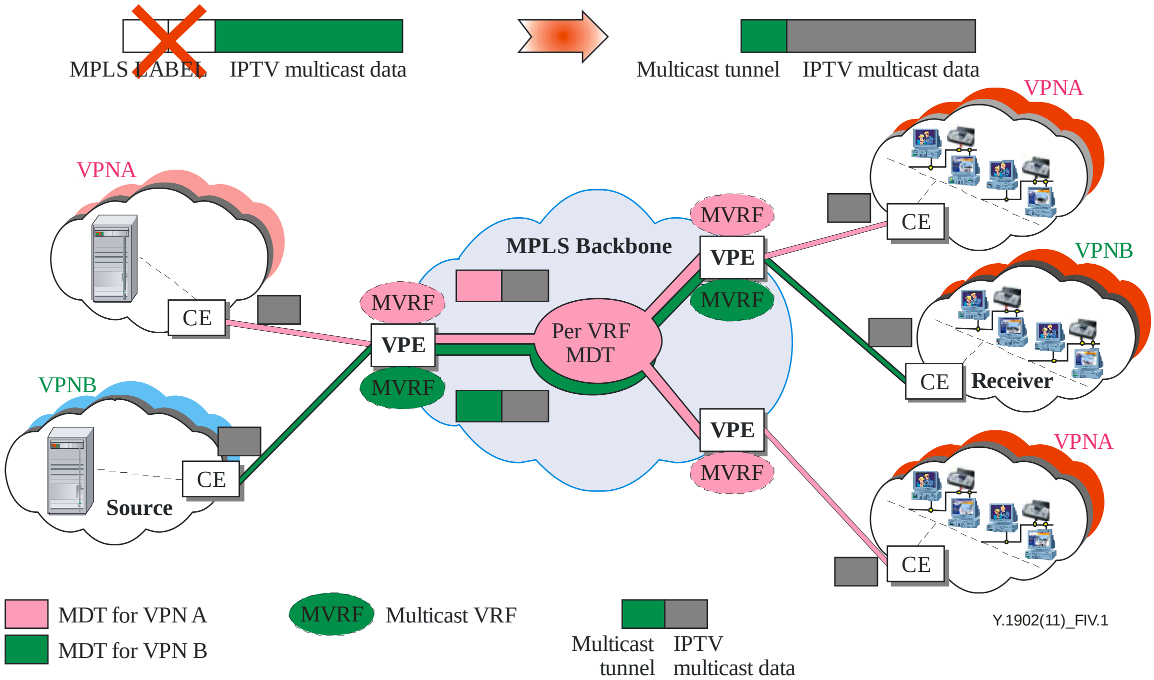

Figure IV.1 – Multicast VPN overview

On a PE router, each virtual routing and forwarding (VRF) can have an associated multicast routing and forwarding table configured, referred to as a multicast VRF (mVRF). The mVRF contains all the multicast routing information for that VPN. When a PE router receives multicast data or control packets from a CE router interface in a VRF, multicast routing is performed on the associated mVRF.

mVPN makes use of multicast distribution trees (MDT) for the multicast traffic transmission between the different VPN sites of the mVPN.

Bibliography

[b-ITU-T M.1400] Recommendation ITU-T M.1400 (2006), *Designations for interconnections among operators' networks*.

[b-ITU-T X.601] Recommendation ITU-T X.601 (2000), *Multi-peer communications framework*.

[b-ITU-T X.603] Recommendation ITU-T X.603 (2004) | ISO/IEC 16512-1:2005, *Information technology – Relayed multicast protocol: Framework.*

[b-ITU-T Y.2111] Recommendation ITU-T Y.2111 (2008), *Resource and admission control functions in next generation networks*.

[b-IETF RFC 1035] IETF RFC 1035 (1987), *Domain Names – Implementation and Specification*.

[b-IETF RFC 2236] IETF RFC 2236 (1997), *Internet Group Management Protocol*, Version 2.

[b-IETF RFC 2475] IETF RFC 2475 (1998), *An architecture for Differentiated Services*.

[b-IETF RFC 2710] IETF RFC 2710 (1999), *Multicast Listener Discovery (MLD) for IPv6*.

[b-IETF RFC 3376] IETF RFC 3376 (2002), *Internet Group Management Protocol*, Version 3.

[b-IETF RFC 3411] IETF RFC 3411 (2002), *An Architecture for Describing Simple Network Management Protocol (SNMP) Management Frameworks*.

[b-IETF RFC 3810] IETF RFC 3810 (2004), *Multicast Listener Discovery Version 2 (MLDv2) for Ipv6*.

[b-IETF RFC 4541] IETF RFC 4541 (2006), *Considerations for Internet Group Management Protocol (IGMP) and Multicast Listener Discovery (MLD) Snooping Switches*.

[b-IETF RFC 4601] IETF RFC 4601 (2006), *Protocol Independent Multicast – Sparse Mode (PIM-SM)*.

[b-IETF RFC 4604] IETF RFC 4604 (2006), *Using Internet Group Management Protocol Version 3 (IGMPv3) and Multicast Listener Discovery Protocol Version 2 (MLDv2) for Source-Specific Multicast*.

[b-IETF RFC 4605] IETF RFC 4605 (2006), *Internet Group Management Protocol (IGMP)/Multicast Listener Discovery (MLD)-Based Multicast Forwarding ("IGMP/MLD Proxying")*.

[b-IETF RFC 5693] IETF RFC 5693 (2009), *Application-Layer Traffic Optimization (ALTO) Problem Statement*.

[b-CDN] Pathan, A., Buyya, R., *A Taxonomy and Survey of Content Delivery Networks*, 2007. <http://www.gridbus.org/reports/CDN-Taxonomy.pdf>

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