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Supplement 10

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

ITU-T Y.2000-series – Supplement on distributed service network (DSN) use cases

ITU-T Y-series Recommendations – Supplement 10

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Supplement 10 to ITU-T Y-series Recommendations

ITU-T Y.2000-series – Supplement on distributed service network (DSN) use cases

Summary

The purpose of Supplement 10 to ITU-T Y-series Recommendations is:

– to describe the general characteristics of distributed service network (DSN) service delivery from both control and data plane perspectives;

– to identify, classify and define some examples of DSN services by means of use cases;

– to further illustrate capabilities to be utilized in DSN; and

– to elaborate on the procedures for the deployment and operation of the corresponding DSN services.

History

Edition	Recommendation	Approval	Study Group
1.0	ITU-T Y Suppl. 10	2010-01-29	13

FOREWORD

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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.

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Supplement 10 to ITU-T Y-series Recommendations

ITU-T Y.2000-series – Supplement on distributed service network (DSN) use cases

1 Scope

Distributed service network (DSN) is an evolution of next generation networks (NGN) as well as legacy IP-based networks. It is a way to implement the service stratum and enhancements to the transport stratum which provide distributed and manageable capabilities to support various multimedia services. This supplement provides an overview of DSN and the general characteristics of DSN service delivery, as well as a set of DSN use cases which are informative illustrations of how DSN services can be designed, deployed and operated. From the operator's perspective, use cases have been categorized in terms of service aspects, which are further elaborated in terms of the capability aspects.

2 References

[ITU-T H.264] Recommendation ITU-T H.264 (2007), *Advanced video coding for generic audiovisual services*.

[ITU-T Y.101] Recommendation ITU-T Y.101 (2000), *Global Information Infrastructure terminology: Terms and definitions*.

[ITU-T Y.2011] Recommendation ITU-T Y.2011 (2004), *General principles and general reference model for Next Generation Networks*.

[ITU-T Y.2211] Recommendation ITU-T Y.2211 (2007), *IMS-based real-time conversational multimedia services over NGN*.

3 Terms and definitions

3.1 Terms defined elsewhere

This supplement uses the following term defined elsewhere:

3.1.1 service node [ITU-T Y.101]: A network element that contains one or several of the service control functions, service data functions, specialized resource functions and service switching/control function to provide a service in the context of GII.

3.2 Terms defined in this supplement

This supplement defines the following terms:

NOTE 1 – The following terms should be re-defined in relevant ITU-T Recommendations, and this supplement should be revised based on such definitions in future.

NOTE 2 – The terms distributed service network (DSN), DSN node, core node and user node also appear in Recommendation ITU-T Y.2206 with the same definitions.

3.2.1 content node: A distributed service network (DSN) node which can be used for the media content distribution, storage and/or caching, etc.

3.2.2 control node: A distributed service network (DSN) node which provides service control and transport control functionalities.

3.2.3 core node: A distributed service network (DSN) node deployed in the service provider domain.

3.2.4 distributed service network (DSN): An overlay network which provides distributed and manageable capabilities to support various multimedia services.

3.2.5 distributed service network (DSN) node: One of the nodes composing a distributed service network (DSN) and therefore providing distributed functionalities, including distributed routing and distributed storage.

NOTE – When classified by their positions in terms of the network domain, DSN nodes include core nodes and user nodes. When classified by their functional behaviour, DSN nodes include control nodes, relay nodes and content nodes.

3.2.6 overlay network: A network of nodes and logical links that is built on top of the underlying, e.g., transport, network with the purpose of providing a network service that is not available in the underlying network.

3.2.7 relay node: A distributed service network (DSN) node which can be used to relay the user traffic.

3.2.8 user equipment (UE): A device through which a user can access distributed service network (DSN) services.

3.2.9 user node: A distributed service network (DSN) node deployed in the user domain, e.g., personal computer, mobile terminal, etc.

4 Abbreviations and acronyms

This supplement uses the following abbreviations and acronyms:

API	Application Programming Interface
C/S	Client/Server
CAPEX	Capital Expenditure
CDR	Call Detail Record
CPU	Central Processing Unit
CSCF	Call Session Control Function
DHT	Distributed Hash Table
DSN	Distributed Service Network
GII	Global Information Infrastructure
HSS	Home Subscriber Server
IM	Instant Messaging
IMS	Internet Protocol Multimedia Subsystem
LAN	Local Area Network
MMTel	Multimedia Telephony
MSISDN	Mobile Station Integrated Services Digital Network number
NAT	Network Address Translation
NGN	Next Generation Network
OPEX	Operational Expenditure
P2P	Peer-to-Peer
PC	Personal Computer

PoP	Point of Presence
QoS	Quality of Service
RCS	Rich Communication System
SNS	Social Network Service
SP/CP	Service Provider/Content Provider
SVC	Scalable Video Coding
UE	User Equipment
VoD	Video on Demand
VoIP	Voice over IP

5 Conventions

Within this supplement, the keywords "multimedia telephony" and "MMTel" indicate the same service as the term "IMS-based real-time conversational multimedia services" which is defined in [ITU-T Y.2211].

The figures in this supplement use the visual conventions provided by Figure 5-1.

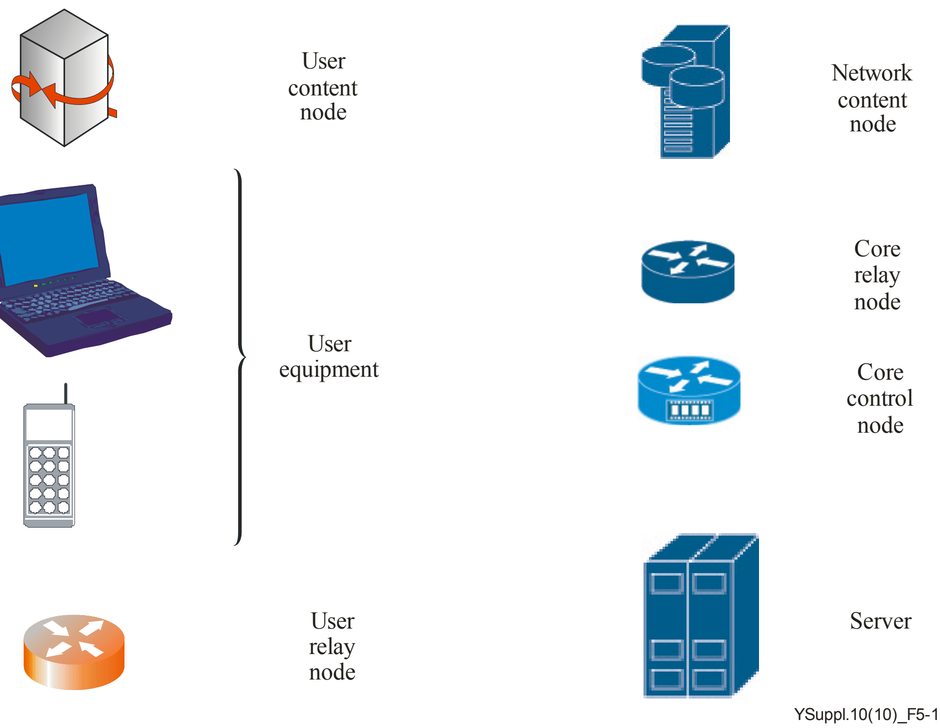

Figure 5-1 – Symbols used in this supplement

6 Overview of DSN

In traditional telecommunication networks, service nodes [ITU-T Y.101] are organized in a centralized manner which leads to some inherent drawbacks, e.g., load imbalance between different service nodes and single point of failure. It is also a problem for operators to extend capacities of service nodes continuously and in a timely fashion.

Many of these problems can be resolved or eased by using distributed paradigms. In a distributed environment, load can be distributed to different service nodes and a failed service node's responsibility can be taken by another one. It is also possible to give great flexibility for system capacities by exploiting users' physical resources in a distributed manner.

DSN introduces a distributed paradigm to resolve the issues described above. On one hand, DSN renovates traditional MMTel services through the adoption of distributed technologies (e.g., peer-to-peer) to achieve a more robust system at a relatively low cost. On the other hand, DSN also aims at providing content-based services via distributed mechanisms (e.g., linear streaming, video on demand, content sharing).

To accelerate the development and deployment of new services, DSN exposes a set of network capabilities for the service layer (e.g., operator-hosted services and third-party services) to increase the utilization of the network.

DSN is viewed as a homogenous network in which the enabling software that supports different network capabilities can be run on common platforms (e.g., PC x86) though the platforms have different performance levels. Thus, network capabilities can be configured interchangeably, manually or automatically, on any DSN nodes.

6.1 DSN distributed control plane and data plane

In general, functions in the network can be classified as belonging to the control plane, data plane or management plane. The concept of DSN can be applied to the control plane and data plane. The following clauses describe the DSN distributed control plane (which is the application of DSN to the control plane) and the DSN distributed data plane (which is the application of DSN to the data plane). The applicability of DSN to the management plane is for further study.

6.1.1 DSN distributed control plane

As defined in [ITU-T Y.2011], the control plane is the set of functions that controls the operation of entities in the stratum or layer under consideration, plus the functions required to support this control. The DSN distributed control plane is the application of DSN to the control plane. That is, functions belonging to the control plane are distributed among DSN nodes and processed by these DSN nodes. It should be noted that functions which were processed by entities in the service provider domain before introducing DSN can be distributed among and processed by core nodes, user nodes or both of them.

The DSN distributed control plane is capable of providing continuous service delivery. Specifically, DSN can survive a single point of failure based on peer-to-peer mechanisms. When the single point of failure occurs, other DSN nodes located in the same DSN network can easily take over the duties of the failed DSN node to maintain continuous service.

In addition, the DSN distributed control plane is capable of providing self-adaptive load balancing. DSN is able to distribute load across the DSN nodes to achieve better resource utilization; DSN can also adjust the traffic in a timely fashion to handle traffic explosions when necessary (e.g., as a result of disaster or festivals).

6.1.2 DSN distributed data plane

As defined in [ITU-T Y.2011], the data plane is the set of functions used to transfer data in the stratum or layer under consideration. The DSN distributed data plane is the application of DSN to the data plane. That is, the source of data is distributed among DSN nodes including the user node. There are various ways of distributing data sources. One possible way is that each user equipment (UE) receives data from a different source; another possible way is that one UE receives data from multiple sources. It should be noted that additional control functions are required to indicate which data source(s) are appropriate for each UE.

The DSN distributed data plane is capable of providing continuous service delivery and self-adaptive load balancing capabilities in the same fashion as the DSN distributed control plane which is described in clause 6.1.1.

The DSN distributed data plane is capable of accumulating bandwidth among multiple DSN nodes to increase traffic throughput. This capability can be applied to optimize transmission for streaming services and file downloading.

In addition, the DSN distributed data plane is capable of providing distributed storage to meet the rapidly growing storage requirements of the services (e.g., web 2.0, video sharing).

Lastly, different applications have different quality of service (QoS) requirements. Unfortunately, best effort IP routing cannot address the requirements of different applications for the data plane. The DSN distributed data plane is capable of optimizing media traffic of the data plane since there are multiple possible paths, including paths using relay nodes, and each DSN node can choose the appropriate one.

6.2 DSN model

As shown in Figure 6-1, the DSN is comprised of the DSN nodes, including core nodes and user nodes that provide DSN control functions related to location and delivery of distributed resources.

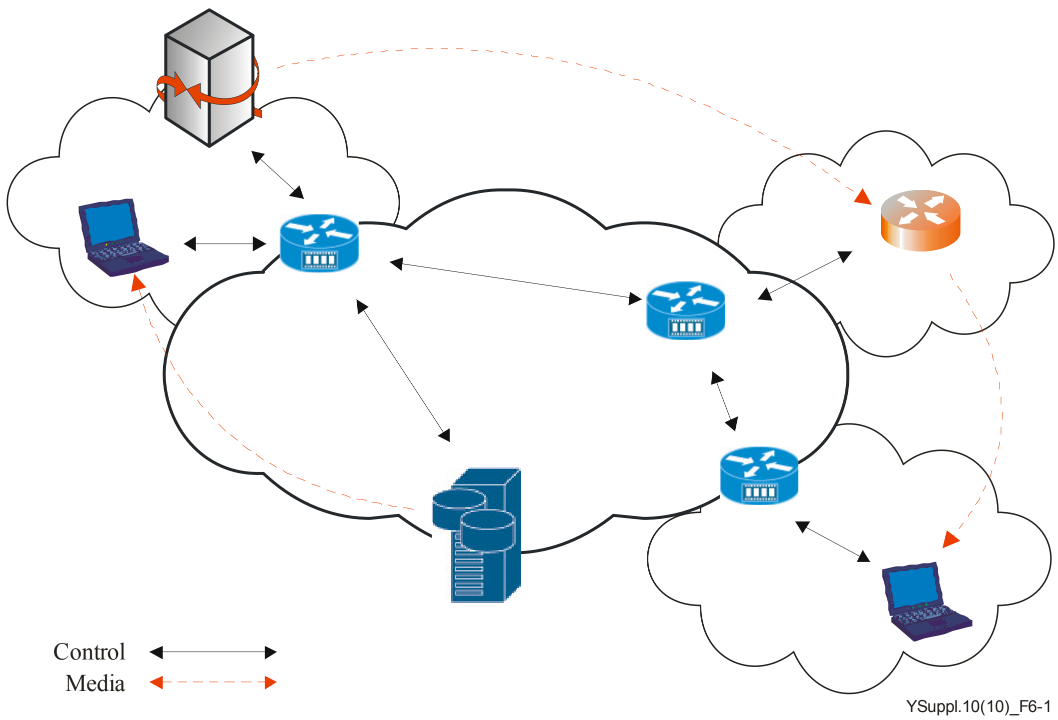

Figure 6-1 – DSN model

Control nodes are dedicated to providing service/transport control functions for DSN. Content nodes provide distributed storage capability and distribution of the contents to the other DSN nodes or UEs. Relay nodes are used for constructing alternate delivery paths in the case of network congestions or NAT traversal.

6.3 Network deployment scenario

It is true that all the core nodes could be deployed in one unified overlay network to offer the DSN services. However, it is difficult to manage a network which is too large either geographically or in terms of the number of core nodes it contains. Therefore, deploying the DSN with multiple zones is an important option. The zones can be divided by geographical location of the DSN nodes. Each zone is an independent and self-organized peer-to-peer (P2P) sub-network. Multiple zones may be managed as one administrative domain. In this scenario, the P2P algorithm is run separately in each zone, which restricts the signalling traffic to local paths if the communication is between two DSN nodes in the same zone. If the requested DSN node is outside of the local zone, a mechanism is required to forward the request to the right destination.

An application use case is given in Figure 6-2, where the DSN is composed of three geographic zones, and control nodes are separated into different zones.

1) Control nodes A and B are located in zone 1; the traffic between them is local traffic which is restricted to zone 1.

2) Control nodes B and C are located in zone 1 and zone 2, respectively; the traffic between them does not belong to a local zone, and inter-zone signalling is required.

The information on where traffic should enter may be stored and queried in the network.

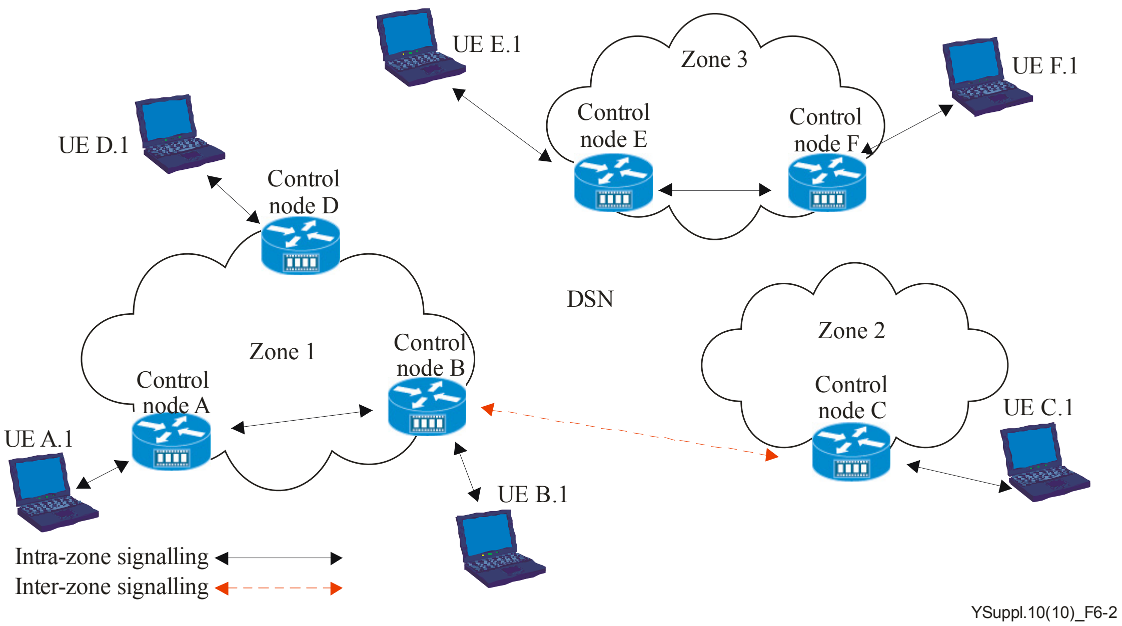

Figure 6-2 – Multi-zone communication scenario

6.4 DSN service deployment scenario

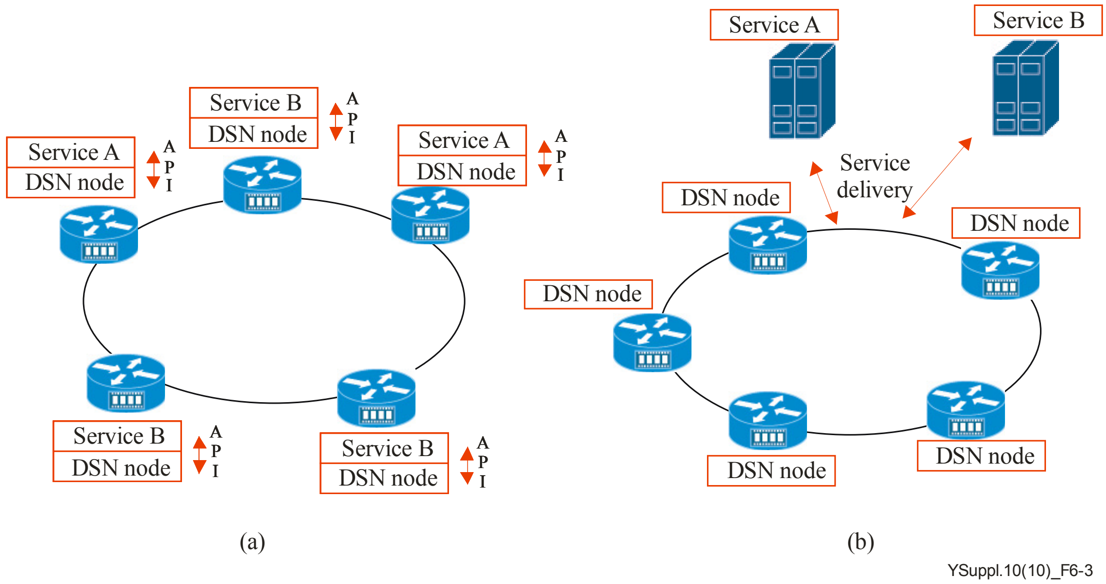

Figure 6-3 – Two means of DSN service deployment

As shown in Figure 6-3, there are two means for DSN service deployment.

In the scenario shown in Figure 6-3a, the services are deployed in the DSN node which constitutes DSN. The service logic will call different application programming interfaces (APIs) to use capabilities provided by DSN.

In the scenario shown in Figure 6-3b, the DSN service is deployed in a stand-alone application server. The capabilities of DSN will be used for the service provision by means of message exchange.

7 DSN use cases from a service perspective

7.1 Multimedia telephony (MMTel) service

Description

With DSN, the operator can build a cost-effective and scalable MMTel service system. MMTel services are controlled by DSN nodes which collaborate with each other in a P2P paradigm.

Thanks to the application of P2P mechanisms, DSN nodes appear as homogeneous entities and can support the functions of home subscriber server (HSS), call session control function (CSCF), etc., in one node. Backup between different DSN nodes is possible to the greatest extent, which allows DSN to achieve scalability, high equipment utilization ratio and load balance across the whole network.

Based on P2P mechanisms, the DSN runs as a distributed and self-organized entity, which avoids most manual intervention so as to significantly reduce the cost of operation.

Pre-conditions

The control node is implemented in a core node to facilitate management and operations.

Operational flows

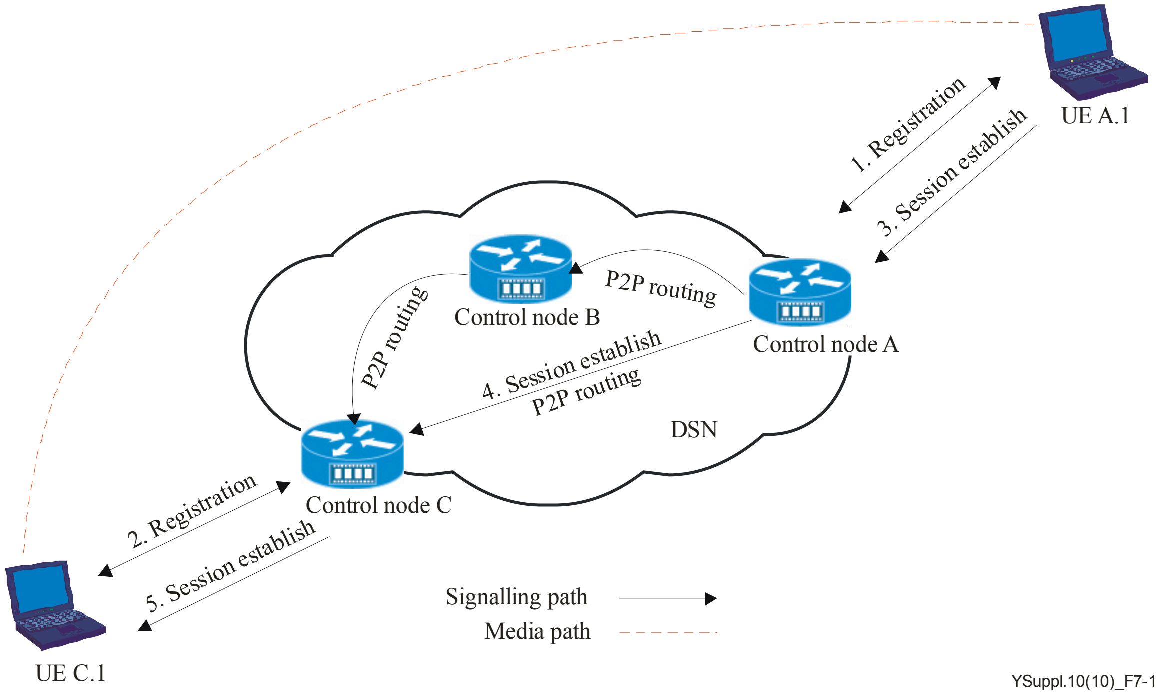

Figure 7-1 – DSN-based multimedia telephony

1) UE A.1 registers with control node A in the overlay, while control node A is selected according to P2P algorithms or by other means.

2) Similarly, UE C.1 registers with control node C.

3) UE A.1 initiates an MMTel request to UE C.1. Control node A locates UE C.1's control node C by P2P routing through control node B.

4) Having established the routing, control node A forwards the MMTel request to UE C.1 via control node C.

5) The MMTel session is established between UE A.1 and UE C.1 successfully when control node C forwards the request to UE C.1.

7.2 Streaming service

Description

A streaming service provides content distribution of multimedia streams such as on-line streaming video or music, on-line educational programmes and entertainment. Providing a streaming service through the client-server model suffers from a performance bottleneck and poor scalability as the number of receivers increases. Streaming service providers need to increase the number of streaming servers to maintain the desired level of service quality which leads to increases in capital/operational expenditure (CAPEX/OPEX). By providing a streaming service in DSN, the user node not only downloads the streaming content but also uploads streaming content for other UEs. This concept can effectively reduce the burden on the original streaming server and improve the scalability of the streaming service.

Pre-conditions

Content node B.1 has the multimedia streaming content and its related information (e.g., content characteristics, size, quality, accounting, etc.). Control node A has the information needed to locate the content which is provided by content node B.1.

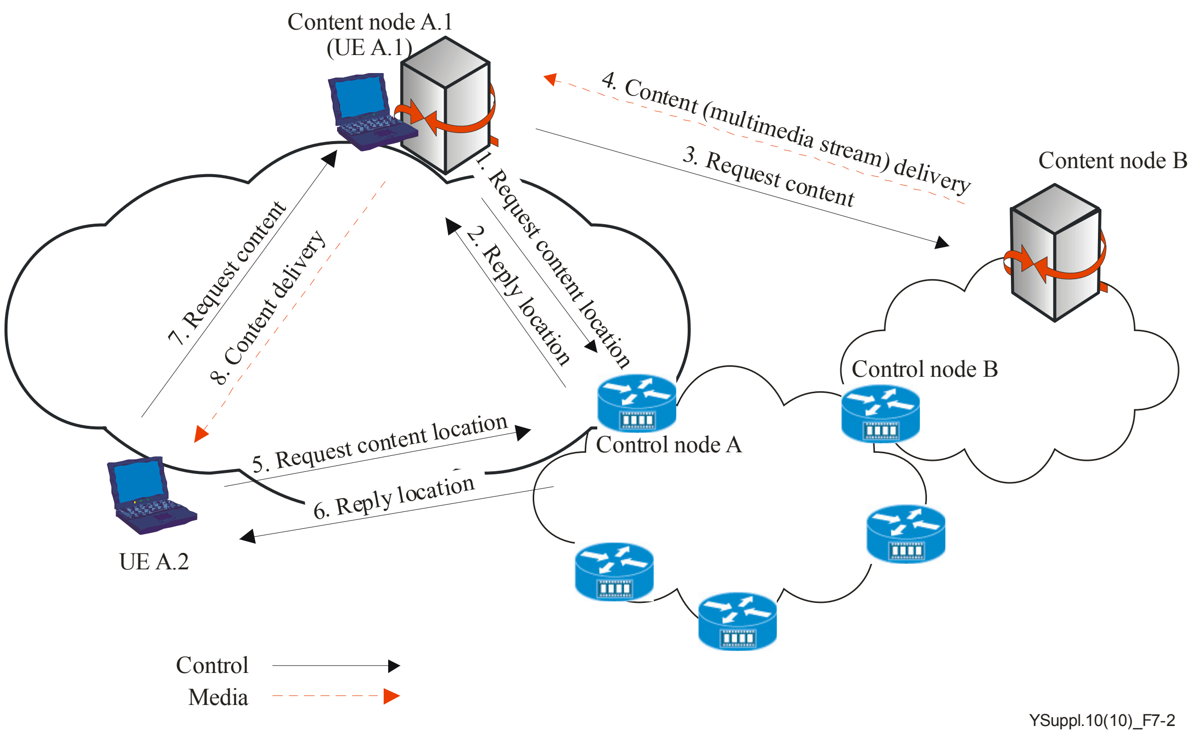

Figure 7-2 – DSN streaming service

Operational flows

1) UE A.1 sends a request to control node A asking for the content location of the streaming service content.

2) Control node A answers the request with the content location information. This information is based on the best conditions for the requesting UE (in this case, content node B.1).

3) UE A.1 requests content node B.1 to send the content of the multimedia streaming service.

4) By establishing a connection with content node B.1, UE A.1 is provided with the multimedia streaming service.

5) Next, UE A.2 asks control node A for the content location.

6) Control node A evaluates the preference (e.g., terminal capability, QoS) of UE A.2 and decides to send the location information of content node A.1 (UE A.1) which can offer the service with the best conditions.

7) UE A.2 requests content node A.1 (UE A.1) to send the content.

8) Content node A.1 streams the content to UE A.2.

7.3 Content storage and distribution service

7.3.1 Content storage

Description

Figure 7-3 depicts a content storage use case, e.g., network disk service. A network disk service is one kind of network storage service designed to provide storage space to store user data, while users can share the same storage space with other user.

In this use case, a user's content can be stored in different DSN nodes in the network. Spreading the content amongst different DSN nodes has some advantages, including:

1) The size of the stored file may exceed the storage capacity of a single node.

2) The back-ups can be stored in different nodes for fault tolerance.

Pre-conditions

None.

Operational flows

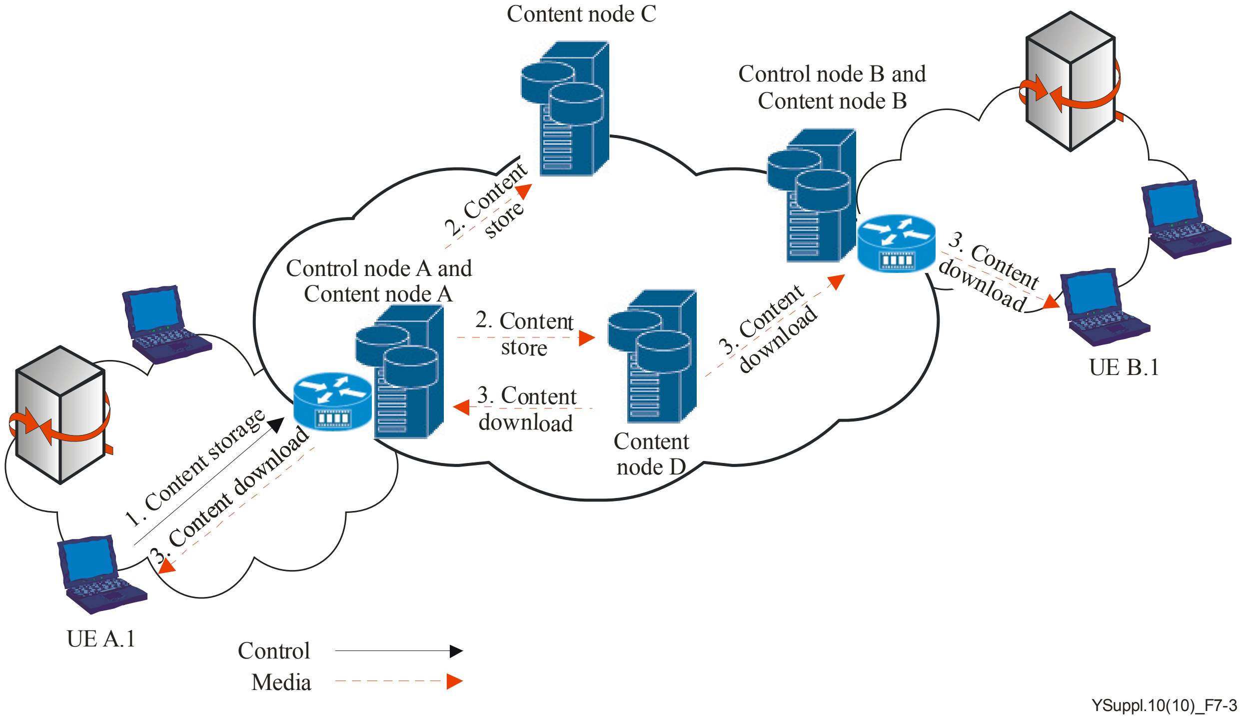

Figure 7-3 – Content storage

1) UE A.1 sends a request to control node A at which the UE A.1 is registered for the content storage service, and uploads the content to be stored.

2) Content node A may store some or all of the content itself. As well, it sends some or all of the content to content nodes C and D. These latter nodes are selected according to the P2P algorithm, e.g., distributed hash tables (DHT), by control node A (which is collocated with content node A).

3) UE A.1 can retrieve the content from the content nodes which store it. If authorized, UE B.1 can also download the content that UE A.1 shared.

NOTE – Further information about DHT can be found in [b-Chord].

7.3.2 Content distribution

Description

In this use case, depicted in Figure 7-4, the control nodes maintain the lists of the content nodes that hold the pieces of a certain file, and the content nodes store data to provide a downloading service for users. A content node can be either a core node or a user node.

Pre-conditions

Control node B stores the index information for file X. Content nodes A and A.1 each store part or all of the content of file X.

Operational flows

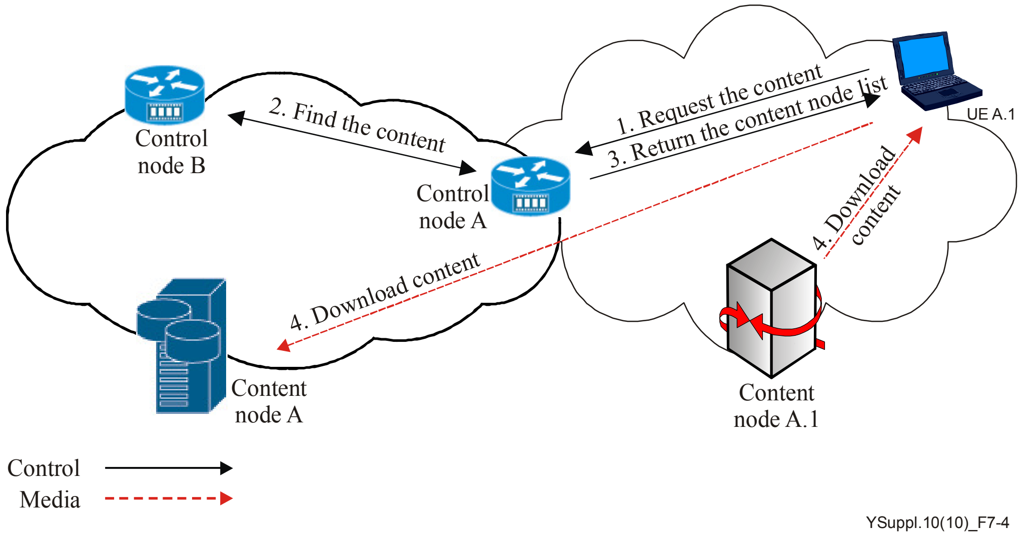

Figure 7-4 – Content distribution

1) UE A.1 wants to download file X, and sends the request to control node A.

2) According to the P2P algorithm, e.g., DHT, control node A finds control node B and requests the list of nodes that can provide the content of file X.

3) Control node A passes on the content node list to UE A.1.

4) Based on the content node list, UE A.1 downloads file X from content node A and content node A.1. In this case, content node A is a core node, while content node A.1 is a user node.

8 DSN use cases from a capability perspective

8.1 Traffic control and optimization

DSN traffic can be optimized according to certain objectives, such as traffic location, route optimization, inter service provider traffic minimization, average delay and bandwidth minimization, etc.

8.1.1 Traffic control and optimization based on locations of user nodes

Description

Because content can be obtained from multiple sources, including remote peers, content sharing among peers may cause increased network traffic. Therefore, it is beneficial for DSN to realize traffic localization where the data traffic is limited to the local network area (e.g., same LAN, same service point of presence (PoP), etc.).

Pre-conditions

Content node A.1 provides content to UE D.1. Content node D.3 can serve the same content as content node A.1. Content node D.3 and UE D.1 are within the same local network area.

Operational flows

Figure 8-1 depicts a use case of traffic optimization based on location.

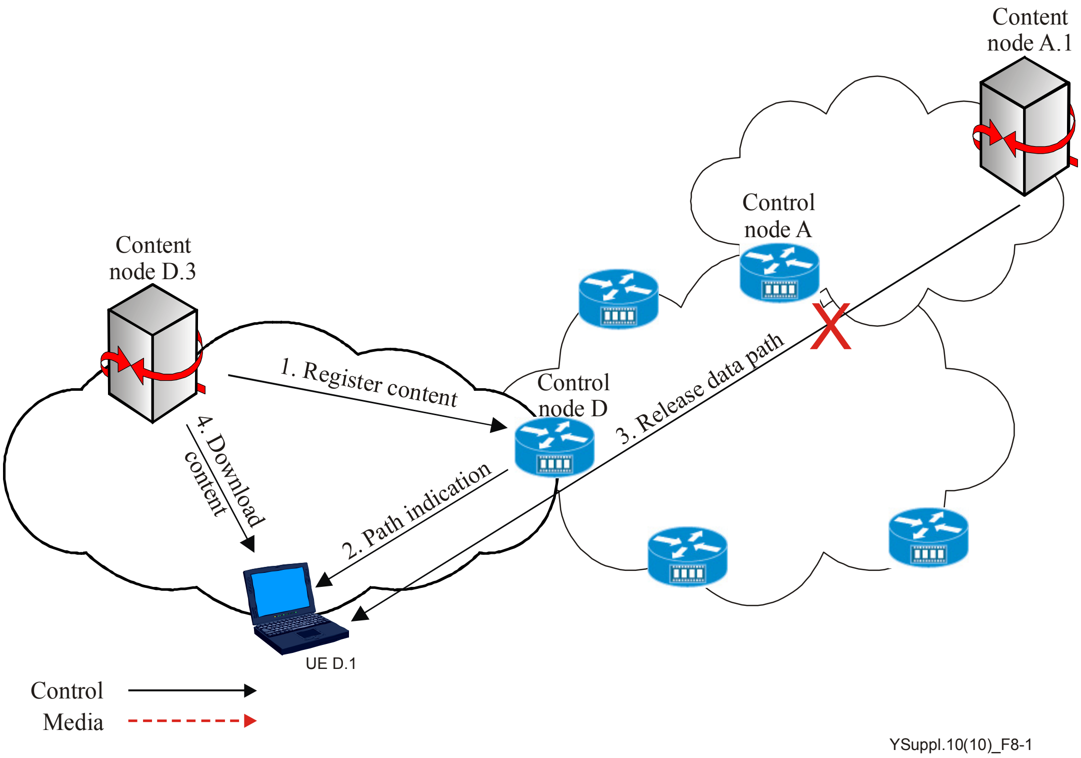

Figure 8-1 – Traffic optimization based on traffic localization

1) Content node D.3 registers content information with control node D.
2) Control node D indicates to set up a new data path between content node D.3 and UE D.1.
3) Control node D indicates to release the existing data path between content node A.1 and UE D.1.

8.1.2 Traffic control and optimization based on other policies

Description

Based on other optimization objectives, service providers have more powerful control on the traffic distribution of DSN. At the same time, traffic optimization also improves user performance as seen by the user, as the operator is able to route user requests to bypass congested areas.

Pre-conditions

Both content node A.1 and content node C.4 can provide content to UE D.1. A traffic control and optimization server dispatches network information to control node D that content node C.4 is preferred to provide content to UE D.1, rather than content node A.1.

Operational flows

Figure 8-2 depicts a use case of traffic optimization based on bandwidth price or bandwidth occupied.

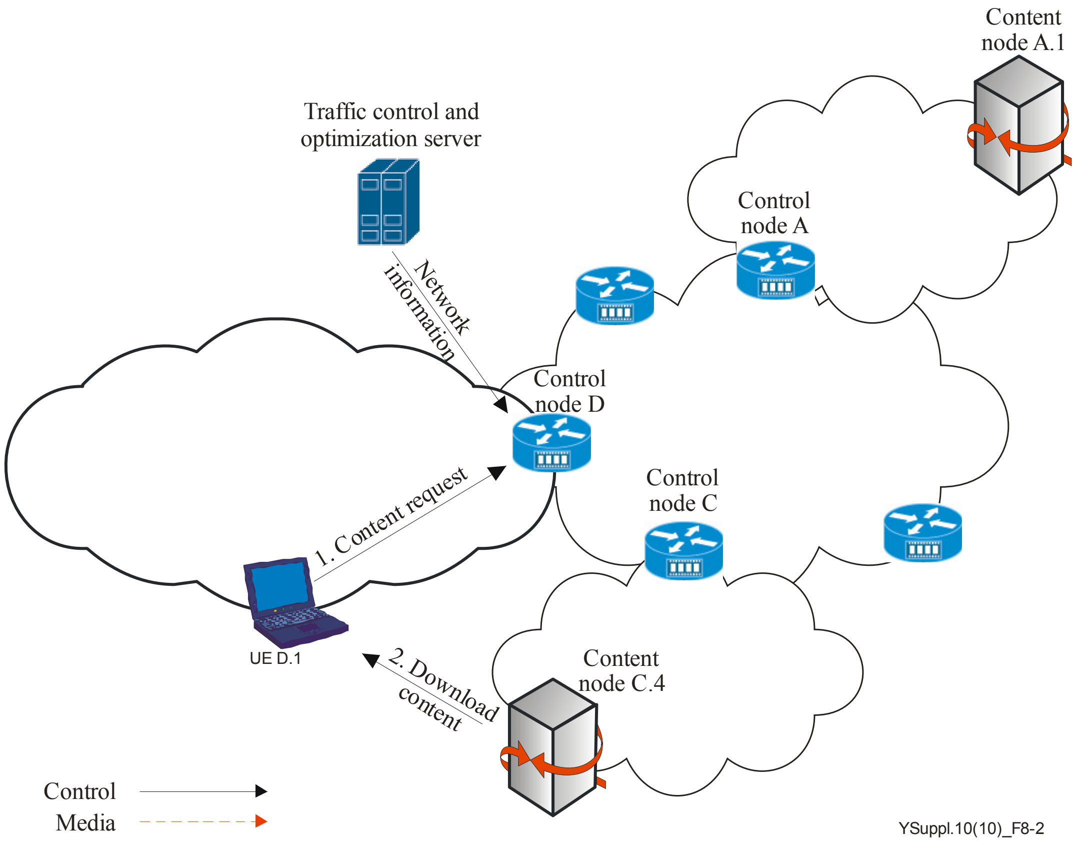

Figure 8-2 – Traffic optimization based on other policies

1) UE D.1 requests for content via control node D.

2) Control node D knows that content node C.4 should be chosen for UE D.1 (e.g., the path from content node A.1 to UE D.1 is already heavy loaded, or traffic from content node C.4 to UE D.1 is cheaper).

8.2 P2P cache

Description

Caching will efficiently reduce the network traffic among peers.

Pre-conditions

Content node A.1 provides content to UE D.1. A cache is close to UE D.1 and UE D.2 and stores the content transferred between content node A.1 and UE D.1. UE D.2 requests the same content as UE D.1.

Operational flows

Figure 8-3 depicts a cache use case.

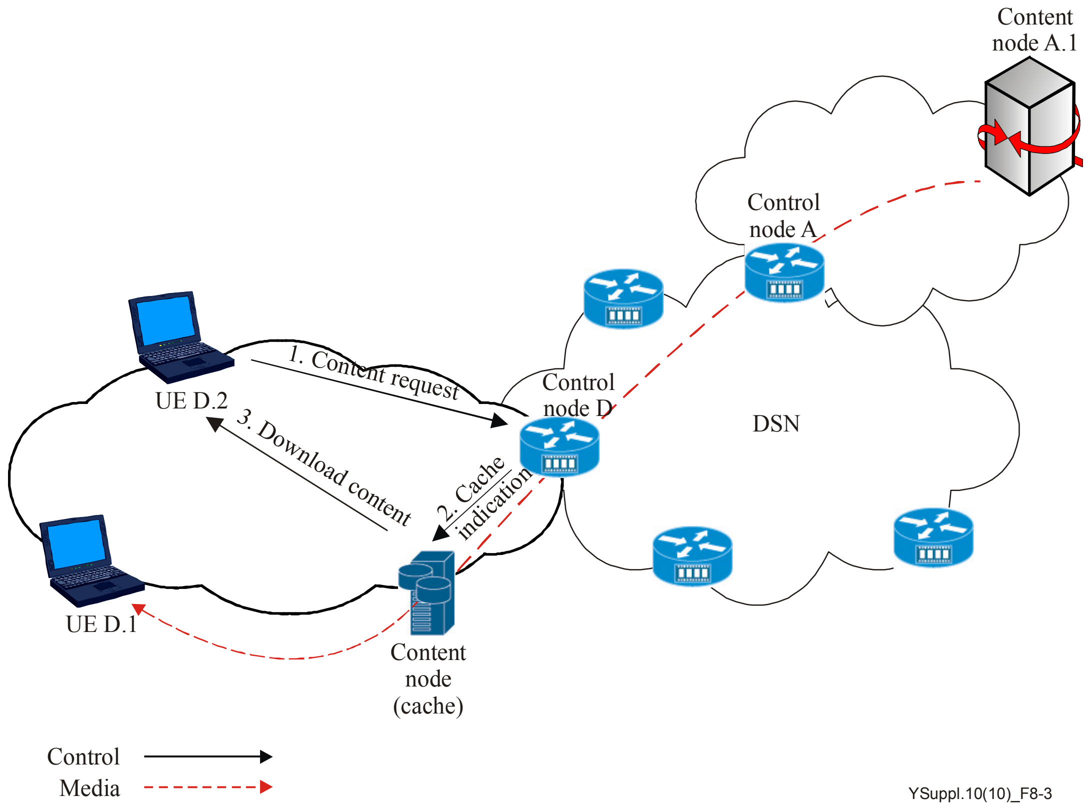

Figure 8-3 – P2P cache

1) UE D.2 requests content via control node D.

2) Although content node A.1 can be selected to provide content to UE D.2, control node D can save network traffic by indicating the cache close to UE D.2 to send the content to UE D.2.

3) Downloading proceeds from cache to UE D.2.

8.3 Data relay

Description

The introduction of peer-to-peer technology for data relay will facilitate user interaction and improve user experience.

If some resource is located behind a NAT equipment, it cannot be reached from outside of the NAT equipment. In this case, a relay node with a public IP address can be deployed outside the NAT equipment to make the resource reachable.

In the IP environment, sometimes end-to-end QoS is hard to achieve because, for example, congestion may happen along the media path and a normal "best effort" service feature may ignore the service requirements of real-time applications such as MMTel. In this case, a DSN node acting as a relay node can enhance the real-time service performance by providing an alternative media path via itself [b-Skype].

Pre-conditions

Use case 1

Relay node 1 with a public IP address is used to forward the user traffic from UE A.1 to UE B.1. It will provide better QoS than that obtained in the direct connection between UE A.1 and UE B.1 when the path becomes congested.

Use case 2

UE B.2 is behind an address- and port-dependent NAT, so it cannot be contacted directly from the outside network, and UE A.2 wants to contact UE B.2.

Operational flows

Figure 8-4 shows two use cases of data relay in DSN.

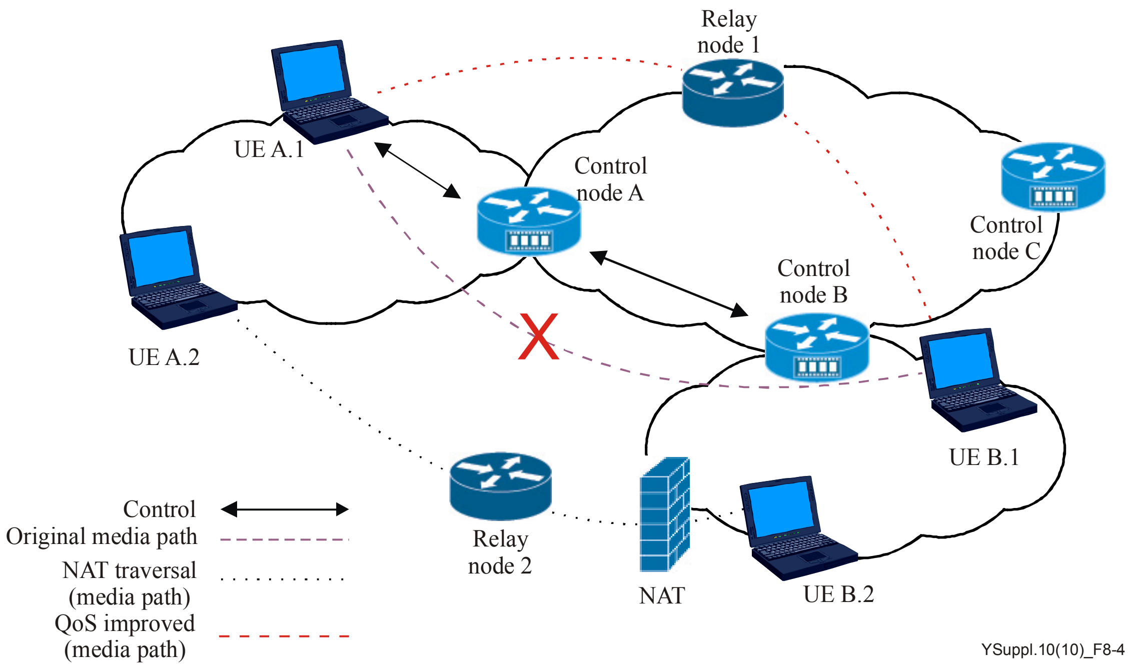

Figure 8-4 – Data relay

Use case 1

1) Relay node 1 starts to relay the traffic between UE A.1 and B.1 so as to enhance the end-to-end QoS between them.

Use case 2

1) UE B.2 connects to relay node 2, which has a public IP address, and maintains connection through the NAT. Relay node 2 acts as proxy/agent of UE B.2.

2) Relay node 2 starts to relay the traffic between UE A.2 and B.2 so as to establish their connection.

8.4 Service availability and reliability

Description

A server is assigned to a user dynamically or by static pre-configuration when the user attaches to the network in the client/server (C/S) system. The failure of the server will cause service failure or service unavailability to the user. In DSN, robustness is one of the key advantages due to self-organization. When one or several DSN nodes have failed, DSN will reconstruct the overlay topology automatically, and the available nodes will be able to provide consistent service to users initially assigned to the failed DSN nodes. Especially, if some disaster (e.g., earthquake, large-scale power outage) occurs, a regional network may suddenly go out of service. The other regional DSN networks will take over the service in the failed regional network, minimizing the impact of the failure.

Pre-conditions

Use cases 1-1, 1-2

UE A.1 and UE B.1 are registered with control node A and control node B, respectively.

Use case 2

UE C.1 and UE D.1 are registered with control node C and control node D, respectively. Relay node A is used to forward the user traffic from UE C.1 to UE D.1 for better QoS.

Operational flows

Figure 8-5 illustrates the flows associated with the use cases of this clause.

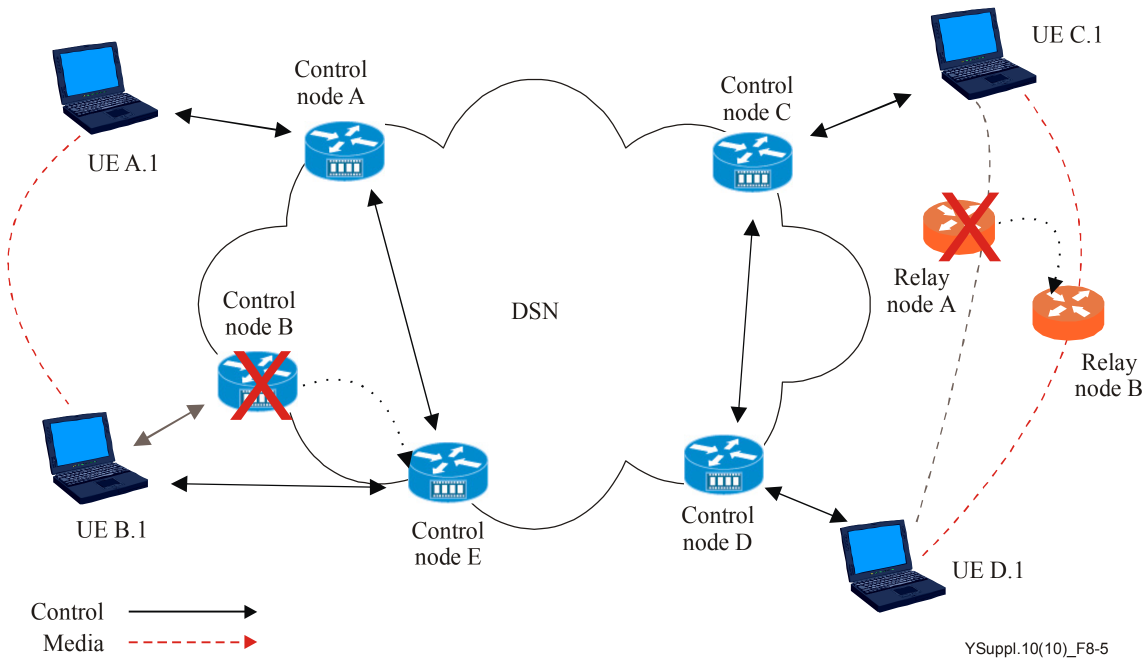

Figure 8-5 – Service availability and reliability

Two use cases for MMTel service survival are depicted as below:

Use case 1-1

– Control node A and control node B are control nodes of UE A.1 and UE B.1, respectively. UE A.1 initiates an MMTel request to UE B.1. Control node A locates UE B.1's control node B. During the session set-up procedure, control node B fails and then control node E acts as UE B.1's control node; the MMTel request is forwarded to UE B.1 via control node E. The MMTel session is established between UE A.1 and UE B.1.

Use case 1-2

– Control node A and control node B are control nodes of UE A.1 and UE B.1, respectively. A session is established between UE A.1 and UE B.1. When control node B fails, DSN reconstructs the topology to exclude control node B; control node E acts as UE B.1's control node, so that the session between UE A.1 and UE B.1 is not impacted.

Use case 2

– Control node C and control node D are control nodes of UE C.1 and UE D.1, respectively. A session is established between UE C.1 and UE D.1 through relay node A. When relay node A fails, relay node B will be inserted into the media path instead of relay node A to maintain the connectivity between UE C.1 and UE D.1.

In the streaming service and content service, DSN node failures would be handled in a similar way.

8.5 Service continuity

Description

The DSN service user should not experience any service interruption caused by changes in service environment. The DSN service can maintain itself until the service is completed or the user explicitly terminates the service. There can be various sources of DSN service environmental changes. Some changes are invoked by the users, such as change of terminals or service preference. Some changes are operational changes to the DSN, such as changes in networking environment or service policy.

This clause deals with two types of changes, which are changes in user terminal and changes in control node.

A user can change terminals while a DSN service is on-going. The service quality may change due to a difference in terminal capability. DSN should adjust to the changes and provide service continuity for the DSN service user by managing the service information, transmitting via a different delivery path, adapting according to context changes, providing assurance of the original quality of service, and adjusting bandwidth appropriately.

The UE can be managed by different control nodes while being served by the DSN service. This can happen through UE roaming or self-organization of DSN control nodes.

Pre-conditions

Content nodes B.1 and C.1 have the service or content which UE B.1 or UE B.2 is receiving.

The user changes terminal from UE B.1 to UE B.2 while a DSN service is being provided. UE B.2 changes control node while the DSN service is being provided.

Operational flows

Figure 8-6 illustrates the use case of service continuity.

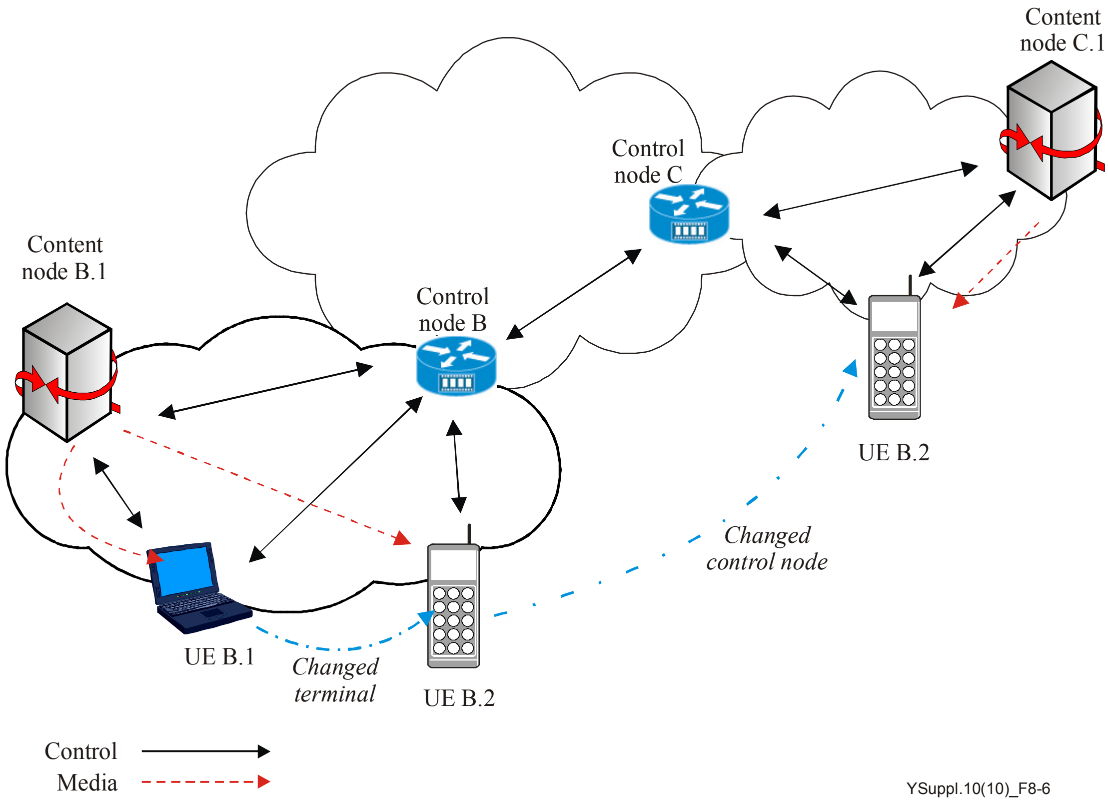

Figure 8-6 – Service continuity

1) UE B.1 connects to control node B and gets information about content node B.1, which stores the content of interest.

2) A service connection is established between content node B.1 and UE B.1, and UE B.2 starts to receive the content from content node B.1.

3) The user of UE B.1 changes terminal, and control node B detects the change of terminal type. Control node B updates the service information for the user to include the capabilities of UE B.2 to adapt and maintain the same service at the user's option. UE B.2 can receive the same content but with different quality adapted to the changed terminal.

4) UE B.2 moves to a different location. Control node B detects the movement of the UE and decides to transfer the service information to control node C.

5) Control node C determines that content node C.1 is most appropriate to provide content to UE B.2, and tells UE B.2 to receive content from content node C.1. UE B.2 establishes a connection with content node C.1 and starts to receive the same content as before from content node C.1.

8.6 Physical resource scheduling

8.6.1 Resource scheduling for server consolidation

Description

In general, different services have different resource consumption patterns, and some patterns are complementary. Therefore, it is preferable to integrate different services into a single DSN core node and introduce a dynamic resource scheduling mechanism for the purposes of energy-conservation and cost-saving.

Pre-conditions

The service workload for service 1 (e.g., VoIP) is high in the daytime and decreases dramatically during the night. The service workload for service 2 (e.g., streaming) remains low in the daytime and increases rapidly at night. The two services are consolidated onto each DSN core node, under the scheduling of the local scheduler.

Operational descriptions

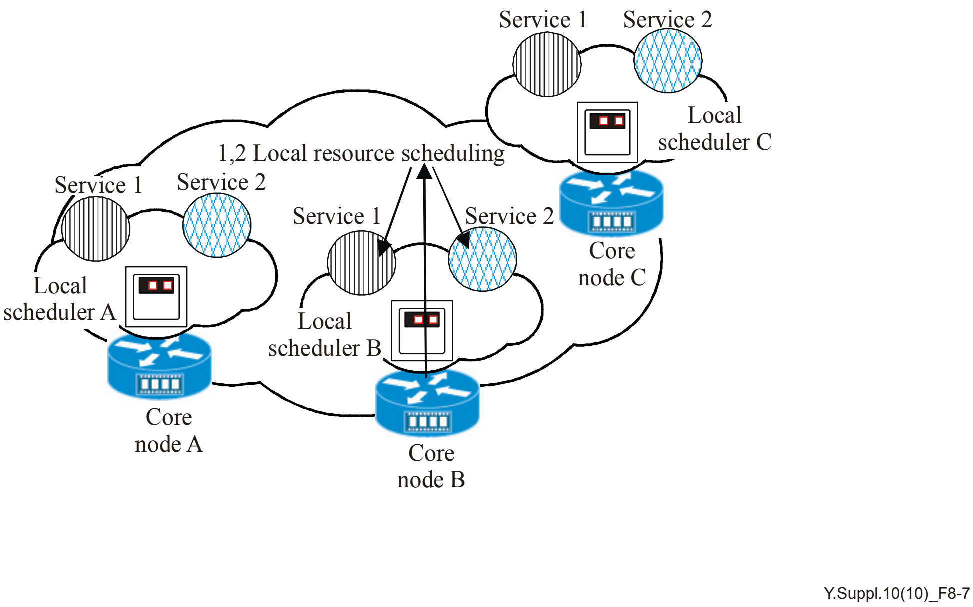

Figure 8-7 – Resource scheduling for server consolidation

Figure 8-7 illustrates the operations in this use case. Physical resources in core node B will be reassigned from service 2 to service 1 in the daytime by the local scheduler and vice versa at night.

8.6.2 Resource scheduling for resolution of resource contention

Description

DSN provides service migration among core nodes to avoid the service interruption caused by resource contention among different services residing in the same core node. The global scheduler is in charge of resource monitoring and scheduling among the core nodes.

Pre-conditions

In some cases, the workload of service 1 reaches its peak at midnight, while other services (e.g., service 2) residing on the same core node are still busy handling service requests. The local scheduler fails to schedule resources successfully because the resources in core node A are inadequate to satisfy both services. Moreover, service 1 has a higher priority than service 2.

Operational flows

Figure 8-8 illustrates the use case of resource scheduling for resource competition resolution.

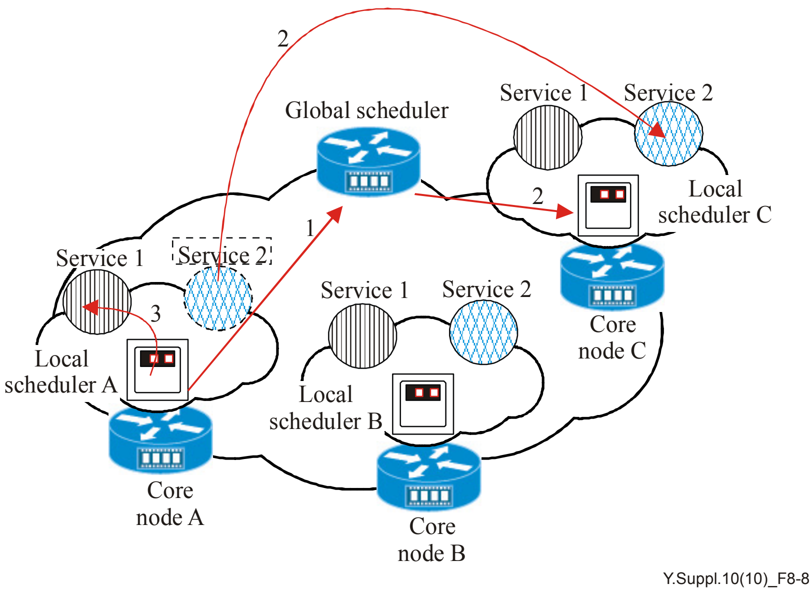

Figure 8-8 – Resource scheduling for resource competition resolution

1) Since service 1 has higher priority than service 2, the local scheduler at core node A requests the global scheduler to perform a service migration for service 2.

2) Based on a predetermined strategy, the global scheduler will migrate service 2 from core node A to core node C.

3) Resources in core node A that had been previously occupied by service 2 will be used for the workload of service 1.

8.6.3 Resource scheduling for shutting down lightly-loaded core nodes

Description

DSN provides service migration among core nodes to further perfect the utilization of physical resources.

Pre-conditions

During a certain interval, the service workloads for both service 1 (e.g., VoIP) and service 2 (e.g., streaming) are at a low level.

Operational flows

Figure 8-9 illustrates the use case of resource scheduling for shutting down lightly-loaded core nodes.

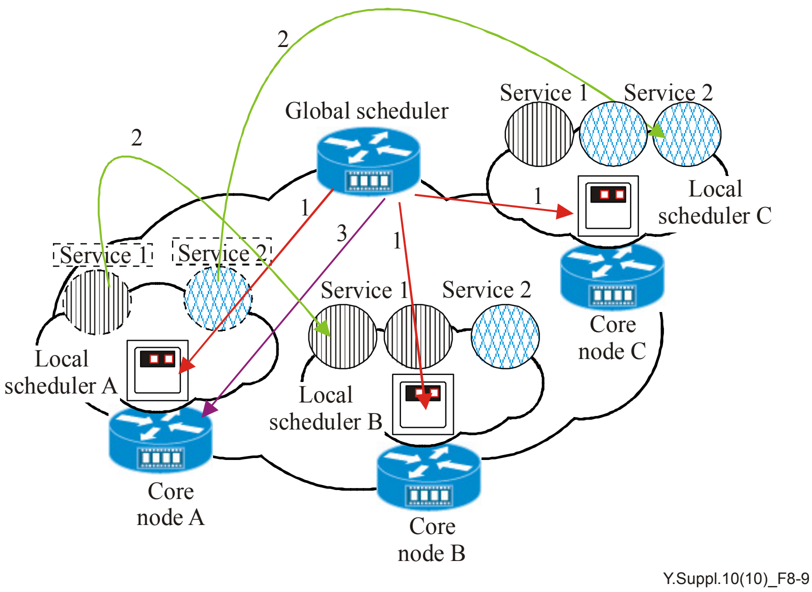

Figure 8-9 – Resource scheduling for shutting down lightly-loaded core nodes

1) The global scheduler communicates with the local schedulers to perform the resource scheduling function for the core nodes.

2) Services 1 and 2 on core node A are migrated to core nodes B and C, respectively.

3) Core node A is turned off after it turns to the idle state.

8.7 Load balancing

Description

In DSN, load balancing is essential to effectively manage the data and provide services. The loaded resources include, but are not limited to, the central processing unit (CPU), memory and storage usage. DSN balances the load across the DSN nodes in the system.

8.7.1 Load balancing when a new node joins

Description

DSN nodes are allowed to join or leave the network. Such behaviours may negatively impact the load balance of the network, even if it is well balanced in the beginning. When the overlay topology changes, DSN will adjust the load between the available DSN nodes dynamically and eventually achieve balance again.

Pre-conditions

In this case, the DSN overlay is composed of DSN nodes A, B and C. The load of the overlay is distributed amongst these DSN nodes and it is balanced. Another node, DSN node D, is allowed to join the overlay.

Operational flows

Figure 8-10 depicts a use case of load balancing when a new node joins.

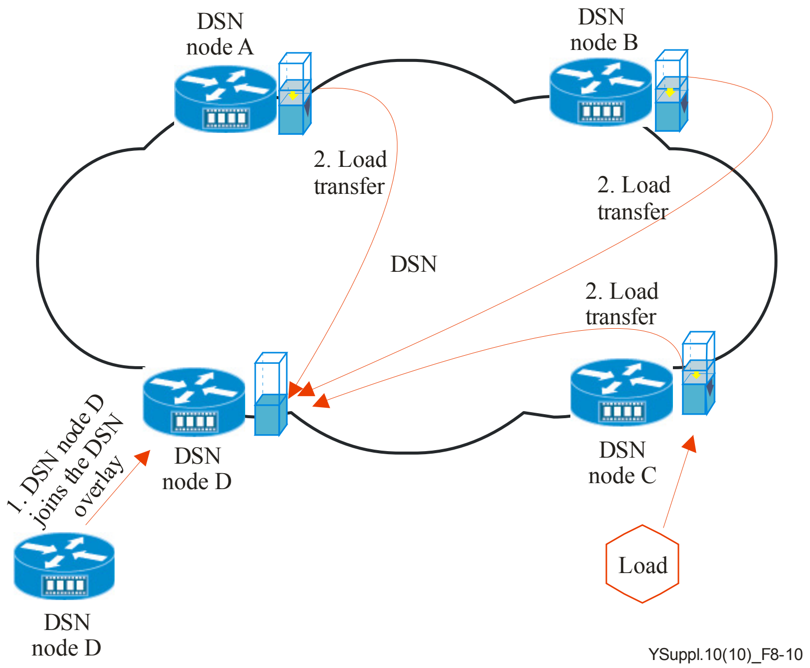

Figure 8-10 – Load balancing when a new node joins

1) A new DSN node D joins.

2) DSN adjusts the load automatically, the load will transfer from some of the other DSN nodes to the new DSN node.

3) After the adjustment process, the DSN achieves load balance again.

8.7.2 Load balancing when a node leaves

Description

DSN nodes are allowed to join or leave the network. Such behaviour may negatively impact the load balance of the network, even if it is balanced in the beginning. When the overlay topology changes, the DSN will adjust the workload between the available DSN nodes dynamically and eventually achieve balance again.

Pre-conditions

In this case, DSN overlay is composed of DSN nodes A, B, C, D and E. The workload of the DSN is distributed amongst the DSN nodes and it is balanced. After DSN node A leaves, the whole DSN workload of DSN does not exceed the current capability. The workload of DSN node A is required to be taken over by other DSN nodes to guarantee service continuity or the integrity of data, for example, for some important service or data resource.

Operational flows

Figure 8-11 depicts a use case of load balancing when a node leaves.

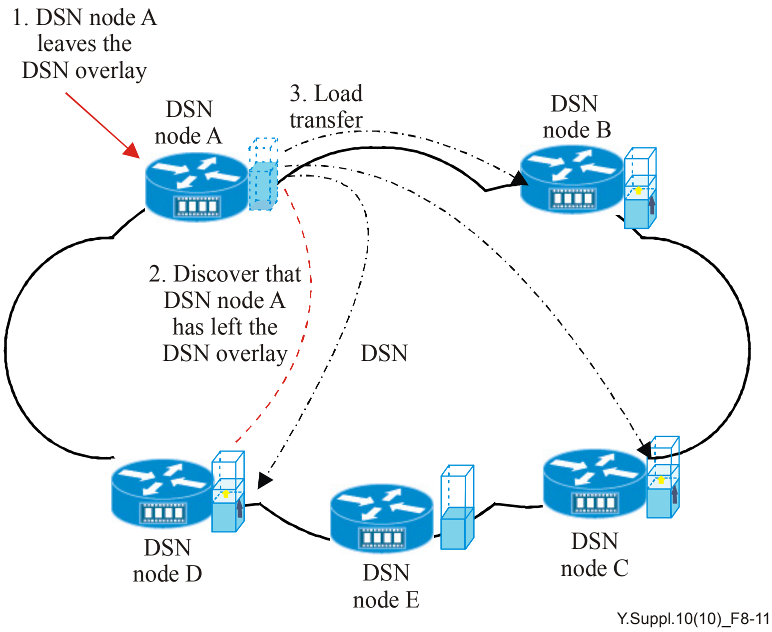

Figure 8-11 – Load balancing when a node leaves

1) DSN node A leaves the DSN overlay.

2) DSN finds that DSN node A has left the DSN overlay.

3) DSN adjusts the workload automatically. The workload of DSN node A will be taken over by DSN nodes B, C and D according to the load balancing policy.

After the above process, the DSN achieves load balancing again.

8.7.3 Load balancing to avoid DSN node overloading

Description

When the load on a DSN node reaches its upper threshold in a short time, DSN will automatically adjust the load distribution to lower the load on the DSN node so as to regain load balance.

Pre-conditions

In this case, the DSN overlay is composed of DSN nodes A, B, C and D. The load on DSN node D exceeds the threshold, which triggers the load rebalancing procedure.

Operational flows

Figure 8-12 depicts a use case of load balancing to avoid DSN node overloading.

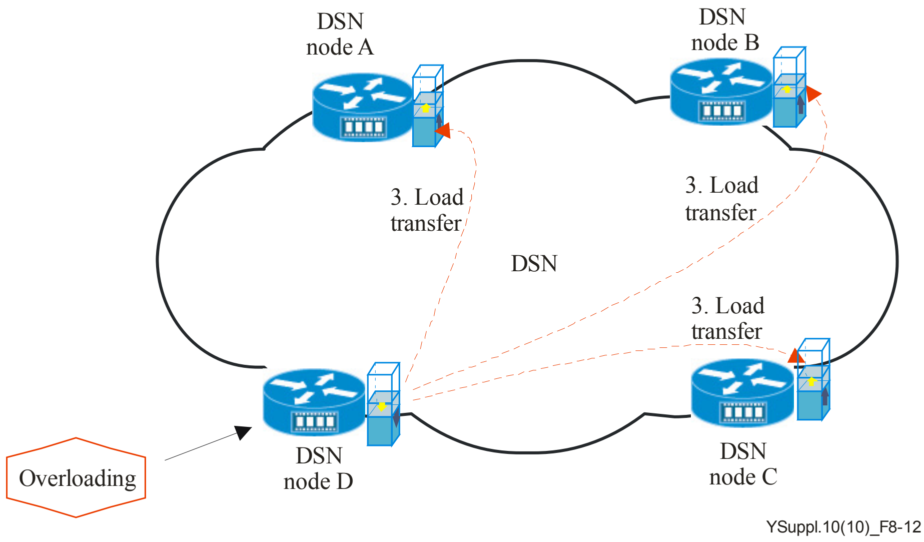

Figure 8-12 – Load balancing to avoid DSN node overloading

1) DSN node D is hit by a surge of requests which overload it.

2) According to a predetermined strategy, some DSN nodes, including nodes A, B and C, are selected for the load distribution.

3) DSN adjusts the load automatically. Some load is transferred from DSN node D to the selected nodes so as to regain load balance.

8.8 Node resource contribution and usage management

Description

Node resource contribution and usage management keeps track of the contribution record of the entities participating in DSN. The contribution record is used by the DSN service provider to provide incentives. The control node maintains a record of the contributions and service usage for each user.

The DSN service provider can use the collected information to provide incentives based on the measured resource contribution and usage. Node resource contribution and usage management is not limited to content resources.

The incentive can be in various forms, such as providing discounts or allocating more capacity to contributors or blocking service to non-contributors.

Node resource contribution and usage information can also be used as a basic material for providing load balancing and for designing network configuration.

Pre-conditions

Control node A maintains information on node resource contribution and usage.

Content node A.3 has the contents needed by content node A.1 (UE A.1) and UE A.2.

Operational flows

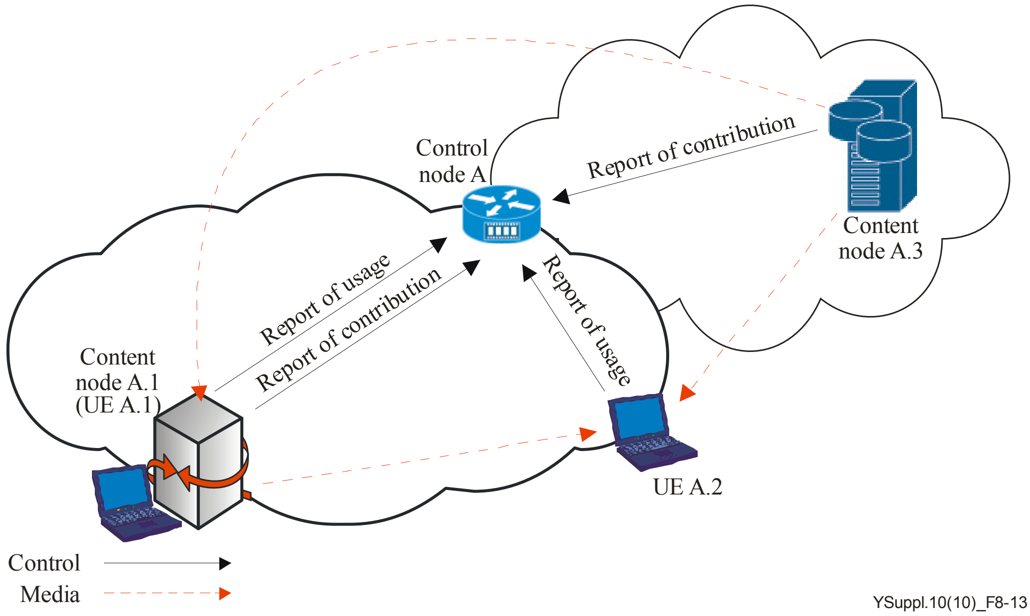

Figure 8-13 – Node resource contribution and usage management

1) Content node A.1 receives content from content node A.3 and provides content for UE A.2.

2) UE A.2 receives content from content node A.3 and content node A.1.

3) After transmission is completed, content node A.1 reports to control node A of content usage from content node A.3 and of content contribution to UE A.2. UE A.2 reports to control node A of content usage from content node A.3 and content node A.1. Content node A.3 reports its content contribution to content node A.1 and UE A.2.

4) Control node A stores the collected information, including the content contribution and usage information. Therefore, control node A can manage node resource contribution and usage.

8.9 QoS guarantee

Description

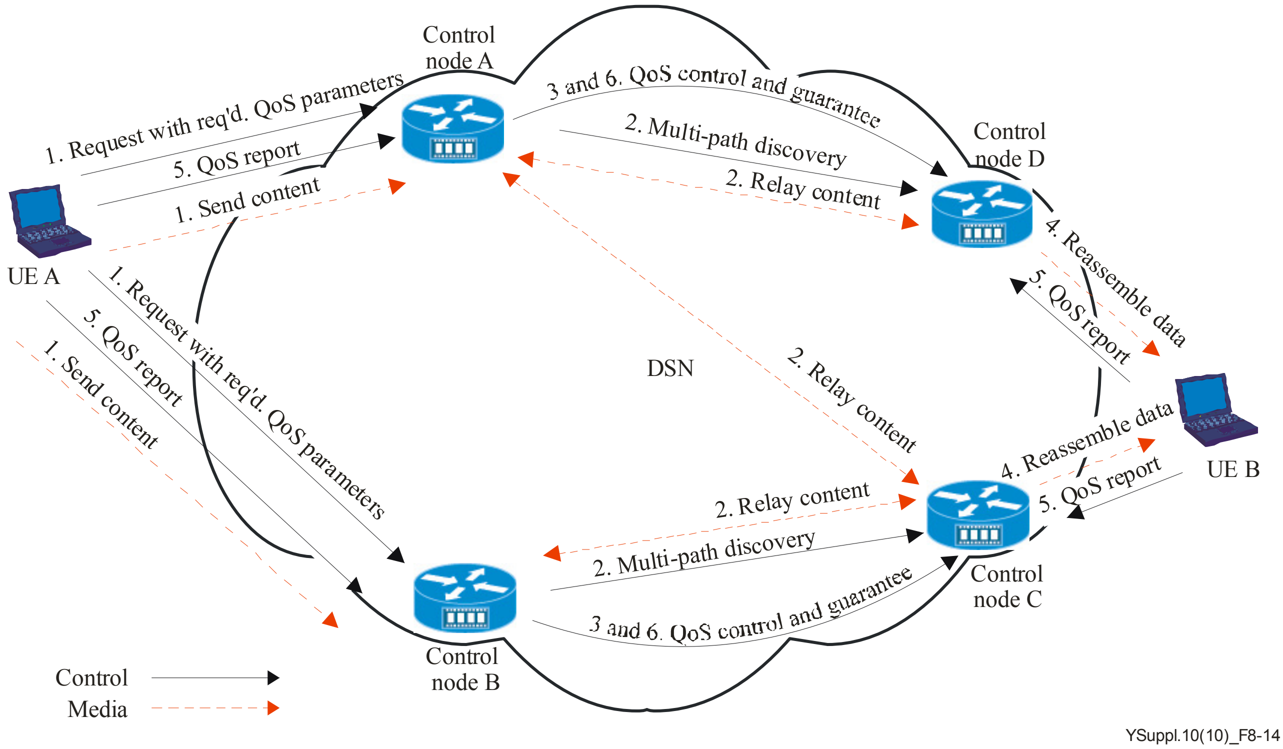

Figure 8-14 – QoS guarantee

Given the popularity of multimedia terminal equipment and the importance of data applications, it is strongly desired to ensure high end-to-end bandwidth in many types of usage, e.g., high-quality teleconferencing or high-speed transmission between two ends. High-quality teleconferencing requires a dedicated high-speed network environment, which is hard to achieve in the current Internet.

QoS can be achieved in different layers: the IP layer and overlay. DSN can be used to support applications requiring high end-to-end bandwidth or applications requiring low delay in non-dedicated networks by using the resources of DSN nodes, as shown in Figure 8-14. Multi-path routing and some special scheduling algorithms are needed between the DSN control nodes to realize this.

Pre-conditions in case 1

There is a 100 Mbytes file to be sent from UE A to UE B with a minimum speed requirement of 20 Mbit/s and low loss rate of 10^{-3}. However, the network is under heavy congestion and the control node resource is limited with a high loss rate. The steps to realize the requirements are as follows:

Operational flows in case 1

Figure 8-14 illustrates the operation both for case 1 and for case 2 below.

1) UE A requests to the serving control nodes A and B with the QoS requirement parameters.

2) Control nodes A and B explore all the possible overlay paths in the DSN and relay the packets from UE A to these paths.

3) Every control node executes the packet scheduling algorithms to optimize control node resource utilization and avoid congestion.

4) The relayed packets are redirected to UE B to reassemble the data.

5) UE A and UE B jointly measure the receiving loss rate and transmission speed, and notify the corresponding control node if it fails to meet the requirements.

6) Control nodes take some error control actions in DSN overlay transmission after the QoS parameters are received.

Pre-conditions in case 2

A video conference is to be set up between UE A and UE B. The conference requires 1 Mbit/s of bandwidth with a maximum end-to-end delay of 150 ms.

Operational flows in case 2

The steps to realize the requirements are similar to case 1, except step 5 and 6:

5) UE A and UE B jointly measure the end-to-end delay and transmission speed and notify the corresponding control node if it does not meet the requirements.

6) Control nodes make some path optimization actions after the QoS parameters are received.

8.10 Content brokering

Content brokering is a DSN service which retrieves the requested resources/content on behalf of the UE from DSN. DSN can be involved in the content delivery process based on the properties or characteristics of content.

There are two possible methods to control content delivery, including control from a control node and control from the UE. Thus, use cases for content brokering can be divided according to the controller for content delivery.

These use cases also cover delivery of content fragments. A content node can have all or a part of the content. For large content, it is much more efficient to have multiple content nodes to deliver fragments of content. The content fragments can be delivered simultaneously to the requesting UE, which can reduce total retrieval time.

8.10.1 Content brokering with delivery control by control node

Description

In some cases, content needs detailed delivery management from the DSN. The control node needs to keep track of content distribution and control the delivery of the content by invoking the content node for delivery.

The content node is selected based on the policy relating to the UE, network topology, etc. The UE has minor or no privileges in selection of the content node, but can choose to refuse delivery from a selected content node.

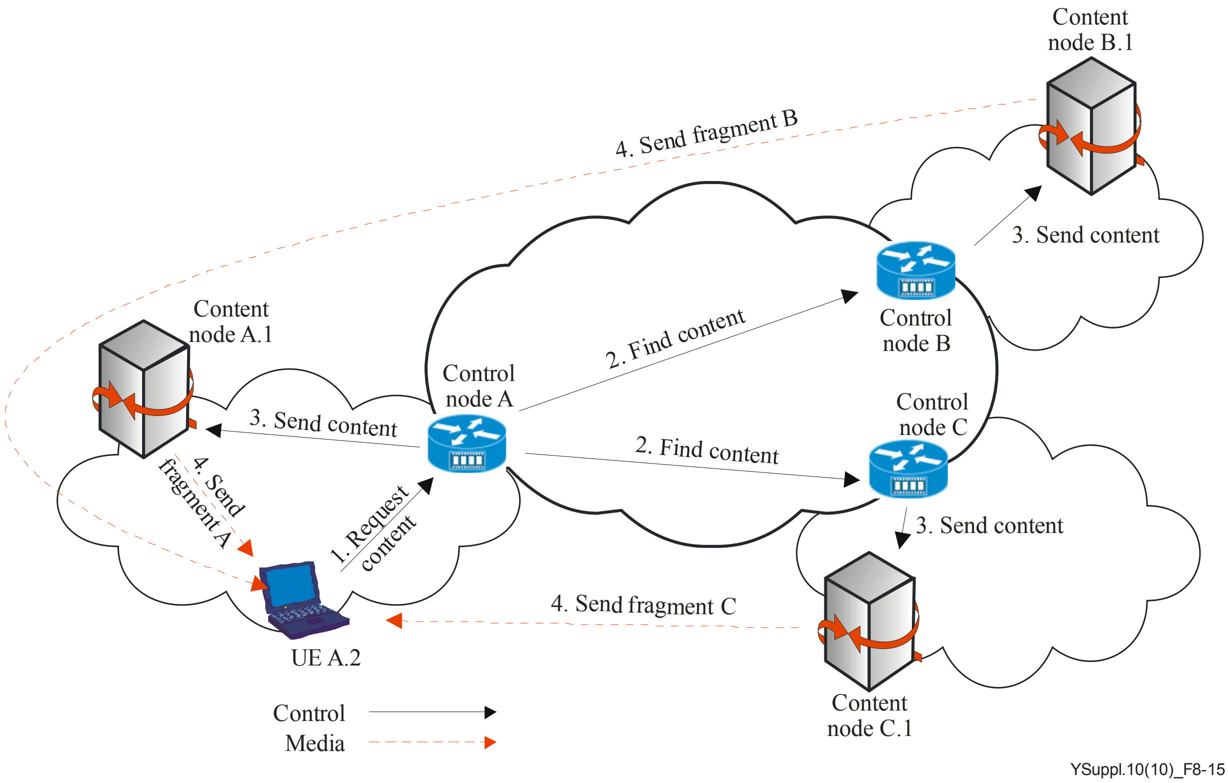

Figure 8-15 – Content brokering with delivery control by control node

Pre-conditions

Content is divided into three fragments A, B and C. Fragment A is stored in content node A.1, fragment B in content node B.1, and fragment C in content node C.1.

Operational flows

The operational flows for the use case are illustrated in Figure 8-15.

1) UE A.2 sends a request for content to control node A.

2) Control node A has information about fragment A only; thus, it requests other control nodes to find the rest of the content.

3) Control node A selects an adequate content node, which is content node A.1, to deliver fragment A. Control node A keeps a record of fragment A distribution to UE A.2 during this process. Control nodes B and C will follow a similar process as control node A to select the corresponding content node to deliver the related fragments and keep a record of fragment distribution to UE A.2.

4) Content node A.1 sends fragment A directly to UE A.2 as shown by the dotted line. Content node A.1 reports successful transmission to control node A. Content nodes B.1 and C.1 will follow a similar process as A.1 to send the corresponding fragments to UE A.2 and report to corresponding control node.

8.10.2 Content brokering with delivery control by UE

Description

In some cases, content such as free content does not need DSN control of content delivery. The control node provides location information for several content nodes to the UE with preference based on network topology, service efficiency, etc.

The UE controls the content delivery by selecting a content node. The content node can refuse to deliver content.

Although the UE controls content delivery by selecting the content node, the control node can reside within the signalling path, if necessary, for the purpose of billing, access control, etc.

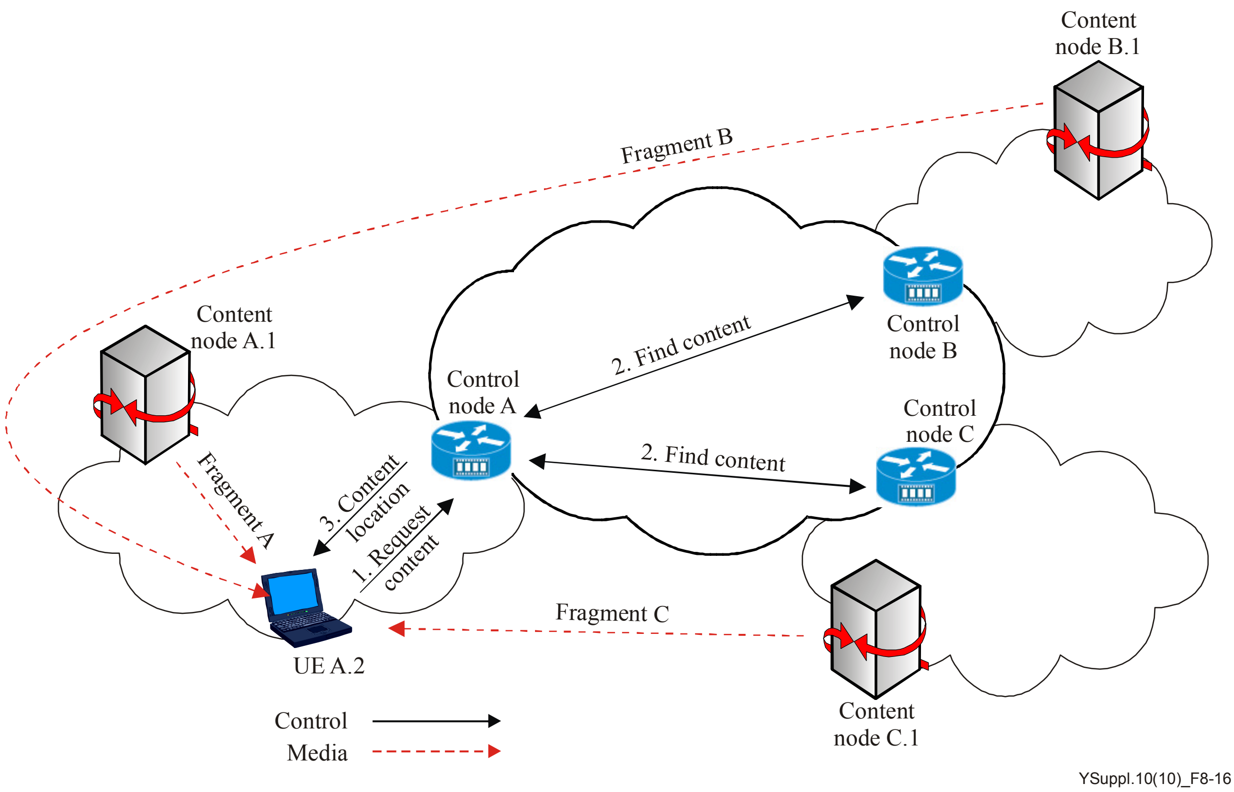

Figure 8-16 – Content brokering with delivery control by UE

Pre-conditions

Content is divided into three fragments A, B and C, which are held at content nodes A.1, B.1 and C.1, respectively.

Operational flows

Figure 8-16 illustrates the flows in this use case.

1) UE A.2 sends a request for free content to control node A.

2) Control node A has information about fragment A; thus, it requests other control nodes to locate the rest of the content. Control node B and control node C provide location information for the remaining fragment.

3) Control node A provides content location information to UE A.2, and UE A.2 requests for content directly to content nodes A.1, B.1 and C.1 for content fragments as shown by the dotted lines.

8.11 Common interface to utilize network capability

Description

The operators' DSN provides basic service enablers, such as VoIP and streaming, which encapsulate DSN network capabilities, such as signalling routing and session establishment. These service enablers are open for service providers to build service applications such as MMTel, instant messaging (IM), live video on demand (VoD) streaming, etc. These can in turn help service providers to make various service products for users in collaboration with content providers, e.g., rich communication systems (RCSs), social network system (SNS) services, online games, etc.

Figure 8-17 illustrates the relationship between service enablers, service applications and service products.

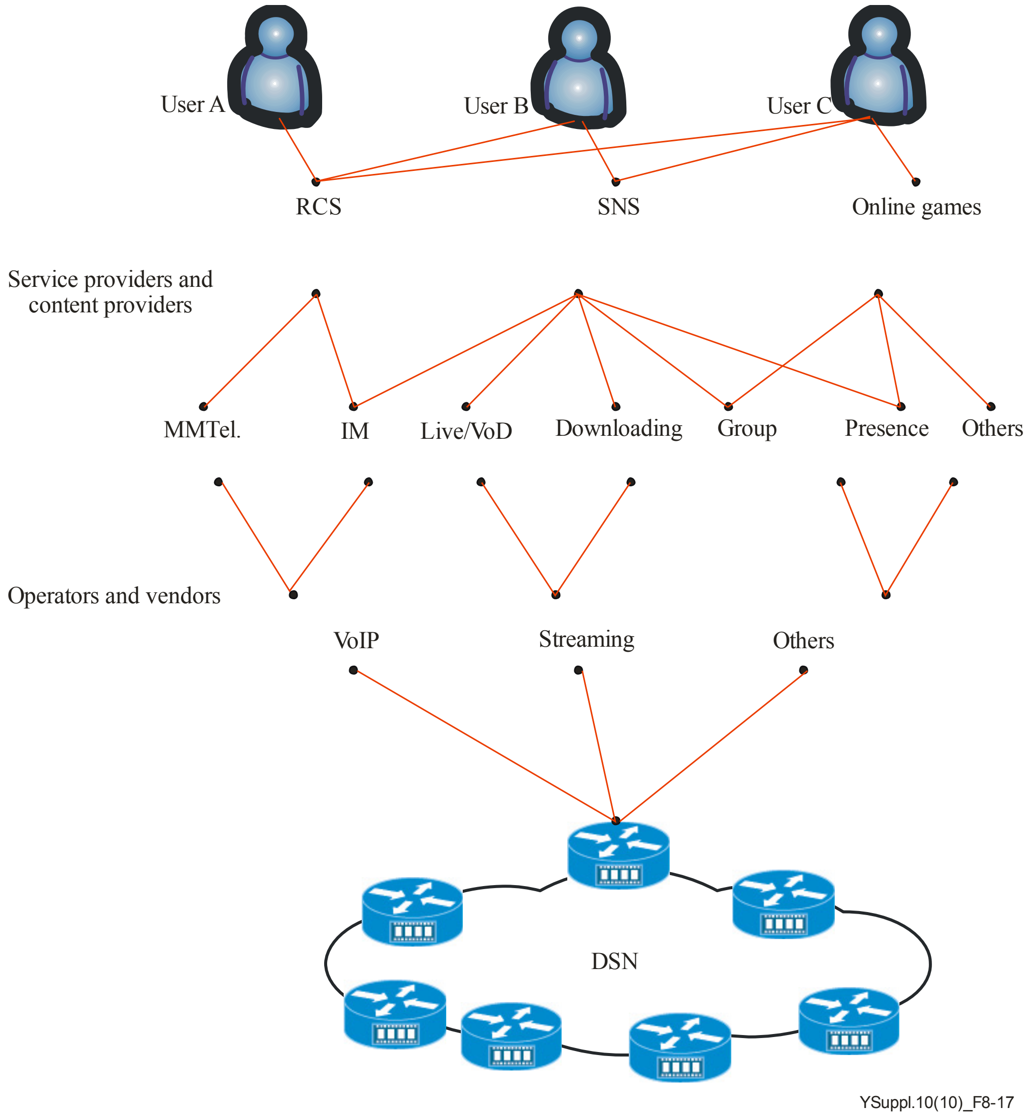

Figure 8-17 – A paradigm of the open service environment hierarchy

For example, the operator (e.g., operator A) builds VoIP, streaming and other service enablers over its DSN and opens them to service providers (e.g., service provider B). Service provider B then develops and releases an SNS platform, which can offer MMTel, IM, search, online gaming, as well as other popular Internet services, by encapsulating these service enablers. A user of service provider B can register by using its DSN number (perhaps a MSISDN number assigned by operator A) and all his or her bills can be paid by the account associated with this number. Moreover, all the services that the user can enjoy are combined together and accessible through unified client software, which can be installed either on a fixed UE or a mobile UE. Thus, the user can talk with his or her friends, watch a video guide or execute a personalized and location-related search while playing online games, even when he or she is in a moving vehicle.

The service enabler is a chosen set of network capabilities which can be encapsulated into a program. The program can be invoked through a well-defined interface such as an API. When the service provider needs to utilize certain network capabilities, e.g., establishing sessions between certain pairs of users, the API can be invoked if it has been integrated into the service application program.

In practice, the functionality of the service enablers is most probably built by the operators within the DSN core network, since it is quite related to the core network capabilities. One feasible way is to distribute the enablers' logical functions into DSN core nodes. The service enablers can be open to both the operator itself and service providers.

Pre-conditions

None.

Operational flows

None.

8.12 Charging

The charging use cases are categorized based on services because different services have different business models and charging use cases. Streaming and MMTel services are two of the most common services supported by DSN, and the charging use cases for streaming and MMTel are described below.

8.12.1 Offline charging use cases

8.12.1.1 Offline charging use case for DSN streaming

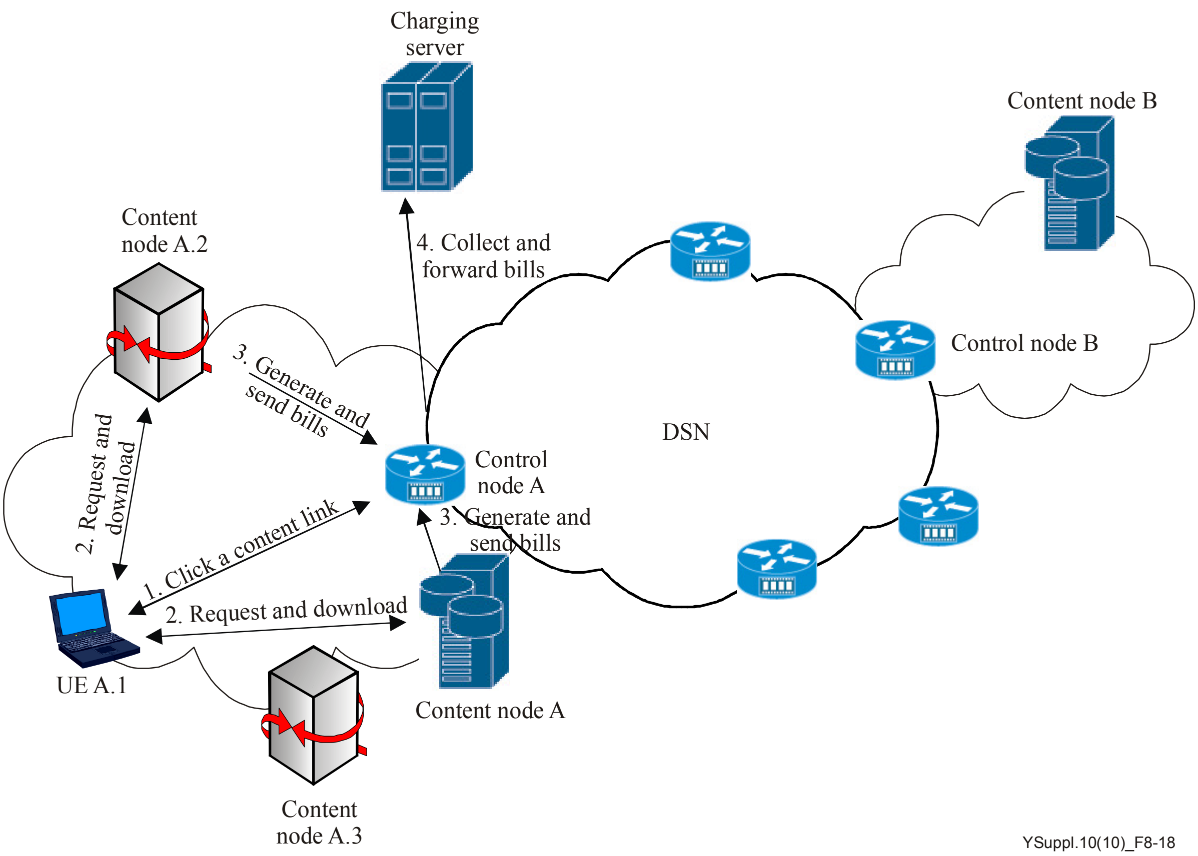

Figure 8-18 – Offline charging use case of DSN streaming

Description

A call detail record (CDR) is generated after the streaming is released and then is transferred to the charging server. A billing record will be generated and delivered to subscribers based on the collected offline CDRs periodically (e.g., every month). This type of charging pattern is applicable to post-paid subscribers, who have a relatively good financial reputation.

Pre-conditions

Content node A.2 and content node A.3 are neighbours of UE A.1 in the same domain. To ensure the accuracy of the CDR, the control servers and the charging server shall be trusted network entities and usually are deployed and managed by operators.

Operational flows

Figure 8-18 illustrates an offline charging use case for DSN streaming.

1) UE A.1 sends a request to play video to control node A, control node A parses the user request for streaming media content, locates the resource list for the desired content, and returns the resources list to UE A.1.

2) UE A.1 requests the streaming media content fragments from content nodes in accordance with the content link, and the content nodes upload the pieces to UE A.1.

3) At the same time, the content nodes generate the charging information, which is sent to control node A.

4) Control node A collects this charging information and sends it to the charging server in the form of a CDR to allow billing for the service.

8.12.1.2 Offline charging use cases for DSN MMTel

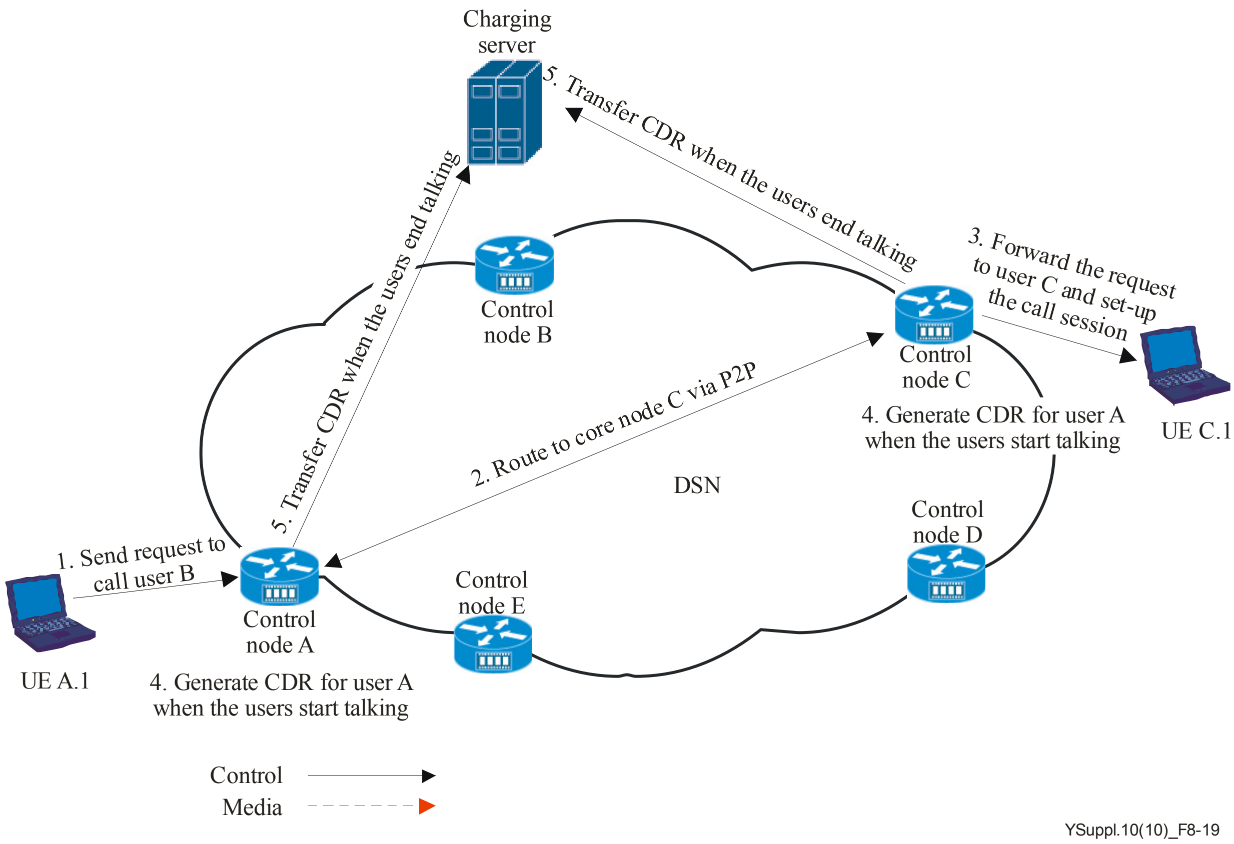

Figure 8-19 – Offline charging use case of DSN MMTel

Description

A CDR is generated after the MMTel call is released and then it is transferred to the charging server. A billing record will be generated and delivered to subscribers based on the collected CDRs periodically (e.g., every month). This type of charging pattern is applicable to post-paid subscribers, who have a relatively good financial reputation.

Pre-conditions

UE A.1 corresponds to user A, while UE C.1 corresponds to user B. To ensure the accuracy of the CDR, the control servers and the charging server shall be trusted network entities and usually are deployed and managed by operators.

Operational flows

Figure 8-19 illustrates a use case of offline charging for DSN MMTel.

1) UE A.1 initiates a call to UE C.1 and sends the request to control node A, which is assigned to serve UE A.1.
2) Control node A routes the call via P2P to control node C, which is assigned to serve UE C.1.
3) Control node C forwards the request to UE C.1 and continues call session set-up with originating UE A.1.
4) The correlative CDRs are generated on control nodes A and C when the users start and finish talking.
5) After the call, the CDRs are transferred to the charging server.

8.12.2 Online charging use cases

8.12.2.1 Online charging use cases for DSN streaming

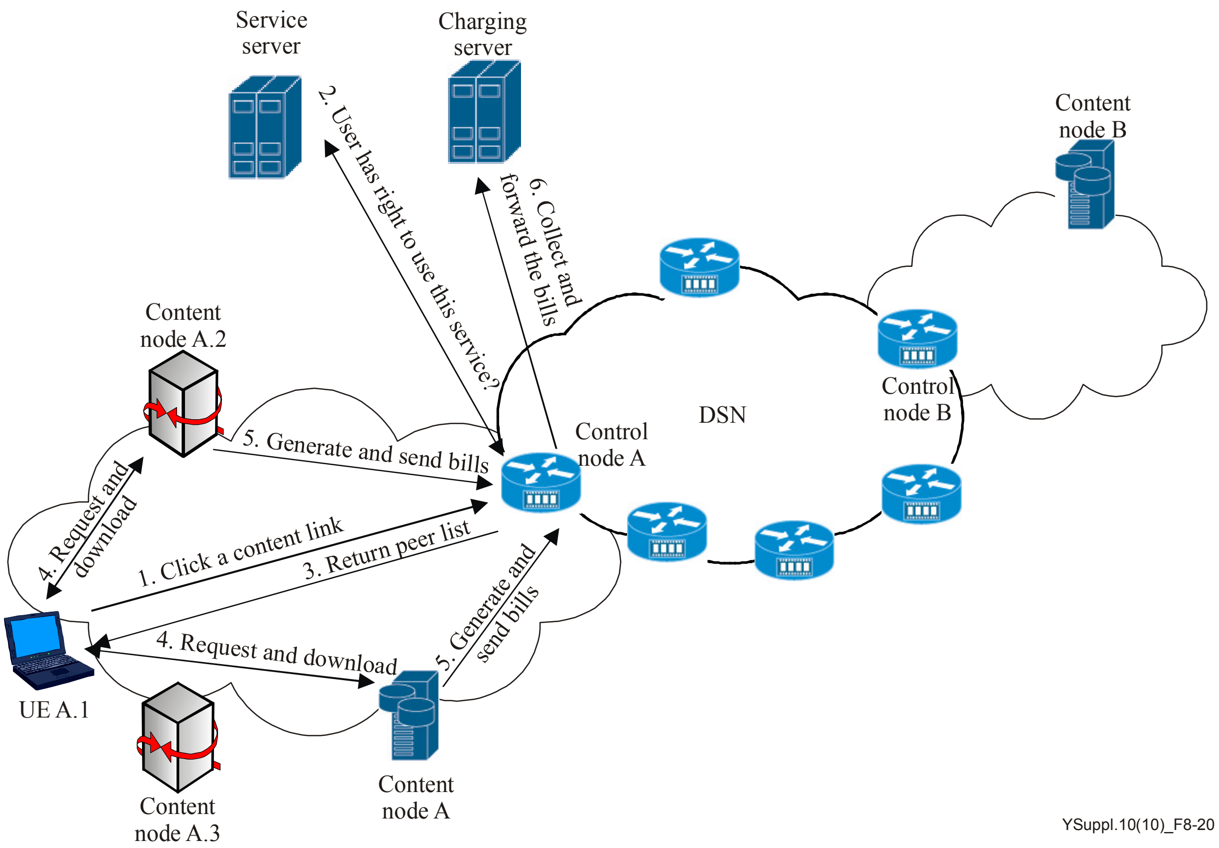

Figure 8-20 – Online charging use case of DSN streaming

Description

The balance in the charging server is checked immediately before streaming is set up and deducted real-time immediately after streaming is released. This type of charging pattern is applicable to pre-paid subscribers, who have a relatively poor financial reputation.

Pre-conditions

Content nodes A.2 and A.3 are neighbours of UE A.1 in the same domain. To ensure the accuracy of the CDR, the control servers and the charging server shall be trusted network entities, and usually are deployed and managed by operators.

Operational flows

Figure 8-20 describes an online charging use case for DSN streaming.

1) UE A.1 sends a request to play video to control node A.

2) The service system queries the charging information for the user-requested streaming media content, and determines whether UE A.1's account balance is sufficient to cover the streaming media content through the pre-paid system interface. If there is sufficient account balance, then these funds are frozen and the operation continues to the next step; if the balance is insufficient, then an error message will be returned to UE A.1.

3) Control node A parses the user request for streaming media content, locates the corresponding resource list, and returns the resource list to UE A.1.

4) The UE A.1 requests streaming media content fragments from content nodes in accordance with the resource list, and the content nodes upload the fragments to UE A.1.

5) At the same time, the content nodes generate charging information, which is sent to control node A.

6) Control node A collects this charging information and sends it to the charging system in the form of a CDR in order to generate the charging bill.

8.12.2.2 Online charging use cases for DSN MMTel

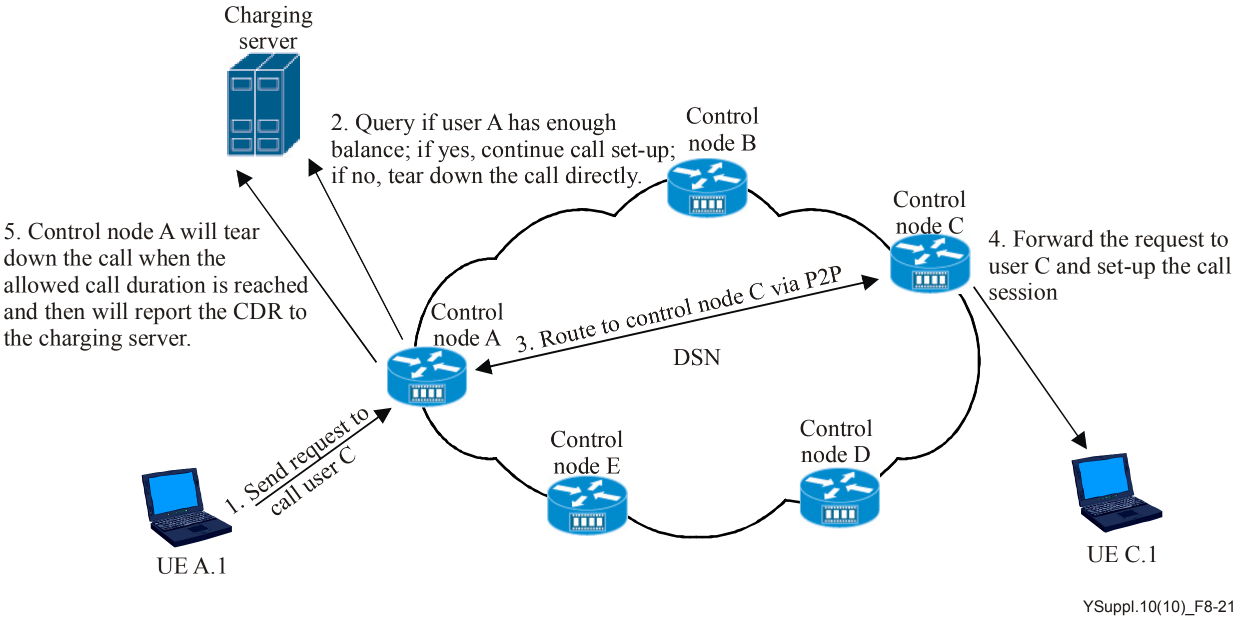

Figure 8-21 – Online charging use case of DSN MMTel

Description

The balance in the charging server is checked immediately before the MMTel call is set up and the cost of the call is deducted in real-time immediately after the MMTel call is released. This type of charging pattern is applicable to pre-paid subscribers, who have a relatively poor financial reputation.

Pre-conditions

UE A.1 corresponds to user A, while UE C.1 corresponds to user B. To ensure the accuracy of the CDR, the control servers and the charging server shall be trusted network entities, and usually are deployed and managed by operators.

Operational flows

Figure 8-21 illustrates an online charging use case for DSN MMTel.

1) UE A.1 initiates a call to UE C.1 and sends the request to control node A, which is assigned to serve UE A.1.

2) Control node A initiates a query to the charging server to check if user A has sufficient balance to initiate the call. If yes, the call is allowed to continue and the maximum allowed call duration is indicated by the charging server. If no, the call is terminated immediately and, meanwhile, an announcement is played back to user A.

3) Control node A routes the call to control node C, which is assigned to UE C.1.

4) Control node C forwards the request to UE C.1 and continues call session setup with originating UE A.1.

5) After the call is established, the call will be torn down by control node A if the maximum allowed call duration is reached. At that point or when the call finishes naturally, control node A reports the CDR to the charging server.

8.12.3 Credits earned through download of advertisements

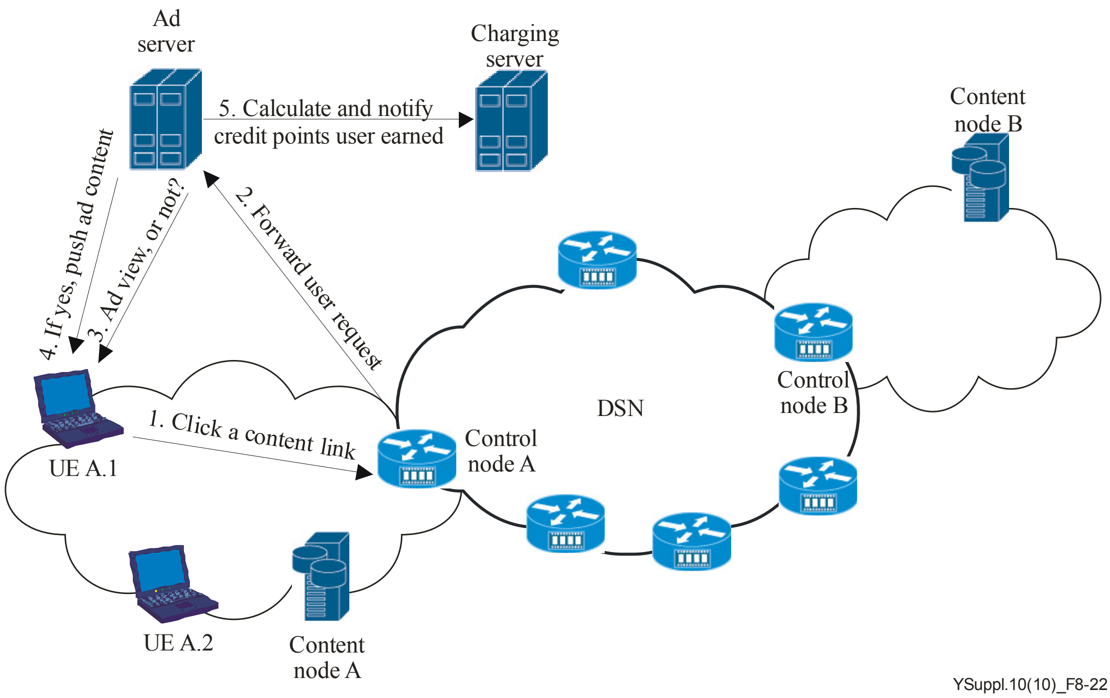

Figure 8-22 – Credits earned through download of advertisements

Description

To encourage more UEs to view advertisements, UEs can receive credits from the ad server.

Pre-conditions

To ensure the accuracy of the CDR and the advertising information, the control servers, the Ad server and the charging server shall be trusted network entities and usually are deployed and managed by operators.

Operational flows

Figure 8-22 describes a use case about credits earned through download of advertisement.

1) UE A.1 sends a request to play video to the streaming web portal, and the request is passed to control node A.

2) Control node A forwards the user request to the background advertising server system.

3) The advertising server resolves the user's preferences based on user interest registration information, and pushes the relevant advertising information to the user, allowing the user to choose whether and when to view the advertising.

4) If the user chooses to receive ads, the advertising server pushes relevant advertising content to UE A.1 and, at the same time, collects statistical information related to user behaviour.

5) The advertising server calculates the credit points for the user based on collected user behaviour information, such as the advertisement content that the user received, advertisement viewing time and user feedback to the advertisement, and sends the calculated credit to the charging server.

8.12.4 Relay charging use case

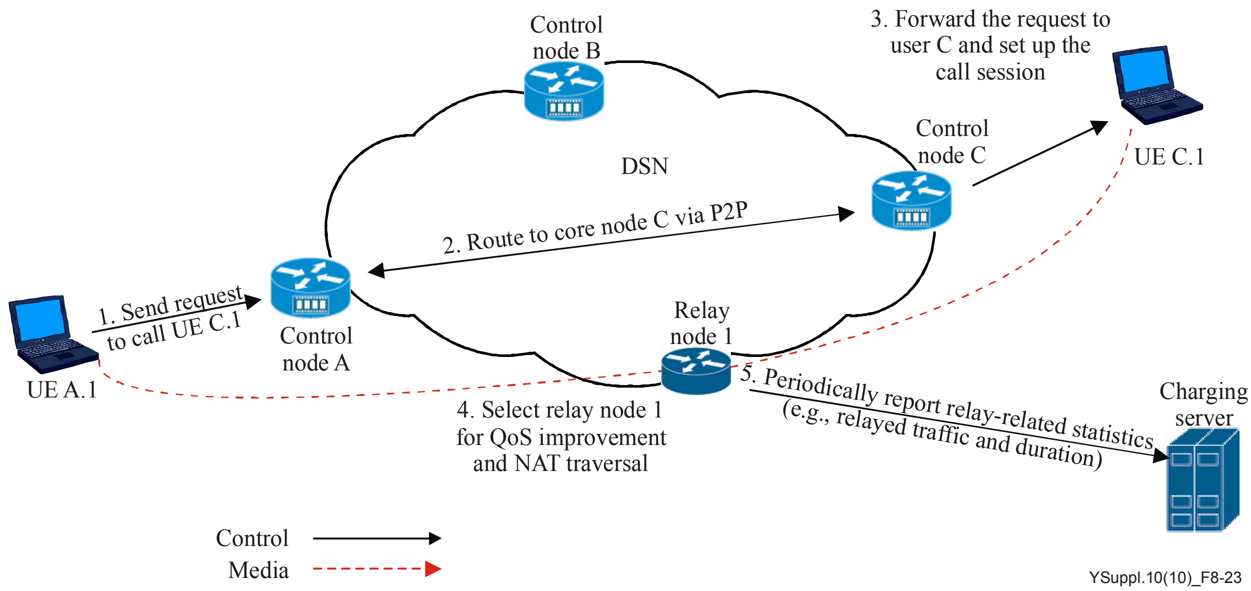

Figure 8-23 – Relay charging use case

Description

To encourage more UEs to contribute their free resources, the relay-related statistics generated by user nodes serving as relay nodes should be collected to reward the contributing users. So the relay node periodically reports relay-related statistics to the charging server (e.g., relayed traffic and duration).

Pre-conditions

To ensure the accuracy of the CDR, the control server and the charging server shall be trusted network entities, and usually are deployed and managed by operators. Since the relay node may be a user node and cannot be fully trusted, the statistics generated from UEs should be carefully verified by the charging server.

Operational flows

Figure 8-23 illustrates a use case of relay charging for DSN MMTel.

1) UE A.1 initiates a call to UE C.1 and sends the request to control node A, which is assigned to serve UE A.1.
2) Control node A routes the call to control node C, which is assigned to UE C.1.
3) Control node C forwards the request to UE C.1 and continues call session set-up with originating UE A.1.
4) Due to QoS improvement and NAT transversal, relay node 1 is selected to relay the media flow.
5) Relay node 1 periodically reports the relay-related statistics to the charging server (e.g., relayed traffic and duration).

8.13 Multicasting of linear streaming service

Description

Figure 8-24 illustrates a use case where many UEs request the same linear streaming service simultaneously (e.g., IPTV). To avoid the waste of network resources (e.g., bandwidth) that would result from delivery of multiple copies of identical content via DSN, a DSN node can forward the content to one or more DSN nodes. For effective service distribution, DSN nodes support adaptive multicast construction to provide optimal delivery paths. For this, DSN nodes evaluate variable network information such as transmission bandwidth, topology, link state, traffic and so on. Furthermore, DSN supports control of user behaviours such as dynamic joining or leaving and QoS negotiation, if necessary.

Pre-conditions

A multicast path is constructed by the DSN nodes for the linear streaming service. In the multicast path construction, factors considered include the heterogeneity of networks and of DSN nodes in terms of incoming/outgoing network bandwidth, link delay, expected QoS, etc.

Relay nodes A, B, C and D do not cache or store content but only distribute content to pertaining nodes including both content nodes and UEs.

Operational flows

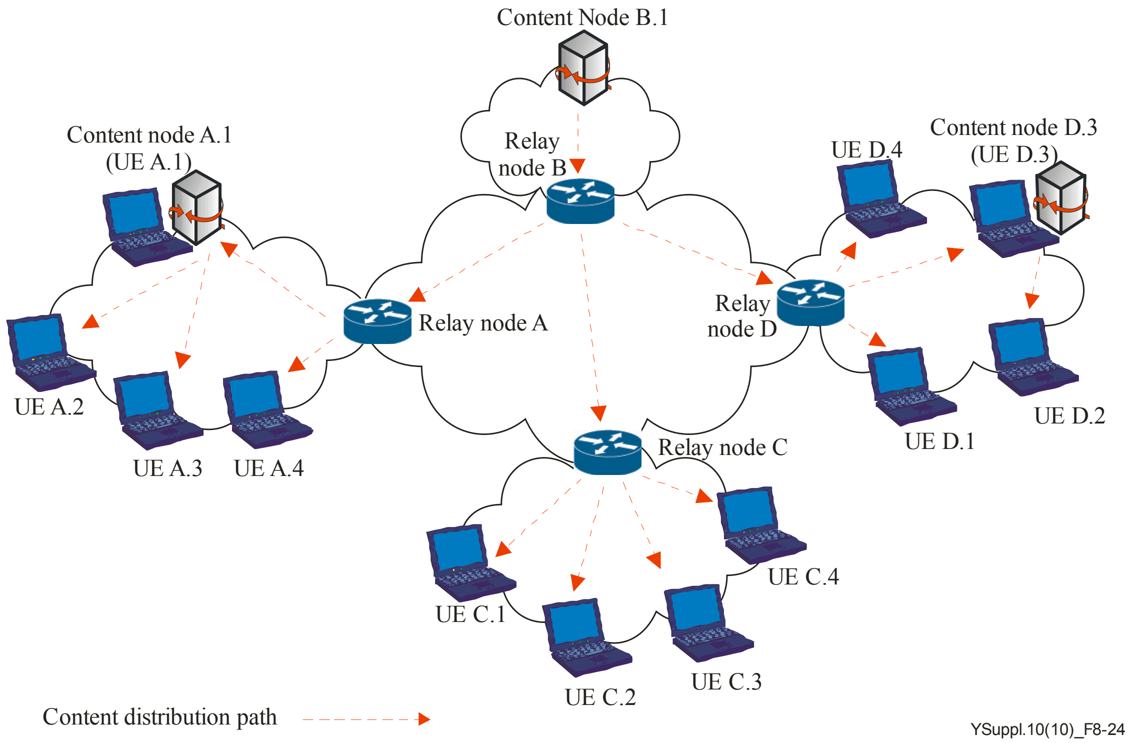

Figure 8-24 – Multicasting of linear streaming service

1) Content node B.1 provides a linear streaming service through relay node B, and sends the streaming data to relay node B.

2) Relay node B distributes the streaming data to DSN nodes across the network, including relay nodes A, C and D.

3) Each relay node forwards streaming data to receiving nodes simultaneously.

4) Content node A.1 consumes and stores content from relay node A, and provides content to UE A.2 and UE A.3.

5) Content node D.3 consumes and stores content from the relay node D, and provides content to UE D.2.

8.14 Content adaptation for streaming service

Description

Figure 8-25 shows a use case about content adaptation for a streaming service. UE A.1 is a fixed terminal. UE B.1 is a mobile terminal connected to DSN through a wireless network such as 3G/LTE. Though mobile terminals have some limitations in screen size and bandwidth, they can share streaming data with fixed terminals by scalable video coding (SVC), which is defined in Annex G of [ITU-T H.264]. By using SVC, the low quality streaming data can be derived from high quality streaming data without re-encoding, thus achieving content adaption between fixed terminals and mobile terminals, or between terminals with different capabilities.

Pre-conditions

1) Content node A registers its content to control node A.

2) Content node A.1 registers its content to control node B.

3) The streaming content which is shared among content node A, content node A.1 and UE B.1 is encoded with SVC.

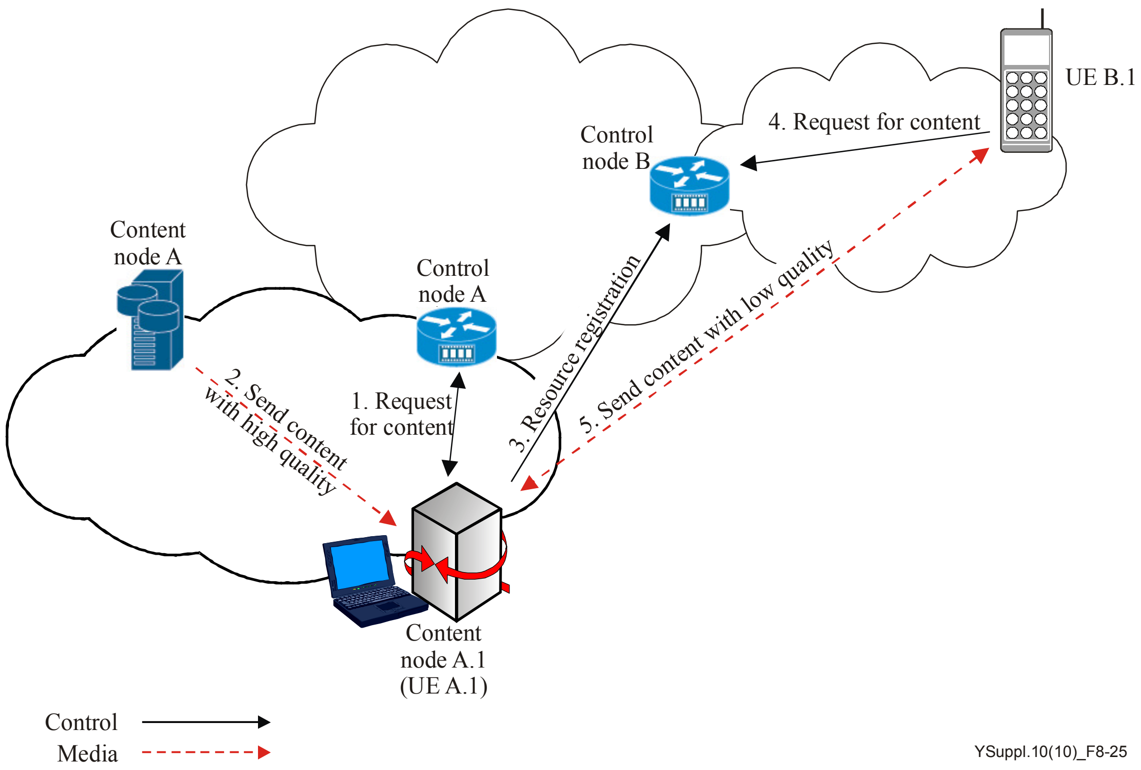

Figure 8-25 – Streaming service with content adaptation

Operational flows

1) UE A.1, which is a fixed terminal with a high screen resolution and a high-speed access connection, sends a request for streaming content to control node A. Control node A returns content node A as a source in this case.

2) Streaming content with high quality is sent from content node A to UE A.1.

3) UE A.1 stores the content which has been downloaded and registers it to control node B.

4) UE B.1, which is a mobile terminal with lower screen resolution and limited access bandwidth, chooses the same streaming content and sends a request to control node B for the location which can provide the requested streaming content. Control node B returns the location information of UE A.1. Because UE A.1 has registered its content information and UE A.1 can share its content, so UE A.1 can act as a content node.

5) UE B.1 connects to content node A.1 and tells it which level of streaming content is appropriate for its limited terminal and access capabilities. Then content node A.1 provides the relevant data encoded with SVC.

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