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SERIES G: TRANSMISSION SYSTEMS AND MEDIA, DIGITAL SYSTEMS AND NETWORKS

Multimedia Quality of Service and performance – Generic and user-related aspects

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Measurement-based methods for improving the robustness of IPTV performance

Recommendation ITU-T G.1082

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Recommendation ITU-T G.1082

Measurement-based methods for improving the robustness of IPTV performance

Summary

Recommendation ITU-T G.1082 provides a framework for improving the robustness of IPTV performance based on the results of real-time measurements. The primary application of this framework is to control the media and network resources based on the measurement information and according to policy rules to support high quality of experience of IPTV services.

For IPTV services, service providers and network providers may have separate monitoring systems. Measurement information is provided by the monitoring system. This Recommendation first describes the possible measurement information used in different monitoring domains and the information exchanged between providers. It then gives guidance on how to take these factors into account to adjust media and network resources in order to maintain the quality of experience for IPTV services.

Source

Recommendation ITU-T G.1082 was approved on 29 April 2009 by ITU-T Study Group 12 (2009-2012) under Recommendation ITU-T A.8 procedure.

Keywords

IPTV, measurement, QoE, QoS, resource adjustment.

FOREWORD

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Measurement-based methods for improving the robustness of IPTV performance

1 Scope

This Recommendation describes some methods by which measurement information of IPTV service quality can be used to dynamically control the performance of an IPTV service such as network resource allocation, FEC redundant encoding, delivery path selection or media encoding bit rate if scalable encoding is employed.

This Recommendation defines the subset of QoS/QoE performance parameters to be obtained from the IPTV monitoring system and methods for analysing them to provide media resource and transport network resource control in support of high quality end-to-end delivery of IPTV services.

It also provides guidance on the collaboration between different providers and defines the metrics to be exchanged between them for resource management.

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 G.1080] Recommendation ITU-T G.1080 (2008), *Quality of experience requirements for IPTV services*.

[ITU-T G.1081] Recommendation ITU-T G.1081 (2008), *Performance monitoring points for IPTV*.

[ITU-T Y.1540] Recommendation ITU-T Y.1540 (2007), *Internet protocol data communication service – IP packet transfer and availability performance parameters*.

3 Definitions

This Recommendation does not define any special terms.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

DiffServ Differentiated Services

FEC Forward Error Correction

GOP Group Of Pictures

IP Internet Protocol

IPDV IP packet Delay Variation

IPLR IP packet Loss Ratio

IPTD IP packet Transfer Delay

IPTV	Internet Protocol Television
MMPAP	Monitoring Management and Performance Analysis Platform
MMRP	Measurement-based Methods for improving the Robustness of IPTV Performance
MOS	Mean Opinion Score
MPLS	Multi-Protocol Label Switching
NP	Network Provider
QoE	Quality of Experience
QoS	Quality of Service
RFC	Request For Comments
RTCP	RTP Control Protocol
RTP	Real-time Transport Protocol
SLA	Service Level Agreement
SP	Service Provider
STB	Set-Top Box
UDP	User Datagram Protocol
VoD	Video on Demand

5 Conventions

None.

6 Overview of the framework of measurement-based methods for improving the robustness of IPTV performance (MMRP)

In IPTV services, the QoE is a great concern to the end users. The user expects the perceptual quality of IPTV services to be as good as or even better than that of conventional TV service. In order to achieve the user's expectation, a QoS/QoE monitoring system becomes an indispensable part of the IPTV services.

In a conventional monitoring system, the measurement information is only used for evaluating network performance and QoE of end users. However, this information can also be valuable input for providing media resource and transport network resource control in support of high quality of experience of IPTV services. The SP and NP can adjust the media and network resources based on the measurement information. The resource adjustment procedure includes the steps of reporting measurement information, exchanging information between SP and NP, and deciding resource adjustment methods by SP and NP. Figure 1 depicts a reference model for a MMRP system.

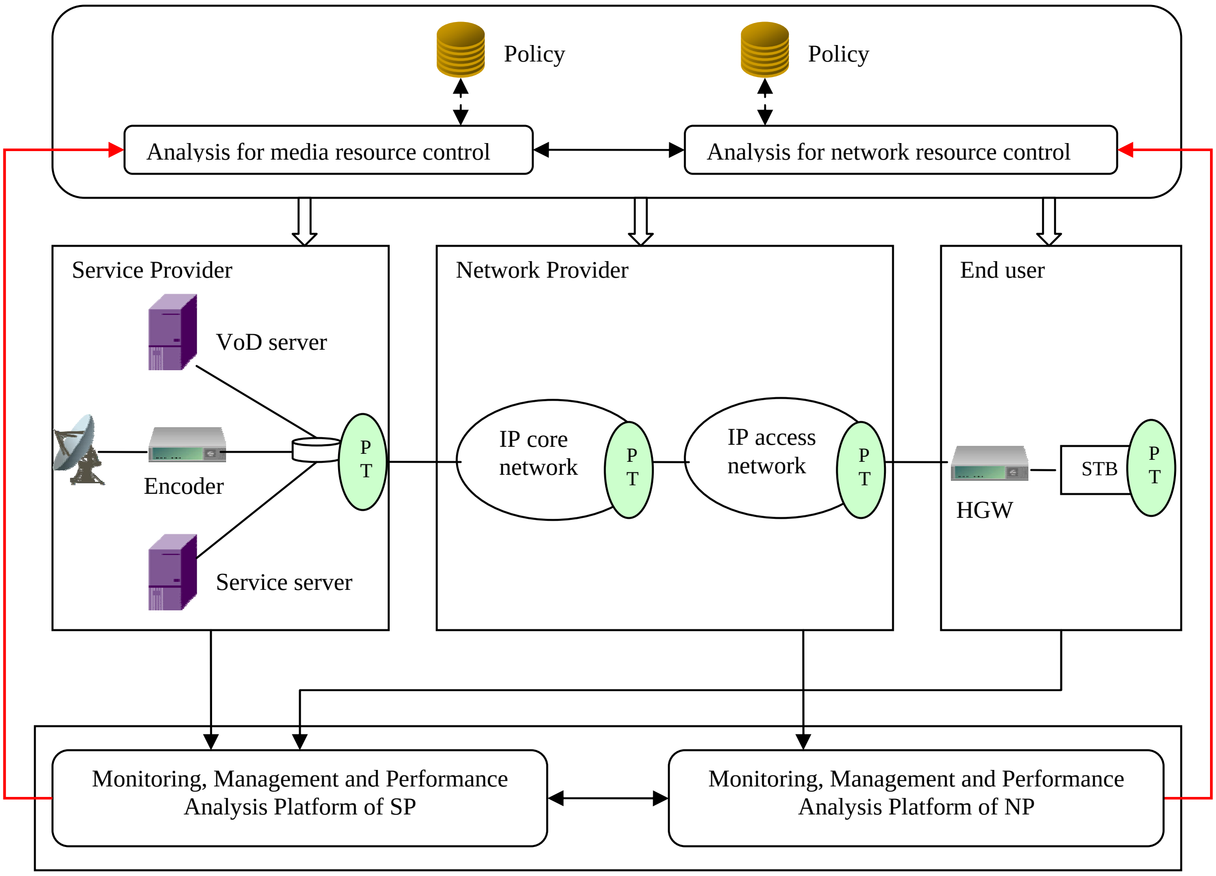

Figure 1 – Reference model

A monitoring system includes monitoring points (labelled PTs) and a monitoring, management and performance analysis platform (MMPAP). MMPAP manages one or multiple domains and collects measurement data from the monitoring points. The MMPAP of the SP collects information from the head-end system and the end-user system. The MMPAP of the NP collects information from backbone and access network domains. Note that the monitoring points located in a service provider's domain have different capabilities from those located in a network provider's domain. Based on the measurement data collected from monitoring points, the MMPAP provides the QoE metrics and other information of IPTV services. If the QoE metrics are below a certain predefined value, which is defined in the policy, it may trigger a network resource adjustment procedure, a media resource adjustment procedure or both. Since one single provider has limited measurement information, the SP and NP may share a set of information to decide on a resource adjustment method. During the procedures, the end users may not perceive the quality degradation of IPTV services.

7 Process of end-to-end quality improvement

MMPAP is located in the SP and NP administrative areas. The measurement-based resource adaptive control function collects the information from one or more MMPAP. The media and network resource is adjusted in a centralized model or in a distributed model.

Centralized model

A single resource adaptive control function is responsible for the management of media and network resources. It collects measurement information from all the MMPAPs. If a MMPAP is under a different administrative area, it is not easy to aggregate the information and control the resource of entire domains.

Distributed model

A number of adaptive resource control functions are responsible for the management of media and network resources. Each resource adaptive control function collects measurement information from its associated MMPAP and manages the resource of administrative domains. The measurement information is exchanged between adaptive resource control functions which collaborate with each other for the end-to-end quality maintenance.

This Recommendation describes a distributed model. The SP and NP collect measurement information from their MMPAP and share a part of the measurement information with each other. Based on measurement and auxiliary information, SP and NP first decide which provider is responsible for adjusting the resource. Then, the media and transport network resource is adapted to maintain the end-to-end quality. Figure 2 illustrates this process.

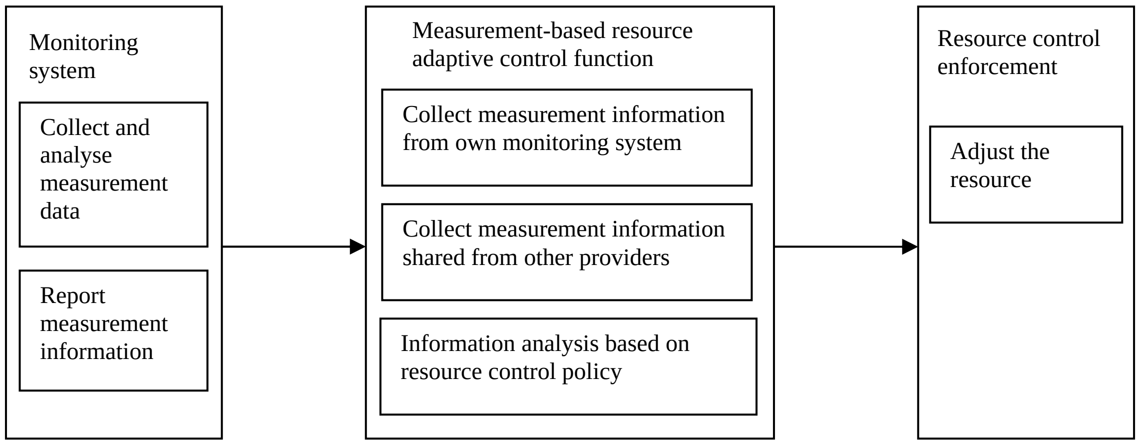

Figure 2 – Resource control process

7.1 Monitoring system

The monitoring points collect measurement metrics. The MMPAP entities will process these metrics, e.g., correlate and aggregate metrics, etc., and generate measurement reports. The reporting information obtained by processing metrics extracted from a different domain is described in clause 8.

7.2 Measurement-based resource adjustment function

Based on the reported measurement information, the NP and SP first decide the status of the perceived quality. If the measurement information indicates a trend of degradation or occurring degradation, the NP and SP will analyse how to adjust the resource to maintain the perceived quality at an expected level.

Because of the limited ability of the SP and NP, one single provider may not be able to obtain all the information needed for resource control. The SP and NP share information with each other. The SP needs the network resource and network performance information to adjust the media resource. The NP needs the expected or experienced QoE of the user to make sure that the resource adjustment facilitates QoE. The information to be exchanged and methods for exchange are described in clause 9.

The resource control policy instructs the SP and NP what to do. For example, if measurement information indicates mild quality degradation, one provider may adjust the network resource to improve the experienced quality. If serious degradation occurs, the SP and NP need to enforce the resource adjustment simultaneously. In order to adapt media and network resources, measurement information reported by MMPAP is analysed. Clause 10 describes the measurement-based resource adaptive methods.

7.3 Resource control enforcement

The last step is to enforce resource adjustment in media processing devices and network devices to ensure a high quality of experience.

8 Measurement information reporting

As shown in Figure 3, there are 5 types of monitoring points, depending on the location. Along with the IPTV services delivery path, the monitoring points, which possess different capabilities, collect the required measurement data.

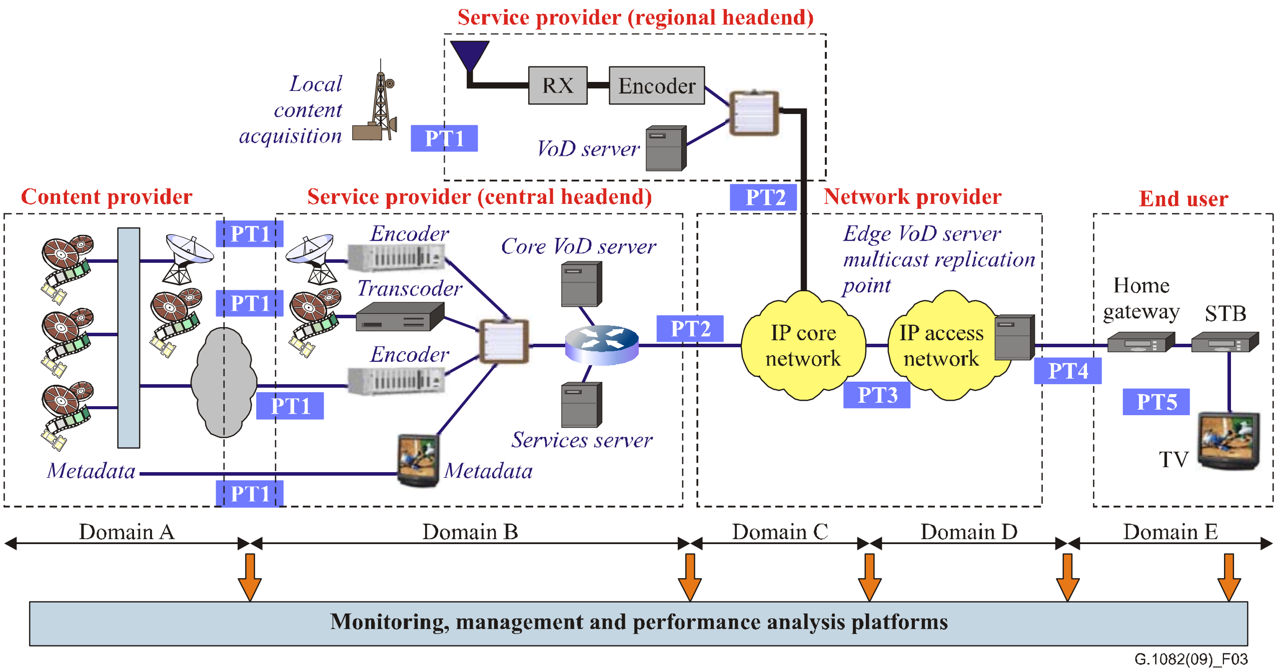

Figure 3 – Monitoring points (PT1 to PT6)

8.1 Reported measurement information

The MMPAP collects the measurement data from the monitoring points. After MMPAP processing, a set of metrics will be sent to the measurement-based adaptive resource control function.

In Figure 3, Domain A provides content-related information, which is outside of the scope of this Recommendation.

Domain B, in Figure 3, provides media encoded parameters and service quality. The following information elements may be reported by MMPAP after processing the information extracted from this domain.

Information	Description
Identifier of media flow	One example is 5-tuple of IP packet. It is transmitted with measurement information.
General program attribute	
– Service type.	Indicate the application, e.g., linear TV, VoD. The resource control policy and method is different for each application.
– Total bit rate.	For multimedia services, it is the sum of the bit rate of video, audio, embedded program information when present.
Video parameters	
– Bit rate of video.	
– Encoding format of video content.	
– Resolution of video content.	
– GOP parameters.	Include GOP size, e.g., 9, 12, etc., and GOP structure, e.g., III, IBP, IBBP, etc.
– Timestamp of I frames.	In encoding processing, the timestamp that reflects the sampling instant of I frames is derived. It may be provided to NP for frame-related metrics calculation.
Audio parameters	
– Number of audio channels.	
– Bit rate of each audio channel.	
– Encoding format of audio channels.	
Video quality.	The video quality (e.g., in terms of MOS) before being sent into the network.
Audio quality.	The audio quality (e.g., in terms of MOS) before being sent into the network.
Multimedia quality.	The multimedia quality (e.g., in terms of MOS) before being sent into the network.

The monitoring points located in domains C and D collect network-related metrics for monitoring media flows, including packet loss, delay, jitter, etc. The MMPAP deployed in the network domain collects and processes these metrics. The following measurement information elements may be reported by the MMPAP:

Information	Description
Identifier of media flow.	One example is 5-tuple of IP packet. It is transmitted with measurement information.
IP network capacity information.	The metrics are defined in [b-IETF RFC 5136] and Appendix VIII of [ITU-T Y.1540], including available link capacity and available path capacity.
IP network performance.	Measurement points in mid-point get network performance parameters. The metrics are defined in [ITU-T Y.1540], including IPLR, IPTD and IPDV.

Information	Description
One-way loss pattern related performance.	For real-time IPTV services, burst packet loss is essential and may be taken into account in performance analysis. The metrics are defined in [b-IETF RFC 3357], including loss distance, loss period, and in Appendix VII of [ITU-T Y.1540] for impaired interval ratio.
Video quality.	Indicate the video quality (e.g., in terms of MOS) in the network domain.
Audio quality.	Indicate the audio quality (e.g., in terms of MOS) in the network domain.
Multimedia quality.	Indicate the multimedia quality (e.g., in terms of MOS) in the network domain.

The monitoring points located in domain E (home network) are capable of collecting more sophisticated metrics. The following measurement information elements may be presented by the MMPAP that manages this domain.

Information	Description
Identifier of media flow.	One example is a 5-tuple. It is transmitted with measurement information.
Video quality.	Indicate the experienced video quality (e.g., in terms of MOS) perceived by the end user.
Audio quality.	Indicate the experienced audio quality (e.g., in terms of MOS) perceived by the end user.
Multimedia quality.	Indicate the experienced multimedia quality (e.g., in terms of MOS) perceived by the end user.

Packet network measurements on the home network may require an additional monitoring point at the home gateway, and are for further study.

8.2 Intra-domain interactions

The MMPAP sends the measurement information to the measurement-based resource adaptive control function. The interaction mainly includes the following three mechanisms.

Request-response transactions

When the adaptive resource control function needs current performance status, it may request the MMPAP to provide the information. For example, the adaptive network resource control function may request the latest network available resource to adjust the delivery path.

Notification

The MMPAP may predefine the threshold of measurement information and report the metric which exceeds the threshold. For example, the QoE-related metric collected from end-points can be informed of the media resource adaptive control function in SP immediately, if it is below a predefined value.

Periodic reports

The MMPAP may report the measurement information in a periodical manner.

9 Information exchanged between providers

In the end-to-end IPTV services delivery, service providers (SPs) and network providers (NPs) might be under different administrative domains and be responsible for head-end processing and media flow delivery, respectively. Since the SPs and the NPs have different capabilities to access the media-related information and network-related information, there is a need to exchange information between SPs and NPs. It is not mandatory that the information listed below be shared. Some information may be difficult to be obtained/exchanged in some scenarios. Conversely, there may be some other information that is essential.

9.1 Information provided by SPs

In general, the IPTV service providers deploy head-end and end-point (i.e., STB) systems. At the head-end, it is capable of providing the codec-related information such as codec type, bit rate, etc. At the end-point, it is capable of monitoring the end-to-end QoE-related performance experienced by the end user.

9.2 Information provided by NPs

As for the network providers, they provide the bearer network for IPTV services. They are capable of providing network-related information such as packet loss, delay, jitter, available bandwidth, etc.

9.3 Information exchanged between SPs and NPs

In clause 8, it has been described that MMPAPs of SPs and NPs collect and report different monitoring information. Performance metrics collected in different domains may be gathered for more comprehensive analysis.

The NP needs 1) the information collected from the head-end system to analyse QoE related performance; 2) information about the detailed behaviour at the head-end system, the quality experienced at the end-user side and SLA information, while deciding how to control the network resources. The following information may be provided from SP to NP through their MMPAPs for the first purpose, and through their adaptive resource control functions for the second purpose. Some information can be used for both purposes.

Information	Description
Identifier of media flow.	It is transmitted with the exchanged data. According to the identifier, the NP can find the information of the same media flow, collected from the network domain.
General program attribute.	
– Service type.	Based on service type, e.g., linear TV, VoD, the network resource is adjusted by different methods.
– Total bit rate.	It may be exchanged between MMPAPs when the NP needs to analyse QoE-related performance.
Video parameters.	They are exchanged between MMPAPs if the NP needs to analyse QoE-related performance.
– Bit rate of the video.	Besides QoE-related performance analysis, the NP considers the encoded bit rate for encoded layer adjustment when a scalable encoding method is used at the head end system.
– Encoding format of video content.	
– Resolution of video content.	
– GOP parameters.	It may be used in frame-related metrics calculation.
– Timestamp of I frames.	It may be used in frame-related metrics calculation.

Information	Description
Audio parameters.	They are exchanged between MMPAPs if the NP needs to analyse QoE-related performance.
– Bit rate of each audio channel.	
– Encoding format of the audio channels.	
Video/Audio/Multimedia quality from domain E.	It triggers the NP to adjust the network resource. If the NP has the ability to collect this value from the end user, the value does not need to be exchanged.
SLA information.	Help the NP take a reasonable resource control decision if quality degradation is detected.
– User's agreement on experienced quality of IPTV services.	It may be an exact value or a range of accepted values. It is used for encoded layer adjustment in the network domain.
Configuration of application-layer error correction and concealment (e.g., forward error correction type and block size).	May be adjusted for network conditions, and can be used to enhance measurement efficiency and applicability.

On the other hand, the head-end system needs to know the network conditions in order to manage media resources. For this purpose, the following information may be provided from NP to SP:

Information	Description
Identifier of media flow.	It is transmitted with the exchanged data. Using the identifier, the SP finds the information of the same media flow collected from the head end system.
IP network capacity information.	
– Available path capacity.	It indicates the capacity of an end-to-end delivery path or a path between two network nodes. The SP adjusts the media resource according to the network's available capacity.

9.4 Inter-domain interactions

NPs and SPs may have inter-provider agreements, which determine the interaction mechanism between them. In the above clauses, information may be transmitted from one provider to another. Two kinds of mechanisms are used for sharing information.

Request-response transactions

One provider may request the other one to provide measurement information. It may take place between MMPAP entities for performance analysis or between resource adaptive control functions to adjust media and network resources. For example, NP may request encoding information for QoE performance analysis, or SP may request network resource information for media resource adjustment.

Notifications

One provider may inform the other one in an on-demand manner. For example, if the GOP parameters are adjusted in the encoder, the SP may notify the NP of the new GOP parameters. Another example is that, if the SP detects that the perceived quality of a broadcast service is below the agreed value, it may inform the perceived QoE and other necessary information to the NP to trigger the resource adjustment in network domains.

10 Measurement-based adaptive resource control for IPTV services

Based on the measurement information collected in various domains, SPs and NPs can dynamically control the media resource and network resource. If the measurement value exceeds the predefined threshold, SP and NP may share some necessary information and choose a proper method to adjust the resource to maintain the QoE.

Information on the performance of network and end-to-end quality is fundamental for resource control.

In order to implement the QoE assessment at the network mid-point, the SP and NP will collaborate with each other. The media server provides codec parameters of a certain media flow. The SP shares it with the NP. After receiving the codec information, the NP either distributes it to the monitoring points for evaluating QoE separately, or evaluates the QoE in a centralized MMPAP. In each situation, monitoring points or the MMPAP first recognize the media flow according to the flow identifier which is transmitted with the codec information. Then, they extract the QoS metrics of such media flow monitored at a monitoring point. QoE is assessed based on the QoS and codec information. Appendix I gives an example about QoE evaluation at network mid-point.

10.1 Media resource control

Media resource is associated with media processing, such as codec parameters, established media service connections, etc. The head-end system in the SP domain manages media resources in encoding processing. Besides it, the network device which is aware of media resource can also manage it by analysing measurement information. The following media resource control mechanisms may be enforced in the device.

10.1.1 Encoded bit rate adjustment

If the QoE perceived by the end user is below a predefined threshold, a possible reason is that the network cannot provide sufficient resources for the service. Both the encoded bit rate and network available bandwidth resources have an impact on QoE. In order to solve the degradation problem and minimize the impact on other services, the encoding bit rate may be adjustable without interfering with network resource allocation decision. Appendix II provides an example in which the encoded bit rate adjustment mechanism is deployed by SPs for a VoD service.

10.1.2 Encoded layer adjustment

The scalable encoding method separates a media flow into two or more encoded layers. The base layer provides a basic level of video quality. The enhancement layers provide a higher experienced quality of media flow. For broadcast services, the media server often encodes the media flow into multi-layers. The end user can receive a set of encoded layers based on its ability and the delivery path capacity. The encoded layer delivered from the network node to the end user is adjusted according to the network capacity and the user's expectation. SP and NP can both adjust the encoded layer with each other's assistance. Appendix III illustrates this mechanism used in the access node and in the STB, respectively.

10.2 Network resource control

Network providers may have the ability to obtain network performance and adjust network resources to guarantee end-to-end quality. Transport network resources mainly include the network bandwidth. This clause describes the way the NP adjusts network resources to provide high quality service.

10.2.1 Resource allocation adjustment

NP predefines a method to control network resources. For example, if the reported QoE of a critical service indicates degradation caused by insufficient network resources, NP may re-allocate the network resource, e.g., degrade/pause/stop less critical services. This adjustment method may be used to control the access network resource when linear TV, VoD and data services are transmitted to the home network simultaneously. When the access network is insufficient to support all the services, the adaptive network-resource control function will determine the amount of re-allocated resources from less crucial services in terms of transmission performance (e.g., data service, etc.) to highly critical services (e.g., VoD, etc.) based on access link capacity, for example.

10.2.2 FEC adjustment

A FEC block encapsulated in RTP packets can be used to minimize the effects of packet loss. The media adaptive resource control function is capable of adjusting the FEC redundant block in the head-end system based on the network condition. If the perceived quality reported by the end user system (e.g., STB) is good enough, the packet loss ratio seems to be under a threshold. The adaptive media resource control function decreases the FEC redundancy. The released network resource is then allocated to other services, e.g., best effort service. Otherwise, the adaptive media resource control function increases the FEC redundant block to facilitate the reconstruction of lost information at the receiver side, i.e., more network resource is allocated to FEC blocks. SP may use this mechanism to control the redundancy in encoding of VoD media flow, for example.

10.2.3 Delivery path adjustment

The quality report from the end user devices often indicates the trend of degradation. If it is caused by network congestion, a possible method to avoid the congestion area is to re-establish the delivery path. Network devices may decide a new delivery path to improve the quality. In this mechanism, NP collects topology and resource information under the administrative area. It decides all potential delivery paths between edge nodes and calculates the cost of each path in the network domain. NP may choose a path based on the cost to avoid the congestion area, e.g., the path with least cost is selected. In a manageable network, NP can use this mechanism to adjust the network resource for both linear TV and VoD service. Appendix IV illustrates an example for adjusting the delivery path in an MPLS backbone network.

11 Security consideration

There are no specific security considerations in this Recommendation.

Appendix I

QoE evaluation in mid-point

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

I.1 Introduction

The service monitoring server and network monitoring server are regarded as instances of MMPAP in SP and NP, respectively. The service monitoring server collects codec parameters from the media server. The network monitoring server manages the monitoring points and collects performance data from these. This appendix describes how to calculate QoE-related performance in mid-point.

I.2 Collaboration between SP and NP to evaluate QoE in mid-point

The media server provides codec information, including general program attribute, video parameters and audio parameters of media flows (1a). The monitoring point in the network domain monitors QoS information, e.g., IP network performance, one-way loss pattern related performance, etc. (1b). SP and NP already have an agreement to share information for QoE performance analysis. The service monitoring server notifies the codec information to the network monitoring server (2). The QoE of a media flow can be evaluated separately in the monitoring points or centrally in the network monitoring server. Figure I.1 shows a distributive QoE assessment example.

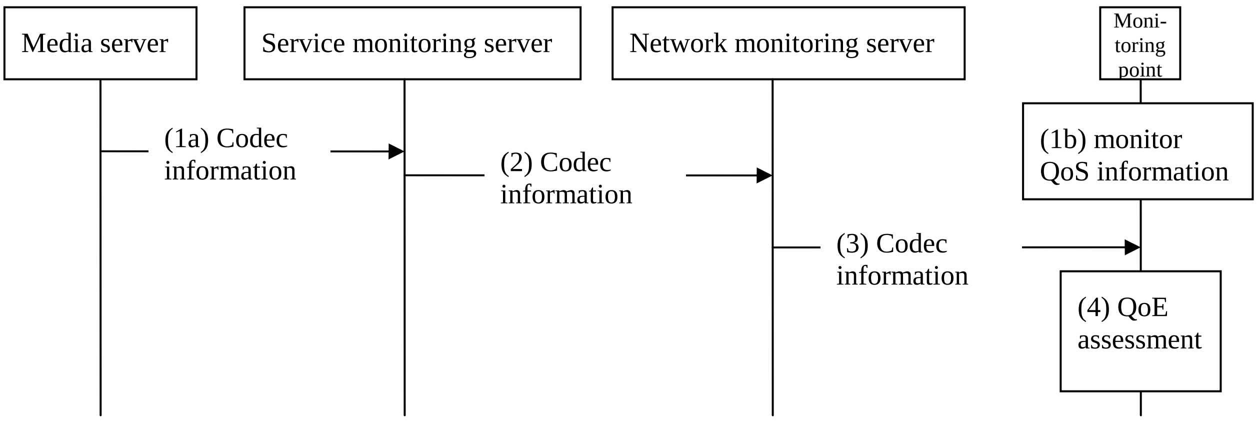

Figure I.1 – Example for QoE assessment in monitoring points

The network monitoring server sends the codec information of multiple media flows to monitoring points located in the network (3). The monitoring point monitors QoS metrics of the media flow transmitted through it. It correlates codec information and QoS metrics of the same media flow using the flow identifier. QoE performance of each monitored media flow is evaluated at monitoring points based on these two kinds of information.

In a centralized scenario, the network monitoring server embeds a QoE assessment method. The network monitoring server sends a part of codec information to the monitoring points for QoS metrics calculation. Monitoring points report the QoS metrics of monitored media flow to the network monitoring server. The network monitoring server associates the codec information with QoS metrics using the flow identifier. QoE performance of media flow is evaluated by network monitoring server based on these two kinds of information.

In both scenarios, monitoring points may calculate frame-related QoS metrics. The codec information includes GOP parameters and timestamp of I frames, which are sent from the service monitoring server to the network monitoring server. The network monitoring server distributes the information to monitoring points for frame type analysis of each RTP packet. The monitoring point extracts the timestamp from RTP packets, compares the timestamp of I frames with the RTP timestamp. If there is a match, the corresponding RTP packet is marked as I frame. According to the GOP parameters, the frame type of other RTP packets in the same GOP is estimated. Based on the frame type of each RTP packet, monitoring points will analyse frame-related QoS metrics.

Appendix II

Encoded bit rate adjustment in the head-end system

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

This appendix provides an example in which the SP adjusts the media encoded bit rate of the VoD service.

The media resource controller, located in the SP's administrative area, collects media resource information (1a) and the quality experienced by the end user (1b).

The network resource controller, located in the NP's administrative area, collects the network performance information (1c).

The media resource controller will decide on a new bit rate to maintain the experienced quality according to the network resource information. The media server is required to adjust the encoded bit rate. Figure II.1 illustrates the interaction between NP and SP and the process followed to adjust the encoded bit rate.

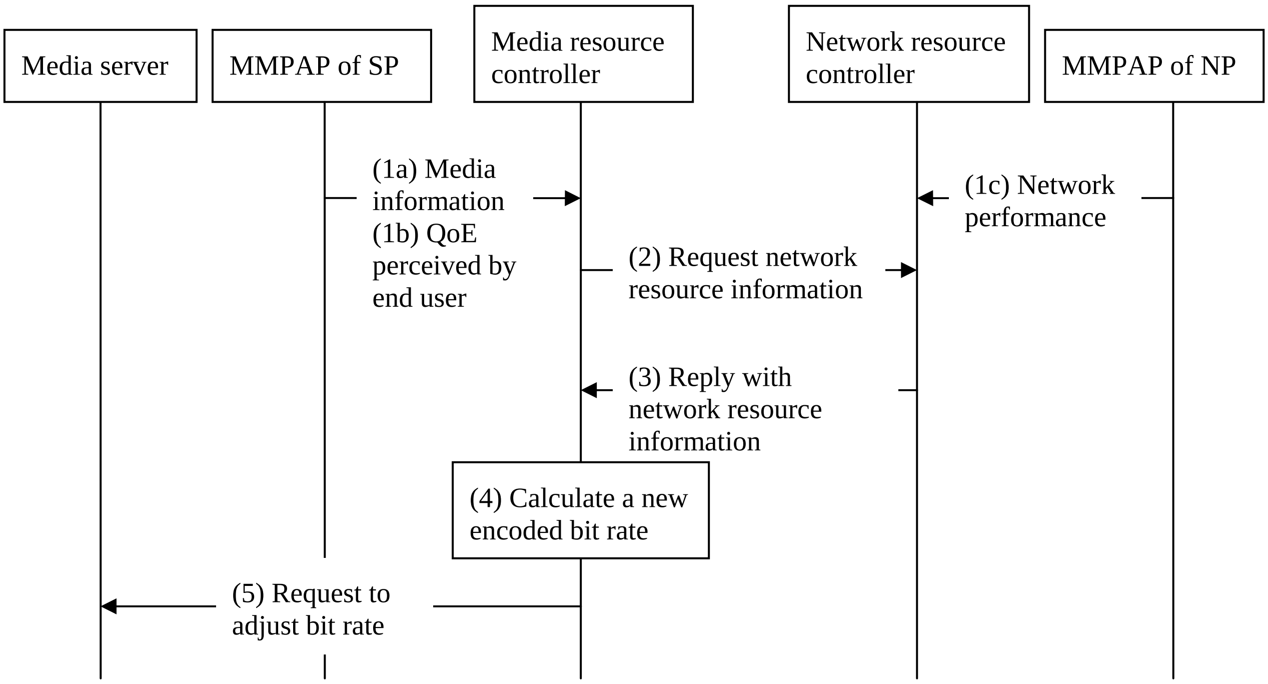

Figure II.1 – Encoded bit rate adjustment

If the QoE reported by the end user indicates that quality is below a predefined value for the VoD service, the SP is chosen to mitigate the degradation. In order to decide a new encoded bit rate, the media resource controller needs the following information:

1) Available path capacity: the media resource controller requests the current network available capacity of the transport path for the affected VoD service, from network resource controller (2). The network resource controller finds out the transport path of this service and the corresponding available link capacity. The minimum available link capacity is chosen as the available capacity of an end-to-end delivery path. The network resource controller replies with the available path capacity (3).

2) Expected QoE value: the quality a user expects to perceive. The media resource controller obtains the expected QoE value from the end user or from predefined agreement profile.

3) Current media encoded bit rate: the media server encodes the media flow at this bit rate. The media resource controller obtains the current encoded bit rate from the media server.

The media resource controller collects the above three kinds of information and sends it to the media resource management mechanism as inputs for analysis. The encoded bit rate adjustment method includes two aspects. The first one defines how to calculate a new encoded bit rate according to available path capacity, current media encoded bit rate and an expected QoE. A mapping table or formula is used. The second aspect defines the highest or lowest encoded bit rate to the end user.

The adjusted bit rate should not exceed the limit. The expected bit rate is determined according to the predefined adjustment method (4).

The media resource controller requests the media server to adjust the encoded bit rate to the expected value (5).

Appendix III

Encoded layer adjustment

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

III.1 Introduction

The performance of the access network is variable. If the quality experienced by the end user is impaired by congestion occurring in the access network, the transmitted encoded layer may be adjusted to comply with network performance. This appendix illustrates two adjustment approaches implemented by NP or SP, respectively.

III.2 Network device adjusts the encoded layer

In scenario 1, program 1 (P1) is a broadcast media flow and encoded in one base layer (P1-B) with two enhancement layers (P1-E1, P1-E2). The network resource requirements of the three encoded layers are different. Program 1 has a multicast IP address which is explicit to the end-point, e.g., STB. Encoded layers are transmitted in three separate multicast groups which are unknown to the end-point. The end-point sends a request to join the multicast group of P1 (e.g., IGMP) when choosing this program. The access node translates the multicast address of P1 into three encoded layers' multicast addresses and requests the resource access. The access decision will be made based on the access network's available capacity, e.g., three encoded layers are accepted. The access node receives and keeps the resource access decision. The media server sends three media flows of program 1. The access node enforces the access decision in two steps, replaces the multicast IP address of accepted encoded layers to the multicast IP address of program 1, and then forwards the accepted encoded layers to the end user.

The accepted encoded layers may be adjusted according to the access network performance. Figure III.1 illustrates the adjustment of the encoded layers that are transmitted on the access network.

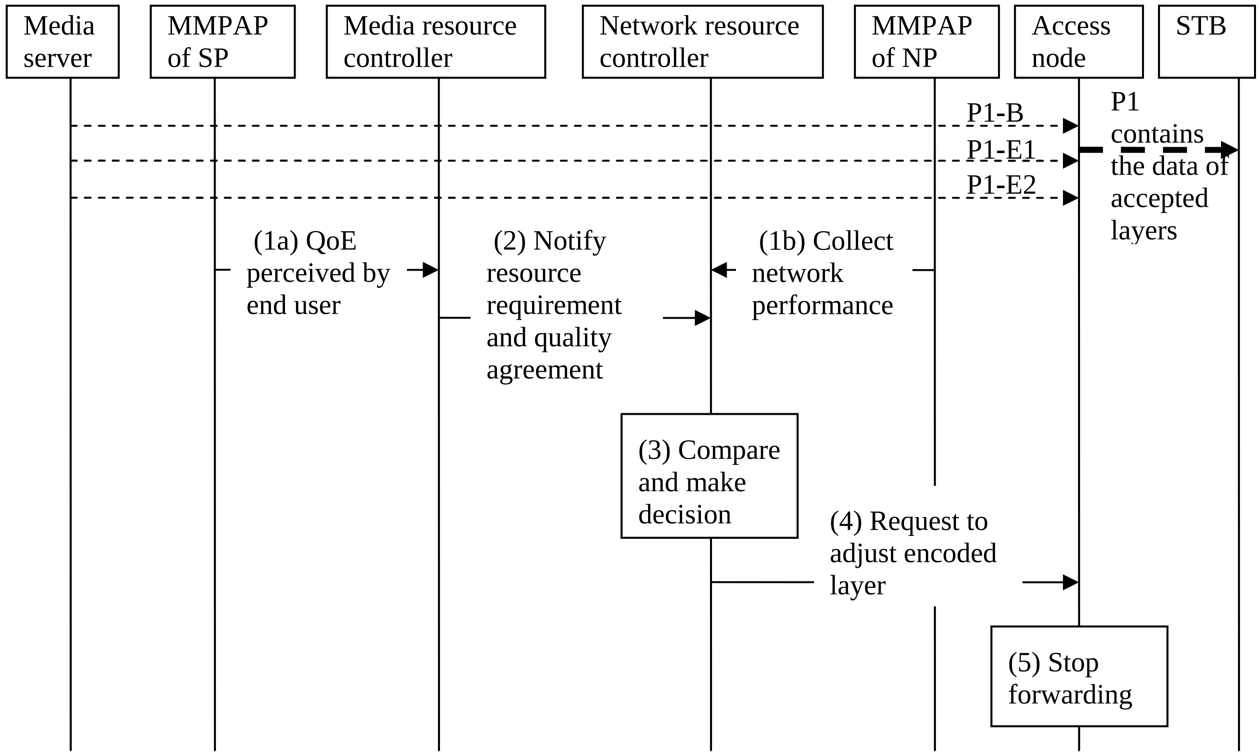

Figure III.1 – Encode layer adjustment by access node

SP and NP receive the perceived quality and network performance metrics from MMPAP respectively (1a, 1b). If congestion occurs in the access network and the user's quality reports indicate the trend of QoE degradation, the NP is chosen to adjust the resource. SP notifies NP of the required resource of codec layers and the user's agreement about the accepted range of encoded layers (2). The network resource controller compares access network capacity with the required resource (3). Since the QoE will be improved because of less impairment, the decision is to remove some enhancement layers to mitigate the congestion, e.g., the highest layer P1-E2. The adjustment should not exceed the user's agreement of accepted range of the encoded layers. The access node receives the decision (4) and stops forwarding the media flow of P1-E2 (5). When the access network has enough resources, the highest encoded layer is resumed.

This mechanism requires the network resource controller to be aware of the relation between program and its encoded layers and the resource requirement of each encoded layer. The end user is not aware of the encoded layer adjustment because it joins the multicast group of the program and receives the media flow of the program.

III.3 STB adjusts the encoded layer

In scenario 2, program 1 (P1) is a broadcast media flow and encoded in one base layer (P1-B) with two enhancement layers (P1-E1, P1-E2). STB is aware of the separate multicast IP addresses of the three encoded layers. STB sends three requests to join P1-B, P1-E1 and P1-E2 multicast groups (e.g., IGMP) when choosing P1. Compared with scenario 1, the network node need not keep the correlation between program and the encoded layers.

STB is requested to join or leave multicast groups of a certain program according to network performance. Figure III.2 illustrates the adjustment procedure.

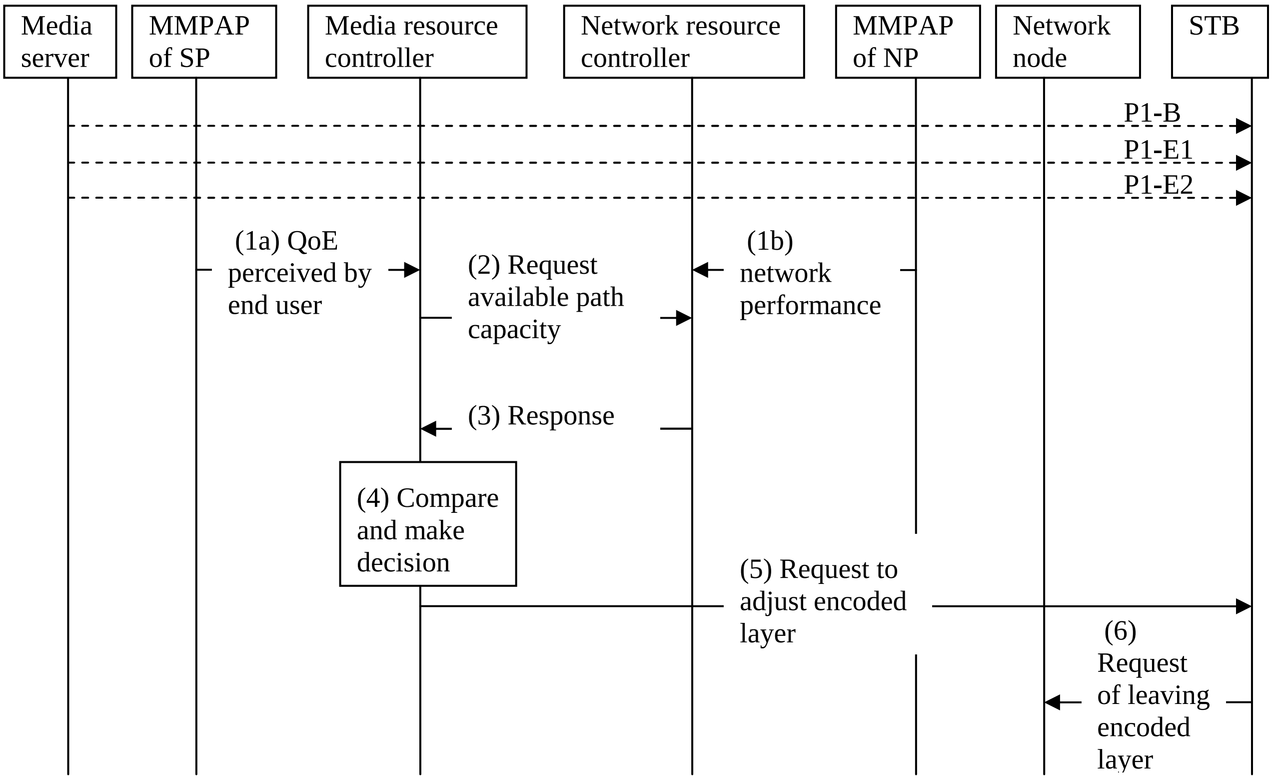

Figure III.2 – Encode layer adjustment by STB

SP and NP receive the perceived quality and network performance metrics from MMPAP (1a) and (1b) respectively. If network performance results in quality degradation, the media resource controller requests the available path capacity of the end user from the network resource controller (2). The network resource controller replies with the measurement metrics (3). The response information is compared with the requirement of each encoded layer (4). For example, the highest encoded layer (P1-E2) needs to be removed to guarantee quality. The media resource controller sends the adjustment decision to STB (5). STB sends a request to leave the multicast group of P1-E2 (e.g., IGMP) to the network node (6), e.g., an access node. The network node receives the multicast group leaving request, and stops forwarding the media flow of P1-E2 to the end user.

Appendix IV

Delivery path adjustment

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

The core network implements MPLS technology for DiffServ purposes. The network resource controller is deployed to collect the network measurement information from MMPAP in the core network. The network resource controller constructs a network resource information database of administrative area, uses the database to establish potential paths and calculates the cost of each path in the managed area. The delivery path of media flow is selected from potential paths based on the cost. Network resource is allocated to the media flow. If the current delivery path is congested and results in quality degradation, the network resource controller will select again a new path for the impacted media flow based on the cost. Network resource is reallocated. Figure IV.1 provides a detailed description.

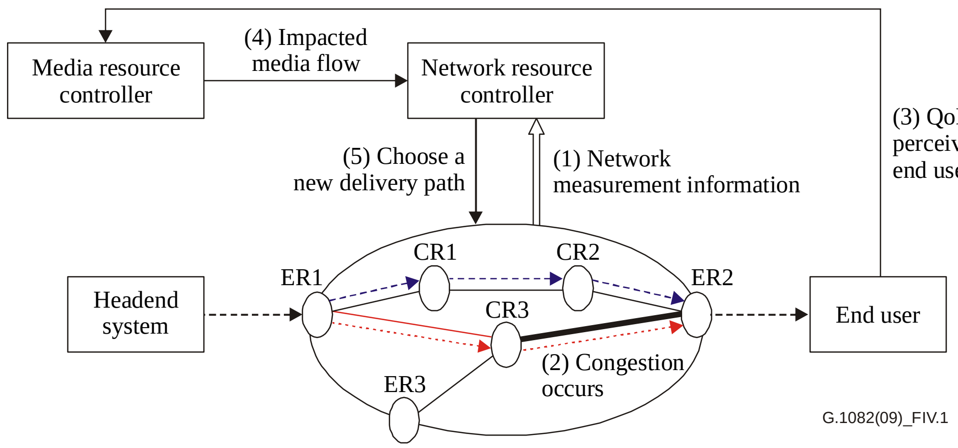

Figure IV.1 – Delivery path adjustments in sub-network

The network resource controller constructs a network resource information database based on the resource and topology information, which includes the network node, the label switched path (LSP) ID and the LSP cost, in the administrative area. LSP here indicates the logical connection between routers, e.g., edge router 1 (ER1) to core router 1 (CR1), CR1 to CR2, etc. LSP cost is estimated from a physical connection attribute, such as link available capacity between routers. In the preparation process, the network resource controller calculates all potential delivery paths according to the topology information. Each path connects a pair of ERs in the core network. For example, between ER1 and ER2, there are two potential paths (ER1-CR1-CR2-ER2, ER1-CR3-ER2); between ER1 and ER3, there is one potential path (ER1-CR3-ER3); between ER2 and ER3, there is one potential path (ER2-CR3-ER3). The path cost is calculated by aggregating the weighted cost of LSPs along this path. The network resource controller collects the LSP cost from MMPAP and updates the path cost in a real-time manner.

When the end user requests a media service, the network resource controller finds the pair of ingress and egress nodes according to the identifier of media flow (e.g., the media flow will traverse the network from ER1 to ER2). The possible delivery path of the media flow is filtered (e.g., ER1-CR1-CR2-ER2 and ER1-CR3-ER2) from all potential paths. The path of the least cost, e.g., ER1-CR3-ER2 is selected. If congestion (e.g., CR3-ER2) occurs in the delivery path (2), the user's report indicates the trend of quality degradation (3). The SP notifies the NP of the impacted media flow for which network resource adjustment (4) has to be requested. Network resource controller updates the cost of paths between ER1 and ER2, and selects a new least cost path, e.g., ER1-CR1-CR2-ER2. The rerouting decision is implemented in the related network node, e.g., ER1 (5). The network resource along the new path is allocated to the media flow.

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