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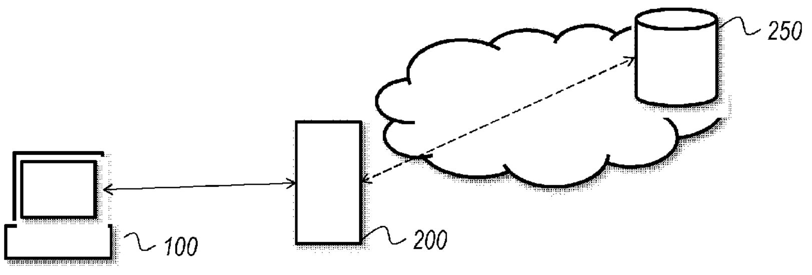
(54) **Title:** METHOD AND APPARATUS FOR MONITORING TRANSMISSION CHARACTERISTICS IN A NETWORK

Figure 1



(57) **Abstract: A** method for monitoring transmission characteristics in a network comprising a media client (100), a media server (200), and a data processor (250), the method comprising: establishing (300) a connection with said data processor (250); establishing (310) an end-to-end encrypted channel between said media client (100) and said data processor (250) for exchanging streaming media content over said connection; sending (320) a probing message to said data processor (250) over said channel, said probing message carrying a first timestamp indicating the sending time of said probing message; receiving (330) a response to said probing message from said data processor (250), said response carrying a second timestamp indicating the arrival time of said probing message at said data processor; and deriving (350) latency information, including an upstream latency between said media client (100) and said data processor (250), from a difference between said second timestamp and said first timestamp.

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Method and Apparatus for Monitoring Transmission Characteristics in a Network

Field of the Invention

The present invention relates to streaming media networks, and in particular to monitoring transmission characteristics in such networks.

Background

The architecture used by streaming protocols such as RTMP requires a media server to interact with the media client. Any media processing cloud (hereinafter generically referred to as "data processor") thus needs to be connected to a number of these servers. In an interactive application with several users, one or many of these media servers can be used, for streaming from the clients to the data processor and back. The whole set of networks providing data transport between the media client and the data processor will hereinafter be referred to as the "transport network".

Presently, no satisfactory mechanisms exist to characterize the full transport network that is being used for multimedia streaming, in terms of bandwidth, delay, burstiness, packet loss probability etc. These parameters affect the quality experienced by the end user.

Summary

According to an aspect of the invention, there is provided a method for monitoring transmission characteristics in a network comprising a media client, a media server, and a data processor, the method comprising the following steps at the media client: establishing a connection with the data processor, the connection comprising a first connection segment between the media client and the media server and a second connection segment between the media server and the data processor; establishing an end-to-end encrypted channel between the media client and the data processor for exchanging streaming media content, the end-to-end encrypted channel being carried by the connection; sending a probing message to the data processor over the end-to-end encrypted channel, the probing message carrying a first timestamp indicative of a sending time of the probing message; receiving a response to the probing message from the data processor, the response carrying a second timestamp indicative of an arrival time of the probing message at the data processor; and deriving latency information, wherein the latency information comprises an upstream latency characteristic of the connection between the media client and the data processor, calculated from a difference between the second timestamp and the first timestamp.

Embodiments of the present invention are based on the insight of the inventors that in streaming protocols such as RTMP, message types normally used for monitoring or management purposes may never reach the streaming server or the data processor due to the presence of firewalls, gateways, proxies, and the like. Embodiments of the present invention are further based on the insight that end-to-end tunneling between the media client and the data processor, which is used for certain dedicated tasks such as invoking remote procedure calls, may advantageously be used for monitoring of the transmission channel characteristics.

Embodiments of the invention further present the advantage of being able to determine latency values for the entire upstream path between the media client and the data processor .

Embodiments of the invention further present the advantage of performing latency measurements on the same channel that is actually used for content transfer, and not on a different (out-of-band management) channel.

In an embodiment of the method according to the present invention, the response further carries a third timestamp indicative of a sending time of the response, and the method further comprises determining a fourth timestamp indicative of a time of arrival of the response; wherein the latency information further comprises a downstream latency characteristic of the connection between the data processor and the media client, calculated from a difference between the fourth timestamp and the third timestamp.

This embodiment of the invention further presents the advantage of being able to determine latency values for the entire downstream path between the data processor and the media client.

In an embodiment of the method according to the present invention, the second timestamp and the third timestamp are expressed in the response as a single value.

This embodiment is based on the insight that, when the response is known to have been sent by the data processor substantially immediately after receipt of the probing message, a single timestamp suffices for determining the latency for both the upstream and the downstream path.

In an embodiment, the method according to the present invention further comprises repeating the sending of the probing message, the receiving of the response, and the deriving of latency information at regular intervals; and deriving jitter information from the repeatedly derived latency information.

This embodiment has the advantage of providing jitter information derived from the collected latency information.

In an embodiment of the method according to the present invention, the jitter information comprises a coefficient of variance .

In an embodiment, the method according to the present invention further comprises sending a request to the media server to modify a stream characteristic when the jitter information is indicative of jitter exceeding a predetermined level.

This embodiment is based on the insight of the inventors that jitter is a parameter that greatly affects the quality of experience for a streaming media service. Accordingly, this embodiment provides the advantage of adapting streaming parameters when the jitter reaches a level that is expected to negatively affect the end users' experience.

In an embodiment of the method according to the present invention, the stream characteristic to be modified comprises one of a frame rate, an image resolution, and a compression ratio.

In an embodiment of the method according to the present invention, the exchanging of streaming media content takes place by means of an RTMP protocol.

According to an aspect of the invention, there is provided a computer program configured to cause a processor to execute a method as described above.

According to an aspect of the invention, there is provided an apparatus for receiving a media stream over a network, the apparatus comprising: a protocol engine configured to establish a connection with a data processor, the connection comprising a first connection segment between the apparatus and a media server and a second connection segment between the media server and the data processor; an encryption agent configured to establish an end-to-end encrypted channel between the apparatus and the data processor for exchanging streaming media content, the end-to-end encrypted channel being carried by the connection; a clock; a probing agent, operatively coupled to the clock and the encryption agent, the probing agent being configured to send a probing message to the data processor over the end-to-end encrypted channel, the probing message carrying a first timestamp indicative of a sending time of the message, and to receive a response to the probing message from the data processor, the response carrying a second timestamp indicative of an arrival time of the probing message at the data processor; and a latency derivation agent, operatively coupled to the probing agent, the latency derivation agent being configured to calculate an upstream latency characteristic of the connection between the media client and the data processor from a difference between the second timestamp and the first timestamp.

In an embodiment of the apparatus according to the present invention, the response carries a third timestamp indicative of a sending time of the response by the data processor, and the latency derivation agent is further configured to determine a fourth timestamp indicative of receiving time of the response and to calculate a downstream latency characteristic of the connection between the data processor and the media client from a difference between the fourth timestamp and the third timestamp.

In an embodiment of the apparatus according to the present invention, the second timestamp and the third timestamp are expressed in the response as a single value.

In an embodiment of the apparatus according to the present invention, the latency derivation agent is further configured to derive jitter information from repeatedly derived latency information.

In an embodiment of the apparatus according to the present invention, the jitter information comprises a coefficient of variance.

In an embodiment of the apparatus according to the present invention, the protocol engine is further configured to transmit a request to the media server to modify a stream characteristic when the jitter information is indicative of jitter exceeding a predetermined level.

The advantages of the program and apparatus according to embodiments of the present invention correspond, *mutatis mutandis,* to the advantages expressed above for the corresponding methods according to embodiments of the present invention.

Brief Description of the Figures

Some embodiments of apparatus and/or methods in accordance with embodiments of the present invention are now described, by way of example only, and with reference to the accompanying drawings, in which:

Figure 1 presents an overview of an exemplary network in which the present invention can be deployed;

Figure 2 presents a block diagram of an apparatus according to an embodiment of the present invention; and

Figure 3 provides a flow chart of a method according to an embodiment of the present invention.

Detailed Description of Embodiments

Figure 1 illustrates an exemplary network in which the present invention can be deployed. The figure includes an apparatus **100**, acting as a media client, and connected over a first network segment to a media server **200**, which acts as a front-end for a service provider **250**, terminating the relevant protocol messages towards the media client **100** and towards the data processor **250.** The term "data processor" as used herein refers to the hardware infrastructure used for storing and streaming content, which may consist of one or more servers. This infrastructure may be distributed "in the cloud". Without loss of generality, only one media client **100** and one media server **200** are illustrated in Figure 1.

Throughout the present application, transmission in the direction from the media client **100** to the media server **200** or the data processor **250** will be referred to as "upstream" communication. Transmission in the direction from the media server **200** or the data processor **250** to the media client **100** will be referred to as "downstream" communication.

The connection between the media client **100** and the data processor **250** comprises a first segment (between the apparatus **100** and a media server **200)** and a second segment (between the media server **200** and the data processor **250)**. Each segment may in fact consist of several physical links, interconnected by bridges and/or routers, which are not relevant for the present invention.

The RTMP protocol defines certain control messages to be interchanged between client and server ("Ping" messages), that can be used to infer the status of the upstream or downstream link. This message interchange is not satisfactory for characterizing the transport network, because the messages are not fully described in the RTMP standard and because they only cover the first segment.

Furthermore, the first segment may comprise network elements such as firewalls, proxies, and gateways, which restrict certain kinds of traffic, including control or monitoring traffic, between the media client **100** and the media server **200**.

Restrictions of this type are advantageously overcome by embodiments of the present invention, by using end-to-end encrypted communications between the media client **100** and the data processor **250** as explained in more detail below.

An apparatus **100** according to an embodiment of the present invention will now be described in more detail with reference to the block diagram shown in Figure 2. The apparatus **100** is generally suited for receiving a media stream over a network, and will hereinafter be referred to as media client **100.** Known examples of such media clients include computing devices equipped with an Adobe® Flash® player or a Microsoft® Silverlight® player.

The media client **100** comprises a protocol engine **110** configured to establish **310** a connection with a data processor **250.** The protocol engine **110** includes the necessary hardware and software to provide a network connection, from the physical layer up to the protocol that is responsible for carrying out the content streaming. At the lowest layers, the protocol engine **110** typically includes a physical layer interface according to a standard for wired communication (e.g., IEEE 802.3, xDSL, GPON, ...) or wireless (mobile or non-mobile) communication (e.g. IEEE 802.11, IEEE 802.15, IEEE 802.16, 3G), with corresponding data link logic. The network layer is preferably governed by the Internet Protocol (IP). The transport layer is preferably governed by the Transport Control Protocol (TCP) and/or User Datagram Protocol (UDP). The streaming protocol is preferably Real-Time Messaging Protocol (RTMP), as defined in the RTMP Specification released by Adobe (http://www.adobe.com/devnet/rtmp/) . Details of these protocols and the implementation of the appropriate hardware and software are known to the person skilled in the art.

The media client **100** further comprises an encryption agent **120** configured to establish **320** an end-to-end encrypted channel over the connection between the media client **100** and the data processor **250**, for exchanging streaming media content. The encrypted channel may be established using the RTMPS protocol, which consists of RTMP over a secure SSL connection using HTTPS .

The media client **100** further comprises a clock **130**, which produces timestamps with sufficient accuracy to obtain useful information about the latency of messages travelling over the network. A probing agent **140**, operatively coupled to the clock **130** and the encryption agent **110**, is configured to send **330** probing messages to the data processor **250** over the end-to-end encrypted channel. The probing message carries a first timestamp, generated by the clock **130**, indicative of the time at which the message was sent. The probing agent 140 is further configured to receive a response to the probing message from the data processor **250.** The response carries a second timestamp, which is used to make latency determinations.

The second timestamp, generated by the data processor **250** in accordance with embodiments of the present invention, is indicative of the arrival time of the probing message at the data processor **250.** A latency derivation agent **150**, operatively coupled to the probing agent **140**, is configured to calculate **350** an upstream latency characteristic of the connection between the media client and the data processor from a difference between the second timestamp and the first timestamp .

If the response is transmitted back to the media client **100** immediately after being received by the data processor **250**, the second timestamp is *de facto* also indicative of the sending time of the response. If this is not the case, a separate third timestamp may be provided pertaining to the sending time of the response. The latency derivation agent **150** may be further configured to calculate **350** a downstream latency characteristic of the connection between the data processor **250** and the media client **100** from a difference between the arrival time of the response and the second timestamp (or the separately provided third timestamp pertaining to the sending of the response) .

A method according to an embodiment of the invention will now be described with reference to the flow chart shown in Figure 3 . The method is applied in a network as exemplified in Figure 1, comprising a media client **100**, a media server **200**, and a data processor **250**. Figure 3 comprises three columns, indicating the actions of the respective entities that participate in the method. Unless otherwise indicated, actions will be described hereinafter from the point of view of the media client **100**.

In a first step, a connection is established between the media client **100** and the data processor **250**. The connection comprises a first segment between the media client **100** and the media server **200** and a second connection segment between the media server **200** and the data processor **250**. Accordingly, the establishment of the connection requires an action **300** at the client **100**, an action **301** at the server

200, and an action **302** at the data processor **250**. The connection may be established according to the RTMP protocol .

Once the connection is established, an end-to-end encrypted channel (or a bi-directional security association) is set up between the client **100** and the data processor **250**. Although this channel is physically supported by both segments of the aforementioned connection, the server **200** does not participate in the client - data processor interaction. Setting up the channel requires an action **310** at the client **100** and an action **315** at the data processor **250**. The encrypted channel may be set up according to the RTMPS protocol .

Content may now be streamed between the data processor **250** and the client **100**, unidirectionally or bidirectionally, over the established channel.

In order to monitor the characteristics of the path between the data processor **250** and the client **100**, the media client **100** according to embodiments of the present invention sends **320** a probing message to the data processor **250** over the end-to-end encrypted channel. Unlike traditional "ping" messages, this probing message carries a timestamp, and it is sent over the end-to-end channel (i.e., it is transparently forwarded by nodes operating on lower layers) . The first timestamp is substantially indicative of the time at which the probing message was sent. The message is received **321** by the data processor **250**, which thus already obtains some information about the latency governing transmissions on the upstream path from the media client **100** to the data processor **250**. The latency may be determined by calculating the difference between the time at which the probing message was sent (first timestamp) and the time at which it was received. The data processor **250** replies to the probing message by sending **329** a response message containing a second timestamp, which is substantially indicative of the time at which the probing message was received, and optionally also of the time at which the response message was sent. If the sending of the response **329** does not immediately follow the receiving of the probing message **321**, a separate third timestamp may be provided in the response pertaining to the transmission of the response.

When the media client **100** receives **330** a response to the probing message from the data processor **250**, the former obtains some information about the latency governing transmissions on the upstream path from the media client **100** to the data processor **250**, which may be determined by calculating the difference between the second timestamp pertaining to the arrival **321** of the probing frame at the data processor **250** and the first timestamp. The media client **100** may optionally also derive information on the latency governing transmissions on the downstream path from the data processor **250** to the media client **100**, by calculating the difference between the time at which the response was received **330** at the media client **100** (that moment may be considered as a "fourth timestamp", determined at the media client **100** in step **340)** and the third timestamp pertaining to the departure **329** of the response from the data processor **250** (note again that the "third timestamp" may be a virtual timestamp coinciding in fact with the "second timestamp") .

By combining the latency values of the upstream and downstream paths, a round-trip latency can be determined.

Steps **320-340** may be repeated, preferably at regular intervals, for example 25 times per second (mimicking the frame rate of a video stream, to determine the channel characteristics experienced by such a stream) , to determine jitter values **360** for the upstream path, the downstream path, or the round-trip path. Jitter values for the upstream path may be determined in the same manner at the data processor **250.**

Preferably, the jitter value is calculated as a coefficient of variance (CV) , i.e. a standard deviation of the latency normalized to the average value, according to known methods. The CV provides an intuitive measure of the quality (in terms of jitter) of a transmission channel.

If the jitter exceeds a predetermined level, e.g. if the CV exceeds unity, the channel is considered highly affected by jitter. An assessment **370** of the jitter with respect to a predetermined threshold is preferably carried out, and used to trigger particular actions to improve the quality of the content streaming process. These actions preferably comprise transmitting a request **380** to the media server **200** to modify certain streaming parameters. Parameters to be modified may advantageously include frame rate, image resolution, and compression ratio. Even a choice for another codec, or the same coded with different operational parameters, could be requested in these cases.

Although certain features and advantages have only been described with respect to the apparatus according to embodiments of the present invention or with respect to the methods according to embodiments of the present invention, this is done for reasons of conciseness, and it will be understood that the features are interchangeable between the methods and the corresponding apparatus to obtain the same advantages .

The functions of the various elements shown in the Figures, including any functional blocks labeled as "processors", "agents", or "engines", may be provided through the use of dedicated hardware as well as hardware capable of executing software in association with appropriate software. When provided by a processor, the functions may be provided by a single dedicated processor, by a single shared processor, or by a plurality of individual processors, some of which may be shared. Moreover, explicit use of the term "processor" or "controller" should not be construed to refer exclusively to hardware capable of executing software, and may implicitly include, without limitation, digital signal processor (DSP) hardware, network processor, application specific integrated circuit (ASIC), field programmable gate array (FPGA), read only memory (ROM) for storing software, random access memory (RAM), and non volatile storage. Other hardware, conventional and/or custom, may also be included. Similarly, any switches shown in the Figures are conceptual only. Their function may be carried out through the operation of program logic, through dedicated logic, through the interaction of program control and dedicated logic, or even manually, the particular technique being selectable by the implementer as more specifically understood from the context.

A person of skill in the art would readily recognize that steps of various above-described methods can be performed by programmed computers. Herein, some embodiments are also intended to cover program storage devices, e.g., digital data storage media, which are machine or computer readable and encode machine-executable or computer-executable programs of instructions, wherein said instructions perform some or all of the steps of said above-described methods. The program storage devices may be, e.g., digital memories, magnetic storage media such as a magnetic disks and magnetic tapes, hard drives, or optically readable digital data storage media. The embodiments are also intended to cover computers programmed to perform said steps of the above-described methods.

Claims

1. A method for monitoring transmission characteristics in a network comprising a media client (100), a media server (200), and a data processor (250), the method comprising the following steps at said media client:

- establishing (300) a connection with said data processor (250), said connection comprising a first connection segment between said media client (100) and said media server (200) and a second connection segment between said media server (200) and said data processor (250);
- establishing (310) an end-to-end encrypted channel between said media client (100) and said data processor (250) for exchanging streaming media content, said end-to-end encrypted channel being carried by said connection;
- sending (320) a probing message to said data processor (250) over said end-to-end encrypted channel, said probing message carrying a first timestamp indicative of a sending time of said probing message;
- receiving (330) a response to said probing message from said data processor (250), said response carrying a second timestamp indicative of an arrival time of said probing message at said data processor; and
- deriving (350) latency information, wherein said latency information comprises an upstream latency characteristic of said connection between said media client (100) and said data processor (250), calculated from a difference between said second timestamp and said first timestamp.

2. The method according to claim 1, wherein said response further carries a third timestamp indicative of a sending time of said response, said method further comprising determining (340) a fourth timestamp indicative of a time of arrival of said response; wherein said latency information further comprises a downstream latency characteristic of said connection between said data processor (250) and said media client (100), calculated from a difference between said fourth timestamp and said third timestamp.

3. The method according to claim 2, wherein said second timestamp and said third timestamp are expressed in said response as a single value.

4. The method according to any of the preceding claims, further comprising:

- repeating said sending of said probing message, said receiving of said response, and said deriving of latency information at regular intervals; and
- deriving (360) jitter information from said repeatedly derived latency information.

5. The method according to claim 4, wherein said jitter information comprises a coefficient of variance.

6. The method according to claim 4 or claim 5, further comprising sending (380) a request to said media server (200) to modify (390) a stream characteristic when said jitter information is indicative of jitter exceeding (370) a predetermined level.

7. The method according to claim 6, wherein said stream characteristic to be modified (390) comprises one of a frame rate, an image resolution, and a compression ratio.

8. The method according to any of the preceding claims, wherein said exchanging of streaming media content takes place by means of an RTMP protocol.

9. A computer program configured to cause a processor to execute the method of any of the preceding claims.

10. An apparatus (100) for receiving a media stream over a network, the apparatus comprising:

- a protocol engine (110) configured to establish (310) a connection with a data processor (250), said connection comprising a first connection segment between said apparatus (100) and a media server (200) and a second connection segment between said media server (200) and said data processor (250);
- an encryption agent (120) configured to establish (320) an end-to-end encrypted channel between said apparatus (100) and said data processor (250) for exchanging streaming media content, said end-to-end encrypted channel being carried by said connection;
- a clock (130) ;
- a probing agent (140), operatively coupled to said clock (130) and said encryption agent (110), said probing agent (140) being configured to send (330) a probing message to said data processor (250) over said end-to-end encrypted channel, said probing message carrying a first timestamp indicative of a sending time of said message, and to receive a response to said probing message from said data processor (250), said

response carrying a second timestamp indicative of an arrival time of said probing message at said data processor; and

- a latency derivation agent (150), operatively coupled to said probing agent (140), said latency derivation agent (150) being configured to calculate (350) an upstream latency characteristic of said connection between said media client (100) and said data processor (250) from a difference between said second timestamp and said first timestamp.

11. The apparatus according to claim 10, said response carrying a third timestamp indicative of a sending time of said response by said data processor, wherein said latency derivation agent (150) is further configured to determine a fourth timestamp indicative of receiving time of said response and to calculate (350) a downstream latency characteristic of said connection between said data processor (250) and said media client (100) from a difference between said fourth timestamp and said third timestamp .

12. The apparatus according to claim 11, wherein said second timestamp and said third timestamp are expressed in said response as a single value.

13. The apparatus according to any of claims 10-12, wherein said latency derivation agent (150) is further configured to derive (360) jitter information from repeatedly derived latency information.

14. The apparatus according to claim 13, wherein said jitter information comprises a coefficient of variance.

15. The apparatus according to claim 13 or claim 14, wherein said protocol engine (110) is further configured to transmit a request to said media server (200) to modify (390) a stream characteristic when said jitter information is indicative of jitter exceeding (370) a predetermined level.

Figure 1

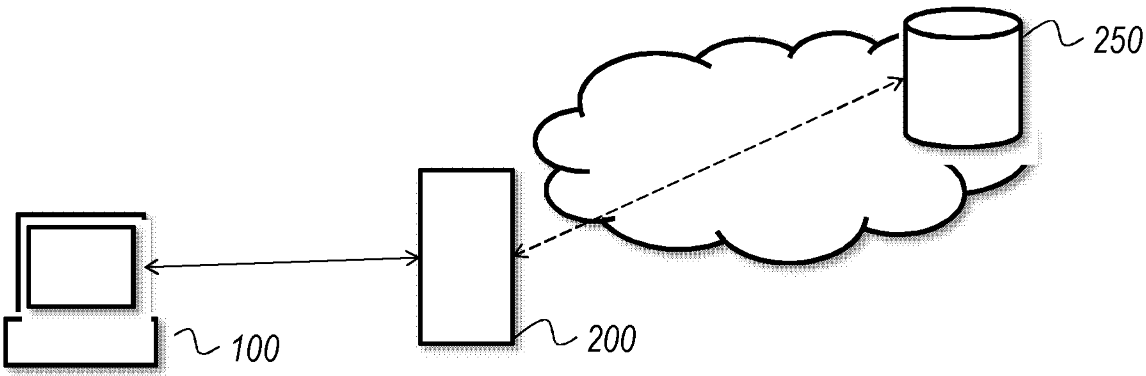


Figure 2

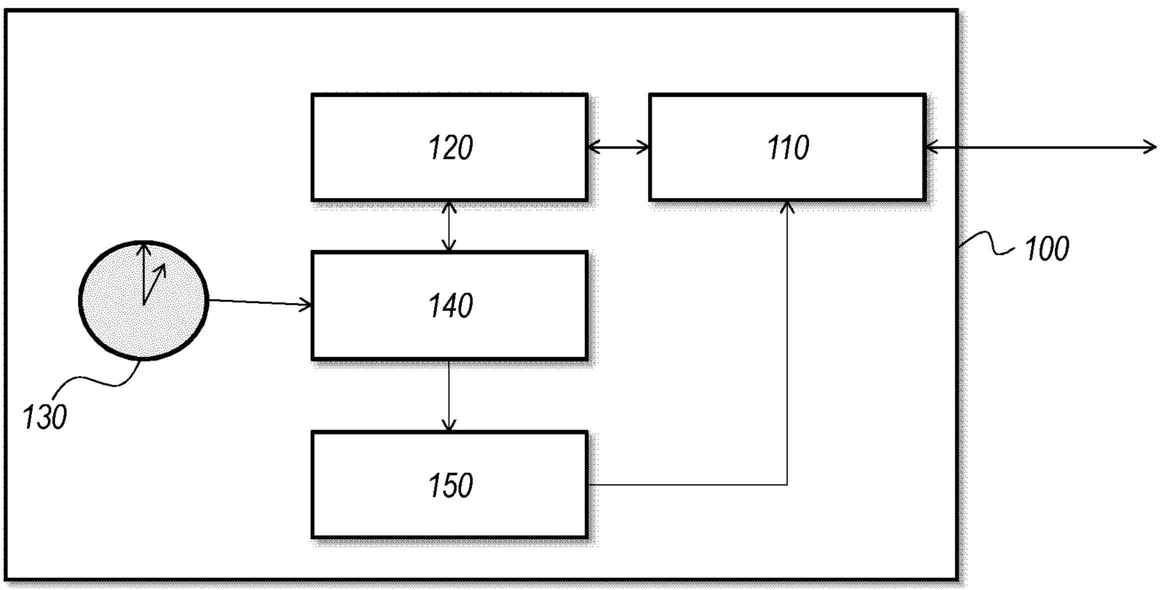
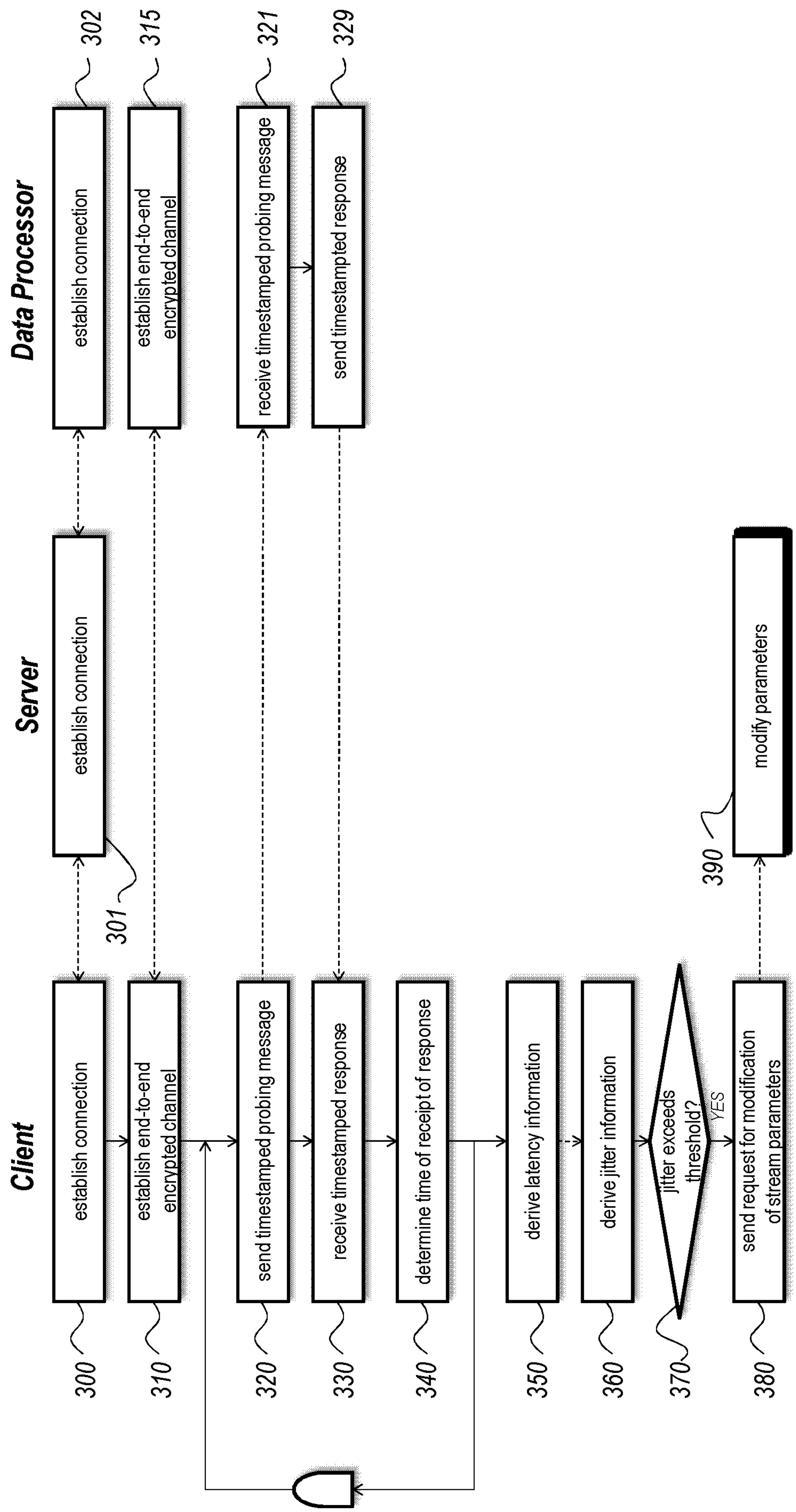


Figure 3


Client
Server
Data Processor
300 establish connection
310 establish end-to-end encrypted channel
320 send timestamped probing message
330 receive timestampted response
340 determine time of receipt of response
350 derive latency information
360 derive jitter information
370 jitter exceeds threshold?
YES
380 send request for modification of stream parameters
301 establish connection
390 modify parameters
302 establish connection
315 establish end-to-end encrypted channel
321 receive timestamped probing message
329 send timestampted response

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2012/074611

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04L12/26
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H04L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal , WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2010/002685 A1 (SHAHAM ELIEZER [IL] ET AL) 7 January 2010 (2010-01-07) the whole document -----	1-15
A	US 2003/105604 A1 (ASH LESLIE E [US] ET AL) 5 June 2003 (2003-06-05) the whole document -----	1-15

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
28 January 2013	04/02/2013

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INTERNATIONAL SEARCH REPORT

Information on patent family members

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