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- (71) Applicant (for all designated States except US): **GENERAL INSTRUMENT CORPORATION** [US/US]; 101 Tournament Drive, Horsham, Pennsylvania 19044 (US).
- (72) Inventors; and
- (71) Applicants (for US only): **RAMACHANDRAN, Anita** [IN/IN]; SG 705, Golden Blossom, Opp Sai Baba, Ashrom, NH 207, Kadugodi, Whitefield, Karnataka, Bangalore 560067 (IN). **PATRICK, Michael, W.** [US/US]; 9 Elizabeth Drive, Assonet, Massachusetts 02702 (US). **RAMANATHAN, Uma** [IN/IN]; 202 Chaithanya Paradise 2, 6th Cr., Kaggadasapura, Karnataka, Bangalore 560093 (IN). **VIJAYARAGHAVAN, Nithya** [IN/IN]; 2581, II Cross, 17th Main, Hal II Stage, Indiranagr, Karnataka, Bangalore 560008 (IN).

- (74) Agents: **WIENER, Stewart, M.** et al.; 600 North US Highway 45, Libertyville, Illinois 60048 (US).
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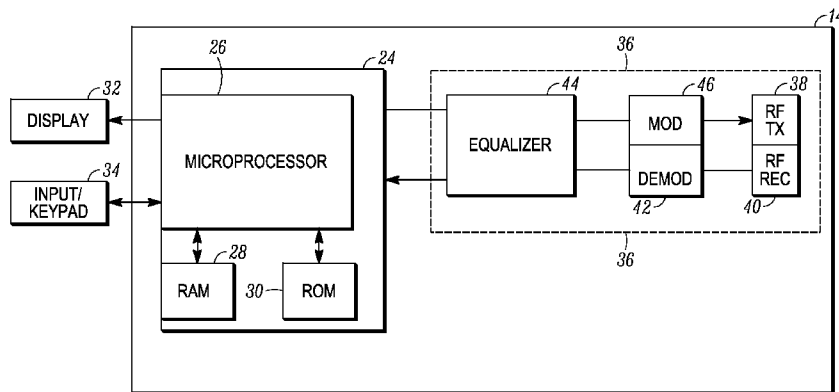


FIG. 2

(57) Abstract: Apparatus and method for load balancing cable modems across channels of a load balancing group on a DOCSIS network are described. At least one Quality of Service (QoS) parameter is collected for each service flow from cable modems actively passing traffic across one channel of the load balancing group. The QoS parameter collected is used to identify at least one cable modem having a service flow with an inferior grade of the QoS parameter relative to a pre-defined threshold of the QoS parameter. The cable modem having service flows with the inferior grade of the QoS parameter is selected first from the cable modems of the load balancing group for being moved from the one channel to a different channel of the load balancing group for purposes of balancing load of active service flows across the channels.

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APPARATUS AND METHOD
FOR LOAD BALANCING IN A CABLE NETWORK

FIELD

[0001] Apparatus and method for providing load balancing of active traffic across multiple channels of a Data-Over-Cable (DOC) network are described.

BACKGROUND

[0002] Cable television networks typically comprise cables such as coaxial cables, optical fiber cables, or a Hybrid Fiber/Coaxial (HFC) cable system which interconnect cable modems (CMs) of subscribers to a headend of the cable network. Subscribers may use their cable modems and the cable network to connect to the Internet and/or other computer networks. The cable modems support data connection to the Internet and other computer networks via the cable network, and the cable networks provide bi-directional communication systems in which data can be sent downstream from the headend to a subscriber and upstream from a subscriber to the headend.

[0003] A Cable Modem Termination System (CMTS) is equipment that is located at the headend of the cable network and that is able to receive data packets from a data network and transmit the data packets downstream via the cable network to a cable modem attached to customer premises equipment (CPE). The customer premises equipment can send signals to the cable modem which, in turn, sends data packets upstream via the cable network to the CMTS. The CMTS then sends the data

packets back to the appropriate host on the data network. An example of a CMTS is the Motorola Broadband Service Router 64000 (BSR 64000).

[0004] The term DOCSIS (Data Over Cable System Interface Specification) refers to a group of specifications that define industry standards for cable headend and cable modem equipment. The types of traffic, referred to as service flows, transmitted across a DOCSIS network can vary and may include, for instance, text-based Web browsing, file transferring, email communications, voice and video communications, and the like. Thus, for instance, customer premises equipment (CPE) may include a telephone or other device capable of sending and receiving video or voice signals via the cable modem and cable network. In such cases, the cable modem will typically have an internal or embedded Media Terminal Adapter (eMTA) which provides network interface functionality that accepts analog voice inputs or video signal and generates IP packets. Voice and video communications tend to require greater throughput rates for acceptable levels of service than that of the other service flows referenced above. The different types of service flows communicated over the cable network may have different Quality of Service parameters and requirements.

[0005] When a user registers a cable modem to use a DOCSIS-compliant network, a series of handshaking steps are initially executed during which the modem identifies itself and the network designates (among other parameters) the level of service and frequency (channel) that the cable modem may use. After registration is complete, the cable modem may periodically or occasionally request the creation of service flows and, if allowed, the allocation of bandwidth to transmit data to the CMTS in the upstream direction.

[0006] Typically, thousands of cable modems are connected to each CMTS, and a number of customer premises equipment (CPE), such as computers, Voice-over-Internet-Protocol (VoIP) compliant devices, wireless routers, portable hand-held devices, smartphones and the like, communicate with each cable modem at the subscriber location. Many users typically share a channel, or a group of channels, and their interests compete for the bandwidth of the channel. The full bandwidth available to the multi-channel network for data transmission comprises the sum of bandwidths of the individual channels. Overcrowding of traffic on any one channel will cause degraded performance to a user on that channel.

[0007] To address the need to distribute traffic across upstream and/or downstream channels, a CMTS can be set to implement algorithms to provide load balancing for traffic across multiple channels. The algorithms are applied to a set of cable modems using a set of channels referred to as a "load balancing group". Three such techniques used for distributing voice, video, data and other traffic across upstream and downstream channels include manual, static and dynamic load balancing. For example, after registration, cable modems can be manually moved by the actions of operation personnel to balance the number of cable modems evenly among a defined group of upstream channels. In contrast, static upstream load balancing can be utilized to automatically move a newly registered cable modem to a least-loaded upstream channel. Conventionally, static load balancing has been based solely on cable modem count on each upstream channel. As a further alternative, dynamic load balancing can be used to automatically move cable modems from a channel with highest utilization to a channel with lowest utilization in an attempt to

more evenly distribute active traffic across upstream and/or downstream channels within a defined load balancing group.

[0008] Conventionally, algorithms for dynamic load balancing have taken into account actual bandwidth utilization of each channel that is configured for a load balancing group, actual bandwidth utilized by each modem on the highest utilized channel, and pre-set utilization thresholds. For example, if one channel is operating at 70% utilization capacity and another is being operated only at 30% utilization capacity, dynamic load balancing may be automatically implemented to balance the traffic on the channels. However, if the delta between the two channels is relatively small (i.e., less than a pre-set threshold value), dynamic load balancing may not be implemented by the CMTS at a given point in time.

[0009] When thresholds are met and load balancing is performed by the CMTS, cable modems are caused to be moved across channels while they are actively passing traffic. This is achieved as discussed above by considering certain channel parameters, such as utilization, number of cable modems on the channel, or number of active service flow identifiers on the channel. With conventional load balancing techniques as discussed above, it is possible that a cable modem generating traffic that has service flows with relatively high Quality of Service (QoS) attributes and requirements may be selected for being moved to another channel. Quality of Service generally refers to the speed and reliability of data transmission and like performance parameters needed for an acceptable or guaranteed level of service. An example of one such QoS parameter is Minimum Reserved Rate (MRR). Conventional load balancing techniques ignore QoS parameters of modem service flows, relying only on the currently active utilization of the cable modem. Multiple movements of active

cable modems according to conventional techniques across channels may result in an aggregation of currently inactive cable modems with high QoS requirements on the same channel. When any such aggregated, high-QoS cable modem becomes active, it may be unable to achieve its required QoS. This can result in service interruption for those cable modems or, alternatively, a required interruption of load balancing.

SUMMARY

[0010] This disclosure describes a method of load balancing cable modems across multiple channels of a Data Over Cable System Interface Specification (DOCSIS) network. At least one Quality of Service (QoS) parameter for each service flow from a plurality of cable modems actively passing traffic across one channel of the load balancing group is collected. The at least one QoS parameter collected for each service flow is used to identify at least one cable modem having a service flow with an inferior grade of the at least one QoS parameter relative to a pre-defined threshold. The at least one cable modem having the service flow with the inferior grade of the at least one QoS parameter relative to the pre-defined threshold is selected for being moved from the one channel of the load balancing group to a different channel of the load balancing group for balancing load of active service flows across the channels of the load balancing group. The collecting, using and selecting steps of the method are performed automatically by an electronic communication device at a headend of the DOCSIS network communicating with the plurality of cable modems.

[0011] This disclosure also describes a signal processing electronic device for communicating with cable modems across channels of a load balancing group on a Data Over Cable System Interface Specification (DOCSIS) network. The signal processing electronic device has a processing unit configurable to run an algorithm for performing a load balancing operation for the cable modems across the channels of the load balancing group. The processing unit is configured to collect at least one Quality of Service (QoS) parameter for each service flow from the cable modems that are actively passing traffic across one channel of the load balancing group. The processing unit is also configured to identify at least one cable modem having a service flow with an inferior grade of the at least one QoS parameter relative to a pre-defined threshold and is further configured to select the at least one cable modem having the service flow with the inferior grade of the at least one QoS parameter relative to the pre-defined threshold from the cable modems of the load balancing group for being moved from the one channel to a different channel of the load balancing group for balancing load of active service flows across the channels of the load balancing group.

[0012] Yet further, this disclosure describes at least one non-transitory computer readable storage medium having computer program instructions stored thereon that are arranged to perform the above referenced operations.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] Various features of the embodiments described in the following detailed description can be more fully appreciated when considered with reference to the accompanying figures, wherein the same numbers refer to the same elements.

[0014] FIG. 1 illustrates an exemplary cable network system in accordance with an embodiment.

[0015] FIG. 2 illustrates an exemplary CMTS architecture in accordance with an embodiment.

[0016] FIG. 3 is a flowchart illustrating a procedure for selecting cable modems of a load balancing group for being moved from a channel of highest utilization to a channel of lesser utilization in accordance with an embodiment.

DETAILED DESCRIPTION

[0017] For simplicity and illustrative purposes, the principles of the embodiments are described by referring mainly to examples thereof. In the following description, numerous specific details are set forth in order to provide a thorough understanding of the embodiments. It will be apparent however, to one of ordinary skill in the art, that the embodiments may be practiced without limitation to these specific details. In some instances, well known methods and structures have not been described in detail so as not to unnecessarily obscure the embodiments.

[0018] FIG. 1 illustrates an exemplary network 10 in which a plurality of cable modems 12 or like network elements are connected to a Cable Modem Termination System (CMTS) 14 at the headend 16 of the cable network 10. Each cable modem 12 may connect to the CMTS 14 through a cascade of Hybrid Fiber

Coax (HFC) components including taps, passives, cabling, nodes, and Radio Frequency (RF) amplifiers indicated generally as HFC network 18 in FIG. 1. In a typical network 10, the CMTS 14 will be connected to a plurality of network taps, each of which are connected to a plurality of cable modems 12 or like network elements such that the CMTS 14 may serve and communicate with many hundreds or more of cable modems 12. In turn, each cable modem 12 may be connected to one or more customer premises equipment (CPE) (not shown), i.e., computer, router, set top box, media center, gaming console, and the like.

[0019] At the headend, the CMTS 14 may be connected to numerous program providers, television networks and stations, Internet broadcasters/service providers, and the like 20 for providing content via the CMTS 14 to the cable modems 12 and CPE. Transmission of signals from the CMTS 14 to the cable modems 12 are considered downstream transmissions and signal transmissions from the cable modems 12 to the CMTS 14, which are typically in the form of burst type transmissions, are considered upstream transmissions.

[0020] FIG. 2 illustrates an example of logical architecture of the CMTS 14 which may include a processing unit 24 having a microprocessor 26 that receives information, such as instructions and data from a RAM 28 and a ROM 30. The processing unit 24 controls the operation of the CMTS 14 and is preferably connected to a display 32 which may display status information such as station maintenance and an input keypad 34 which may permit an operator to provide commands, instructions, processing requests and/or data to processing unit 24. The CMTS 14 may further include an RF transceiver (transmitter/receiver) unit 36 having a plurality of transmitters 38 and receivers 40 providing bi-directional communication capability

with a plurality of cable modems 12 or other network elements on the network 10. Each RF receiver 40 of the CMTS may provide support for a hundred or more cable modems 12 or like network elements. The RF transceiver unit 36 may include a demodulator unit 42 and an equalizer 44 to which received RF signals are provided and may also include a modulator 46 which receives downstream signals from equalizer unit 44, modulates the signals, and provides the modulated signals to RF transmitters 38.

[0021] As discussed above, when a cable modem 12 is registered with the CMTS 14, it is assigned to a load balancing group with perhaps hundreds of other cable modems. Such a group typically permits the cable modem 12 to be moved across multiple defined upstream and downstream channels. By way of example, a particular load balancing group may enable its modems to receive/transmit traffic flows on a total of four downstream channels and three or four upstream channels.

[0022] One of the functions typically performed by the CMTS 14 is to balance traffic across the multiple channels of a load balancing group. Conventionally, this may be accomplished by balancing the number of cable modems assigned to each channel (i.e., static load balancing) or by balancing and periodically re-balancing the total amount of active traffic on the channels (i.e., dynamic load balancing). For this purpose, the processing unit 24 or other processing unit of the CMTS 14 typically includes software, microprocessors, other modules, or the like for running and controlling load balancing operations.

[0023] The CMTS and its load balancing software, microprocessors, modules, or the like according to this disclosure balances traffic across channels by taking into account Quality of Service (QoS) parameters associated with the active

traffic or cable modems with active traffic. Thus, candidates for load balancing are selected based on the value or values of their QoS parameter or parameters. In particular, candidates are selecting using a QoS parameter value that is generally of an inferior grade (e.g. a lower minimum reserved rate) compared to other candidates. The inferior grade candidates will have QoS requirements that are easier to satisfy when aggregated with other cable modems on a channel. An example of selecting an inferior grade QoS parameter would be to consider as candidates for moving only modems with service flows with a Minimum Reserved Rate (MRR) less than a particular threshold. Thus, during load balancing, Quality of Service parameters of active traffic are considered when selections are made by the CMTS with respect to which cable modems are to be moved from one channel to another channel within a load balancing group. More specifically, cable modems and/or active traffic that are classified as having “easier to satisfy” Quality of Service parameters are first considered to be moved across channels in an effort to re-balance load before cable modems and/or active traffic that have Quality of Service parameters that are more difficult to satisfy are considered.

[0024] By taking into account Quality of Service parameters during load balancing and not just the total number of cable modems per channel or amount of active traffic per channel, interruptions for customers subscribed to premium services with higher levels or grades of Quality of Service are reduced due to the reduced DOCSIS Upstream Channel Change (UCC) and DOCSIS Dynamic Channel Change (DCC) operations applied to these cable modems during load balancing events. In addition, the probability of realizing relatively-inactive future service flows on a channel or channels with relatively-high Quality of Service demands will necessarily

be maximized better ensuring that the guaranteed Quality of Service levels are provided to the subscriber/customer.

[0025] For purposes of this disclosure, a service flow is a unidirectional flow of packets that provides a particular Quality of Service (QoS). The DOCSIS protocol classifies traffic into service flows with each service flow having its own set of QoS parameters. For example, DOCSIS service flow types for upstream service flows (from cable modem to CMTS) may include: a best effort service flow type; a non-real-time polling service (NRTPS) flow type; a real-time polling service (RTPS) flow type; an unsolicited grant service (UGS) flow type; and an unsolicited grant service with activity detection (UGS-AD) flow type. Simply for purposes of example, a best effort service flow type may be standard internet traffic such as web browsing, email, or instant messaging. An example of a NRTPS flow type may be standard Internet traffic that requires high throughput or variable-size data grants on a regular basis. An example of a RTPS flow type may be MPEG video, and an example of an UGS flow type may be VoIP.

[0026] DOCSIS defines QoS parameters for each of the above service flow types. By way of example, the QoS parameters for a best effort service flow type include traffic priority, request transmission policy, maximum sustained traffic rate, maximum traffic burst, minimum reserved traffic rate, and assumed minimum reserved-traffic-rate packet size. The QoS parameters for a NRTPS flow type include traffic priority, request transmission policy, maximum sustained traffic rate, maximum traffic burst, minimum reserved traffic rate, assumed minimum reserved-traffic-rate packet size, and nominal polling interval. The QoS parameters for a RTPS flow type include request transmission policy, maximum sustained traffic rate,

maximum traffic burst, minimum reserved traffic rate, assumed minimum reserved-traffic-rate packet size, nominal polling interval, and tolerated poll jitter. The QoS parameters for an UGS flow type include request transmission policy, unsolicited grant size, grants per interval, nominal grant interval, and tolerated grant jitter. The QoS parameters for an UGS-AD flow type include request transmission policy, nominal polling interval, tolerated poll jitter, unsolicited grant size, grants per interval, nominal grant interval, and tolerated grant jitter.

[0027] According to the above recited definitions or other definitions, an algorithm set to run on the processing unit 24 or like unit on the CMTS 14 can be pre-set with one or more defined thresholds relative to one or more Quality of Service parameters that can be used to distinguish a cable modem and/or traffic type or a set of cable modems and/or traffic types that have so-called “easier to satisfy” Quality of Service parameters than another cable modem or set of cable modems within a load balancing group of cable modems. Thereafter, during the selection process performed by the CMTS 14 to identify cable modems to be moved from a first channel to a second channel, cable modems pre-selected as having active traffic with easier to satisfy Quality of Service parameters are first considered for being moved during a load balancing procedure. Only if rebalancing cannot be fully achieved solely with movement of cable modems considered as having easier to satisfy Quality of Service parameters are cable modems from the remaining cable modems of the load balancing group considered for selection for movement to re-balance load across the channels. If this occurs, a cable modem having active traffic with the easiest to satisfy Quality of Service parameters remaining is selected before a cable modem having relatively

harder Quality of Service parameters is selected. The selection process is performed in iterations until the desired or pre-set level of re-balancing is achieved.

[0028] QoS parameters may also be considered when determining the number of times a cable modem can be moved to a different channel within a load balancing group during consecutive load balancing events. For example, dynamic load balancing may occur at intervals of about every five minutes, and any single cable modem may be limited from being moved repeatedly back-and forth between channels in a ping-pong manner during a given number of consecutive load balancing events. Here, a cable modem identified as having so-called easier to satisfy QoS parameters may be permitted to be moved up to five times during consecutive load balancing events; whereas, a cable modem considered as having harder to satisfy QoS parameters may only be permitted to be moved two times during consecutive load balancing events. Thus, after being moved in two consecutive load balancing operations, the cable modem is then prevented from being moved when the next load balancing operation occurs.

[0029] As discussed above, one of the steps of the load balancing method is to distinguish cable modems having service flows with so-called easier to satisfy Quality of Service parameters from cable modems having service flows with relatively harder to satisfy Quality of Service parameters. These decisions can be implemented by providing algorithms applied by the CMTS 14 defined by one or more set of rules for use in making load balancing selections. For example, a cable modem that does not have an eMTA may be placed in a list of cable modems identified as having easier to satisfy Quality of Service parameters as compared to a cable modem having an eMTA. This is because the eMTA is used for streaming

voice or video communications, such as required for providing VoIP communicating services. This type of service flow generally has harder to satisfy Quality of Service parameters. Thus, cable modems without an eMTA may be considered for being moved to a different channel during load balancing operations before cable modems having eMTAs.

[0030] Of course, there are many other examples of rules for distinguishing cable modems having service flows with easier to satisfy Quality of Service parameters from other cable modems within a load balancing group. For instance, cable modems having service flows with fewer distinct Service Class Names or types will have QoS parameters that are easier to satisfy than a cable modem having service flows with more distinct Service Class Names or types, and cable modems having service flows with a lower total sum of Minimum Reserved Rate (MRR) will have QoS parameters that are easier to satisfy than a cable modem having service flows with a higher total sum of MRR.

[0031] The algorithms applied by the CMTS 14 can focus on each active service flow of a cable modem to select modems for movement across channels during load balancing. Here, a cable modem can be selected as having QoS parameters easier to satisfy than another cable modem based on each of its service flows being relatively easier to satisfy than the service flows of another modem. For example, a service flow that is without a defined MRR has QoS parameters that are easier to satisfy than a service flow with a defined MRR. Likewise, a service flow with a lower MRR has QoS parameters that are easier to satisfy than a service flow with a higher MRR. Also by way of example, a service flow that is without a defined jitter tolerance has QoS parameters that are easier to satisfy than a service flow with a

defined jitter tolerance, and a service flow with a higher jitter tolerance has QoS parameters that are easier to satisfy than a service flow with a lower jitter tolerance.

[0032] As additional examples, a service flow that is without a defined maximum traffic rate has QoS parameters that are easier to satisfy than a service flow with a defined maximum traffic rate, and a service flow with a lower maximum traffic rate has QoS parameters that are easier to satisfy than a service flow with a higher maximum traffic rate. Still further, a service flow with a smaller total maximum traffic burst has QoS parameters that are easier to satisfy than a service flow with a higher total maximum traffic burst; a service flow with fewer Unsolicited Grant Service (UGS) grants per interval has QoS parameters that are easier to satisfy than a service flow with more UGS grants per interval; and a service flow with a smaller UGS grant interval has QoS parameters that are easier to satisfy than a service flow with a larger UGS grants interval. Of course, these provide just a few examples.

[0033] A method for considering QoS parameters during load balancing is shown in the flowchart of FIG. 3 and can include the following steps. A series of thresholds distinguishing between QoS parameters that are considered easier to satisfy from those considered more difficult to satisfy are defined and are entered into the algorithms run by the processing unit 24 of the CMTS 14 via use of Command Line Interface (CLI) commands entered by an operator via input keypad 34. (See step 50.) As an example of a threshold, a value of "x" can be entered as a threshold for the QoS parameter Minimum Reserved Rate (MRR). If the active traffic of a cable modem is of a service flow type of best effort, NRTPS or RTPS and has a MRR QoS parameter of a value that is equal to or less than "x", then the cable modem can be considered as having easier to satisfy QoS parameters and can be considered a proper candidate for

being moved from a channel with highest utilization to another channel during load balancing. Alternatively, if the above referenced value is greater than “x”, the cable modem should only be considered for being moved to another channel after all other modems having easier to satisfy QoS parameters are first considered and moved.

[0034] At runtime of the load balancing algorithm, the CMTS 14 detects whether or not a pre-defined amount of imbalance exists on a channel of highest utilization. (See step 52). If not, the CMTS 14 continues to detect for imbalances or checks for imbalances at a next pre-defined interval. (See step 54). However, if a pre-defined imbalance exists, the CMTS begins selecting cable modems for UCC or DCC for purposes of re-balancing the load across the channels of the load balancing group. Thus, the CMTS begins collecting a pre-defined QoS parameter for each service flow of cable modems actively passing traffic across the channel of highest utilization. (See step 56.)

[0035] According to one embodiment, a “First List” is defined as including all the cable modems assign to pass traffic across a particular channel. From this “First List”, cable modems that provide a Quality of Service that is better or superior to the pre-set thresholds for QoS parameters are removed from the “First List” and placed in a “Second List” or second subset. In this manner, only cable modems that do not meet the quality thresholds and/or are considered as having inferior grades of service with “easier to satisfy” QoS parameters remain in the “First List”, or first subset for being considered as a candidate to be moved across channels in a load balancing effort. (See step 58.)

[0036] For purposes of example, the “Second List” can be compiled as follows. For each cable modem in the “First List”: (a) identify the cable modem’s

active service flow identifiers (SFIDs) on which there is active traffic; (b) for each such SFID, obtain the service flow attributes (i.e., QoS parameters and values thereof); and (c) if the service flow attributes of any of the SFIDs of the cable modem are of a quality that surpass the thresholds as defined by the rules stored in the algorithm of the CMTS, then move the cable modem to the “Second List”, if not, permit the cable modem to remain in the “First List”.

[0037] After the First and Second Lists are compiled, an attempt is made to achieve a pre-defined level of load balancing by applying UCC and/or DCC operations to at least some or possible all of the cable modems listed in the “First List” (i.e., list of cable modems considered to have easier to satisfy QoS parameters). (See steps 62 and 66.) If the pre-defined level of re-balancing has been achieved (see steps 68 and 70), the current load balancing operation can be terminated and the process can return to detecting for imbalance (see steps 72 and 52). Alternatively, if after all cable modems in the “First List” have been moved across channels (see step 60) and the pre-defined level of re-balancing has not be achieved (see steps 68 and 70), a needed number of the cable modems in the “Second List” are moved to another channel (see steps 64 and 66) until the pre-defined level of re-balancing has been achieved. Here, a cable modem in the “Second List” that has the easiest to satisfy QoS parameter of all the remaining cable modems in the “Second List” is the first to be moved. This process continues with the remaining cable modems in the “Second List” until the pre-defined level of re-balancing is achieved.

[0038] The above described “QoS-aware” load balancing algorithm can be run in conjunction with other algorithms and rules set for the CMTS. For instance, algorithms defining the threshold for when the next load balancing operation begins

or ends, how many consecutive movements of a cable modem is permitted before the cable modem is not permitted to be moved, or which cable modems are always prevented from being moved can be used in conjunction with the “QoS-aware” load balancing algorithm. Further, the “QoS-aware” load balancing algorithm can be applied to all cable modems on all channels or only certain pre-defined cable modems or pre-defined channels.

[0039] A specific example is provided below. In this example, there are two rules by which the load balancing algorithm makes decisions. “Rule 1” requires that a dynamic load balancing operation be started if the utilization of an upstream channel in the load balancing group equals or surpasses 80%. “Rule 2” requires that for any cable modem having an active service flow with a minimum reserved traffic rate QoS parameter of greater than 600,000, the cable modem should be moved to “List 2” which represents a list of cable modems that do not have so-called “easier to satisfy” QoS parameters.

[0040] In this example, cable modem 1 (CM1) is configured with a service class having a minimum reserved traffic rate of 800,000; cable modem 2 (CM2) is configured with a service class having a minimum reserved traffic rate of 700,000; and cable modem 3 (CM3) is configured with a service class having a minimum reserved traffic rate of 500,000. In this example, all cable modems (CM1, CM2, CM3) are actively passing traffic on the same upstream channel and the utilization on this upstream channel crosses 80%. This initiates a load balancing operation to be performed by the CMTS according to the requirement of “Rule 1”. A “List 1” is generated in which CM1, CM2 and CM3 are identified. The algorithm selects CM1 and CM2 to be removed from “List 1” and placed in “List 2” according to the

requirements of “Rule 2”. Since “List 1” now represents cable modems considered to have “easier to satisfy” QoS parameters, CM3 is selected for UCC and gets moved to a different (less utilized) channel in the load balancing group in an effort to balance load across the channels of the load balancing group. If the utilization of the upstream channel on which CM1 and CM2 remain falls below 80%, the load balancing operation concludes. Otherwise, if utilization on the channel remains at or above 80% after moving CM3 and “List1” is empty, cable modems from “List 2” are now considered for load re-balancing. Here, the algorithm selects CM2 for being moved to a less utilized channel because the MRR for CM2 is less than (i.e., easier to satisfy) the MRR for CM1. Thus, CM2 is moved.

[0041] The devices, units, modules and storage discussed above can physically be provided on a circuit board or within an electronic device and can include various processors, microprocessors, controllers, chips, disk drives, and the like. It will be apparent to one of ordinary skill in the art that the modules, processors, controllers, units, and the like may be implemented as electronic components, software, hardware or a combination of hardware and software. For example, a means to perform the above discussed algorithm can be provided as at least one computer readable storage medium having computer program instructions stored thereon that are arranged to perform the above referenced operations.

[0042] While the principles of the invention have been described above in connection with specific devices, systems, and methods, it is to be clearly understood that this description is made only by way of example and not as limitation on the scope of the invention as defined in the appended claims.

I claim:

1. A method of load balancing cable modems across channels of a load balancing group on a Data Over Cable System Interface Specification (DOCSIS) network, comprising the steps of:

collecting at least one Quality of Service (QoS) parameter for each service flow from a plurality of cable modems actively passing traffic across one channel of the load balancing group;

using the at least one QoS parameter collected during said collecting step for each service flow to identify at least one cable modem having a service flow with an inferior grade of the at least one QoS parameter relative to a pre-defined threshold; and

selecting the at least one cable modem having the service flow with the inferior grade of the at least one QoS parameter relative to the pre-defined threshold for being moved from the one channel of the load balancing group to a different channel of the load balancing group for balancing load of active service flows across the channels of the load balancing group;

said steps of collecting, using and selecting being performed automatically by an electronic communication device at a headend of the DOCSIS network communicating with the plurality of cable modems.

2. A method according to claim 1, wherein the pre-defined threshold defines a grade of service threshold for the at least one QoS parameter, and wherein the at least

one QoS parameter is selected from a group consisting of minimum reserved traffic rate, jitter tolerance, maximum sustained traffic rate, total maximum traffic burst, unsolicited grant service (UGS) grants per interval, UGS grant interval, traffic priority, request transmission policy, assumed minimum reserved-traffic-rate packet size, nominal polling interval, and unsolicited grant size.

3. A method according to claim 1, wherein, during said using step, a first subset of cable modems of the load balancing group actively passing traffic across the one channel and having service flows with the inferior grade of the at least one QoS parameter is identified from a second subset of cable modems of the load balancing group actively passing traffic across the one channel and having service flows not having the inferior grade of the at least one QoS parameter.

4. A method according to claim 3, wherein, during said selecting step, cable modems from the second subset of cable modems are not considered for being selected for being moved from the one channel unless all cable modems in the first subset of cable modems have been moved and further load balancing is required.

5. A method according to claim 4, wherein during said selecting step, if all the cable modems in the first subset of cable modems have been moved and further load balancing is required, a cable modem from the second subset of cable modems having a service flow with a lowest grade of the at least one

QoS parameter relative to the service flows of other cable modems remaining in the second subset is selected for being moved from the one channel for balancing load.

6. A method according to claim 1, further comprising the step of configuring the electronic communications device with the pre-defined threshold of the at least one QoS parameter via user interface before said collecting, using and selecting steps.

7. A method according to claim 1, further comprising the step of applying at least one of an upstream channel change (UCC) operation and a dynamic channel change (DCC) operation to the at least one cable modem selected during said selecting step.

8. A method according to claim 7, further comprising the step of detecting if a pre-defined level of load balancing has been achieved after said applying step, wherein if the pre-defined level of load balancing has not yet been achieved, said using, selecting and applying steps are repeated for cable modems remaining on the one channel, and wherein if the pre-defined level of load balancing has been achieved, load balancing is terminated until a later imbalance is detected.

9. A method according to claim 1, further comprising the step of detecting if a pre-defined amount of imbalance of active traffic on the

channels of the load balancing group exists, wherein if the pre-defined amount of imbalance is detected, a load balancing operation is initiated by proceeding with said collecting step.

10. A method according to claim 1, wherein the electronic communications device is a Cable Modem Termination System (CMTS).

11. A signal processing electronic device for communicating with cable modems across channels of a load balancing group on a Data Over Cable System Interface Specification (DOCSIS) network, comprising:

a processing unit configurable to run an algorithm for performing a

load balancing operation for the cable modems across the channels of the load balancing group;

said processing unit being configured to collect at least one Quality of

Service (QoS) parameter for each service flow from the cable modems that are actively passing traffic across one channel of the load balancing group;

said processing unit being configured to identify at least one cable

modem having a service flow with an inferior grade of the at least one QoS parameter relative to a pre-defined threshold; and

said processing unit being configured to select the at least one cable

modem having the service flow with the inferior grade of the at least one QoS parameter relative to the pre-defined threshold from the cable modems of the load balancing group for being

moved from the one channel to a different channel of the load balancing group for balancing load of active service flows across the channels of the load balancing group.

12. A signal processing electronic device according to claim 11, wherein the signal processing electronic device is a Cable Modem Termination System (CMTS).

13. A signal processing electronic device according to claim 11, further comprising a transceiver unit connected to said processing unit for transmitting and receiving communication signals to and from the cable modems across the channels of the load balancing group.

14. A signal processing electronic device according to claim 11, wherein said processing unit includes at least one microprocessor for controlling the load balancing operation.

15. A signal processing electronic device according to claim 11, wherein the pre-defined threshold defines a grade of service threshold for the at least one QoS parameter, and wherein the at least one QoS parameter is selected from a group consisting of minimum reserved traffic rate, jitter tolerance, maximum sustained traffic rate, total maximum traffic burst, unsolicited grant service (UGS) grants per interval, and UGS grant interval,

traffic priority, request transmission policy, assumed minimum reserved-traffic-rate packet size, nominal polling interval, and unsolicited grant size.

16. A signal processing electronic device according to claim 11, wherein the processing unit is configured to identify a first subset of cable modems of the load balancing group actively passing traffic across the one channel and having service flows with the inferior grade of the at least one QoS parameter from a second subset of cable modems of the load balancing group actively passing traffic across the one channel and having at least one service flow not having the inferior grade of the at least one QoS parameter.

17. A signal processing electronic device according to claim 16, wherein the processing unit is configured to select cable modems from the first subset of cable modems for being moved from the one channel before selecting any cable modems from the second subset.

18. A signal processing electronic device according to claim 17, wherein, if all the cable modems in the first subset have been moved and further load balancing is required, said processing unit is configured to select a cable modem from the second subset having a service flow with a lowest grade of the at least one QoS parameter relative to the service flows of other cable modems remaining in the second subset for being moved from the one channel for balancing load of active service flows across the channels of the load balancing group.

19. A signal processing electronic device according to claim 11, wherein the processing unit is configured to apply at least one of an upstream channel change (UCC) operation and a dynamic channel change (DCC) operation to the at least one cable modem selected for being moved.

20. At least one non-transitory computer readable storage medium having computer program instructions stored thereon that are arranged to perform the following operations:

collecting at least one Quality of Service (QoS) parameter for each service flow from cable modems of a load balancing group actively passing traffic across one channel of a pre-defined set of channels of the load balancing group;

using the at least one QoS parameter collected during said collecting step for each service flow to identify at least one cable modem having a service flow with an inferior grade of the at least one QoS parameter relative to a pre-defined threshold; and

selecting the at least one cable modem having the service flow with the inferior grade of the at least one QoS parameter relative to the pre-defined threshold from the cable modems of the load balancing group for being moved from the one channel to a different channel of the load balancing group for balancing load of active service flows across the pre-defined set of channels of the load balancing group.

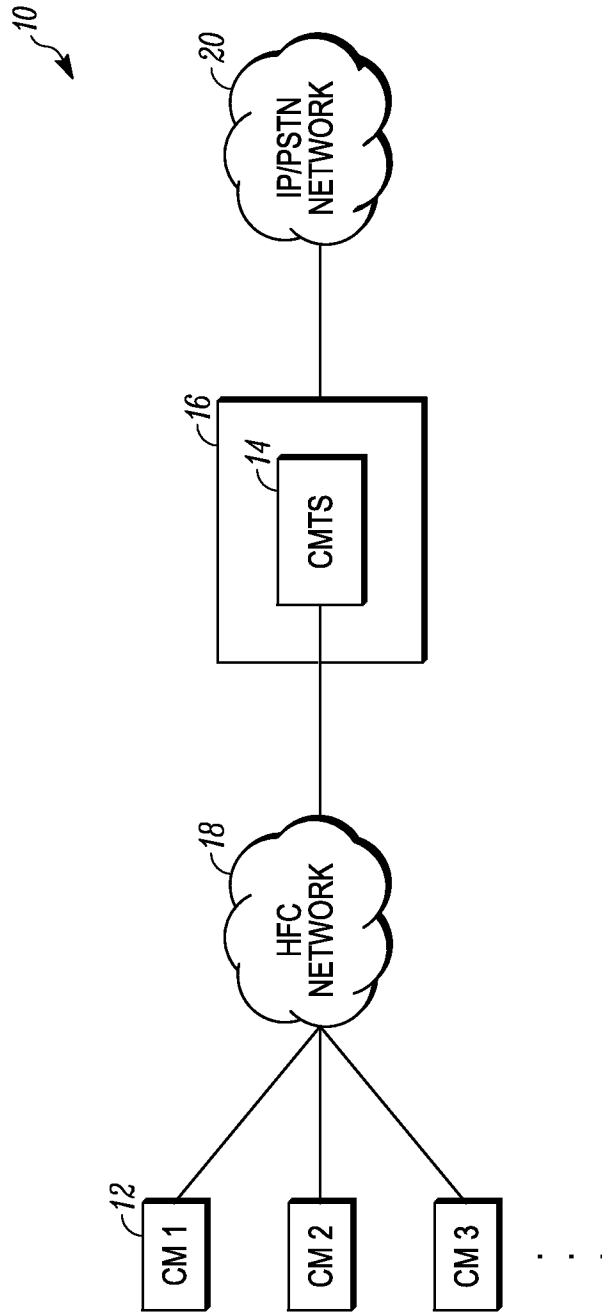


FIG. 1

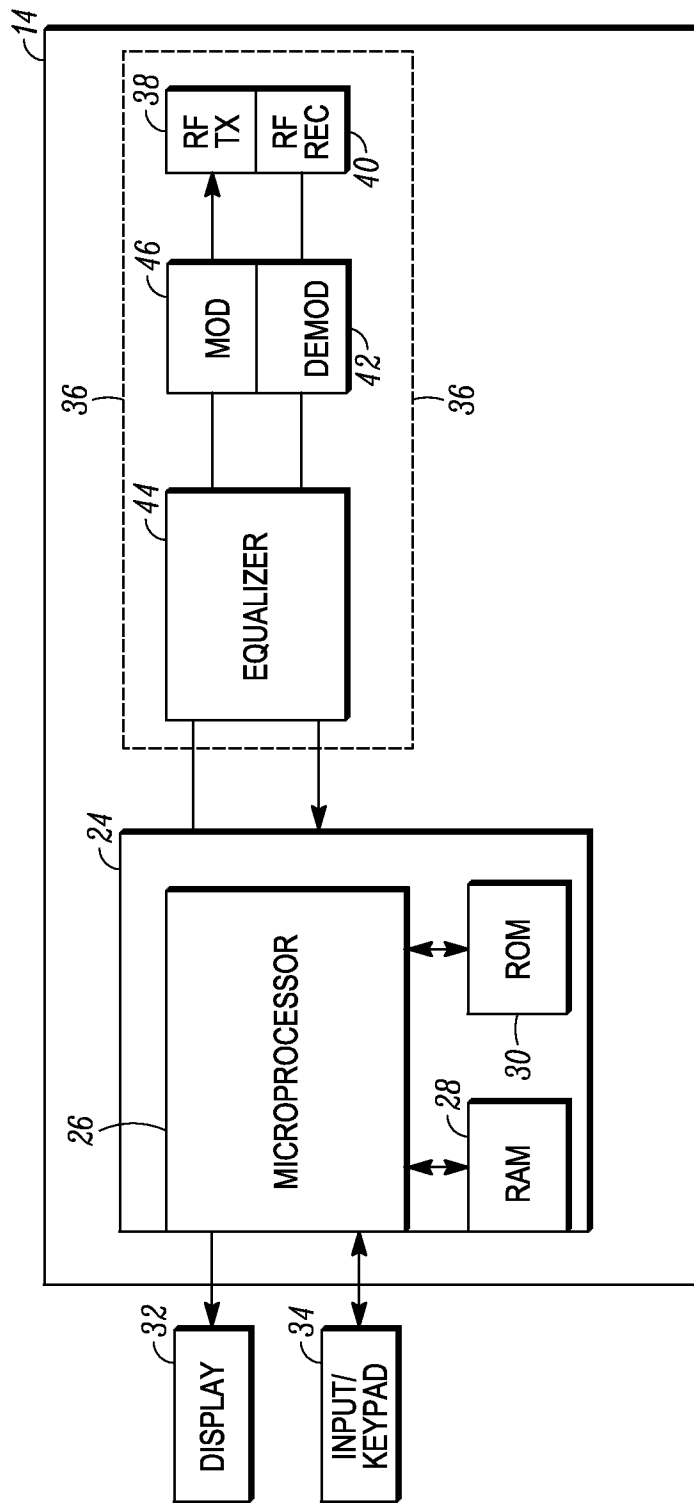


FIG. 2

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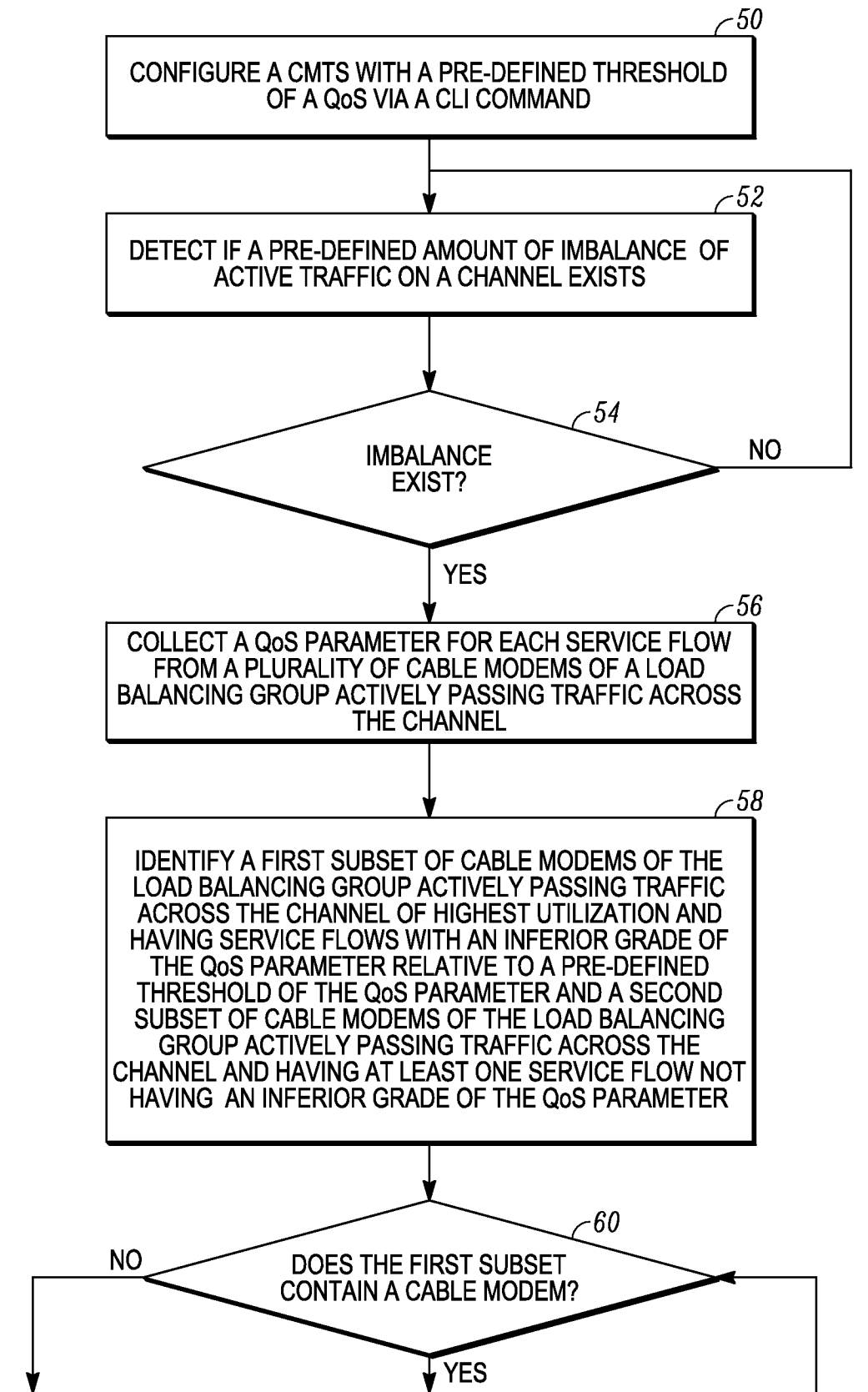


FIG. 3A

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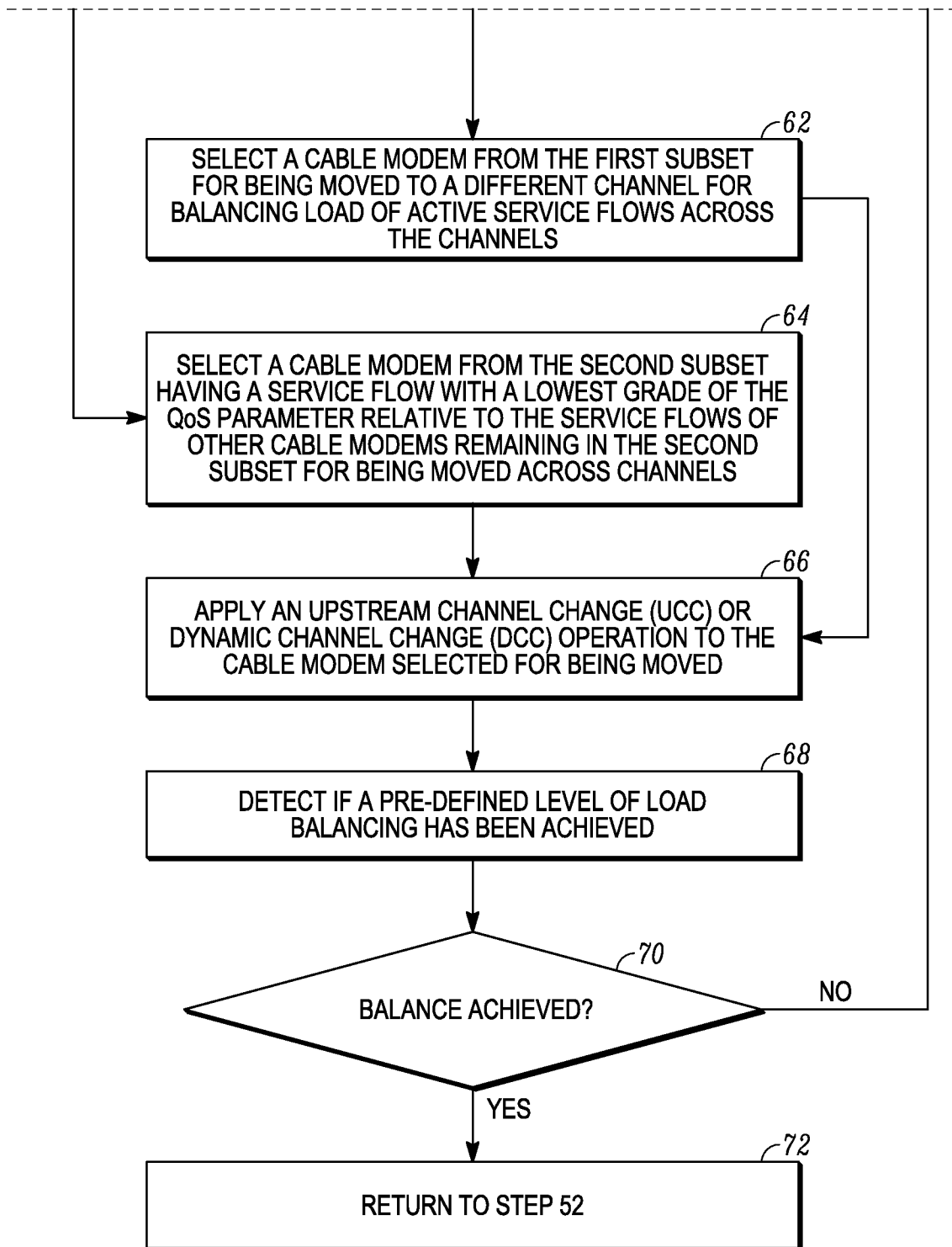


FIG. 3B

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2012/056338

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04L47/24
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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 6 822 940 B1 (ZAVALKOVSKY ARTHUR [IL] ET AL) 23 November 2004 (2004-11-23) figures 2,3,5 column 2, line 36 - line 49 column 3, line 61 - line 67 column 5, line 1 - line 23 column 6, line 10 - line 22 column 13, line 23 - line 31 column 15, line 32 - line 46 column 16, line 10 - line 31 ----- -/--	1-20

Further documents are listed in the continuation of Box C.

See patent family annex.

* Special categories of cited documents :

- "A" document defining the general state of the art which is not considered to be of particular relevance
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- "O" document referring to an oral disclosure, use, exhibition or other means
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- "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
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- "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
- "&" document member of the same patent family

Date of the actual completion of the international search 14 November 2012	Date of mailing of the international search report 20/11/2012
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Authorized officer Mircescu, Alexander

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2012/056338

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2011/019551 A1 (ADAMS JOHN LEONARD [GB] ET AL) 27 January 2011 (2011-01-27) figures 4,5,7,13 page 1, paragraph 6 - paragraph 14 page 2, paragraph 32 - paragraph 34 page 3, paragraph 56 - paragraph 62 page 5, paragraph 100 - paragraph 105 page 6, paragraph 114 - paragraph 115 -----	1-20
A	US 6 999 420 B1 (CHIU ANGELA L [US] ET AL) 14 February 2006 (2006-02-14) figures 2,3,7 column 1, line 25 - line 42 column 4, line 16 - line 31 column 7, line 7 - line 56 -----	1-20

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2012/056338

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 6822940	B1	23-11-2004	NONE
US 2011019551	A1	27-01-2011	NONE
US 6999420	B1	14-02-2006	NONE