(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
12 September 2013 (12.09.2013)

WIPO | PCT

(10) International Publication Number
WO 2013/134663 A1

(51) International Patent Classification:
H04J 14/00 (2006.01)

(21) International Application Number:
PCT/US2013/029923

(22) International Filing Date:
8 March 2013 (08.03.2013)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
61/608,632 8 March 2012 (08.03.2012) US

(71) Applicant: **ENTROPIC COMMUNICATIONS, INC.** [US/US]; 6290 Sequence Drive, San Diego, California 92121 (US).

(72) Inventor: **ZONG, Wu**; 10522 Hunters Ridge Place, San Diego, California 92127 (US).

(74) Agent: **BACHAND, Richard A.**; 6290 Sequence Drive, San Diego, California 92121 (US).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*

Published:

— *with international search report (Art. 21(3))*

— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))*

(54) Title: METHOD AND APPARATUS FOR UNIFYING AN EPON ACCESS NETWORK AND A COAX-BASED ACCESS NETWORK

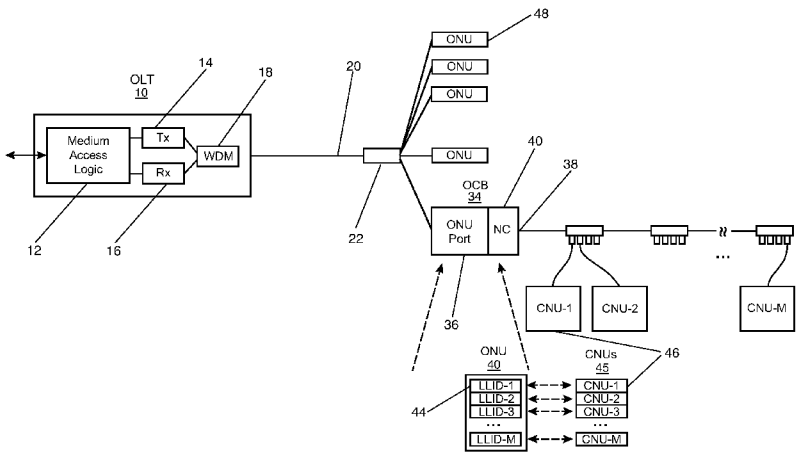

FIG. 3

(57) Abstract: A MSO deploying a standard OLT, and installed with ONUs to be used by customers to whom the MSO can connect using optical fiber. For customers that cannot be reached with optical fiber, the MSO deploys a converter between the optical fiber and the coax network so that the MSO can use the same standard OLT, and use CNUs for those customers attached to the coax network.

WO 2013/134663 A1

METHOD AND APPARATUS FOR UNIFYING AN EPON ACCESS NETWORK AND A COAX-BASED ACCESS NETWORK

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U. S. Provisional Application No. 61/608,632, filed March 8, 2012, the specification of which is incorporated by reference.

FIELD

[0002] This disclosure is related to a communication network and more particularly to bridging Ethernet passive optical networks with coax based access networks.

BACKGROUND INFORMATION

[0003] There are two different types of access networks for packet data transmission. These are shown in Figs. 1 and 2. Fig. 1 shows a typical Ethernet passive optical network (EPON) consisting of an optical line terminal (OLT) **10** at the headend side of the system. A typical OLT has medium access logic **12** connected to transmitter (Tx) **14** and receiver (Rx) **16** that is connected to wavelength division multiplexer (WDM) **18**. The data packets are sent and received through optical fiber **20**. Optical fiber **20** is connected to 1: N optical splitter **22** which is dispersed to a plurality of optical network units (ONUs) **24** on the customer premises side.

[0004] A second type of access network is shown in Fig. 2. This is a coaxial cable-based access network. In this system access network controller **26** at the headend side, is linked by coaxial cable **28** to a plurality of coax networks units (CNUs) **30** at the customer premises side.

SUMMARY

[0005] The embodiments disclosed herein are for a multi-system operator (MSO) to deploy a standard OLT and install ONUs so the MSO can connect ONUs to the OLT to via an optical fiber. For users that do not have access to an optical fiber,

the MSO deploys a converter between the optical fiber and a coax network so that the MSO can use the standard OLT to communicate with CNUs.

[0006] The following presents a simplified summary of one or more embodiments in order to provide a basic understanding of some aspects of such embodiments. This summary is not an extensive overview of the one or more embodiments, and is intended to neither identify key or critical elements of the embodiments nor delineate the scope of such embodiments. Its sole purpose is to present some concepts of the described embodiments in a simplified form as a prelude to the more detailed description that is presented later.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] The disclosed method and apparatus, in accordance with one or more various embodiments, is described with reference to the following figures. The drawings are provided for purposes of illustration only and merely depict examples of some embodiments of the disclosed method and apparatus. These drawings are provided to facilitate the reader's understanding of the disclosed method and apparatus. They should not be considered to limit the breadth, scope or applicability of the claimed invention. It should be noted that for clarity and ease of illustration, these drawings are not necessarily made to scale.

[0009] Fig. 1 is an illustration of an EPON in an optical access network consisting of an optical line terminal (OLT) at the headend side and several (i.e., N) optical network units (ONUs) at the customer premise side.

[0010] Fig. 2 illustrates a coaxial cable-based access network.

[0011] Fig. 3 illustrates an embodiment of the disclosed method and apparatus in which the same OLT is used for both customers that are reachable through optical fiber, and those that are not reachable through optical fiber, but are reachable through coaxial cable.

[0012] Fig. 4 is an illustration of an embodiment in which a standard EPON access network is connected to a coaxial cable access network, through an optical fiber to coax bridge (OCB: Optical-to-Coax Bridge) device.

[0013] The figures are not intended to be exhaustive or to limit the claimed invention to the precise form disclosed. It should be understood that the disclosed method and apparatus can be practiced with modification and alteration, and that the invention should be limited only by the claims and the equivalents thereof.

DETAILED DESCRIPTION

[0014] The presently claimed invention solves the problem of the ability of using a standard OLT to communicate with both ONUs and CNUs without the OLT having to distinguish the difference between the network units.

[0015] Disclosed is a MSO deploying a standard OLT, and installed with ONUs to be used by customers to whom the MSO can connect using optical fiber. For customers that cannot be reached with optical fiber, the MSO deploys a converter between the optical fiber and the coax cable network so that the MSO can use the same standard OLT, and use CNUs for those customers attached to the coax cable network.

[0016] Fig. 3 shows one embodiment whereby the same OLT **10** is used for both types of customers, those who are reachable through optical fiber, and those who are not reachable through optical fiber, but are reachable through coaxial cable, such as Entropic Communications' c.Link access network, via a pass-through device that passes data between the OLT **10** and at least one CNU. This pass-through device preferably is flexible in several ways, such as allowing the MSO to use different portions of the RF spectrum, including more or less spectrum as available. Additionally, for the OLT, the behavior of a CNU must be functionally equivalent or emulates an ONU so that the OLT does not know the difference. This is achieved by the pass-through device that translates the behaviors of the CNUs into that of one or plural ONUs relative to the OLT, and translates the behaviors of the OLT into that of the coax network's network coordinator. Further, for interoperability between different vendors, it is desirable for a standard to exist that governs how this pass-through device and the CNUs work.

[0017] A standard EPON access network is connected to a coaxial cable access network through optical fiber **20** to coax bridge, such as optical-fiber-to-coax bridge (OCB) **34**. In this embodiment, OLT **10** is preferably a standard EPON OLT.

This embodiment is used when there are two types of devices at customer premises, a first type is a standard EPON ONU, used for customers who can be reached by optical fiber, and the second type is a coaxial cable-based access CNU, which includes c.LINK access CPE, DOCSIS Cable Modem CPE, WiFi Station, and the like. First, an optical splitter **22** provides access to each of the plurality of ONUs **48** which operate in the normal fashion. Optical splitter **22** also provides access to at least one OCB **34**. Optical-fiber-to-coax bridge or OCB **34** device preferably has an ONU port **36** and coax port **38**. A network coordinator (NC) **40** of the coaxial cable access network (or equivalently the CMTS of the DOCSIS network, or Access Point of the WiFi network), manages the regular operation of the coaxial cable access network, like node admission, TDMA scheduling, etc. Relative to the standard OLT, OCB **34** behaves as a standard ONU **40**, with multiple LLIDs **44**. For each CNU **46** (i.e. a cable CPE), OCB **34** creates a set of LLIDs **44**. There can be one or more LLIDs in a set. Thus, the OCB's ONU port **36** has M sets of LLIDs **44,** which represents M CNUs **45**. For example, a coaxial access network with M CNUs **45**, OCB **34** will thus create M sets of LLIDs **44**.

[0018] For downstream traffic from OLT **10**, OCB **34** receives all the packets, but will discard those packets whose LLIDs **44** and destination MAC address do not belong to this OCB **34**, and will store the packets that are destined to this OCB **34** and/or the CNUs **46**. Concurrently, OCB **34** schedules and transmits downstream packets to CNUs **46**, following the protocol of the coaxial cable access network, like c.LINK.

[0019] For upstream traffic from CNUs **46** to OCB **34**, the OCB schedules them and receives them, following the protocol of the coaxial cable access network, like c.LINK. Concurrently, OCB **34** uses REPORT messages to request EPON bandwidth for individual LLIDs **44** and queues to OLT **10**, and the OLT uses GATE messages to grant time slots for individual LLIDs **44** and queues. Upon receiving GATE messages, OCB **34** transmits packets for appropriate LLIDs **44** and queues. For EPON admission/registration, OCB **34** will register the OCB's ONU port **36** as if it is a standard ONU **48**, with all the LLIDs **44** needed to support all the CNUs **46** of the coaxial cable access network.

[0020] For network provisioning and management, data over cable service interface specification (DOCSIS) provisioning of EPON (DPoE) can be used directly. OLT **10** considers the ONU port **36** of OCB **34** as if it is a standard ONU **48**. For whatever operations that OLT **10** performs, the logic ONU and the OCB **34** will translate them into corresponding operations in the coaxial cable access network, and report back results when appropriate. In this respect, logically ONU port **36** is considered as the DPoE API of a standard ONU **48**, and the coaxial cable network operations is considered as the actual execution of the DPoE operations inside a standard ONU device.

[0021] A second embodiment of an OCB device is shown in Fig. 4. Like the embodiment of Fig. 1, this embodiment has an OLT **10** with all of the inclusions of Fig. 1. As in the previous embodiment, an optical splitter **22** provides access to each of the plurality of ONUs **62** which operate in the normal fashion. Optical splitter **22** also provides access to at least one OCB **60**. In this embodiment, each OCB has an ONU port **50** and coax port **52**. It is the network coordinator (NC) **54** of the coaxial cable access network, (or equivalently the CMTS of the DOCSIS network, or Access Point of the WiFi network), managing the regular operation of the coaxial cable access network, like node admission, TDD scheduling, etc. Relative to a standard OLT **10**, the OCB's ONU port **50** behaves as M virtual ONUs **56**, each with one or multiple LLIDs, where M is the number of CNUs **58** in the coaxial cable access network. M virtual ONUs **56** are co-located at the same physical location in the OCB **60**. Each virtual ONU **64** has its own MAC address, and is uniquely mapped to a CNU for data flows.

[0022] For downstream traffic from OLT **10**, OCB **60** receives and stores the packets for each virtual ONU **56** and discards packets that are not destined to any of the virtual ONUs **56** and concurrently, OCB **60** schedules and transmits downstream packets to CNUs **58**, following the protocol of the coaxial cable access network, like c.LINK.

[0023] For upstream traffic from CNUs **58** to OCB **60**, the OCB schedules them and receives them from CNUs **58**, following the protocol of the coaxial cable access network, like c.LINK and concurrently, OCB **60** uses REPORT messages to request EPON bandwidth for individual virtual ONUs **56** and their respective

LLIDs and queues to OLT **10**. The OLT uses GATE messages to grant time slots for individual virtual ONUs **64** and their respective LLIDs and queues. Upon receiving GATE messages, the OCB transmit packets for appropriate ONUs (and LLIDs and queues). For EPON admission, OCB **10** will register each virtual ONU **64** separately as if it is a standard real ONU **62**. Virtual ONU **64** is formed by OCB **10** when a CNU **58** is admitted into the coaxial cable access network by the OCB's NC **54** entity. For network provisioning and management, DPoE can be used directly. OLT **10** considers M virtual ONUs **56** in the OCB as if they are standard ONUs **62**. For whatever operations that OLT **10** performs on each virtual ONU **56**, the OCB will translate them into corresponding operations in the coaxial cable access network, and report back results when appropriate. In this respect, a virtual ONU is considered as the DPoE API of a standard ONU, and the coaxial cable network operations are considered as the actual execution of the DPoE operations inside a standard ONU device.

[0024] The introduction of ONU port **50** and virtual ONUs **56** effectively dissociates the optical fiber network segment and the coaxial cable network segment. The two networks thus operate concurrently but asynchronously. The OLT scheduler does not need to distinguish virtual ONUs **56** from standard ONUs **62**. In fact, the OLT does not need to be aware that there is coaxial cable access network connected to the EPON system. There is no constraint on wire speed for any of the two network segments. The queue buffers in the OCB can be implemented in various ways depending on the number of CNUs supported, the speed, throughput, and latency of the coaxial cable access network. The OCB can do data flow control between the OLT and the CNUs by coordinating the different data flow control mechanisms between the OLT and the OCB (emulated ONU, or ONUs), and between the NC and the CNUs.

[0025] Note that with this architecture, the coaxial cable access network may be replaced by any other networks, like a c.LINK network, a new coaxial cable based network to be standardized, a WiFi network where the AP takes the place of the NC in the OCB, a DOCSIS network where the CMTS/headend replace the NC in the OCB, a HomePlug network, a HPNA network, a G.Hn network or any similar type network.

[0026] In the prior art or known systems, there are several shortcomings that have been overcome by the presently claimed invention. They include, a standard EPON OLT has no definition or awareness of a coaxial media converter (CMC), so there is an issue of doing network provisioning and management by DPoE. Additionally, framing, modulation, and forward error correction (FEC) on optical fiber needs to be different from framing on coax because of physical channel difference. 1G-EPON adopts optional frame-based FEC. When the FEC is not used in EPON, either the coax segment will suffer serious packet error rate or the CMC will need to add FEC for the coax segment, which increases the latency, and requires the CMC to first recover the packets and then add FEC. 10G-EPON uses mandatory stream-based FEC where parity symbols generated after each data block are inserted immediately after the FEC parity codeword that they are protecting, resulting in an interleaving pattern of data blocks and parity blocks. Because the coax segment typically has a lower throughput, the CMC must first do the reverse FEC, discard packets not needed, and then re-do FEC for the needed packets and silence stream. If the speed on coax is different than on fiber, and standard OLT is unaware of such a thing, there are problems because of the very low latency between the GATE message and the allocated transmission slot. The minimum time interval from the Grant message to the allocated transmit time is 1024x16ns. This latency is easily exceeded by the CMC. Since all packets between the OLT and the CNUs pass through CMC, the OLT may need to instruct CMC how traffic between the CMC and CNUs must be coordinated, but current OLT is not aware of CMC. Ranging between the OLT and the CNU must get coordination from CMC. There is different need for power control in optical segment and the coaxial cable segment, CMC needs to get involved.

[0027] The virtual ONU concept disclosed in this filing effectively avoids all these problems, and still enables network provisioning through DPoE. Each network segment (optical and coaxial) can use the PHY and MAC mechanisms best suited for that medium.

[0028] While various embodiments of the disclosed method, apparatus, and computer program have been described above, it should be understood that they have been presented by way of example only, and should not limit the claimed invention.

Embodiments of the claimed invention may be implemented in method steps, hardware, firmware, software, or any combination thereof. Embodiments of the invention may also be implemented as non-transitory computer-executable storage medium. Likewise, the various diagrams may depict an example architectural or other configuration for the disclosed method and apparatus. This is done to aid in understanding the features and functionality that can be included in the disclosed method, apparatus, and computer program. The claimed invention is not restricted to the illustrated example architectures or configurations, rather the desired features can be implemented using a variety of alternative architectures and configurations. Indeed, it will be apparent to one of skill in the art how alternative functional, logical or physical partitioning and configurations can be implemented to implement the desired features of the disclosed method and apparatus. Also, a multitude of different constituent module names other than those depicted herein can be applied to the various partitions. Additionally, with regard to flow diagrams, operational descriptions, and method claims, the order in which the steps are presented herein shall not mandate that various embodiments be implemented to perform the recited functionality in the same order unless the context dictates otherwise.

[0029] Although the disclosed method and apparatus is described above in terms of various exemplary embodiments and implementations, it should be understood that the various features, aspects and functionality described in one or more of the individual embodiments are not limited in their applicability to the particular embodiment with which they are described. Thus, the breadth and scope of the claimed invention should not be limited by any of the above-described exemplary embodiments.

[0030] Terms and phrases used in this document, and variations thereof, unless otherwise expressly stated, should be construed as open ended as opposed to limiting. As examples of the foregoing: the term "including" should be read as meaning "including, without limitation" or the like; the term "example" is used to provide exemplary instances of the item in discussion, not an exhaustive or limiting list thereof; the terms "a" or "an" should be read as meaning "at least one," "one or more" or the like; and adjectives such as "conventional," "traditional," "normal,"

"standard," "known" and terms of similar meaning should not be construed as limiting the item described to a given time period or to an item available as of a given time, but instead should be read to encompass conventional, traditional, normal, or standard technologies that may be available or known now or at any time in the future. Likewise, where this document refers to technologies that would be apparent or known to one of ordinary skill in the art, such technologies encompass those apparent or known to the skilled artisan now or at any time in the future.

[0031] A group of items linked with the conjunction "and" should not be read as requiring that each and every one of those items be present in the grouping, but rather should be read as "and/or" unless expressly stated otherwise. Similarly, a group of items linked with the conjunction "or" should not be read as requiring mutual exclusivity among that group, but rather should also be read as "and/or" unless expressly stated otherwise. Furthermore, although items, elements or components of the disclosed method and apparatus may be described or claimed in the singular, the plural is contemplated to be within the scope thereof unless limitation to the singular is explicitly stated.

[0032] The presence of broadening words and phrases such as "one or more," "at least," "but not limited to" or other like phrases in some instances shall not be read to mean that the narrower case is intended or required in instances where such broadening phrases may be absent. The use of the term "module" does not imply that the components or functionality described or claimed as part of the module are all configured in a common package. Indeed, any or all of the various components of a module, whether control logic or other components, can be combined in a single package or separately maintained and can further be distributed in multiple groupings or packages or across multiple locations.

[0033] Additionally, the various embodiments set forth herein are described in terms of exemplary block diagrams, flow charts, and other illustrations. As will become apparent to one of ordinary skill in the art after reading this document, the illustrated embodiments and their various alternatives can be implemented without confinement to the illustrated examples. For example, block diagrams and their

accompanying description should not be construed as mandating a particular architecture or configuration.

[0034] Several embodiments are specifically illustrated and/or described herein. However, it will be appreciated that modifications and variations of the disclosed embodiments are covered by the above teachings and within the purview of the appended claims without departing from the spirit and intended scope of the invention.

CLAIMS

WHAT IS CLAIMED IS:

1. A method of transmitting and receiving data packets between an Ethernet passive optical network (EPON) optical line terminal (OLT) (10) and at least one coaxial network unit (CNU) (45), the method characterized by:

converting data transmissions over an optical fiber network to data transmissions over a coax network, and data transmissions of the coax network to data transmissions over the optical fiber network, via an optical coax bridge (OCB) (34);

creating in the OCB (34) a set of logical link identifiers (LLIDs) (44) for each CNU (46); and

transmitting (14) and receiving (16) the data packets between the OLT (10) and the at least one CNU (45).

2. The method of claim 1 wherein the OCB (34) emulates an optical network unit (ONU) (40) relative to the OLT (10) and/or the step of the OCB (34) filtering out any data packets from the OLT (10) that are not destined to any of the OCB LLIDs (44), and keeping and forwarding all data packets that are destined for any of the OCB LLIDs (44) and/or the step of controlling the coax network and managing the operation of the coax network by the OCB (34) and/or the step of receiving all the data packets by the OCB (34) from the OLT (10), storing destined data packets, scheduling time-slots on the coax network and transmitting the destined data packets to an appropriate CNU (46) and/or the steps of receiving data packets from the at least one CNU (45) by the OCB (34), storing the data packets according the corresponding LLIDs (44), requesting the OLT (10) for transmission time-slots, waiting for the scheduled time-slots from the OLT (10) and transmitting the data packets to the OLT (10) and/or wherein the OCB (34) comprises a flexible OCB for operating with varying portions of an RF spectrum.

3. A system for transmitting and receiving data packets between an Ethernet passive optical network (EPON) optical line terminal (OLT) (10) and at least one coaxial network unit (CNU) (45) characterized by:

a converter for converting data transmissions over an optical fiber network to data transmissions over a coax network, and data transmissions of the coax network to data transmissions over the optical fiber network, via an optical coax bridge (OCB) (34);

a set of logical link identifiers (LLIDs) (44) for each CNU (46) created in the OCB (34); and

a transceiver (14, 16) for transmitting and receiving the data packets between the OLT (10) and the at least one CNU (45).

4. The system of claim 3 wherein the OCB (34) emulates an optical network unit (ONU) (40) relative to the OLT (10) and/or wherein the OCB (34) further is characterized by a filter for filtering out any data packets from the OLT (10) that are not destined to any of the OCB LLIDs (44), and keeping and forwarding all data packets that are destined for any of the OCB LLIDs (44) and/or wherein the OCB (34) controls the coax network and manages the operation of the coax network and/or wherein the OCB (34) receives all the data packets from the OLT (10), stores destined data packets, schedules time-slots on the coax network and transmits the destined data packets to an appropriate CNU (46) and/or wherein the OCB (34) receives data packets from the at least one CNU (46), stores the data packets according the corresponding LLIDs (44), requests the OLT (10) for transmission time-slots, waits for the scheduled time-slots from the OLT (10), and transmits the data packets to the OLT (10) and/or wherein the OCB (34) is characterized by a flexible OCB for operating with varying portions of an RF spectrum.

5. A non-transitory computer-executable storage medium characterized by program instructions which are computer-executable to implement transmission and receipt of data packets between an Ethernet passive optical network (EPON) optical line terminal (OLT) (10) and at least one coaxial network unit (CNU) (45), the storage medium characterized by:

program instructions that cause a conversion of data transmissions over an optical fiber network to data transmissions over a coax network, and data transmissions of the coax network to data transmissions over the optical fiber network, via an optical coax bridge (OCB) (34);

program instructions that cause a creation in the OCB (34) a set of logical link identifiers (LLIDs) (44) for each CNU (46); and

program instructions that cause a transmission and receipt of the data packets between the OLT (10) and the at least one CNU (46).

6. The non-transitory computer-executable storage medium of claim 5 wherein the OCB (34) emulates an optical network unit (ONU) relative to the OLT (10) and/or further characterized by program instructions that cause a presentation of multiple sets of LLIDs (44) by the OCB (34), with each set of LLIDs (44) representing one CNU (46) and/or further characterized by program instructions that cause the OCB (34)to filter out any data packets from the OLT (10) that are not destined to any of the OCB LLIDs (44), and keeping and forwarding all data packets that are destined for any of the OCB LLIDs (44) and/or further characterized by program instructions that cause the coax network to be controlled and managed by the OCB (34) and/or further characterizes as program instructions that cause all the data packets to be received by the OCB (34) from the OLT (10), storing destined data packets, scheduling time-slots on the coax network and transmitting the destined data packets to an appropriate CNU (46) and/or further characterized by program instructions that cause the OCB (34) to receive data packets from the at least one CNU (45), storing the data packets according the corresponding LLIDs (44), requesting the OLT (10) for transmission time-slots, waiting for the scheduled time-slots from the OLT (10) and transmitting the data packets to the OLT (10) and/or wherein the OCB (34) comprises a flexible OCB for operating with varying portions of an RF spectrum.

7. A method of transmitting and receiving data packets between an Ethernet passive optical network (EPON) optical line terminal (OLT) (10) and at least one coaxial network unit (CNU) (66), the method characterized by:

converting data transmissions over an optical fiber network to data transmissions over a coax network, and data transmissions over the coax network to data transmissions over the optical fiber network, via an optical coax bridge (OCB) (60);

emulating in the OCB (60) M virtual optical network units (vONUs) (56), with each vONU (64) comprising a set of logical link identifiers (LLIDs), each vONU (64) representing one CNU (58), wherein M CNUs (66) are on a coaxial network and the M vONUs (56) are co-located in the OCB (60); and

transmitting (14) and receiving (16) the data packets between the OLT (10) and the at least one CNU (58).

8. The method of claim 7 further characterized by the step of the OCB (60) filtering out any data packets from the OLT (10) that are not destined to any of the OCB vONUs (56), and keeping and forwarding all data packets that are destined for any of the OCB vONUs (56) and/or further characterized by the step of controlling the coax network and managing the operation of the coax network by the OCB (60) and/or further characterized by receiving all the data packets destined to any of the vONUs (56) emulated by the OCB (60), by the OCB (60) from the OLT (10), storing the received tined data packets, scheduling time-slots on the coax network and transmitting the data packets to an appropriate CNU (58) and/or further characterized by the steps of receiving data packets from the at least one CNU (58) by the OCB (60) that are destined to the OLT (10), storing the data packets according the corresponding vONUs (56) and its associated LLIDs, requesting the OLT (10) for transmission time-slots, waiting for the scheduled time-slots from the OLT (10) and transmitting the data packets to the OLT (10) and/or wherein the OCB (60) comprises a flexible OCB for operating with varying portions of an RF spectrum.

9. A system for transmitting and receiving data packets between an Ethernet passive optical network (EPON) optical line terminal (OLT) (10) and at least one coaxial network unit (CNU) (66), the method characterized by:

a converter for converting data transmissions over an optical fiber network to data transmissions over a coax network, and data transmissions over the coax network to data transmissions over the optical fiber network, via an optical coax bridge (OCB) (60);

an emulator for emulating in the OCB (60) M virtual optical network units (vONUs) (56), with each vONU (64) comprising a set of logical link identifiers (LLIDs),

each vONU (64) representing one CNU (58), wherein M CNUs (66) are on a coaxial network and the M vONUs (56) are co-located in the OCB (60); and

a transceiver (14, 16) for transmitting and receiving the data packets between the OLT (10) and the at least one CNU (58).

10. The system of claim 9 further characterized by a filter for filtering out any data packets from the OLT (10) that are not destined to any of the OCB vONUs (56), and keeping and forwarding all data packets that are destined for any of the OCB vONUs (56) and/or further characterized by a controller for controlling the coax network and managing the operation of the coax network by the OCB (60) and/or further characterized by the OCB (60) receiving all the data packets destined to any of the vONUs (56) emulated by the OCB (60) from the OLT (10), storing the received destined data packets, scheduling time-slots on the coax network and transmitting the data packets to an appropriate CNU (58) and/or further characterized by the OCB (60) receiving data packets from the at least one CNU (66) that are destined to the OLT (10), storing the data packets according the corresponding vONUs (56) and its associated LLIDs, requesting the OLT (10) for transmission time-slots, waiting for the scheduled time-slots from the OLT (10) and transmitting the data packets to the OLT (10) and/or wherein the OCB (60) comprises a flexible OCB for operating with varying portions of an RF spectrum.

11. A non-transitory computer-executable storage medium comprising program instructions which are computer-executable to implement transmission and receipt of data packets between an Ethernet passive optical network (EPON) optical line terminal (OLT) (10) and at least one coaxial network unit (CNU) (66), the storage medium characterized by:

program instructions that cause a conversion of data transmissions over an optical fiber network to data transmissions over a coax network, and data transmissions over the coax network to data transmissions over the optical fiber network, via an optical coax bridge (OCB) (60);

program instructions that cause an emulation in the OCB (60) M virtual optical network units (vONUs) (56), with each vONU (64) comprising a set of logical link

identifiers (LLIDs), each vONU (64) representing one CNU (46), wherein M CNUs (46) are on a coaxial network and the M vONUs (56) are co-located in the OCB (34); and

program instructions that cause a transmission and receipt of the data packets between the OLT (10) and the at least one CNU (58).

12. The non-transitory computer-executable storage medium of claim 11 further characterized by program instructions that cause the OCB (60) to filter out any data packets from the OLT (10) that are not destined to any of the OCB vONUs (56), and keeping and forwarding all data packets that are destined for any of the OCB vONUs (56) and/or further characterized by program instructions that cause the coax network to be controlled and managed the operation of the coax network by the OCB (60) and/or further characterized by program instructions that cause the OCB (60) to receive all the data packets destined to any of the vONUs (56) emulated by the OCB (60) from the OLT (10) , store the received tined data packets, schedule time-slots on the coax network and transmit the data packets to an appropriate CNU (58) and/or further characterized by program instructions that cause the OCB (60) to receive data packets from the at least one CNU (58) that are destined to the OLT (10), store the data packets according the corresponding vONUs and its associated LLIDs, request the OLT (10) for transmission time-slots, wait for the scheduled time-slots from the OLT (10) and transmit the data packets to the OLT (10) and/or wherein the OCB (60) comprises a flexible OCB for operating with varying portions of an RF spectrum.

13. A method of transmitting and receiving data packets between a first access network, an Ethernet passive optical network (EPON) optical line terminal (OLT) (10) and at least one second network (45), the method is characterized by:

converting data transmissions over the first access network comprising, an optical fiber network, to data transmissions over the at least one second access medium network, and data transmissions of the at least one second access medium network to data transmissions over the first access network, via a bridge (34);

creating in the bridge (34) a set of logical link identifiers (LLIDs) (44) for each network unit of the at least one second access network (46); and

transmitting (14) and receiving (16) the data packets between the OLT (10) and the network unit of the at least one second access medium network (45).

14. The method of claim 13 wherein the at least one second access network (45) comprises a member from the group consisting of a c.LINK network, a standardized coaxial cable based network, a WiFi network, a DOCSIS network, a HomePlug network, a HPNA network, and a G.Hn network.

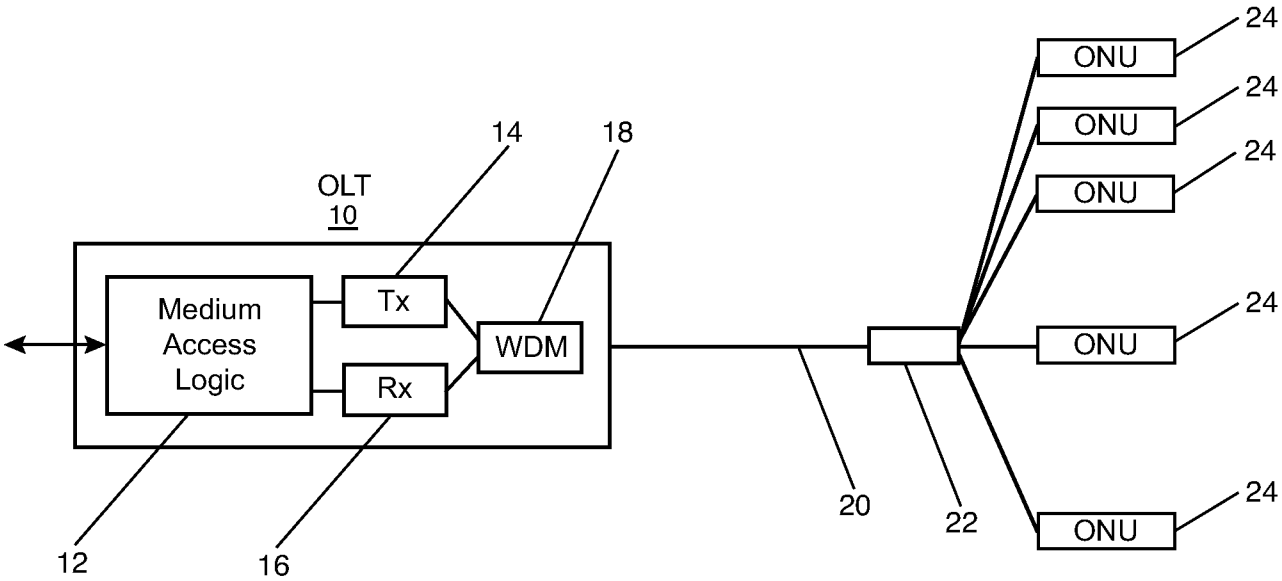

FIG. 1
Prior Art

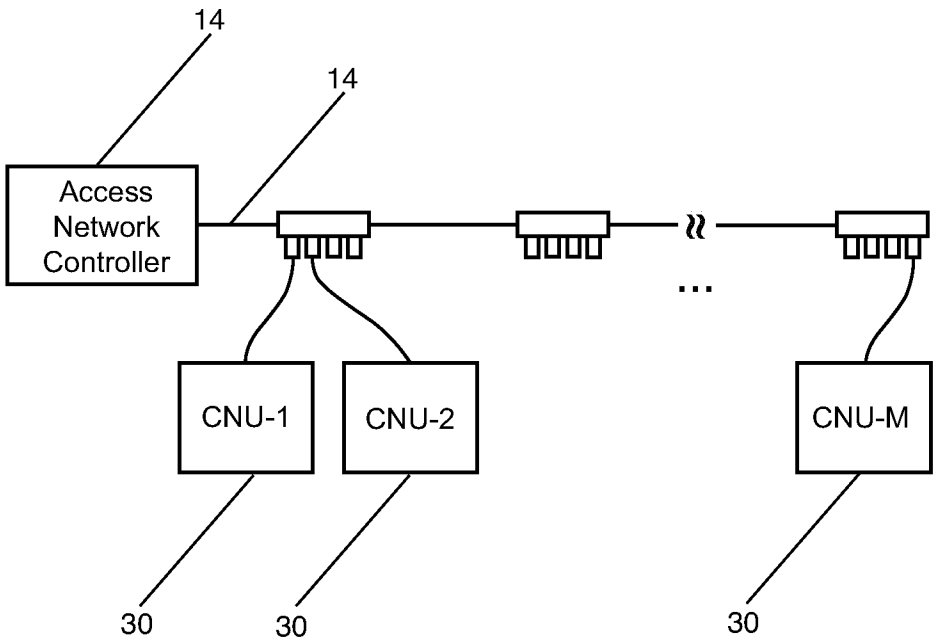

FIG. 2
Prior Art

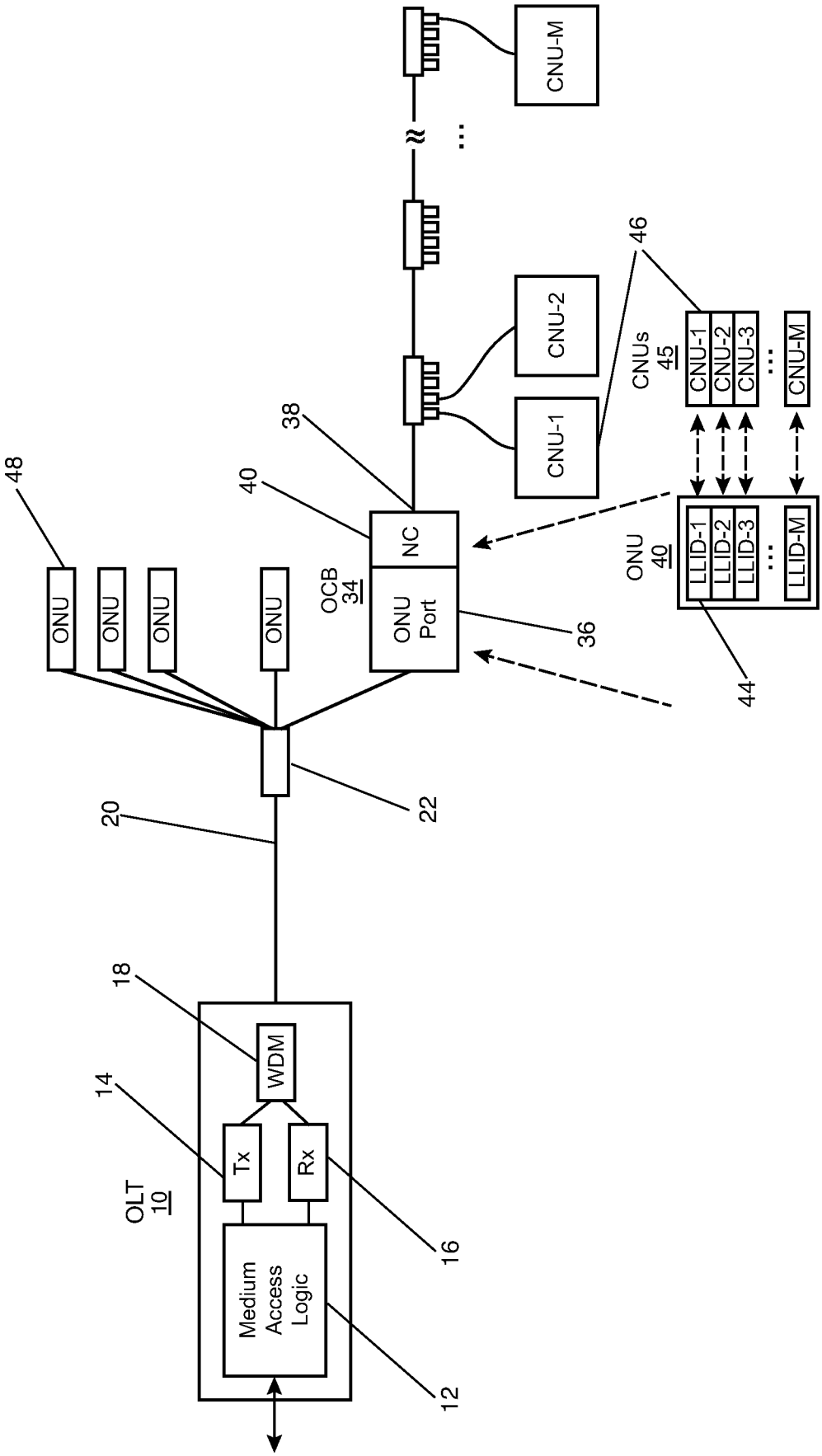
OLT
10
Medium Access Logic
12
Tx
14
Rx
16
WDM
18
20
22
ONU
ONU
ONU
ONU
48
OCB
34
NC
ONU Port
36
38
40
CNU-1
CNU-2
CNU-M
CNUs
45
46
ONU
40
LLID-1
LLID-2
LLID-3
LLID-M
44

FIG. 3

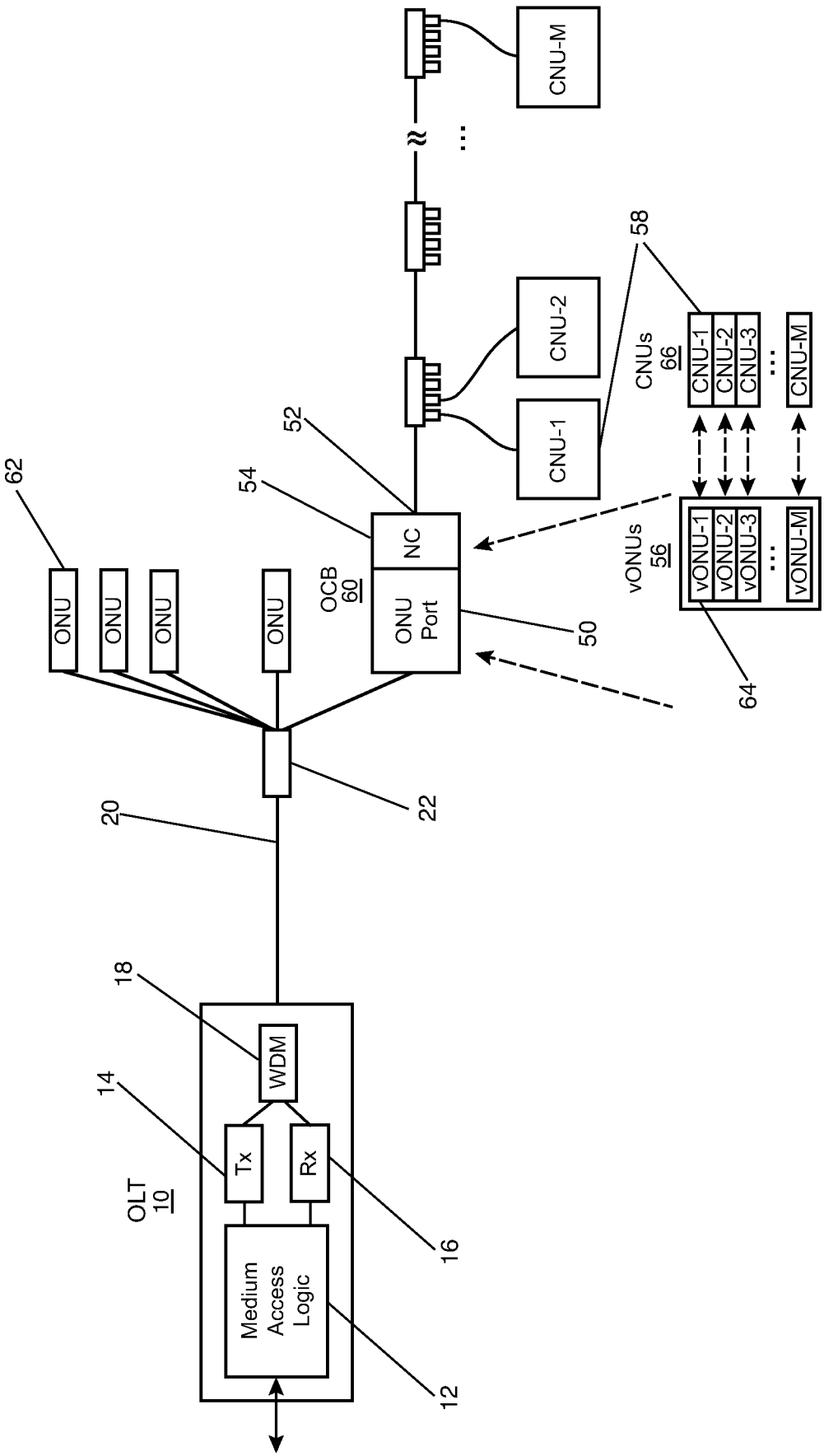
OLT
10
Medium Access Logic
12
Tx
14
Rx
16
WDM
18
20
22
ONU
ONU
ONU
ONU
62
OCB
60
NC
ONU Port
50
52
54
CNU-1
CNU-2
CNU-M
58
CNUs
66
CNU-1
CNU-2
CNU-3
CNU-M
vONUs
56
vONU-1
vONU-2
vONU-3
vONU-M
64

FIG. 4

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US13/29923

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - H04J 14/00 (2013.01)
USPC - 398/68
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)
IPC(8): H04J 14/00; H04L 12/28 (2013.01)
USPC: 398/68; 370/401

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)
MicroPatent (US-G, US-A, EP-A, EP-B, WO, JP-bib, DE-C,B, DE-A, DE-T, DE-U, GB-A, FR-A); Google/Google Scholar; IEEE; DialogPRO; Ethernet, passive, optical, network, EPON, optical, line, terminal, OLT, coaxial, unit, CNU, coax, bridge, OCB, logical, link, identifier, LLID, virtual, packets, vCNU, vONU

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2011/0058813 A1 (BOYD E et al.) March 10, 2011, paragraphs [0018], [0019], [0022], [0026], [0031], [0039], [0042]	1-14
A	US 2005/0058118 A1 (DAVIS L et al.) March 17, 2005, abstract and paragraphs [0016], [0074]	1-14
A	US 2006/0039390 A1 (BOYD E et al.) February 23, 2006, paragraphs [0053]-[0055]	1-14
A	US 2006/0182132 A1 (KIM S et al.) August 17, 2006, paragraphs [0012], [0013]	1-14
A	US 2010/0124420 A1 (SHIOTA M) May 20, 2010, paragraphs [0015], [0016]	1-14

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

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"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
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"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	Date of mailing of the international search report
21 June 2013 (21.06.2013)	10 JUL 2013
Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-3201	Authorized officer: Shane Thomas PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US13/29923

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

Group I: Claims 1-6; Group II: Claims 7-12; Group III: Claims 13 and 14

This application contains the following inventions or groups of inventions which are not so linked as to form a single general inventive concept under PCT Rule 13.1. In order for all inventions to be examined, the appropriate additional examination fee must be paid.

Group I: Claims 1-6 are directed toward a method of transmitting and receiving data packets between an Ethernet passive optical network (EPON) optical line terminal (OLT) (10) and at least one coaxial network unit (CNU) (45), the method characterized by: converting data transmissions over an optical fiber network to data transmissions over a coax network, and data transmissions of the coax network to data transmissions over the optical fiber network, via an optical coax bridge (OCB) (34); creating in the OCB (34) a set of logical link identifiers (LLIDs) (44) for each CNU (46); and transmitting (14) and receiving (16) the data packets between the OLT (10) and the at least one CNU (45).
-***-Continued Within the Extra Page-***-

1. ☒ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US13/29923

-Continued from Box No. III: Observations where unity of invention is lacking-

Group II: Claims 7-12 are directed toward a method of transmitting and receiving data packets between an Ethernet passive optical network (EPON) optical line terminal (OLT) (10) and at least one coaxial network unit (CNU) (66), the method characterized by: converting data transmissions over an optical fiber network to data transmissions over a coax network, and data transmissions over the coax network to data transmissions over the optical fiber network, via an optical coax bridge (OCB) (60); emulating in the OCB (60) M virtual optical network units (vONUs) (56), with each vONU (64) comprising a set of logical link identifiers (LLIDs), each vONU (64) representing one CNU (58), wherein M CNUs (66) are on a coaxial network and them vONUs (56) are co-located in the OCB (60); and transmitting (14) and receiving (16) the data packets between the OLT (10) and the at least one CNU (58).

Group III: Claims 13 and 14 are directed toward a method of transmitting and receiving data packets between a first access network, an Ethernet passive optical network (EPON) optical line terminal (OLT) (10) and at least one second network (45), the method is characterized by: converting data transmissions over the first access network comprising, an optical fiber network, to data transmissions over the at least one second access medium network, and data transmissions of the at least one second access medium network to data transmissions over the first access network, via a bridge (34); creating in the bridge (34) a set of logical link identifiers (LLIDs) (44) for each network unit of the at least one second access network (46); and transmitting (14) and receiving (16) the data packets between the OLT (10) and the network unit of the at least one second access medium network (45).

The common technical feature shared by Groups I, II and III are a method of transmitting and receiving data packets between an Ethernet passive optical network (EPON) optical line terminal (OLT) (10) and at least one coaxial network unit (CNU) (45). However, this common feature is previously disclosed by US 2011/0058813 A1 (Boyd). Boyd discloses a method of transmitting and receiving data packets between an Ethernet passive optical network (EPON) optical line terminal (OLT) (10) and at least one coaxial network unit (CNU) (45) (a EPON MAC to be used end-to-end from an optical line terminal to a coaxial network unit, abstract).

Since the common technical feature is previously disclosed by the Boyd reference, this common feature is not special and so Groups I, II and III lack unity.