US008160448B2

(12) **United States Patent**
Tsuge et al.

(10) **Patent No.: US 8,160,448 B2**
(45) **Date of Patent: *Apr. 17, 2012**

(54) **COMMUNICATION SYSTEM USING PASSIVE OPTICAL NETWORK AND PASSIVE OPTICAL NETWORK**

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(73) Assignee: **Hitachi, Ltd.**, Tokyo (JP)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 283 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **12/405,455**

(22) Filed: **Mar. 17, 2009**

(65) **Prior Publication Data**

US 2009/0232498 A1 Sep. 17, 2009

Related U.S. Application Data

(63) Continuation-in-part of application No. 12/147,616, filed on Jun. 27, 2008.

(30) **Foreign Application Priority Data**

Oct. 17, 2007 (JP) 2007-269647
Oct. 10, 2008 (JP) 2008-263388

(51) **Int. Cl.**
H04B 13/02 (2006.01)

(52) **U.S. Cl.** **398/115**; 398/116; 398/74; 398/66; 398/58

(58) **Field of Classification Search** 398/45, 398/58, 66, 67, 70–72, 115, 116, 74
See application file for complete search history.

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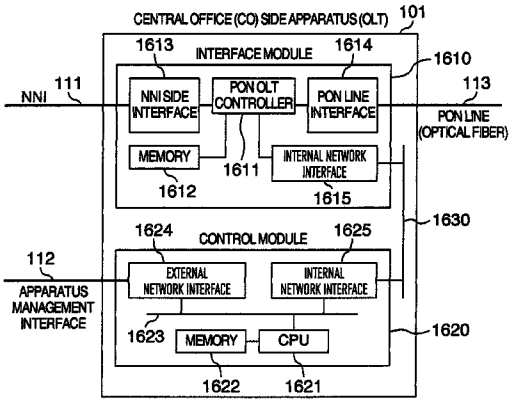
(Continued)

Primary Examiner — Kenneth N Vanderpuye
Assistant Examiner — Hibret Woldekidan
(74) *Attorney, Agent, or Firm* — Antonelli, Terry, Stout & Kraus, LLP.

(57) **ABSTRACT**

An OLT transmits and receives a CMTS/CM apparatus control signal through an apparatus physical management interface which is physically identical to or different from a main signal interface (NNI) and processes the CMTS apparatus control signal by itself. When connection of a new ONU is detected by an ONU apparatus control signal, an IP address is allocated by using the CM apparatus control signal in a manner similar to the CM. The CM apparatus control signal regarding the ONU is transmitted and received by using the IP address and a mutual conversion is performed between the CM apparatus control signal and the ONU apparatus control signal. The ONU processes the ONU apparatus control signal in a manner similar to the ONU based on an ordinary PON standard.

7 Claims, 17 Drawing Sheets



Charter Communications, Inc. - Exhibit 1006
Charter Communications, Inc. v. Iarnach Technologies, Ltd.

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Bernstein et al., "A Proposal for DOCSIS® 4.0: The Best of Both Worlds, DOCSIS and PON", Emerging Technologies Jan. 15, 2008.

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FIG.1

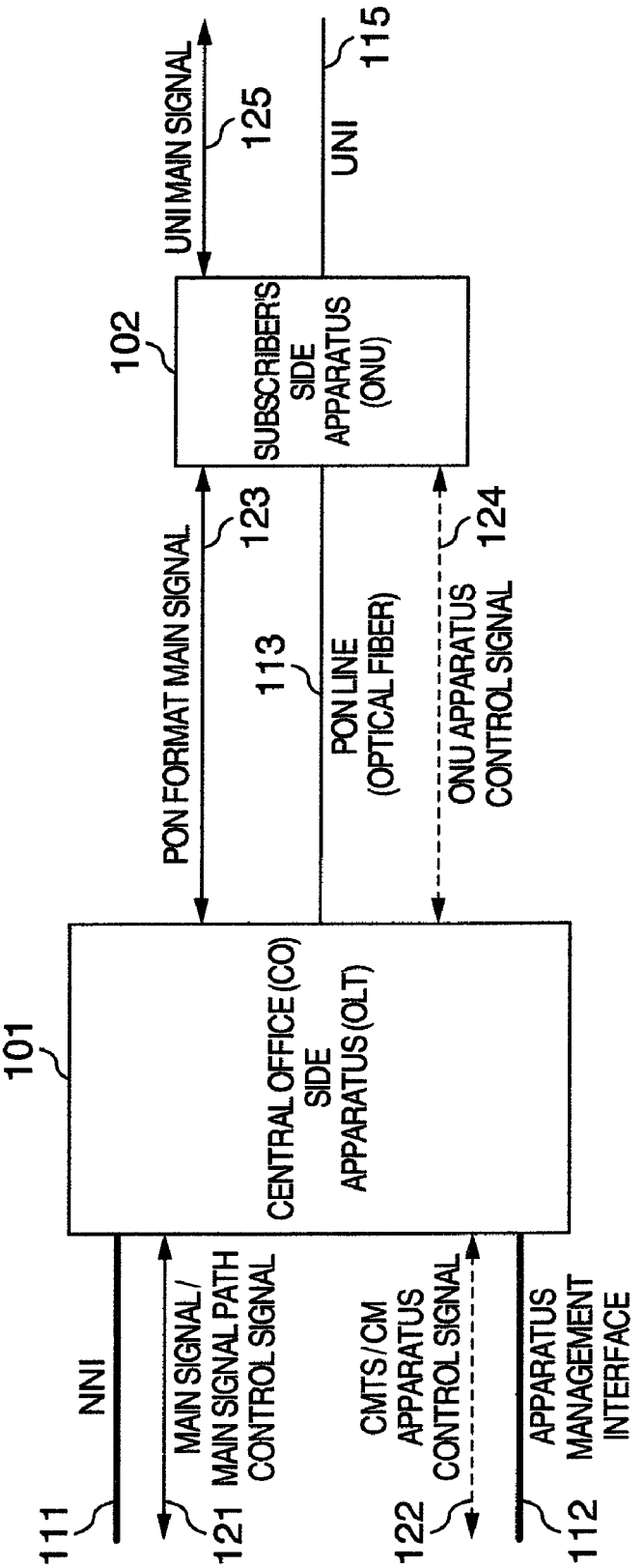

101
CENTRAL OFFICE (CO) SIDE APPARATUS (OLT)
102
SUBSCRIBER'S SIDE APPARATUS (ONU)
111
NNI
121
MAIN SIGNAL / MAIN SIGNAL PATH CONTROL SIGNAL
122
CMTS / CM APPARATUS CONTROL SIGNAL
112
APPARATUS MANAGEMENT INTERFACE
113
PON LINE (OPTICAL FIBER)
123
PON FORMAT MAIN SIGNAL
124
ONU APPARATUS CONTROL SIGNAL
125
UNI MAIN SIGNAL
115
UNI

FIG.2

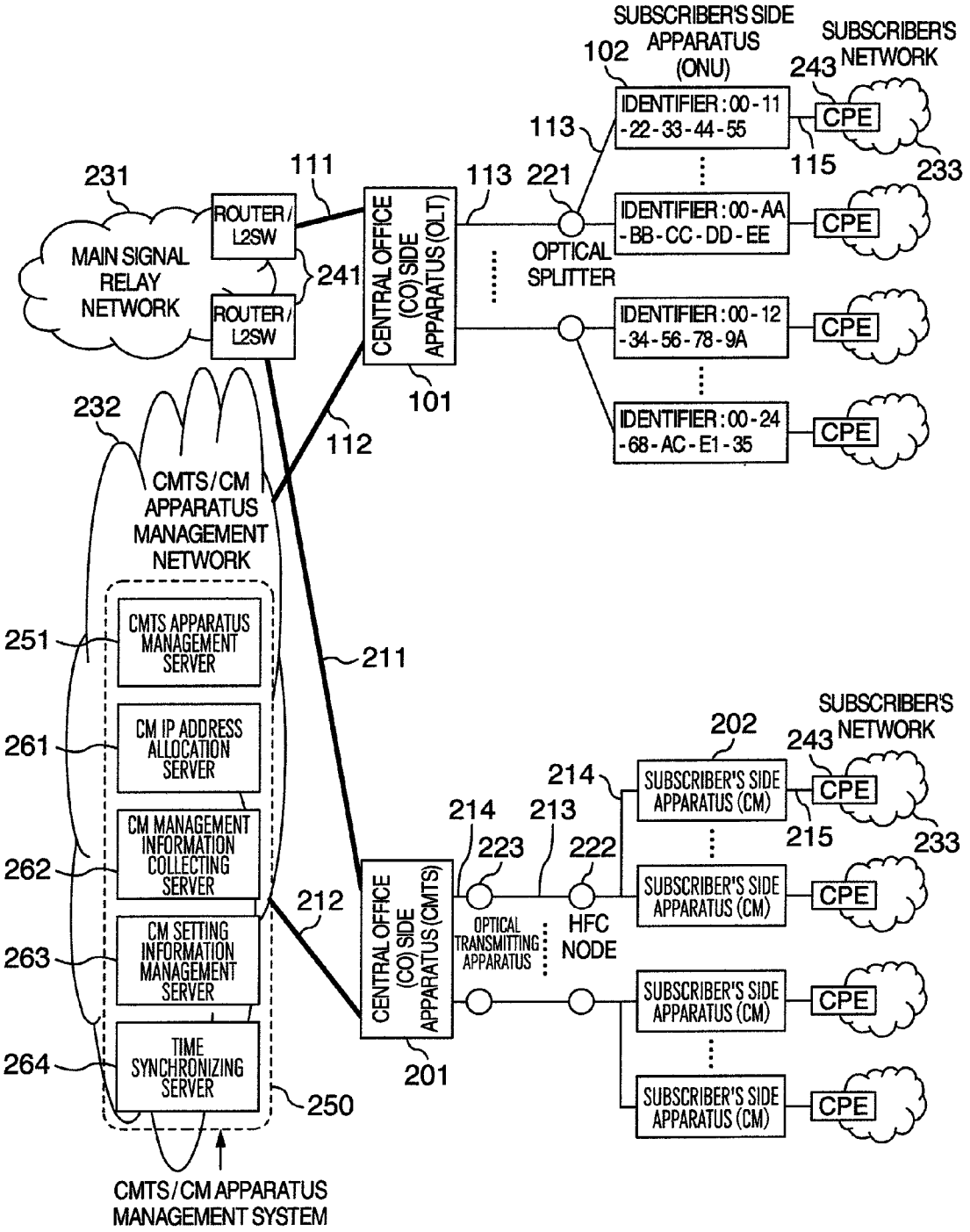

SUBSCRIBER'S SIDE APPARATUS (ONU)
102
SUBSCRIBER'S NETWORK
243
IDENTIFIER:00-11-22-33-44-55
113
115
CPE
233
231
111
113
221
ROUTER/L2SW
MAIN SIGNAL RELAY NETWORK
241
ROUTER/L2SW
CENTRAL OFFICE (CO) SIDE APPARATUS (OLT)
OPTICAL SPLITTER
IDENTIFIER:00-AA-BB-CC-DD-EE
IDENTIFIER:00-12-34-56-78-9A
IDENTIFIER:00-24-68-AC-E1-35
101
232
112
CMTS/CM APPARATUS MANAGEMENT NETWORK
CMTS APPARATUS MANAGEMENT SERVER
251
211
CM IP ADDRESS ALLOCATION SERVER
261
CM MANAGEMENT INFORMATION COLLECTING SERVER
262
CM SETTING INFORMATION MANAGEMENT SERVER
263
212
TIME SYNCHRONIZING SERVER
264
250
CENTRAL OFFICE (CO) SIDE APPARATUS (CMTS)
201
OPTICAL TRANSMITTING APPARATUS
214
223
213
222
HFC NODE
202
SUBSCRIBER'S SIDE APPARATUS (CM)
215
CMTS/CM APPARATUS MANAGEMENT SYSTEM

FIG.3

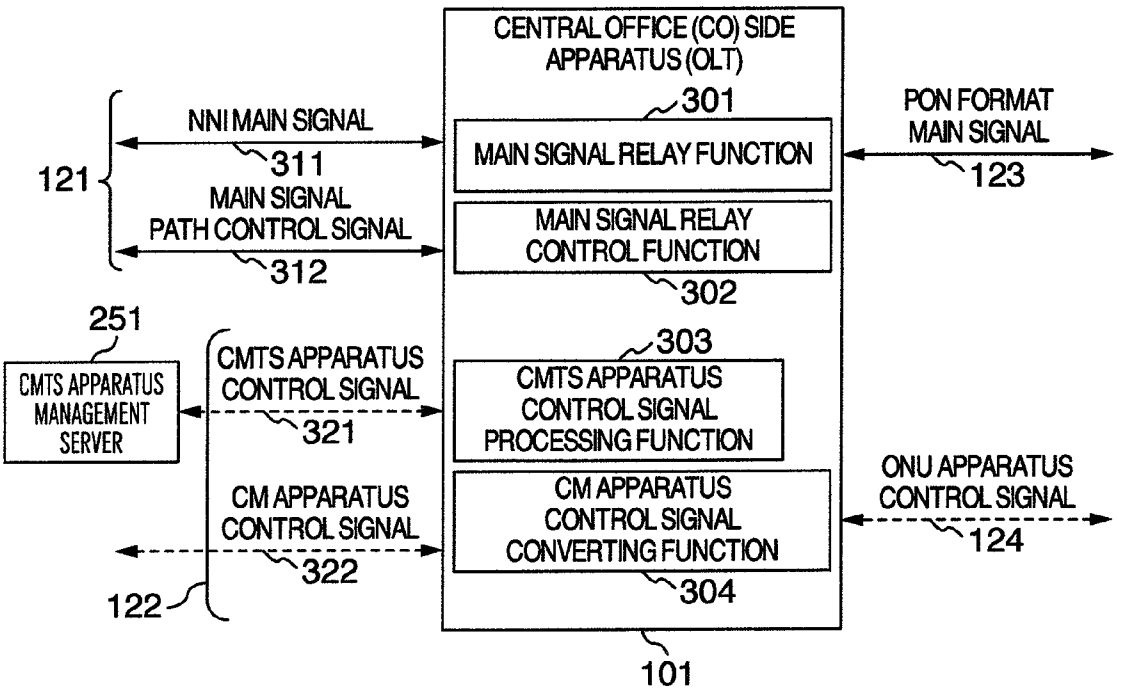

CENTRAL OFFICE (CO) SIDE APPARATUS (OLT)
301
MAIN SIGNAL RELAY FUNCTION
MAIN SIGNAL RELAY CONTROL FUNCTION
302
303
CMTS APPARATUS CONTROL SIGNAL PROCESSING FUNCTION
CM APPARATUS CONTROL SIGNAL CONVERTING FUNCTION
304
101
NNI MAIN SIGNAL
311
MAIN SIGNAL PATH CONTROL SIGNAL
312
121
PON FORMAT MAIN SIGNAL
123
251
CMTS APPARATUS MANAGEMENT SERVER
CMTS APPARATUS CONTROL SIGNAL
321
CM APPARATUS CONTROL SIGNAL
322
122
ONU APPARATUS CONTROL SIGNAL
124

FIG.4

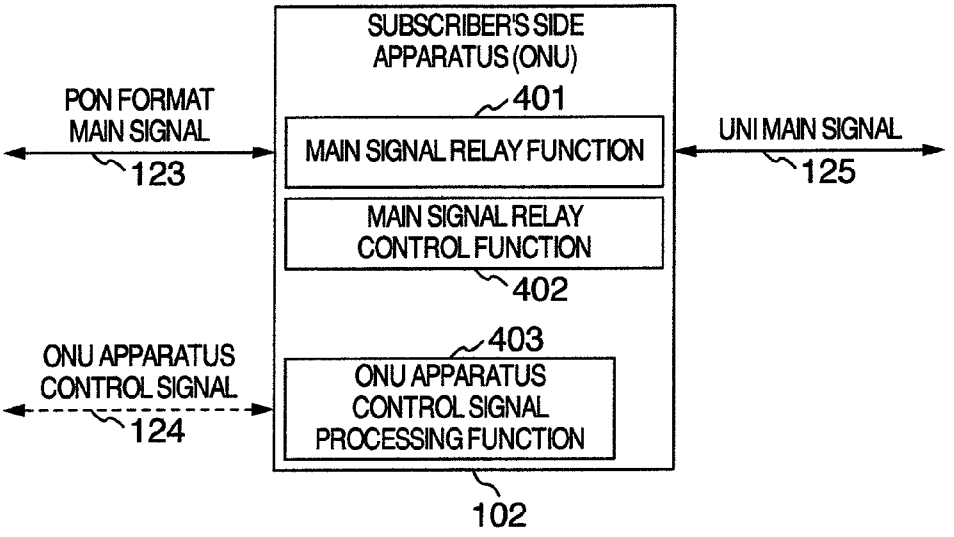

SUBSCRIBER'S SIDE APPARATUS (ONU)
401
MAIN SIGNAL RELAY FUNCTION
MAIN SIGNAL RELAY CONTROL FUNCTION
402
403
ONU APPARATUS CONTROL SIGNAL PROCESSING FUNCTION
102
PON FORMAT MAIN SIGNAL
123
UNI MAIN SIGNAL
125
ONU APPARATUS CONTROL SIGNAL
124

FIG.5

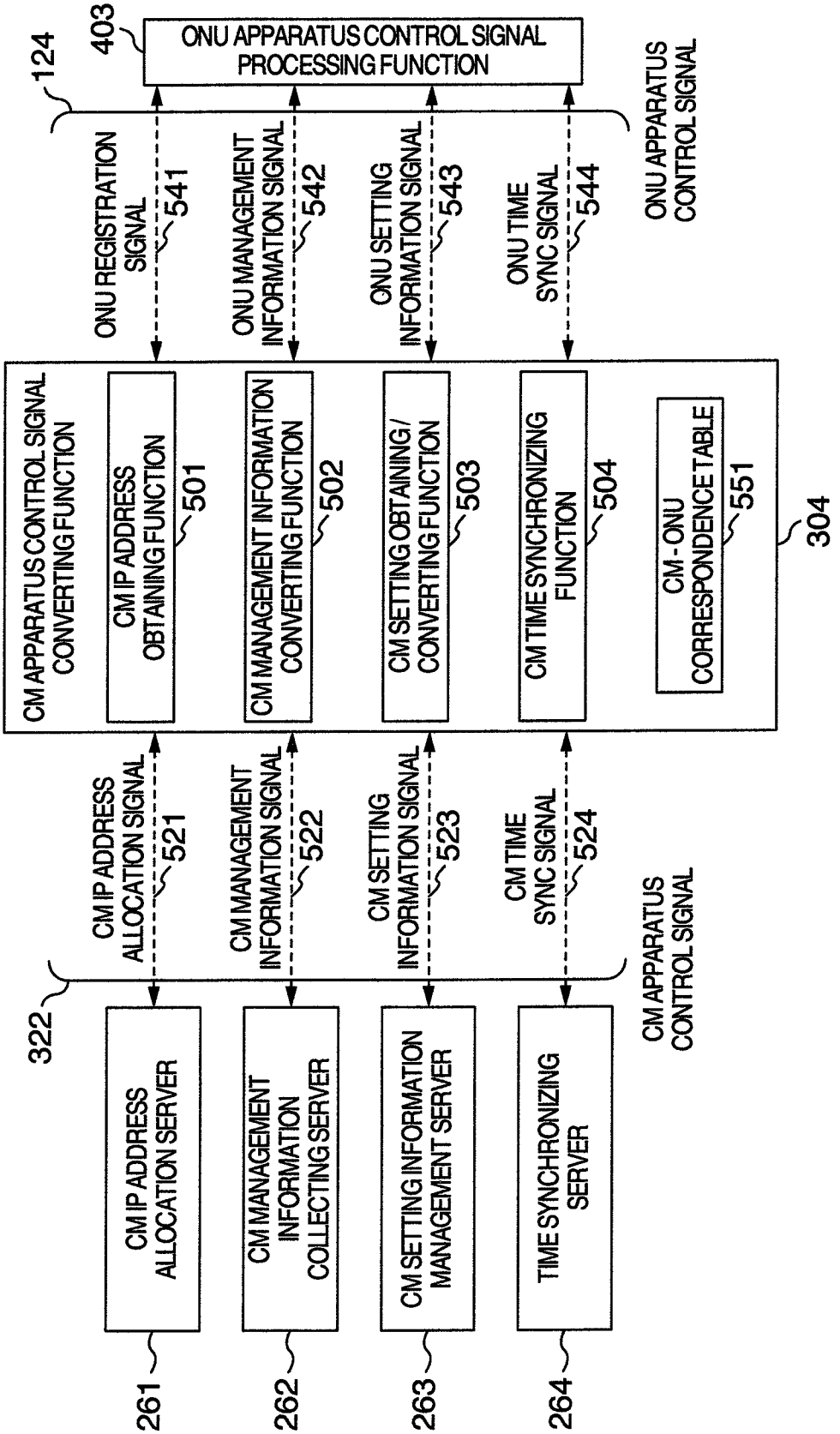

124
403
ONU APPARATUS CONTROL SIGNAL PROCESSING FUNCTION
ONU APPARATUS CONTROL SIGNAL
ONU REGISTRATION SIGNAL
541
ONU MANAGEMENT INFORMATION SIGNAL
542
ONU SETTING INFORMATION SIGNAL
543
ONU TIME SYNC SIGNAL
544
CM APPARATUS CONTROL SIGNAL CONVERTING FUNCTION
CM IP ADDRESS OBTAINING FUNCTION
501
CM MANAGEMENT INFORMATION CONVERTING FUNCTION
502
CM SETTING OBTAINING/ CONVERTING FUNCTION
503
CM TIME SYNCHRONIZING FUNCTION
504
CM - ONU CORRESPONDENCE TABLE
551
304
CM IP ADDRESS ALLOCATION SIGNAL
521
CM MANAGEMENT INFORMATION SIGNAL
522
CM SETTING INFORMATION SIGNAL
523
CM TIME SYNC SIGNAL
524
CM APPARATUS CONTROL SIGNAL
322
CM IP ADDRESS ALLOCATION SERVER
CM MANAGEMENT INFORMATION COLLECTING SERVER
CM SETTING INFORMATION MANAGEMENT SERVER
TIME SYNCHRONIZING SERVER
261
262
263
264

FIG.6

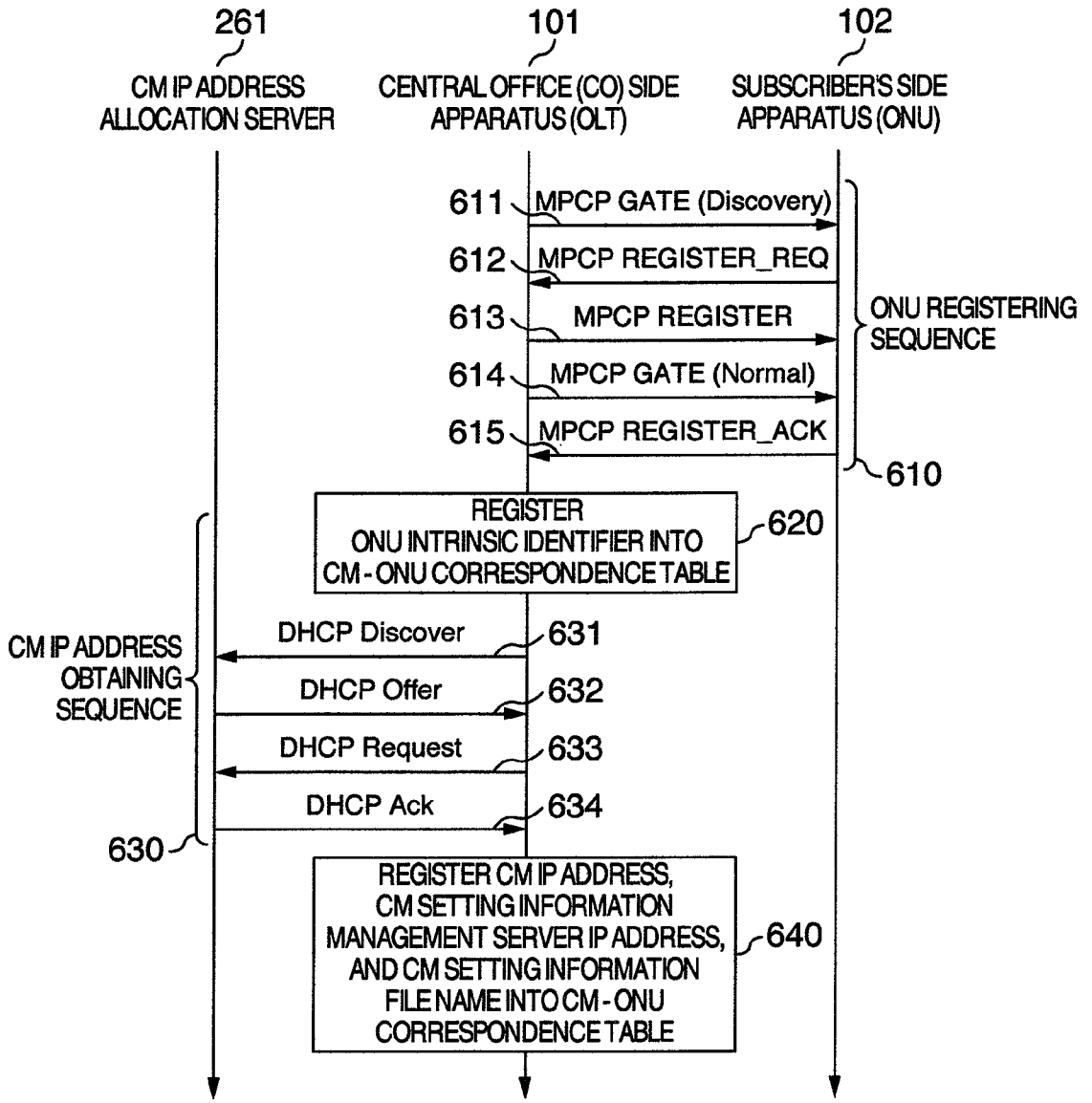

261
CM IP ADDRESS ALLOCATION SERVER
101
CENTRAL OFFICE (CO) SIDE APPARATUS (OLT)
102
SUBSCRIBER'S SIDE APPARATUS (ONU)
611 MPCP GATE (Discovery)
612 MPCP REGISTER_REQ
613 MPCP REGISTER
614 MPCP GATE (Normal)
615 MPCP REGISTER_ACK
ONU REGISTERING SEQUENCE
610
REGISTER ONU INTRINSIC IDENTIFIER INTO CM - ONU CORRESPONDENCE TABLE
620
CM IP ADDRESS OBTAINING SEQUENCE
DHCP Discover 631
DHCP Offer 632
DHCP Request 633
DHCP Ack 634
630
REGISTER CM IP ADDRESS, CM SETTING INFORMATION MANAGEMENT SERVER IP ADDRESS, AND CM SETTING INFORMATION FILE NAME INTO CM - ONU CORRESPONDENCE TABLE
640

FIG.7

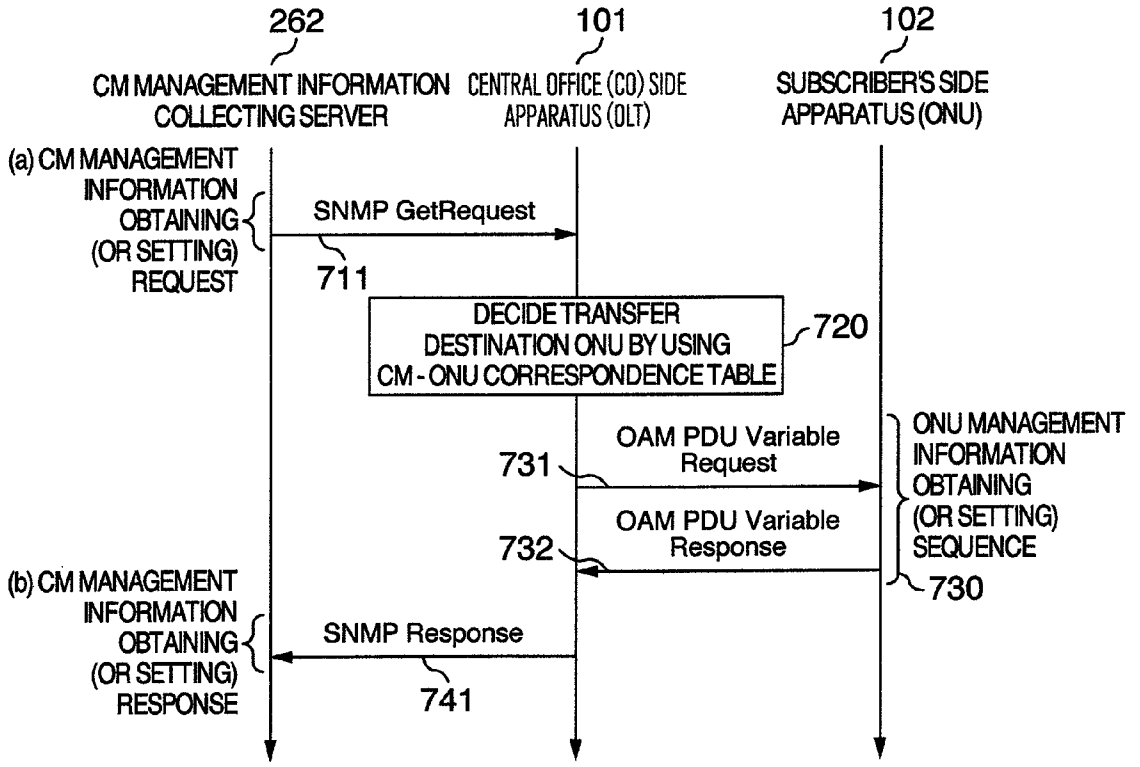

262
101
102
CM MANAGEMENT INFORMATION COLLECTING SERVER
CENTRAL OFFICE (CO) SIDE APPARATUS (OLT)
SUBSCRIBER'S SIDE APPARATUS (ONU)
(a) CM MANAGEMENT INFORMATION OBTAINING (OR SETTING) REQUEST
SNMP GetRequest
711
DECIDE TRANSFER DESTINATION ONU BY USING CM-ONU CORRESPONDENCE TABLE
720
OAM PDU Variable Request
731
OAM PDU Variable Response
732
ONU MANAGEMENT INFORMATION OBTAINING (OR SETTING) SEQUENCE
730
(b) CM MANAGEMENT INFORMATION OBTAINING (OR SETTING) RESPONSE
SNMP Response
741

FIG.8

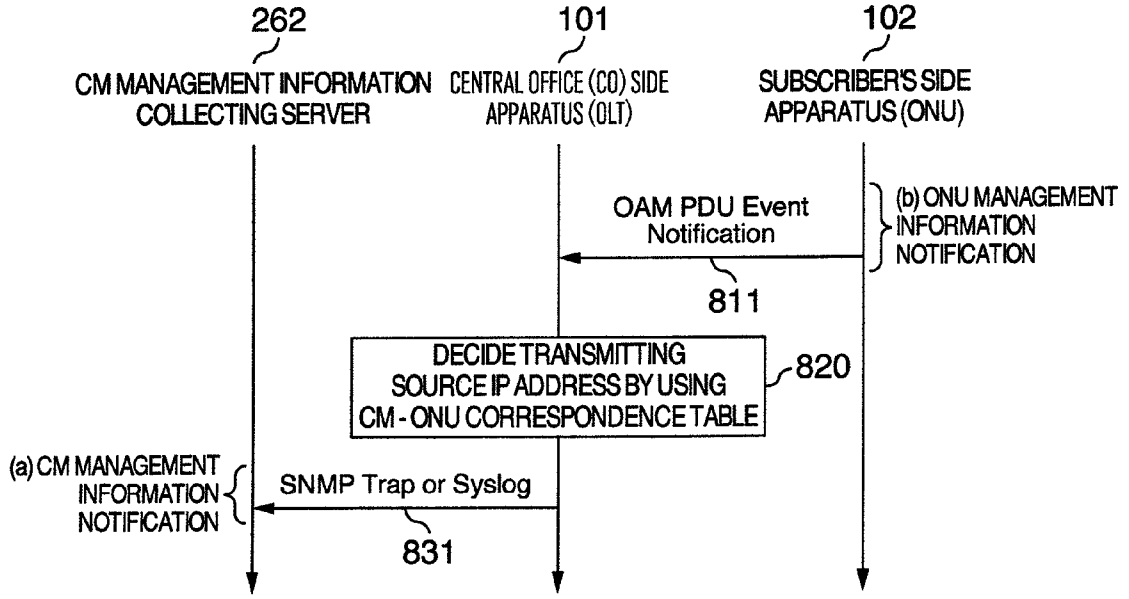

262
101
102
CM MANAGEMENT INFORMATION COLLECTING SERVER
CENTRAL OFFICE (CO) SIDE APPARATUS (OLT)
SUBSCRIBER'S SIDE APPARATUS (ONU)
OAM PDU Event Notification
811
(b) ONU MANAGEMENT INFORMATION NOTIFICATION
DECIDE TRANSMITTING SOURCE IP ADDRESS BY USING CM-ONU CORRESPONDENCE TABLE
820
(a) CM MANAGEMENT INFORMATION NOTIFICATION
SNMP Trap or Syslog
831

FIG.9

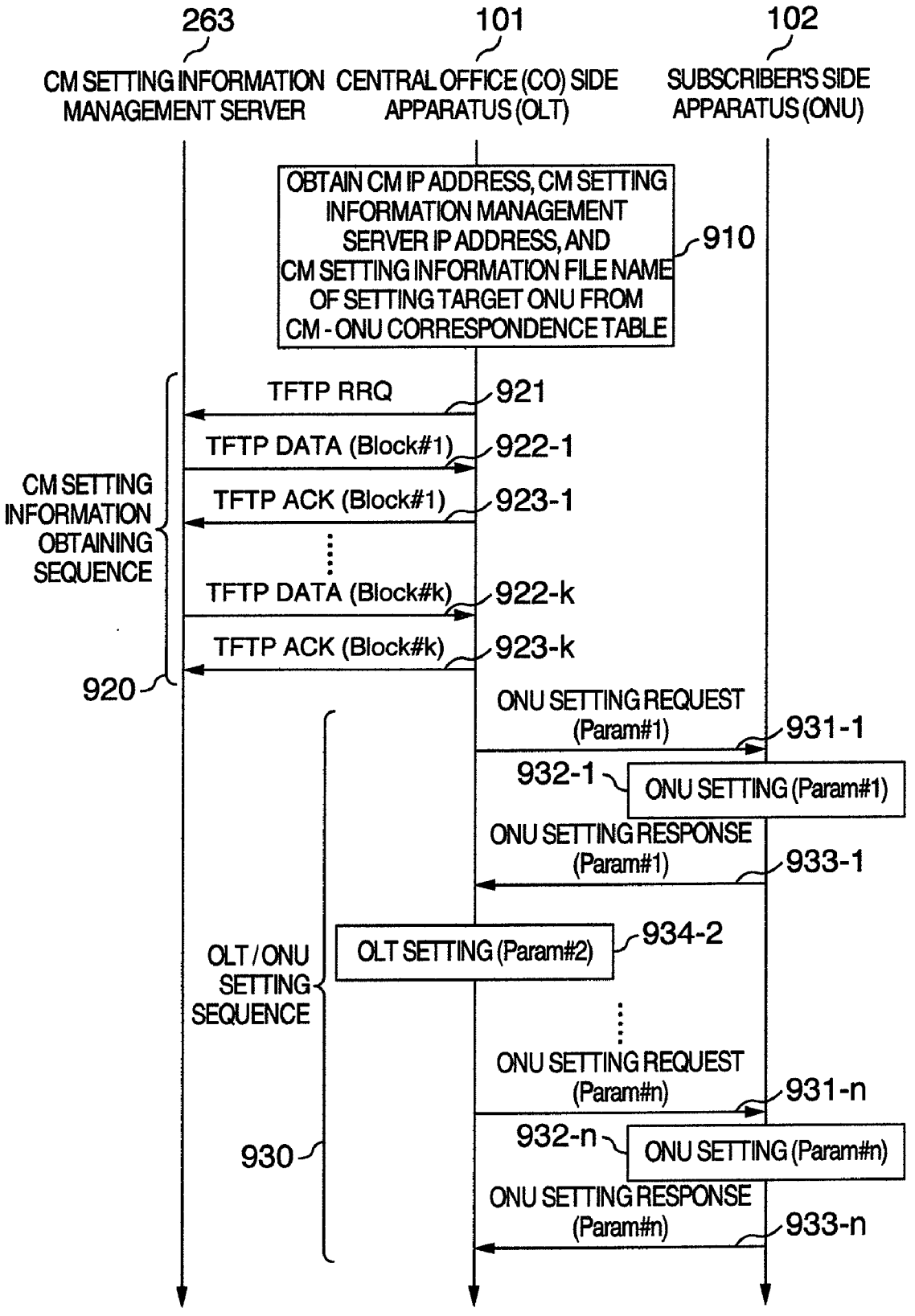

263
101
102
CM SETTING INFORMATION MANAGEMENT SERVER
CENTRAL OFFICE (CO) SIDE APPARATUS (OLT)
SUBSCRIBER'S SIDE APPARATUS (ONU)
OBTAIN CM IP ADDRESS, CM SETTING INFORMATION MANAGEMENT SERVER IP ADDRESS, AND CM SETTING INFORMATION FILE NAME OF SETTING TARGET ONU FROM CM - ONU CORRESPONDENCE TABLE
910
TFTP RRQ
921
TFTP DATA (Block#1)
922-1
TFTP ACK (Block#1)
923-1
CM SETTING INFORMATION OBTAINING SEQUENCE
TFTP DATA (Block#k)
922-k
TFTP ACK (Block#k)
923-k
920
ONU SETTING REQUEST (Param#1)
931-1
932-1
ONU SETTING (Param#1)
ONU SETTING RESPONSE (Param#1)
933-1
OLT SETTING (Param#2)
934-2
OLT / ONU SETTING SEQUENCE
ONU SETTING REQUEST (Param#n)
931-n
932-n
ONU SETTING (Param#n)
930
ONU SETTING RESPONSE (Param#n)
933-n

FIG.10

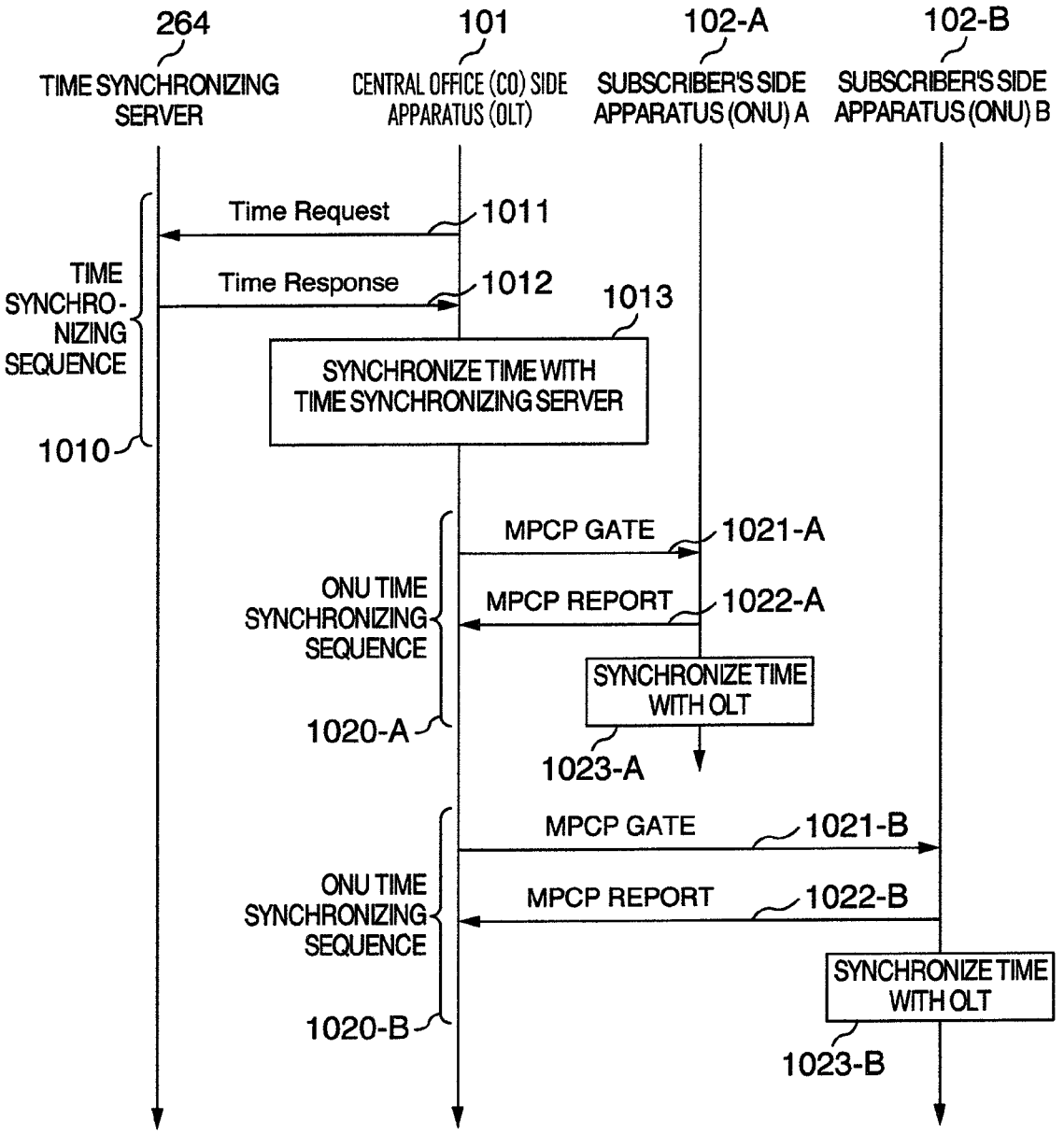

264
TIME SYNCHRONIZING SERVER
101
CENTRAL OFFICE (CO) SIDE APPARATUS (OLT)
102-A
SUBSCRIBER'S SIDE APPARATUS (ONU) A
102-B
SUBSCRIBER'S SIDE APPARATUS (ONU) B
Time Request
1011
Time Response
1012
1013
TIME SYNCHRO-NIZING SEQUENCE
SYNCHRONIZE TIME WITH TIME SYNCHRONIZING SERVER
1010
MPCP GATE
1021-A
ONU TIME SYNCHRONIZING SEQUENCE
MPCP REPORT
1022-A
SYNCHRONIZE TIME WITH OLT
1020-A
1023-A
MPCP GATE
1021-B
ONU TIME SYNCHRONIZING SEQUENCE
MPCP REPORT
1022-B
SYNCHRONIZE TIME WITH OLT
1020-B
1023-B

FIG.11

551

1101 CM IP ADDRESS	1102 CM SETTING INFORMATION MANAGEMENT SERVER IP ADDRESS	1103 CM SETTING INFORMATION FILE NAME	1104 ONU INTRINSIC IDENTIFIER
10.1.2.3	10.100.1.253	default.cm	00-11-22-33-44-55
10.1.2.4	10.100.1.253	default.cm	00-AA-BB-CC-DD-EE
10.1.2.129	10.100.1.253	premium.cm	00-12-34-56-78-9A
⋮	⋮	⋮	⋮

FIG.12

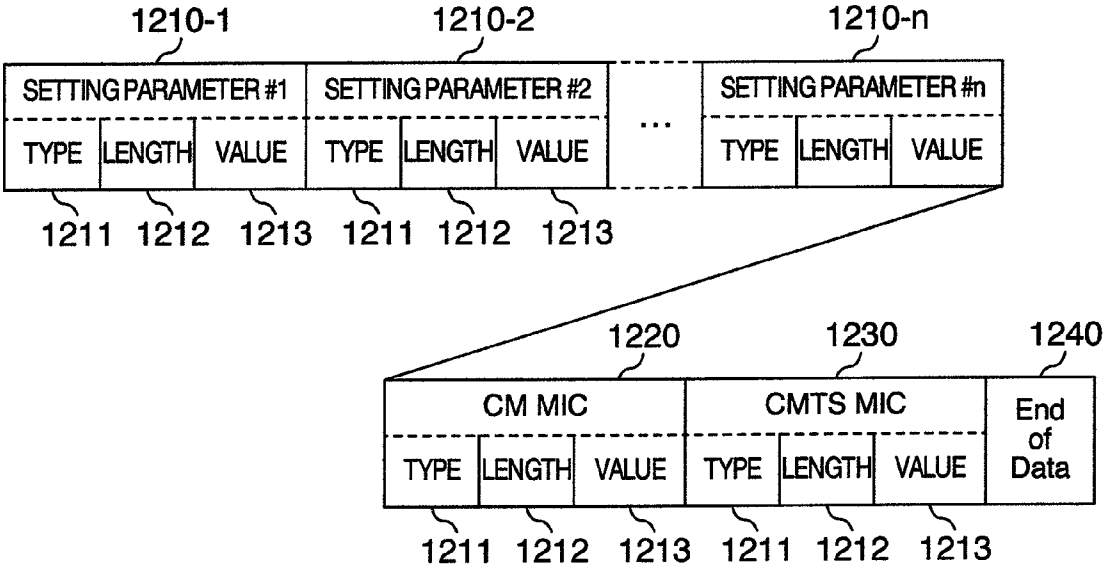


FIG.13

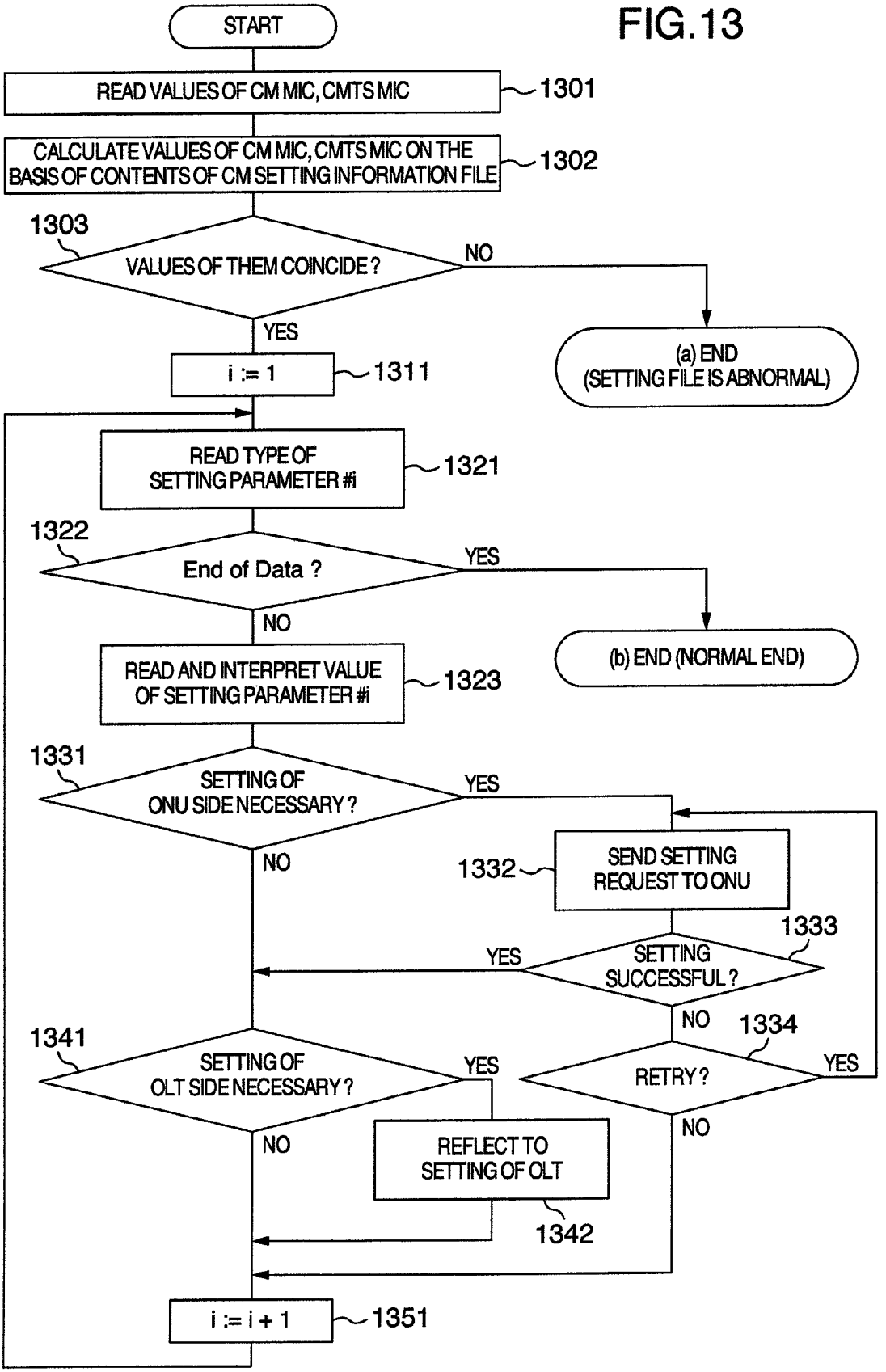

START
READ VALUES OF CM MIC, CMTS MIC
1301
CALCULATE VALUES OF CM MIC, CMTS MIC ON THE BASIS OF CONTENTS OF CM SETTING INFORMATION FILE
1302
1303
VALUES OF THEM COINCIDE ?
NO
YES
(a) END (SETTING FILE IS ABNORMAL)
i := 1
1311
READ TYPE OF SETTING PARAMETER #i
1321
1322
End of Data ?
YES
NO
(b) END (NORMAL END)
READ AND INTERPRET VALUE OF SETTING PARAMETER #i
1323
1331
SETTING OF ONU SIDE NECESSARY ?
YES
NO
1332
SEND SETTING REQUEST TO ONU
1333
SETTING SUCCESSFUL ?
YES
NO
1334
RETRY ?
YES
NO
1341
SETTING OF OLT SIDE NECESSARY ?
YES
NO
REFLECT TO SETTING OF OLT
1342
i := i + 1
1351

FIG.14

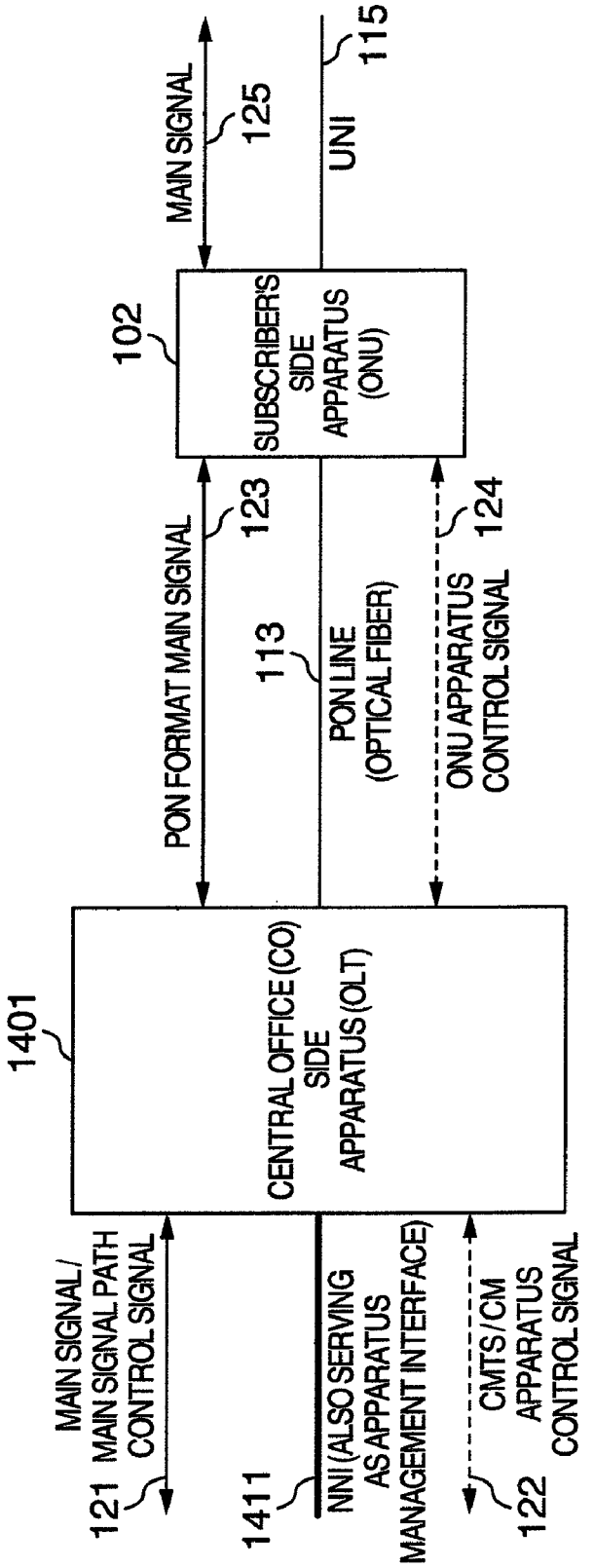

MAIN SIGNAL
125
UNI
115
102
SUBSCRIBER'S SIDE APPARATUS (ONU)
PON FORMAT MAIN SIGNAL
123
113
PON LINE (OPTICAL FIBER)
ONU APPARATUS CONTROL SIGNAL
124
1401
CENTRAL OFFICE (CO) SIDE APPARATUS (OLT)
MAIN SIGNAL / MAIN SIGNAL PATH CONTROL SIGNAL
121
1411
NNI (ALSO SERVING AS APPARATUS MANAGEMENT INTERFACE)
CMTS/CM APPARATUS CONTROL SIGNAL
122

FIG.15

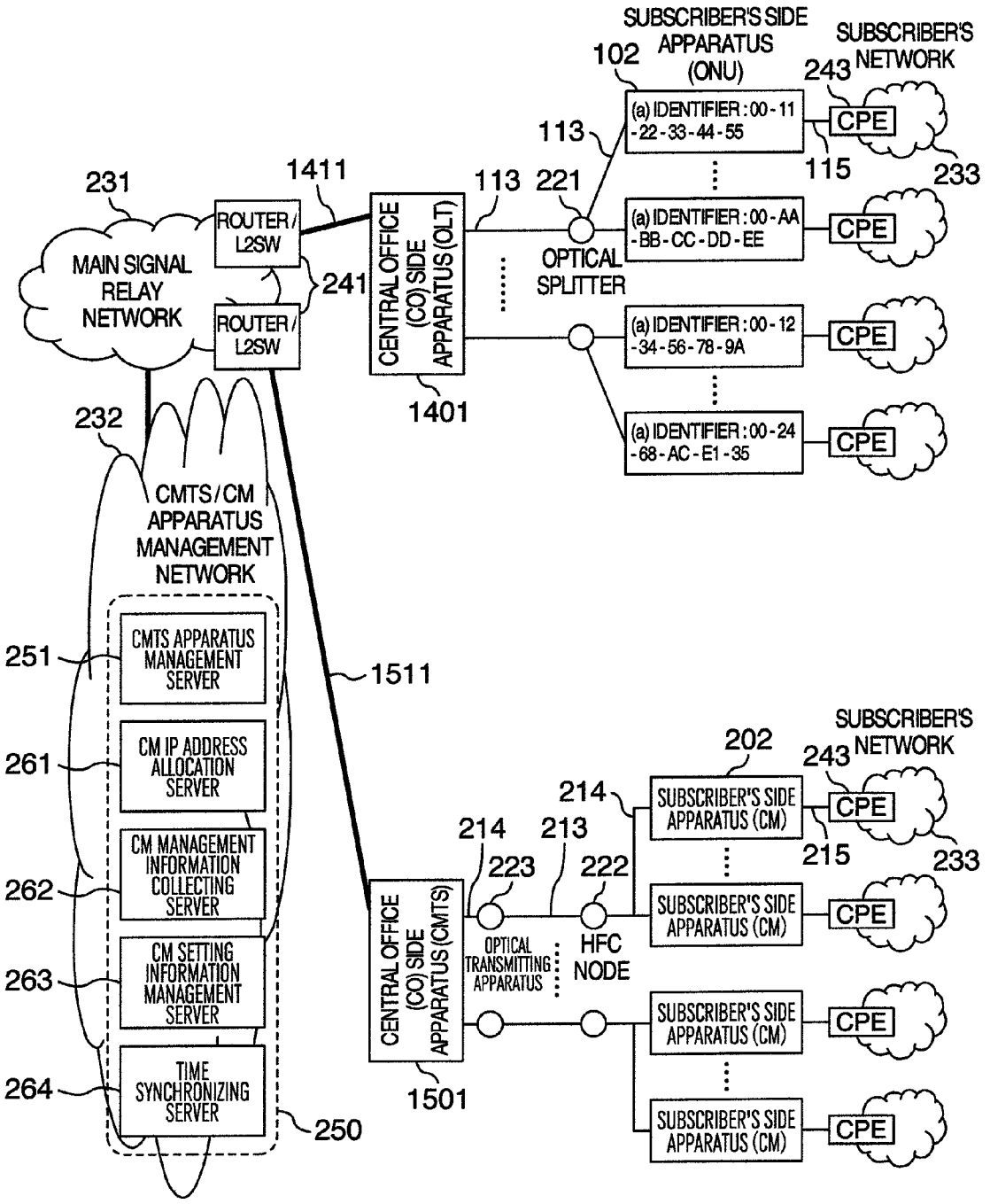

SUBSCRIBER'S SIDE APPARATUS (ONU)
102
SUBSCRIBER'S NETWORK
243
(a) IDENTIFIER : 00 - 11 - 22 - 33 - 44 - 55
113
115
CPE
233
231
1411
113
221
ROUTER / L2SW
CENTRAL OFFICE (CO) SIDE APPARATUS (OLT)
(a) IDENTIFIER : 00 - AA - BB - CC - DD - EE
MAIN SIGNAL RELAY NETWORK
241
OPTICAL SPLITTER
(a) IDENTIFIER : 00 - 12 - 34 - 56 - 78 - 9A
1401
(a) IDENTIFIER : 00 - 24 - 68 - AC - E1 - 35
232
CMTS / CM APPARATUS MANAGEMENT NETWORK
CMTS APPARATUS MANAGEMENT SERVER
251
1511
CM IP ADDRESS ALLOCATION SERVER
261
CM MANAGEMENT INFORMATION COLLECTING SERVER
262
CM SETTING INFORMATION MANAGEMENT SERVER
263
TIME SYNCHRONIZING SERVER
264
250
202
SUBSCRIBER'S NETWORK
243
214
SUBSCRIBER'S SIDE APPARATUS (CM)
214
213
223
222
215
233
CENTRAL OFFICE (CO) SIDE APPARATUS (CMTS)
OPTICAL TRANSMITTING APPARATUS
HFC NODE
1501

FIG.16

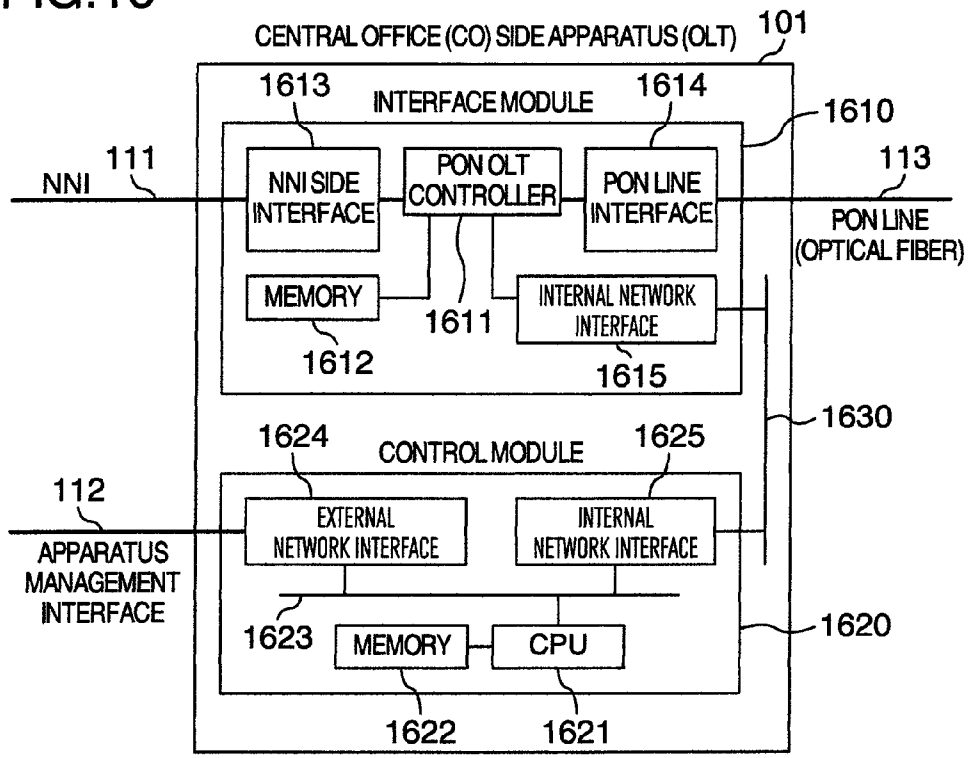

CENTRAL OFFICE (CO) SIDE APPARATUS (OLT)
101
1613
INTERFACE MODULE
1614
1610
NNI
111
NNI SIDE INTERFACE
PON OLT CONTROLLER
PON LINE INTERFACE
113
PON LINE (OPTICAL FIBER)
MEMORY
1611
INTERNAL NETWORK INTERFACE
1612
1615
1630
1624
CONTROL MODULE
1625
112
EXTERNAL NETWORK INTERFACE
INTERNAL NETWORK INTERFACE
APPARATUS MANAGEMENT INTERFACE
1623
MEMORY
CPU
1620
1622
1621

FIG.17

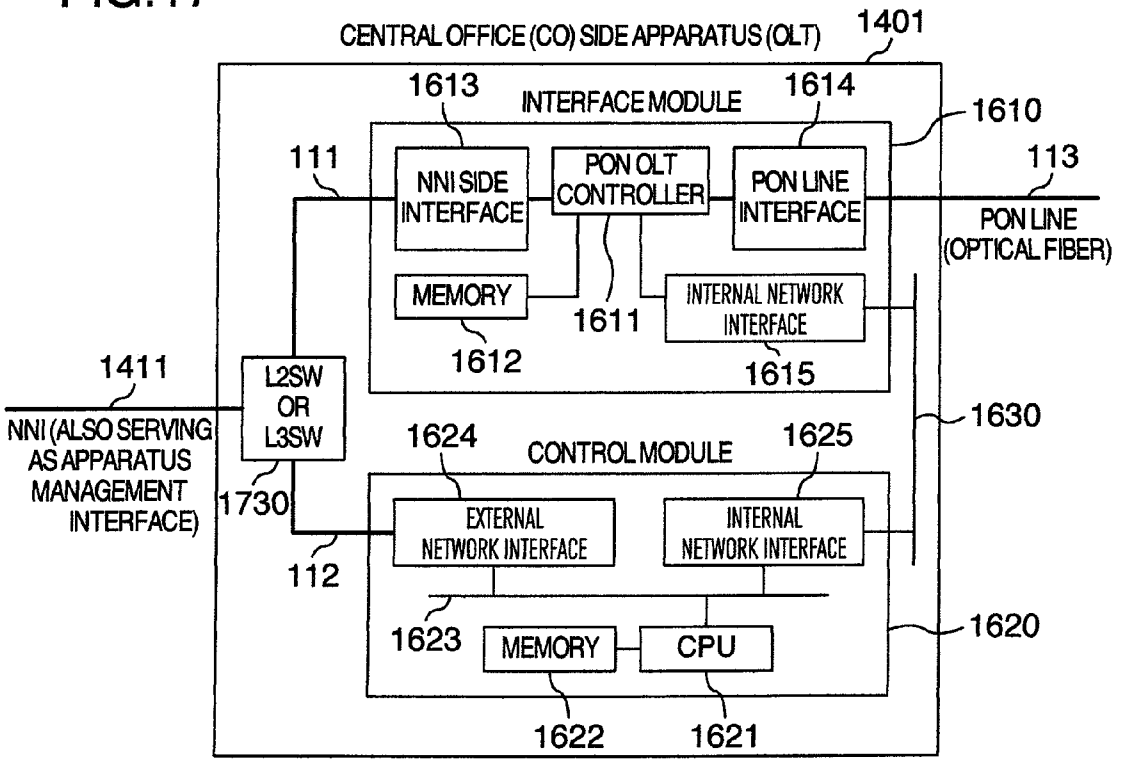

CENTRAL OFFICE (CO) SIDE APPARATUS (OLT)
1401
1613
INTERFACE MODULE
1614
1610
111
NNI SIDE INTERFACE
PON OLT CONTROLLER
PON LINE INTERFACE
113
PON LINE (OPTICAL FIBER)
MEMORY
1611
INTERNAL NETWORK INTERFACE
1612
1615
1411
L2SW OR L3SW
1630
NNI (ALSO SERVING AS APPARATUS MANAGEMENT INTERFACE)
1624
CONTROL MODULE
1625
1730
EXTERNAL NETWORK INTERFACE
INTERNAL NETWORK INTERFACE
112
1623
MEMORY
CPU
1620
1622
1621

FIG.18

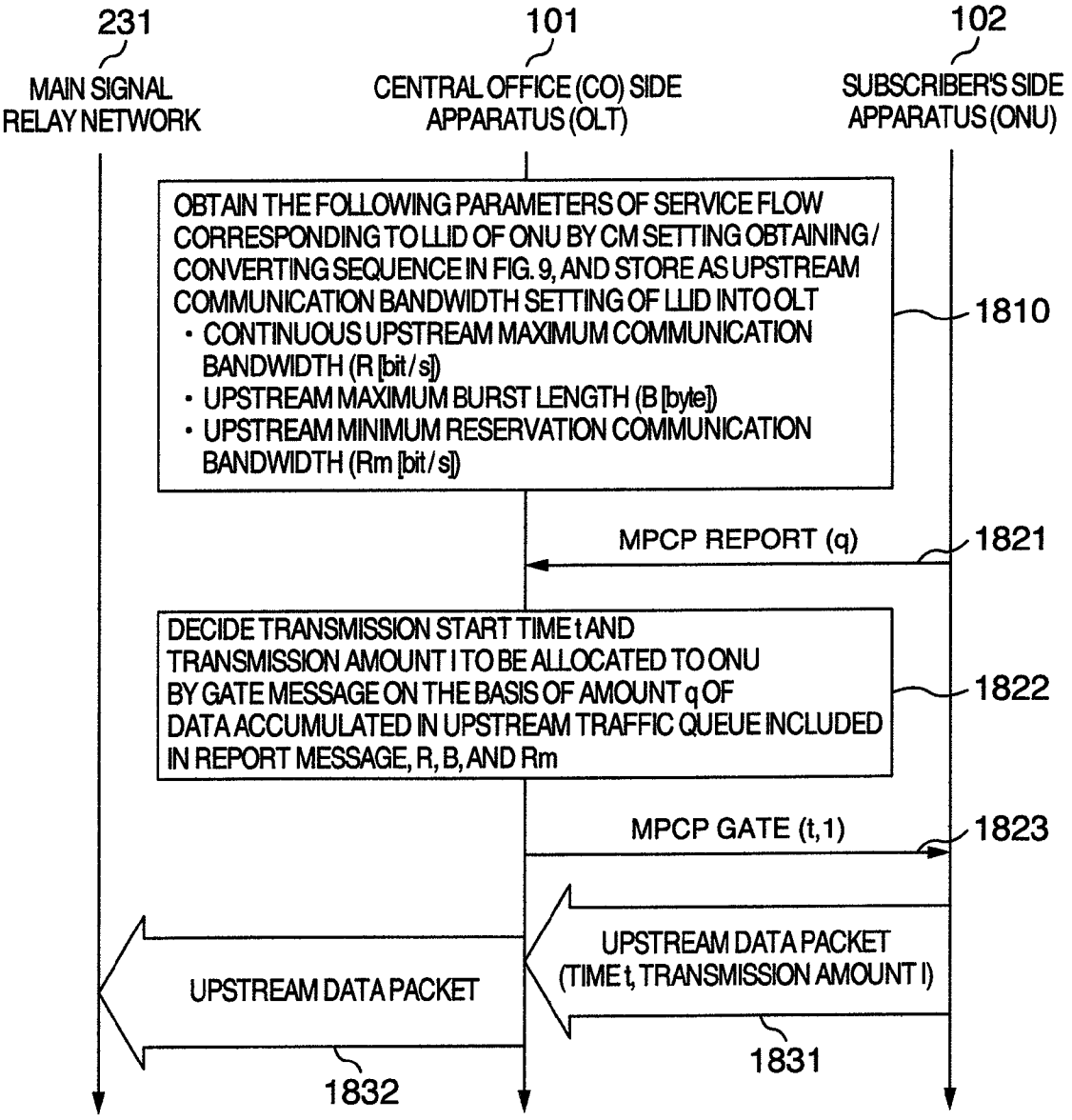

231
MAIN SIGNAL RELAY NETWORK
101
CENTRAL OFFICE (CO) SIDE APPARATUS (OLT)
102
SUBSCRIBER'S SIDE APPARATUS (ONU)
OBTAIN THE FOLLOWING PARAMETERS OF SERVICE FLOW CORRESPONDING TO LLID OF ONU BY CM SETTING OBTAINING / CONVERTING SEQUENCE IN FIG. 9, AND STORE AS UPSTREAM COMMUNICATION BANDWIDTH SETTING OF LLID INTO OLT
• CONTINUOUS UPSTREAM MAXIMUM COMMUNICATION BANDWIDTH (R [bit/s])
• UPSTREAM MAXIMUM BURST LENGTH (B [byte])
• UPSTREAM MINIMUM RESERVATION COMMUNICATION BANDWIDTH (Rm [bit/s])
1810
MPCP REPORT (q)
1821
DECIDE TRANSMISSION START TIME t AND TRANSMISSION AMOUNT l TO BE ALLOCATED TO ONU BY GATE MESSAGE ON THE BASIS OF AMOUNT q OF DATA ACCUMULATED IN UPSTREAM TRAFFIC QUEUE INCLUDED IN REPORT MESSAGE, R, B, AND Rm
1822
MPCP GATE (t,1)
1823
UPSTREAM DATA PACKET (TIME t, TRANSMISSION AMOUNT l)
1831
UPSTREAM DATA PACKET
1832

FIG.19

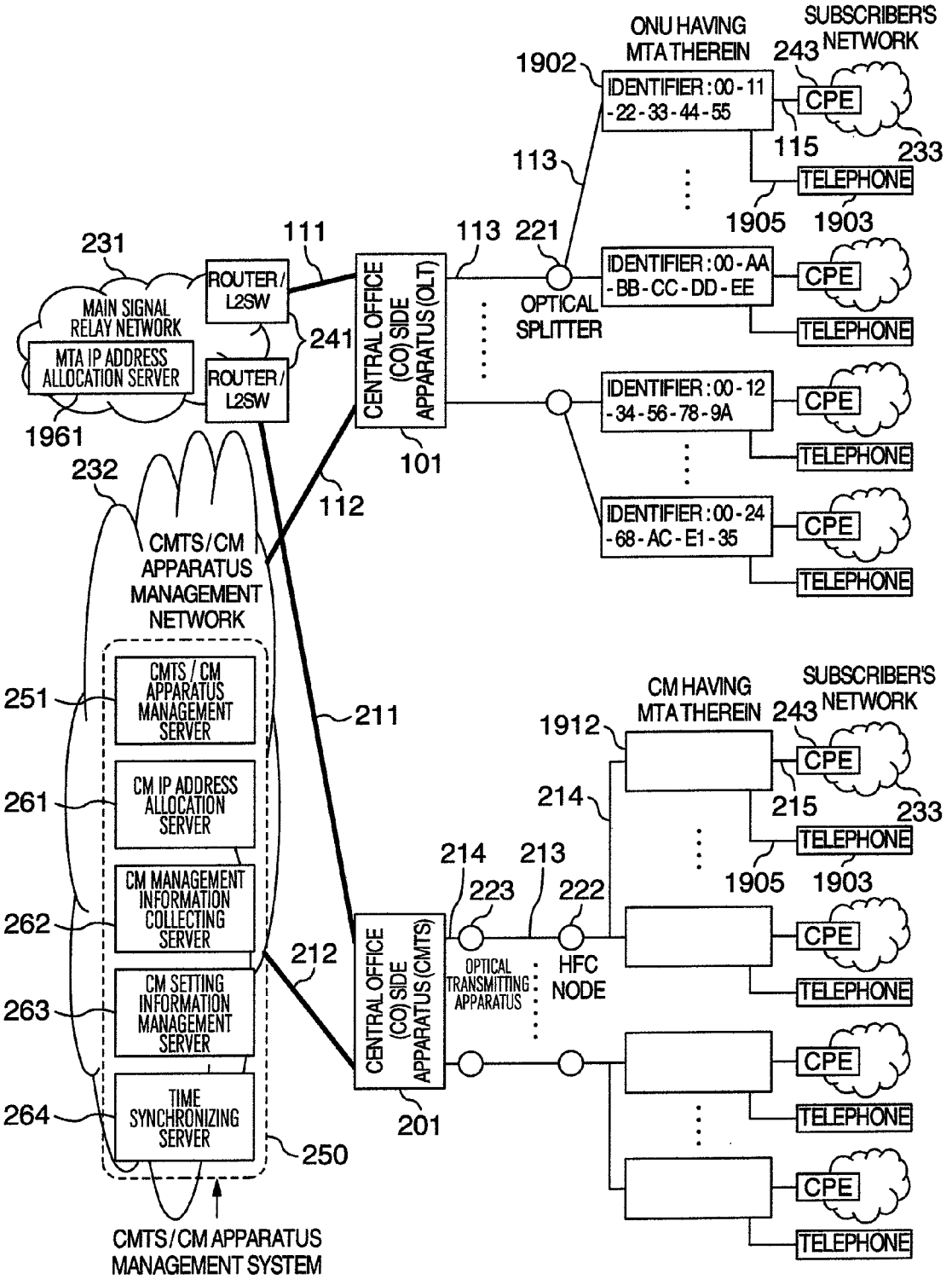

ONU HAVING MTA THEREIN
SUBSCRIBER'S NETWORK
1902
243
IDENTIFIER : 00 - 11 - 22 - 33 - 44 - 55
CPE
115
233
113
TELEPHONE
1905
1903
231
111
113
221
IDENTIFIER : 00 - AA - BB - CC - DD - EE
CPE
ROUTER / L2SW
CENTRAL OFFICE (CO) SIDE APPARATUS (OLT)
OPTICAL SPLITTER
TELEPHONE
MAIN SIGNAL RELAY NETWORK
241
MTA IP ADDRESS ALLOCATION SERVER
ROUTER / L2SW
IDENTIFIER : 00 - 12 - 34 - 56 - 78 - 9A
CPE
1961
101
TELEPHONE
232
112
IDENTIFIER : 00 - 24 - 68 - AC - E1 - 35
CPE
CMTS / CM APPARATUS MANAGEMENT NETWORK
TELEPHONE
CM HAVING MTA THEREIN
SUBSCRIBER'S NETWORK
1912
243
CMTS / CM APPARATUS MANAGEMENT SERVER
251
211
CPE
214
215
233
CM IP ADDRESS ALLOCATION SERVER
261
TELEPHONE
214
213
1905
1903
CM MANAGEMENT INFORMATION COLLECTING SERVER
223
222
262
CPE
212
OPTICAL TRANSMITTING APPARATUS
HFC NODE
CM SETTING INFORMATION MANAGEMENT SERVER
263
TELEPHONE
CENTRAL OFFICE (CO) SIDE APPARATUS (CMTS)
CPE
TIME SYNCHRONIZING SERVER
264
201
TELEPHONE
250
CPE
TELEPHONE
CMTS / CM APPARATUS MANAGEMENT SYSTEM

FIG.20

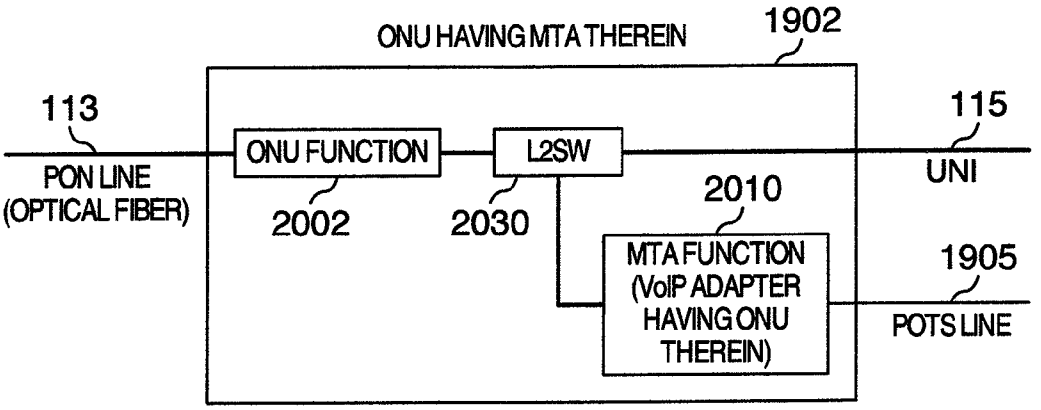
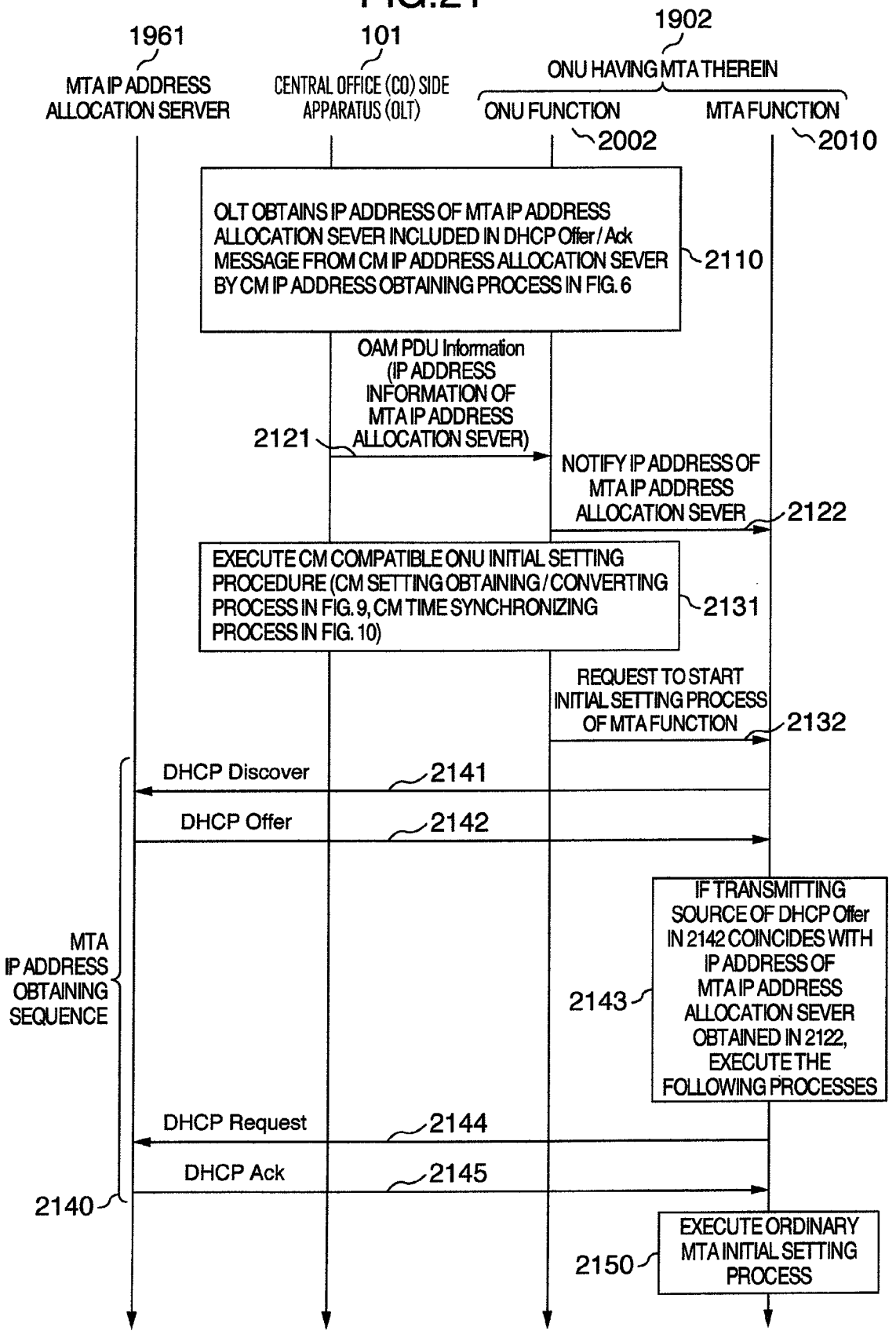

ONU HAVING MTA THEREIN
1902
113
PON LINE
(OPTICAL FIBER)
ONU FUNCTION
2002
L2SW
2030
115
UNI
2010
MTA FUNCTION
(VoIP ADAPTER
HAVING ONU
THEREIN)
1905
POTS LINE

FIG.21


1961
MTA IP ADDRESS ALLOCATION SERVER
101
CENTRAL OFFICE (CO) SIDE APPARATUS (OLT)
1902
ONU HAVING MTA THEREIN
ONU FUNCTION
2002
MTA FUNCTION
2010
OLT OBTAINS IP ADDRESS OF MTA IP ADDRESS ALLOCATION SEVER INCLUDED IN DHCP Offer / Ack MESSAGE FROM CM IP ADDRESS ALLOCATION SEVER BY CM IP ADDRESS OBTAINING PROCESS IN FIG. 6
2110
OAM PDU Information (IP ADDRESS INFORMATION OF MTA IP ADDRESS ALLOCATION SEVER)
2121
NOTIFY IP ADDRESS OF MTA IP ADDRESS ALLOCATION SEVER
2122
EXECUTE CM COMPATIBLE ONU INITIAL SETTING PROCEDURE (CM SETTING OBTAINING / CONVERTING PROCESS IN FIG. 9, CM TIME SYNCHRONIZING PROCESS IN FIG. 10)
2131
REQUEST TO START INITIAL SETTING PROCESS OF MTA FUNCTION
2132
DHCP Discover
2141
DHCP Offer
2142
IF TRANSMITTING SOURCE OF DHCP Offer IN 2142 COINCIDES WITH IP ADDRESS OF MTA IP ADDRESS ALLOCATION SEVER OBTAINED IN 2122, EXECUTE THE FOLLOWING PROCESSES
2143
MTA IP ADDRESS OBTAINING SEQUENCE
DHCP Request
2144
DHCP Ack
2145
2140
EXECUTE ORDINARY MTA INITIAL SETTING PROCESS
2150

COMMUNICATION SYSTEM USING PASSIVE OPTICAL NETWORK AND PASSIVE OPTICAL NETWORK

INCORPORATION BY REFERENCE

The present application claims priority from Japanese applications JP2007-269647 filed on Oct. 17, 2007 and JP2008-263388 filed on Oct. 17, 2008, the content of which is hereby incorporated by reference into this application.

CROSS-REFERENCE TO RELATED APPLICATION

This application is a continuation-in-part of copending U.S. application Ser. No. 12/147,616, filed Jun. 27, 2008, the disclosure of which is hereby incorporated by reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention relates to a communication system which is constructed by an optical fiber line, an optical splitter, and apparatuses arranged at both ends thereof, which enables transmission and reception of a data packet between the apparatuses at both ends, and which enables one of the apparatuses to make management and setting of the other apparatus, wherein a passive optical network (hereinbelow, abbreviated to PON) is used as a network constructed by presuming use of a CMTS (Cable Modem Termination System) and a CM (Cable Modem).

2. Description of the Related Art

In recent years, video distribution services of an IP (Internet Protocol) base mainly according to a video-on-demand form by a communication carrier who provides Internet connection services or a video service providing entrepreneur on the Internet are increasing. Realization of high picture quality of those services is also expected in the future. Therefore, realization of a further high speed of data communication is also demanded in an access line between the communication carrier and general homes or general enterprises as customers (hereinbelow, they are collectively called subscribers).

To realize the high speed of the access line, a construction of the access line using an optical fiber is progressing in each district. Although there are various kinds of systems as communication systems using the optical fibers, the system which has been spread most in the access line is a PON system. The PON system is constructed by the following three kinds of apparatuses: an OLT (Optical Line Terminal) which is provided on a central office (CO) side of the communication carrier and corresponds to a master station; an optical splitter for branch-relaying a photosignal received from one optical fiber toward a plurality of optical fibers as it is; and an ONU (Optical Network Unit; also called ONT (Optical Network Terminal)) which is provided in an individual subscriber's home or a building in which a plurality of subscribers exist and corresponds to a slave station. One optical fiber which connects the OLT and the optical splitter is branched to a plurality of optical fibers by the optical splitter and each optical fiber is connected to one ONU.

As one of forms of the conventional Internet connection services, there is a cable Internet using a coaxial cable line provided for video distribution of a cable television. Although the access line of the cable Internet is generally either a coaxial cable in which the whole interval is a kind of electric wire or an HFC (Hybrid Fiber Coax) in which an interval on the side (upstream side) close to the central office (CO) has been replaced by an optical fiber, the coaxial cable is used in an interval on the side (downstream side) close to the subscriber's home in any of the coaxial cable and the HFC. Generally, the CMTS (Cable Modem Termination System) and the CM (Cable Modem) are used for the apparatus on the central office (CO) side and the apparatus on the subscriber's home side, respectively. The CMTS is an apparatus which has a coaxial cable interface and operates as a router or a layer 2 switch. The CM is an apparatus which has a coaxial cable interface and operates as a bridge or a broadband router.

The cable Internet in which the coaxial cable is used for the access line is disadvantageous in terms of a line speed as compared with the PON in which the whole interval of the access line is the optical fiber. As disclosed in JP-B-2007-516644 and JP-A-2007-124336, a method of improving a communication speed by binding a plurality of channels is also considered as one of measures for solving such a problem. However, even if four channels are bound, the line speed of up to about 160 Mbits/sec can be provided for the subscriber. On the other hand, the PON system using the standard of GPON (Gigabit PON) or GE-PON (Gigabit Ethernet PON) (Ethernet is a registered trademark) which is a main stream at present can provide the line speed of 1 Gbits/sec or higher for the subscriber.

It is considered that the most effective and simplest method of raising the speed of the access line of the cable Internet is a method whereby the station side apparatus is replaced by the OLT from the CMTS, the subscriber's apparatus is replaced by the ONU from the CM, and the access line between those apparatuses is replaced by the optical fiber and the optical splitter.

However, in such a case, it is necessary that each of the OLT and the ONU which are used for replacement has an interface which can be connected, without a problem, to a communicating apparatus which has already been used in its peripheral network.

That is, when mentioning about communication of a main signal, it is necessary that an interface of an upstream side network of the OLT (hereinbelow, called NNI (Network Node Interface) or SNI (Service Node Interface)) has compatibility with an interface of an upstream side network of the CMTS (hereinbelow, called NSI (Network Side Interface)) and can be connected to the router or layer 2 switch locating on the upstream side. It is also necessary that an interface of a downstream side network of the ONU (hereinbelow, called UNI (User Network Interface)) has compatibility with an interface of a downstream side network of the CM (hereinbelow, called CMCI (Cable Modem to CPE Interface)) and can be connected to a PC (Personal Computer) or a CPE (Customer Premise Equipment) such as a broadband router locating on the downstream side.

Further, when mentioning about communication of a control signal, it is necessary that, in place of the CMTS, the OLT receives a CMTS control signal for operating management, setting, and the like for the CMTS and reflects it to its own operation. In addition, it is necessary that the OLT relays a CM control signal which has been transmitted to the CM through the CMTS toward the ONU and the ONU receives the CM control signal and reflects it to its own operation.

Among those requirements, with respect to the main signal interface, since any of the NNI of the OLT and the NSI of the CMTS is substantially the same as the interface which the general router or layer 2 switch has, it can be also connected to peripheral communicating apparatuses without any problem. Also with respect to each of the UNI of the ONU and the CMCI of the CM, since it is a LAN (Local Area Network)

interface which is used in a general home or enterprise, there is no problem in connecting performance.

However, with respect to the control signals, the control signals of the PON system and the control signals of the CMTS and the CM differ largely. The CMTS/CM control signals conform with the standard regarding the cable Internet which is generally called DOCSIS (Data-Over-Cable Service Interface Specifications) which is a trademark of Cable Television Laboratories, Inc. and has been specified by CableLabs (which is a trademark of Cable Television Laboratories, Inc.). The standard of those control signals differ from the standard of the OLT and the ONU. For example, in the DOCSIS standard, with respect to a data structure called MIB (Management Information Base) of a communicating apparatus management protocol called SNMP (Simple Network Management Protocol), it is specified that the CMTS and the CM should cope with such a data structure. However, a part of the data structure is unique to the DOCSIS standard and other communicating apparatuses including the OLT and the ONU do not cope with such a part of the data structure.

Particularly, with respect to the control of the CM, not only the control signal data structure such as an MIB of the SNMP but also a control method differ from those of the ONU. That is, according to the DOCSIS standard, the CM obtains an IP address of the CM itself from a DHCP server by using an IP address allocation protocol called DHCP (Dynamic Host Configuration Protocol). Address information of a TFTP (Trivial File Transfer Protocol) server, a file name of initial setting information which should be received from the TFTP server, and address information of a Time server are included in a message received from the DHCP server. Based on those information, the CM executes transmission of management information to an SNMP manager, obtainment of the initial setting information from the TFTP server, and IP communication for time synchronization with the Time server. Those various kinds of servers are generally located in a network of an upstream side of the CMTS.

The ONU does not have the IP address for control communication and does not execute the obtainment of the IP address which is executed by the DHCP. Therefore, the ONU itself does not execute communication of the SNMP, TFTP, and Time protocols as communication using an IP layer. In place of it, between the OLT and the ONU (hereinbelow, referred to as a PON interval), similar functions are realized by using a communication protocol based on the standard of the PON which is used by those apparatuses (or to which an expansion unique to a vendor has been added). For example, in the GE-PON, initial registration communication and time synchronous communication of the ONU to the OLT are made by an MPCP (Multi Point Control Protocol) protocol of the IEEE (Institute of Electrical and Electronics Engineers, Inc.) 802.3ah standard and communication of management information regarding the ONU is made by an OAM (Operation, Administration and Maintenance) sub-layer of the IEEE 802.3ah standard.

A method whereby while the difference between the PON and the CMTS/CM mentioned above is left, the PON is provided and operated is also considered. In such a case, however, since it is necessary that both of an apparatus management system for the CMTS/CM and an apparatus management system for the PON are provided for an upstream apparatus management network, the management becomes complicated. Further, although a method of integrating only a user interface for management of both of them is also considered, large development costs are required in such a case.

As another solving method, a method of changing the control communicating method of the PON interval to a method similar to that between the CMTS and the CM is also considered. In such a case, however, not only the control communication of the PON interval differs largely from that of the PON standard but also a development for making control communication similar to that between the CMTS and the CM is necessary for both of the OLT and the ONU.

SUMMARY OF THE INVENTION

It is an object of the invention to provide a PON system which can be easily installed by a communication carrier in which a CMTS and a CM have already been installed in place of the CMTS and the CM without largely changing peripheral apparatuses or system such as an apparatus management system and the like and without largely changing a communication system of a PON interval from a PON standard and which can make management similar to that of the CMTS and the CM.

To accomplish the above object, in a PON which is used in a communication system of the invention, an OLT as its station side apparatus transmits and receives control signals of the same format as that of apparatus control signals of a CMTS and a CM (hereinbelow, simply referred to as a CMTS apparatus control signal and a CM apparatus control signal) through its apparatus management interface.

The OLT processes the received CMTS apparatus control signal by itself. In the case of transmitting the apparatus control signal from the apparatus management interface, the OLT transmits it in a format of the CMTS apparatus control signal.

The OLT converts the CM apparatus control signal received in the apparatus management interface into an ONU apparatus control signal which is used in the PON interval and transmits toward the ONU. On the contrary, the OLT converts the ONU apparatus control signal received from the ONU through the PON interval into the CM apparatus control signal and transmits it from the apparatus management interface.

More specifically speaking, when the OLT detects that a new ONU has been connected to the OLT by a protocol of the PON interval, the OLT receives by itself an IP address which should inherently be received by the CM by using the DHCP and stores the IP address in correspondence to the ONU.

Subsequently, the OLT receives the initial setting information of the CM by using the address information and the file name of the TFTP server obtained by the DHCP and makes initial setting corresponding to its contents to the ONU by using the protocol of the PON interval (or, reflects it to the setting of the OLT itself). For example, in the case of the PON based on the GE-PON standard, the setting of an upstream communication bandwidth included in an initial setting file is reflected to the setting of a communication bandwidth control (hereinbelow, referred to as a DBA (Dynamic Bandwidth Allocation)) function of the PON interval by using the MPCP.

When an SNMP message is received in the apparatus management interface, the OLT discriminates which ONU (or the OLT itself) should process the SNMP message on the basis of its destination IP address and transfers the message converted into the protocol of the PON interval toward the ONU. On the contrary, when the apparatus management information according to the protocol of the PON interval is received from the ONU, the OLT examines the IP address allocated to the ONU by using a correspondence table of the ONU and the allocated IP address. The apparatus management information is converted into the SNMP message and the SNMP message

is transmitted from the apparatus management interface by using the IP address as a transmitting source.

The ONU of the invention transmits and receives the ONU apparatus control signal to/from the OLT through the PON interval in a manner similar to that of the ONU based on the PON standard. That is, the ONU of the invention is the same as the ONU of the general PON system.

Since the PON of the invention is seen in a manner similar to that of the CMTS and the CM from the apparatus management system, the system administrator can control the PON system by a method similar to that of the CMTS and the CM. The control signals which are used in the PON interval of the PON system are similar to those of the general PON system.

According to the invention, the communication carrier in which the CMTS and the CM have already been installed can easily install the PON merely by installing the optical fiber and providing the PON system of the invention with hardly modifying the apparatus management system. Moreover, since the same apparatus management system as that for the CMTS and the CM can be used, the system administrator can easily manage the PON and can also suppress an additional investment to the apparatus management system. Owing to the installation of the PON, the access line of a speed of 1 Gbits/sec or higher which cannot be provided by the cable Internet using the coaxial cable can be provided to the subscriber.

The communication in the PON interval which is made by the PON of the invention is the same as the general PON system using the PON standard and the functions which the ONU of the invention has are the same as those of the ONU of the general PON system. Therefore, the system can be also formed by combining the OLT of the invention with another general ONU using the same PON standard.

Other objects, features and advantages of the invention will become apparent from the following description of the embodiments of the invention taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is an explanatory diagram showing an example of a construction of apparatuses of a PON and a communication interface and a construction of signals which are transmitted and received;

FIG. **2** is a system constructional diagram showing an example of a construction of a communication system using the PON of the invention;

FIG. **3** is a block constructional diagram showing an example of a construction of internal functions of an OLT provided for the PON of the invention and signals which are transmitted and received by the respective functions;

FIG. **4** is a block constructional diagram showing an example of a construction of internal functions of an ONU provided for the PON of the invention and signals which are transmitted and received by the respective functions;

FIG. **5** is a block constructional diagram showing an example of a construction of a CM apparatus control signal converting function provided for the OLT and a construction of signals which are transmitted and received;

FIG. **6** is a sequence diagram showing an example of the operation of a CM IP address obtaining function provided for the OLT;

FIG. **7** is a sequence diagram showing an example of the operation of a CM management information converting function provided for the OLT;

FIG. **8** is a sequence diagram showing an example of the operation of the CM management information converting function provided for the OLT;

FIG. **9** is a sequence diagram showing an example of the operation of a CM setting obtaining/converting function provided for the OLT;

FIG. **10** is a sequence diagram showing an example of the operation of a CM time synchronizing function provided for the OLT;

FIG. **11** is a constructional diagram of a memory showing an example of a construction of a CM-ONU correspondence table provided for the OLT;

FIG. **12** is a frame constructional diagram showing an example of a construction of a CM setting information file which is obtained from a CM setting information management server;

FIG. **13** is an operation flowchart showing an example of the operation of the CM setting obtaining/converting function provided for the OLT;

FIG. **14** is an explanatory diagram showing another example of a construction of apparatuses of the PON and the communication interface and a construction of signals which are transmitted and received; and

FIG. **15** is a system constructional diagram showing another example of a construction of the communication system using the PON of the invention.

FIG. **16** is a block constructional diagram showing a constructional example of the OLT of the invention.

FIG. **17** is a block constructional diagram showing an example of another OLT of the invention.

FIG. **18** is a sequence diagram showing an example of the operation for reflecting the settings of the upstream communication bandwidth obtained by the OLT by the CM setting obtaining/converting sequence in FIG. **9** to the DBA setting of the PON interval of the ONU.

FIG. **19** is a system constructional diagram showing another constructional example of the communication system using the PON of the invention.

FIG. **20** is a block constructional diagram showing a constructional example of the ONU having the MTA therein.

FIG. **21** is a sequence diagram showing an operation example of an initial setting process of the ONU having the MTA therein.

DESCRIPTION OF THE INVENTION

A construction and the operation of a communication system using a PON of the invention will be described in detail hereinbelow with reference to the drawings. Although an example in which a GE-PON which has been standardized by the IEEE standard 802.3ah is used as a PON of the invention will be described hereinbelow, the invention can be also embodied by applying another PON such as a GPON or the like which has been standardized by the ITU-T standard G.983.

FIG. **1** is an explanatory diagram showing an example of a construction of apparatuses of the PON and a communication interface and a construction of signals which are transmitted and received.

The PON of the invention is constructed by an OLT **101** as a station side apparatus and an ONU **102** as a subscriber's side apparatus. In an interval between the OLT **101** and the ONU **102** (PON interval), they are connected by a PON line **113**. Generally, a physical media of the PON line **113** is an optical fiber. Although a construction in which a branch-combining apparatus (of a photosignal) called an optical splitter for executing a process such as branch/combination or the like to

the photosignal is provided on the way of the PON line **113** and a plurality of ONUs **102** are provided is a general construction, it is not omitted in the diagram. The invention can be embodied without a problem irrespective of the construction in which one ONU is provided or the construction in which a plurality of ONUs are provided.

The OLT **101** has an NNI **111** and an apparatus management interface **112** serving as physical interfaces which are connected to a network on an upstream side of the OLT. Although each of the NNI **111** and the apparatus management interface **112** is shown as one physical interface in the diagram, it can be also constructed by a plurality of physical interfaces. The ONU **102** has a UNI **115** as a physical interface which is connected to a network on a downstream side of the ONU. The UNI **115** may be constructed by a plurality of physical interfaces in a manner similar to the NNI **111**.

The OLT **101** transmits and receives a main signal and a main signal path control signal **121** to/from the network on the upstream side through the NNI **111**. The OLT **101** also transmits and receives an apparatus control signal **122** of the CMTS and the CM to/from the upstream network through the apparatus management interface **112**. Further, the OLT **101** transmits and receives a main signal **123** of a PON format and an apparatus control signal **124** of the ONU to/from the ONU **102** through the PON line **113**. The ONU **102** transmits and receives a main signal **125** to/from the downstream network through the UNI **115**. Further, the ONU **102** transmits and receives the main signal **123** of the PON format and the apparatus control signal **124** of the ONU to/from the OLT **101** through the PON line **113**. Various control signals which are transmitted and received between a communicating apparatus arranged on the upstream network of the OLT **101** and a communicating apparatus arranged on the downstream network of the ONU **102** are also included in the main signal.

FIG. **2** is a system constructional diagram showing an example of a construction of a communication system using the PON of the invention.

Although the construction in which an optical splitter **221** is arranged on the way of the PON line **113** and the OLT **101** includes a plurality of PON lines **113** is illustrated in the diagram, the invention can be also embodied irrespective of the presence or absence of the optical splitter **221** and the number of PON lines **113** which can be enclosed in the OLT **101**. Although one OLT **101** is arranged in the diagram, the invention can be also embodied even if a plurality of OLTs **101** are arranged.

The NNI **111** of the OLT **101** is connected to a router or layer 2 switch **241** serving as a node to a main signal relay network **231**. The apparatus management interface **112** is connected to an apparatus management network **232** of the CMTS and the CM. The UNI **115** of the ONU **102** is connected to a CPE **243** serving as a node to a subscriber's network **233**.

Besides the OLT **101**, a CMTS **201** as a station side apparatus of the cable Internet is connected to a downstream of the main signal relay network **231** and the CMTS/CM apparatus management network **232**. The CMTS is connected to the router or layer 2 switch **241** serving as a node to the main signal relay network **231** through an NSI **211** and is connected to the CMTS/CM apparatus management network **232** through an apparatus management interface **212**.

Generally, the downstream side interface of the CMTS **201** is a coaxial cable **214** and it is connected to a CM **202** as a subscriber's side apparatus. Although there is a case where the CMTS **201** and the CM **202** are directly connected by the coaxial cable **214**, there is also a case where they are temporarily connected through an optical fiber **213**. In the case where they are connected through the optical fiber **213**, a conversion between an electric signal of the coaxial cable **214** and a photosignal of the optical fiber **213** is executed by an optical transmitting apparatus **223** arranged on the station side and an HFC node **222** arranged on the way of the line. A CMCI **215** of the CM **202** is connected to the CPE **243** serving as a node to a subscriber's network **233**.

The invention can be embodied irrespective of the construction of the downstream network of the CMTS **201**. Although one CMTS **201** is arranged in the diagram, the invention can be also embodied even if a plurality of CMTSs **201** are arranged or even if no CMTSs **201** are arranged.

The main signal relay network **231** is a network for enabling communication between the subscriber's networks **233** or communication between the subscriber's network **233** and a host existing in the main signal relay network **231** by transmitting and receiving the main signal to/from the station side apparatus. A network of the communication carrier who provides the communication services to the subscribers is included in the main signal relay network **231**, or a network or Internet of another communication carrier may be included. The subscriber's networks **233** is a network of the subscriber himself constructed in a home, an enterprise base point, or the like.

The CMTS/CM apparatus management network **232** is a network of the communication carrier having a CMTS/CM apparatus management system **250**. The network administrator of the communication carrier operates and monitors the CMTS/CM apparatus management system **250**, thereby managing the CMTS **201** and the CM **202**. As will be described in detail hereinbelow, the PON system of the invention can manage by using the CMTS/CM apparatus management system **250**.

The CMTS/CM apparatus management system **250** has a CMTS apparatus management server **251**, a CM IP address allocation server **261**, a CM management information collecting server **262**, a CM setting information management server **263**, and a time synchronizing server **264**.

The CMTS apparatus management server **251** manages the CMTS **201** and the OLT **101** by transmitting and receiving the CMTS apparatus control signal between the CMTS **201** and the OLT **101**.

The CM IP address allocation server **261** allocates an IP address for CM apparatus management and communication to the CM **202** and the PON by transmitting and receiving the a CM IP address allocation signal between the CM **202** and the PON (OLT **101**) of the invention. Since the IP address allocated to the PON corresponds to an identifier of the ONU **102** or the like as will be described hereinafter, the PON can be easily provided for the system comprising the CMTS and the CM as mentioned above or as will be described in detail hereinafter.

The CM management information collecting server **262** collects apparatus management information of the CM **202** and the ONU **102** by transmitting and receiving a CM management information signal between the CM **202** and the PON.

The CM setting information management server **263** makes an initial setting of the CM **202** and the ONU **102** by transmitting and receiving a CM setting information signal between the CM **202** and the PON.

The time synchronizing server **264** sets proper time into the CM **202** and the ONU **102** by transmitting and receiving a CM time sync signal between the CM **202** and the PON.

The name and function share of each of the foregoing servers are shown as an example. Even if the construction of the servers in the CMTS/CM apparatus management system

250 (for example, the number and kinds of servers) is other than the foregoing construction, the invention can be embodied by another construction so long as functions and operations as will be described hereinafter are executed. For example, a part of the functions of the CMTS apparatus management server **251** may be included in the CM management information collecting server **262**, or the functions of both of the CM setting information management server **263** and the time synchronizing server **264** may exist physically together in the same server, or servers other than the servers shown in FIG. **2** can be also included in the CMTS/CM apparatus management system **250**.

FIG. **3** is a block constructional diagram showing an example of a construction of internal functions of the OLT provided for the PON of the invention and signals which are transmitted and received by the respective functions.

The OLT **101** has a main signal relay function **301**, a main signal relay control function **302**, a CMTS apparatus control signal processing function **303**, and a CM apparatus control signal converting function **304**. A detailed construction and the operation of each of the functions will be described hereinbelow.

The main signal relay function **301** receives an NNI main signal **311** in the main signal/main signal path control signal **121** from the NNI, converts it into the PON format main signal **123**, and transmits to the PON line. If the PON is, for example, the GE-PON specified by IEEE 802.3ah, the PON format main signal **123** is a layer 2 frame in which an LLID (Logical Link ID) indicative of a destination (or transmitting source) ONU is included in a part of a preamble. The main signal relay function **301** receives the PON format main signal **123** from the PON line, converts it into the NNI main signal **311**, and transmits to the NNI. The main signal relay function **301** receives information necessary to decide a proper relay destination when the NNI main signal **311** and the PON format main signal **123** are received from the main signal relay control function **302**, CMTS apparatus control signal processing function **303**, and CM apparatus control signal converting function **304**.

The main signal relay control function **302** receives a main signal path control signal **312** in the main signal/main signal path control signal **121** from the NNI and executes a path control process according to its contents. There is also a case where the path control process is executed by using a part of packet data of the NNI main signal **311** and the PON format main signal **123**. A result of the path control process is reflected to the process for deciding the relay destination of the main signal which is executed by the main signal relay function **301**. In the case where the main signal relay function **301** relays the packet by Layer 3, the main signal relay control function **302** has functions such as various kinds of routing protocol processes, ARP (Address Resolution Protocol) process, IGMP (Internet Group Management Protocol) process, and the like. In the case where the main signal relay function **301** relays the packet by layer 2, the main signal relay control function **302** also has functions such as MAC (Media Access Control) address learning process, STP (Spanning Tree Protocol) process, IGMP snooping process, and the like.

The CMTS apparatus control signal processing function **303** receives a CMTS apparatus control signal **321** in the CMTS/CM apparatus control signal **122** from the CMTS apparatus management server **251** in the CMTS/CM apparatus management system **250** and executes a control process of the OLT **101** in accordance with contents of the signal **321**. The CMTS apparatus control signal processing function **303** transmits the CMTS apparatus control signal **321** toward the CMTS apparatus management server **251** in the CMTS/CM apparatus management system **250** in accordance with a processing result of the received CMTS apparatus control signal **321** and an operation situation of the OLT **101**. Owing to the above functions, the CMTS/CM apparatus management system **250** can obtain management information of the OLT **101** and can make various kinds of settings by substantially the same method as that of the CMTS.

The CM apparatus control signal converting function **304** receives a CM apparatus control signal **322** in the CMTS/CM apparatus control signal **122** from the CMTS/CM apparatus management system **250**, converts it into the ONU apparatus control signal **124**, and transmits it to the PON line. The CM apparatus control signal converting function **304** also receives the ONU apparatus control signal **124** from the PON line, converts it into the CM apparatus control signal **322**, and transmits it toward the CMTS/CM apparatus management system **250**. Owing to such functions, the CMTS/CM apparatus management system **250** can obtain management information of the ONU **102** and can make various kinds of settings by substantially the same method as that of the CM.

FIG. **4** is a block constructional diagram showing an example of a construction of internal functions of the ONU provided for the PON of the invention and signals which are transmitted and received by the respective functions.

The ONU **102** has a main signal relay function **401**, a main signal relay control function **402**, and an ONU apparatus control signal processing function **403**. A detailed construction and the operation of each of the functions will be described hereinbelow.

The main signal relay function **401** receives the PON format main signal **123** from the PON line, converts it into the UNI main signal **125**, and transmits it to the UNI. The main signal relay function **401** also receives the UNI main signal **125** from the UNI, converts it into the PON format main signal **123**, and transmits it to the PON line. The main signal relay function **401** receives information necessary to decide a proper relay destination when the UNI main signal **125** and the PON format main signal **123** are received from the main signal relay control function **402** and the ONU apparatus control signal processing function **403**.

The main signal relay control function **402** executes a path control process by using a part of packet data of the UNI main signal **125** and the PON format main signal **123**. A result of the path control process is reflected to the deciding process of the relay destination of the main signal which is executed by the main signal relay function **401**. The main signal relay control function **402** has the IGMP snooping process and the like.

The ONU apparatus control signal processing function **403** receives the ONU apparatus control signal **124** from the OLT **101** and executes a control process of the ONU **102** in accordance with contents of the ONU apparatus control signal **124**. The ONU apparatus control signal processing function **403** transmits the ONU apparatus control signal **124** to the OLT **101** in accordance with a processing result of the received ONU apparatus control signal **124** and an operation situation of the ONU **102**.

The functions of the ONU **102** described above are substantially the same as those of the general ONU.

FIG. **5** is a block constructional diagram showing an example of a construction of the CM apparatus control signal converting function provided for the OLT and a construction of signals which are transmitted and received.

The CM apparatus control signal converting function **304** has a CM IP address obtaining function **501**, a CM management information converting function **502**, a CM setting obtaining/converting function **503**, and a CM time synchro-

nizing function **504**. The CM apparatus control signal converting function **304** also has a CM-ONU correspondence table **551**.

By an ONU registration signal **541** as a kind of ONU apparatus control signal **124**, the CM IP address obtaining function **501** knows that the ONU **102** has newly been registered in the OLT **101**. By using this timing as a trigger, the CM IP address obtaining function **501** requests the CM IP address allocation server **261** in the CMTS/CM apparatus management system **250** to obtain the IP address for management and communication of the CM apparatus by using a CM IP address allocation signal **521** as a kind of CM apparatus control signal **322**. Thus, when the IP address is successfully obtained, a correspondence between the IP address and the ONU is recorded into the CM-ONU correspondence table **551**.

The CM management information converting function **502** receives a management information obtaining (or setting) request based on a CM management information signal **522** as a kind of CM apparatus control signal **322** and converts it into the management information obtaining (or setting) request based on an ONU management information signal **542** as a kind of ONU apparatus control signal **124**. A proper ONU is decided as a transfer destination of the request on the basis of a destination IP address of a management information obtaining (or setting) request message by using the CM-ONU correspondence table **551**. The request obtained after the conversion is transferred toward the ONU.

When a management information obtaining (or setting) response based on the ONU management information signal **542** is received from the ONU **102**, the CM management information converting function **502** converts it into a management information obtaining (or setting) response based on the CM management information signal **522**. A response in which each of the transmitting source/destination IP addresses included in an IP header of the management information obtaining (or setting) request corresponding to the management information obtaining (or setting) response is set to a destination/transmitting source IP address is transferred toward the CM management information collecting server **262** in the CMTS/CM apparatus management system **250**.

When a management information notification based on the ONU management information signal **542** is received from the ONU **102**, the CM management information converting function **502** converts it into a management information notification based on the CM management information signal **522**. A CM IP address corresponding to the transmitting source ONU of the management information notification based on the ONU management information signal **542** is decided by using the CM-ONU correspondence table **551**. A notification in which such an IP address is set to a transmitting source is transferred toward the CM management information collecting server **262** in the CMTS/CM apparatus management system **250**.

By using the IP address registered in the CM-ONU correspondence table **551** as its own side IP address, the CM setting obtaining/converting function **503** obtains CM setting information based on a CM setting information signal **523** as a kind of CM apparatus control signal **322** from the CM setting information management server **263** in the CMTS/CM apparatus management system **250**. The CM setting information is set in the OLT itself and converted into an ONU setting information signal **543** as a kind of ONU apparatus control signal **124**. The ONU setting information signal **543** obtained after the conversion is transferred toward the ONU which has been made to correspond to the foregoing self-side IP address by the CM-ONU correspondence table **551**.

By using a CM time sync signal **524** as a kind of CM apparatus control signal **322**, the CM time synchronizing function **504** synchronizes the time of the OLT **101** with the time of the time synchronizing server **264** in the CMTS/CM apparatus management system **250**. By using an ONU time sync signal **544** as a kind of ONU apparatus control signal **124**, the CM time synchronizing function **504** makes the time synchronization of each ONU registered in the CM-ONU correspondence table **551**.

The CM-ONU correspondence table **551** is a table for recording the correspondence between the IP address obtained by a procedure similar to that of the CM and the ONU which has been made to correspond to the IP address.

If the protocol is based on the DOCSIS standard, the protocols such as DHCP, SNMP (a part of the management information notification is Syslog), TFTP, and Time are used for the CM IP address allocation signal **521**, CM management information signal **522**, CM setting information signal **523**, and CM time sync signal **524**, respectively.

If the PON is the GE-PON, the MPCP protocol of the IEEE 802.3ah standard is used for a part or all of the ONU registration signal **541**, ONU setting information signal **543**, and ONU time sync signal **544**. An OAM sub-layer of the same standard is used for a part or all of the ONU management information signal **542** and the ONU setting information signal **543**.

FIG. **6** is a sequence diagram showing an example of the operation of a CM IP address obtaining function provided for the OLT and is a diagram showing an example of a CM IP address obtaining process.

The OLT **101** executes an ONU registering sequence by transmitting and receiving the ONU registration signal **541** to/from the ONU **102** which has newly been connected (step **610**). In more detail, if the PON is the GE-PON, a P2MP (Point to Multipoint) discovery procedure of the MPCP is used and the process is executed by a procedure of a transmission of a GATE (Discovery) message to the ONU (step **611**), a reception of a REGISTER_REQ message from the ONU (step **612**), a transmission of a REGISTER message to the ONU (step **613**), a transmission of a GATE (Normal) message to the ONU (step **614**), and a reception of a REGISTER_ACK message from the ONU (step **615**). Thus, the OLT **101** enables communication with the ONU **102** to be made, thereby obtaining information such as an unique identifier or the like of the ONU **102**.

Subsequently, the OLT **101** registers the ONU unique identifier obtained in step **610** into the CM-ONU correspondence table **551** (step **620**).

Subsequently, the OLT **101** executes the CM IP address obtaining sequence by using the CM IP address allocation signal **521** (step **630**) in order to obtain the IP address corresponding to the ONU registered in step **620**. According to the DOCSIS standard, the DHCP is used and the packet transmission and reception are executed in order of a transmission of a Discovery message to the CM IP address allocation server **261** (step **631**), a reception of an Offer message from the CM IP address allocation server **261** (step **632**), a transmission of a Request message to the CM IP address allocation server **261** (step **633**), and a reception of an Ack message from the CM IP address allocation server **261** (step **634**).

Since the unique identifier of the ONU **102** and the CM IP address which has been made to correspond thereto are obtained by the above processes, this pair is recorded into the CM-ONU correspondence table **551** (step **640**). Other information obtained in steps **610** and **630** can be also recorded

into the CM-ONU correspondence table **551**. For example, if the protocol is based on the DOCSIS standard, since the IP address of the CM setting information management server **263** and the file name of the setting information are obtained in step **630**, those information may be recorded into the CM-ONU correspondence table **551**.

FIG. **7** is a sequence diagram showing an example of the operation of a CM management information converting function provided for the OLT and is a diagram showing an example of a CM management information obtaining process.

The OLT **101** receives a CM management information obtaining (or setting) request message in which one of the IP addresses recorded in the CM-ONU correspondence table **551** is set to a destination from the CM management information collecting server **262** (step **711**). The CM management information obtaining (or setting) request message is one of the CM management information signal **522** and according to the DOCSIS standard, a GetRequest message, a SetRequest message, or the like of the SNMP is used.

By using the CM-ONU correspondence table **551**, the OLT **101** decides the ONU **102** which has been made to correspond to the destination IP address of the CM management information obtaining (or setting) request message received in step **711** (step **720**). The contents of the CM management information obtaining (or setting) request message is converted into the proper ONU management information signal **542** and an ONU management information obtaining (or setting) sequence is executed together with the decided ONU **102** by using the message obtained after the conversion (step **730**). If the PON is the GE-PON, for example, the process is executed by using a PDU (Protocol Data Unit) of the OAM sub-layer by a procedure of a transmission of a Variable Request message to the ONU (step **731**) and a reception of the Variable Response message from the ONU (step **732**). However, another means may be used. By executing the above sequence, the OLT **101** obtains the proper management information (or setting execution result) regarding the ONU **102** as a management information obtaining (or setting) target.

Subsequently, the OLT **101** returns a CM management information obtaining (or setting) response message in which the destination of the original CM management information obtaining (or setting) request message is set to a transmitting source and the transmitting source is set to a destination (step **741**). Information obtained by converting the result obtained in step **730** mentioned above into a format of the CM management information signal **522** is included in this response message. According to the DOCSIS standard, a Response message of the SNMP is used as a CM management information obtaining (or setting) response message.

FIG. **8** is a sequence diagram showing an example of the operation of the CM management information converting function provided for the OLT and is a diagram showing an example of a CM management information notifying process.

The OLT **101** receives an ONU management information notification message from the ONU **102** (step **811**). The ONU management information notification message is one of the ONU management information signal **542**. If the PON is the GE-PON, for example, although an Event Notification message of the OAM sub-layer is used, another means may be used.

By using the CM-ONU correspondence table **551**, the OLT **101** decides the IP address which has been made to correspond to the transmitting source ONU **102** of the ONU management information notification message received in step **811** (step **820**). The contents of the ONU management information notification message are converted into the proper CM management information signal **522** and a CM management information notification message in which the IP address decided in step **820** is set to the transmitting source is transmitted toward the CM management information collecting server **262** (step **831**). The CM management information notification message is one of the CM management information signal **522**. According to the DOCSIS standard, a Trap message of the SNMP, a Syslog protocol message, or the like is used.

Although the management information notification message which is transmitted from the ONU to the OLT has been shown in step **811** in FIG. **8**, it is also possible to use a construction in which the management information notification message is periodically sent from the OLT to the ONU, the OLT receives a response message from the ONU corresponding to the management information notification message, and the OLT executes the processes in step **820** and subsequent steps by using a change in contents of such a response as a trigger.

FIG. **9** is a sequence diagram showing an example of the operation of a CM setting obtaining/converting function provided for the OLT and is a diagram showing an example of the CM setting process.

By using the CM-ONU correspondence table **551**, the OLT **101** obtains the CM IP address which has been made to correspond to the ONU as a target of the setting process, the IP address of the CM setting information management server **263**, and the file name of the CM setting information (step **910**). With respect to the IP address of the CM setting information management server **263** and the CM setting information file name, values which have been preset in the OLT may be used instead of obtaining them from the CM-ONU correspondence table **551**. The above process is generally executed just after the end of the processes in FIG. **6** (or, further after completion of the time synchronization). In such a case, since the CM IP address, the IP address of the CM setting information management server **263**, and the CM setting information file name have already been known until step **640** in FIG. **6**, step **910** can be omitted.

The OLT **101** executes the CM setting information obtaining sequence by using the information obtained by the foregoing procedure (step **920**). Specifically speaking, the CM setting information file is obtained from the CM setting information management server **263** by using the IP address of the CM setting information management server **263** and the CM setting information file name. The CM IP address which has already been obtained is used as a PON side IP address at the time when the CM setting information obtaining sequence is executed. The CM setting information obtaining sequence is executed by using the CM setting information signal **523**. According to the DOCSIS standard, the sequence is executed in a form of obtaining the file by the TFTP. That is, the sequence is executed by repeating the following procedure k times (k denotes the total number of blocks in the case where the CM setting information file is divided into TFTP data blocks): a transmission of an RRQ (Read ReQuest) message to the CM setting information management server (step **921**); a subsequent reception of a DATA message from the CM setting information management server (step **922**); and a transmission of an ACK message to the CM setting information management server (step **923**).

Subsequently, the OLT **101** executes an OLT/ONU setting sequence by using the obtained CM setting information file (step **930**). Specifically speaking, by using an algorithm shown in FIG. **13** which will be described in detail hereinafter, the OLT **101** sequentially interprets setting parameters included in the CM setting information file. The contents of

the setting parameters are converted into the ONU setting information signal **543** or the settings to the OLT itself or into both of them (there is also a possibility that the contents of the setting parameters are not converted into any of them). In the case where they are converted into the settings to the OLT itself, the settings are reflected to the OLT (step **934**). In the case where they are converted into the ONU setting information signal **543**, an ONU setting request message is transmitted to the ONU **102** as a setting target (step **931**). The ONU **102** which received the ONU setting request message reflects the requested setting to itself (step **932**) and returns an ONU setting response message toward the OLT (step **933**). Each of the ONU setting request message and the ONU setting response message is one of the ONU setting information signal **543**.

A specific protocol and a detailed message transmitting and receiving sequence which are used for the ONU setting request message and the ONU setting response message differ depending on the setting contents. For example, in the case of in the GE-PON, the MPCP and the OAM sub-layer of IEEE 802.3ah standard are used as an ONU setting request message and the ONU setting response message accordingly.

FIG. **10** is a sequence diagram showing an example of the operation of a CM time synchronizing function provided for the OLT and is a diagram showing an example of a CM time synchronizing process.

The OLT **101** executes a time synchronizing sequence by using an IP address of the time synchronizing server **264** obtained by the CM IP address obtaining sequence in step **630** (FIG. **6**) or by a previous setting (step **1010**). As a PON side IP address in this instance, either one of the CM IP addresses registered in the CM-ONU correspondence table **551** or another IP address allocated to the OLT **101** of the invention can be used. The CM time synchronizing sequence is executed by using the CM time sync signal **524**. According to the DOCSIS standard, the sequence is executed by using, for example, a Time protocol. However, another time synchronizing protocol, for example, an NTP (Network Time Protocol) may be used. In the case of using the Time protocol, in this time synchronizing sequence, the packet transmission and reception are executed in order of a transmission of a Request message to the time synchronizing server **264** (step **1011**) and a reception of a Response message from the time synchronizing server **264** (step **1012**). On the basis of an execution result of the time synchronizing sequence, the OLT **101** synchronizes the time of a built-in timer with the time synchronizing server **264** (step **1013**).

The OLT **101** properly executes the ONU time synchronizing sequence together with each ONU **102** which has already been registered in the PON (step **1020**). The ONU time synchronizing sequence is executed by using the ONU time sync signal **544**. In the case of the GE-PON, the MPCP is used and the sequence is executed by a procedure of a transmission of a GATE message to the ONU (step **1021**) and a reception of a REPORT message from the ONU (step **1022**). On the basis of an execution result of the ONU time synchronizing sequence, the ONU **102** synchronizes the time of the built-in timer with the OLT **101** (step **1023**).

FIG. **11** is a constructional diagram of a memory showing an example of a construction of the CM-ONU correspondence table provided for the OLT.

A CM IP address **1101** obtained by the CM IP address obtaining process and an ONU unique identifier **1104** corresponding to the CM IP address are recorded in the CM-ONU correspondence table **551**. Although the MAC address of the ONU **102** is used as an ONU unique identifier **1104** here, another information can be used so long as it can unconditionally identify the ONU **102**. For example, a combination of an LLID allocated to each ONU and the number which unconditionally indicates a PON line to which the ONU has been connected can be also used. Further, for example, various kinds of information such as CM setting information management server IP address **1102**, CM setting information file name **1103**, and the like which are set every CM may be included in the CM-ONU correspondence table **551**.

FIG. **12** is a frame constructional diagram showing an example of a construction of the CM setting information file which is obtained from the CM setting information management server by the OLT by the CM setting information obtaining sequence.

The CM setting information file is constructed by 0 or more setting parameters **1210**, a CM MIC (Message Integrity Check) **1220**, a CMTS MIC **1230**, and an End of Data **1240**.

Each parameter (including CM MIC, CMTS MIC) other than the End of Data **1240** has a TLV (Type-Length-Value) format constructed by a type **1211**, a length **1212**, and a value **1213**. A type value showing the meaning of each parameter **1210** is stored in the type **1211**. A specific type value allocated to each of the CM MIC **1220** and the CMTS MIC **1230** is stored in each of them. The length **1212** indicates a byte length of the value **1213**. A setting value of each setting parameter **1210** is stored in the value **1213**. A hash value calculated on the basis of all or a part of the setting parameters is stored in the value **1213** of the CM MIC **1220** and the CMTS MIC **1230**. The End of Data **1240** is constructed only by a specific type value indicative of a termination of the file.

Although the CM setting information file format according to the DOCSIS standard has been used in the above description, the invention can be also embodied even if it does not conform with such a format.

FIG. **13** is an operation flowchart showing an example of the operation of the CM setting obtaining/converting function provided for the OLT and is a diagram showing an example of a process which is executed by the OLT/ONU setting sequence.

When the CM setting information file is obtained by the CM setting information obtaining sequence in FIG. **9**, first, the CM setting obtaining/converting function **503** in the OLT **101** searches for the parameters of the CM MIC and the CMTS MIC from the file and reads out their values (step **1301**). Subsequently, hash values of the CM MIC and CMTS MIC are calculated on the basis of all or a part of the setting parameters in the CM setting information file (step **1302**). The MIC value in step **1301** and the MIC value in step **1302** are compared (step **1303**). If they do not coincide, it is regarded that there is an abnormality in the CM setting information file, and the process regarding the CM setting information file is finished. If they coincide, the processing routine advances to next step.

Subsequently, a loop variable i is initialized to "1" in order to sequentially read the setting parameters (step **1311**) and the type of the ith setting parameter from the top is read out (step **1321**). If the type value indicates the End of Data (step **1322**), it is regarded that the setting corresponding to the setting file has been completed, and the process regarding the CM setting information file is finished.

If the type value indicates other than the End of Data, the value of the setting parameter is read out and what kind of settings are necessary in the PON are interpreted together with the type value (step **1323**).

If the setting of the ONU is necessary (step **1331**) as a result of the interpretation in step **1323**, the corresponding ONU setting request message is transmitted to the ONU (step **1332**). Thus, if the setting has successfully been made (if an

ONU setting response message showing the success in the setting has been received or if it is a setting request without the corresponding ONU setting response message), step **1341** follows (step **1333**). If the setting has failed (if an ONU setting response message showing the failure of the setting has been received), whether or not the setting should be retried is discriminated on the basis of the contents of the failure, the number of retry times so far, or the like (step **1334**). If the setting should be retried, the processing routine is returned to step **1332**. If the setting should not be retried, step **1351** follows.

If the setting on the ONU side is unnecessary or if the setting on the ONU side has successfully been made, the necessity about the setting on the OLT side is discriminated (step **1341**) on the basis of the result of the interpretation in step **1323**. If the setting on the OLT side is necessary, the setting is reflected to the OLT (step **1342**).

If the setting process of the ith setting parameter from the top is finished by the above operation, the loop variable i is incremented by "1" (step **1351**) and the processing routine is returned to step **1321**. Although the MIC value checking process in steps **1301** to **1303** is included as a process based on the DOCSIS standard, the invention can be also embodied even if such a process is not executed.

FIG. **16** is a functional block diagram showing a constructional example of the OLT of the invention.

Two kinds of hardware modules of one or more interface modules **1610** and one or more control modules **1620** are included in the internal hardware of the OLT **101** of the invention. Although the diagram is illustrated on the assumption that one interface module **1610** is included in one OLT **101** and one interface module **1610** is connected to one NNI **111** and one PON line **113**, a plurality of interface modules **1610** may be included in one OLT **101** or one interface module **1610** may be connected to a plurality of NNIs **111** or connected to a plurality of PON lines **113**. Although the diagram is illustrated on the assumption that one OLT **101** has one control module **1620**, one OLT **101** may have a plurality of control modules **1620** and a redundancy construction can be also formed by using them.

The interface module **1610** and the control module **1620** are mutually connected by an internal network **1630**. A CPU **1621** of the control module **1620** communicates with a PON OLT controller **1611** of the interface module **1610** through the internal network **1630**, thereby controlling the interface module **1610** and the ONUs connected from the interface module through the PON lines.

The interface module **1610** is the same as the interface module included in the OLT of the ordinary PON system. The interface module **1610** has therein the PON OLT controller **1611**, a memory **1612**, an NNI side interface **1613**, a PON line interface **1614**, and an internal network interface **1615**. The internal network interface **1615** is connected to the internal network **1630**. The NNI side interface **1613** provides the NNI **111** to the outside of the OLT apparatus. The PON line interface **1614** is connected to the PON line **113** out of the OLT apparatus.

The PON OLT controller **1611** makes control communication with the control module **1620** through the internal network interface **1615**. A result of the control communication is reflected to the interface module **1610** itself and to the ONU connected through the PON line. The PON OLT controller **1611** properly relays the main signal data packet between the NNI side interface **1613** and the PON line interface **1614**. The memory **1612** is a storage device for storing programs and data which are necessary for the PON OLT controller **1611** to operate properly.

The control module **1620** has therein the CPU **1621**, an external network interface **1624**, and an internal network interface **1625**. They are connected through a control module internal bus **1623**. The control module **1620** also has a memory **1622** and is connected to the CPU **1621**. The internal network interface **1625** is connected to the internal network **1630**. The external network interface **1624** provides the apparatus management interface **112** to the outside of the OLT apparatus.

The CPU **1621** of the control module **1620** transmits and receives the CMTS/CM control signal **122** through the external network interface **1624**, properly processes this control signal, and makes control communication of the interface module **1610** and the ONU based on a processing result through the internal network interface **1625**. The memory **1622** is a storage device for storing programs and data which are necessary for the CPU **1621** to operate properly.

FIG. **18** is a sequence diagram showing an example of the operation for reflecting the settings of the upstream communication bandwidth obtained by the OLT by the CM setting obtaining/converting sequence in FIG. **9** to the DBA setting of the PON interval of the ONU and is a diagram showing an example of the processes according to the CM setting obtaining/converting function.

The OLT **101** obtains a CM setting information file corresponding to a certain ONU by the CM setting information obtaining sequence **920** shown in FIG. **9**. The setting information of the upstream communication bandwidth of the service flow corresponding to the LLID allocated to the ONU is included in the CM setting information file. Based on the DOCSIS standard, information such as continuous upstream maximum communication bandwidth, upstream maximum burst length, and upstream minimum reservation communication bandwidth is included in the upstream communication bandwidth setting. Those upstream communication bandwidth setting information is stored as setting for the LLID into the OLT by the OLT•ONU setting sequence **930** shown in FIG. **9** (step **1810**).

Subsequently, the ONU **102** periodically transmits a packet for reporting an amount of data accumulated in an upstream traffic queue in the ONU to the OLT **101** (step **1821**). For example, in the case of a GE-PON, an REPORT message of the MPCP is used as such a packet.

The OLT **101** which received the report of the amount of data accumulated in the upstream traffic queue in the ONU decides an upstream traffic transmission start time and a transmission amount which are allocated to the ONU by using such information and the upstream communication bandwidth setting information which has been preset in step **1810** (step **1822**). This deciding algorithm is out of the scope of the invention and an arbitrary algorithm can be applied.

Subsequently, the OLT **101** returns a packet for notifying the ONU **102** of the upstream traffic transmission start time and the transmission amount decided in step **1822** to the ONU **102** (step **1823**). For example, in the case of the GE-PON, a GATE message of the MPCP is used as such a packet.

The ONU **102** transmits an upstream traffic of the LLID toward the OLT **101** in accordance with the upstream traffic transmission start time and the transmission amount notified in step **1823** (step **1831**). The OLT **101** relays the upstream traffic of the LLID received from the ONU **102** toward the main signal relay network **231** through the NNI **111** (step **1832**).

Another constructional example and the operation of a communication system using the PON of the invention will be further described hereinbelow with reference to the drawings. FIG. **14** is an explanatory diagram showing another

example of a construction of apparatuses of the PON and the communication interface and a construction of signals which are transmitted and received.

In the PON described above, the NNI **111** as a physical interface for the main signal/main signal path control signal **121** and the apparatus management interface **112** as a physical interface for the CMTS/CM apparatus control signal **122** are the different physical interfaces. The communication system which will be described hereinbelow differs from the foregoing PON with respect to a point that a same NNI (also serving as an apparatus management interface) **1411** is used as both of the physical interfaces.

The main signal/main signal path control signal **121** and the CMTS/CM apparatus control signal **122** are logically separated at layer 2 by a VLAN (Virtual LAN) or the like or distinguished by the transmitting source or destination IP address of the packet.

FIG. **15** is a system constructional diagram showing another example of a construction of the communication system using the PON of the invention.

In the communication system described above, also with respect to the CMTS **201**, the NSI **211** as a physical interface for the main signal/main signal path control signal and the apparatus management interface **212** as a physical interface for the CMTS/CM apparatus control signal are the different physical interfaces. On the other hand, in a CMTS **1501** of another communication system shown in the diagram, their physical interfaces are a same NSI (also serving as an apparatus management interface) **1511**.

Both of the NNI (also serving as an apparatus management interface) **1411** of an OLT **1401** and the NSI (also serving as an apparatus management interface) **1511** of the CMTS **1501** are connected to the router/layer 2 switch **241** serving as a node of the main signal relay network **231**. The CMTS/CM apparatus control signal passes temporarily through the main signal relay network together with the main signal and is relayed to the CMTS/CM apparatus management network **232** by the layer 2 switching or the IP routing.

FIG. **17** is a block constructional diagram showing a constructional example of another OLT which is used in the PON having another construction shown in FIGS. **14** and **15**.

The OLT **1401** has a Layer-2 switch or Layer-3 switch **1730** therein besides the interface module **1610** and the control module **1620**.

In the OLT, the NNI side interface **1613** of the interface module **1610** and the external network interface **1624** of the control module **1620** are connected to the Layer-2 switch or Layer-3 switch **1730**. The Layer-2 switch or Layer-3 switch **1730** provides the NNI (also serving as an apparatus management interface) **1411** to the outside of the OLT apparatus. Between those interfaces, the Layer-2 switch or Layer-3 switch **1730** relays the main signal and a main signal path control signal **121** and the CMTS/CM control signal **122** by a Layer-2 switching or an IP routing.

FIG. **19** is a system constructional diagram showing another constructional example of the communication system using the PON of the invention.

A construction of the system shown in the diagram is substantially the same as that of the system shown in FIG. **2** except that the ONU **102** is replaced by an ONU **1902** having an MTA therein, the ONU **1902** having the MTA therein has a POTS (Plain Old Telephone Service) line **1905** to which an analog telephone **1903** can be connected, and an MTA IP address allocation server **1961** is provided in the main signal relay network **231**.

The ONU **1902** having the MTA therein has an MTA (Media Terminal Adapter) function in the apparatus in a manner similar to a CM **1912** having an MTA therein. The MTA is a VoIP adapter function based on the PacketCable standard as a VoIP (Voice over IP) standard specified by CableLabs (Cable Television Laboratories, Inc.). The ONU **1902** having the MTA therein communicates with the MTA IP address allocation server **1961** by the same communication path as that for the main signal and receives an allocation of an IP address for the MTA function. According to the PacketCable standard, a DHCP protocol is used for the IP address allocation.

The MTA function of the ONU **1902** having the MTA therein makes VoIP communication by using the IP address obtained for the MTA function, thereby providing a speech function to the telephone **1903** connected to the POTS line **1905**.

Although not shown, generally, besides the MTA IP address allocation server **1961**, various kinds of servers for making the initial setting—management—speech control of the MTA function of the ONU **1902** having the MTA function are provided in the main signal relay network **231** or the CMTS/CM apparatus management network **232**. Those various kinds of servers may be the same as the servers defined in the PacketCable standard.

FIG. **20** is a block constructional diagram showing a constructional example of the ONU having the MTA therein.

The ONU **1902** having the MTA therein has an ONU function **2002** and an MTA function **2010** therein. The ONU function **2002** has substantially the same function as that of the ordinary ONU **102** except that the transmitting and receiving process of the IP address information of an MTA IP address allocation server, which will be explained hereinafter, is executed. The MTA function **2010** is a portion for providing the VoIP adapter function based on the PacketCable standard and is equivalent to the MTA function of the CM **1912** having the MTA therein.

In the apparatus, the MTA function **2010** is connected to the UNI side of the ONU function **2002** and operates as a CPE. In the apparatus, by branching the UNI by using an L2SW 2030, both of the MTA function **2010** and the CPE **243** prepared by the subscriber can be connected to the UNI.

FIG. **21** is a sequence diagram showing an operation example of an initial setting process of the ONU having the MTA therein.

First, by the CM IP address obtaining process shown in FIG. **6**, the OLT **101** obtains the IP address which has been made to correspond to the ONU function **2002** in the ONU **1902** having the MTA therein from the CM IP address allocation server **261** and records it. In the CM IP address obtaining sequence **630** during the CM IP address obtaining process, the OLT **101** also obtains the information of the IP address of the MTA IP address allocation server **1961** besides the IP address which has been made to correspond to the ONU function **2002** and the IP address and the file name of the setting information of the CM setting information management server **263** (step **2110**).

Subsequently, by using the proper ONU apparatus control signal **124**, the OLT **101** notifies the ONU function **2002** in the corresponding ONU **1902** having the MTA therein of the IP address of the MTA IP address allocation server **1961** obtained in step **2110** (step **2121**). In the case of the GE-PON, a method of notifying by an Information message as a kind of PDU of an OAM sub-layer is considered. However, another message format may be used. The ONU function **2002** which received such a notification notifies the MTA function **2010** of the IP address of the notified MTA IP address allocation server **1961** by intra-apparatus communication of the ONU

1902 having the MTA therein (step 2122). The MTA function 2010 stores the notified IP address of the MTA IP address allocation server 1961.

Subsequently, the OLT 101 and the ONU function 2002 in the ONU 1902 having the MTA therein executes a CM compatible ONU initial setting procedure subsequent to step 2110. The CM setting obtaining/converting process in FIG. 9 and the CM time synchronizing process in FIG. 10 are included in the procedure (step 2131). When step 2131 is finished and the MTA function 2010 is enabled to communicate with the main signal relay network 231 through the ONU function 2002 and the OLT 101, the ONU function 2002 notifies the MTA function 2010 of a request for starting the initial setting process of the MTA function by the intra-apparatus communication of the ONU 1902 having the MTA therein (step 2132).

The MTA function 2010 which received the starting request for the initial setting process starts an MTA IP address obtaining sequence 2140. According to the PacketCable standard, the IP address obtainment is performed by using the DHCP. First, the MTA function 2010 transmits a DHCP Discover message by using a broadcast address as a destination (step 2141). The MTA IP address allocation server 1961 which received the DHCP Discover message returns a DHCP Offer message to the MTA function 2010 (step 2142). The information of the IP address which is allocated to the MTA function 2010 is included in the Offer message.

The MTA function 2010 which received the DHCP Offer message confirms whether or not its transmitting source IP address coincides with the IP address of the MTA IP address allocation server which received the notification in step 2122. If they do not coincide, the initial setting process of the MTA function is interrupted and step 2144 and subsequent steps are not executed (step 2143). Thus, even in the case where an illegal DHCP server which received the DHCP Discover message has returned the DHCP Offer message including illegal information to the MTA function 2010, by ignoring it, the MTA function 2010 can prevent the illegal initial setting from being performed.

In step 2143, if the transmitting source IP address of the Offer message coincides with the IP address of the MTA IP address allocation server which received the notification in step 2122, the MTA function 2010 transmits a DHCP Request message toward the relevant IP address (step 2144). In response to it, the MTA IP address allocation server 1961 returns a DHCP Ack message to the MTA function 2010 (step 2145). The information of the IP address which is allocated to the MTA function 2010 is included in the Ack message, so that the IP address allocation to the MTA function 2010 is completed. After that, the initial setting process similar to the ordinary MTA is executed (step 2150).

It should be further understood by those skilled in the art that although the foregoing description has been made on embodiments of the invention, the invention is not limited thereto and various changes and modifications may be made without departing from the spirit of the invention and the scope of the appended claims.

The invention claimed is:

1. A communication system for making communication by an optical fiber between two points, wherein

said communication system has a first communicating apparatus arranged at a first point and a second communicating apparatus arranged at a second point,

said first communicating apparatus has a first communication interface for communicating with said second communicating apparatus and a second communication interface and a third communication interface for connecting to communicating apparatuses outside of said communication system,

said second communicating apparatus has a fourth communication interface for communicating with said first communicating apparatus and a fifth communication interface for connecting to communicating apparatuses outside of said communication system,

said first communication interface of said first communicating apparatus and said fourth communication interface of said second communicating apparatus are connected by an optical fiber or a communication path, constructed by a combination of the optical fiber and an apparatus for relaying a photo signal,

said first communicating apparatus and said second communicating apparatus relay a main signal communication packet, between said second communication interface of said first communicating apparatus and said fifth communication interface of said second communicating apparatus, by using a path through said first communicating apparatus, said communication path and said second communicating apparatus,

said first communicating apparatus executes control of an operation and collection of state information of said second communicating apparatus by transmitting and receiving a control signal based on a first control protocol through said communication path,

unlike said first control protocol, said first communicating apparatus receives the control of the operation and the collection of the state information of said second communicating apparatus by transmitting and receiving a control signal based on a second control protocol which is used for control of a plurality of cable modems through said third communication interface,

said first communicating apparatus converts said second control protocol received from said third communication interface into said first control protocol and sends it to said first communication interface,

said first communicating apparatus converts said first control protocol received from said first communication interface into said second control protocol and sends it to said third communication interface,

wherein when said first communicating apparatus detects a registration of said second communicating apparatus by said first control protocol, said first communicating apparatus requests an allocation of an identifier which is allocated every said cable modem by using said second control protocol, and by receiving a response to said request, said first communicating apparatus manages a correspondence between the allocated received identifier and said second communicating apparatus, and

wherein an identifier which is allocated every said cable modem is an Internet protocol address and a communication protocol which is used to allocate said identifier is a DHCP (Dynamic Host Configuration Protocol).

2. A communication system for making communication by an optical fiber between two points, wherein

said communication system has a first communicating apparatus arranged at a first point and a second communicating apparatus arranged at a second point,

said first communicating apparatus has a first communication interface for communicating with said second communicating apparatus and a second communication interface and a third communication interface for connecting to communicating apparatuses outside of said communication system,

said second communicating apparatus has a fourth communication interface for communicating with said first communicating apparatus and a fifth communication interface for connecting to communicating apparatuses outside of said communication system,

said first communication interface of said first communicating apparatus and said fourth communication interface of said second communicating apparatus are connected by an optical fiber or a communication path, constructed by a combination of the optical fiber and an apparatus for relaying a photo signal,

said first communicating apparatus and said second communicating apparatus relay a main signal communication packet, between said second communication interface of said first communicating apparatus and said fifth communication interface of said second communicating apparatus, by using a path through said first communicating apparatus, said communication path and said second communicating apparatus,

said first communicating apparatus executes control of an operation and collection of state information of said second communicating apparatus by transmitting and receiving a control signal based on a first control protocol through said communication path,

unlike said first control protocol, said first communicating apparatus receives the control of the operation and the collection of the state information of said second communicating apparatus by transmitting and receiving a control signal based on a second control protocol which is used for control of a cable modem through said third communication interface,

said first communicating apparatus converts said second control protocol received from said third communication interface into said first control protocol and sends it to said first communication interface,

said first communicating apparatus converts said first control protocol received from said first communication interface into said second control protocol and sends it to said third communication interface,

wherein when said first communicating apparatus receives a communication message of a request for an obtainment or setting of management information to said cable modem by said second control protocol, said first communicating apparatus executes the obtainment or the setting of the management information to said second communicating apparatus by using said first control protocol and transmits a communication message of a response by said second control protocol, and

wherein a communication protocol for transmitting and receiving the management information regarding said cable modem included in said second control protocol is an SNMP (Simple Network Management Protocol) or Syslog.

3. A communication system for making communication by an optical fiber between two points, wherein

said communication system has a first communicating apparatus arranged at a first point and a second communicating apparatus arranged at a second point,

said first communicating apparatus has a first communication interface for communicating with said second communicating apparatus and a second communication interface and a third communication interface for connecting to communicating apparatuses outside of said communication system,

said second communicating apparatus has a fourth communication interface for communicating with said first communicating apparatus and a fifth communication interface for connecting to communicating apparatuses outside of said communication system,

said first communication interface of said first communicating apparatus and said fourth communication interface of said second communicating apparatus are connected by an optical fiber or a communication path constructed, by a combination of the optical fiber and an apparatus for relaying a photo signal,

said first communicating apparatus and said second communicating apparatus relay a main signal communication packet, between said second communication interface of said first communicating apparatus and said fifth communication interface of said second communicating apparatus, by using a path through said first communicating apparatus, said communication path and said second communicating apparatus,

said first communicating apparatus executes control of an operation and collection of state information of said second communicating apparatus by transmitting and receiving a control signal based on a first control protocol through said communication path,

unlike said first control protocol, said first communicating apparatus receives the control of the operation and the collection of the state information of said second communicating apparatus by transmitting and receiving a control signal based on a second control protocol which is used for control of a cable modem through said third communication interface,

said first communicating apparatus converts said second control protocol received from said third communication interface into said first control protocol and sends it to said first communication interface,

said first communicating apparatus converts said first control protocol received from said first communication interface into said second control protocol and sends it to said third communication interface,

wherein when said first communicating apparatus receives management information of said second communicating apparatus by said first control protocol, said first communicating apparatus transmits a communication message for transmitting the management information from said cable modem by using said second control protocol, and

wherein a communication protocol for transmitting the management information regarding said cable modem included in said second control protocol is an SNMP (Simple Network Management Protocol) or Syslog.

4. A communication system for making communication by an optical fiber between two points, wherein

said communication system has a first communicating apparatus arranged at a first point and a second communicating apparatus arranged at a second point,

said first communicating apparatus has a first communication interface for communicating with said second communicating apparatus and a second communication interface and a third communication interface for connecting to communicating apparatuses outside of said communication system,

said second communicating apparatus has a fourth communication interface for communicating with said first communicating apparatus and a fifth communication interface for connecting to communicating apparatuses outside of said communication system,

said first communication interface of said first communicating apparatus and said fourth communication interface of said second communicating apparatus are connected by an optical fiber or a communication path,

constructed by a combination of the optical fiber and an apparatus for relaying a photo signal,

said first communicating apparatus and said second communicating apparatus relay a main signal communication packet, between said second communication interface of said first communicating apparatus and said fifth communication interface of said second communicating apparatus, by using a path through said first communicating apparatus, said communication path and said second communicating apparatus,

said first communicating apparatus executes control of an operation and collection of state information of said second communicating apparatus by transmitting and receiving a control signal based on a first control protocol through said communication path,

unlike said first control protocol, said first communicating apparatus receives the control of the operation and the collection of the state information of said second communicating apparatus by transmitting and receiving a control signal based on a second control protocol which is used for control of a cable modem through said third communication interface,

said first communicating apparatus converts said second control protocol received from said third communication interface into said first control protocol and sends it to said first communication interface,

said first communicating apparatus converts said first control protocol received from said first communication interface into said second control protocol and sends it to said third communication interface, and

wherein when said first communicating apparatus receives a communication message regarding a setting request of communication quality of the main signal which is transmitted and received by said cable modem by said second control protocol, said first communicating apparatus stores said communication quality setting as a setting for said second communicating apparatus which has been made to correspond to said cable modem, and

when a communication message including information regarding a transmission waiting data amount of the main signal which is transmitted toward said first communicating apparatus by said second communicating apparatus is transmitted to said first communicating apparatus by said second communicating apparatus by using said first control protocol, on the basis of the information of said transmission waiting data amount and said communication quality setting, said first communicating apparatus calculates a start time and a transmission period of time at which said second communicating apparatus should transmit the main signal toward said first communicating apparatus and makes a response of a communication message for notifying said second communicating apparatus of said start time and said transmission period of time toward said second communicating apparatus by using said first control protocol.

5. A communication system for making communication by an optical fiber between two points, wherein

said communication system has a first communicating apparatus arranged at a first point and a second communicating apparatus arranged at a second point,

said first communicating apparatus has a first communication interface for communicating with said second communicating apparatus and a second communication interface and a third communication interface for connecting to communicating apparatuses outside of said communication system,

said second communicating apparatus has a fourth communication interface for communicating with said first communicating apparatus and a fifth communication interface for connecting to communicating apparatuses outside of said communication system,

said first communication interface of said first communicating apparatus and said fourth communication interface of said second communicating apparatus are connected by an optical fiber or a communication path, constructed by a combination of the optical fiber and an apparatus for relaying a photo signal,

said first communicating apparatus and said second communicating apparatus relay a main signal communication packet, between said second communication interface of said first communicating apparatus and said fifth communication interface of said second communicating apparatus, by using a path through said first communicating apparatus, said communication path and said second communicating apparatus,

said first communicating apparatus executes control of an operation and collection of state information of said second communicating apparatus by transmitting and receiving a control signal based on a first control protocol through said communication path,

unlike said first control protocol, said first communicating apparatus receives the control of the operation and the collection of the state information of said second communicating apparatus by transmitting and receiving a control signal based on a second control protocol which is used for control of a plurality of cable modems through said third communication interface,

said first communicating apparatus converts said second control protocol received from said third communication interface into said first control protocol and sends it to said first communication interface,

said first communicating apparatus converts said first control protocol received from said first communication interface into said second control protocol and sends it to said third communication interface,

wherein when said first communicating apparatus detects a registration of said second communicating apparatus by said first control protocol, said first communicating apparatus requests an allocation of an identifier which is allocated every said cable modem by using said second control protocol, and by receiving a response to said request, said first communicating apparatus manages a correspondence between the allocated received identifier and said second communicating apparatus, and

further comprising a third communicating apparatus in addition to said first communicating apparatus and said second communicating apparatus, and

wherein said third communicating apparatus is connected to said second communicating apparatus through said fifth communication interface and transmits and receives an allocating request of a second identifier which is allocated every said third communicating apparatus and its response to/from said second communication interface through said second communicating apparatus, said communication path, and said first communicating apparatus,

when said first communicating apparatus receives an allocation response of the identifier which is allocated every said cable modem, if information of a third identifier showing a legal transmitting source of an allocation response of said second identifier is included in said response, said first communicating apparatus notifies said second communicating apparatus of said third iden-

tifier by using said first control protocol, said second communicating apparatus notifies said third communicating apparatus of said third identifier through a fifth communication interface,

said third communicating apparatus confirms whether or not the transmitting source of the allocation response of said second identifier coincides with said third identifier, and only when they coincide, said third communicating apparatus regards said second identifier included in said response as an identifier which has legally been allocated.

6. A system according to claim **5**, wherein said second identifier and said third identifier are Internet protocol addresses and a communication protocol which is used to allocate said second identifier is a DHCP (Dynamic Host Configuration Protocol).

7. A system according to claim **5**, wherein a fourth communicating apparatus includes therein a function corresponding to said second communicating apparatus and a function corresponding to said third communicating apparatus, and said communication system has said fourth communicating apparatus in place of said second communicating apparatus.

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