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

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- (54) **Title:** CIRCUIT EMULATION SERVICE FOR CARRYING TIME DIVISION MULTIPLEXED SCADA TRAFFIC

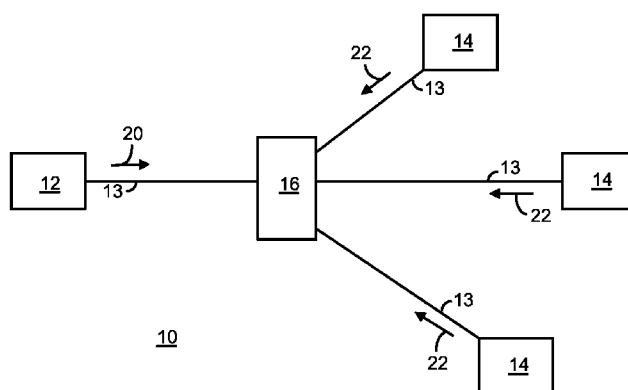


FIG. 1

- (57) **Abstract:** Embodiments of the invention employ specially adapted P2MP and MP2P transmission techniques to communicate traffic of a TDM based SCADA system over an IP/MPLS based network. Advantageously, by specially adapting P2MP and MP2P transmission techniques to carry TDM based SCADA traffic over an IP/MPLS network, an existing TDM based SCADA system can be migrated to an IP/MPLS network and operated in an easy to manage and bandwidth efficient manner as compared to a solution that employs point-to-point connections between a SCADA master node and subsystems over an IP/MPLS network. Furthermore, since TDM based SCADA equipment would not need to be replaced with IP based SCADA equipment in such a migration, significant equipment and installation costs associated with such replacement can be avoided.

CIRCUIT EMULATION SERVICE FOR CARRYING TIME DIVISION MULTIPLEXED SCADA TRAFFIC

Field of the Invention

[001] The invention is directed to communication networks, particularly to systems and methods for carrying time division multiplexed (TDM) traffic over a packet switched network (PSN) to and from multiple destinations simultaneously.

Background of the Invention

[002] Supervisory Control and Data Acquisition (SCADA) systems have been in operation for many years now and they are widely used for monitoring and/or controlling various remote subsystems. For example, SCADA based solutions are deployed in various power grids, gas pipelines, and railway systems throughout the globe today. Through the use of SCADA systems operators can read data, such as actual resource usage or flow, from individual subsystems and/or can control the subsystem, for example to open or shut a gas pipeline. A communication network is therefore required between the remote SCADA subsystems and the main node, which is also referred to herein as a master node. Legacy, time division based communication networks are already in place to provide the required connectivity between the master node and the subsystems. However, many of these networks are slowly reaching their useful life and many vendors of the equipment used in these networks are terminating support for their legacy equipment. Operating such aging gear is also becoming difficult as equipment vendors are not manufacturing such legacy equipment anymore.

[003] Another issue is the requirement to introduce new services like Voice over Internet Protocol (VoIP), video surveillance, and so on into SCADA systems.

Given the age of the legacy networks providing connectivity in many SCADA solutions, the network nodes typically do not have the capacity for additional bandwidth demanding applications. Migrating to a modern Internet Protocol (IP)/Multi-protocol Label Switching (MPLS) based solution while preserving investments made in existing TDM-based non-IP SCADA equipment is a key challenge. SCADA systems typically make use of a point-to-multipoint (P2MP) and multipoint-to-point (MP2P) transmission provided via multi-drop data bridge/bus (MDDB) configurations. While such transmission can be provided for asynchronous traffic by existing IP/MPLS capabilities, providing such transmission for TDM traffic over IP/MPLS is currently undefined. At present, carrying TDM traffic over an IP/MPLS network operates solely in a point-to-point manner. However, for SCADA systems with dozens or even hundreds of subsystems providing such point-to-point connections over an IP/MPLS network becomes cumbersome to manage and an inefficient use of network bandwidth and other resources.

[004] One way to modernize a SCADA system is to invest in new IP capable SCADA equipment. That is, to replace each SCADA subsystem and associated master node with a new IP based SCADA subsystem and IP based master node. However, to do so can be a very costly, time consuming and service interrupting process.

[005] In view of the foregoing it appears that an easy to manage and bandwidth efficient way to communicate traffic of a TDM based non-IP SCADA system over an IP/MPLS based infrastructure would be desirable.

Summary

[006] Embodiments of the invention employ specially adapted P2MP and MP2P transmission techniques to communicate traffic of a TDM based SCADA system over an IP/MPLS based network.

[007] According to an aspect of the invention a method is provided of communicating SCADA traffic between TDM based SCADA equipment over a PSN performed at a PE node. The method includes the steps of: determining if a TDM SCADA message has been received over a serial link, if a TDM SCADA message has been received encapsulating the TDM SCADA message in a CES packet and if a TDM SCADA message has not been received generating a filler frame and encapsulating the filler frame in a CES packet; setting a serial number of the CES packet to null; and transmitting the CES packet over the PSN.

[008] According to another aspect of the invention a network node is provided. The network node comprises: a serial interface for coupling to a serial link to communicate TDM traffic; a packet interface for coupling to a packet switched network to communicate packet traffic; a processor coupled to the serial and packet interfaces; a memory coupled to the processor; a program of computer readable instructions stored in the memory that when executed by the processor cause the network node to perform a method of communicating SCADA traffic between TDM based SCADA equipment over a PSN. The method comprises: determining if a TDM SCADA message has been received over a serial link, if a TDM SCADA message has been received encapsulating the TDM SCADA message in a CES packet and if a TDM SCADA message has not been received generating a filler frame and encapsulating the filler frame in a CES packet; setting a serial number of the CES packet to null; and transmitting the CES packet over the PSN.

[0009] According to yet another aspect of the invention a network node is provided that comprises: a serial link interface; a packet interface; and a CES function adapted to be operable to encapsulate in a CES packet a TDM SCADA message received over the serial link interface, to set a serial number of the packet to null, and to transmit the CES packet over the packet interface.

[0010] Advantageously, by specially adapting P2MP and MP2P transmission techniques to carry TDM based SCADA traffic over an IP/MPLS network, an existing TDM based SCADA system can be migrated to an IP/MPLS network and operated in an easy to manage and bandwidth efficient manner as compared to a solution that employs point-to-point connections between a SCADA master node and subsystems over an IP/MPLS network. Furthermore, since TDM based SCADA equipment would not need to be replaced with IP based SCADA equipment in such a migration, significant equipment and installation costs associated with such replacement can be avoided.

Brief Description of the Drawings

[0011] The foregoing and other objects, features and advantages of the invention will be apparent from the following more particular description of the preferred embodiments, as illustrated in the appended drawings, where:

Figure 1 depicts a prior art SCADA system.

Figure 2 depicts a SCADA system according to a first embodiment of the invention.

Figure 3 is a functional block diagram of a provider edge (PE) node of **Figure 2** according to a second embodiment of the invention.

Figure 4 is a flow chart of a method of communicating SCADA traffic between TDM based SCADA equipment over a PSN network according to a third embodiment of the invention.

Figure 5 depicts the architecture of the PE node of **Figure 2** according to a fourth embodiment of the invention.

In the figures like features are denoted by like reference characters.

Detailed Description

[0012] **Figure 1** depicts a prior art SCADA system **10**. The SCADA system **10** includes a master node **12** communicatively coupled to a MDDB **16** via a serial link **13**. The SCADA system **10** also includes three SCADA subsystems **14**, each of which are connected to the MDDB **16** by a respective serial link **13**. In operation, the master node **12** sends control messages **20** to the subsystems **14** via the MDDB **16** and serial links **13**. Each subsystem **14** in turn replies with a data message **22** when requested to do so by a control message **20** addressed to it. The data message **22** may alternatively or additionally include a status indication of the subsystem **14** or other information. The control messages **20** and data messages **22** are also referred to herein as traffic of a SCADA system or SCADA traffic.

[0013] The MDDB **16** typically provides a bridge or bus function whereby the master node **12** broadcasts the control messages **20** to the subsystems **14**, and by which the subsystems **14** communicate their respective data messages **22** over a shared connection to the master node **12**.

[0014] Figure 2 depicts a SCADA system **100** according to a first embodiment of the invention. The master node **12** and SCADA subsystems **14** are each connected via a respective serial link **13** to a packet switched network (PSN) **102**, which by way of non-limiting example could be an Ethernet network (i.e. p2p, bridged, etc), an IP network, or an IP/MPLS network which would be agnostic to underlying Layer-II infrastructure (i.e. Layer-2 NW can be Packet over SONET/SDH, PPP, etc). The PSN **102** includes at its edge a respective provider edge (PE) node **104** coupled to each of the serial links **13**. The PSN **102** communicatively couples the PE nodes **104** via a bidirectional routed connection **106** that takes the form of a point-to-multipoint (P2MP) connection to communicate control messages **20** from the master node **12** to the SCADA subsystem nodes **14**, and a multi-to-point (MP2P) connection to communicate data messages **22** from the SCADA subsystems **14** to the master node **12**. In this way, operation of the PSN **102**, the PE nodes **104**, and the bidirectional routed connection **106** emulate the functionality of the MDDB **16**.

[0015] Among other functions, each PE node **104** forms one or more packets, which are referred to hereinafter for convenience as control packets **108**, from a control message **20** that it receives over one of the serial links **13**, and then transmits the control packet(s) **108** into the PSN **102** for transport to other PE nodes **104** over the bidirectional routed connection **106**. Similarly each PE node **104** forms one or more packets, which are referred to hereinafter for convenience as data packets **110**, from a data message **22** that it receives over one of the serial links **13** and then transmits the data packet(s) **110** into the PSN **102** for transport to other PE nodes **104** over the bidirectional routed connection **106**. Such packet formation includes encapsulating bits of a control or data message **20**, **22** into a packet payload by adding thereto an appropriate header according to the technology of the PSN **102**, e.g. Ethernet, IP, IP/MLS, etc. Conversely, each PE node **104** forms a corresponding control or data message **20**, **22** from bits received in the payload of one or more control or data packets **108**, **110** that

it receives from other PE nodes **104** over the bidirectional routed connection. The PE node **104** then serially transmits the control or data message **20**, **22** so formed over one of the serial links **13** to the master node **12** in the case of control messages **20** and to the SCADA subsystems **14** in the case of data/status messages **22**.

[0016] Figure 3 is a functional block diagram **200** of the PE node **104** in Figure 2 according to a second embodiment of the invention. The figure also shows the PE node **104** in operation performing certain steps of a method of communicating SCADA traffic between non-IP SCADA equipment over a IP/MPLS network according to a third embodiment of the invention.

[0017] The PE node **104** includes a Circuit Emulation Service (CES) function **202** that has been adapted for application in a SCADA system. Specifically, the CES function **202** has been adapted so that CES can be used in a point-to-multipoint and multipoint-to-point manner to carry traffic from non-IP SCADA equipment over an IP/MPLS network infrastructure. To do so, the SCADA traffic is treated like a bit stream. This avoids needing to augment IP/MPLS nodes in the PSN **102** with capabilities to handle non-IP/MPLS protocols used in TDM based SCADA networks. In operation, traffic (e.g. control message **20**) received from the SCADA master node **12** is interworked into a specially adapted CES packet (e.g. control packet **108**). Likewise, traffic (e.g. data message **22**) received from any of the SCADA subsystems **14** is interworked into a specially adapted CES packet (e.g. data packet **110**).

[0018] CES known in the prior art is designed to keep track of sequence numbers in both directions. However, given the nature of point-to-multipoint delivery where only the intended SCADA subsystem **14** is to process a control message **20** address to it, the CES function **202** has been adapted to have sequence number tracking disabled. Disabling the sequence number tracking

allows the SCADA subsystems **14** to transmit and receive asynchronously over an IP/MPLS network via the specially adapted Circuit Emulation Service. Without the sequence numbers, a SCADA master issued frame (e.g. the control message **20**) is delivered to all subsystems **14** and only the subsystem designated as the destination at SCADA layer ends up processing the control information carried in the message **20**. The converse is also true. A subsystem **14** with data to transmit will end up transmitting a data message **22** asynchronously, which could potentially result in multiple subsystems **14** transmitting their messages **22** simultaneously. The master node **12** would end up receiving these messages **22** in any order given that the PE nodes **14** with the adapted CES function **202** do not try to sort the frames, or discard them based on the sequence number tracking function.

[0019] It should be noted that the specially adapted CES packets can then be transported directly as Ethernet payload (e.g. per RFC 5087). In that case, CES over Ethernet traffic would then be handed to Ethernet bridging service for multipoint delivery. The specially adapted CES packets can also be interworked to MPLS, User Datagram Protocol (UDP)/IP, etc for delivery over different network types. In the case of UDP/IP, IP multicast can be used for multipoint deliver as an example. The principles described herein for communicating traffic of TDM based SCADA systems still hold irrespective of the encapsulation type.

[0020] The PE node **104** also includes an activity detection function **204**. With prior art CES functionality each endpoint is expected to transmit continuously. However, in a SCADA system since the subsystems **14** can transmit their data messages **22** asynchronously, a time period **206** of transmission inactivity can appear on the serial link **13** that connects a given SCADA subsystem **14** to a given PE node **104**. If a valid bit stream is not received at the PE node **104**, the activity detection function **204** detects this occurrence and signals the adapted CES function **202** to generate one or more filler frames **210** for the time period

206. The filler frames **210** are detected and dropped at the receiving PE node **104** so that only messages **20**, **22** are exchanged between the master node **12** and the SCADA subsystems **14**.

[0021] **Figure 4** is a flow chart of a method **300** of communicating SCADA traffic between TDM based SCADA equipment over a PSN **102** according to a third embodiment of the invention. After starting **302** the method **300** proceeds to checking **304** if a TDM SCADA message has been received on a serial link **13** by a PSN node that is implementing the method **300**, for example one of the PE nodes **104** of **Figure 2**. If a TDM SCADA message (e.g. a control or data message **20**, **22**) has been received, then the method proceeds to encapsulating **306** the TDM SCADA message in a specially adapted CES packet (e.g. a control or data packet **108**, **110**), the adaptation comprising setting the serial number of the packet to null, blank, zero, omitting it, or other treatment that will have the effect of providing no sequential ordering indication of the CES packets that are communicated over the PSN network. If a TDM SCADA message has not yet been received since the method **300** was started **302** or after expiration of a predetermined time interval (e.g. the time period **206**), then the method **300** proceeds by generating **310** a filler frame. The predetermined time interval could be defined in many ways, for example it could be an integer multiple of a timeslot defined by the TDM techniques employed by the SCADA equipment. The method **300** then proceeds to encapsulating **412** the filler frame into a specially adapted CES packet. The method **300** then proceeds to transmitting **308** the specially adapted CES packet over the PSN **102**. If the serial link **13** is coupled to a master node **12**, the specially adapted CES packet is transmitted over a P2MP routed connection to other PE nodes **104** that have serial links coupled to SCADA subsystems **14** that are to communicate with the master node **12**. If the serial link **13** is coupled to one of the SCADA subsystems **14**, then the specially adapted CES packet is transmitted over a MP2P routed connection to the PE node **104** that is coupled to the master node **12**.

[0022] Upon receiving a specially adapted CES packet over the PSN **102**, the method **300** includes de-encapsulating the received specially adapted CES packet to obtain the TDM SCADA message carried in the packet's payload, and transmitting the TDM SCADA message over the serial link **13** coupled to the master node **12** in the case where the TDM SCADA message is a data message **22**, or the serial link coupled to a respective SCADA subsystem **14** in the case where the TDM SCADA message is a control message **20**.

[0023] **Figure 5** depicts the architecture **400** of the PE node **104** of **Figure 2** according to a fourth embodiment of the invention. The PE node **104** includes a processor **402** communicatively coupled to a memory **404** so as to enable the processor **402** to read data from the memory **404** and write data to the memory **404**. The data could take the form of program instructions, SCADA traffic messages, and specially adapted CES packets among other things. The memory **404** has a program **406** of computer readable instructions stored therein which when accessed and executed by the processor **402** cause the PE node **104** to perform the method **300** of communicating SCADA traffic between TDM based SCADA equipment over a PSN **102**. The PE node **104** also includes a TDM interface **408** for receiving and transmitting TDM traffic **410** such as the TDM SCADA messages previously mentioned, as well as a packet interface **412** for receiving and transmitting packet traffic **414** such as the specially adapted CES packets previously described. The TDM interface **408** and the packet interface **412** are each communicatively coupled to the processor **402** so as to enable the processor **402** to receive traffic or information contained therein from the interfaces **408**, **412**, and to transmit traffic or information to be contained therein to the interfaces **408**, **412**. With respect to the foregoing example SCADA system **100** the TDM interface **408** would be connected to one of the serial links **13** and the packet interface **412** would be connected to other nodes in the PSN **102**.

[0024] Numerous modifications, variations and adaptations may be made to the embodiments of the invention described above without departing from the scope of the invention, which is defined in the claims.

WHAT IS CLAIMED IS:

1. A method of communicating Supervisory Control and Data Acquisition (SCADA) traffic between time division multiplexed (TDM) based SCADA equipment over a packet switched network (PSN) performed at a provide edge (PE) node, comprising:

- determining if a TDM SCADA message has been received over a serial link;

- if a TDM SCADA message has been received:

- encapsulating the TDM SCADA message in a circuit emulation service (CES) packet;

- if a TDM SCADA message has not been received:

- generating a filler frame;

- encapsulating the filler frame in a CES packet;

- setting a serial number of the CES packet to null; and

- transmitting the CES packet over the PSN.

2. The method of claim 1 wherein:

- determining if a TDM SCADA message has been received further comprises determining if the serial link is coupled to a SCADA master node; and

- transmitting further comprises transmitting the CES packet over a point-to-multipoint (P2MP) routed connection responsive to the serial link being coupled to a SCADA master node.

3. The method of claim 1 wherein:

- determining if a TDM SCADA message has been received further comprises determining if the serial link is coupled to a SCADA subsystem; and

transmitting further comprises transmitting the CES packet over a multipoint-to-point (MP2P) routed connection responsive to the serial link being coupled to a SCADA subsystem.

4. The method of claim 1 wherein determining if a TDM SCADA message has been received further comprises determining if a TDM SCADA message has not yet been received after expiration of a predetermined time interval.

5. The method of claim 4 wherein the predetermined time interval corresponds to a timeslot defined by TDM techniques employed by the SCADA equipment.

6. A network node comprising:

- a serial link interface;

- a packet interface; and

- a circuit emulation service (CES) function adapted to be operable to encapsulate in a CES packet a TDM Supervisory Control and Data Acquisition (SCADA) message received over the serial link interface, to set a serial number of the packet to null, and to transmit the CES packet over the packet interface.

7. The network node of claim 6 further comprising:

- an activity detection function operable to detect that a TDM SCADA message has not been received over the serial link interface upon expiration of a predetermined time interval and to provide an indication to that effect to the CES function,

- wherein the CES function is further operable to generate a filler frame responsive to the indication from the activity detection function, to encapsulate the filler frame into a CES packet having a null serial number, and to transmit the CES packet to the packet interface.

8. The network node of claim 6 wherein the CES function is further operable to:

determine if the serial link is coupled to a SCADA master node; and
transmit the CES packet over a point-to-multipoint (P2MP) routed connection responsive to the serial link being coupled to a SCADA master node.

9. The network node of claim 6 wherein the CES function is further operable to:
determine if the serial link is coupled to a SCADA subsystem; and
transmit the CES packet over a multipoint-to-point (MP2P) routed connection responsive to the serial link being coupled to a SCADA subsystem.

10. The network node of claim 6 wherein the CES function is further operable to determine if a TDM SCADA message has not yet been received after expiration of a predetermined time interval that corresponds to a timeslot defined by TDM techniques employed by the SCADA equipment.

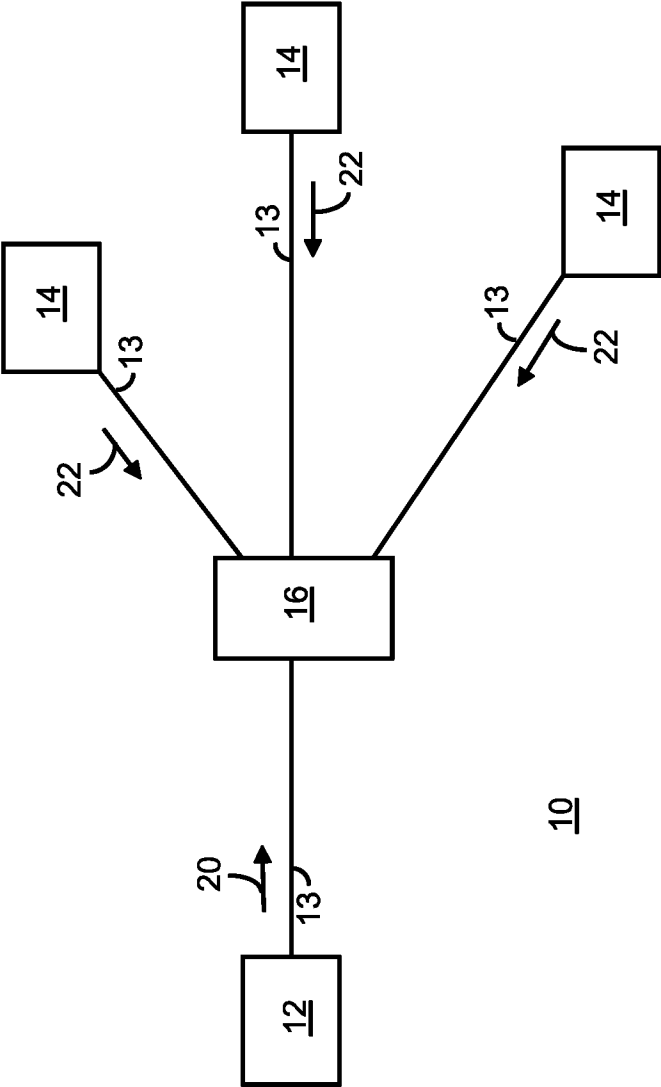


FIG. 1

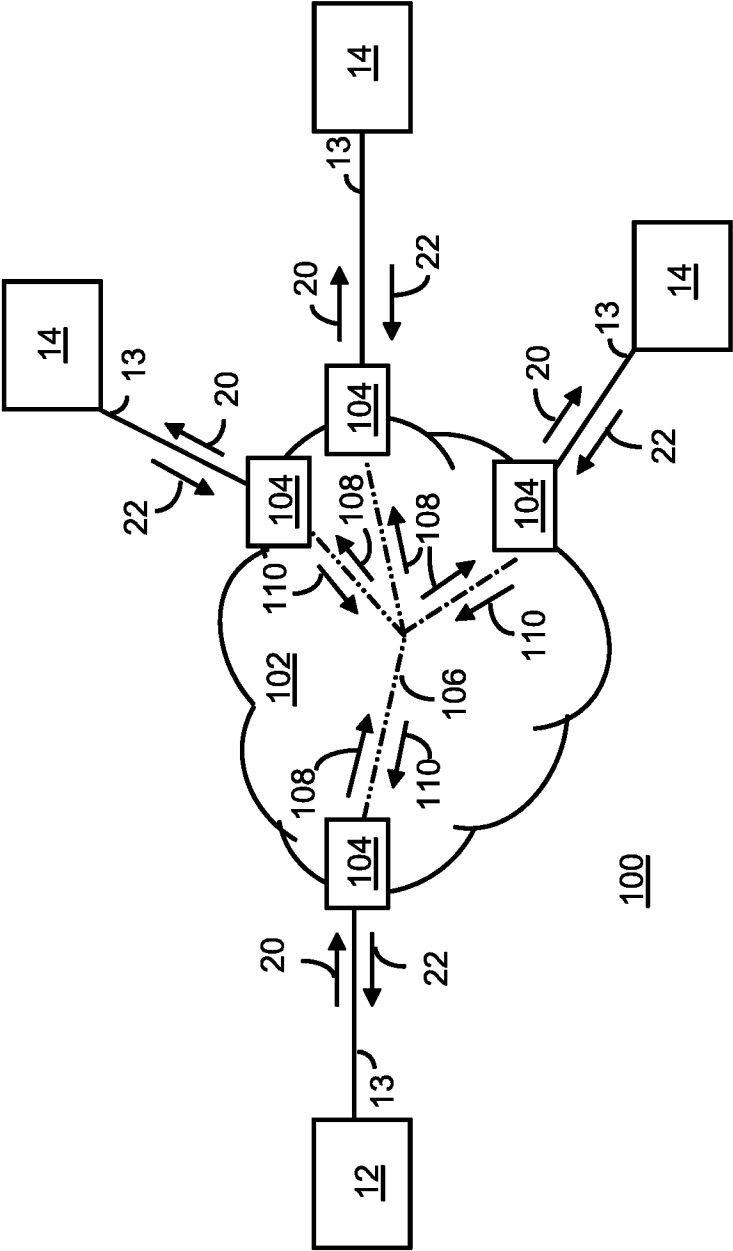


FIG. 2

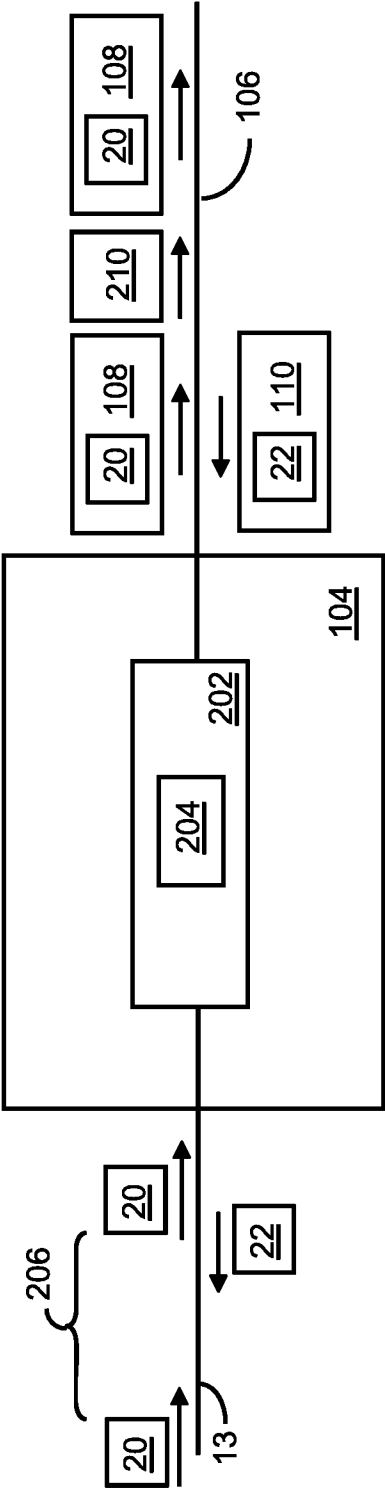


FIG. 3

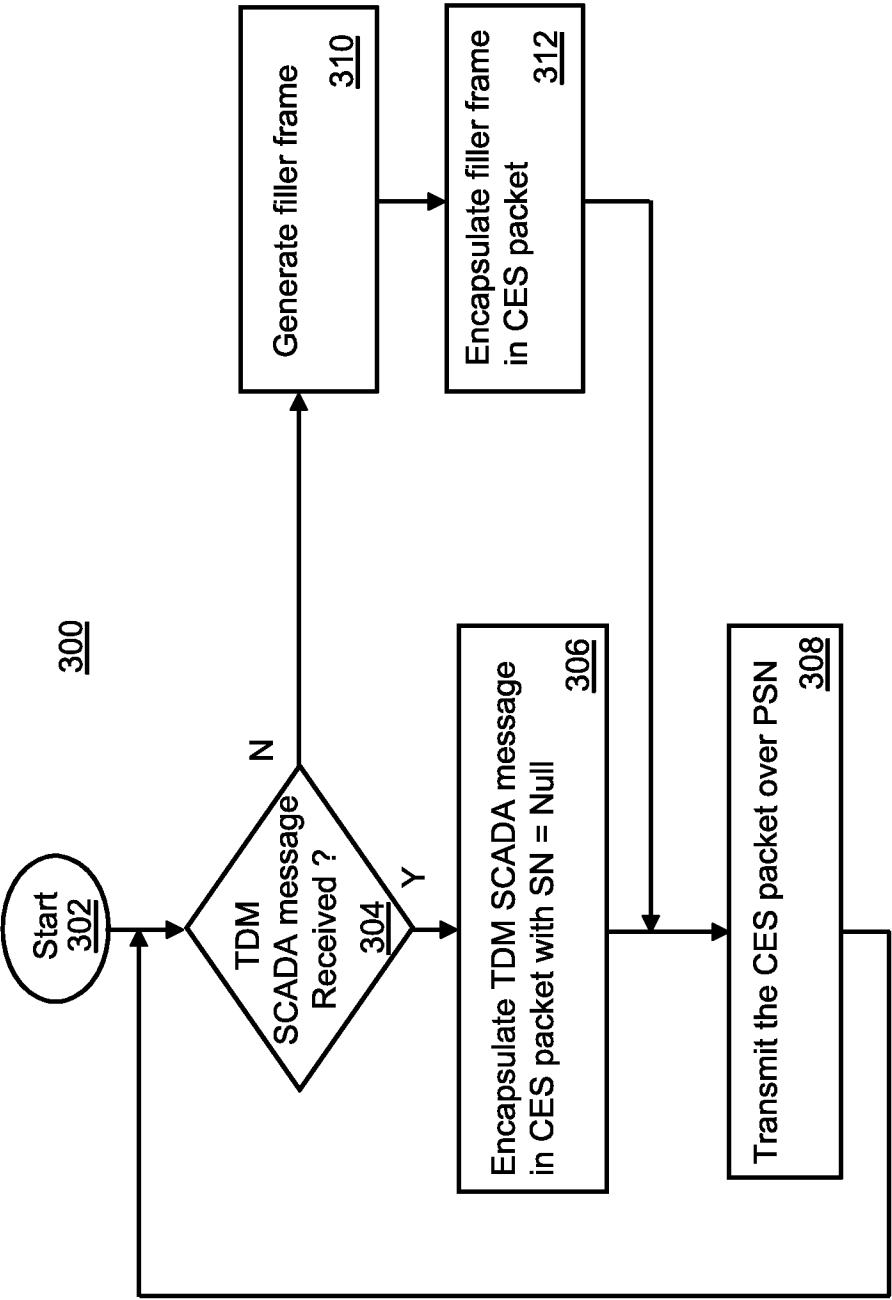


FIG. 4

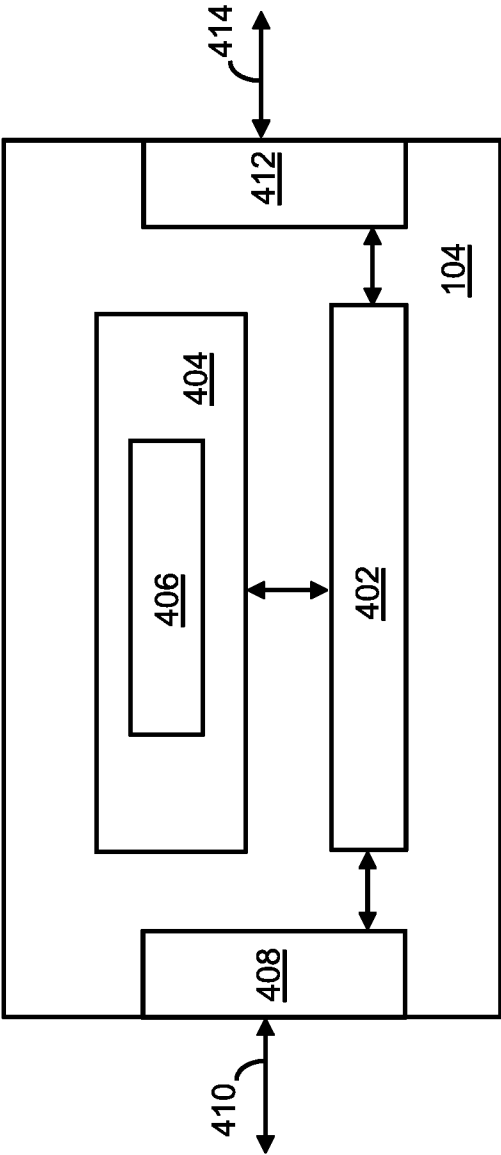


FIG. 5

INTERNATIONAL SEARCH REPORT

International application No

PCT/US2013/065022

A. CLASSIFICATION OF SUBJECT MATTER

INV. H04Q11/04 H04J3/12
ADD.

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H04Q H04J

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

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

EP0-Internal, PAJ, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 2 068 471 A1 (NOKIA SIEMENS NETWORKS SPA [IT]) 10 June 2009 (2009-06-10) paragraphs [0020] - [0027], [0050] - [0061] claims 1,2,7,9; figures 3,6,12,13a,13b -----	1-10
X	US 2004/190548 A1 (HAREL RAFI [IL] ET AL) 30 September 2004 (2004-09-30) paragraphs [0117] - [0124] figure 10 -----	1,6
X	EP 2 434 717 A1 (ZTE CORP [CN]) 28 March 2012 (2012-03-28) paragraphs [0014] - [0016], [0032] - [0034] claims 9-11; figure 2 ----- -/--	1,6



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

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Date of the actual completion of the international search

18 December 2013

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07/01/2014

Name and mailing address of the ISA/

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INTERNATIONAL SEARCH REPORT

International application No

PCT/US2013/065022

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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A	----- CN 202 261 320 U (PETROCHINA CO LTD) 30 May 2012 (2012-05-30) abstract -----	1-10

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