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

(54) Title: METHODS, SYSTEMS, AND COMPUTER READABLE MEDIA FOR MONITORING AND/OR TESTING NET-WORK COMMUNICATIONS
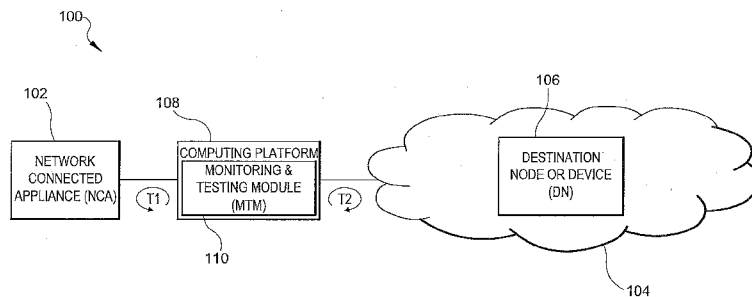
FIG. 1

(57) Abstract: Methods, systems, and computer readable media for monitoring and/or testing network communications are dis-closed. A method for monitoring network communications includes receiving packets from a network connected device, determining features associated with either the network connected device or a communications network to which the network connected device is connected by actively or passively monitoring or testing the packets, and automatically switching between passively monitoring or testing the packets and actively monitoring or testing the packets in response to receiving a packet carrying instructions.

DESCRIPTION
METHODS, SYSTEMS, AND COMPUTER READABLE MEDIA FOR MONITORING AND/OR TESTING NETWORK COMMUNICATIONS

5   PRIORITY CLAIM

This application claims the benefit of U.S. Patent Application No. 14/537,851, filed November 10, 2014; the disclosure of which is incorporated herein by reference in its entirety.

10   TECHNICAL FIELD

The subject matter described herein relates to monitoring and testing network communications. More specifically, the subject matter relates to methods, systems, and computer readable media for monitoring and testing "Audio Video Bridging" (AVB) network communications.

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BACKGROUND

Existing Information Technology (IT) type networks are configured to move data through a network as quickly as possible with minimum cost and minimal management. This is generally sufficient, so long as the data does 20   not include one or more audio/video (A/V) streams having more stringent timing and/or delivery requirements, which overwhelm conventional IT buffers. Even minor delays in the transmission and/or delivery of A/V content as a result of using traditional buffers is unacceptable in high-level and/or high-quality A/V applications.

25   To overcome the drawbacks of existing IT type networks, "Audio Video Bridging" (AVB) technology has emerged as a solution for delivering "no compromise" streaming quality, characterized by (i) precise synchronization between all networked devices for synchronized endpoint playback of media streams; (ii) traffic shaping for media streams; (iii) 30   reservation or "admission control" for reserving or pre-allocating bandwidth and frequency for transmitting/receiving media streams; and (iv) identification of non-participating (i.e., "non-AVB") devices within the network. AVB networks implement a set of protocols being developed by the IEEE 802.1 Audio/Video Bridging Task Group.

Issues arise when attempting to use and/or allocate resources within an AVB network efficiently. In particular, challenges exist in negotiating control plane traffic and synchronizing the time base between networked devices. Currently, there is not an efficient system and/or method for

5   monitoring and testing the AVB network or the networked devices prior to communicating a media stream through the network; thus, there is not an adequate level of assurance in meeting and/or adhering to stream reservation protocols.

Accordingly, a need exists for improved methods, systems, and

10 computer readable media for monitoring and testing network communications.

SUMMARY

Methods, systems, and computer readable media for monitoring

15 and/or testing network communications are disclosed. According to one method for monitoring network communications, the method includes, at a computing platform, receiving packets from a network connected device, determining performance metrics associated with either the network connected device or a communications network to which the network

20 connected device is connected by actively or passively monitoring or testing the packets, and automatically switch between passively monitoring or testing the packets and actively monitoring or testing the packets in response to receiving a packet carrying instructions.

According to one system for monitoring network communications, the

25 system comprises a computing platform comprising at least one processor, and a monitoring and testing module (MTM) implemented via the at least one processor. The MTM is configured to receive packets from a network connected device, determine various features or performance metrics associated with either the network connected device or a communications

30 network to which the network connected device is connected by actively or passively monitoring or testing the packets, and automatically switch between passively monitoring or testing the packets and actively monitoring or testing the packets in response to receiving a packet carrying instructions.

The subject matter described herein may be implemented in software in combination with hardware and/or firmware. For example, the subject matter described herein may be implemented in software executed by a processor. In one exemplary implementation, the subject matter described

5   herein may be implemented using a computer readable medium having stored thereon computer executable instructions that when executed by the processor of a computer control the computer to perform steps. Exemplary computer readable media suitable for implementing the subject matter described herein include non-transitory devices, such as disk memory

10 devices, chip memory devices, programmable logic devices, and application specific integrated circuits. In addition, a computer readable medium that implements the subject matter described herein may be located on a single device or computing platform or may be distributed across multiple devices or computing platforms.

15   As used herein, the term "node" refers to a physical computing platform including one or more processors and memory.

        As used herein, the terms "function" or "module" refer to hardware, firmware, or software in combination with hardware and/or firmware for implementing features described herein.

20   As used herein, the term "link" refers to any path, route, or type(s) of connection between devices. For example, a link may include one or more communications nodes, networks, or media, such as a wire, cable, fiber optics, radio, or other medium. In a second example, a link may also include a trunk and/or logical connection.

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                    BRIEF DESCRIPTION OF THE DRAWINGS

        The subject matter described herein will now be explained with reference to the accompanying drawings of which:

        Figure 1 is a network diagram illustrating an exemplary process for

30 monitoring and testing network communications according to an embodiment of the subject matter described herein;

Figure 2 is a network diagram illustrating another exemplary process for monitoring and testing network communications according to another embodiment of the subject matter described herein;

Figure 3 is a block diagram illustrating the computing platform for monitoring and testing network communications according to an embodiment of the subject matter described herein; and

Figure 4 is a block diagram illustrating an exemplary process for monitoring and testing network communications according to an embodiment of the subject matter described herein.

DETAILED DESCRIPTION

The subject matter described herein includes methods, systems, and computer readable media for monitoring and testing network communications. In some embodiments, the methods and systems described herein are configured to monitor and test Audio Video Bridging (AVB) networks and/or networked devices.

In some embodiments, the subject matter herein includes a system comprising a computing platform having a monitoring and testing module, which may be positioned adjacent to and/or between a pair of networked (i.e., network connected) nodes or devices. The networked nodes or devices may include a "talker" node or device and a "listener" node or device, which collectively form synchronized endpoints for communicating an audio media stream, a video media stream, and/or an audio/video (A/V) media stream in an AVB network.

In some embodiments, the monitoring and testing systems and methods described herein are configured to actively and/or passively monitor and test communications within a network, including communications directed to and/or from any one of the talking and listening devices, communications between the talking and/or listening devices, and/or communication between any devices (e.g., switches, routers, bridges) within the network. The functionality of the monitoring and testing module may also be implemented by the actual talking and listening nodes or devices within an AVB network, for example, by imparting such functionality thereto via

additional hardware and/or software, without departing from the scope of the subject matter described herein.

In some embodiments, the monitoring and testing systems and methods described herein are configured to monitor and test performance
5   metrics including time synchronization, latency, and packet jitter required for high quality A/V transmissions over a network. Time synchronization allows for (i) synchronized recording and playback of media stream(s) (e.g., at a same speed) without "jumps"; (ii) synchronizing data from multiple sources of media streams (e.g., multiple cameras, a camera and a microphone, a
10   speaker, etc.) thereby enabling downstream devices to use the multiple signals to produce a combined, aligned result (e.g., combining video from multiple sources to create a combined image with a time difference between the sources); and/or for (iii) synchronizing actions taken at the same time (e.g., starting/stopping recordation of a media stream at multiple recording
15   devices).

In some embodiments, the monitoring and testing systems and methods described herein assure minimum packet jitter, packet delay variation, and/or latency for high-quality A/V applications (e.g., without buffering). Monitoring and testing systems and methods described herein
20   may be used for various high-level or high-quality A/V applications not limited to AVB applications for "live" broadcasts; movie production applications (e.g., having a plurality of A/V recording cameras and microphones); high-definition (HD) streaming applications; security system applications (e.g., security systems using A/V streaming, multiple cameras,
25   etc.); vehicle applications (e.g., autonomous vehicle networks); aircraft applications (e.g., a jet pilot seeing accurate data from a camera in as close to "real-time"); any A/V streaming applications (e.g., from a central location); combinations thereof, and/or use in any and all types of AVB networks and applications.

30   In some embodiments, the monitoring and testing systems and methods described herein are configurable for operability in a plurality of different modes. As used herein the terms "actively monitor" and/or "active mode" denote instances where the monitoring and testing system generates

and inserts or transmits packets (e.g., test packets, emulated packets, etc.) for verifying aspects associated with a network connection. Inserted packets may also be specially coded (e.g., with a source identifier) for authentication purposes, such that data within a secure system is not susceptible to

5   "faking". As used herein, the terms "passively monitor" and/or "passive mode" denote instances where the monitoring and testing system divert and inspect packets, but do not generate and/or insert new packets within the data stream. In the passive mode, the monitoring and testing system is configured to merely pass packets through a monitoring and testing device

10   for monitoring and/or testing purposes.

In some embodiments, systems and methods herein may be configured to test network connected AVB devices (e.g., talker/listener devices), to test the AVB network prior to using the AVB devices, and/or to monitor the network and/or communications between any of the network

15   connected devices during A/V streaming. In some embodiments, the device may alert a user and/or take corrective action based upon the testing and/or monitoring of network communications.

Reference will now be made in detail to exemplary embodiments of the subject matter described herein, examples of which are illustrated in the

20   accompanying drawings. Wherever possible, the same reference numbers will be used throughout the drawings to refer to the same or like parts.

Figure 1 illustrates an exemplary system **100** for which any and/or all network communications are monitored and/or tested according to an embodiment of the subject matter described herein. In some embodiments,

25   system **100** includes a monitoring and testing node or device configured to monitor and test network elements, including nodes or devices for transmitting and/or receiving A/V communications (e.g., talker and listener nodes) within a network.

In some embodiments, system **100** includes a communications

30   network **104**. Network **104** may include an AVB network through which streams of media packets (e.g., audio, video, and/or A/V data packets) are communicated between endpoints (e.g., a talker and a listener). A plurality of network elements is configured to communicate A/V data via network **104**.

For example, network **104** includes at least one source node or device (e.g., a talker), such as a network connected appliance (NCA) **102**, and at least one destination node or device (DN) **106** (e.g., a listener). For illustration purposes, NCA **102** is illustrated as being disconnected and/or isolated from

5   network **104** by a monitoring and testing module (MTM) for monitoring and testing purposes (e.g., mode 1, mode 2) as described further below. However, NCA **102** and DN **106** may comprise elements of network **104**.

In some embodiments, any number of additional network elements (e.g., routers, switches, bridges, etc.) may be provided or disposed along the

10   communication path defined by and/or between NCA **102** and DN **106** for facilitating data communication. In some embodiments, at least one computing platform **108** including a MTM **110** is disposed in the path between NCA **102** and DN **106** for monitoring and testing network **104** and/or elements thereof (e.g., NCA **102**, DN **106**, etc.). Notably, MTM **110**

15   may include a layer 2 (L2) switch or switching functionality whereby the MTM **110** automatically switches between active and passive testing modes in response to receiving instructions (e.g., a packet carrying instructions) from another node, device, a network operator, and/or a network administrator.

Network **104** may represent any suitable entity or entities (e.g., one or

20   more nodes or devices) associated with sending and/or receiving audio, video, or A/V traffic (e.g., one or more packets). In some embodiments, network **104** may include an AVB network configured to implement a set of protocols being developed by the IEEE 802.1 Audio/Video Bridging Task Group. As used herein, the term "talker" denotes an A/V stream source

25   while "listener" denotes an A/V stream destination. Thus, the talker and listener devices include synchronized endpoint devices (e.g., A/V cameras, microphones, broadcasting equipment, recording equipment, playback equipment, speakers, etc.) for providing synchronized actions including synchronized playback, recording, etc. NCA **102** and DN **106** may be

30   individually synchronized to a system or network clock (not shown) and may also exchange time based packets for maintaining synchronicity. One or more AVB bridges or switches may be disposed between the talkers (e.g.,

NCA **102**) and listener (e.g., DN **106**) endpoints for communicating A/V packets there between.

In some embodiments, NCA **102** and DN **106** include endpoint network elements (e.g., computing platforms, devices, and/or nodes)

5   associated with one or more flows (e.g., one or more related packets). For example, NCA **102** may include a talker endpoint, DN **106** may include a listener endpoint, and computing platform **108** may include an in-line AVB device by which communications to, from, and/or between NCA **102** and DN **106** may be monitored or tested via MTM **110**. The functionality of computing

10   platform **108** and MTM **110** may also be imparted directly to NCA **102** and/or DN **106** via additional hardware and/or software, without departing from the scope of the subject matter described herein.

In some embodiments, NCA **102**, DN **106**, and computing platform **108** may each include multiple communications interfaces and may

15   communicate A/V data using a variety of communication protocols. For example, network elements including NCA **102**, DN **106**, and computing platform **108** may include functionality for communicating or facilitating A/V communications with one or more nodes or modules in network **104**. Exemplary communications interfaces within network **104** may include a

20   Real-time Transport Protocol (RTP) interface, a software defined network (SDN) related interface, an Internet protocol (IP) interface, a graphical user interface (GUI), a command line interface (CLI), and/or an application programming interface (API). Exemplary protocols may include an extensible markup language (XML) protocol, a hypertext transfer protocol

25   (HTTP), an IP protocol, a Diameter protocol, an OpenFlow protocol, and/or other protocols.

In some embodiments, NCA **102**, DN **106**, and/or computing platform **108** may include and/or be hosted by a virtual server and include one or more virtual machines (VM). In this example, NCA **102**, DN **106** VMs may

30   be configured to generate, record, transmit, and/or playback media packets associated with one or more flows (e.g., of related packets). Computing platform **108** VMs may be configured to divert, monitor, and/or test data flows communicated from or to NCA **102** and/or DN **106**. Computing

platform **108** may also actively generate and insert packets (e.g., test packets, encrypted packets, emulated packets, etc.) during communication of a data stream, where desired.

5   In some embodiments, the talker, NCA **102** and the listener, DN **106** reserve communication resources according to a reservation protocol within network **104** in advance of communicating A/V data for guaranteeing that a communication path between endpoints is available, and for reserving the communication resources defining the path.   In some embodiments, computing platform **108** is configured to test the communication path and/or

10   communication resources prior to reserving resources and/or prior to transmission of one or more media streams therethrough via MTM **110**. In further embodiments, computing platform **108** is further configured to monitor the communication path between the talker, NCA **102** and listener, DN **106** during transmission of one or more packet media or data streams.

15   In some embodiments, computing platform **108** and MTM **110** include a single efficient in-line testing device disposed between NCA **102** and DN **106**, which is operable and/or configured for operability in a plurality of different "modes" as described herein, for monitoring and/or testing purposes. In other embodiments, the functionality of computing platform **108**,

20   including MTM **110**, may be embedded within network elements (e.g., NCA **102** "talker" and/or DN **106** "listener") without departing from the scope of the instant subject matter. In some embodiments, computing platform **108**, including MTM **110**, is operable in at least four different modes as described in Table 1 below, each of which are also described in more detail below.

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TABLE 1	
MODE IDENTIFIER	BRIEF DESCRIPTION OF EACH MODE
Mode 1 (Local test mode)	A single node is locally tested for assessing functionality, the node being tested is only connected to the monitoring and testing module (MTM, e.g., **110** (Fig. 1) or **210** (Fig. 2)
Mode 2 (Emulation mode)	MTM **110/210** emulates a talker or listener node for running tests

TABLE 1	
Mode 3 (Bypass or "passive" mode)	MTM **110/210** monitors traffic in both directions for passively monitoring the network for quality
Mode 4 (Network test mode)	MTM **110/210** inserts packets within a data stream for running network tests and/or for monitoring the network

Notably, MTM **110** is configured to automatically change modes (e.g., switch between any of modes 1 to 4) on demand, in some aspects upon detection or receipt of specially coded data packets and/or notifications sent via specially coded packets. For example, a network operator, administrator, or manager may instruct MTM **110** via packet instructions to activate or engage a L2 switch, whereby MTM **110** is enabled for active mode and for generation and insertion of packets. MTM **110** may be operable for testing and/or monitoring one node, a plurality of nodes, and/or an entire network **104** for synchronization verification and quality both before and during packet communications. Notably, computing platform **108** is configured to validate connectivity, reliability, operation, timing measurements (e.g., latency, packet jitter, and/or packet delay variation), synchronization, accuracy, and/or latency within network **104** and/or at one or more nodes thereof, via MTM **110**.

Still referring to Figure 1, aspects of mode 1 and mode 2 are illustrated. Regarding operability in mode 1 and in some embodiments, NCA **102** and/or DN **106** may be tested prior to use in communicating data, for example, at a point in time before any data packets are transmitted, exchanged, and/or communicated along the path between NCA **102** and DN **106**. MTM **110** may be used to generate test packets for locally testing NCA **102** prior to transmittal of any data packets by NCA **102** via an active and unidirectional test **T1** or test loop, as indicated by the arrowed line. During a local test, NCA **102** may be isolated from and/or disconnected from network **104**. In some embodiments, and during mode 1, NCA **102** may only be connected with computing platform **108** having MTM **110** installed thereon and/or executed thereby. MTM **110** is configured to generate, transmit, and

exchange packets with NCA **102** to ensure operability of NCA **102** prior to initiating communication of a media stream via NCA **102**. NCA **102** may then be connected to network **104** upon verification of its quality and functionality via MTM **110**. MTM **110** may also verify that NCA **102** is
5   appropriately synchronized upon connection to network **104**.

Regarding operability in mode 2, in some embodiments MTM **110** is configured to emulate a talker node (e.g., NCA **102**) or a listener node (e.g., DN **106**) for running tests regarding connectivity, reliability, proper installation, proper operability, proper functionality, proper timing, proper
10   synchronization, latency, packet jitter, packet delay variation, combinations thereof, and/or any other tests in regards to network **104** and/or any of the networked elements. When in mode 2, MTM **110** is configured to both receive packets from a media stream and insert (e.g., generate and transmit) packets into the media stream. Thus, in addition to mode 1, mode 2 may
15   also include an active monitoring and/or testing mode.

When operating in mode 2, NCA **102** may be disconnected from network **104** such that MTM **110** may communicate with network **104** on behalf of NCA **102** as indicated by test loop **T2**. That is, MTM **110** is configured to copy packets received from NCA **102**, and emulate NCA **102**
20   upon communicating with network **104**. MTM **110** may communicate and/or exchange packets with network **104** and/or elements thereof. Mode 2 may be employed to test various performance metrics (e.g., synchronization, functionality, timing, packet jitter, packet delay variation, latency, etc.) associated with network **104**, network elements (e.g., DN **106**), and/or any or
25   all communications therewith. Mode 2 may also be useful in running tests where the presence of the emulated device (e.g., NCA **102**) would interfere with the test (e.g., test loop **T2**).

Whether operating in mode 1 or mode 2, MTM **110** may be configured to receive, divert, and/or intercept some, any, or all communications to, from,
30   and/or within network **104** for testing and monitoring purposes. In some embodiments, NCA **102**, network **104**, and/or DN **106** may be tested before communicating A/V data, for example, when the elements are negotiating a path and/or exchanging synchronized packets having synchronized frames

for verifying timing within network **104**. As mentioned above, synchronization is important for facilitating synchronized recording or playback of a media stream at endpoints, synchronizing multiple media streams, and for performing actions (e.g., starting or stopping of recording) at a same time.

5   Figure 2 illustrates an exemplary system **200** for which any and/or all network communications are monitored and/or tested according to an embodiment of the subject matter described herein. In some embodiments, system **200** includes a plurality of monitoring and testing nodes or devices for monitoring and testing a plurality of network elements, including nodes or

10   devices for transmitting and/or receiving A/V communications (e.g., talker and listener nodes) within a network. Components in Figure 2 are similar to those described in Figure 1 above; however, system **200** includes more than one (e.g. multiple) testing nodes or devices are provided for illustrating operability in modes 3 and 4, discussed briefly above in Table 1.

15   Notably, monitoring and testing devices as described herein (e.g., MTMs) are each configurable in a plurality of different modes (e.g., mode 1 to mode 4), which may be active, passive, and automatically interchanged as needed upon receiving packet instruction (e.g., packets including unique identifiers, specially coded headers, etc.) to the MTMs described herein. The

20   specially coded packets may designate an operating mode. If a mode is not designated, MTMs described herein may be configured to operate in a default mode, which, in some embodiments is mode 3.

In some embodiments, system **200** includes a source or talker endpoint including NCA **202**. NCA **202** may include the source endpoint of

25   one or more media streams. System **200** further includes a destination or listener endpoint DN **204** which is synchronized with NCA **202**. DN **204** may include the destination endpoint of the one or more media streams. The endpoints may communicate with each other via transmitting packets across and/or through a network **206**, which in some embodiments includes an AVB

30   network. System **200** further includes a plurality of computing platforms, such as a first computing platform **208A** and a second computing platform **208B** at which monitoring and testing equipment may be provided or

installed. In some embodiments, each computing platform **208A** and **208B** includes a MTM **210**.

Each computing platform **208A** and **208B** may include an in-line AVB device by which communications to, from, and/or between NCA **202** and DN **204** may be diverted for monitoring or testing via at least one MTM **210**. The functionality of MTM **210** may also be imparted directly to talker NCA **202** and/or listener DN **204** via additional hardware and/or software, without departing from the scope of the subject matter described herein.

In some embodiments, NCA **202**, DN **204**, and computing platforms **208A** and **208B** may include multiple communications interfaces and may communicate A/V data using a variety of protocols. For example, network elements including NCA **202**, DN **204**, and computing platforms **208A** and **208B** may include functionality for communicating or facilitating A/V communications with one or more nodes or modules in network **206**.

Network **206** may include an AVB network through which streams of media packets (e.g., audio, video, and/or A/V data packets) are communicated. A plurality of network elements may be configured to communicate A/V data within and/or through network **206**. For example, at least one source node or device (e.g., NCA **202**) is configured to communicate with at least one destination node or device (e.g., DN **204**) via network **206**. Any number of additional network elements (e.g., routers, switches, bridges, etc.) may be provided or disposed along the communication path defined by and/or between NCA **202** and DN **204** for facilitating data communication. In some embodiments, each computing platform **208A** and **208B** includes an MTM **210** disposed in the path between NCA **202** and DN **204** for monitoring and testing network **206** and/or elements thereof. In some embodiments, first computing platform **208A** is disposed at and/or in-line with NCA **202** and second computing platform **208B** is disposed at and/or in-line with DN **204**.

Network **206** represents any suitable entity or entities (e.g., one or more nodes or devices) associated with sending and/or receiving audio, video, or A/V traffic (e.g., one or more packets). In some embodiments, network **206** may include an AVB network configured to implement a set of

protocols being developed by the IEEE 802.1 Audio/Video Bridging Task Group. In some embodiments, NCA **202** and DN **204** include synchronized endpoints (e.g., A/V cameras, microphones, broadcasting equipment, recording equipment, playback equipment, etc.) for providing synchronized

5   playback, recording, etc. NCA **202** and DN **204** may be individually synchronized to a system or network clock (not shown) and/or NCA **202** and DN **204** may exchange time based packets for maintaining synchronicity.

Still referring to Figure 2, aspects of mode 3 and mode 4 are illustrated. In some embodiments, mode 3 may include a default mode in

10   which MTMs **210** are configured to passively monitor network communications. For example, mode 3 may include a bypass mode, in which NCA **202** and DN **204** communicate via network **206**, and MTMs **210** divert, intercept, inspect, and passively monitor network traffic in at least two directions, **D1** and **D2**. MTMs **210** may not generate and/or insert packets

15   within the data stream during operation in mode 3. MTMs **210** are configured to passively monitor network **206** and components thereof (e.g., NCA **202**, DN **204**, etc.) for quality, and detect specially coded messages or packets in which the mode of operation may be automatically changed. Specially coded packets destined for MTMs **210** may not seen by the other

20   devices (e.g., NCA **202**, DN **204**, etc.) in network **206**.

As Figure 2 illustrates, at least one MTM **210** may be provided in-line with NCA **202** having functionality to passively monitor communications between NCA **202** and network **206**, where the term "passively" monitoring refers to a mode where MTM **201** does not generate and insert packets into

25   a media stream. Rather, MTM **210** intercepts and tests or monitors packets passing from NCA **202** prior to reaching network **206**. MTM **210** is configured to monitor packets destined for network **206** by isolating the packets and diverting or passively tapping into the media stream.

As Figure 2 illustrates, at least one MTM **210** may also provided in-

30   line with DN **204** having functionality to passively monitor communications between network **206** and DN **204**. MTM **210** may be configured to divert, intercept, and test or monitor packets prior to the packets being received by DN **204**. Each MTM **210** may test and monitor a media stream for assuring

timing, assuring quality (e.g., minimized latency, packet jitter, and packet delay variation), assuring reliability of the network and/or components thereof, assuring operability and/or functionality of the network and/or components thereof, assuring accuracy, etc.

5   Regarding operability in mode 3 and in some embodiments, communications directed from or to NCA **202** and/or DN **204** may be passively monitored and tested *in situ*, or while data is being communicated (e.g., streamed) between endpoints (e.g., NCA **202**, DN **204**). For example, MTM **210** may passively test and/or monitor packets during transmission, 10   exchange, and/or communication of data packets along the path between NCA **202** and DN **204** for detecting quality, functionality, operability, and/or synchronization, latency, packet jitter, or packet delay variation. As Figure 2 illustrates, each MTM **210** may be used to bi-directionally test a data stream (e.g., bi-directionally test/monitor a data stream) as indicated by the arrowed 15   lines or directions **D1** and **D2**. During a passive testing/monitoring or bypass testing/monitoring mode (e.g., mode 3), NCA **202** and/or DN **204** may be isolated from network **206** via MTM **110**.

Regarding operability in mode 4, MTM **210** may be configured to test the network. In this mode, each networked device (e.g., NCA **202**, DN **204**) 20   may transmit and/or receive data, and MTMs **210** may also generate and insert packets into the data stream data stream for running network tests and/or for monitoring the network or network communications. Mode 4 may be used, in some embodiments, to run networks tests while NCA **202** and DN **204** are streaming data to assure network quality. In some 25   embodiments, each MTM **210** may be configured to alert a user or network operator and/or take corrective actions based upon the testing and/or monitoring of network communications.

In an exemplary embodiment, mode 4 allows generation and insertion of unique flows or groups of packets into the data stream, which identify the 30   computing platform as a testing and/or monitoring source. This is advantageous, for example, in security applications (e.g., having remote security cameras, etc.) as it provides an encrypted and/or authenticated data stream. This may provide more robust security systems which can prevent

"faking" of data, as MTM **210** includes an intelligent agent configured to insert specially identified packets.

It will be appreciated that Figures 1 and 2 are for illustrative purposes only and that various nodes and/or modules, locations, and/or functionality
5   described above in relation to Figure 1 may be changed, altered, added, or removed.

Figure 3 is a block diagram illustrating computing platforms described herein (e.g., **108/208A/208B**), which include functionality for monitoring and testing network communications according to embodiments of the subject
10   matter described herein. Computing platform **108/208A/208B** includes at least one MTM **110/210** configured to monitor and test network communications. In some embodiments, MTM **110/210** may be implemented as a single entity at a single computing platform. In other embodiments, MTM **110/210** may be implemented as a distributed entity
15   across multiple computing devices or platforms. For example, MTM **110/210** may be implemented as a software module executing on processors associated with computing platform **108/208A/208B** and/or other entities, such as network elements **102, 106, 202, 204**, etc.

In some embodiments, MTM **110/210** is disposed between a source
20   node (SN) **302** and a destination node or device (DN) **304** for monitoring and/or testing the devices (e.g., synchronization, timing, latency, packet jitter, packet delay variation, quality, functionality, etc.) both before data transmission and/or at any time during data transmission. Packet headers, routing tables, and/or combinations thereof may be used to divert or route
25   flows or media streams (e.g., audio data, video data, and/or A/V data) through MTM **110/210**.

In some embodiments, packets originating from at least one talker node and/or destined for at least one listener node may be passively monitored or tested and/or actively tested or monitored (e.g.,. copied and
30   emulated) via MTM **110/210**. In some embodiments, MTM **110/210** identifies and intercepts media packets originating from a talker and/or destined for a listener are identified via routing information and/or unique data structures included in a media packet header. Routing information

and/or unique data structures may include or identify a path assignment, a path identifier, a unique identifier, a flow tuple, or any other suitable identifier which MTM **110/210** may access from a storage device not limited to a database, a hash table, an associative array, and/or a content-addressable

5   memory (CAM).

In other embodiments, packets may be automatically diverted or routed through MTM **110/210** via control plane assignments and/or stream reservation protocols. Routing information may include a path assignment table, where each entry in the path assignment table may include an

10   association between one or more destination nodes and a path identifier (e.g., VLAN identifier, a MPLS label, or a path label) that affects the data path a packet traverses. Exemplary assignment values for causing media to route through MTM **110/210** may include a flow tuple or other identifier, a hash of a flow tuple or other identifier, and/or data in a key-value data

15   structure.

In some embodiments, MTM **110/210** may communicate with one or more of network connected devices (e.g., SN **302** or DN **304**) or modules using an interface, for example, an RTP interface, a SDN related interface or any other suitable interface. Exemplary SDN related interfaces may include

20   an OpenFlow protocol interface or a Diameter protocol interface.

When in a default monitoring and testing mode (e.g., a passive, bypass mode, mode 3) as described above, packets from network elements, including one of SN **302** and DN **304**, may be routed or diverted into MTM **110/210** and to a Passive Tap Module (PTM) via one or more Tap Mode

25   Control/Isolator Modules (TMC/IMs). For example, packets may encounter a first TMC/IM **306A** configured to route packets into PTM **308** when computing platform is operable in a default mode (e.g., mode 3). When in an active mode (e.g., modes 1, 2, or 4) first TMC/IM **306A** may route packets to an Active Tap Module (ATM) **310**. After packets are tested or monitored via

30   PTM **308**, the packets may then exit MTM **110/210** and be directed towards DN **304** via a second TMC/IM **306B**.

In some embodiments, when in a passive mode, packets may be directed along the path designated by broken lines. For example, ingress

and egress packets associated with one or more AVB network connected nodes or devices in an AVB network, or packets flowing between nodes (e.g., SN **302**, DN **304**) within an AVB network may be routed through MTM **110/210** and passively monitored via PTM **308**. PTM **308** is configured to

5   monitor packet timing for detection/inspection of synchronization, latency, packet delay variation and/or packet jitter. PTM **308** is also configured to monitor network quality and/or operability of SN **302** and/or DN **304**. In some embodiments, PTM **308** may be configured to alert another network element (e.g., a node, device, module, system component, system operator,

10   administrator, etc.) and/or initiate a corrective action based upon the testing and/or monitoring of network communications.

In some embodiments, MTM **110/210** is configured to operate in the default mode (e.g., passive/bypass mode 3) until triggered to engage a L2 switch for copying, emulating, and/or transmitting packets, thereby initiating

15   or engaging in an active mode. MTM **110/210** may be triggered to engage an active mode upon receiving specially coded packets that signal, alert, or otherwise trigger computing platform **108/208A/208B** to switch between a passive mode and one or more active modes as described above.

In some embodiments, when in an active mode, packets pass into

20   ATM **310** via a L2 Switch and Packet Copy Module (SPCM) **312**. The flow path within ATM **310** is designated in solid lines. Packets are directed into and out of SPCM **312** via TMC/IM **306A** and/or **306B** as indicated by the solid lines extending from TMC/IM **306A** and **306B**. Once SPCM **312** is engaged, MTM **110/210** may actively generate and transmit packets to

25   network elements for testing network communications, network devices, authentication of and/or ensuring security of the data stream, and/or combinations thereof.

For example, in mode 1, a single network element (e.g., SN **302**, DN **301**, etc.) may be actively tested via TPGM **314**. When in mode 1, SN **302**

30   and/or DN **304** may be disconnected from a communications network and only communicate with MTM **110/210** via ATM **310** and SPCM **312**. SN **302** or DN **304** may be tested for assessing functionality and/or operability before transmission of a media stream and/or media packets between SN **302** and

DN **304**. In some aspects, TPGM **314** is configured to generate test packets for running local tests of SN **302** or DN **304** for ensuring that the device is functional. This may advantageously reduce the amount of control plane traffic in reserving and allocate resources (e.g., adhering to stream

5   reservation protocols), as defective resources may be weeded out ahead of time in advance of performing the stream reservation protocol. MTM **110/120** may generate test packets via TPGM **314** and output the test packets to the tested node via SPCM **312** and TMC/IM **306A** or **306B**.

In mode 2, MTM/**210 110** is configured to emulate a network

10 connected device or apparatus (NCA) such as a talker node (e.g., SN **302**) or a listener node (e.g., DN **304**) for running tests regarding connectivity, reliability, proper installation, proper operability, proper functionality, proper timing, proper synchronization, latency, packet jitter, packet delay variation combinations thereof, and/or any other tests in regards to an AVB network

15 and/or any of the AVB networked elements. When in mode 2, MTM **110/210**, using ATM **310**, is configured to both receive packets from a media stream and insert (e.g., generate and transmit) packets into the media stream.

For example and when operating in mode 2, ATM **310** is configured to

20 emulate a network connected appliance (NCA, e.g., SN **302**) via an NCA Emulator Module (NCA-EM) **316**. In some aspects, SPCM **312** is adapted to copy packets diverted from SN **302**, and emulate the packets via NCA-EM **318** for testing purposes. A network and/or elements thereof (e.g., DN **304**) may receive the emulated packets generated and transmitted by MTM

25 **110/210**, however, such packets appear to come from SN **302**. MTM **110/210** thus communicates with other nodes and/or the network in general as a proxy for SN **302**. When in emulation mode, SN **302** may be disconnected with the remainder of the network, and all communications to DN **304** may be copied and generated at MTM **110/210** via NCA-EM **316**.

30 This may be useful for running tests on the network where the presence of SN **302** would interfere with the test. Mode 2 may be employed to test various performance metrics (e.g., synchronization, functionality, timing,

packet delay variation, packet jitter, latency, etc.) associated with network **104**, network elements (e.g., DN **106**), and/or communications therewith.

In mode 4, MTM **210** is configured to test the network, for example, by emulating a network device (e.g., a router, gateway, switch, etc.) In mode 2 described above, the talker (e.g., NCA or SN **302**) may be emulated. In mode 4, any other network device may be emulated. In this mode, MTM **110/210** may actively generate, transmit, and insert packets into the data stream data stream for running network tests and/or for monitoring the network during transmission of a media stream. Packets (e.g., instructions for automatic switching between active and passive modes) destined for MTM may not be seen by and/or encountered by other devices (e.g., SN **302**, DN **304**) within and/or connected to network **206**. Mode 4 may be used, in some embodiments, to run networks tests while SB **302** and DN **304** are actively streaming data to assure network quality. MTM **110/210** may also be configured to alert another network element and/or a network operator to implement corrective actions based upon the testing and/or monitoring of network communications.

Figure 4 is a block diagram illustrating an exemplary process for monitoring and testing network communications according to an embodiment of the subject matter described herein. In some aspects, the process is performed at a computing platform including a MTM (e.g., Figs. 1-3).

In block **400**, a packet data stream carrying audio, video, or audio/video (A/V) data from a network connected device may be received at the computing platform. The functionality of the computing platform may be disposed at a single node, across multiple nodes, and/or embedded within synchronized endpoints (e.g., talker and listener nodes) without departing from the scope of the instant subject matter.

In block **402**, various performance metrics associated with either the network connected device or a communications network to which the network connected device is connected are determined by actively or passively monitoring or testing packets within the packet data stream.

Various performance metrics of either the network connected device (e.g., SN **302**, DN **304**) or the network to which the network connected

device is connected (e.g., an AVB network) may be monitored or tested by examining the packet data stream. For example, the computing platform is configured to monitor and/or test various performance metrics or aspects including connectivity of network connected device, reliability of the network
5   and/or network connected device, operability of the network connected device, packet timing, synchronization, accuracy, latency, packet delay variation, and/or packet jitter.

In some embodiments, the packets in a packet data stream may be diverted to the computing platform and passively monitored and/or tested, or
10   actively monitored and/or tested. During passive monitoring or testing (e.g., mode 3, the default mode) packets in a packet data stream are passively inspected via a PTM (Fig. 3). During active monitoring or testing, the packet data stream is diverted to computing platform and packets are actively tested and/or inspected via an ATM (Fig. 3). As noted above, the term "actively
15   tested" refers to the ATMs ability to generate and insert packets within the packet data stream. The ATM may generate new test packets or copy and emulate another device.

In block **404**, the computer platform is configured to automatically switch between passively monitoring or testing the packet data stream and
20   actively monitoring or testing the packet data stream in response to receiving specially coded packet instructions. Specially coded packet instructions include packets containing unique routing information and/or unique data structures for identifying a path assignment. For example, the specially coded packet instructions may include a packet having a unique path
25   identifier, a unique identifier, a flow tuple, or any other suitable identifier.

The subject matter described herein for testing and monitoring network communications improves the functionality of networks and/or networked devices by providing more efficient and effective resource utilization. The subject matter herein tests and monitors network
30   communications in an AVB network for minimizing the amount of control plane traffic in reserving and allocating AVB network elements while improving confidence that the network will meet and adhere to stream reservation protocols. It should also be noted that a computing platform that

implements the subject matter described herein includes a special purpose computing device usable to test and monitor network communications, namely communications in an AVB network.

It will be understood that various details of the subject matter described herein may be changed without departing from the scope of the subject matter described herein. Furthermore, the foregoing description is for the purpose of illustration only, and not for the purpose of limitation, as the subject matter described herein is defined by the claims as set forth hereinafter.

CLAIMS

What is claimed is:

1.   A method for monitoring and/or testing network communications, the method comprising:

5   at a computing platform:

                receiving packets from a network connected device; and

                determining performance metrics associated with either the network connected device or a communications network to which the network connected device is connected by actively or passively

10   monitoring or testing the packets; and

                automatically switching between passively monitoring or testing the packets and actively monitoring or testing the packets in response to receiving a packet carrying instructions.

2.   The method of claim 1, wherein the communications network

15 comprises via an Audio Video Bridging (AVB) network.

3.   The method of claim 1, wherein the packets include audio, video, or audio/video (A/V) packets.

4.   The method of claim 1, wherein the network connected device includes an audio/video (A/V) recording camera, a microphone, a speaker,

20 broadcasting equipment, recording equipment, or A/V playback equipment.

5.   The method of claim 1, wherein determining performance metrics includes verifying at least one of:

                connectivity of the network connected device, connectivity of the communications network, operability of the network connected device,

25 quality of the communications network, reliability of the communications network, reliability of the network connected device, packet timing, synchronization of the network connected device, latency, packet jitter, packet delay variation, or combinations thereof.

6.   The method of claim 1, wherein automatically switching between

30 passively monitoring or testing the packets and actively monitoring or testing the packets comprises engaging a Layer 2 (L2) switch to route the packets between a passive testing module (PTM) and an active testing module (ATM).

7.   The method of claim 1, wherein the network connected device only communicates with the computing platform.

8.   The method of claim 1, further comprising generating one or more test packets and transmitting the one or more test packets to the network
5   connected device.

9.   The method of claim 8, wherein the one or more test packets emulate a network communication.

10.   The method of claim 1, further comprising generating one or more test packets and inserting the one or more test packets in a media stream flowing
10   between the network connected device and a destination node.

11.   The method of claim 1, further comprising copying the packets received from the network connected device, emulating the packets copied from the network connected device, and transmitting the emulated packets to at least one other network connected device.

15   12.   The method of claim 1, further comprising passively monitoring a plurality of packets exchanged between a plurality of network connected devices.

13.   The method of claim 1, wherein the network connected device comprises an audio/video (A/V) source node, and wherein the packets are
20   received at the computing platform prior to communication of an A/V data stream from the source node to a destination node.

14.   A system for monitoring and/or testing network communications, the system comprising:

a computing platform comprising at least one processor; and
25   a monitoring and testing module (MTM) implemented via the at least one processor, wherein the MTM is configured to:

receive packets from a network connected device;

determine performance metrics associated with either the network connected device or a communications network to which the
30   network connected device is connected by actively or passively monitoring or testing the packets; and

automatically switch between passively monitoring or testing the packets and actively monitoring or testing the packets in response to receiving a packet carrying instructions.

15.   The system of claim 14, wherein the communications network comprises an Audio Video Bridging (AVB) network.

16.   The system of claim 14, wherein the packets include audio, video, or audio/video (A/V) packets.

17.   The system of claim 14, wherein the network connected device includes an audio/video (A/V) recording camera, a microphone, a speaker, broadcasting equipment, recording equipment, or A/V playback equipment.

18.   The system of claim 14, wherein the performance metrics include at least one of connectivity of the network connected device, connectivity of the communications network, operability of the network connected device, quality of the communications network, reliability of the communications network, reliability of the network connected device, packet timing, synchronization of the network connected device, latency, packet jitter, packet delay variation, or combinations thereof.

19.   The system of claim 14, wherein the MTM includes a Layer 2 (L2) switch configured to switch them MTM from a passive mode for passively monitoring or testing the packets and an active mode for actively monitoring or testing the packets.

20.   The system of claim 14, wherein the network connected device only communicates with the computing platform.

21.   The system of claim 14, wherein the MTM is configured to generate one or more test packets and transmit the one or more test packets to the network connected device.

22.   The system of claim 21, wherein the one or more test packets emulate a network communication.

23.   The system of claim 14, wherein the MTM is configured to generate one or more test packets and insert the one or more test packets in a media stream that flows between the network connected device and a destination node.

24.   The system of claim 14, wherein the MTM is configured to copy the packets received from the network connected device, emulate the packets copied from the network connected device, and transmit the emulated packets to at least one other network connected device.

5   25.   The system of claim 14, further comprising a passive testing module (PTM) configured to passively monitoring a plurality of packets exchanged between a plurality of network connected devices.

26.   The system of claim 14, wherein the network connected device comprises an audio/video (A/V) source node, and wherein the packets are
10   received at the computing platform prior to communication of an A/V data stream from the source node to a destination node.

27. A non-transitory computer readable medium comprising computer executable instructions embodied in the non-transitory computer readable medium that when executed by a processor of a computer perform steps
15   comprising:

receiving packets from a network connected device; and

determining performance metrics associated with either the network connected device or a communications network to which the network connected device is connected by actively or passively monitoring or testing
20   the packets; and

automatically switching between passively monitoring or testing the packets and actively monitoring or testing the packets in response to receiving a packet carrying instructions.
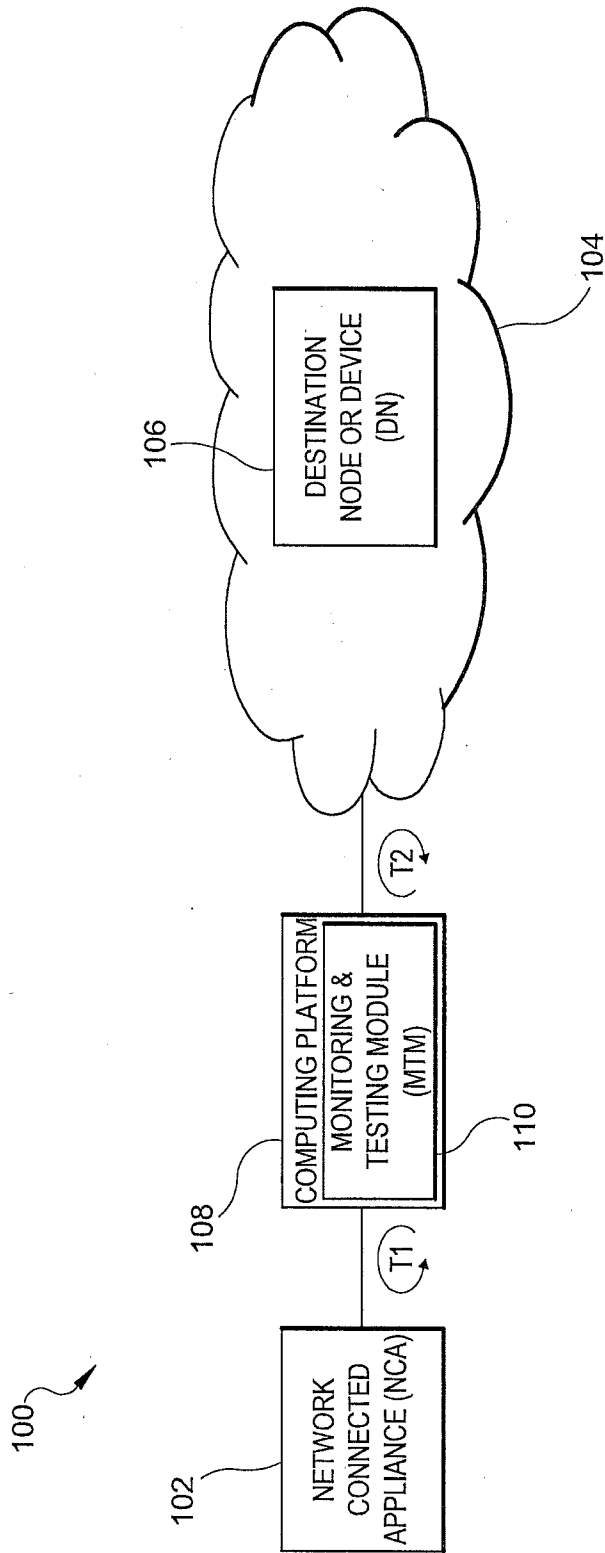
1/4

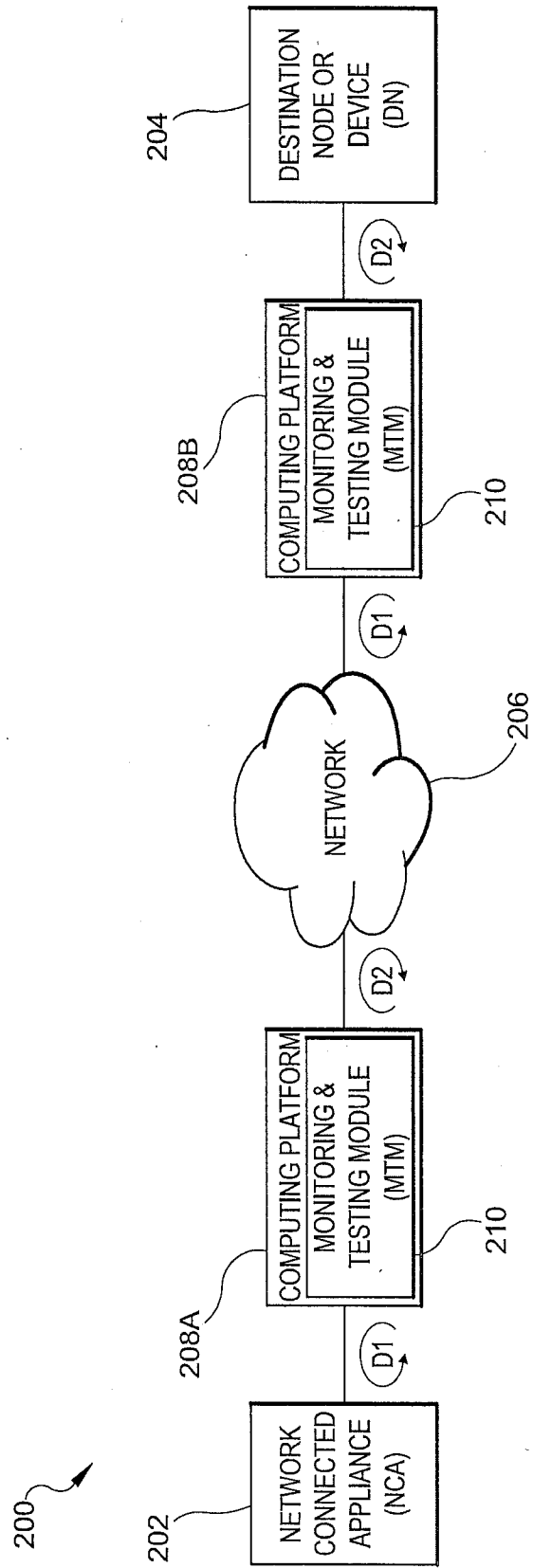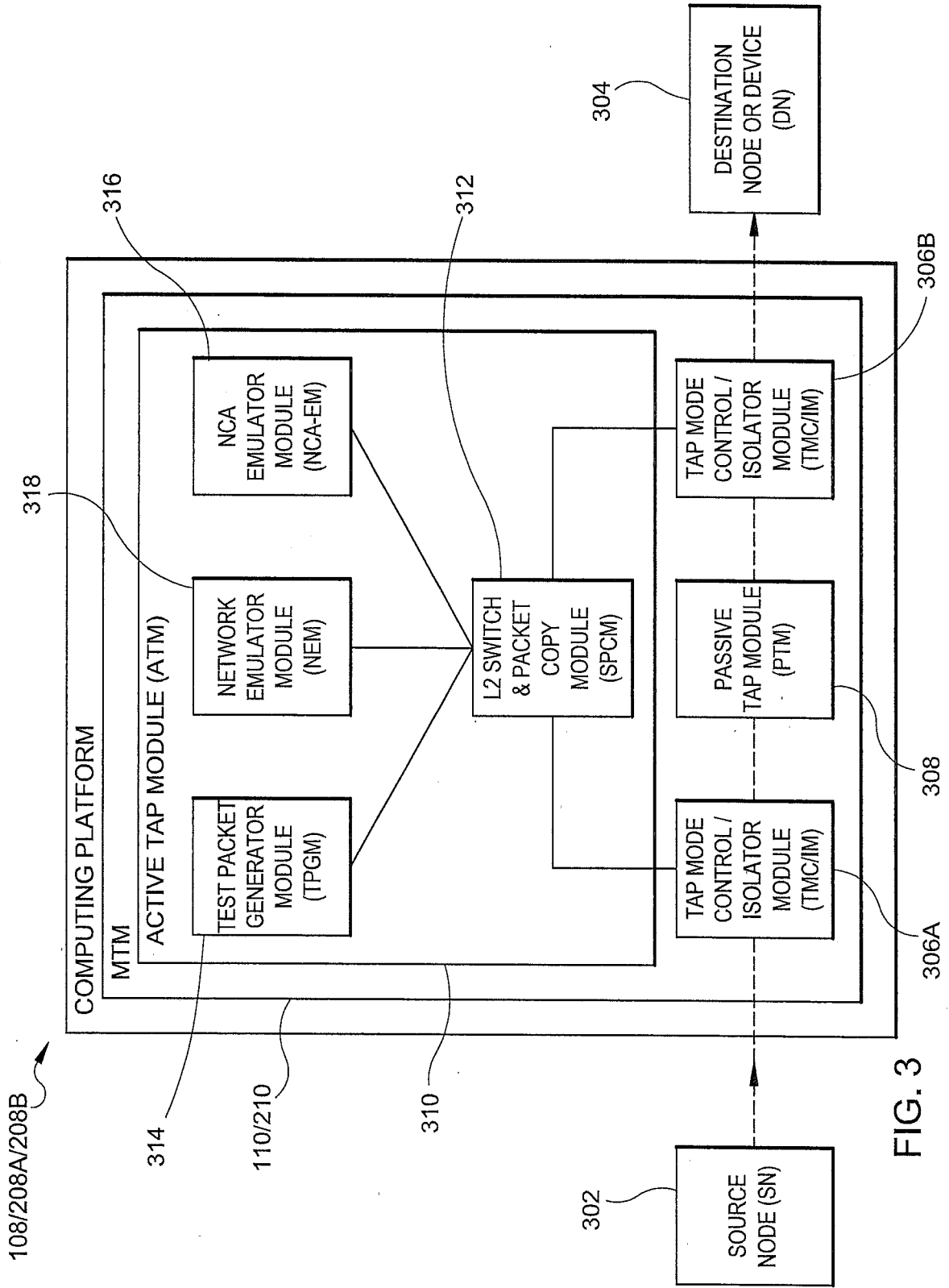NETWORK
CONNECTED
APPLIANCE (NCA)

102

100

108

COMPUTING PLATFORM

MONITORING &
TESTING MODULE
(MTM)

110

T1

T2

106

DESTINATION
NODE OR DEVICE
(DN)

104

FIG. 1

FIG. 2

3/4

FIG. 3

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┌─────────────────────────────────────────┐
│ RECEIVING  PACKETS   FROM   A   NETWORK   │
│ CONNECTED DEVICE                          │       400
└─────────────────────────────────────────┘
                     │
┌─────────────────────────────────────────┐
│ DETERMINING      PERFORMANCE     METRICS  │
│ ASSOCIATED  WITH  EITHER  THE  NETWORK    │
│ CONNECTED  DEVICE  OR  A  COMMUNICATION   │
│ NETWORK    TO    WHICH    THE    NETWORK  │       402
│ CONNECTED   DEVICE   IS   CONNECTED   BY  │
│ ACTIVELY  OR  PASSIVELY  MONITORING  OR   │
│ TESTING THE PACKETS                       │
└─────────────────────────────────────────┘
                     │
┌─────────────────────────────────────────┐
│ AUTOMATICALLY      SWITCHING     BETWEEN  │
│ PASSIVELY  MONITORING  OR  TESTING  THE   │
│ PACKETS  AND  ACTIVELY  MONITORING  OR    │
│ TESTING  THE  PACKETS  IN  RESPONSE  TO   │       404
│ RECEIVING  A  PACKET  CARRYING  SPECIALLY │
│ CODED INSTRUCTIONS                        │
└─────────────────────────────────────────┘
```
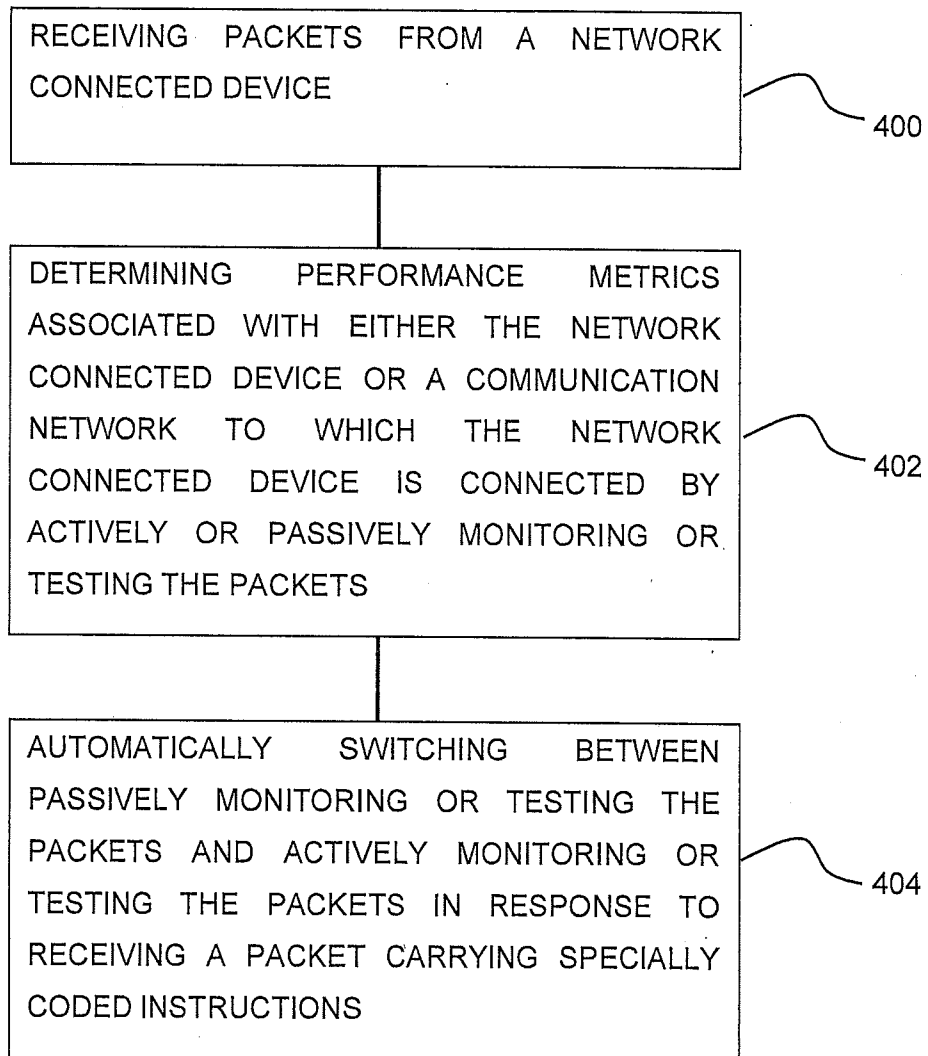
FIG. 4

A.   CLASSIFICATION OF SUBJECT MATTER

H04L 12/26(2006.01)i

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

B.   FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H04L 12/26; G06F 15/16; H04H 20/47; G06F 15/173; G06F 9/00; H04H 20/61; H04W 24/08

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean utility models and applications for utility models
Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS(KIPO internal) & Keywords: network, packet, monitor, test, active, passive, switching, audio, video, bridging, AVB

C.   DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2010-0177644 A1 (DAVID KUCHARCZYK) 15 July 2010 See paragraphs [0002]-[0008], [0013], [0026], [0031]-[0032], [0041]; claim 27; and figures 1-2.	1,5-12,14,18-25,27
Y		2-4,13,15-17,26
Y	US 2008-0126561 A1 (HYUN-SURK RYU et al.) 29 May 2008 See paragraphs [0017], [0033], [0052]-[0053], [0093]; and figure 2.	2-4,13,15-17,26
A	US 6763380 B1 (KIM IRVIN MAYTON et al.) 13 July 2004 See column 6, line 27 - column 10, line 44; and figure 2.	1-27
A	US 2011-0170433 A1 (DONALD MACGREGOR SCOBBIE) 14 July 2011 See paragraphs [0010]-[0012], [0051]-[0057]; and figure 1.	1-27
A	KR 10-1401990 B1 (INTER. M CORPORATION) 05 June 2014 See paragraphs [0034]-[0046]; and figures 1-2.	1-27

☐ Further documents are listed in the continuation of Box C.   ☒ See patent family annex.

* Special categories of cited documents: "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents,such combination being obvious to a person skilled in the art "&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
23 February 2016 (23.02.2016)	**24 February 2016 (24.02.2016)**

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Facsimile No. +82-42-472-7140	Telephone No. +82-42-481-5916

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US 6763380 B1	13/07/2004	None	
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KR 10-1401990 B1	05/06/2014	None	