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Yadav et al.

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(54) **SESSION LAYER FOR MONITORING UTILITY APPLICATION TRAFFIC**

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This patent is subject to a terminal disclaimer.

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Related U.S. Application Data

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(51) **Int. Cl.**
G06F 15/173 (2006.01)
H04L 12/26 (2006.01)

(52) **U.S. Cl.**
CPC ***H04L 43/0876*** (2013.01); ***H04L 43/04*** (2013.01); ***H04L 43/08*** (2013.01); ***H04L 43/18*** (2013.01); *H04L 43/087* (2013.01); *H04L 43/0829* (2013.01); *H04L 43/0852* (2013.01); *H04L 43/106* (2013.01); *H04L 43/16* (2013.01)

(58) **Field of Classification Search**
CPC H04L 43/16; H04L 47/10; H04L 45/38; H04L 45/22; H04W 28/02
USPC 709/217, 224, 232
See application file for complete search history.

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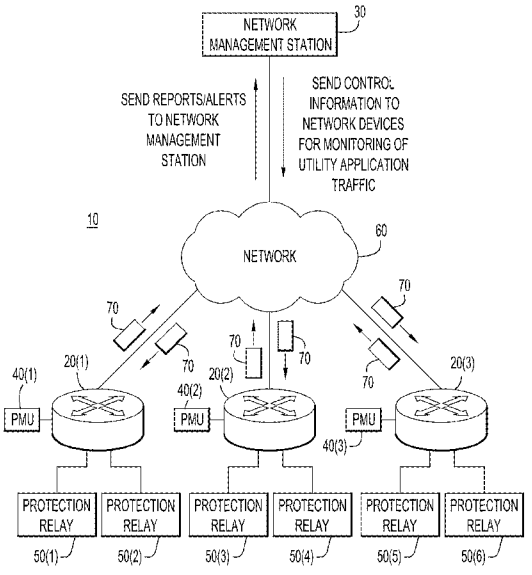
(57) **ABSTRACT**

Techniques are provided to facilitate monitoring of utility application traffic streams. At a network device that routes utility application traffic for utility devices, control information is received, where the control information is configured to cause the network device to monitor utility application traffic that passes through the network device. The network device monitors a header inserted into utility application traffic messages based on the control information.

20 Claims, 17 Drawing Sheets



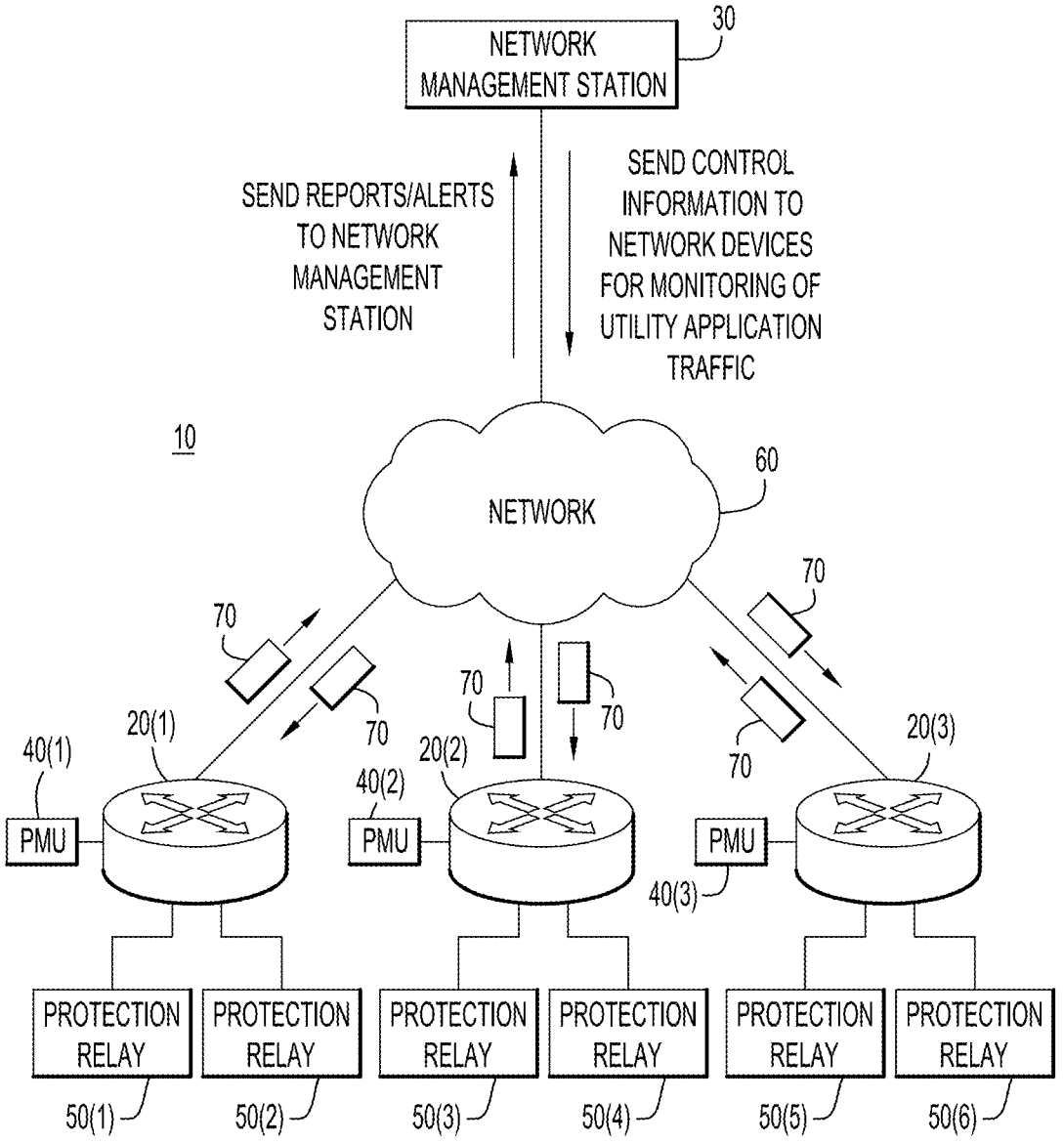

NETWORK MANAGEMENT STATION
30
SEND REPORTS/ALERTS TO NETWORK MANAGEMENT STATION
SEND CONTROL INFORMATION TO NETWORK DEVICES FOR MONITORING OF UTILITY APPLICATION TRAFFIC
10
NETWORK
60
70
70
70
70
70
70
20(1)
20(2)
20(3)
40(1)
40(2)
40(3)
PMU
PMU
PMU
PROTECTION RELAY
PROTECTION RELAY
PROTECTION RELAY
PROTECTION RELAY
PROTECTION RELAY
PROTECTION RELAY
50(1)
50(2)
50(3)
50(4)
50(5)
50(6)

FIG.1

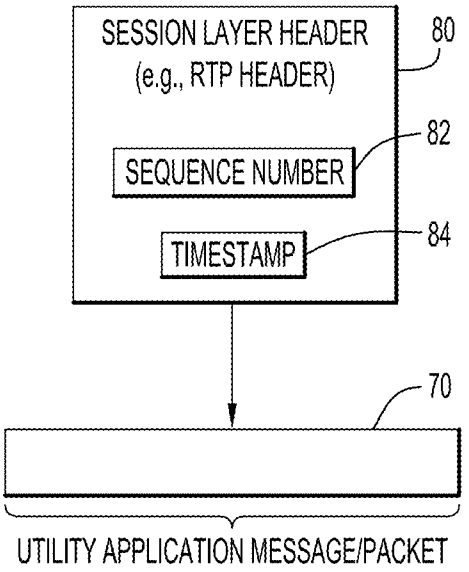
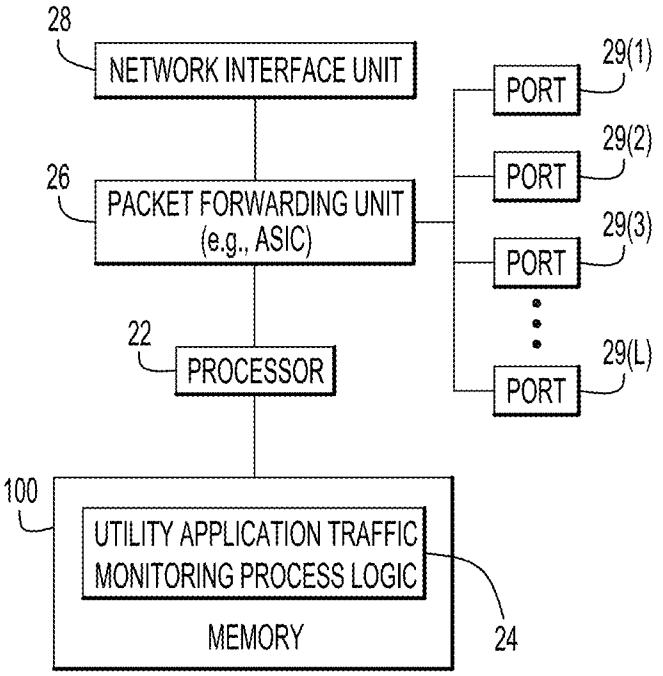

SESSION LAYER HEADER
(e.g., RTP HEADER)
80
SEQUENCE NUMBER
82
TIMESTAMP
84
70
UTILITY APPLICATION MESSAGE/PACKET

FIG.2


28
NETWORK INTERFACE UNIT
26
PACKET FORWARDING UNIT
(e.g., ASIC)
22
PROCESSOR
100
UTILITY APPLICATION TRAFFIC
MONITORING PROCESS LOGIC
MEMORY
24
PORT
29(1)
PORT
29(2)
PORT
29(3)
PORT
29(L)

20(i)

FIG.3

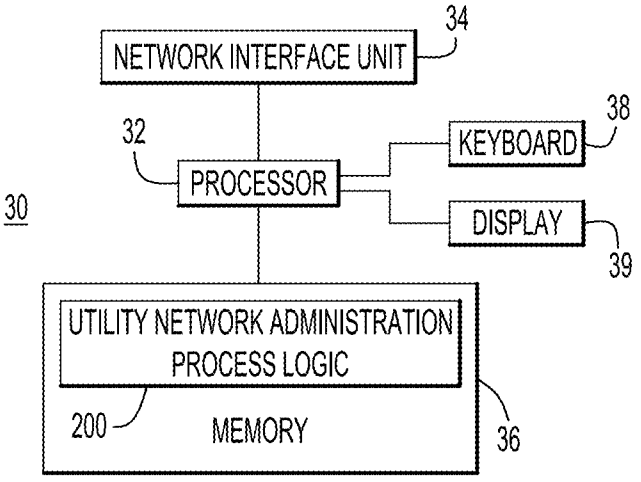

NETWORK INTERFACE UNIT
34
32
PROCESSOR
KEYBOARD
38
DISPLAY
39
30
UTILITY NETWORK ADMINISTRATION PROCESS LOGIC
200
MEMORY
36

FIG.4

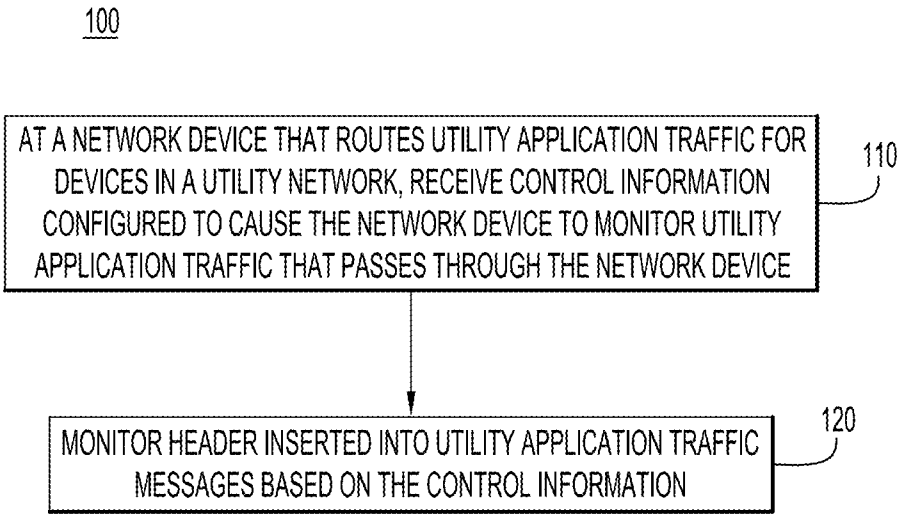

100
AT A NETWORK DEVICE THAT ROUTES UTILITY APPLICATION TRAFFIC FOR DEVICES IN A UTILITY NETWORK, RECEIVE CONTROL INFORMATION CONFIGURED TO CAUSE THE NETWORK DEVICE TO MONITOR UTILITY APPLICATION TRAFFIC THAT PASSES THROUGH THE NETWORK DEVICE
110
MONITOR HEADER INSERTED INTO UTILITY APPLICATION TRAFFIC MESSAGES BASED ON THE CONTROL INFORMATION
120

FIG.5

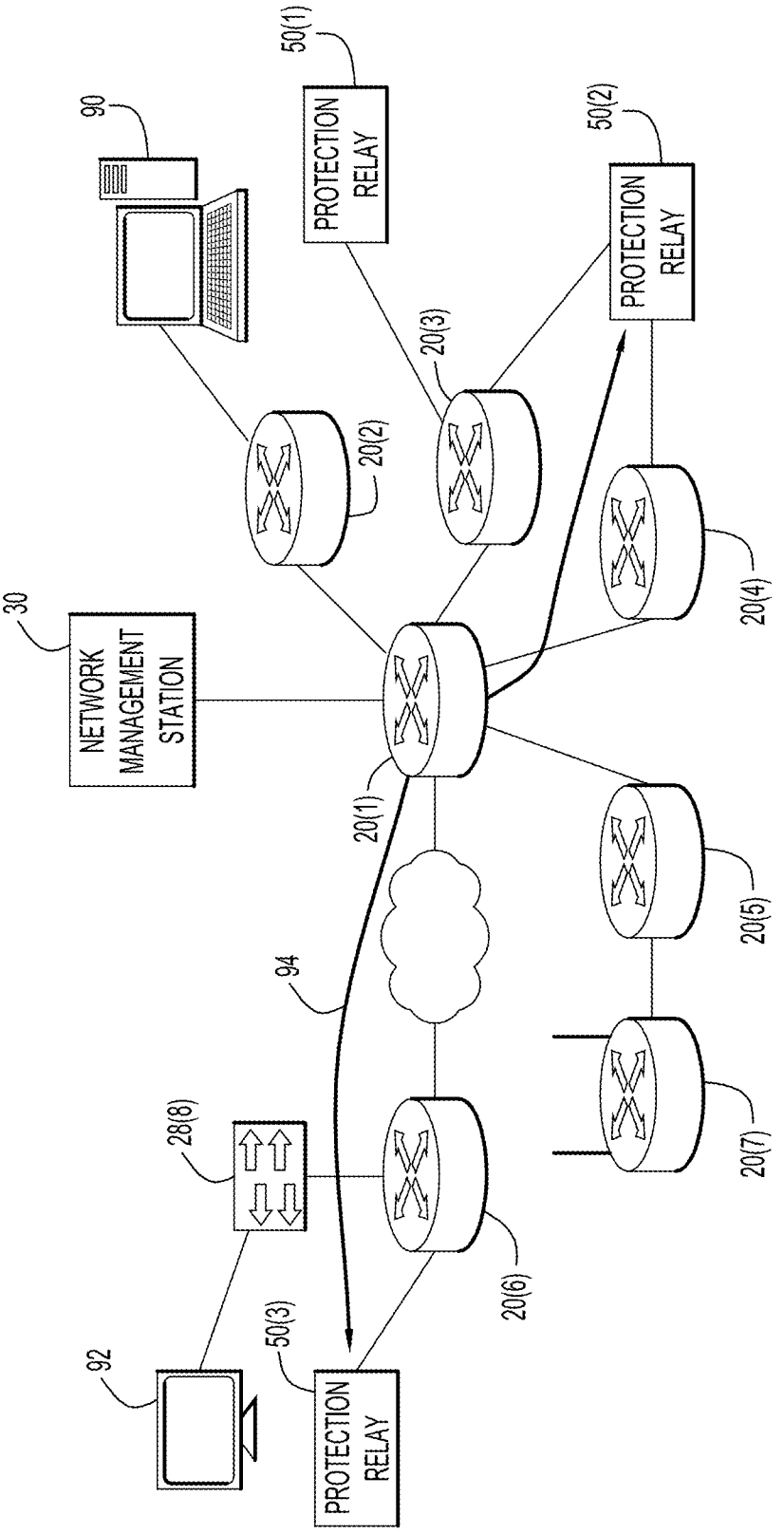

50(1)
PROTECTION RELAY
90
50(2)
PROTECTION RELAY
20(3)
20(2)
30
NETWORK MANAGEMENT STATION
20(4)
20(1)
20(5)
94
28(8)
20(7)
20(6)
50(3)
92
PROTECTION RELAY

FIG.6

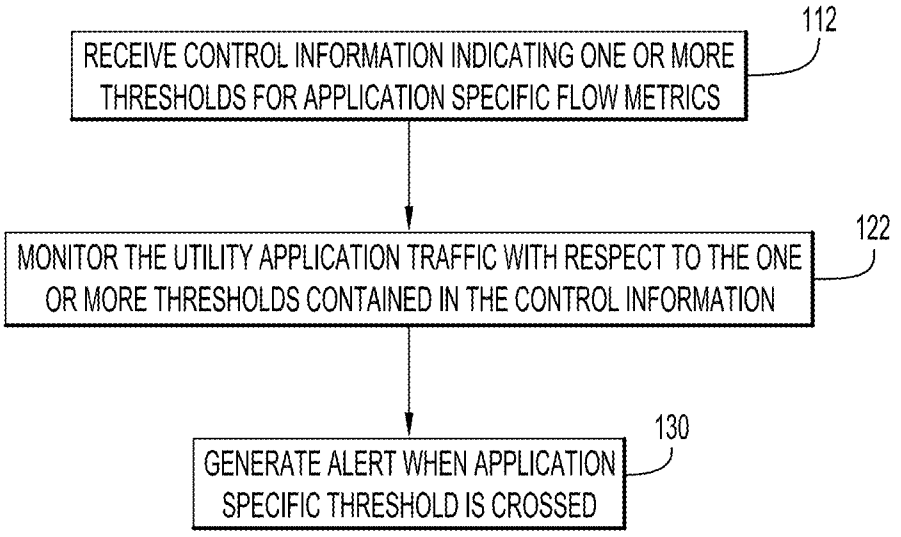

RECEIVE CONTROL INFORMATION INDICATING ONE OR MORE THRESHOLDS FOR APPLICATION SPECIFIC FLOW METRICS
112
MONITOR THE UTILITY APPLICATION TRAFFIC WITH RESPECT TO THE ONE OR MORE THRESHOLDS CONTAINED IN THE CONTROL INFORMATION
122
GENERATE ALERT WHEN APPLICATION SPECIFIC THRESHOLD IS CROSSED
130

FIG.7

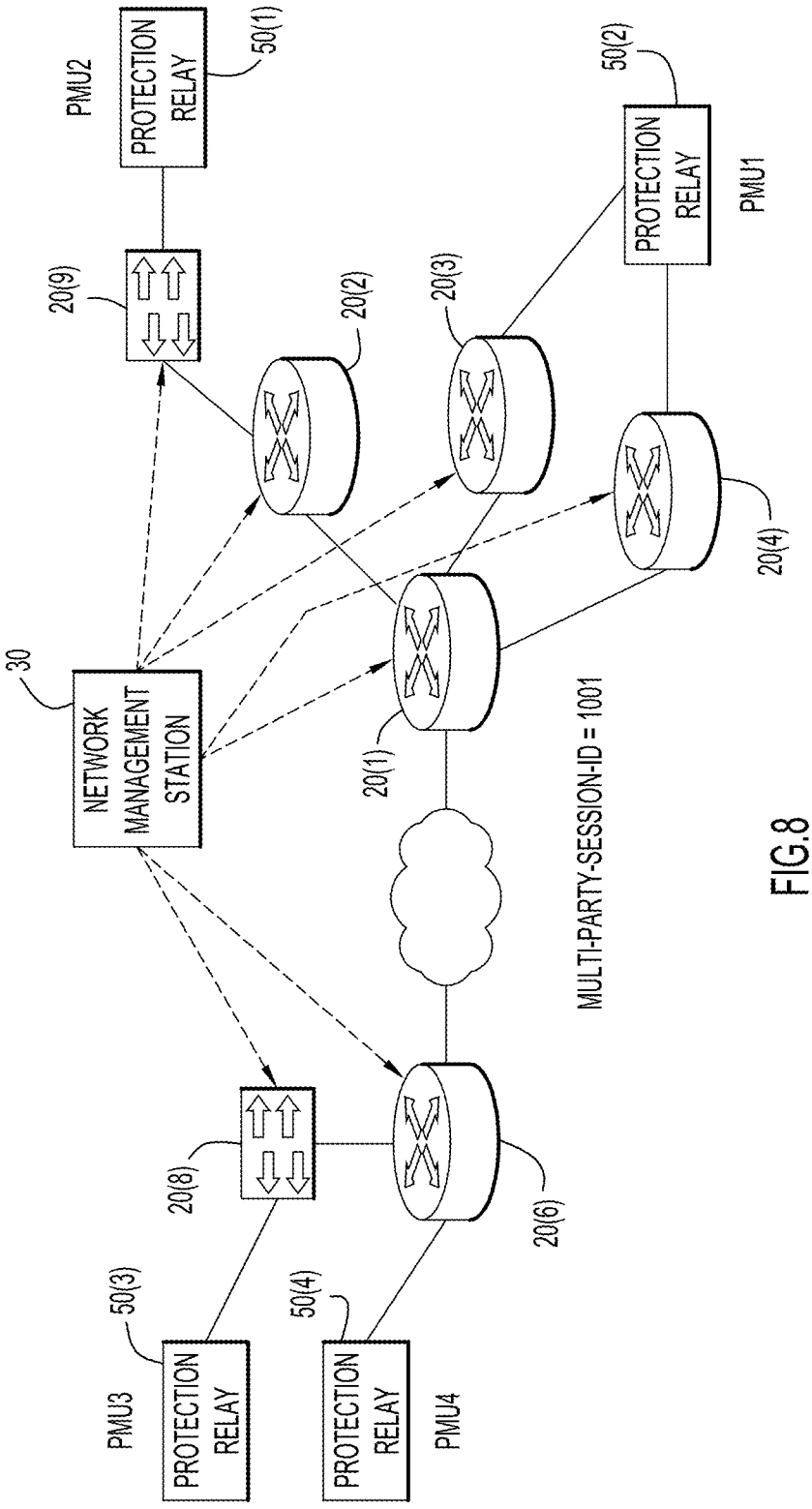

PMU2
PROTECTION RELAY
50(1)
50(2)
PROTECTION RELAY
PMU1
20(9)
20(2)
20(3)
30
NETWORK MANAGEMENT STATION
20(1)
20(4)
MULTI-PARTY-SESSION-ID = 1001
20(8)
20(6)
50(3)
50(4)
PMU3
PROTECTION RELAY
PROTECTION RELAY
PMU4

FIG.8

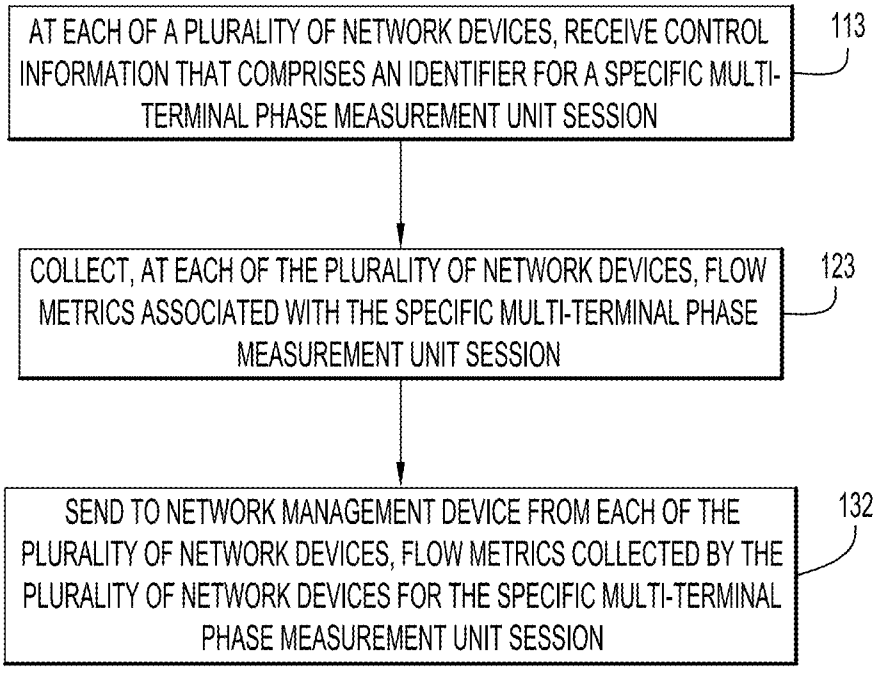

AT EACH OF A PLURALITY OF NETWORK DEVICES, RECEIVE CONTROL INFORMATION THAT COMPRISES AN IDENTIFIER FOR A SPECIFIC MULTI-TERMINAL PHASE MEASUREMENT UNIT SESSION
113
COLLECT, AT EACH OF THE PLURALITY OF NETWORK DEVICES, FLOW METRICS ASSOCIATED WITH THE SPECIFIC MULTI-TERMINAL PHASE MEASUREMENT UNIT SESSION
123
SEND TO NETWORK MANAGEMENT DEVICE FROM EACH OF THE PLURALITY OF NETWORK DEVICES, FLOW METRICS COLLECTED BY THE PLURALITY OF NETWORK DEVICES FOR THE SPECIFIC MULTI-TERMINAL PHASE MEASUREMENT UNIT SESSION
132

FIG.9

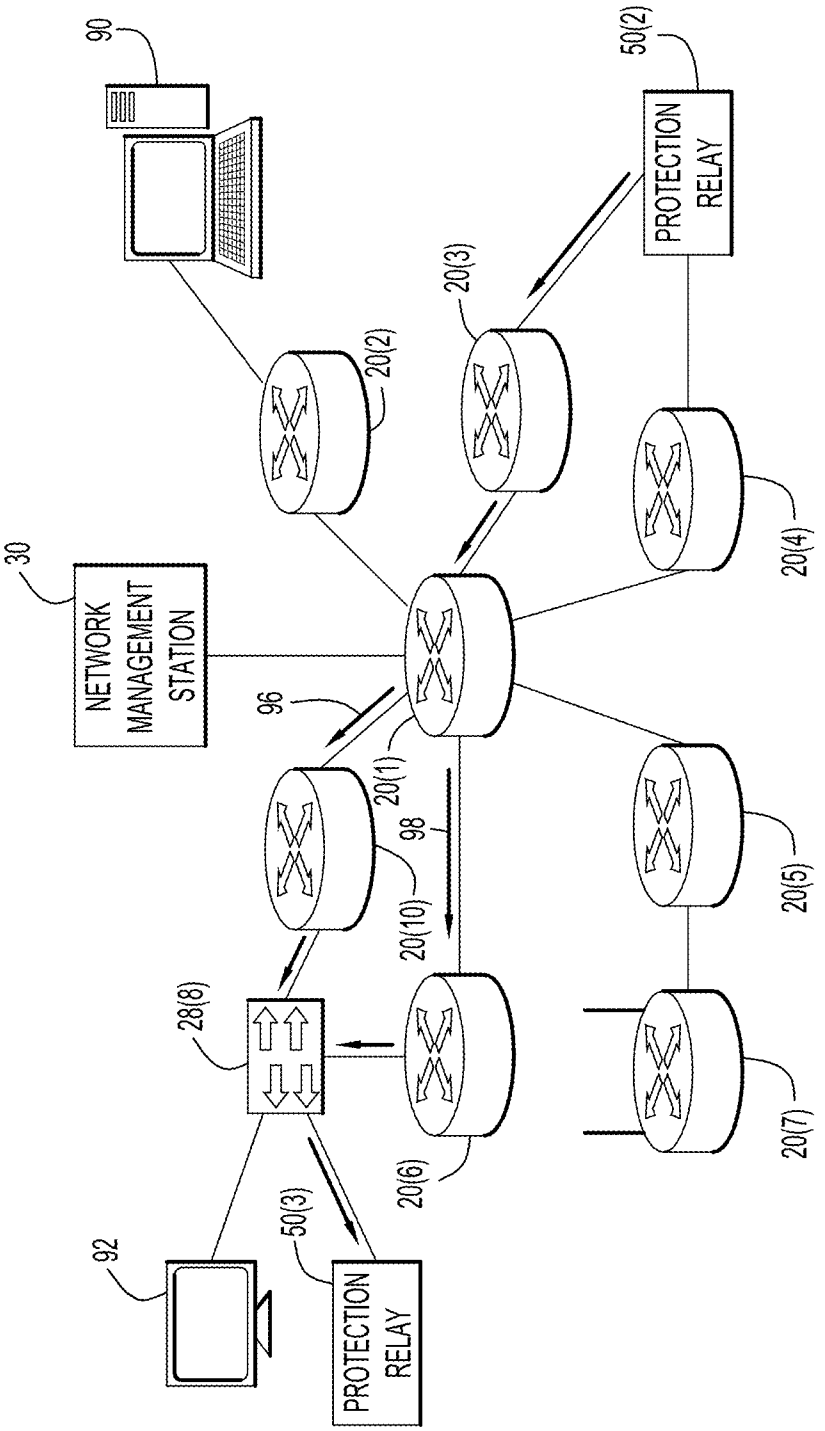

90
50(2)
PROTECTION RELAY
20(3)
20(2)
30
NETWORK MANAGEMENT STATION
20(4)
96
20(1)
98
20(10)
20(5)
28(8)
20(6)
20(7)
92
50(3)
PROTECTION RELAY

FIG.10

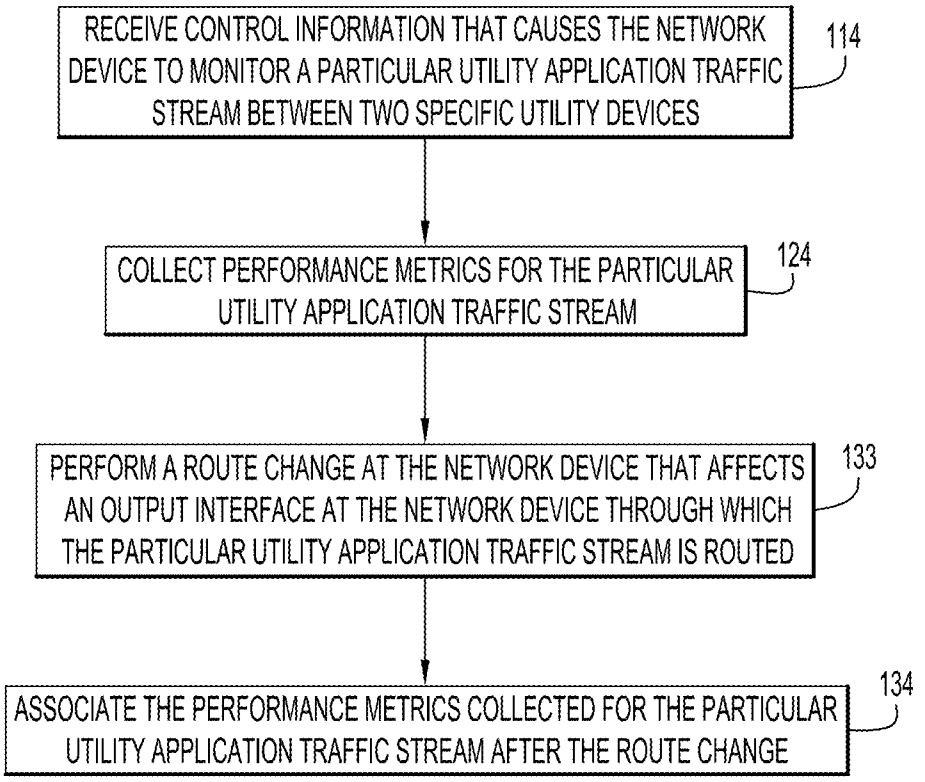

RECEIVE CONTROL INFORMATION THAT CAUSES THE NETWORK DEVICE TO MONITOR A PARTICULAR UTILITY APPLICATION TRAFFIC STREAM BETWEEN TWO SPECIFIC UTILITY DEVICES
114
COLLECT PERFORMANCE METRICS FOR THE PARTICULAR UTILITY APPLICATION TRAFFIC STREAM
124
PERFORM A ROUTE CHANGE AT THE NETWORK DEVICE THAT AFFECTS AN OUTPUT INTERFACE AT THE NETWORK DEVICE THROUGH WHICH THE PARTICULAR UTILITY APPLICATION TRAFFIC STREAM IS ROUTED
133
ASSOCIATE THE PERFORMANCE METRICS COLLECTED FOR THE PARTICULAR UTILITY APPLICATION TRAFFIC STREAM AFTER THE ROUTE CHANGE
134

FIG.11

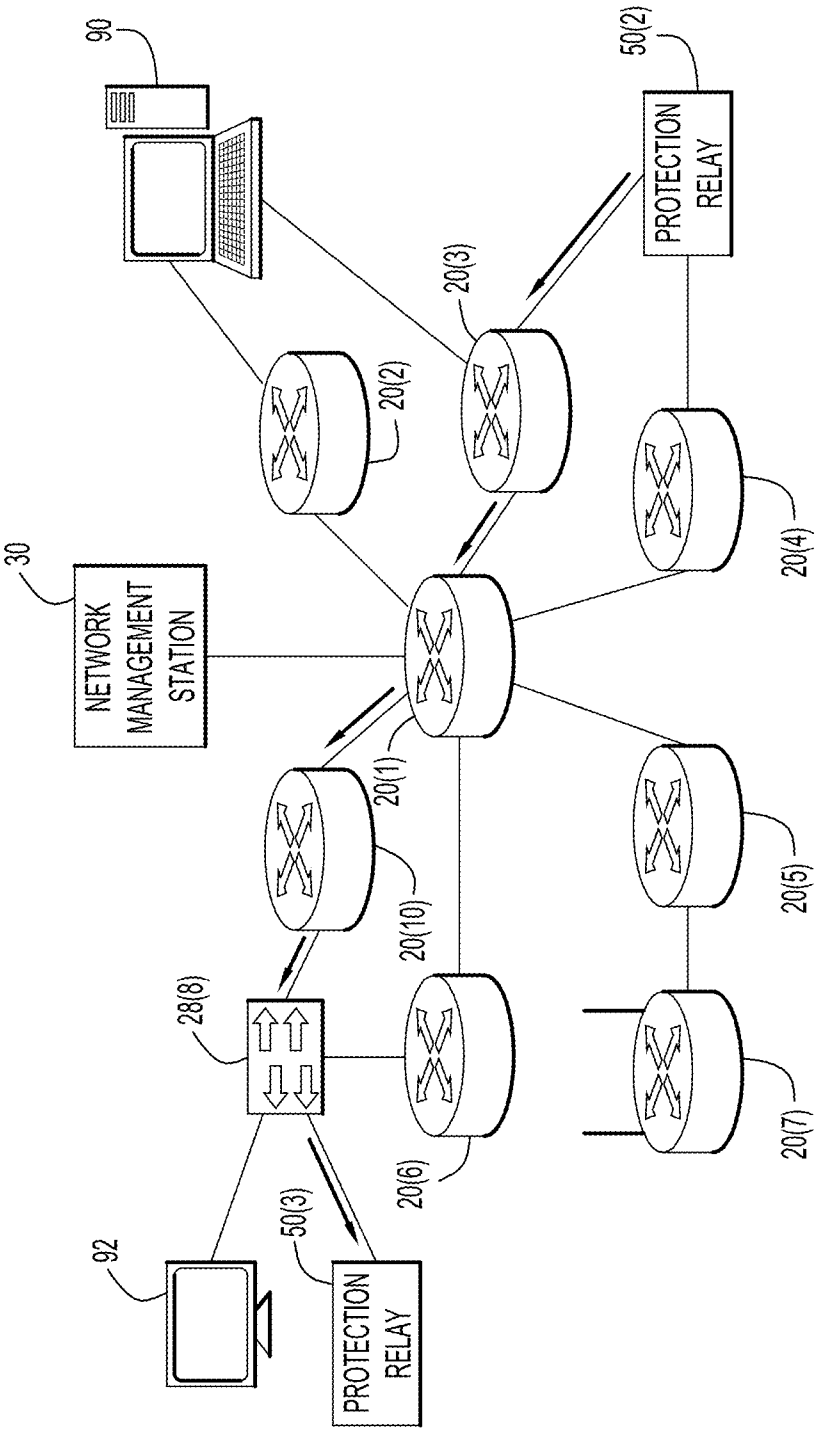

90
50(2)
PROTECTION RELAY
20(3)
20(2)
20(4)
30
NETWORK MANAGEMENT STATION
20(1)
20(10)
20(5)
28(8)
20(6)
20(7)
92
50(3)
PROTECTION RELAY

FIG.12

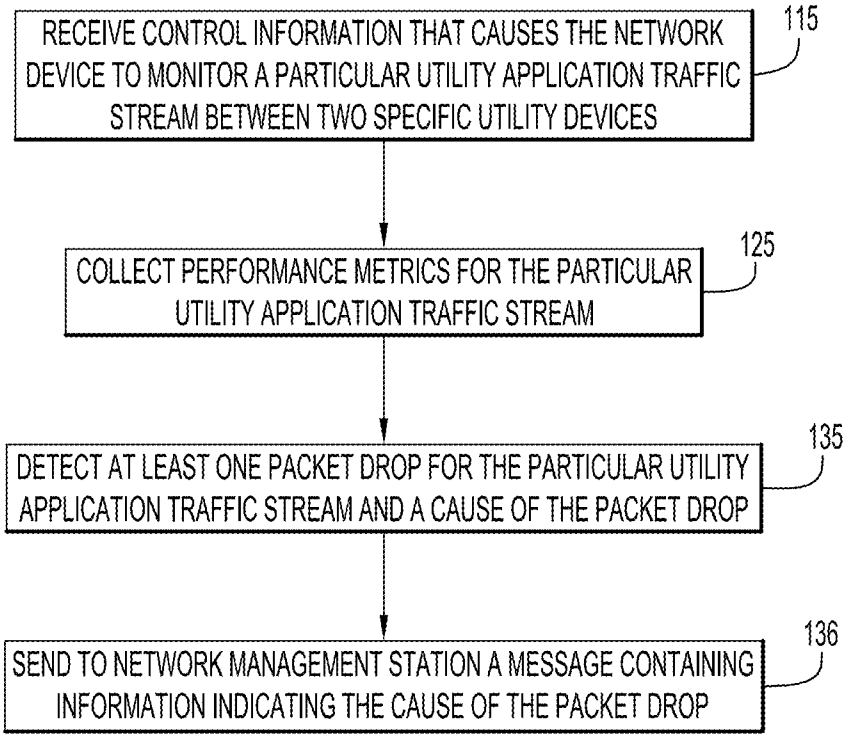

RECEIVE CONTROL INFORMATION THAT CAUSES THE NETWORK DEVICE TO MONITOR A PARTICULAR UTILITY APPLICATION TRAFFIC STREAM BETWEEN TWO SPECIFIC UTILITY DEVICES
115
COLLECT PERFORMANCE METRICS FOR THE PARTICULAR UTILITY APPLICATION TRAFFIC STREAM
125
DETECT AT LEAST ONE PACKET DROP FOR THE PARTICULAR UTILITY APPLICATION TRAFFIC STREAM AND A CAUSE OF THE PACKET DROP
135
SEND TO NETWORK MANAGEMENT STATION A MESSAGE CONTAINING INFORMATION INDICATING THE CAUSE OF THE PACKET DROP
136

FIG.13

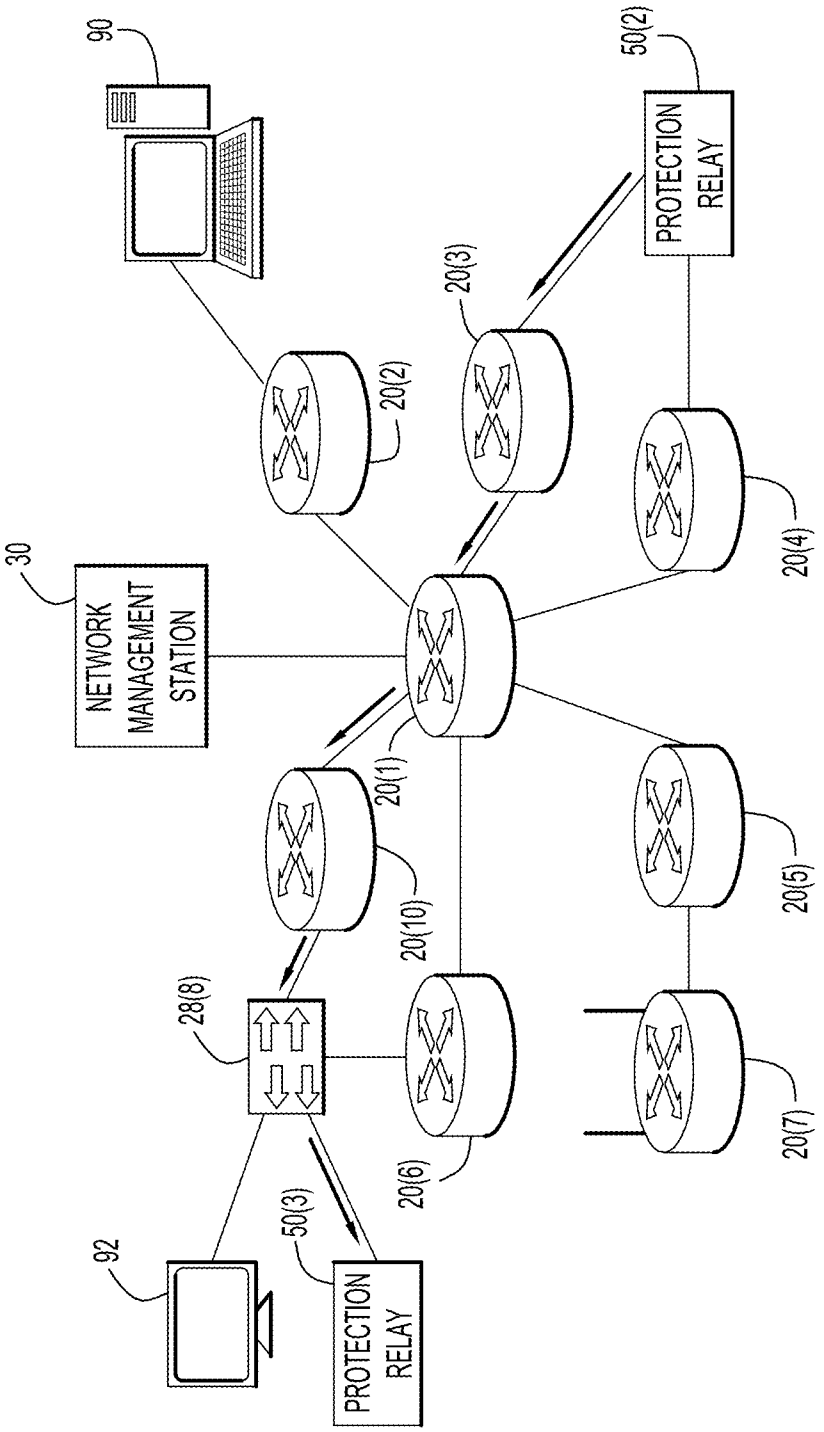

90
50(2)
PROTECTION RELAY
20(3)
20(2)
30
NETWORK MANAGEMENT STATION
20(4)
20(1)
20(10)
20(5)
28(8)
20(6)
20(7)
92
50(3)
PROTECTION RELAY

FIG.14

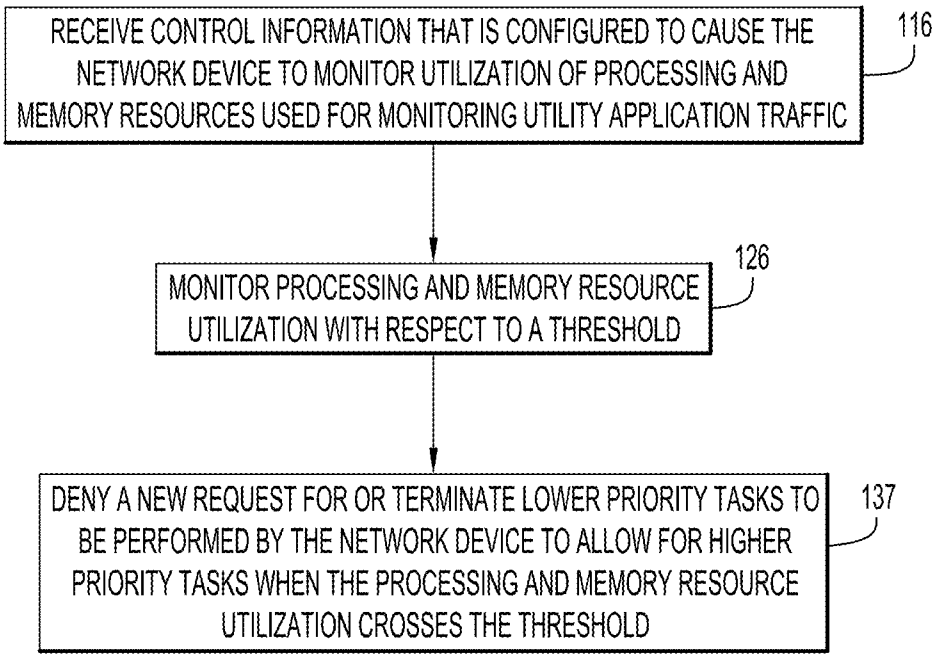

RECEIVE CONTROL INFORMATION THAT IS CONFIGURED TO CAUSE THE NETWORK DEVICE TO MONITOR UTILIZATION OF PROCESSING AND MEMORY RESOURCES USED FOR MONITORING UTILITY APPLICATION TRAFFIC
116
MONITOR PROCESSING AND MEMORY RESOURCE UTILIZATION WITH RESPECT TO A THRESHOLD
126
DENY A NEW REQUEST FOR OR TERMINATE LOWER PRIORITY TASKS TO BE PERFORMED BY THE NETWORK DEVICE TO ALLOW FOR HIGHER PRIORITY TASKS WHEN THE PROCESSING AND MEMORY RESOURCE UTILIZATION CROSSES THE THRESHOLD
137

FIG.15

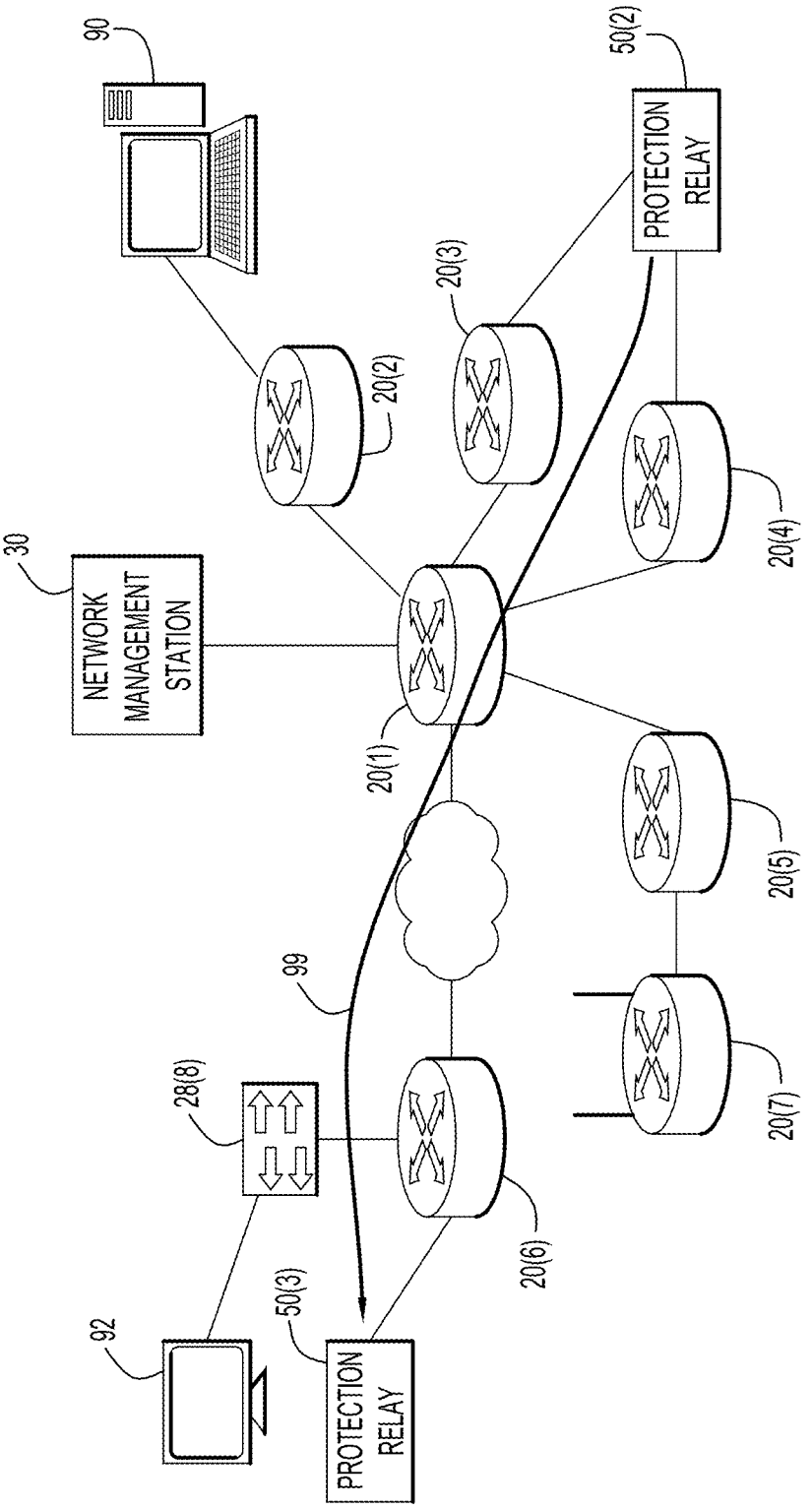

90
50(2)
PROTECTION RELAY
20(3)
20(2)
20(4)
30
NETWORK MANAGEMENT STATION
20(1)
20(5)
99
28(8)
20(7)
20(6)
50(3)
92
PROTECTION RELAY

FIG.16

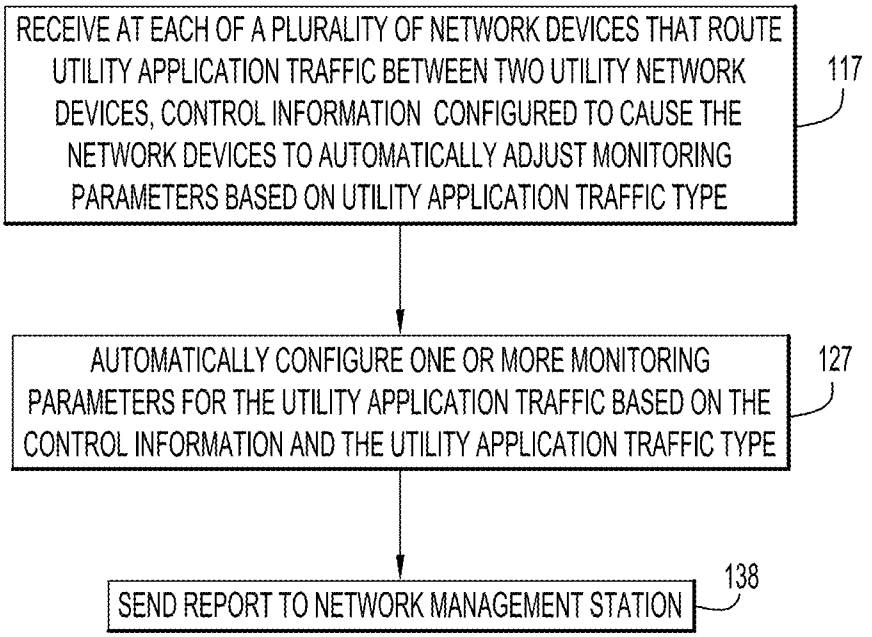

RECEIVE AT EACH OF A PLURALITY OF NETWORK DEVICES THAT ROUTE UTILITY APPLICATION TRAFFIC BETWEEN TWO UTILITY NETWORK DEVICES, CONTROL INFORMATION CONFIGURED TO CAUSE THE NETWORK DEVICES TO AUTOMATICALLY ADJUST MONITORING PARAMETERS BASED ON UTILITY APPLICATION TRAFFIC TYPE
117
AUTOMATICALLY CONFIGURE ONE OR MORE MONITORING PARAMETERS FOR THE UTILITY APPLICATION TRAFFIC BASED ON THE CONTROL INFORMATION AND THE UTILITY APPLICATION TRAFFIC TYPE
127
SEND REPORT TO NETWORK MANAGEMENT STATION
138

FIG.17

SESSION LAYER FOR MONITORING UTILITY APPLICATION TRAFFIC

CROSS REFERENCE TO RELATED APPLICATION

This application is a continuation of U.S. application Ser. No. 13/219,773, filed Aug. 29, 2011, the entirety of which is incorporated herein by reference.

TECHNICAL FIELD

The present disclosure relates to monitoring utility application traffic flows.

BACKGROUND

In utility networks, such as power, water, natural gas, etc., a data network is deployed alongside the utility equipment to manage and monitor operation of the utility equipment. In current utility networks, existing monitoring systems are not capable of providing sufficient information to troubleshoot failure points in the network. Current networks also make it difficult to locate potential where failures have previously occurred. Moreover, current networks do not facilitate testing of the network to determine whether it is ready to support a utility application traffic stream.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a block diagram showing an example network in which utility application traffic is routed and monitored using a session layer header inserted into utility application traffic packets.

FIG. **2** is a diagram showing an example session layer header inserted into a utility application traffic packet.

FIG. **3** is a block diagram showing an example of a network device configured to monitor utility application traffic according to the techniques described herein.

FIG. **4** is a block diagram showing an example of a network management station configured to send control information to network devices to monitor utility application traffic according to the techniques described herein.

FIG. **5** is a flow chart depicting an example of operations performed in a network device to monitor utility application traffic based on control information received from the network management station.

FIG. **6** is a diagram showing a first example scenario for the utility application traffic monitoring techniques described herein.

FIG. **7** is a flow chart depicting an example of operations performed in a network device for the scenario of FIG. **6**.

FIG. **8** is a diagram showing a second example scenario for the utility application traffic monitoring techniques described herein.

FIG. **9** is a flow chart depicting an example of operations performed in a network device for the scenario of FIG. **8**.

FIG. **10** is a diagram showing a third example scenario for the utility application traffic monitoring techniques described herein.

FIG. **11** is a flow chart depicting an example of operations performed in a network device for the scenario of FIG. **10**.

FIG. **12** is a diagram showing a fourth example scenario for the utility application traffic monitoring techniques described herein.

FIG. **13** is a flow chart depicting an example of operations performed in a network device for the scenario of FIG. **12**.

FIG. **14** is a diagram showing a fifth example scenario for the utility application traffic monitoring techniques described herein.

FIG. **15** is a flow chart depicting an example of operations performed in a network device for the scenario of FIG. **14**.

FIG. **16** is a diagram showing a sixth example scenario for the utility application traffic monitoring techniques described herein.

FIG. **17** is a flow chart depicting an example of operations performed in a network device for the scenario of FIG. **16**.

DESCRIPTION OF EXAMPLE EMBODIMENTS

Overview

Techniques are provided to facilitate monitoring of utility application traffic streams. At a network device that routes utility application traffic for utility devices, control information is received, where the control information is configured to cause the network device to monitor utility application traffic that passes through the network device. The network device monitors a header inserted into utility application traffic messages based on the control information.

Example Embodiments

Referring first to FIG. **1**, a block diagram is shown of a utility network environment **10** including a plurality of routers/switches **20**(**1**)-**20**(N) and a network management station/device **30**. For simplicity, the term "network device" is used for the routers/switches **20**(**1**)-**20**(N), and is meant to include a router, a switch, a combination switch/router, a wireless router, a combined switch/firewall device, etc. The term network management station used herein is meant to include a traditional network management station as well as any device or functions that are meant to provision, configure, manage, monitor, and audit the network devices and the health and performance of network devices. Each network device **20**(**1**)-**20**(N) is connected to one or more utility devices, such as a phasor measurement unit (PMU) and protection relay. A PMU measures the electrical waves on an electricity grid to determine the "health" of the system. A PMU can be a dedicated device, or the PMU function can be incorporated into a protection relay or other device.

A phasor is a complex number that represents both the magnitude and phase angle of the sine waves used in electricity grids. Phasor measurements that occur at the same time are called "synchrophasors", as are the PMU devices that allow their measurement. Measurements made by PMUs are sampled from widely dispersed locations in the power system network and synchronized from a common time source of a global positioning system (GPS) radio clock.

In the example shown in FIG. **1**, there is a PMU **40**(**1**) coupled to network device **20**(**1**), a PMU **40**(**2**) coupled to network device **20**(**2**) and a PMU **40**(N) coupled to network device **20**(N). Multiple PMUs may be coupled to any given network device, and the arrangement shown in FIG. **1** is only an example. Similarly, there are protection relays **50**(**1**)-**50**(N) coupled to respective network devices as shown in FIG. **1**. A protection relay is a switch configured for the protection of electrical transmission lines, and is designed with accurate operating characteristics to detect overload, short-circuits, and other faults.

The network management station **30** communicates with the network devices **20**(**1**)-**20**(N) by way of network **60**. The network **60** may include a wired local area network, wired wide area network, wireless local area network and a wireless

wide area network, or any combination thereof. The network management station **30** sends control information to the network devices **20**(**1**)-**20**(N) to configure them to monitor utility application traffic. The network devices **20**(**1**)-**20**(N) send reports and alerts generated from monitoring of utility application traffic to the network management station **30**. Utility application packets or messages that pass through the network devices **20**(**1**)-**20**(N) are shown in FIG. **1** at reference numeral **70**.

According to the techniques described herein, a session layer header is inserted into utility application traffic packets or messages. Turning to FIG. **2**, a diagram is shown of a utility application packet/message **70**. A session layer header is shown at reference numeral **80** that comprises a sequence number field **82** and a timestamp field **84**. There may be other fields in the header **80**, but these two fields are of primary interest because they introduce more information to the session layer of packets **70** that do not otherwise have this information embedded in the session layer. The header **80** therefore allows for performance monitoring of flows of utility application traffic packets **70** based on latency, jitter, order of delivery, packet drops, etc., that would not otherwise be possible. An example of a utility application protocol is International Electrotechnical Commission's (IEC) 61850 standard for electrical substation automation. An example of header **80** is a Real-time Transport Protocol (RTP) header, such as that defined in RFC 3550. Examples of utility applications include, Teleprotection, Centralized Remedial Action Scheme (CRAS), PMUs, etc. The session layer information is generated by the device that is the source of the packet. This may be a PMU or a protection relay, such as those depicted in FIG. **1**. Additionally, if the source of the packet does not insert these fields, then the first hop switch/router (e.g., any of the routers **20**(**1**)-**20**(N)) may also insert extra fields in the session header to carry this information.

Reference is now made to FIG. **3** for a description of a block diagram of a network device, shown generically at reference numeral **20**(*i*), according to one example. The network device **20**(*i*) is a packet switching, routing or forwarding device that operates in accordance with the Ethernet protocol, for example. The network device **20**(*i*) comprises a processor **22**, a memory **24**, a packet forwarding/switching unit **26**, a network interface unit **28** and a plurality of ports **29**(**1**)-**29**(L). The processor **22** is a data processor, e.g., a microprocessor or microcontroller, that is configured to execute software instructions stored in memory **24**. The packet forwarding unit **26** includes one or more application specific integrated circuits (ASICs) configured to perform the packet queuing and routing operations of the network device **20**(*i*). The network interface unit **28** is a network interface card that enables Ethernet communications over a wired network. The ports **29**(**1**)-**29**(L) are ingress and egress ports used to receive incoming packets and to output outgoing packets. The packet forwarding unit **26** performs hashing operations on packets to determine to which of the egress ports (among ports **29**(**1**)-**29**(L)) packets are output from the network device **20**(*i*) into the network.

The memory **24** may comprise read only memory (ROM), random access memory (RAM), magnetic disk storage media devices, optical storage media devices, flash memory devices, electrical, optical, or other physical/tangible memory storage devices. The memory **24** stores computer executable software instructions for utility application traffic monitoring process logic **100**. The utility application traffic monitoring process logic **100** comprises software instructions that cause the processor **22** to monitor utility application traffic, and particularly the headers **80** of packets **70** (shown in FIGS. **1** and **2**), according to the techniques described herein. Thus, in general, the memory **24** may comprise one or more tangible computer readable storage media (e.g., a memory device) encoded with software comprising computer executable instructions and when the software is executed (by the processor **22**) it is operable to perform the operations described herein in connection with process logic **100**.

Turning now to FIG. **4**, a block diagram is shown for the network management station **30**. The network management station **30** is a computing device that is configured to cause the network devices **20**(**1**)-**20**(N) in FIG. **1** to perform certain application traffic monitoring (reporting and alerting) functions. The network management station **30** comprises a processor **32**, a network interface unit **34**, a memory **36**, a keyboard **38** or other user input device and a display **39**. Instructions are stored in memory **36** for utility network administration process logic **200** that, when executed by the processor **32**, cause the processor **32** to perform various operations described herein from the perspective of the network management station **30**. The utility network administration process logic **200** causes the processor **32** of network management station **30** to generate the control information that is sent in suitable messages to one or more network devices.

Reference is now made to FIG. **5** for a general description of the operations of the utility application traffic monitoring process logic **100**. Again, these operations are performed at one or more of the network devices **20**(**1**)-**20**(L), where the network device routes utility application traffic for utility devices or equipment in a utility network. At **110**, the network device receives control information configured to cause the network device to monitor utility application traffic that passes through the network device. At **120**, the network device monitors a header inserted into utility application traffic messages/packets based on the control information. By monitoring the header, and in particular, the sequence number and timestamp information contained in the header, the network device can obtain performance metrics for the utility application traffic including out of sequence conditions, packet drops, latency, jitter, round-trip delay, etc. FIG. **5** is a high level depiction of the operations of utility application traffic monitoring process logic **100**.

Reference is now made to FIGS. **6**-**17** for a description of several example scenarios for utility application traffic monitoring process logic **100**. In these figures, operations with reference numerals between **111**-**119** refer to more detailed examples of operation **110**, and operations with reference numerals between **121**-**129** refer to more detailed examples of operation **120**. Moreover, operations labeled with reference numeral **130** and higher are additional operations of the utility application traffic monitoring process logic **100**.

FIGS. **6** and **7** depict an example scenario for an application-aware flow threshold alert. In this scenario, a network administrator enters data to the network management station **30** to generate control information that is sent to at least one network device to monitor traffic for certain utility applications, and to receive an alert when certain application specific flow metrics cross certain thresholds. This allows the network management station **30** to take action in order to prevent network induced drops of quality to the utility application(s).

In this example, the network devices are shown at reference numerals **20**(**1**)-**20**(**8**), where network devices **20**(**1**)-**20**(**6**) are routers, network device **20**(**7**) is a wireless router and network device **20**(**8**) is a switch. FIG. **6** also shows protection relays **40**(**1**)-**40**(**3**), where protection relay **50**(**1**) is coupled to network device **20**(**3**), protection relay **50**(**2**) is coupled to network device **20**(**4**) and protection relay **50**(**3**) is coupled to

network device **20**(**6**). Connected to network device **20**(**2**) is a block of servers or other computing devices (e.g., laptop computer) shown at reference numeral **90**. Connected to network device **20**(**8**) is a user terminal **92**.

Referring to FIG. **7**, operations of the utility application traffic monitoring process logic **100** running in network device **20**(**1**) are described for the scenario depicted in FIG. **6**. A network administrator with access to the network management station **30** uses a suitable interface, e.g., Command Line Interface (CLI), to cause the network management station **30** to send control information that causes the network device **20**(**1**) to perform passive performance metrics collection for all flows associated with a particular utility application, such as Teleprotection flows. An example of such a flow between protection relays **50**(**2**) and **50**(**3**) is shown at reference numeral **94** in FIG. **6**. At **112**, the network device **20**(**1**) receives from the network management station **30** control information indicating one or more threshold for application specific flow metrics for Teleprotection flows. At **122**, the network device **20**(**1**) automatically monitors the headers (that have been inserted into the utility application traffic packets as shown in FIG. **2**) for the Teleprotection traffic flows with respect to the one or more thresholds contained in the control information received at **112**. For example, the network device **20**(**1**) evaluates packet drops/loss, delay, latency and jitter of the Teleprotection traffic with respect to thresholds for packet drops, delay, latency and/or jitter. At **130**, the network device **20**(**1**) generates an alert when an application specific threshold is crossed. For example, the network device **20**(**1**) generates an alert when the packet loss/drop rate and/or jitter for the Teleprotection traffic that passes through the network device **20**(**1**) crosses a corresponding threshold. The network device **20**(**1**) may generate the alert via a Syslog or Simple Network Management Protocol (SNMP) trap to report the threshold crossing event, together with additional information, such as current metrics, node and flow information, and other information that identifies the session that is being monitored.

FIGS. **8** and **9** illustrate another example scenario in which multi-party PMU session flow metrics are monitored. For example, a network administrator desires to monitor a multi-party PMU session that involves multiple PMU/Protection relays for multi-terminal protection. Again, a network administrator, through the network management station **30**, uses suitable interface to send control information to multiple network devices to cause them to perform passive performance metric collection to monitor flow metrics with a specific multi-party session identifier (ID). FIG. **8** shows an example multi-party PMU session ID of "1001". At **113**, each of a plurality of network devices which are to participate in this monitoring scenario receive control information that comprises an identifier for a specific multi-party (multi-terminal) PMU session to monitor. For example, network devices **20**(**1**)-**20**(**4**), **20**(**6**), **20**(**8**) and **20**(**9**) receive the control information from the network management station **30** with the specified multi-party PMU session ID. At **123**, each of these network devices collects flow metrics associated with the specific multi-terminal PMU session. At **132**, the network devices each send their collected flow metrics for the specific multi-terminal PMU session to the network management station **30**. The network management station **30** then correlates the flow metric data received from the plurality of network devices with the identifier for the specific multi-terminal PMU session, e.g., "1001" in the example shown in FIG. **8**. Examples of flow metric data may include packet drop rates, jitter, latency, etc. This allows the network management station **30** to present the overall flow conditions in the network in order to give a network administrator a complete view of the specific multi-terminal PMU session.

FIGS. **10** and **11** illustrate an example scenario for flow metrics correlation with a route change at a network device. In this scenario, a network administrator wants to monitor a flow to collect statistics associated with the flow even after a route change at a router or switch. As shown in FIG. **10**, there is a path **96** for a flow Teleprotection between protection relay **50**(**2**) and protection relay **50**(**3**) that passes through routers **20**(**3**), **20**(**1**), **20**(**10**) and **20**(**8**). However, at some point in time, router **20**(**1**) makes a route change (due to traffic load conditions or other reasons) so that the Teleprotection flow route is changed to path **98** through router **20**(**6**) instead of through router **20**(**10**).

A network administrator uses a suitable interface via network management station **30** to send control information to network device **20**(**1**) causing it to perform passive performance metrics collection for Teleprotection traffic between protection relay **50**(**2**) and protection relay **50**(**3**). As shown in FIG. **11**, at **114**, the network device **20**(**1**) receives control information from the network management station **30** that causes the network device **20**(**1**) to monitor a particular utility application traffic stream, e.g., Teleprotection traffic stream, between two specific utility devices, e.g., protection relay **50**(**2**) and protection relay **50**(**3**). The control information specifies the application type (Teleprotection) and includes an identifier for the particular traffic stream, e.g., 5-tuple identifying information for a particular Teleprotection stream between protection relay **50**(**2**) and protection relay **50**(**3**). At **124**, the network device collects the performance metrics for the specified flow traffic based on application type and information identifying the particular Teleprotection stream. At **133**, the network device **20**(**1**) makes a route change that affects an output interface through which the particular utility application traffic (Teleprotection) stream is routed from network device **20**(**1**), i.e., so that it now goes to router **20**(**6**) instead of **20**(**10**), on path **98**. At **134**, the network device **20**(**1**) associates the performance metrics collected for the particular utility application traffic stream after the route change. Further, the network device **20**(**6**) initiates passive performance monitoring and reports the data based on thresholds to the network management station **30**.

FIGS. **12** and **13** depict a scenario for packet drop reason reporting. In this scenario, when a packet drop is observed, the network administrator wants to determine the reason for the packet drop. The network administrator uses a suitable interface via the network management station **30** to send control information to network device **20**(**1**) to enable passive performance metrics collection at network device **20**(**1**) for Teleprotection traffic between protection relay **50**(**2**) and protection relay **50**(**3**). At **115**, the network device **20**(**1**) receives control information from the network management station **30** that causes the network device **20**(**1**) to monitor a particular utility application (e.g., Teleprotection) traffic stream between two specific utility devices, e.g., between protection relay **50**(**2**) and protection relay **50**(**3**). At **125**, the network device **20**(**1**) collects performance metrics for the particular utility application traffic stream. At **135**, the network device **20**(**1**), through the use of the header information inserted into packets for the particular utility application traffic stream, detects at least one packet drop for the particular utility application traffic stream and a cause of the packet drop, e.g. low Quality of Service (QoS) priority, or network traffic congestion. At **136**, the network device **20**(**1**) sends to the network management station **30** a message containing information indicating presence of the packet drop, number of packets dropped, and the cause of the packet drop.

FIGS. **14** and **15** illustrate an example scenario for resource throttling for passive monitoring. In this scenario, a network administrator wants to ensure that certain application utility traffic monitoring tasks do not consume too much of the resources on a network devices so that the basic functionality of the network devices is not impacted. The network administrator uses a suitable interface via the network management station **30** send to network device **20**(**1**) control information containing a threshold for processing and memory resources utilization for monitoring utility application traffic. At **116**, the network device **20**(**1**) receives from the network management station **30** control information that is configured to cause the network device **20**(**1**) to monitor utilization of processing and memory resources used for monitoring utility application traffic with respect to a specified threshold. At **126**, the network device monitors processing and memory resources utilization with respect to the threshold. For example, when the network device **20**(**1**) receives a monitoring request from the network management station **30**, it checks current processing and memory resource utilization/consumption level (for monitoring operations) with respect to the threshold. At **137**, the network device **20**(**1**) denies a new monitoring request or terminates an existing one (depending on its relative priority) to allow for higher priority tasks to be continued or performed when the processing and memory resource utilization crosses the threshold. In this way, the network device **20**(**1**) will be able to continue to have the resources to perform its higher priority tasks.

FIGS. **16** and **17** illustrate an example scenario for metadata-based monitoring configuration. In this scenario, the network administrator wants the network to automatically adjust certain monitoring parameters, such as timeout value, sampling rate, etc., based on knowledge of a utility application traffic type. The network administrator uses a suitable interface via the network management station **30** to enable passive performance metrics collection on network devices **20**(**1**), **20**(**3**) and **20**(**6**) to monitor traffic from protection relay **50**(**2**) to protection relay **50**(**3**). This traffic stream is shown at reference numeral **99** in FIG. **16**.

Referring to FIG. **17**, at **117**, each of the network devices **20**(**1**), **20**(**3**) and **20**(**6**) that routes utility application traffic between two utility devices, receives control information from the network management station that is configured to cause the network devices to automatically adjust monitoring parameters based on utility application traffic type. At **127**, the network devices **20**(**1**), **20**(**3**) and **20**(**6**) automatically configure one or more monitoring parameters for the utility application traffic based on the control information and the metadata indicating the utility application traffic type. For example, the network devices may automatically configure themselves to monitor sampling rate, timeout value, and metering priority parameters associated with a Teleprotection traffic stream. At **138**, the network devices send reports to the network management station.

The techniques described herein provide inline utility application-aware passive performance monitoring and instrumentation to ease the deployment, management and operation of a utility data network.

The above description is intended by way of example only.

What is claimed is:

1. A method comprising:

at a network device of a plurality of network devices which routes utility application traffic, receiving control information indicating one or more thresholds for application specific flow metrics associated with utility application traffic streams, the control information configured to cause the network device to monitor utility application traffic messages that pass through the network device from a specific first utility device to a specific second utility device via a particular utility application traffic stream;

monitoring the utility application traffic with respect to the one or more thresholds, by monitoring a header inserted into the utility application traffic messages, based on the received control information; and

identifying the utility application traffic from the specific first utility device to the specific second utility device based on the header.

2. The method of claim **1**, wherein monitoring comprises monitoring metadata associated with the particular utility application traffic stream.

3. The method of claim **1**, wherein monitoring comprises evaluating a sequence number and a timestamp contained in the header of the utility application traffic messages.

4. The method of claim **1**, wherein monitoring comprises:

collecting performance metrics for the particular utility application traffic stream specified by the control information;

detecting a route change at the network device that affects an output interface at the network device through which the particular utility application traffic stream is routed; and

associating the performance metrics collected for the particular utility application traffic stream after the route change.

5. The method of claim **1**, wherein monitoring comprises:

collecting performance metrics for the particular utility application traffic stream;

detecting at least one packet drop for the particular utility application traffic stream and a cause of the packet drop; and

further comprising sending to a network management device a message containing information indicating the cause of the packet drop.

6. The method of claim **1**, wherein the control information is configured to cause the network device to automatically adjust monitoring parameters based on utility application traffic type, and further comprising automatically configuring one or more monitoring parameters for the utility application traffic based on the control information and the utility application traffic type.

7. The method of claim **1**, and further comprising generating an alert when the utility application traffic crosses loss, delay and/or jitter thresholds, and sending the alert from the network device to a network management device.

8. The method of claim **1**, wherein receiving comprises:

receiving the control information to monitor utilization of processing and memory resources used for monitoring the utility application traffic;

monitoring comprises monitoring processing and memory resource utilization with respect to a threshold; and

denying a new request to monitor the utility application traffic or terminating lower priority monitoring tasks to be performed to allow for higher priority monitoring tasks when the processing and memory resource utilization crosses the threshold.

9. The method of claim **1**, wherein receiving comprises receiving the control information from a network management station.

10. An apparatus comprising:

a network interface unit configured to enable communications over a network and to receive control information

indicating one or more thresholds for application specific flow metrics associated with utility application traffic streams;

switch hardware configured to route packets in the network;

a processor coupled to the network interface unit and switch hardware, the processor configured to:

monitor utility application traffic messages in the network from a specific first utility device to a specific second utility device via a particular utility application traffic stream in order to monitor utility application traffic with respect to the one or more thresholds contained in the control information, by monitoring a header inserted into the utility application traffic messages, based on the received control information; and

identify the utility application traffic from the specific first utility device to the specific second utility device based on the header.

11. The apparatus of claim **10**, wherein the processor is configured to monitor metadata associated with the particular utility application traffic stream.

12. The apparatus of claim **10**, wherein the processor is configured to monitor the utility application traffic messages by evaluating a sequence number and a timestamp contained in the header of the utility application traffic messages.

13. The apparatus of claim **10**, wherein the processor is configured to cause the network device to automatically adjust monitoring parameters based on utility application traffic type, and to automatically configure one or more monitoring parameters for the utility application traffic based on the control information and the utility application traffic type.

14. The apparatus of claim **10**, wherein the processor is configured to generate an alert when the utility application traffic crosses loss, delay and/or jitter thresholds, and to send the alert to a network management device.

15. The apparatus of claim **10**, wherein the processor is configured to:

obtain control information configured to monitor utilization of processing and memory resources used for monitoring the utility application traffic;

monitor processing and memory resource utilization with respect to a threshold; and

deny a new request to monitor the utility application traffic or terminate lower priority monitoring tasks to be performed to allow for higher priority monitoring tasks when the processing and memory resource utilization crosses the threshold.

16. One or more non-transitory computer readable storage media encoded with software comprising computer executable instructions and when the software is executed operable to:

obtain control information indicating one or more thresholds for application specific flow metrics associated with utility application traffic streams, the control information configured to cause a processor in a network device to monitor utility application traffic messages in a network from a specific first utility device to a specific second utility device via a particular utility application traffic stream;

monitor utility application traffic with respect to the one or more thresholds contained in the control information, by monitoring a header inserted into the utility application traffic messages, based on the control information; and

identify the utility application traffic from the specific first utility device to the specific second utility device based on the header.

17. The computer readable storage media of claim **16**, wherein the instructions that are operable to monitor comprise instructions that are operable to monitor the utility application traffic messages by evaluating a sequence number and a timestamp contained in the header of the utility application traffic messages.

18. The computer readable storage media of claim **16**, and further comprising instructions that are operable to cause the processor to automatically adjust monitoring parameters based on utility application traffic type, and to automatically configure one or more monitoring parameters for the utility application traffic based on the control information and the utility application traffic type.

19. The computer readable storage media of claim **16**, and further comprising instructions that are operable to generate an alert when the utility application traffic crosses loss, delay and/or jitter thresholds, and to send the alert from the network device to a network management device.

20. The computer readable storage media of claim **16**, and further comprising instructions that are operable to:

obtain control information to monitor utilization of processing and memory resources used for monitoring the utility application traffic;

monitor processing and memory resource utilization with respect to a threshold; and

deny a new request to monitor the utility application traffic or terminate lower priority monitoring tasks to be performed to allow for higher priority monitoring tasks when the processing and memory resource utilization crosses the threshold.

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