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(54) **SYSTEM AND METHOD FOR LOAD
BALANCING OF NETWORK PACKETS
RECEIVED FROM A MME WITH SMART
FILTERING**

(58) **Field of Classification Search**
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(71) Applicant: **NetScout Systems, Inc.**, Westford, MA
(US)

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(72) Inventors: **Rajeev Nadkarni**, Chelmsford, MA
(US); **Abhishek Saraswati**, Santa
Clara, CA (US); **Anil K. Singhal**,
Carlisle, MA (US); **Bruce A. Kelley,**
Jr., Westford, MA (US); **Narendra**
Byrapuram, Westford, MA (US); **John**
Peter Curtin, Richardson, TX (US);
Tauras Liubinskas, Lexington, KY
(US)

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Primary Examiner — Eron J Sorrell

(73) Assignee: **NetScout Systems, Inc.**, Westford, MA
(US)

(74) *Attorney, Agent, or Firm* — Foley & Lardner LLP

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(57) **ABSTRACT**

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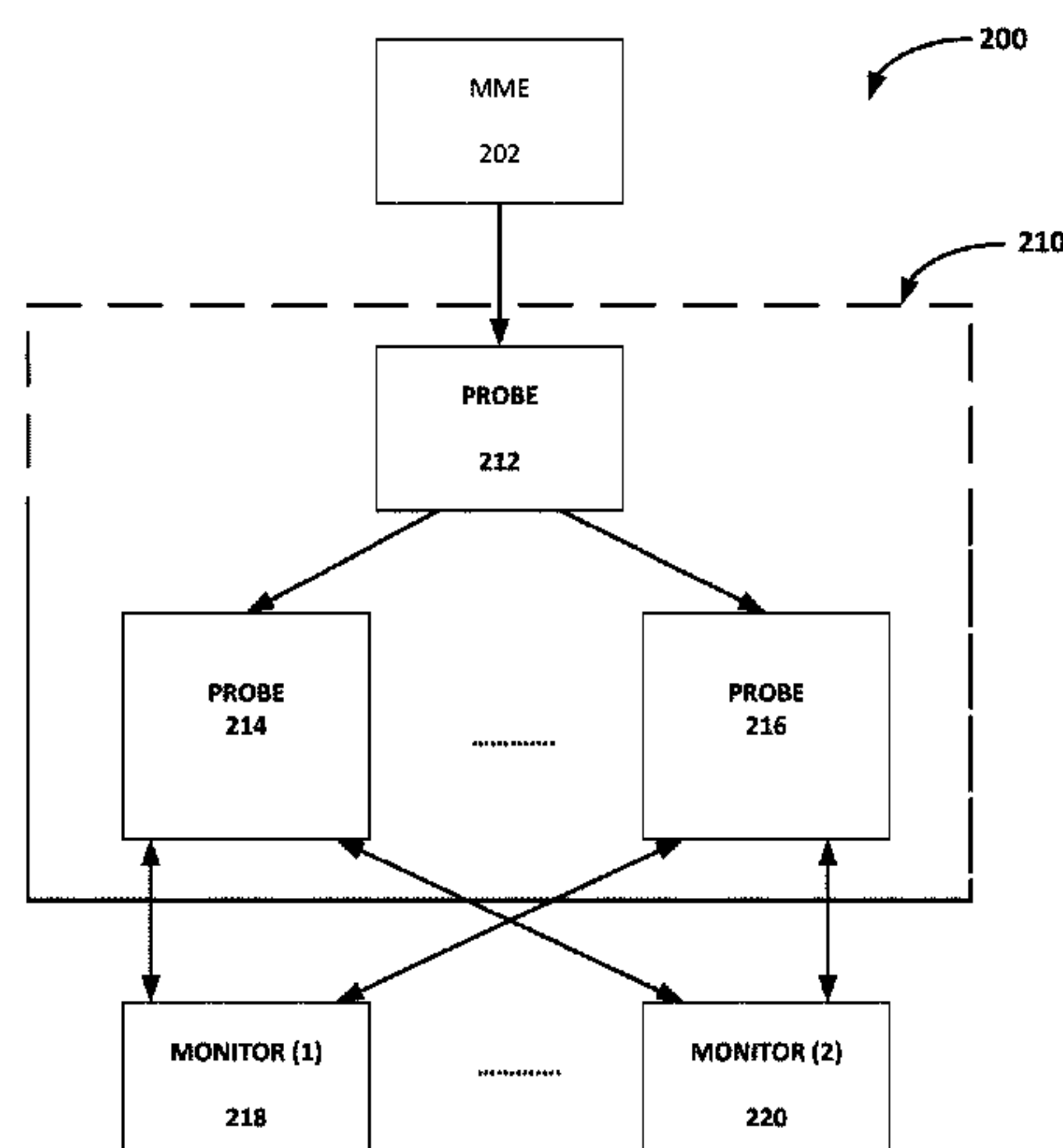
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CPC **H04W 24/08** (2013.01); **G06F 9/45558**
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A system and method for monitoring one or more Mobility Management Entities (MMEs) with a plurality of scalable network probe devices arranged in a cluster format. A ciphered packet is received from one or more MMEs at a packet switching device. The packet switching device in turn sends all the ciphered packets to each of the plurality of clustered probes. Each of the network probes then in turn decipheres the packets received from the MME and extracts metadata from the deciphered packet to identify subscriber session information contained in the received packet. Each of the network probes then selectively retains deciphered packet information relating to a subscriber session and/or other prescribed criteria designated for that particular network probe and discards the remaining deciphered packet or portions of the packet so as to balance the load amongst the plurality of probes based upon prescribed load balancing criteria. KPI and other session related data is generated in a network probe associated with a subscriber session from the retained deciphered packet information. Subscriber session related data from each clustered network probe is then aggregated with at least one monitoring device operably

(Continued)



coupled to the clustered probes such that a user of the monitoring device is provided with the perception that the monitoring device is coupled to a single probe.

19 Claims, 3 Drawing Sheets

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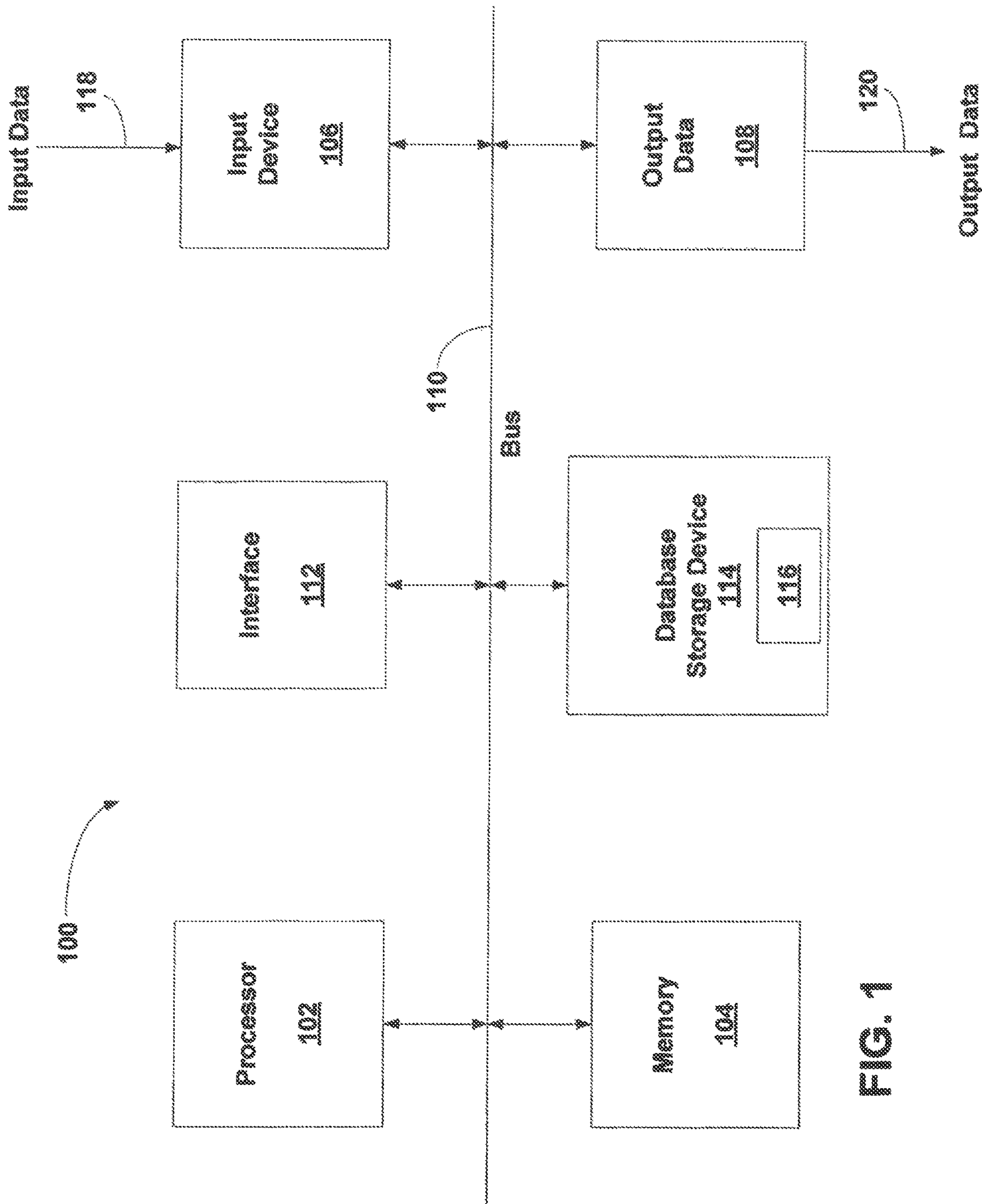


FIG. 1

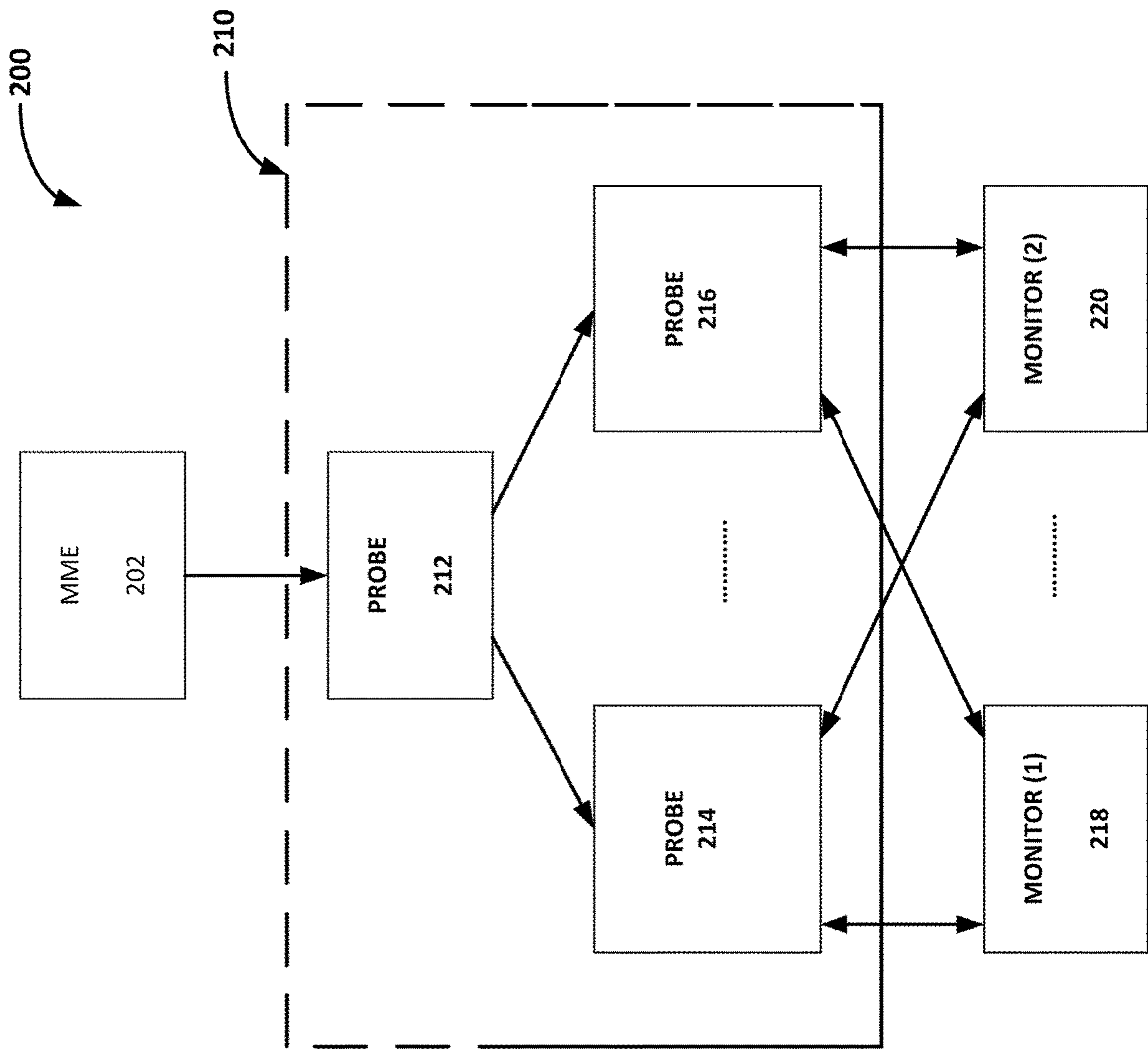
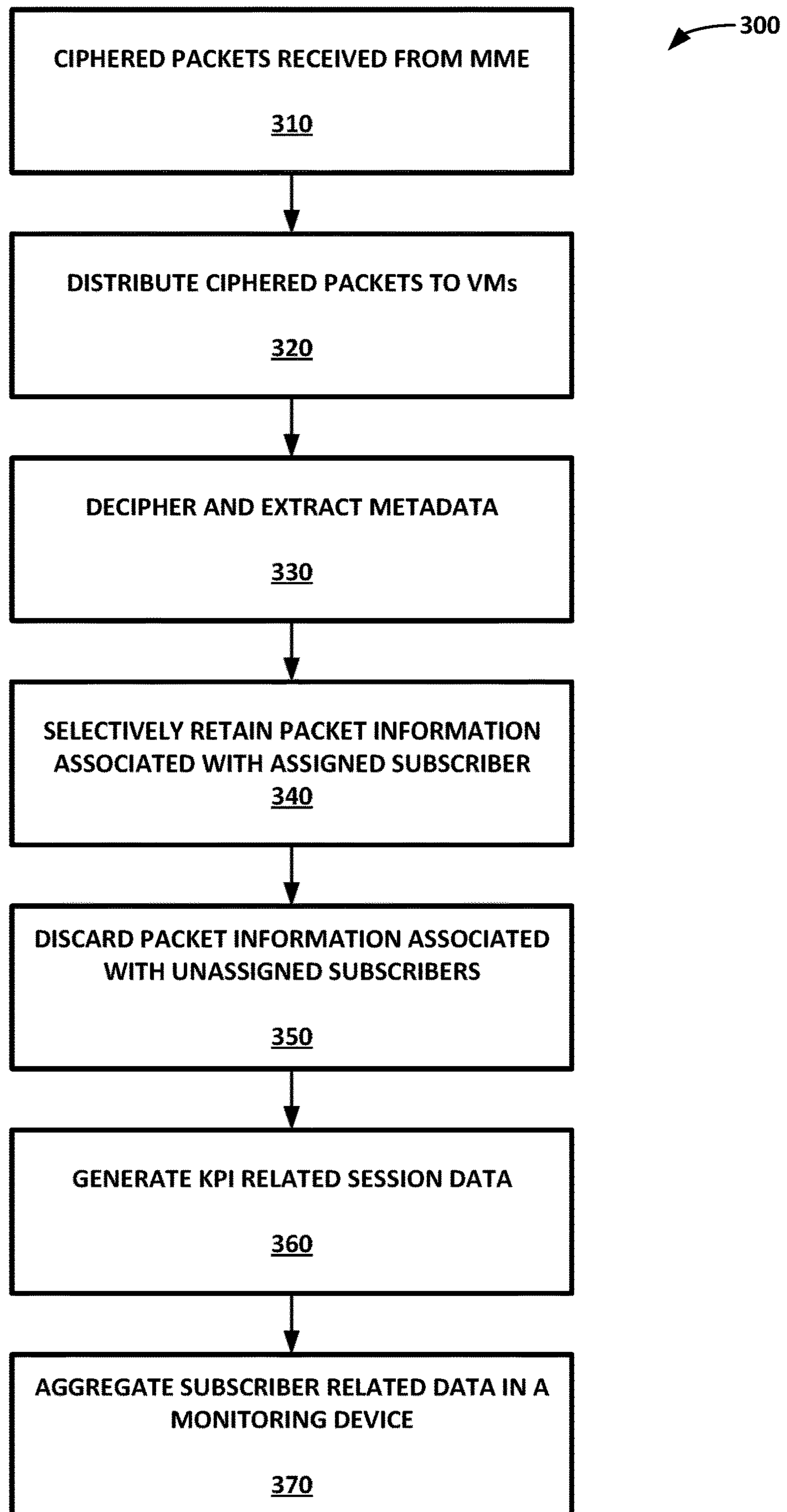


FIG. 2

FIG. 3

SYSTEM AND METHOD FOR LOAD BALANCING OF NETWORK PACKETS RECEIVED FROM A MME WITH SMART FILTERING

Matter enclosed in heavy brackets [] appears in the original patent but forms no part of this reissue specification; matter printed in italics indicates the additions made by reissue; a claim printed with strikethrough indicates that the claim was canceled, disclaimed, or held invalid by a prior post-patent action or proceeding.

CROSS REFERENCE TO RELATED APPLICATIONS

[This application claims priority to U.S. Patent Application Ser. No. 62/833,949 filed Apr. 15, 2019 which is incorporated herein by reference in its entirety.] *This application is a reissue of U.S. Pat. No. 11,122,452, issued on Sep. 14, 2021, which claims priority to U.S. Provisional Application No. 62/833,949, filed on Apr. 15, 2019, which patent and applications are incorporated herein by references in their entirety.*

FIELD OF THE INVENTION

The disclosed embodiments generally relate to monitoring data packets transmitted over a network, and more specifically to load balancing of packets between multiple network probes using smart filtering techniques.

BACKGROUND OF THE INVENTION

To optimize the performance and operation of modern computer networks, network operators routinely use network probes to monitor network traffic as well as measure end-user experience by calculating performance and quality parameters in real-time. These parameters include, but are not limited to, bit rate, jitter, packet drop rate or bit error rate, and packet latency.

However, the enormous, and increasing, amounts of data transmitted over wired and wireless networks at high data transfer speeds, particularly with the introduction of the 10 gigabit ("10 GbE") networking standard, present a challenge to real-time monitoring of network performance.

Network performance monitoring is further complicated by telecommunications routers and gateways using new architectures, some of which are designed to support the 10 GbE networking standard for mobile networks. These architectures are also used, in part, to enable network service providers to prioritize certain types of network traffic.

SUMMARY OF THE INVENTION

The purpose and advantages of the below described illustrated embodiments will be set forth in and apparent from the description that follows. Additional advantages of the illustrated embodiments will be realized and attained by the devices, systems and methods particularly pointed out in the written description and claims hereof, as well as from the appended drawings.

To achieve these and other advantages and in accordance with the purpose of the illustrated embodiments, in one aspect, the illustrated embodiments relate to a system and method for monitoring one or more Mobility Management Entities (MMEs) with a plurality of scalable network probe

devices arranged in a cluster format. A ciphered packet is received from one or more MMEs at a packet switching device. The packet switching device in turn sends all the ciphered packets to each of the plurality of clustered probes.

Each of the network probes then in turn decipheres the packets received from the MME and extracts metadata from the deciphered packet to identify subscriber session information contained in the received packet. Each of the network probes then retains deciphered packet information relating to a subscriber session and/or other prescribed criteria designated for that particular network probe and discards the remaining deciphered packet or portions of the packet so as to balance the load amongst the plurality of probes based upon prescribed load balancing criteria. KPI and other session related data is generated in a network probe associated with a subscriber session from the retained deciphered packet information. Subscriber session related data from each clustered network probe is then aggregated with at least one monitoring device operably coupled to the clustered probes such that a user of the monitoring device is provided with the perception that the monitoring device is coupled to a single probe.

Exemplary advantages provided by the illustrated embodiments includes monitoring high-capacity MMEs by using smart filter software logic integrated with individual network probes whereby packets are sent from high-capacity MMEs to each of a plurality of clustered network probes. Each network clustered probe is provided with smart-filtering software logic executed by each of the clustered network probes using minimal/efficient use of computer resources provided by the network probes. The smart filter software logic integrated with each individual network probe is configured to tag each received packet with filterable keys, such as IMSI, IMEI, Cell-Id, etc., which tags are preferably utilized for providing the filter logic. Monitoring devices (such as an nGeniusOne (nG1) and a sessions analyzer (nSA), commercially available from NetScout Technologies Inc.) aggregate data from the probe cluster for presentation to a user of a monitor device as if the data originated from a single probe.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying appendices a d/or drawings illustrate various non limiting, example, inventive aspects in accordance with the present disclosure:

FIG. 1 depicts an exemplary computing system in which certain components of the below illustrated embodiment of FIG. 2 may be implemented;

FIG. 2 depicts an illustrative embodiment of a network transmission system in accordance with the illustrated embodiments; and

FIG. 3 is a flow chart depicting an exemplary process of operation for the system of FIG. 2 in accordance with the illustrated embodiments.

DETAILED DESCRIPTION OF CERTAIN EMBODIMENTS

The illustrated embodiments are now described more fully with reference to the accompanying drawings wherein like reference numerals identify similar structural/functional features. The illustrated embodiments are not limited in any way to what is illustrated as the illustrated embodiments described below are merely exemplary, which can be embodied in various forms, as appreciated by one skilled in the art. Therefore, it is to be understood that any structural

and functional details disclosed herein are not to be interpreted as limiting, but merely as a basis for the claims and as a representation for teaching one skilled in the art to variously employ the discussed embodiments. Furthermore, the terms and phrases used herein are not intended to be limiting but rather to provide an understandable description of the illustrated embodiments.

Where a range of values is provided, it is understood that each intervening value, to the tenth of the unit of the lower limit unless the context clearly dictates otherwise, between the upper and lower limit of that range and any other stated or intervening value in that stated range is encompassed within the illustrated embodiments. The upper and lower limits of these smaller ranges may independently be included in the smaller ranges is also encompassed within the illustrated embodiments, subject to any specifically excluded limit in the stated range. Where the stated range includes one or both of the limits, ranges excluding either both of those included limits are also included in the illustrated embodiments.

Unless defined otherwise, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this invention belongs. Although any methods and materials similar or equivalent to those described herein can also be used in the practice or testing of the illustrated embodiments, exemplary methods and materials are now described. All publications mentioned herein are incorporated herein by reference to disclose and describe the methods and/or materials in connection with which the publications are cited.

It must be noted that as used herein and in the appended claims, the singular forms “a”, “an,” and “the” include plural referents unless the context clearly dictates otherwise. Thus, for example, reference to “a stimulus” includes a plurality of such stimuli and reference to “the signal” includes reference to one or more signals and equivalents thereof known to those skilled in the art, and so forth.

As used herein, the term “software” is meant to be synonymous with any code or program that can be in a processor of a host computer, regardless of whether the implementation is in hardware, firmware or as a software computer product available on a disc, a memory storage device, or for download from a remote machine. The embodiments described herein include such software to implement the equations, relationships and algorithms described above. One skilled in the art will appreciate further features and advantages of the illustrated embodiments based on the above-described embodiments. Accordingly, the illustrated embodiments are not to be limited by what has been particularly shown and described, except as indicated by the appended claims. All publications and references cited herein are expressly incorporated herein by reference in their entirety.

Turning now descriptively to the drawings, in which similar reference characters denote similar elements throughout the several views, FIG. 1 depicts an exemplary computing system in which below illustrated embodiments may be implemented.

A generalized computing embodiment in which the illustrated embodiments can be realized is depicted in FIG. 1 illustrating a processing system 100 which generally comprises at least one processor 102, or processing unit or plurality of processors, memory 104, at least one input device 106 and at least one output device 108, coupled together via a bus or group of buses 110. In certain embodiments, input device 106 and output device 108 could be the same device. An interface 112 can also be provided for

coupling the processing system 100 to one or more peripheral devices, for example interface 112 could be a PCI card or PC card. At least one storage device 114 which houses at least one database 116 can also be provided. The memory 104 can be any form of memory device, for example, volatile or non-volatile memory, solid state storage devices, magnetic devices, etc. The processor 102 could comprise more than one distinct processing device, for example to handle different functions within the processing system 100. Input device 106 receives input data 118 and can comprise, for example, a keyboard, a pointer device such as a pen-like device or a mouse, audio receiving device for voice controlled activation such as a microphone, data receiver or antenna such as a modem or wireless data adaptor, data acquisition card, etc. Input data 118 could come from different sources, for example keyboard instructions in conjunction with data received via a network. Output device 108 produces or generates output data 120 and can comprise, for example, a display device or monitor in which case output data 120 is visual, a printer in which case output data 120 is printed, a port for example a USB port, a peripheral component adaptor, a data transmitter or antenna such as a modem or wireless network adaptor, etc. Output data 120 could be distinct and derived from different output devices, for example a visual display on a monitor in conjunction with data transmitted to a network. A user could view data output, or an interpretation of the data output, on, for example, a monitor or using a printer. The storage device 114 can be any form of data or information storage means, for example, volatile or non-volatile memory, solid state storage devices, magnetic devices, etc.

In use, the processing system 100 is adapted to allow data or information to be stored in and/or retrieved from, via wired or wireless communication means, at least one database 116. The interface 112 may allow wired and/or wireless communication between the processing unit 102 and peripheral components that may serve a specialized purpose. Preferably, the processor 102 receives instructions as input data 118 via input device 106 and can display processed results or other output to a user by utilizing output device 108. More than one input device 106 and/or output device 108 can be provided. It should be appreciated that the processing system 100 may be any form of terminal, server, specialized hardware, or the like.

It is to be appreciated that the processing system 100 may be a part of a networked communications system. Processing system 100 could connect to a network, for example the Internet or a WAN. Input data 118 and output data 120 could be communicated to other devices via the network. The transfer of information and/or data over the network can be achieved using wired communications means or wireless communications means. A server can facilitate the transfer of data between the network and one or more databases. A server and one or more databases provide an example of an information source.

Thus, the processing computing system environment 100 illustrated in FIG. 1 may operate in a networked environment using logical connections to one or more remote computers. The remote computer may be a personal computer, a tablet device, smart phone device, a server, a router, a network PC, a peer device, or other common network node, and typically includes many or all of the elements described above.

It is to be further appreciated that the logical connections depicted in FIG. 1 include a local area network (LAN) and a wide area network (WAN), but may also include other networks such as a personal area network (PAN). Such

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networking environments are commonplace in offices, enterprise-wide computer networks, intranets, and the Internet. For instance, when used in a LAN networking environment, the computing system environment **100** is connected to the LAN through a network interface or adapter. When used in a WAN networking environment, the computing system environment typically includes a modem or other means for establishing communications over the WAN, such as the Internet. The modem, which may be internal or external, may be connected to a system bus via a user input interface, or via another appropriate mechanism. In a networked environment, program modules depicted relative to the computing system environment **100**, or portions thereof, may be stored in a remote memory storage device. It is to be appreciated that the illustrated network connections of FIG. **1** are exemplary and other means of establishing a communications link between multiple computers may be used.

FIG. **1** is intended to provide a brief, general description of an illustrative and/or suitable exemplary environment in which certain components of the below described present invention may be implemented. FIG. **1** is an example of a suitable environment and is not intended to suggest any limitation as to the structure, scope of use, or functionality of an embodiment of the present invention. A particular environment should not be interpreted as having any dependency or requirement relating to any one or combination of components illustrated in an exemplary operating environment. For example, in certain instances, one or more elements of an environment may be deemed not necessary and omitted. In other instances, one or more other elements may be deemed necessary and added.

In the description that follows, certain embodiments may be described with reference to acts and symbolic representations of operations that are performed by one or more computing devices, such as the computing system environment **100** of FIG. **1**. As such, it will be understood that such acts and operations, which are at times referred to as being computer-executed, include the manipulation by the processor of the computer of electrical signals representing data in a structured form. This manipulation transforms the data or maintains them at locations in the memory system of the computer, which reconfigures or otherwise alters the operation of the computer in a manner understood by those skilled in the art. The data structures in which data is maintained are physical locations of the memory that have particular properties defined by the format of the data. However, while an embodiment is being described in the foregoing context, it is not meant to be limiting as those of skill in the art will appreciate that the acts and operations described hereinafter may also be implemented in hardware.

It is to be further appreciated, embodiments may be implemented with numerous other general-purpose or special-purpose computing devices and computing system environments or configurations. Examples of well-known computing systems, environments, and configurations that may be suitable for use with an embodiment include, but are not limited to, personal computers, handheld or laptop devices, personal digital assistants, tablet devices, smart phone devices, multiprocessor systems, microprocessor-based systems, set top boxes, programmable consumer electronics, network, minicomputers, server computers, game server computers, web server computers, mainframe computers, and distributed computing environments that include any of the above systems or devices. Embodiments may be described in a general context of computer-executable instructions, such as program modules, being executed by a computer. Generally, program modules include routines,

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programs, objects, components, data structures, etc., that perform particular tasks or implement particular abstract data types. An embodiment may also be practiced in a distributed computing environment where tasks are performed by remote processing devices that are linked through a communications network. In a distributed computing environment, program modules may be located in both local and remote computer storage media including memory storage devices.

With the exemplary computing system environment **100** of FIG. **1** being generally shown and discussed above, reference is now made to FIG. **2** which illustrates an embodiment of a network transmission system **200** capable of transmitting packets from a Mixed Mobility Entity (MME) **202** to a cluster of network probes **210**. The example network transmission system **200** is also configured to balance the network monitoring load between several network probes **214**, **216** at or near the data transmission rate ("line rate" or "approximate line rate"—1.5M pps) of the network transmission system **200**. In the illustrative embodiments, it is to be understood the MME **202**, may consist of (but is not to be understood to be limited to) the following types of network interfaces: S1-MME, S3, S10 and S6a feed interfaces. The MME **202** may be either hardware and/or software based.

In certain illustrative embodiments, it is to be appreciated a ciphered packet received at a probe **214**, **216** contained in the cluster of network probes **210** (as described below) from the MME **202**, via a packet switching device **212** (as also described further below), may be a synthetic packet containing messages and filter terms for a plurality of subscribers. Each probe **214**, **216** in the network probe cluster **210** preferably includes smart filter software logic configured and operational to decipher the ciphered packet received from the packet switching device **212**, and generate multiple synthetic packets from a received synthetic packet such that each generated packet is associated with an individual subscriber session. Each probe **214**, **216** in the cluster of network probes **210** is operational to retain packet information associated with a certain subscriber session and discard the remaining synthetic packets associated with other subscriber sessions. As discussed further below, a monitor device **218**, **220** preferably communicates with each probe **214**, **216** contained in the cluster of network probes **210** to provide instructions to the smart filter software logic associated with each probe **214**, **216**, which instructions prescribe which probe **214**, **216** is to be assigned to which subscriber session so as to retain packet information relating to that assigned subscriber session and discard other packet information relating to other subscriber sessions to achieve load balancing amongst the cluster of network probes **210**.

Each probe **214**, **216** in the cluster of network probes **210**, preferably via its smart filter software logic, is configured and operational to extract metadata from packets received from the packet switching device **212**, which metadata may include filter terms such as IMSI, IMEI-SV and Cell-Id information (which may be utilized to generate the ASI data) for example. It is to be appreciated these filter terms generated by each probe **214**, **216** in the cluster of network probes **210** preferably results from efficient state machine processing. This extracted metadata also preferably consists of session information to be utilized by the probes **214**, **216** in the cluster of network probes **210** for performing parallel processing of packet sessions across multiple subscriber session threads—so as to optimize VM computer processing resources associated with the cluster of network probes **210**. Also, the deciphering of packets in each probe **214**, **216** of

the cluster of network probes **210** preferably determines Temporary Identifiers (M-TMSI) assigned to an individual subscriber. Additionally, the probes **214**, **216** in the cluster of network probes **210** are further to be understood to be configured and operational to process handovers between eNodeBs such that deciphered packet information relating to an individual subscriber session assigned to that probe **214**, **216** is retained while the other non-assigned subscriber session portions are discarded, preferably via its smart filter software logic.

As shown in the illustrated embodiment of FIG. 2, the cluster of network probes **210** are coupled to a packet switching device **212** configured to distribute packets received from the MME **202** to each one of the probes **214**, **216** contained in the cluster of network probes **210**. Examples of the packet switching device **212** include network routers and filters capable of monitoring and directing data packets, such as the NGENIUS **1500** produced by NetScout Systems, Inc. of Westford, Mass. The packet flow switching device **212** distributes packets received from the MME **202** preferably to each of the probes **214**, **216** contained in the cluster of network probes **210** connected to packet switching device **212**. It is to be appreciated the packet flow switching device **212** can also distribute the packets to other systems, including, but not limited to, security, and financial transaction systems (such as billing), and other systems using the packets for any of a variety of purposes.

One or more monitor devices **218**, **220** are each preferably coupled to the network probes **214**, **216** for performing various analytic functionalities relating to subscriber packets received from the MME **202**, as discussed further below. Transmission links preferably convey subscriber packets from the MME to the cluster of network probes **210** through any of a variety of networks, including the Internet (e.g., networks using TCP/IP protocol transmission), wireless communication networks (e.g., 3G, 4G LTE protocol networks), networks internal to an organization or entity (e.g., WLAN, LAN), and combinations thereof.

In accordance with the illustrative embodiment of FIG. 2, the probes (e.g., **214**, **216**) in the cluster of network probes **210** are to be understood to be hardware, software, firmware, or combinations thereof, for monitoring data transmission through a plurality of transmission links. While generally the network probes **210** may be deployed at any of a variety of locations or links of a network to collect network data packets transmitted, in this case the network probes **210** are connected to a network through the packet switching device **212** which, as described herein, receives packets having subscriber session information from a MME **202**. It is to be understood, the network probes **210** may be a special purpose computing device or a software component (not limited to a single process) dedicated to monitoring data communicated via a network. Alternatively, the network probes **210** may be a computing device with specialized software components installed thereon. In one embodiment, the network probes **210** are a NGENIUS COLLECTOR, NGENIUS PROBE or NGENIUS INFINISTREAM ("ISNG device"), available from NetScout Systems, Inc. of Westford, Mass.

For ease of illustration, only two probes **214**, **216** are shown coupled to the smart cluster probe **212**, however, it is to be understood any number of probes may be coupled to the packet switching device **212** in accordance with the teachings herein. It is to be appreciated each ISNG device provided in the cluster of probes **210** is configured and operational to generate Adaptive Service Intelligence (ASI)

data relating to a subscriber packet session subject to analysis of an ISNG device. ASI data is to be understood to include key performance indicators and adaptive session records ("ASRs") as described in U.S. patent application Ser. No. 12/756,638 entitled "Real-Time Adaptive Processing of Network Data Packets for Analysis" and filed on Apr. 8, 2010. The methods and systems described in U.S. patent application Ser. No. 12/756,638 to enable the network probes **210** to analyze network performance and end user experience in real-time, without extensive network buffering and analysis. This application also incorporates by reference in its entirety U.S. Pat. No. 9,923,808.

Additionally, in the illustrative example of FIG. 2, each probe **214**, **216** in the cluster of network probes **210** may be configured as a Virtual Machine (VM), however, and as stated above, each probe **214**, **216** may consist of hardware, software, firmware, or combinations thereof, for monitoring data transmission through the plurality of transmission links. While generally the cluster of network probes **210** may be deployed at any of a variety of locations or links of a network to collect network data packets transmitted through certain links, in this case the network probes **214**, **216** are connected to the network through the packet switching device **212**. As discussed herein, each probe **214**, **216** in the cluster of network probes **210** is preferably provided with smart filter software logic that provides balancing of subscriber packets received from the MME **202** between the multiple network probes **214**, **216**. In accordance with an illustrated embodiment, a monitoring device **218**, **220** prescribes the instructions to the smart filter software logic of each of the multiple of network probes **214**, **216** for enabling and conducting load balancing of packets received from the MME **202** amongst the cluster of network probes **210** (as described herein).

It is to be understood the network transmission system **200** is shown in FIG. 2 to include a single cluster of network probes **210** coupled to a single MME **202** for ease of illustration purposes only as the it is to be understood the network transmission system may consists of multiple clusters of network probes **210** coupled to multiple MMEs **202** in accordance with the teachings of the illustrative embodiments. Additionally, each cluster of network probes **210** may be coupled to any multiple of monitoring devices, and is not to be understood to be limited to the two monitor devices **218**, **220** shown in FIG. 2.

With certain components of system **200** described above, a description of operation of the network transmission system **200** of FIG. 2 is now provided with reference to process **300** of FIG. 3 (and with continuing reference to system **200** of FIG. 2). It is to be understood network system **200** provides a system and method for monitoring one or more Mobility Management Entities (MMEs) **202** with a plurality of scalable Virtual Machines (VM)("probes") **210** arranged in a cluster format so as to aggregate data from the clustered VMs **214**, **216** for distribution to one or more monitoring devices **218**, **220**. In operation, ciphered packets are received from a MME **202** at the packet switching device **212** (step **310**). The ciphered packets are then distributed to preferably all the probes **214**, **216** provided in the cluster of network probes **210** (step **320**). Each probe **214**, **216** provided in the cluster of network probes **210** preferably contains smart filter software logic configured and operational to decipher the ciphered packet received from the MME **202** and extract metadata from the deciphered packet to identify subscriber information contained in the received packet (step **330**).

Each probe **214, 216** provided in the cluster of network probes **210** then preferably retains packet information relating to a subscriber session designated for that probe **214, 216** (step **340**). Each probe **214, 216** is additionally configured and operational to discard the remaining packet information relating to other subscriber sessions which are not designated for processing by that particular network probe **214, 216** so as to achieve load balancing amongst the cluster of network probes **210** (step **350**). It is to be understood the load balancing performed by each probe **214, 216** of the cluster of network probes **210** is preferably based upon prescribed load balancing criteria such that each packet received from the MME **202** for an identified subscriber session is maintained in a same network probe (e.g., probe **214**) such that load balancing is performed on a per subscriber session basis and/or with other state-based criteria. The load balancing performed amongst the cluster of network probes **210** by each of the network probes **214, 216** is preferably performed in accordance with a stateful process, and may include deep packet inspection of a packet received from the MME **220** via the packet switching device **212**. It is to be further understood the load balancing performed by the network transmission system **210** is scalable such that individual probes **214, 216** may be added or subtracted (e.g., activated, inactivated) from the cluster of probes **210** preferably predicated upon network demand of the MME **202** to provide scalability and efficient cluster based monitoring provided by the network transmission system.

Upon receipt of a packet from the packet switching device **212**, a receiving probe (e.g., **214**), preferably after discarding the packet information relating to subscriber sessions not designated (assigned) for processing by that particular network probe (e.g., **214**) (as discussed above), generates KPI session related data associated with subscriber session information associated with the maintained packet session information designated for processing by that particular network probe (e.g., **214**)(step **360**). The subscriber related data is then preferably aggregated from each network probe **210** with at least one monitoring device **218** operably coupled to the clustered network probes **210** wherein a user of the monitoring device **218, 220** is provided with the perception that the monitoring device **218, 220** is coupled to a single VM (e.g., VM **214**)(step **370**). The subscriber related data generated by each probe **214, 216** in the cluster of probes **210** upon processing of the received deciphered packet information is preferably stored in a memory device (e.g., a disk, database, etc.) associated with the probe **214, 216**. Additionally, it is to be understood KPI information relating to a subscriber session generated by each probe **214, 216** in the cluster of probes **210** is preferably distributed for storage in a monitoring device **218, 220**.

It is to be appreciated that each monitor device **218, 220** is configured to perform on-demand and/or real-time analysis of subscriber packet information received in the cluster of network probes **210**. For instance, when performing on-demand analysis, subscriber data is aggregated preferably from each probe **214, 216** of the cluster of network probes **210**. The monitor device **218, 220** is preferably configured to aggregate Key Performance Indicator (KPI) data from the clustered probes **210** associated with subscribers. In such an exemplary embodiment, the monitor device may consist of an nGeniusOne device sold by NetScout Systems, Inc. of Westford, Mass.

It is to be appreciated that when performing real-time analysis, a monitor device **218, 220** is configured and operational to perform real-time analysis of subscriber packet information by querying and retrieving subscriber

information from the cluster of probes **210** relating to a user analysis request in a certain monitor device **218, 220** so as to retrieve subscriber session data from an individual VM probe (e.g., **216**) regarding a subscriber session associated with that user analysis. In such an exemplary embodiment, a monitor device **218, 220** may consist of a packet session analyzer (“nsa”) (e.g., Iris Session Analyzer sold by NetScout Systems, Inc. of Westford, Mass.) configured to analyze subscriber calls and sessions, being preferably configured to perform deep packet analysis on the retrieved subscriber data.

It is to be further understood and appreciated that when the aforesaid network transmission system **200** is monitoring one or more Mobility Management Entities (MMEs) **202** with a cluster of network probes **210** as described above, subscriber sessions across X2 and S1 handovers are also monitored and tracked by the system **200**. Additionally, the system **200** is further configured and operational to detect session transitions during MME handovers and during inter-RAT handovers. Still further, the system **200** of the illustrative embodiment shown and described in FIGS. **2** and **3** may be further configured and operational to: decipher of packets in the network probes **210** to determine M-TMSI assigned to an individual subscriber; monitor subscriber sessions across idle and active transitions; monitor subscriber session across X2 and S1 handovers; detect session transitions during MME handovers; and detect session transitions during inter-RAT handovers by the illustrative network transmission system **200**, which all of the above are also applicable when monitoring a Unified Serving Node (USN).

With certain illustrated embodiments described above, it is to be appreciated that various non-limiting embodiments described herein may be used separately, combined or selectively combined for specific applications. Further, some of the various features of the above non-limiting embodiments may be used without the corresponding use of other described features. The foregoing description should therefore be considered as merely illustrative of the principles, teachings and exemplary embodiments of this invention, and not in limitation thereof. Additional description of the illustrated embodiments are attached as Appendix A.

It is to be understood that the above-described arrangements are only illustrative of the application of the principles of the illustrated embodiments. Numerous modifications and alternative arrangements may be devised by those skilled in the art without departing from the scope of the illustrated embodiments, and the appended claims are intended to cover such modifications and arrangements.

What is claimed is:

1. A computer implemented method [for monitoring one or more Mobility Management Entities (MMEs) with a plurality of clustered Virtual Machines (VMs),] comprising: receiving, at a virtual machine (VM) of a plurality of VMs, a ciphered [packets in] a packet switching device [from one or more MMEs; sending each of], wherein the received ciphered [packets] packet is sent from the packet switching device to each VM of the plurality of [clustered] VMs; [receiving, in each of the plurality of clustered VMs, the ciphered packets sent from the packet switching device;] deciphering, [in each of the plurality of clustered VMs] at the VM, the received ciphered [packets] packet; extracting metadata from the deciphered [packets in each of the plurality of clustered VMs] packet, the metadata comprising first deciphered packet information relating to an individual subscriber assigned to the VM and

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- second deciphered packet information relating to one or more subscribers not assigned to the VM;*
 retaining *the first* deciphered packet information, based upon analysis of *the* extracted metadata *at the VM*, [at each individual respective VM of the plurality of clustered VMs] wherein the [retained] *first deciphered* packet information is associated with [an] *the* individual subscriber assigned to [a respective] *the* VM retaining the *first deciphered* packet information; and discarding, *at the VM*, the *second* deciphered packet information [at each individual respective VM of the plurality of clustered VMs], *based upon analysis of the extracted metadata at the VM*, wherein the discarded *second deciphered* packet information is associated with one or more subscribers not assigned to [a respective] *the* VM discarding the *second deciphered* packet information.
2. The method [as recited in] of claim 1, further [including the steps] *comprising*:
 generating [KPI] *key performance indicator (KPI)* data, in each of the plurality of VMs, associated with [an] *the* individual subscriber assigned to [a respective] *the* VM; and
 [aggregating subscriber related data from the plurality of clustered VMs in at least one monitoring device operably coupled to the plurality of clustered VMs wherein a user of the at least one monitoring device is provided with the perception that the monitoring device is coupled to a single VM] *providing the KPI data to a monitor device, wherein the monitor device aggregates subscriber related data from a plurality of clustered VMS.*
3. The method [as recited in] of claim 2, [wherein each of the plurality of clustered VMs is configured to generate multiple synthetic packets from a received synthetic packet wherein each of the multiple synthetic packets is associated with an individual subscriber whereby each of the plurality of VMs retains packet information associated with a certain subscriber as prescribed by the monitoring device and discards the remaining synthetic packets associated with other subscribers] *wherein the received packet is a received synthetic packet, the method further comprising generating multiple synthetic packets from the received synthetic packet, wherein each of the multiple synthetic packets is associated with the individual subscriber.*
4. The method [as recited in] of claim 1, wherein the metadata consists of session information utilized by the [plurality of VMs] *VM* for parallel processing of packet sessions across multiple subscriber session threads.
5. The method [as recited in] of claim 1, wherein [the] deciphering [of] *comprises deciphering* packets in [each of the plurality of VMs determines Temporary Identifiers (M-TMSI)] *the VM to determine a temporary identifier assigned to [an] the individual subscriber.*
6. The method [as recited in] of claim 1, further including detecting subscriber session transitions during MME handovers or inter-RAT handover.
- [7. The method as recited in claim 1, further including detecting session transitions during inter-RAT handovers.]
- [8. The method as recited in claim 1, wherein a plurality of monitoring devices are operably coupled to the plurality of clustered VMs.]
9. The method [as recited in] of claim 2, wherein the *subscriber related data is aggregated using* at least one monitor device [is configured to perform] *and performs* on-demand analysis of subscriber packet information.

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- [10. The method as recited in claim 9, wherein the at least one monitoring device includes aggregated subscriber information received from the plurality of clustered VMs such that subscriber data is aggregated from each of the plurality of clustered VMs.]
- [11. The method as recited in claim 10, wherein the monitoring device is configured to aggregate Key Performance Indicator (KPI) data from each of the plurality of clustered VMs associated with one or more subscribers.]
12. The method [as recited in] of claim 1, wherein [the at least one] *a* monitor device is configured to perform real-time analysis of subscriber packet information by querying and retrieving subscriber information from each *VM* of the plurality of [clustered] VMs relating to a user analysis request so as to retrieve subscriber data from an individual VM regarding a subscriber associated with the user analysis request.
- [13. The method as recited in claim 1, wherein each VM is a network probe device.]
- [14. The method as recited in claim 13, wherein each network probe device is an ISNG device configured to generate Adaptive Service Intelligence (ASI) data.]
- [15. The method as recited in claim 1, wherein the MME includes at least one of S1-MME, S3, S10 and S6a feed interfaces.]
16. A computer system [for monitoring one or more Mobility Management Entities (MMEs),] *comprising*:
 a packet switching device coupled to [one or more MMEs configured for receiving] *a mobility management entity (MME), wherein the packet switching device receives ciphered packets from the [one or more MMEs] MME;*
 a virtual machine (VM) of a plurality of [clustered] VMs coupled to the packet switching device, [each of the plurality of clustered VMs configure to:] *wherein the VM includes programmed instructions that when executed cause the VM to:*
 receive *a* ciphered [packets] *packet* sent from the packet switching device;
 decipher the received ciphered [packets] *packet*;
 extract metadata from the deciphered [packets] *packet, the metadata comprising first deciphered packet information relating to an individual subscriber assigned to the VM and second deciphered packet information relating to one or more subscribers not assigned to the VM;*
 selectively retain *the first* deciphered packet information, based upon analysis of *the* extracted metadata, wherein the retained *first deciphered* packet information is associated with [an] *the* individual subscriber assigned to [a respective] *the* VM retaining the packet information; and
 discard *the second* deciphered packet information *based upon analysis of the extracted metadata*, wherein the discarded *second deciphered* packet information is associated with one or more subscribers not assigned to [a respective] *the* VM discarding the *second deciphered* packet information.
17. The computer system [as recited in] of claim 16, wherein *key performance indicator (KPI) data associated with the individual subscriber assigned to the VM is generated* [in each of the plurality of VMs relating to an individual subscriber assigned to VM generating the KPI data].
18. The computer system [as recited in] of claim 17, further [including] *comprising*:
 at least one monitoring device operably coupled to the plurality of [clustered] VMs, *wherein the at least one*

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monitoring device is configured to aggregate subscriber related data from the plurality of [clustered] VMs, wherein a user of the at least one monitoring device is provided with the perception that the *at least one* monitoring device is coupled to a single VM.

19. The computer system [as recited in] of claim 18, wherein [each of the plurality of clustered VMs is configured to generate multiple synthetic packets from a received synthetic packet wherein each of the multiple synthetic packets is associated with an individual subscriber whereby each of the plurality of VMs retains packet information associated with a certain subscriber as prescribed by the monitoring device and discards the remaining synthetic packets associated with other subscribers] *the received packet is a received synthetic packet, the method further comprising generating multiple synthetic packets from the received synthetic packet, wherein each of the multiple synthetic packets is associated with the individual subscriber.*

20. The computer system [as recited in] of claim 18, wherein the at least one monitoring device includes aggregated subscriber information received from the plurality of [clustered] VMs such that subscriber data is aggregated from each of the plurality of [clustered] VMs.

21. *One or more non-transitory computer-readable media storing computer program instructions that, when executed by one or more processors, effectuate operations comprising:*

receiving, at a virtual machine (VM) of a plurality of VMs, a ciphered packet from a packet switching device, wherein the received ciphered packet is sent from the packet switching device to each VM of the plurality of VMs;

deciphering, at the VM, the received ciphered packet;

extracting metadata from the deciphered packet, the metadata comprising first deciphered packet information relating to an individual subscriber assigned to the VM and second deciphered packet information relating to one or more subscribers not assigned to the VM;

retaining the first deciphered packet information, based upon analysis of the extracted metadata at the VM,

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wherein the first deciphered packet information is associated with the individual subscriber assigned to the VM retaining the first deciphered packet information; and

discarding, at the VM, the second deciphered packet information, based upon analysis of the extracted metadata at the VM, wherein the discarded second deciphered packet information is associated with one or more subscribers not assigned to the VM discarding the second deciphered packet information.

22. *The one or more non-transitory computer-readable media of claim 21, wherein the operations further comprise: generating key performance indicator (KPI) data associated with the individual subscriber assigned to the VM; and*

providing the KPI data to a monitor device, wherein the monitor device aggregates subscriber related data from a plurality of clustered VMS.

23. *The one or more non-transitory computer-readable media of claim 22, wherein the received packet is a received synthetic packet, the method further comprising generating multiple synthetic packets from the received synthetic packet, wherein each of the multiple synthetic packets is associated with the individual subscriber.*

24. *The one or more non-transitory computer-readable media of claim 22, wherein the subscriber related data is aggregated using at least one monitor device and performs on-demand analysis of subscriber packet information.*

25. *The one or more non-transitory computer-readable media of claim 21, wherein the metadata consists of session information utilized by the VM for parallel processing of packet sessions across multiple subscriber session threads.*

26. *The one or more non-transitory computer-readable media of claim 21, wherein a monitor device is configured to perform real-time analysis of subscriber packet information by querying and retrieving subscriber information from each VM of the plurality of VMs relating to a user analysis request so as to retrieve subscriber data from an individual VM regarding a subscriber associated with the user analysis request.*

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