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(54) INTELLIGENT TELEMETRY MONITORING AND STREAMING FOR DATACENTERS

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G06F 11/00 (2006.01)

(52) **U.S. Cl.**
CPC ***G06F 11/004*** (2013.01); *G06F 2201/88* (2013.01)

(58) **Field of Classification Search**
CPC . G06F 11/004; G06F 11/3409; G06F 11/3006
See application file for complete search history.

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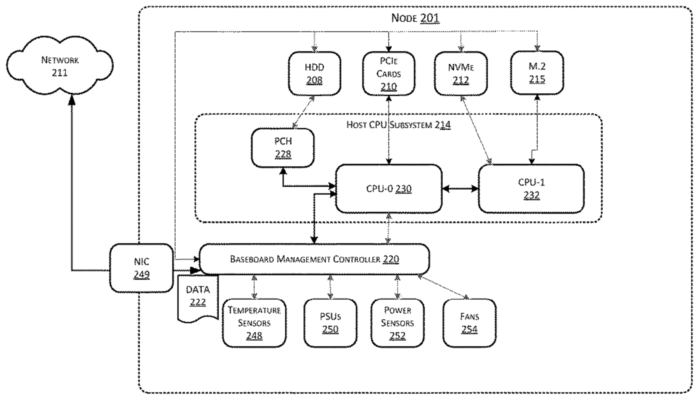
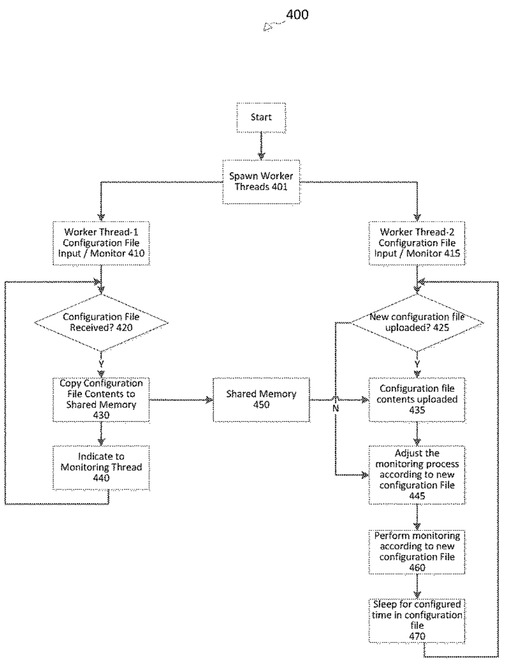
(57) **ABSTRACT**

A system receives, from a policy command service executing in a control plane of a distributed computing system, a configuration file defining parameters to be monitored at the computing node, a timing factor indicating when the parameters are to be monitored, and a threshold for when the parameters are to be sent from the computing node. Based on the configuration file, while the computing node is operational in the distributed computing system, the baseboard management controller is configured to monitor the computing node in accordance with the configuration file. The baseboard management controller sends, to a storage at the distributed computing system, the parameters defined in the configuration file for analysis of maintenance and health of the computing node.

19 Claims, 6 Drawing Sheets




400
Start
Spawn Worker Threads 401
Worker Thread-1 Configuration File Input / Monitor 410
Worker Thread-2 Configuration File Input / Monitor 415
Configuration File Received? 420
New configuration file uploaded? 425
Y
Y
N
Copy Configuration File Contents to Shared Memory 430
Shared Memory 450
Configuration file contents uploaded 435
Indicate to Monitoring Thread 440
Adjust the monitoring process according to new configuration File 445
Perform monitoring according to new configuration File 460
Sleep for configured time in configuration file 470

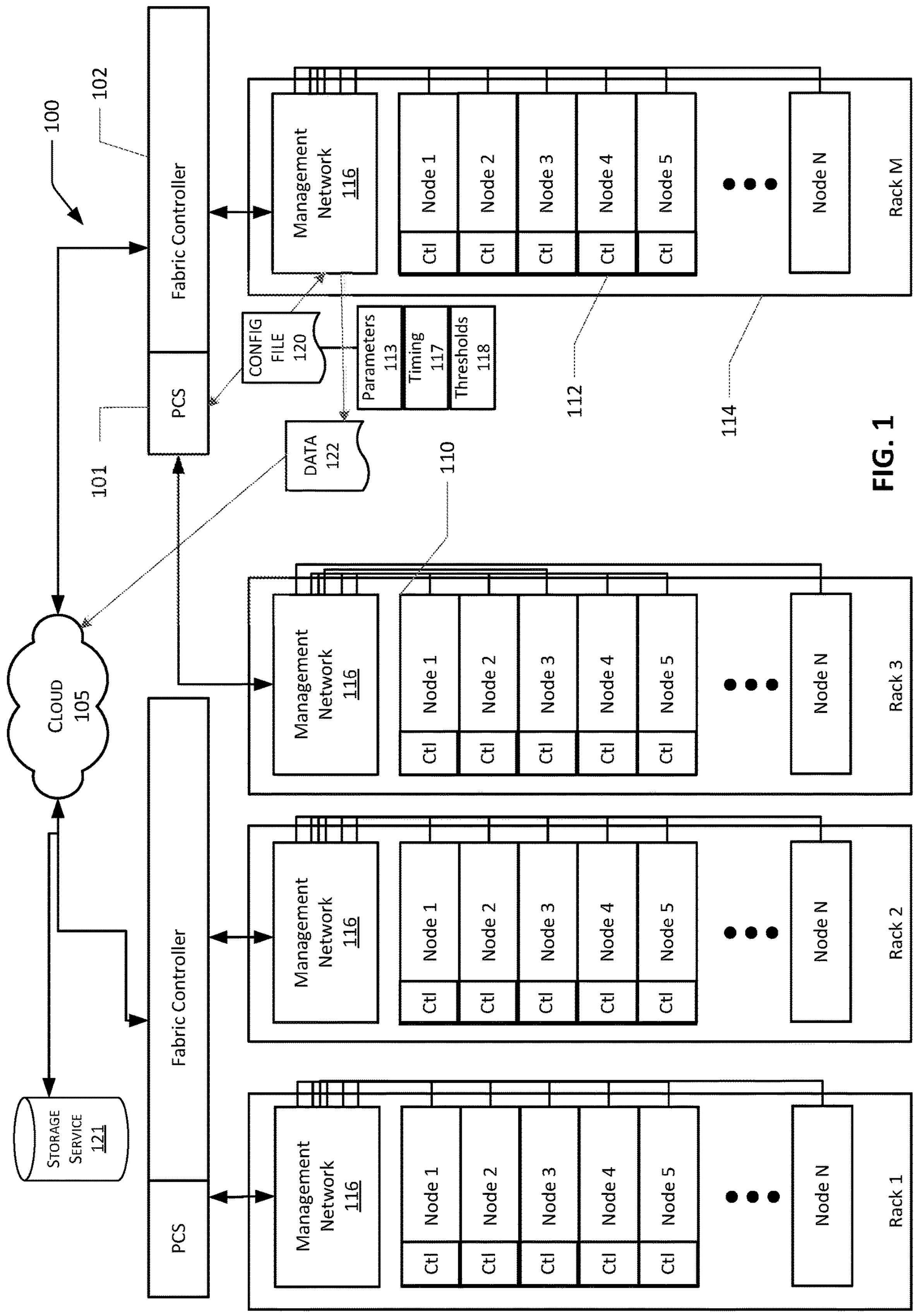

100
102
101
Fabric Controller
PCS
Cloud 105
Storage Service 121
CONFIG FILE 120
Parameters 113
Timing 117
Thresholds 118
DATA 122
110
112
114
Management Network 116
Node 1
Node 2
Node 3
Node 4
Node 5
Node N
Ctl
Rack 1
Rack 2
Rack 3
Rack M

FIG. 1

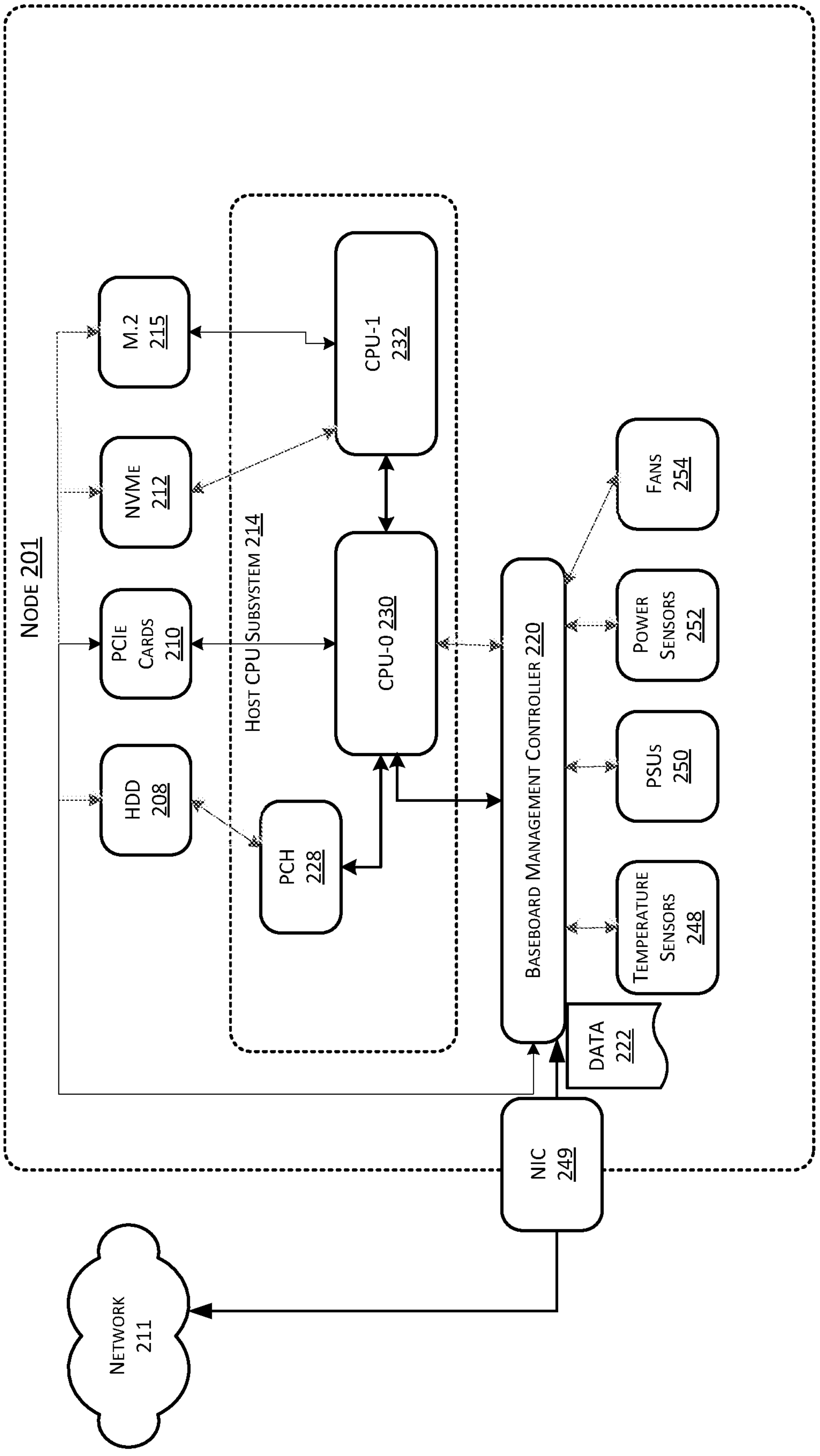

Node 201
M.2 215
NVMe 212
PCIe Cards 210
HDD 208
Host CPU Subsystem 214
CPU-1 232
CPU-0 230
PCH 228
Fans 254
Power Sensors 252
PSUs 250
Temperature Sensors 248
Baseboard Management Controller 220
Data 222
NIC 249
Network 211

FIG. 2

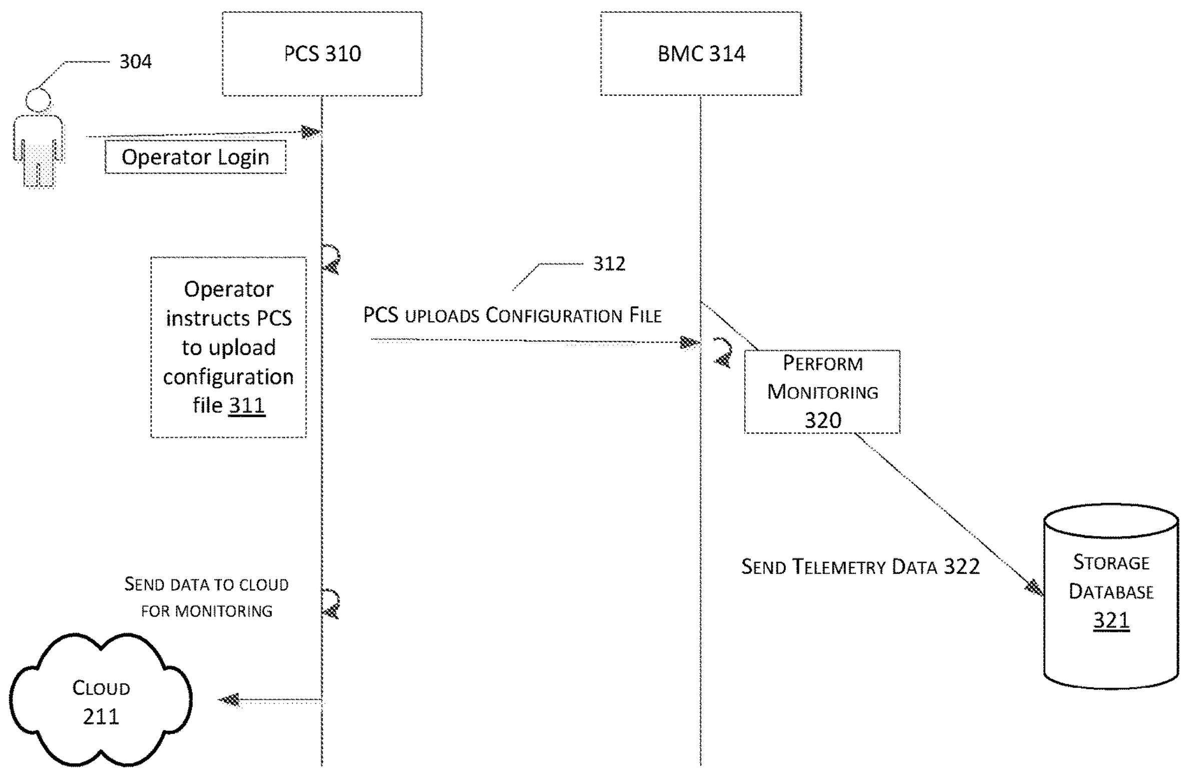

304
PCS 310
BMC 314
Operator Login
Operator instructs PCS to upload configuration file 311
312
PCS uploads Configuration File
Perform Monitoring 320
Send Telemetry Data 322
Storage Database 321
Send data to cloud for monitoring
Cloud 211

FIG. 3

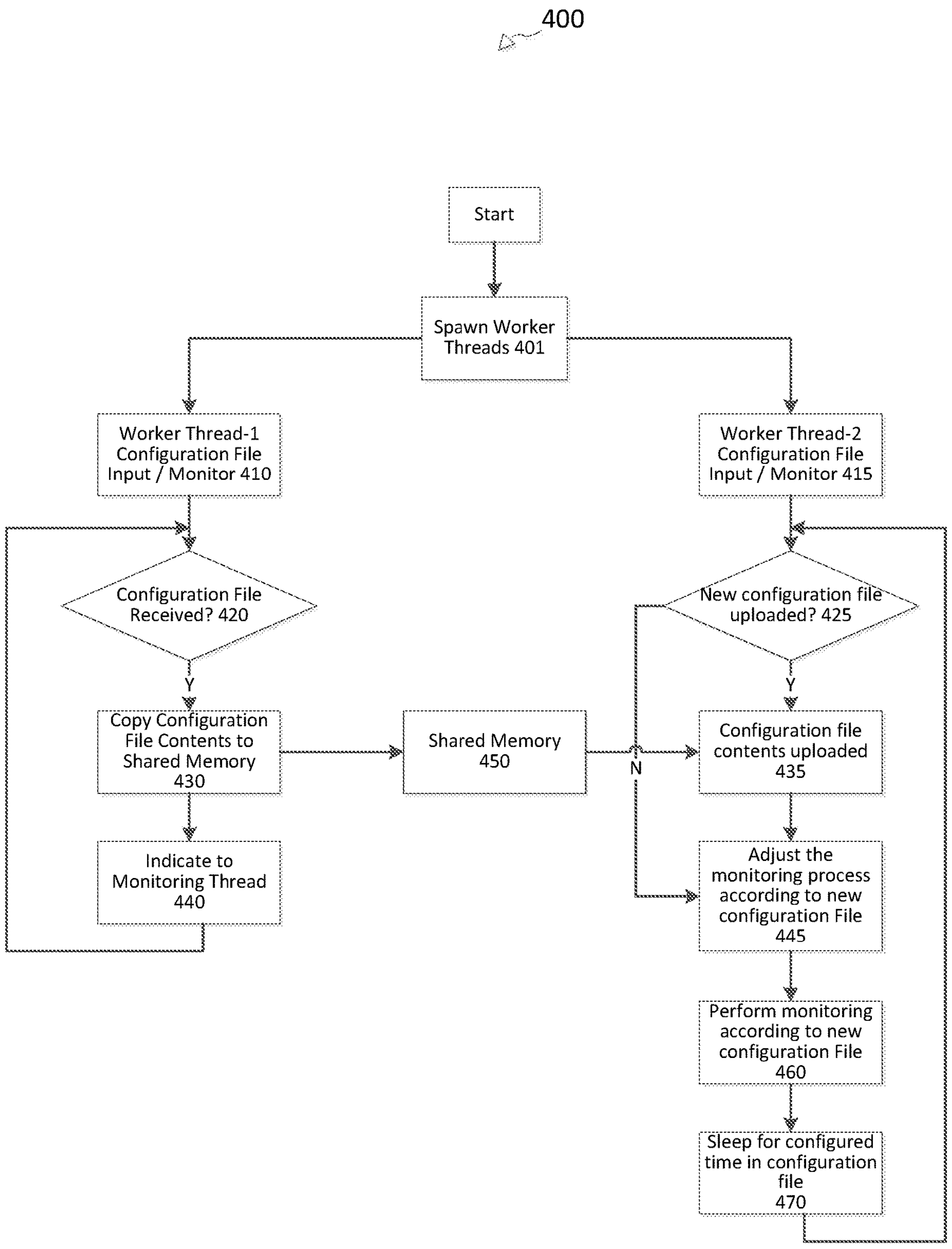

400
Start
Spawn Worker Threads 401
Worker Thread-1 Configuration File Input / Monitor 410
Worker Thread-2 Configuration File Input / Monitor 415
Configuration File Received? 420
New configuration file uploaded? 425
Y
Y
N
Copy Configuration File Contents to Shared Memory 430
Shared Memory 450
Configuration file contents uploaded 435
Indicate to Monitoring Thread 440
Adjust the monitoring process according to new configuration File 445
Perform monitoring according to new configuration File 460
Sleep for configured time in configuration file 470

FIG. 4

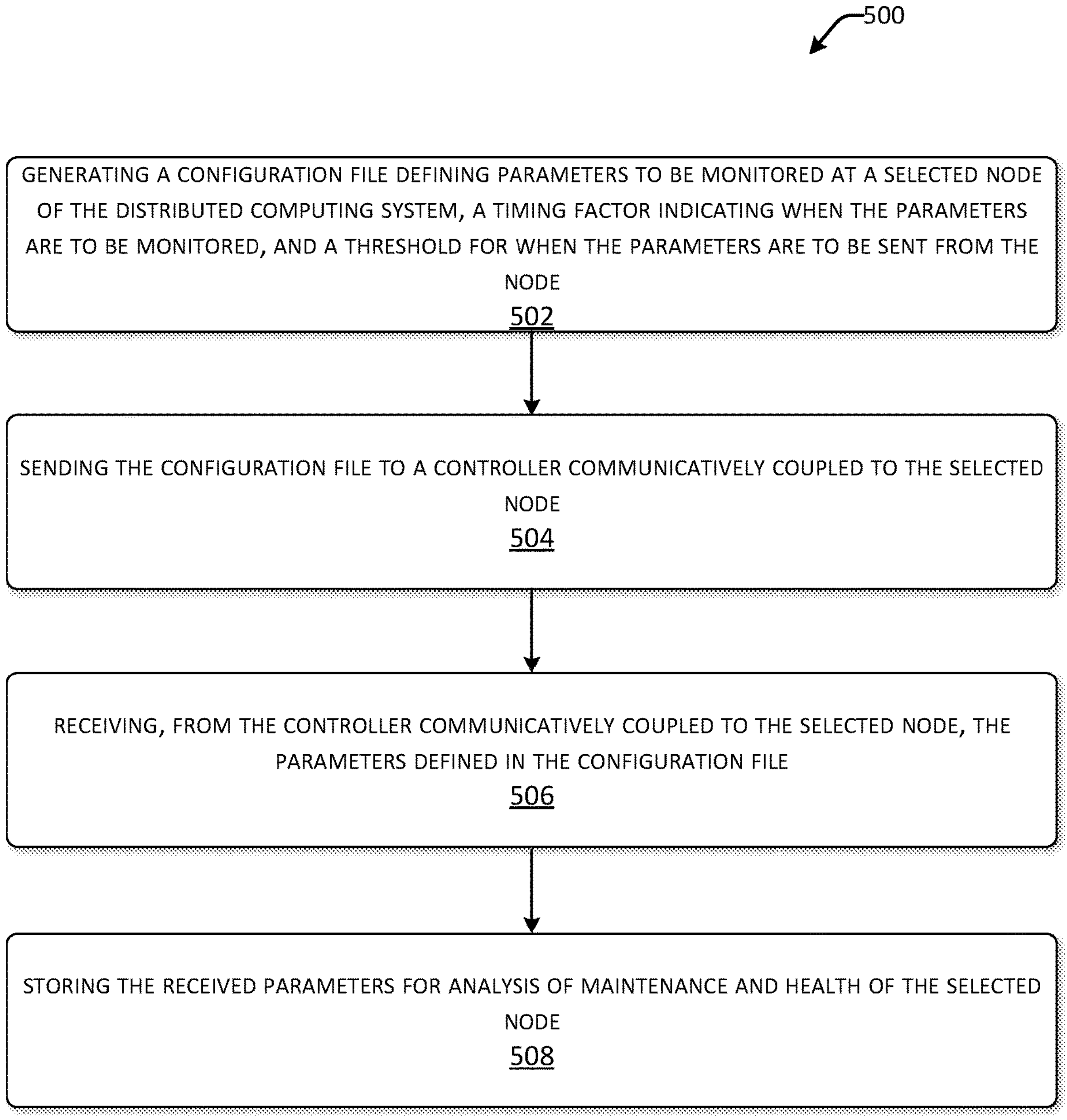

500
GENERATING A CONFIGURATION FILE DEFINING PARAMETERS TO BE MONITORED AT A SELECTED NODE OF THE DISTRIBUTED COMPUTING SYSTEM, A TIMING FACTOR INDICATING WHEN THE PARAMETERS ARE TO BE MONITORED, AND A THRESHOLD FOR WHEN THE PARAMETERS ARE TO BE SENT FROM THE NODE
502
SENDING THE CONFIGURATION FILE TO A CONTROLLER COMMUNICATIVELY COUPLED TO THE SELECTED NODE
504
RECEIVING, FROM THE CONTROLLER COMMUNICATIVELY COUPLED TO THE SELECTED NODE, THE PARAMETERS DEFINED IN THE CONFIGURATION FILE
506
STORING THE RECEIVED PARAMETERS FOR ANALYSIS OF MAINTENANCE AND HEALTH OF THE SELECTED NODE
508

FIG. 5

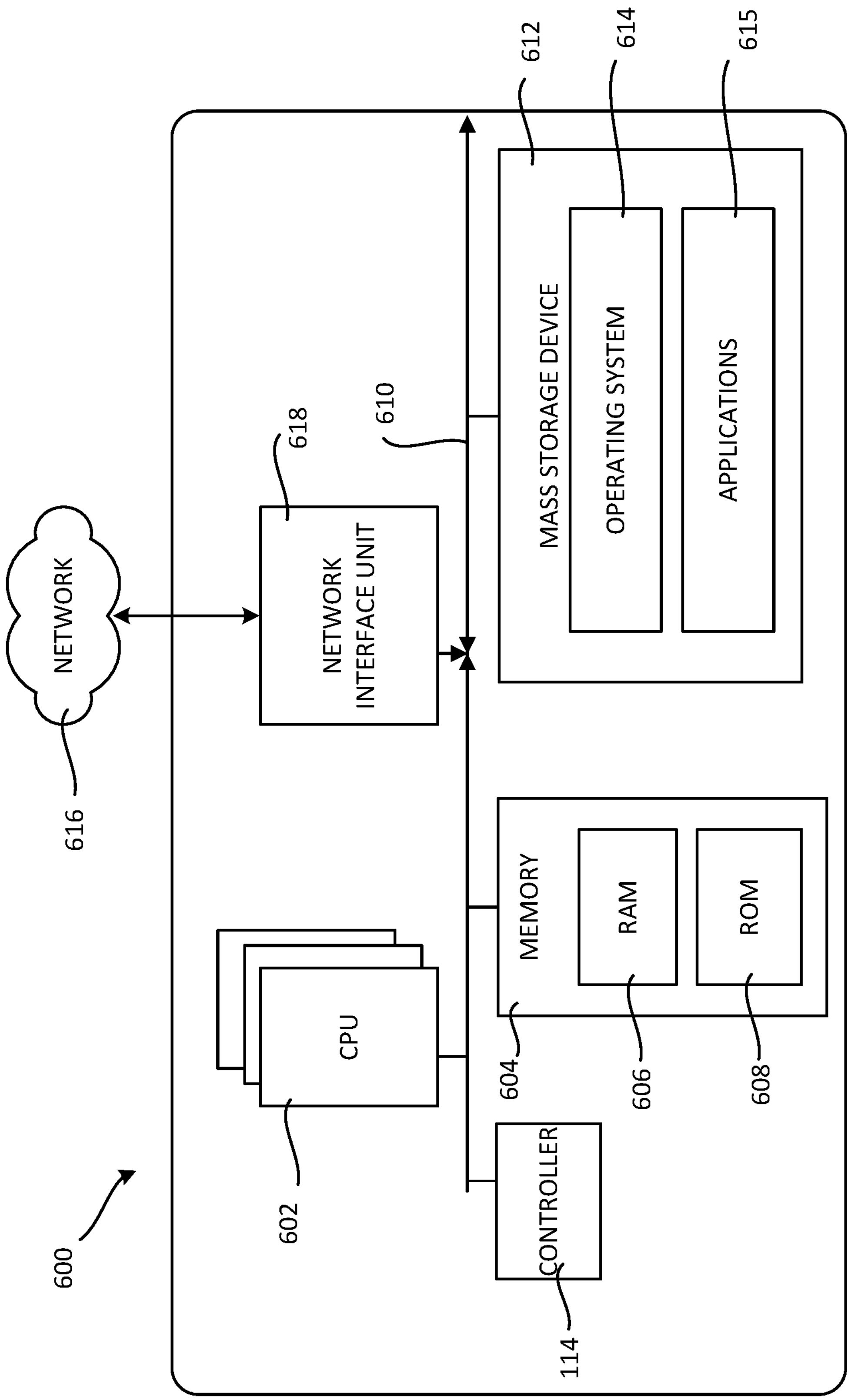

600
NETWORK
616
NETWORK INTERFACE UNIT
618
610
612
MASS STORAGE DEVICE
OPERATING SYSTEM
614
APPLICATIONS
615
CPU
602
MEMORY
604
RAM
606
ROM
608
CONTROLLER
114

FIG. 6

INTELLIGENT TELEMETRY MONITORING AND STREAMING FOR DATACENTERS

BACKGROUND

Data centers can have thousands or millions of nodes such as servers that provide various cloud-based services. The servers collectively need to operate reliably in order to provide high-performance cloud-based services. It is therefore important to provide an effective monitoring mechanism to detect anomalies early, take corrective action, and track each node over its lifecycle to maintain node health and avoid downtime, which otherwise can lead to revenue loss and customer dissatisfaction.

To maintain node health and serviceability, telemetry plays a significant role in enabling and collecting health parameters. With the scale and size of today's data centers, existing static telemetry mechanisms are inadequate and inefficient. When the monitoring of telemetry parameters is static, any change required to monitor a new telemetry parameter requires a firmware change which is a costly operation in a data center and one that makes the telemetry mechanisms less adaptive.

In a cloud-based system (e.g., one or more data centers) that includes thousands or millions of nodes, the inability to maintain node health and serviceability can have consequences such as processing delays, increased costs, frustrated customers, etc.

SUMMARY

Present day telemetry systems typically monitor and store all available parameters from each of the servers in a data center. Furthermore, monitoring of telemetry parameters is static and cannot be adapted to the conditions at the data center—i.e., there is no closed loop mechanism to adapt to changing conditions at the data center. Each data center typically requires different telemetry parameters to be monitored and stored based on environmental and other conditions as well as the workloads at each node in the data center. As used herein, a node is also referred to as a computing node, and can include a computing device such as a server. The prediction methods that need to be applied for each telemetry parameter can also vary.

Additionally, existing solutions consume a large amount of storage space as existing solutions tend to collect parameters that are not needed. Existing mechanisms may work for low scale data centers. However, in today's large scale data centers, static mechanisms can result in excessive monitoring and storage of data, resulting in inefficient and counterproductive processes for analyzing maintenance issues. This is especially true when the majority of a node's parameter values are within normal operating range for most of the node's lifecycle.

The techniques disclosed herein implement a smart telemetry monitoring and streaming (STMS) system that improves upon today's static telemetry systems with reduced storage and network bandwidth consumption and with a more efficient and flexible approach that improves overall resource utilization, overhead cost, and serviceability. One of the ways that STMS provides these benefits is by granular control of the telemetry data that is sent out of each node.

In an embodiment, each node at a data center includes a baseboard management controller (BMC) that is configured with functionality to support the health monitoring and operation of a server. The BMC performs telemetry parameter monitoring and streams the values for storage according to a desired configuration in order to aid in debugging and monitoring of the nodes in the data center.

In an embodiment, a policy command service (PCS) is implemented in the control plane fabric of the data center. The PCS is used to generate and push configuration files onto each node's BMC. The configuration files sent by the PCS include the list of parameters of interest for each node.

This Summary is provided to introduce a selection of concepts in a simplified form that are further described below in the Detailed Description. This Summary is not intended to be used as an aid in determining the scope of the claimed subject matter. The term "techniques," for instance, may refer to system(s), method(s), computer-readable instructions, module(s), algorithms, hardware logic, and/or operation(s) as permitted by the context described above and throughout the document.

BRIEF DESCRIPTION OF THE DRAWINGS

The Detailed Description is described with reference to the accompanying figures. In the figures, the left-most digit(s) of a reference number identifies the figure in which the reference number first appears. The same reference numbers in different figures indicate similar or identical items. References made to individual items of a plurality of items can use a reference number with a letter of a sequence of letters to refer to each individual item. Generic references to the items may use the specific reference number without the sequence of letters.

FIG. **1** illustrates an example environment in which a computing node (e.g., a server) is configured to receive a configuration file for monitoring parameters.

FIG. **2** illustrates further detail of a node in FIG. **1**.

FIG. **3** illustrates an example workflow diagram for monitoring a system.

FIG. **4** illustrates an example flow diagram of an example method for monitoring a system.

FIG. **5** illustrates an example flow diagram of an example method for monitoring a system.

FIG. **6** is an example computer architecture diagram illustrating an illustrative computer hardware and software architecture for a computing system capable of implementing aspects of the techniques and technologies presented herein.

DETAILED DESCRIPTION

The following Detailed Description discloses techniques and technologies for monitoring a distributed computing system comprising a plurality of nodes. Various examples, scenarios, and aspects are described below with reference to FIGS. **1**-**6**.

Referring to FIG. **1**, illustrated is a cloud service with a data center **100** and a PCS service **101** that is capable of communicating with nodes **110** in the data center **100**. In an embodiment, the PCS service **101** runs on a fabric controller **102** in a control plane of the data center **100** and communicates with nodes **110** using a network connection that is available on a controller **112** of each node **110**. The PCS service **101** has a distributed service architecture implemented at the cloud infrastructure and communicates with nodes **110** and clusters (not shown) in the data center as shown in FIG. **1**. In an embodiment, and as further described below, the controller **112** can be a baseboard management controller (BMC). The nodes can be servers that are arranged in racks **114**.

FIG. **1** illustrates one example of how a node connection architecture can be arranged in data center **100**. Data center **100** contains physical racks **114** which consist of multiple nodes **110** (e.g., servers) racked/placed per rack **114**. Each rack **114** has an individual power supply that provides power supply to the nodes **110** and a management network infrastructure **116** for each rack **114**. The management network infrastructure **116** in FIG. **1** represents a network infrastructure for the data center **100** and can include network switches, VLAN and network topologies, etc. according to data center requirements.

The fabric controller **102** is part of the management/control plane in data center **100**. In an embodiment, the fabric controller **102** comprises a pool of physical servers which hosts multiple management services that manage allocated server racks. A data center supervisor/operator can log in to the fabric controller **102** and perform status checks and initiate action on the individual nodes **110** as needed. The fabric controller **102** communicates to the controllers **112** of various nodes **110** over a network connection provided by the controllers **112**. The fabric controller **102** can check current monitoring parameters, error logs, and events from each node **110** by requesting the data from the controllers **112**. The fabric controller **102** can send a new payload to the controllers **112** which can be configuration files **120**, firmware update payloads, etc.

In an embodiment, the PCS service **101** is hosted on the fabric controller **102** as shown FIG. **1**. In an example, an operator logs into a fabric controller **102** and configures the required configuration files **120** that are to be pushed to each node **110** in the data center **100**. In an embodiment, the PCS service **101** is hosted locally inside data center **100** on each of the fabric controllers **102** to avoid network latency, deployment latency, etc. and to enable real time configuration changes when possible. If configuration files **120** need to be pushed remotely from a global cloud service via cloud **105** to the individual nodes **110** in the data center **100**, this may include multiple transmission hops, monitoring of the deployment of the configuration files **120**, monitoring of possible deployment aborts, etc. which need to be monitored with varying cadence and processes. By pushing such functions locally onto the fabric controllers **102**, the complexity of the deployment can be reduced and failed deployments can be avoided.

The PCS service **101** also sends information about the current configuration file **120** for each node to the cloud service provider via cloud **105** for storage on databases such as storage service **121** which can be viewed remotely by any operator. The PCS service **101** also sends audit logs containing the time when configuration files **120** were pushed, the owner or operator who entered the configuration files **120**, any aborts of the configuration file push, etc. to the cloud service provider for auditing and monitoring purposes.

FIG. **2** illustrates an example environment which depicts an example node **201**, which can be a server (e.g., Intel 2 CPU Server). As shown in FIG. **2**, the BMC **220** is the main monitoring controller on the node **201** which is connected to various sensors and other devices on the node **201**. Node **201** includes a CPU subsystem **214** with CPU-**0** **230** and CPU-**1** **232**, as well as platform controller hub (PCH) **228** which acts as a central interface between the CPU-**0** **230** and CPU-**1** **232**, memory, and I/O devices on a motherboard of node **201**. Memory devices can include hard disk drive (HDD) **208** and M.2 SSDs **215**. I/O devices can include Peripheral Component Interconnect Express (PCIe) card **210** and Non-Volatile Memory Express (NVMe) **212**.

In an embodiment, the BMC **220** is a service processor that is capable of monitoring the physical state of the node memory, other hardware components, and/or peripheral devices using sensors and/or other mechanisms. The BMC **220** is configured on the main circuit board of a computing device (e.g., a server) such as node **201** and can implement remote communications via a shared or a dedicated network interface card (NIC) **249**. In one example the BMC **220** is configured to perform tasks that otherwise would need to be performed by a user physically visiting the node in a server rack. For example, considering a cloud platform (e.g., AMAZON WEB SERVICES, GOOGLE CLOUD PLATFORM, MICROSOFT AZURE) with a large number of network servers executing cloud tenant workloads via a data plane, the BMC **220** is part of a manageability subsystem that forms part of a control plane in the cloud platform. The control plane can be used to collect telemetry data across the network servers for administrative or operational purposes. Consequently, the BMC **220** is configured to harvest and report the telemetry data for the network servers configured within data center(s) of a cloud platform.

Data **222** from the temperature sensors **248**, power sensors **252**, fans **254**, PSUs **250**, etc. are collected by the BMC **220**. The collected data **222** is monitored for threshold crossing events and raising events and system event logs (SELs) when any sensor crosses a configured threshold such as thresholds **118** in FIG. **1**. In an embodiment, the sensor monitoring and SEL logging functionality can be in accordance with industry specific Intelligent Platform Management Interface (IPMI) specifications.

The BMC **220** is connected to external networks through NIC **249** as shown in FIG. **2**. An external client can download a file or submit a request for sensor data, SEL logs, etc. through NIC **249**. In an embodiment, a communication mechanism is implemented using a secured Hypertext Transfer Protocol Secure (HTTPS) channel between the external client and the BMC **220**.

The various components and functions illustrated in FIGS. **1** and **2** provide functionality for a smart telemetry monitoring and streaming (STMS) system. In an embodiment, a method is implemented for monitoring a distributed computing system comprising a plurality of nodes, such as data center **100** in FIG. **1**. In an example, the nodes **110** of FIG. **1** can be servers communicatively coupled to controllers **112** configured to monitor local conditions at the nodes **112**. The policy command service **101** executes in a control plane of the data center **100**. The policy command service **101** generates configuration file **120** defining parameters **113** to be monitored at a selected node of the distributed computing system, a timing factor **117** indicating when the parameters are to be monitored, and a threshold **118** for when the parameters **113** are to be sent from the node **110**.

The configuration file **120** is sent to controller **112** communicatively coupled to a selected node **112**. The configuration file **120** is usable to configure the controller **112** that is communicatively coupled to the selected node **112** to monitor the selected node **110** in accordance with the configuration file **120**. The controller **112** is configured while the selected node **110** is operational in the data center **100**. The parameters **113** defined in the configuration file **120** are received as data **122** from the controller **112**. In an embodiment, the data **122** is received by additional devices in the network such as a rack manager (not shown). In other embodiments, the data **122** can be received by other components shown in FIG. **1**. The received parameters **113** are stored at storage service **121** for analysis of maintenance and health of the selected node **110**.

Referring to FIG. **3**, illustrated is an example workflow for managing nodes in a data center in accordance with the disclosure. The PCS service **310** pushes the configuration file **312** for each node present in the data center. The configuration file for each node can be determined by a data center operator **304** who instructs the PCS **310** to upload **311** the configuration file. In some embodiments, the configuration file for each node can be determined by an artificial intelligence (AI)/machine learning (ML) algorithm that uses attributes such as server location, ambient temperature, datetime value (seasonal changes) or parameters such as CPU temperature, fan speed, server workloads, etc. Trigger conditions can be specified in the configuration file for each of the attributes.

By implementing the disclosed embodiments, the telemetry monitoring and streaming process using a BMC **314** is not static and will read the configuration file and adjust the monitoring algorithms according to the configuration file. The BMC **314** will perform monitoring **320** of parameters in accordance with the configuration file. If the trigger conditions described in the configuration file are met, the BMC **314** will send out, from the node, the telemetry parameters **322** identified in the configuration file. This allows for reduction of the telemetry data to only information that has been identified as being desired for monitoring. The telemetry data can be stored in a storage database **321** for analysis. This approach optimizes the data being sent out of the node as well as the timing of the data. PCS **310** also sends the current configuration file, audit log, and other information for each server node to the cloud via network **211** for auditing and monitoring.

The configuration file can be a preset template or a custom configuration file defined by the data center operator or other means. In an embodiment, the configuration file can be a JavaScript Object Notation (JSON) file. The custom configuration file can also be determined through AI/ML algorithms at runtime that is running at the data center.

An example configuration file for monitoring a server subsystem can be used for monitoring server system related parameters with a monitoring frequency (e.g., 60 seconds). The example server subsystem monitoring configuration file can include:

- Trigger conditions defined based on system sensors—e.g., CPU temperature, CPU power, dual in-line memory module (DIMM) temperature, graphics processing unit (GPU) Power, NIC power, server workload parameters, etc.
- Trigger thresholds such as the rate of change of the sensor values or a direct comparison with a predetermined value.

Based on the configuration file for monitoring the server subsystem, the BMC takes a snapshot of all system-related sensor values when the trigger conditions are met and streams the data for storage.

As another example, a balanced monitoring policy file can be used for monitoring only CPU related parameters as well as selected hardware sensors with a preset monitoring frequency (e.g., 3 minutes). The example balanced monitoring policy file can include:

- Trigger conditions defined based on system sensors—e.g., CPU temperature, CPU power, voltage regulator (VR) temperature.
- Trigger thresholds such as the rate of change of the sensor values or a direct comparison with a predetermined value.

Based on the balanced monitoring policy file, the BMC takes a snapshot of all system-related sensor values when the trigger conditions are met and streams the data for storage.

An example aggressive monitoring policy file can be used for aggressive monitoring policies which will monitor all temperature sensors, voltage sensors, firmware status, hardware interface links, etc. with a preset monitoring frequency (e.g., 30 seconds).

- Trigger conditions defined based on system sensors such as CPU temperature and power, VR temperature, DIMM sensors, GPU power and temperature, BMC firmware status, Basic Input/Output System (BIOS) system management interrupts (SMI) status/rate, PCIe link status, GPU error-correcting code (ECC) status, field programmable gate array (FPGA) firmware status, etc.
- Trigger thresholds such as the rate of change of the sensor values or a direct comparison with a predetermined value

The BMC takes a snapshot of all monitored sensor values, the BMC CPU and memory consumption, and file handler descriptor count when the trigger conditions are met and streams the data for storage.

A custom configuration file can be used for setting custom configuration definitions by the data center operator or can be generated through AI/ML algorithms from a cloud service running at the data center. The frequency, trigger conditions, and monitoring rules are defined in the custom configuration file. The BMC will read the configuration file and monitor and stream the data according to the defined trigger conditions.

Referring to FIG. **4**, illustrated is a functional flow chart **400** for configuring a BMC to monitor parameters in accordance with the disclosure. In an embodiment, a monitoring application is implemented in the BMC. The monitoring application is started on boot-up of the associated node or server. The monitoring application internally spawns worker threads **401** to perform configuration file input checks and monitor functionality according to the received configuration file for worker thread-**1** **410** and worker thread-**2** **415**. The worker threads work in synchronization to share the received configuration file through inter-process communication (IPC). The monitoring thread is operable to change the monitoring processes according to the received configuration file and is therefore not statically configured.

For worker thread-**1**, if a configuration file is received **420**, then the contents of the configuration file are copied **430** to shared memory **450**. An indication is provided to the monitoring thread **440**, and operation continues at operation **420**. For worker thread-**2**, if a new configuration file is received **425**, then the contents of the configuration file are read and uploaded **435**. The monitoring process is adjusted according to the new configuration file **445**. Monitoring is then performed according to the new configuration file **460**. The worker thread-**2** then sleeps **470** or otherwise waits for a time period as defined in the configuration file.

In some embodiments, the PCS service reads the current parameters from the node and generates a configuration file using an AI/ML model. The AI/ML model can be trained using monitored data and predicted and actual system faults. The generated configuration file can be uploaded to the BMC to perform the desired monitoring. The AI/ML model can be configured to receive and analyze past faults and monitored data that occurred over a predetermined period of time. The AI/ML model is configured to predict, as an output, a failure of a node. A maintenance action can be initiated in response to a predicted failure.

The AI/ML model can be any one of various predictive models. For instance, the AI/ML model can use any one of neural networks (e.g., convolutional neural networks, recurrent neural networks such as Long Short-Term Transformer, etc.), Naïve Bayes, k-nearest neighbor algorithm, majority classifier, support vector machines, random forests, Classification and Regression Trees (CART), gradient-boosted decision trees (GBDTs), and so on.

Technical benefits of the disclosed embodiments include configurability, flexibility and control of health monitoring of nodes in a data center. Currently, the telemetry data points are statically configured and embedded in the firmware image of the nodes, which in turn determines what data is sent out from a node and at what rate/frequency. This inflexible design leads to high network bandwidth consumption and frequent firmware updates and deployment in the field, which leads to inefficiencies and waste. With implementation of the disclosed embodiments, the required parameters are dynamically configurable, as well as the data rates streamed from the device to storage. This approach provides improved flexibility and configurability, enabling system resources to be utilized more efficiently.

Technical benefits of the disclosed embodiments also include reduction of the storage requirements for monitored data. Currently, telemetry data are provided from millions of nodes without any filtration mechanism, leading to vast amounts of storage consumption. Typically, most of the stored telemetry data is unused in any debugging scenario, leading to wasted resources and cost. The disclosed embodiments enable streaming of only relevant data that is provided at the desired times. This allows storage requirements to be significantly reduced, lowering the overall cost of maintenance.

Additionally, since only the data that is important for debugging and serviceability are streamed out of the nodes, a smaller and more relevant data set is provided for analysis. This allows more efficient analysis and prediction of faults, which in turn allows for corrective measures to be determined efficiently and for the corrective measures to be taken prior to an actual fault and thus avoid costly downtime.

Technical benefits of the disclosed embodiments also include avoidance of firmware qualification, BMC downtime, and firmware deployment efforts at the data center. The disclosed embodiments allow for monitored parameters, monitoring rules, and associated trigger conditions to be dynamically configurable. Accordingly, firmware changes are not required to introduce new monitoring conditions, such as for a new sensor or for changing the rules or trigger conditions for existing monitored sensors.

FIG. **5** represents an example process implemented in accordance with various examples from the description of FIGS. **1**-**4**. The example operations shown in FIG. **4** can be implemented on or otherwise embodied in one or more components shown in FIGS. **1**-**4**.

The order in which the operations are described is not intended to be construed as a limitation, and any number of the described operations can be combined in any order and/or in parallel to implement each process. Moreover, the operations in FIG. **5** can be implemented in hardware, software, and/or a combination thereof. In the context of software, the operations represent computer-executable instructions that, when executed by one or more processing units, cause the one or more processing units to perform the recited operations. For example, modules and other components described herein can be stored in a computer-readable storage media and executed by at least one processing unit to perform the described operations.

FIG. **5** illustrates a flow diagram of an example method **500** for monitoring a distributed computing system comprising a plurality of nodes, where the nodes communicatively coupled to controllers configured to monitor local conditions at the nodes. The operations in FIG. **5** can be implemented by data center **100**.

At operation **502**, a policy command service executing in a control plane of the distributed computing system generates a configuration file defining parameters to be monitored at a selected node of the distributed computing system, a timing factor indicating when the parameters are to be monitored, and a threshold for when the parameters are to be sent from the node;

At operation **504**, the configuration file is sent to a controller communicatively coupled to the selected node. The configuration file is usable to configure the controller communicatively coupled to the selected node to monitor the selected node in accordance with the configuration file. The controller communicatively coupled to the selected node is configured while the selected node is operational in the distributed computing system.

At operation **506**, the parameters defined in the configuration file are received from the controller communicatively coupled to the selected node.

At operation **508** the received parameters are stored for analysis of maintenance and health of the selected node.

FIG. **6** is a computer architecture diagram showing an illustrative computer hardware and software architecture for a computing device that can implement the various technologies presented herein. In particular, the architecture illustrated in FIG. **6** can be utilized to implement the node **110** in FIG. **1**.

The computing device **600** illustrated in FIG. **6** includes a central processing unit **602** ("CPU"), a system memory **604**, including a random-access memory **606** ("RAM") and a read-only memory ("ROM") **608**, and a system bus **610** that couples the memory **604** to the CPU **602**. A basic input/output system ("BIOS" or "firmware") containing the basic routines that help to transfer information between elements within the computing device **600**, such as during startup, can be stored in the ROM **608**. The computing device **600** further includes a mass storage device **612** for storing an operating system **614**, applications **615**, and/or other types of programs.

The mass storage device **612** is connected to the CPU **602** through a mass storage controller connected to the bus **610**. The mass storage device **612** and its associated computer readable media provide non-volatile storage for the computing device **600**. Although the description of computer readable media contained herein refers to a mass storage device, such as a hard disk, CD-ROM drive, DVD-ROM drive, or USB storage key, it should be appreciated by those skilled in the art that computer readable media can be any available computer storage media or communication media that can be accessed by the computing device **600**.

Communication media includes computer readable instructions, data structures, program modules, or other data in a modulated data signal such as a carrier wave or other transport mechanism and includes any delivery media. The term "modulated data signal" means a signal that has one or more of its characteristics changed or set in a manner so as to encode information in the signal. By way of example, and not limitation, communication media includes wired media such as a wired network or direct-wired connection, and wireless media such as acoustic, radio frequency, infrared and other wireless media. Combinations of any of the above should also be included within the scope of computer readable media.

By way of example, and not limitation, computer storage media can include volatile and non-volatile, removable and non-removable media implemented in any method or technology for storage of information such as computer readable instructions, data structures, program modules or other data. For example, computer storage media includes, but is not limited to, RAM, ROM, EPROM, EEPROM, flash memory or other solid-state memory technology, CD-ROM, digital versatile disks ("DVD"), HD-DVD, BLU-RAY, or other optical storage, magnetic cassettes, magnetic tape, magnetic disk storage or other magnetic storage devices, or any other medium that can be used to store the desired information and which can be accessed by the computing device **600**. For purposes of the claims, the phrase "computer storage medium," and variations thereof, does not include waves or signals per se or communication media.

According to various configurations, the computing device **600** can operate in a networked environment using logical connections to remote computers through a network such as the network **616**. The computing device **600** can connect to the network **616** through a network interface unit **618** connected to the bus **610**. It should be appreciated that the network interface unit **618** can also be utilized to connect to other types of networks and remote computer systems.

It should be appreciated that the software components described herein, when loaded into the CPU **602** and executed, can transform the CPU **602** and the overall computing device **600** from a general-purpose computing device into a special-purpose computing device customized to facilitate the functionality presented herein. The CPU **602** can be constructed from any number of transistors or other discrete circuit elements, which can individually or collectively assume any number of states. More specifically, the CPU **602** can operate as a finite-state machine, in response to executable instructions contained within the software modules disclosed herein. These computer-executable instructions can transform the CPU **602** by specifying how the CPU **602** transitions between states, thereby transforming the transistors or other discrete hardware elements constituting the CPU **602**. FIG. **6** further illustrates that the controller **112** is also connected to the bus **610**.

Encoding the software modules presented herein also may transform the physical structure of the computer-readable media presented herein. The specific transformation of physical structure may depend on various factors, in different implementations of this description. Examples of such factors may include, but are not limited to, the technology used to implement the computer-readable media, whether the computer-readable media is characterized as primary or secondary storage, and the like. For example, if the computer-readable media is implemented as semiconductor-based memory, the software disclosed herein may be encoded on the computer-readable media by transforming the physical state of the semiconductor memory. For example, the software may transform the state of transistors, capacitors, or other discrete circuit elements constituting the semiconductor memory. The software also may transform the physical state of such components in order to store data thereupon.

Conditional language such as, among others, "can," "could," "might" or "may," unless specifically stated otherwise, are understood within the context to present that certain examples include, while other examples do not include, certain features, elements and/or steps. Thus, such

conditional language is not generally intended to imply that certain features, elements and/or steps are in any way required for one or more examples or that one or more examples necessarily include logic for deciding, with or without user input or prompting, whether certain features, elements and/or steps are included or are to be performed in any particular example. Conjunctive language such as the phrase "at least one of X, Y or Z," unless specifically stated otherwise, is to be understood to present that an item, term, etc. may be either X, Y, or Z, or a combination thereof.

The terms "a," "an," "the" and similar referents used in the context of describing the invention (especially in the context of the following claims) are to be construed to cover both the singular and the plural unless otherwise indicated herein or clearly contradicted by context. The terms "based on," "based upon," and similar referents are to be construed as meaning "based at least in part" which includes being "based in part" and "based in whole" unless otherwise indicated or clearly contradicted by context.

It should be appreciated that any reference to "first," "second," etc. elements within the Summary and/or Detailed Description is not intended to and should not be construed to necessarily correspond to any reference of "first," "second," etc. elements of the claims. Rather, any use of "first" and "second" within the Summary, Detailed Description, and/or claims may be used to distinguish between two different instances of the same element (e.g., two different types, two different requests, etc.).

In closing, although the various configurations have been described in language specific to structural features and/or methodological acts, it is to be understood that the subject matter defined in the appended representations is not necessarily limited to the specific features or acts described. Rather, the specific features and acts are disclosed as example forms of implementing the claimed subject matter. All examples are provided for illustrative purposes and is not to be construed as limiting.

The disclosure presented herein also encompasses the subject matter set forth in the following clauses.

Example Clause A, a method for monitoring a distributed computing system comprising a plurality of nodes, the nodes communicatively coupled to controllers configured to monitor local conditions at the nodes, the method comprising: generating, by a policy command service executing in a control plane of the distributed computing system, a configuration file defining parameters to be monitored at a selected node of the distributed computing system, a timing factor indicating when the parameters are to be monitored, and a threshold for when the parameters are to be sent from the node; sending the configuration file to a controller communicatively coupled to the selected node, wherein the configuration file is usable to configure the controller communicatively coupled to the selected node to monitor the selected node in accordance with the configuration file, wherein the controller communicatively coupled to the selected node is configured while the selected node is operational in the distributed computing system; receiving, from the controller communicatively coupled to the selected node, the parameters defined in the configuration file; and storing the received parameters for analysis of maintenance and health of the selected node.

Example Clause B, the peripheral device cartridge of Example Clause A, wherein the policy command service runs in a fabric controller in the distributed computing system.

Example Clause C, the peripheral device cartridge of Example Clause A, wherein the configuration file is generated based on inputs provided by a machine learning model.

Example Clause D, the peripheral device cartridge of any one of Example Clause A through Example Clause C, wherein the threshold for when the parameters are to be sent from the node comprise trigger conditions for a sensor on the node.

Example Clause E, the peripheral device cartridge of any one of Example Clause A through Example Clause D, wherein the trigger conditions comprise a rate of change of sensor outputs or a comparison with a predetermined value.

Example Clause F, the peripheral device cartridge of any one of Example Clause A through Example Clause E, wherein the controller comprises a baseboard management controller.

Example Clause G, the peripheral device cartridge of any one of Example Clause A through Example Clause F, further comprising: generating, by the policy command service, an updated configuration file defining updates to the parameters to be monitored at the selected node; and sending the updated configuration file to the controller communicatively coupled to the selected node.

Example Clause H, the peripheral device cartridge of any one of Example Clause A through Example Clause G, further comprising: analyzing the stored parameters to predict a failure of the selected node.

Example Clause I, the peripheral device cartridge of any one of Example Clause A through Example Clause H, further comprising: in response to the predicted failure, initiating a maintenance action for the selected node.

Example Clause J, a computing node comprising a baseboard management controller configured to perform operations comprising: receiving, from a policy command service executing in a control plane of a distributed computing system, a configuration file defining parameters to be monitored at the computing node, a timing factor indicating when the parameters are to be monitored, and a threshold for when the parameters are to be sent from the computing node; based on the configuration file, configuring, while the computing node is operational in the distributed computing system, the baseboard management controller to monitor the computing node in accordance with the configuration file; and sending, by the baseboard management controller to a storage at the distributed computing system, the parameters defined in the configuration file for analysis of maintenance and health of the computing node.

Example Clause K, the host computing system of Example Clause J, wherein the threshold for when the parameters are to be sent from the node comprise trigger conditions for a sensor on the node.

Example Clause L, the host computing system of Example Clause J or Example Clause K, wherein the trigger conditions comprise a rate of change of sensor outputs or a comparison with a predetermined value.

Example Clause M, the host computing system of any one of Example Clause J through Example Clause L, the baseboard management controller further configured to perform operations comprising: receiving, from the policy command service, an updated configuration file defining updates to the parameters to be monitored at the computing node; and sending the updated configuration file to the controller communicatively coupled to the computing node.

Example Clause N, the host computing system of any one of Example Clause H through Example Clause M, the baseboard management controller configured to perform operations comprising: receiving, from the policy command service, an updated configuration file defining updates to the parameters to be monitored at the computing node; and configuring, while the computing node is operational in the distributed computing system, the baseboard management controller to monitor the computing node in accordance with the updated configuration file.

Example Clause O, the host computing system of any one of Example Clause H through Example Clause N, wherein the baseboard management controller is configured to communicate directly to the distributed computing system via a network interface.

Example Clause P, the host computing system of any one of Example Clause H through Example Clause O, wherein baseboard management controller is communicatively coupled to a plurality of sensors on the computing node, and the parameters are collected by the baseboard management controller from the communicatively coupled sensors.

Example Clause Q, a baseboard management controller configured to perform operations comprising: receiving, from a policy command service executing in a control plane of a distributed computing system, a configuration file defining parameters to be monitored at a computing node communicatively coupled to the baseboard management controller, a timing factor indicating when the parameters are to be monitored, and a threshold for when the parameters are to be sent from the computing node; based on the configuration file, configuring, while the computing node is operational in the distributed computing system, the baseboard management controller to monitor the computing node in accordance with the configuration file; and sending, by the baseboard management controller to a storage at the distributed computing system, the parameters defined in the configuration file for analysis of maintenance and health of the computing node.

Example Clause R, the server device of Example Clause Q, wherein the threshold for when the parameters are to be sent from the node comprise trigger conditions for a sensor on the node.

Example Clause S, the server device of Example Clause Q or Example Clause R, wherein the trigger conditions comprise a rate of change of sensor outputs or a comparison with a predetermined value.

Example Clause T, the server device of any one of Example Clause Q through Example Clause S, wherein the operations further comprise: receiving, from the policy command service, an updated configuration file defining updates to the parameters to be monitored; and configuring, while the baseboard management controller is operational, the baseboard management controller to monitor the computing node in accordance with the updated configuration file.

What is claimed is:

1. A method for monitoring a distributed computing system comprising a plurality of server nodes, each of the server nodes communicatively coupled to a baseboard management controller configured to monitor local conditions at the server nodes, the method comprising:

generating, by a policy command service executing in a control plane of the distributed computing system, a configuration file defining parameters to be monitored at a selected server node of the distributed computing system, a timing factor indicating when the parameters are to be monitored, and a threshold for when the parameters are to be sent from the selected server node;

sending the configuration file to a baseboard management controller communicatively coupled to the selected server node, wherein the configuration file is usable to configure the baseboard management controller communicatively coupled to the selected server node to monitor the selected server node in accordance with the configuration file, wherein the baseboard management controller communicatively coupled to the selected server node is configured while the selected server node is operational in the distributed computing system and wherein the baseboard management controller is configured to: copy content of the configuration file to a shared memory, and spawn worker threads to upload content of the configuration file from the shared memory and monitor the selected server node according to the configuration file;

receiving, from the baseboard management controller communicatively coupled to the selected server node, the parameters defined in the configuration file; and

storing the received parameters for analysis of maintenance and health of the selected node.

2. The method of claim **1**, wherein the policy command service runs in a fabric controller in the distributed computing system.

3. The method of claim **1**, wherein the configuration file is generated based on inputs provided by a machine learning model.

4. The method of claim **1**, wherein the threshold for when the parameters are to be sent from the node comprise trigger conditions for a sensor on the node.

5. The method of claim **4**, wherein the trigger conditions comprise a rate of change of sensor outputs or a comparison with a predetermined value.

6. The method of claim **1**, further comprising:

generating, by the policy command service, an updated configuration file defining updates to the parameters to be monitored at the selected node; and

sending the updated configuration file to the controller communicatively coupled to the selected node.

7. The method of claim **6**, further comprising:

analyzing the stored parameters to predict a failure of the selected node.

8. The method of claim **7**, further comprising:

in response to the predicted failure, initiating a maintenance action for the selected node.

9. A computing node comprising a baseboard management controller configured to perform operations comprising:

receiving, from a policy command service executing in a control plane of a distributed computing system, a configuration file defining parameters to be monitored at the computing node, a timing factor indicating when the parameters are to be monitored, and a threshold for when the parameters are to be sent from the computing node;

based on the configuration file, configuring, while the computing node is operational in the distributed computing system, the baseboard management controller to monitor the computing node in accordance with the configuration file, and further to copy content of the configuration file to a shared memory, and spawn worker threads to upload content of the configuration file from the shared memory and monitor the computing node according to the configuration file; and

sending, by the baseboard management controller to a storage at the distributed computing system, the parameters defined in the configuration file for analysis of maintenance and health of the computing node.

10. The computing node of claim **9**, wherein the threshold for when the parameters are to be sent from the node comprise trigger conditions for a sensor on the node.

11. The computing node of claim **10**, wherein the trigger conditions comprise a rate of change of sensor outputs or a comparison with a predetermined value.

12. The computing node of claim **10**, the baseboard management controller further configured to perform operations comprising:

receiving, from the policy command service, an updated configuration file defining updates to the parameters to be monitored at the computing node; and

sending the updated configuration file to the controller communicatively coupled to the computing node.

13. The computing node of claim **9**, the baseboard management controller configured to perform operations comprising:

receiving, from the policy command service, an updated configuration file defining updates to the parameters to be monitored at the computing node; and

configuring, while the computing node is operational in the distributed computing system, the baseboard management controller to monitor the computing node in accordance with the updated configuration file.

14. The computing node of claim **9**, wherein the baseboard management controller is configured to communicate directly to the distributed computing system via a network interface.

15. The computing node of claim **9**, wherein baseboard management controller is communicatively coupled to a plurality of sensors on the computing node, and the parameters are collected by the baseboard management controller from communicatively coupled sensors.

16. A baseboard management controller configured to perform operations comprising:

receiving, from a policy command service executing in a control plane of a distributed computing system, a configuration file defining parameters to be monitored at a computing node communicatively coupled to the baseboard management controller, a timing factor indicating when the parameters are to be monitored, and a threshold for when the parameters are to be sent from the computing node;

based on the configuration file, configuring, while the computing node is operational in the distributed computing system, the baseboard management controller to monitor the computing node in accordance with the configuration file, and further to copy content of the configuration file to a shared memory, and spawn worker threads to upload content of the configuration file from the shared memory and monitor the computing node according to the configuration file; and

sending, by the baseboard management controller to a storage at the distributed computing system, the parameters defined in the configuration file for analysis of maintenance and health of the computing node.

17. The baseboard management controller of claim **16**, wherein the threshold for when the parameters are to be sent from the node comprise trigger conditions for a sensor on the node.

18. The baseboard management controller of claim **17**, wherein the trigger conditions comprise a rate of change of sensor outputs or a comparison with a predetermined value.

19. The baseboard management controller of claim **18**, wherein the operations further comprise:

receiving, from the policy command service, an updated configuration file defining updates to the parameters to be monitored; and

configuring, while the baseboard management controller is operational, the baseboard management controller to monitor the computing node in accordance with the updated configuration file.

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