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(54) **SYSTEMS AND METHODS FOR SCHEDULED POLICY DEPLOYMENT IN OPERATIONAL TECHNOLOGY NETWORKS**

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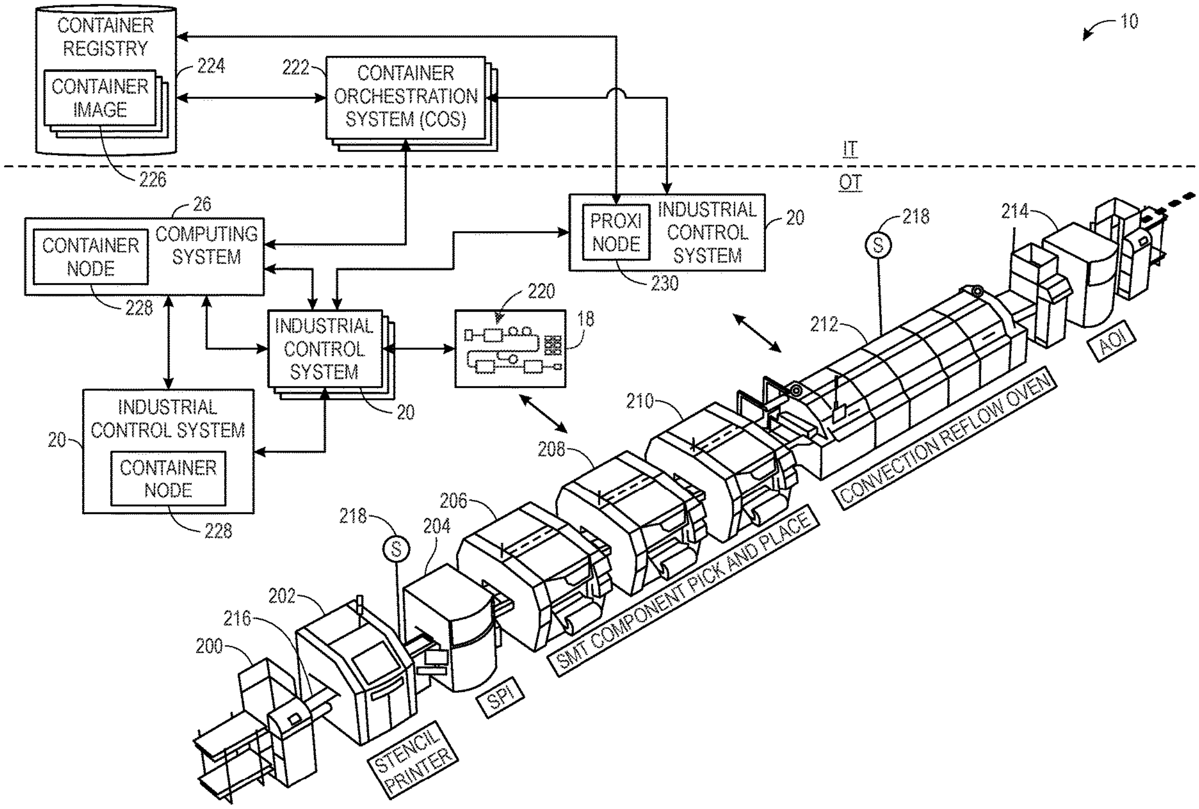
(57) **ABSTRACT**

An OT device includes a processor and a memory, accessible by the processor. The memory stores a first policy that includes a first set of settings associated with operation of the OT device. The memory also stores instructions that, when executed by the processor, cause the processor to enforce the first policy, receive a second policy and an indication of a trigger, wherein the second policy comprises a second set of settings associated with the operation of the OT device, receive an indication that the trigger is enabled, determine that the trigger is true, and, in response to the receiving the indication that the trigger is enabled and the determining that the trigger is true, enforce the second policy.



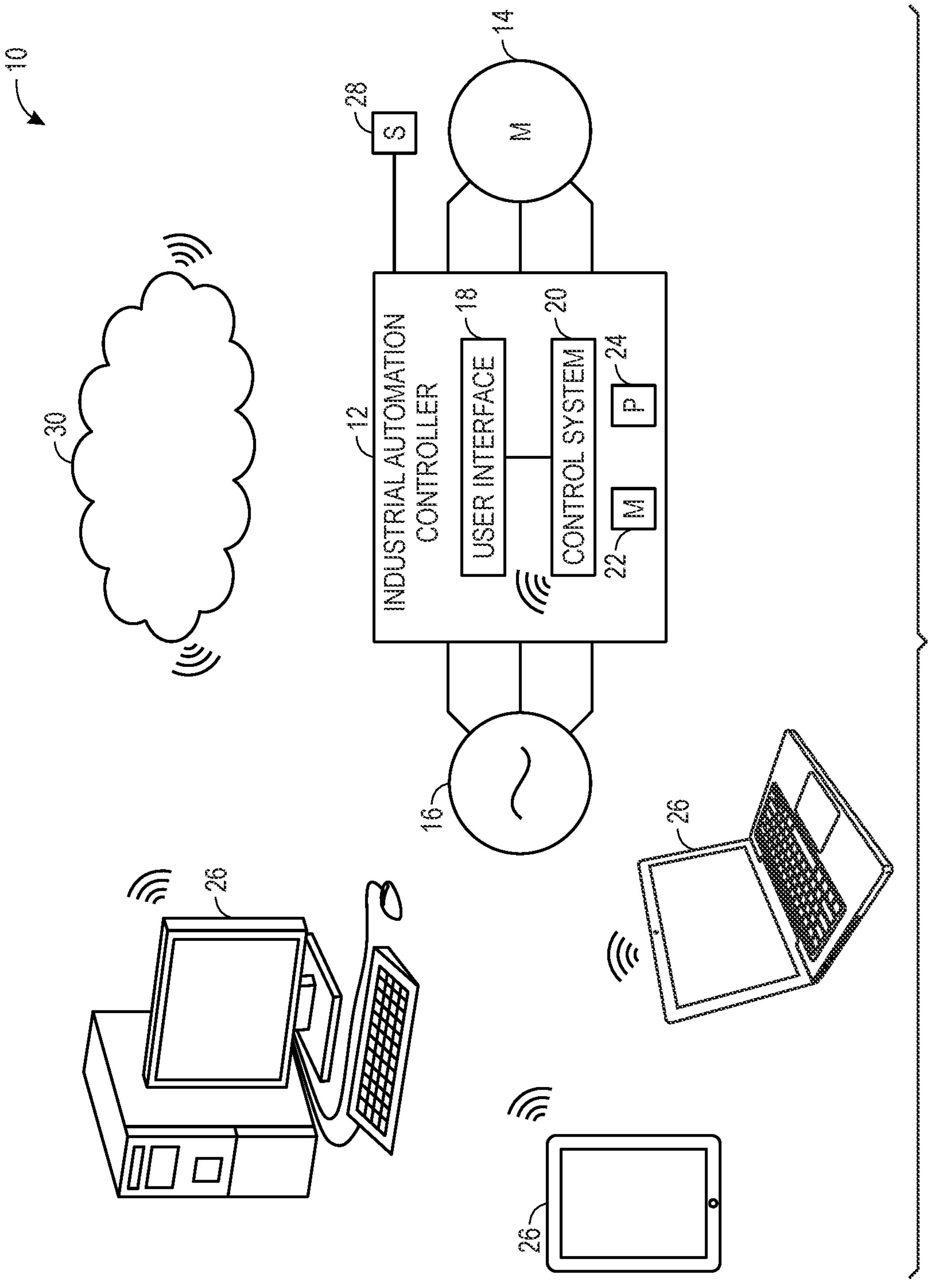

10
30
12
INDUSTRIAL AUTOMATION CONTROLLER
18
USER INTERFACE
20
CONTROL SYSTEM
22
M
24
P
28
S
14
M
16
26
26
26

FIG. 1

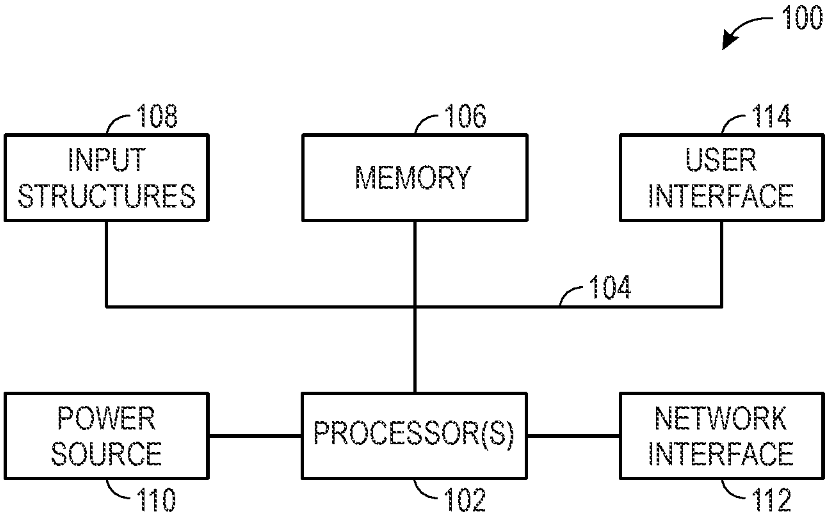

100
108
INPUT STRUCTURES
106
MEMORY
114
USER INTERFACE
104
POWER SOURCE
110
PROCESSOR(S)
102
NETWORK INTERFACE
112

FIG. 2

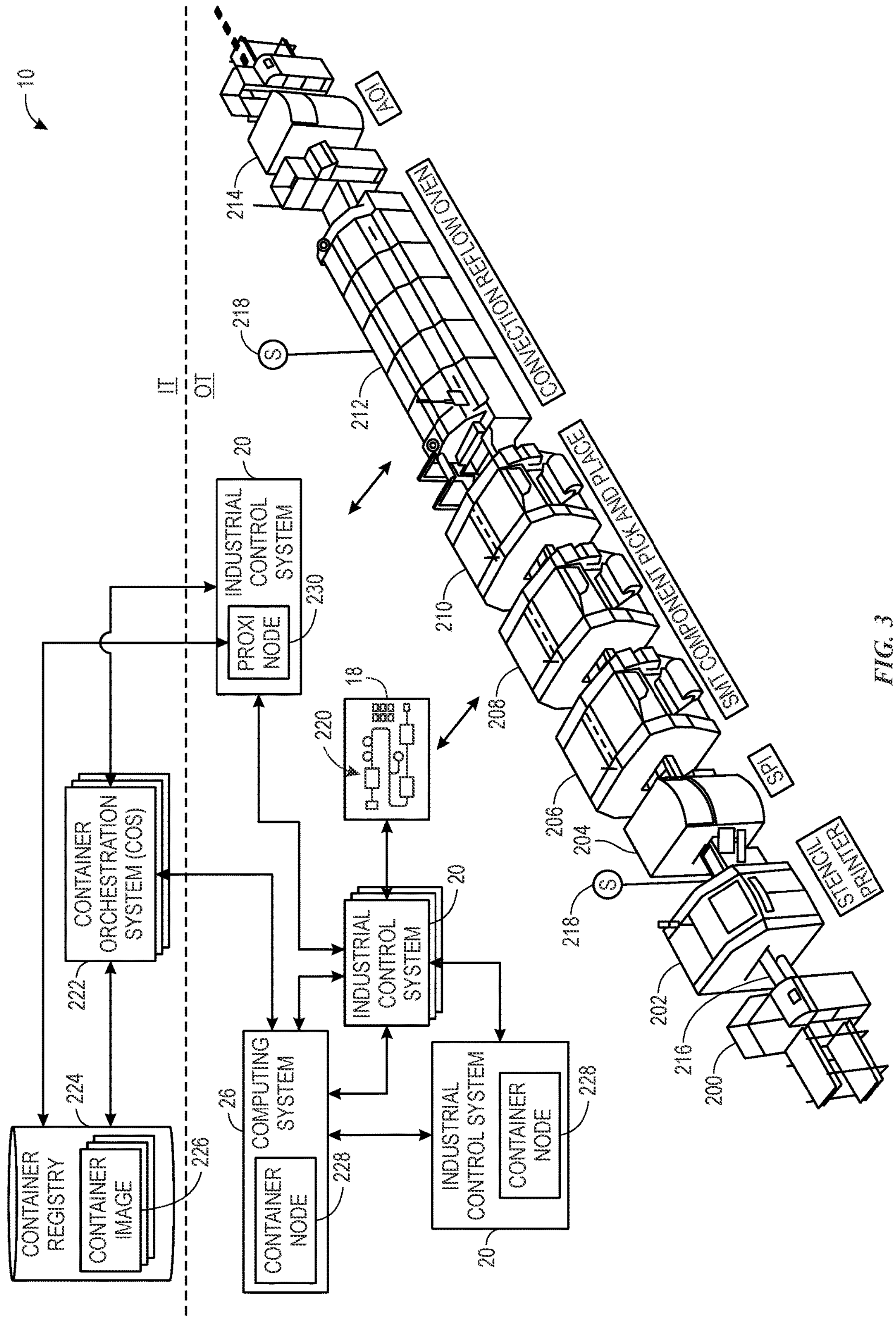

10
IT
OT
CONTAINER REGISTRY
CONTAINER IMAGE
224
226
CONTAINER ORCHESTRATION SYSTEM (COS)
222
COMPUTING SYSTEM
CONTAINER NODE
26
228
INDUSTRIAL CONTROL SYSTEM
PROXI NODE
230
20
INDUSTRIAL CONTROL SYSTEM
20
INDUSTRIAL CONTROL SYSTEM
CONTAINER NODE
228
20
18
220
AOI
214
CONNECTION REFLOW OVEN
218
S
212
SMT COMPONENT PICK AND PLACE
210
208
206
SPI
204
S
218
STENCIL PRINTER
202
216
200

FIG. 3

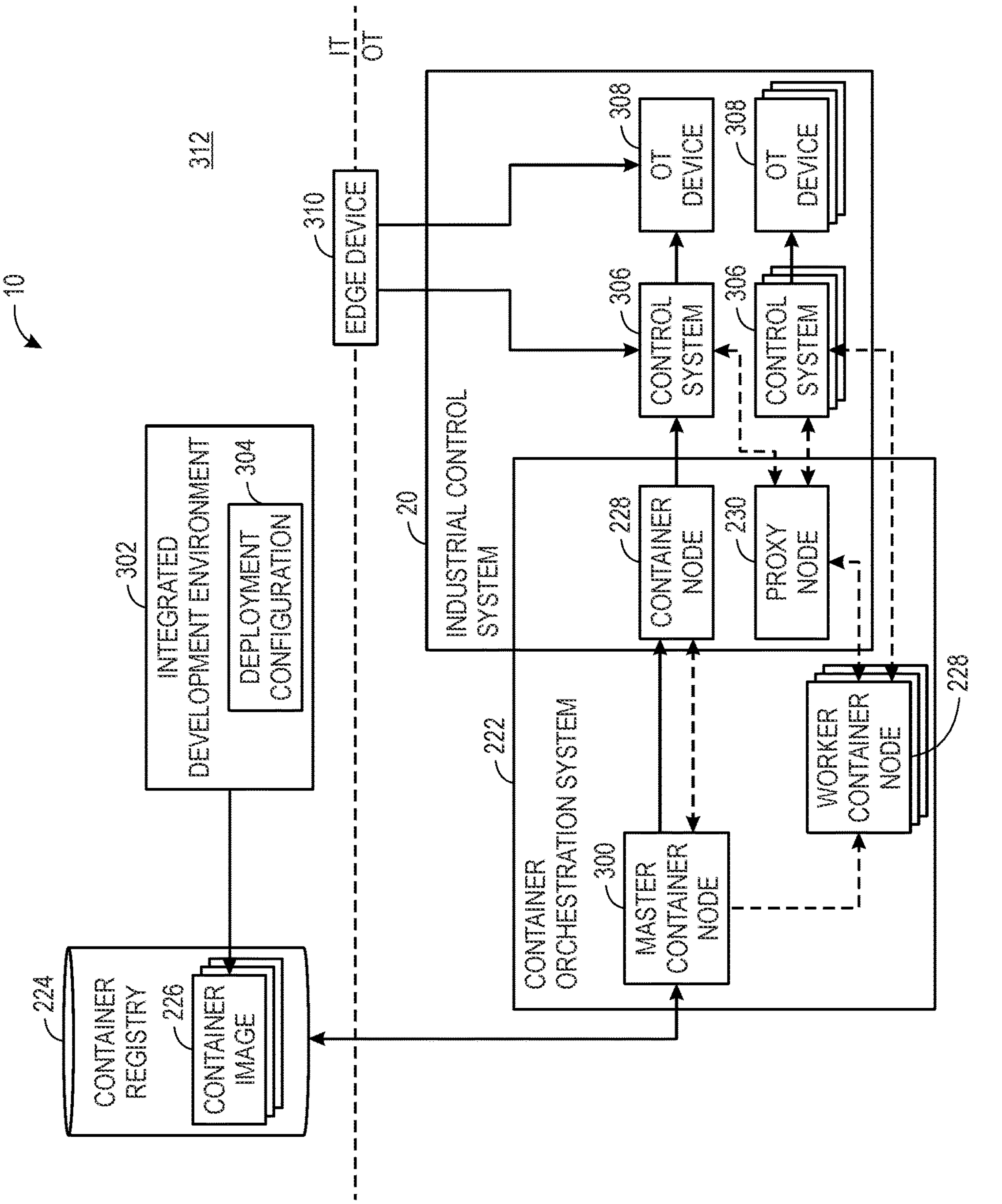

10
312
IT
OT
310
EDGE DEVICE
302
INTEGRATED DEVELOPMENT ENVIRONMENT
304
DEPLOYMENT CONFIGURATION
224
CONTAINER REGISTRY
226
CONTAINER IMAGE
20
INDUSTRIAL CONTROL SYSTEM
306
CONTROL SYSTEM
306
CONTROL SYSTEM
308
OT DEVICE
308
OT DEVICE
228
CONTAINER NODE
230
PROXY NODE
222
CONTAINER ORCHESTRATION SYSTEM
300
MASTER CONTAINER NODE
228
WORKER CONTAINER NODE

FIG. 4

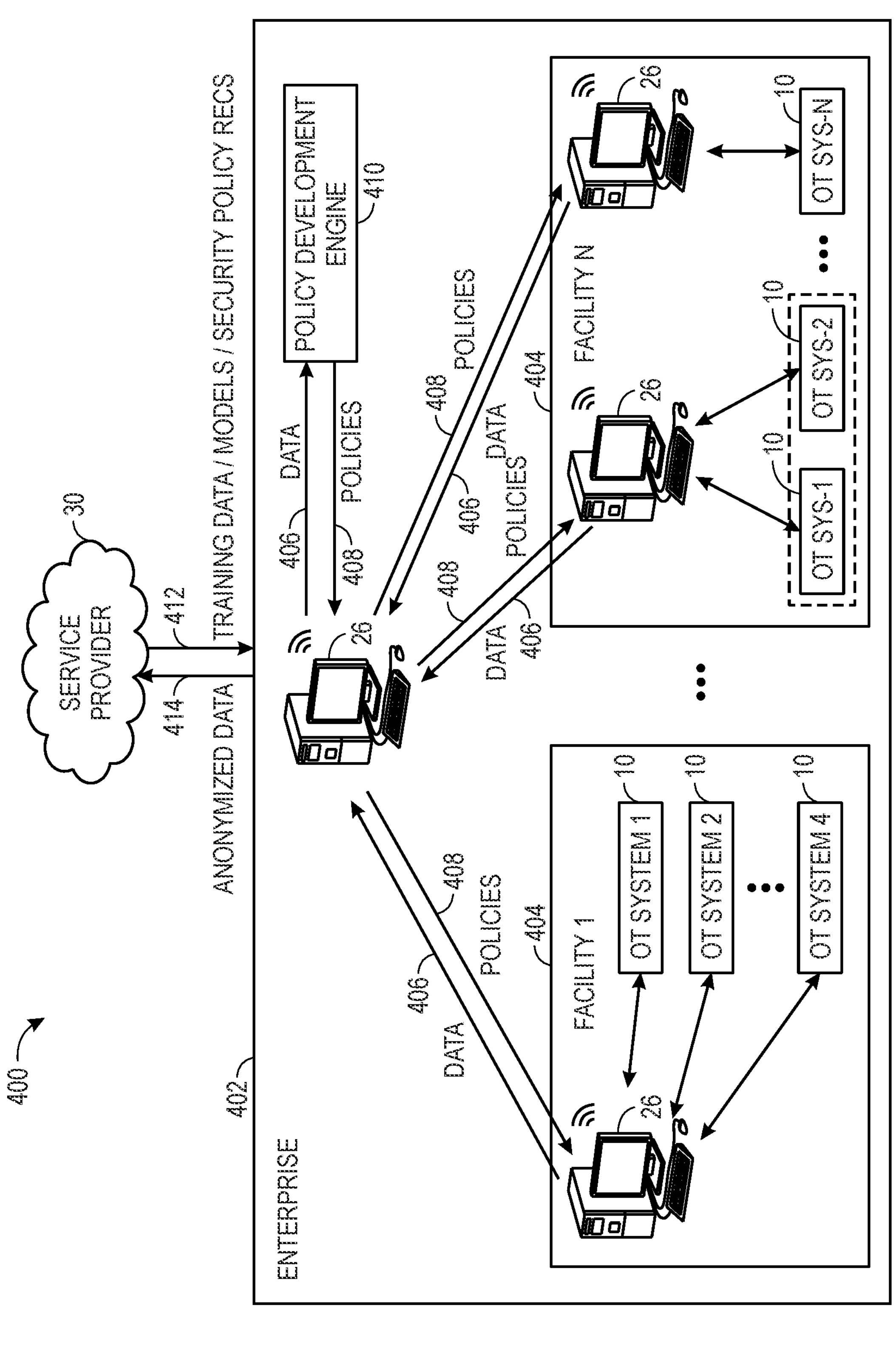

400
SERVICE PROVIDER
30
412
414
TRAINING DATA / MODELS / SECURITY POLICY RECS
ANONYMIZED DATA
402
ENTERPRISE
POLICY DEVELOPMENT ENGINE
410
26
DATA
POLICIES
406
408
FACILITY 1
404
OT SYSTEM 1
OT SYSTEM 2
OT SYSTEM 4
10
FACILITY N
OT SYS-1
OT SYS-2
OT SYS-N

FIG. 5

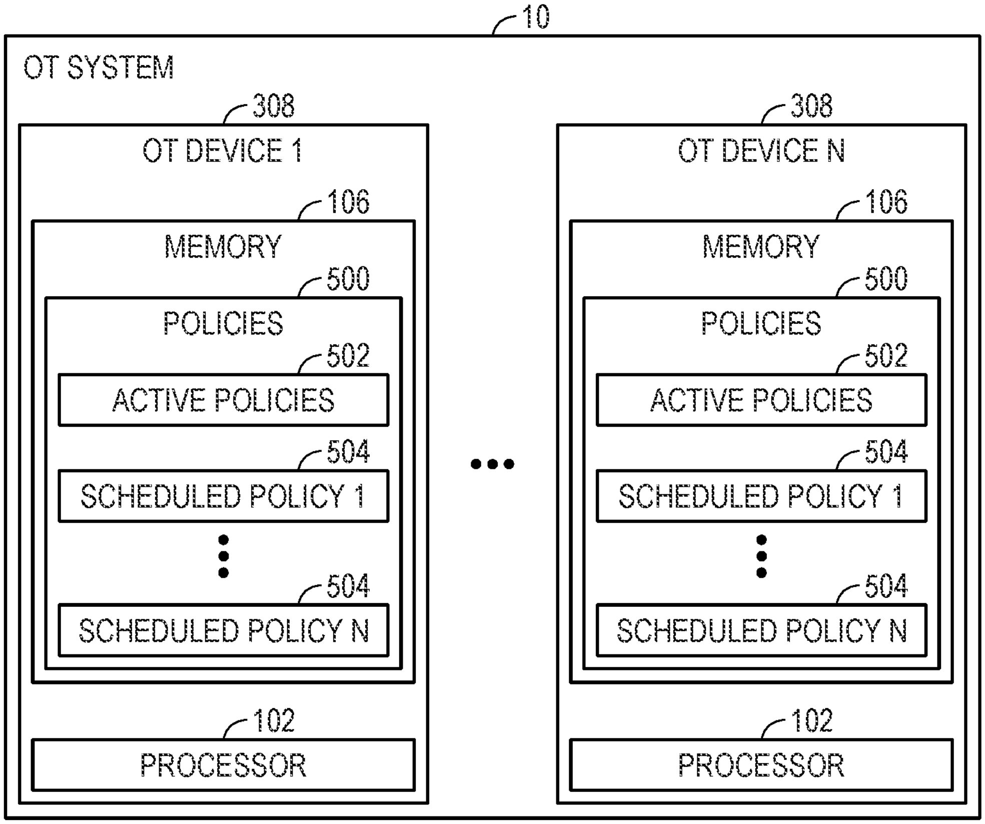

10
OT SYSTEM
308
OT DEVICE 1
106
MEMORY
500
POLICIES
502
ACTIVE POLICIES
504
SCHEDULED POLICY 1
504
SCHEDULED POLICY N
102
PROCESSOR
308
OT DEVICE N
106
MEMORY
500
POLICIES
502
ACTIVE POLICIES
504
SCHEDULED POLICY 1
504
SCHEDULED POLICY N
102
PROCESSOR

FIG. 6

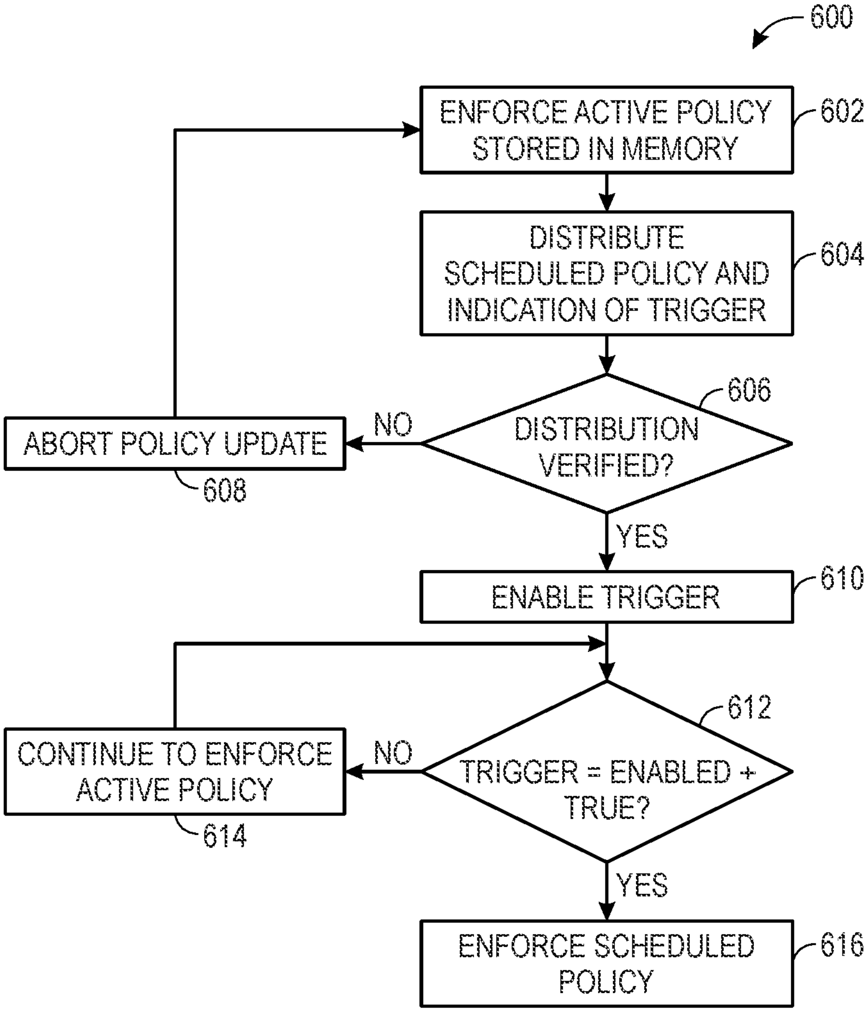

600
ENFORCE ACTIVE POLICY STORED IN MEMORY
602
DISTRIBUTE SCHEDULED POLICY AND INDICATION OF TRIGGER
604
DISTRIBUTION VERIFIED?
606
NO
ABORT POLICY UPDATE
608
YES
ENABLE TRIGGER
610
TRIGGER = ENABLED + TRUE?
612
NO
CONTINUE TO ENFORCE ACTIVE POLICY
614
YES
ENFORCE SCHEDULED POLICY
616

FIG. 7

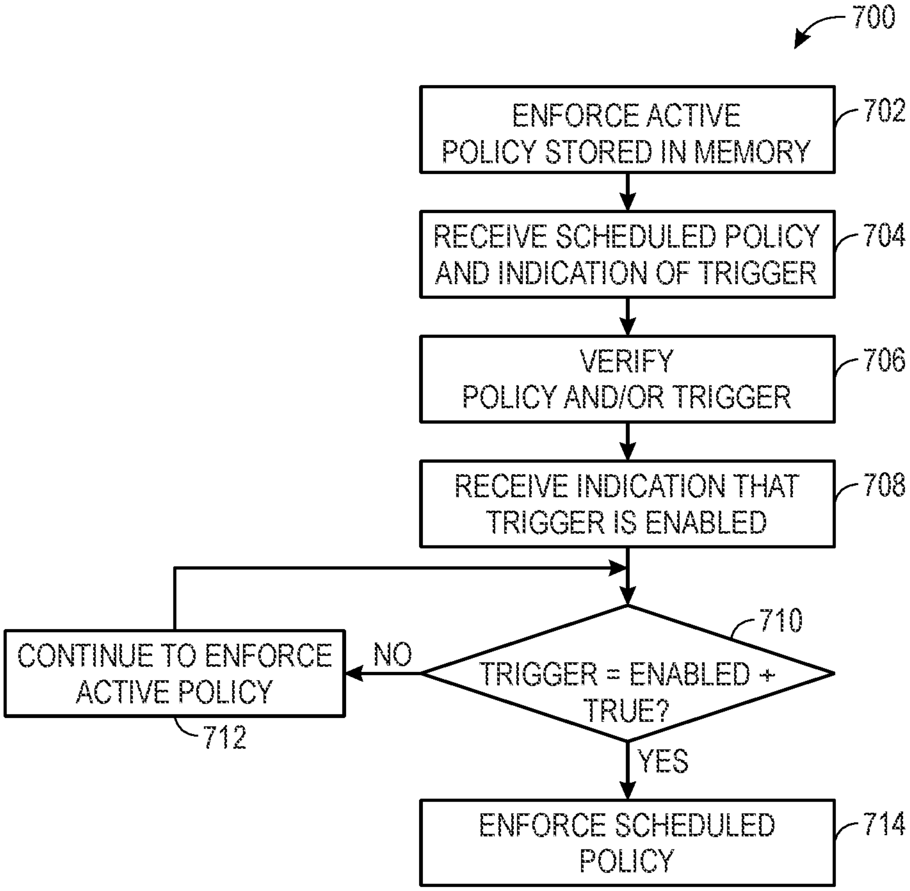

700
ENFORCE ACTIVE POLICY STORED IN MEMORY
702
RECEIVE SCHEDULED POLICY AND INDICATION OF TRIGGER
704
VERIFY POLICY AND/OR TRIGGER
706
RECEIVE INDICATION THAT TRIGGER IS ENABLED
708
TRIGGER = ENABLED + TRUE?
710
NO
CONTINUE TO ENFORCE ACTIVE POLICY
712
YES
ENFORCE SCHEDULED POLICY
714

FIG. 8

SYSTEMS AND METHODS FOR SCHEDULED POLICY DEPLOYMENT IN OPERATIONAL TECHNOLOGY NETWORKS

BACKGROUND

[0001] The present disclosure generally relates to tools for deploying policies in operational technology (OT) networks.

[0002] Industrial automation systems may be used to provide automated control of one or more actuators in an industrial setting. OT networks may be used to communicatively couple industrial automation systems and/or industrial automation components within an industrial automation system. Policies may dictate access to and operation of OT assets within the OT network. When new policies are deployed, network communication lags, processing delays, devices being out of synchronization, and so forth may cause new policies to be deployed at different times, resulting in devices in the OT network attempting to comply with or enforce different policies simultaneously. Accordingly, improved techniques for deploying new policies in OT networks are desired.

[0003] This section is intended to introduce the reader to aspects of art that may be related to various aspects of the present disclosure, which are described and/or claimed below. This discussion is believed to be helpful in providing the reader with background information to facilitate a better understanding of the various aspects of the present disclosure. Accordingly, it should be understood that these statements are to be read in this light, and not as admissions of prior art.

BRIEF DESCRIPTION

[0004] A summary of certain embodiments disclosed herein is set forth below. It should be understood that these aspects are presented merely to provide the reader with a brief summary of these certain embodiments and that these aspects are not intended to limit the scope of this disclosure. Indeed, this disclosure may encompass a variety of aspects that may not be set forth below.

[0005] In an embodiment, an OT device includes a processor and a memory, accessible by the processor. The memory stores a first policy that includes a first set of settings associated with operation of the OT device. The memory also stores instructions that, when executed by the processor, cause the processor to enforce the first policy, receive a second policy and an indication of a trigger, wherein the second policy comprises a second set of settings associated with the operation of the OT device, receive an indication that the trigger is enabled, determine that the trigger is true, and in response to the receiving the indication that the trigger is enabled and the determining that the trigger is true, enforce the second policy.

[0006] In another embodiment, an edge device is configured to be disposed within an OT network and includes a processor and a memory. The memory stores a policy that includes a set of settings associated with operation of one or more OT devices within the OT network, as well as an indication of a trigger for implementing the policy. The memory also stores instructions that, when executed by the processor, cause the processor to transmit, to a first OT device of the one or more OT devices within the OT network, the policy and the indication of the trigger, receive, from the first OT device, verification of the policy and the indication of the trigger, and transmit, to the first OT device, an indication that the trigger is enabled, wherein the OT device is configured to begin enforcing the policy in response to the receiving the indication that the trigger is enabled and a determination that the trigger is true.

[0007] In a further embodiment, a method includes receiving first data associated with first event, identifying a first action in response to the first event based on a first policy, wherein the first policy comprises a first set of settings associated with operation of an operation technology (OT) device, performing the identified first action, receiving a second policy and an indication of a trigger, wherein the second policy includes a second set of settings associated with the operation of the OT device, verifying the second policy, wherein verifying the second policy comprises confirming receipt of the second policy and the indication of the trigger, determining that the OT device is capable of enforcing the second policy, or verifying an authenticity of the second policy, or any combination thereof, transmitting a message indicating that the second policy has been verified, receiving an indication that the trigger is enabled, determining that the trigger condition is true, and in response to the receiving the indication that the trigger is enabled and the determining that the trigger condition is true, enforcing the second policy. Enforcing the second policy includes receiving second data associated with a second event, identifying a second action in response to the second event based on the second policy, and performing the identified second action.

[0008] Various refinements of the features noted above may exist in relation to various aspects of the present disclosure. Further features may also be incorporated in these various aspects as well. These refinements and additional features may exist individually or in any combination. For instance, various features discussed below in relation to one or more of the illustrated embodiments may be incorporated into any of the above-described aspects of the present disclosure alone or in any combination. The brief summary presented above is intended only to familiarize the reader with certain aspects and contexts of embodiments of the present disclosure without limitation to the claimed subject matter.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] These and other features, aspects, and advantages of the present embodiments will become better understood when the following detailed description is read with reference to the accompanying drawings in which like characters represent like parts throughout the drawings, wherein:

[0010] FIG. **1** is a schematic view of an industrial automation system, in accordance with embodiments presented herein;

[0011] FIG. **2** is a block diagram of example components that could be used in the industrial automation system of FIG. **1**, in accordance with embodiments presented herein;

[0012] FIG. **3** is a perspective view of an example of the industrial automation system of FIG. **1** controlled by an industrial control system, in accordance with an embodiment;

[0013] FIG. **4** is a block diagram of an example operational technology (OT) network, including the industrial control system of FIG. **3**, that coordinates with a container orchestration system, in accordance with an embodiment;

[0014] FIG. **5** is a schematic illustrating an architecture for managing policies within an enterprise, in accordance with embodiments presented herein;

[0015] FIG. **6** is a schematic of an OT system that is configured to perform a scheduled policy deployment;

[0016] FIG. **7** is a flow chart of a process for coordinating scheduled policy deployment in the OT system of FIG. **6**; and

[0017] FIG. **8** is a flow chart of a process for scheduled policy deployment from the perspective of a device in the OT system of FIG. **6**.

DETAILED DESCRIPTION

[0018] One or more specific embodiments will be described below. In an effort to provide a concise description of these embodiments, not all features of an actual implementation are described in the specification. It should be appreciated that in the development of any such actual implementation, as in any engineering or design project, numerous implementation-specific decisions must be made to achieve the developers' specific goals, such as compliance with system-related and enterprise-related constraints, which may vary from one implementation to another. Moreover, it should be appreciated that such a development effort might be complex and time consuming, but would nevertheless be a routine undertaking of design, fabrication, and manufacture for those of ordinary skill having the benefit of this disclosure.

[0019] When introducing elements of various embodiments of the present disclosure, the articles "a," "an," "the," and "said" are intended to mean that there are one or more of the elements. The terms "comprising," "including," and "having" are intended to be inclusive and mean that there may be additional elements other than the listed elements.

[0020] The present disclosure is directed to techniques for scheduled policy deployment in an operational technology (OT) network in order to reduce or eliminate an amount of time during which different devices in the OT network apply conflicting policies. Specifically, a scheduled policy and an indication of a trigger for implementing the scheduled policy may be distributed to one or more OT devices in an OT network. The OT devices may verify the received policy. Verification may include, for example, confirming receipt of the scheduled policy, determining that the OT device is capable of enforcing the policy, verifying authenticity of the scheduled policy. Further, in some embodiments, synchronization data may be transmitted to OT devices to synchronize clocks of the OT devices. Messages may be transmitted to the OT devices that the trigger is enabled. Upon determination that the trigger is enabled and that the trigger is true, the OT devices may begin enforcing the scheduled policy. The trigger may be receipt of the indication that the trigger is enabled, passage of a particular moment in time, a state or condition being detected, a network message being received (e.g., instructions to enforce the scheduled policy), or any combination thereof. Additional details with regard to scheduled policy deployment in OT devices in accordance with the techniques described above will be provided below with reference to FIGS. **1**-**8**.

[0021] By way of introduction, FIG. **1** is a schematic view of an example industrial automation system **10** in which the embodiments described herein may be implemented. As shown, the industrial automation system **10** includes a controller **12** and an actuator **14** (e.g., a motor). The industrial automation system **10** may also include, or be coupled to, a power source **16**. The power source **16** may include a generator, an external power grid, a battery, or some other source of power. The controller **12** may be a stand-alone control unit that controls multiple industrial automation components (e.g., a plurality of motors **14**), a controller **12** that controls the operation of a single automation component (e.g., motor **14**), or a subcomponent within a larger industrial automation system **10**. In the instant embodiment, the controller **12** includes a user interface **18**, such as a human machine interface (HMI), and a control system **20**, which may include a memory **22** and a processor **24**. The controller **12** may include a cabinet or some other enclosure for housing various components of the industrial automation system **10**, such as a motor starter, a disconnect switch, etc.

[0022] The control system **20** may be programmed (e.g., via computer readable code or instructions stored on the memory **22**, such as a non-transitory computer readable medium, and executable by the processor **24**) to provide signals for controlling the motor **14**. In certain embodiments, the control system **20** may be programmed according to a specific configuration desired for a particular application. For example, the control system **20** may be programmed to respond to external inputs, such as reference signals, alarms, command/status signals, etc. The external inputs may originate from one or more relays or other electronic devices. The programming of the control system **20** may be accomplished through software or firmware code that may be loaded onto the internal memory **22** of the control system **20** (e.g., via a locally or remotely located computing device **26**) or programmed via the user interface **18** of the controller **12**. The control system **20** may respond to a set of operating parameters. The settings of the various operating parameters may determine the operating characteristics of the controller **12**. For example, various operating parameters may determine the speed or torque of the motor **14** or may determine how the controller **12** responds to the various external inputs. As such, the operating parameters may be used to map control variables within the controller **12** or to control other devices communicatively coupled to the controller **12**. These variables may include, for example, speed presets, feedback types and values, computational gains and variables, algorithm adjustments, status and feedback variables, programmable logic controller (PLC) control programming, and the like.

[0023] In some embodiments, the controller **12** may be communicatively coupled to one or more sensors **28** for detecting operating temperatures, voltages, currents, pressures, flow rates, and other measurable variables associated with the industrial automation system **10**. With feedback data from the sensors **28**, the control system **20** may keep detailed track of the various conditions under which the industrial automation system **10** may be operating. For example, the feedback data may include conditions such as actual motor speed, voltage, frequency, power quality, alarm conditions, etc. In some embodiments, the feedback data may be communicated back to the computing device **26** for additional analysis.

[0024] The computing device **26** may be communicatively coupled to the controller **12** via a wired or wireless connection. The computing device **26** may receive inputs from a user defining an industrial automation project using a native application running on the computing device **26** or using a website accessible via a browser application, a software application, or the like. The user may define the industrial automation project by writing code, interacting with a visual programming interface, inputting or selecting values via a graphical user interface, or providing some other inputs. The user may use licensed software and/or subscription services to create, analyze, and otherwise develop the project. The computing device **26** may send a project to the controller **12** for execution. Execution of the industrial automation project causes the controller **12** to control components (e.g., motor **14**) within the industrial automation system **10** through performance of one or more tasks and/or processes. In some applications, the controller **12** may be communicatively positioned in a private network and/or behind a firewall, such that the controller **12** does not have communication access outside a local network and is not in communication with any devices outside the firewall, other than the computing device **26**. The controller **12** may collect feedback data during execution of the project, and the feedback data may be provided back to the computing device **26** for analysis. Feedback data may include, for example, one or more execution times, one or more alerts, one or more error messages, one or more alarm conditions, one or more temperatures, one or more pressures, one or more flow rates, one or more motor speeds, one or more voltages, one or more frequencies, and so forth. The project may be updated via the computing device **26** based on the analysis of the feedback data.

[0025] The computing device **26** may be communicatively coupled to a cloud server **30** or remote server via the internet, or some other network. In one embodiment, the cloud server **30** may be operated by the manufacturer of the controller **12**, a software provider, a seller of the controller **12**, a service provider, operator of the controller **12**, owner of the controller **12**, etc. The cloud server **30** may be used to help customers create and/or modify projects, to help troubleshoot any problems that may arise with the controller **12**, develop policies, or to provide other services (e.g., project analysis, enabling, restricting capabilities of the controller **12**, data analysis, controller firmware updates, etc.). The remote/cloud server **30** may be one or more servers operated by the manufacturer, software provider, seller, service provider, operator, or owner of the controller **12**. The remote/cloud server **30** may be disposed at a facility owned and/or operated by the manufacturer, software provider, seller, service provider, operator, or owner of the controller **12**. In other embodiments, the remote/cloud server **30** may be disposed in a datacenter in which the manufacturer, software provider, seller, service provider, operator, or owner of the controller **12** owns or rents server space. In further embodiments, the remote/cloud server **30** may include multiple servers operating in one or more data center to provide a cloud computing environment.

[0026] FIG. **2** illustrates a block diagram of example components of a computing device **100** that could be used as the computing device **26**, the cloud/remote server **30**, the controller **12**, or some other device within the system **10** shown in FIG. **1**. As used herein, a computing device **100** may be implemented as one or more computing systems including laptop, notebook, desktop, tablet, HMI, or workstation computers, as well as server type devices or portable, communication type devices, such as cellular telephones and/or other suitable computing devices.

[0027] As illustrated, the computing device **100** may include various hardware components, such as one or more processors **102**, one or more busses **104**, memory **106**, input structures **108**, a power source **110**, a network interface **112**, a user interface **114**, and/or other computer components useful in performing the functions described herein.

[0028] The one or more processors **102** may include, in certain implementations, microprocessors configured to execute instructions stored in the memory **106** or other accessible locations. Alternatively, the one or more processors **102** may be implemented as application-specific integrated circuits (ASICs), field-programmable gate arrays (FPGAs), and/or other devices designed to perform functions discussed herein in a dedicated manner. As will be appreciated, multiple processors **102** or processing components may be used to perform functions discussed herein in a distributed or parallel manner.

[0029] The memory **106** may encompass any tangible, non-transitory medium for storing data or executable routines. Although shown for convenience as a single block in FIG. **2**, the memory **106** may encompass various discrete media in the same or different physical locations. The one or more processors **102** may access data in the memory **106** via one or more busses **104**.

[0030] The input structures **108** may allow a user to input data and/or commands to the device **100** and may include mice, touchpads, touchscreens, keyboards, controllers, and so forth. The power source **110** can be any suitable source for providing power to the various components of the computing device **100**, including line and battery power. In the depicted example, the device **100** includes a network interface **112**. Such a network interface **112** may allow communication with other devices on a network using one or more communication protocols. In the depicted example, the device **100** includes a user interface **114**, such as a display that may display images or data provided by the one or more processors **102**. The user interface **114** may include, for example, a monitor, a display, and so forth. As will be appreciated, in a real-world context a processor-based system, such as the computing device **100** of FIG. **2**, may be employed to implement some or all of the present approach, such as performing the functions of the controller, the computing device **26**, and/or the cloud/remote server **30** shown in FIG. **1**, as well as other memory-containing devices.

[0031] FIG. **3** is a perspective view of an example of the industrial automation system **10** of FIG. **1**. The industrial automation system **10** includes stations **200**, **202**, **204**, **206**, **208**, **210**, **212**, **214** having machine components and/or machines to conduct functions within an automated process, such as silicon wafer manufacturing, as is depicted. The automated process may begin at a station **200** used for loading objects, such as substrates, into the industrial automation system **10** via a conveyor section **216**. For example, objects may be transported along the conveyor section **216** to station **202** to perform a first action, such a printing solder paste to the substrate via stenciling. As objects exit from the station **202**, the objects may be transported via the conveyor section **216** to a station **204** for solder paste inspection (SPI) to inspect printer results, to a station **206**, **208**, and **210** for surface mount technology (SMT) component placement, to a station **212** for convection reflow oven to melt the solder to make electrical couplings, and finally to a station **214** for automated optical inspection (AOI) to inspect the object manufactured (e.g., the manufactured printed circuit board). After the objects proceed through the various stations, the objects may be removed from the station **214**, for example, for storage in a warehouse or for shipment. It should be understood, however, that, for other applications, the particular system, machine components, machines, stations, and/or conveyors may be different or specially adapted to the application.

[0032] For example, the industrial automation system **10** may include machinery to perform various operations in a compressor station, an oil refinery, a batch operation for making food items, chemical processing operations, brewery operations, mining operations, a mechanized assembly line, and so forth. Accordingly, the industrial automation system **10** may include a variety of operational components, such as electric motors, valves, actuators, temperature elements, pressure sensors, or a myriad of machinery or devices used for manufacturing, processing, material handling, and other applications. The industrial automation system **10** may also include electrical equipment, hydraulic equipment, compressed air equipment, steam equipment, mechanical tools, protective equipment, refrigeration equipment, power lines, hydraulic lines, steam lines, and the like. Some example types of equipment may include mixers, machine conveyors, tanks, skids, specialized original equipment manufacturer machines, and the like. In addition to the equipment described above, the industrial automation system **10** may also include motors, protection devices, switchgear, compressors, and the like. Each of these described operational components may correspond to and/or generate a variety of operational technology (OT) data regarding operation, status, sensor data, operational modes, alarm conditions, or the like, that may be desirable to output for analysis with IT data from an IT network, for storage in an IT network, for analysis with expected operation set points (e.g., thresholds), or the like.

[0033] In certain embodiments, one or more properties of the industrial automation system **10** equipment, such as the stations **200**, **202**, **204**, **206**, **208**, **210**, **212**, **214**, may be monitored and controlled by the industrial control systems **20** for regulating control variables. For example, sensing devices (e.g., sensors **218**) may monitor various properties of the industrial automation system **10** and may be used by the industrial control systems **20** at least in part in adjusting operations of the industrial automation system **10** (e.g., as part of a control loop). In some cases, the industrial automation system **10** may be associated with devices used by other equipment. For instance, scanners, gauges, valves, flow meters, and the like may be disposed on or within the industrial automation system **10**. Here, the industrial control systems **20** may receive data from the associated devices and use the data to perform their respective operations more efficiently. For example, a controller of the industrial automation system **10** associated with a motor drive may receive data regarding a temperature of a connected motor and may adjust operations of the motor drive based on the data.

[0034] The industrial control systems **20** may include or be communicatively coupled to the display/operator interface **18** (e.g., a human-machine interface (HMI)) and to devices of the industrial automation system **10**. It should be understood that any suitable number of industrial control systems **20** may be used in a particular industrial automation system **10** embodiment. The industrial control systems **20** may facilitate representing components of the industrial automation system **10** through programming objects that may be instantiated and executed to provide simulated functionality similar or identical to the actual components, as well as visualization of the components, or both, on the display/operator interface **18**. The programming objects may include code and/or instructions stored in the industrial control systems **20** and executed by processing circuitry of the industrial control systems **20**. The processing circuitry may communicate with memory circuitry to permit the storage of the component visualizations.

[0035] As illustrated, a display/operator interface **18** may be configured to depict representations **220** of the components of the industrial automation system **10**. The industrial control system **20** may use data transmitted by the sensors **218** to update visualizations of the components via changing one or more statuses, states, and/or indications of current operations of the components. These sensors **218** may be any suitable device adapted to provide information regarding process conditions. Indeed, the sensors **218** may be used in a process loop (e.g., control loop) that may be monitored and controlled by the industrial control system **20**. As such, a process loop may be activated based on process inputs (e.g., an input from the sensor **218**) or direct input from a person via the display/operator interface **18**. The person operating and/or monitoring the industrial automation system **10** may reference the display/operator interface **18** to determine various statuses, states, and/or current operations of the industrial automation system **10** and/or for a particular component. Furthermore, the person operating and/or monitoring the industrial automation system **10** may adjust to various components to start, stop, power-down, power-on, or otherwise adjust an operation of one or more components of the industrial automation system **10** through interactions with control panels or various input devices.

[0036] The industrial automation system **10** may be considered a data-rich environment with several processes and operations that each respectively generate a variety of data. For example, the industrial automation system **10** may be associated with material data (e.g., data corresponding to substrate or raw material properties or characteristics), parametric data (e.g., data corresponding to machine and/or station performance, such as during operation of the industrial automation system **10**), test results data (e.g., data corresponding to various quality control tests performed on a final or intermediate product of the industrial automation system **10**), or the like, that may be organized and sorted as OT data. In addition, sensors **218** may gather OT data indicative of one or more operations of the industrial automation system **10** or the industrial control system **20**. In this way, the OT data may be analog data or digital data indicative of measurements, statuses, alarms, or the like associated with operation of the industrial automation system **10** or the industrial control system **20**.

[0037] The industrial control systems **12** described above may operate in an OT space in which OT data is used to monitor and control OT assets, such as the equipment illustrated in the stations **200**, **202**, **204**, **206**, **208**, **210**, **212**, **214** of the industrial automation system **10** or other industrial equipment. The OT space, environment, or network generally includes direct monitoring and control operations that are coordinated by the industrial control system **20** and a corresponding OT asset. For example, a programmable logic controller (PLC) may operate in the OT network to control operations of an OT asset (e.g., drive, motor, and/or high-level controllers). The industrial control systems **20**

may be specifically programmed or configured to communicate directly with the respective OT assets.

[0038] A container orchestration system **222**, on the other hand, may operate in an information technology (IT) environment. That is, the container orchestration system **222** may include a cluster of multiple computing devices that coordinates an automatic process of managing or scheduling work of individual containers for applications within the computing devices of the cluster. In other words, the container orchestration system **222** may be used to automate various tasks at scale across multiple computing devices. By way of example, the container orchestration system **222** may automate tasks such as configuring and scheduling deployment of containers, provisioning and deploying containers, determining availability of containers, configuring applications in terms of the containers that they run in, scaling of containers to equally balance application workloads across an infrastructure, allocating resources between containers, performing load balancing, traffic routing, and service discovery of containers, performing health monitoring of containers, securing the interactions between containers, and the like. In any case, the container orchestration system **222** may use configuration files to determine a network protocol to facilitate communication between containers, a storage location to save logs, and the like. The container orchestration system **222** may also schedule deployment of containers into clusters and identify a host (e.g., node) that may be best suited for executing the container. After the host is identified, the container orchestration system **222** may manage the lifecycle of the container based on predetermined specifications.

[0039] With the foregoing in mind, it should be noted that containers refer to technology for packaging an application along with its runtime dependencies. That is, containers include applications that are decoupled from an underlying host infrastructure (e.g., operating system). By including the run time dependencies with the container, the container may perform in the same manner regardless of the host in which it is operating. In some embodiments, containers may be stored in a container registry **224** as container images **226**. The container registry **224** may be any suitable data storage or database that may be accessible to the container orchestration system **222**. The container image **226** may correspond to an executable software package that includes the tools and data employed to execute a respective application. That is, the container image **226** may include related code for operating the application, application libraries, system libraries, runtime tools, default values for various settings, and the like.

[0040] By way of example, an integrated development environment (IDE) tool may be employed by a user to create a deployment configuration file that specifies a desired state for the collection of nodes of the container orchestration system **222**. The deployment configuration file may be stored in the container registry **224** along with the respective container images **226** associated with the deployment configuration file. The deployment configuration file may include a list of different pods and a number of replicas for each pod that should be operating within the container orchestration system **222** at any given time. Each pod may correspond to a logical unit of an application, which may be associated with one or more containers. The container orchestration system **222** may coordinate the distribution and execution of the pods listed in the deployment configuration file, such that the desired state is continuously met. In some embodiments, the container orchestration system **222** may include a master node that retrieves the deployment configuration files from the container registry **224**, schedules the deployment of pods to the connected nodes, and ensures that the desired state specified in the deployment configuration file is met. For instance, if a pod stops operating on one node, the master node may receive a notification from the respective worker node that is no longer executing the pod and deploy the pod to another worker node to ensure that the desired state is present across the cluster of nodes.

[0041] As mentioned above, the container orchestration system **222** may include a cluster of computing devices, computing systems, or container nodes that may work together to achieve certain specifications or states, as designated in the respective container. In some embodiments, container nodes **228** may be integrated within industrial control systems **20** as shown in FIG. **3**. That is, container nodes **228** may be implemented by the industrial control systems **20**, such that they appear as worker nodes to the master node in the container orchestration system **222**. In this way, the master node of the container orchestration system **222** may send commands to the container nodes **228** that are also configured to perform applications and operations for the respective industrial equipment.

[0042] With this in mind, the container nodes **228** may be integrated with the industrial control systems **20**, such that they serve as passive-indirect participants, passive-direct participants, or active participants of the container orchestration system **222**. As passive-indirect participants, the container nodes **228** may respond to a subset of all of the commands that may be issued by the container orchestration system **222**. In this way, the container nodes **228** may support limited container lifecycle features, such as receiving pods, executing the pods, updating a respective filesystem to included software packages for execution by the industrial control system **20**, and reporting the status of the pods to the master node of the container orchestration system **222**. The limited features implementable by the container nodes **228** that operate in the passive-indirect mode may be limited to commands that the respective industrial control system **20** may implement using native commands that map directly to the commands received by the master node of the container orchestration system **222**. Moreover, the container node **228** operating in the passive-indirect mode of operation may not be capable to push the packages or directly control the operation of the industrial control system **20** to execute the package. Instead, the industrial control system **20** may periodically check the file system of the container node **228** and retrieve the new package at that time for execution.

[0043] As passive-direct participants, the container nodes **228** may operate as a node that is part of the cluster of nodes for the container orchestration system **222**. As such, the container node **228** may support the full container lifecycle features. That is, container node **228** operating in the passive-direct mode may unpack a container image and push the resultant package to the industrial control system **20**, such that the industrial control system **20** executes the package in response to receiving it from the container node **228**. As such, the container orchestration system **222** may have access to a worker node that may directly implement commands received from the master node onto the industrial control system **20**.

[0044] In the active participant mode, the container node **228** may include a computing module or system that hosts an operating system (e.g., Linux) that may continuously operate a container host daemon that may participate in the management of container operations. As such, the active participant container node **228** may perform any operations that the master node of the container orchestration system **222** may perform. By including a container node **228** operating in the OT space, the container orchestration system **222** is capable of extending its management operations into the OT space. That is, the container node **228** may provision devices in the OT space, serve as a proxy node **230** to provide bi-directional coordination between the IT space and the OT space, and the like. For instance, the container node **228** operating as the proxy node **230** may intercept orchestration commands and cause industrial control system **20** to implement appropriate machine control routines based on the commands. The industrial control system **20** may confirm the machine state to the proxy node **230**, which may then reply to the master node of the container orchestration system **222** on behalf of the industrial control system **20**.

[0045] Additionally, the industrial control system **20** may share an OT device tree via the proxy node **230**. As such, the proxy node **230** may provide the master node with state data, address data, descriptive metadata, versioning data, certificate data, key information, and other relevant parameters concerning the industrial control system **20**. Moreover, the proxy node **230** may issue requests targeted to other industrial control systems **20** to control other OT devices. For instance, the proxy node **230** may translate and forward commands to a target OT device using one or more OT communication protocols, may translate and receive replies from the OT devices, and the like. As such, the proxy node **230** may perform health checks, provide configuration updates, send firmware patches, execute key refreshes, and other OT operations for other OT devices.

[0046] FIG. **4** illustrates a block diagram that depicts the relative positions of the container node **228** and the proxy node **230** with respect to the container orchestration system **222**. As mentioned above, the container orchestration system **222** may include a collection of nodes that are used to achieve a desired state of one or more containers across multiple nodes. As shown in FIG. **4**, the container orchestration system **222** may include a master node **300** that may execute control plane processes for the container orchestration system **222**. The control plane processes may include the processes that enable the container orchestration system **222** to coordinate operations of the container nodes **228** to meet the desired states. As such, the master container node **300** may execute an applications programming interface (API) for the container orchestration system **222**, a scheduler component, core resource controllers, and the like. By way of example, the master container node **300** may coordinate all of the interactions between nodes of the cluster that make up the container orchestration system **222**. Indeed, the master container node **300** may be responsible for deciding the operations that will run on container nodes **228** including scheduling workloads (e.g., containerized applications), managing the workloads' lifecycle, scaling, and upgrades, managing network and storage resources for the workloads, and the like. The master container node **300** may run an API server to handle requests and status updates received from the container nodes **228**.

[0047] By way of operation, an integrated development environment (IDE) tool **302** may be used by an operator to develop a deployment configuration file **304**. As mentioned above, the deployment configuration file **304** may include details regarding the containers, the pods, constraints for operating the containers/pods, and other information that describe a desired state of the containers specified in the deployment configuration file **304**. In some embodiments, the deployment configuration file **304** may be generated in a YAML file, a JSON file, or other suitable file format that is compatible with the container orchestration system **222**. After the IDE tool **302** generates the deployment configuration file **304**, the IDE tool **302** may transmit the deployment configuration file **304** to the container registry **224**, which may store the file along with container images **226** representative of the containers stored in the deployment configuration file **304**.

[0048] In some embodiments, the master container node **300** may receive the deployment configuration file **304** via the container registry **224**, directly from the IDE tool **302**, or the like. The master container node **300** may use the deployment configuration file **304** to determine a location to gather the container images **226**, determine communication protocols to use to establish networking between container nodes **228**, determine locations for mounting storage volumes, locations to store logs for the containers, and the like.

[0049] Based on the desired state provided in the deployment configuration file **304**, the master container node **300** may deploy containers to the container host nodes **228**. That is, the master container node **300** may schedule the deployment of a container based on constraints (e.g., CPU or memory availability) provided in the deployment configuration file **304**. After the containers are operating on the container nodes **228**, the master container node **300** may manage the lifecycle of the containers to ensure that the containers specified by the deployment configuration file **304** are operating according to the specified constraints and the desired state.

[0050] Keeping the foregoing in mind, the industrial control system **20** may not use an operating system (OS) that is compatible with the container orchestration system **222**. That is, the container orchestration system **222** may be configured to operate in the IT space that involves the flow of digital information. In contrast, the industrial control system **20** may operate in the OT space that involves managing the operation of physical processes and the machinery used to perform those processes. For example, the OT space may involve communications that are formatted according to OT communication protocols, such as FactoryTalk LiveData, EtherNet/IP. Common Industrial Protocol (CIP), OPC Direct Access (e.g., machine to machine communication protocol for industrial automation developed by the OPC Foundation), OPC Unified Architecture (OPCUA), or any suitable OT communication protocol (e.g. DNP3, Modbus, Profibus, LonWorks, DALI, BACnet, KNX, EnOcean). Because the industrial control systems **20** operate in the OT space, the industrial control systems may not be capable of implementing commands received via the container orchestration system **222**.

[0051] In certain embodiments, the container node **228** may be programmed or implemented in the industrial control system **20** to serve as a node agent that can register the industrial control system **20** with the master container node **300**. The node agent may or may not be the same as the proxy node **230** shown in FIG. **3**. For example, the industrial control system **20** may include a PLC that cannot support an operating system (e.g., Linux) for receiving and/or implementing requested operations issued by the container orchestration system **222**. However, the PLC may perform certain operations that may be mapped to certain container events. As such, the container node **228** may include software and/or hardware components that may map certain events or commands received from the master container node **300** into actions that may be performed by the PLC. After converting the received command into a command interpretable by the PLC, the container node **228** may forward the mapped command to the PLC that may implement the mapped command. As such, the container node **228** may operate as part of the cluster of nodes that make up the container orchestration system **222**, while a first control system **306** (e.g., PLC) that coordinates the OT operations for a second OT device **308** in the industrial control system **12**. The first control system **306** may include a controller, such as a PLC, an HLC, a programmable automation controller (PAC), or any other controller that may monitor, control, and operate an industrial automation device or component.

[0052] The OT device **308** may correspond to an industrial automation device or component. The OT device **308** may include any suitable industrial device that operates in the OT space. As such, the OT device **308** may be involved in adjusting physical processes being implemented via the industrial system **10**. In some embodiments, the OT device **308** may include motor control centers, motors, HMIs, operator interfaces, contactors, starters, sensors, drives, relays, protection devices, switchgear, compressors, network switches (e.g., Ethernet switches, modular-managed, fixed-managed, service-router, industrial, unmanaged, etc.) and the like. In addition, the OT device **308** may also be related to various industrial equipment such as mixers, machine conveyors, tanks, skids, specialized original equipment manufacturer machines, and the like. The OT device **308** may also be associated with devices used by the equipment such as scanners, gauges, valves, flow meters, and the like.

[0053] In the present embodiments described herein, the control system **306** may thus perform actions based on commands received from the container node **228**. By mapping certain container lifecycle states into appropriate corresponding actions implementable by the control system **306**, the container node **228** enables program content for the industrial control system **20** to be containerized, published to certain registries, and deployed using the master container node **300**, thereby bridging the gap between the IT-based container orchestration system **222** and the OT-based industrial control system **20**.

[0054] In some embodiments, the container node **228** may operate in an active mode, such that the container node may invoke container orchestration commands for other container nodes **228**. For example, a proxy node **230** may operate as a proxy or gateway node that is part of the container orchestration system **222**. The proxy node **230** may be implemented in a sidecar computing module that has an operating system (OS) that supports the container host daemon. In another embodiment, the proxy node **230** may be implemented directly on a core of the control system **306** that is configured (e.g., partitioned), such that the control system **306** may operate using an operating system that allows the container node **228** to execute orchestration commands and serve as part of the container orchestration system **222**. In either case, the proxy node **230** may serve as a bi-directional bridge for IT/OT orchestration that enables automation functions to be performed in IT devices based on OT data and in OT devices **308** based on IT data. For instance, the proxy node **230** may acquire OT device tree data, state data for an OT device, descriptive metadata associated with corresponding OT data, versioning data for OT devices **308**, certificate/key data for the OT device, and other relevant OT data via OT communication protocols. The proxy node **230** may then translate the OT data into IT data that may be formatted to enable the master container node **300** to extract relevant data (e.g., machine state data) to perform analysis operations and to ensure that the container orchestration system **222** and the connected control systems **306** are operating at the desired state. Based on the results of its scheduling operations, the master container node **300** may issue supervisory control commands to targeted OT devices via the proxy nodes **230**, which may translate and forward the translated commands to the respective control system **306** via the appropriate OT communication protocol.

[0055] In addition, the proxy node **230** may also perform certain supervisory operations based on its analysis of the machine state data of the respective control system **306**. As a result of its analysis, the proxy node **230** may issue commands and/or pods to other nodes that are part of the container orchestration system **222**. For example, the proxy node **230** may send instructions or pods to other worker container nodes **228** that may be part of the container orchestration system **222**. The worker container nodes **228** may corresponds to other container nodes **228** that are communicatively coupled to other control systems **306** for controlling other OT devices **308**. In this way, the proxy node **230** may translate or forward commands directly to other control systems **306** via certain OT communication protocols or indirectly via the other worker container nodes **228** associated with the other control systems **306**. In addition, the proxy node **230** may receive replies from the control systems **306** via the OT communication protocol and translate the replies, such that the nodes in the container orchestration system **222** may interpret the replies. In this way, the container orchestration system **222** may effectively perform health checks, send configuration updates, provide firmware patches, execute key refreshes, and provide other services to OT devices **308** in a coordinated fashion. That is, the proxy node **230** may enable the container orchestration system to coordinate the activities of multiple control systems **306** to achieve a collection of desired machine states for the connected OT devices **308**.

[0056] As shown in FIG. **4**, the industrial automation system **10** may include one or more edge devices **310** that deploy, enforce, and/or implement one or more policies or policy updates to one or more policy enforcement points (e.g., OT assets **306**, **308**) within the industrial automation system **10**. In some embodiments, the edge device **310** itself may act as a policy enforcement point. As used herein, an "edge device" **310** is a device within the industrial automation system **10** that controls data flow within the industrial automation system **10** (e.g., the OT network) as well as between the industrial automation system **10** (e.g., the OT network) and an IT network **312**. For example, the edge device **310** may be a router, a switch, or the like. In certain embodiments, the edge device **310** may receive a policy update (e.g., a security update) from the network **312** that may include, for example, an enterprise system, a server device, a plant management system, or the like. The enterprise system may include software and/or hardware components that support business processes, information flows, reporting, data analytics, and the like for an enterprise. The server device may include a policy server that manages communication between the components of the industrial automation system **10**. That is, the policy server may manage one or more policies that include provisions or instructions that detail how communication between the components of the industrial automation system **10** is performed. As such, the server device may implement a policy (e.g., a security update) related to centrally managing communications between the components of the industrial automation system **10**. The plant management system may include any suitable management computing system that receives data from a number of control systems (e.g., industrial control systems **20**). As such, the plant management system may track operations of one or more facilities and one or more locations. In addition, the plant management system may issue control commands to the components of the industrial automation system **10**.

[0057] A policy is a set of one or more rules or procedures that govern access and use of an organization's OT assets (e.g., industrial automation devices associated with OT machines). Characteristics of policies may include confidentiality, availability, integrity, authentication, operation, and non-repudiation of the organization's OT assets. A policy may include a set of two or more settings that identify data or information for components of the industrial automation system **10**, or endpoints thereof, that are to be trusted, information regarding which communication ports to use, and the like. As such, a policy sets forth provisions that may govern management of OT assets, access to such assets, backups of such assets, security of such assets, operation of such assets, management of data used and/or generated by such assets, and the like. For example, a policy may define provisions addressing acceptable usage of OT/IT assets, antivirus management, data backup and disaster recovery, change management, cryptography usage, data and asset classification, data retention, data support and operations, data usage, email/messaging protection policies, user identity and access management, incident response, threat protection, internet usage restrictions, mobile device policy, OT/IT network security, password and credential protocols, firmware/patch management, personnel security, physical and environmental security, malware/spyware/ransomware detection, system update schedules, wireless network access, guest access, and so forth. Accordingly, a policy may govern, for example, how to manage who has access to what OT devices, what files and/or communications should be encrypted, what ports can be used for what purposes, characteristics of passwords (e.g., number of characters, upper and lower case letters, numbers, special characters), how often users must change their passwords, how often backups are done, how long backups are retained, guidelines for accessing wireless internet, what happens when a threat occurs, processes for onboarding/offboarding users as they start and leave positions, the process that occurs when a user changes roles, maintenance procedures, and so forth.

[0058] As used herein, a "policy update" may refer to a new policy, or set of policies, to be implemented by the OT asset or enforced at one or more policy enforcement points within the industrial automation system **10**, an update to an existing policy implemented by the OT asset or enforced at the one or more policy enforcement points within the industrial automation system **10**, a new setting to be implemented by the OT asset, an update to an existing setting implemented by the OT asset, a new rule to be implemented by the OT asset, an update to an existing rule implemented by the OT asset, software (e.g., code) to be implemented by the OT asset, an update to at least a portion of software (e.g., code) implemented by the OT asset, data (e.g., configuration data) to be utilized by the software implemented by the OT asset, an update to existing data (e.g., configuration data) utilized by the software implemented by the OT asset, a new version of firmware to be implemented by the OT asset, an update to an existing version of firmware implemented by the OT asset, or the like. After receiving one or more policy updates from the network **312**, the edge device **310** may push a policy update to the components of the industrial automation system **10**, or the components of the industrial automation system **10** may pull the policy update from the edge device **310**. As described in more detail below, policy updates may be deployed (e.g., enforcement of the new policies may begin) at a scheduled time, upon receipt of a trigger message, upon some triggering event taking place, etc., or some combination thereof.

[0059] Policies may be developed and implemented based on design artifacts of the industrial automation system **10** and/or information about the architecture of the industrial automation system **10** and how the industrial automation system **10** is intended to operate (e.g., product being produced, industry, location, anticipated operating conditions, and so forth). Further, once a set of policies have been implemented and/or enforced at one or more policy enforcement points while the industrial automation system **10** is operating, data collected during the operation of the industrial automation system **10** (e.g., run-time data, help ticket data, incident data, vulnerability data, data received from one or more service providers, one or more customers, one or more partner organizations, one or more suppliers, and so forth) may be used to generate recommended updates to the current set of implemented and/or enforced policies.

[0060] FIG. **5** illustrates a schematic of an architecture **400** for managing policies within an enterprise **402**. As shown, the enterprise **402** may operate multiple facilities **404**, each having one or more industrial automation systems **10**, managed by one or more computing devices **26**. Operations of each facility **404** may be managed by one or more computing devices **26** that may be on premises at the facility or located remote from the facility **404**. Though not shown, in some embodiments, some facilities **404** may be further subdivided into areas having one or more industrial automation systems **10** under the control of a respective management system (e.g., a computing device **26** running control software). The industrial automation systems **10** may be disposed behind firewalls and/or within private networks defined by one or more firewalls. A single private network may encompass an entire facility **404**, an area of a facility **404** that includes one or more industrial automation systems **10**, or individual industrial automation systems **10** within a facility **404**, or spanning multiple facilities **404**. One or more computing devices **26** disposed throughout the enterprise **402**, may run software for managing operations of the enterprise **402**.

[0061] For example, a user may utilize a policy management tool to manage policies for the entire enterprise **402**. That is, the policy management tool may be utilized to create new policies, edit existing policies, remove existing policies, activate policies, schedule policy activation, deactivate policies, deploy specific policies to specific facilities **404**, areas, industrial automation systems **10**, and/or devices operated by the enterprise, and/or make adjustments to how policies are enforced throughout the enterprise **402**. In some embodiments, policies may only be managed downstream of where the policy management tool is instantiated. For example, a user accessing the policy management tool may be able to manage policies for the entire enterprise **402**, whereas a user accessing the policy management tool at Facility **1** may be able to manage policies within Facility **1**, but may not be authorized to manage policies for Facility N. Similarly, a user accessing the policy management tool via Facility N may only be able to manage policies for the industrial automation systems **10** that are within the facility **404** (e.g., OT SYS-**1** and OT SYS-**2**, but not OT SYS-N). However, in other embodiments, authority to manage policies within an enterprise **402** may be determined based on other factors, such as authority granted to specific users or user profiles, the type of policies to be managed, components affected by changes, etc.

[0062] Computing devices **26** within the enterprise **402** that run the policy management tool may act as enforcement points for policies or otherwise facilitate enforcement of policies within the enterprise **402**. For example, if a user makes a modification to a policy, the modification is reflected in the other instantiations of the policy management tool throughout the enterprise **402** such that Facility **1** may make sure that the policy is enforced as modified by the industrial automation systems **10** within the facility **404**. However, it should be understood that computing devices **26** running the policy management tool may not be the only enforcement points within an enterprise **402**. Indeed, other devices, such as edge devices, firewalls, controllers, and even industrial automation systems **10** themselves may act as policy enforcement points.

[0063] The policy management tool may also be used to analyze collected data to develop new policies and/or modifications to existing policies. In some embodiments, the collected data may be discovery data and/or network topology data that may be analyzed to determine characteristics of the OT network and, in some embodiments, generate visualizations (e.g., network maps) of the OT network. Specifically, characteristic information (e.g., IP addresses, MAC addresses, serial numbers, etc.) may be used to identify and/or characterize components that appear in data until a topology (e.g., map) of the whole OT network can be generated. In such embodiments, the data may include a manufacturer name, a product name, a model name, a model number, a serial number, a firmware version, a software version, a port status, captured network traffic, Common Industrial Protocol (CIP) discovery data, link layer discovery protocol (LLDP) data, network traffic data, Open Platform Communications Unified Architecture (OPC-UA) data, and so forth. Data **406** may also be collected from the industrial automation systems **10** in a facility **404** during operation. The collected data may include, for example, design artifacts, help ticket data, incident data, vulnerability data, network traffic data, captured network traffic (e.g., data packets), device logs, data received from one or more service providers, notes provided by an operator, software/firmware update data, warning data, error code data, operational data, temperature data, pressure data, speed/rotation data, quality control data, and so forth. Design artifacts and/or operational data **406** may be aggregated and used to generate recommended policies **408** or modifications to existing policies (e.g., via a policy development engine **410**). The recommended policies **408** are implemented and/or enforced (e.g., via one or more policy enforcement points) within the enterprise **402** and/or distributed to the facilities **404** or particular industrial automation systems **10** within the enterprise **402**. Once policies **408**, or updates to policies, have been implemented and/or enforced, new data **406** may be collected and used to retrain and/or refine the policy development, or to evaluate revised policies **408**.

[0064] Though the embodiment shown in FIG. **5** uses the computing device **26** at the enterprise level to aggregate data **406**, interface with or run the policy development engine **410**, and implement, enforce, and/or disseminate policies **408**, it should be understood that embodiments are envisaged in which computing devices at the facility, system, or device level performs these functions. That is, aggregating data **406**, running the policy development engine **410**, and implementing/enforcing policies **408** may be performed at various levels of an enterprise's structure (e.g., the device level, the system level, the facility level, the enterprise level, one or more intermediate levels, or distributed among multiple levels).

[0065] In some embodiments, the policy development engine **410** may be run on an edge device in an OT network. In such embodiments, the edge device may receive design artifacts and/or run-time data **406** from one or more devices on an OT network, input the received data to a policy development engine **410** running on the edge device, and generate a set of recommended policies, which may be automatically implemented/enforced, presented to a user for approval, presented to a user for consideration, or some combination thereof, via the policy management tool. The policy development engine **410** may run on a processor of the edge device within an operating system, or the policy development engine **410** may run in a container that is managed by the container orchestration system **222** of FIGS. **3** and **4** (e.g., Docker, KUBERNETES®) instead of, or in addition to, the edge device. As previously described, the container orchestration system may operate in an IT environment and may include a cluster of multiple computing devices that coordinates an automatic process of managing or scheduling work of individual containers (e.g., operating system level virtualization) for applications within the computing devices of the cluster. In other words, the container orchestration system may be used to automate various tasks at scale across multiple computing devices.

[0066] In some embodiments, the enterprise **402** may purchase or subscribe to services **412**, such as machine learning models, training data for training machine learning models, and/or recommended policies to the enterprise **402**, provided by a service provider **30**. In some embodiments, the enterprise may collect data **414** to transmit to the service provider **30** that provides some information about the effectiveness of the policies deployed within the enterprise **402**. Accordingly, the service provider **30** may use data **414**

collected from one or more customer enterprises **402** to improve machine learning models and/or the training data provided to the enterprises **402**. Customers may choose to opt in or opt out of providing data **414** to the service provider **30**. In some cases, because enterprises may be hesitant to share data, data may be anonymized, masked, pseudonymized, generalized, or otherwise scrubbed before being transmitted to the service provider. For example, characteristic data elements (e.g., names, addresses, IP addressed, MAC addresses, phone numbers, network names, passwords, employee names, employee numbers, employee information, etc.) within the data **414** may be identified and removed and/or changed before being transmitted. Further, data elements related to industrial processes, settings of the industrial automation systems, set points, trade secrets, intellectual property, or other proprietary information may be identified and removed or changed before being transmitted. Further, the service provider **30** may take additional steps to secure the data received by the enterprise **402**, such as using a secure communication channel, encrypting data for transmission, encrypting data for storage, and so forth.

[0067] As OT systems **10** become more connected and complex, policy management may become more dynamic, resulting in more frequent changes to policies. For example, as shown in FIG. **5**, an enterprise **402** may use a service provider **30** to provide suggestions **412** for how to improve its operations and/or run more efficiently, notifications about possible security vulnerabilities for the enterprise, and so forth. Further, software updates, firmware updates, new hardware, changes to industry standards, changes to laws/regulations, etc. may lead an enterprise to implement new policies or modify existing policies frequently to better fit the changing environment. However, given the size and complexity of modern OT systems **10**, policy updates may be received, processed, and implemented by different devices within a network at different times, resulting different devices within a network attempting to implement different policies at the same time. For example, if a policy is deployed stipulating that all transmitted data is to be encrypted, a first device may receive and implement the policy faster than a second device such that at a given moment in time the first device may transmit encrypted data while the second device transmit unencrypted data, resulting in problems for a third device interpreting encrypted data from the first device and unencrypted data from the second device. Such transition periods in which devices on the network are enforcing or adhering to different/conflicting policies may result in network vulnerabilities, down time, and/or outages while all of the devices on the network receive and implement the policy update.

[0068] Accordingly, the present techniques are directed to scheduled deployment of policies within an OT network such that enforcement of a new policy starts at the same time across the OT network, thus reducing the transition period during which different devices in the OT network are enforcing or otherwise adhering to different and/or conflicting policies. FIG. **6** is a schematic of an OT system **10** configured to perform scheduled deployment of policies and/or policy updates. As shown, the OT system **10** includes one or more OT devices **308**. The OT devices **308** may include motor control centers, motors, HMIs, operator interfaces, contactors, starters, sensors, drives, relays, protection devices, switchgear, compressors, network switches (e.g., Ethernet switches, modular-managed, fixed-managed, service-router, industrial, unmanaged, etc.), edge devices, mixers, machine conveyors, tanks, skids, specialized original equipment manufacturer machines, scanners, gauges, valves, flow meters, and the like. Each of the OT devices **308** may include a memory **106** and a processor **102**. Though not shown, it should be understood that the OT devices **308** may include other components, such as communication circuitry (e.g., network interface), a power source, a user interface, input structures, sensors, actuators, etc.

[0069] The memory **106** of each OT device **308** may include volatile and non-volatile memory. The memory **106** may be configured to store policies **500**, which may include one or more active policies **502** and one or more scheduled policies **504**. Though not shown, the memory **106** may also store various other data, such as operational data, configuration data, synchronization data, user profile data, system data, sensor data, databases and/or database tables, routines, control programs/files, instructions defining applications, programs, algorithms, scripts, machine learning models, and so forth.

[0070] The policies **500** may be defined as a set of two or more settings that set forth how the OT device **308** is configured, how the OT device **308** operates, and/or how the OT device may be accessed. For example, policies **500** may dictate network addresses, how network addresses are assigned, allowed communication ports, allowed operational parameters, allowed configuration settings, groups of allowed settings during operation, who is allowed to access what devices, etc. Policies **500** may be defined by text, scripts, portions of code, and so forth. The policies may be written directly by a user (e.g., a control engineer), or generated based on inputs provided by a user (e.g., via a graphical user interface). In some embodiments, policies **500** may be generated on or by the OT device **308**, whereas in other embodiments, policies **500** may be generated on a different device (e.g., a computing device) and provided to the OT device **308** (e.g., as a patch or a policy update) through the IT/OT network (e.g., via a policy management tool). Accordingly, in some embodiments, policies **500** may be defined and deployed within an OT network in bulk, crosschecked at the system level, deployed, and only accessible by authorized parties. In other embodiments, policies may be defined and deployed with specific OT devices **308** in mind. For larger enterprises, policies may be defined by control engineers and then loaded onto OT devices by OT administrators.

[0071] The active policies **502** are stored in memory **106** and are the policies that are actively enforced by the OT device **308**. Accordingly, the active policies **502** may be stored in the memory **106** separate from (e.g., different partition or different memory all together) the scheduled policies **504**, or may be otherwise distinguished from the scheduled policies **504** using tags, labels, flags, and so forth. During enforcement of the active policies **502**, the OT device **308** may receive data indicative of an event to which the OT device **308** may respond. The event may be, for example, a request for access, a request for data, instructions to change configurations or settings, and so forth. The OT device **308** may receive and process the received data and then reference the active policies **502** to determine what action, if any, should be taken. For example, if the event is a request for access to the OT device **308**, the OT device may determine whether the active policies **502** authorize access to the requesting device and then allow or deny access based upon the active policies **502**.

[0072] The scheduled policies **504** are also stored in memory **106**, but are not actively enforced by the OT device **308**. As previously discussed, the scheduled policies **504** may be stored in the memory **106** separate from (e.g., different partition or different memory all together) the active policies **502**, or may be otherwise distinguished from the active policies **502** using tags, labels, flags, and so forth. As with the active policies **502**, scheduled policies **502** may be defined by text, scripts, portions of code written directly by a user (e.g., a control engineer), generated based on inputs provided by a user (e.g., via a graphical user interface), by the OT device **308**, or by a different device (e.g., a computing device) and provided to the OT device **308** (e.g., as a patch or a policy update) through the IT/OT network (e.g., via a policy management tool). As with the active policies **502**, the scheduled policies **504**, once implemented, may dictate how the OT device **308** responds to events (e.g., requests for access, requests for data, instructions to change configurations or settings, etc.) and/or received data. Accordingly, once implemented, the scheduled policy may become an active policy **502**.

[0073] The scheduled policies **504** may include both a definition of a policy, as well as information regarding implementation of the scheduled policies **504**. For example, the scheduled policies **504** may identify an implementation trigger that causes implementation of the scheduled policy **504** (e.g., the scheduled policy **504** becomes an active policy **502**). The trigger may include, for example, a time of implementation, receipt of a trigger message, a condition, a state, etc., or some combination thereof. For example, the trigger may be the completion of a batch, completion of a process, completion of a shift, entry into a stand-by mode, entry into a safe mode, entry into a maintenance/service mode, and so forth. Further, in some embodiments, the scheduled policies **504** may include or accompany synchronization data to make sure that the clocks of the devices on the OT networks are synchronized such that clocks times are consistent across the OT network. In other embodiments, the trigger may include multiple elements, such as a trigger message received or a condition or state detected after some moment in time or after some period of time has elapsed. In other embodiments, the trigger may be some period of time elapsing after a message is received or some condition or state is detected.

[0074] Though FIG. **6** shows the scheduled policies **504** being implemented by an OT device **308**, it should be understood that embodiments are envisaged in which scheduled policies **504** are implemented via OT control systems, edge devices, computing devices, containers, tablets, mobile devices, human-machine interfaces, etc. Accordingly, the embodiment shown in FIG. **6** is not intended to be limiting.

[0075] FIG. **7** is a flow chart of a process **600** for scheduled policy deployment within OT networks from the perspective of a policy distribution device (e.g., an edge device, a computing device running a policy management tool, etc.). At block **602**, the process **600** enforces one or more active policies stored in memory. Policy distribution devices may or may not enforce policies themselves. The active policies define settings, guidelines, and/or rules that define various aspects of how OT devices are to be configured and operate. Accordingly, the OT device may reference the active policies at decision points to determine how to respond to events that occur. Active policies may govern, for example, access and use of an organization's OT assets (e.g., industrial automation devices associated with OT machines). For example, the process **600** may receive data indicative of an event. The event may be anything that may trigger a response from the OT device. For example, the event may include a request for access, a request for data, instructions to change configurations or settings, and so forth. In response, the process **600** may identify an action to take in response to the event based on the one or more active policies being enforced. For example, the process **600** may receive and process the received data and then reference the active policies to determine what action, if any, should be taken. For example, if the event is a request for access to the OT device, the process **600** may determine whether the active policies authorize access to the requesting device and then allow or deny access based upon the active policies. In some embodiments, the identified action may be to take no action.

[0076] At block **604**, the process distributes a scheduled policy and an indication of a trigger to devices within the OT network. For example, the trigger may be a time of implementation (e.g., an activation timestamp), receipt of a trigger message, or a state/condition that, when detected, causes implementation of the scheduled policy. In some embodiments, if the indication of the trigger identifies a time at which to implement the policy, the indication of the trigger may include synchronization data (e.g., assignment of a central time, or a central time master to specify a reference time) in order to synchronize the clocks of the devices receiving the scheduled policy and the indication of the trigger such that the scheduled policy is implemented at the same time across the network.

[0077] At decision **606**, the process communicates with the devices to which the scheduled policy was distributed to verify receipt of the scheduled policy. In some embodiments, the devices may merely confirm that the scheduled policy was received. In other embodiments, the devices may analyze the received scheduled policy and confirm that they are capable of implementing the scheduled policy. In some embodiments, the devices may verify the authenticity of the scheduled policy (e.g., checking hash codes, keys, etc.) and/or intent to implement the scheduled policy.

[0078] If the distribution of the scheduled policy is not verified by all receiving devices, the process **600** proceeds to block **608** and aborts the policy update. In some embodiments, a notification or alert may be generated. In such cases, the process may return to block **602** and continue to enforce the existing active policies.

[0079] If the distribution of the scheduled policy is verified by all receiving devices, the process **600** proceeds to block **610** and enables the trigger. Enabling the trigger may include, for example, communicating to the devices implementing the policy that the trigger has been enabled and the policy is ready for implementation. In some embodiments, enabling the trigger may be like arming the system for deployment of the scheduled policy. Accordingly, the devices may wait until the trigger, or a trigger condition, is true to deploy the scheduled policy.

[0080] At decision **612**, the process **600** determines whether the trigger is both enabled and true. If the trigger is not both enabled and true, the process **600** proceeds to block **614** and continues to enforce the active policy. If the process

600 determines that the trigger is both enabled and true, the process **600** proceeds to block **616** and enforces the scheduled policy. In some embodiments, if the trigger is a particular time, a particular amount of time elapsing, and/or detection of some condition or state, the process **600** may wait until the particular time has arrived, the particular amount of time has elapsed, and/or the condition or state has been detected in order to enforce the scheduled policy. However, in other embodiments, the trigger may be a communication (e.g., a network message instructing the devices to implement the scheduled policy). In such embodiments, the trigger enablement message may also act as the trigger message. However, in other embodiments, the trigger message may proceed the trigger enablement message. In some embodiments, multiple triggers may be used in combination, or a trigger may involve multiple conditions.

[0081] FIG. **8** is a flow chart of a process **700** for scheduled policy deployment within OT networks from the perspective of a device receiving and implementing the policy. At block **702**, the process **700** enforces one or more active policies stored in memory. The active policies define settings, guidelines, and/or rules that define various aspects of how OT devices are to be configured and operate. Accordingly, the OT device may reference the active policies at decision points to determine how to respond to events that occur. Active policies may govern, for example, access and use of an organization's OT assets (e.g., industrial automation devices associated with OT machines). For example, the process **700** may receive data indicative of an event. The event may be anything that may trigger a response from the OT device. For example, the event may include a request for access, a request for data, instructions to change configurations or settings, and so forth. In response, the process **700** may identify an action to take in response to the event based on the one or more active policies being enforced. For example, the process **700** may receive and process the received data and then reference the active policies to determine what action, if any, should be taken. For example, if the event is a request for access to the OT device, the process **700** may determine whether the active policies authorize access to the requesting device and then allow or deny access based upon the active policies. In some embodiments, the identified action may be to take no action.

[0082] At block **704**, the process **700** receives a scheduled policy and an indication of a trigger. The scheduled policy and the indication of the trigger may be stored in memory. At block **706**, the process **700** verifies the scheduled policy and the indication of the trigger. Verification may include, for example, confirming receipt of the scheduled policy and the indication of the trigger. In other embodiments, the process **700** may analyze the received scheduled policy and/or indication of the trigger to confirm that the device is capable of implementing the scheduled policy. In some embodiments, the process **700** may verify the authenticity of the scheduled policy (e.g., by checking hash codes, keys, etc.) and/or intent to implement the scheduled policy. In some embodiments, verification may be performed in response to a request from the device(s) distributing the scheduled policy and the indication of the trigger. In other embodiments, verification may be performed in response to receiving the scheduled policy and the indication of the trigger, or without verification being prompted/requested.

[0083] A block **708**, the process **700** receives an indication that the trigger has been enabled. The indication may be a network message, a change to a tag or flag, and so forth. In some embodiments, the indication may include communication indicating that the trigger has been enabled and the policy is ready for implementation. In this way, enabling the trigger may be like arming the system for deployment of the scheduled policy. Accordingly, the devices may wait until the trigger, or a trigger condition, is true to deploy the scheduled policy.

[0084] At block **710**, the process **700** determines whether the trigger is both enabled and true. If the trigger is not both enabled and true, the process **700** proceeds to block **712** and continues to enforce the active policy. If the process **700** determines that the trigger is both enabled and true, the process **700** proceeds to block **714** and enforces the scheduled policy. As previously described, if the trigger is a particular time, a particular amount of time elapsing, and/or detection of some condition or state, the process **700** may wait until the particular time has arrived, the particular amount of time has elapsed, and/or the condition or state has been detected in order to enforce the scheduled policy. However, in other embodiments, the trigger may be a communication (e.g., a network message instructing the devices to implement the scheduled policy). In such embodiments, the trigger enablement message may also act as the trigger message. However, in other embodiments, the trigger message may proceed the trigger enablement message. In some embodiments, multiple triggers may be used in combination, or a trigger may involve multiple conditions.

[0085] The present disclosure is directed to techniques for scheduled policy deployment in an OT network in order to reduce or eliminate an amount of time during which different devices in the OT network apply conflicting policies. Specifically, a scheduled policy and an indication of a trigger for implementing the scheduled policy may be distributed to one or more OT devices in an OT network. The OT devices may verify the received policy. Verification may include, for example, confirming receipt of the scheduled policy, determining that the OT device is capable of enforcing the policy, verifying authenticity of the scheduled policy. Further, in some embodiments, synchronization data may be transmitted to OT devices to synchronize clocks of the OT devices. Messages may be transmitted to the OT devices that the trigger is enabled. Upon determination that the trigger is enabled and that the trigger is true, the OT devices may begin enforcing the scheduled policy. The trigger may be receipt of the indication that the trigger is enabled, passage of a particular moment in time, a state or condition being detected, a network message being received (e.g., instructions to enforce the scheduled policy), or any combination thereof. Technical effects of using the present techniques include reduced network vulnerabilities, down time, and/or outages that may be caused by OT devices in an OT network enforcing different/conflicting policies. Further, use of the disclosed techniques may allow for more predictable and smoother deployment of new policies within an OT network.

[0086] The specific embodiments described above have been shown by way of example, and it should be understood that these embodiments may be susceptible to various modifications and alternative forms. It should be further understood that the claims are not intended to be limited to the particular forms disclosed, but rather to cover all modifications, equivalents, and alternatives falling within the spirit and scope of this disclosure.

[0087] The techniques presented and claimed herein are referenced and applied to material objects and concrete examples of a practical nature that demonstrably improve the present technical field and, as such, are not abstract, intangible or purely theoretical. Further, if any claims appended to the end of this specification contain one or more elements designated as "means for [perform]ing [a function] . . . " or "step for [perform]ing [a function] . . . ", it is intended that such elements are to be interpreted under 35 U.S.C. 112(f). However, for any claims containing elements designated in any other manner, it is intended that such elements are not to be interpreted under 35 U.S.C. 112(f).

1. An operational technology (OT) device, comprising:

a processor; and

a memory, accessible by the processor, the memory storing:

a first policy comprising a first set of settings associated with operation of the OT device; and

instructions that, when executed by the processor, cause the processor to perform operations comprising:

enforcing the first policy;

receiving a second policy and an indication of a trigger, wherein the second policy comprises a second set of settings associated with the operation of the OT device;

receiving an indication that the trigger is enabled;

determining that the trigger is true; and

in response to the receiving the indication that the trigger is enabled and the determining that the trigger is true, enforcing the second policy.

2. The OT device of claim **1**, wherein enforcing the first policy comprises:

receiving data associated with an event;

identifying an action in response to the event based on the first policy; and

performing the identified action.

3. The OT device of claim **2**, wherein enforcing the second policy comprises:

receiving second data associated with a second event;

identifying a second action in response to the second event based on the second policy; and

performing the identified second action.

4. The OT device of claim **1**, wherein the operations comprise:

verifying the second policy, wherein verifying the second policy comprises confirming receipt of the second policy and the indication of the trigger, determining that the OT device is capable of enforcing the second policy, or verifying an authenticity of the second policy, or any combination thereof; and

transmitting a message indicating that the second policy has been verified.

5. The OT device of claim **1**, wherein the operations comprise:

receiving synchronization data; and

synchronizing a clock of the OT device based on the synchronization data.

6. The OT device of claim **1**, wherein the trigger comprises passage of a particular moment in time.

7. The OT device of claim **1**, wherein the trigger comprises a state or condition being detected.

8. The OT device of claim **1**, wherein the trigger comprises a network message being received.

9. The OT device of claim **8**, wherein the network message comprises instructions to enforce the second policy.

10. The OT device of claim **1**, wherein the trigger comprises receipt of the indication that the trigger is enabled.

11. An edge device configured to be disposed within an operational technology (OT) network, comprising:

a processor; and

a memory, accessible by the processor, the memory storing:

a policy comprising a set of settings associated with operation of one or more OT devices within the OT network;

an indication of a trigger for implementing the policy; and

instructions that, when executed by the processor, cause the processor to perform operations comprising:

transmitting, to a first OT device of the one or more OT devices within the OT network, the policy and the indication of the trigger;

receiving, from the first OT device, verification of the policy and the indication of the trigger; and

transmitting, to the first OT device, an indication that the trigger is enabled, wherein the OT device is configured to begin enforcing the policy in response to the receiving the indication that the trigger is enabled and a determination that the trigger is true.

12. The edge device of claim **11**, wherein the verification of the policy and the indication of the trigger comprises confirmation of receipt of the policy and the indication of the trigger, confirmation of a determination that the first OT device is capable of enforcing the policy, or confirmation of an authenticity of the policy, or any combination thereof.

13. The edge device of claim **11**, wherein the operations comprise transmitting, to the first OT device, synchronization data, wherein the synchronization data is configured to be used by the first OT device to synchronize a clock of the first OT device.

14. The edge device of claim **11**, wherein the trigger comprises receipt of the indication that the trigger is enabled.

15. The edge device of claim **11**, wherein the trigger comprises passage of a particular moment in time.

16. The edge device of claim **11**, wherein the trigger comprises a state or condition being detected.

17. The edge device of claim **11**, wherein the trigger comprises a network message being received.

18. A method, comprising:

receiving first data associated with first event;

identifying a first action in response to the first event based on a first policy, wherein the first policy comprises a first set of settings associated with operation of an operation technology (OT) device;

performing the identified first action;

receiving a second policy and an indication of a trigger condition, wherein the second policy comprises a second set of settings associated with the operation of the OT device;

verifying the second policy, wherein verifying the second policy comprises confirming receipt of the second policy and the indication of the trigger condition, determining that the OT device is capable of enforcing the second policy, or verifying an authenticity of the second policy, or any combination thereof;

transmitting a message indicating that the second policy has been verified;

receiving an indication that the trigger condition is enabled;

determining that the trigger condition is true; and

in response to the receiving the indication that the trigger condition is enabled and the determining that the trigger condition is true, enforcing the second policy, wherein enforcing the second policy comprises:

receiving second data associated with a second event;

identifying a second action in response to the second event based on the second policy; and

performing the identified second action.

19. The method of claim **18**, wherein the first event and the second event comprise a request for data, a request for access, a request to install software, or a request to establish a connection, or any combination thereof.

20. The method of claim **18**, wherein the trigger condition comprises receipt of the indication that the trigger condition is enabled, passage of a particular moment in time, a state or condition being detected, a network message being received, or any combination thereof.

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