Outcome Optimizing Control: **Incorporating Enterprise Data and Analytics into Traditional Control Processes**

Introduction

Traditional industrial control systems are viewed as static components and are not tied to business objectives in real-time, making it difficult for businesses to achieve optimal outcomes across a fleet, between disparate systems, or in response to changing external conditions. Many businesses realize that real improvements to profitability can only be realized by optimizing complex industrial processes at the source. Moreover, while enterprise automation and optimization software and processes are rapidly evolving, complexities like latency and security continue to be a challenge.

In Industrial Internet era, a new generation of control system is required that brings powerful analytics tools much closer to devices and equipment to greatly enhance productivity, efficiency, and security by adapting in real-time to a wide range of variables. Outcome Optimizing Control solutions are designed to offer businesses all the benefits of traditional industrial control systems but with greater flexibility, accessibility, and connectivity to leverage external data for analyzing and optimizing industrial operations.

Background

Before the 1970s, companies operating industrial processes used simple devices such as relays and interlocks to achieve a minimal degree of automation and control.

Programmable Logic Controllers (PLCs)

During the 1970s, Programmable Logic Controllers (PLCs) were developed to replace relay-based systems. While PLCs offer much greater flexibility for programming compared to relay-based systems, they were still programmed using ladder-logic to mimic the appearance of wiring diagrams used by control engineers representing physical relays and connections among them.

Programmable Automation Controllers (PACs)

In the early 2000s, GE pioneered some of the first Programmable Automation Controllers (PACs). PACs provide a single platform that operates in multiple domains such as motion, discrete and process control applications. More importantly, PACs provide a more open and modular architecture to integrate and interoperate with other devices, networks and enterprise systems.

While PACs offer a higher level of flexibility and interoperability with enterprise systems compared to PLCs, they are unable to dynamically adjust to changing business objectives and are viewed as static components, infrequently changed and heavily constrained by design spec at installation.

1. **See:** Sensors collect data that provides real-time status of the equipment under control.
2. **Think:** Controllers process sensor data and calculate real-time adjustments necessary to keep equipment within operating limits
3. **Do:** Outputs implement the adjustments ensuring the equipment is operating within specification
4. **Optimize:** Edge device utilizes controller data, external data and algorithmns created by domain experts to “recommend” optimizing adjustments to the controller

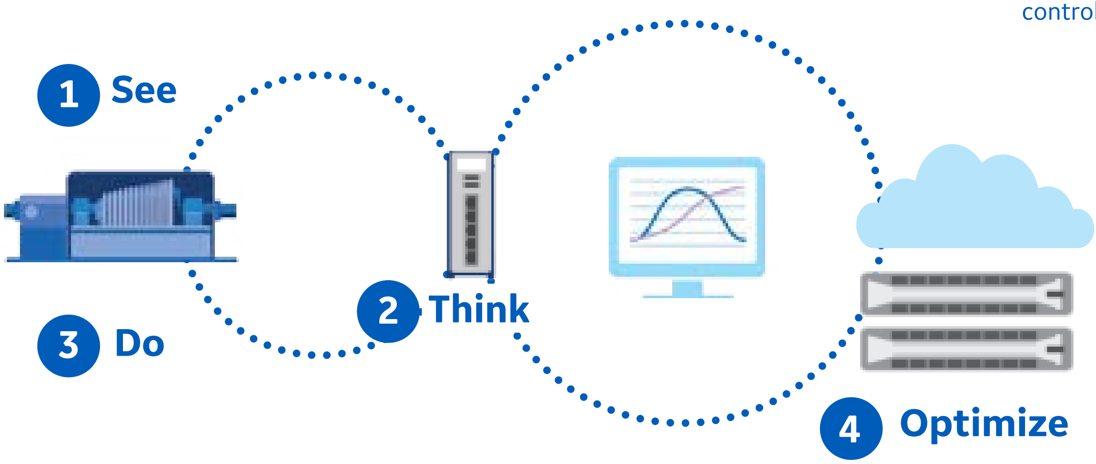


Figure 1. Outcome optimizing controllers allows the incorporation of an “outer loop”, an “advise” layer on top of the typical “see-think-do” control loop that can optimize the control application

PAC Edge: Outcome Optimizing Control

Outcome Optimizing Control (OOC) offers a generational advancement to PAC-based industrial control systems by enabling safe, secure communication between real-time deterministic control and non-deterministic applications that leverage external data to analyze and optimize business operations. OOC provides software defined controls with enhanced optimization capabilities while maintaining the stringent safety and security required in industrial applications.

OOCs utilize PAC Edge technology running on a general purpose operating system such as Linux next to the real time deterministic control to optimize control processes using data and analytics from external sources such as enterprise, ecological and environmental databases via the Industrial Internet. While on today’s PACs, customers can write rudimentary analytics utilizing IEC61551 languages; OOCs enable modern programing languages such as C/C++, Python and Java to be used to apply complex optimization algorithms or analytics to operations without impacting the control process. This allows the incorporation of an “outer loop”, an “advise” layer on top of the typical “see-think-do” control loop that can optimize the control application. In the event of a disruption to this “outer loop”, the real-time deterministic control remains unaffected and provides the same functions as a traditional PAC device today (see Figure 1).

The foundation of OOC is a multicore hypervised processor that provides a secure, cooperative framework to run near-real time analytics locally in parallel with control processes (see Figure 2). The ability to run the two operating systems (a RTOS such as VxWorks and general purpose OS such as Linux) in tandem provides an entirely new approach to the optimization of control processes. Hypervisor technology makes it possible to run analytics and optimization applications at the machine level without directly impacting deterministic, real-time control.

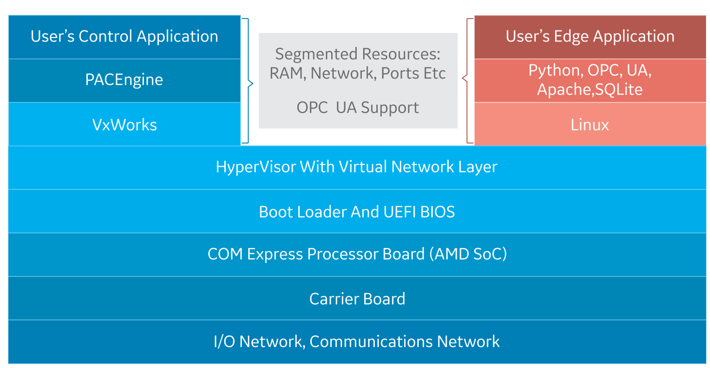
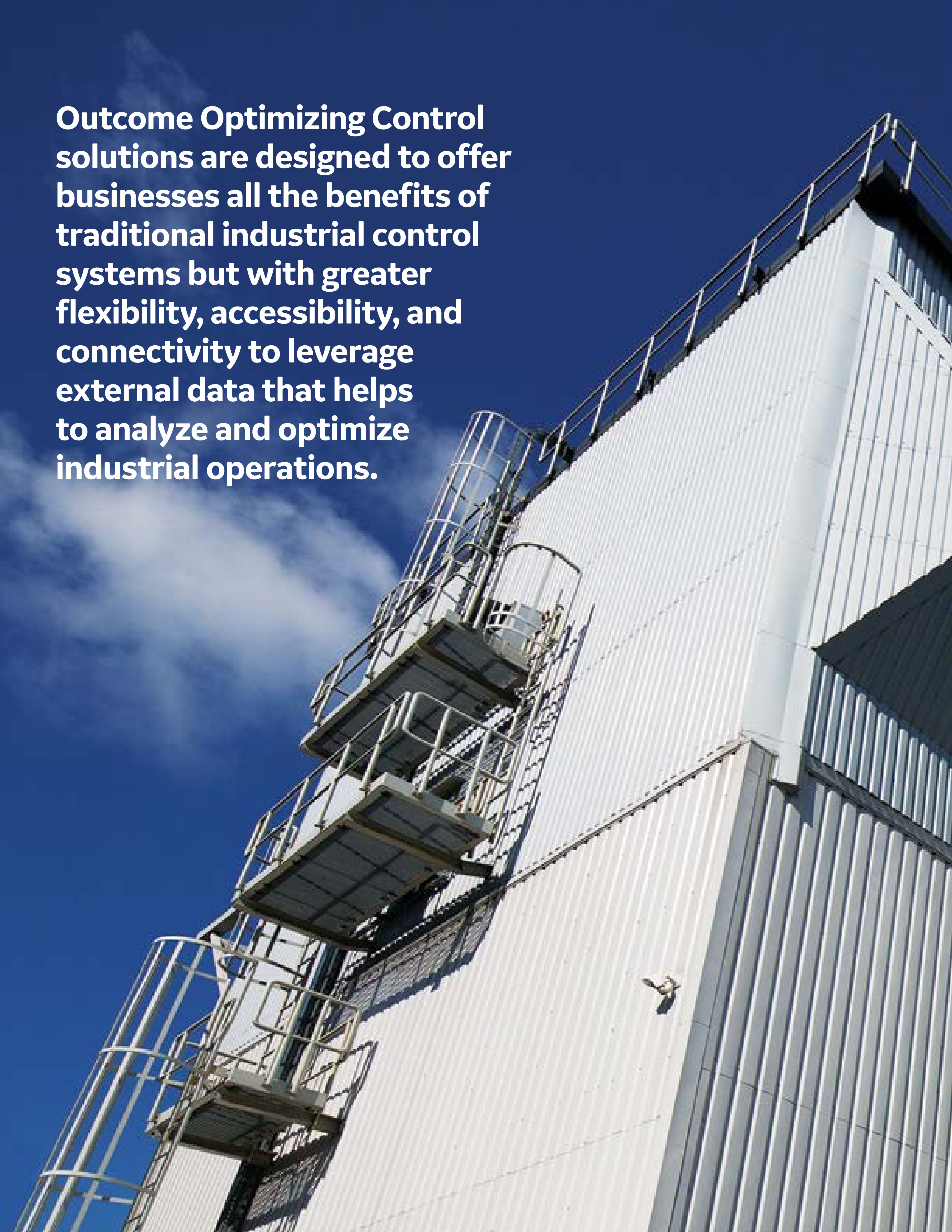


Figure 2. Realtime hypervisor technology provides several cores within a single CPU to enable virtual machines and support both realtime deterministic control and analytic functions simultaneously.

Outcome Optimizing Control solutions are designed to offer businesses all the benefits of traditional industrial control systems but with greater flexibility, accessibility, and connectivity to leverage external data that helps to analyze and optimize industrial operations.



OOC Anticipatory Monitoring & Control Applications

Traditional PLCs and PACs use feedback control where the process is manipulated so that a measured variable tends towards the desired setpoint value. In feedback control, the system waits for an error to occur between the measured value and the setpoint before responding, making the system reactionary. With OOC, it is possible to gain a much higher level of efficiency and productivity by running predictive analytics on operational data and automating responses according to the results of these analytics. This process would be akin to feedforward control where the prediction is used to respond to the process before an error occurs, hence making the process more efficient. The applications that follow are provided as examples of how OOC can be implemented to leverage Industrial Internet data.

Loop Tuning

Traditionally, proportional integral derivative (PID) loops are tuned manually, which can take anywhere from minutes to weeks depending on the application. Manual tuning requires an engineer to come out on-site at significant cost to manually tune each PID loop, sometimes taking many days. In some cases, PID loops have to be fine-tuned periodically to get the best output from the machine over time. Using OOC, it is now possible to automatically tune PID loops with great precision using techniques in the outer loop to analyze process dynamics to determine optimal gains automatically. Businesses can not only reduce the initial time of setting up a PID control loop, but it also gives them the opportunity to dynamically adjust the loop according to changing variables and

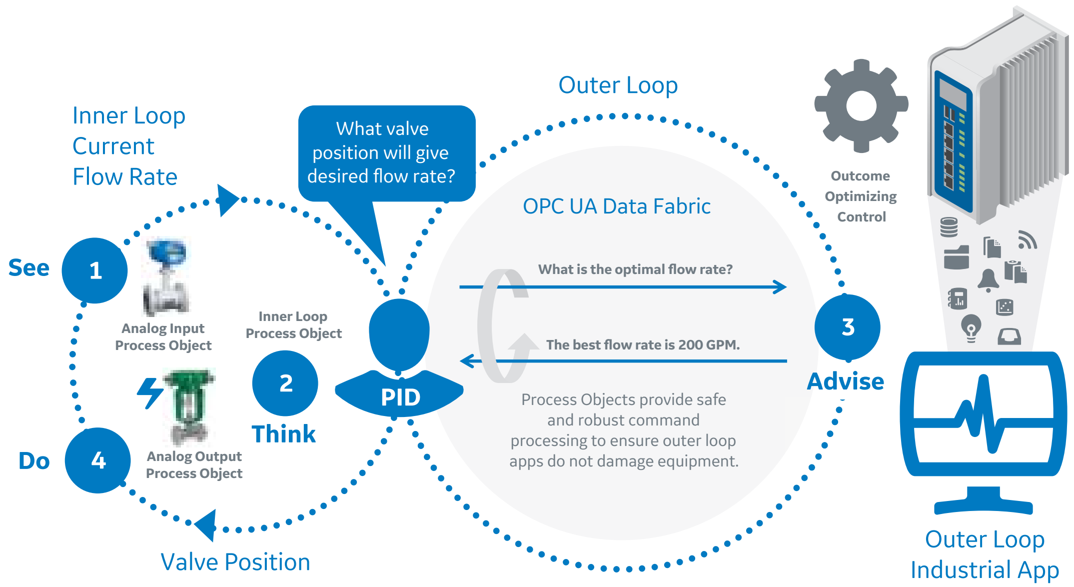


Figure 3. Outcome optimizing controllers allows the incorporation of an “outer loop”, an “advise” layer on top of the typical “see-think-do” control loop that can optimize the control application

operational circumstances increasing their time to market and making their processes run more efficiently over time.

Voice assisted HMI

Voice assistants are increasingly gaining adoption in the consumer space. OOC provides a secure strategy to use voice assisted HMI in the future. Using a third party IoT kit such as Amazon's green grass IOT kit, OOCs can be integrated quite easily with voice assistants such as Amazon Alexa. This kind of technology used alongside HMI visualization systems in a secure manner could help provide productivity gains in the industrial settings in coming years especially by helping to reduce training and troubleshooting time for operators.

Remote Monitoring of Control System Health

Larger operations and OEMs with large fleets or with numerous remote assets find it very difficult today to assess the health of their systems. While the SCADA systems usually provide alerts for alarms and events, it can be quite challenging to actually debug and diagnose the issue in the field especially in remote areas. OOC makes it possible to use Edge technology to monitor and diagnose a fleet of control systems remotely using cloud-based services in a secure manner. Access to detailed fault logs, hardware and firmware versions and sweep time enables operators to debug faults remotely to reduce operational costs and unplanned downtime. It is even possible to run batch updates to a fleet remotely in a secure manner to potentially address faults with zero windshield time.

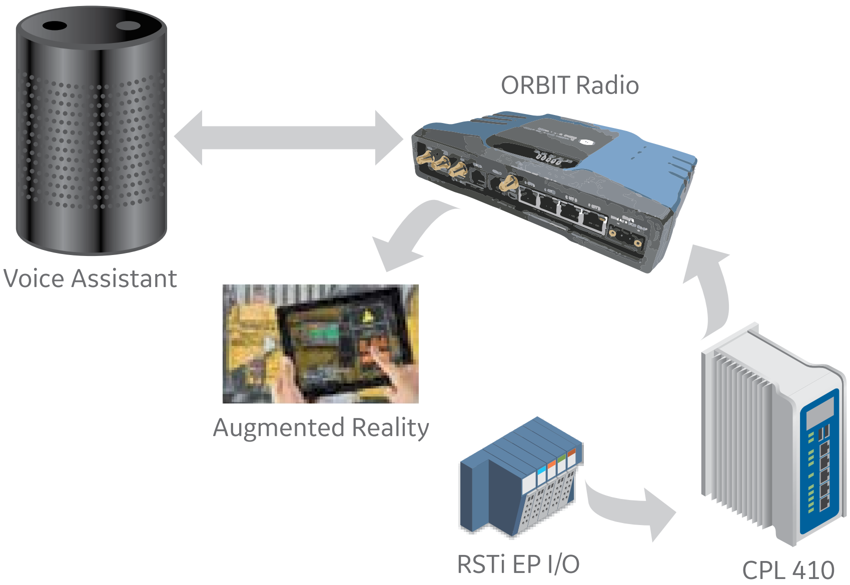


Figure 4. Voice HMI

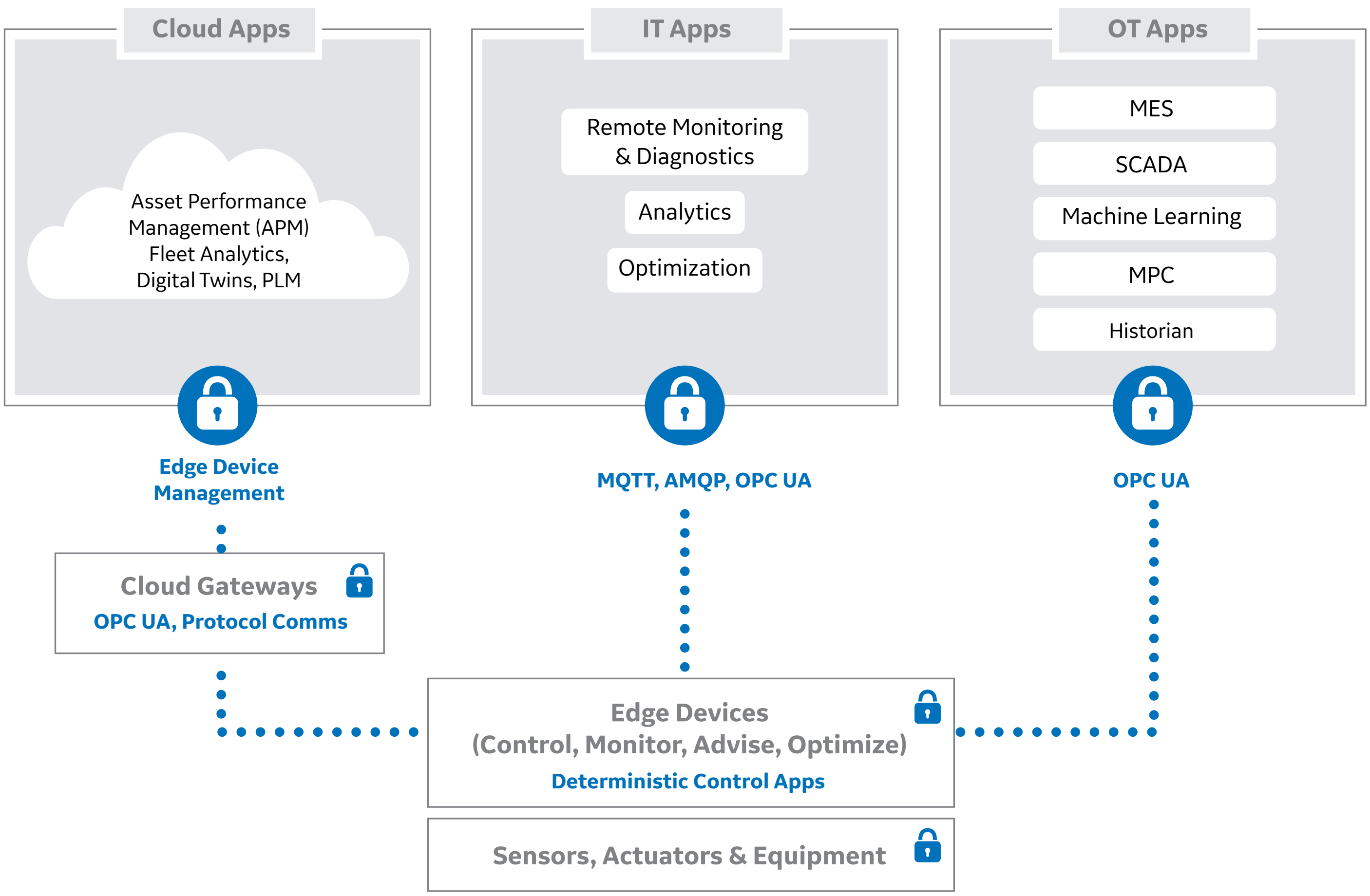


Figure 5. A truly connected enterprise solution brings IT, OT and cloud applications together.

Connected Enterprise - Bringing IT, OT and cloud applications together

OOCs facilitate the integration of a wide range of different devices and equipment with business automation tools using standard communications protocols, making it possible to achieve a new level of business automation. Highly efficient maintenance and supply schedules can easily be set up, with notifications sent directly from the device to third-party suppliers and contractors. Also, it is now possible to connect to IT, OT and Cloud infrastructure directly from the control system to flatten architecture and enable new levels of efficiency.

Figure 6. GE Outcome Optimizing Controller (RX3i CPE400)

GE's Outcome Optimizing Control Solution

GE has engineered an OOC solution in two distinct form factors: CPL 410 with PAC Edge and CPE400 with Predix Edge (see Figure 6). All GE OOCs use a Type 1 hypervisor running real-time deterministic control via PACEngine over VxWorks on one virtual machine and an analytics platform on the second virtual machine in a safe, secure and cooperative manner.

CPL410 runs PACEdge technology on a Linux partition that consists of SQLite database, Apache webserver, OPC UA client and Python interpreter to allow users to easily collect, integrate, correlate, control and visualize all information produced and consumed by the control partition. CPL410 can be used solely for on premise applications, but is also cloud agnostic and can leverage data from a variety of cloud service providers directly at the Edge (see Figure 7 and 8).

CPE400 runs GE's Predix Edge technology on a Linux partition to connect to GE's Predix cloud and run GE Predix based applications such as Equipment Insight and Asset Performance Management (APM).

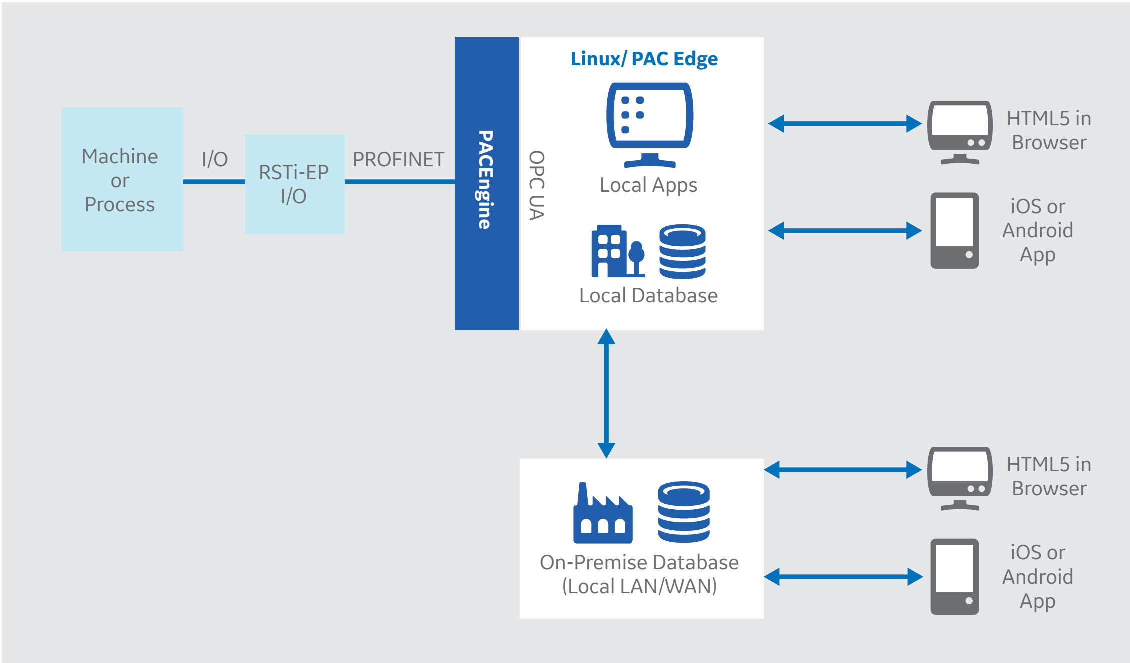


Figure 7.
On-premise
application

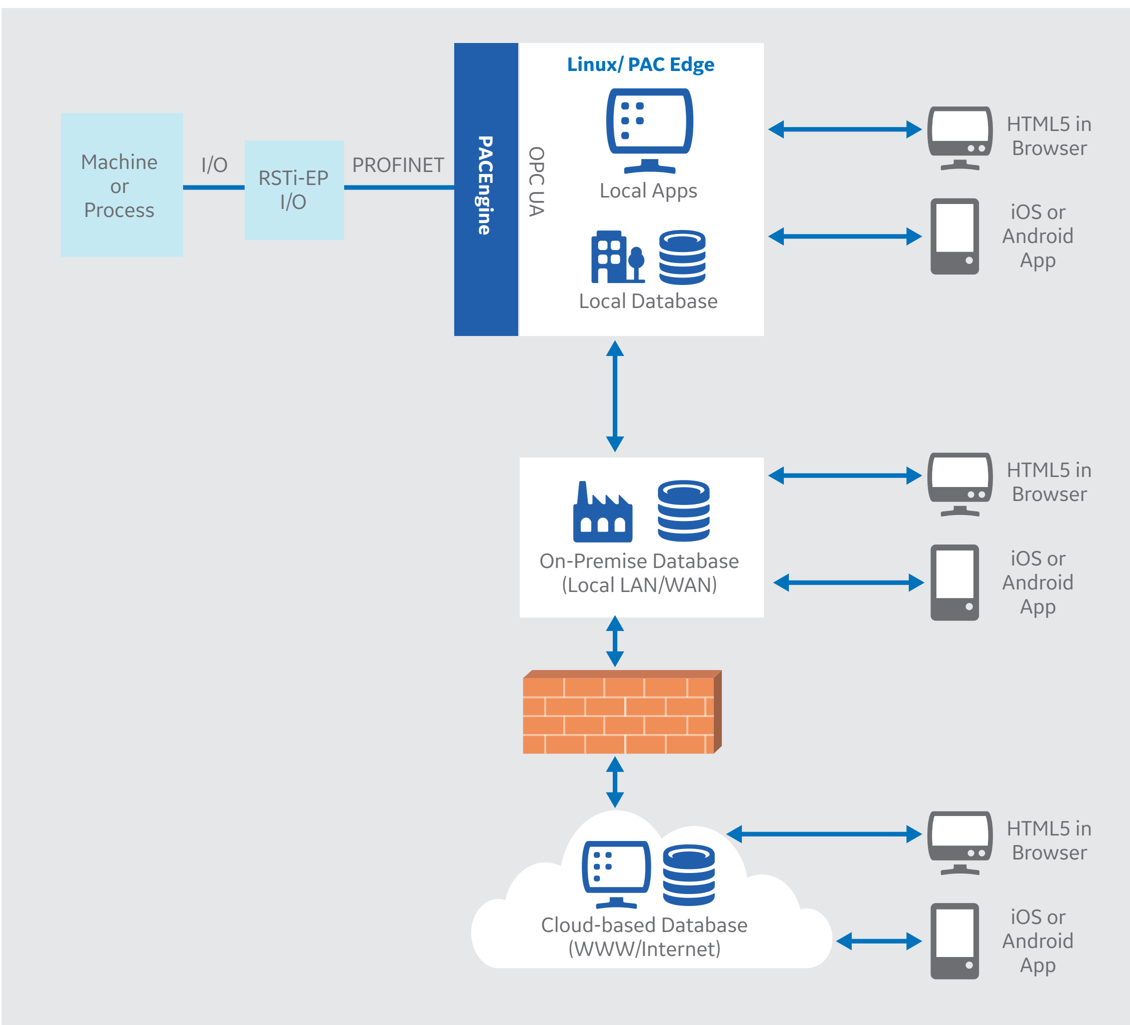


Figure 8.
Cloud
application

OOC Example Applications

Co-Processor

PAC Edge can act as a co-processor, performing processing of data outside of the PACSystem engine. Co-processor applications can read data from the user application running on the PACEngine using OPC UA, perform calculations, then write results back to the user application. Calculations can be implemented using any suitable mechanism, including python and Java. Calculations can include historical data from a SQL database and external data via PACEdge Ethernet interface, including Internet data.

Local web based HMI

PAC Edge can act as a secure web server serving text or graphical HTML5 pages via HTTPS protocol to an external client device running a HTML5 browser or dedicated app.

PAC Edge can also read data from the user application running on the PACEngine using OPC UA, populate HTML5 web pages, then allow an external client to read the HTML5 web pages via the Apache secure web server and display them in a HTML5 browser or dedicated app via secure HTTPS protocol. The HTML5 browser or dedicated app can also securely write results back to the user application via an Apache web server and OPC UA.

"Black Box" recorder & data logger

PACEdge can act as a "Block Box" recorder or data logger, writing data to a file or SQL database for later analysis. PACEdge can read data from the user application running on the PACEngine using OPC UA, then write the data to a SQL database or to archive files. The data then can be used for post-event analysis. The data can be extracted manually or via an HTML5 web page generated in the Apache secure web server or via an SFTP server.

Remote, Monitoring and Diagnostics

Using CPE400, customers can utilize GE's Predix-based Equipment Insight application. Equipment Insight enables OEMs to securely collect and analyze fleet data, and then provide actionable information maintenance engineers and end users who have purchased their equipment. Equipment Insight makes it easier for OEMs to understand how customers use their machines while helping end users optimize asset performance, processes and profitability.

For customers who are using a third party cloud provider, a similar kind of application can be developed on CPL410 using PACEdge.

OOC Industrial Use Case Examples

GE has decades of experience developing industrial control systems to safely and securely automate a wide range of different industrial processes, and its range of OOCs are suitable for a variety of industries and environmental conditions. These include renewable energy systems, water and wastewater treatment, metro, industrial steam, oil & gas, discrete manufacturing, modular machine design and any other applications which requires a highly optimized, efficient and secure control regime to improve productivity and revenue.

The following are OOC use-cases being piloted globally to realize real-world benefits.

Wastewater/Water Management

To increase the operational efficiency of its operations, a wastewater treatment facility can utilize OOC solution to automate the chemical feed process, with the controller taking care of calculating requirements and operating the feed to adjust the amount of chemicals according to the characteristics of the wastewater. By taking advantage of the connectivity provided by OOC solution, the operator can have chemicals ordered directly

by the OOC controller when supplies are running low. Using predictive software at the controller allows the operator to identify approaching peak periods and automatically organize the supply of chemicals and equipment maintenance in a way that maximizes efficiency and reduces cost.

In a second case, a system integrator is creating an application that allows farmers using the water pumps based upon GE OOC to actively monitor the remaining amount of allocated energy, energy price, and pump operation in tandem so that they can shift production between pumps to manage their energy costs, all from their smartphone, saving them up to $11,000 a month.

Hypervised control makes it possible for a technician to obtain industrial data with just a smartphone, eliminating the need for intermediary devices such as an HMI panel or cloud-based server. In another example, a service technician phone app for water industry can provide station data instantaneously to a technician the moment he connects to the Wi-Fi at the water station. The app can detect when he is connected, unlock the door, and as soon as he walks in, provide, using the CPL410 Linux platform, 90 days of plant data, making it simple evaluate performance data and events such as error codes, trips, and faults. Additionally, the Linux platform makes it simple only to make select data, such as KPIs available, to reduce data costs.

Control System Migration

Another application is that of a signaling application for a rail network. In this instance, a C-block was developed on a legacy control system and was approved by the country's rail authority over twenty years ago. A migration might have required the C-block to be recoded. As a result, this new C-block would have to be recertified by the rail authority and would have added almost two years to the project. The customer was looking to maintain the same control infrastructure and avoid recoding the C-block. The CPL solution allows the customer to host the C-block in the PAC Edge portion of the CPL and communicate to existing control logic infrastructure via OPC-UA. This solution makes a rip and replace and recertification unnecessary, saving the customer a significant amount of time and expense. As an additional benefit, the OOC provides the customer with a new capability to design and deploy analytics at the edge for monitoring and diagnostics

Manufacturing

A manufacturer producing ceramic bathroom fixtures is trying to use GE' OOC solution to effectively track and trace good parts vs. bad parts. They are in process of creating a small PACEdge based application to connect their conveyor belt seamlessly to the operators' mobile device and their Enterprise SQL server. Operator is using augmented reality to identify the fixture and see the statistics of the fixtures on the conveyor belt live from their database reducing their manufacturing errors.

Infrastructure

A system integrator in China is creating a remote monitoring application that connects to the private cloud of highway tunnel authority. Using this application, they plan to remotely monitor and diagnose control system faults in the remote highway tunnel reducing their operational costs drastically.

Conclusion

In today's technologically driven world, businesses cannot afford to miss any opportunity to auomate industrial processes and integrate on-site industrial control systems with dynamic business objectives and target outcomes. Outcome optimizing controllers, part of GE's Industrial Internet Control System, offer generational advancement over PACs to provide businesses with a way to increase connectivity and information-sharing across their IT, OT and cloud based systems. GE's outcome optimizing controller portfolio can help businesses reach a new level of organizational and operational efficiency and business automation today.

Imagination at work

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