



Building Industrial IoT from Edge to Cloud

*Next-generation distributed I/O and
control open new possibilities for
connected infrastructure*

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Opto 22

43044 Business Park Drive • Temecula • CA 92590-3614

Phone: 800-321-6786 or 951-695-3000

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BUILDING INDUSTRIAL IOT FROM EDGE TO CLOUD

Next-generation distributed I/O and control open new possibilities for connected infrastructure

WHAT'S THE GOAL?

By now, most anyone working in a role involving industrial automation has heard about digital transformation, the internet of things (IoT), or the industrial IoT (IIoT). These initiatives involve ever smarter devices communicating progressively closer to the “edge,” perhaps connected to an internet “cloud,” or even through some kind of intermediate “fog.”

Even if we consolidate these terms under the umbrella of IIoT, for most folks a simple question remains: what is the goal of the IIoT?

Simply put, end users would like the IIoT to create a cohesive system of devices and applications able to share data seamlessly across machines, sites, and the enterprise to help them optimize production and discover new cost-saving opportunities.

Sharing process data has long been a goal of industrial automation, but traditional operational technology (OT) architectures are poor at scaling, priced prohibitively, and demand complex configuration and support.

So what is changing to achieve this new, more ambitious goal?

Much as consumer hardware and software technologies have shifted to improve ease-of-use and connectivity, industrial products and methods are following the same trend. By adopting information technology (IT) capabilities, they are making it easier to connect industrial equipment with computer networks, software, and services, both on premises and in the cloud.

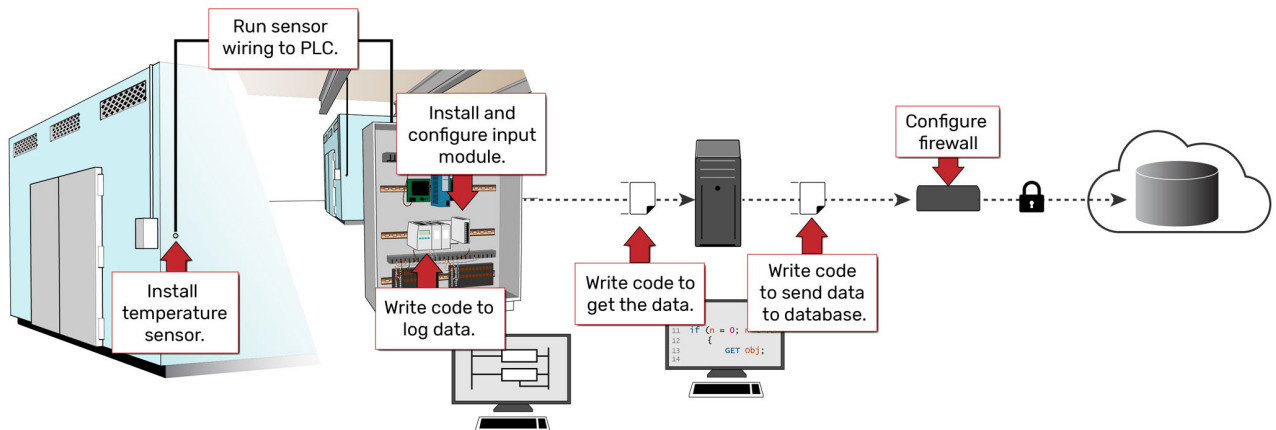
This white paper discusses how a more distributed global architecture is enabling connectivity from the field to the cloud for sensors and actuators, and for the input/output (I/O) systems and controllers linked to them.

UP AND DOWN THE ARCHITECTURE

Industrial automation architectures generally address data processing from a hierarchical perspective, as with the [classic Purdue model](#). One good feature of this hierarchy is the clarity it provides with regard to where data can originate, be stored, undergo processing, and be delivered.

However, the task of transporting data and processing it in context is often quite difficult, because so many layers of equipment are required to connect devices and applications.

For example, the illustration below shows a traditional method of acquiring temperature data from facility



Traditional data acquisition methods require configuring and maintaining many layers in a hierarchy of hardware and software.

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equipment and moving it to a back-end client, like a database.

The lowest level of an automation architecture is made up of the physical devices residing on process and machinery equipment: sensors, valve actuators, motor starters, and so on. These are connected to the I/O points of control system programmable logic controllers (PLCs) and human-machine interfaces (HMIs), both of which are well suited for local control but less useful for advanced calculations and data processing.

However, using industrial communications protocols, these low-level devices can respond to data requests from upstream supervisory control and data acquisition (SCADA) systems where it might be historized or made available to corporate-level analytical software. Sharing data within multi-vendor systems, however, often requires additional middleware, such as OPC device drivers, to translate the various industrial protocols.

More advanced site manufacturing execution system (MES) and overall enterprise resource planning (ERP) software also reside at higher levels of the architecture, hosted on PCs or servers on site or in the cloud, where the cloud is defined as large-scale, internet-based, shared computing and storage.

Information generally flows up to higher levels to be analyzed and used to optimize operations, but the middle layers are required in order to interpret, translate, filter, and format the raw data produced by low-level devices and protocols.

Since these low-level devices typically lack protection against cyber-intrusion, a clear division must also be

The problem with traditional architectures is the amount of work it takes to design, physically connect, configure, digitally map, communicate, and then maintain field data points.

maintained between high-level systems exposed to external networks and low-level systems.

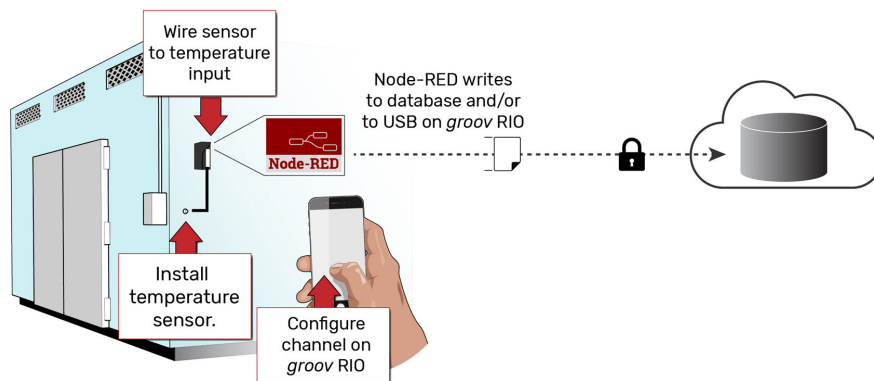
Developments over the past decade are significantly altering this traditional hierarchy, flattening and simplifying it to a great extent.

SPANNING EDGE, FOG, AND CLOUD

The hierarchical approach was necessary when computing capability, network bandwidth, and security features were much less available. Each step up the hierarchy from a basic hardwired sensor to cloud computing systems was required to access greater computing and networking resources. It also clearly delineated the security measures networks required around unsecured field equipment.

Today, the relationship has changed because sensors and other edge devices are far more capable, with some of them including processing and communications abilities similar to a PC. Security protections like embedded firewalls are also becoming a standard feature, allowing each device to act as a peer on the network instead of passively listening and responding to high-level systems.

The architecture is evolving to become flatter and more distributed, as in the image below, which illustrates the same data acquisition scenario but replaces several layers



Modern edge devices, such as the Opto 22 groov RIO®, flatten and simplify the architecture required to connect field I/O signals to business and control applications.

with a low-level device capable of sending data directly to its destination.

The edge, made up of low-level networks, is still a critical source of data, and the cloud is still a valuable resource for heavyweight computing. However, the resources in between, especially at the site level, are becoming a blend of data-generating devices and data-processing infrastructure.

This fuzzy middle ground earns the name *fog*, because it is akin to a widespread, pervasive, and middleweight *cloud*.

Many other factors besides advancing technology are driving this shift to a flatter architecture. The most straightforward motivation is to balance computing and networking demands between the edge and higher-level systems. Edge computing offloads central processing, preserves data fidelity, improves local responsiveness and security, and increases data transfer efficiency to the cloud.

Ultimately, however, this new edge-to-cloud architecture depends on having new options at the edge for acquiring, securing, storing, and processing field data.

DISTRIBUTED I/O EVOLVES

Field data can be raw I/O points connected at the edge or derived calculation values. Either way, the problem with traditional architectures is the amount of work it takes to design, physically connect, configure, digitally map, communicate, and then maintain these data points. Adding even one point at a later date may require revisiting all these steps.

To create more scalable, distributed systems, some vendors are making it possible to bypass these layers between the real world and intermediate or top-level analytics systems.

With enough computing power, all the necessary software for enabling communications can be embedded directly in an I/O device. Instead of requiring a controller to configure, poll, and communicate I/O data to higher levels, I/O devices can transmit information on their own.

This kind of edge data processing is becoming possible also due to a proliferation of IIoT tools, for example:

- **MQTT with Sparkplug B**—A secure, lightweight, open-source publish-subscribe communications protocol designed for machine-to-machine communications, with a data payload designed for mission-critical industrial applications

- **OPC UA**—A platform-independent OPC specification, useful for machine-to-machine communication with legacy devices
- **Node-RED**—A low-code, open-source IoT programming language for managing data transfer across many devices, protocols, web services, and databases

Today's smart remote I/O, also known as edge I/O, takes advantage of these technologies and combines them with standard IT protocols like TLS (transport layer security) encryption, VPN (virtual private networking) for secure remote connection, and DHCP (dynamic host configuration protocol) for automatic addressing. Rather than requiring layers of supporting middleware, edge I/O devices are first-class participants in distributed systems.

Another obstacle to scalability for IIoT systems based on classic I/O hardware is the work required to provide power, network connections, and the right I/O module types. To address these issues, vendors are taking advantage of new technologies to make distributed I/O more feasible and flexible.

Power plus networking

One example is power over Ethernet (PoE) capability, which uses an Ethernet network cable to simultaneously supply low-voltage power and network connectivity.



groov RIO edge I/O module

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When PoE is embedded into an edge I/O device, it can even supply I/O power, simplifying electrical panel design and saving money on additional components and labor.

Flexible I/O

To make it easier for designers to specify the right I/O interface types, some new I/O devices also offer more flexible configuration, like mixed and multi-function I/O channels. These provide extensive options to mix and match I/O signal types as needed on one device, reducing front-end engineering work and spares management.

The combination of these features within edge I/O devices makes it possible for implementers to easily add I/O points anywhere they are needed, starting with a few points and scaling up as much as necessary at any time. Wiring needs are minimized, so long as networking infrastructure is accessible.

For more comprehensive integration, control, and calculation, any number of edge controllers can also be integrated.

EDGE CONTROLLERS BRING IT ALL TOGETHER

As with traditional I/O hardware, traditional industrial controllers are limited in scope and require intermediary systems in order to connect process data to the rest of the organization. Like edge I/O, modern edge programmable industrial controllers (EPICs) leverage new technologies to assimilate more automation functions than previous generations could.

With industrially hardened components, secure networking options, multi-language programming, and multi-core processing, edge controllers can deliver traditional real-time I/O control while also hosting communications, visualization, and even database servers.

In the case of IIoT applications, edge controllers can use this flexibility to communicate with an array of data producers, transform their data in meaningful ways, and deliver it securely to data consumers.

groov EPIC edge programmable industrial controller



Edge controllers like Opto 22's *groov EPIC*® combine sensing and control of traditional I/O, intelligent device fieldbus protocols, and modern edge I/O. They can also host OPC UA servers like Ignition Edge® from Inductive Automation® to communicate with a variety of networked devices, making them uniquely efficient at bridging disparate automation networks.

Then, with support for IT-compatible MQTT and REST interfaces and a variety of networking options, EPICs can securely connect OT networks to IT systems while reducing the layers of middleware required to do so.

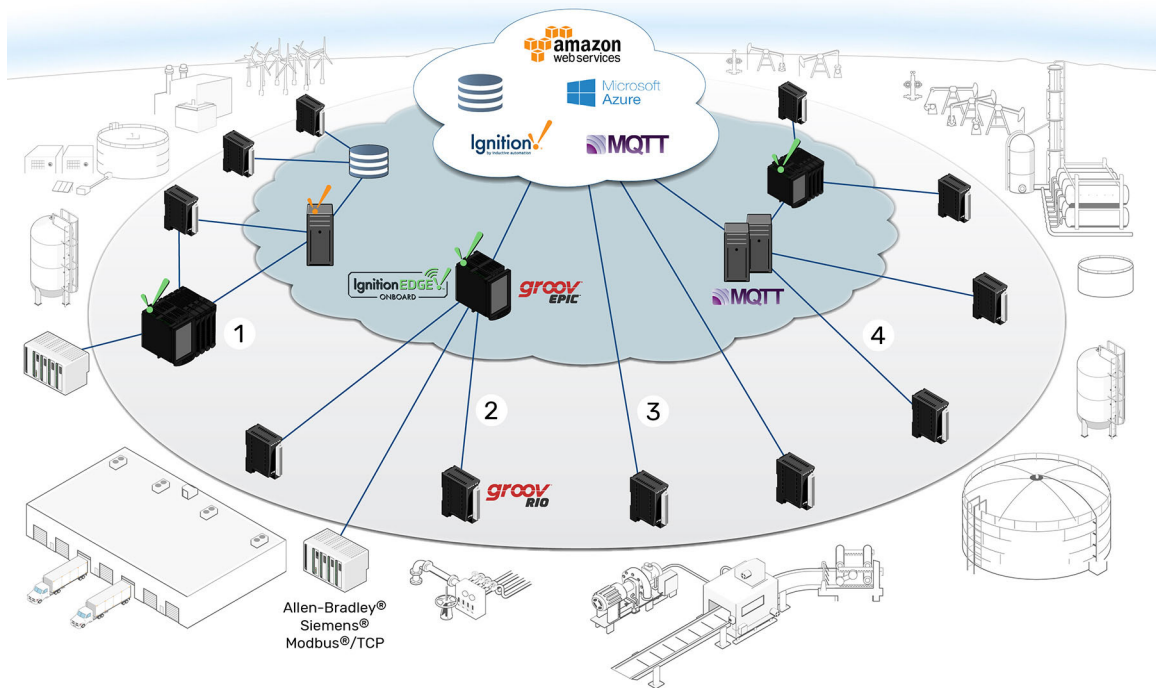
The combination of edge I/O and edge control leads to a new distributed data architecture.

NEW ARCHITECTURE OPTIONS

So what new architectural possibilities are available to industrial automation designers using modern edge I/O and edge controllers?

With edge devices making local data available to computing resources at the edge and at higher organizational levels, the logical hierarchy can be flattened even as the geographical distribution is expanded (see the image on [page 7](#)).

Here you can see some examples of new information architectures that are becoming possible for use in places like remote equipment installations, commercial facilities, campuses, laboratories, and industrial plants.



Edge controllers and edge I/O enable new information architectures in which devices can share data locally and across the organization, through edge, fog, and cloud:

- 1. Shared infrastructure with edge data processing**
- 2. Legacy device integration with edge controller as IoT gateway**
- 3. Direct-to-cloud I/O network**
- 4. Many-to-many MQTT infrastructure**

Shared infrastructure with edge data processing

Where field signals are distributed over large geographic areas or multiple sites, edge devices can facilitate data transmission to networked applications and databases, improving the efficiency and security of local infrastructure or replacing high-maintenance middleware such as Windows PCs.

For example, area 1 in the image above shows edge I/O (*groov RIO*) placed at multiple remote sites with an edge controller (*groov EPIC*) at another site integrating data from existing PLCs. Two of the edge I/O modules are sourcing, processing, and communicating field data directly into a central corporate database, using Node-RED. The EPIC and other edge I/O exchange data for local control while also transmitting data to a central SCADA over MQTT. Data processing is distributed throughout the edge network, allowing central systems to ingest data more efficiently.

The combination of smart hardware and software closes the gap between OT and IT systems, creating a unified data network that is scalable and centrally managed.

Legacy device Integration with edge controller as IoT gateway

Edge I/O can form a basic data processing fabric for existing equipment I/O in brownfield sites and work in combination with more powerful edge controllers and gateways using OPC UA to integrate data from legacy RTUs, PLCs, and PACs. This approach improves security and connectivity without interfering with existing control systems.

The example in area 2 of the image demonstrates this pattern. An edge controller acts as a secure gateway for legacy devices, allowing them to interact with cloud-hosted IoT platforms, SCADA, or MQTT clients while protecting them against unauthorized access from external networks. At the same time, edge I/O is used to integrate

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facility equipment (pumps, blowers, temperature sensors) and new equipment skids into the same network. The *groov* EPIC may control the *groov* RIO modules, aggregate and buffer their data in an embedded database, or simply transmit data to external systems.

Direct-to-cloud I/O network

Engineers can also design simple, flat, data processing networks using only edge I/O devices (without controllers or gateways), expanding as needed to monitor additional field signals. A distributed I/O system like this can process and report data directly to cloud-based supervisory systems, predictive maintenance databases, or MQTT brokers.

In our example, area 3 of the image shows two *groov* RIO modules reporting data from the factory directly to the cloud, via Node-RED or MQTT. There's no need for intermediary control hardware, because each module provides configurable firewall and data encryption settings as well as a data processing engine to combine, filter, and format data. Since each edge I/O module is independent, the network can grow incrementally, reducing capital project expenditures required to integrate new equipment.

Many-to-many MQTT infrastructure

Edge devices with embedded MQTT clients can publish field data directly to a shared MQTT broker/server or redundant MQTT server group located anywhere the network reaches: on premises, in the cloud, or as part of regional fog computing resources. The broker can then manage subscribers to that data—any number of interested network clients across the organization, including control systems, web services, and other edge devices.

Area 4 of the image shows this architecture. Both *groov* RIO and *groov* EPIC have embedded MQTT clients, allowing any of the other architectures to be combined into an efficient data-sharing network. Two of the edge I/O modules in this example are publishing to a regional server group. The other two are communicating with an edge controller at another site, which is using the edge modules as distributed I/O and publishing their data into the MQTT network. Once data is published to the broker, devices and services that need that data can subscribe to it from wherever they are on the network.

SEAMLESS CONNECTIVITY IS POSSIBLE

Seamless connectivity is now a reality, thanks to technologies that make ubiquitous data exchange possible. New hardware and software products enable interconnectivity among physical locations in the field, at the local control room, in the front office, across geographic regions, and up to global data centers.

Distributed edge I/O, edge controllers, and associated networking technologies support data transfer through the edge, fog, and cloud portions of an industrial architecture. Using this approach, you can erase the former boundaries between IT and OT domains and get the data you need to optimize operations.

ABOUT OPTO 22

Opto 22 was started in 1974 by a co-inventor of the solid-state relay (SSR), who discovered a way to make SSRs more reliable.

Opto 22 has consistently built products on open standards rather than on proprietary technologies. The company developed the red-white-yellow-black color-coding system for input/output (I/O) modules and the open Optomux® protocol, and pioneered Ethernet-based I/O.

Famous worldwide for its reliable industrial I/O, the company in 2018 introduced *groov* EPIC® (edge programmable industrial controller). EPIC has an open-source Linux® OS and provides connectivity to PLCs, software, and online services, plus data handling and visualization, in addition to real-time control.

The company's latest product line, *groov* RIO®, provides compact, autonomous edge I/O that is ideal for communicating field data in IIoT applications.

All Opto 22 products are manufactured and supported in the U.S.A. Most solid-state SSRs and I/O modules are guaranteed for life. The company is especially trusted for its continuing policy of providing free product support and free pre-sales engineering assistance.



For more information, visit opto22.com or contact Opto 22 **Pre-Sales Engineering** using the **Contact Us form** on our website.

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OPTO 22 www.opto22.com
43044 Business Park Dr. Temecula, CA 92590-3614

SALES sales@opto22.com
800-321-6786 • 1-951-695-3000

SUPPORT support@opto22.com
800-835-6786 • 1-951-695-3080