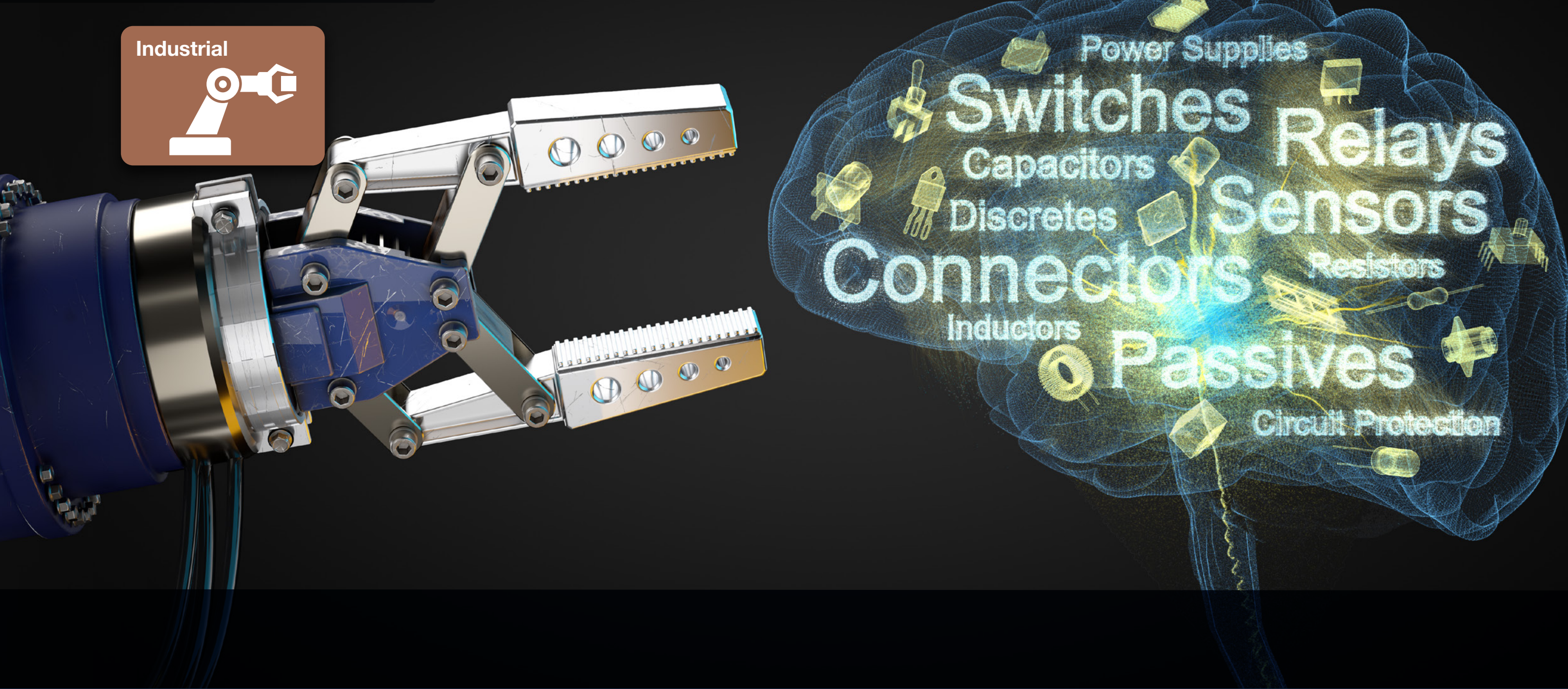
Whitepaper



How Industry 4.0 is Changing the Architecture of Industrial Automation

By Felix Corbett, TTI Europe

Executive Summary

The fourth industrial revolution, also known as “Industry 4.0”, is happening now, enabled by IIoT technologies, fueled by Big Data, and adopted by businesses keen to improve performance by connecting their manufacturing equipment, assets, and people. Rigid hierarchies and data flows are being transitioned into more pervasive, any-to-any channels that are eliminating the traditional divide between the operational -technology (OT) and IT-systems domains.

The prize is digital transformation, unlocking new and more powerful ways to improve production processes across borders, create extra value for customers and new revenue streams for the business – for example through new service related business models – and achieve environmental goals. The challenge is to realise these gains without trading the robustness, safety and real-time performance bred into traditional industrial automation over many generations. It calls for a judicious approach to infusing new technology with proven standards and protocols.

Industry 4.0: A Data-Driven, Networking Revolution

Businesses are eagerly embracing the fourth industrial revolution, Industry 4.0, as a necessity to achieve increasingly ambitious goals in relation to growth, efficiency, and customer satisfaction, as well as innovation of new products and creating extra value through services to support them. Speed is of the essence: rapid adoption gives first-mover advantage, while failure to react to change has often spelt the end, even for organisations assumed to be too big to fail.

Although information technology (IT) systems may be adapting quickly to changing business practices and the Big-Data revolution, industrial infrastructures are known to change at a conservative pace. The operational technology (OT) domain is complex, multi-faceted, and represents a long-term investment in both expenditure and knowledge.

Flattening Hierarchies, Bridging Divides

Industry 4.0 is breaking down the traditional IT/OT divide, calling for all equipment, assets, and people throughout an organisation to become interconnected. The transition will supersede the rigid communication channels and hierarchies that traditionally have dominated industrial automation, defined by the 5-layer Purdue model (figure 1), also known as "Automation Pyramid". Ultimately, connections will extend back into the supply chain, as well as forward to reach equipment deployed at customers' premises.

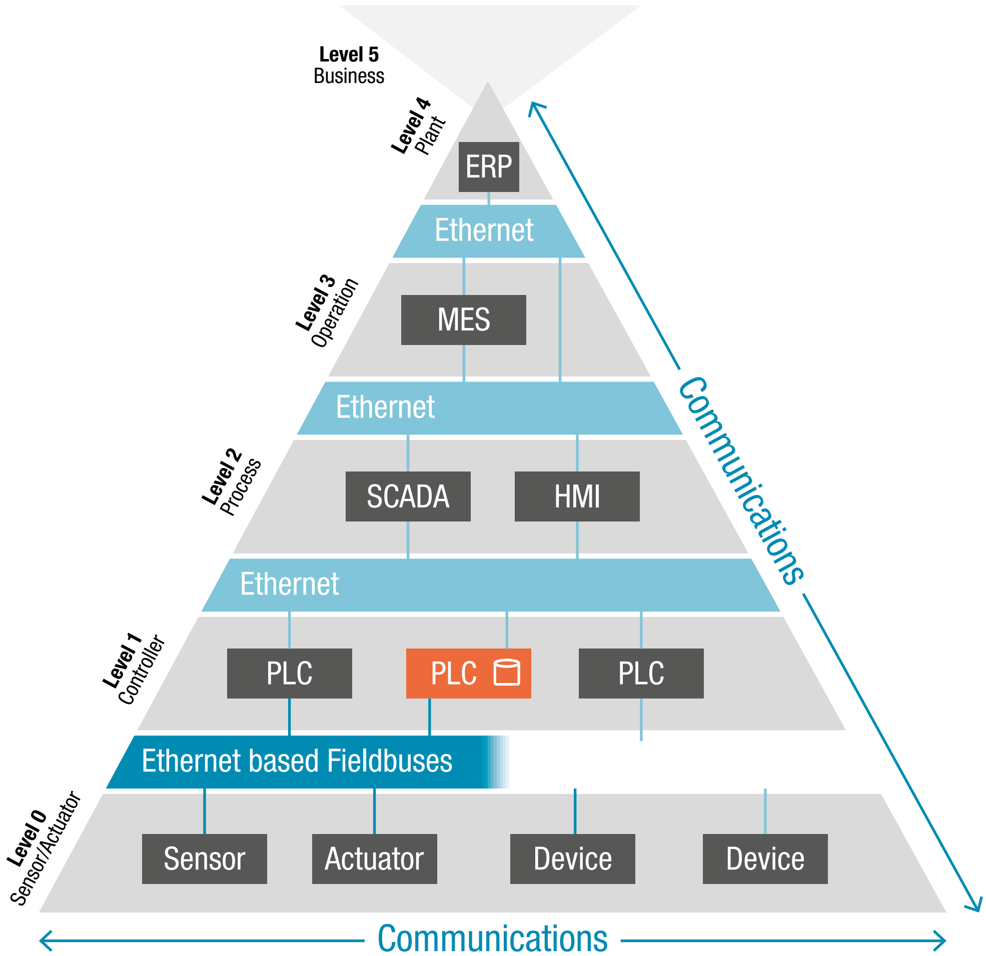


Figure 1: Traditional 5-layer Industrial Automation architecture

Figure 2: Traditional control systems tend to restrict the flow of data into the IT domain

Historically, the traditional hierarchical model for industrial communication has provided a reliable structure for managing devices on the OT side, particularly at the lower levels. Those devices, which have little or no on-board intelligence or decision-making authority, simply report information one level upwards through the pyramid, and receive commands from the next higher layer. Now, however, the rigidness of those structures is proving restrictive, as cheaper, easier access to compute power and storage enables greater intelligence and responsiveness at the lower levels while also driving a hunger at the higher levels for more and richer data from which to extract insights that can drive further business improvements. The implementation of smart sensors and actuators at the lowest level of the pyramid represents just the beginning of the transformation.

As more sensors capture more data, in greater resolution and for additional evaluation purposes than "just" controlling processes, limitations in the data-handling capabilities of traditional control systems are exposed, highlighting a bottleneck at the OT/IT border (figure 2).

Change is needed, to enable IT systems to capture the data they need. With more intelligence embedded in the sensors, actuators and controllers at the lower levels, it makes sense to handle latency-critical tasks in or close to these devices. The concept of edge computing is evolving to address this demand. Only a subset of the data generated at the lower levels is relevant for IT systems and analytics applications. Fog computing describes the processing and filtering this data, to pass into the IT domain. The filtered data, arriving in the Cloud, creates the body of historical data that enables analytics applications to extract valuable business insights throughout the longer term. These applications can themselves be adapted, upgraded, or replaced as the needs of the enterprise evolve. Here, of course, the application of artificial intelligence and machine learning presents an exciting opportunity to unlock even greater value from Big Data.

Retaining Robustness, Ensuring Interoperability

In the Industrial Internet of Things (IIoT), communication infrastructures are reshaping to handle the changing nature of the data exchanges between OT devices, IT systems, and the Cloud. The IIoT's reliance on ubiquitous Internet connectivity technologies enables this to be achieved cost-effectively. Figure 3 shows how new IoT-enabled I/O modules are introduced to handle the large quantities of data coming from smart sensors and actuators, to make this available to IT systems quickly and efficiently, but not blocking data mandatory to control any process in real time, i.e. data flow between sensor and PLC.

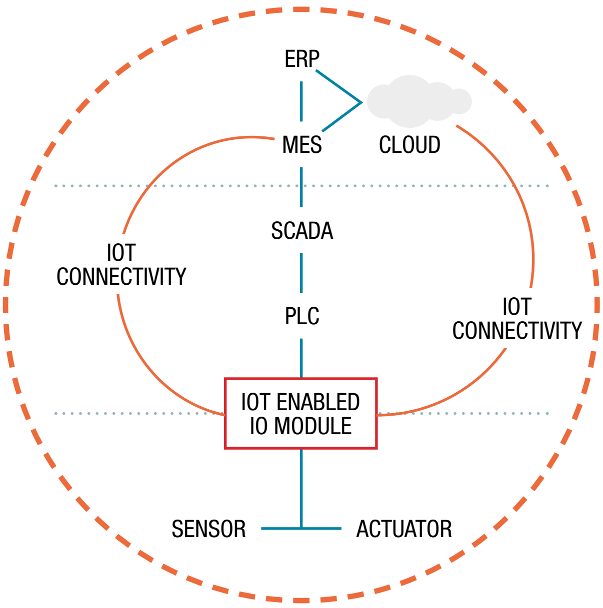


Figure 3: New I/O modules bypass data bottlenecks associated with the traditional rigid hierarchy

This change toward less hierarchical and regimented data exchanges brings its own challenges. The traditional poll-response mechanism, in which data-gathering terminals repeatedly request data from providing devices, is not easily scalable or adaptable. Communication standards such as OPC UA (Object linking and embedding for Process Control Unified Architecture) and MQTT (Message Queuing Telemetry Transport) address this issue by making data readily available to any system that needs it through publish/subscribe messaging, which is both scalable and flexible. In publish/subscribe unlike the traditional poll/response model, each sensor publishes its data immediately making it available to all devices that are programmed as subscribers. Changing subscriptions, or adding or removing sensors, can be accomplished quickly and easily, and pressure on network bandwidth is relieved. Both OPC UA and MQTT include security mechanisms for authenticating users and restricting access; security, of course, being arguably more important to IIoT use cases than consumer IoT, as these are typically mission critical and frequently safety- or life-critical.

At the control level, PLCs are also evolving to address the opportunities of Industry 4.0, for example by adding more compute power and memory, support for standards like OPC UA, easy Cloud connectivity, and new software tools and libraries. On the other hand, communication with sensors and actuators is likely to enshrine established industrial Ethernet standards – such as Profinet – for some time. These are well adapted to industrial-specific demands such as robust real-time performance, special profiles for handling equipment such as drives or I/Os, and features for safety in hazardous environments.

The transition to Internet-based communication between factory-floor and IT systems for analytic data processing also focuses attention on interoperability and a need to move away from bespoke approaches to automation based on custom or proprietary data formats. Initiatives to standardise the way data is presented include MTConnect, which specifies standard data-item definitions and leverages XML as a widely supported data format. By eliminating variations between machines, controls, sensors, or software from different manufacturers, data exchanges between shop-floor equipment and IT systems should become easier to setup as well as more flexible and cost effective.

Enabling Digital Transformation

The adoption of IIoT technologies in the enterprise, transforming the production process and sharing of manufacturing data, is an important enabler for digital transformation, which has the power to improve business performance in numerous respects, including asset management, customer service, new-product creation, and consumption of energy and materials.

Asset Management

By capturing rich data from each process and each item of equipment on the factory floor, Cloud-based analytics applications can track machine wear trends or other deteriorations to accurately predict equipment maintenance requirements and coordinate condition-based servicing. Maintenance can be scheduled at a time that will cause minimal disruption, and unexpected failures that can halt production can be avoided.

New-Product Creation

As a further extension, leveraging powerful Cloud computing to combine product CAD data with real-time sensor data to create a live virtual model, or "digital twin", of new or existing products. A digital twin strategy can be used in various ways, such as virtualizing new-product development to accelerate time to market and reduce prototyping costs, while also avoiding costly product redesigns or recalls from the field.

Customer Service

Moreover, by collecting data from products already in the field, installed at customer sites, a digital twin strategy can be extended to enhance customer relationships and create new services around products that simultaneously deliver extra value for users and create new revenue streams. Armed with the power of Cloud analytics, equipment suppliers can analyse remotely the ways their customers are using or maintaining equipment, and so provide value-added services such as how to improve performance or efficiency, or identify training needs and customise a suitable package. By continuously analysing sensor data to identify trends, predictive maintenance can also become a reality for products in the field.

By combining basic product-design data with individualised customer specifications – captured directly in a standard digitised format and stored in the Cloud to be merged at the correct time – Industry 4.0 makes it possible to personalise production down to the level of a unique individual unit ("lot size = 1") or short-run batch, for a single customer.

Energy Efficiency

The industry 4.0 approach to managing operations also extends to improving the energy efficiency of manufacturing leveraging concepts such as the industrial DC microgrid. Digitalisation encompassing intelligent network control and management of integrated energy storage e.g. in form of battery stacks, is a key enabler for DC microgrids, which simplify integration of renewable energy sources and reuse of recovered energy, as well as reducing energy consumption by eliminating conventional AC-to-DC conversion losses.

Moving Forward and Future Developments

The transformation process as such needs a clear concept, and a good advice is always to get started with small production cells where current processes are "trouble-making".

Going forward, the differences between IIoT connectivity and that of the ordinary non-industrial IoT could become markedly different. Whereas consumer or commercial use cases typically involve exchanging small packets of sensor data at infrequent intervals, smart-factories' IIoT infrastructures are constantly buzzing with rich data sets from large numbers of sources. While the ordinary IoT world is contemplating LPWAN or narrowband GSM for long-range communication, the increasing machine-to-machine data rates offered by enhanced mobile broadband (eMBB) could make 5G an exciting prospect for future IIoT deployments. With ultra-low latency and network slicing, 5G is a candidate for intra-machine, factory floor, and floor-to-Cloud connections, as well as cable replacement in harsh environments.

Conclusion

Industry 4.0 is dramatically changing the way manufacturing information is generated, distributed, and processed, transforming traditional communication infrastructures and demanding closer integration of OT and IT domains. At the operational levels, however, enthusiasm for revolution must coexist with the need to retain advantages such as safety and real-time performance that are ingrained in existing industrial network technologies, and ensure interoperability through standardisation of data formats.

Successfully managing these changes in the factory data infrastructure is critical to achieve the digital transformation that forward-looking enterprises know they must realise in order to survive.

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