QorIQ processor integrates four technologies needed for Industry 4.0

By Joseph Byrne and Jeff Steinheider, NXP

NXP's new QorIQ Layerscape LS1028A processor integrates on a single chip the 4 technologies needed in next-generation industrial systems: time-sensitive networking, high-performance processing, hardware-accelerated user interfaces, and high security.

■ Under a transformation known as Industry 4.0, leading manufacturers are busy conceiving and creating the intelligent industrial enterprise of the future. By merging their information technology (IT) and operational technology (OT) domains, they're building next-generation smart systems to optimize manufacturability, improve operations, enhance customer support, and analyze real-time data provided by the Industrial Internet of Things (IoT). The IoT concept, in its most reduced form, is about connecting embedded systems to the broader world. More broadly, it encompasses data analysis (often in the cloud), human interaction, and security. The challenge is to assemble in one place four requisite industrial IoT technologies: networking, processing, user interface, and security. The new NXP QorIQ Layerscape LS1028A processor meets this challenge.

The merger of IT and OT is only possible by adapting the networks that bind each domain. Because the domains differ so greatly in function, their networks fundamentally differ. The IT domain encompasses systems that transform data into useful information. For a manufacturer, it includes common systems like accounting, email, and customer-relationship management, and it also includes manufacturing-specific systems for planning and logistics. These are computer-based systems without hard real-time constraints and can use the best-effort approach of regular Ethernet. The OT domain includes the systems used to make materials into products, real-time embedded systems for process control, workflow management, and process monitoring. A factory may use an Industrial Ethernet technology that adapts standard Ethernet to deliver real-time response and work with legacy industrial communication protocols. Unfortunately, the many Industrial Ethernet protocols neither interoperate with each other nor with standard Ethernet, limiting the economies of scale for technology suppliers and thus slowing innovation. A single machine in a factory may connect to different Industrial Ethernet networks, each running its specific protocol, for different control functions, as figure 1 shows. The manufacturer must deploy gateways to pass data among the different networks or to IT systems.

Because of their limited interoperability, Industrial Ethernet protocols are not well suited to Industry 4.0. At the same time, standard IT-oriented Ethernet does not deliver the real-time performance that control systems demand. The IEEE, however, in 2004 had formed a group for audio/video streaming for consumer applications, later extending its efforts to meet professional standards. This group developed a family of audio/video bridging (AVB) standards for synchronizing devices on a network to the same timebase (borrowing from IEEE 1588), traffic shaping, and admission controls. Although not perfectly suited to industrial applications, these standards provided a framework for managing Ethernet traffic.

Recognizing the potential to adapt AVB for industrial use, the IEEE group changed its name to Time-Sensitive Networking (TSN) and began revising the 802 standards family to address the needs of industrial and automotive applications, as well as improving features for professional audio-video use. New standards define time-aware traffic shaping and policing to enable scheduling critical traffic. To facilitate scheduling, new standards enabled the preemption of non-critical frames. A new standard for redundant network paths improves network reliability. Industrial companies can now deploy a single IEEE-standard Ethernet network that carries both the time-critical control traffic of OT systems and the regular best-effort traffic of IT systems. Now that pivotal networking technologies for the industrial IoT are defined, these companies can focus on the strategic benefits of OT-IT convergence and Industry 4.0.Just as networks must support time-critical functions, so must processing. A real-time operating system (RTOS) helps ensure that a CPU is available to receive and process control packets when they arrive on a TSN-enabled port. The ability to respond to control packets also helps the CPU to address events coming to the processor from other inputs and to execute loops controlling the system the processor is part of. These loops may need to run up to every 30 microseconds or faster - a degree of precision that a conventional IT-derived operating system cannot meet. The need for more automation requires increased processing capabilities in embedded controllers. Higher performance processing can be used to reduce control loop timing, moving robotic arms and assembly lines faster and increasing factory output. It can also increase the number of axes managed by a single motion controller, leading to robots with more articulated joints, which can operate in tighter spaces or perform tasks that the previous generation of factory robots could not address. Robots that can learn tasks from a human operator will require image processing, along with new machine learning algorithms.

Commercial RTOSs include VxWorks from Wind River and Nucleus from Mentor Graphics. These vendors have a long history of supporting the NXP QorIQ family and its predecessors. With the emergence of industrial-grade Linux, open-source alternatives are another option. These provide industrial enterprises and OEMs the agility to add new capabilities to their systems. Unlike IT-focused and non-real-time embedded Linux distributions, industrial-grade ones provide the determinism, manageability, industrial networking, and security required of OT.

One approach to adding real-time capability to Linux is to apply the PREEMPT_RT patch to the kernel to eliminate situations where a software process is blocked indefinitely by another process. In this scheme, applications are coded to the usual Linux API. Another approach taken by Xenomai is to add classic RTOS APIs to a Linux system, facilitating porting traditional RTOS applications to Linux. This supplier also provides mechanisms for device drivers to respond to peripherals in real time, firming up the real-time guarantees Linux can offer. To ease the transition to Linux from a classic RTOS, NXP is working with the industrial Linux community on a distribution integrating the various real-time enhancements and TSN stacks while maintaining standard Linux capabilities.

Processing capacity must also be available for analytics. The IoT is not only about networking embedded systems but about capturing data from sensors, analyzing the data, and directing the system responses. A common notion is that distant servers in the cloud perform the analysis. However, the amount of data to be transported and analyzed, the time-criticality of the decisions to be made, and the proprietary nature of the data will lead manufacturers to process manufacturing data locally. Analysis could be done not only on a computer at a factory site but even within production machinery, given sufficiently powerful processors. Beyond analysis, processing capacity in an Industry 4.0 regime will be used to manage operations remotely, to enable machines to coordinate among themselves autonomously, and to gain efficiencies from linking production data and IT systems such as those for enterprise resource planning.

Another function demanding processing power is the human-machine interface (HMI). Smartphone-inspired interfaces will increasingly permeate the staid world of industrial equipment. Easy-to-use, visual interfaces simplify operator control of machines. High-resolution screens enable viewing the output of high-definition (or better) cameras inspecting goods as they are manufactured. Driving these screens will be the same type of graphics processing units (GPUs) found in smartphones. Although this 3D performance of GPUs will be scaled down from what is in a smartphone to reduce cost and power, they will support large, high-resolution screens; overlays of

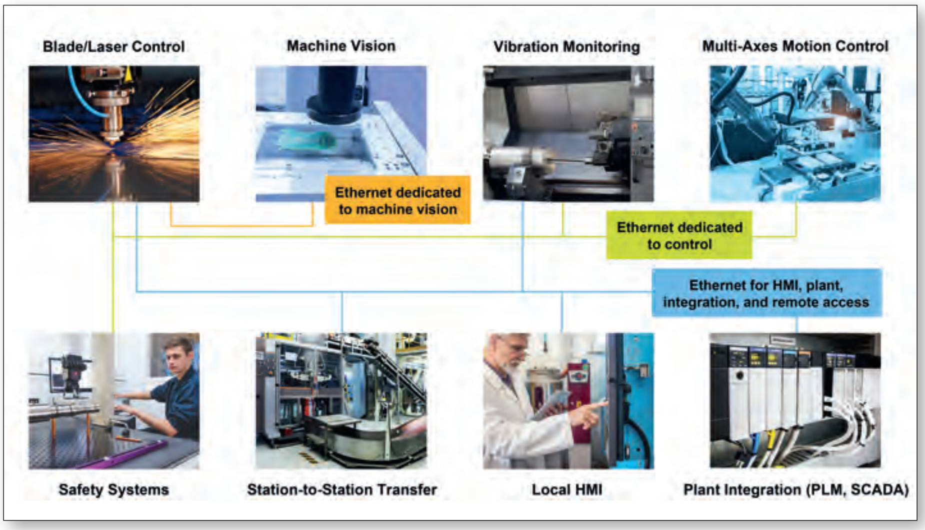

Figure 1. Modern machines which can be linked to the Industrial Internet of Things via different protocols.

graphics, video and text; and slick user interfaces. Convergence of OT and IT increases the risk of security threats. In the past, operations were isolated - almost impenetrable from the outside world. A hacker would need a physical link to attack a machine. A converged industrial setting erodes barriers isolating operations so that information can be shared among systems to improve efficiency. New barriers must be erected to ensure the integrity of systems while maintaining permeability to data flow. The first step for equipment manufacturers is to secure processing platforms in their equipment. They must ensure that their systems execute only approved software and connect securely to other systems. These systems must be securely commissioned and periodically updated and resist tampering of their hardware and software. A recent NXP white paper on IoT security discusses security and trust considerations in more detail. Although the paper context is consumer IoT, the same considerations apply to the Industrial IoT. The financial and safety risk in the industrial context is higher, however, amplifying its need for secure systems.

NXP is proud to enable Industry 4.0 equipment manufacturers to incorporate state-of-the-art networking, processing, HMI, and security in their designs with its new QorIQ Layerscape LS1028A processor. This SoC integrates in one place the technologies needed in next-generation industrial systems: time-sensitive networking, high-performance processing, hardware-accelerated user interfaces, and high security. The LS1028 integrates a four-port Gigabit Ethernet switch and two additional Ethernet ports running at up to 2.5Gbps, all implementing TSN protocols. Two powerful 64-bit ARM CPUs provide the computing performance required for modern industrial applications and support RTOSs such as Linux with preemptive real-time patches, Xenomai Linux, Nucleus from Mentor Graphics, and VxWorks from Wind River. The GPU and LCD interface of the processor allows it to support high resolution displays and touch screen inputs. NXP software includes an open-source industrial Linux SDK with real-time performance and support for TSN standards. Importantly, the processor integrates NXP trust architecture, helping to enable bullet-proof IoT security. ■