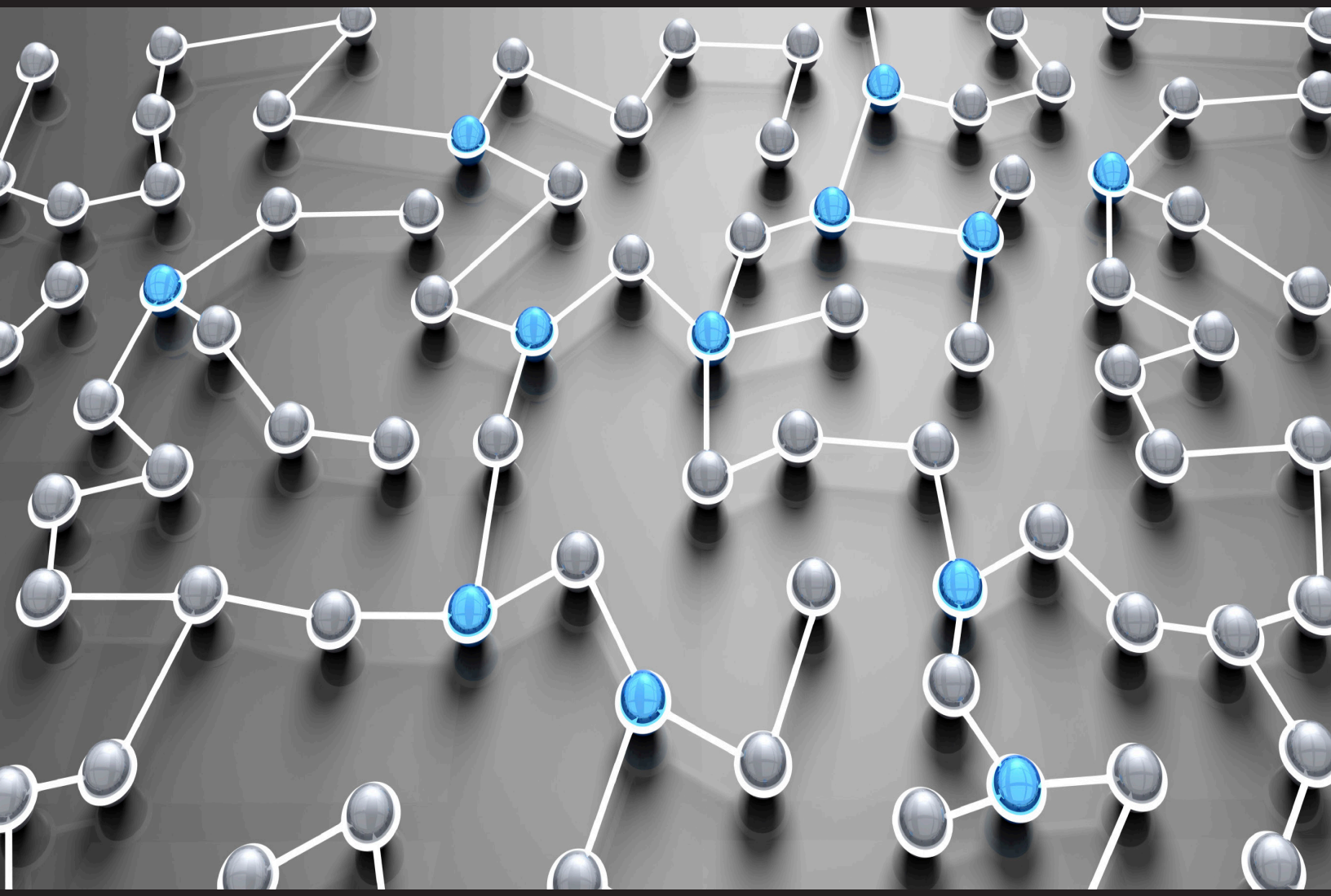
WIND RIVER

The Intelligence in the Internet of Things

# THE RTOS AS THE ENGINE POWERING THE INTERNET OF THINGS

*By Bill Graham and Michael Weinstein*



INNOVATORS START HERE.

## EXECUTIVE SUMMARY

Driven by the convergence of cloud technology, rapidly growing data volumes, and increasingly connected devices, the Internet of Things (IoT) poses new challenges and presents a host of new opportunities that businesses of all sizes and industries can seize right now. This system-of-systems is fundamental to realizing business value—unlocking the insight hidden in data, identifying and creating new services, enhancing productivity and efficiency, improving real-time decision making, solving critical problems, and developing new and innovative user experiences. Billions of intelligent devices and systems make up IoT. The majority of these "things" are embedded systems, many of which are running a real-time operating system (RTOS). This paper outlines the critical features and characteristics an RTOS must have in order to meet the specific challenges and realize the enormous opportunities of IoT.

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## THE CHALLENGES

To fully take advantage of the opportunity offered by IoT, manufacturers of embedded systems must meet multiple challenges:

- Bring connected devices to market faster
- Differentiate products with leading-edge features and capabilities
- Address security risks that the pervasive connectivity in IoT entails
- Build flexibility into existing products so as to be able to tap new market opportunities as they emerge
- Ensure the product offering remains relevant and competitive as markets evolve
- Reduce system development costs and risks

To help manufacturers of embedded devices meet these challenges, an RTOS must evolve to deliver the scalability, modularity, connectivity, security, safety, and cutting-edge feature set that are demanded by the new, highly connected, security-conscious, remotely managed world of machine-to-machine (M2M) networks and IoT (see figure 1).

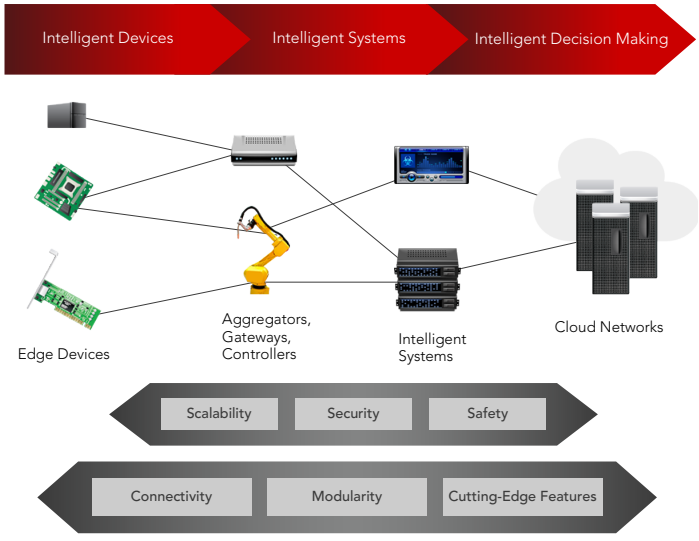


*Figure 1: RTOSes must adapt to meet the new challenges of IoT*

## KEY RTOS REQUIREMENTS FOR IOT

### Modularity

The IoT and M2M landscape is evolving faster than the release cycles for the traditional RTOS, which means the design and deployment of the RTOS need to adapt. Traditionally monolithic in nature, an RTOS has historically been delivered all at once as a large bundle of software, board support packages (BSPs), middleware, operating system, and tools. Updates to this baseline have been mostly for bug and security fixes rather than to add new features, due to the prohibitive amount of coding and testing required to implement them.

The days of dedicated functions with little or no updates or expansion are over. Intelligent devices need to adapt to changing needs in the network. The reinvented RTOS must be built on a modular, upgradeable, future-proof architecture that separates the core kernel from middleware, protocols, applications, and other packages. The RTOS of the future will provide a stable core so that add-on components can rely on this stability for a relatively extended period of time (for example, three years). Middleware, new protocols, and other packages can be added or upgraded without changing the core. An application store model can provision components for all aspects of the RTOS above the base kernel.

An RTOS with a modular architecture will help manufacturers of embedded devices better differentiate their products and maintain them competitively over longer periods of time by enriching them with new features and capabilities without changing the system core as standards and market requirements evolve. This new RTOS will also allow manufacturers to extend the useful life of the system core to several generations of products, which increases the return on their investment in the operating system.

### Scalability

IoT can create an incentive for manufacturers of embedded devices to maintain a broader product portfolio that includes different classes of devices, ranging from small form factor, simple, single-application devices to large-scale, complex, multi-application systems. A single RTOS that can scale to meet the unique memory footprint, functionality, and processing power requirements of

multiple product classes can help manufacturers of embedded systems increase the return on their operating system investment, cut development costs by leveraging the economies of scope, and reduce time-to-market (see figure 2).

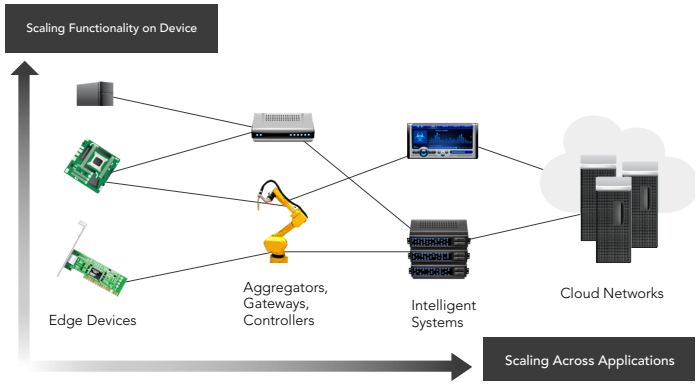


*Figure 2: A single RTOS that can scale for different classes of devices can cut costs and reduce time-to-market*

### Security

Next-generation embedded systems must be designed with security in mind as the pervasive connectivity in IoT results in a substantially larger exposure to threats. A winning RTOS for IoT would give customers the flexibility to design their embedded system to the necessary level of security by leveraging a comprehensive set of built-in features (see figure 3) covering:

- Design
- "Boot and execute"
- Operation
- Power down

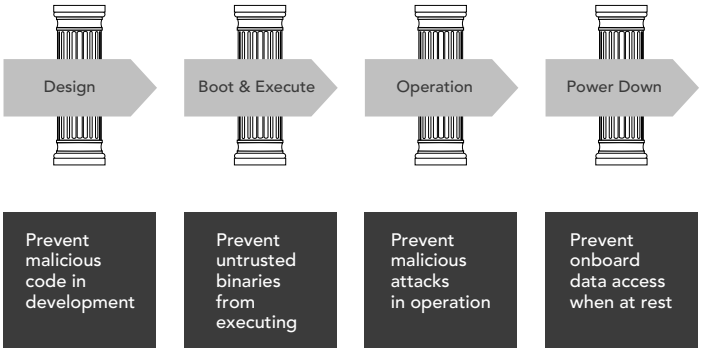


*Figure 3: The pillars of security for IoT devices*

A good RTOS needs to support security features not only to protect against malware and unwanted or rogue applications, but also to deliver secure data storage and transmission and tamper-proof designs. OS-level support for these features is critical, since adding them at the user or application level is ineffective, expensive, and risky. Consider, for example, sensor hubs that aggregate a representative data set from numerous packets of sensed data. These RTOS-based devices will require the logic to open those packets, validate their integrity, analyse their contents, and verify that these actions have taken place securely. Security threats and vulnerabilities are ever-changing. An RTOS needs to support the secure upgrade, download, and authentication of applications to help keep devices secure going forward.

### Safety

Safety is paramount in many embedded operating systems because they control machines that can endanger life, or their malfunction can cause injury or death. Although well established in aerospace, medical, and industrial markets, safety standards are now being applied by regulators to new markets. Also, better applications of existing standards to such systems as smart grid meters or medical devices are being sought. As standards evolve, manufacturers increasingly look to RTOS vendors to deliver the appropriate safety and security capabilities and certifications in order to make it easier to obtain required safety and security certifications for their end products.

### Connectivity

Embedded devices have traditionally been isolated, but are now increasingly connected to corporate or public networks for a wide range of applications, forming the Internet of Things. Small standalone sensor devices are connected together using low-power wireless technology. Industrial control systems are interconnected and controlled remotely. Medical devices used at the home send diagnostic data back to the hospital.

A reinvented RTOS for IoT needs to support industry-leading communications standards and protocols such as CAN, Bluetooth, Continua, ZigBee, Wi-Fi, and Ethernet, and deliver high-performance networking capabilities out of the box. In addition, an RTOS that is modular in nature can help retrofit existing devices with the required connectivity options so that many of the previously disconnected devices can be brought online without reworking the core of their embedded software.

### Cutting-Edge Feature Set

A broad feature set, delivered by the modern RTOS and its ecosystem of compatible third-party applications, is essential to enabling manufacturers of embedded systems to create a differentiated product offering and secure a sustainable competitive advantage.

- **Rich user interface:** With customer experience and the user interface becoming key differentiating features for products ranging from mobile phones to medical devices to industrial control systems, powerful human–machine interaction capabilities are becoming a must for an RTOS for IoT. This includes quality 2D and 3D graphics engines, support for multiple monitors and touch screens, and rich graphics designer tools.
- **Custom-tailored RTOS:** Embedded systems manufacturers who are early adopters of IoT in industries such as networking, industrial, and medical can enjoy even faster time-to-market by leveraging an RTOS that has been purposely customized and packaged to address the needs of their industry out of the box. For example, an RTOS for the industrial vertical would provide industrial device manufacturers with essential multimedia and connectivity middleware, including drivers and protocols for connected devices on the factory floor, wireless peripherals, and other devices within the network infrastructure. An RTOS customized for medical devices would incorporate technology solutions designed to meet the unique needs of medical device manufacturers who need to get approvals from the U.S. Food and Drug Administration. A platform for network equipment manufacturers would enable them to rapidly create, test, deploy, maintain, and manage high-quality wired and wireless infrastructure devices. Such a platform would also offer an extensive suite of security protocols to protect network data.
- **Multi-core:** As embedded systems grow in complexity and capability along with the desire for consolidation, multi-core processors are becoming the platform of choice. A modern RTOS must provide flexible architectural choices on multi-core processors and high performance with low overhead. Multi-core support in middleware and tools is also essential.
- **64-bit processing:** In the days of 8- and 16-bit-only processors, the use of 32-bit processing for embedded systems seemed far-fetched. Embedded systems today have already reached the limitations of 32-bit processors, and the 64-bit processor era is emerging. A modern RTOS should provide 64-bit processing for highly scalable and largely consolidated systems. Support for 64-bit in middleware and tools is also essential.

### Compatible Software and Hardware Ecosystem

In addition to delivering rock-solid real-time performance and other cutting-edge features, an RTOS of the IoT era must support a broad ecosystem of tested and verified complementary hardware and software solutions. This would allow device manufacturers to differentiate their product offerings with leading-edge features and capabilities, accelerate time-to-market through rapid, lower-risk integration of best-in-class third-party technology, and cut costs by deploying systems integrated and validated out of the box.

## DETERMINISM, FOOTPRINT, AND THE NEED FOR A COMMERCIAL RTOS

A challenge for the IoT vision is making the edge devices connected, managed, and interoperable with the rest of the architectures. These edge devices, which are where the RTOS is found, vary greatly in capability and requirements. But there are some common key requirements that need to be met that are critical to the device's operation and its role in the IoT universe.

- **Determinism:** Meeting critical timing deadlines is essential in embedded systems and typically differentiates them from other types of devices. The edge devices still need to operate safely and efficiently, and only RTOS determinism provides this guarantee.
- **Scalable footprint:** The edge devices in IoT are likely to be very small scale due to cost and power constraints. But these devices still require the security and connectivity offered by a modern commercial RTOS in order to satisfy IoT requirements. Other OS options such as Linux are usually too heavyweight, power hungry, and memory hungry for this type of device.
- **Commercial off-the-shelf:** The IoT marketplace is moving rapidly, and device manufacturers need to react quickly. Paradoxically, however, once these devices are deployed their lifespans are measured in years and decades. Open source and free solutions, although initially cost-effective, soon become a maintenance, liability, and risk burden. Commercial solutions offer quicker time-to-market, less risk and cost, and long term support.

## VXWORKS: THE RTOS FOR IOT

VxWorks® is uniquely positioned as the platform of choice for IoT embedded solutions. The reason is clear: Superior safety, scalability, security, modularity, and connectivity provide the greatest capability and the least risk for device manufacturers. Compared to other embedded OS options, VxWorks provides critical deterministic behavior, a certifiable safety pedigree, and a highly scalable memory footprint. As a proven solution already powering 1.5 billion devices, VxWorks is supported by expert services, training, and support that open source and free software cannot offer. The future of IoT is brighter with VxWorks at the core of each device.

## CONCLUSION

The era of the Internet of Things requires a modular, configurable, and expandable RTOS. The reinvented RTOS will add improved scalability, connectivity, security, safety, and an extended feature set to the solid real-time performance, low latency, and multi-core processor support of the RTOS of today. The RTOS of the future is here now with VxWorks, giving manufacturers of embedded systems a competitive edge in the world of IoT by enabling them to bring industry-leading devices to market faster while reducing risks and development and maintenance costs.

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Wind River is a world leader in embedded software for intelligent connected systems. The company has been pioneering computing inside embedded devices since 1981, and its technology is found in more than 1 billion products. To learn more, visit Wind River at www.windriver.com

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