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Engineers' Guide to IoT & M2M

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Engineers' Guide to IoT & M2M

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Special Thanks to Our Sponsors

Welcome to the Engineers' Guide to IoT & M2M 2014!

After the *Consumer Electronics Show*, *Embedded World*, and *Mobile World Congress*, there can be no doubt in anyone's mind that the Internet of Things (IoT) is THE technology trend to watch. The thing itself isn't nearly as new as the hype—after all, the term was coined way back in the dark ages of 1999. (For context, that was the year that AltaVista, HotBot and Northern Light were the top search engines.) And unlike typical CES exhibitors, embedded developers were all over machine-to-machine communications long before that fancy-pants Internet gizmo started getting top billing.

But there's no denying the pull from the market, the push from developers, and the flood of innovations that support today's IoT.

In this issue, we dive right in. You won't want to miss our round-table discussion, in which experts from Imagination Technologies, Intel and Wind River provide fascinating insights into the the rapid changes—both in technology and business models—that this growing phenomenon is driving. Freescale offers a fabulous real-life case study on the challenges in managing the firehose volume of sensor data that the IoT is creating. Silicon Labs walks us through the IoT at home: breaking down microcontroller decisions within smart home applications. And Wind River explains how the IoT defines future real-time operating system requirements.

In addition, Extension Media's Content Director, John Blyler, checks in on a couple of different angles on the IoT, from processor technologies to business models.

Enjoy this issue, and don't miss the Internet of Things Developers Conference, (sponsored by EECatalog, among others) – May 7-8, 2014 in Santa Clara: http://www.iot-devcon.com/.

Cheryl Berglund Coupé

Cheryl Berglund Coupé

Managing Editor

PS: To subscribe to our series of Engineers' Guides for embedded developers and engineers, visit: www.eecatalog.com/subscribe .

EECatalog Extension MEDIA

Contents

What's Up Next in the IoT?

The Internet of things shares many of the same challenges as human-Internet interactions, including the need for connectivity standards, improved security, and new power innovations—but there are twists.

By Cheryl Coupé, Managing Editor

Kevin Kitagawa, Imagination Technologies

Jeff Fortin, Wind River

Adam Burns, Intel

Our Internet of Things roundtable is a deeply insightful look at the rapid changes—both in technology and business models—that this growing phenomenon is driving. I'm especially excited about our panel's thoughts on what the next big breakthroughs will be, and what impacts we can expect. Many thanks to Kevin Kitagawa, director of strategic marketing, Imagination Technologies; Jeff Fortin, director of product management, Wind River; and Adam Burns, product marketing director, IoT Gateways, IoT Solutions Group, Intel for participating.

EECatalog: What still has to happen in terms of standards to support the breathless growth forecasts for the Internet of Things (IoT)?

Kevin Kitagawa, Imagination Technologies: In order for IoT to really take off in the huge volumes predicted by analysts, standardization is a must in areas from device-to-device communication, data analytics, better low-power connectivity and protocols and even operating environments for IoT devices. We are seeing progress in several areas. The AllSeen Alliance has been formed to create a universal development framework to address some of these areas and remove roadblocks to IoT adoption. Collectively as an industry, we can create standards, overcome other challenges and advance IoT adoption.

Jeff Fortin, Wind River: The sheer magnitude of the Internet of Things, along with the introduction of unattended devices (devices with no or limited human interaction), have presented challenges to nearly all existing standards for connectivity, management and security. Standards need to evolve to account for the non-homogeneous nature of IoT. Systems that were not designed to communicate with each other are being connected through IoT gateways which has the potential for increasing security vulnerabilities. In addition, data semantics may not be compatible between systems, leading to costly data- or protocol-conversion processing in order to normalize the data for use by analytic software in the datacenter. Standards leadership is needed to understand how we can combine standalone systems into systems-of-systems in a secure and cost effective way in order to foster the faster innovation promise of the IoT.

> ***The industrial IoT lives in a world where safety goes hand-in-hand with security.***

Adam Burns, Intel: The industrial Internet of Things (IoT) encompasses a wide range of use cases where the majority includes legacy infrastructure and sensors. The wide variety of sensor/fieldbus protocols, along with the increasingly growing number of SCADA/cloud protocols makes most deployments unique. As industrial IoT moves forward, standardization of these protocols will continue to make the deployments more repeatable and simpler to maintain.

EECatalog: How do the technical requirements and design challenges differ between the "industrial" Internet of Things (what we might think of as more traditional embedded applications) and the consumer side of the phenomenon?

Compact Devices for IoT Applications

Integrated security, connectivity and manageability

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Enabling an Intelligent Planet

Advantech's wide product portfolio varies from COM Express modules, SBC to complete systems in order to meet customers' needs to build an intelligent system in the IoT (Internet of Things) market. Our products have increased connectivity and manageability as well as provide device security and rich network options. With our solid product revision control and longevity commitment, customers can now focus on their smart IoT applications with minimal system integration effort.

Advantech's UTX-3115 is integrated with Intel's Intelligent Systems Framework (ISF) and Wind River's Intelligent Device Platform (IDP) while the UBC-200 with Freescale i.mx6 offers a different option from the PC architecture.

Fanless Compact Box PC
UTX-3115
- The IoT Gateway
- Intel ISF and IDP bundled
- -20~60C rugged design

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MIO-5251
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- MIO Extension Bus for more I/Os
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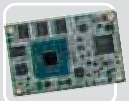
RISC Compact Box PC
UBC-200
- Freescale i.mx6 IoT solution
- Support WIFI or 3G module
- -20~70C rugged design



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The explosion of the Internet of Things (IoT) market in the previous years has evidently started to change the way we live and work. The combination of increasingly connected devices, cloud economics, and dispatch of big data analytics are what conveys this new reality. Industry experts foresee that the technology and computing industry will be centered in an IoT world through which self-configuring devices will be connected to billions of other devices and enabled through intelligent entities which query each other and create intelligent information and services.

Today, Advantech recognizes that the notable shift to the IoT era is creating various groundbreaking opportunities for companies. These include establishing new services, bettering real-time decision making, increasing productivity, overcoming demanding obstacles, and expanding new and innovative user experiences.

Advantech understands that intelligent systems need enhanced connectivity, security, and manageability and requires not only hardware performance improvements, but also new silicon design, software integration, and new user interfaces. By working closely and developing strong ecosystem partnerships with silicon vendors, software providers and system integrators, Advantech can drive this vision and direction towards the IoT era. Advantech's stated mission of "Enabling an Intelligent Planet" openly welcomes the Internet of Things age and reaches towards the vision of a ubiquitous network which can connect anyone, anything, anytime, anyhow, and anywhere through innovative smart technologies.

With over 30 years of technological know-how across diverse sectors, combined with its full design and manufacturing infrastructure, Advantech provides embedded computing solutions designed specifically for IoT applications.

Advantech's IoT Products:

UTX-3115

- The new fanless UTX-3115 system is a powerful miniature industrial-grade solution that features extended temperature operation and a 5-year long life cycle with strict revision control. The unit is an Intel® Intelligent Systems Framework (Intel® ISF) ready solution perfect as an IoT gateway/edge device as well as a M2M communication device.
  - The IoT Gateway
  - Intel Intelligent Systems Framework (ISF) ready
  - -20~60C rugged design

UBC-200

- UBC-200 is an ARM-based compact and high performance solution powered by the Freescale ARM® Cortex™-A9 i.MX6 dual/quad core high performance processor with metal chassis, DIN rail and wall-mount support, fanless design, 9 ~ 24V wide range power input, and multiple I/O options. UBC-200 is a stable, efficient solution that is able to operate 24/7 and is targeted at IoT cloud-based services and solutions.
  - Freescale i.mx6 IoT solution
  - Support WIFI or 3G module for data communication
  - -20~70C rugged design

MIO-5251

- MIO-5251 is the latest 3.5" single board computer based on the latest Intel Celeron J1900/ATOM E3825. Along with Advantech's innovative MIO design concept (simple thermal design, unified mounting hole, easy I/O expansion via off-the-shelf MIOe module), MIO-5251 features dual Gigabit Ethernet and 3 independent display support (48bit LVDS, HDMI/DP and VGA) making it ideal for rapid system solution designs even in harsh environments.
  - Intel® Atom™ E3845/E3825 Celeron® J1900 SoC
  - Advantech MIO Extension Bus for I/O expansions
  - 5.75" x 4"; 0 to 60°C (operation)

SOM-7567

- SOM-7567 embedded COM solution consists of CPU, memory and flash story in a tiny 84mm x 55 mm module. It adopts Intel latest Atom processor which provides 2X+ computing performance and 5X+ 3D graphic performance than previous generations. With its strong performance, low power consumption and minuscule size, SOM-7567 is ideal for markets such as factory automation, portable device, in-vehicle equipment and instrumentation.
  - Intel® Atom™ E3800 Family/Celeron® N2920/J1900 SoC
  - Onboard 4GB DDR3L memory; flash up to 64GB (MLC)
  - 3.3" x 2.17"; 0 to 60°C (operation)

Advantech is continuously developing and delivering cutting edge boards and systems with proven high performance, reliability, longevity and excellent design quality for IoT applications.

SusiAccess

In the past, customers contacted Advantech mainly for single boards or chassis/system products; however, in the ever-growing Intelligent Systems and IoT era, customers need an even more integration embedded solution that can better support their applications and make their products well-equipped for the market. SUSIAccess, Advantech's unique remote device management software, is designed to build intelligence into embedded devices, transforming them to "intelligent systems." It constantly monitors the health of multiple devices and sends out alarm notifications via e-mails and SMS message if abnormal conditions exist. SUSIAccess also provides other powerful utilities such as system recovery (powered by Acronis), system protection (powered by McAfee) and remote KVM to protect and recover faulty systems.

The next generation SUSIAccess will feature Cloud-based Protection, Seamless Interconnection, and 3D Map-view Device Management, making it easier to manage intelligent systems through mobile devices, anytime, anywhere, on any device!

Embedded M2M/IoT Module Integration Services

Embracing IoT Frameworks in Smarter Cities

Today's embedded devices have the ability to communicate, transforming simple dedicated devices into "Interconnected Smart Devices." In the Internet of Things (IoT) era, where wireless connectivity is everywhere, intelligent systems require more and more storage and memory. Already, many kinds of I/O sensors for smart city applications are creating more convenient, efficient and safer urban environments, but IoT applications are getting complicated due to the need for smarter, faster and more accurate intelligent systems. In response to this trend, Advantech provides embedded M2M/IoT module integration services in order to minimize the workload of system integrators.

Advantech provides complete hardware modules and platforms from data acquisition/transmission, computing, peripherals and decision I/O in order to help domain users design intelligent systems using our extensive resources. Customers can focus on their smart applications with minimal system integration effort. Our one-stop integration services are fully compatible with all Advantech's product lines, and provide all the components customers need for building an intelligent system.

High Compatibility, High Performance and High Reliability Peripheral Modules

The knowledge database is the most important part of an intelligent system. Advantech provides Computer on Modules (COM), Single Board Computers (SBC), Industrial Motherboards (IMB) and Embedded Box PC (EBC) for all kinds of applications. Peripherals are always the main bottle neck of these devices, so we designed multiple embedded module product lines such as Wireless, NAND Flash, Industrial Memory and I/O interface card with fully tested compatibility guarantees so that system integrators can rely on our one-stop service to get their intelligent systems up and running quickly .

One-stop Service from Data, and Information to Decisions

From data capture, communication network, intelligent computing and decision I/O, the integrating module services enable System Integrators (SIs) to embrace IoT frameworks in Smart City applications with minimum efforts, rapid schedule and maximum benefits. Advantech defines its brand mission as“Enabling an Intelligent Planet,” and we provide integrated products and services to empower innovative technologies and solutions in the IoT era.

Kitagawa, Imagination Technologies: Usually in the industrial IoT, especially on the factory floor, there is a need for deterministic real-time behavior. These devices must be highly reliable with dependable quality of service (QoS). These same requirements are seen in the automotive market. On the consumer side, these requirements and certifications aren't as stringent.

On the consumer side, devices usually leverage connectivity such as Bluetooth LE, Wi-Fi, Zigbee and cellular technologies. On the industrial side, there are different connectivity standards to ensure deterministic behavior. Often instead of connecting directly to the Internet or cloud, industrial devices connect to a private Internet which Cisco calls the "Fog."

Across the spectrum from industrial to consumer, connecting to the cloud or the fog, all IoT devices have IP addresses. Another important commonality across all of these areas, from industrial to automotive to consumer, is the need for device security. Ensuring device security is a clear mandate for all designers of IoT devices.

Fortin, Wind River: The industrial IoT lives in a world where safety goes hand-in-hand with security. Industrial IoT devices will be connected or a part of systems that affect society. Concerns over the social values of health and privacy led to government oversight of these systems in the form of regulations, and the technical requirements for the industrial IoT must account for these regulations. It is also important to remember that these regulations are non-uniform across the globe, and many IoT systems are expected to be deployed globally, leading to architectural challenges of how to adapt the system to conform to the local regulatory requirements. Before IoT, industrial systems had the befit of isolating themselves from the Internet. But now, in order to receive the benefits of IoT (cost reduction, new revenue streams, faster innovation), these system need to be connected to either the public Internet or at least to other industrial systems. These new interfaces must be designed to maintain the integrity of the original system to meet the social obligations of health, safety and privacy inherent in industrial applications.

Many IoT systems are expected to be deployed globally, leading to architectural challenges of how to adapt the system to conform to the local regulatory requirements.

Burns, Intel: Industrial IoT has a wide variety of challenges that are not present in the consumer phenomenon. Whether it is operating a sensor or gateway in a dusty field on a tractor, next to an engine that reaches industrial temperatures, on a remote windmill without basic connectivity or in a factory that requires precise measurement and uptime, the complexity of the deployments is almost always greater. Unique communication, management, security and hardware requirements are all part of making Industrial IoT a reality.

EECatalog: We haven't come close to solving all the security issues around computing in human-to-machine applications. What's different in machine-to-machine applications, and where are we in solving security challenges there?

Kitagawa, Imagination Technologies: In M2M, issues that must be addressed include ensuring that devices are tamper-resistant, making sure that collected data is stored securely on the device and transmitted securely to the cloud or another device. In addition, only authenticated devices should be able to communicate with each other. These requirements are generally understood. Security is something Imagination is extremely focused on, ensuring that our products are designed with technologies for secure execution, secure boot and secure communications.

Fortin, Wind River: Security is a primary consideration and concern in this connected world and a security plan must be defined for any IoT system. In many ways machine-to-machine systems are no different than human-to-machine applications from a security perspective. In both systems, guards or policies must be put in place to protect against security threats, whether those threats are intentionally malicious or simply the result of faulty execution. One aspect that is unique to machines is the sheer speed at which machines can operate, which means that new security threats can be generated much faster than the policies can be created to guard against them. This leads system developers to establish positive security policies allowing systems to accept actions they normally would reject. An example is signing a potentially dangerous system command message with a security certificate from a trusted source, allowing the local system to take the positive action to accept the command based on the security credentials provided. Positive security measures can go a long way in addressing the security risks in a machine-to-machine IoT environment.

Burns, Intel: Security is one of the most critical vectors of the industrial IoT. One of the unique aspects of industrial IoT use cases is that the sensors and gateways are often focused on a specific task. This promotes the ability for tamper-resistant boot/runtime hardware and software to be able to detect variations in a use case. For example, whitelisting is an effective way to protect gateways from running unwanted software. Additionally, secure-boot technologies can help to measure the platform image to ensure that it is in a known good state. The ability to securely manage and update these policies is equally important in the lifecycle of IoT computing.

EECatalog: What's the next big IoT technical breakthrough you're anticipating and what will the impact be?

Kitagawa, Imagination Technologies: One of the next big technical breakthroughs will be in standardization. With standard APIs and protocols, all devices will be able to communicate with each other, and this will cause an explosion in consumer and industry adoption.

The next breakthrough will not come from technology, but will come from understanding the business models of how to harness this technology.

Extreme/ultra-low power devices that go well beyond what we can deliver today are also on the horizon. Such devices will ultimately remove our reliance on batteries. This is crucial since with IoT, devices must be in place for years, not just days or months. It will be critical to enable devices to be powered through techniques such as energy harvesting through motion or sunlight.

Fortin, Wind River: All of the technical elements to accelerate the IoT are already in place, such as low-cost computing power, low-cost access to wide-area connectivity and the creation of powerful analytic algorithms. I'm going to turn the question around, though, and say that the next breakthrough will not come from technology, but will come from understanding the business models of how to harness this technology. IoT will revolutionize the way the world does business, moving us from selling machines to selling the capacity to perform a service. The breakthrough will occur when companies and individuals learn how to exploit this technology to improve the welfare of society. IoT offers us the possibility to use the limited resources of the planet in a more efficient way, improving our daily lives in ways that we cannot even imagine today. Efficient use of energy in buildings, smart city initiatives and intelligent predictive maintenance are some of the ways we are looking to use IoT now, but there will be many more as the pace of innovation increases with the blossoming of this new paradigm.

Burns, Intel: Intel anticipates that with the lower cost of computing, purpose-built IoT devices may start to be replaced with more flexible general-purpose gateways. This will provide customers with a more flexible approach to implement their unique business logic on top of existing validated building blocks. A good example of this is being able to run custom analytics closer to the edge in order to allow for a more scalable solution. Another example might be to simply store the data locally on a gateway and upload it when connectivity is present or costs less in off hours.

Cheryl Berglund Coupé is managing editor of EECatalog.com. Her articles have appeared in EE Times, Electronic Business, Microsoft Embedded Review and Windows Developer's Journal and she has developed presentations for the Embedded Systems Conference and ICSPAT. She has held a variety of production, technical marketing and writing positions within technology companies and agencies in the Northwest.

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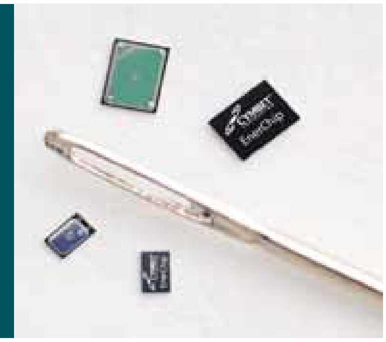

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Section VIII - IEC, NEMA/ANSI
Section IX- United Nations Transportation Air Safety Regulations
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SMT Assembly	✓	-	-
Low self discharge	✓	X	✓
Stable output voltage	✓	X	✓
Smaller area	✓	X	X
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Power Fail Indicator	✓	X	X
Integrated DC-DC Converter	✓	X	X

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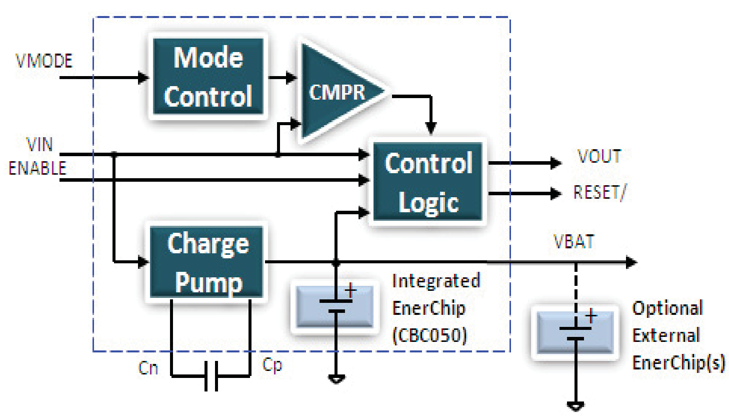
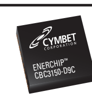
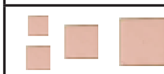
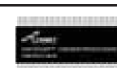
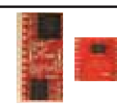
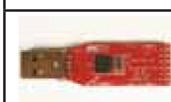
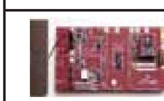
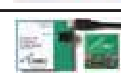
EnerChip™ CC CBC3150 Block Diagram



Cymbet Product Solutions

Product	EnerChip Batteries
	CBC3105 - EnerChip CC 5uAh Rechargeable battery with PMIC 4x5mm 16-pin DFN
	CBC012 - EnerChip 12uAh Rechargeable Solid State Battery 5x5 6-pin DFN
	CBC3112 - EnerChip CC 12uAh battery with integrated PMIC 7x7mm 20-pin DFN
	CBC050 - EnerChip 50uAh Rechargeable Solid State Battery 8x8 mm 16-pin QFN
	CBC3150 - EnerChip CC 50uAh Rechargeable battery with integrated PMIC 9x9mm 20-pin DFN. All EnerChips use SMT assembly and are reflow tolerant
	EnerChip Bare Die - 1uAh, 5uAh, 12uAh, 50uAh. Wire bond or bumped attachment.
	EnerChip Real Time Clocks
	CBC34123 - EnerChip RTC SPI-bus with 5uAh EnerChip. 5x5mm 16pin QFN
	CBC34803/34813 - EnerChip RTC I2C/SPI with 5uAh EnerChip. 5x5mm 16pin QFN
	EnerChip Energy Processor for EH
	CBC915 - EnerChip EH Universal Energy Processor for Energy Harvesting. 38 pin TSSOP uses SMT and reflow solder
	Evaluation Kits
	CBC-Eval-05B - EnerChip CC with CBC3112 and CBC3150 on a 24-pin DIP format and a CBC3105 on a 16-pin DIP format. Perfect for testing various EnerChip configurations
	CBC-Eval-06 - EnerChip CC Real Time Clock Power Backup Eval Kit on USB stick. Uses a Microcrystal 2123 RTC with oscillator and a CBC3112 for power backup with PC GUI
	CBC-Eval-09 - EnerChip EP Universal Energy Harvesting Eval Kit for solar, piezoelectric, thermoelectric or electromagnetic EH transducers. Uses CBC915 with PC GUI
	CBC-Eval-10B - EnerChip CC Solar Energy Harvesting Eval Kit uses CBC3150 for single chip EH power conversion.
	CBC-Eval-11 - EnerChip RF Induction Charging Eval Kit uses near field RF to charge CBC3150 battery
	CBC-Eval-12 - EnerChip RTC eval kit has USB stick to CBC34123 tab or CBC34803 tab. PC GUI for setting RTC registers

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Getting Your M2M Cellular Design Connected

Cellular designs are becoming increasingly critical in both commercial and industrial M2M applications. Devices need robust, reliable connectivity, and are replacing Wi-Fi with cellular modules and solutions. Choosing the right cellular partner is an important step in the design process.

By Symmetry Electronics Corp.

M2M Communications

Machine to machine (M2M) technologies are being implemented across countless industries to track assets, automate intelligent buildings, and monitor utilities and smart meters for an assortment of conditions, among other uses. A major architecture migration is under way in which commercial and industrial devices are replacing Wi-Fi connectivity with cellular modules which connect directly to the Internet or VPN, or other IT Service infrastructure.

There are six major considerations for OEM cellular design:

1. Determining the wireless carrier
2. Testing and certifications
3. Antenna requirements
4. Additional functionalities
5. Budget
6. Future roadmap

Most cellular designs will use a module or a solution rather than a chip due to the significant effort and cost required to certify devices on a cellular network. The economics of a discrete cellular design do not occur until volumes reach close to a million units. Cellular modules are typically certified on networks, though the designs they are built into may require further carrier certifications. There are also fully enclosed modem solutions certified as end devices. These solutions allow customers to use a modem without any additional certification.

Whether your cellular design requires a module or a solution, Symmetry Electronics can get you connected.

Modules

When selecting parts for a cellular design, it is important to choose a cellular module partner rather than opting for a module based solely on price and a datasheet. A good module partner will have various network approved modules to support the different cellular technologies and be able to help with design reviews. A module partner who has developed a common software command set for their modules can save significant time with future designs. The module providers who have well documented hardware and software user manuals are much more capable of supporting different applications. A stable development kit that supports multiple modules will help accelerate the design cycle. Telit, a global leader in M2M communication modules, has proven to be a good choice for customers needing an experienced module partner.

Telit offers the most flexible and smallest size modules in the market. Their modules are fully PTCRB and FCC certified and include a Jamming Detection report feature for increased security. Telit has a unified form factor and extensive AT command set across the different cellular standards, simplifying cross-network designs, and Telit designed and owns its own GSM protocol stack, reducing customer risk and enabling Telit to offer new services faster than the competition. Telit also offers a future upgrade path with Firmware Over The Air (FOTA), extending the lifecycle of designs.

In addition to offering a variety of modules and features for cellular networks, Telit's experience can help guide the component selection process, advising on considerations such as data speed, service and connectivity charge, physical dimensions, power consumption, environmental operating conditions, embedded GNSS, special certifications, manufacturing constraints, and other factors. Telit can also assist developers through the device certification process, reducing the time and cost of wireless product development.

Solutions

Should your design require a solution instead of a module, Symmetry offers a range of solutions incorporating Telit modules.

Nimbelink offers the smallest embedded cellular modem available, allowing for the addition of robust, certified cellular connectivity to M2M devices. Their self-contained devices require no training to install and can be used for simple remote monitoring.

Janus Remote Communications provides state-of-the-art wireless products and services as well as custom design solutions for the global M2M marketplace. Additionally, Janus offers numerous technologies enabling designers to build their own M2M communication solutions, including off the shelf products for an immediate, ready-to-perform answer.

For customers wanting a full-featured, standalone end product, Multi-Tech has a broad product offering for all levels of M2M integration with an extensive range of embedded modules, complete box modems, and full solutions. Multi-Tech products provide a shortened time to market, network interoperability, and reliability in ready to use, plug and play formats.

Other M2M Needs

Symmetry also has the components and peripherals necessary to finalize M2M designs, including antennas, host controllers, power management, and evaluation and development kits, along with RF products, Bluetooth products, Wi-Fi, sensors, MCUs, GPUs, SOCs, SOMs, SBCs, and more.

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Tracking vehicle movement in 3 dimensions

Why vehicle telematics systems need more than just satellites

By Uffe Pless, Alexander Somieski, Michael Amman, Carl Fenger, u-blox

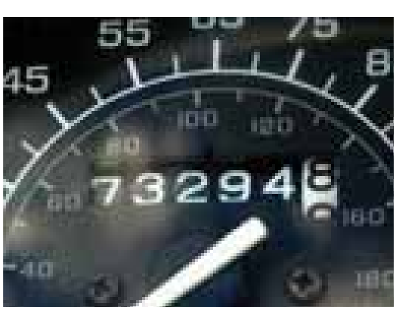
Many vehicle systems rely on accurate satellite positioning as a basis for their correct operation. Navigation, tracking, emergency call, anti-theft, road-pricing and insurance systems all depend on uninterrupted positioning in order to deliver a dependable service.

In reality, availability of global positioning satellite signals can be intermittent or absent.

3-Dimensional Automotive Dead Reckoning ("3D ADR") aids traditional Global Navigation Satellite System (GNSS) navigation via intelligent algorithms based on distance, direction and elevation changes made during satellite signal interruption. 3D ADR GNSS blends satellite navigation data with individual wheel speed, gyroscope and accelerometer information to deliver accurate positioning regardless of changes in a vehicle's speed, heading or elevation, even when satellite signals are partially or completely blocked.

A solution: GNSS positioning enhanced with 3D Dead Reckoning

To solve these problems, u-blox has integrated 3D ADR functionality into its GNSS satellite receiver chip technology. Based on advanced "Sensor Fusion Dead Reckoning" technology, the 3D ADR solution maintains accurate positioning while travelling through regions of poor or no GNSS reception. Based on the last known position, vehicle sensors (typically wheel speed sensor, gyroscope and accelerometer) feed information to the GNSS receiver indicating how far and in what direction, as well as what altitude change a vehicle has experienced based on wheel tick and vehicle pitch.

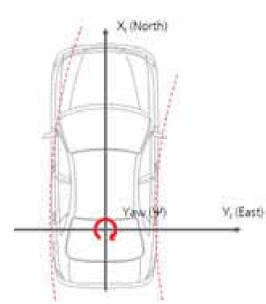


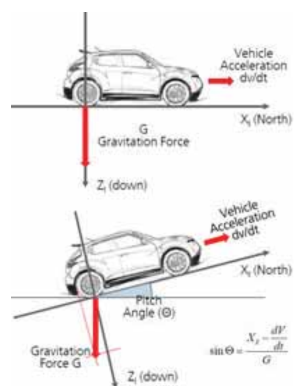
Sensing distance travelled

There are a variety of sensor techniques for detecting distance travelled. Typically a direct connection to the vehicle's odometer (wheel tick) is enough.

Sensing direction

Dead Reckoning in a 2 dimensional plane is achieved by measurements reported by a yaw rate sensor gyroscope. The gyro measures the vehicle's rotation rate along the Z axis. By combining rotation rate and distance travelled, Dead Reckoning is possible through curves.





Sensing changes in altitude

Gravity and vehicle accelerations information is gathered from three accelerometers placed in an orthogonal configuration. Combined with information about vehicle heading, any changes in the pitch of the vehicle can be calculated, for instance when climbing a ramp within a park house. Combined with distance measurement, change in altitude can be calculated.

A 3D ADR solution

u-blox' 3D ADR is a semiconductor solution based on the fusion of sensor data with GNSS satellite data. Based on the Kalman Filter, a mathematical concept first published in 1960 by Hungarian-American mathematician, Rudolf E. Kalman, the concept is widely used in control systems, avionics, and space vehicles. The filter is very powerful and able to estimate present and future states of a system, even when the precise nature of the system is unknown.

In the case of u-blox' implementation, a tightly-coupled Kalman filter algorithm is programmed in the GNSS receiver chip to determine vehicle location based on weighted averages of multiple sensor data input provided by the GNSS receiver, wheel-tick and gyroscope and accelerometers. The result is an estimated position that lies in-between the predicted and measured location that is far more accurate than if either methods were used alone. This process is repeated iteratively, with the new estimate used in the following calculation.

3D Dead Reckoning GNSS extends navigation to areas without satellite reception such as tunnels and park houses, while boosting accuracy along multi-level roads and urban canyons

During times of good GNSS signal reception, the measurements from the vehicle sensors are constantly calibrated. If later a situation with bad or no GNSS signals is encountered, the solution continues to provide a highly accurate location based on the vehicle sensors' inputs.

Ideal for first-mount navigation systems, u-blox' 3D ADR Solution blends data from GNSS satellites with wheel tick, gyroscope and accelerometer information available from the vehicle CAN bus. Making use of the data available from the vehicle data bus brings cost savings; no additional sensors are required to implement Dead Reckoning. The solution runs entirely on the u blox GNSS receiver chip, the UBX-M8030-Kx-DR, and is a highly-accurate solution for car navigation and vehicle telematics systems, regardless of satellite visibility.

The solution requires minimum pre-configuration, and after initial set-up remains permanently calibrated

Benefits of the 3D ADR solution:

- Suitable not only for car navigation, but for many other car telematics applications such as eCall, pay-as-you-drive insurance, road-pricing, and stolen vehicle tracking
- Able to track all visible GPS, GLONASS and BeiDou GNSS satellites in operation, as well as concurrent operation (GPS+GLONASS, GPS+BeiDou, GLONASS+BeiDou)

Reduced hardware costs

- Utilizes sensor data taken directly from the vehicle bus
- Supports high-end (wheel tick + gyro + accelerometer) to low-end, low-cost (wheel tick only) configurations
- Minimal host processing required to execute Dead Reckoning
- Automatically adapts to sensor head unit misalignment via software calibration
- Standard and automotive grades

Flexible implementation

- Supports various sensor configurations
- Easily supports vehicle variants
- Rich set of communication interfaces (I2C, SPI, UART, USB)
- Self-calibrating, both initially and on a continuously to compensate for sensor aging and temperature affects
- Based on external flash allowing for future improvements and updates to adapt to new GNSS systems (e.g. Galileo)
- Embedded map-matching input to further refine navigation performance

Simple integration

- Easy testing
- Simple and modular production set-up: needs only vehicle parameters
- Minimal eBOM

Industry proven

- Successfully deployed by multiple major car manufacturers

For a 2-minute video demonstration of 3D Automotive Dead Reckoning, see the YouTube video located online at:

www.youtube.com/watch?v=ykR0TWL-_oA

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Smarter Ways to Use the Internet of Things

By Wind River

The Internet of Things (IoT) is transforming the way businesses operate, differentiate themselves, and increase profits. With enhanced situational awareness—the ability to perceive and respond to the surrounding environment—IoT adds valuable intelligence for complex decision making in a broad range of industries, including energy, automotive, healthcare, and more.

With billions of units generating more than $1 trillion in revenue today, the IoT market is already big—and it's growing fast. Predictions include a double-digit compound annual growth rate (CAGR), and IDC forecasts that revenues will double by 2015. The challenge is to translate the intelligence in connected embedded devices into new products and services that solve customer problems, drive customer engagement and loyalty, and deliver even higher value to the economy.

Macroeconomic trends, as well as trends that impact specific industries or groups of adopters, drive IoT momentum. Key factors include the following:

- **High labor costs:** It typically costs at least three times more for a human to perform a task than a machine. Intelligent systems can now perform many tasks that require intelligence and situational awareness.
- **Huge real-time demand for Big Data:** Data has become the new currency of business, and intelligent systems can supply both the raw material and sophisticated, real-time analytics that shape and guide more intelligent business decisions.
- **Cloud:** Through IoT, businesses can develop new services and offer them through software-as-a-service (SaaS) models, creating new efficiencies and economies.
- **Ecological considerations:** Machines can perform power management tasks with finer precision and faster response times than manual, human-dependent systems.
- **"Instant gratification" culture**: Customers want everything now—whether it's just-in-time servicing, real-time order fulfillment, or immediate answers to complex questions.

Companies with a stake in IoT have to address a series of questions. What is the best way to allow the wealth of new applications, systems, and devices to connect to complex, often fragile networks? How can Big Data inform and guide the design of systems and devices for better connectivity? How can data be exchanged among siloed vertical markets, systems, and applications? How can the operational efficiencies of IoT-enabled systems be scaled to create higher profit potential? And how can successes be leveraged more broadly across multiple vertical markets?

Operators and device manufacturers have very different perspectives on the opportunities, but all are looking to develop solutions that will scale efficiently, increase revenue, and create competitive differentiation, while responding to the needs of specific vertical industries. And both are trying to respond to the same challenges.

In dealing with these challenges, operators and device manufacturers sometimes take a do-it-yourself (DIY) approach, building internal competence rather than outsourcing key aspects of new device and service creation for the IoT market. All too often, that investment strategy doesn't match their value equation. Customers perceive the highest value in the application and the device-specific middleware. In many cases research and development (R&D) investments are being made lower down in their run-time or embedded stack, where customers perceive little to no value.

The net result, in many cases, is an excessive investment in R&D that detracts from the creation of the differentiating applications and services valued by customers, along with delays due to complexity and lack of experience. Businesses end up driving operating expenditures (OPEX) higher, missing market windows, and failing to exploit opportunities.

For most operators and device manufacturers, it makes sense to invest at the application level and let a qualified partner focus on the non-differentiating, foundational "application-ready" technology rather than technical competence with little competitive advantage. The move to a service-centric model is an evolutionary process. Many operators have already taken the first step by offering connectivity services for IoT applications.

As a global leader in embedded solutions, Wind River® is working with industry partners and customers to address challenges, eliminate barriers, and bring IoT concepts to life. With deep experience in a broad range of sectors and mission critical applications, we understand end-user requirements and help design intelligent components from the ground up to be reliable, manageable, and secure. We are perfectly positioned to help companies in any industry leverage IoT to improve performance, launch new services, and generate new revenue streams.

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Mixed Signal and Microcontrollers Enable IoT

With the dawning of the IoT, design complexity will spread from every physical-world sensor node to every cloud-based server receiving data from or transmitting to that node.

By John Blyler, Chief Content Officer

The Internet of Things (IoT) has become such a hot topic that many business and technical experts see it as a key enabler for the fourth industrial revolution–following the steam engine, the conveyor belt and the first phase of IT automation technology (McKinsey Report). Still, for all the hype, the IoT concept seems hard to define.

"There are two ways in which the "things" in the IoT interact with the physical world around us," explains Diya Soubra, CPU Product Manager for ARM's Processor Division. "First they convert physical (analog) data into information and second they act in the physical world based on information. An example of the first way is a temperature sensor that reports temperature while an example of the second way is a door lock opens upon receiving a text message."

For many in the chip design and embedded space, IoT seems like the latest iteration of the computer-communication convergence heralded from the last decade. But this time, a new element has been added to the mix, namely, sensor systems. This addition means that the role of analog and mixed signal system must now extend beyond RF and wireless devices to include smart sensors. This combination of analog mixed signal, RF-wireless and digital microcontrollers has increase the complexity and confusion among chip, board, package and end product semiconductor developers.

"Microcontrollers (MCUs) targeting IoT applications are becoming analog-intensive due to sensors, AD converters, RF, Power Management and other analog interfaces and modules that they integrate in addition to digital processor and memory," says Mladen Nizic, Engineering Director for Mixed Signal Solutions at Cadence Design Systems. "Therefore, challenges and methodology are determined not by the processor, but by what is being integrated around it. This makes it difficult for digital designers to integrate such large amounts of analog. Often, analog or mixed-signal skills need to be in charge of SoC integration, or the digital and analog designer must work very closely to realize the system in silicon."

The connected devices that make up the IoT must be able to communicate via the Internet. This means the addition of wired or wireless analog functionality to the sensors and devices. But a microcontroller is needed to convert the analog signal to digital and to run the Internet Protocol software stacks. This is why IoT requires a mix of digital (Internet) and analog (physical world) integration.

Team Players?

Just how difficult is it for designers–especially digital–to incorporate analog and mix signal functionality into their SoCs? Soubra puts it this way: "In the market, these are two distinct disciplines. Analog is much harder to design and has its set of custom tools. Digital is easier since it is simpler to design, and it has its own tools. In the past (prior to the emergence of IoT devices), Team A designed the digital part of the system while Team B designed the analog part separately. Then, these two distinct subsystems where combined and tested to see which one failed. Upon failure, both teams adjusted their designs and the process was repeated until the system worked as a whole. These different groups using different tools resulted in a lengthy, time-consuming process."

Contrast that approach with the current design cycle where the entire mixed signal designers (Teams A and B) work together from the start as one project using one tool and one team. All tool vendors have offerings to do this today. New tools allow viewing the digital and analog parts at various levels and allow mixed simulations. Every year, the tools become more sophisticated to handle ever more complex designs.

Simulation and IP

Today, all of the major chip-and board-level EDA and IP tool vendors have modeling and simulation tools that support mixed signal designs directly (see Figure 1).

Verification of the growing analog mixed-signal portion of SoCs is leading to better behavioral models, which abstract the analog upward to the register transfer level (RTL). This improvement provides a more consistent handoff between the analog and digital boundaries. Another improvement is the use of real number models (RNMs), which enable the discrete time transformations needed for pure digital solver simulation of analog mixed-signal verification. This approach enables faster simulation speeds for event-driven real-time models–a benefit over behavioral models like Verilog-A.

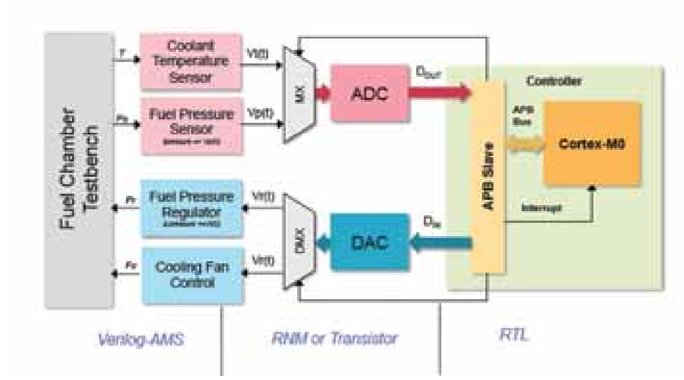


Figure 1: Block diagram of pressures-temperature control and simulation system. (Courtesy Cadence)

AMS simulations are also using assertion techniques to improve verification – especially in interface testing. Another important trend is the use of statistical analysis to handle both the analog nature of mixed signals and the increasing number of operational modes.

For digital designers, there is a lot to learn in the integration of analog systems. However, the availability of ready-to-use analog IP does make it much easier than in the past. That's one reason why the analog IP market has grown considerable in the last several years and will continue that trend. As reported earlier this year, the wireless chip market will be the leading growth segment for the semiconductor industry in 2013, predicts IHS iSuppli Semiconductor ("Semiconductor Growth Turns Wireless").

The report states that original-equipment-manufacturer (OEM) spending on semiconductors for wireless applications will rise by 13.5% this year to reach a value of $69.6 billion – up from $62.3 billion in 2012.

The design and development of wireless and cellular chips–part of the IoT connectivity equation–reflects a continuing need for related semiconductor IP. All wireless devices and cell phones rely on RF and analog mixed-signal (AMS) integrated circuits to convert radio signals into digital data, which can be passed to a baseband processor for data processing. That's why a "wireless" search on the Chipestimate.com website reveals list after list of IP companies providing MIPI controllers, ADCs, DACs, PHY and MAC cores, LNAs, PAs, mixers, PLLs, VCOs, audio/video codecs, Viterbi encoders/decoders, and more.

Real-World Examples

"Many traditional analog parts are adding more intelligence to the design and some of them use microcontrollers to do so," observes Joseph Yiu, Embedded Technology Specialist at ARM. "One example is an SoC from Analog Device (ADuCM360) that contains a 24-bit data acquisition system with multichannel analog-to-digital converters (ADCs), an 32-bit ARM Cortex-M3 processor, and Flash/EE memory. Direct interfacing is provided to external sensors in both wired and battery-powered applications."

But, as Soubra mentioned earlier, the second way in which the IoT interacts with the physical world is to act on information–in other words, through the use of digital-to-analog converters (DACs). An example of a chip that converts digital signals back to the physical analog world is SmartBond DA14580. This System-on-Chip (SoC) is used to connect keyboards, mice and remote controls wirelessly to tablets, laptops and smart TVs. It consists of Bluetooth subsystem, a 32 -bit ARM Cortex M0 microcontroller, antenna connection and GPIO interfaces.

Challenges Ahead

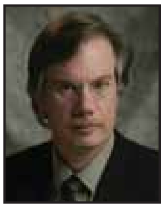
In addition to tools that simulated both analog, mixed signal and digital designs, perhaps the next most critical challenge in IoT hardware and software development is the lack of standards.

"The industry needs to converge on the standard(s) on communications for IoT applications to enable information flow among different type of devices," stressed Wang, "software will be the key to the flourish of IoT applications, as demonstrated by ARM's recent acquisition of Sensinode." A Finnish software company, Sensinode builds a variation of the Internet Protocols (IP) designed for IoT device connection. Specifically, the company develops to the 6LoWPAN standard, a compression format for IPv6 that is designed for low-power, low-bandwidth wireless links.

If IoT devices are to receive widespread adoption by consumers, then security of the data collected and acted upon by these devices must be robust. (Security will be covered in future articles).

Analog and digital integration, interface and communication standards, and system-level security have always been challenges faced by leading edge designers. The only thing that changes is the increasing complexity of the designs. With the dawning of the IoT, that complexity will spread from every physical world sensor node to every cloud-based server receiving data from or transmitting to that node. Perhaps this complexity spreading will ultimately be the biggest challenge faced by today's intrepid designers.

John Blyler is the Chief Content Officer for Extension Media, which publishes Chip Design and Embedded Intel® Solutions magazine, plus over 36 EECatalog Resource Catalogs in vertical market areas.



Sensors Are a Primary Source for Big Data

New IoT applications—from medical to smart energy to animal husbandry—drive the need for more layered intelligence to address security and privacy concerns, and to manage stunning volumes of data.

By Ian Chen, Freescale

Consider a conference that is simultaneously transmitted to audiences in three cities. When a presenter asks the audience a survey question, they can respond by raising their hands to signify agreement to the proposition. As the vote is taking place, the total vote tallied across all three cities is displayed to the presenter and the audience in real time.

Actually, that futuristic set-up became reality recently at Freescale. We did that, in part, to illustrate the potential of the Internet of Things (IoT). Here is how it works. Each audience member is fitted with a wristband embedded with motion sensors. Sensor data from the wristband captures the movement of the audience member's wrist. To minimize communications bandwidth consumed by this exercise and reduce the power consumption for wireless communications, contextually aware algorithms running on the wristband interpret sensor data and look for data patterns that suggest vertical displacements congruent to a user raising his hand. When such a signature movement is present, the wristband transmits its data to a wireless access point situated at that conference location.

The wireless access points time-stamp the data they receive from the wristbands and then forward the information expeditiously to a cloud-based application. That application uses the results from the wristbands in all three conference locations to deduce when the presenter is taking a vote. Whereas the algorithms running in the wristband can recognize vertical motion, it is difficult for them to discern whether the sensor is moving vertically because a user is raising his hand, or simply because a listener is fidgeting or standing up. The intelligence in the cloud, however, can notice that during a narrow window of time the sensors carried by a larger portion of the audience are moving up simultaneously and deduce that it is a vote that it should tally.

Sensors at the Source

This example illustrates many of the architecture challenges for the IoT (see Figure 1). At the source of an IoT-connected device is often one or more sensors. Sensors convert signals from physical environments such as motion, magnetic field or ambient pressure into digital data. Because sensors provide data continuously and autonomously, sensor data can quickly exceed human-generated data in volume. To alleviate data congestion and associated transmission costs, smart sensors can make a real-time determination on the salience or relevance of the data and transmit them only when they are deemed potentially useful by upstream applications. For example, an algorithm on a motion sensor can determine that the sensor has been stationary and skip an update. A more sophisticated contextual algorithm may be able to differentiate between the wearer raising his hand and other actions such as standing up. Placing intelligence at the data source can reduce the communications bandwidth consumed by sensor data and prolong the battery lives of battery-powered wireless sensor nodes. However, computation capacity at the sensor node is more costly than cloud computing, and intelligent sensors designed

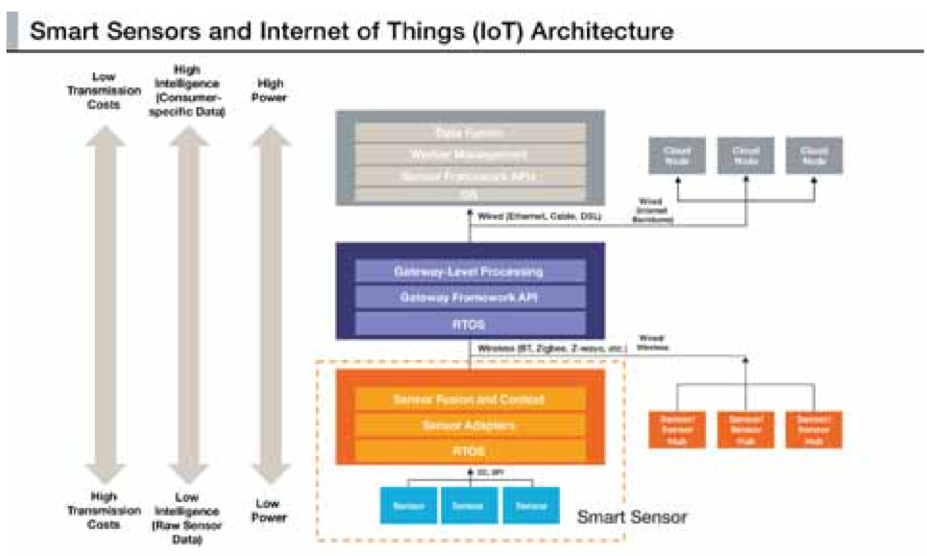


Figure 1. An example of IoT architecture Freescale used for the live vote tallying exercise

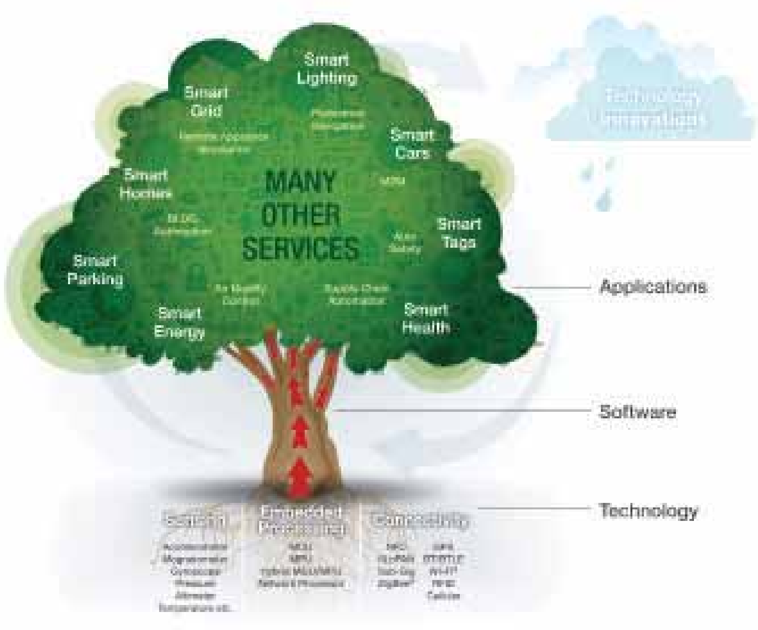


Figure 2. Sensors are the root as a primary source of data for the Internet of Things, bringing layered intelligence to enrich human experiences

for a specific application may be less effectively adapted to a different purpose.

Intelligence at the data source is also critical where security is a concern. Different security and privacy protocols are being discussed that aim to require negotiation between cloud-based applications and data sources for permission to use their data, in part or as a whole. This is particularly sensitive in body-worn sensors that can record signals which may seem meaningless to the individual. When these signals are combined with other information in a data-mining algorithm, they can unintentionally breach consumer privacy.

At the gateway level, the demands generated by sensor data can also be acute. Sensor data is real-time data, so gateways may be required to help synchronize different sets of sensor data and control data latency. Sometimes further contextual processing may occur at the gateway to further reduce uplink bandwidth requirement. Within the cloud, the same set of sensor data would be made available to a large number of task workers from multiple servers and applications, so the same wristband that is tracking the votes of a conference could also be monitoring the wearer's activity level, and helping to predict the daily traffic pattern. Invariably, one finds layered intelligence at the core of sensor-based IoT deployments.

IoT-connected devices, like the wristband given in our example, will dwarf all connectivity by 2020, including human-to-human, human-to-machine and machine-to-machine connections. This trend is fueled by four factors:

- The decreasing cost of sensors and actuators, especially based on MEMS technology, make the vast deployment more feasible.
- The decreasing cost of Wi-Fi routers makes massive connectivity more feasible.
- IPv6 extends the number of unique Internet addresses to connect trillions of physical objects.
- Ubiquitous smartphones and tablets demonstrate the process and results of unprecedented connectivity.

Industrial Applications Drive the Future

Although the example we used—and indeed, much of today's attention on IoT has been associated with wearable devices—much greater business potential for IoT lies in industrial applications. When McKinsey & Company1, Cisco2 and GE3 all pointed to IoT making a multi-trillion dollar impact on our economy by 2025, they were looking at gains in healthcare and infrastructure deployments.

Wearable technologies today are not limited to satisfying consumers' quantified lifestyles and providing fodder for social media. They are also being used to improve asset tracking for animal husbandry. For example, valuable race horses are wearing sensor patches and sensor-equipped horseshoes to help their trainers monitor their health, record their gait and upload the data so algorithms can monitor the behavior of the horse, diagnose illness and help promote the overall wellness of the animal. Simple motion sensors like the ones in an activity-tracking wristband are being used to detect and report tampering with smart meter installations to protect system integrity. Motion sensors along with pressure sensors are being used to monitor bedridden patient comfort, measuring respiratory and heart rates, and even alerting the nurse's station to summon assistance when a patient is trying to get out of bed.

Today, we serve over 150 unique sensor applications per year. We see sensors integrating more intelligent functions and we see the need to more closely integrate our sensors with MCU and digital networking offerings as systems solutions. Our observations reflect the need for more layered intelligence across our product families to address power conservation, security and connectivity concerns. With the coming waves of IoT applications, we believe sensor systems to become more complex, more context and environmentally aware, and, fortunately for all of us who are working with them, more interesting.

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Ian Chen manages marketing, systems architecture, software and algorithm development for Freescale's Sensor Solution Division. Ian received bachelor and master's degrees in electrical engineering and an MBA, all from the University of Illinois at Urbana-Champaign. He holds more than ten patents.

Microcontroller and Connectivity Options for Smart Home and IoT Devices

IoT end nodes and gateways that offer the best combination of energy-efficiency, performance, cost effectiveness and appealing features—regardless of MCU bit size—will be in the driver's seat in the race to our IoT future.

By Greg Hodgson, Silicon Labs

We're at the dawn of a new era in connectivity and convenience unlike anything we've experienced before. The Internet of Things (IoT) promises to deliver on the vision of anywhere/anytime knowledge and control of our home and work environments, and depending on the side of Geoffrey Moore's "chasm" you sit, the IoT may already be here. Today I can monitor my connected home and ensure my family is safe, optimize my home energy usage and check on my pets, all while at home or on the road. There will be a tipping point; a handful of innovative consumer products and services that even the late adopters won't be able to ignore, after which there will be little question that the IoT has arrived.

If it hasn't already happened, soon your company's management team will propose products to participate in the IoT. How will you respond? The good news is that many of the application building blocks for the IoT are available today, just waiting for you and your team to add your creative genius. In this article we'll examine common architectures for the connected home and technology considerations to help navigate the IoT.

We all want to be in control of the security of our home and family, and it only takes a fire or burglary to remind ourselves of this need. A number of upstarts and cable operators have introduced products for the connected home that provide fire, security and convenience services. A typical connected home system architecture comprises a number of sensor nodes ranging from simple to complex, a wireless network featuring a gateway to connect to the Internet wirelessly and potentially provide localized system intelligence, and cloud services to connect to mobile devices. Figure 1 shows such a connected home architecture.

Embedded systems designers must consider a number of competing requirements in designing a gateway or sensor nodes, such as processing speed, memory size, regulatory considerations, energy consumption, system latency, connectivity options, system segmentation, security requirements, interoperability, future migration and system cost, to name a few.

Figure 1: The Connected Home

The system gateway might be a cable set-top box or a standalone system. See Figure 2 for an example of a typical gateway architecture. The gateway microcontroller (MCU) is most likely based on an ARM Cortex-M or Cortex-A class processor combined with connectivity options such as Ethernet, Wi-Fi, ZigBee and sub-GHz/ISM wireless. Considerations for selecting the optimal MCU include memory size and processing requirements for the communications stacks and gateway services, system latency requirements for "real-time" or offline operation, and connectivity. Considerations for selecting the RF subsystem include local regulations (FCC, ETSI, etc.), whether connection to a broader ecosystem is desired (which requires a standard) or if the system will be self-contained (a proprietary stack can be used), protocol stack requirements, link budget (which translates into RF range) and system cost. Wireless transceiver energy consumption is relevant to the system architecture since it affects sensor node range and battery lifetime.

A "thin" gateway that only passes sensor and environmental data via Ethernet or an RF subsystem to the cloud could suffice with a smaller, less -xpensive Cortex-M class MCU, particularly if the communications stack requirements are kept minimal. The advantage of a thin gateway is that intelligence and interoperability between nodes can be managed by cloud services, but the disadvantage is the potential for roundtrip while waiting for cloud services to process and

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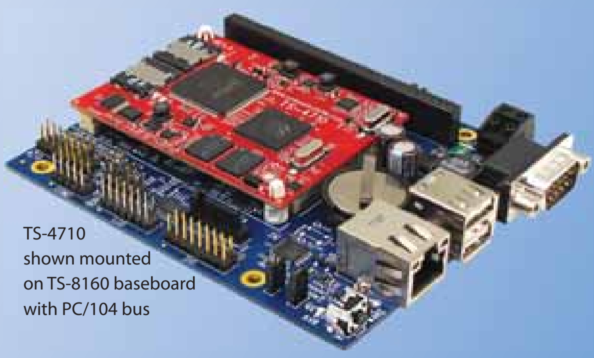

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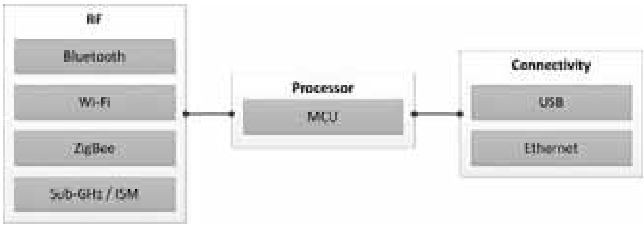

Figure 2: Example of Connected Home Gateway Architecture

Figure 3: Basic Sensor Node Architecture

Figure 4: Advanced Sensor Node Architecture

return command and control data. At the other extreme, a "smart" gateway provides the command and control intelligence onboard and has the advantage of minimal latency and full functionality if the cloud connection is lost. However, smart gateway applications must manage the business logic and must be future-proofed to support system upgrades. Nobody wants to buy a wireless lighting control system today that requires a new gateway tomorrow.

The basic connected home node might be a door sensor, wireless light or a smoke detector, as shown in Figure 3. The MCU is likely to be a low-energy 8-bit device or a 32-bit ARM Cortex-M class device. Considerations for selecting the optimal MCU include memory and processing requirements for the RF stack and sensor management, energy consumption, device footprint and cost. Considerations for selecting the RF protocol include energy consumption, link budget and cost. Typical wireless connectivity options include a proprietary sub-GHz/ISM stack, ZigBee, Bluetooth or Wi-Fi. Of these options, sub-GHz and ZigBee are the most commonly used protocols for home automation as they provide the energy efficiency, long battery life (typically 3-5 years) and extended range required to locate a sensor node anywhere in a house without the inconvenience of having to change batteries frequently. Bluetooth lacks adequate range for many wireless sensor node applications because it there is no provision for repeaters. The power requirements of Bluetooth are also significantly greater than ZigBee. Wi-Fi requires higher power consumption than ZigBee and sub-GHz and is thus not appropriate for battery-powered applications in which the battery cannot be easily recharged.

For sub-GHz star endpoints or flooding-capable RF stacks and space-constrained applications such as sensor nodes, a small footprint, ultra-low energy 8-bit MCU and RF transceiver, or SoC with integrated MCU and transceiver may offer the most cost-effective solution. For ZigBee mesh networking applications, an SoC with integrated MCU and RF subsystems might be the best option, particularly where PCB area is at a premium. Look for MCU and RF transceiver suppliers who offer low-energy 8-bit and 32-bit Cortex-M MCUs and wireless SoCs along with the development tools to simplify implementing the RF stack requirements.

The advanced IoT end node might be a smart thermostat, wireless camera or a white goods device such as a washing machine, as shown in Figure 4. The main system MCU is likely to be a 32-bit ARM Cortex-M or Cortex-A class device combined with one or more secondary 32-bit Cortex-M class or 8-bit MCUs used to offload the primary processor, provide features such as capacitive touch sensing, or optimize the energy efficiency of the system by consolidating sensor functions.

Key considerations for selecting the primary MCU include memory and processing requirements for the RF stacks, sensor and system management, and cost. Energy consumption will be of concern for battery-powered-solutions. Considerations for selecting the secondary MCU include integrated features and energy efficiency. Look for MCU suppliers that offer the most energy-friendly 8-bit and 32-bit MCUs. Considerations for selecting the optimal RF connectivity solution include bandwidth, energy consumption link budget and cost, with ZigBee, Bluetooth and Wi-Fi being the most common options. Wi-Fi is the most widely used protocol for bandwidth-intensive applications such as a wireless camera, while ZigBee is ideal for thermostat applications with multiple nodes and lower data rates. Wi-Fi or Bluetooth provide easy connectivity with smart phones and tablets, which end users typically use to control their connected home applications.

IoT developers must consider this question when optimizing their end node application's energy efficiency: "Which is more important for my low-energy application—suspend current or active current?" The answer depends on the active time duty cycle. Some energy-friendly ARM Cortex-M class MCUs can consume as little as 110 µA/MHz in active mode and 900 nA in deep sleep with brown-out detection active, which means suspend and active operation contribute equally at 0.1% duty cycle at 8 MHz operation. Navigating MCU vendor datasheets to compare performance for low-energy applications can be a challenge. Look for MCU suppliers that offer energy estimation and profiling tools and offer excellent suspend and active current performance.

Another frequently asked question concerns the choice of MCU bit size for IoT applications: "When should I consider using an 8-bit MCU instead of a 32-bit solution for my end node application? Why not migrate to a modern 32-bit MCU based on an ARM Cortex-M architecture that supports expanded memory requirements, native 32-bit math and advanced peripherals?"

For many performance-intensive IoT applications, the 32-bit choice is of course the right answer, particularly where portability and future platform reuse are key concerns. However, for end-node applications where the goal is to fit in the absolute smallest footprint, run a lightweight RF stack or offload computation tasks from the main MCU, a streamlined and highly optimized 8-bit solution is often the right answer. A common misconception of an 8-bit architecture is that it suffers from low code density. In reality, this is true only when attempting 16- or 32-bit math. Control applications such as those found in offloading the main processor do not suffer from low density, and in fact, because 8-bit MCUs have very little overhead code, overall code density for control-type functions is higher than equivalent functions implemented on 32-bit MCUs.

Another common misconception is that 32-bit MCU pricing is comparable to 8-bit options. Developers will hear this from MCU suppliers that are no longer investing in an 8-bit portfolio or competitive in the 8-bit market. The reality is that the 32-bit architecture and peripherals are significantly larger in gate count than 8-bit architectures and consume more silicon area when compared to 8-bit solutions in the same process geometry. Moving to a smaller process geometry shrinks the digital portion (which is about half of a typical MCU) and increases the system cost. When considering a comprehensive IoT solution provider, look for MCU vendors that are actively investing in both 8-bit and 32-bit MCU portfolios, and you will find the most flexible MCU options, the best technical solutions and the best pricing.

The IoT is the vision of a road to a hyper-connected world in which end users have dramatically expanded knowledge and control of their environments—at home, at work and on the road wherever they may be. Elegantly designed and innovative IoT connected devices, apps and cloud services will be most successful in driving the IoT revolution. IoT end nodes and gateways that offer the best combination of energy-efficiency, performance, cost effectiveness and appealing features—regardless of MCU bit size—will be in the driver's seat in the race to our IoT future. Are you ready?

Greg Hodgson is director of marketing for Silicon Labs' microcontrollers group. He joined Silicon Labs in 2004 and has held senior roles in applications and systems engineering focusing on broadcast audio and in marketing focusing on 8-bit and 32-bit microcontroller products. Prior to joining Silicon Labs he was staff engineer at National Instruments focusing on design of audio analyzer equipment. Mr. Hodgson holds a BSECE from Ohio State University.

The Internet of Things Defines the Future RTOS

The RTOS of the future will give embedded systems manufacturers a competitive edge in the IoT by helping them bring industry-leading devices to market faster while reducing risks and development and maintenance costs.

By Prashant Dubal , WindRiver

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 e¬fficiency, improving real-time decision making, solving critical problems, and developing new and innovative user experiences. Billions of intelligent devices and systems make up the Internet of Things. The majority of these "things" are embedded systems, many of which are running a real-time operating system (RTOS).

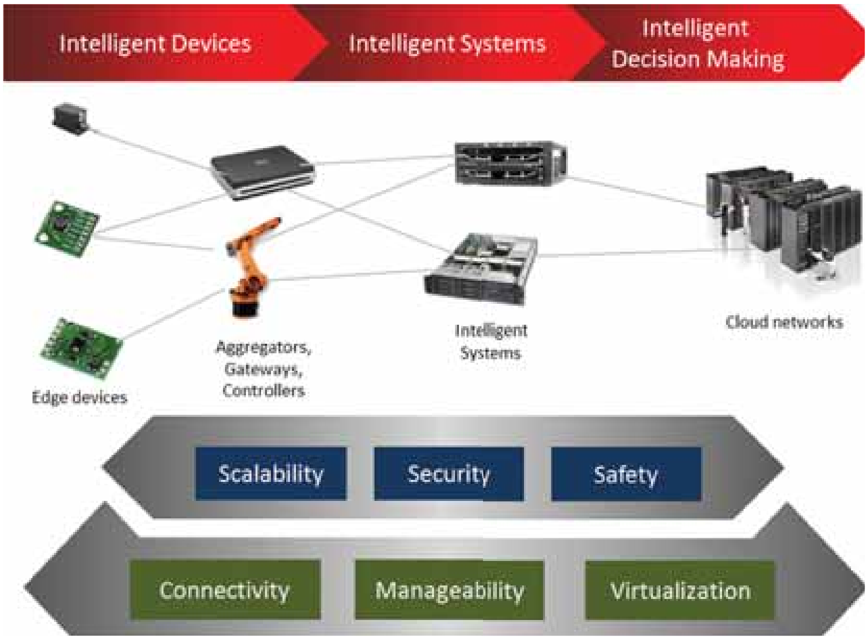

Figure 1: Core attributes and platform features of an RTOS for the IoT

To fully take advantage of the opportunity offered by the Internet of Things, 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 pervasive connectivity of the Internet of Things 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 a cutting-edge feature set that are demanded by the new, highly connected, security-conscious, remotely managed world of machine to machine (M2M) networks and the IoT (see Figure 1).

Scalability

The Internet of Things 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).

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 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.

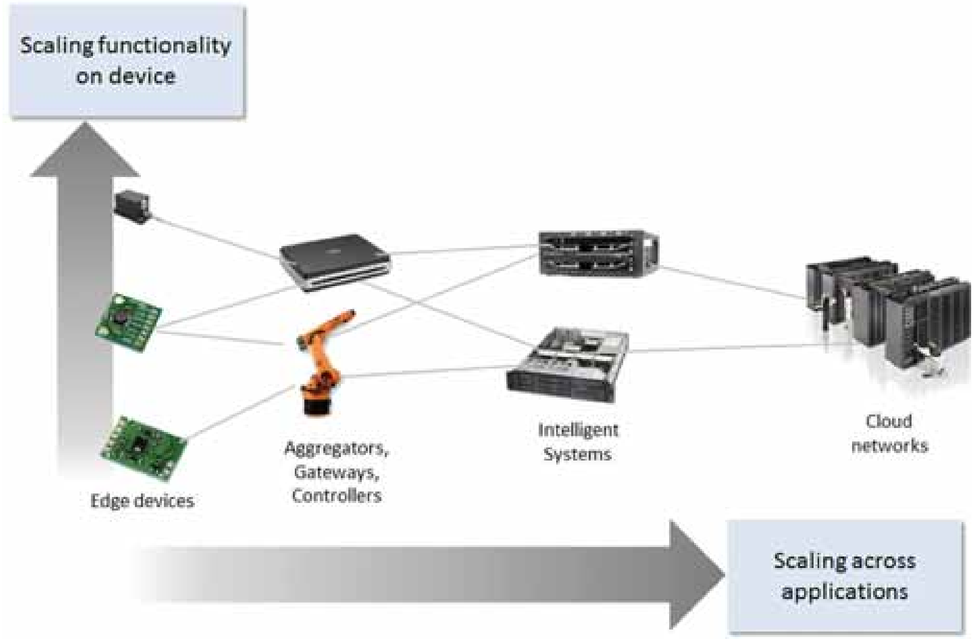

Figure 2: A modern RTOS must support these axes of scalability in order to deliver the most value in the IoT

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. Components for all aspects of the RTOS, above the base kernel, can be provisioned by an application store model.

A modular architecture of an RTOS 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. The 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.

Connectivity

While traditionally isolated, embedded devices are increasingly connected to corporate or public networks for a wide range of applications that are forming the Internet of Things. Small standalone sensor devices are being 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 a 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, a modular nature of the new RTOS 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.

Security

A critical aspect of IoT is security, and next-generation embedded systems must be designed with security in mind as their pervasive connectivity 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 covering (see Figure 3):

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. Operating system-level support for these features is critical since adding them at the user or application level is ineffective, expensive and risky. Take, 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-

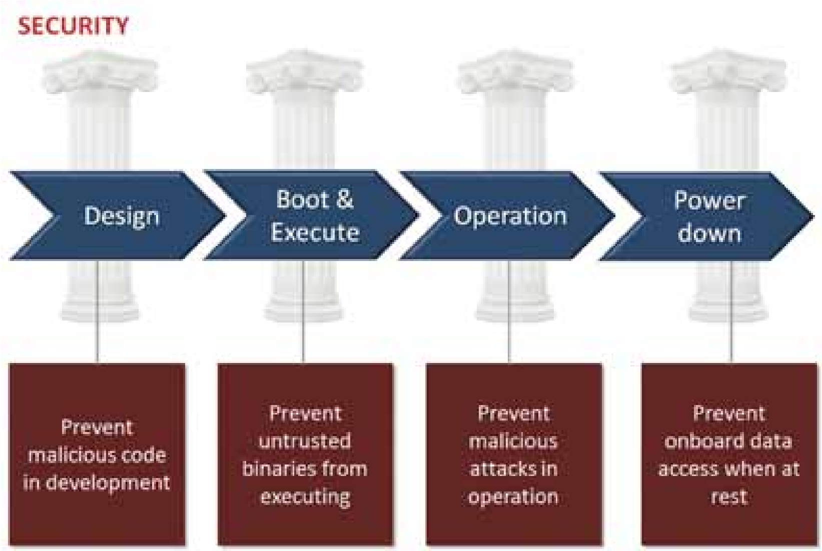

Figure 3: Four pillars of RTOS security

established in aerospace, medical and industrial markets, safety standards are being applied by regulators to new markets. Also, better applications of existing standards to such systems as smart grid meters or medical devices are sought. As standards evolve, manufacturers increasingly look to RTOS vendors to deliver the appropriate safety and security capabilities and certifications, so as to make it easier for them to obtain required safety and security certifications for their end products.

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 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, as well as 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 times 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 related to getting 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.

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 offering 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.

Summary

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 will give 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.

Prashant Dubal is a product owner at Wind River managing VxWorks, development tools and the infrastructure product management team. He has held several roles at Wind River, including technical account manager and solution architect. Dubal has 13+ years of experience in the embedded industry, and holds a bachelor's degree in electronics engineering from Mumbai University, India.