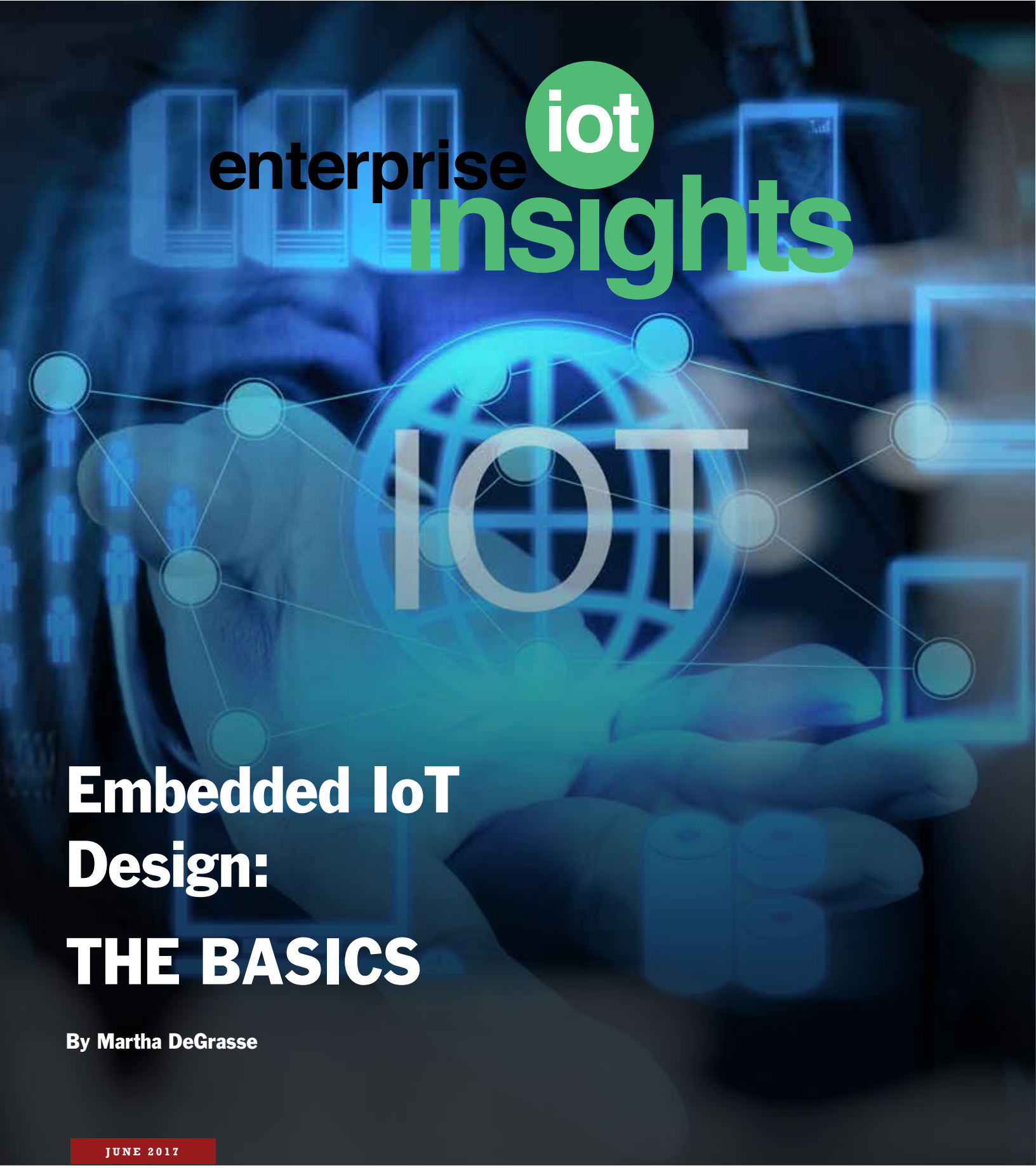



enterprise iot insights

# Embedded IoT Design: THE BASICS

By Martha DeGrasse

JUNE 2017

*Report Sponsors:*

SEQUANS COMMUNICATIONS

LITEPOINT A Teradyne Company

*Featured Analyst*

**Lee Ratliff, Senior Principal Analyst, Connectivity & IoT, IHS Markit**

**Introduction**

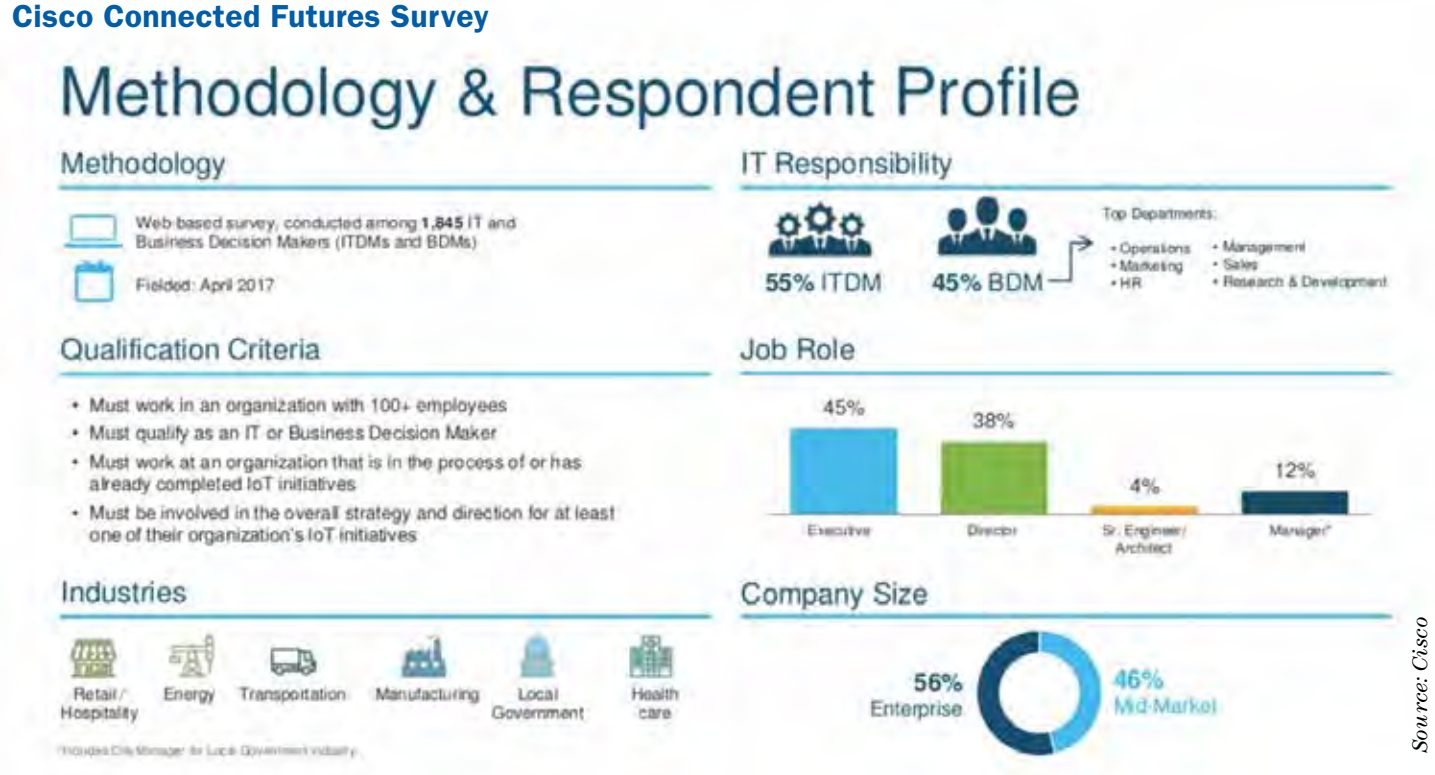
Low-cost sensors, microcontrollers and connectivity solutions are enticing more and more enterprises to explore embedded connectivity for a wide range of devices and systems. But there are many choices to be made. The internet of things is a Wild West of competing standards, networks, platforms, modems, modules and gateways.

The number of decisions and choices can be overwhelming for many companies. According to a recent survey commissioned by Cisco, 60% of enterprise IoT initiatives stall at the proof of concept stage. When projects do advance to completion, they do not always deliver the expected results. One-third of the companies that had implemented an IoT project did not consider it successful, while just over a quarter said their projects were successful.

Cisco found that the more successful organizations often engaged an IoT partner at every stage of the process, including strategic planning, design and architecture, implementation, maintenance and support, and data analytics. Picking the right partners is critical for enterprises, and in order to evaluate potential partners it is helpful to have some understanding of embedded IoT design.

"The decisions made in the earliest stages - - like what kind of application processor you use - - matter," said Joe Cozzarelli, senior manager of IoT embedded solutions at Verizon. "Those elements are where security starts. Security touches every fundamental element of the solution from the

## Cisco Connected Futures Survey




*Source: Cisco*

**"Security needs to be considered in every fundamental element of your solution."** *Joe Cozzarelli, senior manager of IoT embedded solutions, Verizon*

device through the network, to the cloud and back again."

In addition to security, the building blocks chosen for an embedded IoT solution will impact cost, performance, interoperability and scalability. This report will outline some of the basic IoT building blocks and terminology, and offer some practical pointers for enterprises that want to embed connectivity and compute capabilities into assets.

### Hardware and software overview

An embedded IoT node is hardware that includes a basic set of components and software to which applications can be added to accomplish specific tasks. Every IoT node will include at least four basic hardware components:

1. **A sensor and/or an actuator.** Sensors are meant to measure something (light, temperature, motion, sound, activity level, flow rate, etc.) and record information. Actuators cause a device to do something. For example, an actuator can be used to open and close a valve.
2. **A processor, usually a microcontroller.** This is the "brains" of the node, which processes the information collected by the sensor and/or creates instructions for an actuator.
3. **A connectivity chipset.** Nodes can connect wirelessly or through a wired network, but either way they need a chipset that tells them how to communicate with a network.
4. **A power supply.** For wireless devices, this will be a battery. Because IoT nodes are usually small, all the chipsets on the device will typically share one battery.

Like smartphones, IoT nodes are frequently brought to market with chipsets that integrate both the processor and the connectivity chipset. Developers of microcontrollers have embedded short-range protocols like Wi-Fi, Bluetooth, and Zigbee into their chips, and now LTE chip makers like Sequans and Qualcomm are starting to introduce chipsets that integrate modems and microcontrollers.

Analyst Lee Ratliff of IHS Markit explained that one microcontroller can be used to run connectivity software and applications software in an IoT node.

"Typically in the past, the connectivity solution would be a standalone system-on-chip that's just running its own stack, and the application software would be separate, but more and more these days you're seeing those integrated," Ratliff said.

In addition to connectivity software and applications software, IoT nodes need platform software to collect data and manage devices.


*Source: Sequans*

Sequans Monarch SX chipset integrates an ARM Cortex-M4 processor with support for LTE Category M1 and narrowband IoT.

**Lee Ratliff, senior principal analyst at IHS Markit, sees increasing integration of the functionality in embedded IoT chipsets.**

"If you look at IoT in the most rudimentary way… you need to consider three basic elements to create your solution," said Cozzarelli. "You need some kind of connectivity, you need platform elements, and you need applications so you can do something with data you collect."

The value of connected devices is usually in the data they generate, and the devices themselves may not have enough compute power to store or analyze all the data. The data often needs to go to servers in a public or private cloud, or to an intelligent gateway nearer to the endpoints.

Gateway computers can run platform and applications software, so they can be used to manage endpoints and collect data. Most gateways send data onto the cloud for analysis. Some will parse the data first, sending only useful data to the cloud and discarding the rest.

Gateways can also be used as protocol converters. For example, gateways often collect data from a low-power wide area network that uses unlicensed spectrum, and then send that data to the cloud via a cellular network.

For designers of connected systems, some of the biggest decisions are around how much processing and analytics happens in the cloud versus in a gateway or within the IoT endpoints. Microcontroller manufacturers are packing more and more processing power into extremely compact form factors, and that enables more sophisticated edge computing.

"We are of the very strong opinion that the computational capability of a node on an edge-based system is going to scale much faster than bandwidth is going to scale," said Jamie Smith, business and technology director at National Instruments. "So the more computation, algorithms, and compute you can do at the edge, the more you can do in general."

### Development tools: boards, shields and starter kits

Chipmakers want successful developers to create products based on their chipsets, so they offer development kits to get them started. IoT development kits are based on printed circuit boards built around a microcontroller unit. Boards

**"The computational capability of a node on an edge-based system is going to scale much faster than bandwidth is going to scale."** *Jamie Smith, business and technology director at National Instruments*

SEQUANS COMMUNICATIONS

streamLITE™

Introducing

# monarchSX

## Powerful New System-on-Chip for Integrated IoT Devices

### Ideal for Wearables, Trackers and Sensors

MonarchSX is based on Sequans Monarch LTE-M / NB-IoT platform and integrates these components all in a single piece of silicon:

- ARM Cortex-M4 Processor
- Graphics Display Controller
- Media Processing Engine
- Sensor Hub
- <90 mm²

To learn how you can integrate MonarchSX with your IoT application, visit sequans.com/monarchsx

may include connectivity ports for Ethernet, USB, or Bluetooth. Makers of IoT development boards include Texas Instruments, Renesas, Intel, NXP, STMicroelectronics, Qualcomm, Silicon Labs, Raspberry Pi and Arduino.

Arduino, creator of an open-source software protocol that can be used as a controller, makes one of the most popular development boards: the Arduino 101. The board is based on Intel's coin-sized Curie module, which targets developers of wearable devices and industrial edge products. Curie in turn is based on Intel's 32-bit Quark SE system-on-chip. It connects to the internet via a Bluetooth-enabled gateway or smartphone. Intel is planning a software development kit for Curie designed to enable developers to run a real-time operating system on the module.

By adding accessories like cables and wireless connectivity modules to a board, chipmakers can create an IoT development kit. Other ecosystem players have leveraged existing boards to create their own IoT starter kits. For example, AT&T and Microsoft both offer IoT starter kits.

The AT&T IoT starter kit is based on the NXP FRDM K64F development board. The kit includes an Avnet cellular shield, which is based on the Wistron Neweb M14A2A module. The module includes the modem chip and the RF frontend to enable connection to the AT&T network. The starter kit also includes an AT&T LTE SIM card, two LTE antennas, two USB cables, an AC power adapter, and a microSD card.

Richard Finn, lead product marketing manager for IoT solutions at AT&T, said the starter kit targets enterprise developers in big companies and in startup environments.

"Our customers want to get started in IoT even before talking to us," said Finn. "With the kit, these companies can now experiment and make IoT prototypes. **...** Our starter kits allow developers to build IoT projects around cellular connectivity from the start."

### Shields

A shield is a separate board that attaches to a development board to add functionality. Many companies have created shields for popular Arduino boards. For example, Gemalto's Cinterion Connect shield can be mounted onto an Arduino board to add cellular connectivity. The shield includes an LTE Cat 1 modem with 2G fallback, a basic set of sensors and an external antenna.

*Source: AT&T*

The AT&T IoT starter kit is based on the NXP FRDM K64F development board and includes an Avnet cellular shield, an AT&T LTE SIM card, two LTE antennas, two USB cables, an AC power adapter, and a microSD card.

Gemalto plans to migrate the shield to narrowband IoT technology during the second quarter of 2017.

Verizon makes a variety of shields to add LTE connectivity to the most popular development boards. Cozzarelli said the company is working on Category M1 LTE shields for boards made by the leading providers of microcontroller units. He said Verizon is collaborating with a wide variety of ecosystem partners to provide original equipment manufacturers with options, so that they can work with the partners with which they are most comfortable.

"The goal is to be agnostic and helpful to the OEMs. Their job is difficult enough without having to navigate a closed ecosystem," said Cozzarelli.

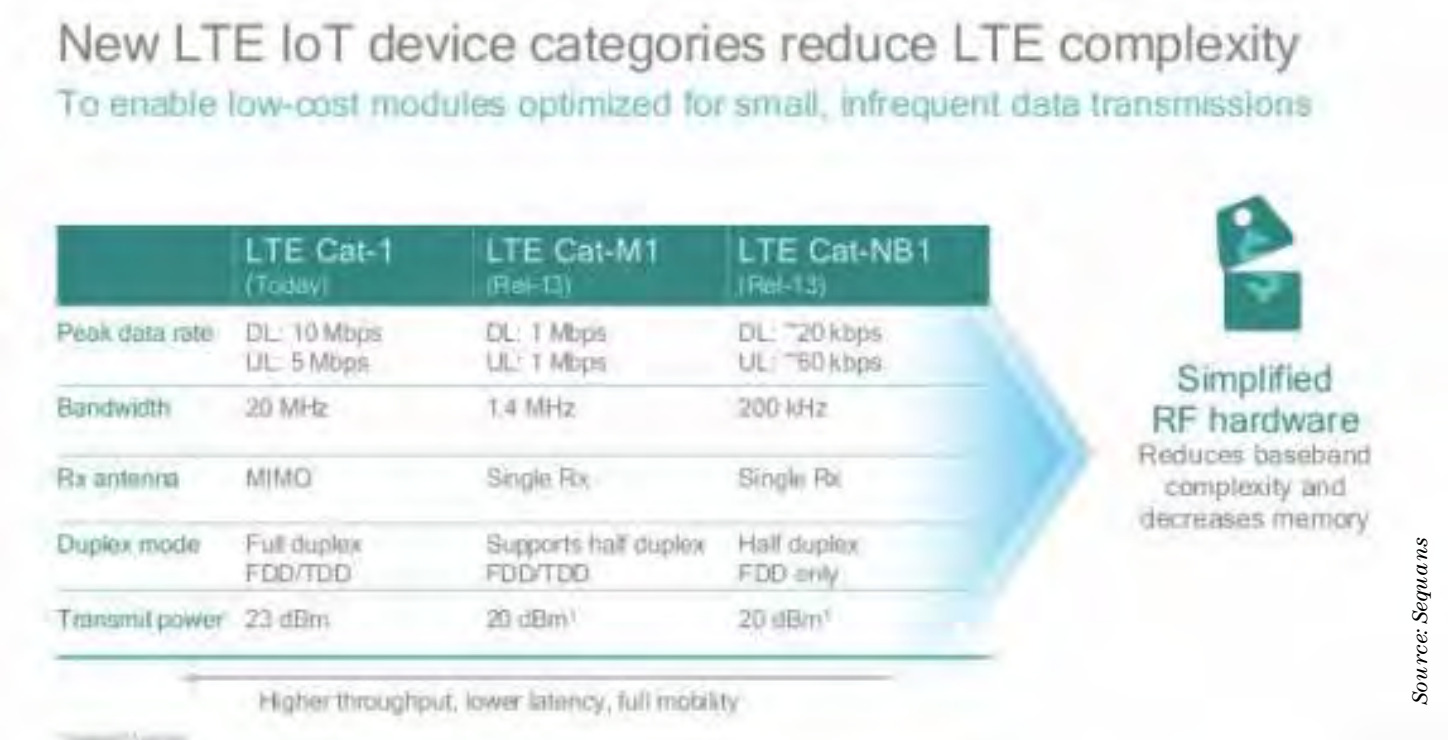
### Cellular connectivity standards

The IoT uses low-power cellular connectivity so that endpoints can operate for long periods of time without recharging. Legacy applications often rely on 2G networks. Newer applications will typically rely on LTE protocols developed specifically for IoT. These include Category 1, Category M1 and narrowband IoT. Chipsets that support these protocols are made by Sequans, Qualcomm and Altair Semiconductor, which is part of Sony.

Source: Gemalto

Gemalto's Cinterion Connect Shield adds cellular connectivity to an Arduino board.

Cat 1 limits download speeds to




Source: Sequans


*Source: NimbeLink*

NimbeLink's CatM1 modem is certified for Verizon's network.

10 megabits per second and limits upload speeds to 5 megabits per second. Cat M1 caps both at 1 megabit per second. Cat 1 uses up to 20 megahertz of bandwidth while Cat M1 uses just 1.4 megahertz of bandwidth.

AT&T and Verizon Wireless now support both Cat 1 and Cat M1. Sprint will support Cat 1 later this year, and Cat M1 is coming next year. T-Mobile US has an IoT business but has not yet released a timeline for Cat 1 or Cat M1.

"We are seeing a lot of demand for cellular radio **...** it does have potential to be bigger than short-range wireless," said Ron Konezny, CEO of embedded module maker Digi International. He said some customers want to add cellular to an existing product and others want to create a brand new design.

Konezny said customers often want to use a specific carrier network. For example, Verizon customers often want to run their IoT deployments on the Verizon network, while some international customers want the AT&T network because it extends into Mexico.

Digi and NimbeLink are two companies that make pre-certified modems for cellular IoT deployments. They combine modem chipsets with RF front end components and then work with the service providers to achieve network certification, so that customers can buy their products and connect directly to carrier networks.

Konezny said U.S. carriers should focus carefully on IoT data plans as they roll out their IoT network technologies. With affordable data plans, customers may start to see cellular as a competitive alternative to dedicated low-power wide area networks like LoRa and Sigfox.

When AT&T launched its Cat M1 network earlier this year, the carrier said data plans would start at $1.50 per month per device, and Cat M1 modules would be priced as low as $7.50.

The next IoT technology expected from U.S. wireless carriers is narrowband IoT, or NB-IoT. Originally developed by Huawei, narrowband

**"We are seeing a lot of demand for cellular radio."** *Ron Konezny, CEO, Digi International*

IoT was defined in 3GPP Release 13. NB-IoT does not support mobility. It uses just 200 kilohertz of bandwidth and caps data speeds at 0.2 megabits per second. It is a half-duplex technology, so data can only move in one direction. While NB-IoT will be less capable that Cat M1 in some respects, it will also be less expensive.

"With narrowband IoT, the major advantage you are getting is really a little bit better price," said Sequans CEO Georges Karam. Sequans makes a modem that supports both NB-IoT and Cat M1. Right now, Karam sees more demand for Cat M1, which he says is applicable to more use cases because it

supports voice and mobility.

"You go to Cat M1 for the majority of the use cases, and NB-IoT for something that is very **...** low-cost and low-speed," Karam said. "For example, if you are talking about a tracker device, NB-IoT could be ideal, assuming the tracker is static. If you start talking about mobility, then you need to go to Cat M1."

NB-IoT has been positioned by some as the cellular industry's direct competitor to low-power wide area technologies like LoRa and Sigfox, which use unlicensed spectrum. Sprint has said it will support NB-IoT on its network, as has Sprint parent SoftBank. Karam expects NB-IoT to be deployed via carrier network software updates, just as Cat M1 was. He said it made sense for AT&T and Verizon to launch Cat M1 before launching NB-IoT, because Cat M1 covers more use cases.

**"If you are talking about a tracker device, NB-IoT could be ideal, assuming the tracker is static. If you start talking about mobility, then you need to go to Cat M1."** *Sequans CEO Georges Karam*

But NB-IoT has the potential to make IoT deployments a possibility for industries that want to connect endpoints in remote locations and need the reliability and security of cellular. NB-IoT endpoints have the potential to maintain connections for months or even years if data is sent only periodically to the network.

"NB-IoT has some significant advantages around the power envelope," said David Formisano, director of IoT strategy at Intel. "Customers I've been talking to are very interested."

Formisano also said he has a lot of customers who are very interested in LoRa, especially in the construction and oilfield industries.

"For the foreseeable future I think we're going to see a proliferation of many, many different standards," Formisano said. "Over the long term there will be some level of standardization."

Analyst Lee Ratliff agreed that trying to decide which IoT connectivity standard will eventually dominate is less productive than trying to decide which standard will be right for a given deployment, now and in the future.

"There's a really wide gamut of requirements and capabilities and there's no one technology that can span all of that in an ideal way," Ratliff said. "The IoT is always going to be a heterogeneous type of network."

**"For the foreseeable future I think we're going to see a proliferation of many, many different standards."** *David Formisano, director of IoT strategy, Intel*


## Focus on creating the next big thing, not on how to test it.

LitePoint test solutions are designed from the ground up to be simple to deploy and simple to use, so your product gets into consumer hands, fast.

LitePoint. **Simply Innovative.**

LITEPOINT

### IoT connectivity modules

Companies that want to develop cellular IoT solutions for a particular market will often choose to develop with an existing module, instead of trying to incorporate an LTE modem directly into their design. There are a number of companies that make cellular IoT modules, including SIMCom, Gemalto, U-Blox, Telit, Sierra Wireless, Digi, Wistron Neweb, Huawei, Wisol, Fibocom, and Foxconn. These companies start with a cellular modem chip and add hardware and software to support common developer requirements, like graphics processing or support for Java. Different modules target different industries and applications. Modules are often marketed to developers who are trying to create an IoT solution for a specific vertical market.

"These companies usually aren't staffed with a ton of RF engineers," observed Adam Smith, marketing director at test equipment maker LitePoint. Using a module as a basis for a design enables IoT solution providers to get to market faster, and to leverage the relationships that module makers have with ecosystem partners like LitePoint.

"We create reference designs for tests and we work very closely with the chipset and the module companies," said Smith. "We work with chipset companies and when that chipset goes in the module, we work with the module companies … and then the IoT product company will buy that module and then at that point we have a solution that just plugs in and we test the wireless."

Like cellular modems, modules will be certified for specific carrier network technologies. For example, when Verizon announced its Cat M1 network, the carrier also announced a list of chips and modules that had been certified for the network.

**"We work very closely with the chipset and module companies."** *Adam Smith, marketing director, LitePoint*

Sequans and Qualcomm are Verizon's modem chip partners, and its module partners include Gemalto, Sierra Wireless, U-Blox, and Telit.

Even when using a certified module, a developer will still need to certify his or her device on the chosen carrier network, unless he or she uses a pre-certified modem solution. "Out-of-the-box" modem solutions will include RF front end components, and in some cases they will include antennas as well.

The carrier certification process can cost tens of thousands of dollars, money that is saved by using a pre-certified modem. However, each modem is likely to cost $50 to $100, so developers who are planning large production volumes may want to invest in the certification process.

### Chip-down designs

A chip-down design is like baking a cake from scratch instead of using a cake mix. Like a cake mix, a module will save time, but it will cost more.

"If you have the skill set to do a chip-down design, you will most likely see lower bill of materials cost and possibly more compact designs," said Verizon's Cozzarelli. "This is clearly a more complicated path to production and requires a deep RF

bench. Module based design has the potential to get you to market sooner and may also make sense if the volumes you are forecasting make it the practical path to production."

Cozzarelli said that at times he has been surprised to see companies attempt "chip-down" designs, only to find out later that those companies had a "strong RF bench," which enabled a successful project.

Qualcomm has created a development board called the 410c for makers who want to attempt chip-down designs using Qualcomm's 410E processor. The 410E targets applications for smart homes, digital signage, medical equipment, industrial automation, digital media players and smart surveillance. Qualcomm said the 410c board can also be used to prototype designs that will be implemented using modules that use the 410E processor.

While the economics of a chip-down design may seem compelling, analysts say that in the long run it may be cheaper to design with a module. Most IoT projects fall apart at the proof of concept stage, so it is less expensive in the long run to fail fast and move on.

Analyst Paul Teich of Tirias Research advises clients to save time by using modules for the parts of a design that are not meant to be unique.

"If it's not a core competence, if it's not going to differentiate your product, then buy it from someone else," Teich said. "A lot of people spend too much time and effort trying to build their own vertical stack and what we're seeing is that the horizontal layers in the stack are starting to become fairly well defined, and security is the very first layer there."

### Security

Last year's emergence of the Mirai malware was a wake-up call for many IoT system designers. Mirai targets connected devices like security cameras that may be running out-of-date versions of Linux. It takes over the devices and uses them to launch network attacks.

Keeping software up-to-date is one way to guard against malware like Mirai, but updating software on IoT devices can be much harder than updating a smartphone or personal computer. These devices may not have daily interaction with humans and they may be hard to access, meaning that remote software updates are required.

Secure boot, secure key storage, secure credentialing, device firewalling and device monitoring are all important elements of IoT security. Analysts say that many of the techniques that will enable secure devices are available now, but developers may choose not to implement them because of the expense.

"The one requirement that


Source: Qualcomm

Qualcomm's 410c development board enables a chip-down design using the 410E processor.


*Source: Redwolf Security*

The Mirai malware attacks were a reminder of the vulnerability of connected devices.

stands out always is 'It's got to be low-cost,' and the only thing I would say to that is 'You can't make it so low-cost that you compromise security,'" said Cozzarelli.

"There's so much opportunity in the future for compromising physical infrastructure, that security is first and foremost," said analyst Paul Teich. "Think about that before you think about anything else in IoT." Teich said most developers should not attempt to create their own security solutions because there are already good solutions on the market.

"Unless you're a leader here, partner on security - buy security," Teich advised.

Buying security can mean choosing chipsets that embed security at the hardware level. Chipsets can be designed with the digital equivalent of fences and walls to partition the different applications running on the chip.

"The root of trust needs to be provided at the hardware level," said Ravi Malhotra, senior software product marketing manager at NXP. "The hardware, the silicon, needs to insure that nobody is able to tamper with the software that's running on top of it."

"Any application that's running on the ARM cores has a dedicated set of resources, whether it's network ports, whether it's access to the crypto engine, whether it's files that are stored on a disk," explained Malhotra. "Everything is strongly partitioned, and that partition is actually enforced by all these blocks which are in the hardware."

Malhotra said these security features can be implemented in software, but NXP builds them into the hardware since even the lowest level of software is vulnerable to attack. He said that hacks can come in several different forms: network attacks, application software that infiltrates the trusted system software, or even physical attacks in which a hacker removes a chip that has been added to a board to secure it.

**"Unless you're a leader here, partner on security - buy security."** *Paul Teich, Tirias Research*

**"The root of trust needs to be provided at the hardware level."** *Ravi Malhotra, senior software product marketing manager at NXP.*

**Conclusion: Best practices for getting to market**

There are many best practices that will expedite an IoT deployment; here are a few that came out of the research for this report.

1. **Don't try to reinvent the wheel.** Companies that develop solutions based on existing modules usually get to market faster than those that attempt chip-down designs. According to research from Gemalto, a successful module-based solution can be ready to deploy in about a third of the time it takes to develop and deploy a bespoke solution.
2. **Invest in intelligence at the edge.** Storing and processing data at the edge means response times can be shorter and it means that IoT devices are not completely dependent on remote servers in the cloud. In addition, edge computing is usually more scalable than cloud computing because processing power can be added to a solution without increasing the network bandwidth to move more and more data to and from the cloud.
3. **Secure your endpoints.** Security is not the place to try to cut costs. Secure boot, secure key storage, key encryption and credentialing should all be requirements for an embedded IoT solution.
4. **Define your deliverables.** Decide what data you want to collect and try to estimate how much network traffic the solution will generate. These decisions will inform your choices about connectivity, data compression, and processing.
5. **Choose the right connectivity.** Think about how your solution will be used today and in the future. For example, if you need to monitor endpoints now, but might ultimately want to control them, you should consider bi-directional connectivity, even if you don't need it right away.
6. **Don't give up.** 60% of IoT projects fail at the proof of concept stage, according to Cisco, but that's just half the story. 64% of the decision makers surveyed by Cisco said stalled or failed IoT initiatives have helped accelerate their organization's investment in IoT.

# Featured Companies


**Sequans**

Sequans Communications S.A. (NYSE: SQNS) is a 4G chipmaker and leading provider of single-mode LTE chipset solutions to wireless device manufacturers worldwide. Founded in 2003, Sequans has developed and delivered six generations of 4G technology and today Sequans has become a leader in LTE chipsets for the Internet of Things (LTE for IoT). Today, Sequans offers two LTE product lines: StreamrichLTE™, optimized for feature-rich mobile computing and home/portable router devices, and StreamliteLTE™, optimized for the IoT, including M2M, wearables, and all types of connected devices for industry, home, and business. Sequans is based in Paris, France with additional offices in the United States, United Kingdom, Israel, Hong Kong, Singapore, Taiwan, South Korea, and China. www.sequans.com


**LitePoint**

LitePoint is the leading provider of test solutions for manufacturers of wireless chipsets, modules, and electronics including smart phones, tablets, and many of the most innovative IoT products. LitePoint products have been used to test over 3 billion wireless devices. Visit http://www.litepoint.com/ for more information.

RCRWireless
INTELLIGENCE ON ALL THINGS WIRELESS

enterprise iot insights

# Need guaranteed leads? Thought leadership? Incremental content marketing opportunities?

Sponsor an RCR Wireless News' multi-platform, editorial program and receive the following benefits:

**Editorial Webinar** – sponsorship includes 250 guaranteed leads, participation as sponsored guest and recognition as sponsor in all promotional materials. Sponsors will receive webinar registration and attendee list, responses to pre and post surveys and polling responses gathered during webinar.

**Editorial Feature Report** – in addition to recognition as sponsor in program promotion, sponsorship includes 250 guaranteed leads, distinct from webinar leads, one-page ad spread or advertorial in feature report, and responses to lead capture survey questions.

For information contact
sales@rcrwireless.com

25% discount
When you sponsor 2 or more programs

**Fast facts about RCR Wireless News digital network (May 2017)**

- 382,000 monthly page views
- 170,000 unique monthly visitors to websites
- 81,000+ opt in newsletter subscribers
- 220,526 monthly video minutes viewed on RCR Wireless News Youtube channel
- 45,000 leads generated annually
- Industry leading demand generation programs and results


http://www.rcrwireless.com/category/free-reports

**UPCOMING 2017 EDITORIAL PROGRAMS INCLUDE:**

**JULY 2017**

*Hardware Series:*
Spectrum new needs and technologies for antenna vendors

**AUGUST 2017**

*Test & Measurement Series:*
Testing and analyzing spectrum interference

*Industrial IoT Series:*
Smart city analytics

**SEPTEMBER 2017**

*Wireless Infrastructure Series:*
Reducing opex through infrastructure

*Analyst Angle Series with Senza Fili:*
Enterprise: evolving role and needs, a growing opportunity for mobile operators

**OCTOBER 2017**

*Analyst Angle Series with ACG Research:*
Meeting latency + reliability objectives for 5G services in fronthaul, backhaul

*Wireless Infrastructure Series:*
Wireless and wireline convergence

**NOVEMBER 2017**

*Test & Measurement Series:*
Optimization in a 5G world: How testing is evolving to meet operator needs

*Analyst Angle Series with Senza Fili:*
IoT: How the infrastructure will have to change

**DECEMBER 2017**

*Industrial IoT Series:*
IIoT manufacturing and smart metering

*Telecom Software Series:*
Management and orchestration in hybrid network architectures

*Each program is limited to three (3) sponsors*