BOXING CLEVER:
CELLULAR ADVANCES
ASSET TRACKING

DATA FARMING:
AGRICULTURE
GETS SMART

Riding High

Bluetooth is booming.
Find out what's next
for this tech trailblazer

NORDIC
SEMICONDUCTOR

Contents

Welcome

Geir Langeland
Director of Sales & Marketing

This is the 50th edition of Nordic's magazine and to mark the occasion the publication has a new look, editorial emphasis, and title.

Since the early 2000s, Nordic's engineers have specialized in the development of ultra low power (ULP) wireless technology. Such technology enabled the company to carve a healthy niche with proprietary 2.4–GHz wireless and ANT+ devices that used much less battery power than competitive products. The proprietary technology led directly to the development of Bluetooth Low Energy, perhaps the fastest growing RF technology ever and now a mainstay of consumer, commercial, and industrial wireless connectivity.

Recently, a focus on the IoT has encouraged Nordic to expand its product offerings. First the company's engineers introduced chips and tools that supported development of products using the popular smart–home and –industry wireless protocols Thread and Zigbee. And in December 2018, after an intensive four year R&D program by its cellular and low power wireless engineers, Nordic launched the nRF9160 SiP, a low power cellular IoT solution, with integrated LTE–M/NB–IoT modem and GPS, for kilometer range wireless connectivity.

Nordic is looking to a future where it is one of the leading suppliers to the wireless local and wide area networks that will form a critical part of the IoT, an industry area that will transform education, work, health, transport, energy, leisure, and just about every other part of our lives.

That makes it the right time for *ULP WirelessQ* to become *Wireless Quarter* and expand both its editorial scope and pagination to cover everything in wireless IoT. I hope you enjoy the new look and content.

> " Nordic is looking to a future where it is one of the leading suppliers to the wireless local and wide area networks that will form a critical part of the IoT

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News

The latest developments from Nordic Semiconductor

Open source cellular asset tracker 'a world first'

Finnish open source electronics specialist, Ruuvi Innovations, has laid claim to the world's first open source, multipurpose, industrial grade 5G gateway, environmental sensing, and asset tracking node. The company says the product will enable wide scale IoT deployments in applications and environments not previously viable.

Ruuvi Node is a maintenance free, industrial grade node solution and employs a Nordic Semiconductor nRF9160 SiP cellular IoT module and an ultra low power nRF52840 multiprotocol Bluetooth LE SoC. Ruuvi Node will also include an embedded solar panel to support energy harvesting, a full range of environmental sensors, GPS positioning, and NFC for securely reading device IDs and configuration parameters. A large capacity 40–Wh battery and support for external power for high duty applications are included.

In addition to being able to function as a standalone IoT asset tracker and sensor node, the device will also be able to act as a cellular gateway for any of Ruuvi's existing RuuviTag Bluetooth sensor beacons located nearby.

"We're really excited about employing Nordic Semiconductor's brand new [low power cellular IoT] module in our new product," says Lauri Jämsä, Founder and CEO of Ruuvi Innovations. "Pairing the LTE–M and NB–IoT cellular module with our multi–use energy harvester node enables totally new kinds of asset tracking, gateway, and sensor uses. The products enables large IoT deployments in places where it previously wasn't viable."

The company says its open source approach has gained interest from customers such as Bosch Connected Industry. Ruuvi aims to launch the product during Q2 and Q3 2019.

Ruuvi Node enables new asset tracking applications such as container cargo

Mobile firm Telenor and Nordic partner to capitalize on IoT

With strong IoT growth expected across multiple industries, two world class Norwegian companies, mobile operator Telenor and Nordic Semiconductor, are collaborating to make it easy to develop IoT applications on 4G networks using fast and robust wireless technology.

Last autumn, Telenor became one of the first firms worldwide to rollout a 4G wireless network that supported both versions of cellular IoT (LTE–M and NB–IoT). Then, in December, Nordic announced worldwide availability of its nRF9160 SiP multimode module that offers both cellular IoT technologies.

"Using new technology from Nordic Semiconductor, we have developed a tool that makes it easier for developers to create good solutions that use IoT over 4G," says Ove Fredheim from Telenor Bedrift.

"The development tool is delivered with SIM cards from Telenor. We are the first mobile phone company in the world to offer this service, and we now hope that more people will have the opportunity to take advantage of the enormous opportunities the Internet of Things can provide."

"That Nordic's nRF9160 SiP can be used for both NB–IoT and LTE–M makes it possible to prototype and test both technologies to find out which is best for an IoT application or sensor," says Peder Rand, Product Manager for Cellular IoT at Nordic Semiconductor.

"This functionality, combined with support for GPS and the nRF9160's small size, is unique to the cellular IoT market. The nRF9160 also has the market's lowest current draw, which enables new battery–powered applications with many years of battery life."

In Brief

NORDIC CERTIFIED AS ALIBABA IoT PARTNER

Nordic's nRF52 Series has received certification under the Alibaba IoT Ecosystem Partner program. Established in 2018 by Alibaba Cloud IoT, part of e–commerce giant Alibaba, the program aims to drive and develop a stronger, more mature IoT sector. To receive certification under the program, partners are required to support the AliOS Things Operating System and have AliOS Things certification.

PRIMARY SCHOOLCHILDREN TO RECEIVE MICRO:BIT

A four–year, $2.3m program will see the micro:bit distributed to 100,000 year 5 to 7 pupils in Norway's primary schools to stimulate interest in computing and the IoT. The nRF51822 SoC powered compact programmable computer is designed to teach children IT and coding skills. Nordic has already donated over 3000 micro:bits to institutions in Norway.

Logistics & Transport

Smart rope load sensors assist crew when mooring vessels and enhance safety

Norwegian shipping company, Wilhelmsen Ships Service, has launched a series of Bluetooth LE smart ropes, designed to assist ship crews when mooring vessels in port.

The Timm Mooring Assistance smart ropes comprises up to 22 ropes—depending on the size of the vessel being moored—each fitted with a single load sensor to provide feedback on safety and efficiency parameters. For example, the load and temperature data can alert crew members to the load distribution between individual ropes, safety alerts for potential rope snaps, as well as predicting the lifetime of individual ropes. Access to this data allows the crew to take immediate corrective action in case of a problem.

Sensor data from the ropes is wirelessly relayed to a 'collector box' on the vessel using Bluetooth 5 technology's long range feature enabled by Nordic's nRF52840 SoC. The collector box comprises a Bluetooth LE Ethernet router which relays data to the vessel's bridge via a wired LAN for immediate analysis by crew members via a dashboard on a tablet or PC.

The Bluetooth 5 nRF52840's new radio architecture with on-chip power amplifier (PA) provides -96-dBm RX sensitivity and a maximum output power of 8 dBm.

Bluetooth 5 tech's long range feature enables the smart rope to transmit wireless signals—in a tough environment dominated by RF absorbing substances such as steel and water—to a collector box sited up to 100 meters away from the sensor

"It is essential for us to use a low power consumption solution with a global standard as our customers are operating vessels around the world," says Tore Strand, Subject Matter Expert at Wilhelmsen Ships Service. "The high link budget and long range feature, which help overcome the challenging RF environment, are the most important capability of the Nordic SoC for our application."

By the Numbers

$271 million
in revenue

Nordic Semiconductor has reported full 2018 revenue of $272 million, representing growth of 14.9 percent over 2017's full year revenue. The result comes on the back of continued strong performance in Bluetooth LE, particularly in the first half of 2018, that saw revenue grow 50 percent year-on-year. For Bluetooth LE; healthcare and wearables markets grew revenue significantly in 2018 over 2017, up 58 percent and 17 percent respectively.

1 trillion
semiconductor unit shipments

According to analyst, IC Insights, annual semiconductor unit shipments, including integrated circuits, optoelectronics, sensors, and discrete devices, grew 10 percent in 2018 and surpassed the one trillion unit mark for the first time. According to IC Insight's 2019 *McClean Report – A Complete Analysis and Forecast of the Integrated Circuit Industry*, semiconductor unit shipments climbed to 1,068.2 billion units in 2018 and are expected to climb to 1,142.6 billion in 2019. Starting in 1978 with 32.6 billion units, the CAGR for semiconductor units is forecast to be 9.1 per cent through 2019.

Smart Health

Insulin monitor records dosage

Taiwan based DIABNEXT, a healthcare services company, has launched an insulin injection monitoring and recording device called CLIPSULIN. The device attaches to all commonly used disposable and reusable insulin pens and employs a vibration sensor to accurately detect insulin dosage and record injected insulin units.

Using Bluetooth LE or NFC wireless connectivity provided by Nordic's nRF52832 SoC, the data is automatically transmitted to the user's smartphone, from where the patient can then retrieve important information from the DIABNEXT app. The iOS and Android app functions as a digital logbook for a diabetes patient, not only recording their treatment data, but also enabling the patient to monitor blood sugar levels and physical activity.
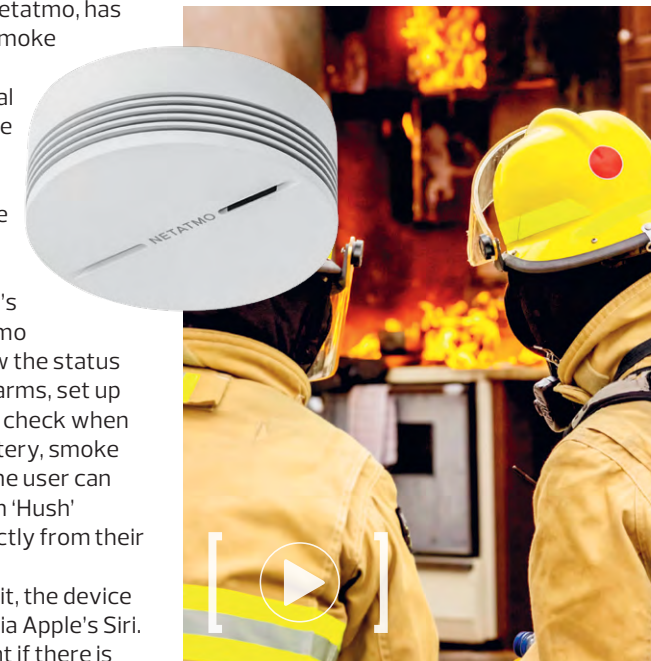
Smart Home

Apple HomeKit–compatible alarm pinpoints smoke source

French smart home company, Netatmo, has released a Bluetooth LE smart smoke alarm that not only triggers an 85-dB alarm but also sends a real time alert to a user's smartphone indicating in which room smoke has been detected.

The Smart Smoke Alarm can be paired to the user's smartphone or tablet using Bluetooth LE connectivity provided by Nordic's nRF52832 SoC. From the Netatmo Security app the user can review the status of one or more Smart Smoke Alarms, set up sound test reminders, as well as check when the unit last self checked its battery, smoke sensor, and Wi-Fi connection. The user can also use the Smart Smoke Alarm 'Hush' feature to silence the alarm directly from their smartphone.

Compatible with Apple HomeKit, the device can be also be voice controlled via Apple's Siri. Users can ask the voice assistant if there is smoke in the home or if the device's batteries are working properly.

The Smart Smoke Alarm is powered by two non replaceable lithium batteries with a 10-year lifespan, which covers the entire service life of the device. Battery life is enhanced by the nRF52832's design which minimizes power consumption with features such as the 2.4–GHz radio's 5.5 mA peak RX/TX currents and a fully automatic power management system that reduces power consumption by up to 80 percent compared with Nordic's nRF51 Series SoCs.

Nordic partners with one of world's largest cellular data carriers

Nordic Semiconductor has struck a deal with one of the world's largest international cellular carriers in voice, data, and IoT services, iBASIS. The deal with the company makes global LTE–M and NB–IoT cellular IoT connectivity automatic and instant when using Nordic's nRF9160 SiP module.

Nordic's cellular IoT customers get instant high quality global connectivity without having to negotiate and manage multiple relationships with individual local cellular carriers around the world. Using eSIM technology, the developer can use iBasis as a single global connectivity supplier, with a single contract, and a single monthly bill.

"iBASIS believes that for IoT to succeed, connecting things should be easy," says Ajay Joseph, CTO of the company. "We're delighted to partner with Nordic Semiconductor to provide an eSIM for Nordic's cellular IoT modules. We are reducing complexity, making it easy to support Nordic's customers' global deployment, using a single eSIM, for a remotely programmable on demand service."

A globally–usable iBASIS eSIM with 10 MB of free data is now provided with all nRF9160 Development Kits. The developer then registers the eSIM on Nordic's nRF Connect for Cloud website to then connect to iBASIS's Global Access for Things network and gain access to an entire range of configurations, monitoring, and connectivity services.

Power transmitter wirelessly charges consumer electronics

Powercast Corporation, a U.S. based technology company, has launched the first FCC and ISED approved solution for "wireless power over distance" for mobile consumer electronics.

Employing a 915–MHz RF signal, the PowerSpot transmitter outputs up to 3 W Effective Isotropic Radiated Power (EIRP) (and associated ID data) that can directly power or charge up to 30 portable low power devices—including fitness bands, wireless headphones, game controllers, hearing aids, and a variety of smartcards—that are fitted with Powercast's patented embeddable Powerharvester technology.

The Powerharvester solution consists of a proprietary converter chip and a boost converter chip that once integrated in end devices, harvest energy from the PowerSpot wireless transmitter as well as ambient RF energy from other RF sources.

The chips then convert that energy to DC power that can then be used to charge batteries or directly power the enabled devices.

Acting as the main 'brain' of the PowerSpot TX91503 wireless transmitter, the 32–bit Arm Cortex M0 microprocessor in the Nordic nRF51422 SoC makes the transmitte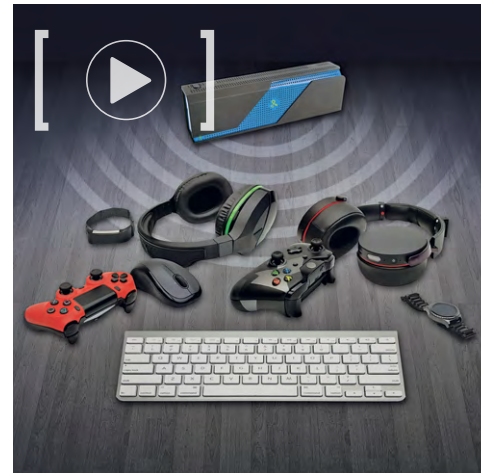r configurable and controllable. For example, it configures and controls the transmitter's 915–MHz oscillator/PA subsection that feeds the power antenna and turns off the transmitter when wirelessly connected devices are fully charged. The nRF51422 also provides Bluetooth LE wireless connectivity for communication between the user's end devices and the transmitter to monitor the battery status of connected devices.

The PowerSpot wireless transmitter automatically powers enabled devices it detects within its charging zone and stops charging when no devices are within range. According to the company, the wireless transmitter can charge and power smaller, less power hungry devices—such as smart cards and basic sensors—at distances up to 24 meters while for more power hungry devices like game controllers, headphones, and smartwatches, the most suitable charging range is typically 30 cm or less.

Biomedical engineers develop wearable respiration monitor

Researchers at the University of California have developed a wearable, disposable respiration monitor that provides high fidelity readings on a continuous basis and is designed to help children with asthma, cystic fibrosis, and other chronic pulmonary conditions.

The inexpensively produced sensors were created by University of California biomedical engineers using the popular children's toy Shrinky Dinks with thin sheets of plastic that are painted or drawn on and then shrunk with heat. Placed in two positions—one between the ninth and 10th ribs and another on the abdomen—the devices track the rate and volume of the wearer's respiration by measuring the local strain on the application areas. Signals from embedded sensors can be transmitted via Bluetooth LE and displayed on a smartphone app. The information gleaned could, in the case of asthma, help warn of an oncoming attack.

"The current standard of care in respiration monitoring is a pulmonary function test that's often difficult to perform and limited in terms of the [information] it provides a patient's respiratory health," says Michael Chu, a graduate student researcher in biomedical engineering at the university. "The stretch sensors allow users to walk around and go about their lives while vital information on the health of their lungs is being collected."

NB–IoT successfully tested in German smart buildings

Europe's largest telecommunication provider, German–based Deutsche Telekom, in collaboration with real estate service provider, ista, has successfully conducted wide scale field testing of an NB–IoT network in apartment buildings across Cologne and Bonn.

The pilot project was a part of a technology partnership between the two companies to investigate how NB–IoT can be optimally used for the end–to–end communication of battery powered devices in buildings.

According to the telecom giant, in 99.75 per cent of the tested metering points across some 60 apartments, it was possible to establish a stable connection that enabled rapid, energy optimized data transmission that exceeded the performance of existing technologies.

"We have over 23 million IoT capable devices in use throughout Europe and the number is increasing every day," says Achim Dicke, CTO at ista. "The successful field trial shows that NB–IoT has everything needed to become a global interoperable standard in the M2M sector."

nRF52811 brings Bluetooth 5.1 Direction Finding to advanced wireless applications

Direction finding adds precise positioning to Bluetooth low power wireless technology, opening up many new applications

Bluetooth LE products such as beacons have benefited from Bluetooth 5 tech's received signal strength indicator (RSSI) capability which enables a crude measure of proximity. This estimate of position is employed for applications, for example, that rely on triggering a notification on a smartphone when the beacon detects a consumer close by. Unfortunately, the system is limited to approximate positional estimates which restrict its usefulness.

Now, however, the latest revision of the Bluetooth Core Specification, Bluetooth 5.1, brings precise positioning of things in three–dimensional space to the popular low power wireless technology. (See page 24.)

"Bluetooth 5.1 Direction Finding is a very important addition to the technology," says John Leonard, Senior Product Marketing Manager with Nordic Semiconductor. "Nordic believes it can have a similar impact for indoor situations as GPS did for outdoor positioning. Where GPS has fundamentally changed the world on a macro scale for cars, people and objects, Direction Finding will have a similar impact on the micro scale inside buildings and properties."

The Bluetooth SIG predicts some 400 million Bluetooth "location services" products per annum by 2022.

Bluetooth 5.1 SoC support

Following its strategy of bringing new capabilities of Bluetooth LE to developers as soon as they're adopted by the SIG, Nordic has added an SoC to its nRF52 Series that supports Bluetooth 5.1 Direction Finding. The nRF52811 was unveiled at Embedded World in Nuremberg, Germany, in February this year. "The nRF52811 joins the comprehensive family of Nordic multiprotocol products that address the widest scope of applications found today," says Leonard.

The SoC expands Nordic's nRF52 Series platform by adding a device that combines Direction Finding with the low cost of Nordic's baseline nRF52810 and the multiprotocol support of the mid–range nRF52832 and advanced nRF52840. The SoC is a good option as a connectivity chip for applications that feature a companion microprocessor. Examples include home and industry gateways that demand low power wireless support for Bluetooth 5, Thread, and Zigbee smart applications such as those used with smart light networks, HVAC, and security systems. The SoC is also a good choice for cost-constrained Bluetooth beacon applications requiring Bluetooth 5 technology's extended range or for tomorrow's precise indoor location systems.

The nRF52811 is accompanied by an updated version of Nordic's nRF5 SDK which includes the S112 SoftDevice (a Bluetooth 5 certified RF software protocol "stack") and a large selection of examples, libraries, and drivers, making it simple for a designer to quickly start product development.

The chip is produced in a 6 by 6–mm QFN48 package with 32 GPIOs, a 5 by 5–mm QFN32 with 17 GPIOs, and a 2.5 by 2.5–mm wafer level CSP32 with 15 GPIOs. All packages are compatible with those of the nRF52810 enabling reuse of the same PCB layout. All versions of the nRF52811 are available now with full capabilities—including Bluetooth 5 Long Range, Bluetooth 5.1 Direction Finding, and Zigbee 3.0—made available through software releases during 2019.

Finding the way

Bluetooth 5.1 Direction Finding enables positioning solutions that not only rely on RSSI but also the actual direction of a signal. This improves accuracy significantly and opens up new applications. There are two types of methods for determining direction: Angle of arrival (AoA), where the direction of the received signal is calculated; and angle of departure (AoD), where the direction of the transmitted signal is calculated. Direction finding can operate in either two or three dimensions depending on the selected design complexity and antenna array.

In AoA applications, for example, a device transmits a specific direction–finding packet, using just one antenna. The receiving device is equipped with multiple antennas and the incoming signal from the transmitter arrives at the antennas at slightly different times. Using the time shift information an algorithm can precisely calculate the three–dimensional position of the receiver relative to the transmitter.

The nRF52811 SoC is a good choice as a transceiver for both the AoA or AoD scenarios.

Tech check

The nRF52811 includes a 2.4GHz radio (4dBm output power with –97dBm sensitivity (at 1Mbps in Bluetooth 5 mode)), 64MHz, 32–bit Arm Cortex M4 processor, and 192kB Flash and 24kB RAM memory. The nRF52811 SoC also includes a wide range of analog and digital interfaces

N52811
QFAAAA
1836AA

Smart City

Air quality sensors drive cleaner cities

Urban zones are using the IoT to limit pollution and improve citizens' lives

> " Tomorrow's smart cities must offer fresh hope for fresh air by using the big data generated by the IoT to bring air pollution under control

At the top of the list of challenges for the world's megacities is air pollution. Alarmingly, nine out of 10 people in the world breathe air containing high levels of pollutants and it's leading to ill health. In 2016 there were 4.2 million ambient pollution related deaths from heart disease, strokes, lung cancer, and chronic respiratory diseases, according to a 2018 World Health Organization (WHO) report.

Air pollution levels are determined in part by the amount of particulate matter (PM) per cubic meter. So-called PM2.5 (2.5 μm diameter) particles are the most dangerous to human health because they lodge deep in the lungs for many years.

PM2.5 is created by households, industry sectors like waste management, agriculture, and transport. Research from various international bodies has revealed that approximately 30 percent of PM2.5 alone comes from vehicle exhaust emissions. While this number is significant and explains why cities work hard to encourage electric vehicles, it also suggests rapidly growing cities need to do more than implement cleaner transport if air pollution is to be substantially reduced. Tomorrow's smart cities must offer fresh hope for fresh air.

The power of big data

How can governments, private enterprises, innovators, and individuals do more to deliver on this promise? The answer lies in accessing and analyzing the 'big data', generated by large networks of wireless air quality sensors. Such technology can provide the detailed environmental and health information needed to bring air pollution under control. And the more sensors the better; larger networks generate greater volumes of more accurate data, and more accurate data means greater insight into how and where pollution is generated and the effectiveness of air quality improvement initiatives.

In the same way awareness and social conscience can lead citizens to reduce water usage during periods of drought, it's expected that urban populations will choose to become part of clean air solutions if they're informed and educated. For example, people are likely to choose public transport rather than their own cars when advised via live updates (triggered by weather, temperature, traffic flow, and travel pattern that have been shown to increase particulate pollution).

A scalable IoT solution

Through the large-scale deployment of wireless sensors— widely integrated with existing city infrastructure— accurate volatile organic compound (VOC)- and PM-levels can be delivered in real time to authorities who can then use the information to trigger preventative action. For example, if high PM levels are detected in a particular area of a city, smartphone notifications sent over local

Need to Know

Polluted city air makes its way indoors and sensor makers are addressing the challenges of poor domestic air quality with new technology. For example, Yongin, Korea-based technology company, SoluM, makes the Keyco Air which monitors air quality (as well as humidity and temperature) in the home, in turn detecting unhealthy or potentially harmful levels of pollution.

Bluetooth LE beacons or the cellular network would be able to immediately alert people to the potential risks, offer advice on how to proceed or detail temporary driving restrictions.

Some major cities have already embraced this responsibility. For example, in 2014 Chicago began creating a citywide network of environmental air quality sensors mounted to lamp posts, with a long-term goal of being able to analyze the collected data to predict and prevent poor air quality incidents. More recently, Hong Kong has used smart lamp posts fitted with IoT sensors for real-time collection of the city's air quality and vehicle flow data.

These initiatives have received a boost through the commercial availability of compact low power sensors. This technology combines a sensing element (for example, the metal oxide semiconductor (MOS) monitor of a VOC sensor) with a wireless receiver incorporating a powerful embedded processor to perform some basic edge computing before data is wirelessly transmitted across a network.

For a city's sensor data to be crunched and distributed into databases of meaningful, shareable information, hundreds or thousands of wireless sensors must be wirelessly connected to the Cloud. The solution lies in Bluetooth LE connectivity in the sensor, combined with cellular IoT gateways. These gateways leverage a new

generation of LTE-M/NB-IoT modems connected to established cellular infrastructure that aggregate and further process data from a local sensor network before passing to the Cloud via LPWANs. The falling cost of low power cellular IoT is even convincing some OEMs to prototype sensor products combining Bluetooth LE and cellular IoT inside a single device.

It's a powerful combination and will become further enhanced as Bluetooth LE mesh networks take advantage of the long range and high throughput advantages of Bluetooth 5 tech to encourage the deployment of many more smartphone configurable, compact, inexpensive, and low maintenance monitors. Such networks will gather the vast amount of real time data needed to make accurate predictions of air quality for specific places and times.

Technology offers help

WHO guidelines call for PM2.5 to be limited to 25 μg/m³ daily mean and 10 μg/m³ annual mean. With figures such as Beijing's 90 μg/m³ (2018) annual mean, Los Angeles' 18 μg/m³ (2018) annual mean and Paris' peak reading of 55 μg/m³ in February 2018, the world's largest cities need plenty of help to approach those levels. That makes for a lucrative market for OEMs developing air quality IoT applications for smart cities, but better yet, striving for purer air ensures citizens of the world's megacities will enjoy a much healthier future.

Svein-Egil Nielsen
CTO: Nordic Semiconductor

What makes cellular so reliable?

Standards compliance only takes vendors so far, robust wireless connectivity comes from 'ownership' of every part of the system

What's the most reliable wireless technology? The answer is cellular. For example, armed with decent 4G coverage and a smartphone data plan, consumers find cellular (is more robust, more secure, and often just as fast as Wi-Fi. This reliability is even more remarkable considering cellular is the most complex wireless technology ever designed.

Just a handful of highly experienced vendors design and manufacture the cellular base stations and network infrastructure across the globe. This experience, together with the positive pressure that comes from a highly competitive market, leads to 'ownership' of the whole system. For example, the three largest vendors in the cellular infrastructure sector (Ericsson, Nokia and Huawei) make it their business to own every component that impacts system performance.

At the other end of the wireless link, the mobile handset, the same is true; a handful of vendors make it their business to deeply understand every element of their product's construction. And when they've designed and built their solutions, they test and retest, then continue to make performance improvements throughout the product's lifecycle.

Theory collides with reality

Control over every aspect of infrastructure and end points is the key to reliability not just in cellular but in any wireless application. It's the difference between theory (off-the-shelf software or hardware intellectual property (IP) conforming to a standard should work perfectly together) and reality (unforeseen factors that impact real world performance are numerous, so while compliance to a standard helps, it is by

no means a guarantee of reliability).

As a former Chair of the Bluetooth SIG and now CTO for wireless chip vendor Nordic Semiconductor, I know only too well that even with a solid, universally agreed and vetted open standard underpinning a wireless technology there are numerous subtle differences between end solutions from different suppliers. These nuances cause unprecedented interoperability problems.

All wireless connectivity relies on successfully linking to another party's device. In Bluetooth that's things like smartphones, tablets, and PCs. In cellular, it's base stations. If products using wireless technologies can't connect reliably and transfer data securely, it's 'game over'; the products are destined for poor reviews and lackluster sales.

Moreover, wireless connectivity can throw up technical glitches that are hard to resolve. Diagnoses and fixes only come when a vendor can test and adjust every software and hardware technical parameter that could affect wireless performance. This detailed control isn't easy; it requires designing and building the connectivity technologies in-house— from the physical layer and protocol stack to development and test tools— instead of buying in modular, low cost, off-the-shelf IP. But vendors that take an ownership and control path are destined to be the winners as wireless connectivity becomes ever more pervasive.

Riding High

Bluetooth is buoyant and the technology's trailblazers are pioneering applications unimagined when the specification was adopted. WQ reports

In Short

In two decades Bluetooth technology has become ubiquitous

The introduction of Bluetooth LE in 2010 dramatically expanded the technology's range of applications beyond consumer to industry and commerce

Next in line for Bluetooth LE are indoor location services and high quality audio

North Yungas Road, known locally as 'death road', is an 80-km stretch of 'highway' connecting La Paz and Coroico in western Bolivia. A popular destination for thrillseeking bike riders, the dirt track offers an unbroken 64 km downhill stretch peppered with sheer drops, treacherous hairpins, and frequent rockfalls. The consequences of an error are severe.

Few would attempt this ride without a companion, but thanks to the now near ubiquity of wireless technology, a support crew is on hand almost anywhere, even on death road. Late last year, U.S. cycling equipment company Specialized released its ANGi sensor. Attach ANGi to your helmet, pair it via Bluetooth LE to your smartphone, and the device's built-in accelerometer and gyroscope will detect any potentially dangerous incident. If a fall is detected, the sensor relays the data to the user's smartphone, and if the alert isn't cancelled by the rider via the partner app, a text alert will be sent to the rider's emergency contacts notifying them of the accident and its location. It's a salient reminder how far Bluetooth has come for a technology yet to see its 21st birthday, and originally conceived by Swedish cellphone manufacturer Ericsson as a means to enable a short range radio link between computer peripherals.

Ericsson—alongside Nokia, Intel, IBM, and Toshiba—met in 1996 and made two fundamental decisions: Create an interoperable protocol forming a standard and form an industry alliance whose charter was the development of an open specification for hardware and software. In May 1998 the Bluetooth Special Interest Group (SIG) came into being, and by the end of that year, membership had swelled. Within two years not only was the Bluetooth 1.0 Specification launched, but the first Bluetooth cellphone and wireless headset were too.

Things moved quickly. The Bluetooth SIG's membership ballooned and last year nearly four billion Bluetooth devices were shipped. Today, Bluetooth is native in smartphones, tablets, and PCs; wireless headphones and speakers are found in practically every home; nine of ten new cars that roll off the production line are Bluetooth equipped; wearables are universal; we have not just smart homes, but smart industries, and cities. We live on 'Planet Bluetooth'.

This rapid adoption is founded not only on the open standard but also, crucially a power frugal version, Bluetooth LE, as a hallmark element of the Bluetooth 4.0 Specification in 2010. Bluetooth LE was born out of a 2001 Nokia venture to develop a wireless technology which would operate from coin cell batteries and allow peripherals such as heart rate monitors to connect to the Finnish company's handsets. After further development

Specialized's Angular and G-Force indicator (ANGi) incorporates GPS tracking, crash detection, and safety beacon in a compact package

with partners including Nordic Semiconductor, the technology was released to the public in October 2006 under the brand name Wibree. The advent of Bluetooth LE was a game changer. Its ultra low power consumption enabled a new way of gathering data from sensors without comprising range or requiring frequent battery recharge or replacement. As a result, the applications to which Bluetooth tech could be applied broadened exponentially.

BLUETOOTH EVERYWHERE

Health and fitness companies in particular sat up and took notice, launching a range of wearables that gathered movement data and sent it to the wearer's smartphone. According to analyst Euromonitor, in 2014, 28.8 million wearable devices shipped; last year the figure was 125 million. By 2022, wearable shipments are forecast to reach nearly 200 million, a 594 percent surge in just eight years.

Over that time the concept of what a 'wearable' is has changed as dramatically as their sales. From basic wristbands that counted steps, wearables today have become sophisticated analytical tools, with some even offering medical grade information. While sales of basic wearables are now in decline, the forecast for more sophisticated wearables is anything but.

"The decline in mature markets is by no means worrisome as these markets are in the midst of transitioning to more sophisticated wearables," says Jitesh Ubrani, Senior Research Analyst for International Data Corporation (IDC). "While the previous generation of wearables was focused on providing feedback like step counts, the current and upcoming generations are far more capable and are on track to becoming prescriptive and diagnostic tools."

Where sports and fitness once dominated, healthcare applications are now increasingly finding their feet in the wearables space thanks to both an inevitable disintermediation between patients and medical practitioners in an overworked healthcare sector and a recognition by the U.S. Federal Drug Administration (FDA) that wearable technology is an ally in health management.

"We know consumers and healthcare providers are increasingly embracing digital health technologies to inform everyday decisions," says FDA Commissioner, Scott Gottlieb. "From fitness trackers to mobile applications tracking insulin, these digital tools provide consumers with a wealth of valuable health information. Clinical evidence demonstrates consumers who are better informed about health make better and more efficient decisions."

As a result, the FDA has promoted guidelines to fast track the previously lengthy FDA approval process that has held back wearable tech companies from trying to get medical-grade technology into consumer devices, and the result has been demonstrable. Smart asthma inhalers, Bluetooth LE blood glucose monitors, epinephrine autoinjectors, and supervised care wearables for seniors, to name a few, have proliferated; to the point analyst Markets and Markets claims the global market for medical wearable devices will reach $12.1 billion by 2021.

Left: Bluetooth LE sensors will enable farmers to increase yields and enhance crop quality

Center: Bluetooth tech promises to make Bolivia's infamous 'death road' a little safer

Below: Intelligent home products such as smart speakers wouldn't exist without Bluetooth tech

> "
> Bluetooth technology is one of the key technologies underpinning the consumer wireless revolution

THE FUTURE HOME

Thanks to Bluetooth LE, there is little in today's home that can't be prefixed with "smart". Locks, lights, smoke alarms, appliances, even toilets ... all can now be made intelligent.

Smart home device manufactures have several low power wireless protocols to choose from, but Bluetooth has one key advantage, its unique interoperability with smartphones and tablets. The smartphone's user interface is not only the easiest and best understood way for consumers to interact with home automation devices, it can also act as the gateway between the smart home device and the Internet. As a result, the global installed base

of smart home products reached 361 million devices in 2017 and was expected to expand to about 560 million devices by the end of 2018, at a value of some $28 billion.

Strengthening Bluetooth LE's suitability for smart home applications was the release of the Bluetooth mesh 1.0 specification in July 2017. Mesh networking allows devices within a network to communicate using packets relayed via other nodes without recourse to a central hub device. The mesh specification has strengthened Bluetooth tech's hand for future smart home application development, a fact recognized by the Bluetooth SIG earlier this year with the formation of a new Smart Home Subgroup.

"For the smart home market to grow, it needs true global wireless mesh networking standards that can meet the reliability, security, and performance needs of the market," says Dian Fan, General Manager of Xiaomi IoT Platform. "We're confident that Bluetooth mesh is one of those standards and will enable tremendous growth and innovation in home automation for years to come."

If Bluetooth mesh will be key to smart home growth, it is also set to play a key role in another area of Bluetooth LE's expansion, the industrial IoT. Networks that can collect data to monitor and control production lines, inventory, and energy, rely on sensors and devices at the edges of the network. These are capable of receiving and sending data via the network to the Cloud, so a central system can analyze and react to, for example, remove bottlenecks or perform predictive maintenance. According to a PwC report, *Industry 4.0: Building the digital enterprise*, industrial products firms will invest $907 billion per year through 2020 in realizing the smart factory. "Industry 4.0 is no longer a 'future trend' – for many companies it is now at the heart of their strategic and research agenda," states PwC. "The major focus of investment will be on digital technologies like sensors or connectivity devices."
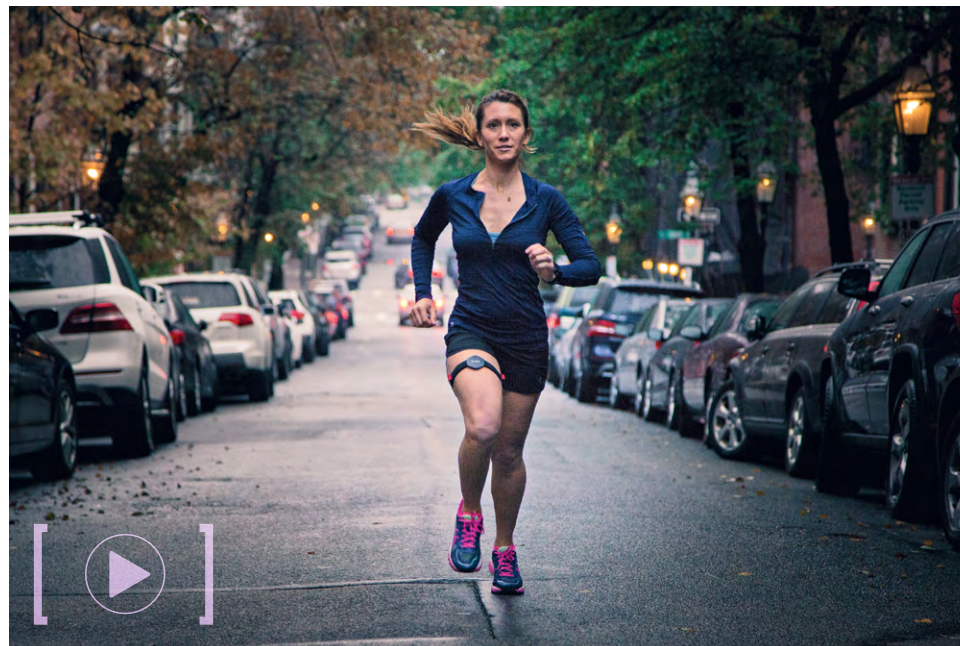
BLUETOOTH NEXT?
The rise of Planet Bluetooth has been enabled both by constant enhancements to the Bluetooth Specification and the ultra low power wireless connectivity solutions that power increasingly sophisticated applications.

"Over the last 20 years, Bluetooth has ... been one of the key technologies underpinning the consumer wireless revolution," says Stuart Carlaw, Chief Research Officer

Bluetooth beyond:
Between a ship and a hard place

Bluetooth 5 tech's long range functionality has expanded Bluetooth LE applications. Wilhelmsen Ships Service has embedded a Nordic nRF52840 SoC load sensor in a network of ropes to assist ship crews when mooring vessels in port. In a challenging environment dominated by RF absorbing substances such as steel and water, the Timm Mooring Assistance load sensors provide safety feedback via Bluetooth LE wireless connectivity on potential rope snaps up to 100 m away, enabling the crew to take immediate corrective action in case of a problem. (*See page 4*.)

Above: A new generation of wearables such as the Humon Hex Muscle Monitor, which determines muscle hemoglobin saturation, is moving wearables from feedback to diagnostic tools

Right: Bluetooth 5.1 Direction Finding will enable smartphone users to pinpoint their location in indoor situations such as underground train stations and airports

at ABI Research. "The Bluetooth community continues to grow ... as the technology enhances its specification in order to retain its prominent position."

For example, the introduction of Bluetooth 5 in mid 2016 added some key capabilities to Bluetooth tech, notably increased range and throughput. While (theoretically) quadrupling range, Bluetooth 5 comes with the trade off of reduced data rates, longer transmission times, and a greater risk of interference. But for some applications—notably smart agriculture—the compromise is worth it.

Using big data to make informed farming decisions that can bolster production and profit has obvious appeal but retrieving this data from many acres has proved economically prohibitive. With Bluetooth 5 sensors that roadblock is removed. (*See page 18*.) Agricultural IoT and big data farming is on the rise, and according to a BI Intelligence report, more than 75 million IoT devices will be installed for agricultural purposes by the end of this decade, a rise of 150 percent from 2015.

DIRECTION FINDING
Another application of Bluetooth technology anticipated to loom large in 2019 and beyond is direction finding, thanks to the latest update to the Bluetooth Specification, Bluetooth 5.1. Together with received signal strength indication (RSSI), Bluetooth 5.1's Direction Finding feature yields is an improvement in location accuracy from meters to centimeters, opening up new possibilities for accurate indoor positioning of assets and people. (*See page 24*.)

"Location services is one of the fastest growing solution areas for Bluetooth technology, and is forecasted to reach over 400 million products per year by 2022," says Mark Powell, Bluetooth SIG Executive Director.

"Since the introduction of Bluetooth Low Energy in 2010, developers have been able to create powerful, low cost location services solutions for a variety of applications spanning across consumer, retail, healthcare, public venues, and manufacturing," says Andrew Zignani, Senior Analyst, ABI Research. "The new direction finding feature ... will further accelerate the adoption of Bluetooth for location services in existing markets, while unlocking business opportunities for new applications."

AUDIO OVER BLUETOOTH LE
As for Bluetooth LE's next horizon, you need look no further than audio. The proven reliability of classic Bluetooth audio has not only inspired manufacturers to design the audio jack out of current iterations of smartphones, but with over 1.2 billion annual shipments of Bluetooth audio and entertainment devices—headsets, headphones, speakers, and earbuds account for over 80 per cent of that market—the opportunity for Bluetooth LE to overcome the limitations of classic Bluetooth is obvious.

"Classic Bluetooth doesn't handle true wireless stereo [TWS]," explains John Leonard, Tactical Marketing Manager at Nordic Semiconductor. "The conventional system sends

> " With Bluetooth 5.1 tech's Direction Finding feature, location accuracy will improve from meters to centimeters

the stream to one device, which then splits the channels via a wire. TWS also requires two separate devices to receive the audio stream and emit each channel in perfect synchronization. So, while [the current system] is great for banded headsets linked by wires, totally wireless devices have had to rely on proprietary solutions."

The Bluetooth SIG is working to formalize an Audio Profile supported by Bluetooth LE to be formally adopted by the Bluetooth SIG later this year. "Work is ongoing on the new audio specification, but we anticipate this profile to be well-suited to hearables and other low-power devices," says Leonard. "Power consumption could be reduced by as much as 10 times, which could have just as big an impact on product development as the increased speed."

Bluetooth LE is now omnipresent in our lives. Whether the consumer knows it or not, there is almost certainly no home in the developed world that doesn't contain at least one Bluetooth LE device. Moreover, the home is just the start. Whether you are a mountain biker hurtling down death road in Bolivia, a farmer standing in his field in midwestern Iowa, or indeed simply trying to pinpoint your position as you navigate your way around the Louvre in Paris, make no mistake, you are now on Planet Bluetooth.

Need to Know

In 2016, the global IoT market was valued at $157 billion. By 2020, it is anticipated to grow to $457 billion with applications for smart cities, the industrial IoT, connected health, and smart homes contributing almost 85 percent of that total

Is classic Bluetooth heading for obsolescence?

To all but the most tech-savvy consumer, Bluetooth is Bluetooth, a means of neatly pairing their smartphone with their wireless headphones, smartwatch, car, speaker, or smart home product. The adoption of Bluetooth LE in the Bluetooth Core Specification Version 4.0 in 2010 may have passed without fanfare from the general public, but for developers it was another matter, and as such consumers have been enjoying the inherent benefits of Bluetooth LE ever since.

Initially, the pros and cons of classic Bluetooth versus Bluetooth LE depended on the individual demands of the application. For applications powered by coin cell batteries and therefore requiring low power consumption, Bluetooth LE was the answer, and the wearables market for one, exploded as a result. But there was a drawback – throughput. While both classic Bluetooth and Bluetooth LE offered a similar theoretical range of around 100 meters, Bluetooth LE could only support a raw data bandwidth of 1 Mbps, approximately half that of classic Bluetooth. This was not a problem for wearables or other devices transferring small amounts of data infrequently, but impractical for continuous, data heavy applications, not least audio streaming to wireless headphones and speakers. As such, classic Bluetooth had its place.

But subsequent iterations of the Bluetooth Core Specification have not so much leveled the playing field, as bulldozed it completely. With the introduction of Bluetooth 5 in mid 2016, a 2 Mbps 'high speed' mode allowed developers to increase the throughput near to classic Bluetooth levels at the cost of a small range reduction. A 125 or 500 kbps 'long range' mode meanwhile enabled an increase in range to hundreds of meters. Current work by the Bluetooth SIG to introduce an audio-over-Bluetooth LE solution later this year will erode classic Bluetooth's position further. While classic Bluetooth provides a satisfactory audio solution, a revised Audio Profile based on Bluetooth LE promises not only enhanced battery life, but synchronization between left and right audio channels, support for playback streaming to multiple devices, and broadcasting.

The Bluetooth SIG's 2018 Bluetooth market update forecasts that by 2022, 97 percent of all Bluetooth chips shipped will include Bluetooth LE technology. All the consumer cares about is that Bluetooth works, is easy to set-up, and doesn't rapidly drain their smartphone or Bluetooth device battery. Bluetooth LE does all that and more. For now, classic Bluetooth retains an edge in mains or large battery powered applications such as PCs and smartphones, but a few more amendments to the Bluetooth Specification could see Bluetooth LE's parent consigned to history.

Boxing Clever

The shipping container is a glorious success, transporting over $7 trillion of goods across the globe annually. But things still get damaged, and logistics firms want answers

In Short

Shipping containers move 90 per cent of consumer goods around the world in 750 million unit movements annually. The system is fast and inexpensive

Transport and logistics companies have embraced IT and IoT technology to handle documentation and keep track of individual shipping containers

But damage to the cargo within, such as that caused by impact, high temperature, and water, runs to billions of dollars per year and is often undetected until arrival at the customer

Low power cellular IoT and short range wireless technology offers an inexpensive, low maintenance solution to monitoring and reporting the condition of goods inside a shipping container

Forget the World Trade Organization (WTO), the Panama Canal, Amazon, FedEx, and the unimpeded transfer of money across borders, the shipping container is the thing most responsible for the revolution in international trade. According to *The Economist*, a U.K. based newspaper, this humble steel box has been more of a driver of globalization than all trade agreements in the past 50 years put together.

The secret of the shipping container's success is "intermodalism", or the ability to be conveyed seamlessly by two or more forms of transport. Goods can be packed into a standard (ISO) container, with double doors at one end, measuring 8 ft (2.43m) wide by 8.5 ft (2.59m) high and one of two lengths, 20 ft (6.06m) and 40 ft (12.2m). And then transported by purpose designed ship and offloaded onto a train or truck without the contents ever being disturbed. (Or even the doors being opened; only around 5 per cent of shipping containers are visually inspected in the U.S. and even fewer in Europe.) Compared with what went before, this is a brave new world.

As Marc Levinson explains in his book *The Box: How the Shipping Container Made the World Smaller and the World Economy Bigger*, before shipping containers were first used in 1956, shifting cargo 15 km by land transport and loading onto a ship at the port of departure and then unloading it onto to a truck or train for a 15-km trip to its final destination cost just as much as all the rest of a 6,500-km export voyage.

The ease with which goods can be moved in containers and the cost savings that this convenience yields has prompted a boom in international trade; according to the World Bank, in 1973, global container port traffic was four million TEUs ('twenty-foot equivalent (container) units'). That rose to 225 million TEUs by the turn of the century, and a staggering 753 million TEUs by 2017. Shanghai alone handled over 37 million TEUs that year.

It would seem that transporting cargo efficiently and inexpensively around the world is a challenge that's been solved. The shipping industry has computerized the documentation and shipping containers are carefully tracked as they cross the high seas. Many containers carrying high value cargo are fitted with GPS tracking devices and radio transceivers that can connect to the IoT. But what happens inside those 38 or 76–m³ boxes during transit remains literally and figuratively shrouded in darkness. That represents an opportunity for IoT entrepreneurs.

BREAKING THE BOTTLENECK
Loading and unloading of individual goods in barrels, sacks, and wooden crates from shore–to–ship and back again changed little in the two millennia from the Roman Empire until half way through the 20th century. Things started to change when American Malcom P. McLean realized it would be much simpler and quicker to have one container that could be lifted from a train or truck directly onto a ship without having to unload its contents. A decade later, on 23 April 1966, Sea–Land's *Fairland* sailed from Port Elizabeth, U.S., to Rotterdam, The Netherlands, with 236 containers aboard in the first international voyage of a container ship.

Fifty one years later, Orient Overseas Container Line (OOCL) took delivery of the *OOCL Hong Kong*, the first container ship in the world to surpass 21,000 TEU capacity. This is a ship so enormous it will dedicate its working years to sailing from Asia to Northern Europe via Africa, avoiding the Panama Canal through which it is too large to pass.

The *OOCL Hong Kong* is one of a class of Ultra Large Container Ships (ULCS) comprised of those with a capacity of 10,000 TEUs and over. *Maritime News* reports that at the beginning of 2018 there were 451 ULCS operating, while another 129 were on order for delivery by 2020. And, if the market remains buoyant the 30,000 TEU vessel could be with us within a decade. Elsewhere, analyst McKinsey forecasts modest but continuous growth in cargo moved by shipping containers of between 1.9 and 3.2 per cent for the next five decades. It seems nothing is about to threaten the shipping container's dominance.

LOST AT SEA
While the shipping container is a remarkable invention that has transformed the logistics industry over the past 60 years, in its basic form it's merely a cheap steel box – albeit a robust one. The true value, of course, is in what the container holds. According to analyst, Statista, that value

> With today's technology, it's practical to deploy dozens of wireless sensors inside a single shipping container to monitor the condition of the cargo

is considerable; global shipping container trade is believed to account for approximately 60 per cent of all ocean trade, equating to 1.83 billion tonnes and $7 trillion in 2017. At any one time, 20 million shipping containers are moving across the oceans and continents, and 90 percent of everything a consumer purchases arrives by ship. That means shipping containers hold everything from ball bearings to Bugattis, cherryade to Château Mouton Rothschild, and jeans to jet turbines.

Considering the volume of container ship traffic and the fact that the ocean is hardly known for its benevolence, the modest amount of valuable cargo lost overboard is remarkable. According to Shipping and Freight Resource, the World Shipping Council's (WSC) surveys in 2011, 2014, and 2017 accurately determined how many shipping containers were lost at sea. The WSC found that during a nine year period, on average, 1,582 shipping containers fell overboard each year and of those 64 per cent were lost due to catastrophic events such as storms and ship collisions. Such limited attrition is testament to the mechanical systems used to secure containers to ships.

Once the shipping containers make it to land, they

rarely go missing. The boxes are somewhat obtrusive, so criminals prefer to empty the container and move the ill-gotten gains via other methods. The shipping industry is secretive, making the exact cost of theft hard to ascertain but *Ship Technology Global* reports "The marine industry loses billions to cargo theft and cargo loss each year."

The thieves are getting cleverer too with the magazine explaining: "Gangs were resorting to 3D printing to copy security devices to break into containers. Criminals were then creating replicas of well-known cable seals and using these to obscure any signs of theft, such as a broken seal."

While losses due to theft are a pain, the impact remains relatively small and is improving. Of much higher priority is knowing where the cargo is and whether it's in good condition. Logistics companies are good at the first, but less so at the second.

KEEPING TRACK
Each shipping container (and its cargo) is documented through a computerized paper chain. A sheaf of notes accompanies the container including the one that identifies the box's own "unit number" (duplicated on the container itself), the Bill of Lading (the main maritime document identifying shipper, consignee, and goods), and the Commercial Invoice (which contains more explanation about the type of cargo).

Keeping track of the actual shipping container is also a well-honed process. The ship's position is precisely tracked via GNSS and the other forms of transport upon which the shipping container travels are increasingly being equipped with their own GNSS tracking solutions reporting to remote supervisors via cellular modems. For some high-value cargoes, commercial solutions exist combining a sensor, data logger, long range radio transceiver, and GPS tracking system integrated into a single unit. The device is secured to the outside of the shipping container, and can transmit through shipboard communications systems, even if the container is deep within the hull. The device also

stores location history and reports it back when in range of land-based cellular networks. The downsides of these devices are their cost and high maintenance due to short battery life.

But even if a shipping container makes it to the destination in good time there is still much that could have gone wrong inside. And the first time the customer knows about it is when the doors are opened. Damage to cargo is a major problem for logistics companies and the most common causes include: Loss of integrity of the shipping container (for example, due to the doors being broken and coming open or road traffic accidents denting the container); dropped containers; heat damage from external fires; contamination of the cargo from previous goods carried in the container; infestation by pests; water exposure due to container leakage; refrigeration failure; and frozen cargo (when it's not meant to be frozen).

There is also the unique phenomenon of "container rain". This is the condensation and moisture that builds up in a sealed shipping container. Loading at a humid location makes matters worse. Many goods also release moisture during transport, compounding the problem. During transit, the moisture drips onto the rest of the cargo and leads to damage such as corrosion, warping, and mildew.

Bluetooth LE sensors paired with low power cellular IoT modems offer a solution for precisely monitoring the environment inside a container as it travels, and triggering notification if something goes wrong. Unlike the expensive units that track the geographical position of the shipping container, these IoT devices are inexpensive, compact, able to form networks, and run for months from small batteries. With today's technology, it's practical to deploy dozens of these sensors inside a single shipping container, even to the extent of one for every piece of a high value cargo.
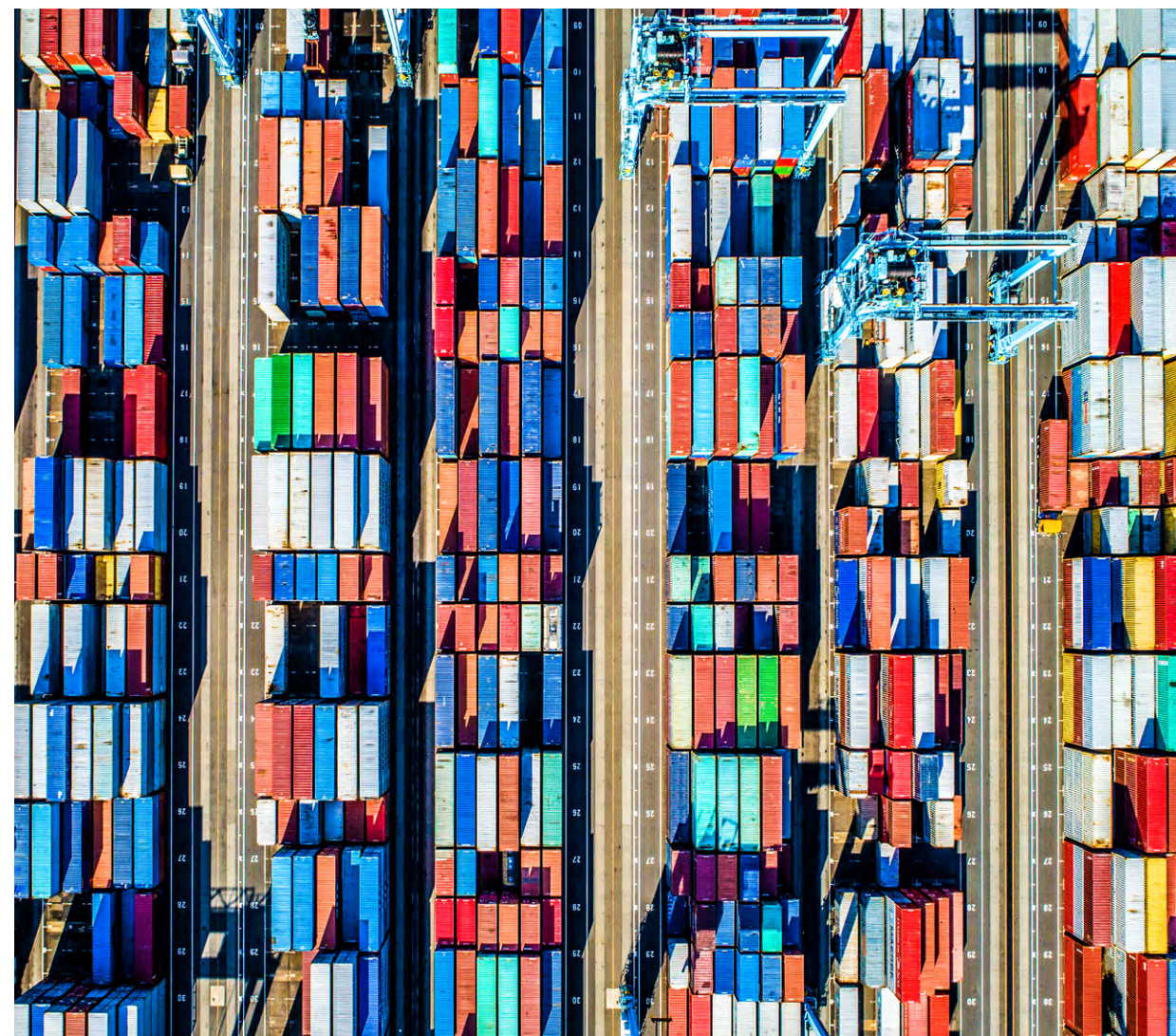
Bluetooth LE devices can be equipped with proven monitoring technology such as accelerometers to measure impact and monitor vibration, and sensors to check temperature, humidity, and even air quality. These sensors are interoperable with smartphones allowing authorized personnel the opportunity to determine current and historical conditions in the container at any time simply by using an app on a smartphone.

Such sensors can transmit data to a module combining Bluetooth LE with a low power cellular IoT modem which offers sufficient memory and computational power to store weeks of data and process that data for instant upload to the Cloud (via an external antenna on the container) once the container is in range of land based cellular networks.

WHAT NEXT?
The logistics industry is rapidly embracing technology to keep track of the tens of millions of shipping containers that are on the move at any moment. And analyst Deloitte reports: "[Transport and Logistics] companies have embraced the IoT in diverse settings ... including real time tracking of shipments, warehouse-capacity optimization, predictive asset maintenance, route optimization, improved last-mile delivery, and more".

The next step is to extend that embrace to what's inside the containers. Pressure to do so is coming from both

The birth of intermodalism

For thousands of years the work of loading and unloading a ship was slow, cumbersome, dangerous, and incredibly labor intensive. Worse yet, the ship—a major capital asset—could easily spend more time in port than at sea while workers shifted cargo in and out of impractically tight spaces below decks. Some basic inventions—for example, rope for bundling timber, sacks for carrying coffee beans, and pallets for stacking and transporting bags or sacks—improved the situation. But the spread of railways highlighted the inadequacies of the cargo shipping system. It took forever to move cargo from hold to railcar.

American Malcom P. McLean worked out it would be much better to drive truck trailers onto ships and transport the whole trailer to the next port, where it could be attached to a new truck and driven away. The drawbacks were the valuable cargo space taken up by the wheels on the trailers, and the lack of an opportunity to stack trailers on top of one another. That problem was solved by lifting just the truck container into the ship, leaving the intact vehicle behind. In May 1956 the modern container era was born when McLean's ship, the *Ideal-X* set sail with 58 33-ft aluminum containers aboard.

Standardization was encouraged by the U.S. during the war in Vietnam. The military favored the 20-ft (6.06-m) container (later extended to 40-ft (12.2 m) which quickly became the norm.

"Intermodalism" enables shipping containers to be moved seamlessly between ships, trucks and trains making the process highly efficient. That efficiency reduced costs and encouraged adoption: According to U.S. magazine, *The Atlantic*, it's less expensive to ship Scottish cod 16,000 km in a refrigerated container (known as a "reefer") to China to be fileted there and then sent 16,000 km back to Scotland than it is to pay Scottish workers to do the job. Granted, Chinese labor is inexpensive, but shipping costs are even lower, often at less than $1 per kilometre. Further, shipping by containers is quick: In his book *The Box: How the Shipping Container Made the World Smaller and the World Economy Bigger*, Marc Levinson cites the example of a 13.5-tonne container of coffee makers that leaves the factory in Malaysia by truck and is then loaded aboard a ship to cover the 14,000 km to Los Angeles in 16 days. The day after, the container is mounted on a train bound for Chicago, where it's transferred immediately to a truck headed for Cincinnati. The near 18,000-km trip from the Malaysian factory to the Ohio warehouse is covered at a rate of over 800 km per day, at a cost lower than a first class air ticket for the same route.

customers and cargo insurers in order to address the damage that the U.S. National Cargo Security Council estimates has an annual global financial impact of $50 billion.

Some companies are ahead of the curve. Bosch Connected Industry, for example, offers a system called Nexeed Track and Trace which uses wireless technology to send information about the current location and status of a shipping container to the Cloud. This system allows schedulers to view location, and information about temperature, vibration, and humidity. The scheduler quickly knows if conditions are not right for the cargo inside.

The investment in low power cellular IoT and short range wireless technology as part of a wider deployment of IoT for transport and logistics companies could also yield much more than just reduced insurance claims and happier customers. Access to real time and historical information about what precisely has happened to millions of shipments opens up the potential for many new business models. These business models can either be taken up by transport and logistics companies themselves or, as analyst McKinsey forecasts: "By digital start-ups and additional moves by tech giants like Amazon, Alibaba, and Uber, [who plan to] take over and extract value from customer relationships."

The first half century of the shipping container's success was due to its intermodalism, the second half looks set to be driven by connecting the boxes to the IoT.

Need to Know
Ruuvi Innovation's RuuviTags, Nordic Semiconductor-powered Bluetooth LE sensors, form part of Bosch Connected Industry's "logistics 4.0" solution, Nexeed Track and Trace. The Bosch Connected Industry's product is designed for asset tracking in logistics applications. Ruuvi is now developing the Ruuvi node, based on Nordic's low power cellular IoT module, which is able to operate as an IoT gateway for a network of RuuviTags
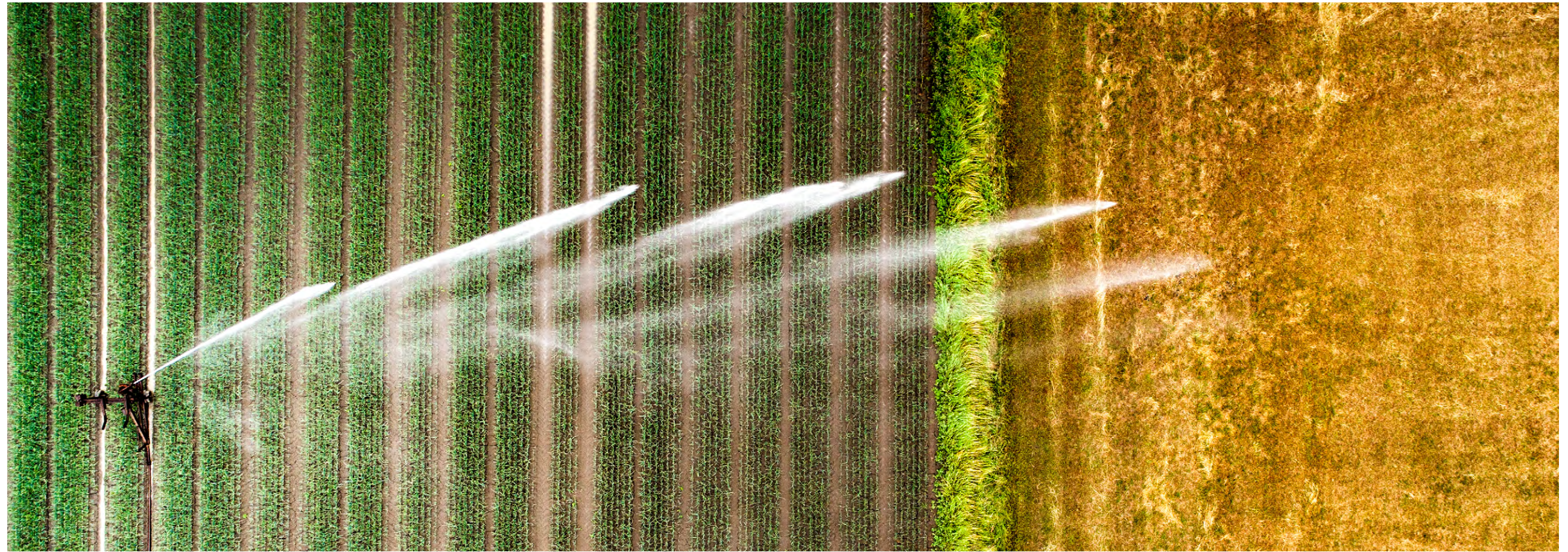
Data Farming

The IoT promises to help farmers save water yet boost production by 70 percent to feed ten billion mouths by 2050

The constant upswing in agricultural productivity over decades is remarkable; according to the U.S. Department of Agriculture (USDA), for example, crop output per unit area of farmland increased by 285 percent between 1957 and 2015. But these gains haven't come easily or cheaply; for instance, fertilizer use rose by 240 percent and pesticides by over 2000 percent during the same period.

And while nutrition and pest control are important, they're not the major factor in ensuring crop yields. Irrigation is the critical operation for maximizing growth because even if everything else is perfectly balanced to boost output, without adequate water plants curl up and die. To boost crop output to the record highs of recent decades, agriculture uses 80 percent of the U.S.'s annual consumption of water.

And things are set to get tighter. Farming output is driven by demand. In the same 58-year period that crop output has risen nearly threefold, the population of the U.S. increased from 175 million to 321 million and the average daily energy intake for each person increased from around 11,700 kJ to 15,060 kJ per day. The bigger picture forecasts global population expanding from 7.7 billion today to 9.8 billion in 2050; and energy intake is set to increase from a global average per person of 12,000 kJ today to around 13,700 kJ then if the trend of the last three decades is maintained. Some experts estimate food production will need to expand by a further 70 percent to meet

> Hundreds of Bluetooth LE sensors can be deployed across a crop field and provide fine grained soil moisture level data directly to a gateway

the needs of Earth's burgeoning population. The challenges are difficult.

Traditional farming already consumes 40 percent of the Earth's land and finding more space to grow crops means destroying rainforests and other environmentally sensitive areas. But the real problem is finding enough water to keep many more crops alive. The IoT promises the answer.

LESS IS MORE

Actually, the problem is not so much finding more water, rather managing the resources we have more carefully. Although agribusiness has made great strides in recent years, farm irrigation is still a notoriously wasteful process. Farmers lack information about soil moisture content so tend to err on the side of safety by overwatering. Because the soil can only absorb a certain amount, the excess water drains away. Research has shown that up to 70 to 90 percent of water applied to the soil can disappear without going anywhere near plant roots.

The information farmers need to make informed decisions to minimize water usage yet keep crops healthy has been missing because it's been uneconomic to build traditional process control systems over vast swathes of farm land. However, today, the IoT could allow farmers to take advantage of closed loop control to monitor irrigation and manage precious water resources at a fraction of the cost of conventional industrial control systems.

Compact, battery-powered, ruggedized wireless soil moisture sensors can be easily deployed, moved, and maintained. Such sensors would send data to a gateway for aggregation and analysis before forwarding information to the Cloud via cellular networks. The sensors allow constant, precise monitoring of soil moisture levels around the crops. And, by using bidirectional wireless connectivity, signals are sent in return to actuators controlling irrigation to ensure the optimum environment for a particular crop is maintained.

IoT connectivity enables an agricultural wireless network leverage of Cloud resources that would otherwise be inaccessible. Third parties offer straightforward connection to the Cloud and access to "If This Then That" (IFTTT) platforms that simplify process control by implementing proven automated routines. For example, an algorithm could trigger irrigation when the soil moisture content drops below a pre-set threshold while also sending a notification to the farmer's smartphone to inform him or her that irrigation is in progress.

However, the true power of the IoT lies in the long term analysis of the frequent stream of data transmitted by the sensor. Learning algorithms enable Cloud servers to recognize, for example, that a 0.75°C increase in temperature for 24 hours will lead to a soil moisture level decrease of 4 percent decreasing yield at harvest time by 0.1 percent. Such information would allow the farmer to set the system to automatically trigger earlier watering when the forecast is for higher temperatures – thus preventing the moisture decrease and protecting crop yields.

MAKING FARMING SMART

The IoT technology to build agricultural wireless monitoring isn't in the research lab, it's commercially available now. Sensors that combine accurate soil moisture level measurement with wireless transceivers are available from a number of vendors. Bluetooth LE is particularly suited for wirelessly connecting sensors to a gateway because it is not only power frugal, proven, and interoperable with smartphones, but also includes (in the latest Bluetooth 5 specification) a long range capability.

Bluetooth 5 tech's long range capability boosts transmission distance by employing a forward error correction (FEC) algorithm – effectively increasing the sensitivity of the receiver with no power penalty. Range is dependent on conditions, but the user could expect at least a doubling of communication distance compared with a system running conventional Bluetooth 5 tech. The key advantage of the technology is that it overcomes the need for the sensors to be connected to a mesh network (where each device communicates indirectly with the gateway using short range hops between other sensors). With Bluetooth 5 tech's long range capability, hundreds of Bluetooth LE sensors can be deployed across a crop field and provide fine grained soil moisture level data directly to a gateway without the complexity and power penalty of a mesh network.

Low power cellular IoT is the ideal LPWAN gateway technology to connect a fleet of agricultural Bluetooth LE sensors to the Cloud. Products such as Nordic's award winning nRF9160 SiP with integrated LTE-M/NB-IoT modem and GPS (working in conjunction with a Bluetooth LE SoC to receive data from field based sensors) provide reliable and secure connectivity to the established cellular network anywhere in the world. The nRF9160 is purpose designed to maximize battery life while also incorporating the processor power and memory capacity to perform edge computing that reduces the need to forward raw data to the Cloud – minimizing data charges.

Feeding the world in the coming decades is not going to be trivial, but with the advance of the IoT it will be possible and perhaps most importantly, sustainable.

State of Play

Where our fresh water goes

Three quarters of the planet is covered by water, but only two percent of it is fresh and much of that is underground. Freshwater withdrawals have tripled over the last half century with demand increasing by 64 billion m³ each year. That's putting increasing stress on finite supplies. Agriculture is by far the largest consumer, dwarfing industrial and consumer use

70% agriculture

20% industry

10% domestic
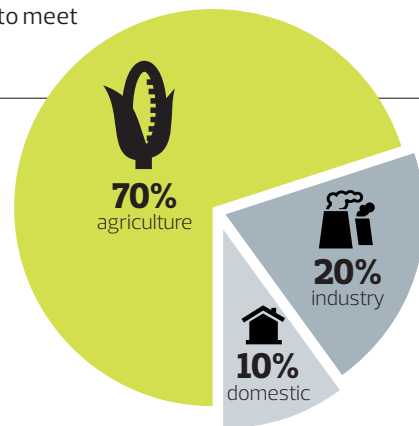
Education

Harry Potter Kano Coding Kit

This Bluetooth Low Energy wand and app based coding kit teaches people of all ages how to code and develop 'magical' creations

According to analyst, Zion Market Research, the market for smart or connected toys was valued at around $3.87 billion in 2017, but is expected to grow rapidly to reach approximately $5.41 billion by 2024, thanks to a growing awareness of technology, advancements in artificial intelligence, and the increasingly sedentary lifestyle of urban populations

From the Kano app, users can follow 70 step-by-step coding challenges using intuitive coding 'blocks' and a JavaScript inspector. Once paired with a tablet, laptop, or desktop computer, makers can see their wand movements brought to life on screen, for example, moving floating feathers, growing pumpkins, or throwing flames

17,000 individually labeled wand boxes, and more than 3,000 wands, were used as props during the filming of the eight Harry Potter films. Daniel Radcliffe, who played Harry Potter, went through 10 wands per film as he would use them as drumsticks between takes

The origins of the 'magic wand' are unclear, but it may have originated with the idea of a talking stick, one of the most rudimentary ways of keeping order in a group determining whose turn it is to speak. Alternatively, it may have derived from early scepters, a staff carried by rulers and allegedly endowed with magical or divine authority
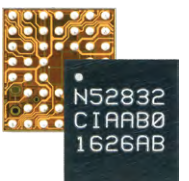
Having sold more than 500 million copies worldwide since 1997, Harry Potter by J. K. Rowling is the best selling book series in history and has been translated into 80 languages, as well as spawning eight Hollywood films that have generated combined global box office takings in excess of $7.72 billion

N52832
CIAAB0
1626AB

Tech Check

This Bluetooth LE wand employs a nine-degrees-of-freedom (9DoF) inertial measurement unit (IMU)—including a three-axis accelerometer, three-axis gyroscope, and three-axis magnetometer—that tracks the wand's movement, speed, and direction of use. The Nordic nRF52832 SoC's powerful Arm Cortex M4F processor manages the raw sensor data and wirelessly relays the data to the user's device

Wearables

Advanced performance tracking wearable delivers elite athlete data

Bluetooth LE connectivity and STATSports' APEX wearable device combine to help professional sports coaches engage with live athlete performance metrics in real time

Monitoring and analyzing the physical performance of athletes through the lens of live sport specific metrics is not only the way of the future, it's an approach currently kicking goals for many major sporting organizations around the globe, including 13 professional soccer clubs from the renowned English Premier League (EPL). With 380 matches contested throughout an EPL season, that's more than 12,540 man hours of running, passing, shooting, and tackling of elite players putting their bodies on the line in the pursuit of individual and team success. Then there are the countless hours spent on the training ground or undergoing rehabilitation from injuries.

With so much at stake both on and off the field, it's only natural for modern sporting organizations and their valuable assets to seek a technology- and data-driven edge. The more detailed the information available to coaches and sports scientists, the more powerful the physical training and strategic preparation methods for elite sportspeople can be. With direct, uninterrupted access to highly accurate and reliable performance-related information across numerous metrics, coaches are now armed with an abundance of critical data from which to make informed decisions regarding training sessions, recovery programs, team selections, and on field tactics.

Performance edge

Thanks to STATSports, a Northern Ireland based data tracking solutions company, EPL clubs of the likes of Manchester United and Liverpool—alongside hundreds of other professional sporting organizations across Europe, North America, and the rest of the world—are already benefiting from this data advantage.

STATSports' groundbreaking APEX advanced athlete performance tracking wearable device is embedded in a custom lightweight vest worn by the athlete during activity. The APEX device uses built in sensors and augmented GPS to gather a comprehensive range of performance metrics including total distance covered, current and maximum speed, number of sprints, maximum and average heart rate, accelerations, impacts, dynamic stress load, step balance, and more.

"With the APEX device capable of calculating up to 50 live sport specific metrics in real time, coaches always have access to the data that really matters," says Arthur McMahon, Chief Technical Officer at STATSports. "Live data gives coaches the ability to make decisions based on objective information about whether to increase or decrease training intensity."

Not surprisingly, the availability of such data has proved compelling for the professional sports sector. "Professional sport is a very competitive and demanding workplace. It is imperative to have players in peak physical
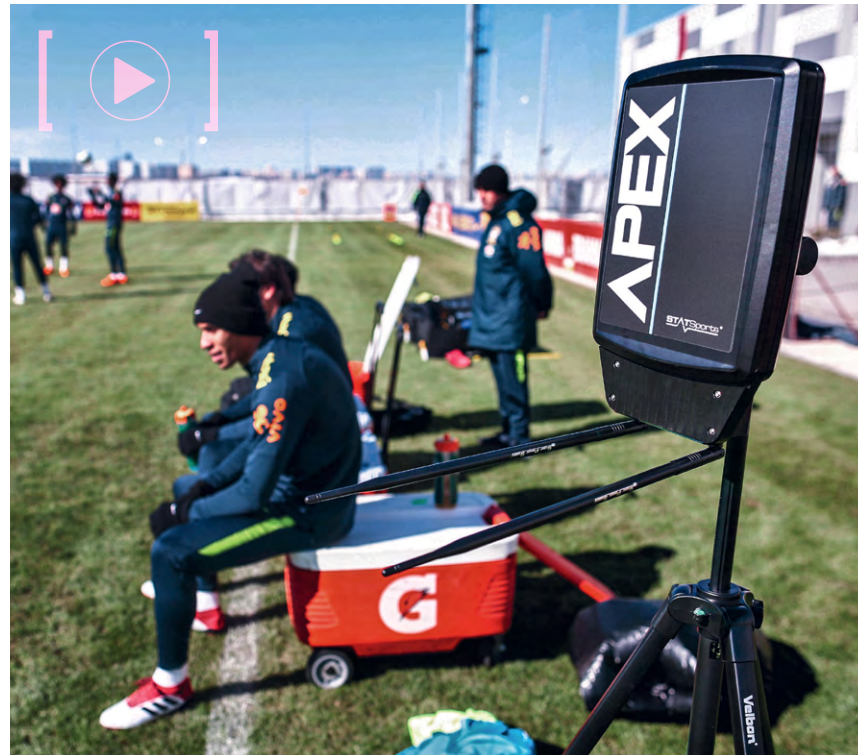
condition for the competitive games," explains McMahon.

"Key to ensuring this is to manage the workload of a player through their demanding schedules of games and training over the course of a season. Sports science is fundamental to maximizing the players' peak performances, and the accurate data captured by our systems provides those insights that are critical to help the sports scientists make informed decisions on managing players' workloads."

The STATSports Cloud infrastructure offers a platform for the company's clients to store and secure the valuable data collected by their APEX wearables. "Our clients often have many teams within their organizations and the Cloud gives multiple users the ability to monitor and analyze all the players across all their teams," says McMahon. "It is now possible with the data in the Cloud to provide a wider array of insights into a specific player's performance by using cognitive and machine learning services."

The Bluetooth LE advantage

The Bluetooth LE wireless connectivity enabled by the integration of Nordic's nRF52840 advanced multiprotocol SoC allows APEX users to engage with the live metrics as they are calculated in real time using the data gathered

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> This market is in its infancy and as sports science evolves the understanding of factors that improve elite athlete performance will continue

by the body sensors, through the STATSports APEX app on a paired iOS or Android smartphone, tablet, PC, or smartwatch. Users can create live drills and sessions using the partner app, whilst easily sharing relevant data with coaching staff and other team members.

"The industry trend for on-the-body sensing devices is to use Bluetooth LE and we needed the connectivity provided by the Nordic SoC to establish a robust, reliable, and secure low power wireless link between our APEX wearable and various personal devices," says McMahon.

When in range of a STATSports beacon installed around the stadium or training facility, APEX transmits the live data to the beacon using Ultra Wideband (UWB) radio technology. The data is then relayed via a Wi-Fi LAN to multiple APEX software applications for immediate review. APEX also acts as a hub to collect and forward data from a network of peripheral on body sensors (for example, a heart rate monitor or muscular activity sensor) concurrently, while transmitting the data from the APEX's own sensors to a mobile device via the Bluetooth LE connectivity. These applications are made possible by the Nordic nRF52840's S140 SoftDevice, which offers concurrent Central, Peripheral, Broadcaster, and Observer Bluetooth LE roles and supports up to 20 connections with variable bandwidth.

What about the future of advanced athlete performance tracking? "This market is in its infancy and as sports science evolves the understanding of factors that improve elite athlete performance will continue to drive this industry," says McMahon. "Predicting potential injuries is a key goal which will maximize players' playing time across a season, but also will help to extend their playing careers."

Tech Check

Alongside the nRF52840 multiprotocol SoC—Nordic's most advanced ultra low power wireless solution—the APEX wearable integrates a 6600-Hz accelerometer, 3200-Hz high impact accelerometer, 6600-Hz gyroscope, 100-Hz magnetometer, and 18-Hz augmented GPS, calculating up to 50 live sports metrics and relaying the data to coaching staff in real time

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Engineer mentors under represented kids in coding

Hi, I'm Markus Tacker and I'm a Senior Research & Development Engineer based in Trondheim, Norway. I work in the IoT Labs team and I am responsible for architecting and developing the Cloud based infrastructure for Nordic's IoT platform, nRF Connect for Cloud, which enables easy connection and configuration of Bluetooth LE and LTE-M IoT prototypes in the Cloud.

My favorite part of the job is the opportunity to work with the next generation of IoT hardware, sometimes years before anybody else in the world. As I need to develop entirely new solutions for connecting our devices to the Internet, it is not possible to simply 'Google' a problem.

Working with Nordic hardware, especially the nRF91 Series, is a major shift in device capabilities and computing power at the edge. There is no existing best practice or use cases for IoT products built with these devices.

The work I do here at Nordic will influence future customer deployments, which is a big responsibility and a fantastic motivator. Also, being involved in enabling our SDKs to connect for the first time ever to 5G networks, which are only just beginning to get deployed worldwide, is a truly unique experience.

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> I really love being outside to explore and take pictures of the many different faces of 'fjells' and fjords

This year, for example, I worked extensively on building the first version of the nRF Connect for Cloud Device API, which enables our customers to interact with their devices and easily react to data sent by devices using their own business platforms without needing to know too much about the intricacies of IoT hosting. This involved spending a lot of time doing market research in order to understand what capabilities our customers would most likely need from an IoT Cloud

Profile

Name: Markus Tacker
Job Title: Senior R&D Engineer
Joined Nordic: August 2017
Based: Trondheim, Norway
Interests: Family, exploring, nature photography, teaching, conference speaking

service when starting to develop their IoT product with Nordic hardware. It was a challenging process, but I always strive to understand the entire value chain, and having the resources at Nordic to dig deep into a topic helps us build a solid foundation for completely new service offerings.

I originally moved from Germany to Norway for the spectacular nature. I really love being outside—in both summer and winter—to explore and take pictures of the many different faces of Norwegian 'fjells' and fjords. I am also passionate about teaching and mentoring people from under represented groups, helping them to take the first steps towards becoming a software engineer, which I do through CodeDoor, a Frankfurt, Germany-based initiative. I also speak at various conferences each year, mostly about certain aspects of my work and the things I learn there. I believe that we as an industry can grow by sharing and learning from each other. It is important that we occasionally leave the bubble of our workplace and engage with other professionals from outside our typical settings.

As for the future, I am looking forward to the first real world IoT projects using the nRF91. It has been on my desk for one-and-a-half years now and I can't wait to see what our customers do with it.

Direction Finding enhances Bluetooth Locating Services

A new version of the Bluetooth Core Specification has been released by the Bluetooth Special Interest Group (SIG) supporting a feature called Direction Finding. The feature enhances existing Bluetooth Locationing Services with improved accuracy in real time locationing and indoor positioning systems beyond what was previously possible with Bluetooth technology.

Before the release of this latest version of the specification (version 5.1), Bluetooth Locationing Services relied on signal strength to calculate distances and determine indoor positioning between devices in applications such as proximity marketing, personal 'find me' tags, and

asset tracking. By adding Direction Finding capabilities to these systems, a device can now know the direction of a signal from another Bluetooth device, in addition to distance information, and improve location accuracy.

"Nordic Semiconductor is excited to see this enhancement coming to Bluetooth as it allows its customers to build better positioning accuracy into their Bluetooth locationing applications," says Kjetil Holstad, Product Manager for Short Range Connectivity at Nordic. "There is a strong need for good and accurate location services both at the consumer level and in the B2B segment. This opens up the possibility of not just knowing approximate distance, but
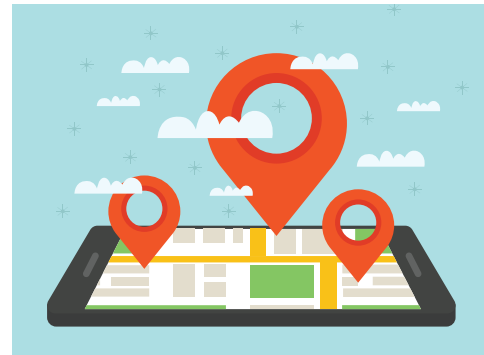
also direction in three dimensions that will allow our customers to build even better locationing systems.

"Our R&D teams not only contributed to the Bluetooth 5.1 standardization work but also made sure we have a new device available, the nRF52811, capable of supporting all the latest features of Bluetooth v5.1."

Internet of Things

Power management solution increases battery life tenfold

Norwegian firm, Nanopower, has released a module for IoT developers working with highly restricted power budgets that dramatically reduces sleep mode power consumption while increasing battery life tenfold.

Based on Nordic's nRF52832 SoC, the nP-BLE52 module employs a proprietary power management IC which enables it to cut power to the SoC, putting it in sleep mode, before waking it up at a preset time and in the same state as before it was put to sleep. The SoC's power consumption in sleep mode is reduced to 10 nA, making the module a good choice for IoT applications where battery life is critical.

Once the Nordic SoC has completed its tasks, it instructs the nP-BLE52 to put it to sleep and wake it up again at the pre-set time. The nP-BLE52 then stores the SoC's

state variables and waits until it needs to be powered up again. On wake-up, the device uploads the stored state variables, allowing the SoC to be restored to the same operational state as before the power was switched off.

The nP-BLE52 module also features a low power MCU which can be set to handle external sensors and actuators when the Nordic chip is switched off. In this state, the module still monitors sensors and buffer readings and can trigger wake ups if these readings are above predetermined thresholds, while consuming less than 1 uA.

The module is suitable for any battery powered device which is not required to be constantly active, for example, asset tracking, remote monitoring, beacons, and some smart home applications.

The module either extends battery life and/ or reduces the size of the battery required to power the application thereby shrinking the end product footprint. Longer battery life also reduces or eliminates battery swaps and enables the developer to better adjust for remaining useful battery life.

Nordic and Adero unite on Zephyr

Nordic nRF52840 and nRF52810 Bluetooth LE SoCs running the Zephyr RTOS have been selected by California-based Adero for its suite of intelligent organization products.

Nordic has been a member of the Zephyr project since 2016 and Nordic developers have made extensive contributions to Zephyr since then, including to the Bluetooth LE Link Layer and MCU Manager device management protocol for device firmware update (DFU).

"The existing features in Zephyr, and Nordic's ability to support us on some central elements like the open source Bluetooth stack, allowed us to focus most of our efforts on our application which was really critical to use during our product development," says Adrian Yanes, Vice President of Product Development at Adero.

As a result of the Nordic and Adero collaboration, the Zephyr project now includes the world's first open source, fully qualified, and production ready Bluetooth LE stack.

Tech Briefing

Accelerating product development for the Internet of Things with Python coding

Zerynth IoT middleware enables developers to use the Python high-level coding language to program Nordic's SoCs for rapid integration with sensors, actuators, and Cloud services

For the technical specialist, Python is an interpreted, object-oriented, high-level programming language with dynamic semantics and built in data structures, combined with dynamic-typing and -binding that make it useful for rapid application development. For many others in the large Python community, it's a good choice for the inexperienced who need a readable and easy-to-use and -understand, general-purpose programming language which can be employed for a wide variety of applications.

That ease of use comes in part from Python being an interpreted language, meaning that programs written using it don't need to be compiled in order to run. That in turn makes it easy to test small snippets of code and easily move Python programs between platforms. First developed in the late 80s by Guido van Rossum, Python is currently in its third version.

But while the language is in widespread use, powering, for example, some of the world's most sophisticated websites, it's uncommon in embedded processing. That's now changing fast with, among other initiatives, Zerynth, a new York-based IoT software developer, bringing Python to Nordic's high-end multiprotocol chip, the nRF52840 SoC. "Nordic is one of the world's leading wireless IoT companies and our recent technical partnership has enabled us to push Zerynth to a wider community," explains Gabriele Montelisciani, CEO of Zerynth.

Easing application programming

Zerynth's 'IoT middleware' is designed to accelerate IoT product development by simplifying application software programming of the processors at the heart of connected electronics. The middleware works with 32-bit microprocessors such as the 64-MHz Arm Cortex device embedded in the nRF52840.

Key to Zerynth's functionality are two development tools: Zerynth Virtual Machine (VM) and Zerynth Studio. Zerynth VM is a multithreaded, stack-based virtual machine built on top of a real-time operating system (RTOS). The virtual machine has been developed with the aim of bringing Python to the embedded world with support for multithread and cross board compatibility. It supports most high-level features of Python including modules, classes, multithreading, callback, timers, and exceptions.

The virtual machine is independent of the hardware, allowing code reuse on a wide range of 32-bit microcontrollers. When running on the Nordic nRF52840, the virtual machine uses just 60 to 80kB of the chip's 1MB Flash allocation and 3 to 5kB of its 256kB RAM allocation. But while the firmware takes up little space, the large memory allocation is vital to smooth running of the final application software. "Although the Zerynth VM has a tiny footprint, the nRF52840's generous Flash and RAM are prerequisites for demanding end-user applications,"
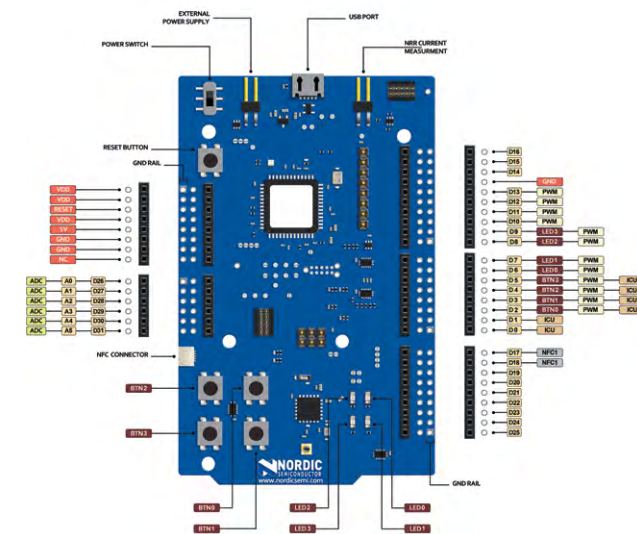
explains Montelisciani. "And Nordic's well-structured software development kit was an ideal starting point that allowed us to build the virtual machine for the SoC quickly and smoothly."

Zerynth Studio is a free-to-download, powerful IDE and toolchain for developing Python or (hybrid) C/ Python applications. (C/Python is a hybridization of the programming language C and Python. This hybrid language is useful for low-level coding for time-critical tasks while retaining Python's flexibility and readability for other tasks.) The IDE includes a compiler, debugger, and an advanced code editor, alongside tutorials and example projects for rapid learning.
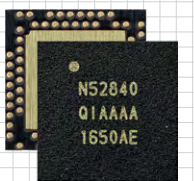
Cloud connectivity

While vital, coding wireless application software is just one step in the process of developing an IoT solution. Data and information need to move from the wireless sensors to the Cloud too. Zerynth has thought of this and its IoT middleware supports secure connection to leading Cloud services and eases hardware integration with sensors, actuators, and industrial protocols. The supported Cloud services—for example, AWS, Google Cloud Platform, and IBM Cloud—enable the developer to view and manipulate their data using either the Zerynth app or a third-party IoT Dashboard.

A free license to access the Zerynth VM is granted once the developer creates a Zerynth account. The VM is then installed on the nRF52840 enabling the developer to start programming using Zerynth Studio. The Nordic SoC's over-the-air device firmware update (OTA-DFU) feature ensures the embedded virtual machine can be regularly updated.

Tech Check

Zerynth has extended the availability of its 'IoT middleware' to Nordic's nRF52840 multiprotocol SoC. The middleware simplifies IoT development by providing an easy way to program 32-bit microcontrollers using Python and connect them securely to the Cloud

Python is available via the nRF52 DK. (Zerynth compiler pin mapping illustrated)

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Nordic is one of the world's leading wireless IoT companies and our recent technical partnership has enabled us to push Zerynth to a wider community

Building the next generation of Bluetooth beacons without the complexity

Bluetooth Low Energy beacons now promise more by leveraging the advertising extensions feature included in Bluetooth 5. John Leonard explains

The beacon technology supported by Bluetooth LE versions 4.0, 4.1 and 4.2 defined a simple service that effectively used one side of a full Bluetooth exchange. In normal use, a Bluetooth device sent a periodic advertisement ('discovery') message that invited pairing, and subsequent data exchange. In contrast, a beacon's advertisement message contained a reserved address that identified it as not soliciting pairing and preceded a short data 'payload' that could be acted on directly.

Now with Bluetooth 5 tech's advertising extensions feature, instead of being able to send just a URL to a smartphone which a consumer must then visit for more information, a retailer can, for example, use the chained 255-Byte packets to convey specific information about a special deal or new product.

Nordic's nRF52810 SoC is a good choice for developers wishing to take advantage of advertising extensions for beacons. The chip is Nordic's entry-level Bluetooth 5/Bluetooth LE product targeted at cost- and space-constrained applications. The SoC inherits the performance of the higher specification nRF52 Series SoCs and integrates 196 kB Flash and 24 kB RAM. The memory allocation is ample to run application code typical of high-volume, low-cost applications such as beacons and supports OTA firmware updates. For beacon applications, Nordic recommends using the chip with the S112 SoftDevice (Nordic's RF protocol software), a Bluetooth 5-compatible protocol stack which occupies just 100 kB of Flash memory.

Beacon design

While an SoC like the nRF52810 is a complete Bluetooth LE solution, a fully-functioning beacon system requires additional components, for example, PCB, power supply, passive devices for tuning circuits, antenna and crystal(s) for timing. Skill and experience are required to implement impedance matching and antenna positioning. To aid the developer, Nordic offers an nRF52810 beacon reference design which ensures good RF performance for a first prototype and shortens the process of optimizing the hardware for the application. The reference design (including PCB layout and BoM) is available from www.nordicsemi.com.

An alternative approach for those with no RF hardware design experience is to invest in the nRF52 Development Kit (DK). The DK can be connected to a PC or Mac for development purposes and forms all the hardware needed for prototyping a beacon design with the nRF52810 SoCs. The DK provides simple access to all the SoC's I/Os and interfaces via connectors and includes four user programmable-LEDs and -buttons. Another handy feature is that the DK is hardware compatible with the Arduino Uno (Revision 3) standard.

When using Nordic technology, the developer will need three essential tools to create his or her beacon application software: an integrated development environment (IDE) with a Nordic-supported compiler (for example, SEGGER Embedded Studio); Nordic's nRF5 Software DK (SDK); and nRF5x Command Line Tools (which allows the developer to do extra things like combine up to three HEX files into a single file). The SDK and Command Line Tools are free downloads from www.nordicsemi.com.

To ease the complexity of beacon application code development, the nRF5 SDK contains software examples, source files, and other useful development items. The SDK works within the IDE and, together with the Command Line Tools, specifically supports the application coding for Nordic chips. Once the developer has written his or her own code—or modified the Nordic beacon example code to suit their application—the IDE compiles the code for porting straight to the nRF52810.

The programmed hardware (in this case the DK) can then be used to check out the functionality of the design (by, for example, wirelessly sending beacon data from the DK to a smartphone). The developer can then use the development tools to easily debug his or her code, add more functionality, and optimize code performance.

And when things get tough, the first-time beacon designer can turn to Nordic's DevZone and gain access to 25,000 fellow designers who are likely to come up with an answer to the trickiest beacon design question.

John Leonard is Senior Product Marketing Manager with Nordic Semiconductor

> "When things get tough, the first-time beacon designer can turn to Nordic's DevZone and gain access to 25,000 fellow designers who will come up with an answer to the trickiest beacon design question
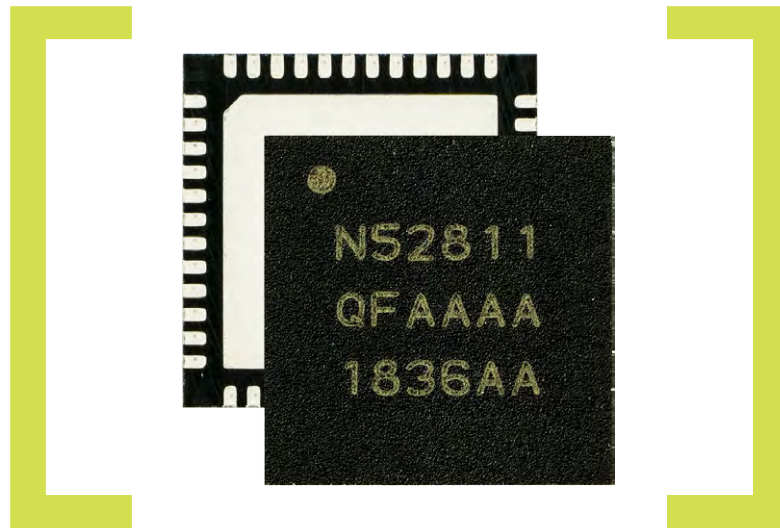
Need to Know

Advertising extensions enable 'chaining' of advertising packets to create greater advertising data payloads of up to 255 bytes. Nordic's nRF52 Series SoCs support this feature plus Bluetooth 5 tech's high throughput. The nRF52840 and new nRF52811 additionally support the specification's long range feature

Product Guide

ICS	nRF9160	nRF52840	nRF52832	nRF52811	nRF52810	nRF51822	nRF51422	nRF51824
OPERATING BAND	LTE: 1, 2, 3, 4, 5, 8, 9, 12, 13, 17, 18, 19, 20, 26, 28	2.4GHz	2.4GHz	2.4GHz	2.4GHz	2.4GHz	2.4GHz	2.4GHz
WIRELESS PROTOCOL								
BLUETOOTH 5.1				●				
BLUETOOTH 5		●	●		●			
BLUETOOTH LOW ENERGY		●	●	●	●	●	●	●
ANT		●	●		●	●	●	
THREAD		●		●				
ZIGBEE		●		●				
802.15.4		●						
2.4GHZ PROPRIETARY		●	●	●	●	●	●	●
LTE-M	●							
NB-IOT	●							
GPS	●							
IC TYPE								
SYSTEM-ON-CHIP		●	●	●	●	●	●	●
SYSTEM-IN-PACKAGE	●							
ON-CHIP								
CPU	Arm Cortex-M33	Arm Cortex-M4	Arm Cortex-M4	Arm Cortex-M4	Arm Cortex-M4	Cortex M0	Cortex M0	Cortex M0
LTE MODEM	●							
FPU & DSP	●	●	●					
ARM TRUSTZONE	●							
MEMORY	1MB Flash 256kB RAM	1MB Flash 256kB RAM	512kB or 256kB Flash 64kB or 32kB RAM	192kB Flash 24kB RAM	192kB Flash 24kB RAM	128kB or 256kB Flash 32kB or 16kB RAM	128kB or 256kB Flash 32kB or 16kB RAM	256kB Flash 16kB RAM
MPU	●	●	●	●	●			
PA	●	●						
ON-CHIP BALUN	●	●		●	●			
CLOCKS	64MHz / 32kHz	64MHz / 32kHz	64MHz / 32kHz	64MHz / 32kHz	64MHz / 32kHz	16MHz / 32kHz	16MHz / 32kHz	16MHz / 32kHz
GPS	●							
NFC-A TAG		●	●					
PERIPHERALS								
2-WIRE	●	●	●	●	●	●	●	●
ADC	●	●	●	●	●	●	●	●
AES	●	●	●	●	●	●	●	●
ANALOG COMPARATOR	●	●	●	●	●	●	●	●
I2S	●	●	●					
PDM	●	●	●	●	●			
PWM	●	●	●	●	●	●	●	●
REAL TIME CLOCK	●	●	●	●	●	●	●	●
ARM CRYPTOCELL	●	●						
TRNG	●	●	●	●	●	●	●	●
SPI	●	●	●	●	●	●	●	●
QSPI		●						
TEMPERATURE SENSOR	●	●	●	●	●	●	●	●
UART	●	●	●	●	●	●	●	●
USB		●						
PC PERIPHERALS		●	●		●	●	●	
SPORTS & FITNESS		●	●		●	●	●	
GAMING / VR + AR		●	●		●	●	●	
MESH NETWORKS		●	●		●	●		
CONSUMER ELECTRONICS		●	●		●	●	●	
AUTOMATION		●	●		●	●	●	●
APPLICATIONS								
INDUSTRIAL SYSTEMS	●							
AGRICULTURE	●							
HEALTHCARE		●	●		●	●	●	
TOYS		●	●		●	●	●	
WEARABLES	●	●	●		●	●	●	
SMART HOME		●	●	●	●	●	●	
SMART BUILDINGS	●							
SMART CITY	●							
ASSET TRACKING	●							
METERING	●			●				
BEACON		●	●		●	●	●	●
AUTOMOTIVE GRADED								
REF. DESIGNS			PC Desktop, Smart Remote, Smartphone Demo Apps			PC Desktop, Smart Remote, Smartphone Demo Apps, Beacon	Smartphone Demo Apps	Smartphone Demo Apps
DEV TOOLS	nRF9160 Dev Kit	Single Board Dev Kit, Power Profiler Kit	Single Board Dev Kit, Power Profiler Kit, Nordic Thingy:52		Single Board Dev Kit, Power Profiler Kit	Single Board Dev Kit, Dongle	Single Board Dev Kit, Dongle	Single Board Dev Kit, Dongle
WLCSP	●	●	●		●	●	●	

nRF52811

Bluetooth 5.1 Direction Finding SoC boosting accuracy in positioning solutions

Software support: nRF5 SDK v15.3.0 / S112 v6.1.1

Bluetooth® 5   **ᵠHREAD**   **zigbee**   **2.4GHZ**   **ANT+**

FIND YOUR LOCAL DISTRIBUTOR
https://www.nordicsemi.com/nRF52811