

ultra low power wireless

QUARTER 2 | SUMMER 2015

COVER STORY

Doing more with Bluetooth Smart

Fifty years of
Moore's Law

Open standards
vital for IoT success

Inspiring tomorrow's
innovators



OPINION

Geir Langeland



Encouraging tomorrow's coders

Asian countries such as Hong Kong, Taiwan, and Singapore regularly top the lists of high educational achievers. What's more, these countries do exceptionally well at the so-called STEM subjects (science, technology, engineering, and math).

Students educated in STEM subjects often go on to become engineers and scientists - essential disciplines for boosting a nation's gross domestic product (GDP) - a fact that has encouraged western nations to address their educational performance in order to compete with Asia.

According to the Organisation for Economic Co-operation and Development (OECD), a grouping of countries dedicated to promoting economic growth, Australia, Ireland, and the U.K., for example, are reforming their national school curricula to increase STEM education, and Norway and Austria have introduced new national test to measure the effectiveness of their STEM initiatives. And in the U.S., the federal government introduced a five-year strategic plan in 2013 to boost participation in STEM education.

As a leading technology company whose lifeblood is its highly-skilled engineers, Nordic is a keen advocate of STEM education. But the company's support for initiatives goes far beyond its own staff requirements because we realize that our customers need engineering skills such as software coding to make the most of Nordic's technology. The company works with a lot of creative start-up firms developing connected accessories and gadgets for the Internet of Things. Though they have great ideas we sometimes find that they sometimes have limited code development expertise, which can be a big barrier to entry in the ultra low power wireless market.

That's why Nordic is taking part in a new major initiative by the BBC, the highly respected U.K. media organization. The "Make it Digital" campaign aims to get children interested in coding and technology by supplying an entry-level piece of programmable hardware to every British schoolchild aged 11 and 12.

"Micro Bit" is a small wearable device with an LED display that's plugged into a computer in order to be programmed. Each of the million boards will have a Nordic Bluetooth Smart chip on it, which will allow the youngsters to wirelessly connect a Micro Bit to their smartphones or tablets, opening up a world of possibilities for new applications they can design themselves.

The program will also demonstrate the ease of use of Nordic's Bluetooth Smart chips. The chip was, in part, selected because it offers unparalleled simplicity to both experienced and would-be coders; it's simple enough to allow those without any wireless or programming experience whatsoever to use it. This ease-of-use will be validated when the schoolchildren succeed in connecting the Micro Bit board to their personal electronic devices.

Helping young people to fulfill their potential is a worthy cause; but combining it with the opportunity to promote digital tech as a cool industry to work in, plus the ability to inspire tomorrow's generation of developers is what makes this initiative exciting.

Nordic's hopes to encourage the idea that making things using digital technology can be fun, and that developing code is accessible to everyone. Hopefully, some of the most talented U.K. students will become the next generation of developers and engineers in digital industries. Some of them might even join Nordic Semiconductor one day! (See pages 16 and 17 of this issue for more about Micro Bit.)

Yours Sincerely,

Geir Langeland
Director of Sales & Marketing



Nordic's launch of the nRF52 Series allows developers to do much more with a single-chip wireless solution

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www.ecritech.com

Editor

Steven Keeping
e-mail: steven@ecritech.com

Assistant Editor

Andrew Woolls-King
e-mail: andrew@ecritech.com

News Editor

Chris Williams
e-mail: chris@ecritech.com

Art Editor

Tim Plummer
e-mail: production@ecritech.com

Image Editor

Neale Hobday
e-mail: production@ecritech.com

Print & Distribution

Printech Europe



Page 9

Ståle "Steel" Ytterdal is Director of Sales & Marketing - Asia. Here he explains why the Internet of Things must be built on open standards such as Bluetooth Smart



Page 11

Caroline Hayes is a tech writer specializing in semiconductors. On page 11 she looks at how Gordon Moore's fifty-year-old law is still influencing chip technology



Page 16

Sally Ward-Foxton is an electronics freelance journalist. Here she describes how STEM education is becoming increasingly important and how Nordic is getting involved



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NEWS

The latest developments from Nordic Semiconductor

Round-the-clock blood glucose monitoring 'a world first'

U.S. blood glucose monitoring firm, Dexcom, has released what it claims is the world's first continuous diabetic monitoring solution, offering 24 hour, seven day-a-week remote monitoring thanks to Nordic Semiconductor's technology.

The Dexcom G4 Platinum Continuous Glucose Monitoring System with Share uses a secure Bluetooth Smart wireless connection to a partner app on a diabetic's smartphone to monitor dynamic trends in blood glucose levels and securely share this data with others.

Dexcom has added Nordic's μ Blue™ nRF8001 Single-Chip-Connectivity solution to its existing G4 Platinum CGM (Continuous Glucose Monitoring) product, enabling the blood glucose monitor to securely



Blood glucose readings are taken up to every five minutes, seven days a week with Dexcom's Continuous Glucose Monitoring System

transmit data to a free Dexcom app running on any iOS (and shortly Android) Bluetooth Smart Ready smartphone.

The device allows blood glucose readings to be measured at a frequency of up to once every five minutes and shared with the mobile devices of up to five designated 'follower' recipients who can receive alerts from almost anywhere in the world with cellular network coverage.

"The Dexcom Share represents a new paradigm in diabetic treatment whereby dynamic trends (up, down, and stable) in a diabetic's blood glucose levels can be monitored and shared on a 24x7 basis for the first time," says Jorge Valdes, Dexcom's CTO.

"This will not only give much greater insight and more accurate and timely management of the diabetic's condition compared to traditional finger sticks, it will also give diabetics, their loved ones and/or their caregivers the peace of mind to know they are safe at any time."

In brief

Bluetooth made fast and simple

The Bluetooth SIG has launched the beta version of its Bluetooth Developer Studio, a graphical, GATT-based development and debugging tool that could shorten Bluetooth product development time by as much as 70 percent. Drag and drop functionality lets developers find the Bluetooth profile they need, build on it and create their project quickly. The tool auto-generates code from third-party solutions and can test with both virtual and physical device options.

WLCSPs make for tiny modules

Japanese company Taiyo Yuden, is using the wafer level chip scale package (WLCSP) versions of Nordic Semiconductor's nRF51822 and nRF51422 Systems-on-Chip (SoCs) to shrink the size of its Bluetooth Smart module and Bluetooth Smart/ANT+ multiprotocol module. By using the WLCSP versions of the Nordic SoCs, the modules use 50 percent less PCB space. The modules are targeted at space constrained application such as wearables for sport and fitness monitoring.

Wearable tech privacy fears

Concerns about privacy have been raised by U.K. researchers who have discovered how easy it is to monitor and record signals from smartphones and wearable devices. Context Information Security demonstrated the ease of monitoring and recording Bluetooth Smart signals. The company says that by using cheap hardware it is possible to identify and locate a specific device within 100 meters in the open air, raising privacy issues.

A million schoolchildren to be given Nordic-powered programable computer

Every 11 and 12 year old school child in the U.K. will soon receive a programable hardware coding device, complete with a Nordic Semiconductor Bluetooth Smart wireless chip, as part of a BBC initiative to inspire a new generation with digital technology.

The flagship Make it Digital initiative will see every year 7 child in the U.K. receive a "Micro Bit" programable hardware device, a small, standalone, wearable device with an LED display that children can program in a number of ways using entry-level coding by simply plugging into a computer.

The national broadcaster says the aim of the initiative is to help younger audiences discover their creative potential in the field of coding, programing, and digital technology.

As an official design, manufacture, and distribution partner of the program, Nordic Semiconductor will supply a million nRF51 Series Bluetooth Smart wireless chips to provide the

devices with wireless connectivity.

"Micro Bit overcomes the significant barriers to entry for young people getting involved with genuine technology development," comments Geir Langeland, Nordic Semiconductor's Director of Sales & Marketing.

BBC Director-General, Tony Hall, says the BBC hopes to transform a new generation from being passive consumers of technology, to creators and innovators, by learning basic coding and programming that will in turn act as a springboard for future transitioning to more advanced programming platforms. (See feature on page 16.)

The Micro Bit device will be issued to every year 7 schoolchild in the U.K.



In brief

Smart lighting to enter mainstream

Low power wireless standards combined with a rapid migration to LED lighting has made smart lighting a catalyst for the Internet of Things (IoT), according to global technology research firm ON World. The company said smart LED light bulb sales increased by 2900 percent in 2014 compared with 2012. By 2019, the company said, annual shipments for smart wireless LED light bulbs will increase by over 4000 percent to 400 million units. LED lighting is increasing in popularity because it consumes less energy than traditional light sources.

Rapid wearable development

QuickLogic has released its TAG-N wearable sensor hub evaluation kit, designed to allow rapid development and testing of ultra low power (ULP) wearable devices. The kit's ULP programmable sensor hub consumes only 75 microwatts of power and is designed to support "always-on", "always-aware" applications in wearable devices. It connects directly to Nordic's nRF51 Series Development Kit that allows OEMs to test, evaluate, and develop Bluetooth Smart wearable devices.

Dominating mobile audio

Bluetooth was the technology of choice in more than 95 percent of wireless headphones and mobile speakers shipped in 2014, research firm SAR Insight & Consulting has claimed. The company said an estimated 65 million Bluetooth-enabled home audio devices were shipped in 2014, and this is expected to double by 2020. It said the ubiquity of Bluetooth coupled with simplified pairing between devices has driven the use of Bluetooth as the consumer's audio streaming technology of choice.

3D headphones provide 'superior immersive sound'

A French startup has developed a pair of '3D' audio headphones said to provide a surround sound experience superior to any current home theater system. The headphones use Nordic's Bluetooth Smart technology.

The Neoh 3D audio headphones from 3D Sound Labs are claimed to produce a truly immersive, 3D spatial sound using the company's binaural algorithms that employ advanced nine-axis motion-sensing to track the smallest movements of the user's head. This means the sound field remains static even if the wearer moves their head to look left or right, for example.

The Nordic nRF51822 System-on-Chip (SoC) is used to send the motion sensors' data to a free partner Neoh player app running on any Bluetooth Smart Ready smartphone or tablet. From the app multiple sound formats are 'converted' via complex audio signal processing to produce a



The Neoh 3D audio headphones, a home theater for one

360° sound field of up to 30 unique channels, so the sound feels like it's moving around the user and perceived to come from any distance or direction

"This not only creates a truly astonishing surround sound it is also truly portable and can be taken and enjoyed by the user anywhere," says 3D Sound Labs Co-founder and VP of Product &

Operations, Dimitri Singer.

"And what's great is that gamers can gain an incredible tactical advantage by improving their perception of the gaming environment and reacting more quickly to game events."

The headphones are powered by a 3.7 V Li-ion battery and can run for at least 18-hours between recharges.

Arm-worn dual protocol heart-rate monitor improves user comfort

U.S. consumer technology company Scosche has developed a heart-rate monitor (HRM) designed to be worn on the arm instead of the chest, which is said to provide more accurate readings and greater user comfort.

The low-profile, one-size-fits-all RHYTHM+ is fastened to the forearm just below the user's elbow and uses an optical sensor to measure blood flow in the arm to determine pulse rate and calories burned.

The HRM employs Nordic's nRF51422 multiprotocol chip to provide both ANT+ and Bluetooth Smart wireless communications to smartphones, sports watches, bike computers, and gym equipment. By offering compatibility with both ANT+ and Bluetooth Smart technologies, Scosche says the RHYTHM+ will work with

virtually all third-party fitness hardware and apps on the market.

The RHYTHM+ is powered by a 3.7 V lithium-polymer battery that offers up to eight-hours of continuous use between recharges. It has a wireless range of up to 30 meters, and is made from a silicone and polycarbonate hybrid with a 'breathable' Lycra arm-strap that is both sweat and waterproof.

"Heart rate based training and exercise has yet to reach the mainstream population largely due to the price and inconvenient form factor of chest straps," says Joshua Duffy of Scosche.

"The RHYTHM+ is designed to be low cost and comfortable to wear, and can work with pretty much any third-party fitness kit regardless of whether it happens to employ ANT+ or Bluetooth Smart wireless technology."



The dual protocol heart rate monitor is worn on the forearm not the chest

Nordic sponsors Bluetooth SIG training series targeting IoT developers

Nordic Semiconductor is sponsoring a new training initiative introduced by the Bluetooth Special Interest Group (SIG), targeting Internet of Things (IoT) developers.

Called the Bluetooth Innovation Training Series, the Bluetooth SIG says it will arm developers through hands-on practical training and in-depth knowledge with the skill set needed to build connected products and applications with Bluetooth Smart technology, and bring them to market faster in IoT segments such as the smart home.

The Bluetooth SIG says the training series is designed to remove the mystery from developing connected products and applications for the IoT and will include a global series of one-day training events that will



feature Nordic wireless technology and development kits.

The SIG says the program is designed for both newcomers to Bluetooth technology looking for a springboard to create their first Bluetooth products, and the more experienced looking for insights

The SIG's training series is suitable for newcomers and experienced IoT developers

on how to do it better and faster.

Attendees will get to work with the SIG's new software development toolkit - Bluetooth Developer Studio - that is said to

reduce education time by up to 50 percent and shorten development by up to 70 percent.

"Nordic Semiconductor recognizes that with the standardization of Bluetooth Smart the development and product differentiation challenge has shifted from hardware engineering to also include firmware and software apps," says Geir Langeland, Nordic's Director of Sales & Marketing.

"That's why Nordic Semiconductor is giving developers ever more open and easy access to our nRF51 Series Bluetooth Smart development kits, tools, and reference designs; prioritizing technical support to all customers regardless of size or experience."

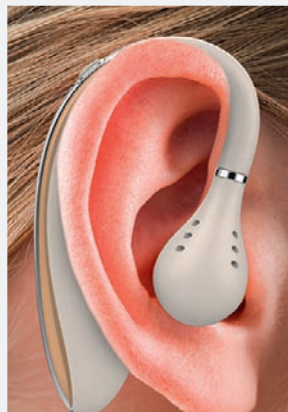
Developers can register for the training at Bluetooth.org.

Ear-mounted wearable stops people snoring without waking

Chinese wearable health technology startup, VVFly Electronics, has developed what the company claims is the world's first ear-worn snore detection and prevention device.

The VVFly Intelligent Snore Stopper is supplied in an ear-worn hearing aid form-factor and is said to detect when a user starts snoring by using a sophisticated combination of sound and bone vibration signal detection and analysis.

When snoring is detected, the device will start to gently vibrate and 'speak' to the snorer gently telling them to stop. If snoring continues to be detected, the intensity of vibration and loudness of the spoken communication will gradually increase until the user stops snoring by moving slightly or subconsciously responding to the spoken instructions. VVFly claims this method will typically stop the user snoring without actually waking them up.



Snore no more with the VVFly Intelligent Snore Stopper

The Intelligent Snore Stopper uses Nordic's nRF51822 System-on-Chip (SoC) to provide Bluetooth Smart wireless communications with smartphones or tablets. Sleep data is continuously recorded via a free partner app, allowing the device to act as a sleep quality monitor so users can track sleep pattern improvements from using the device over time.

"Snoring can cause serious sleep deprivation-related health issues both for the snorer and their partners and can also interrupt the supply of oxygen to the brain," says VVFly Founder, Johnson Luo.

"Sleep deprivation has been linked to all kinds of mental and physical health problems including impaired cognitive abilities and a higher risk of being involved in accidents of all kinds, depression, stress, anxiety, cardiovascular disease, as well as dying: it's that serious."

Smart security boom

Some 15 million more U.S. homes will invest in new connected home security services in the next five years as device providers increasingly see security monitoring as the launching pad for the widespread introduction of home automation, ABI Research has claimed. The analyst said demand for smart, self-monitored home security solutions was threatening traditional security monitoring services as they were perceived to offer better value. "Consumers can now choose from an array of non-traditional suppliers," says Jonathan Collins, Principal Analyst with ABI.

Record IoT M&A activity

Nearly \$15 billion has been spent so far this year on 39 mergers and acquisitions related to the Internet of Things (IoT), surpassing the \$14.3 billion spent on 62 such companies in the whole of 2014, according to analyst 451 Research. The 'land grab' was in part being driven by IT service and infrastructure companies keen to both broaden and deepen their IoT competencies ahead of the predicted IoT boom, the analyst said. "While the IoT is still in its infancy ... the deal-making accelerates unabated, and we see no end in sight," says Brian Partridge, a VP with 451 Research.

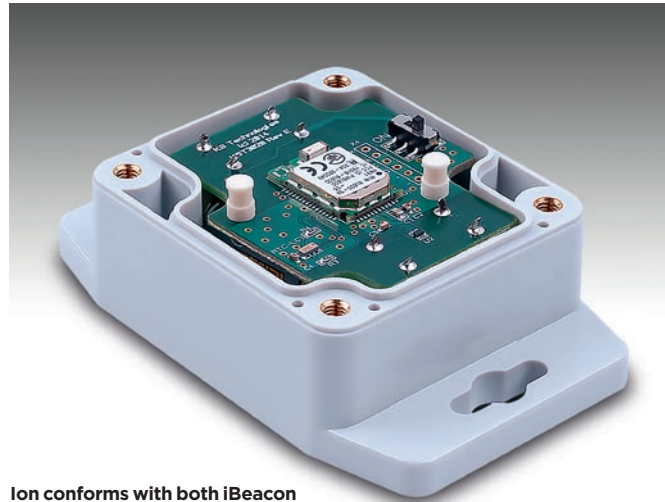
In brief

Customizable proximity beacon delivers 'contextually rich' content to consumers

▶ U.S. mobile hardware engineering company, KST Technologies (KST), has unveiled the Ion proximity beacon, capable of delivering contextual rich content to Bluetooth Smart Ready devices in applications ranging from museums and schools to theme parks and car dealerships.

Ion conforms with either the Apple iBeacon or Google UriBeacon specifications, or a combination of both, to talk to smartphones or tablets. It emits 'advertisements' which can be discovered by a user's mobile device, enabling indoor or outdoor navigation, asset tracking, and 'microlocation' based content delivery.

For instance, in schools when a student enters a classroom the in-situ Ion beacon could send a push notification to their Bluetooth Smart device with the agenda for the day. It could also be used to automatically check attendance, or notify a new



Ion conforms with both iBeacon and UriBeacon specifications

student if they are in the wrong location and provide a map on their device to show them where they need to go.

KST is using Nordic's nRF51822 System-on-Chip (SoC) to provide Ion's Bluetooth Smart connectivity to both iOS- and

Android-compatible devices.

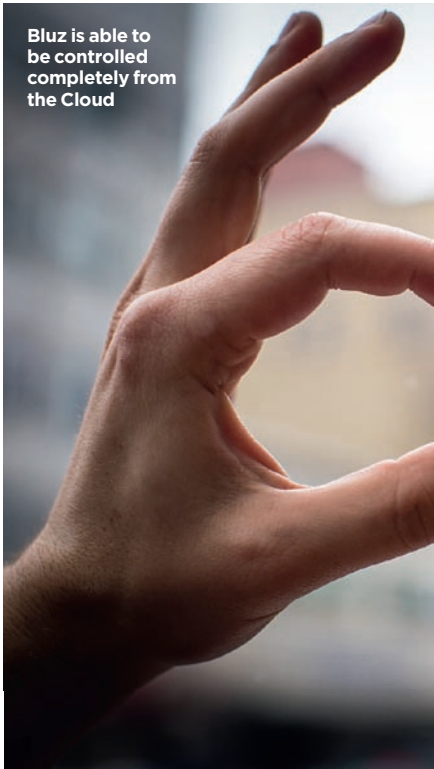
KST has added technology that allows developers to create an app that can update key beacon parameters as well as interrogate the batteries to determine their current life. The Nordic nRF51822 SoC also

enables over-the-air device firmware upgrades (OTA-DFU) for in-situ beacons. Powered by two, replaceable AA batteries, the ultra low power operating characteristics of the nRF51822 extend battery life up to one year in 24 hour, seven-day-a-week operation, although an onboard real time clock allows calendar functions to extend battery life yet further.

"KST has engineered all the technology itself, the end result is a beacon that is highly customizable and flexible," says Bob Kressin, KST's President.

"Beacons have the potential to become a 'killer application' for Bluetooth Smart," says Geir Langeland, Nordic Semiconductor's Director of Sales & Marketing. "But that potential will only be recognized if suppliers offer quality-engineered beacon products that are easy to work with and install. KST is making that happen."

Bluz is able to be controlled completely from the Cloud



Bluetooth Smart IoT development kit comes Cloud connected out-of-box

A Bluetooth Smart Internet of Things (IoT) development kit that is claimed to come Cloud connected out-of-the-box could pave the way for the production of a whole new category of wearable IoT devices, according to its developer.

Called Bluz, the development kit from U.S. startup, Easier To Use, is a basic Bluetooth Smart, Arduino-style, Spark Core/Photon pin-compatible platform that allows users to build pretty much any Cloud-connected Bluetooth Smart IoT application they want from scratch, at a low cost.

Employing a Nordic nRF51822 System-on-Chip (SoC) based module, Bluz is a standalone board that is said to break out all the major functions of the nRF51822, such as SPI, I2C, and UART, as well as 18 GPIO pins. It can also be paired with a number of stackable shields, such as an accelerometer, battery, or prototype shield to allow quick and easy creation of custom prototypes. Bluz can operate from a coin-cell battery for months or years.

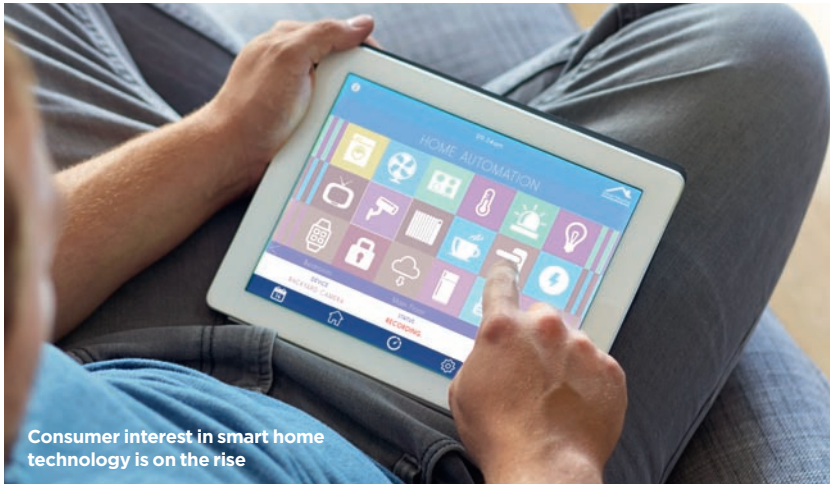
Cloud-connectivity is provided by a Wi-Fi dongle, or for wearables, a user's Bluetooth Smart Ready smartphone powered by low cost Cloud-connectivity specialist Spark, and compatible with app-based product control services such as IFTTT and Tinker for triggering events and processes.

By combining with Spark, Bluz is able to be controlled completely from the Cloud. According to Easier To Use, this Cloud access, alongside the ultra low power consumption of Bluetooth Smart, means a whole new category of battery powered IoT devices can easily be built.

The devices are said to be perfect for wearables or applications where many devices need to be deployed but a constant power source isn't available.

ULP WIRELESS TRENDS

The latest developments in technology



Consumer interest in smart home technology is on the rise

Consumers believe smart homes will be mainstream by 2020

Consumers are increasingly accepting the smart home as reality, but will demand simplicity and cost-effectiveness before it becomes mainstream, a new survey of 4000 U.S., U.K., and German consumers has revealed.

The Bluetooth Special Interest Group's (SIG) survey found 6 percent of respondents believed the era of the smart home had already arrived, while 46 percent said smart home devices would be mainstream by 2020. The strong consumer interest was tempered by high expectations for simplicity, with 54 percent of respondents claiming the devices will have to be straightforward to use, and 41 percent believing devices should be easy to set up.

In order to make smart home devices more desirable, 42 percent of consumers warned companies to keep their data safe and offer competitive prices when marketing the devices. According to the Bluetooth SIG this highlighted a major barrier to smart device adoption - trust. Sixty seven percent of those surveyed were concerned that some smart home devices would make their data vulnerable.

"Niche technologies simply cannot provide the simplicity, interoperability and security that consumers demand [for the smart home]. Bluetooth Smart technology offers all those things," says Mark Powell, Executive Director of the Bluetooth SIG.



The Precision power meter provides rich, in-ride data for cyclists

Crank power meter improves cyclists' performance

Canada-based 4iiii Innovations has launched a bicycle crank-mounted power meter, designed for cyclists who want to improve their performance. The 4iiii Precision power meter is compatible with both ANT+ and Bluetooth Smart Ready devices and provides cyclists with in- and post-ride power data on, for example, their bike computer or smartphone.

The meter boasts a battery life of up to 200 hours, and can be installed on most existing left or right cranks, or factory installed on new compatible cranks.

According to 4iiii Innovations CEO, Kip Fyfe, understanding exertion levels helps riders mitigate injuries and also serves as a comparison point between cyclists.

"There are some excellent power meters out there but we saw a way to offer another feature-rich device at a lower price point," says Fyfe. "Now everyone has the option of monitoring their power."

Internet of Things data capture rising amidst Edge computing shift

The volume of data captured by Internet of Things (IoT) connected devices such as Bluetooth Smart sensors is forecast to grow seven-fold by 2020, with Edge, not Cloud computing leading the way.

A report from ABI Research estimates the volume of data captured by compact IoT-connected sensors and other devices exceeded 200 exabytes in 2014.

"Only a tiny fraction of this vast data mass is actually being captured for storage or further analysis," says Principal Analyst Aapo Markkanen. "And of the captured volume, on average over 90 percent is stored or processed locally without a Cloud element ... so far the locally dealt data has typically been largely inaccessible for analytics, but that is



now starting to change."

The research claims the IoT is currently undergoing a major paradigm shift from Cloud computing toward Edge computing. Edge computing involves pushing processing for certain data intensive, remote applications away from traditional large

centralized datacenters closer to the end user - or edge - where the interactions are actually happening.

On one hand, this shift is opening up Edge-based data to meaningful analysis, by distributing the analytic workloads across the network. On the other, it is also shoring up the Cloud-level capabilities by making the transmitted data more actionable, by enriching and contextualizing the payloads.

"Edge computing is a huge challenge for the entire IoT value chain, as we can see from the way that cloud platforms, analytics vendors, and gateway suppliers are scrambling to collaborate with each other," says ABI Research Practice Director, Dan Shey.

Combining power and efficiency to redefine single-chip Bluetooth Smart

Nordic's nRF52 Series System-on-Chip features ARM Cortex M4F processor, 2.4GHz ultra low power radio, fully automatic power management, and on-chip NFC for Touch-to-Pair

“Single-chip Bluetooth Smart solutions have struggled to keep up with the rate of innovation in Bluetooth Smart – the fastest growing wireless market in history – particularly in applications such as wearables and IoT,” says Thomas Embla Bonnerud, Nordic Semiconductor's Director of Product Management. “Until now greater performance has only been achieved at the expense of power efficiency. But Nordic Semiconductor's new nRF52 Series overcomes this challenge by uniquely merging a high level of performance together with power efficiency.”

ARM Cortex M4F power

The nRF52832 is Nordic's latest product and is the first chip in the nRF52 Series. The device derives its barrier-breaking performance from a 64MHz ARM Cortex M4F processor. The processor enables the nRF52832 to reach an Embedded Microprocessor Benchmark Consortium (EEMBC) 215 CoreMark score and delivers up to 60 percent more generic processing power adding up to ten times the Floating Point and twice the digital signal processing (DSP) performance compared with competing ARM Cortex M0/M3 based Bluetooth Smart solutions.

The processor contributes to the SoC's overall ultra low power consumption by delivering 90 CoreMark/mA – double the efficiency of competing solutions.

The 2.4GHz radio is a high performance, ultra low power, multiprotocol Bluetooth Smart, ANT, and proprietary 2.4GHz radio with -96dB RX sensitivity, 5.5mA peak RX/



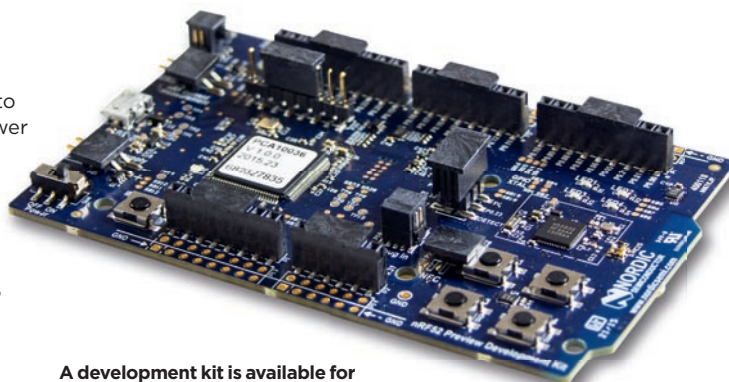
The nRF52832 features a more powerful processor, enhanced 2.4GHz multiprotocol radio and lower power consumption for the most demanding single-chip Bluetooth Smart applications

TX currents, and an on-chip RF Balun to reduce the number of peripheral components required. The high performance radio supports up to double the connection reliability, robustness to interference, range, and data throughput. Such features support a wider range of network topologies, greater protocol complexity,

and advanced security features. A unique fully-automatic power management system also makes it easy for designers to optimize power consumption.

The System-on-Chip (SoC) also integrates 512kB of Flash and 64kB of RAM enabling it to cope with the most demanding Bluetooth Smart applications. In addition, the nRF52832

“The nRF52 Series will free developers to be even more creative when designing Bluetooth Smart products and applications”



A development kit is available for engineers working with the nRF52832

features an on-chip Near Field Communication (NFC) tag for consumer-friendly Touch-to-Pair.

Energy harvesting

The combination of the nRF52832's high processor performance, powerful radio, ultra low power consumption and on-chip RF balun supports more compact products with a lower bill of materials (BOM). The SoC's power efficiency enables longer battery life, the use of smaller, lighter batteries, or makes the nRF52832 a good solution for being powered by energy harvesting.

The nRF52832 features a full range of on-chip analog and digital peripherals for glueless interfacing to external components such as sensors, displays, touch controllers, LEDs, keypads, motors, digital microphones, and audio Codecs. The SoC's architecture is based on a 55nm wafer fabrication process and packaging options include a 6 by 6mm QFN and a 3.0 by 3.2mm chip scale package (CSP).

“Applications that require the sort of processing power and performance packed into this chip have, until now, had to use a two-chip solution,” explains Bonnerud. “Our new SoC will free developers to be even more creative when designing Bluetooth Smart products and applications.”

Target applications for the nRF52 Series include wearables, human interface devices (HIDs) such as remote controllers, toys, smart home devices and appliances, and wireless charging.

Development Kits, QFN-packaged samples, software, and documentation are available now. Volume production is scheduled for December 2015. ■



Open standards vital for IoT growth

The IoT will only meet its full potential if it employs interoperable technology rather than relying on proprietary techniques. Ståle “Steel” Ytterdal explains



Ståle “Steel” Ytterdal is Director of Sales & Marketing – Asia, Nordic Semiconductor

The excitement about the Internet of Things (IoT) is understandable. The Internet as we know it today has transformed the world in just a quarter of a century, yet extending it to billions of tiny, inexpensive sensors that continuously generate useful data will dramatically multiply the network’s power.

There are thousands of examples of applications of the IoT, but far fewer practical implementations. Most people have heard of the “smart refrigerator” – an IoT-connected fridge can tell you it is out of milk via SMS because its internal camera notices there is none left, or that the carton is past its use-by date – but hardly anybody owns one.

But some progress has been made where there is a financial imperative. For example, in the U.K., smart electricity meters are being rolled out following government incentives. These smart meters have clever functions that let consumers precisely control how they use power, even remotely.

Such commercial inducements are vital to get things moving. Whereas the Internet was originally financed as a U.S. Department of Defense project, then used as an academic and scientific tool, only later being made freely available for leveraging by commercial companies, the IoT will only grow if it can be used to make money.

The IoT is more than smart homes and connected appliances, though. A fully-fledged system will include smart cities – with infrastructure such as traffic monitoring that adjusts signals to optimize traffic flow, or trash cans that signal when they need emptying – and industry, with



The IoT will enable traffic monitoring and signalling to optimize traffic flow in tomorrow’s smart cities

“Without standardization there’s a danger of network fragmentation as commercial interests see manufacturers develop solutions that don’t easily play with each other”

connected sensors monitoring everything from jet engines to crop irrigation. (See ULP Wireless Q Spring 2015, pg10.)

Infrastructure challenge

Network equipment maker Cisco Systems described the IoT as the convergence of Internet Protocol (IP) networks – millions of computers and billions of other IP devices in the home and office – with mobile networks – billions of data packets from Internet-capable mobiles – to form a network of a trillion “end points”, using a common infrastructure.

It’s that “common infrastructure” that’s perhaps the biggest challenge to the growth of the IoT. Without standardization there’s a danger of network fragmentation as commercial interests see manufacturers develop solutions that don’t easily play together. IoT technology must be based on an open standard because it’s been shown many times in different sectors that interoperability is a catalyst for rapid adoption.

Analysts say that of the up to 30

billion nodes that will be shipped in the next decade, more than half will be for applications that as yet don’t exist. If this promise is to be realized, IoT players such as Nordic Semiconductor need to make it extremely easy for developers to focus on innovation – instead of worrying about aligning protocols or getting gateways to communicate – by providing products based on open standards that work “right out of the box”.

Bluetooth Smart is a good candidate for connecting many of the “things” making up the IoT because it’s a proven technology based on an open standard that’s purpose-designed for ultra low power wireless connectivity.

For its part, Nordic is proud to say that it’s the first company to build a complete IP stack on top of Bluetooth Smart and release it as a commercial solution to developers. The company’s IPv6 over Bluetooth Smart development kits and tools have been available since December last year.

Previously, industry observers

doubted it was possible to run IP on compact wireless sensors (“end nodes”) because it would make the device too complex and unacceptably increase power consumption. But these people were assuming that the end nodes would use proprietary solutions connecting to the Internet via gateways (relatively expensive devices with sufficient computing power to “translate” Bluetooth Smart into IPv4 or IPv6). (See ULP Wireless Q Spring 2015, pg18.)

But for over three years Nordic has been able to supply a low cost, ultra low power System-on-Chip that can run an IPv6 stack allowing a sensor to connect directly to the Internet via a “headless” router (a cheap, “dumb” unit that simply relays IP packets from the sensor to Cloud-based servers). (See ULP Wireless Q Spring 2015, pg8.)

This technology, along with other standard wireless technologies such as Wi-Fi and IEEE 802.15.4, will power a tsunami of change that will make the impact of today’s Internet seem like a ripple. ■



Beacons bring art to the masses

Beacons are capable of driving more than just retail sales, as one art gallery is discovering. ULP Wireless Q reports

There was a time when the two questions any parent dreaded when they took their children to an art gallery and made them stand and stare at an important piece of art were: “can we go home yet?”, or worse: “why is it important?”

“We’ve only just got here” and “because it is” were not deemed satisfactory answers, but it was all we had. Fast forward to 2015 and at least for parents taking their kids to the Colorado Springs Fine Arts Center (FAC) in Colorado, U.S. things have changed.

The advent of Bluetooth Smart proximity detection beacons is reimagining the art gallery experience in Colorado Springs, with the FAC deploying the technology throughout the facility, allowing the organization to deliver contextually sensitive and relevant information to visitors as they pass by certain exhibits, ‘pinging’ their Bluetooth Smart Ready device via the partner app with supporting video, photography, and text.

According to FAC President and CEO, David Dahlin, the days of clunky audio headsets, explanatory wall plaques, and curator-led tours are numbered.

“We’re tremendously excited about how the technology enhances the visitor’s experience,” says Dahlin. “Art institutions like ours are finding that it’s not enough to hang art on the walls. If we’re going to stay relevant into the coming decades, we need to make each visit more interactive and exciting. We believe this new app is helping us to get there, really changing the way people view art.”

The company behind the FAC installation is Colorado Springs-based mobile hardware engineering firm, KS Technologies (KST). KST has worked with the FAC to deploy its Ion proximity



beacons throughout the gallery. Ion conforms with either Apple’s iBeacon or Google’s UriBeacon specifications, or a combination of both, to ‘talk’ to a user’s Bluetooth Smart Ready device, employing Nordic Semiconductor’s ultra low power hardware to provide the wireless connectivity.

Enhanced experience

KST President, Bob Kressin, says while a lot of attention has been paid to the use of beacons in retail environments (see ULP WQ *Winter 2014*, pg10), the FAC installation demonstrates that the technology could actually enhance an end user’s experience, not just drive retail sales.

“I’m standing in front of this piece of art, I want to learn more about it, I don’t want to poke around in an app, I don’t want to read the sign, I just want the app to present me the appropriate information, and that’s how we

are using the beacons at the FAC,” says Kressin.

“Old museum audio headsets get in the way. You have to pause and stop it, or wait because the audio is talking about something, but not what you’re looking at.

“When you are within the beacon’s range of three-to-five meters you’re being told exactly

what you’re in front of, and we can pull it up right on the app. It’s a very seamless experience.”

Beyond improving the user experience the beacons also have a hidden advantage, helping the FAC shape the gallery and design future exhibitions. Every time a device is pinged by a beacon the unique identifier of the device is recorded and time stamped, effectively allowing the FAC to track foot patterns, showing how visitors are actually using the institution, where they are going, and where they aren’t.

“Of the 12 pieces of art in the collection, did one phone visit all 12 pieces, or did one phone just go to the special exhibits gallery, or did they go to the permanent collection?” explains Kressin.

“Right now the FAC has no idea, they can look and get an idea where people are going, but the facility is 6000 square meters and they want to try and increase the traffic flow to certain parts of the museum. Now the data is there they should be able to optimize the experience.”

KST and the FAC are continuing to brainstorm ways to use the beacon technology to improve interactivity for youngsters in particular. Beacon-guided scavenger hunts using Apple’s iPod touch being one example. Whether the older generation will embrace beacons is less clear, but Kressin remains hopeful.

“The app is extremely simple, the way we use the beacons is incredibly simple, and we believe hopefully the older generation will also start engaging,” says Kressin.

“It’s interesting in the FAC we didn’t hide the beacons, and it’s because of the older generation; it’s one of the lessons we learned from installing there. If seniors see a sign that says ‘this is a beacon and you can interact with this art’ it sends a different message. If it’s invisible it’s less tangible, so the FAC hopes that attracts the older generation to start playing with the technology and ask questions.”

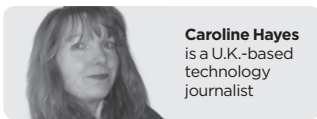
And if the beacons don’t attract mums and dads to ask questions, they will at least help them answer one. When their children next ask why a painting is important, the technology will help them do a lot better than “because it is”. ■



The beacons (shown here) are sited next to exhibits (top picture). The close presence of visitors triggers content to supplement the viewing experience

Five decades on Moore's Law still drives chip sector

When Gordon Moore made an observation about the IC he was working on, he could not have imagined that it would turn into a 'law' still relevant 50 years later. By Caroline Hayes

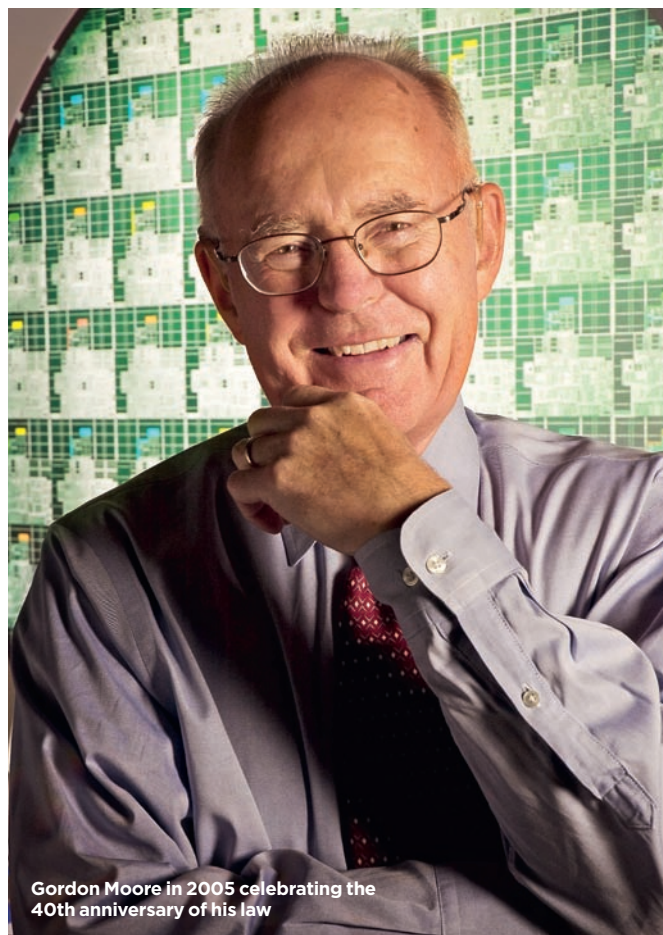


Caroline Hayes
is a U.K.-based
technology
journalist

Little else, certainly not in the semiconductor industry, has stood the test of time like Moore's Law. As a 36-year-old Director of R&D at Fairchild Semiconductor in 1965, Gordon Moore was asked to predict the next 10 years in the industry. He noted that a contemporary IC had 64 transistors on it, double the amount it had the year before. He wrote, in an article published in April 1965^[1], that the number of transistors that can affordably be placed on an IC would double every year and that this rate of increase would continue for the next 10 years.

In 1975, then Executive Vice President at Intel, a company he co-founded in 1968 with Fairchild colleague, Robert Noyce, Moore saw a subtle slowdown and amended his eponymous law to explain that the number of components on an IC would double every two years. The revision reflected trends in yield and production. While an increase in the number of chips produced lowered the cost, as circuits became more complex, the manufacturing costs to produce them increased.

While the wording of Moore's Law sounds innocuous, predicting relatively modest-sounding growth every two years, it belies the astonishing change in performance that the industry has experienced. Comparing today's Intel Core i5 processor to the 1971 Intel 4004 with 2,300 transistors, there is a 3,500 times increase in processing power, 90,000 times better energy efficiency and an



Gordon Moore in 2005 celebrating the 40th anniversary of his law

order of magnitude lower cost.

For five decades, Moore's Law has been used as a measure for R&D to deliver more computing power, at a lower cost and smaller form factor. Without that driver, the advent of the smartphone would have been delayed. Similarly, would the Internet of Things (IoT) be here, without the energy efficient performance to deliver and process data? Without Moore's Law to spur on design teams, computers might still take up whole rooms, instead of fitting into the palm of the hand, or even being worn on the wrist.

"Moore's Law hit a technology and marketing nerve. It set a standard of excellence to be achieved that was adopted by the whole industry"

Future trends

After half a century, is there still life in Moore's Law? The man himself said, at a 50th celebration

in May, that it won't last forever, but with good engineering, it could apply for another five to 10 years. In earlier interviews, he has spoken of progress reaching saturation point in 2015 and the physical limitations of a chip being reached by 2017.

Certainly difficulties with etching smaller and smaller chips present their own set of challenges, and the investment costs to design and manufacture them continues to rise. Yet the public appetite for small, low cost, energy-efficient, high performance chips has not waned.

A recent example of the levels of integration, complexity, and small chip size enabled by fabrication processes following the trend predicted by Moore's Law is the nRF52 Series, Nordic Semiconductor's new family of ultra low power (ULP) wireless Systems-on-Chip (SoCs). The nRF52 Series uses TSMC's 55-nanometer ultra-low power (55ULP) wafer fabrication process. The process enables a high level of integration while simultaneously reducing power consumption and chip size.

According to Svenn-Tore Larsen, Nordic Semiconductor's CEO, these characteristics make the nRF52 Series an ideal choice for future wearable and IoT applications. (See page 8 this issue.)

Moore's Law hit a technology and marketing nerve. It set a standard of excellence to be achieved that was adopted by the whole industry. Most tellingly, 50 years on, it is still a point of reference for today's semiconductor community. ■

[1] "Cramming More Components onto Integrated Circuits," *Gordon E. Moore*, Electronics, April 1965.

Ultra low power wireless connectivity solutions

Find the chip you need using this latest listing of every Nordic product

ICs Integrated Circuits "chips"	Operating Band	Wireless Protocol	IC Type			On-Chip			Peripherals														Applications											Ref. Designs	Dev Tools	WLCSP Wafer-level chip-scale package option		
			System-on-Chip	Connectivity	Transceiver	CPU	Memory OTP: One Time Programmable	Balun	Oscillators	NFC-A tag	2-Wire	ADC	AES	Analog Comparator	Battery Monitor	I2S	PDM	MDU	PWM	Real Time Clock	RNG	SPI	S/PDIF	Temperature Sensor	UART	USB	Apposories	PC Peripherals	Sports & Fitness	Gaming	Cellphone Accessories	Consumer Electronics	Automation				Healthcare	Toys
nRF52 Series																																						
nRF52832	2.4GHz	Bluetooth Smart v4.x, Proprietary & ANT	●			Cortex M4F	64kB RAM 512kB Flash	●	32MHz / 32kHz Crystal 64MHz / 32kHz RC	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	-	Single Board Preview Dev Kit	●
nRF51 Series																																						
nRF51822	2.4GHz	Bluetooth Smart v4.x & Proprietary	●			Cortex M0	32kB or 16kB RAM 128kB or 256kB Flash		16MHz / 32kHz Crystal 16MHz / 32kHz RC		●	●	●	●				●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	PC Desktop, Smart Remote, Smartphone Demo Apps, Beacon	Single Board Dev Kit, Dongle	●	
nRF51422	2.4GHz	Bluetooth Smart v4.x, Proprietary & ANT	●			Cortex M0	32kB or 16kB RAM 128kB or 256kB Flash		16MHz / 32kHz Crystal 16MHz / 32kHz RC		●	●	●	●				●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	Smartphone Demo Apps	Single Board Dev Kit, Dongle	●		
nRF8000 Series																																						
nRF8001	2.4GHz	Bluetooth Smart v4.x		●		-	-		16MHz / 32kHz Crystal 32kHz RC										●	●					●	●	●	●	●	●	●	●	PC Desktop, Smart Remote, Smartphone Demo Apps	nRFgo Dev Kit, Prog. Kit				
nRF8002	2.4GHz	Bluetooth Smart v4.x	●			-	-		16MHz Crystal 32kHz RC																								Key Tag, Smartphone Demo Apps	nRFgo Dev Kit, Prog. Kit				
nRF24AP Series																																						
nRF24AP2-1CH	2.4GHz	ANT		●		-	-		16MHz / 32kHz Crystal											●						●	●	●	●	●	●	●	Smartphone Demo App	ANT Dev Kit				
nRF24AP2-8CH	2.4GHz	ANT		●		-	-		16MHz / 32kHz Crystal											●						●	●	●	●	●	●	●	Smartphone Demo App	ANT Dev Kit				
nRF24AP2-USB	2.4GHz	ANT		●		-	-		16MHz Crystal														●			●	●	●	●	●	●	●	ANT USB Dongle	ANT Dev Kit				
nRF24L Series																																						
nRF24LE1	2.4GHz	Proprietary	●			8051	1kB + 256kB RAM 16kB + 1.5kB Flash		16MHz / 32kHz Crystal 16MHz / 32kHz RC		●	●	●	●						●						●	●	●	●	●	●	●	PC Desktop, Smart Remote, R/C Toy	nRFgo Dev Kit, Prog. Kit				
nRF24LE1 OTP	2.4GHz	Proprietary	●			8051	1kB + 256kB RAM 16kB + 1kB OTP		16MHz / 32kHz Crystal 16MHz / 32kHz RC		●	●	●	●						●						●	●	●	●	●	●	●	PC Desktop, Smart Remote, R/C Toy	nRFgo Dev Kit, Prog. Kit				
nRF24LU1+	2.4GHz	Proprietary	●			8051	2kB + 256kB RAM 16/32kB Flash		16MHz Crystal				●							●						●	●	●	●	●	●	●	PC Desktop, Smart Remote, R/C Toy	nRFgo Dev Kit, Prog. Kit				
nRF24LU1+ OTP	2.4GHz	Proprietary	●			8051	2kB + 256kB RAM 16kB + 1kB OTP		16MHz Crystal				●							●						●	●	●	●	●	●	●	PC Desktop, Smart Remote, R/C Toy	nRFgo Dev Kit, Prog. Kit				
nRF24L01+	2.4GHz	Proprietary		●		-	-		16MHz Crystal											●						●	●	●	●	●	●	-	Eval Kit					
nRF24 Series																																						
nRF2460 (mono)	2.4GHz	Proprietary		●		-	-		16MHz Crystal		●																●	●	●	●	●	Microphone	nRFgo Dev Kit					
nRF900 Series																																						
nRF9E5	Sub 1-GHz	433 / 868 915MHz	Proprietary	●		8051	4kB + 256kB RAM		4 / 8 / 12 / 16 / 20MHz Crystal			●								●												-	Eval Kit					
nRF905	Sub 1-GHz	433 / 868 915MHz	Proprietary		●	-	-		4 / 8 / 12 / 16 / 20MHz Crystal											●												-	Eval Kit					

Unveiling the secrets of the nRF52 Series

Nordic's new product line builds on the success of its award winning ARM-based SoCs by offering faster processing yet lower power consumption. ULP Wireless Quarter reports

When Nordic Semiconductor launched its nRF51 Series

Systems-on-Chip (SoCs) in June 2012, Bluetooth Smart was in its infancy. Now it is a mainstream technology forecast to exceed one billion shipments a year by 2016, according to the Bluetooth Special Interest Group (SIG).

The success of Bluetooth Smart is encouraging developers to consider new applications of the technology beyond its consumer electronics roots. For example, the Bluetooth Smart is being touted as a foundation technology for the Internet of Things (IoT), an extension of the conventional Internet that adds connectivity to billions of devices, appliances, and sensors.

For that to become reality, Bluetooth Smart sensors will need the computing power to support not only the Bluetooth Smart stack and application software, but also an Internet Protocol (IP) stack to enable IPv6-based communication with all the other devices connected to the network. (See ULP Wireless Q *Spring 2015*, pg 8.) In addition, the sensors will need to consume minimal power allowing them to run for months or years from a tiny battery, or, better yet, be self-powered using energy harvested from their surroundings.

Nordic's new nRF52 Series is perfectly suited to this challenge - and thousands of other demanding Bluetooth Smart, ANT+, and 2.4GHz proprietary wireless applications besides - because it marries the power of a 64MHz ARM Cortex M4F processor with a highly efficient radio and fully-automatic power management system. Better yet, the nRF52 Series builds on the



The nRF52 Series marries processing might with ultra low power consumption to meet the challenge of the most demanding wireless connectivity applications

nRF51 Series' proven architecture allowing developers a smooth migration path when moving to the enhanced product family.

Single-chip power

One of the key upgrades of the nRF52 Series is the replacement of the nRF51 Series 16MHz ARM Cortex M0 processor with a more powerful 64MHz ARM Cortex M4F.

The nRF52 Series SoC's high processor performance enables developers to create Bluetooth

Smart wireless applications with more features and improved user experience. To achieve comparable performance, designers would previously have had to use a two-chip (separate radio and processor) solution, increasing cost, size and complexity.

The ARM Cortex M4F processor enables the nRF52 Series SoC to record an Embedded Microprocessor Benchmark Consortium (EEMBC) CoreMark of 215 - the best

CoreMark of any commercially-available Bluetooth Smart SoC. (The CoreMark is an industry accepted quantitative measure of an embedded processor's basic performance.) The nRF52832 SoC's Floating Point performance is up to ten times better, and digital signal processing (DSP) performance up to two times better than competing products with proportional reductions in power consumption. The ARM Cortex M4F is a highly efficient

processor providing a CoreMark/mA figure (from Flash) of 90 - again superior to any competing solution.

As with the nRF51 Series, developers will benefit from the advantages of working with well-known and mature ARM-based toolchains from Keil and IAR, and code re-use including that from existing open-source libraries.

Redesigned radio

The nRF52 Series features an enhanced 2.4GHz radio that is on-air compatible with Nordic's nRF51 Series, nRF24L, and nRF24 devices. The radio features a maximum receive (RX) sensitivity of -96 dB and a maximum TX output of +4 dBm (programmable in 4 dB steps) for an improvement in link budget of up to 8 dB compared to the previous generation of devices. The increase in link budget increases the range of the radio and/or improves robustness.

The radio's power consumption is up to 30 percent lower than the nRF51 Series. Peak RX and TX (at 0dBm) currents are 5.5 mA, with the TX current rising to 7 mA at +4dBm. The radio also features integrated RF matching circuitry eliminating the need for an external balun. A full Bluetooth Smart implementation (including 11 passives and a 32MHz crystal (with a 32kHz crystal option)) consumes less than 8 by 9 mm of PCB area.

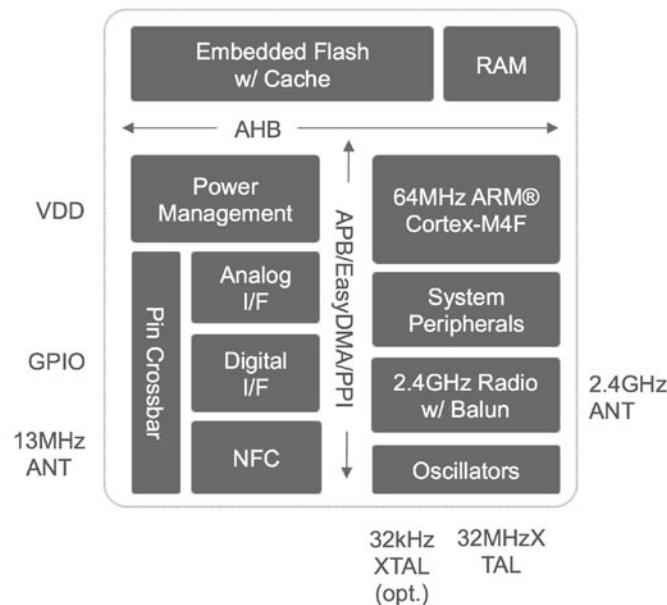
The nRF52 Series retains the nRF51 Series' EasyDMA (Direct Memory Access) functionality allowing the radio to access data directly from memory, convert to packets, and transmit.

The nRF52 Series SoC operates from a single 1.6 to 3.6-V power supply and features fully-automatic power management. Modules request power and the system monitors total current and supply levels to select the optimum regulator from the buck DC-to-DC regulator and low drop out linear regulators (LDO) on the chip.

The nRF52 Series SoC features several ultra low power sleep modes: It consumes 1.4 μ A in "ON" (idle) mode with real time clock (RTC), 900 nA in "ON" (idle) mode and just 500 nA in "OFF" mode.

The fully automatic power

Figure 1: A schematic of Nordic's nRF52 Series. At its heart lies a new radio and ARM Cortex M4F processor



"The shared software between the nRF51 and nRF52 Series allows for a smooth migration path and code re-use"

management minimizes power consumption and relieves developers of the power management design burden. The improved performance and lower power consumption allow the nRF52 Series radio to support more complex protocols and network topologies while improving security, extending battery life and minimizing packet loss. Battery life could be extended by up to 500 percent compared to like-for-like applications using the previous generation of Bluetooth Smart solutions.

The nRF52 Series is the first Bluetooth Smart solution to incorporate an on-chip Near Field Communication (NFC)-A tag for consumer friendly Touch-to-Pair. The technology does away with the complicated manual pairing that puts some consumers off Bluetooth Smart technology.

NFC is a contactless RF technology that enables devices to share information at a distance of less than 4cm. NFC's bidirectional communication ability is ideal for establishing connections by the simplicity of touch. NFC employs electromagnetic induction

between two loop antennae allowing devices to exchange information using the unlicensed 13.56 MHz band. Data rates range between 106 and 424 kbit/s.

The nRF52 Series SoCs' Touch-to-Pair functionality will allow consumers to pair Bluetooth Smart and Bluetooth Smart Ready devices by bringing them in to close proximity. NFC technology completes the steps of enabling, pairing, and establishing the Bluetooth Smart connection. No complicated manual pairing is required.

Proven architecture

While featuring a new processor and redesigned radio, the nRF52 Series retains the absolute differentiation between application and protocol code and their associated requirements that was introduced with the nRF51 Series. (See ULP Wireless Q Summer 2012, pg12.) A key advantage of this approach is that it ensures essential resources associated with RF protocol operation have guaranteed access and guaranteed speed of response. The RF protocol is a precompiled and linked binary

and as such has no compile or run time dependencies that often plague developers when working within a vendor's framework.

The nRF52 Series SoCs' architecture uses two discrete functional blocks that have complete autonomy from each other. The first block is the developer's application, the second is the RF protocol block (the SoftDevice). The shared software between the nRF51 and nRF52 Series allows for smooth migration between the product families and re-use of stable application code.

The nRF52 SoCs also retain the Programmable Peripheral Interconnect (PPI) feature from the nRF51 Series. This is an ingenious approach to peripheral interaction that allows peripherals to operate autonomously and independently of the ARM microcontroller. An enhancement of the nRF52 Series is that PPI can now be used for all peripherals rather than a select group.

A final retained feature from the previous product series is the Tasks & Events module which takes on the job of managing the I/O pin allocations. This feature allows the nRF52 Series SoCs to eschew fixed pin locations, instead allowing any pin to be allocated to any part of the chip's architecture, or even other pins. Unused pins can be disconnected for additional power savings.

The nRF52 Series' greater processor performance enables developers to make their products more attractive to consumers, including adding new features and improving the user-experience. The high level of integration supports smaller products and a lower bill of materials (BOM) and the increased power efficiency supports greater battery life and/or the use of smaller, lighter batteries. Enhanced radio performance supports up to twice the connection reliability, robustness to interference, improved range and enhanced data throughput plus support for greater network topology and protocol complexity, and advanced security features. ■

For more on the nRF52 Series go to www.nordicsemi.com.



Inspiring young consumers to become digital innovators

Initiatives to promote coding to young people as a cool career option are important if the industry is to continue to flourish, writes Sally Ward-Foxton



Sally Ward-Foxton
is a freelance
journalist specializing
in electronics

Digital technology is one of the biggest growth markets in the world today. The Internet of Things (IoT), for example, is set to connect billions of previously 'dumb' objects worldwide, introducing digital tech to practically every corner of every industry. And as electronic products proliferate so will the requirement for the application specific software that brings them to life.

Of course, most developed nations are extremely keen to try to harness some of this growth in the technology sector so that it can benefit their economies. The trouble is that in order to build globally competitive digital industries, people with the right skills are required to make it all happen. An assessment carried out by Parthenon Analysis last year revealed the U.K., for example, is facing a significant skills shortage, with 1.4 million "digital professionals" needed by 2019. These digital professionals need the right educational background in science, technology, engineering, and math (the so-called STEM subjects).

In the U.S., the Obama Administration has "challenged the nation" to boost STEM education by creating 100,000 new effective STEM teachers over the decade from 2013. The aim is to move American students from the "middle to the top of the pack in science and math achievement".

Initiatives to encourage young people at university to pursue such an educational path are



The next generation of digital professionals will need a strong background in STEM education. And they need to be attracted early

probably too late - efforts should be aimed at a younger audience to encourage enthusiasm and continued participation in STEM subjects at secondary school level and beyond.

That's why the BBC, a leading global broadcaster, is targeting 11 and 12 year-olds with its new Micro Bit program. This major initiative by one of the world's biggest media companies will provide every year 7 child in the U.K. with a programmable board to let the youngsters have a go at coding and hopefully discover their digital creative potential. The aim is to inspire them to consider

a career in the digital industries of tomorrow.

Digital Legacy

The BBC has a long heritage in teaching people about technology. A previous initiative by the organization in the 1980s, the BBC Computer Literacy project, placed microcomputers in U.K. schools to enable and encourage young people to learn about how to use the machines. At the time, it was seen as vital for students to become "computer literate" in order to be employable in the industries of the future (that is, the 1990s).

This nationwide program fostered many people's first experience of using a computer; there is no doubt that it was instrumental in inspiring many of today's generation of programmers and digital professionals into a career in the area.

The new programme will provide a small piece of hardware for each student to work on. The Micro Bit is a standalone, entry-level device that can be programmed in a variety of ways with a choice of software editors. The board will have a processor which can be programmed via a USB link to a computer, an LED display, and a Nordic Semiconductor Bluetooth radio chip.

"Traditionally there have been very significant barriers to entry when it comes to young people getting involved with genuine technology development," says Geir Langeland, Sales and Marketing Director at Nordic Semiconductor. "But with the advent of modern smartphones, tablets, and apps there has been major shift towards making technology easier and simpler to use in general: not just for users - but also for developers. This opens up the door to young people and all their creativity if they have the right basic skills.

"While Nordic is based in Norway, we're still keen to be involved in this venture because the BBC is recognized as a first-rate global organization with a track record for promoting digital technology."

The boards are designed to provide a hands-on learning experience for younger children to start to learn the concepts involved in basic coding. The idea of code as a set of instructions that computers can understand, the scope of coding and how it allows everything computers



Specially developed content which ties in with some of the BBC's biggest brands, including the popular Dr Who series, will help inspire young people to consider a career in coding

written the world's first computer program. Lovelace worked with Charles Babbage on his Analytical Engine, the first computer, and imagined a future where computers did more than just crunch numbers.

Another documentary will investigate Gordon Welchman, who alongside Alan Turing was a key codebreaker at Bletchley Park, Britain's HQ dedicated to breaking the German Enigma codes during the Second World War. A drama has also been commissioned based on the making of *Grand Theft Auto*, one of the most popular video console games of all time which was developed in Scotland, as well as a series of radio programs celebrating the history of coding and computing.

As well as factual content, there will be opportunities too for young coders to get involved through some of the BBC's biggest brands, including British TV soap *EastEnders* and the widely loved *Dr Who* franchise. For example, aspiring digital creatives will be able to program new levels for the platform game *The Doctor and the Dalek*. This game uses pseudo-code to allow users to build their own levels, gradually increasing in complexity. There will also be superhero-themed games and animation kits which don't require any coding experience, as part of the BBC's annual *Children in Need* charity appeal.

It is hoped that this material will help make digital technology 'cool' in the eyes of younger students and encourage them to continue to study STEM subjects and potentially even consider coding as a career option.

Those receiving the BBC Micro Bit board in 2015 will be graduating university around 2023, and will hopefully be on track to become the digital visionaries the developed world will then need to continue innovation and keep up with the pace of change in emerging economies. ■

do today, and how programming languages work are just some of the concepts the Micro Bit board can illustrate for children in an intuitive way. The idea is that it will be an entry point, with the children hopefully inspired to progress to more complex platforms such as Arduino and Raspberry Pi as they learn.

Nordic's chip was chosen for two key reasons. First, its Bluetooth technology allows easy connection with smartphones and tablets: all 11 and 12-year-olds are very familiar with mobile devices and what they can do. Connecting to the Micro Bit and then making the smartphone do something as a result of what has been programmed onto the board will be a great illustration of the implications of coding. Second, the Nordic chip has an architecture that makes it particularly simple to work with; something that has already made it popular with amateur engineers, hobbyists, and makers across the globe.

"We're confident that the

schoolchildren will have fun with our chip and will manage to get it to do something useful," says Langeland. "And one day, when some of them end up in coding jobs, we hope they remember that playing with a Nordic chip was what inspired them to embark on that career path. You never know, a few may even end up working for us!"

Inspiring Young Minds

A big part of the BBC's strategy for inspiring young coders will be tie-ins with some of its biggest brands. The BBC reaches 97 percent of people in the U.K., and many millions more worldwide through its broadcasting and online presence; the reach of this program therefore can't be underestimated.

Some of the U.K.'s best known personalities, including Stephen Fry and Will.i.am, have already announced their support for the project, but the BBC is thinking even bigger. A whole season of content entitled "Make It Digital" will showcase "how Britain

"Traditionally there have been very significant barriers to entry when it comes to young people getting involved with genuine technology development"

Geir Langeland

has helped shape the digital world, why digital skills matter, and inspire our audiences to become creators as well as digital consumers," in the words of the BBC. The content commissioned will cover, amongst other things, the history of British computing. There will be a documentary on Ada Lovelace, the British mathematician born in 1815 who is widely considered to have

The BBC Micro Bit board will be provided to all year 7 children in UK schools; a million boards have been commissioned



At a glance

- The U.K. is facing a significant skills shortage, with 1.4 million digital professionals needed by 2019
- A standalone, entry-level device, complete with wireless communication capability will be provided for all 11 and 12 year-olds in British schools to help them learn about coding in a hands-on way
- The BBC is planning a season of broadcast and interactive content about digital technology to help inspire youngsters

Nordic Developer Zone: An innovator's 'gold mine'

Nordic's 'devzone' is rapidly growing in popularity with professional engineers and hobbyists alike. ULP Wireless Q finds out why

Nordic Semiconductor's Developer Zone ('devzone') continues to grow in popularity. A mix of blogs, comments, technical information, and shared experiences has caught the imagination of innovative professionals and amateurs keen to maximize the potential of the company's ultra low power (ULP) wireless solutions.

ULP Wireless Q wanted to find out what developers thought about the online community so we tracked down six users and occasional contributors and asked them to tell us how the devzone helps them come up with novel ULP wireless-equipped designs.

'Cocoa' is the CTO of a European technology start up who has been working with ULP wireless since Apple's adoption of Bluetooth Version 4.0. He works with Bluetooth Smart and sub 1-GHz wireless technology. Nikita Sergeevich Polotnyanko is an Electronics Engineer involved with the entire electronics design cycle. He has worked with ULP wireless technology for three years and Nordic technology for the past 18 months. His key interest is Bluetooth Smart.

'Hoan' is a professional Hardware & Software Engineer and a Maker at the same time. He works in product R&D working with Bluetooth Smart and Wi-Fi. He has been developing with Nordic's nRF51822 since January 2014. Marek Novák is an Electronics Engineer involved in wireless design for a commercial company as well as research

"The devzone is a community of people helping each other out, so it's quite a nice place to hang out for a few minutes a day"

Roland, retired Programmer and Hobbyist

Looking for inspiration? Visit the Nordic devzone



projects at the Czech Technical University. He started working with Nordic's proprietary technology about 3 years ago and moved on to the nRF51 Series (both Bluetooth Smart and ANT) in early 2014.

'John D' is a Principal Firmware Engineer whose work involves the architecture, design, implementation, and support of the firmware used in his company's products. He has been working with ULP wireless for around five years and Nordic's Bluetooth Smart technology for two years. 'Roland' is a retired Programmer who says he now has lots of free time to spend on hobbies. He originally worked with host Bluetooth Smart programming before moving to peripheral programming using

a Nordic Bluetooth Smart development kit.

'Awesome resource'

All the devzone users interviewed by ULP Wireless Q praised the online community's information resources. Cocoa described the devzone's content as "A gold mine", while Nikita found the information particularly useful for people unfamiliar with Nordic technology, saying "If you are new [to] Nordic products, then you can find here all the necessary information for your first steps". It was a view echoed by John D. who said: "It is a great way to learn about parts of the Nordic offerings I am currently not using" and added that the devzone was "an awesome source of technical information". Marek noted that the devzone's resources helped engineers of all abilities: "It is a great information source for beginners as well as professionals," he said.

We asked our interviewees whether this treasure trove of information was directly useful to their specific design projects. "If you are having a problem or struggling to understand some aspect of the Nordic technology usually someone else has already asked the question and been helped and you can leverage that information," explained John D. "Plus there are some Nordic customers who are extremely knowledgeable and helpful on the devzone." Cocoa noted: "There is always someone who knows a detail or a method better than you. Hours and hours saved." Nikita agreed, explaining: "You can find here the problems encountered by other people and learn from their experience so that in the future, you won't run into this problem yourself." Marek said that the information provided by the devzone had helped him overcome design roadblocks: "When I'm stuck in development, I generally go to the [devzone] and find an answer."

All of the interviewees noted that the devzone benefited greatly from the rapid and expert responses provided by Nordic's own engineers. "I can get some information from Nordic employees that is not available in [the] product specification," noted Nikita. "The active involvement of Nordic employees on a daily basis really makes the devzone helpful and effective," added John D, who also suggested that; "Other vendors do not seem to have the active employee participation the devzone has and I think that makes a huge difference." Roland explained that Nordic engineer involvement delivered expert advice that was not available elsewhere: "Many of the answers came directly from the Nordic engineers who really understand the product and gave great advice."

Blog benefits

But nothing is perfect and our interviewees made many constructive suggestions about what aspects of the devzone could be improved. Cocoa was keen to see more OS X and GNU Compiler Collection (GCC)



NORDIC DEVELOPER ZONE ask questions, share info, and be inspired!

support while Hoan added: "It would be nice to perhaps divide question into sections related to each chip family. [Also] a table of contents for the tutorials and blogs would be nice." Roland expanded on the blog theme explaining: "It would be nice to see more blogs. There are certain topics which seem to generate more questions and those can benefit from a blog post explaining the topic in-depth. [For] example, there are a lot of questions about DFU [Device Firmware Update] because it's reasonably complicated and has quite a few moving parts; the recent blog post about 'how DFU works' was very helpful explaining the basic concepts."

But in general participants in our survey praised the usefulness, design, and content of the devzone. John D. also appreciated that it was a two-way street that provided benefit to Nordic too, saying: "Things get complicated in the wireless world quickly and it is impossible for Nordic to document everything. The devzone does a great job filling in the details and making things easy to find." It's a view echoed by Nikita who said: "The devzone is very helpful for Nordic as it allows [the company] to see the good and bad points of their product[s] so that they can [be] improved."

The last word goes to Marek, who noted that the devzone provided a resource that hobbyists

have taken for granted for years but which has been sadly lacking for professional engineers. "Being stuck with professional products which do not have any 'devzone' [support] can be quite frustrating," he explained. "[The] professional world is a lot different from the hobbyist's one. [For example], Arduino has a huge fan base, maybe millions of people.

"A lot of tutorials are made, even videos. You will find a lot of Arduino fans in your country, maybe even city. But in [the] professional field, that does not exist. When it comes to Nordic Semiconductor products, how many people actually develop production-capable devices with bare chips? Thousands? Trying to put them into one place [such as the devzone] is a very ambitious project which I am very grateful for."

So there you have it. Developers of all persuasions are tapping into this resource every day and finding it helps them do their jobs or expand their hobbies. Isn't it time you had a look? Visit the devzone and "ask questions, share info, and be inspired" to create your next wireless design. The devzone can be found at devzone.nordicsemi.com. ■

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Nordic Semiconductor's *ULP Wireless Q* keeps you up to date on everything that's happening in the Bluetooth Smart, ANT+, and proprietary ultra low power wireless technology sector



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Book excerpt: ‘Getting Started with Bluetooth Low Energy’

The third excerpt from a book on the fundamentals of Bluetooth Low Energy/Bluetooth Smart wireless technology looks at protocols and profiles

From its inception, the Bluetooth specification introduced a clear separation between the distinct concepts of protocols and profiles.

Protocols are building blocks used by all devices conformant to the Bluetooth specification. Protocols are the layers that implement the different packet formats, routing, multiplexing, encoding, and decoding that allow data to be sent effectively between peers.

Profiles are “vertical slices” of functionality covering either basic modes of operation required by all devices (Generic Access Profile, Generic Attribute Profile) or specific use cases (Proximity Profile, Glucose Profile). Profiles essentially define how protocols should be used to achieve a particular goal, whether generic or specific.

Generic profiles are defined by the specification, and it’s important to understand how two of them are fundamental to ensuring interoperability between Bluetooth low energy (BLE) devices from different vendors. The Generic Access Profile (GAP) covers the usage model of the lower-level protocols to define roles, procedures, and modes that allow devices to

broadcast data, discover devices, establish connections, manage connections, and negotiate security levels. GAP is, in essence, the topmost control layer of BLE. This profile is mandatory for all BLE devices, and all must comply with it.

Dealing with data exchange in BLE, the Generic Attribute Profile (GATT) defines a basic data model and procedures to allow devices to discover, read, write, and push data elements between them. It is, in essence, the topmost data layer of BLE. (See sidebar below.)

GAP and GATT are so fundamental to BLE that they are often used as the foundation for application programmer interfaces (APIs) as the entry point for the application to interact with the protocol stack.

Use-Case Profiles

Use-case-specific profiles in this section are limited to GATT-based profiles. This means that all of these profiles use the procedures and operating models of the GATT profile as a base building block for all further extensions.

No non-GATT profiles exist at the time of writing, but the introduction of L2CAP connection-oriented channels in version 4.1 of the specification

might mean that GATT-less profiles might start to appear in the future.

SIG-Defined Profiles

The Bluetooth SIG goes beyond providing a solid reference framework for the topmost control and data layers of devices involved in a BLE network. Just like the USB specification, it also provides a predefined set of use-case profiles, based on GATT, that completely cover all procedures and data formats required to implement a wide range of specific use cases, including the following.

Find Me Profile: Allows devices to physically locate other devices (use a keyring to find the phone or vice versa).

Proximity Profile: Detects the presence or absence of nearby devices (beep if an item is forgotten when leaving a room).

HID over GATT Profile: Transfers HID data over BLE (keyboards, mice, remote controls).

Glucose Profile: Securely transfers glucose levels over BLE.

Health Thermometer Profile: Transfers body temperature readings over BLE.

Cycling Speed and Cadence Profile: Allows sensors on a bicycle to transfer speed and cadence data mobile or tablet.

A full list of SIG-approved profiles is available at the Bluetooth SIG’s Specification Adopted Documents page. Additionally, you can browse Bluetooth services and characteristics directly at the Bluetooth Developer Portal and, more specifically, the list of all currently adopted services.

Vendor-Specific Profiles

The Bluetooth specification also allows vendors to define their own profiles for use cases not covered by the SIG-defined profiles. Those profiles can be kept private to the two peers involved in a particular use case (for example, a health accessory and a smartphone application), or they can also be published by the vendor so that other parties can provide implementations of the profile based on the vendor-supplied specification.

Some examples of the latter include Apple’s iBeacon and Apple Notification Center Service. ■

This is the third in a series of extracts from “Getting Started with Bluetooth Low Energy” by Kevin Townsend, Carles Cufi, Akiba, and Robert Davidson and is reproduced with permission of the book’s publishers O’Reilly (www.oreilly.com). Copies of the book are available from <http://shop.oreilly.com/product/0636920033011>, do, as well as from Amazon. Co-author Carles Cufi is a Senior Software Engineer with Nordic Semiconductor.



The Generic Attribute Profile

The Generic Attribute Profile (GATT) establishes in detail how to exchange all profile and user data over a BLE connection. In contrast with GAP which defines the low-level interactions with devices, GATT deals only with actual data transfer procedures and formats.

GATT also provides the reference framework for all GATT-based profiles which cover precise use cases and ensure interoperability between devices from different vendors. All standard BLE profiles are therefore based on GATT and must comply with it to operate correctly. This makes GATT a key section of the BLE specification, because every single item of data relevant to applications and users must be formatted, packed, and sent according to its rules.

GATT uses the Attribute Protocol as its transport protocol to exchange data between devices. This data is organized hierarchically in sections called services, which group conceptually related pieces of user data called characteristics. This determines many fundamental aspects of GATT discussed in this chapter.

Cycling helmets first came into use in the 1880s, using pith or cork, the best materials available at the time. From 1900 until the 1970s 'helmets' made of strips of leather-covered padding were in popular use. Fast forward to the 2012 Olympic Games and helmets had a dual shell design, an outer structure made from rigid ABS plastic of the type found in golf club heads, and a core made of aerospace grade lightweight aluminum honeycomb. The visor was made from an iridium-coated polycarbonate.

According to research from the University of Texas, an elite Tour De France cyclist can maintain a power output of about 6.8 watts per kilogram of body weight for 20 minutes. A good recreational rider could generate about 4 watts per kilogram, which would translate to a speed of about 32km/hr on a flat road. The elite cyclist meanwhile would be travelling at 55km/hr, a speed the recreational rider would be unlikely to be able to even reach, let alone maintain for 20 minutes.

The LifeBEAM helmet uses Nordic Semiconductor's nRF51422 System-on-Chip (SoC) with Nordic S310 SoftDevice to provide both ANT+ and Bluetooth Smart wireless connectivity to smartphone apps, smartwatches, and cycling computers. The chip's ultra-low power (ULP) operating characteristics allows the LifeBEAM helmet to be used up to four times a week, for a whole month, before requiring a recharge.

According to analyst IHS, sales of sports, fitness, and activity tracking devices will explode from 84 million devices in 2013, to 120 million devices by 2019, with as many as 37 million measuring heart rate. And the traditional chest strap heart rate monitor is by no means the only option, LifeBEAM's smart helmet measures heart rate from the forehead, and counts calories too

The LifeBEAM Smart Helmet features embedded medical grade biosensing technology. The optical sensor employs the same dual beam infrared (IR) technology employed in emergency room pulse oximeters to measure heart rate in real time from the rider's forehead, eliminating the need for a chest strap. A proprietary algorithm filters out motion-generated noise caused by rider changes in direction and velocity, and environmental noise caused by sweat, rain, and ambient operating temperatures.

LifeBEAM Smart Cycling Helmet

This helmet measures heart rate and calorie consumption from the forehead and delivers biometrics to Bluetooth Smart and ANT+ devices



Bringing IP to the end node

How will end-to-end IP comms, enabled by the adoption of IPv6, affect the IoT?



By **Sally Ward-Foxton**, European Correspondent, IoT Embedded Systems

Today, the internet of things often takes the form of separate networks, such as a consumer's personal area network, connected to the Internet by bridges, such as a smartphone app. Would the IoT be better off without the bridges, as an integral part of the internet as we know it?

Thomas Embla Bonnerud, Director of Product Management at Nordic Semiconductor, thinks so.

"When we started putting together our strategy for IoT, one of the fundamental discussions we had was about end-to-end IP. We asked ourselves: the internet is IP end-to-end, why should the IoT be any different?" he says.

"Most of the arguments that came up were related to the practical challenges of running a complete IP stack on a small, low power, low cost SoC. If you choose not to do IP you still need to find a solution for transport, routing and end-to-end security. We concluded that end-to-end IP is extremely valuable because it allows us to use proven Internet technologies for these three things."

The present situation for wearables, with a smartphone app bridging between IP and Bluetooth Smart, is good enough for a personal area network, explains Bonnerud, but it's not a great solution for things in the wider IoT, like non-personal things we want to be connected to the internet even when we are not around with our smartphones. For these things, a better solution is a 'headless' router, just like the Wi-Fi access points we know and love, but with support for Bluetooth Smart.

At CES in January, Nordic demonstrated its IPv6 over Bluetooth Smart stack and



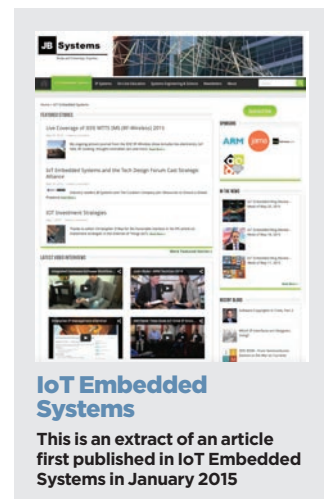
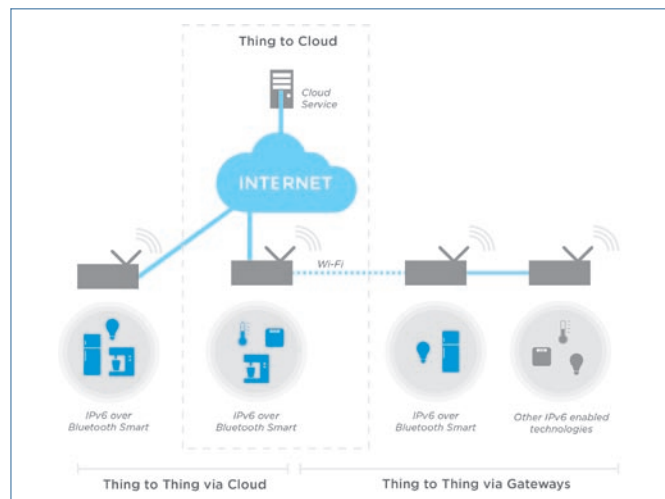
IPv6 over Bluetooth Smart is attracting the attention of smart home designers and (below) Nordic's IPv6 over Bluetooth Smart solution

software development kit (SDK) for its nRF51 SoC. The SDK uses the new Internet Protocol Support Profile (IPSP) from the Bluetooth SIG, as well as 6LoWPAN, to allow Bluetooth Smart devices to communicate using IP and thereby enable headless routers of the kind that Bonnerud describes. Native IP means Bluetooth Smart devices can communicate directly

with each other, as well as with other devices using IPv6-enabled wired or wireless technologies (WiFi, Ethernet, ZigBee IP, etc.), without accessing the Cloud, as shown in the graphic.

"We see an incredible interest in our IPv6 over Bluetooth Smart solution in a range of segments that traditionally have not been using Bluetooth," Bonnerud adds.

"These segments include Smart Home, Retail and Commercial and Industrial Automation. In the end, the IoT will be a massive heterogeneous network based on different connectivity technologies. We believe IPv6 over Bluetooth Smart is one of the key technologies, specifically for cost, power and size constrained applications." ■



IoT Embedded Systems

This is an extract of an article first published in IoT Embedded Systems in January 2015

PEOPLE & PLACES

Morten Staale



A return after six years sees a lot of change, but not to everything

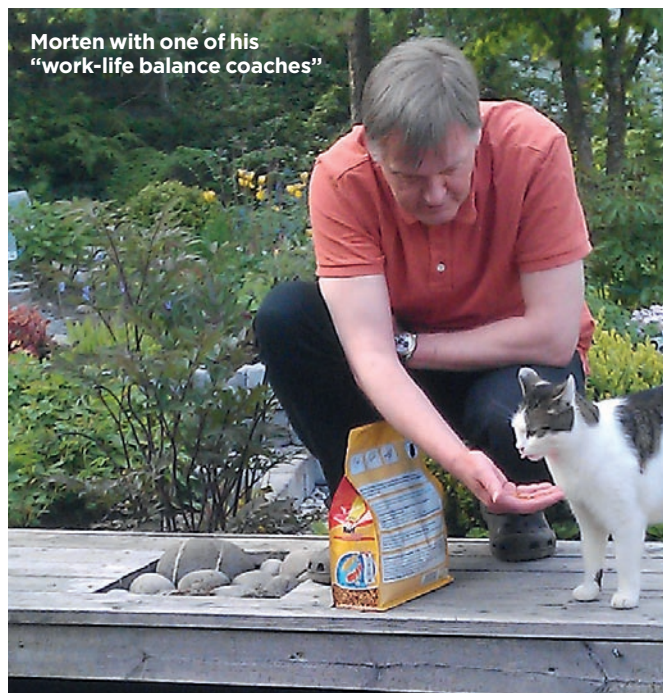
Hi, I'm Morten Staale. I joined Nordic initially in 2001, and worked at the company for eight years. I started in sales and distribution management. And in the early days because Nordic was much smaller I covered three regions simultaneously: Scandinavia, UK and Ireland, and the Americas.

Over time this reduced to just the Americas. I specialized as a Key Account Manager responsible for major companies in consumer electronics and sports. Because I was based in Oslo, I became known as the most widely travelled person in the company!

Today, however, I am working much closer to home and taking over as Distribution Sales Manager for the whole of extended Europe (EMEA). My main role is to ensure that the various distribution channels run smoothly. This demands good planning, execution, and regular reviews with all distributors in the region.

The reason I came back to Nordic is that it's an extremely well-managed and successful company. I also get to work with colleagues that I rank as among the best I've ever worked with.

Nordic has changed a lot since I've been with the company. In the early days Nordic was a small, specialist design consultancy of mixed-signal ASICs for a lot



Personal Profile

NAME:

Morten Staale

JOB TITLE:

Distribution Sales Manager - Europe

JOINED NORDIC:

2001 & 2015 (rejoined)

BASED:

Oslo, Norway

INTERESTS INCLUDE:

Gardening; Slot cars; Model kit building

"I always remember there being a strong culture of fighting fair even if we had our backs to the wall. Today I still see that culture as strong and alive as ever"

of diverse market segments. Today it's a much larger company focused on just one specialty - ultra low power wireless.

But some things - and to me some of the most important - haven't changed. For example, I

always remember there being a strong culture of fighting fair even if we had our backs to the wall. Today I still see that culture as strong and alive as ever within the organization.

Outside of work I'm not a typical Norwegian in that although I do own a pair of skis, I haven't used them in the last 10 years!

Instead I enjoy winding down during the summer building things for home improvement and fun outside, while my wife gardens.

When it's too cold to spend so much time outdoors, I turn to model kit building. I have a small workshop with a spray booth, but often take construction into the living room - not necessarily with my wife's approval.

In my workshop-come-hobby room-come-home office, I also have a digital slot car track that is a perpetual project. A lot of the kits I have (I am not a collector, rather a builder) are used there.

I have two four-legged purring work-life balance coaches that warn me when I work too much by laying on my work area or computer keyboard.

This occasionally results in a random selection of people from my address book receiving cryptic emails from me. I hope the day doesn't come when, by pure chance, one of these emails makes sense. Otherwise I'll have some explaining to do! ■



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