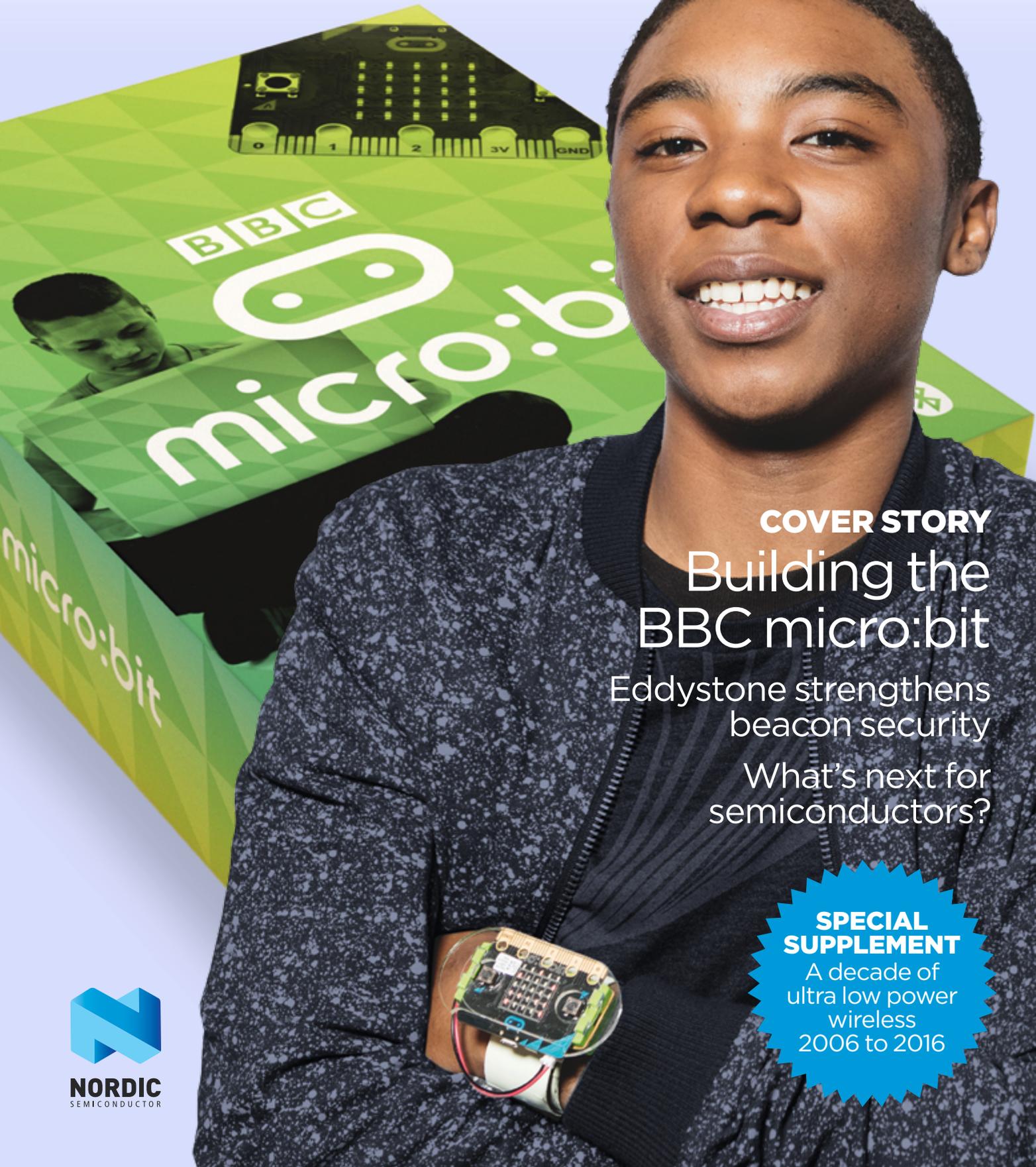


ultra low power wirelessQ

QUARTER 2 | SUMMER 2016



COVER STORY

Building the BBC micro:bit

Eddystone strengthens
beacon security

What's next for
semiconductors?

SPECIAL SUPPLEMENT

A decade of
ultra low power
wireless
2006 to 2016

OPINION

Geir Langeland



Internet of Things promises to democratize connectivity

The success of a company depends on things like skilled staff, visionary management, investment in R&D, and of course, products that people want, plus a little luck. I'm not suggesting that Nordic Semiconductor is perfect, like other companies we've made some wrong turns, but over the last decade we have got many of those success factors about right. That's propelled the company from a healthy, niche supplier of proprietary ultra low power (ULP) wireless technology to the forefront of the Bluetooth low energy segment.

To coincide with the tenth anniversary of *ULP Wireless Q*, first published back in June 2006 (just as Nordic was teaming up with Nokia and other enterprising firms to form an alliance to develop a smartphone-friendly form of ULP wireless called Wibree, the predecessor of Bluetooth low energy) this edition includes a special eight-page anniversary supplement looking back over that decade.

But in an increasingly competitive world there's little time for reminiscence and today the company is charting a course to become an important player in the Internet of Things (IoT) sector. We're looking beyond the hype that talks about connecting 10, 20 or even 50 billion 'things' to the cellular network, the conventional Internet and each other, to [come up with answers](#) to the formidable engineering problems that need to be solved before the IoT becomes reality. Such is the magnitude of the challenge that it will require a collaborative effort between many companies spanning several technology sectors including semiconductors, network infrastructure, and Cloud computing platforms. Nordic hopes to play a significant role.

That's not to say the company is only focused on the big projects. One of the promises of the IoT is that it promises to democratize connectivity far beyond even that achieved by today's Internet. Soon, for just a few dollars, even the most inexperienced maker or hobbyist will be able to make their project 'smart' by adding a Bluetooth low energy wireless connection. This is not a dream; in this issue (*see page 16*), for example, you can read about the Arduino Primo, the latest single-board computer from the world's largest open-source ecosystem. The company says the Primo is the first Arduino product to allow makers and hobbyists to take advantage of the embryonic IoT. The Primo is powered by Nordic's nRF51822 Bluetooth low energy solution which can also support IPv6. Tomorrow, that technology will allow the Primo to connect to the IoT without needing the resources of a sophisticated gateway such as a smartphone.

Today, Nordic Bluetooth low energy chips are found in hundreds of millions of products around the world. If our engineers' talents are nurtured and we continue to enjoy a share of good fortune, it's possible that when we take a glance back from June 2026 we'll see a good share of the 50 billion things making up the IoT being powered by one of our devices.

Yours Sincerely,

Geir Langeland
Director of Sales & Marketing

Contributors



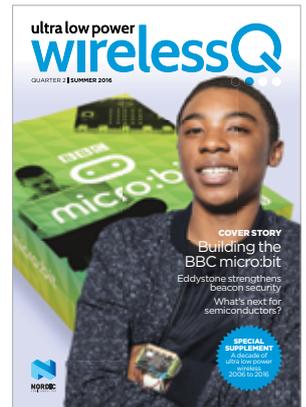
Yamazaki Mitsuo is Nordic's Regional Sales Manager in Japan. Here he looks at how the nRF52 Series SoC is powering a new generation of RF modules



Sally Ward-Foxton is an electronics freelance journalist. On page 10 she speaks to the man behind the BBC micro:bit and finds out why Nordic's chip lies at the heart of the device



Caroline Hayes is a tech writer specializing in semiconductors. In this issue she explores the state of play in wireless charging, finding an industry undergoing rapid change



The BBC micro:bit is now in the hands of a future generation of engineers

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NEWS

The latest developments from Nordic Semiconductor

New Arduino base board offers native Bluetooth low energy

Open source prototyping platform developer, Arduino, is to use Nordic Semiconductor's nRF52832 Bluetooth low energy System-on-Chip (SoC) in its new Internet of Things (IoT) programmable single board computer: the Arduino Primo.

For the first time the low cost single board computer—or base board—features native Bluetooth low energy wireless connectivity alongside Near Field Comms (NFC), Wi-Fi, and infrared (IR) technologies. Previously users were required to add shields to the board to enable Bluetooth low energy technology.

In addition to being able to wirelessly connect to a wide array of Bluetooth low energy sensors, the Arduino Primo can act as a fully functional TCP / IP Internet



Arduino Primo now offers built-in wireless connectivity for makers embarking on IoT projects

client and server over Wi-Fi, offers embedded IR for traditional remote control, and employs the Nordic SoC's integrated NFC tag for secure authentication and 'Touch-to-Pair' operation.

As well as controlling the Bluetooth low energy RF protocol software stack and application code, the nRF52832's ARM processor has the computational

overhead to supervise and control the Arduino Primo's on-board accelerometer, temperature, humidity, and pressure sensors. For all but the most advanced projects, programming will be done via the established and easy-to-use Arduino Integrated Development Environment (IDE) programming interface.

However, professional developers and Makers who want to access the most advanced features and functionality of the Arduino Primo will be able to use any Nordic nRF52 Series-compatible Software Development Kit (SDK). For example, the [nRF5 SDK for IoT](#) allows more experienced users to develop IPv6 over Bluetooth low energy applications enabling the Arduino Primo to connect directly to the Internet.

In brief

BBC micro:bit now for sale

The BBC micro:bit, a pocket-sized programmable device that can be coded and customized to bring ideas to life, is being made available to buy in the U.K. by element14, the BBC's micro:bit partner. The widespread availability follows gifting of the BBC micro:bit to one million school children across the U.K. The micro:bit can be pre-ordered from element14 as a single unit; a starter kit with four project ideas to get users started; or in a pack of 10 devices.

Bluetooth sector set for huge lift

Analyst Beige Market Intelligence, claims the Bluetooth low energy market will be worth \$3 billion by 2021, driven by major expansion in the industrial Internet of Things (IoT) sector, and high demand from Asia Pacific. The report claims the region will contribute more than 50 percent of the revenue in the Bluetooth low energy market and identifies Nordic Semiconductor as a key vendor. Close to 4 billion Bluetooth chips are likely to be shipped worldwide in 2021.

Flexible security solution unveiled

Experimental physicists at Saarland University in Germany have developed an outdoor security solution that issues a warning if someone has attempted to cross over a flexible cable. The cable contains a linear array of highly sensitive magnetic-field sensors that are capable of detecting the smallest changes in the ambient magnetic field at distances of up to several meters, issuing a message via Bluetooth technology to a smartphone or tablet.

Soccer sensors track player performance for post-game analysis

U.S. wearable sports technology company, Zepp Labs, has launched a new wearable soccer sensor that monitors a range of in-game player attributes to provide coaches and players with a tool to analyze and improve performance post game.

The Zepp Soccer sensors are strapped to a player's calves, and record running and sprint distance, passing, and preferred foot metrics, employing Nordic Semiconductor's [nRF52832 System-on-Chip \(SoC\)](#) to sync the data via a Bluetooth low energy wireless link to compatible iOS or Android smartphones.

The Zepp Soccer sensors place a high demand on the Nordic SoC, as the application is required to support more than 30 sensors and provide sufficient bandwidth between the sensors and a smartphone to cope with, for example, more than 100x the data generated by a heart rate monitor. Zepp Labs also required low power consumption in both 'active' and 'standby' modes to achieve up to 15 hours of game time between recharges.

From a smartphone running the Zepp Soccer app, a coach or 'host' can also record game time



The Zepp Soccer sensors place a high demand on Bluetooth low energy technology

and capture individual player video. The app will then generate a report for post-game review.

"We needed a Bluetooth Smart solution with a powerful CPU, excellent Floating Point and DSP performance, to perform the data manipulation, as well as large RAM capacity to buffer all the information being gathered by the sensors," explains Dong Li, Zepp Labs Hardware Director. "But we also needed to minimize power consumption. For those reasons the nRF52832 Bluetooth Smart SoC was the logical choice."

In brief

Bluetooth device boom coming

Market intelligence firm ABI Research, predicts annual Bluetooth device shipments will reach 5 billion by 2021, with Bluetooth low energy delivering the strongest growth, driven by new opportunities in beacons, home automation, and wearables. Though smartphones will still make up 43 percent of Bluetooth shipments by 2021, ABI claims Bluetooth low energy devices will increase to 27 percent of shipments on the back of enhancements in mesh networking and IPv6, as well as improvements in efficiency, range, and size reductions.

Monitoring heart rate

China-based Shenzhen DO Intelligent Technology Co has selected Nordic's [nRF51822](#) Bluetooth Smart System-on-Chip for its "ID 107" real-time dynamic heart rate monitor wearable. The multifunction wristband is equipped with a photoelectric diode and a green LED on the underside of the bracelet. Heart rate data is calculated based on a proprietary algorithm and wirelessly synced to the user's smartphone via Bluetooth low energy, allowing them to determine the level of effort maintained during exercise.

Energy costs fuel smart home lift

The global smart home market is predicted to grow from \$46.97 billion in 2015 to \$121.73 billion by 2022, as advancements in the Internet of Things (IoT) sector drive consumer adoption, analyst MarketsandMarkets claims. It said increasing consumer demand for convenience, safety, and security, as well as a rising need for energy saving would see manufacturers expand their smart home product portfolios. The lighting control market is expected to grow at the highest rate during the forecast period.

A million schoolchildren receive Nordic-powered BBC micro:bit

Britain's public broadcaster, the BBC, is delivering up to one million free codeable computers called micro:bits to every 11-12 year old school child in the U.K., each driven by a Nordic Semiconductor nRF51822 Bluetooth low energy System-on-Chip (SoC).

Announced at a launch event hosted at the London Stock Exchange, the BBC said the project aimed to encourage the next generation to take an interest in technology. Following the nationwide rollout, the micro:bit hardware and much of the software will be open-sourced, and the micro:bit made available to buy from a range of retailers.

Nordic Semiconductor is an official BBC micro:bit partner, and the nRF1822 SoC sits at the heart of the micro:bit, integrating the computer's 'brain'—a 32-bit ARM Cortex M0 microprocessor—where the school child-created software code runs, and that also allows the micro:bit to wirelessly



BBC micro:bit aims to inspire the next generation

communicate with other micro:bits, and wirelessly sync to smartphones and computers.

Nordic pioneered the development of ultra low power wireless in the early 2000s, and later became a key contributor in the creation and evolution of Bluetooth low energy technology.

Since then Nordic has worked to make ultra low power wireless connectivity simple, and open to

the widest number of people, including for those from a non-electronics background.

"The ability to code is now as important as math skills and can unlock new career options," says Simon Segars, CEO of ARM. "I can easily imagine a new wave of entrepreneurs looking back and citing [the BBC micro:bit launch] as the day their passion for technology began."

Smoke and motion detectors provide networked protection from fire and theft

Norwegian safety connected device company, sfty, has released a wireless, smartphone app-controlled combined smoke- and motion-detector. The unit is designed for use in multi-dwelling units and apartments to protect the owner against fire and theft, as well as provide temperature and relative humidity data.

The sfty Sense device employs Nordic Semiconductor's multiprotocol nRF51822 System-on-Chip (SoC) to deliver communication across a 2.4 GHz low power mesh network while simultaneously providing smartphone connectivity.

From the sfty app, users can create a social network of friends, family, and neighbors who are notified via the app on their own mobile device in the event of a sfty Sense detector alarm being triggered. The user can also manage their safety devices from the app to turn on and off the burglar alarm, as well as notify their network if they are in need of assistance.

The device employs a home Wi-Fi network via a standard router to communicate with the sfty Cloud for configuration, status reports, and

sfty Sense offers networked protection against apartment fires



signaling, while the low power mesh network is used for signaling between devices to trigger or cancel smoke or motion alarms in the individual home, or trigger building-wide smoke alarms.

"With the impending announcement of Bluetooth Smart Mesh, the support for Bluetooth in smartphones will allow direct interaction between the user's mobile and our devices when they are at home," says Espen Schröder, COO of sfty. "This capability is something that competing standards are not in a position to provide for the foreseeable future."

IoT platform enables end-to-end wireless monitoring and control

Swedish industrial Internet of Things (IoT) system provider, Free2move, has unveiled its 2Connect building management and industrial automation IoT platform, a complete IoT architecture comprising sensors and actuators, wireless gateways and middleware, analytics, and presentation.

The platform incorporates Cloud services for automating and connecting 'things' with building and industrial automation applications and services. The fundamental part of 2Connect is the Celebes scalable wireless gateway which employs Nordic Semiconductor's [nRF52832](#) multiprotocol System-

on-Chip (SoC) to enable either or both Bluetooth low energy and the company's own legacy Free2move Radio Air Protocol (FRAP)-wireless connectivity to a range of IoT devices, sensors, beacons, and actuators.

2Connect monitors humidity, temperature, air quality, air and water flow, volatile organic compounds (VOCs), vibration, movement, light, pressure, energy consumption, as well as traces of fungus, using a layered analytics and decision architecture. The platform assumes full responsibility for the capture of IoT data, analyzing real time information and taking corresponding remedial actions with automatic, wirelessly-



2Connect monitors a host of environmental variables

triggered motor-, switch-, lock-, alarm-, and valve-actuation, and visualization.

"2Connect provides our

customers with the opportunity to rapidly deploy technology for monitoring buildings without being impeded by 'legacy' systems," says Anders Due-Boje, Free2move CEO.

"The IoT is undergoing rapid development and early IoT adopters need a capability to support proprietary legacy technologies in the short term," says Geir Langeland, Director of Sales & Marketing with Nordic Semiconductor.

"2Connect cleverly takes advantage of the nRF52832 SoC's multiprotocol support to offer users both Bluetooth low energy and legacy FRAP stacks, thus 'future proofing' customer installations."

Nordic expands with new offices in mainland China

Nordic Semiconductor has opened two new sales, marketing, and customer support offices in mainland China. The offices enable the company to provide fast sales and technical support to China's burgeoning wireless design and manufacturing sector. The facilities are in addition to Nordic's Asian HQ in Hong Kong.

The offices officially opened on March 1, 2016, and are based in Shanghai in north-east China, and Shenzhen in Guangdong province in the south of China. Each office is staffed by a Technical Sales representative and Field Applications Engineer and managed by Nordic's existing Regional Sales Managers in China.

The opening of the offices is a response to the dramatic growth of companies designing and developing Bluetooth low energy solutions in China, particularly in the area of wearables, IoT, toys, health



Nordic's Shanghai office celebrates its opening



While the Shenzhen office also opens for business

care, payment systems, and smart remote control with voice command.

"China has been growing steadily every year since Nordic started out in Asia in 2001," says Ståle "Steel" Ytterdal, Nordic's Director of Sales & Marketing - Asia.

"However, when we introduced Bluetooth low energy in 2010 sales exploded. That showed Nordic that there was a lot of innovation going on in China and we needed to position ourselves to closely support these customers."

The opening of the Shanghai and Shenzhen offices strengthens Nordic's relationship with its current distribution partners - Avnet, Arrow, Honestar, New Spirit, Rutronik, and Xuntong - providing an increased presence in mainland China and the basis for further collaboration on joint meetings with potential and existing customers.

Global IoT security spending to climb

Worldwide spending on Internet of Things (IoT) security will reach \$348 million in 2016, a 23.7 percent increase from 2015 spending of \$281.5 million, according to analyst Gartner Inc. Although overall spending will initially be moderate, Gartner predicts IoT security market spending will increase at a faster rate after 2020, as improved skills, organizational change, and more scalable service options improve execution. The company claims that by 2020 more than 25 percent of identified enterprise attacks will involve the IoT.

New modules v4.2 compatible

Taiyo Yuden, has selected Nordic's nRF52832 Bluetooth low energy System-on-Chip (SoC) for its new EYSHCNZXX and EYSHJNZXX Bluetooth low energy modules. The modules are fully-tested Bluetooth low energy solutions compatible with the latest version of the Bluetooth Core Specification (4.2), simplifying the design of a wide range of connected products where performance, small size, and low power consumption are key factors. The use of Nordic wireless technology for the modules continues a long-term design partnership.

In brief

Bluetooth low energy gives model railroads a 21st century makeover

▶ One of the world's largest model railroad makers has transformed a decades old market with the introduction of the first Bluetooth low energy controlled trains. *E-Z App* from Bachmann Trains brings smartphone and tablet wireless touchscreen control and app-based interactivity to the model train market for the first time, reducing the start-up cost and complexity for model railroad enthusiasts.

E-Z App was developed in conjunction with Bluetooth model train PCB design specialist, BlueRail Trains, using Nordic Semiconductor's [nRF51822](#) System-on-Chip (SoC)-based BMD-200 modules from U.S. engineering firm Rigado. Bachmann says *E-Z App* brings simple wireless touchscreen control and intuitive app-based interactivity to the traditional model train market for the first time.

"This includes putting, quite literally, at a user's fingertips features such as speed table controls [acceleration and deceleration rates], volume



E-Z App represents the biggest technological advance in model railroads for nearly 30 years

controls for sound effects, lighting effects, and many other variables," says Rich Janyszek, Senior VP of Sales & Marketing at Bachmann.

"In addition, the *E-Z App* control system automatically keeps track of all locomotives that are present on a track layout and lists them on the program's opening screen in a roster that can be accessed at any time. This

makes it possible for multiple users to simultaneously control their locomotives on a single layout."

Janyszek adds that *E-Z App* supports wireless smartphone and tablet control of any of its *E-Z App* compatible model trains over a range of up to 33 meters, and is also compatible with all MFI-approved game controllers.

"It has been incredibly refreshing to see adults, young children, and experienced hobbyists downloading the app because of its simplicity, and rediscovering the pleasure of model trains," comments David Rees, CEO & Creative Director at Bluerail Trains.



Nordic nRF52 Series SoC wins CEM Editor's Choice Award

Nordic Semiconductor's next generation nRF52832 Bluetooth low energy System-on-Chip, has won the *China Electronic Market (CEM) Editor's Choice Award 2015* in the "Most Competitive Interface Products in China" category.

Jointly hosted by *CEM* magazine and China Electronic Exhibition & Information Communication Co., Ltd., the selection criteria for the award considered brand influence, market share, technological innovation, and product service. The nRF52832 SoC was judged to fulfill all of these criteria, including a sound sales performance in the

Chinese market.

The nRF52832 SoC featured among the best of its peers in market share and boasted one or more innovative features—in particular its unique Near-Field Communication (NFC) tag—while Nordic also demonstrated pre-sales, sales, and after-sales

services that were fast, meticulous, and thoughtful, resulting in higher customer satisfaction, according to the *CEM* editors.

"The applications base for

Bluetooth low energy technology has seen strong growth, but the recent emergence of wearable health-care devices and smart-home applications will provide a strong impetus for further growth in the Bluetooth market," comments Ståle "Steel" Ytterdal, Nordic Semiconductor's Director of Sales & Marketing in Asia.

"Our nRF52 Series SoCs address these markets with compact high-integration solutions that support the ULP wireless capability these new markets demand. We are very honored to receive the Editor's Choice Award from *CEM*."



Nordic's nRF52832 SoC was praised for its innovation and customer satisfaction



ULP WIRELESS TRENDS

The latest developments in technology



Schoolchildren are taking a hands-on approach to coding thanks to the BBC micro:bit

School project sees BBC micro:bit carried to edge of space and back

A school in Yorkshire, England recently launched a BBC micro:bit to the edge of space, carried up into the stratosphere by a helium balloon.

The project was the brainchild of computer teacher Peter Bell, and saw pupils from Rishworth School design and engineer a module integrating the micro:bit, sensors, a GPS tracking device, and an on-board camera to take pictures and record video on its journey.

A team of 20 pupils tracked the weather balloon and its cargo as it made its way up to a height of 32,588 meters, before the balloon burst and the module began its descent, reaching a speed of 290 km/hr when a parachute deployed and returned the module to Earth safely. Thanks to the GPS tracking device, the school was able to follow the module's descent and locate it in a farmer's field some 100 miles away from where it was launched.

"We were in two cars following the signal and it was very exciting. We heard later from a pilot that air traffic was rerouted because something was coming down to earth fast and it was our computer," says Bell.

At the heart of the micro:bit is a Nordic Semiconductor nRF51822 System-on-Chip (SoC).



Wireless standards slash IoT costs

Smart cities of the future may look towards open wireless standards to save billions in Internet of Things (IoT) deployment costs, according to market intelligence firm Machina Research.

The firm said choosing open standards - for example Bluetooth low energy - would lead to more interoperability between networks and applications, cutting costs by as much as 30 percent, and encouraging deployment of IoT solutions.

Machina Research predicts that by 2025 smart cities may spend \$1.12 trillion on deploying smart technology, but could save up to \$341 billion if they use open wireless standards instead of proprietary technology. On top of the lowered cost for deployment, Machina also predicts 27 percent more connected devices by 2025 if open wireless standards are adopted by smart cities and IoT providers.

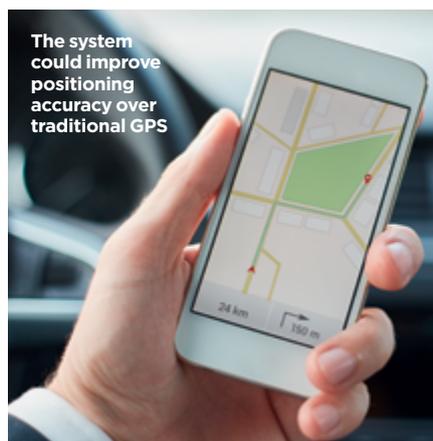
The firm said the current issue is IoT providers are bundling proprietary wireless technology with their deployment software, instead of using open source alternatives.

Wireless transmitters deliver pinpoint location information

Apple has been awarded a patent for a system of city-wide low power wireless transmitters capable of sending pinpoint-accurate location data as well as environmental alerts to iPhones.

The patent entitled "[System with wireless messages to enhance location accuracy](#)" attempts to solve signal reception issues that crop up in densely populated cities, while increasing the granularity of positioning data. The solution is said to consume less power than A-GPS, Wi-Fi positioning, and cellular triangulation techniques.

The patent calls for a multitude of stationary transmitters to be installed at strategic locations near a city's roads. Each transmitter is a smart wireless hub supporting



Bluetooth low energy, Wi-Fi, and GPS.

In operation, a stationary waypoint device would broadcast its location via Bluetooth low energy messages. Each message would be sent out at a known signal strength, allowing the receiving device, like an iPhone, to extrapolate its relative location based on a received signal strength indicator value, thereby determining its absolute position depending on the number and quality of messages received.

Applied to navigation, the system could be configured to track vehicle movement with a high degree of accuracy, for example, along off-ramps and on-ramps or forks in a road, where traditional GPS systems often fail to resolve user position adequately.



New Eddystone beacon format addresses security concerns

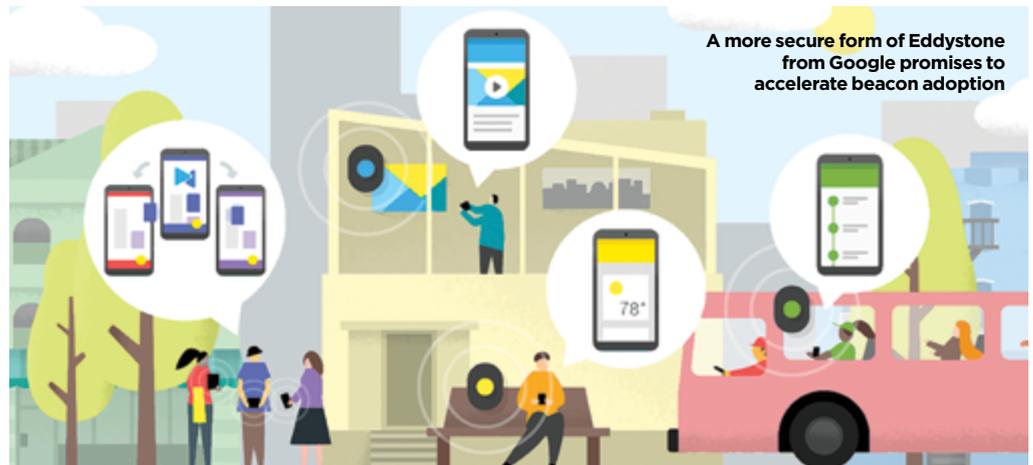
The Ephemeral Identities addition to Google's more secure Eddystone beacon format is now supported by a dedicated Nordic Software Development Kit

Beacons are driving new proximity-based services. The devices comprise low-cost Bluetooth low energy transmitters for indoor or outdoor use, placed in a particular location or point of interest. The beacon transmits its identity to any Bluetooth 4.0-equipped mobiles in range; those hosting a companion app can be located and the software can trigger various types of notifications.

Because beacons have the potential to identify the location of smartphones to within a few meters, they enable content delivery specifically targeted to that location for users who want it. As such, the technology is predicted to be rapidly adopted by stores as a way to boost sales. Analyst Business Insider, for example, estimates that the top 100 U.S. retailers could reap \$44.4 billion in sales by the end of this year as a result of the influence of beacon-triggered smartphone notifications.

However, despite the potential, beacons have taken a little longer than initially predicted to catch on. "Beacons are a core building block of the Internet of Things," explains Reidar Martin Svendsen, Technical Product Manager with Nordic Semiconductor, "but security and privacy has been a concern with today's beacon formats."

The root of the problem is Bluetooth low energy technology's use of a unique identifier to pair with mobile devices for the exchange of information. In most applications this is not an issue, but because a beacon is designed to pair with any mobile device that comes within range, a fixed identifier can leave open a 'back door' for the unethical to eavesdrop on communications and perhaps access private information



A more secure form of Eddystone from Google promises to accelerate beacon adoption

"Beacons are a core building block of the Internet of Things but security and privacy has been a concern with today's beacon formats"

about a consumer with the intention of malicious attack.

This perceived vulnerability is holding back beacon deployment. "Privacy is the top consumer barrier to wide adoption of beacons," Adam Silverman, an analyst with Forrester Research, told technology publication *Wired*.

Hardening beacon security

In April, Google introduced new technology to enhance beacon privacy by launching Eddystone-Ephemeral Identities (EID), an addition to the Eddystone beacon format that itself was announced in mid 2015.

The company explains that Eddystone-EID provides developers more power to control who can make use of a beacon's signal, enabling a new set of use cases for users to be able to exchange information securely and privately. The secret of the technology is a beacon 'frame' (or signal) that changes periodically, and consequently is only recognizable to a controlled set of users (those that have signed up to the service).

An Eddystone-EID beacon uses an AES-encrypted eight-byte beacon identifier that changes pseudo-randomly with an average period (from one second to just over nine hours) determined by the developer. The identifier is generated using a key and timer running on the beacon. The key is generated and exchanged with a resolution service using a defined protocol and only the beacon and the service to which it is registered have access to the key. If registered with the service beacon 'attachments' are served in the normal way across a secure link to a consumer's mobile.

Apart from the security improvement, Eddystone-EID also introduces other enhancements such as an ability to broadcast URLs. "[Now, for example] advertising posters [could have] the ability to broadcast a relevant web address to smartphones nearby - making it easy for interested parties to find out more about the advertised item without having to download an app first," notes

Nordic's Svendsen.

Nordic is one of fifteen manufacturers currently supporting Eddystone-EID, a list which also includes Sensoro and Estimote, beacon makers that use Nordic's Bluetooth low energy wireless technology. When Google introduced Eddystone-EID, Nordic simultaneously announced its Software Development Kit (SDK) and supporting tools for engineers looking to work with the more secure beacon technology.

The [nRF5 SDK for Eddystone](#) enables development of Eddystone-EID beacons to provide real-world context to users in a huge variety of proximity-based beacon applications. The SDK also features a Generic Attribute Profile (GATT) that allows beacons to be configured from a smartphone.

The SDK is designed for Nordic's nRF52 Series Bluetooth low energy Systems-on-Chip (SoCs). A future upgrade will also allow for the existing nRF51 or nRF52 Eddystone beacons to be updated to Eddystone-EID via an over-the-air (OTA) firmware update. ■



Nordic's nRF52 Series powers new generation of RF modules

The nRF52832 SoC is enabling manufacturers to build a powerful new breed of Bluetooth low energy modules based on proven architecture, says Mitsuo Yamazaki



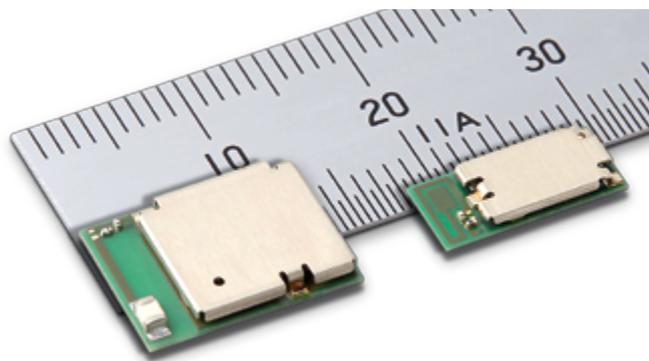
By Mitsuo Yamazaki,
Regional Sales
Manager - Japan,
Nordic Semiconductor

The RF modules market is booming. According to IHS, in mid 2015, modules made up about a third of the overall low power wireless market and the company expected that proportion to grow to 40 percent by 2018. This statistic should come as no surprise; the lure of a pre-engineered, tested and compliant RF solution for manufacturers with little or no experience with wireless connectivity, yet needing to make their products “smart”, is compelling.

U.S.-based Bachmann Trains, for example, one of the world's oldest and largest traditional model railroad and train manufacturers, teamed up with RF module maker Rigado to bring Bluetooth low energy technology to model train engines. Bachmann says wireless connectivity brings touchscreen control and app-based interactivity to the model trains for the first time. (See *this issue pg6.*)

In addition to Bachmann, scores of manufacturers find the trade-offs brought by choosing a module—higher cost bill of materials and fewer opportunities for product customization compared to an RF solution assembled from discrete components—are well worth making to simplify design and manufacturing. A single module, for example, can be reused across multiple products, easing the problem of supporting numerous unique wireless designs.

The [Rigado RF module](#) selected by Bachmann



Small but powerful: Taiyo Yuden's smallest Bluetooth low energy module measures just 5.1 by 11.3 by 1.3 mm but incorporates a 64 MHz, 32-bit ARM Cortex M4F processor

Trains was based on Nordic Semiconductor's nRF51822 Bluetooth low energy System-on-Chip (SoC). The SoC integrates an ARM Cortex M0 processor, 2.4 GHz multiprotocol radio, up to 256 kB Flash, and up to 32 kB RAM.

The SoC also features a unique software architecture that separates the RF software protocol from the developer's application code ensuring that during software development the RF protocol can't be corrupted. Launched in mid-2012, the nRF51822 is now used in millions of products across the world.

Rigado is not the only company to base a module on Nordic Bluetooth low energy technology. Nordic [lists](#) dozens of third-party nRF51822 SoC-powered modules on its website including those from companies such as Fujitsu, Laird, and u-blox.

Boosting performance

Last year's launch of the Nordic nRF52832 Bluetooth low energy SoC allowed module makers to design a new generation of modules with significantly greater performance than those which came before.

“Because the nRF52832 SoC's hardware and software architecture are compatible with the nRF51 Series modules, it makes it much easier for customers to upgrade”

The [nRF52832](#) SoC is based on the proven software- and hardware-architecture of the nRF51 Series but features a 64 MHz, 32-bit ARM Cortex M4F processor delivering up to 60 percent more generic processing power, offering ten times the Floating Point performance, and twice the Digital Signal Processing (DSP) performance compared to competing solutions. The SoC has an enhanced 2.4 GHz multiprotocol radio offering Bluetooth low energy (fully compatible with Bluetooth 4.2), with -96 dB (receive) sensitivity

as well as 512 kB Flash memory and 64 kB RAM.

The ARM processor enables the SoC to run applications that previously demanded a two-chip (2.4 GHz transceiver plus separate microcontroller) solution. At the time of launch, the nRF52832 SoC was the world's most powerful single-chip Bluetooth low energy device and was recently recognized by *China Electronic Market* magazine as “the most competitive interface product in China”. (See *this issue pg6.*)

Several module makers already launched nRF52832 SoC-based products. Here in Japan, Taiyo Yuden has [added to its range](#) of nRF51 Series-based modules with two nRF52 Series-based units measuring as small as 5.1 by 11.3 by 1.3 mm.

“The ARM processor and greater memory allocation makes the nRF52832 SoC a better choice for single-chip Bluetooth Smart solutions for complex IoT applications,” says Mikio Aoki, Taiyo Yuden Project Manager. Aoki went on to add: “Because the nRF52832 SoC's ARM processor and software architecture are compatible with the nRF51 Series modules, it makes it much easier for our customers to upgrade to the new modules.”

And in the U.S., Argenox Technologies has also introduced a [nRF52832 SoC-based module](#), measuring 9.7 by 14.3 by 2 mm and certified to FCC, ETSI, and CE standards.

“The nRF52832 SoC makes Bluetooth low energy products smarter and better,” explains Argenox Technologies Founder and CEO, Gustavo Litovsky. “The chip makes the end solution faster to develop, lower cost, and more reliable, while allowing the designer to make fewer trade-offs in their selection of features.” ■



The BBC micro:bit project is inspiring the next generation of computer science engineers



Building the BBC micro:bit

Sally Ward-Foxton speaks to the man behind the BBC's ambitious educational project



Sally Ward-Foxton is a freelance journalist specializing in electronics

The British Broadcasting Corporation's (BBC) educational project to give every year 7 schoolchild in the U.K. a free programmable learning device is almost fully rolled out, with nearly one million devices already in the hands of their new owners. The devices, called "micro:bits", are small (and wearable) boards equipped with a basic LED display, various sensors and buttons, and a Bluetooth low energy wireless chip with embedded ARM processor. The intention is to teach children the basics of programming with the hope of encouraging them into studying science, technology, engineering,

and math (STEM) subjects and eventually pursuing careers in computer science. It's a laudable aim, but how did this ambitious project come about?

Howard Baker was with the BBC's education department, the team which drove development of the micro:bit. He explains that the initial idea followed a 2011 report from the U.K.'s worldwide renowned Royal Society.

The report identified a steep decline in the number of students studying computer science at university. The report also revealed that the students' skill level when they arrived at university had steadily declined.

"[This was all happening] at a time when [future] jobs required more and more of these skills," Baker says. "That's thinking skills associated with computer programming or organizing things in a way that a computer

As soon as Nordic Semiconductor stepped in we knew we'd solved most of the hardware problems. Its chip is a brilliant solution"

Howard Baker

understands. We'd stopped learning these skills."

Repeating history

The current generation had no idea that programming skills were in demand in the U.K, Baker says. It came as a surprise to many schoolchildren that there is a strong British industry creating games and movies which represents an exciting potential career path for computer science and STEM graduates.

The U.K. government changed the school curriculum as a result of the Royal Society report, but BBC Learning felt there was more that could be done. The BBC has a history of getting involved with practical projects to educate its home country; in the 1980s, a similarly ambitious venture called the BBC Computer Literacy project placed microcomputers in U.K. schools to encourage young people to learn to use them. A basic level of computer literacy was seen to be extremely important to prepare the workforce for the impending microcomputer revolution.

Called the BBC Micro, the computer given to schools in the 1980s could be programmed using BASIC computer language and represented many people's first experience of using a computer. It was a successful project and is believed to have kick-started the



U.K.'s fledgling digital industries, in particular, the games industry.

"The revolution did happen, every home did have a microcomputer – computers are now ubiquitous," Baker says. "The skills that we learned in the 1980s took us through the revolutions that followed very quickly after that. We were capable of building games, we were capable of coming up with the world wide web. But it was obvious [in 2011] that those skills were dipping."

Baker's Innovations team at BBC Learning started working with Manchester Metropolitan University, assembling panels of skills experts and teachers to discuss what form a potential educational project might take. Early ideas included a software version of the BBC Micro to teach basic programming. Kids loved the prototype, Baker says, but it was especially loved by parents who had used the original BBC Micro at school.

As this was happening, a new breed of electronics hobbyists called 'makers' — tech enthusiasts, engineers, and students — started to emerge. The rise of the Maker Movement coincided with the early part of the BBC Learning project and encouraged the notion that there ought to be a piece of hardware involved, that the kids could touch and play with, to make it feel more real. Some small smartphone-controlled robots were built as part of the project, which reacted to signals embedded in popular BBC TV programmes, and they were a huge success with children. This led to the Innovations team approaching the BBC's flagship children's TV

programme, *Blue Peter*, with the idea of encouraging basic electronic assembly. However, the cost of materials for *Blue Peter* projects is limited to around GBE2 (\$2.89), which meant that more expensive electronics projects weren't appropriate.

"I was cycling home and thought: 'what's the cheapest, smallest thing we could put in their hands, what could we give them that would be a kickstart?'," Baker says. "We'd have to be able to give it away, so it would have to be very cheap and it would have to have something on there that would immediately fascinate, like LEDs to write a message or make an animation. It needs buttons, an input/output to attach to a sensor, and it must be the easiest thing in the world to program. Like the BBC Micro - just tap in an instruction and the thing does it."

Thinking bigger

The BBC micro:bit was born. A proof of concept device was made up by BBC R&D and trialed at various events with great success. But the project really gained momentum when newly-appointed Director General of the BBC, Tony Hall, announced that the BBC's big educational project of 2015 would be "Make It Digital", an initiative to, in his words, "get the nation coding again". By then an integral part of this initiative, the micro:bit team realized they could, and should, think bigger. An initial idea to build 10,000 devices was scrapped in favor of giving a device away to every child in a whole year group – a million devices in total. Towards the end of 2014, the Innovations team put out a

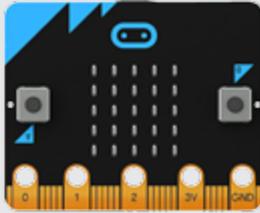



KEY POINTS

Rollout of the BBC's project to provide a million free micro:bit boards to help teach U.K. schoolchildren to code is almost complete

The code written by the children is run on the Nordic nRF51822 Bluetooth low energy SoC

The micro:bits will soon be able to connect to the wider Internet as part of the IoT, helping prepare young coders to develop the IoT applications of tomorrow



FRONT



BACK

call for commercial partners to help with hardware, software, learning resources, and finance. The partners worked together to finalize the spec of the device, which now included an on-board accelerometer and compass. U.K. IP vendor ARM developed and tested the basic hardware, Technology Will Save Us designed the shape, look and feel of the device, and it was manufactured by distributor Farnell element14.

ARM designed the hardware with simplicity in mind. This included a high level of integration leading to the selection of a Bluetooth low energy chip with an embedded ARM processor. Nordic Semiconductor's [nRF51822](#) is the brain of the micro:bit combining the latest Bluetooth low energy, ANT+ and proprietary wireless technology with a 32-bit ARM Cortex-M0 microprocessor.

The nRF51822's microprocessor is powerful enough to look after the wireless connectivity while also running the code written by the kids and looking after the board's other capabilities (with the exception of the USB functionality which is supervised by an NXP Semiconductors microprocessor). The wireless connectivity allows a micro:bit to communicate with other micro:bits, and Bluetooth 4.0 compatible smartphones, tablets, and computers.

"We knew from working with ARM that we wanted an ARM Cortex-M0, but as soon as Nordic Semiconductor stepped up with a [Bluetooth low energy System-on-Chip (SoC) with an embedded ARM microprocessor], and showed it can do all this stuff we



U.K. 11 and 12 year old school children are now exploring the capabilities of the BBC micro:bit, a wirelessly-connected, programmable computer



knew very quickly we'd solved most of the hardware problems," Baker explains. "It was a brilliant solution; in one step, the micro:bit was equipped to do all the things it needed to do.

"Shake it and something happens, point it in a direction and something happens, tap it and a smartphone does something. That's what turns the children on and underneath, Nordic's chip is making it all possible."

The other important chip on the board is NXP's USB controller, chosen because it enables code to be ported to the board without first downloading a loader program (a potential obstacle to setting up the micro:bit). The company also provided the MEMS accelerometer and compass chips. The board also has 25 LEDs arranged in a grid, two buttons, pins to link to other sensors via crocodile clips, and an edge connector which can be used to connect to other hardware, such as Raspberry Pi or Arduino.

For the micro:bit's software Microsoft volunteered its "Touch Develop" platform and built a web app around it, before adding Google's Blockly language at Baker's request.

Baker was also keen to include Python, a software language widely used in the teaching community, and with the support of the Python Foundation, a special version of Python for embedded devices was added. Code Kingdoms was responsible



Nordic's John Leonard (far left) and partners at the micro:bit U.K. roll-out

for the micro:bit's Javascript editor, and C++ is also available through ARM mbed, the development environment used by many embedded engineers.

"The kids have a pathway where they can start with moving graphical blocks, like a jigsaw puzzle [in Blockly], then play with Python and Javascript, and then even move on to C++ on a clear pathway," Baker says.

Key to connecting the hardware and software is a C++ library which implements the interactions referred to by the higher languages. This important library was built by Lancaster University; it's now a fully fledged open-source embedded operating system with a range of functionalities that the various communities using the micro:bit can build on.

Since most schoolchildren are very familiar with mobiles, connection to a smartphone is

a great practical illustration of what coding can do. Samsung built an Android app which allows the micro:bit to be programmed wirelessly by a smartphone, and some of the smartphone's functions to be controlled by the micro:bit. Smartphones equipped with Bluetooth 4.0 and later can communicate via the Nordic nRF51822 SoC which hosts a specially written Bluetooth Profile and Services, courtesy of the Bluetooth SIG.

"Not only does Bluetooth low energy mean I can sit on the bus and write my program on my smartphone, and transfer it directly to the micro:bit, but I can also get the micro:bit talking to and controlling the smartphone," explains Baker.

Get ready for the IoT

Although the micro:bits are almost fully rolled out to the first target group, this isn't the

end of the project. The micro:bit hardware is now on sale to the general public through Farnell element14 and several other retailers and there will be add-on kits available from partners like Kitronik which will incorporate additional sensors and other learning materials. The micro:bits might also eventually be able to transfer data between each other, using the nRF51822 SoC's proprietary radio functionality.

Another potentially exciting development is that the BBC is working with Nominet (the U.K. web domain name registry) to get micro:bits connected to the wider Internet, using a Raspberry Pi or smartphone as a gateway. Internet connectivity will effectively make a million-plus micro:bits a genuine part of the Internet of Things (IoT). The micro:bits can then act as sensor or actuator nodes for the Raspberry Pi or smartphone, connected via Bluetooth low energy, a USB cable or through the edge connector.

"The micro:bit is not just a tool to help kids code, it's a tool to help kids get ready for the IoT," Baker says. His view is that comparable to the microcomputer revolution in the 1980s, the IoT is the next technology revolution our society faces. "The micro:bit is absolutely about building IoT technology, it's about experimenting with building things for the new world, and having the opportunity to do that," he says. ■



ULP Wireless Q now available on Apple iPad and iPhone, Android tablets, and Amazon Kindle

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

The Apple iPad version of ULP Wireless Q (tinyurl.com/WQipad) is now joined by iPhone, Android (tinyurl.com/WQandroid), and Amazon Kindle (tinyurl.com/WQkindle) versions.

The digital version of ULP Wireless Q is designed to make the most of tablet devices' large high-resolution display, and includes all the interactivity you'd expect, including links back to relevant articles archived on the Nordic website, new product releases, analysts' information, blogs, videos, and much more.

ULP Wireless Q digital – your essential quarterly guide to ultra low power wireless technology in a mobile-device friendly format

A decade of collaboration

Kat Kent looks back over ten years of successful and productive cooperation between ANT Wireless and Nordic Semiconductor



Kat Kent is a Canada-based technology journalist and a wireless applications engineer

The ANT RF software protocol ('ANT') was developed in response to a need to wirelessly transport data, using very little battery power, from a footpod to a device such as a sportswatch. Invented by Dynastream Innovations, based in Cochrane, Alberta, ANT was launched in 2003.

During those early years Dynastream worked closely with Nordic Semiconductor to develop silicon solutions that would bring ANT to life. The result of that collaboration was Nordic's nRF24AP1, launched in 2005 and comprising a 2.4 GHz silicon radio running ANT. The transceiver was designed to work with a separate power-efficient microprocessor.

In 2006, Dynastream was acquired by Garmin Ltd, the U.S.-based company best known for its navigation devices and sportswatches. ANT was a strategic technology employed by the Garmin 'Edge' series of bike computers and ensured interoperability with peripheral wireless devices — such as speed, cadence, and power sensors — from a wide range of companies. ANT quickly became a de facto wireless standard for the cycling sector including the elite riders of the Tour de France.

2007 saw the formal creation of the ANT+ Alliance, a group of companies committed to developing standardized and interoperable ANT+ products. 2008 saw the first ANT+ Symposium, an annual event hosted by Dynastream and sponsored by Nordic Semiconductor that continues each fall in the Canadian Rockies.

ANT+ Alliance Members form technical working groups to



ANT was invented to link footpods to sportswatches and today is a key player in the new field of advanced running sensors

Garmin

focus on the solutions needed for their products and industry sectors. The collaboration between cycling companies has strengthened over the decade, with an impressive array of standards released. ANT+ Bike Speed and Cadence (2007), Power (2007), and Heart Rate (2008) Device Profiles were released shortly after the alliance was formalized. These device profiles were followed by Light Electric Vehicle (2011), Suspension (2014), Seatpost (2015), Bike lights (2015), Radar (2015), and Shifting (2016).

2009 saw the launch of the Nordic nRF24AP2 single-chip ANT solutions in both single channel and 8-channel variants. The cost-optimized single channel variant was used for ANT+ sensor products, while the 8-channel variant allowed products such as bike computers and sportswatches to synchronize with eight sensors concurrently.

Nordic brought an improved silicon technology to the new chip design, significantly lowering the purchase price,

and taking 20 percent off the nRF24AP1's peak current draw. For its part, Dynastream added several key features to ANT for the nRF24AP2's release: proximity search, continuous scan, and frequency agility.

The Garmin subsidiary Dynastream has retained development responsibility for ANT, ensuring interoperability and backwards compatibility between each generation of ANT chips. This business model continues with the latest generations of Systems-on-Chip (SoCs) from Nordic; the nRF51 Series (launched in 2012) and 2015's nRF52832 multiprotocol SoCs. 'SoftDevices' (essentially RF protocol stacks) S332 (ANT & Bluetooth low energy) and S212 (ANT) can be installed on the nRF52832 chip. Documentation and technical support specific to the ANT stack is provided directly by Dynastream, while Nordic provides support for the S132 SoftDevice and for any other issues.

"Our chip and protocol partnership has grown from the small radio-only nRF2401 to

Nordic's flagship nRF52832 SoC platform that offers customers ultra-low power protocol options, like ANT, to solve our mutual customers' unique connectivity use-cases," says James Fujimoto, Director of ANT Wireless. "We highly value our partnership with Nordic, a partnership that has successfully brought ultra-low power connectivity solutions to market, and we look forward to many more years of successful partnering."

Today, ANT has evolved into a technology for high node count networks that require low power operation across the network. Being highly configurable, ANT can be used to form point-to-point, broadcast, shared, and a variety of mesh network topologies that operate as part of proprietary network designs. ANT+ continues to lead the way in standardized solutions for the cycling sector, is strong in the fitness industry where high node count coexistence and manufacturer interoperability is key, and is a key player in the developing field of advanced running sensors. ■

Ultra low power wireless connectivity solutions

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

ICs	Operating Band	Wireless Protocol	IC Type			On-Chip					Peripherals														Applications										Ref. Designs	Dev Tools	WLCSF Wafer-level chip-scale package option						
			System-on-Chip	Connectivity	Transceiver	CPU	FPU	DSP	Memory OTP: One Time Programmable	MPU	Balun	Oscillators	NFC-A tag	2-Wire	ADC	AES	Analog Comparator	Battery Monitor	I2S	PDM	PWM	Real Time Clock	RNG	SPI	S/PDIF	Temperature Sensor	UART	USB	PC Peripherals	Sports & Fitness	Gaming	Cellphone Accessories	Consumer Electronics	Automation				Healthcare	Toys	Wearables	Smart Home	Beacon	Wireless Charging
nRF52 Series +																																											
nRF52832	2.4GHz	Bluetooth Smart v4.2, Proprietary & ANT	•			Cortex M4F	•	•	64kB RAM 512kB Flash	•	•	32MHz / 32kHz Crystal 64MHz / 32kHz RC	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	-	Single Board Dev Kit	•			
nRF51 Series +																																											
nRF51822	2.4GHz	Bluetooth Smart v4.2 & 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 v4.2, 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	•		
nRF51824	2.4GHz	Bluetooth Smart v4.2 & Proprietary	•			Cortex M0			16kB RAM and 256kB Flash	•		16MHz / 32kHz Crystal 16MHz / 32kHz RC	•	•	•	•			•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	Smartphone Demo Apps	Single Board Dev Kit, Dongle	•		
nRF8000 Series +																																											
nRF8001	2.4GHz	Bluetooth Smart v4.0	•			-			-			16MHz / 32kHz Crystal 32kHz RC											•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	PC Desktop, Smart Remote, Smartphone Demo Apps	nRFgo Dev Kit, Prog. Kit			
nRF8002	2.4GHz	Bluetooth Smart v4.0	•			-			-			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 + 256B 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 + 256B 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 + 256B 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 + 256B 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 +																																											
nRF90E5	Sub 1-GHz	433 / 868 915MHz	Proprietary	•		8051			4kB + 256B 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	



CEO Federico Musto, leads Arduino S.r.l.'s foray into the IoT

Arduino readies for the IoT

The world's most successful open-source ecosystem has embraced native wireless connectivity. ULP Wireless Q finds out the reasons why

The thriving Maker community owes a big debt to Hernando Barragán.

In 2004, the Colombian created an electronics development platform called "Wiring" for his Master's thesis while studying at the Interaction Design Institute Ivrea (IDII) in Italy. His goal was to create low-cost, simple tools for non-engineers to develop digital projects. The Wiring platform comprised a PCB using an Atmel ATmega128 microcontroller and an Integrated Development Environment (IDE) to ease programming.

To reduce platform cost, Gianluca Martino led the design of a new platform based on a cheaper Atmel microcontroller, the ATmega8. Massimo Banzi,

together with David Mellis (another IDII student) and David Cuartielles, 'forked' the Wiring project software and added support for the new board. They christened their board and their software fork "Arduino" (named after a bar in Ivrea which in turn was named after Arduin of Ivrea, who was King of Italy from 1002 to 1014).

Arduino hardware and software were 'open source', available via a public license ("open source", as defined by the Open Source Hardware Association (OSHW), is "hardware whose design is made publicly available so that anyone can study, modify, distribute, make, and sell the design or hardware based on that design").

In the ensuing decade,

Arduino has forged a sustainable ecosystem beloved of the maker and developer community. That ecosystem comprises a range of single board computers (SBC - now based on processors from several major vendors in addition to Atmel), expansion boards, software libraries, an easy-to-use IDE (which encourages the use of license-free design tools), and a worldwide development community dedicated to sharing information, software, and technical solutions.

[Makers](#) are a growing global grouping of spare-time designers, hobbyists, and amateur engineers (see ULP Wireless Q *Winter 2014 pg16*) who use their spare time to construct fun, often useful, and occasionally commercial, devices from electronics, mechanical

components, and plastic packaging.

One U.S. maker association estimates that around 75 percent of its members base the electronics for their projects on Arduino and other open-source hardware platforms, while most of the others build their own SBCs from schematics detailing Arduino hardware. Actual numbers are hard to find, but anecdotal evidence from organized gatherings such as "Maker Faires" across the world seem to confirm this estimate. That makes for a lot of Arduinos in the wild, approaching one million according to recent calculations.

Lowering the shields

It hasn't taken long for the maker community to latch on to



commercial manufacturers' use of wireless connectivity to make their products 'smart'. 'Dumb' objects working in isolation become a whole lot more useful when equipped with a wireless connection to communicate with other devices, sensors, computing platforms such as smart phones and PCs, and ultimately data center services and analytics processing in the Cloud.

Anticipating demand for extensions to its base board to endow Arduino SBCs with greater functionality, Arduino cleverly incorporated standard connectors which enabled the use of expansion boards (or "shields") to add specific functionality. For example, an Ethernet shield allowed an Arduino board to connect to the Internet via an RJ45 connector and a few simple software instructions. Later, shields incorporating Wi-Fi and Bluetooth connectivity allowed Arduino users to connect to other devices or the Internet without needing a cable.

But the pervasiveness of wireless connectivity and the promise of the Internet of Things (IoT)—an extension of the Internet to even the most mundane objects via a bidirectional RF link—convinced the Arduino organization to make RF technology a fundamental part of an Arduino base board.

"Many developers know Arduino through the Arduino Uno - our original and best-selling product. We decided it was time for a natural evolution of the Uno—a decade after its introduction—embracing 'native' wireless connectivity," explains Federico Musto, CEO and President of Arduino S.r.l. (Arduino S.r.l. was formed from the manufacturing firm called Smart Projects, an Italian factory that's assembled Arduino products since 2005.)

"Developers familiar with the Uno wanted an Arduino that enabled them to design IoT applications without the need for shields," says Musto. "To meet that demand it was clear to us that such a new product had to be equipped with Bluetooth low energy because the technology offers advantages such as low power consumption

and interoperability with consumer electronics."

The demand from developers resulted in the Arduino Primo, launched with fanfare at a major maker gathering in San Francisco during May (see *this issue pg3*). With the Primo, developers and makers no longer need to add shields to wirelessly link to other devices. The board incorporates Bluetooth low energy—ensuring seamless connectivity with smartphones, tablets, and desktop computers equipped with Bluetooth 4.0 (and later) technology as well as a rapidly growing family of Bluetooth low energy sensors. In addition, the Primo platform also includes a Wi-Fi module to easily link it with existing Wi-Fi networks, and for when greater bandwidth than can be provided by the Bluetooth technology is needed (at the cost of higher power consumption).

Bluetooth low energy connectivity is provided courtesy of Nordic's nRF52832 System-on-Chip (SoC) which also endows the board with Near Field Communication (NFC), a nifty, user-friendly "Touch-to-Pair" mechanism for quickly associating Bluetooth low energy devices. (See [ULP Wireless Q Winter 2015, pg9](#).)

Better yet, the nRF52832 SoC's embedded ARM Cortex M4F processor has plenty in reserve to run the non-Bluetooth low energy functionality of the Arduino Primo. ("The nRF52832 is the heart of the Primo," says Musto.) The SBC houses another

processor, an STMicroelectronics device, that looks after the Arduino IDE programming and debugging while the ARM M4F does all the other computational heavy lifting.

Apart from the hardware, the Arduino ecosystem's other strength is its ease of programming via the IDE which allows the inexperienced to get started quickly. While the Primo retains that advantage, if makers want to get really adventurous they can leverage the SBC's full capabilities by turning to development tools such as Nordic's nRF52 or nRF5 IoT Software Development Kits (SDK). These SDKs enable more experienced engineers to explore the nRF52832 SoC's full functionality which includes the capability to support even enterprise-level IoT applications.

Targeting the IoT

According to Musto, the Primo is one of the organization's first attempts to enable users to build projects that take advantage of the fledgling IoT. The Primo's Bluetooth low energy technology can communicate with sensors (or other Primos) and then relay information to the Internet via a 'gateway' such as a smartphone or desktop computer, or a newer model IoT hub/gateway that includes both Bluetooth and Wi-Fi connectivity.

The organization has produced a 'stripped-down' Arduino Primo called the Primo Core. The Primo Core is an elegantly-

designed circular SBC in a 40 mm diameter form factor, again based on Nordic's nRF52832 SoC, targeted at wearable or sensor applications. The SBC is specifically designed to operate as a wireless sensor interfacing with the Primo. An Arduino developer could, for example, set up a home temperature and humidity monitoring system based on Primo Core sensors with one or two Primos collating the information in order to download the data to a smartphone or IoT hub/ gateway.

Moreover, IoT applications running on Primo or Primo core can already take advantage of IPv6—the latest Internet Protocol—to communicate directly with other connected objects and Cloud-based computing resources via cheap, simple relays or 'bridges' that can forward packets to the Internet proper. (Security remains a challenge but is being addressed by Internet engineering groups.)

"IPv6 capability is another important reason why we selected the Nordic Bluetooth low energy chip," says Musto. "Today, the Primo's nRF52832 chip is already capable of communicating with the Primo Core using IPv6 over Bluetooth low energy. Tomorrow, that technology will enable the Primo to directly connect with the IoT without an extra gateway. That's an exciting prospect for the maker community and is sure to further enhance the Arduino ecosystem in the future." ■



"Developers familiar with the Uno wanted an Arduino that enabled them to design IoT applications without the need for shields"



Over the horizon: what next for the semiconductor industry?

The Internet of Things and open source hardware are the great hopes for a revitalized semiconductor industry. ULP Wireless Q reports



Connected people, connected cities: The IoT will evolve into a networked 'everything'

It is eighteenth century English physicist Sir Isaac Newton who is widely credited with coining the phrase "what goes up, must come down", and while Newton may have been trying to make a point about gravity, you don't need to be an economist to know the principle holds equally true for industry.

Few sectors can claim to be immune to the business cycle, and semiconductors are no different. Rapid growth has been accompanied by periodic corrections and times of volatility in its relatively short 50 year history.

Earlier this year Rambus Inc., a semiconductor and IP vendor, and the Global Semiconductor Alliance (GSA), an organization comprising some 400 member companies in 35 countries throughout the semiconductor industry supply chain, released a report entitled "Charting a New Course for Semiconductors",

which acknowledged that, despite sometimes difficult market conditions in the broader economic landscape in the last 20 years, the global semiconductor industry had largely managed to expand and innovate. Key to the sector's health was identifying and adopting a variety of new business models, the most notable of which was the advent of fabless chip companies such as Bluetooth low energy chip vendor Nordic Semiconductor.

"This innovative approach has dramatically lowered the barriers to entering the semiconductor industry by enabling design-oriented companies to outsource most or all of their chip production needs to contract suppliers, which can spread the high cost of building and operating chip fabrication, assembly, and test facilities across numerous customers," says the report.

To that end, fabless chipmakers

now account for nearly 40 percent of all semiconductor revenue, which peaked at \$340 billion in 2014. That's the good news. Today, however, the industry is negotiating another period of slowing sales, tightened margins, and consolidation, and it has left some observers to question whether the semiconductor sector is finally losing its mojo.

"Even as semiconductors continue to contribute to a wide array of revolutionary, potentially transformative technological advances ... long-time industry watchers have begun to suggest the industry is moving into a new era of slower growth, increasingly commoditized products, diminishing profits and, inevitably, fewer competitors," notes the report.

The question now, the report suggests: "is whether chipmakers will be able to respond to these latest challenges by once again

developing new business models and fresh revenue streams to reignite growth?"

IoT leads way

If the answer to this question is to be "yes", then, the report claims, salvation is less likely to be found in the existing PC and mobile markets, but from new verticals across multiple industries from the automotive and medical sectors, to industrial operations and security, headlined quite possibly by the fledgling Internet of Things (IoT) sector.

"The so-called Internet of Things may very well be the industry's long awaited blockbuster technology platform capable of driving yet another generation of explosive semiconductor growth," asserts the report. "Indeed, the IoT is expected to usher in a plethora of new technologies and business models - helping to steer industry growth back into the fast lane."



Industry experts appear to agree. The report cites Morgan Stanley analyst Mark Edelstone who predicts the IoT will “drive semiconductor demand for years” as it evolves from networked consumer electronics products, to networked industries, and beyond to “networked everything”.

It’s a prediction firmly backed by Nordic Semiconductor,

“Nordic is already the leader in the Internet of ‘my’ things, but the bigger opportunity is in the Internet of Things around us.”

It’s an opportunity not lost on Nordic’s customers either. Swedish industrial IoT system provider, Free2move, is now in its twelfth year of working with Nordic, and while the company began life as a Bluetooth module provider, it is now in the process of transforming into a pure IoT play.

“In total we’ve deployed approximately 100,000 devices using Nordic architectures, from airport trolley tracking, to gas cylinder tracking, to military ordnance security, and laptop tracking,” says Anders Due-Boje, Free2move’s CEO. “It might be a small number compared to consumer applications, but with our new IoT approach we hope to go an order of magnitude higher.”

The company recently launched its Nordic nRF52832-powered 2Connect IoT platform (see *this issue pg5*) that monitors a host of industrial environmental variables using a layered analytics and decision architecture, analyzing real time information and taking corresponding, automatic wirelessly-triggered remedial actions.

“We are more concerned with realizing true automation than the presentation of big data, and we are a subscriber to the philosophy that the IoT should operate without screens,” continues Harnevie. “We believe successful IoT systems should take action based on set-policies rather than having to ask humans for decisions for every action.”

The Rambus and GSA report claims another possible solution

“Nordic is already the leader in the Internet of ‘my’ things, but the bigger opportunity is in the Internet of Things around us”

to the semiconductor sector’s growth predicament may be to take a lead from the software industry’s trend towards open source. The report quotes Eric Weddington, an open source architect for GPS technology vendor, Trimble, who claims “integrated circuits could be the final frontier of open source.”

Inspired by open source

The report notes several hardware initiatives inspired by the open source concept have launched in recent years, primarily for students, hobbyists, and independent developers, or makers. Among the leaders of the Maker Movement is Arduino, an open source platform for developing microcontroller-based prototypes.

Arduino recently launched a low cost IoT-targeted programmable single board computer (or ‘base board’) called the Arduino Primo (see *this issue pg3 and pg16*), at the heart of which sits Nordic’s nRF52832 System-on-Chip (SoC).

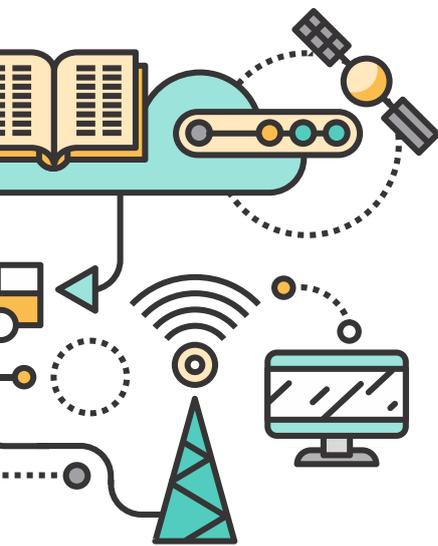
“It has been estimated that the number of connected devices worldwide will increase from today’s approximately 15 billion to 200 billion in 2020,” says

Federico Musto, CEO & President of Arduino S.r.L. “These numbers are astonishing ... makers, entrepreneurs, small and large companies, kids, and venture capitalists are paying close attention, and the playing field is very broad. From smart homes, to data analytics, to security, the applications are endless.”

“One of Nordic’s strategies is to closely support the maker and hobbyists communities so that they can painlessly incorporate Bluetooth low energy wireless connectivity into their electronic development projects,” comments Geir Langeland, Nordic’s Director of Sales & Marketing. “Because Arduino-based electronics make up around 70 to 80 percent of amateur engineers’ projects, it was an easy decision when Arduino asked us to supply the nRF52832 SoC to form the heart of its first native Bluetooth low energy wireless base board.”

Indeed the future of the semiconductor sector looks bright, notwithstanding the set of challenges it, as any industry in its relative infancy, faces. The IoT looms as a potential ‘killer app’, while forward thinking companies look to tap into new markets slowly, but increasingly, built on open source. Collaboration will be key, but semiconductor companies know it, and are progressively embracing innovation models built on interdependence, as the sector as a whole moves towards a sustainable and bright future.

Rambus and GSA’s “Charting a New Course for Semiconductors” report is available from the GSA Global website at gsaglobal.org. ■



from the top down. “I’ve been preaching the IoT almost before anyone used the word,” says Svann-Tore Larsen, Nordic’s CEO. “We all know the IoT is a massive opportunity for wireless. HBR [*Harvard Business Review*] believes there will be more than 28 billion sensors in 2020. Some people might be skeptical but we firmly believe in that number.

Open source hardware could be the final frontier for the semiconductor sector





Wireless charging technology awaits the first killer app

Adapters and connecting cables are a headache that could be consigned to the history books by intelligent, wireless charging. But the industry needs to get its act together first, says Caroline Hayes



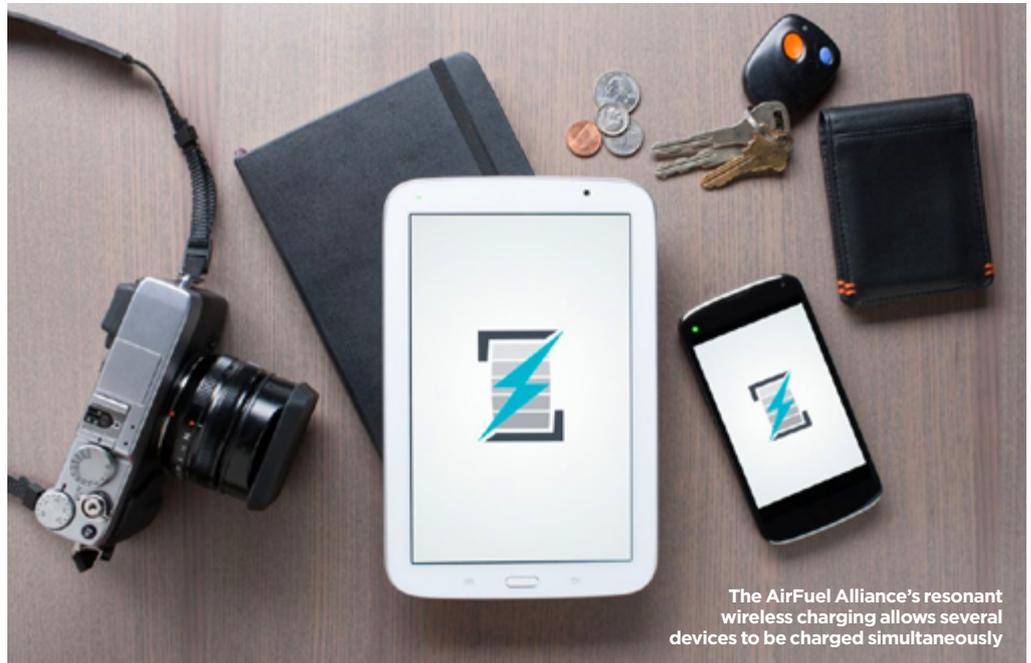
Caroline Hayes
is a U.K.-based
technology
journalist

For most people, utopia is a world without wires. No more rats' nest of cables behind equipment or in drawers, no trailing wires to trip over while charging phones or laptops, and no cables to lose or leave behind in hotels, offices, and homes.

Such a vision goes some way to explain why awareness of wireless charging is growing. More than three quarters (76 percent, an increase of 36 percent since 2014) of respondents to a consumer survey (*Wireless Charging Consumer Insights Report*) conducted by analysts IHS in June 2015 had heard of wireless charging technology. However, just 20 percent of respondents made use of the technology, and only 16 percent employed it on a daily basis.

Why is wireless charging, which is as simple in concept as placing a smartphone, tablet, camera, or smartwatch on a charging pad or mat, not already ubiquitous? Part of the reason is because, like consumers, the industry itself is still getting its act together. Groups championing various standards have realigned themselves recently with the merger of the Alliance for Wireless Power (A4WP) and the Power Matters Alliance (PMA) last year to form the AirFuel Alliance – tasked with promoting consumer-friendly wireless charging and its ecosystem. Another standards body is known as Wireless Power Consortium (WPC). (See [ULP WQ Spring 2016, pg11.](#))

To make matters even more complex, there are two



The AirFuel Alliance's resonant wireless charging allows several devices to be charged simultaneously

established wireless charging technologies, inductive and resonant. The AirFuel Alliance primarily promotes resonant charging (under the 'Rezence' specification), while the WPC touts its inductive charging standard known as 'Qi' (pronounced "chee").

Charging technologies

Resonant wireless charging uses two coils tuned to resonate at the same (relatively high) frequency. The oscillating current generated by the primary coil (in a charging pad) creates an oscillating magnetic field, which induces an alternating current in the secondary coil (the receiver, housed in the device to be charged) that can be used to do useful work such as charging a battery.

Inductive charging is also based on two coils, but the

transmitter and receiver coils are tuned to (slightly) different relatively low frequencies. Again, the alternating magnetic field generated by the transmitter coil is converted to electrical current by the receiver.

With inductive charging, the transmitter has to be precisely aligned with the receiver for efficient charging to take place. As a result, the range is limited to between 2 to 10 mm, and each receiver coil can only power a single transmitter coil. Resonant charging is more flexible, with charging over a distance of up to 50 mm, and without the need for the coils to be precisely aligned or even parallel to each other. In addition, each primary coil can power several secondary coils.

Inductive charging is markedly more efficient than resonant technology, but this is countered by resonant charging's

convenience of a wider field, the ability to charge through surfaces, and the capability to charge multiple devices simultaneously.

The commercial lines are becoming blurred as the most recent WPC Qi receivers (built into mobile devices) can operate in both inductive and resonant mode. The operation mode is defined by the transmitter. The AirFuel Alliance is also working to incorporate both resonant and inductive technologies into a single certification to accelerate commercialization of its wireless charging.

"The playing field is quite open, and a first, 'killer app' is needed," says John Leonard, Product Marketing Manager with Nordic Semiconductor. Adding intelligence using a control loop, managed by Bluetooth low energy wireless technology such as that supplied by Nordic could



produce such a differentiating application.

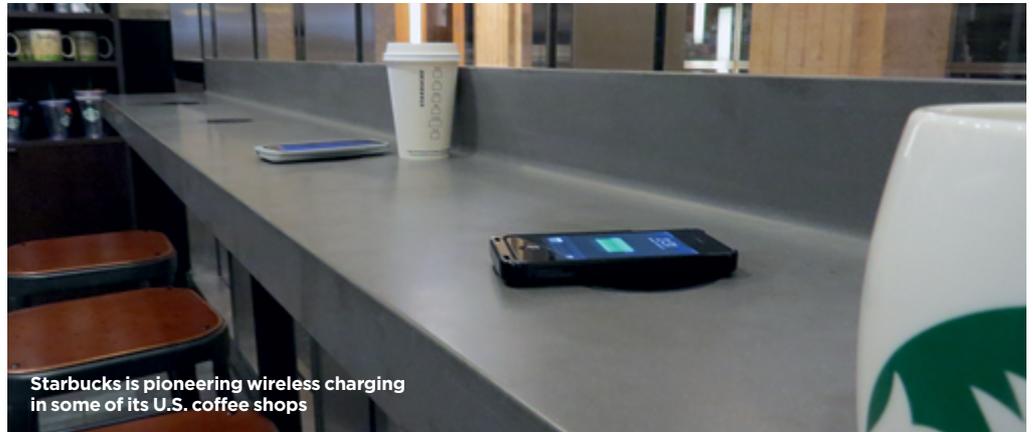
Unlike Qi, in which charging pads are live all the time, the Airfuel Alliance technology uses Bluetooth low energy wireless connectivity to periodically check if a mobile device is present and needs charging. The bidirectional wireless link between the transmitter and receiver coils allows a Power Transmitter Unit (PTU) to 'advertise' for a Power Receiving Unit (PRU), such as a mobile or smartwatch. When detected, the PTU communicates with the PRU over the wireless link. In this way, the PTU engages the charging sequence, determines how much charge is required, and any other PTUs in the vicinity that have detected the PRU can return to sleep mode.

This power saving feature could be critical, says Leonard. "While generating a field may not be significant, it still consumes energy," he points out. If multiple PTUs are placed in a single area for convenience (for example, an office), only the one closest to the PRU needs to be active.

Bluetooth low energy technology's communication between the PTU and PRU also controls the charge. The PRU can signal when, for example, it is 80 percent charged and the remainder of the charge can be scaled down to avoid overcharging - a significant feature considering the dangers of overcharging the fragile lithium-ion batteries at the heart of today's consumer electronics devices.

Leonard believes that the ability of the Airfuel Alliance's resonant charging technology to penetrate through surfaces, such as a wooden desk, marks the first wave of innovation. Because of resonant charging technology's wider field, the device to be charged does not have to be precisely aligned with the transmitter. The transmitter pad does not even have to be visible, it can be embedded in worktops or furniture. This opens up opportunities for designing in a PTU to a work surface and simultaneously charging a smartphone, tablet computer, and a smartwatch, for example.

A single PTU can simultaneously wirelessly charge



Starbucks is pioneering wireless charging in some of its U.S. coffee shops

several devices, in part due to the multichannel communication support of chips such as Nordic's nRF51822 Bluetooth low energy solution. Nordic has released a version of the System-on-Chip (SoC) with a special protocol stack (an 'S120 SoftDevice') which enables a PTU to independently supervise up to eight charging devices. When used with the company's nRF51 Wireless Charging Software Development Kit (SDK), the SoC and SoftDevice enable developers to design resonant wireless charging applications for multiple devices.

Support for Bluetooth low energy-enabled wireless charging continues at Nordic, explains Leonard, with a reference design planned for release this summer. The design will address the layout

of charging chips supplied by third parties, as well as software to adapt designs to specific requirements.

Future ambitions

The ease and convenience of resonant charging opens up many design possibilities. Charging in the proximity of a PTU with Bluetooth low energy control means that wireless charging can begin almost without the user thinking about it. The scope for embedding PTUs into work surfaces or furniture in the home or office appeals to the aesthetics of interior design and is practical for users. Leonard cites a future scenario of being able to place a recipe book over a transmitter embedded in the worksurface and still wirelessly charge a

device without interruption while preparing dinner.

For medical environments, eliminating cables will increase safety and convenience, and also contribute to maintaining sterile environments by minimizing contact.

Resonant charging in cars will also be convenient and practical. As there is no need for precise alignment, even if bumps in the road dislodge the mobile, charging continues uninterrupted.

During the Consumer Electronics Show (CES) 2016, there were announcements around wireless charging, some designed to bridge the gulf between WPC's Qi and the Airfuel Alliance's standards. NuCurrent, for example, introduced circular antennae supporting both standards, and Convenient Power announced the industry's first Rezence v1.3-certified wireless charger.

Wireless charging is even progressing to the automotive sector, with Mercedes announcing that its next-generation Mercedes S-Class Plug-in Hybrid Electric Vehicle (PHEV) will use wireless charging for its batteries from summer 2017.

So it seems that while progress thus far has been slow, the proclamation from analysts IHS that "2016 is set to be a great year for wireless charging technology designers and electronics manufacturers alike", appears to be well founded. The consumer will soon start to see the benefits when convenient, intelligent, and energy-efficient wireless charging is integrated into mainstream devices to accelerate deployment and design innovation. ■

Support for wireless charging is surging with companies such as NuCurrent announcing a resonator for the Airfuel Alliance standard at CES 2016. It is pictured with the 20 mm round Qi-type coil





Tangram Factory Smart Rope

This smart jump rope not only counts the number of successful rope jumps but also displays the total in the user's line of sight

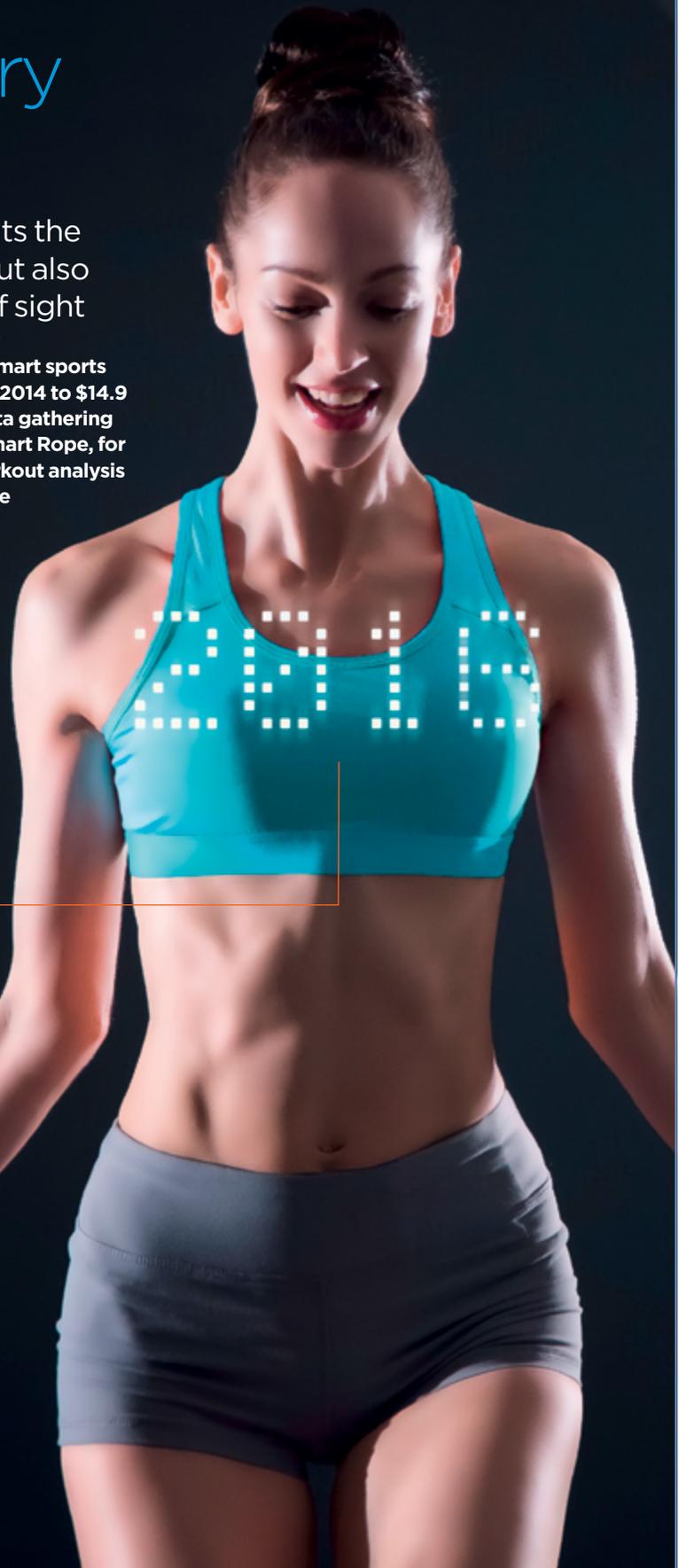
According to WinterGreen research the market for smart sports and fitness devices is set to grow from \$3.5 billion in 2014 to \$14.9 billion in 2021, as better technology and superior data gathering capabilities drive adoption. The Tangram Factory Smart Rope, for example, provides an extensive dataset for post-workout analysis via the complementary app on the user's smartphone

Rope jumping is one of the most physically taxing activities, with three 10 minute sessions per day burning upwards of 400 calories. By comparison engaging in high impact aerobics, basketball, rowing, squash, swimming, or cross country skiing for a similar length of time would burn less than 300 calories.

Alaskan-born [Peter Nestler](#) holds a number of extreme jump rope records including most rope jumps on a unicycle in one minute, most rope jumps while keeping a soccer ball in the air in one minute, as well as most jumps while wearing flippers, and most underwater rope jumps. He also holds the most rope jumps in one hour record with 12,702 jumps - an average of 3.5 jumps per second.

Smart Rope's proprietary sensors detect full 360-degree revolutions of the rope, tracking them as successful jumps. The rope itself is embedded with 23 LEDs in a flexible printed circuit board (FPCB) design, that display the number of successful jumps in the jumper's line of vision.

Tangram Factory's [Smart Rope](#) employs Nordic's nRF51822 System-on-Chip (SoC) to provide Bluetooth low energy connectivity to smart devices. Powered by a 300-mAh Li-polymer battery, the Smart Rope can be used for up to 36 hours between recharges.



PEOPLE & PLACES

Chris Hansen



Keen hiker joins Nordic to create new opportunities from IoT boom

Hi, I'm Chris Hansen and I joined Nordic earlier this year to manage the company's new Internet of Things (IoT) Labs Group based in Portland, Oregon, U.S.

I previously worked at Intel Corporation where among my many responsibilities I served on the Bluetooth SIG Board of Directors. The Board role was interesting but being an engineer at heart I also joined the technical Core Specification Working Group. That's where I learned about the technical details of Bluetooth wireless technology.

I think my biggest contribution to Bluetooth was being the Chair of the Board during the establishment and development of Bluetooth 4.0 that included Bluetooth low energy as a hallmark feature. It was a challenge from both a technical and organizational perspective because it involved balancing the needs of member organizations and target applications, many new to Bluetooth technology.

Nordic's IoT Lab was formed to enable the company's devices to become integral to the tremendous growth of the IoT. The initial focus is on helping developers to connect to the Internet as easily as possible.

The IoT has the potential to be a game changer for the



Outside of work, Chris Hansen enjoys outdoor activities in the beautiful landscapes near his home in Oregon

wireless market because the capacity of the internet is going up while the cost is going down. Simultaneously, there are countless devices in homes and businesses that can benefit from low-cost wireless connectivity, monitoring and control.

Today, the same processes are in motion in the IoT that happened in computing over the last 30 years. Not only does this make the future of the IoT exciting, it also adds the potential to create new IoT business opportunities for Nordic in new applications and technologies.

My job is to make this happen starting early in 2017. I predict that there will be impacts on

from other groups at Nordic. I'm an easy person to work with and promise to bring beer from Portland on my frequent trips to Oslo in an attempt to win friends and influence people!

Outside of work I enjoy outdoor activities such as hiking and skiing. Oregon is a great place for both. The Cascade Mountain Range is an hour's drive east of Portland with its prime ski areas and thousands of miles of hiking trails. West of Portland is home to many established hikes that overlook the Pacific Ocean.

Did I mention beer? It's not a coincidence that the new Nordic office is situated in the 'brewery blocks' of Portland given that the first employee here got a say in the location!

Indoors, I like to relax by fixing and restoring things. Later this year I'll be restoring a 1970 Ford Mustang Fastback with my 14-year old daughter. But my ongoing passion is designing and repairing old vacuum tube amps.

Ebay is a great place to buy old amps. My wife gets upset every time Fedex shows up with another new amplifier. She says I have enough littering the house already, but I know what she really means is it could and should have been another surprise gift for her! I guess after 22 years of marriage I've still got a bit to learn. ■

Personal Profile

NAME:
Chris Hansen
JOB TITLE:
Director of IoT Labs
JOINED NORDIC:
January 2016
BASED:
Portland, Oregon, U.S.
INTERESTS INCLUDE:
Classic car & valve amp restoration, fishing, hiking, skiing

our design tools and developer support, and even on the next generations of our silicon. The team in Portland will be very small so I am counting on help

"The same processes are now in motion in the IoT that previously happened in computing. This makes the future exciting with the potential to create new opportunities for Nordic"



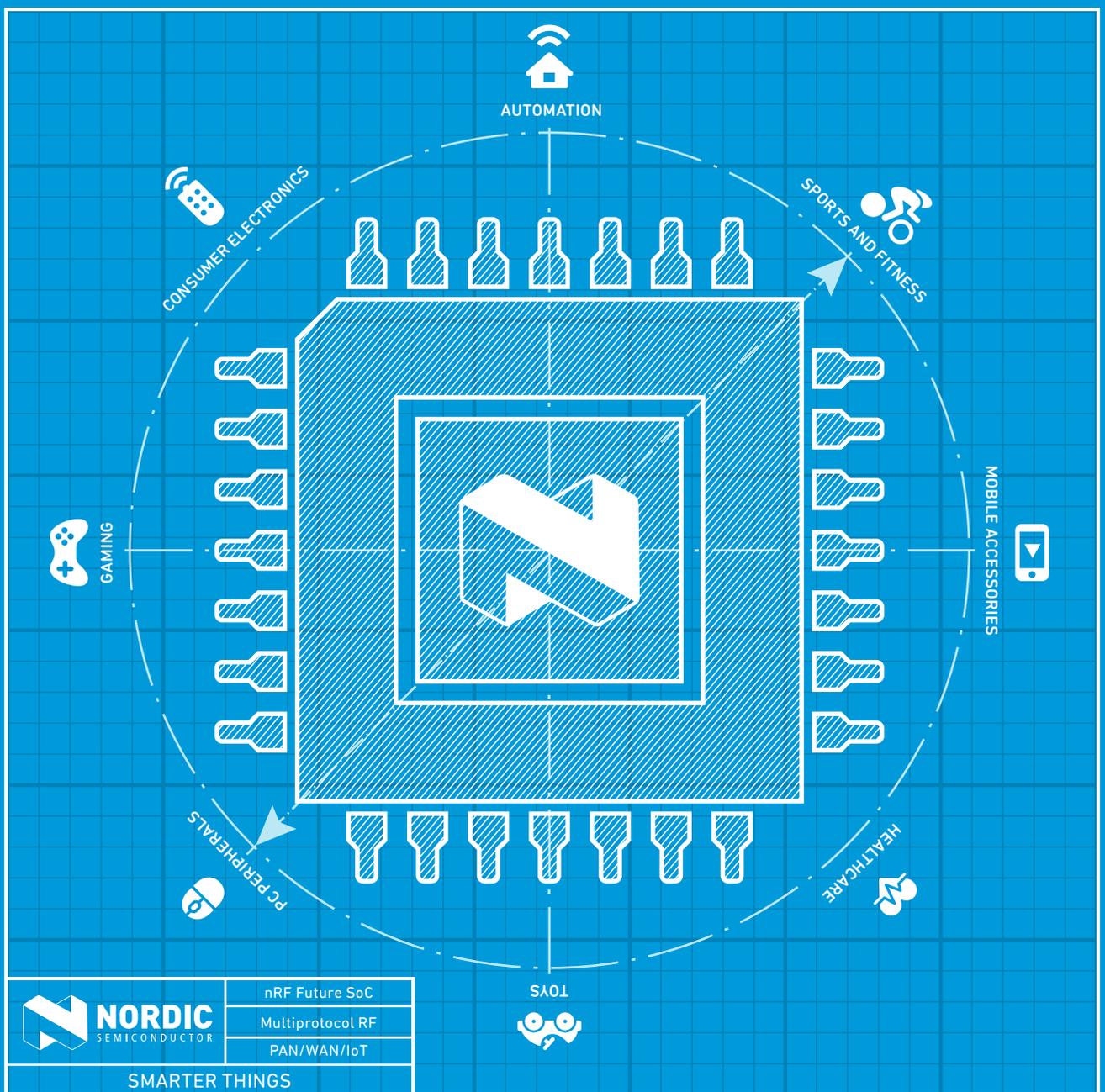
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A decade of ultra low power wireless



2006 to 2016

Building a billion-dollar IoT company: Bluetooth low energy is just the beginning

The last ten years and the next decade encompass Nordic Semiconductor's IoT strategy. At the midpoint, Nordic's CEO, Sverre-Tore Larsen, takes stock

Over the past ten years, Nordic Semiconductor has transformed from a little-known supplier of sub 1 GHz and 2.4 GHz proprietary ultra low power chips into the largest Bluetooth low energy solutions provider in the world. Such a change resulted in Nordic being voted 2015's 'Outstanding EMEA Semiconductor Company' by the Global Semiconductor Alliance.

But what's behind this meteoric rise and will the company be able to sustain it? Sverre-Tore Larsen, Nordic's CEO for the past 14 years, thinks so: he's predicting the company could become a billion-dollar Internet of Things (IoT) giant in just a few years from now.

"The biggest successes in the semiconductor business come from taking the biggest risks," says Larsen. "If it's not bold, big, and somewhat 'out-there', it's what everybody else is doing. And if everybody is doing it, the results don't bring significantly more value to customers and will struggle to differentiate the company competitively.

"This doesn't mean I'm advocating recklessness. Agonizingly and carefully thought-through, deliberate, managed risk-taking, based on in-depth market and customer research, is not reckless. But even so, nobody can predict the future. And between making a decision and seeing if it

plays out, there will often be years of sleepless nights, on-going investment with no revenue, criticism and doubt from concerned investors and analysts, and frankly a lot of tedious and exhausting work to be done. But you have to have faith that it will pay off."

Handsome pay off

Part of what Larsen refers to is the decision by Nordic to back Bluetooth low energy technology. Entering the sector required the company to overcome enormous financial, technological, and commercial challenges. "It was almost six years between the birth of [Bluetooth low energy technology's forerunner] Wibree in 2005 [a technology adopted by the Bluetooth SIG in 2007] before the first products and any revenues," Larsen explains. "Six years waiting to see if a strategic decision transitions into a commercially viable technology is a lifetime in this business."

"But eventually it paid off handsomely," he continues. "However, today we face greater challenges to growth than ten years ago."

Larsen explains that while outsiders regard Nordic as a pure Bluetooth low energy company, it's actually been at the forefront of the Internet of Things (IoT) for more than a decade. "The IoT can be traced all the way back to the world's first wearables in 2004: [Nordic chip-based] Suunto t6 sportswatches with wireless heart-rate, speed & distance monitors, and a computer dongle," says Larsen. "These were the IoT in miniature PAN [personal area network] format, but nonetheless comprised wireless sensors bringing data from the real world to the Cloud: albeit a 'Cloud' which then comprised little more than a computer with Internet access."

Larsen continues: "Bluetooth low energy expanded this further by allowing a network of wireless sensors to talk to a smartphone. This is heading towards a wireless sensor network able to deliver data to the Cloud from anywhere in the world via a global ecosystem

of wireless WANs [wide area networks].

"This technology will be needed by governments, organizations, and individuals which are being forced to do more with less. Countries face unprecedented challenges, such as aging populations and diminishing workforces. The old economic and business models just aren't going to be sustainable or viable anymore."

Larsen says this technology will be massive in scale: global and ubiquitous; simple to use making it applicable to the mass-market; low cost; simple to install and maintain, and battery operable. Such a technology will make it possible to bring economies of scale, automation, and optimization to everything.

The IoT is the game changer

"The IoT will enhance every aspect of how we live, work, and play in the coming years. That's the real promise; the game changer," Larsen explains. "So to me the IoT is inevitable. It will also be orders of magnitude bigger than Bluetooth low energy is today, but will be impossible to achieve without that technology, making Bluetooth low energy ubiquitous. But the IoT will require much more than Bluetooth low energy to operate."

Nordic's recent recruitment of highly-talented cellular RF engineers [formerly employed by the Finnish arms of Nokia, Ericsson, Motorola, and Broadcom] represents an ambitious bet on a Bluetooth low energy-based cellular WAN solution that Larsen believes will become a fundamental part of the IoT.

"Nobody has more ultra low power wireless engineering expertise or is investing so much revenue in developing the perfect IoT solution than Nordic," he concludes. "The last ten years and the next ten years are all part of the same story, the only difference from a decade ago is that we now know we're only half way towards our aspiration to become a world-leading IoT company." ■

"Between making a decision and seeing if it plays out, there will be years of sleepless nights, investment with no revenue, and criticism and doubt from investors and analysts, plus a lot of tedious and exhausting work. But you have to have faith"

SVENN-TORE LARSEN, CEO, NORDIC SEMICONDUCTOR



From Wibree to IoT: ten years of development in ULP wireless connectivity

In June 2006 Nordic Semiconductor mapped out a strategy to be a leader in a new, interoperable form of ultra low power wireless technology which was to become Bluetooth low energy. Today that strategy has played out and the company now sets its sights on the Internet of Things. Here are some of the milestones passed on the way

The last decade has seen Nordic Semiconductor progress from a small niche company to the leader in ultra low power (ULP) wireless connectivity. Back in 2006, the company designed sub-1 GHz and 2.4 GHz transceivers, running proprietary RF protocol software, teamed with separate 8-bit processors; today it dominates in the field of highly-integrated 2.4 GHz ULP multiprotocol Systems-on-Chip (SoCs) sporting embedded 32-bit ARM M0 and M4F processors.

Those early transceivers carved a niche powering wireless mice, keyboards, and sportswatches while today SoCs are found in everything from wearables to home automation, asset tracking to beacons, and audio streaming to wireless charging.

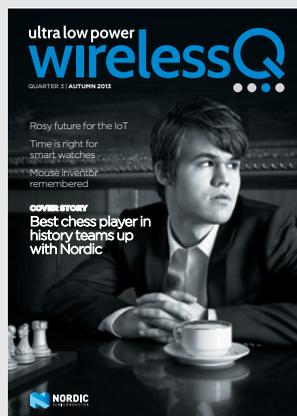
Nordic's products have found favor with developers of all levels of expertise from senior engineers with giant consumer electronics companies, through junior engineers in start-ups, to makers and hobbyists, and even schoolchildren.

And while this product development has

progressed, the company's staff has found time to play key roles in the Wibree Alliance, ANT Alliance, and Bluetooth Special Interest Group (SIG); while management has invested heavily in R&D, sales, support, distribution, and training. There's even been a little time to enjoy the kudos that comes from winning awards for innovative products and making outstanding contributions to the chip industry. This timeline recalls key product, application, and business milestones from the last ten years as the company looks forward to a new decade dominated by the IoT.



ULP Wireless Q has covered key milestones in Nordic's success since June 2006





ANT powered

Finnish sportswatch maker Suunto chose Nordic's nRF2401A transceiver and ANT's RF protocol software for its t6 heart rate monitor, one of the world's first 'wearables'

2006



Point and click

The nRF24L01 chip was used to power Philips' wireless mouse which boasted one-year battery life and was unveiled at CES, the world's largest consumer electronics event

2007



Nordic inside Fitbit

U.S. fitness company Fitbit selected the nRF24AP1 ANT chip for its Fitbit Tracker and wireless base station. At the time the company was just twelve months old

2008



Wireless wins tour

Nine out of the top ten riders in road cycling's premier event, the Tour de France, relied on Nordic ANT chips to monitor their performance during the 2009 edition of the race

2009



Affordable RF remote control

Philips chose Nordic 2.4 GHz wireless technology, including the nRF24LU1+, for its Bellagio controller which incorporated a scroll wheel

2010



Boosted battery life

Casio's G-SHOCK watch used Nordic's nRF8001 Bluetooth low energy chip to communicate with smartphones while boasting a battery life of two years

2011



Cycling fun

Pioneer, the Japanese consumer electronics giant, selected Nordic's nRF24AP2 ANT chip for its Potter-Navi bike computer for guiding riders while gathering fitness data

2012



Google support completes picture

Google announced support for Bluetooth 4.0 making it easier for Bluetooth low energy devices to connect with the Android platform

2013



Real time fitness tracking

adidas' FIT SMART fitness tracker eliminated the need for separate sensors to gather data. The company employed nRF51822 SoCs to send information to smartphones

2014



Battery life extended

Nordic's nRF51822 SoC helped Logitech's engineers to extend the battery life of its Ultrathin keyboard for the iPad Air 2 to around two years

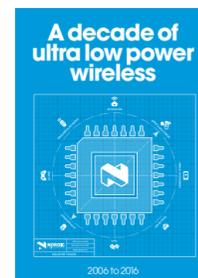
2015



200 cards in one

Maneul Lab's 'The Card' uses Nordic's nRF51822 SoC to power a secure solution, for a range of payment options, that replaces up to 200 cash, membership, and security cards

2016



As Nordic celebrates its success in Bluetooth low energy, a new generation of IoT wireless SoCs is under intensive development

A decade of ultra low power wireless is published on behalf of Nordic Semiconductor by Ecritech

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Building the IoT

Software Development Kits like the nRF5 SDK for Eddystone (beacons) and nRF5 SDK for HomeKit (home automation) simplify application development for the burgeoning IoT sector



Barrier breaking performance

Building on the success of the nRF51 Series architecture, the new nRF52 Series nRF52832 SoC combined an ARM Cortex-M4F processor, enhanced 2.4 GHz radio, 512 kB Flash, and 64 kB RAM to produce the world's most powerful single-chip Bluetooth low energy solution



Over-the-air updates

The Nordic S110 v7.0 SoftDevice, self-contained RF protocol software for the nRF51 Series, was launched. The software was Bluetooth 4.1-compliant and facilitated over-the-air firmware upgrades



Low cost nRF51 series

A low cost 128 kB Flash (instead of the standard product's 256 kB capacity) version of the nRF51822 allowed price-sensitive product makers to enjoy the SoC's powerful wireless capabilities but at lower cost



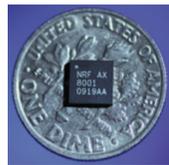
Ultra low power wireless redefined

The launch of the nRF51822 multiprotocol- and nRF51422 ANT-SoCs bring highly-integrated hardware (comprising ARM Cortex-M0 processor, 2.4 GHz radio, Flash, and RAM), and a novel software architecture (separating RF protocol and application code) to ultra low power wireless for the first time



Smart remote

The first nRFReady 2.4 GHz RF Smart Remote reference design simplified the development of advanced RF remotes for consumer appliances



Bluetooth low energy chip first

Nordic introduces one of the first Bluetooth low energy products in the form of the nRF8001 single-mode peripheral chip for watches, sensors, and remote controls



Power consumption slashed

The nRF24AP2 single-channel and eight-channel single chip ANT transceivers set new benchmarks for ultra low power current consumption during RF operation



World's smallest 2.4 GHz SoC introduced

The nRF24LE1, a chip integrating 2.4 GHz radio, 8-bit microcontroller, and Flash memory in a 4 by 4 mm QFN package, was the smallest ULP wireless System-on-Chip at its introduction



Dime-sized USB dongles

The nRF24LU1 was an nRF24L01 transceiver-based single chip solution for a USB dongle, could support up to five wireless desktop peripherals, and ran Nordic's nRF2601 Wireless Desktop Protocol software



CD quality wireless audio

The nRF24ZI stereo audio streamer featured a 4 Mbit/s data rate supporting streaming of audio in 16-bit 48 kHz stereo which was put to use in Asono's DAB radio



Wibree adopted

Nordic fully supported the merger of the Wibree Alliance with the Bluetooth Special Interest Group (SIG) which brought the fledgling interoperable ultra low power technology into the established Bluetooth ecosystem. Nordic immediately became an associate member of the Bluetooth SIG



ANT acquired

GPS equipment maker Garmin's acquisition of Dynastream Innovations, the developer of the ANT wireless protocol, boosted the prospects of Nordic's nRF24AP1 ANT chip



Joining the ANT alliance

Nordic joined the then 70-company strong ANT+ Alliance in a move designed to both strengthen the design partnership with ANT Wireless and enhance support for its ANT chip customers



ULP wireless in health

Nordic joined the Continua Health Alliance, a grouping established to promote specifications and design guidelines for connected health management devices



Bluetooth 4.0 adopted

The Bluetooth Core Specification 4.0, which, for the first time, included Bluetooth low energy as a hallmark feature, is officially adopted by the Bluetooth Special Interest Group



\$29.5m

Record Q1 financials

Nordic reported record financial results with group revenue of \$29.5 million in the quarter, up 182 percent compared to the prior year



ANT chip named networking finalist

The nRF24AP2 was named a finalist in the networking category of the prestigious U.S.-based EDN Innovation Awards



500,000,000

Half a billion ICs shipped

During the Summer of 2011 Nordic shipped its 500 millionth 2.4 GHz ultra low power wireless chip



Elected to the board

Nordic Director Svein-Egil Nielsen was elected to the Board of the Bluetooth Special Interest Group and later become Chair of the organization



nRF51 Series recognized by ANT wireless

Nordic was awarded the ANT+ Premier Developer prize in the 2012 ANT+ Alliance awards for its nRF51 Series SoCs



Nordic sponsors chess great Magnus Carlsen

The company announced sponsorship of the world's greatest ever chess player, Magnus Carlsen. Carlsen was the highest ranking points holder in the history of the game and went on to become world champion



Logitech receives one billionth chip

One of Nordic's longest standing customers, desktop peripherals maker Logitech, was the fitting recipient of the Nordic's one billionth 2.4 GHz ULP wireless chip shipment



Supporting education

Nordic became a partner in the British Broadcasting Corporation's micro:bit initiative. The company's nRF51822 SoC was chosen to power the Bluetooth low energy connectivity and main processing functions of the programmable device destined to end up on the hands of a million schoolchildren



Industry 'Oscar' winner

Nordic won the Global Semiconductor Alliance's coveted Outstanding EMEA Semiconductor Company award. The award was presented in recognition of the company's pioneering work with Bluetooth low energy technology

ULP wireless pioneer's past builds toward an IoT future

After a decade developing Bluetooth low energy technology, three senior Nordic executives tell how the company is using that experience to build its next platform, ultra low power wireless connectivity for the IoT

Bluetooth low energy technology's success looks like it was always assured. But ten years ago no one could be certain if the fledgling technology would catch on. A similar situation is now emerging with the IoT.

"The IoT is a race to win the battle of the Cloud-connected socket," says Svein-Egil Nielsen, the company's CTO. "Wiring is expensive to install and maintain so the sockets will be wireless. Success will depend on how many things a device can connect to and how easily and cost-effectively it can do that. Standards aid both those factors, that's why standards will be fundamental to the IoT.

"But nobody knows which of several wireless standards is going to dominate. Nordic is developing what it thinks will be a game-changing IoT technology based on Bluetooth low energy wireless, but we're not naïve or arrogant enough to think that automatically qualifies us to hit a home run. Sony, for example, thought a technically



Svein-Egil Nielsen,
Nordic's Chief Technology Officer



Thomas Embla Bonnerud,
Nordic's Director of Product Management



Geir Langeland,
Nordic's Director of Sales & Marketing

superior Betamax would win over VHS, but we know how that one played out."

"Nobody really knew if Bluetooth low energy was a viable technology in its early days either," reflects Nielsen, who apart from his senior role with Nordic was also Chair of the Bluetooth SIG from 2011 to 2013. "Before Bluetooth low energy, 'classic' Bluetooth had only proven itself in wireless data transfer between mobile devices, audio, and [less well known] wireless payment

terminals used in retail. There were no guarantees for the low energy version."

However, according to Geir Langeland, Nordic's Director of Sales & Marketing, one thing the company was confident about was that a low energy form of Bluetooth would be based on an ultra low power [ULP] wireless technology similar to that which Nordic had pioneered in the early 2000s. Nordic's technology consumed little power because the radio devices slept for most of the time - waking up very quickly to send data, and returning to sleep as soon as possible. Such techniques allowed the company's technology to operate for months from batteries as small as the coin cells found in watches, while also offering good bandwidth.

"Long experience gave Nordic a technical and commercial edge in the ULP sector," says Langeland. "So we made the decision to promote Bluetooth low energy technology like crazy, while investing heavily in R&D to ensure the products would lead their class. The result of this ambitious program was the first commercial Bluetooth low energy chip in 2010 [nRF8001], intensive developer training, and continuously evangelizing to the world how great Bluetooth low energy was for enabling battery-powered wireless applications that weren't previously viable."

Such an ambitious strategy wasn't easy for a small, relatively unknown Norwegian company with a track record solely in proprietary ULP wireless technology to pull off.

"It did feel like the established Bluetooth technology semiconductor players dismissively laughed at our aspirations to break into the sector," recalls Thomas Embla Bonnerud, Nordic's Director of Product



► Management. “But they’re not laughing now.” “Bluetooth low energy didn’t play out well for the established Bluetooth players,” continues Svein-Egil Nielsen. “For example, Broadcom sold its ULP wireless business and CSR was acquired. These were worthy competitors just two or three years ago, but they couldn’t make their Bluetooth low energy products successful.”

Nielsen believes that Nordic’s success is down to a lack of the large company inflexibility that plagued its competitors. “Big firms were focused on blue-chip accounts; a mistake when much of the activity in ULP wireless technology was in small companies and start-ups. He cites the example of a two-man company that nobody but Nordic took seriously. Today that company is the world’s most successful wearables firm.

A common history

Many industry observers make the mistake of thinking that the Internet of Things (IoT) is a new sector. But Nordic has been connecting ‘things’ to the Internet for well over a decade.

For example, developed with Nordic from 2002, and officially launched in 2004, the nRF2401A-based t6 sportswatch from Finnish company Suunto was the world’s first wearable. It used the ANT RF software protocol developed by Canadian company, Dynastream, that at the time only ran on Nordic chips. The venture was the first of many successful joint design-wins with ANT.

The Suunto sportswatch was also Nordic’s second most significant customer application design win after Logitech—the Swiss-based personal peripherals company—specified Nordic’s ULP proprietary wireless technology into its keyboards and mice in 2003. This was shortly after CEO Svann-Tore Larsen joined the company and made the strategic decision to transform Nordic from a consultancy-based business into a standard components based one specializing in ULP wireless.

“Logitech was the customer that put Nordic Semiconductor on the map,” explains Geir Langeland. “It gave us crucial scale and credibility in our start-up days and supported serious investment in the company and its ULP technology from thereon.”

The partnership with Logitech remains strong to this day with Nordic shipping its billionth ULP wireless chip in December 2014, and that billionth device going to Logitech for use in a commercial product.

The early experience with wireless desktop peripherals was more valuable for building an IoT platform than it might first appear.

“The needs of wireless keyboards and mice talking to a computer dongle, and wireless sportswatches talking to various wireless peripherals are identical to today’s wearables,” explains Thomas Embla Bonnerud. “Wearables have always been a core market for Nordic and continue to be so. All our chips have been designed for wearable applications and no company in the world has more experience of doing this than us.”

The significance of all this, says Bonnerud, is that the Suunto t6, although primitive by

today’s standards, embodied all the basic design elements of the IoT. “The t6 started the IoT race for Nordic,” he says. “As such, the IoT is not new to us, and we have now been working on IoT technology for 15 years.”

More than just great products

Semiconductor development always travels in one direction: greater performance with reduced size and power consumption. Nordic has followed this path with its successive ULP chip generations. But Bonnerud points out that there’s much more to a successful semiconductor company than hardware and software enhancements.

“I always believed the difference between Nordic and its competitors was leadership and the ability to inspire and surprise developers,” he notes.

Bonnerud cites the example of Nordic’s nRF51 Series. Apart from class-leading hardware, the device was the first Bluetooth low energy System-on-Chip to separate the application code from the RF protocol

software (or ‘stack’). This allowed developers with little RF expertise to port their code to the chip using Nordic’s development tools with no risk of corrupting the elegantly-engineered Bluetooth low energy stack.

“Nordic spent millions in R&D dollars to launch the nRF51 Series with its unique separated software and, in addition to many happy customers, we also ensured our competitors had to scrap all their existing product plans, some of which must have been very advanced, and spend millions of dollars over the next several years simply to catch up with what we’d done,” says Bonnerud.

“We extended our leadership with the nRF52 Series, a Bluetooth low energy single-

chip solution that offers such high levels of processing power combined with ultra low power consumption that some customers have specified the chip as the main processor for their product and almost see the Bluetooth low energy technology as a bonus. And that’s not to mention industry-first functionality such as NFC ‘Touch-to-Pair’.”

SoCs like the nRF51 and nRF52 Series, together with design tools and Software Development Kits (SDKs), are already allowing enterprising developers to come up with applications that utilize IPv6 over Bluetooth low energy - thus allowing sensors to connect directly to the Internet without the need of sophisticated and expensive gateways. Such applications are building the foundations of the IoT.

It’s a development not missed by Svein-Egil Nielsen: “ULP wireless and powerful embedded processors will be the main drivers of the IoT,” he says. “But to make the most of the hardware, developers need affordable, easy wireless connectivity that works with

“It did feel like the established Bluetooth technology semiconductor players dismissively laughed at our aspirations to break into the sector. But they’re not laughing now” THOMAS EMBLA BONNERUD Nordic’s Director of Product Management

existing infrastructure and standards, plus design tools that are simple enough not to place limits on creativity and innovation. And we don’t want to add any complications such as making customers sign non-disclosure agreements or go through lengthy registration procedures.”

But the support doesn’t stop there: “I don’t think there’s a ULP wireless semiconductor company in the world that has more ULP wireless engineers than Nordic, and no other company is putting the revenue we’re putting into developing the ‘perfect’ IoT solution,” explains Nielsen.

“Proof of this will come from next year when you can expect to see a ‘tsunami’ of Nordic Bluetooth low energy and IoT products designed to for every major market and to meet every major application.”

Geir Langeland summarizes where all of Nordic’s hard work is heading: “If you want to see how the IoT market will impact the world, the closest parallel right now is the shift to driverless technology in the automotive industry,” he says. “Every major carmaker in the world is hedging their bets, because they know the impact of such a shift would consolidate the car, taxi, and transportation industries into one where anybody can just rent a car when they need it for a fraction of the cost of owning one and with none of the hassle.

“Factor in the possibility of highway speed limits being abolished, traffic jams eliminated, and fatal road traffic accidents slashed, and it’s impossible to see why anyone would want to stop this revolution. The IoT is going to offer very similar disruptive benefits, but across a much broader range of industries.” ■



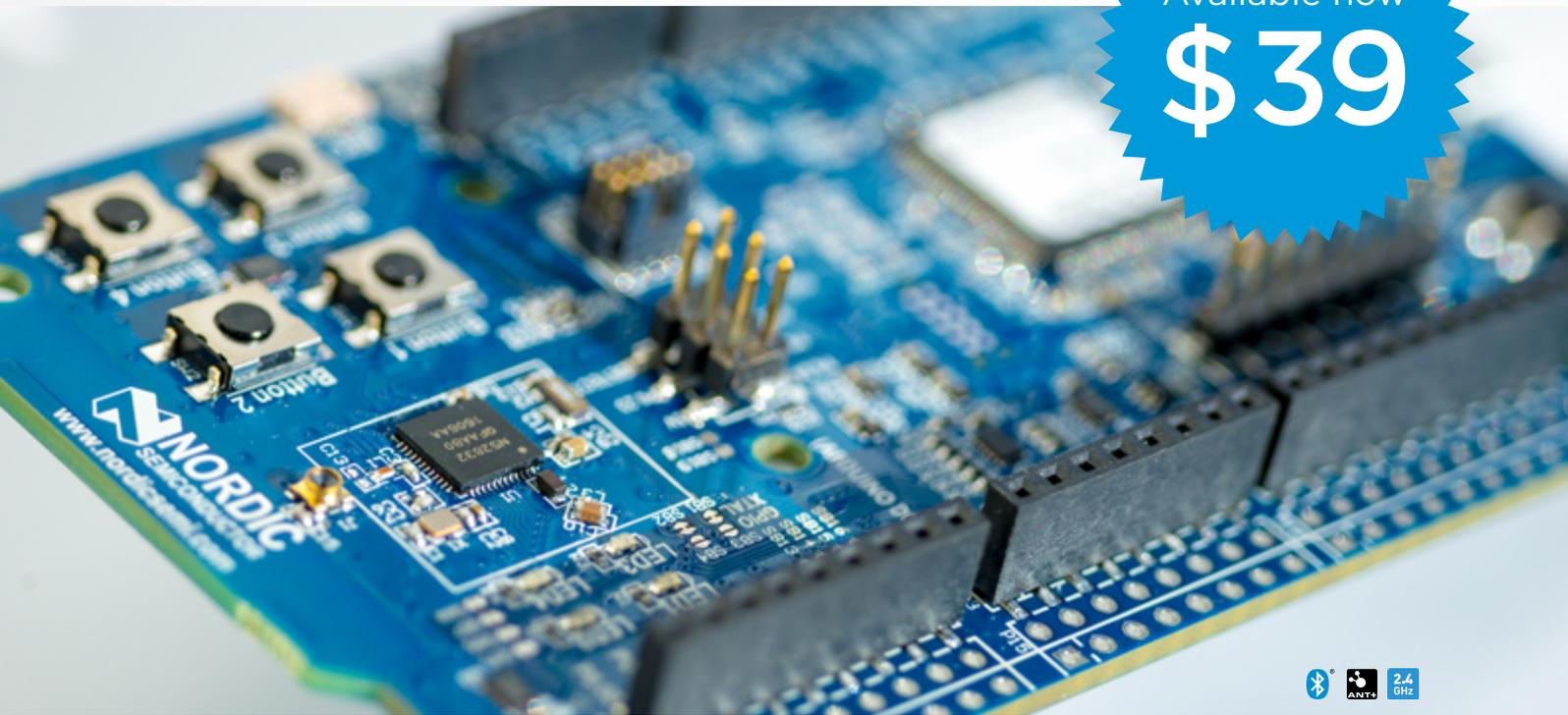
The Nordic-powered Suunto t6 sportswatch was the world’s first wireless fitness wearable

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