

ultra low power wireless

QUARTER 4 | WINTER 2018

COVER STORY

Track everything: Nordic's cellular IoT launched

Bluetooth tech's
final frontier

Building a successful
standard

Wireless transforms
healthcare



NORDIC
SEMICONDUCTOR

OPINION

Peder Rand



Cellular IoT now available for all

That Nordic Semiconductor, together with partner Qorvo, has been working on a cellular IoT module, designed from the ground up to meet the LTE-M and NB-IoT specifications, is no secret. The nRF91 Series multimode [cellular IoT module](#) combines Nordic's nRF91 Series System-in-Package (SiP) with Qorvo's custom RF front-end solution and advanced packaging technology. (See *this issue* pg8.) Details of the module were revealed in Nordic's "sneak peek" back in January this year and the engineering behind the product, plus likely early applications, have been discussed here and elsewhere in the months since.

But what has remained under wraps is the work Nordic has been doing with customers to make sure that upon launch, the nRF91 Series meets all the promises the company has made for it. I can't reveal exactly how many external concerns have worked with pre-production samples of the nRF91 Series, but I can say it's a representative sample of the kind of companies—large and small—that have been crying out for this kind of product.

Nordic's strategy for cellular IoT is exactly the same as that which has seen it become a leader in Bluetooth Low Energy (Bluetooth LE). We don't want our customers to be intimidated or constrained by complex RF hardware and software engineering, instead we want to make it easy for them to rapidly realize their Internet of Things (IoT) application ideas by abstracting away complexity via easy-to-use development tools.

In my role as Nordic's Product Manager for Cellular IoT, I have the pleasure of informing *ULP Wireless Q* readers that the nRF9160 SiP—the first member of Nordic's nRF91 Series—is now available for everyone from sole innovators through modest start-ups to huge global electronics firms. The modules and development tools are now in stock at Nordic's distributors across the world.

This is an important moment in Nordic's history and I'm just one small part of the team that has worked incredibly hard over the last four years to bring the nRF91 Series to this point. From the company's management team and highly talented cellular and low power [wireless experts in Finland](#) and Norway, through to all the support staff, every single person at Nordic has worked tirelessly to ensure the company reached the commercial launch deadline.

Combining the complexity of cellular engineering, a new generation of powerful CPUs, and the nuances of low power consumption in a highly-integrated, compact module with an outstanding price/performance ratio is no mean feat. It's one that would stretch the resources of a giant global chip maker, let alone a small Norwegian firm that originally carved its niche by pioneering coin-cell powered wireless technology. And it's an achievement we're proud of.

But while we're pleased with what we've achieved so far, the true test will be how the product fares in a highly competitive market. Cellular IoT has a promising future and the work Nordic has done so far with customers has given us a high level of confidence that the nRF91 Series is the right product at the right time. I look forward to 2019 with a sense of excitement about how things will proceed from here.

Yours Sincerely,

Peder Rand
Product Manager - Cellular IoT

Contributors



Karl Helmer Torvmark is Technical Product Manager at Nordic Semiconductor. On page 9 he takes a closer look at what is required to make a standard successful



Svein-Egil Nielsen is CTO at Nordic Semiconductor. On page 11 he examines how edge computing will prove invaluable for IoT devices in the future



John Leonard is Tactical Marketing Manager at Nordic Semiconductor. On page 18 he explains how to get started developing a solution using Bluetooth mesh



ESA is using satellites to relay Bluetooth Low Energy signals to Earthbound beacons

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NEWS

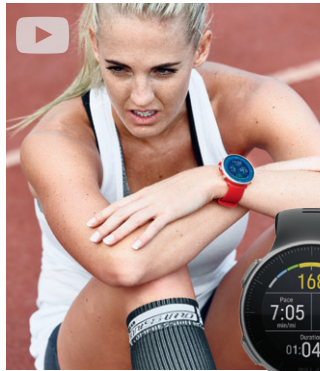
The latest developments from Nordic Semiconductor

Polar GPS multisport watch improves performance across 130 sports

Finland-based wearable pioneer, Polar, has released its 'Vantage V' and 'Vantage M' multisport watches, designed to improve athletic performance across more than 130 different sport profiles.

The waterproof watches feature an 'always-on' 240 by 240-pixel color touchscreen display, GPS tracking, and Polar 'Precision Prime' heart rate technology. Precision Prime employs a 3D accelerometer, electrodes to measure sensor-skin contact, and nine optical LEDs that deploy two wavelengths of light to measure heart-rate data from blood vessels in different skin layers.

According to Polar this sensor fusion technology and its proprietary algorithm provide highly accurate and reliable wrist-based heart-rate readings.



The Polar watches monitor cardiovascular load, muscular load, and perceived load

The Polar Vantage V also offers a barometric altitude sensor.

Both watches feature Polar's Training Load Pro technology. This combines cardiovascular load, muscular load, and an athlete's perception of the

training effort to measure the balance between strain and tolerance helping individuals recognize their personal limits. The technology also informs the user of over- or under-training.

The Polar Vantage V also offers 'Recovery Pro' which offers personalized training guidance based on analysis of heart rate variability (HRV) orthostatic results to help recovery and avoid injury, as well as calculating running power without the need for external sensors.

Using Bluetooth Low Energy connectivity provided by Nordic's nRF52832 System-on-Chip (SoC), this data is synced to the user's smartphone, where they can view detailed training statistics via the iOS- and Android-compatible Polar Flow app.

In brief

Nordic posts record Q3 revenue

Nordic Semiconductor has reported all-time high record revenue of \$78.7 million during Q3 2018. The result represents year-on-year growth of 19.9 percent. Sales of Bluetooth Low Energy solutions contributed \$54.3 million (69 percent of total revenue). Year-on-year growth in both the consumer electronics and healthcare sectors was particularly strong. Nordic's proprietary chips also posted solid returns, delivering 35.5 percent growth over Q3 2017.

Cellular IoT to boom by 2025

Global IoT cellular connections are expected to hit the 5 billion mark by 2025 and China will continue to lead by contributing nearly two-thirds, according to analyst, Counterpoint Research. The research notes that global IoT cellular connections grew 72 percent in the first half of 2018, which the research firm described as "a considerable increase" as compared to the same period last year. China is the world's largest cellular IoT market, accounting for 70 percent of the global total.

BBC: microbit reaches milestone

The Micro:bit Educational Foundation has announced the manufacture and distribution of the 2 millionth BBC micro:bit, the highly popular Nordic-powered programmable computer. The device is now available in over 50 countries, with national projects in Canada, Croatia, Denmark, Hong Kong, Iceland, Uruguay, and Singapore under way. The BBC micro:bit is a pocket-sized computer developed to help young people get creative with technology, whatever their level of programming experience.

IoT gateway and dongle aid development of commercial mesh networking

Fanstel Corp has unveiled an IoT gateway and dongle enabling OEMs to rapidly develop RF solutions for commercial mesh networking applications.

The Scottsdale, AZ-based module manufacturer has developed the 'BWG840F' gateway and 'USB840F' dongle to provide long-range mesh wireless connectivity for IoT Cloud service providers and enterprises employing Cloud servers. The products enable rapid commission and deployment of Internet of Things (IoT) devices in commercial mesh networks via Bluetooth Low Energy (Bluetooth LE) and Thread.

The gateway and dongle employ Fanstel's 'Bluenor



Rapidly developing multiprotocol low power RF solutions for commercial mesh networking applications is easier than ever

BT840F' module for ultra low power and long range IoT applications. The module is based on Nordic's Bluetooth 5 and Thread-compliant nRF52840 System-on-Chip (SoC), enabling multiprotocol wireless connectivity between the gateway or dongle and Bluetooth LE or Thread nodes in a mesh network.

To support rapid development of IoT mesh networking solutions based on the gateway, Fanstel provides the 'DK-BWG840F'

development kit. The kit allows users to load firmware into the BT840F module using Nordic's nRF5 Software Development Kit (SDK) and nRFgo software tools.

The BWG840F gateway's Wi-Fi module provides Internet connectivity, enabling a mesh network to be remotely controlled. Alternatively, the USB840F dongle plugs into a PC's USB port and relays data to any node in the mesh network.

In brief

Sensor innovation fosters IoT growth

New research from analyst Gartner has highlighted the top strategic Internet of Things (IoT) technology trends it says will drive digital business innovation from 2018 to 2023. According to the research, sensor innovation will evolve continuously in the next five years, enabling a wider range of situations and events to be detected, while current sensor solutions will fall in price to become more affordable, or packaged in new ways to support new applications. The report said new algorithms will also emerge to deduce more information from existing sensor technologies.

Beacons help U.S. shoppers find way

The largest shopping mall in North America is leveraging the power of Bluetooth Low Energy beacons to improve customer navigation and guest experience. The Mall of America in Bloomington, MN, encompasses 520 stores on five levels and welcomes more than 40 million visitors each year. After having trouble implementing a Wi-Fi indoor navigation solution, it turned to Bluetooth LE-enabled beacons. In the future it also hopes to take advantage of Bluetooth's asset tracking capabilities to monitor the location of key equipment, or assets in need of maintenance.

Wearables market undergoes change

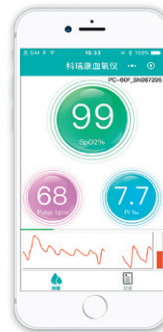
Growth in the sales of wearables continued in Q2 2018, increasing 8.3 percent year-on-year to a total of \$4.8 billion, analyst International Data Corporation has revealed. However, some mature markets in North America and Western Europe saw a decline during the period, it said. "The decline in mature markets is by no means worrisome as these markets are in the midst of transitioning to more sophisticated wearables," IDC said. "While the previous generation of wearables was focused on providing feedback like step counts, upcoming generations are more capable."

Pulse oximeter delivers non-invasive measurement of oxygen saturation

China-based Creative Medical has launched its 'PC-60F' Bluetooth Low Energy (Bluetooth LE) fingertip pulse oximeter for use in hospitals, clinics, and the home. The product uses proprietary algorithms and non-invasive optics to accurately measure an individual's current oxygen saturation (SpO₂), pulse rate (PR), and perfusion index (PI).

SpO₂ is an important physiological parameter reflecting respiration and ventilation function, while PI is a measure of blood flow through the small vessels of the body's extremities. Together the measurements provide medical practitioners with key insights into the health status of patients.

Nordic's nRF52810 System-on-Chip (SoC) acts as the fingertip oximeter's core microcontroller. The SoC's powerful 64MHz, 32-bit Arm Cortex M4 processor enables SpO₂ signal acquisition and algorithm operation, OLED



The PC-60F fingertip pulse oximeter is designed for use in hospitals, clinics, and the home

display operation, and Bluetooth LE wireless connectivity to an individual's Bluetooth 4.0 (and later) smartphone or tablet.

Creative Medical's iOS- and Android-compatible partner app, '@Health', immediately displays the SpO₂, PR value, and other key health metrics, and allows the user to store and manage data.

The fingertip oximeter employs two AAA alkaline batteries to support up to 36 hours of continuous working, thanks in part to the low power

characteristics of the Nordic SoC, as well as the ability for the device to automatically power on or off when a patient's finger is inserted or removed.

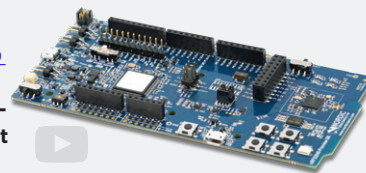
"We selected the nRF52810 SoC for its competitive cost, low power consumption, and high overall performance," says Han Haiyang, a Director at Creative Medical. "The Nordic SoC's powerful CPU capability and Flash memory and RAM resources also allow us to run the SpO₂ arithmetic effectively."

Nordic announces nRF52840 SoC support for Bluetooth LE with Amazon FreeRTOS

Nordic Semiconductor has announced that the nRF52840 multiprotocol Bluetooth Low Energy (Bluetooth LE) System-on-Chip (SoC) is one of the first devices to support Bluetooth LE with Amazon 'FreeRTOS'.

Amazon FreeRTOS is a real time operating system (RTOS) for microcontrollers that makes small, low-power edge devices easy to program, deploy, secure, connect, and manage. The RTOS is based on the FreeRTOS kernel, a popular open-source operating system for microcontrollers, and extends it with software libraries that make it easier to securely connect low-power devices to AWS Cloud services like 'AWS Internet of Things (IoT) Core' or to more powerful edge devices running 'AWS IoT Greengrass'.

"We are delighted to work



The nRF52840 SoC is one of the first chips to support Bluetooth LE with Amazon FreeRTOS

with Nordic Semiconductor," says Dirk Didascalou, Vice President, AWS IoT, Amazon Web Services, Inc. "By allowing Amazon FreeRTOS applications to communicate over Bluetooth LE, we are making it easy for our customers to securely connect their Bluetooth LE devices to AWS IoT via a mobile device. [They can then] build innovative, low power applications including analyzing sensor data, and monitoring and managing fleets of devices."

"We are pleased to see AWS add Bluetooth LE support to Amazon FreeRTOS and name the nRF52840 as one of the first chips to officially support it," says Nordic Semiconductor CTO, Svein-Egil Nielsen.

"As many customers' *de facto*, ultra low power IoT connectivity chip of choice, offering a wide breadth of connectivity options with outstanding energy efficiency, the nRF52840 is an excellent complement to, and expands, the solution and product application range possible with Amazon FreeRTOS."

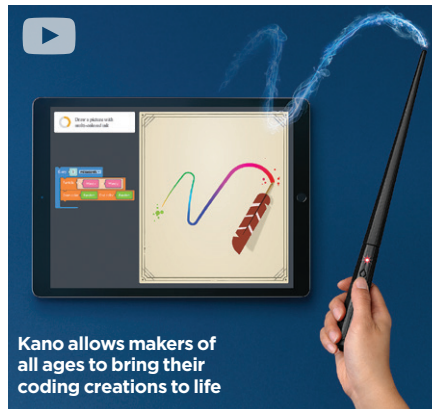
The Beta release of the RTOS includes a GATT/GAP API, a custom profile for provisioning Wi-Fi over Bluetooth LE, and companion iOS and Android software development kits.

Do-it-yourself Harry Potter coding kit teaches programming skills to all ages

A U.K.-based educational technology company, Kano, has released the 'Harry Potter Kano Coding Kit', a Bluetooth Low Energy (Bluetooth LE) do-it-yourself (DIY) wand that helps people of all ages learn how to code.

The coding kit includes a multi-platform Kano app that lets makers follow 70 step-by-step coding challenges using intuitive coding 'blocks' and a JavaScript inspector. Once the wand is paired with a Bluetooth 4.0 (and later) tablet, laptop, or desktop computer, users can bring their coding creations to life.

The wand employs a nine-degrees-of-freedom (9DoF) inertial measurement unit (IMU)—including a three-axis accelerometer, three-axis gyroscope, and three-axis magnetometer—that tracks the wand's



movement, speed, and direction of use, as well as a Nordic [nRF52832](#) System-on-Chip (SoC). The SoC's powerful Arm Cortex M4F

processor manages the raw sensor data and, using Bluetooth LE wireless connectivity, relays the data to the user's device.

From the Kano app hosted on the device, users can see their wand movements brought to life on-screen, for example, moving floating feathers, growing pumpkins, or throwing flames.

"A positive user experience of the Harry Potter Kano Coding Kit relies on the ability to achieve a 'first time, every time' connection between the hardware and the Kano App," explains Ricardo Luz, Senior Technical Product Manager at Kano.

"We wanted to bypass a complex initial set-up, and thanks to Nordic's SoftDevice we were able to implement a seamless and rapid connection between the kit's hardware and the app."

Wireless barriers control access to parking spots

A German smart systems developer is piloting a smart parking barrier solution in the city of Bad Homburg that protects parking spaces and charging stations designated for use by electric vehicles (EVs). Makaio's 'Parketeer' barriers incorporate a Nordic [nRF52832](#) System-on-Chip (SoC) providing Bluetooth Low Energy (Bluetooth LE) wireless connectivity between the EV driver's Bluetooth 4.0 (and later) smartphone, as well as between adjacent barriers and a Nordic [nRF51822](#) SoC-based Laird 'RM186-SM'-powered gateway.

The barrier-to-barrier connectivity allows a barrier that is in Bluetooth LE range of the driver's smartphone to instruct an out-of-range barrier to open if the space it protects is the driver's preference. The gateway relays parking spot availability data to and from the Cloud via LoRaWAN technology.

In operation, when a driver needs to



The smart parking barriers are being trialed in the German city of Bad Homburg

locate a parking spot and/or charging station, they can use the 'Parketeer Bad Homburg' iOS and Android smartphone app to locate and reserve a parking spot to ensure its availability when they reach their destination. When the parking spot is reserved, the request is sent via the Cloud to the gateway, preventing that parking spot being accessed by another user.

As the user approaches the parking spot,

they connect to the barrier via the app and the barrier is lowered enabling access. The barrier in turn relays this data to the gateway, which updates parking spot availability for other users.

When the driver returns to their vehicle and exits the parking space, they press 'stop parking' in the app, the barrier is raised, and the customer's account is billed.

AI advancements boost smart toys

Advancements in artificial intelligence (AI), urban populations, and increasing awareness of technology is set to drive significant growth in the smart toy market, research analyst Zion Market Research claims. The company said the global smart toy market was valued at \$3.87 billion in 2017, but could grow to as much as \$5.41 billion by 2024, with emerging countries such as India and China key in driving the sector's development. However, unsecured connectivity and privacy issues may hamper overall growth the research noted.

Bluetooth LE smart textiles on the rise

According to a new report by research analyst, MarketResearch.Biz, the integration of Bluetooth Low Energy technology into smart textiles is set to provide the sector with significant growth prospects in the next 10 years. It said smart textiles involving this technology could monitor and validate various physiological data such as temperature, heart rate, and blood pressure, and would drive growth particularly in military and defense applications, where smart fabrics could, for instance, change color to produce camouflage effects for protection.

In brief

Gateway and sensors deliver remotely operable home automation

▶ AXAET, a China-based Internet of Things (IoT) solutions company, has released the 'ETMars' smart-home automation ecosystem, designed to provide a connected, remotely-operable home-automation network.

The system comprises a gateway and a range of peripheral sensors to monitor and detect smoke, gas, and water ingress, as well as provide home security, and remotely-control appliances and lighting in the home.

The gateway employs Nordic's [nRF52832](#) System-on-Chip (SoC) to provide wireless connectivity between the gateway and the sensors, as well as the user's Bluetooth 4.0 (and later) smartphone or tablet when they are at home.

The gateway can control up to 20 peripheral sensors simultaneously, thanks to the nRF52832 SoC's ability to support multiple concurrent connections. Each sensor employs Nordic's [nRF52810](#) SoC to enable



The ETMars app allows the user to define individual scenarios or modes—such as 'home mode' or 'away from home mode'—and also offers 'scene linkage', allowing the user to define linked triggers and execution conditions for multiple scenarios.

For example, at night the user could request that once the bedroom lights are dimmed, the curtains close automatically and the security sensors in other parts of the home be activated.

"AXAET selected the nRF52832 SoC for the gateway for its large memory allocation, radio sensitivity, and specifically because of its ability to connect to 20 devices simultaneously," says Mr. Jacky, AXAET Manager.

"The software architecture was key, it enables developers to implement applications directly without having to consider complex protocol logic.

"Such an architecture brings great convenience to application development."

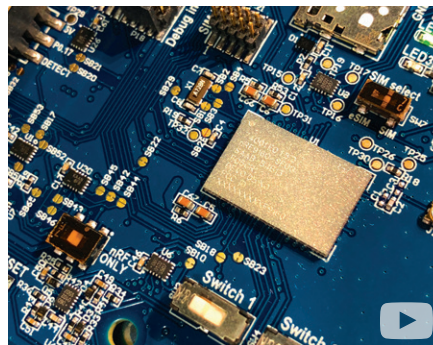
Bluetooth LE communication with the gateway. If the user is away from home, the gateway allows remote monitoring and control of the sensors from the ETMars iOS or Android app on their mobile device via the Cloud.

Nordic nRF91 Series is successfully demonstrated on public cellular network

Nordic Semiconductor has successfully demonstrated its [nRF9160](#) multimode LTE-M/NB-IoT System-in-Package (SiP) module operating in both LTE Cat M1 (LTE-M) and Narrowband IoT (NB-IoT) modes on Telenor Norway's public cellular network.

The nRF9160 SiP connected to Telenor's Norway-wide cellular IoT network which was switched on for the first time at the Nordic Edge Expo, a three-day 'smart city' exhibition and conference held in late September in Stavanger. The new network is the first in Scandinavia to offer commercial support for LTE-M and NB-IoT, a crucial step in the progress of widespread deployment of cellular IoT as a low power wireless area network (LPWAN) technology.

"The nRF91 Series has been extensively tested by Nordic and leading customers for months, but this is the first opportunity we've had to openly demonstrate the



Nordic has successfully demonstrated the nRF9160 SiP on a public network for the first time

product communicating via a commercial network that supports both LTE-M and NB-IoT," says Peder Rand, Product Manager for Cellular IoT, Nordic Semiconductor. "Telenor envisages a sharp ramp-up over

the coming years towards truly massive IoT based on the cellular technologies of LTE-M and NB-IoT," says Ove Fredheim, Head of the Business Market in Telenor Norway/CMO Business. "These devices will enable the world's innovators to build products that will make large scale IoT and smart cities a reality."

Meanwhile, the nRF9160 SiP was also recently named a 2019 CES Innovation Awards Honoree in the 'Embedded Products' category of the CES 2019 Innovation Awards.

A panel of judges, including designers, engineers, and members of the technical media, reviewed submissions based on design, functionality, consumer appeal, engineering, and how the products compare with their competition, before arriving at the decision to honor Nordic's cellular IoT solution.

ULP WIRELESS TRENDS

The latest developments in technology



The future of pacemakers is wireless

Doctors implant and program pacemaker using Bluetooth LE technology

Doctors in the U.K. are among the first in the world to implant and program a pacemaker using Bluetooth Low Energy (Bluetooth LE) technology.

Dr John Paisey, a consultant cardiologist at University Hospital Southampton (UHS) NHS Foundation Trust, performed four of the first five procedures in the world at Southampton General Hospital. After implanting a new longer-life pacemaker known as Azure, doctors then used a lightweight and portable iPad-controlled system known as SmartSync to program the cardiac leads.

The Azure pacemaker is fitted with 'BlueSync', a Bluetooth LE device developed by Medtronic which not only automatically connects the device wirelessly to the programming system, but also to an app on a patient's smartphone to monitor their heart health. It is the first time a pacemaker has been fitted, programmed, and then been able to transmit data immediately to a smartphone app using Bluetooth LE.

"This is extremely exciting technology which enables us to co-ordinate everything from the implantation of a pacemaker and its initial programming through to ongoing real-time monitoring via a smartphone all by [Bluetooth LE]," says Dr Paisey. "It is another major development in using technology to improve efficiency, reliability, and accuracy, and ensure patients can transmit their data consistently and seamlessly through an app - it is the definition of technological innovation in healthcare."

In 2014, doctors at UHS implanted the world's smallest pacemaker, known as the Micra Transcatheter Pacing System, which is one-tenth the size of traditional models and is placed directly in the heart.

The ARMY Bombs can be wirelessly controlled to create stunning visual effects



Wireless lightsticks take center stage

Bluetooth Low Energy (Bluetooth LE) lightsticks are proving a hugely popular addition to Korean pop ('K-pop') concerts, sending synchronized pulsing patterns of light—called 'oceans'—across vast stadiums and arenas.

One of the biggest names in K-pop, Korean boy band, BTS, have long been superstars in Korea, Japan, and China, but in the past few years have played concerts in 32 cities across 16 countries reaching number one on the U.S. charts. The band's adoring fans are known as the 'ARMY', an acronym for Adorable Representative MC for Youth.

Any self-respecting ARMY member is the owner of an 'ARMY Bomb', a Bluetooth LE wirelessly connected glowing lightstick that can be purchased in advance of a concert, enabling every fan to directly play a part in the choreographed light show.

Once the ARMY Bomb has been paired with the user's smartphone, they enter the seat number they will be sitting in at the concert, and register via an app. At the concert the lightstick is set to concert mode, and can then be wirelessly controlled to twinkle on and off, create intricate light patterns, or spell out a message across a crowd of 45,000 fans.

Bluetooth LE-controlled cyborg cockroaches on a mission

A tiny neuro-controller created by researchers at the University of Connecticut (UConn) could provide more precise control of futuristic biobots, such as cyborg cockroaches that are already being tested for use in search-and-rescue missions inside collapsed buildings.

The neuro-controller microcircuit developed at UConn is part of a tiny electronic 'backpack' that can be attached to the insect with its wires connected to the insect's antennae lobes. By sending slight electrical charges to neural tissue in either the insect's left or right antenna lobe,



Cockroaches may one day have an important role to play in search and rescue

operators can trick the insect into thinking it has detected an obstacle, causing it to move in another direction.

The controller's value comes in the form of an advanced 9-axis inertial measurement unit

inside the UConn device that tracks an insect's linear and rotational acceleration, identifies its compass heading, and detects the ambient temperature surrounding the creature.

The information gathered by the microcircuit is transmitted to the operator's smartphone via Bluetooth Low Energy (Bluetooth LE) technology. As the insect's heading, acceleration, and other data comes in, operators can extrapolate the insect's trajectory, adjust the antennae stimuli accordingly, send the appropriate electrical impulses to the insect remotely, and steer it in a desired direction.

Nordic nRF91 Series roll-out brings cellular IoT to any application

From asset tracking to medical monitoring, Nordic's easy-to-design-in cellular IoT delivers a compact, low power, secure LTE-M and NB-IoT module for everything

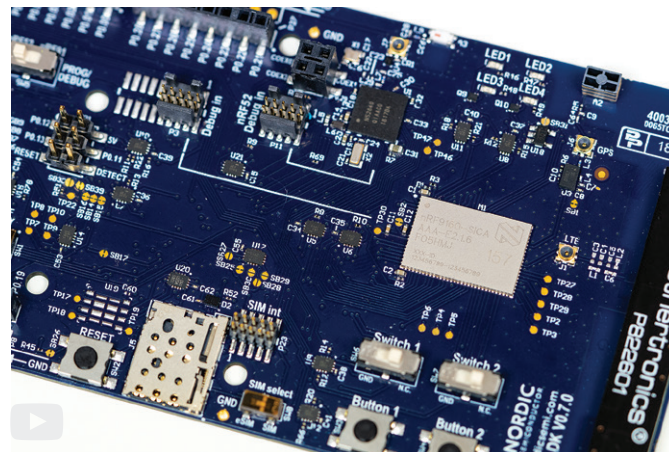
There are 20 million shipping containers in the world and six million are on the move at any time. Each holds around 40m³ of valuable cargo. Keeping track of where everything is and how it's being handled is a logistical nightmare; but Nordic's nRF91 Series promises to sweep away the complexities of asset tracking and do the same for thousands of other monitoring challenges.

Nordic Semiconductor is best known for its commercial and technical leadership in Bluetooth Low Energy. But now, the commercial launch and immediate availability—from key distributors such as Digi-Key Electronics, Mouser Electronics, and Premier Farnell—of the nRF9160 System-in-Package (SiP) extends the company's wireless Internet of Things (IoT) offering to the low power cellular IoT sector.

Cellular IoT is a low power wireless area network (LPWAN) technology that takes advantage of the mature and established global cellular network. Cellular LPWANs form robust, long-range connections between local area networks (LANs) of short-range wireless sensors and the Internet - forming key element of the IoT. (See ULP WQ Spring 2018 pg10.)

"Nordic Semiconductor expanded the application-range of Bluetooth Low Energy by abstracting away from the designer all unnecessary technical complexity," explains Peder Rand, Nordic Semiconductor's Product Manager - Cellular IoT. "The nRF9160 SiP module promises to do the same for cellular IoT by taking a completely different approach to competing solutions."

Cellular is a notoriously complex wireless technology that only a handful of engineering teams worldwide have the expertise and experience to design from the ground-up. Nordic



At just 10 by 16 by 1 mm, the nRF9160 SiP (right of center) integrates everything a cellular connection and IoT application may need

"The nRF9160 SiP offers the developer a different design approach to competing units"

Semiconductor's team came together when the company hired some of the smartest cellular R&D engineers in the world. (See ULP WQ Summer 2018 pg14.) Most of Nordic's cellular IoT design team have been working in cellular for their entire careers and have used that expertise to design the nRF9160 from the ground-up.

Strategic partnership

At just 10 by 16 by 1 mm, the nRF9160 SiP is suitable for even the most compact devices. Yet the product is a complete solution that integrates everything a cellular connection and IoT application needs (apart from battery, SIM, and antenna).

The nRF9160 SiP is GCF certified—the industry 'quality mark' for compliance to the 3GPP LTE specification—along with U.S. FCC and European CE

certifications. Such certifications denote approval for deployment on cellular networks and cellular IoT applications around the world.

Nordic partnered with RF specialist, Qorvo, to design and fabricate a SiP that more closely resembles an integrated chip (IC) than a module. The nRF9160 SiP employs Qorvo's proven RF front-end, advanced packaging, and MicroShield technology to deliver a compact solution that combines high performance with low power consumption.

"[We are] excited to see our leading RF and advanced packaging technology playing a key and enabling part of new products targeting the emerging low power cellular IoT market," says Eric Creviston, President Mobile Products at Qorvo.

The nRF9160 SiP supports global operation with a single SiP thanks to the combination of Nordic's multimode LTE-M/NB-IoT modem, SAW-less transceiver, and Qorvo's custom RF front-end. The SiP features integrated GPS support to allow a combination of GPS and cellular for more accurate positioning than either alone. The product is the first cellular

IoT module to incorporate Arm's latest Cortex M-33 microprocessor core at its heart. The microprocessor is supported by 1 MB of Flash and 256 kB of RAM. The nRF9160 SiP is also the first module to incorporate Arm's TrustZone and CryptoCell security for Internet-level encryption and application protection. Both these technologies are designed for efficient embedded IoT products that require the highest levels of performance in processing, power consumption, and security.

"Security is paramount to any IoT application," explains John Leonard, Tactical Marketing Manager at Nordic. "By incorporating Arm TrustZone, the nRF9160 SiP features both trusted and non-trusted execution zones. Critical aspects such as cryptographic elements and key storage reside in trusted areas which can't be accessed by outsiders. Together with the CryptoCell security, TrustZone ensures the nRF9160 is the cellular IoT device with the most advanced security available."

The nRF9160 SiP is supported by a development kit (DK), SiP module samples, LTE-M firmware, and a software DK with application examples for Cloud connectivity. This includes Nordic's [nRF Connect for Cloud](#) and nRF Connect for Desktop PC-based tool, plus support for Segger Embedded Studio. (See ULP WQ Spring 2018 pg18.)

The tools are designed to accelerate development of sensor-to-Cloud IoT applications including asset tracking, utility metering, industrial connectivity and predictive maintenance, smart city and infrastructure, agrotech, and medical.

The nRF9160 SiP module is available now. NB-IoT and GPS functionality is in limited sampling and will be available for evaluation during Q1 2019. ■

What makes a standard successful?

Just because a wireless technology becomes a standard doesn't guarantee mass adoption. An established ecosystem is vital too, says Karl Helmer Torvmark



Karl Helmer Torvmark is a Technical Product Manager with Nordic Semiconductor

Standards are great and there are so many to choose from! While this statement appears to ring true, closer inspection reveals very few standards reach ubiquity. Some are successful in one or two markets; for example, the Musical Instrument Digital Interface (MIDI) standard—a clever and long-lived technology which allows musical devices that make and control sound to communicate with each other—has remained dedicated to serving a narrow sector since it was first introduced in 1983.

In contrast, standards aiming for true ubiquity must aim for adoption in hundreds of millions (if not billions) of devices. Examples of wired- and wireless-communication standards that have achieved mass adoption include USB, Ethernet (actually, the twisted-pair-based successor to the original coax-based Ethernet), Wi-Fi, and Bluetooth technology. Cellular is another.

Strictly speaking, cellular communications are not governed by a single standard. But from a disjointed start comprising multiple analog implementations through the transitory situation of competing GSM and CDMA standards, we do now have a refined selection of global cellular standards. (Although non-harmonized global spectrum allocations mean engineers must still contend with multiple frequency bands.) GSM turned into EDGE which turned into 3G which morphed into 4G or Long Term Evolution (LTE). And now 5G is the new hot technology.

Is 5G making 4G obsolete? No, because as the LTE name hints, there is a lot of “long term” evolution of 4G still to come. Wi-Fi has come a long way from its humble one-megabit-



“Many standards have failed because they’re too fiddly for the end-user to set-up”

per-second IEEE 802.11-1997 beginnings to the current seven-gigabit-per-second 802.11ad manifestation. And Bluetooth technology has evolved from its early serial-port or wireless-headset focus to spawn the current Low Energy version. This version has cemented its status as the Internet of Things’ (IoT) lingua franca, allowing wireless sensors to communicate with smartphones, tablets, and PCs.

Ecosystem importance

Nine out of 10 start-ups fail, and the same is true of standards. What determines which standards succeed and which fail? Many factors come into play; technical merit, market timing, openness, industry participation, sometimes just luck. But building on an existing ecosystem is perhaps the key contributor to success.

It’s hard to both launch a standard and build a supporting ecosystem from scratch. Even a company with the resources of Intel was reportedly close to giving up on promoting USB before it finally got traction in peripherals after the firm ‘seeded’ the market by supporting the technology in PCs for several years.

Of the other successes, Wi-Fi built on the successful wired Ethernet standard to create “wireless Ethernet”. And Bluetooth Low Energy (Bluetooth LE) started out as the Nokia-sponsored Wibree before merging with the Bluetooth SIG to ensure interoperability with billions of smartphones.

NarrowBand IoT (NB-IoT) and LTE Cat-M1 (LTE-M)—the low power, low bandwidth modem specifications introduced in Release 13 of the 3GPP telecoms alliance’s LTE standard—build on the established cellular ecosystem. With an NB-IoT or LTE-M modem, just a base-station software upgrade enables a battery-powered device to connect to the Cloud from anywhere that has cellular coverage.

In addition to an established ecosystem, adoption of a standard relies on ease of use. Consumers are not generally engineers and demand that their technology “just works”. Many standards have failed because they’re too fiddly for the end-user.

Bluetooth LE is one example where configuration can be made simple. By using Near Field Communication (NFC) to automatically instigate pairing when a Bluetooth LE device and a smartphone are touched together, the technology has eliminated all complexity.

Cellular technology still has some way to go to match Bluetooth LE’s simplicity. Today’s physical SIM cards are a hassle and could stall the introduction of NB-IoT and LTE-M modems. But tomorrow’s eSIMs will automate the modem-commissioning process and make it simple to add a new device to the cellular network.

Such simplicity will multiply the new mobile specifications’ chances of making it as the next big thing in wireless communications. ■

Hybrid connectivity solutions expand IoT boundaries

More companies can now reliably connect to the Cloud thanks to emerging solutions combining Bluetooth Low Energy and LPWANs

To eventually connect billions or even tens of billions of devices to the Internet around the world, Internet of Things (IoT) connectivity solutions will need to deliver on a scale far beyond anything yet seen. To do that requires a technology which bridges the gap between short-range Bluetooth Low Energy (Bluetooth LE), Thread or Zigbee sensor networks, and the Cloud. A Wi-Fi Local Area Network (LAN) affords one solution for fixed installations in offices and buildings but is impractical when sensors are constantly moving or are remotely located.

Low power wide area networks (LPWANs) based on kilometer-plus range, low power consumption RF technology provide an answer. Restricted throughput is the obvious trade-off, but this is not a problem when dealing with the modest data volumes gathered by sensor networks. Working together, the short- and long-range ultra-low-power capabilities of Bluetooth LE and LPWAN technologies open the door to IoT networks for markets including smart cities, smart agriculture, building management, electric metering, and asset tracking.

Projections for LPWAN deployments cover a wide range. For example, IoT Analytics, a provider of IoT market insights, expects there to be more than 1.1 billion LPWAN connections by 2023 following compound annual growth rate of 109 percent over a five-year period. At the other end of the scale, new research by Statista projects that in 2021, approximately 3.44 billion devices worldwide will be connected via LPWAN, compared to 687.4 million in 2016 and just under 1.34 billion in 2018. While



Bluetooth LE and LPWAN technologies open the door to IoT networks that can deliver asset tracking solutions on an unprecedented scale

the numbers are different, the conclusion is the same: LPWANs are among the fastest growing IoT connectivity technologies.

Meanwhile, global demand for Bluetooth LE continues to soar on the back of the IoT market. According to the Bluetooth SIG's *Bluetooth Market Update 2018*, around 5.2 billion Bluetooth chips (of which 97 percent will include LE technology) will be shipped in 2022, up from 3.6 billion in 2017. Given the link between Bluetooth LE and LPWAN will be critical across numerous sectors, these two technologies are likely to develop into a booming market for hybrid Bluetooth LE/LPWAN modules in just a few years.

Modules enter the market

Hybrid modules are already reaching commercialization. One module has been developed by Japan-based company [Braveridge](#). The company's module is a ready-made solution enabling an engineer to build-in

“The growth of LPWANs are likely to stimulate a booming market for hybrid Bluetooth LE/cellular IoT modules in the next few years”

Bluetooth LE and proprietary LPWAN technology into a product, enabling long-range wireless connectivity between Bluetooth LE devices and the Cloud. The module's integrated Nordic [nRF52832](#) Bluetooth LE System-on-Chip (SoC) can communicate with other nearby Bluetooth LE devices and then transfer its aggregated data to the LPWAN chip in the module, which can then forward the data to the Cloud even if the nearest base

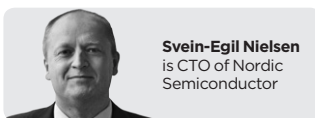
station is kilometers away.

Bluetooth LE/cellular IoT solutions are set to follow. Such modules will combine mature Bluetooth LE SoCs with a new class of low-power cellular IoT modem such as Nordic's forthcoming nRF91 Series. Together with long-range wireless connectivity, these cellular IoT modems incorporate powerful processors and large Flash memory enabling “edge processing” of aggregated sensor data within the modem followed by rapid transmission of valuable information rather than raw data at periodic intervals. Such an operational mode is important when data cost is metered.

A key advantage of cellular IoT LPWANs is that they can leverage existing worldwide cellular IoT infrastructure. The end result? If you can point to dry land on a map, you can probably build a powerful IoT network there using Bluetooth LE and low power cellular wireless technology. ■

Edge computing vital for even simple IoT devices

The lessons learned building advanced Bluetooth Low Energy wearables can be applied to Internet of Things devices, says Svein-Egil Nielsen



Svein-Egil Nielsen
is CTO of Nordic
Semiconductor

Edge computing is a necessary progression for connected devices and applications.

Consider the evolution of Bluetooth Low Energy (Bluetooth LE) Systems-on-Chip (SoCs). Early versions, such as Nordic's nRF51822, had sufficient embedded processing power to maintain the Bluetooth wireless link and run simple applications. But as Nordic's SoCs evolved into the [nRF52 Series](#), they gained sufficient processing power (and the memory to make the most of it) to power activity monitors that not only measured heart rate, steps taken, distance walked, and calories burned but also perform more sophisticated functions such as heart-rate variability monitoring, sleep quality assessment, and fall detection. Today, single-chip [Bluetooth LE solutions](#) are used in the most sophisticated wearables such as the latest generation of medical products like the constant glucose monitors that help Type 1 diabetics keep their blood sugar in a healthy range. (See [this issue pg14](#).)

Each generation of wearables is required to monitor and collate a larger amount of raw data. Developers need increasingly powerful embedded processors to crunch raw data on the device (at the application's edge) before forwarding a refined form (useful "information") to a smartphone app and then the Cloud. This edge computing enables low-latency monitoring



Today's Bluetooth LE wearables look like the forerunners of enterprise IoT devices

"The ability to transfer only the most relevant information will be vital for any commercially-viable IoT application"

by transmitting information without the need for extended on-air transmissions that would otherwise be needed to stream raw data. (And would quickly drain a wearable's modest battery.)

Because users don't always carry their smartphones, wearables must operate autonomously. If there is no wireless connection to pass on information, the wearable waits patiently and stores all the new data until the smartphone is back in range.

Now that personal information

(for example, health data) is transmitted across the wireless link, security is vital. Such information is valuable and attracts the attention of hackers, keen to find and exploit any weakness. Security and encryption mechanisms are now mandatory for any edge-computing device.

Finding the balance

Today's Bluetooth LE wearables look a lot like the forerunner of an enterprise IoT device. Wearables developers solved many of the same challenges facing today's IoT albeit on a smaller scale.

The latest cellular LTE Cat M1 (LTE-M) and NarrowBand IoT (NB-IoT) standards for low power wide area networks (LPWANs) will allow IoT devices to connect to the Cloud over long distances through existing telecoms infrastructure. (See [ULP WQ Autumn 2018, pg9](#).)

But even with the direct connectivity to powerful Cloud

servers that cellular IoT LPWANs will enable, edge computing may be even more important for IoT devices than it's proven to be for Bluetooth wearables. As networks scale to hundreds of millions and then billions of sensors, network data costs quickly escalate. The ability to transfer only the most relevant information will be vital for any commercially-viable application. Most of the raw computing will have to be done at the edge.

Edge computing opens up great opportunities. However, finding the right balance between edge- and Cloud-computing requires end-to-end knowledge of the full application, including the cost of power, data transfer, and Cloud services. Developing end-to-end prototypes could be the easiest way to find the optimum balance. And thanks to simplified development tools, kits, software, and Cloud solutions, this task is becoming much simpler. ■



Connected medical devices transform healthcare



Traditional healthcare systems are close to breaking point, but increasingly sophisticated connected medical devices are now providing a viable alternative. ULP Wireless Q reports

We all want to live a long life, we just don't like the idea of getting old in the process. It's the great paradox of the aging process but life expectancy is on the rise, and so are the health challenges that come with a graying population.

According to the World Health Organization (WHO), for babies born in 2015 average life expectancy now stands at 71.4 years. By 2050, the proportion of the world's population over the age of 60 will nearly double to some two billion people. Today, 125 million people are aged 80 years or older. By 2050, there will be almost this many living in China alone. The problem, according to the WHO, is that there is little evidence to suggest that older people today are experiencing their later years in better health than their parents, meaning we face a major challenge ensuring welfare systems are going to be able to cope in the future.

As the World Economic Forum (WEF) puts it, the

costs of healthcare delivery are spiraling to unsustainable levels, outpacing economic growth and demanding a major transformation in the way all public and private stakeholders approach the delivery of care. Traditional healthcare institutions can't, the WEF says, deliver health all by themselves. But transformative change, fortunately, is in train.

According to a recent report by analyst, Technavio, the global remote patient market is expected to see a CAGR of almost 16 percent between 2018 and 2022, driven by the emergence of digital healthcare services and the concept dubbed 'Healthcare 3.0'. Healthcare 3.0, in essence, is about facilitating a consumer's ability to retrieve and contribute to their personalized health-related data, empowering them to play a more active role in the management of their health rather than relying on traditional healthcare infrastructure.

"The increasing popularity of m-health [delivering healthcare through mobile patient

monitoring devices, such as smartphones] is an emerging trend in the remote patient monitoring market space," states Technavio. "Increasing aging population, chronic diseases, and healthcare costs, are driving the adoption of mobile healthcare technologies, helping healthcare organizations reduce medical costs and utilize effective remote patient monitoring."

Tech empowerment

Founded in 1996 as a spinoff from the Harvard-MIT Division of Health Sciences and Technology, Waltham, MA-based NeuroMetrix is one company pioneering the belief that not only can mobile health technology empower people to reclaim their lives from chronic disease, but also transform medicine as a whole. The company recently released 'Quell 2.0' a wearable device that uses prescription-strength nerve-stimulation technology to block pain signals in the body.

Designed for people with a wide range of chronic pain conditions, the device works

by stimulating sensory nerves in the patient's calf that then carry neural pulses to the user's brain which trigger a natural response to block the pain signals. Employing Nordic-powered Bluetooth Low Energy (Bluetooth LE) connectivity, users can control their device via an app on their smartphone or tablet, wirelessly calibrating Quell to their personalized therapeutic intensity, start or stop therapy, adjust intensity level, track sleep, activity, pain, and gait, as well as modify other settings to meet their unique pain relief needs.

According to Andres Aguirre, Senior Algorithm and Software Engineer at NeuroMetrix, connected medical devices are gaining popularity due, he says, to the convergence of at least two factors: "The near ubiquity of mobile devices has led to the development of apps for nearly every aspect of life including health and medicine and medical devices," says Aguirre. "For example, hearing aids have improved greatly not only by advances in the amplification



Quell 2.0 is a wearable device using prescription-strength nerve-stimulation technology to block pain signals



technology itself, but also by the addition of apps that allow users to modify their hearing depending upon environment and context.

“Second, there are massive un-met medical needs that may be [resolved] at least partly by new connected medical devices. For example, there is also a growing need for solutions to support the aging population. Continuous monitoring of blood pressure and sleep in the home can provide more holistic and real-time information to medical professionals as well as immediate feedback to patients.”

Moving forward, Aguirre says, researchers will be focused increasingly on interpreting the huge amount of data acquired by connected medical devices across populations and within individuals, and using that information to personalize treatment and feedback.

Another company reinventing connected medicine and empowering individuals to proactively manage their own health and wellbeing outside of hospital walls is Milford, Ohio-based Control Bionics.

The developer of wearable electromyography (EMG)



A new range of medical devices is supporting a graying population

solutions, Control Bionics, recently unveiled ‘[NeuroNode](#)’, described as the world’s first wearable EMG assistive technology device, giving people with amyotrophic lateral sclerosis (ALS)—also known as motor neuron disease (MND)—or any other condition causing paralysis and/or loss of speech, the ability to communicate with family, friends, caregivers, and clinicians.

The small, non-invasive, medical-grade wireless sensor is placed on the skin over the muscle chosen to be the ‘switch’. When the user attempts to move that muscle, the NeuroNode interprets the signals sent from the brain to the muscle—even if there is no visible muscle movement—and uses those EMG signals to control the user’s paired computer, tablet, or smartphone via a Nordic-

“There are massive un-met medical needs that may be met at least partly by new connected medical devices”

powered Bluetooth LE wireless link. A companion app allows the user and a clinician to customize the device to match the user’s abilities.

“NeuroNode gives those with ALS/MND, spinal cord injury, or any condition resulting in paralysis and difficulty with speech a connection to the world,” says James Schorey, Chief Technology Officer at Control Bionics. “Because the NeuroNode doesn’t require movement, patient populations that previously couldn’t be served by traditional assistive technology

devices suddenly have the means to communicate with their loved ones and to control their computer and environment.”

Remote care

Applications that not only encourage individuals to play a proactive role in the management of their own health, but also enable both clinician and patient interaction, and the seamless, remote exchange of patient data to healthcare providers are also on the rise. U.S., Florida-based ActiGraph, a leading provider of medical-grade wearable activity and sleep monitoring solutions, recently launched a wearable that provides in-depth user activity data to assist in clinical trials and academic health research.

The ‘[CentrePoint Insight Watch](#)’ comes in a patient-friendly smartwatch form factor and employs a triaxial MEMS accelerometer to capture and record continuous, high-resolution raw acceleration data, providing detailed feedback on the individual’s activity intensity, energy expenditure, steps taken, and sleep efficiency. While a wearable that monitors this sort of activity data is hardly uncommon, the ability to almost instantly relay that information to researchers and clinical trial sponsors enabling them to monitor and manage patient data, wear compliance, and identify trends in near real time, is.

To achieve this, data is transferred from the watch across a high throughput Nordic-powered Bluetooth LE wireless link to a charging cradle, that is in turn connected to a cellular network-enabled home gateway via a USB connection. From there, information is sent to the CentrePoint Cloud platform from where healthcare researchers can easily access and monitor patient data remotely. This is convenient for both clinician and patient.

If the bad news is that the number of people with chronic conditions is on the rise, the good news is that emerging wireless technology and connected medical devices are keeping pace, enabling greater consumerization of healthcare and offering previously unimagined, yet viable solutions. ■



Bluetooth tech's final frontier

Nordic customer, Firmwave, is combining ESA's near-Earth orbit satellites with Nordic's Bluetooth Low Energy beacons to build an inexpensive broadcast system. ULP WQ reports

According to Mike Hibbett, Business Development Manager with Firmwave, a Dublin-based technology design company, "today's technology allows us to reconsider applications that were previously impractical". What Hibbett modestly underplays is that it still takes clever engineers to pick which advanced technology can be best applied to solve a previously intractable engineering problem. And to choose Bluetooth Low Energy (Bluetooth LE), an RF technology designed for low-cost, short range wireless Internet of Things (IoT) applications, as the basis of a low-Earth orbit (LEO) satellite broadcast system borders on genius.

Firmwave is based at DCU Alpha, an innovation campus at Dublin City University (DCU), and specializes in the design of Bluetooth LE IoT solutions such as sensors and gateways. DCU Alpha is also home to the European Space Agency (ESA) [Maker-Space](#) for Satellite Communication, the agency's offshoot that encourages commercial companies to help out with space research.

Back in early 2018, an invitation to tender from ESA Maker-Space fell on Hibbett's desk. The challenge issued by the organization was to enable it to "maximize its spaceborne assets," in other words, increase utilization of satellites. Specifically, ESA Maker-Space asked companies to put together a proposal to use a satellite to transmit Bluetooth LE signals down to Earth and then rebroadcast them using beacons.

A tough challenge

Among other tasks, satellites operate as radio relays. Earth-bound transmitters are limited by obstacles such as mountains and the planet's curvature, but by beaming the message up to a satellite and then using the



A low-cost, beacon-based system will help ESA maximize the use of its spaceborne assets

onboard radio to retransmit, vast swathes of the planet can be serviced from one spacecraft.

ESA Maker-Space realized that if Bluetooth LE signals could be sent via satellite, inexpensive battery-powered receivers could be widely distributed and used to send messages via Bluetooth beacons to smartphones in close proximity. Such a system would form a cost-effective method of conveying information. ESA just needed the help of some innovative engineers to put the idea into practice.

It's not a trivial engineering problem. Bluetooth LE radios operate in the 2.4-GHz industrial, Scientific, and Medical (ISM) band which sits between 2.4 and 2.483 GHz. The signals from the ESA satellites are broadcast in the 'S band' between 2.488 GHz and 2.495 GHz. Further, while ESA's satellites carry radios with a transmit power exceeding 90 dBm, once that signal travels down to Earth, signal strength can be reduced to -77 dBm.

Another complication is the effect of an LEO satellite's velocity. Orbital speed is determined by how far the satellite is from the ground; the lower the craft flies, the faster it has to travel to stay aloft. This velocity imparts Doppler shift on the radio signal affecting its frequency.

ESA's specification called for a system that could communicate with a satellite orbiting at a height of between 160 and 2500 km. At 160 km, the orbital velocity is around 7.8 km/s and Doppler shift adds up to 60 kHz to the signal frequency as the satellite nears and decreases it by up to a 60 kHz as it moves away. The Doppler effect has to be compensated by the radio software, otherwise the signal will be lost.

Finally, when making "non-connected" Bluetooth LE transmissions (i.e. one-way, using the protocol's three advertising channels), the Bluetooth LE RF software (the 'stack') blocks out-of-band signals and continually hops between the

three frequencies. Changing this behavior demands coding changes deep in the stack.

Innovative solutions

Firmwave's engineers demonstrated their expertise by coming up with practical solutions to these tough engineering challenges. Initially the team narrowed down the Bluetooth LE chip selection to Nordic's [nRF52832](#) System-on-Chip (SoC) which, despite being primarily designed for 2.4 GHz ISM band operation, is capable of receiving an RF signal of up to 2.5 GHz. Moreover, the chip features a receive sensitivity of -96 dBm - providing a reasonable margin to receive a weakened signal even when the satellite is orbiting at the high limit of the ESA specification while being low on the horizon.

However, the Nordic SoC's nominal receive sensitivity assumes the use of a linear polarized antenna. These are optimized for picking up signals typical of Bluetooth LE



applications (i.e. transmitted in a horizontal plane over short ranges) but are not so good for the right hand circular polarized (RHCP) S band transmissions coming from overhead. Firmwave's team optimized sensitivity by matching the SoC with an antenna designed specifically for RHCP signals.

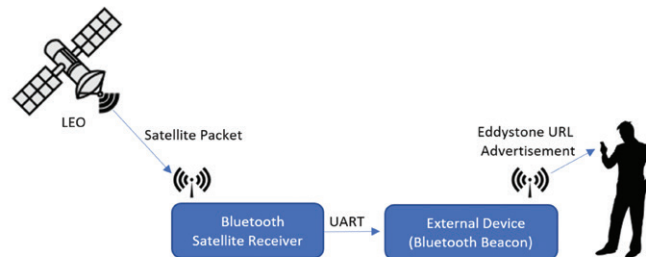
There was also a need to modify some of the Bluetooth LE stack code to make the satellite link work. The key change was to alter the operating frequency to 2.488 GHz to suit the S band transmissions and then to prevent the protocol performing Bluetooth tech's conventional frequency hopping so that it remained locked to the single channel. Other protocol changes included disabling Bluetooth LE tech's cyclic redundancy check (CRC) and modifying advertising packets. The engineers then wrote some firmware to compensate for Doppler shift however fast the satellite is moving and whatever its orbital position.

The Firmwave team quickly realized that engineering a single Bluetooth LE SoC module to perform both the satellite reception and beacon transmission would be impractical. Such an arrangement would require running two Bluetooth stacks, one modified for the former task and a conventional stack to deal with the latter. Although the Nordic chip is capable of concurrently running two stacks, Firmwave took the far simpler route of employing two separate modules (based on Nordic nRF52 Series SoCs) each dedicated to a specific task. Because the modules sit adjacent they can be linked via a wired connection between each SoC's UART port.

"Adding a second module does increase solution cost," explains Hibbett. "But with high-quality, off-the-shelf modules like the [Raytac](#) [nRF52832] product we used costing just \$3.50, it is a small price to pay for shortened development time and increased flexibility of the end product. Some additional cost could be shaved in commercial applications by employing a module with an nRF52810. This is a good option because the



A low-cost, beacon-based system will help ESA maximize the use of its spaceborne assets



Firmwave's solution uses two Bluetooth Low Energy modules connected via the modules' UART ports

chip is ideally suited to beacon applications but less expensive than an nRF52832.

"The modules are certified products and because the one using the modified Bluetooth LE stack only receives, it requires no re-certification. The second module is unmodified so, of course, no additional certification is needed," explains Hibbett.

To prove the concept, the Firmwave team used an Earthbound software defined radio (SDR)—which could accurately emulate the strength and Doppler shift of the LEO satellite's transmissions—and two Nordic nRF52 Development Kits (DKs). One DK acted as the satellite receiver and the other as a Bluetooth (Eddystone) beacon.

Selecting Nordic

Hibbett has worked with Nordic's wireless technology for over a decade and respects the company's ultra low power wireless technology heritage. But while it's a leader, Nordic isn't the only supplier of Bluetooth LE SoCs; so why did Firmwave choose the company's products

therefore faster. For example, the SDK contains an Eddystone beacon example making that side of the process simple.

"Finally, although the Nordic stack [SoftDevice] is good, it is not accessible to external developers. So the fact the chip seamlessly runs alternative open-source stacks such as our choice, MyNewt, allowed us to modify the Bluetooth LE stack but still gain all the advantages of Nordic's proven hardware, software architecture, and development tools," says Hibbett.

Putting it into practice

Part of ESA Maker-Space's requirement was for the company solving the engineering solutions to come up with application ideas. Firmwave's suggestions ranged from the mundane—updating a fleet of beacons' firmware saving a technician being dispatched or sending information to public installations such as bus shelters which could then be passed on via the beacon to passenger smartphones—to the life-saving. One example of the latter is getting emergency information to people where cellphone coverage is non-existent.

"Bluetooth hardware is ideal for these applications because it's robust, inexpensive, has long battery-life and can be constantly updated while in-situ," explains Hibbett.

"A lot of people carry cellphones to areas where there's no signal," he adds. "For example, imagine a mountain pass that has been blocked by a landslide. The satellite could be programmed to send information to beacons located at the bottom of the pass, notifying people that the road tens of kilometers up the mountain is blocked, improving safety.

"But even we can't imagine many of the potential applications based on this technology. After all, who'd have guessed that Bluetooth LE—a technology originally designed for short-range communication between a smartphone and a close-by peripheral—will soon be beamed thousands of kilometers into space and then back down to Earth. Perhaps the Moon will be next." ■

"Bluetooth Low Energy will soon be beamed thousands of kilometers into space and then back down to Earth"

for this application?

"There were four key reasons," explains Hibbett. "First and perhaps most significantly, Nordic's nRF52832's datasheet notes that the radio can operate up to 2.5 GHz, sufficient to pick up the part of the S band we needed to cater for. Just having this information in the datasheet made the component selection far quicker.

"Second, the Nordic chip, particularly when equipped with the RHCP antenna, has excellent receiver sensitivity. Signal strength is one thing when the satellite's overhead, but quite another when it's low in the sky," Hibbett adds. "The extra decibels you gain from a particularly sensitive Bluetooth LE SoC make a lot of difference."

"Third, Nordic's DKs and [software development](#) tools are so comprehensive it makes the design process easier and



Getting started with Bluetooth mesh

Bluetooth Low Energy has been enhanced by the addition of a mesh specification. John Leonard explains how to begin a Bluetooth mesh project



John Leonard is Tactical Marketing Manager, Nordic Semiconductor

The recent adoption of the [Bluetooth mesh 1.0](#) specification allows devices (“nodes”) within a Bluetooth Low Energy (Bluetooth LE) network to communicate directly with companion nodes without recourse to a central hub device. Such a system extends communication range, flexibility, and reliability, and is a prerequisite for a local area network (LAN) Internet of Things (IoT) wireless technology. Key applications for Bluetooth mesh include enterprise lighting installations, back-ends for managed beacons, and industrial monitoring. (For an introduction to Bluetooth mesh see ULP WQ Autumn 2017, pg10.)

However, the Bluetooth mesh specification also brings new design challenges such as provisioning and configuring the network and working with Bluetooth mesh’s “Models”. Fortunately, those challenges can be overcome by turning to the silicon, firmware, development kits (DKs) and [software DKs](#), supplied by Nordic Semiconductor.

What are Models?

Bluetooth mesh offers flexibility when building mesh applications because developers can construct Models which enable devices with many different customized behaviors. Models is a complex subject which merits further reading, but in essence, a Model defines the required mesh “states”, the “messages” that act upon those states and the associated behavior of those states. All



Designing smart lighting is made simpler with Nordic’s Bluetooth mesh development tools

communication across a mesh network is facilitated by messages.

A state is a value representing a condition of an “element”. An element is an addressable entity of a device or node. Each device has at least one (primary) element and might have one or more secondary elements, all of which remain unchanged throughout the node’s lifetime after initial configuration. An element ‘exposing’ a state is called a “Server”. An element ‘accessing’ a state is referred to as a “Client”.

Server, Client and “Control” are the three types of Model defined in the specification. A Server Model is composed of one or more states spanning one or more elements and defines a set of mandatory messages that it can transmit or receive, the element behavior when it deals with the messages, and any additional behavior that occurs after messages are dealt with.

A Client Model defines a set

“Nordic’s SDK accelerates the design of Bluetooth mesh applications”

of messages that a Client uses to request, change, or ‘consume’ corresponding Server states, as defined by a Server Model. The Client Model does not itself have states. A Control Model can combine Client Model functionality (to communicate with other Server Models) and Server Model functionality (to communicate with other Client Models). A Control Model may also contain a set of rules and behaviors that coordinate the Control Model’s interactions between other Models to which the Control Model connects. (See Figure 1.)

Bluetooth mesh doesn’t require Bluetooth LE vendors to update their PHYs or software stacks to support its functionality. In addition, Bluetooth mesh isn’t limited to PHYs compliant with the latest version, Bluetooth 5; legacy products employing Bluetooth 4.0, 4.1, and 4.2 can also support the technology.

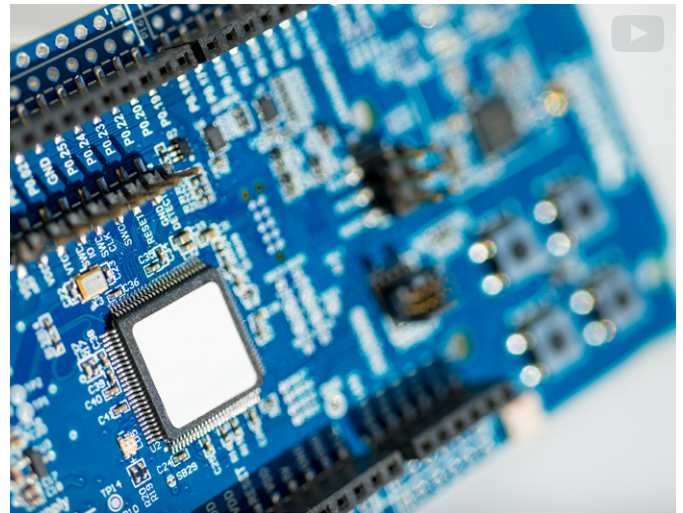
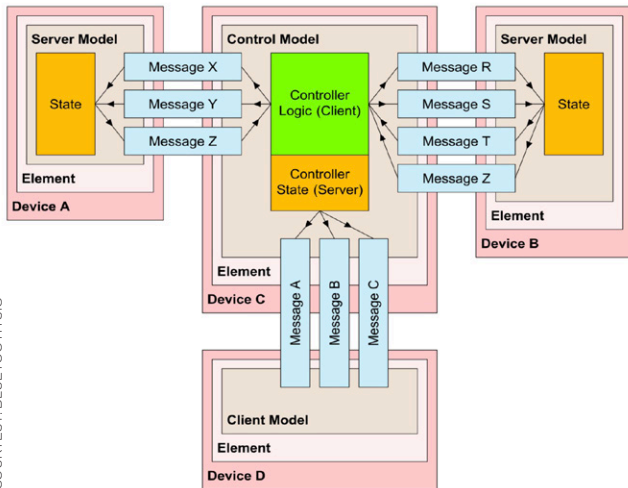
Mesh development tools

However, Bluetooth mesh does require the introduction of the vendor’s implementation of a compliant mesh stack. The stacks include a completely new host layer that shares some concepts with the Bluetooth LE host layer but is not compatible with it.

Nordic’s Bluetooth mesh stack comes as part the nRF5 SDK for Mesh, an SDK that also includes a selection of drivers, libraries and examples for mesh applications. Because Bluetooth mesh requires no changes to existing PHYs or stacks, Bluetooth



Figure 1: The element-Model structure of a Bluetooth mesh device that implements a Control Model



The Nordic nRF52 DK works well with nRF5 SDK for Mesh

COURTESY, BLUETOOTH SIG

mesh development work can be performed using existing (hardware) development kits incorporating the target device such as Nordic's nRF52 DK. (See [ULP WQ Autumn 2018, pg20.](#))

Armed with some familiarity of Nordic development tools and the SDK, and at least three DKs (or one DK and two Nordic SoC-based modules) to form a small network, it is relatively easy for a developer to put together an initial Bluetooth mesh application.

The first step is to build the mesh stack. In Nordic's case the stack is built using one of the Integrated Development Environments (IDEs) that support the company's development tools. For example, with SEGGER Embedded Studio, the stack is built by using one of the examples included with the Bluetooth mesh SDK and compiling using the IDE.

The target PHY on the DK is then erased and reprogrammed with both the compiled Bluetooth mesh stack and SoftDevice (Nordic Bluetooth LE stack). Once the stacks are programmed and verified, the SDK can be used to set-up and build mesh networks.

Provisioning

Nordic's development tools include an application programming interface (API) which is used to add new devices to the mesh network (called "provisioning"). Provisioning is handled by devices previously configured for the provisioning task and already part of the

network, called "provisioners". (In the development case the provisioner is the nRF52 DK.) The provisioner supplies new devices with the information they need to join a network.

The API allows the developer to start listening for the unprovisioned device waiting to join the network. The device will communicate using a broadcast beacon sent on one of Bluetooth LE's three advertising channels. Incoming link requests on the channel will be automatically accepted by the provisioner. When the link has been established, it is authenticated using an out-of-band (OOB) method for enhanced security to ensure that the device joining the network is the intended target. An API event then provides the provisioning data and the device key to the device.

The nRF5 SDK for Mesh includes a light switch example that shows how to develop applications with both provisioner and provisionee roles. In the demo, a light switch Client Model (the switch) is the provisioner and the light switch Server Model (the bulb) is the provisionee.

Nordic's example makes the most of the fact that the simplest server in the Bluetooth mesh specification is a Generic OnOff Server, representing that the server is either "on" or "off". The simplest Client is a Generic OnOff Client that's able to control a Generic OnOff Server via messages defined by the Generic OnOff Model.

The "Configuration Server" is a mandatory requirement for Bluetooth mesh nodes and is used to represent the mesh network configuration of a device. The Configuration Server handles the communication with, and instructions from, the Configuration Client (controlled by the provisioner).

Configuration starts after provisioning is completed. The provisioner reads the composition data of the provisionee to identify the metadata of the device and which Models are bound to which element in the device. Then the application and/or network key(s) are added and bound to the different Models.

Adding more nodes is achieved by repeating the provisioning and configuration process for each new device.

Publishing and subscribing

After adding and configuring network devices, Bluetooth mesh requires the developer to configure the "publication state" of the Models and to set "subscriptions". The publication state includes things like the address used to publish state events, with what key and using what "time-to-live" (TTL) value.

Messages are sent when they are "published" from each Model's publish address. Publication is used, for example, by a sensor node reporting data. Messages can be published just once or repeated and are sent to either a unicast-, group-, or virtual-address. Publication is also

used by Client Models to send messages to Server Models.

Configuration of publication states is generally controlled by a provisioner via the Configuration Model.

When using the Nordic nRF5 SDK, messages are published using the "access_model_publish()" API function, which publishes a message according to the publication settings (interval, destination) of the Publishing Model.

Subscriptions are used to receive unsolicited messages from nodes. The Nordic SDK "access_model_subscription_list_alloc()" API function allocates a subscription list enabling Models to subscribe to an address. The subscriptions allow Models to listen for published messages such as those carrying data from sensor nodes.

During the development process it might be advantageous to connect a non-Bluetooth mesh-enabled device such as a smartphone to the network to, for example, configure smart lighting from an app. This is achieved by adding the smartphone as a Proxy Node interfacing via both the node and device's Generic Attribute Profile (GATT).

Developers familiar with designing using Bluetooth LE will be at an advantage when getting started with Bluetooth mesh. However, Nordic's nRF5 SDK for Mesh does ease the path for inexperienced developers to accelerate the design of Bluetooth mesh applications. ■



Bluetooth 5 range put to the test

German component distributor Rutronik and Nordic performed experiments using the nRF52840 SoC to check the performance of Bluetooth 5 long-range functionality

The introduction of Bluetooth 5 added some key capabilities to Bluetooth wireless technology, notably increased throughput, range, and advertising extensions.

Nordic's nRF52840 SoC was one of the few devices on the market to offer all of Bluetooth 5 wireless' features from the date of adoption. Some competitive chips were slower to offer the long-range feature because it required a significant firmware upgrade. Specifically, the range boost comes from the use of Forward Error Correction (FEC) to detect and fix packet corruptions during data transfer. This improves the Bit Error Rate (BER), effectively increasing the sensitivity of the receiver by enhancing the transmitter. Theoretically, for the Bluetooth 5 long-range feature, the increase in sensitivity should be around 12 dB (throughput 125 kbps) compared to (non-FEC) 1-Mbps mode which is good enough for a quadrupling of range.

Because the technique reduces the packet data payload, the downsides are reduced raw data rates, longer transmission times (reducing battery life), and a greater risk of interference from other 2.4 GHz radio sources. But for some applications, for example smart-lighting or -agriculture, the potential of a quadrupling of range is well worth the trade-off.

But the promise of 4x the range is one thing, actual range in practice is quite another. There are many factors that attenuate a Bluetooth 5 signal. In part this attenuation is due to interference from other 2.4-GHz wireless technologies such as Wi-Fi, ANT+, Thread, and Zigbee, but perhaps a bigger factor is the impact of obstacles between transmitter and receiver. Indoors these obstacles comprise people, walls, and furniture; and outdoors



Bluetooth 5 wireless' long-range feature promises much for outdoor applications such as smart agriculture

“Bluetooth 5 wireless' long-range feature effectively increases the sensitivity of the receiver”

things like trees, buildings, and even the weather get in the way.

Put to the test

Rutronik is a German component distributor of Nordic's wireless SoCs, including the nRF52 Series Bluetooth 5 chips. The company put the nRF52840 SoC's long-range feature to the test using Nordic's nRF52840 Preview Development Kit (PDK) in both indoor and outdoor applications. The results were compared with Nordic SoCs running Bluetooth 5 in 'normal' mode (i.e. without FEC).

Indoors, the results showed that a Bluetooth 5 SoC without FEC (raw throughput 1 Mbps) offered a range of 51 m. With maximum FEC, that improved to 60 m (at similar output power but a raw throughput reduced to 125 kbps); a range improvement

of around 17.5 percent. Outdoors, for similar operational scenarios, range improved from 455 m to 527 m, an improvement of around 16 percent.

While this is a marked improvement in range, such improvement falls well short of what might be theoretically expected from the new technology. Rutronik noted that the indoor radio environment was particularly hostile. The tests were performed in an office with lots of walls, people, and furniture. In addition, many other 2.4-GHz devices such as Wi-Fi routers and wireless mice and keyboards were present. Similarly, the company noted the outdoor results were likely to have been compromised by weather, ground reflection, and less-than-optimum positions of the respective transmitter and receiver antennas. The company further noted that a wider range of tests would need to be performed to establish Bluetooth 5 range performance across a range of typical usage scenarios.

Nordic has performed its own Bluetooth 5 outdoor experiments, which post-

date Rutronik's. The company notes that although a 12-dB increase in receiver sensitivity is theoretically possible, actual devices achieve around 8 dB which equates to a range boost of 2.5 times.

Nordic performed its tests using an nRF52840 SoC running no FEC (raw data throughput of 1 Mbps) then with full FEC (125 kbps). For a normal Bluetooth 5 connection, the range for the former operational mode was 682 m and for the latter 1,300 m. That's an increase of around 91 percent or just under double the range. Nordic's engineers also noted that the impact of external factors is so great that it is impossible to generalize what improvement in range Bluetooth 5 can bring. Tests in the target application are therefore advised.

Further information: Rutronik's white paper, which also considers throughput and energy consumption, is available from www.rutronik.com/white-paper-on-the-real-world-performance-of-bluetooth-low-energy-5/ Nordic's tests are detailed here: tinyurl.com/BT5NordicTest. ■



Freedrum Virtual Drumkit

This Bluetooth Low Energy virtual drumkit allows drummers to practice anywhere by creating sounds from sensor-tracked drumstick movements

According to analyst QY Research Reports the wireless audio market is expected to grow from \$16.3 billion in 2016 to \$31.8 billion by 2023, propelled by increasing consumer demand for audio gadgets. **Freedrum** allows keen drummers to take their virtual drumkit with them wherever they go, listening to the generated audio live on their smartphone or tablet

Extreme Sport Drumming is a competition for determining the world's fastest drummer. A drummer's speed is recorded by a digital counting device to determine who can play the most single strokes in 60 seconds. In 2013, **Thomas Gross** set the current world record at 1208 strokes per minute, equivalent to striking the drum more than 20 times per second

The basic design of the drum has remained virtually unchanged throughout history and is considered to be the oldest musical instrument—other than the human voice—still in existence today. Early drums dating from 6000 BC have been found in Neolithic or 'New Stone Age' period excavations, and are believed to have had a ceremonial rather than musical purpose

Freedrum comprises four wireless devices fitted to a pair of drumsticks and the user's feet. Built-in gyroscopes and accelerometers track the direction and angle of movement, detecting 'impacts' that translate to actual drum sounds on a smartphone app using MIDI-over-Bluetooth Low Energy wireless connectivity

Nordic's **nRF52832** SoC not only provides wireless connectivity for **Freedrum**, but its powerful 64MHz, 32-bit Arm Cortex M4F processor also delivers the processing power required to cope with the complex floating-point computations necessary to run **Freedrum**'s detailed angle-tracking algorithms at high speed. In addition, the processor manages **Freedrum**'s raw sensor values, and supervises the Bluetooth LE RF protocol software



EMG assistive wearable helps people with disabilities stay connected

Thanks to Bluetooth LE connectivity, Control Bionics' NeuroNode allows those with paralysis and loss of speech to communicate with loved ones, reports Kalon Huett



Kalon Huett is an Australia-based freelance journalist

As wirelessly-enabled medical devices prove vitally important across the healthcare sector, one developer of wearable EMG (electromyography) devices has now provided the market with a communication and connectivity solution for sufferers of paralysis and loss of speech.

Cincinnati, Ohio-based Control Bionics describes the 'NeuroNode' as the world's first wearable EMG assistive technology device of its kind. The company has high hopes not only for this revolutionary consumer product, but for the future of the wearable medical device sector.

"The NeuroNode allows people to find their voice again and reconnect with family, friends, and the rest of the world," says James Schorey, Chief Technology Officer at Control Bionics.

"Because the NeuroNode doesn't require any movement, patient populations that previously couldn't be served by traditional assistive technology devices suddenly have the means to communicate with other people and control their own personal devices and environment."

The NeuroNode device uses a small, non-invasive, medical-grade wireless sensor placed on the skin over a muscle to interpret the signals sent from the brain whenever the user attempts to move that muscle. Control Bionics' iOS companion app, the 'NeuroNode Controller', allows the user and clinician to customize the NeuroNode to match the user's abilities.

Designed specifically for people diagnosed with



NeuroNode is out-of-the-box ready to be used on the user's device via Bluetooth LE



amyotrophic lateral sclerosis (ALS)—also known as motor neuron disease (MND)—or any other condition causing paralysis and/or loss or difficulty of speech, the NeuroNode system offers users the invaluable ability to control a paired computer, tablet, or smartphone via EMG signals.

Thanks to this technology, users with a disability are now also able to communicate more effectively with loved ones, caregivers, and clinicians. They can, for example, access social media or send and receive emails and text messages, as well as play games, watch and download online entertainment, use environmental control systems, and operate external devices.

In addition to the helpful role it plays in the lives of individual consumers, the NeuroNode is also being used as an assessment tool for speech language pathologists in both institutions

"The NeuroNode allows people to find their voice again and reconnect with the world"

and private practices across the U.S. and Australia.

Bluetooth LE versatility

Medical device manufacturers like Control Bionics must develop products in accordance with U.S. Federal Communications Commission (FCC) regulations. The FCC oversees the RF spectrum where wireless technologies operate in the U.S. According to Schorey, Nordic's support proved instrumental when Control Bionics was preparing to apply for FCC certification for the NeuroNode. "We needed software to turn the

NeuroNode into a generic 2.4GHz radio for the testing laboratory. Nordic had a ready-made solution for this, and their online support allowed us to take the Nordic radio test software and easily adopt it to our product," he says.

The NeuroNode is compatible with most popular personal devices. By selecting Bluetooth Low Energy (Bluetooth LE)—enabled by Nordic's [nRF52832](#) System-on-Chip (SoC)—over alternative wireless protocols to provide the connectivity for the device, Control Bionics' developers have taken advantage of this wireless technology's in-built interoperability.

"It was important for the NeuroNode system to have cross-platform capability," Schorey says. "By making it function as an HID [human interface device] Bluetooth LE wireless keyboard, the NeuroNode is instantly connectable to iOS/OSX, Android, and Windows platforms. This means the NeuroNode is out-of-the-box ready to be used on the user's preferred device via Bluetooth LE."

The NeuroNode represents the evolution of Control Bionics' earlier EMG assistive technology device, the NeuroSwitch. "This next generation device is a significant upgrade on the NeuroSwitch. Specifically, it is five times smaller, wearable, and features vastly enhanced power consumption as well as Bluetooth LE wireless connectivity," says Schorey.

What is the next step for Control Bionics and how does the company see current and future consumer uptake for wearable medical devices? Schorey says a clear roadmap is in place: "We will continue to evolve by developing lighter, simpler, smaller, and more powerful devices, which will allow us to increase market share and even expand into new markets." ■

PEOPLE & PLACES

Andrzej Puzdrowski



Model engineer mixes work with fun

Hi, I'm Andrzej Puzdrowski and I'm a Senior Firmware Engineer based in Kraków, Poland. At present I am heavily involved in Nordic's real time operating system (RTOS) efforts, simultaneously working as the code-owner for certain codes and on developing [Zephyr](#) software. My main focuses include Flash storage, file systems, bootloader, and device firmware update (DFU) technicalities.

As Zephyr is an open source project, I cooperate and collaborate extensively with engineers from other companies. I also contribute to Internet Engineering Task Force (IETF) standardization works. Prior to my role as a Senior Firmware Engineer, I was an nRF SDK software development team member at Nordic for one-and-a-half years and a Nordic lead developer for Arm Mbed OS for IoT devices. Each time I have changed roles within Nordic my new responsibilities have overlapped to a certain extent with my previous position.

I enjoy working on multinational, multicompany projects such as Zephyr, MCUboot, and formerly Arm Mbed OS. Our internal software team is made up of highly-skilled and open-minded engineers, which helps create an environment conducive to creativity, self-development, and knowledge sharing. The open-source nature of the project also provides opportunities to work with talented external



When he's not assembling a model train at home, Andrzej likes to take his family on adventures

Personal Profile

NAME:
Andrzej Puzdrowski

JOB TITLE:
Senior Firmware Engineer

JOINED NORDIC:
2015

BASED:
Kraków, Poland

INTERESTS INCLUDE:
Traveling, hiking, cycling, swimming, reading, 3D model assembly, computer games, playing guitar

engineers and exchange our combined experience. Thanks to the open-source nature of the project I am also close to the potential end user - I can see their struggles, interact with them, and importantly learn how to create more user-friendly software. From a technical perspective I enjoy working with and learning the latest technologies.

"Our internal software team is made up of highly-skilled and open-minded engineers, which helps create a great environment"

Two years ago, at an internal software team 'hack-week' social event in Trondheim, we organized ourselves into small teams working on interesting projects based on our common ideas. Many of us became so involved in the projects that we ended up working through the night. This was not a business project with a deadline, it was simply a case of

everyone, including myself, being incredibly self-motivated. We are people who enjoy what we do, we love developing products. You could call us enthusiasts and perhaps even geeks!

Outside of work, I am a husband and father of four children. I really appreciate the fact Nordic respects the value of our private lives, so it is not hard to keep the right balance between work and family. Spending quality time with my family is important and special. I really like traveling, hiking, and taking my family to see different sights. Even a small journey with the kids can sometimes be challenging, both physically and mentally, but I love it. I usually take on the role of 'tour guide'.

I also like to keep busy renovating and working on various DIY projects at home. One of my other favorite things to do since childhood is assemble 3D models, although these days I don't find enough time for this hobby. For the past four years I've had the model of a Polish OI-49 steam locomotive on my desk.

Something I always find time for is reading. It could be science fiction, history, physics and astrophysics, military strategy, or science and technology news; whatever I'm reading, I tend to get a little bit addicted.

As for the future, my goal is to help create the best support in open-source projects and provide as much functionality as possible in our products, to establish an advantage over our competitors. ■



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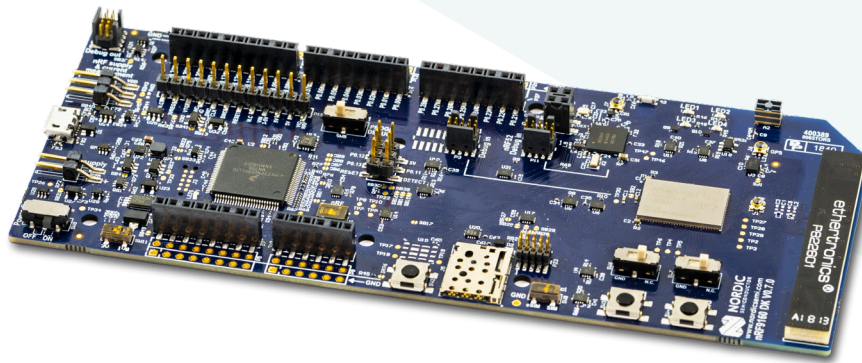
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