WQ
WIRELESS QUARTER

Issue 1, 2020

**UNWIRED FOR SOUND:** THE LE AUDIO MUSIC REVOLUTION

**THE AI OF THINGS:** MAKING SENSE OF THE IoT DATA OVERLOAD

**GET SMART:** BRINGING PRECISION TO ENERGY MANAGEMENT

# Ahead of the Game

## How wireless tech is transforming sports performance

NORDIC AND AMAZON'S SMART HOME ALLIANCE

DEMOCRATIZING SMART ORAL HYGIENE

WHAT'S NEW IN THE BLUETOOTH 5.2 SPEC

NORDIC SEMICONDUCTOR

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# Welcome

Svenn-Tore Larsen
*CEO*

When we planned this edition of *Wireless Quarter*, coronavirus and the disease it causes, COVID-19, was just breaking out in China. It wasn't apparent then that the virus would cause the pandemic that currently afflicts the world. Because of the status of the virus at that time we didn't include anything in this edition about it or its implications. But we have now changed the planned Welcome column because it's vital to acknowledge the huge challenge the world faces and the tens of thousands that have already lost their lives to COVID-19.

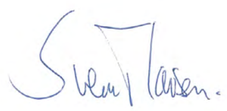
Like the business community across the globe at this challenging time, Nordic places the safety and protection of its staff and community at the top of its prorities. For example, employees are now working remotely to limit exposure to coronavirus. And we are committed to doing our best to contribute to the wellbeing of other people and businesses, in all ways possible.

> Bright lights during this crisis are the Nordic customers using our technology to fight the coronavirus

Bright lights during this crisis are the Nordic customers using our tech to fight the coronavirus. For example, the tech is being used to notify when people have come into contact with infected people and reinforce hygiene regimes. You can read more about this on the news feed at the Nordic website and in our Get [Connected] Blog. And the next edition of *WQ* will include a deeper analysis of the wireless technology being used to fight the virus.

While today's challenge is tough, there will be a time when it's over. In preparation for that day, our operation is largely continuing as previously planned. And we'll continue to develop strong customer relationships and deliver on their expectations.

We believe the technology being developed today will not only help us to fight the current pandemic, but also put us in a better position to fight the next one. Stay safe.

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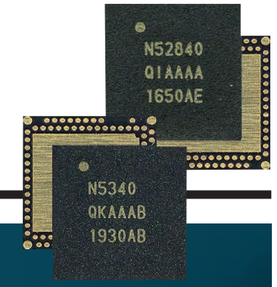
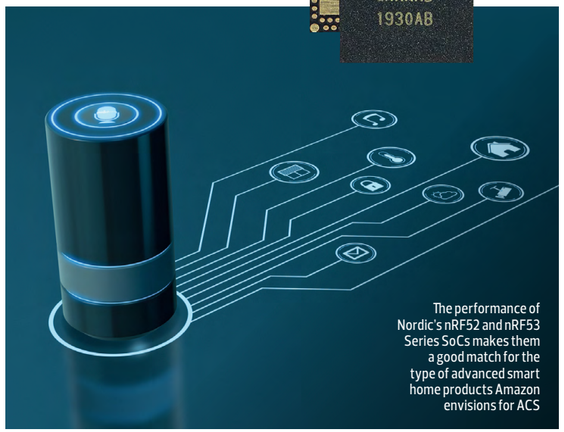
# News

*The latest developments from Nordic Semiconductor*




Smart Home

## Nordic and Amazon partner to speed smart home products


The performance of Nordic's nRF52 and nRF53 Series SoCs makes them a good match for the type of advanced smart home products Amazon envisions for ACS

Nordic Semiconductor is working with Amazon Common Software (ACS) to help accelerate the development of smart home and other wireless products.

ACS provides a single, unified API integration layer for multiple Amazon SDKs including providing components that are prevalidated and memory optimized for common smart home product functions. Amazon says ACS is designed to benefit any developer building products using Amazon SDKs by giving them the ability to use prebuilt and prehardened software components. This will accelerate integration of the SDKs and help reduce both development and maintenance costs.

Amazon says ACS includes an extensive test suite that can be used to verify and debug an ACS implementation. By building on ACS, developers can expect to launch devices more quickly and easily than before, using some of the same technology that Amazon uses in its own devices.

Nordic intends to provide and maintain a Device Porting Kit (DPK) for its wireless chips that allows them to be easily and natively integrated into ACS as a reference platform. Initial DPKs will be based on Bluetooth LE, with other wireless technologies following in the future.

"We're happy that Amazon recognizes the value that Nordic brings through our multiple award-winning wireless chips and extensive customer base," says Kjetil Holstad, Director of Product Management at Nordic.

"Our market leading nRF52 Series and the newly released nRF53 Series Bluetooth LE devices offer very low power consumption, stellar security performance and a high amount of on-chip memory which makes them perfect for the type of advanced smart home products Amazon envisions for [ACS]. We're looking forward to working with Amazon and the device makers using its services to build some great new applications."

## Nordic awards at the double

For the second year in a row and the third time in total, Nordic Semiconductor has been named the 'Most respected emerging public semiconductor company achieving $100 million to $500 million in annual sales' by the members of the Global Semiconductor Alliance (GSA).

Launched in 1996, the GSA Awards recognize the achievements of top performing semiconductor companies. They are widely considered one of the most prestigious awards in the industry.

"We are delighted to receive such high independent recognition ... from the GSA," says Nordic CEO, Svenn-Tore Larsen.

Meanwhile the company's Thingy:91 cellular IoT prototyping platform has won the Technical Innovation Award in the China IoT Innovation Awards, 2020. It is the second year running Nordic has claimed the respected award, last year winning with its nRF Connect for Cloud development tool.

Logistics & Transport

## Cellular IoT and Bluetooth LE asset tracker offers world leading battery life

Norwegian asset tracking specialist, Meshtech, is employing a Nordic nRF9160 SiP and nRF52811 SoC in the world's first environmental asset tracker to combine cellular IoT and Bluetooth wireless tech with a five-year battery life.

The Meshtech Cloud Tracker prevents the ongoing compensation costs routinely incurred in the supply of perishable goods at risk of spoiling, being delivered to wrong customer locations or delivered in the wrong quantities.

"Our Cloud Tracker [detects] delivery or storage issues quickly enough that they can be corrected without jeopardizing an entire consignment," says Meshtech Interim CEO, Preben Skretteberg. "This means perishable goods suppliers now have a viable way to prevent unnecessary compensation costs, while also being able to exceed both current and [increasingly strict] future regulations."

The Meshtech Cloud Tracker not only continuously monitors environmental parameters, but also whether a consignment has been dropped, tilted or folded, the location of individual shipping items within a consignment, the order in which they were loaded and unloaded and the location of the consignment.

"Suppliers [now have] environmental data-driven insights into how their goods are loaded, stored, and shipped that could eliminate the majority of their compensation losses," adds Skretteberg. "None of this was viable before the advent of cellular IoT which has made environmental asset tracking feasible and scalable in a way that wasn't possible before."

Sports & Fitness

# NB-IoT cellular bike security tracker turns up heat on thieves

Northern Ireland cycling startup, See.Sense, has launched the world's first cellular bike security tracker. The tracker uses both NB-IoT and GPS to locate and track bikes from a user's smartphone for up to three months on a single charge from an internal rechargeable lithium polymer battery.

The 80 g See.Sense AIR is about half the size of a deck of playing cards and is designed to fit securely under any bike's seat or bottle cage. The product incorporates Nordic Semiconductor's nRF9160 SiP with integrated LTE-M/NB-IoT modem and GPS.

"We're totally fed up with instances of bike vandalism and theft," says See.Sense CEO, Philip McAleese.

"AIR was developed after listening to what the cycling community wanted. If the bike is moved or tampered with, AIR will sound an alarm and immediately text message the rider; we call this 'Fight' mode.

"If the bike is stolen, AIR will detect this and switch into 'Flight' mode setting, rapidly transmitting high-powered tracking signals to allow the owner to quickly and accurately locate their bike to the nearest couple of meters. This tracking information can then be passed to local law enforcement increasing the chances of recovery."


AIR will not only protect the bike, it will also protect its rider, identifying if the bike's been involved in a crash and sending an SMS with the precise location to the rider's assigned contact.

McAleese says See.Sense considered a wide range of long-range LPWAN wireless technologies including LoRaWAN, Sigfox and NB-IoT's sister cellular technology, LTE-M, before selecting the best protocol for the See.Sense product.

"For us, NB-IoT was a clear winner, providing good range and upload speed at a reasonable power consumption," says McAleese. "We found that NB-IoT also had fewer restrictions on duty cycles and data size limitations than both LoRaWAN and Sigfox, making it a much more appealing platform for the AIR."

Logistics & Transport

## Long range sensor platform


Leading wireless technology company, Laird Connectivity, has released a multisensor device designed to provide reliable sensor data in harsh environments. Use examples include cold chain transport, agriculture and remote asset monitoring applications.

The Sentrius BT510 long-range sensor device comes in a rugged IP67-rated 19 by 80 by 51 mm enclosure with an operating temperature range of –20 to 60 °C, and integrates a magnetic reed switch sensor, temperature sensor, Bluetooth LE beaconing as well as a three-axis MEMS accelerometer for motion and impact detection. It is powered by Laird Connectivity's BL654 BLE module integrating Nordic's nRF52840 SoC to provide full Bluetooth 5 support.

## Thread mesh enables commercial lighting control

India-based IoT company, Zenatix Solutions, has released a mesh-enabled sensor network based on Thread, an open source wireless mesh RF software protocol with native support for IPv6.

The ZenConnect ecosystem can optimize operational energy efficiency for smart lighting and other commercial applications via automated, intelligent monitoring and control. The 'plug and play' solution delivers key benefits including centralized visibility, energy savings and improved asset maintenance.

The platform incorporates a network of battery powered sensors each using a Nordic nRF52840 SoC-based module to report back data via nRF52840-powered mains routers. The routers in turn report to a central gateway that uses Ethernet, Wi-Fi or cellular connectivity to relay data to the Cloud. Each router can support 100 different sensors. Up to 32 routers can then form a multihop wireless network sending data to the gateway. Sensors, routers and gateway communicate locally using the Thread protocol.

The sensors can also enable smart control for enterprise OEMs in, for example, a smart lighting application. The system uses luminosity and occupancy data from sensors to automatically alter lights according to whatever conditions are required. For example, if the occupancy of an office is low, lights can be turned off in unused areas.

Further, the solution enables control of lighting for personalized comfort using the web dashboard or mobile app. Smart lighting actuation is enabled by Zenatix-designed nRF52840 SoC-based lighting control cards, that can be used to turn lights on/off, perform dimming functions or control smart LEDs.

Wearables

# Citizen Watch and Nordic partner on solar powered custom watch

Citizen Watch, one of the world's leading watch manufacturers, has released the Eco-Drive Riiiver, a fully customizable solar powered watch employing Nordic's nRF52810 Bluetooth LE SoC to provide the wireless connectivity.

Unlike conventional watches that have prefixed button functions, Eco-Drive Riiiver allows users to not only customize the buttons to suit their own preferences, but also create up to three miniprograms—known as 'iiideas'—that can be actioned from, or displayed on the smartwatch to suit the user's own lifestyle and interests.

For example, from the iOS and Android compatible Eco-Drive Riiiver app the user can select a 'trigger' (the press of a specific button on the smartwatch) to deliver a 'service', and an 'action'. A specific button could trigger the smartwatch to update the user on the score in a sporting event and display the score via the hands of the smartwatch. Alternatively, a press of a button could trigger the smartwatch to send the user's current location to nominated contacts with a pre-set message, for example "I've arrived".


Wireless connectivity between the smartwatch and the user's smartphone is provided by the Nordic SoC.

Despite its processor-intensive applications, the Eco-Drive Riiiver watch is solar powered, thanks in part to the ultra low power characteristics of the Nordic SoC. The nRF52810 has been engineered to minimize power consumption with features such as the 2.4 GHz radio's 4.6 mA peak RX/TX currents.

"We selected Nordic's SoC for Eco-Drive Riiiver due to its low power consumption and radio sensitivity, which is essential because the watch is a full metal device," says Daisuke Matsuoh, an engineer at Citizen Watch.

## By the Numbers

# $288 million in revenue

Nordic Semiconductor has reported full 2019 revenue of $288.4 million, representing growth of 6.4 percent over 2018's full year revenue. The result comes on the back of all time record Q4 revenue of 83.1 million, an increase of 36 percent on the same time last year. The strong year-on-year growth reflects significantly higher revenue contribution from new tier one Bluetooth LE customers, with Bluetooth revenue amounting to $221.2 million in 2019, up 19 percent from $185.1 million in 2018. The consumer electronics, wearables and building and retail markets continued to perform strongly in 2019.

# $2 billion smart building industry

Next generation smart building solutions are forecast to generate over $2 billion in software and services revenue by 2026, according to a new report from analyst ABI Research. New offerings include emerging applications in space management, environmental monitoring, asset management and cleanliness and hygiene management. The report said space management solutions are being created with a variety of sensors, including contact, motion and occupancy, while asset management solutions are becoming increasingly important within specific commercial buildings, especially healthcare. The use of such solutions for hospitals, for example, improves inventory management and lowers operating costs.

## In Brief

### IoT OFFERS BOOST FOR REMOTE MONITORING

Analyst Facts and Factors Market Research predicts the global IoT healthcare market will increase in value to $21 billion in 2025 from $9.1 billion in 2018, at a CAGR of around 12.59 percent. The analyst said the successful use of the IoT in remotely monitoring diabetics and asthma patients—along with high penetration of connected technology across the health, fitness and wellness industry—had assisted in minimizing hospital stays and readmissions. Such advantages would drive the growth of the IoT healthcare market over the forecast timeline.

### BLUETOOTH HEADPHONES NEXT BIG THING

According to a new report from research company, Canalys, Bluetooth headphones will be the fastest growing category of smart devices over the next several years. With the advent of LE Audio, 726 million units are predicted to ship in 2023, the analyst said. The research said for every 100 smartphones shipping in 2023, 48 smart personal audio devices would be shipped, compared to 16 desktops/notebooks, 14 wearable bands, 13 smart speakers and 8 tablets. Smart speakers will be the second fastest growing category, Canalys said.

### NEW BLUETOOTH 5.2-POWERED MODULES

Tangshan Hongjia Electronic Technology Co, has released two Bluetooth 5.2/Bluetooth LE modules enabling OEMs to develop IoT product designs with Direction Finding and Long Range capability. The HJ-380 module is powered by Nordic's nRF52832 SoC and is designed for complex wireless applications. The HJ-180 module is powered by Nordic's nRF52811 SoC. The SoC is the first product in Nordic's low power wireless range to support Bluetooth Direction Finding. Both modules feature a built-in antenna, inductor and RF matching circuits and operate in low power DC/DC mode to minimize current consumption.

Education

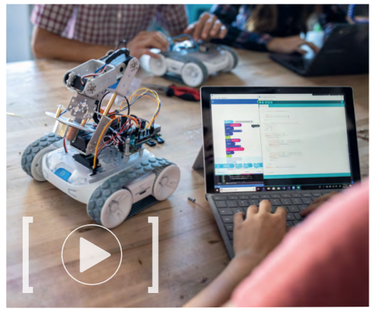
# Bluetooth LE robot encourages coders of all skill levels

Consumer robotics and toy company, Sphero, has released the Sphero RVR, a programmable robot for beginners to advanced coders, Science, Technology, Engineering, Arts and Mathematics (STEAM) educators and students, as well as makers, hackers and hobbyists.

The robot is an all-terrain programmable and expandable product that can be driven right out of the box and customized for unique use cases and applications. For example, RVR could be used as a home security sentry, autonomous metal detector or wirelessly controlled environmental sensor. It features a diverse suite of sensors including ambient light, color, infrared, accelerometer and gyroscope, enabling the robot to interact with its environment.

The robot employs Nordic Semiconductor's nRF52832 Bluetooth LE SoC as the primary processor and low power wireless connectivity solution, allowing users to wirelessly code RVR from the Sphero Edu app on their smartphone or tablet. Alternatively, RVR can be programmed using a Raspberry Pi, Arduino, Nordic-powered micro:bit or the company's own littleBits platform to customize the robot's capabilities further.

RVR includes a rechargeable, high capacity battery to power the robot's motors, as well as cameras, robotic arms, air horns and other external accessories that can be fitted to the robot. "The key features of Nordic's nRF52832 SoC for RVR are its generous Flash and RAM capacity, the powerful Arm processor, and the low power features that achieve longer battery life and leave more power available for the user to drive, play and learn," says Jeff Wiencrot, Director of Firmware & Hardware at Sphero.



Smart City

# Toyota to build prototype city of the future

Multinational giant Toyota has revealed plans to build a prototype smart city of the future on a 708,000 square meter site at the base of Mount Fuji in Japan. Called the Woven City, the establishment will be a fully connected ecosystem powered by hydrogen fuel cells.

Envisioned as a 'living laboratory', the Woven City will serve as a home to full time residents and researchers who will be able to test and develop technologies such as autonomy, robotics, personal mobility, smart homes and artificial intelligence (AI) in a real world environment. Residences will be equipped with the latest in human support technologies.

"Building a complete city from the ground up, even on a small scale like this, is a unique opportunity to develop future technologies," says Akio Toyoda, President, Toyota Motor Corporation. "With people, buildings and vehicles all connected and communicating with each other through data and sensors, we will be able to test connected AI technology ... in both the virtual and the physical realms ... maximizing its potential."

Toyota says it will extend an open invitation to collaborate with other commercial and academic partners and invite interested scientists and researchers from around the world to visit the establishment and work on their own projects in this one-of-a-kind, real world incubator.

For the design of Woven City, Toyota has commissioned Danish architect, Bjarke Ingels.

# Nordic launches nRF52820 Bluetooth 5.2 SoC

Nordic Semiconductor has unveiled the nRF52820 Bluetooth 5.2 SoC, an addition to the lower-end of the company's nRF52 Series. The SoC is a Bluetooth LE, Bluetooth mesh, Thread, Zigbee and 2.4 GHz proprietary wireless solution.

The SoC is capable of all the features of Bluetooth 5, 5.1 and 5.2 including Long Range and high throughput 2 Mbps, Direction Finding, LE Power Control and LE Isochronous Channels. The SoC also includes a USB 2.0 interface.

The chip has a powerful 64-MHz 32-bit Arm Cortex M4 processor and includes 256 KB Flash and 32 KB RAM making it a single-chip option for commercial and industrial applications including asset tracking, HIDs and gaming products.

The nRF52820 is also qualified for operation across an extended industrial temperature range of -40 to 105°C, making it ideal for professional lighting applications. Full Speed (12 Mbps) USB operation is a key feature of the nRF52820. USB is a popular interface that enables communication with a range of host devices such as PCs. USB connectivity also makes device firmware updates-over-USB practical.

News Extra

# Bluetooth SIG heralds next generation of wireless audio

**LE Audio promises high quality streaming stereo and new audio features. Nordic's evaluation platform enables designers to experiment ahead of the spec's release later in 2020**

Audio is by far Bluetooth tech's most lucrative sector with around a billion products shipped last year. Today's technology is based on Classic Audio and while offering good audio performance does have some technical limitations which restrict its applications. The Bluetooth SIG intends to address these limitations with a new version of Bluetooth audio called LE Audio, which, as the name suggests will be based on Bluetooth LE. The Bluetooth SIG says the technology is "the next generation of Bluetooth audio".

LE Audio will support development of the same audio products and use cases as Classic Audio while enhancing wireless audio performance, adding support for hearing aids and enabling 'Audio Sharing' – an entirely new use case.

Key to improved audio clarity is the Low Complexity Communication Codec (LC3). Providing high quality even at low data rates, LC3 also enables design trade-offs between audio quality and power consumption.

## Enabling new use cases

LE Audio introduces 'Multi-Stream Audio' which facilitates the transmission of multiple, independent, synchronized audio streams between an audio source device and multiple audio sinks, overcoming a major drawback of Classic Audio. (*See this issue pg14.*)

Other advantages of the technology include support for the development of Bluetooth hearing aids and 'Broadcast Audio,' enabling an audio source to broadcast one or more audio streams to an unlimited number of sink devices. Broadcast Audio will support the new use case of 'Audio Sharing' which can be personal or location based. The Bluetooth SIG explains that with personal Audio Sharing, people will be able to share their Bluetooth audio experience with others around them; for example, sharing music from a smartphone with family and friends. With location based Audio Sharing, public venues such as airports, bars, gyms, cinemas, and conference centers could, for example, share Bluetooth audio that augmented the visitor experience.

As part of the announcement of the planned specification, the Bluetooth SIG also promoted the hearing support use case noting that LE Audio specifically adds provision for hearing aids. "LE Audio will enable the development of Bluetooth hearing aids that bring all the benefits of Bluetooth audio to the growing number of people with hearing loss," the organization noted in a statement.

The full specification for LE Audio is due for release by the Bluetooth SIG later in 2020.


> The LE Audio Evaluation Platform extends battery life by around 40 percent compared to today's off-the-shelf Bluetooth Classic audio solutions

**Tech Check**

Nordic's LE Audio evaluation platform comprises a reference design based on the nRF52832 SoC, Cirrus Logic's CS47L35 smart codec with an low power Audio DSP and Packetcraft's Bluetooth LE host stack and link layer supporting LE Audio

Nordic's LE Audio Evaluation Platform demonstrates the benefits of LE Audio while also supporting the forthcoming LE Audio specification

In parallel with the Bluetooth SIG's announcement, Nordic Semiconductor, in partnership with San Diego-based Bluetooth LE protocol stack developer, Packetcraft, launched an LE Audio Evaluation Platform. The product demonstrates the benefits of LE Audio while also supporting the forthcoming LE Audio specification.

The LE Audio Evaluation Platform enables engineers to take advantage of the superior quality, power and use-case enhancements of LE Audio using Nordic's mature hardware, software and development tools. The platform allows developers to start evaluating LE Audio products such as wireless speakers, over-the-ear headphones, and true wireless 'earbuds'.

The platform can operate as either an audio source or sink. A pair of devices (one acting as a source and the other as a sink) is required for a complete LE Audio link. The platform also features audio IC leader Cirrus Logic's SoundClear for uplink noise reduction and echo cancellation, and playback enhancement. An acoustic connector for up to six microphones or two speakers, a 3.5-mm headset jack, a 3.5-mm source jack, and a USB connector for charging, debug and acoustic tuning are included.

"Nordic's class-leading nRF52 and nRF53 Series SoCs are an ideal wireless foundation for an LE Audio solution. By also featuring Cirrus Logic's CS47L35 smart codec we are ensuring the platform also meets the highest possible audio performance criteria," explains Kjetil Holstad, Director of Product Management at Nordic. When wirelessly streaming audio from a source device to (sink) earbuds, the LE Audio Evaluation Platform extends battery life by around 40 percent compared to today's off-the-shelf Bluetooth Classic audio solutions.

Nordic has further plans for Bluetooth audio: "[Conventional] Bluetooth audio provides a satisfactory wireless sound, but LE Audio offers significant enhancements. It is destined to be an exciting new sector and Nordic plans to play a key role through the supply of leading LE Audio solutions," says Holstad. "The launch of the LE Audio evaluation platform is just the first step on this journey."

Connected Health

# Smart toothbrushes promote improved global oral hygiene

**With half the world affected by tooth decay and gum disease, affordable connected oral care products can help millions of people bite back**

> The majority of people worldwide, even in North America, still use manual toothbrushes, and the fact is the average user simply does not brush well

Oral hygiene is a worldwide concern. The Global Burden of Disease Study 2016 estimated that 50 percent of the world's population (approximately 3.58 billion people at the time of research) is affected by oral disease. Dental caries (commonly known as tooth decay) is the most prevalent condition, with around 2.4 billion people suffering from caries of permanent teeth. In the U.S. alone, more than 80 percent of people have had at least one cavity by the age of 34, while over 47 percent of adults aged 30 and above have mild, moderate or severe gum disease, according to the Centers for Disease Control and Prevention (CDC). It would appear the global community has neither the know-how nor the capability and resources to look after its teeth and gums effectively.

The overall health implications of poor oral hygiene, compounded by inadequate exposure to fluoride through sources of treated drinking water, are serious. Oral diseases are the most common noncommunicable diseases and they can impact people for life. Gum disease, for example, affects the gum tissue and bone supporting the teeth and if left untreated can lead to tooth loss that limits diet. But worse, research has also linked it to other chronic ailments like diabetes and cardiovascular disease.

However, recognizing the challenges is one thing, coming up with long term solutions is quite another. Brushing one's teeth twice a day, for at least two minutes each time, is considered a minimum requirement. Regular flossing is also highly recommended. But while this sounds simple, in practice it's more complex; brushing and flossing must be done properly or the effects are limited.

Colgate, the global oral hygiene giant, has conducted research which indicates most users miss over 40 percent of plaque surfaces when brushing. If left untreated, plaque build-up can eventually cause tooth decay and tooth loss. Closing this concerning gap in brushing effectiveness largely relies on increasing the population's awareness of their own brushing habits and mistakes.

"The majority of people worldwide, even in North America, still use manual toothbrushes and the fact is the average user simply does not brush well," explains Derek Gordon, Colgate's Head of Global Toothbrush Division.

## Connected oral care

Thankfully, it's not all doom and dentures. Wireless tech is able to provide quality feedback and guidance on brushing technique and its results. Smart toothbrushes and smartphone apps using connected technologies can enhance the ability to take care of dental hygiene by providing an unprecedented level of insight into individual cleaning 'zones' brushing patterns and more. For example, Colgate recently launched the advanced Colgate Smart Electric Toothbrush, a connected brush that uses smart sensors to map a user's mouth and show in real time how well the user is brushing across 16 zones (instead of the market-standard eight). The data is sent to the Colgate Connect app on the user's smartphone via Nordic technology. The app then displays and stores all the brushing events, and offers tailored information and advice so the user can track and improve their brushing behavior to eventually reach dentists' recommendations.

"What's critical about this brush is the coaching capability that comes along with it, so in real time you can see where the toothbrush is in your mouth," says Gordon.

Wider research shows sonic-vibrating electric brushes like the Colgate Smart Electric Toothbrush generally produce better short and long term outcomes than manual brushing. However, it's the power of wireless connectivity that ultimately gives these devices their edge.

### Need to Know

In part, the WHO defines oral wellbeing as: "Being free from periodontal (gum) disease, tooth decay, tooth loss and other diseases and disorders that limit an individual's capacity in biting and chewing." The organization says, "Oral care demands are beyond the capacities of the healthcare systems in most low and middle income countries."

## Democratizing dental hygiene

The oral health challenge is made harder by the high cost of dental care, which accounts for "20 per cent of out-of-pocket health expenditure in most high-income countries," according to the World Health Organization (WHO). That prohibits many people from the opportunity to practice good habits that help prevent oral health deterioration. Even in the Western sphere, socioeconomic status and other factors contribute to exclusion from essential dental services, a lack of oral hygiene education and reduced access to the latest oral hygiene products. That means affordable preventative solutions can make a difference. And affordable connected oral care devices will have the biggest impact of all. Such potential is encouraging leading companies in oral hygiene to 'democratize' their products by pricing them affordably. Colgate, for example, says the Colgate Electronic Toothbrush is accessible for the majority of consumers who are currently using manual toothbrushes.

According to Gordon, the product was launched to "address the inequality" of there being no "affordable" connected toothbrush which teaches how to brush teeth via precision brush coaching on a smartphone app. It also amounts to big business: "The fastest growing part of the toothbrush market right now is electric toothbrushes and connected health platforms," Gordon explains.

"It's not often that a semiconductor company helps enable a product that could genuinely help improve the lives of millions of people worldwide, but this is one of those products," adds Geir Langeland, Nordic Semiconductor's Director of Sales & Marketing.

Competitive solutions are likely to follow Colgate's lead as the oral technology sector gathers steam. Industry analyst Research and Markets predicts the global oral care/hygiene market will reach $53.3 billion by 2025 from $44.5 billion in 2019. Advanced digital technologies are bound to play their part, and high-powered toothbrushes and brush coaching platforms are already enabling smarter cleaning.



Comment

**Kristian Sæther**
*Product Manager for Cellular IoT*

# 2020 will be the year cellular IoT comes of age

**After a long wait, commercial 4G LTE-M and NB-IoT solutions are hitting the mainstream**

At the start of 2019 the only thing operating on cellular networks were cellphones and a few hundred million 2G-based devices such as security alarms (where cellular was used as a last line of communication).

But now, in early 2020, the networks support battery powered security alarms, herding animal trackers, industrial grade asset trackers and environmental sensors, to name but a few. The list grows continuously. By this time next year, I predict it will be difficult to list all the new cellular IoT products and applications on a single page.

What's changed in the last 12 months? The answer is the large-scale rollout of the new IoT-targeted LPWAN version of cellular wireless technology called LTE-M and NB-IoT. Although a long-time in the making (the specification was included in Release 13 of the 3rd Generation Partnership Project (3GPP) cellular wireless technology standard as far back as 2015), this power-optimized version of cellular has now emerged.

The five-year gestation of the spec has allowed development teams such as Nordic's to ensure that LTE-M and NB-IoT products offer the same legendary reliability and security of conventional cellular, but, unlike the 2G modems of old, with power consumption that supports multiyear operation from small batteries.

## Power optimization

But that doesn't mean all LTE-M and NB-IoT products are equal; while chipsets must conform to the same standard, some perform markedly better than others. The main differences are down to design — while the majority of commercial cellular IoT chipsets are redesigns from higher category LTE modems, Nordic uniquely designed its cellular IoT chipset from the ground up. The resulting product, the nRF9160 SiP—with integrated LTE-M/NB-IoT modem and GPS—is optimized for the lowest power consumption cellular IoT operation. Together with impressive RF performance, this is why an ever-growing list of customers (over 300 have worked with samples to date) are designing the nRF9160 SiP into their cellular IoT products and applications.

Cellular IoT allows almost anything to connect to the world's mature cellular networks without recourse to a complex gateway. For the Industrial IoT (IIoT), for example, cellular IoT enables monitoring of location and condition of things like shipping containers (*see WQ Spring 2019 pg14*) and key industrial assets like vehicles and machinery. Cellular IoT has also made healthcare more accessible by making it simpler for patients to use digital health services by eliminating gateways.

Cellular IoT is based on a specification that will evolve over time. Significant upgrades are likely to come in the releases designed to cater for 5G. However, the current commercialized 4G versions of LTE-M and NB-IoT are more than capable of meeting the demands of the first wave of cellular IoT applications. That's why I predict 2020 will be the year that cellular IoT hits the mainstream.

Asset tracking solutions are early adopters of cellular IoT technology

# Ahead of the Game

Sports equipment that tracks individual performance is changing the game for athletes and coaches

**In Short**

Athletes and coaches are looking to find an advantage in the way they practice and prepare for matches

Wireless sensors incorporated into sports equipment provide comprehensive data-driven training solutions

'Smart' sports equipment including bats, balls, boots and pucks can now track individual skills and techniques, analyze performance metrics and deliver digital coaching tips

In baseball, cricket, skiing, ice hockey and other sports, leading equipment manufacturers are relying on wireless tech to make these solutions commercially viable

Coaches often say that 'practice makes perfect' and 'you play the way you train'. In the aspirational world of sport, these mantras promote an ideal of what it takes to be successful. The message from trainers to competitors is clear – reaching your full potential takes 100 percent commitment and attention to detail, 100 percent of the time. While games aren't played every day, good preparation never takes a break.

Yet until recently the process of continually analyzing skills and techniques in order to track improvements could be described as hit and miss. From relying on empirical evidence and putting faith in what a coach sees with their own eyes, to scrutinizing video footage and eventually monitoring individual physiology and movement using sensor-based wearables, the widely available methods have either lacked a scientific foundation or had limited scope for providing valuable in-depth data.

In the past few years, however, the game has started to change. Wireless technology is now being incorporated into sports equipment, adding new dimensions to coaching and performance analysis at all levels of sport from junior and amateur participation to professional leagues. It has suddenly become possible to track, generate, review and learn from comprehensive data based on the precise location and movement of equipment and accessories in action. Whether it's a bat, ball, boot, puck or anything else used to play sport or engage in physical activity, it can be designed to provide a wide range of advanced custom metrics that help boost performance. And all without compromising the natural characteristics and behaviors of the end product.

Wireless performance tracking solutions in sports equipment provide a constant flow of actionable feedback, allowing players to enhance one aspect of their game without it detracting from another. What's more, tracking genuine progress helps athletes stay motivated to continue to push themselves.

This evolution in the sports market matters more than you might think. An athlete can hone skills for hours a day, a coach can implement the most challenging drills, but no amount of effort will lead to meaningful progress if the individual is practicing in a suboptimal manner. Reinforcing bad habits is naturally counterproductive.

When it comes to athletic development and the endless pursuit of perfection, information is most definitely power. And the latest sports tracking technology is able to serve up more powerful information, more efficiently and to more people than ever before. Tailored data-driven training is the future. In other words, only perfect practice makes perfect.

## BAT AND BALL SKILLS

Commercial solutions are increasingly emerging to capitalize on these capabilities in different sports around the world. For example, sports technology startup, F5 Sports, has developed a Bluetooth LE-enabled smart baseball to help pitchers and coaches at any level of the sport. The pitchLogic system uses proprietary algorithms employing 15 channels of built-in sensor data to provide a set of 12 key body movement and pitch performance metrics after each individual throw. These metrics include ball spin rates, acceleration rates, launch angles and braking force. Thanks to Bluetooth LE connectivity, users can instantly access this information through a partner app on a paired smartphone, tablet or laptop, allowing the baseball pitcher to combine their muscle memory with actual data.

The pitchLogic platform "helps players improve their game while reducing the number of practice pitches," says David Rankin, CEO of F5 Sports. "Because the information is available within a second of each pitch, the very next pitch can be an improvement. This helps a player practice efficiently with measurable progress in each session and less time spent practicing the wrong way."

Australia-based sports technology startup, Sportcor, is doing something similar. The Sportcor Smartball is an embedded sensor using an inertial movement system comprising two accelerometers, a gyroscope and a magnetometer, along with proprietary Cloud based algorithms, to track movement data such as ball speed and spin rate. Like the pitchLogic baseball, the Sportcor Smartball delivers a variety of useful information and analytics about the precise behavior of the ball to a smartphone or tablet app via a Nordic SoC-enabled Bluetooth LE link.

The first commercial application of the product is a smart cricket ball developed by Sportcor in partnership with leading cricket equipment manufacturer, Kookaburra Sports. The two companies hope the ball will be adopted by cricket players, coaches, teams, leagues and broadcasters around the world for a multitude of purposes including infotainment and engagement. The amateur and elite bowlers alike will benefit from deeper performance analytics and will be able to experiment with different wrist positions, release points and delivery 'actions' to discover what works best.

> Tracking genuine progress helps athletes stay motivated to continue to push themselves

Developed by Australia-based Sportcor, the Sportcor Smartball, featuring Nordic's nRF52840 SoC, is an embedded sensor for tracking movement data from a cricket ball

Cricket is a game of ball against bat, and India-based sports technology company, StanceBeam, has also teamed up with Kookaburra Sports to develop a cricket bat sensor for both recreational and professional cricketers. Known as StanceBeam Striker, the device attaches to any cricket bat handle and uses its integrated sensors to capture the motion of the bat in action and record 360-degree batting performance data analytics in real time. The product then provides live analysis of the player's batting technique and performance through the associated StanceBeam app. Metrics include backlift and downswing angle, speed at impact and 'shot efficiency' (a comparison between the maximum speed of the swing and the speed at impact with the ball). Using the companion app as a 'virtual coach', the player can easily review each shot ball by ball, recreate and analyze each shot in 3D, and access tailored drills to improve along the way. Users can also conduct a post-session review, produce a summary report and even compare their results against peers or elite players.

StanceBeam Striker is ready for use in a competitive cricket match, where batters rely on their 'timing' and power to launch the ball over the boundary for six runs, particularly in the shortest format of the sport, Twenty20

**Cover Feature:** Sports & Fitness

cricket. Cricket is adored and played by millions of people across the Indian subcontinent, Europe, Africa and Australasia, so it's not hard to imagine a future where smart balls and bats form part of a typical cricket kit.

## WIRELESS WINTER SPORTS

Wireless tech is also being used to expand the provision of metrics for winter sports enthusiasts who want to review their own skills and techniques on the slopes. Austrian ski equipment manufacturer, Atomic, in consultation with biomechanics experts, developed Hawx Connected, a Bluetooth LE ski boot and smartphone app that performs the role of a skier's 'digital coach' and training log. The platform provides direct feedback and analysis of each individual ski run or session.

Based on sister company Suunto's Movesense motion sensing platform, Hawx Connected features various embedded sensors to measure pressure at key contact points inside the boot liner and simultaneously detect turns and ski edge angles through the orientation of the boot. Once the ski boot transmits the Movesense data via Bluetooth LE to a paired smartphone, the user can instantly access all the insights through the Atomic CTD app. Any errors made on one run down the mountain can be rectified on the next, or discussed in detail back at the ski lodge. As the company itself explains, the focus has shifted from being a: "ski equipment manufacturer to a skiing experience provider".

From the snow to the ice, direction finding technology from Quuppa has helped software company Bitwise monetize its commercial package, Wisehockey—a player and puck tracking system—for monitoring professional games in the Finnish domestic ice hockey league, Liiga. Quuppa's Intelligent Locating System is based on Bluetooth LE and accurately tracks the position of fast moving objects, in this case individual players and a puck, enabling the Wisehockey platform to generate a wide array of data including time in possession of the puck, maximum speed and passing accuracy. The system works by locators around the arena receiving Bluetooth LE signals transmitted from tags in the puck. The positional data is then uploaded to a server and can be viewed by subscribers using a mobile app. Since custom information can be made available in seconds, this technology could one day be used by ice hockey teams and coaches to: "enhance tactics, training and performance on the ice," according to Fabio Belloni, Chief Customer Officer at Quuppa. The tech could also be applied to other team sports like soccer, rugby and basketball.

> "For such innovations to be commercially viable, they must be able to function effectively in match conditions and behave identically to the conventional equipment used in a sport

The Bluetooth LE wireless connectivity of Austria-based Atomic's Hawx Connected ski boot provides users with direct sensory feedback while skiing

## COMMERCIAL VIABILITY

For such innovations to be commercially viable, they must be able to function effectively in match conditions and behave identically to the conventional equipment used in a sport. To achieve this goal, developers need the support of compact wireless technologies. The low power consumption provided by wireless protocols like Bluetooth LE allow for smaller batteries, so devices can be built with more compact form factors and integrated seamlessly into a range of specialized end products that will stand the test of time and frequent usage. Moreover, advanced low power wireless connectivity solutions, such as Nordic SoCs and their powerful processors, are able to support the complex applications running computationally intensive—and therefore power hungry—movement tracking, signal processing or direction finding algorithms. Generating useful data is one thing, but ensuring that data is readily available through low latency equipment-to-smartphone connectivity, over a decent range and for a reasonable amount of time before recharge, is the domain of Bluetooth LE wireless technology.

The pitchLogic baseball, for example, uses a rechargeable 40 mAH battery that currently achieves three hours of active use and 10 days of standby time before wireless recharge using Qi, a wireless charging standard that eliminates the need for a micro USB interface in the baseball. The Hawx Connected ski boot employs a Li-Poly battery that provides up to four-and-a-half days of operation in typical usage between recharge. This extended battery life is a major value-add for highly active skiers who spend long days on the ski fields, with performance data continuing to be recorded for as long as the ski boot maintains power.

For the Sportcor Smartball, developers placed a strong emphasis not only on battery life, but on the product's ability to keep working for as long as the ball itself remains useable. After all, the average wireless device isn't necessarily built to absorb a constant barrage of blows from a heavy bat.

"What we supply is a core that replaces the traditional core of a cricket ball. This includes the protective housing for the electronics to make sure they survive the impact of day-to-day use," explains Ben Tattersfield, Founder of Sportcor. "Power management was crucial as we had to get a good life out of the Sportcor Smartball while also maintaining the smallest possible form factor and light weight to ensure we didn't upset the characteristics of the end product, the cricket ball."

What impact could these types of technologies have on the overall sports tracking and performance market moving forward? "Athlete engagement is the exciting part, in particular across the junior to intermediate levels of sport," suggests Tattersfield. "Features that were only available to professionals are now available to almost everyone, including coaches in amateur and junior leagues."

There is virtually no limit to the potential of placing wireless tech and sensors inside modern sports equipment. As further advancements are made in training, development and coaching methods at all levels of sport, innovators need only strike the right balance between providing useful data and successfully monetizing and democratizing their solutions. As such a new mantra, one fittingly borrowed from the worlds of business and technology, has emerged around the global sporting traps: work smarter, not harder. Thanks to wireless tech, perfect practice could soon be standard practice.

NC-based F5 Sports' pitchLogic system, a Bluetooth LE-enabled baseball, employs Nordic's nRF52840 SoC to run complex algorithms and wirelessly sync pitching data and analysis to a smartphone partner app

## The '10,000-hour rule': Merit or myth?

How much dedicated practice is required to attain 'expert' status in a particular field? This question has led to considerable debate since a study by K. Anders Ericsson was popularized by a book called *Outliers*, published in 2008, in which author Malcolm Gladwell claims that becoming truly elite at something requires a commitment of 10,000 hours. The so-called 10,000-hour rule has been loosely applied to explain the remarkable achievements of people like Tiger Woods, Bill Gates, the Beatles and other greats in the worlds of sport, science and technology, and music and the arts.

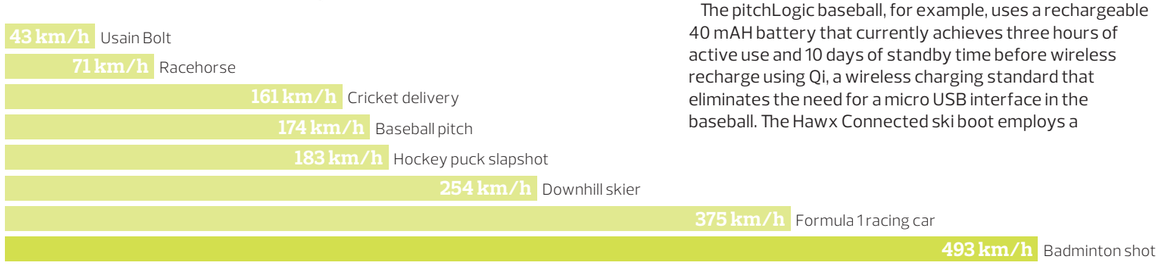
Yet a number of thought leaders have attempted to debunk this theory by countering that multiple factors probably contribute to reaching such a high level of success. One famous opponent is American entrepreneur, educational activist and author of best selling self-help book *The 4-Hour Workweek*, Tim Ferriss, who claims that an individual can actually become 'world-class' (among the top five percent in a given field) within six months - compared to the 10 years of 20 hours per week it would take to hit the 10,000-hour mark. Among his list of arguments, Ferriss asserts: "training method can have an exponential impact on per-hour yield," while: "it's nearly impossible to show cause and effect with observational (versus experimental) data". Even if every top athlete has predictably trained for 10,000 hours in their lifetime, does 10,000 hours of training guarantee a top athlete?

According to Ferriss and others, accomplishments are ultimately determined by individual abilities, the nature of the practice itself, the learning tools available and yes, to some extent the time spent practicing or studying. Essentially, quality beats quantity.

With this in mind, could the strategic use of certain technologies potentially help circumvent the 10,000-hour rule entirely? Moreover, what impact might wireless tech-based solutions have on future sports practice? If 'smart' equipment including bats and balls continue to evolve into effective and affordable digital coaching assets, perhaps the performance levels of countless athletes around the globe will soar to greater heights in significantly less time.

**State of Play**

### Top speeds in sport – how they compare




**Need to Know**

According to analyst Grand View Research, the size of the global sports technology market—comprising devices, smart stadiums, analytics and statistics, and e-sports—was valued at $9.8 billion in 2018, and is estimated to register a CAGR of 20.3 percent over a forecast period up to 2025

# Unwired for Sound

LE Audio promises enhanced audio quality, novel new features and extended battery life for Bluetooth wireless sound

Back in the mid 1990s, Ericsson engineers Sven Mattisson and Jaap Haartsen looked at the tangle of wires linking devices on their desks and wondered whether there was a better way to transfer digital information. After years of hard work their solution replaced traditional RS-232 cables with 2.4-GHz wireless connectivity, and with it our world started to change.

Mattisson and Haartsen's employers coaxed other companies, including Nokia, IBM and Toshiba, to join the initiative, which soon became an open standard. By 1998, these companies had formed the Bluetooth Special Interest Group (SIG), an organization tasked with developing and promoting the wireless technology.

The first consumer Bluetooth product—a hands-free mobile headset—hit the shelves in 1999. Soon after a host of commercial Bluetooth equipped devices were released, including a mobile phone (the Sony Ericsson T36), mice, keyboards, printers and hands-free car kits. By 2003, product shipments had grown to one million per week.

But it was that first product, relaying voice from handset to headset, that pointed the way to the technology's leading success. This was of little surprise to insiders because Ericsson had originally encouraged the standard's development due to its potential for connecting peripheral devices—primarily headsets—to mobiles. And among the first 'profiles' (software that customizes the Bluetooth protocol stack to optimize it for a particular application) adopted was one for wireless voice and headsets.

But growth into higher-end audio applications stalled because Bluetooth tech's 1 Mbps maximum raw data throughput (which diminishes to around 721 kbps in practice because of the intentional transmission delays built into the protocol during operation) proved insufficient to support streaming audio. Things changed as Bluetooth tech rapidly made its way into virtually every smartphone on the planet and music consumption underwent a parallel revolution with the invention and development of the MPEG-1 or MPEG-2 Audio Layer 3 ('MP3') compression format.

### In Short

Bluetooth wireless headsets for transmitting voice were one of the early applications for the technology

The development of the MP3 compression format increased consumer demand for digital audio

An advanced audio profile and commercial codecs underpinned the Bluetooth audio streaming headphone sector but sound quality remained moderate

LE Audio promises an optimized codec and isochronous channels to enhance sound quality, save power and introduce new features such as audio sharing

In response to consumer demand, the Bluetooth SIG introduced the Advanced Audio Distribution Profile (A2DP) which was accompanied by a codec that supported stereo audio streaming. Soon after, several commercial codecs brought further sound enhancements.

Today, Bluetooth audio is big business: "With close to one billion Bluetooth audio products shipped last year, wireless audio is the largest Bluetooth market," noted Mark Powell, CEO of the Bluetooth SIG, in a statement. Nonetheless, wired headphones and speakers are still the choice of many because Bluetooth streamed music still lacks CD-like quality, and the technology lacks flexibility such as the capability to stream to more than one device simultaneously.

But now, the announcement by the Bluetooth SIG of 'LE Audio' (*see this issue pg7*) promises to address these weaknesses. By switching from a Bluetooth Classic radio to a Bluetooth LE version, introducing a new optimized codec and adding new features to the Bluetooth protocol stack, the SIG is promising "the next generation of Bluetooth audio". Is the hype justified?

## MUSIC EVERYWHERE

In 1987, The Fraunhofer Institute in Germany began researching high quality, low bitrate audio coding. The aim was to come up with a method of compressing audio files such that they could be easily stored and moved between the bandwidth and memory constrained computers of the era. In early 1988, The Moving Picture Experts Group (MPEG) was established and later that year the group called for an industry wide audio-coding standard. Soon after, coding developed by Dieter Seitzer, who'd helped Fraunhofer with its research, was integrated into the MP3 standard, along with software from co-contributors. (See sidebar *The science of digital sound*.)

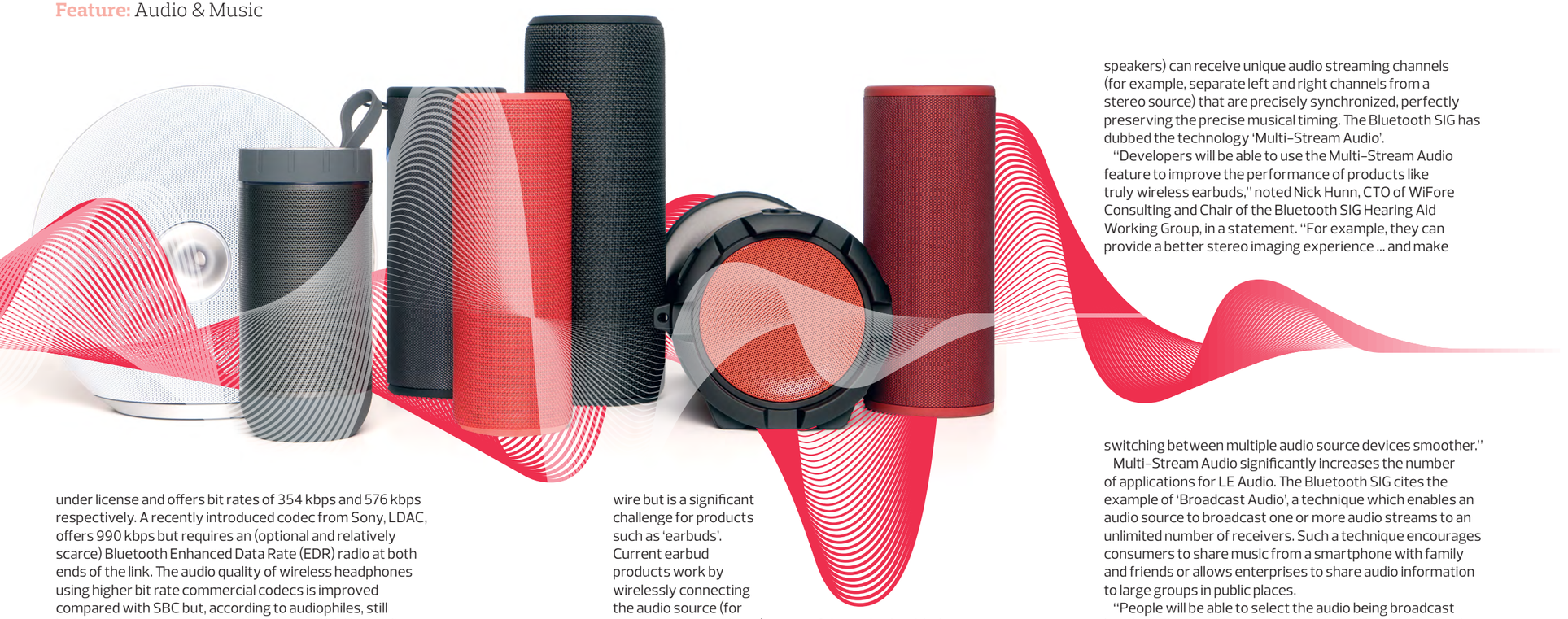
MP3 spawned a huge new business whereby tracks 'ripped' from purchased CDs could easily be shared across the Internet. Initially, music companies claimed this amounted to piracy, but the industry was legitimized by commercial offerings such as Apple's iTunes.

Early MP3 players were equipped with wired headphones, but even then, consumers craved the convenience of wireless. Later, as consumers migrated their MP3 libraries over to Bluetooth equipped smartphones, the Bluetooth SIG recognized the opportunity and pushed through A2DP. The profile defines how to unidirectionally transfer an audio stream in two-channel stereo, either to or from the Bluetooth host. This profile in turn relies on the Generic Audio/Video Distribution Profile (GAVDP).

> "With close to one billion Bluetooth audio products shipped last year, wireless audio is the largest Bluetooth market

However, even with MP3 compression and A2DP, streaming audio across a Bluetooth link is unreliable. Additional compression of the data by a codec is required so that it can be accommodated by the link's restricted throughput. The codec then decompresses the data on the other side of the link to retrieve the audio information stored in the original MP3 file. To that end, the SIG included mandatory support within A2DP for a low-complexity subband codec (SBC) designed to ensure reasonable audio quality at low-to-medium bit rates while using modest processing power. However, while A2DP can theoretically support up to Bluetooth Classic's maximum operational 721 kbps, SBC is limited to a nominal maximum of 345 kbps. And in practice, bit rates using the codec are generally around 256 kbps, limiting audio quality.

A2DP does include optional support for codecs including Advanced Audio Coding (AAC), High-Efficiency AAC (HE-AAC) and Adaptive Transform Acoustic Coding (ATRAC). The profile can also be extended to support manufacturer-defined codecs, such as the Qualcomm-owned aptX and aptX-HD which is available to wireless headphone makers



under license and offers bit rates of 354 kbps and 576 kbps respectively. A recently introduced codec from Sony, LDAC, offers 990 kbps but requires an (optional and relatively scarce) Bluetooth Enhanced Data Rate (EDR) radio at both ends of the link. The audio quality of wireless headphones using higher bit rate commercial codecs is improved compared with SBC but, according to audiophiles, still lacks the dynamic range, depth, timbre and lifelike quality of wired headphones.

## HEAR THE QUALITY

Despite these concerns, Bluetooth audio headphone sales are thriving. Analyst statista noted that 2017 shipments of the products reached 140 million units, compared to around 67 million shipments of the next biggest Bluetooth sector, wearables. Wireless speakers do well too; however, the growth of Bluetooth audio in other applications has been curbed because of technical limitations.

Chief among these is that the technology can only stream audio to a single device. That's not a problem for wireless headphones or speakers where each side is connected by a wire but is a significant challenge for products such as 'earbuds'. Current earbud products work by wirelessly connecting the audio source (for example, a smartphone) to one of the earbuds with the target earbud then employing clever software to wirelessly relay information to its partner. The system works, but it requires significant processing power to keep everything in sync, adding cost and compromising battery life.

The Bluetooth SIG promises LE Audio will resolve these technical challenges—while giving audio quality a further boost—through the introduction of 'LE Isochronous communication'. In part, the quality boost will come from a codec to replace SBC. In addition to enhancing the audio experience, the Low Complexity Communication Codec (LC3) is specifically designed to save battery power.

According to Manfred Lutzky, Head of Audio for Communications at Fraunhofer IIS, LC3 offers great promise. "Extensive listening tests have shown that LC3 will provide improvements in audio quality over SBC included with [Bluetooth] Classic Audio, even at a 50 per cent lower bit rate," he said in a statement. Combined with the Bluetooth LE radio's inherent lower power consumption compared with Bluetooth Classic, the lower throughput afforded by LE Audio will have a significant impact on battery life. While no official figures are yet available, engineers estimate that batteries powering LE Audio should last at least 40 per cent longer than in an identical Bluetooth Classic audio application. That provides an opportunity to extend playback time or shrink earbud size by using smaller batteries while keeping playback time the same.

LE Isochronous communications (which makes use of the LE Isochronous Channels recently introduced as part of Bluetooth 5.2 (*see pg29*) works by transferring 'timebounded' data between devices. With this technology multiple devices (such as a pair of earbuds or stereo wireless speakers) can receive unique audio streaming channels (for example, separate left and right channels from a stereo source) that are precisely synchronized, perfectly preserving the precise musical timing. The Bluetooth SIG has dubbed the technology 'Multi-Stream Audio'.

"Developers will be able to use the Multi-Stream Audio feature to improve the performance of products like truly wireless earbuds," noted Nick Hunn, CTO of WiFore Consulting and Chair of the Bluetooth SIG Hearing Aid Working Group, in a statement. "For example, they can provide a better stereo imaging experience ... and make switching between multiple audio source devices smoother."

Multi-Stream Audio significantly increases the number of applications for LE Audio. The Bluetooth SIG cites the example of 'Broadcast Audio', a technique which enables an audio source to broadcast one or more audio streams to an unlimited number of receivers. Such a technique encourages consumers to share music from a smartphone with family and friends or allows enterprises to share audio information to large groups in public places.

"People will be able to select the audio being broadcast by silent TVs in public venues, and places like theaters and lecture halls will be able to share audio to assist visitors with hearing loss as well as provide audio in multiple languages," said Peter Liu of Bose Corporation and member of the Bluetooth SIG Board of Directors, in a statement.

## NEXT STEPS

Commercial LE Audio solutions are not available today. Instead, what the Bluetooth SIG announced early this year was its intention to release the full specification later in 2020.

"While the introduction of Bluetooth 5.2 brought the LE Isochronous Channels needed for LE Audio, work remains to be done on other important elements of the technology before we'll see commercial chips," explains Kjetil Holstad, Bluetooth chipmaker Nordic Semiconductor's Director of Product Management.

But that doesn't mean developers can't start thinking about new Bluetooth audio products. For example, Nordic Semiconductor has developed an evaluation platform that allows developers to start assessing the fledgling technology for next generation wireless speakers, over-the-ear headphones, and 'true' wireless earbuds.

"Developers keen to understand LE Audio's benefits over conventional Bluetooth audio can experiment with Nordic's LE Audio Evaluation Platform to gain knowledge that will accelerate the design of prototypes when the specification is finally adopted," says Holstad.

While chipmakers like Nordic are moving forward, commercial products like LE Audio headphones and wireless speakers are still several years from hitting the stores. But the message that the future of wireless audio will be based on Bluetooth LE comes over loud and clear. Crystal clear.

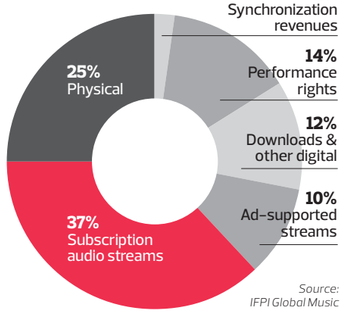
### Tech Check

Bluetooth 5.2 brings more than just LE Isochronous Channels to the technology. Other enhancements include LE Power Control which makes it possible for devices to dynamically optimize the transmission power used in communication between connected devices. Nordic's entire nRF52 and nRF53 Series (including the nRF5340 shown here) are Bluetooth 5.2 compatible


### State of Play

#### Global Recorded Music Revenues by Segment 2018

Digital music has revolutionized how we consume music. According to the IFPI Global Music Report 2019, streaming revenue in 2018 grew by 34 per cent and accounted for almost half of global revenue, driven by a 33 per cent increase in paid subscription streaming. The report says there were 255 million users of paid streaming services at the end of 2018 accounting for 37 per cent of music revenue. Growth in streaming more than offset a 10.1 per cent decline in revenue from 'physical' (CD and vinyl) sales




*Source: IFPI Global Music*

## The science of digital sound

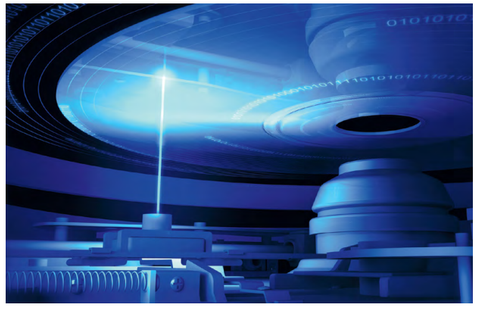
Humans experience sound through analog sensors. According to Steven W. Smith, Ph.D., in his book *The Scientist and Engineer's Guide to Digital Signal Processing*, the human ear is capable of detecting sound waves across a continuous frequency range of 20 Hz to 20 kHz. Smith says the separation of the two ears enables humans to detect the difference between two sound sources that are spaced as little as three degrees apart.

But while we use analog sensors to perceive sound, recording and reproduction is now almost exclusively done by digitizing audio signals. Digitizing is achieved by sampling the signal from a transducer—such as a microphone—to record both amplitude and temporal information about the sound waves. The sampling rate (Hz) and precision (bits) determines how much information from the original sound wave is retained and how well it can be reproduced.

The benchmark for digital audio reproduction is the CD. For CD-quality sound, the original signal is sampled at 44.1 kHz with 16-bit precision. 16-bit precision allows the amplitude of the signal to be subdivided across 216 (65,536) levels between the pre-determined maximum and minimum amplitudes. The resulting data output rate is 1.41 Mbps (44.1 kHz × 16 bits x 2 channels (l and r)). This level of digitization is sufficient to capture all the sounds humans are capable of hearing across the 20 kHz bandwidth of the ear.

Engineers can choose to trade off sampling rate and precision depending on the application. For example, voice-only systems can take advantage of the ear's particular sensitivity to sound with a frequency between 800 Hz and 4 kHz. This bandwidth of 3.2 kHz is sufficient to encompass 80 percent of information carried by the sound wave and more than adequate for the listener to understand speech. The reduction in this bandwidth requirement allows engineers to reduce the sampling rate to 8 kHz. Even with 16-bit precision such a sampling rate reduces the data output requirement to 128 kbps for accurate monoaural reproduction.

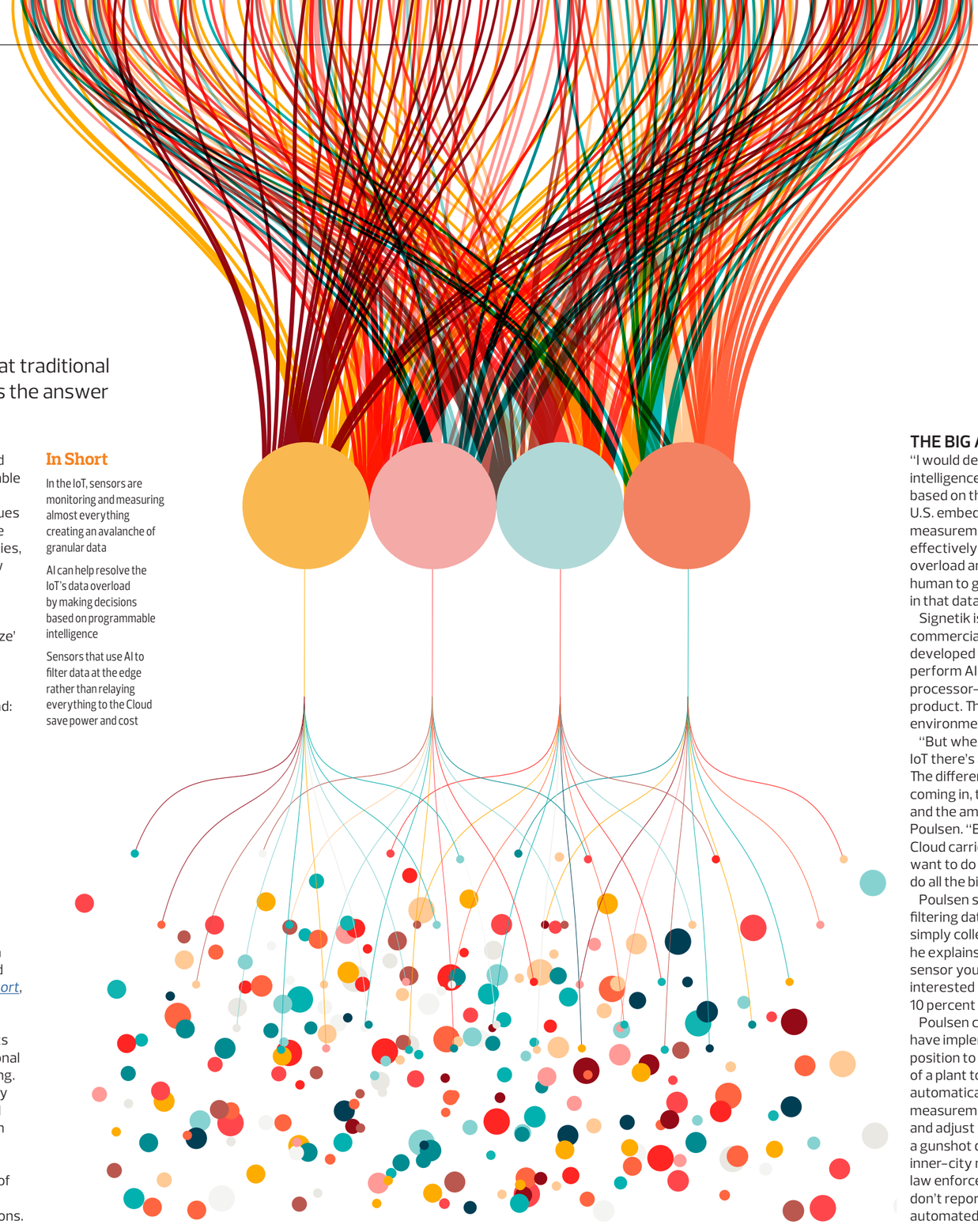
The sampling rate required for satisfactory stereo music streaming results in much larger files, too big for easy transfer and storage. Demand for quick downloads from the early Internet provided the catalyst for compression formats such as MP3. The format relies on 'perceptual coding' which is based on psychoacoustic models that permit the software to discard or reduce the precision of audio components that are less audible to human hearing, and therefore not essential for the brain to decipher the reproduced sound. MP3 compression is highly efficient. For example, an MP3 encoded at a constant bitrate of 128 kbps would result in a file approximately nine per cent the size of a CD quality recording of the same audio while still retaining an acceptable level of reproduction for playback.



Feature: Data Analytics

# The AI of Things

The IoT generates so much raw data that traditional analysis methods struggle to cope. AI is the answer



Tens of thousands of companies have recognized the power of the IoT to solve previously intractable problems and move towards new ways of optimizing their businesses. Momentum continues to build because once one company gains a competitive advantage by successfully implementing IoT technologies, its competitors or counterparts are compelled to follow suit or risk being left behind.

The sensors, processors and wireless technology building blocks of the IoT have made it technologically and commercially viable to monitor, measure and 'digitize' almost everything and anything generating a constant stream of fine grained data. The pay-offs from this 'big data' are boosts in efficiency, convenience, safety, security and cost savings; the downside is data overload: "The IoT comes with the unintended cost of producing more data than that we can cope with, we are drowning in an ever expanding sea of the stuff," says wireless IoT chipmaker Nordic Semiconductor's CTO, Svein-Egil Nielsen.

But AI offers a lifebelt and it's one the pioneering companies have grasped tightly. "I was presenting at an IoT conference recently," recalls Nielsen, "and what struck me was that I was the only presenter there *not* speaking about AI."

Nielsen's views are echoed by professional bodies. According to CB Insights, when the analyst recently ran a study aimed at finding "the 100 most promising AI startups in the world," it received applications from a staggering 5,000 AI startups spanning 13 countries and across 15 industries. And in its 2020 *Emerging Jobs Report*, professional networking organization, LinkedIn, stated that AI and data science roles are proliferating across nearly every single industry. (The organization suggests that when adopting IoT technology, AI is no longer optional and every company in the world will soon start recruiting. If you're just starting out and want a career with healthy employment prospects look no further.) But how will AI resolve the data overflow from the IoT? The answer is in every way. AI is so much an integral part of the IoT that the network is fast becoming the 'AI of Things'. But it is early days yet and while there are various flavors of AI of increasing sophistication (*see sidebar, Types of AI*) that promise much, today there are a few key implementations.

### In Short

In the IoT, sensors are monitoring and measuring almost everything creating an avalanche of granular data

AI can help resolve the IoT's data overload by making decisions based on programmable intelligence

Sensors that use AI to filter data at the edge rather than relaying everything to the Cloud save power and cost

### THE BIG AND SMALL OF AI

"I would define AI in the IoT as any programmable intelligence that takes in data and then makes a decision based on that data," explains Steve Poulsen, President of U.S. embedded design consultant, Signetik. "This allows measurements to be taken much more frequently and cost effectively because the AI reduces or eliminates the data overload and the IoT reduces or eliminates the need for a human to go out and do it. It also allows anomalies or trends in that data to be spotted more quickly and reliably."

Signetik is among the vanguard of companies commercializing the technology and has recently developed a cellular IoT platform called SigCell that can perform AI-powered analysis of data on Nordic's Arm M33 processor-equipped nRF9160 SiP multimode cellular IoT product. The edge-computing solution can perform full environmental sensing and Cloud connectivity.

"But when it comes to practical implementations for the IoT there's a big distinction between 'big AI' and 'small AI'. The difference is dictated by the complexity of the data coming in, the number of decisions being made on this data, and the amount of resultant data going out," continues Poulsen. "Because in the IoT most communication with the Cloud carries a cost and power consumption overhead, you want to do small [simple] AI locally as much as possible and do all the big [complex] AI in the Cloud."

Poulsen says that where small AI comes into its own is for filtering data at the edge. "If you put a sensor out there that simply collects data you will be collecting way too much," he explains. "But if you put a small AI capability into that sensor you can reduce the data down to only what you're interested in. In my experience, this is anywhere from 1 to 10 percent of what the sensor actually collects."

Poulsen cites examples of small AI that his customers have implemented include detecting a sheep or cow's head position to identify sick animals; measuring the 'greenness' of a plant to decide whether or not it needs watering; automatically identifying different types of weeds, and measurement of environmental data to predict occupancy and adjust energy usage. Signetik has even worked on a gunshot detection system designed for high crime inner-city neighborhoods that automatically alerts local law enforcement. Poulsen says that city inhabitants often don't report such incidents making the data generated by automated systems even more crucial to law enforcement.

### By the Numbers

## By 2023...

IoT will represent

**83%**

of the entire AI chipsets market

The global 'AI in embedded IoT devices' market will approach

**$26.2 billion**

The worldwide general AI market will reach

**$50.8 billion**

at 42 per cent CAGR

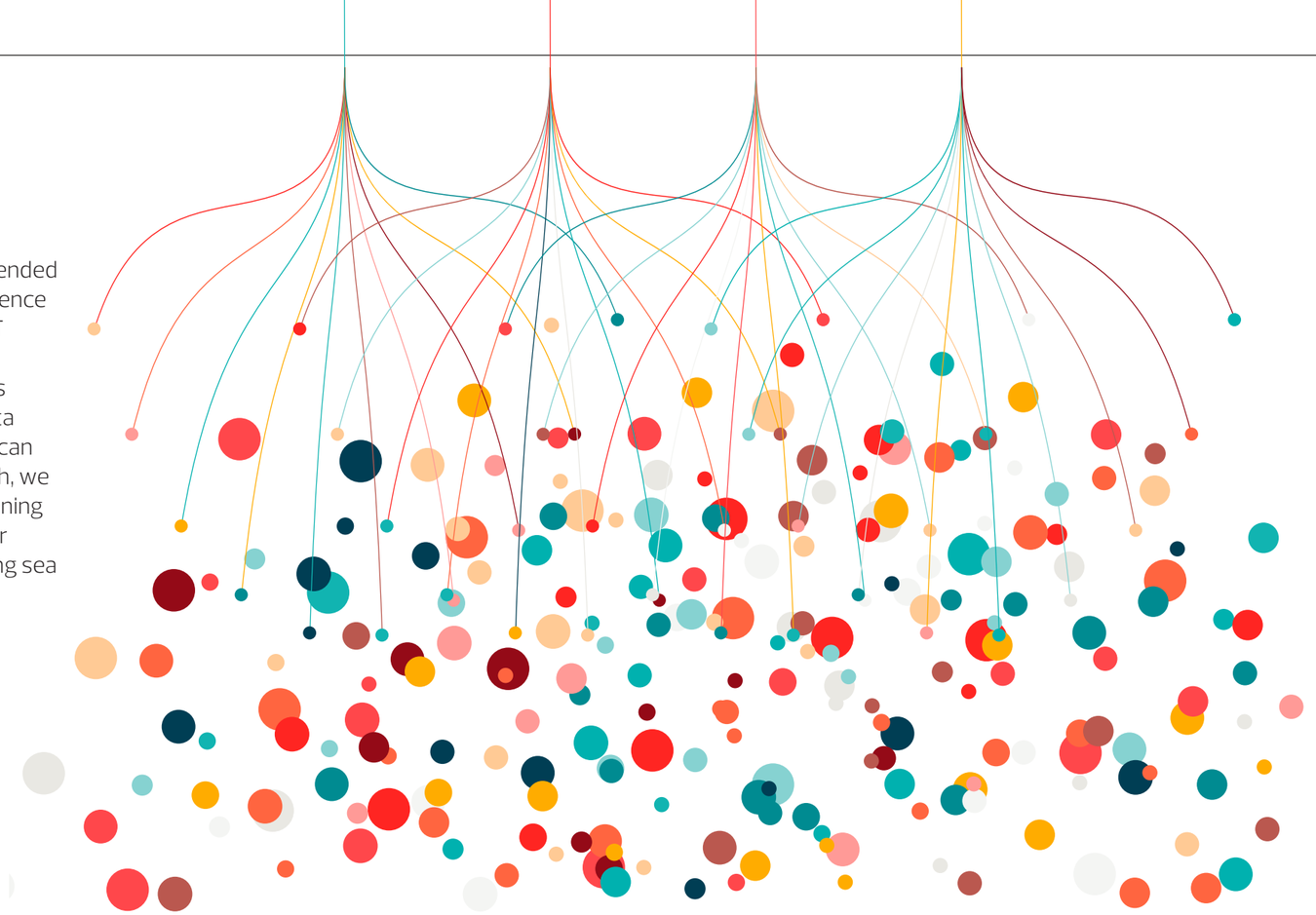
The AI-driven networking solution market is expected to reach

**$5.8 billion**

and over 50 per cent of enterprise organizations will leverage AI technology for networking

*Source: Research And Markets*

**Feature:** Data Analytics



"AI and the IoT go hand-in-hand because the IoT generates too much data for a human to reliably and quickly analyze," explains Poulsen. "At present we estimate around 20 percent of our customers use AI in their IoT applications, and based on current trends we see this rising to over 50 percent within the next few years. However, we've been working on IoT applications for over 20 years — long before it was called IoT.

"What's changed is the commercial viability of powerful but low-cost sensors and LPWAN wireless technologies as a means to collect data from them. The latter now includes cellular IoT for long-distance LPWAN gateway-free connectivity. And cellular IoT is by far the best LPWAN wireless technology out there today, and the one we plan to standardize upon moving forwards."

> An unintended consequence of the IoT is that it produces more data than we can cope with, we are drowning in an ever expanding sea of data

## AI FOR CONSTRAINED DEVICES

Another emerging use of AI in the IoT is where an advanced AI algorithm based on a neural network performs deep learning on particular activity such that it can be distilled in complexity and size to suit a battery-, memory- and processor-constrained IoT edge device.

"We helped develop a gesture-controlled wireless headphone demo shown at this year's CES [a giant U.S. electronics trade event] that employs 'virtual buttons' in the air," says Anders Hardebring, CEO and Co-Founder at edge-AI startup, Imagimob.

The company partnered with radar technology company, Acconeer, on the project. The system uses Acconeer's A111 Pulsed Coherent Radar (PCR) sensor. The A111 radar sensor is optimized for high precision millimeter-level distance ranging and physical detection and features a small footprint and ultra-low power consumption. Inside the headphones the A111 radar sensor is housed on a module called the XM122 IoT Module (that also incorporates Nordic's nRF52840 advanced Bluetooth LE SoC) and is claimed to be the world's first radar system that can run on a coin-cell battery.

"The goal for this project was to create a low power embedded application that could accurately classify five different hand gestures in real time using radar data, with one of the gestures being used to wake up the application," explains Hardebring.

"Gesture control may not seem like much, but to get to a level where the performance feels like it 'always works' requires extreme precision. This is why in this application radar was selected."

Hardebring explains that this level of precision also requires a lot of real time data collection and processing. "On a pair of battery powered headphones you wouldn't want to send this amount of data up to the Cloud in a million years," he says. The solution is to perform the processing locally so that the data doesn't have to be transmitted.

"We used an in-house developed AI neural network algorithm to study and learn how a diverse range of people gestured and to spot the subtle yet critical differences and similarities," explains Hardebring. "This resulted in a high accuracy headphone gesturing model that we then run through our company's flagship software."

### Tech Check

Gesture detection eliminates traditional touch controls or mechanical buttons. Unlike video or IR sensors, Acconeer's pulsed coherent radar does not require a lens and can therefore be hidden inside the end products such as headphones. Interaction is facilitated using fine gesture motions. Imagimob Gesture Detection runs on an Arm M4 processor or similar

That's impressive, but the really clever bit of Imagimob's technology is that the company can take a big AI model of any kind and turn it into highly-optimized software capable of running on a resource-constrained device such as a low power Arm Cortex M4 (the same device as the one used in the Acconeer module in the headphone application). For example, while today the application is gesture control, tomorrow it could be an air quality sensor powered by an Arm M-class processor designed to invoke congestion charging when it observes anomalous nitrogen oxide (a component of vehicle exhaust emissions) readings.

## THE HIDDEN REVOLUTION

"It's still the case that when you mention the IoT or AI most people see it as something futuristic and revolutionary, something that hasn't really started yet," says Nordic's CTO, Nielsen. "I couldn't disagree more strongly. I see the IoT and AI all around us in all kinds of applications that don't necessarily scream out for attention so are easy to miss.

"To me the IoT and AI are like standing on a giant platform that is slowly but steadily rising into the air such that it lifts everything and everyone but so subtly nobody notices.

Nielsen cites many examples, including speech and voice recognition, digital assistants, healthcare, logistics, transportation, utility metering, retail payments, lighting, industrial automation, sports and fitness, toys and gaming, VR and AR and automotive. "It's all being transformed by the IoT and AI right now," he says. Nielsen notes the example of his home city of Oslo—which was voted European Green Capital for 2019—that has smart garbage cans. These have sensors that can automatically detect when the bin is full which eliminates unnecessary visits from garbage trucks while optimizing collection routes so fewer kilometers are driven. The bins are emptied much more quickly when they are full too. "This cuts collections costs, cuts pollution, cuts the unpleasant smell and litter caused by over-full bins," notes Nielsen.

A further example of where the IoT and AI might soon go comes courtesy of trade magazine, *EE Times Asia*, which recently reported how a Taiwanese startup, OmniEyes, is applying a combination of computer vision and AI to the usually discarded footage collected from consumer dashboard cameras to automatically detect incidents of dangerous driving. Such information could be a boon for insurance companies which could then encourage safe drivers and punish risky ones.

## THIS IS ONLY THE START

"All we're hearing is data, data, data," said Steve McLaughlin, Dean of U.S. Georgia Tech's College of Engineering, in an *IEEE Spectrum* article. "Every company in every sector is essentially telling us, 'we're not an energy company, we're a data company now', 'we're no longer logistics [or] an automaker — we're a data firm'. That's what's taking up every bit of oxygen."

Every sign to the future is pointing the same way: The IoT is going to be the biggest source of data and it will generate mountains and mountains of it. For example, a recent forecast from International Data Corporation (IDC) estimated there will be 41.6 billion connected IoT devices, generating 79.4 zettabytes (ZB) of data by 2025. The industrial (and automotive) category will see the fastest data growth rates over the forecast period with a CAGR of 60 percent. AI is probably our only hope of making meaningful sense of it all.

Whether we one day add the 'IoT' or 'AI' revolutions to the industrial and computing ones remains to be seen. But the IoT and AI are such a natural fit that the AI of Things is already forming. And it's equally possible that the IoT, AI and big data may only be a part of a bigger technological revolution that's already happening and also making use of parallel technical advances in fields such as robotics, communications and genetics.

However this revolution develops, exciting—and in equal measure challenging—times are ahead.

### Tech Check

The Signetik SigCell platform uses the Nordic nRF9160 SiP's 64MHz Arm Cortex-M33 processor supported by 1MB of Flash and 256KB of RAM memory to perform sensor data acquisition, edge computing and basic AI data analysis

## Types of AI

AI is a comprehensive academic research area full of scientific terms for various features and functions. However, today there are three broad categories of AI (and even the most advanced of these is considered only the simplest form of what AI could one day become). All use software algorithms to identify patterns in data.

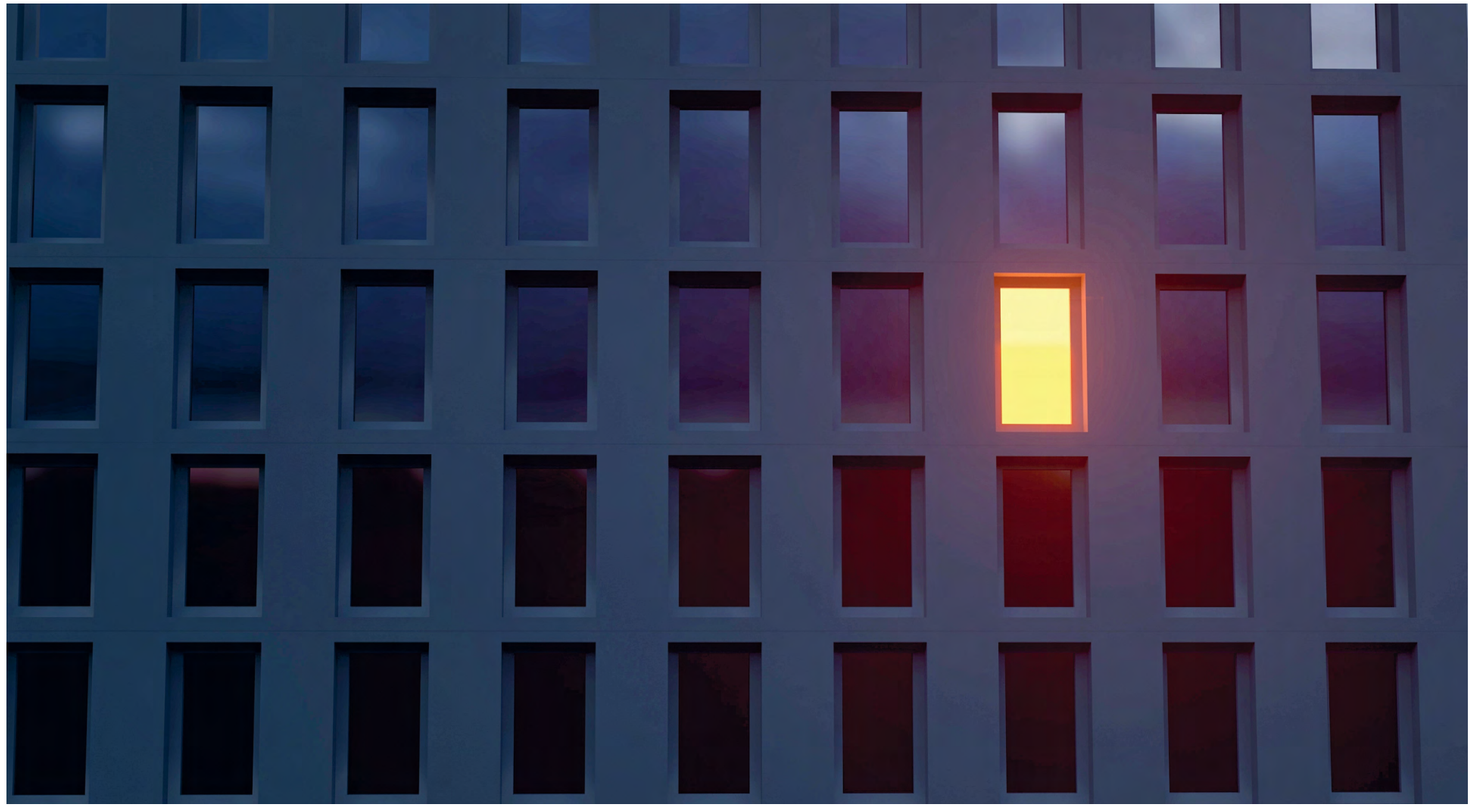
'Simple AI' is programmed completely by humans and has no intelligence of its own. Its intelligence comes solely from its human programmers who tell it exactly what to look for in a given set of data, and what to do if it finds it. Even the format in which the data is presented to the AI cannot change. This is the AI, for example, that makes boxes go red if you fail to fill in a 'mandatory' field within an online form.

'Feature-based machine learning' is the next step up and although again has to be programmed by humans to be directed what to look for in a given set of data (called feature generation), once programmed it can further improve its pattern detection accuracy and speed by a process of trial and error. This type of AI powers 'based on your viewing history you might like' predictions that are common to many modern TV streaming platforms.

'Deep Learning' is the domain of neural networks and removes any of the manual feature generation work that's required in the creation of the machine learning AI's described above. This time the AI is just left to its own devices to learn what data patterns it needs to look for in order to correctly identify or perform a certain task. This is the AI used to develop the Imagimob gesture recognition used in the 'virtual' button headphones described in this article.

# Get Smart

Cellular IoT and Bluetooth LE wireless tech are together bringing precision to energy management



The cost of electricity in the U.S. has risen more than 50 percent in the last 30 years, while household income has not. According to Statista, household income has barely managed 15 percent growth in the same period, and on the graph of power prices versus wage growth, the two lines have been diverging for most of our lifetimes. They continue to do so.

In the hierarchy of unwelcome bills, behind housing and transportation, utility bills are the next biggest drain on household funds, surpassing groceries, insurance and even healthcare. The reason for spiraling power costs are complex. Finite natural resources, vast wastage throughout the supply chain and demand all play a part, but can the rollout of smart meters—that according to Navigant Research will be installed in six out of ten houses by 2028—turn the tide on our energy use and its drain on the family budget?

## AN OLD NEW TECH

Smart meters aren't new. In 1972 a Boeing engineer developed a sensor monitoring system using digital transmission that offered meter reading capabilities. This was the forerunner to today's devices that provide intelligent, wirelessly enabled measurement and control of electricity, gas and water use. In comparison, their analog predecessors dumbly measured data for a meter reader to record in person by attending onsite.

Demand for smart meters initially advanced faster than the technology itself, with governments scrambling to legislate for introduction before the technology had matured. Early connectivity solutions such as PLC and M BUS had their limitations, but now we are at a tipping point. Cellular IoT—a LPWAN technology supported by two versions, LTE-M and NB-IoT—now presents an ideal solution for meter connectivity to the Cloud, while Bluetooth LE offers a consumer friendly, smartphone compatible link between the homeowner and their power consumption data.

"For Cloud connectivity from the meter to the utility, cellular IoT is the best solution because it brings simplicity, security, and speeds up the rollout," says Lorenzo Amicucci, a Business Development Manager with wireless chipmaker Nordic Semiconductor. "A lot of companies have been trying to find proprietary solutions to connect meters, but with cellular you have a solution backed by a lot of companies so it's a future proofed and standardized tech.

"Bluetooth LE is useful for installation and commissioning, and of course if the user wants to connect to the meter, every smartphone has it built in. In some markets there are prepaid meters and Bluetooth LE could be used to recharge the meter, or you can use it to connect the meter to other sensors or switches. Bluetooth LE is getting more popular for smart metering for the human interaction element."

## DRIVING ADOPTION

Wireless solutions that provide a simple and manageable means for utility companies and their customers to access and action their power consumption data is in theory a 'win-win' for both parties, but it is not yet a marriage of equals, and the power companies are the ones driving smart meter adoption.

Utilities want connected meters because they want to be able to accurately bill their customers, they want to know in 'real time' how much each household is using and that consumers are paying for their energy rather than stealing it. The data can also be used to perform advanced analysis and demand response modeling to ensure the grid is performing to its peak and optimized for full profit potential. What power companies care less about is that customers have access to the same data. "It's governments that want utilities to share the data with their users, not the utilities themselves," says Amicucci.

While the profit motive makes power companies unconcerned about providing their customers with the tools to moderate their energy use, or schedule it around offpeak pricing, the benefits for the customer are obvious. "Sharing the data with the consumer gives them a choice," explains Amicucci. "It enables them to decide when's it's the best time to charge the car or use the washing machine. Consumers can now connect to the meter and know how much power they are using every minute.

"Giving consumers the power to manage their own energy consumption can be good for the utility companies too. In a period of peak demand, if everybody turns everything on at the same time the electricity company has a problem. But if consumers have the ability to respond to their own usage based on live pricing some will back away when the cost surges at times of high demand, and the grid will perform better as a whole."

Smart metering in its true sense—beyond 'basic' connectivity to data collection, analysis and 'live' feedback—is still a developing sector, but there are solutions serving both utilities and their customers that are already delivering on this promise. In 2018, Polish IIoT startup, OneMeter, launched its OneMeter Beacon, a device that allows users to monitor and manage their real time energy usage. Originally designed for use in industrial and commercial environments, the solution is now available for the domestic market. It works by simply plugging the device in to an existing electronic electricity meter via an optical port interface – enabling the beacon to receive energy usage data from the meter using the IEC 62056-21/ IEC 1107 protocol.

Once installed, the beacon is paired to a smartphone or tablet using Nordic Bluetooth LE wireless connectivity and allows the user to review the data including active and reactive energy consumption parameters, as well as daily, weekly, and monthly energy usage charts. Companies can perform accurate energy usage cost estimation and avoid penalties for exceeding contracted power by defining power parameter alerts. Certified measurement data can also be shared with energy vendors enabling invoices to be settled based on actual usage instead of forecasts.

> "Giving consumers the power to manage their own energy consumption can be good for the utility companies too

## ONLY THE BEGINNING

The next step for smart meters, Amicucci believes, will be for them to move beyond standalone devices, to part of the broader smart home ecosystem. In Norway, for example, you can already buy a device that attaches to a smart meter that can connect over the Internet to an electric vehicle charger, and in turn make smart decisions about the most economical time to charge the car.

"How we connect the smart meter to other objects in the house and for what benefit is the next step," says Amicucci. "The key question is which protocol will be used. The market for the protocol that's chosen will be huge."

The OneMeter Beacon is a commercial device that provides companies with the ability to monitor and manage their energy usage data in real time

### Tech Check

Gurux, employing Nordic's nRF9160 SiP, has produced an open-source proof-of-concept (PoC) smart electricity meter for cellular IoT smart meter reading. The PoC is designed for use with a DLMS meter and comprises: A cable that connects the nRF9160 DK to the meter (via optical probe or direct serial port connection); the nRF9160 DK programmed with a Gurux MQTT Bridge example; an MQTT Broker, and the client application based on GXDLMS Director. (See WQ Issue 3, 2019, pg26.)

### By the Numbers

The global smart meter total will rise from 665 million in 2017 to more than

**1.2 billion**

by the end of 2024

*Source: Wood Mackenzie*

Wearables

# PitPat

## This Bluetooth LE wearable canine activity tracker monitors pet exercise data to help keep dogs fit and healthy

According to analyst Research and Markets, connected wearables have entered a strong growth phase that will see shipments grow from 116 million units in 2018, to 238 million units by 2023. Fitness and activity trackers currently account for more than 50 percent of these shipments, and with an estimated 900 million dogs on the planet, the non-human wearable market has large potential

In 1979, Jimpa, a labrador/boxer cross, walked 3218 km over the course of 14 months to return home when he was lost by his owner in the outback of Australia. On his trek Jimpa had to negotiate vast tracts of waterless desert as he made his way from Western Australia to the southern state of Victoria

Dogs possess up to 300 million olfactory receptors in their noses and can detect some odors in parts per trillion, meaning their sense of smell is up to 100,000 times as acute as our own. Making the analogy to vision, if a human could see clearly up to 0.5 km away, a dog could see just as clearly up to 50,000 kms away

All dogs require exercise, but some need a lot more than others. At the lazy end of the scale is the basset hound which with its large body and short legs was built for comfort rather than speed. A cattle dog, however, was bred to spend all day chasing a herd, and their endless energy means they need to be on the go and exercising at least two hours a day

Activity data from PitPat is synced to the owner's smartphone or tablet, where from the associated app the user can review the dog's activity data compared to guidelines for over 200 different breeds, as well as set and track a range of canine health goals

PitPat weighs only 15 g and easily attaches to a dog's collar. A three-axis accelerometer tracks the dog's motion throughout the day, and proprietary algorithms interpret this data to identify five specific activity states—walking, running, playing, pottering and resting—and how long the dog spends in each state


### Tech Check

PitPat employs Nordic's nRF52810 Bluetooth LE multiprotocol SoC to provide low latency wireless connectivity between the device and the dog owner's smartphone. The SoC has the lowest power consumption and smallest size (2.482 by 2.464 mm for the CSP package) in Nordic's nRF52 Series, and brings the 2 Mbps higher throughput and improved coexistence benefits of Bluetooth 5 to cost sensitive, high volume applications

@thegrumpycocker/Instagram

Smart Agriculture

# Multiprotocol equine monitoring solution helps farmers monitor horses' health

**Using concurrent Bluetooth LE and Thread wireless connectivity, the Farm Jenny for Horses platform allows horse owners to track the location and wellbeing of animals**

> Since horse owners can't be with their horses 24/7, Farm Jenny provides all of the information they need in one place

For centuries farmers and ranchers had no option but to manually monitor, protect and care for their herds as best they could using limited resources. It's a tough job, especially for those at the smaller end of the commercial farming scale. Thankfully, emerging tech can help reduce the heavy workload and eliminate the reliance on sporadic observations and imperfect recollections of each animal's unique behavior patterns.

Horse owners, for example, can now take advantage of the benefits of a wireless herd tracking solution like Farm Jenny for Horses, a new animal wearable and connected equine monitoring platform. Developed by Pittsburgh-based agricultural technology company, Farm Jenny, the solution is designed to help horse owners keep a closer eye on the various activities and behaviors indicative of a horse's overall health status and potential medical issues. The user tracks this information from either a web based dashboard or the Farm Jenny iOS or Android app on their smartphone or tablet.

"Farm Jenny for Horses provides farmers with freedom and peace of mind by bringing the power of machine learning to small farms," says Rob Crouthamel, Co-founder and COO, Farm Jenny. "Our solution addresses the everyday worries of horse owners such as a horse being out in bad weather and the number one horse emergency, colic." (Colic is a generic term referring to a combination of symptoms of often fatal abdominal problems in a horse.)

The sensor based platform records animal activity levels including walking, lying down, rolling, grazing or running, as well as changes over the past day, week or month. This behavioral data can be used to assess potential signs of illness or injury. In addition, the device's built-in sensors record temperature, humidity and atmospheric pressure, which helps determine the horse's comfort and provides context for evaluating animal behavior. Farm Jenny for Horses also tracks the animal's location, allowing the owner to follow its position in relation to facilities, food and water, as well as other horses in the herd. As Crouthamel explains: "A horse lying down and rolling in a grassy field on a sunny spring day is very different to one rolling in the mud on a [very cold] night."

Remotely tracking each horse's health and location is a key benefit of Farm Jenny for Horses. "Since horse owners can't be with their horses 24/7, Farm Jenny provides all of the information they need in one place," Crouthamel says.

## Multiprotocol connectivity

Farm Jenny for Horses employs a network of wearable sensors, solar powered field receivers, beacons and a gateway, which all communicate through Nordic's advanced concurrent Bluetooth LE and Thread short range wireless connectivity solutions.

In operation, the nRF52832 SoC-powered wearable is fitted in a pouch to the horse's existing halter or bridle, or in a custom headband. The SoC also powers beacons which provide pinpoint location in key areas of interest, such as individual stalls or food and water sources.

The Farm Jenny Field Receiver, one of the world's first 'Built on Thread' certified devices, uses a Thread-powered wireless mesh network providing farmwide wireless connectivity. Both the field receivers and the gateway employ Nordic's nRF52840 advanced multiprotocol SoC, with a Dynamic Multiprotocol feature that uniquely supports concurrent Bluetooth LE/Thread connectivity.

The wearable can relay the sensor data directly to the gateway if the horse is in a barn; to the Cloud via the companion app on a smartphone or tablet if the horse is in transit, on a trail or at a show; and to any nearby solar powered field receiver if the horse is in a pasture. In turn, the field receiver relays the data to a central gateway that then forwards the data via LTE-M or NB-IoT cellular connectivity to the Cloud for review. In all cases, Bluetooth LE connectivity is used for the 'first hop' of data from the animal's wearable sensor. "At any time, on or off the farm, an animal sensor with data to send can expect to find a device capable of relaying the information to Farm Jenny's servers," Crouthamel says.

The open standard Thread protocol is the "backbone" of the on-farm network. "We wanted an IP-based solution which allowed us to deploy new devices and features to existing customers without needing to update fielded infrastructure every time," says Crouthamel.

To this end, Nordic's multiprotocol low power solutions have proved critical. "We selected the nRF52840 for the field receiver because it is one of the few devices that can handle Bluetooth LE and Thread concurrently with a single radio, meaning lower power consumption, lower cost and far fewer regulatory compliance headaches than a multiradio design," explains Crouthamel.

Farm Jenny for Horses provides around-the-clock monitoring anywhere on the farm without the need for rechargeable batteries. The scalable solution uses an: "opportunistic communications system designed to maximize battery run time of the animal sensor," he says. "For the wearable, the SoC's generous memory and processing capability allows us to do more behavior processing on the animal, so we save power by not transmitting as often when everything is okay."

The company is full of praise for Nordic's support and development tools including the nRF5 SDK. "Nordic's Bluetooth LE SDKs are unmatched in the industry," Crouthamel says. "And we know we'll get help promptly when we get stuck. We also know that Nordic will always be at the forefront of low power wireless, providing us months ... of schedule advantage over our competitors."

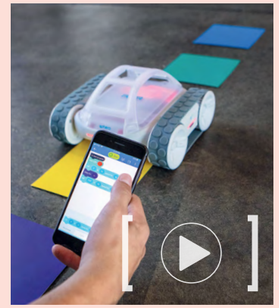
### Need to Know

Farm Jenny employs LTE-M and NB-IoT technology in its gateway product, which performs as a Thread-to-cellular router. LTE-M and NB-IoT provide the Farm Jenny for Horses platform with "improved rural coverage and signal penetration," enabling the company to offer a full end-to-end solution for its customers with a single 'software as a service' subscription that includes data connectivity

## Partnering with Nordic

# Building programmable robots for educators

**Supported by Nordic's development tools, Sphero created the RVR smart robot**



In the fledgling smart toy sector, Boulder, CA-based Sphero has developed a programmable and expandable robot that's suitable for beginner to advanced coders, STEAM educators and students, makers, hackers and hobbyists alike. The sensor-packed device is called Sphero RVR and it's designed to be customized for a wide array of unique user-coded applications, from a home security sentry to an environmental sensor.

But well before Sphero RVR made it to market, the unique software architecture of Nordic's nRF52 Series helped Sphero add key capabilities to the robot such as enabling users to wirelessly code RVR from the Sphero Edu app hosted on a smartphone or tablet. The nRF52832 SoC at the heart of the robot runs Nordic's S132 SoftDevice, a proven Bluetooth 5.1-qualified RF software protocol stack for building advanced Bluetooth LE applications. Nordic's unique software architecture maintains a clear separation between this stack and the customer's application code, ensuring it can't be corrupted during the development process. Such an arrangement significantly eases engineering, compressing project schedules.

> Robots bring code to life and can help support themes and topics that are currently being taught in the classroom

Key to taking advantage of the software architecture is Nordic's nRF5 SDK. "All of our robots run specialized application code written by our team of firmware engineers, and we heavily leveraged the Nordic SDK to speed up that work," says Jeff Wiencrot, Director of Firmware & Hardware at Sphero. According to Wiencrot, the availability of Nordic's S132 SoftDevice and SDK was a "major factor in our decision to select Nordic," with both features proving "extremely powerful and easy to work with for developers".

Together with the development tools, Sphero's design process was helped by Nordic's close involvement during each stage.

"We appreciated Nordic's dedicated, knowledgeable engineering and sales groups. The company's reps are amazingly quick to respond to our questions and the documentation and support pages provided are extremely useful," adds Wiencrot.

"Nordic is a fantastic company to work with and an ideal partner for a company like Sphero."

### Bringing code to life

How does Sphero assess the future prospects for the development of the smart toy market in general and the education sector in particular?

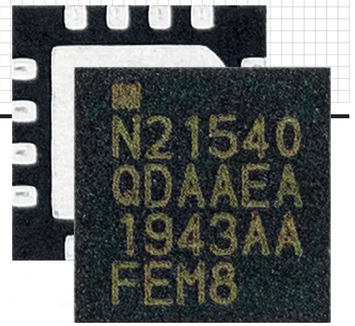
"Educators are looking for ways to teach the 'Four Cs' of critical thinking, collaboration, communication and creativity," explains Wiencrot. "They're seeing the value of robotics, as students work in teams to creatively solve problems and demonstrate these solutions through the robot itself. More than any computer program, robots bring code to life and can help support themes and topics that are currently being taught in the classroom.

"We'll start to see this emerge as companies like Sphero create curriculums that can be used in traditional classrooms to support teachers in integrating robotics and coding."

# [Tech Zone]

*An in-depth look at Nordic's wireless IoT solutions*

## Nordic unveils nRF21540 'plug and play' range extender




Nordic Semiconductor has launched the nRF21540 RF Front End Module (FEM), the company's first power amplifier/low noise amplifier (PA/LNA) product developed to complement the nRF52 and nRF53 Series multiprotocol SoCs.

The RF FEM's PA offers a highly adjustable TX power boost up to +21 dBm, with the LNA providing +13 dB RX gain. The LNA's low noise figure (NF) of only 2.5 dB also ensures increased RX sensitivity for Nordic's Bluetooth 5/Bluetooth LE, Thread, Zigbee and 2.4 GHz RF low power wireless solutions. When combined with an nRF52840 SoC running Bluetooth LE at 1 Mbps, for example, the nRF21540 improves the RX sensitivity by 5 dBm. Coupled with the increased output power, the connection link budget is raised by 18 dBm. For other devices with less than +8 dBm TX power on-chip, the improvements are even larger.

The resulting increase in connection link budget offers significantly longer range and helps lower the number of retransmissions due to corrupt packages. The nRF21540 is a valuable addition for all applications that may require increased range or robust coverage. Some example applications are asset tracking, audio, smart home or industrial use cases.

The nRF21540 is a 'plug and play' complementary device when used with Nordic's short-range wireless SoCs. The nRF21540 connects to the SoC's antenna output and features two additional antenna ports to enable antenna diversity features. The device's gain control, antenna switching and power modes are controlled via GPIO or SPI or a combination of both.

While the device can be used with other radios, the ease of use with Nordic SoCs is further enhanced as driver support will be rolled out as part of future releases of Nordic's nRF5 SDK, nRF5 SDK for Thread and Zigbee, and the nRF Connect SDK.

## Programming language could eliminate IoT device vulnerabilities

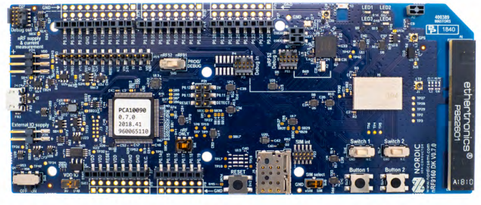
Nordic Semiconductor's nRF9160 SiP cellular IoT solution has been used by U.K.-based consultancy, 42 Technology, to successfully demonstrate what the company claims is the world's first Rust programming language application for a single-chip IoT device.

"Our aim is to help eliminate the security vulnerabilities that too many people have seen, for example, with low cost home security cameras, smart hubs and medical equipment such as insulin pumps," says 42 Technology Senior Consultant, Jonathan Pallant.

"The ability to run Rust in IoT applications could accelerate the development of much more robust and secure low cost, low powered cellular IoT products and systems," continues Pallant. "And [the technology could] play a critical role in unlocking significant new markets for smart industrial and consumer products where security remains a major concern."

42 Technology says the Nordic nRF9160 SiP's ARMv8-M processor architecture's TrustZone security features are particularly exciting. The features enable applications and associated services to operate securely, protected from hacking, misuse and corruption.

In recent field trials conducted in the U.K., 42 Technology says its Rust application made secure encrypted connections to Amazon Cloud computing services via an early LTE-M (cellular IoT) network being rolled out by network operator, O2. The application is also said to support NB-IoT which is currently being launched in the U.K. by Vodafone and other operators.



**Industrial IoT**

## Panasonic module for IIoT use cases

Panasonic Industry, a leading multinational industrial solutions company, has released the PAN1780 module based on Nordic's nRF52840 Bluetooth 5.2/Bluetooth LE SoC. The nRF52840's Bluetooth LE protocol stack incorporates Long Range functionality and increased throughput (2Mbps). Bluetooth Channel Selection Algorithm (CSA#2) enhances the module's immunity to 2.4 GHz interference making the product useful in challenging RF environments.

The Nordic SoC's 64 MHz, 32-bit Arm Cortex M4 processor with floating point unit (FPU) ensures the module can support the most complex IoT applications.

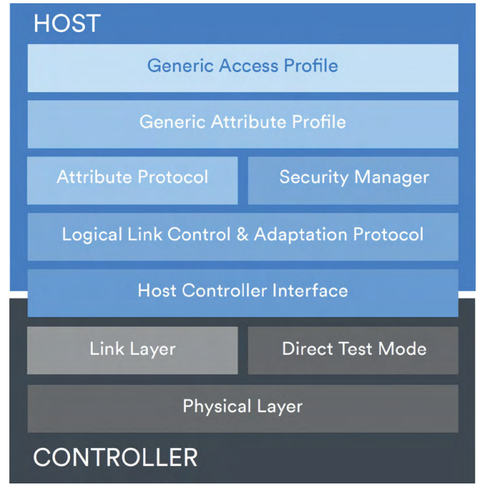
Panasonic has developed a demonstrator for the PAN1780, consisting of a sensor unit measuring temperature, air pressure and humidity data, that transmits it to a second unit that displays the data. Both units are based on the PAN1780 evaluation board, allowing developers to easily build, test and debug product prototypes.

**Tech Perspective**

## What's new in Bluetooth 5.2

Bluetooth 5.2 enhances the short range wireless standard by introducing LE Isochronous Channels to support LE Audio. But that's only the start

While LE Audio took much of the recent fanfare (*see pg14*) the Bluetooth SIG simultaneously adopted a revised Bluetooth Core Specification, version 5.2. The changes brought by the revised specification will be needed to support the new form of Bluetooth audio once its full specification is launched. But the addition of LE Isochronous Channels required for new use cases such as audio sharing is not the only significant enhancement that comes with Bluetooth 5.2. Other new features include an Enhanced Attribute Protocol (EATT) and LE Power Control. Here's an overview.




Bluetooth 5.2 brings Bluetooth LE stack changes including an Enhanced Attribute Protocol (EATT), improvements to the Generic Attribute Profile (GATT) and Logical Link Control & Adaptation Protocol (L2CAP) Enhanced Credit Based Flow Control Mode

### LE Isochronous Channels

LE Isochronous Channels' functionality is important for LE Audio because it allows the communication of time-bound data to one or more devices for time-synchronized processing. The technology extends audio applications because it can be used over connections or broadcast to multiple devices in a connectionless topology.

The existing Bluetooth audio profile, Advanced Audio Distribution Profile (A2DP), defines how Bluetooth can be used for high quality audio applications, such as streaming music from a smartphone to a set of Bluetooth headphones. The drawback of A2DP is the topologies it can support—which define the permitted relationships between audio 'sources' (playback devices like smartphones) and 'sinks' (devices like speakers which render audio)—are limited to one or more point-to-point pairs. There is no way to ensure multiple sinks play their audio stream such that the music is synchronized across a series of associated devices. In practice this means Bluetooth audio devices using AD2P are limited to operating when connected to only one other device.

LE Isochronous Channels addresses this drawback by providing a mechanism that makes sure that multiple sink devices (for example left and right 'earbuds') receiving data from the same source, reproduce it at precisely the same time. Data has a time-limited validity period, at the end of which it expires. Expired data which has not yet been transmitted is discarded. These mechanisms ensure sinks only receive data adhering to rules regarding age and latency.

### Enhanced Attribute Protocol

Bluetooth 5.2 introduces EATT (along with some associated improvements to the Generic Attribute Profile (GATT)). The key benefit of EATT is support for concurrent transactions. This is achieved by interleaving Logical Link Control & Adaptation Protocol (L2CAP) packets relating to Attribute Protocol (ATT) packets from different applications and allows the ATT Maximum Transmission Unit (MTU) to be changed during a connection. The result is a better experience when using devices where there are multiple applications using the Bluetooth LE stack simultaneously; the improvement comes through reducing instances where one application's use of the stack temporarily blocks another. The improvement is a reduction in latency of one or more of the applications and better responsiveness. A further advantage of EATT compared with ATT is that it can only be used over an encrypted connection and is therefore inherently secure.

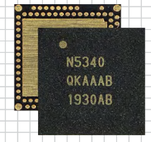
In support of EATT, the revised Core Specification defines a new L2CAP mode called Enhanced Credit Based Flow Control Mode. As the name suggests, this mode provides flow control and so allows applications to regard the protocol as reliable.

### LE Power Control

The third significant addition of Bluetooth 5.2 is LE Power Control. The functionality makes it possible to extend battery life through dynamic optimization of radio transmission power. Bluetooth LE receivers can now monitor signal strength and request transmission power level changes in connected devices, typically to maintain the best trade-off between signal integrity and power consumption. This is an important addition because receivers encountering particularly high signal levels may become saturated causing communication to fail. Conversely, when the receiver signal strength is too low, the error rate increases - impacting throughput and eventually leading to failure.

LE Power Control allows the Bluetooth controller to monitor path loss changes to the Bluetooth host using the concept of 'zones'. Finally, there are enhancements relating to coexistence with other wireless devices close by using the 2.4 GHz frequency range. (For more information see *Bluetooth Core Specification Version 5.2 Feature Overview* available from Bluetooth.com.)

> "LE Isochronous Channels needed for new use cases such as audio sharing is not the only significant enhancement that comes with Bluetooth 5.2




**Tech Check**

All of Nordic's nRF52 and nRF53 Series SoCs are capable of all Bluetooth 5.2 features including the nRF5340 shown here. The SoC is capable of all advanced Bluetooth LE features including high throughput, Long Range, advertising extensions, enhanced channel selection algorithm and Direction Finding

# Inside the nRF9160

Nordic's LTE-M/NB-IoT cellular IoT solution brings robust and secure cellular connectivity to everything beyond the smartphone

Cellular technology promises a solution for connecting IoT sensors directly to the Cloud. It is also an option for connecting local networks powered by short range wireless tech such as Bluetooth LE, Thread or Zigbee, to the Cloud through a gateway.

Key advantages of the cellular IoT technologies LTE-M and NB-IoT are that they are supported by an open standard, operate in a licensed portion of the RF spectrum, leverage existing infrastructure and have coexistence mechanisms that enable scaling to high-node counts per base station.

Nordic Semiconductor's nRF9160, a low power SiP with integrated LTE-M/NB-IoT modem and GPS, has been engineered for energy-efficiency and security whilst simultaneously bringing advanced applications to the IoT. The nRF9160 has been in volume production for almost a year having successfully passed major certifications in many of the LTE bands with more planned. To date, the nRF9160 is qualified by Verizon, Vodafone, Deutsche Telekom, GCF, PTCRB, FCC (U.S.), CE (E.U.), ISED (Canada), ACMA (Australia & New Zealand), TELEC/RA (Japan), NCC (Taiwan) and IMDA (Singapore).

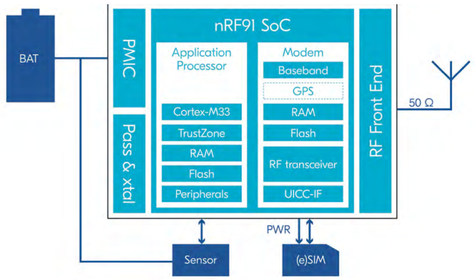
Targeting asset tracking applications, the nRF9160 SiP combines location data from the cellular network with GPS satellite trilateration for precision remote monitoring of its position.

## SiP architecture

The nRF9160 comprises a dedicated application processor and memory, multimode LTE-M/NB-IoT modem with integrated RF front end (RFFE), GPS plus power management in a compact 10 by 16 by 1 mm package. Through high integration and precertification for global operation, the SiP solves the complex wireless design challenges arising when employing cellular technology requiring just an external battery, SIM, antenna and sensors. The nRF9160 supports global operation with a single variant thanks to the combination of Nordic's multimode LTE-M/NB-IoT modem, SAW-less transceiver, and RFFE. The SiP is the first cellular IoT solution to incorporate a 64 MHz Arm Cortex M33 CPU core supported by 1 MB of Flash and 256 KB of RAM onboard memory. The module incorporates Arm TrustZone (*see* WQ *Issue 3, 2019 pg25*) and Arm CryptoCell (*see* WQ *Issue 4, 2019 pg26*) security for Internet-level encryption and application protection.

## LTE-M/NB-IoT modem

The nRF9160 LTE modem integrates RFFE, radio and baseband. The modem offers 700-to-2200 MHz LTE band support and 23 dBm output. LTE-M throughput is (UL/DL) 300/375 kbps while NB-IoT throughput is 30/60 kbps. RX sensitivity is -108 dBm for LTE-M and -114 dBm for NB-IoT. The modem supports half-duplex FDD operation, eDRX and PSM power saving, coverage enhancement modes, SMS, single-pin 50 Ω antenna interface and a UICC interface. The LTE stack layers L1-L3, IPv4/IPv6, TCP/UDP and TLS/DTLS form part of the modem firmware. The application processor communicates with the LTE modem through a BSD secure sockets API and contains the application layer protocol, for example CoAP, MQTT or LWM2M and the application layer itself.




Through high integration and precertification for global operation, the nRF9160 solves the complex wireless design challenges arising when employing cellular technology requiring just an external battery, SIM, antenna and sensors

The nRF9160 LTE modem supports both SIM and eSIM, plug-in or soldered. It provides power and handles all communication automatically.

## Development tools

Nordic's strategy for cellular IoT mirrors that for its short range wireless products and that is to make its solutions easily accessible, easy-to-use and well supported. Cellular is one of the most intricate wireless technologies, but Nordic's development tools shield the designer from its complexity and allow them to focus on the application.

Software development for the nRF9160 SiP starts with the nRF Connect SDK, a software development kit which includes everything needed for a designer to get started on a cellular IoT prototype project. The SDK also includes tools for more advanced design including the Zephyr RTOS, application layer protocols such as CoAP, MQTT and LWM2M, and application examples covering a wide range of use cases.

The SDK also includes software for secure boot, and secure firmware over-the-air (OTA) device updates for both application and cellular modem firmware.

The nRF9160 SiP's tool suite is completed with an affordable, precertified single board development kit, the nRF9160 DK, easing development with LTE-M, NB-IoT and GPS. The DK has a dedicated LTE-M and NB-IoT antenna supporting a wide range of bands and global operation. The DK also includes an nRF52840 advanced multiprotocol SoC enabling the DK to form the basis of a design for a Bluetooth LE to cellular IoT gateway.

Development can be accelerated by designing with the Nordic Thingy:91 cellular IoT prototyping platform. The Thingy:91 is the ideal platform for rapidly developing a prototype for cellular IoT and comes with an eSIM card from iBasis, preloaded with 10 MB of data allowance.

> Nordic's strategy for cellular IoT is to make its solutions accessible, easy-to-use and well supported

### Tech Check

Nordic's Thingy:91 cellular IoT prototyping platform incorporates an nRF9160 SiP and an nRF52840 board controller, supporting Bluetooth LE and NFC. Source code for firmware, hardware layout and schematics for Thingy:91 are all available from Nordic for free

# Product Summary

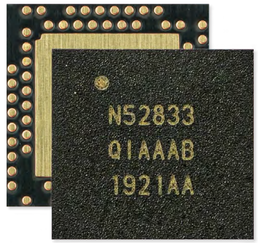
Full product details at: www.nordicsemi.com/Products

| | | nRF 9 SERIES | nRF SERIES 53 | nRF 52 SERIES | | | | | | nRF 5 SERIES | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **nRF9160** | **nRF5340** | **nRF52840** | **nRF52833** | **nRF52832** | **nRF52820** | **nRF52811** | **nRF52810** | **nRF51822** | **nRF51422** | **nRF51824** |
| WIRELESS PROTOCOL | LTE-M | ● | | | | | | | | | | |
| | NB-IOT | ● | | | | | | | | | | |
| | GPS | ● | | | | | | | | | | |
| | BLUETOOTH LOW ENERGY | | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● |
| | BLUETOOTH 5.2 | | ● | ● | ● | ● | ● | ● | ● | | | |
| | DIRECTION FINDING | | ● | | ● | | ● | ● | | | | |
| | 2 MBPS | | ● | ● | ● | ● | ● | ● | ● | | | |
| | LONG RANGE | | ● | ● | ● | | ● | ● | | | | |
| | BLUETOOTH MESH | | ● | ● | ● | ● | ● | | | | | |
| | THREAD | | ● | ● | ● | | ● | ● | | | | |
| | ZIGBEE | | ● | ● | ● | | ● | | | | | |
| | ANT | | ● | ● | | ● | | | ● | | ● | |
| | 2.4 GHZ PROPRIETARY | | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● |
| | NFC | | ● | ● | ● | ● | | | | | | |
| TYPE | SYSTEM-ON-CHIP | | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● |
| | SYSTEM-IN-PACKAGE | ● | | | | | | | | | | |
| CORE SYSTEM | CPU | 64 MHz Arm Cortex-M33 | 128 MHz Arm Cortex-M33 +64 MHz Arm Cortex-M33 | 64 MHz Arm Cortex-M4 | 64 MHz Arm Cortex-M4 | 64 MHz Arm Cortex-M4 | 64 MHz Arm Cortex-M4 | 64 MHz Arm Cortex-M4 | 64 MHz Arm Cortex-M4 | 16 MHz Arm Cortex-M0 | 16 MHz Arm Cortex-M0 | 16 MHz Arm Cortex-M0 |
| | FPU | ● | ● | ● | ● | ● | | | | | | |
| | DSP INSTRUCTION SET | ● | ● | ● | ● | ● | ● | ● | ● | | | |
| | CACHE | ● | ● | ● | ● | ● | | | | | | |
| | MEMORY | 1 MB Flash, 256 kB RAM | 1 MB Flash, 512 kB RAM +256 kB Flash, 64 kB RAM | 1 MB Flash, 256 kB RAM | 512 kB Flash, 128 kB RAM | 512 kB or 256 kB Flash, 64 kB or 32 kB RAM | 256 kB Flash, 32 kB RAM | 192 kB Flash, 24 kB RAM | 192 kB Flash, 24 kB RAM | 128 kB or 256 kB Flash, 32 kB or 16 kB RAM | 128 kB or 256 kB Flash, 32 kB or 16 kB RAM | 256 kB Flash, 16 kB RAM |
| | CLOCKS | 64 MHz / 32 kHz | 128 MHz / 64 MHz / 32 kHz | 64 MHz / 32 kHz | 64 MHz / 32 kHz | 64 MHz / 32 kHz | 64 MHz / 32 kHz | 64 MHz / 32 kHz | 64 MHz / 32 kHz | 16 MHz / 32 kHz | 16 MHz / 32 kHz | 16 MHz / 32 kHz |
| SECURITY | ARM TRUSTZONE | ● | ● | | | | | | | | | |
| | ARM CRYPTOCELL | 310 | 312 | 310 | | | | | | | | |
| | ROOT-OF-TRUST | ● | ● | ● | | | | | | | | |
| | SECURE KEY STORAGE | ● | ● | | | | | | | | | |
| | AES ENCRYPTION | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● |
| RADIO | LTE-M/NB-IOT/GPS MODEM | ● | | | | | | | | | | |
| | CERTIFIED LTE BANDS | 1–5, 8, 12–14, 17–20, 25–26, 28, 66 | | | | | | | | | | |
| | FREQUENCY | 700–2200 MHz | 2.4 GHz | 2.4 GHz | 2.4 GHz | 2.4 GHz | 2.4 GHz | 2.4 GHz | 2.4 GHz | 2.4 GHz | 2.4 GHz | 2.4 GHz |
| | MAXIMUM TX POWER | 23 dBm | 3 dBm | 8 dBm | 8 dBm | 4 dBm | 8 dBm | 4 dBm | 4 dBm | 4 dBm | 4 dBm | 4 dBm |
| | RX SENSITIVITY | -108 dBm (LTE-M), -114 dBm (NB-IoT) | -97.5 dBm (1 Mbps) | -95 dBm (1 Mbps) | -95 dBm (1 Mbps) | -96 dBm (1 Mbps) | -95 dBm (1 Mbps) | -97 dBm (1 Mbps) | -96 dBm (1 Mbps) | -90 dBm (1 Mbps) | -93 dBm (1 Mbps) | -90 dBm (1 Mbps) |
| | ANTENNA INTERFACE | 50 Ω single-ended | Single-ended | Single-ended | Single-ended | Single-ended | Single-ended | Single-ended | Single-ended | Differential | Differential | Differential |
| PERIPHERALS | HIGH SPEED SPI | | ● | ● | ● | | | | | | | |
| | TWI, SPI, UART | 4xTWI/SPI/UART | 4xTWI/SPI/UART +TWI/SPI/UART | 2xTWI/SPI, SPI, 2xUART | 2xTWI/SPI, SPI, 2xUART | 2xTWI/SPI, SPI, UART | 2xTWI/SPI, UART | TWI/SPI, SPI, UART | TWI, SPI, UART | 2xTWI/SPI, UART | 2xTWI/SPI, UART | 2xTWI/SPI, UART |
| | QSPI | | ● | ● | | | | | | | | |
| | USB | | ● | ● | ● | | ● | | | | | |
| | PWM | 4 | 4 | 4 | 4 | 3 | | 1 | 1 | | | |
| | PDM | ● | ● | ● | ● | ● | | ● | ● | | | |
| | I2S | ● | ● | ● | ● | ● | | | | | | |
| | ADC, COMPARATOR | ADC | ● | ● | ● | ● | COMP | ADC, COMP | ADC, COMP | ADC, LPCOMP | ADC, LPCOMP | ADC, LPCOMP |
| | TIMER, RTC | 3, 2 | 3, 2 + 3, 2 | 5, 3 | 5, 3 | 5, 3 | 4, 2 | 3, 2 | 3, 2 | 3, 2 | 3, 2 | 3, 2 |
| | TEMPERATURE SENSOR | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● |
| APPLICATIONS | AGRICULTURE | ● | | | | | | | | | | |
| | ASSET TRACKING | ● | ● | | ● | | ● | ● | | | | |
| | AUTOMATION | | ● | ● | ● | ● | ● | | ● | ● | ● | ● |
| | BEACON | | | ● | ● | ● | | ● | ● | ● | ● | ● |
| | CONSUMER ELECTRONICS | | ● | ● | ● | ● | ● | | ● | ● | ● | |
| | DIRECTION FINDING | | ● | | ● | | ● | ● | | | | |
| | GAMING / VR + AR | | ● | ● | ● | ● | ● | | ● | ● | ● | |
| | HEALTHCARE & MEDICAL | | ● | ● | ● | ● | | | ● | ● | ● | |
| | INDUSTRIAL SYSTEMS | ● | ● | ● | ● | | ● | | | | | |
| | MESH NETWORKS | | ● | ● | ● | ● | ● | | | ● | | |
| | PC PERIPHERALS | | | ● | ● | ● | ● | | ● | ● | ● | |
| | PROFESSIONAL LIGHTING | | ● | | ● | | ● | | | | | |
| | SMART BUILDINGS | ● | ● | ● | ● | | ● | | | | | |
| | SMART CITY | ● | ● | | | | | | | | | |
| | SMART HOME | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | |
| | SMART METERING | ● | | | | | | | | | | |
| | SPORTS & FITNESS | ● | ● | ● | ● | ● | | | ● | ● | ● | |
| | TOYS | | ● | ● | ● | ● | | | ● | ● | ● | |
| | WEARABLES | ● | ● | ● | ● | ● | | | ● | ● | ● | |
| **CERTIFICATIONS** | | GCF, PTCRB, CE, FCC, Verizon ++ | CE, FCC | CE, FCC | CE, FCC | CE, FCC | CE, FCC | CE, FCC | CE, FCC | CE, FCC | CE, FCC | CE, FCC |
| **OPERATING TEMPERATURE** | | -40 to 85 °C | -40 to 105 °C | -40 to 85 °C | -40 to 105 °C | -40 to 85 °C | -40 to 105 °C | -40 to 85 °C | -40 to 85 °C | -40 to 85 °C | -40 to 85 °C | -40 to 105 °C |
| **SUPPLY VOLTAGE RANGE** | | 3.0 to 5.5 V | 1.7 to 5.5 V | 1.7 to 5.5 V | 1.7 to 5.5 V | 1.7 to 3.6 V | 1.7 to 5.5 V | 1.7 to 3.6 V | 1.7 to 3.6 V | 1.8 to 3.6 V | 1.8 to 3.6 V | 1.8 to 3.6 V |
| **DEVELOPMENT KITS** | | nRF9160 DK, Nordic Thingy:91 | nRF5340 PDK | nRF52840 DK nRF52840 Dongle | nRF52833 DK | nRF52 DK Nordic Thingy:52 | nRF52833 DK | nRF52840 DK | nRF52 DK | nRF51 DK, nRF51 Dongle | nRF51 DK, nRF51 Dongle | nRF51 DK, nRF51 Dongle |
| **PACKAGES** | | 10x16x1 mm LGA | 7x7 mm aQFN94 (48 GPIOs) | 7x7 mm aQFN73 (48 GPIOs), 3.5x3.6 mm WLCSP94 (48 GPIOs) | 7x7 mm aQFN73 (42 GPIOs), 5x5 mm QFN40 (18 GPIOs), 3.2x3.2 mm WLCSP (42 GPIOs) | 6x6 mm QFN48 (32 GPIOs), 3.0x3.2 mm WLCSP50 (32 GPIOs) | 5x5 mm QFN40 (18 GPIOs) | 6x6 mm QFN48 (32 GPIOs), 5x5 mm QFN32 (17 GPIOs), 2.48x2.46 mm WLCSP33 (15 GPIOs) | 6x6 mm QFN48 (32 GPIOs), 5x5 mm QFN32 (16 GPIOs), 2.48x2.46 mm WLCSP33 (15 GPIOs) | 6x6 mm QFN48, WLCSP48, Thin CSP | 6x6 mm QFN48, WLCSP48 | 6x6 mm QFN48, WLCSP48 |

## Tech Profile

# nRF52833

nRF 52 SERIES

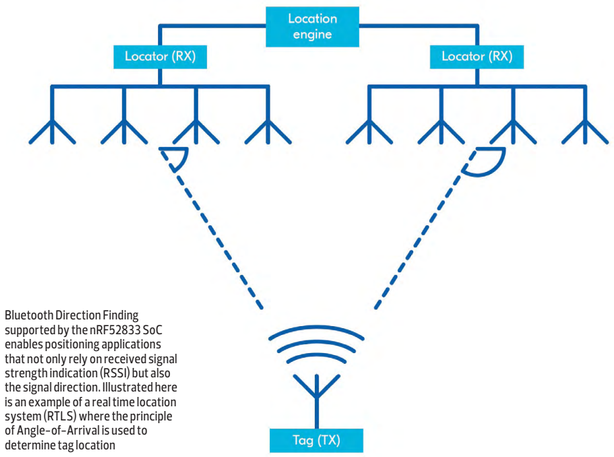



**Description:** The nRF52833 is a multiprotocol SoC with a Bluetooth Direction Finding capable radio, qualified for operation at an extended temperature range of -40 to 105°C. A generous memory allocation and dynamic multiprotocol support ensures the nRF52833 is an ideal device for commercial and industrial applications, including professional lighting and asset tracking. A 1:4 RAM to Flash ratio and adjustable output power make the nRF52833 an ideal choice for wearables or smart home applications where robust coverage is important.

**Hardware:** The nRF52833 incorporates a 64 MHz 32-bit Arm Cortex-M4 processor with floating point unit (FPU), DSP instruction set and cache. The hardware includes 512 KB Flash and 128 KB RAM. The SoC's 2.4 GHz radio features +8 dBm TX power (programmable from -20 dBm in +4 dBm steps) and -95 dBm sensitivity (Bluetooth LE at 1 Mbps) for a link budget of +103 dBm. The radio is capable of all Bluetooth Direction Finding functionality and its large memory can support both receiver and transmitter roles for Angle-of-Arrival (AoA) and Angle-of-Departure (AoD) applications. The SoC has an integrated balun with single-ended output and includes advanced features such as Full-Speed USB and High-Speed SPI. The SoC includes up to 42 GPIOs and a range of analog and digital interfaces, NFC-A, ADC, UART, SPI, TWI, PWM, I2S and PDM. It has a 1.7 to 5.5 V supply voltage range, a two-stage LDO regulator and a DC-DC converter. The SoC is available in a 7 by 7 mm aQFN73 with 42 GPIOs, a 5 by 5 mm QFN40 with 18 GPIOs and a 3.2 by 3.2 mm WL-CSP with 42 GPIOs.

**Software:** The nRF52833 is a multiprotocol wireless SoC supplied with an S113 or S140 SoftDevice. The S113 is a memory-optimized Bluetooth 5 protocol stack for peripherals and the S140 is a feature-rich Bluetooth 5 stack that is Bluetooth 5.1 qualified. The SoC also offers IEEE 802.15.4 support for protocols such as Thread and Zigbee. The chip's dynamic multiprotocol capability is an advantage where concurrent Bluetooth LE and Bluetooth mesh/Thread/Zigbee support is required.

**Development Tools:** The nRF52833 is supported by the nRF5 SDK, nRF5 SDK for Mesh and nRF5 SDK for Thread & Zigbee. The SDKs provide the examples, libraries and drivers needed to get started with Bluetooth LE, Bluetooth mesh, 2.4GHz proprietary and Thread or Zigbee development. The nRF52833 DK is a versatile single board development kit and is compatible with the Arduino Uno Rev3 standard, enabling the use of the compatible Nordic Power Profiler Kit and a wide range of third party shields.




Bluetooth Direction Finding supported by the nRF52833 SoC enables positioning applications that not only rely on received signal strength indication (RSSI) but also the signal direction. Illustrated here is an example of a real time location system (RTLS) where the principle of Angle-of-Arrival is used to determine tag location