

WIRELESS QUARTER

Issue 4, 2021

SILVER LINING:
PANDEMIC TECH PIVOTS
TO WORKPLACE SAFETY

INSIDE TRACK:
LOCATION SERVICES AND
BEACONS DISRUPT RETAIL

A PICTURE OF HEALTH:
HELPING DIABETICS
LEAD BETTER LIVES

Where in the World

Advances in cellular tech, IoT
and the Cloud promise to increase
the reach of location services

ENGINEERING AND IoT
EDUCATION EVOLVES

NON-CELLULAR 5G
BOOSTS MASSIVE IoT

INSIDE NORDIC'S nPM1100
POWER MANAGEMENT IC



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The nRF21540 DB is a dual-kit development bundle for the nRF21540 RF Front End Module, enabling range extension on all nRF52 and nRF53 Series SoCs.

AVAILABLE SOON



Welcome

Ville-Veikko Helppi
Product Manager Cloud Solutions



The world's logistics systems are under huge strain. One example of the challenge facing haulage firms is a shipping container bottleneck. 170 million of these metal boxes are used to transport 90 percent of the world's goods – yet right now it's almost impossible to locate a spare one.

Some problems were evident before the pandemic; for example, according to publisher Forbes, earlier trade conflicts between the U.S. and China created supply and demand volatility, straining the system. But for a system already under some pressure, the huge shock caused by COVID-19 made supply chain problems far worse. For example, lockdowns prevented consumers getting to stores, so instead hundreds of millions switched to buying online – dramatically increasing demand.

Now, system weaknesses ruthlessly exposed by COVID-19 are being addressed by logistics companies. Firms are turning to tech to strengthen their operations. The IoT is the perfect solution; it forms a global network of connected devices to monitor and track anything. Once logistics providers know exactly where goods are and how they're being handled, they can use the data to make their supply chains far more robust and reliable.

Nordic is at the forefront of the logistics sector's transformation. The firm's [short range wireless](#) and [cellular IoT](#) solutions are powering its customers' asset tracking products, and [nRF Cloud Location Services](#) is making it easier for them to configure and locate large asset tracker deployments. (See pg14.)

Today, wireless tech is being used to supervise high value assets, but tomorrow it will be applied to everything on the move. That will guarantee predictability and precision in the movement of goods, harden the logistics system and transform global supply chains.

“The IoT is the perfect solution to the logistics sector's challenges. It forms a global network of connected devices capable of monitoring and tracking everything”

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Wireless Quarter is contract published on behalf of Nordic Semiconductor by Ecritech Media

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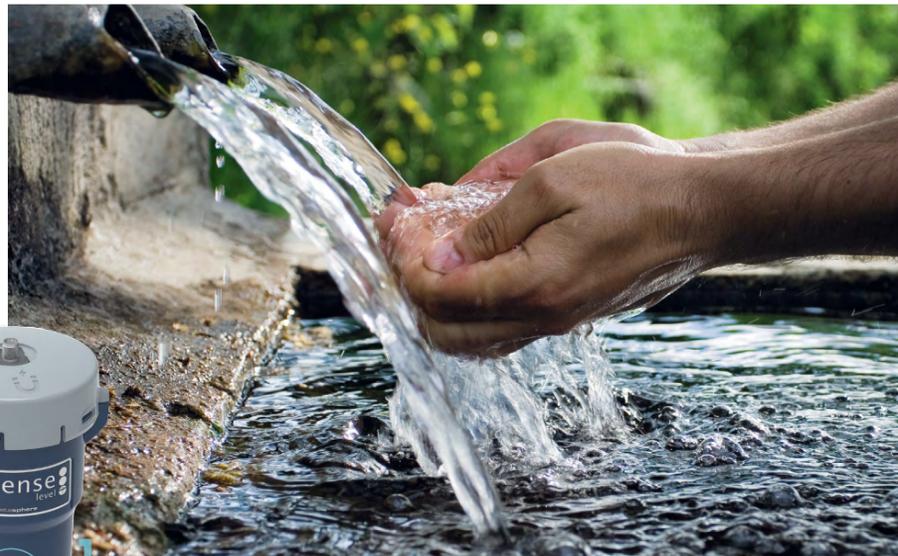
Cellular IoT and AI platform protects environment from wastewater spills

A wastewater and sewerage spill monitoring platform that uses a combination of cellular IoT and AI technologies to protect freshwater and marine ecosystems, has been hailed as a world first by its inventors.

The ART Sewer, developed by U.K. remote telemetry specialist, Metasphere, is targeted at wastewater utilities worldwide. The unit costs as little as one third of legacy GSM cellular systems but adds intelligence and real time network monitoring capabilities.

At the heart of the solution is a coffee cup-sized wireless sensor, powered by Nordic Semiconductor's [nRF9160](#) multimode NB-IoT/LTE-M SiP, that is deployed below utility hole covers in a wastewater network. Each sensor takes a sample measurement of the wastewater level every 15 minutes using radar, with the data sent to Metasphere's data analytics servers once a day via either NB-IoT or LTE-M cellular IoT wireless technology.

"Using AI and machine learning our platform combines historic, current and forecast rainfall data plus ground saturation levels to proactively manage wastewater flow in sewers, pumping stations, manholes and Combined Sewer Overflows (CSOs), as well as detect partial sewer blockages," says



Metasphere CEO, Tim O'Brien. "This all combines to prevent flooding events with a speed and accuracy that wasn't possible until now."

O'Brien says the information enables water utilities to prevent wastewater spills due to high level rainfall, blockages or collapsed or leaking pipes, far more proactively and effectively. He says it also enables maintenance crews to be scheduled and

deployed in a far more optimized and less reactionary way.

"Ultimately this will have a huge positive impact on reducing wastewater pollution from spills that find their way into freshwater and sea water and thus contaminate the natural environment," says O'Brien. "It will also help waste utilities meet increasingly stringent environmental regulations worldwide and to avoid fines."

Smart Health

Continuous glucose monitoring eases lives of diabetics

A Bluetooth LE-powered glucose monitoring system designed to enable patients with diabetes to continuously monitor and record their interstitial fluid glucose levels in real time, has been launched by Chinese healthcare technology developer, SiBionics.

The GS1 Continuous Glucose Monitoring (CGM) System employs a sterilized disposable electrochemical sensor—applied to the user's upper arm by a minimally invasive method—to continuously measure glucose levels, and relay the data to the user's smartphone using Bluetooth LE wireless connectivity.

In addition to providing reliable 24-hour

glucose values, the solution monitors glucose trends and aids in the detection of episodes of hyperglycemia (high blood glucose) and hypoglycemia (low blood glucose) that are not easily detected by traditional monitoring methods.

The device can provide the data for up to two weeks before replacement, thanks in part to the ultra low power characteristics of Nordic Semiconductor's [nRF52832](#) SoC that provides the continuous wireless connectivity to the user's smartphone.

The system automatically generates ambulatory glucose profiles (AGP) for



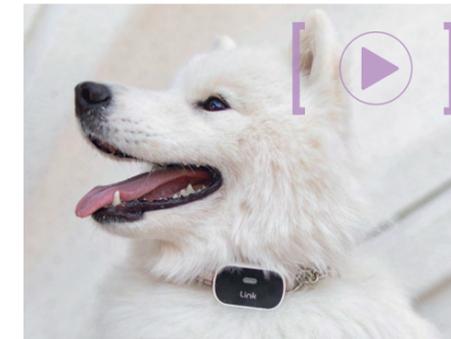
reference during medical consultations, and doesn't affect the patient's everyday activities such as swimming or exercise. (See [this issue pg28](#).)

Wearables

Cellular IoT and Bluetooth LE wearable tracks wandering pets

A smart wearable that employs cellular IoT and Bluetooth LE wireless connectivity to allow owners to track the whereabouts of their lost or absent pets, as well as monitor their activity levels, has been launched by U.S. tech company, Smart Tracking Technologies. Called Link, the device was developed in collaboration with application developer, DiscoverTec, and engineering firm, Paragon Innovations. It employs Nordic Semiconductor's [nRF9160](#) SiP and [nRF52840](#) SoC to enable the pet location data to be relayed to the owner's smartphone.

From the associated smartphone app, owners and pet care facilities can locate and track a pet's whereabouts and movement. If the pet is separated from the owner and wanders outside of smartphone Bluetooth range, the LTE-M connectivity provided by the nRF9160 SiP ensures remote tracking remains possible via a cellular network. From the companion app, users can also create customized zones—triggering notifications if the pet leaves defined areas—access activity recommendations based on the pet's profile and configure tone and vibration training tools to reinforce good pet behavior.



Link features a temperature sensor and an advanced Inertial Measurement Unit (IMU) to track the animal's activity.

To reduce power consumption, the wearable can enter sleep mode whenever it is idle. Once the pet starts moving again a motion detection wakeup feature on the IMU signals the main processor to activate the device. In addition, Link has been purpose-built to seamlessly integrate third-party pet technologies—for example, veterinary health records and pet daycare management systems. (See [WQ Issue 3, 2021 pg14](#) for a feature on pet tracking.)

Toys & Gaming

VR headset and handheld controllers offer low latency gaming

VR/AR technology company, Nolo, has unveiled a Bluetooth LE-powered six-degrees-of-freedom (6DoF) virtual reality (VR) headset and handheld controllers that support SteamVR streaming. The system provides access to more than 6000 SteamVR games, as well as compatibility with other mobile VR games and educational and training applications.

The NOLO Sonic VR features a VR headset and two interactive controllers all integrating the Nordic [nRF52833](#) SoC. The company claims the controllers are the first VR interactive controllers equipped with a wide frequency vibration motor enabling them to simulate hundreds of realistic haptic feedback effects. The controllers also support real time heart rate monitoring (HRM), while the company's proprietary SodarTraq tracking system employs ultrasonic technology for precise positional tracking.



Nordic's [nRF52833](#) SoC not only provides the low latency (<10 ms) Bluetooth LE connectivity to relay data from the controllers to the headset device, but also the processing power to support the controller's vibration motor data processing requirements. The SoC's radio architecture with on-chip PA provides -95dBm RX sensitivity (at 1Mbps in Bluetooth LE mode) helping to ensure robust connectivity between the controllers and headset, while at the same time significantly extending the battery life of the controllers between recharge.

"Nordic's [nRF52833](#) SoC is an ideal solution for NOLO Sonic VR due to the chip's ability to meet core processing and RF requirements without sacrificing power consumption," says Jianing Zhang, Chief Technology Officer, NOLO.

In Brief

STARTUP OFFERS BATTERY-FREE SENSORS



A startup founded by two MIT graduates says it can deploy self powered sensors to handle low intensity IoT tasks, eliminating the need

for batteries or power cabling and adding a new level of flexibility to IoT deployments. Everactive's sensor modules generate power from a variety of sources, including indoor artificial light, the Sun and waste heat. The sensors attack the power problem from the demand side, as well. The company employs sub-microwatt wakeup receivers for its radios, ultra low power ICs, and other power saving technology that allows the sensors to operate with minimal power. (See [WQ Issue 3, 2021 pg28](#) for more on energy harvesting.)

IoT AUTOMATION TECH ON THE RISE



Enterprises are accelerating their use of IoT automation technologies as a response to the increasing difficulty and expense

of hiring human employees, according to a new forecast by market analysis firm, Mobile Experts. The firm said roughly 250 million cellular IoT devices shipped in 2020, 60 percent more than 2018. "The Cellular IoT market is shaping up," commented Chief Analyst Joe Madden. "Many projects are maturing, and now enterprises can adopt automated ground vehicles and asset tracking, fairly readily. The operators [can now] make clear choices between [LTE-M](#) and [NB-IoT](#), and we ... expect [development] to get much easier over the next 10 years."

HUMAN-POWERED BIOELECTRONICS IN REACH



A team of bioengineers at the University of California has invented a novel soft and flexible self powered bioelectronic device. The technology

converts human body motions—from bending an elbow to subtle movements such as a pulse—into electricity to power sensors. The team used microscopic magnets dispersed in a paper-thin silicone matrix to generate a magnetic field that changes in strength as the matrix undulates. As the magnetic field's strength shifts, electricity is generated. "Our finding opens up a new avenue for technologies that are human body centric and can be connected to the IoT," says study leader, Jun Chen.

Smart Home

Bluetooth LE and Thread smart bulb lights up smart home sector

A Bluetooth LE and [Thread](#) enabled smart bulb that can be controlled from a connected device or by voice command has been released by Chinese IoT company, LEEDARSON. The A19 Tunable White Bulb is designed to replace conventional bulbs either in the home or in commercial buildings, and integrates Nordic Semiconductor's [nRF52840](#) SoC for wireless connectivity.

The bulb is dimmable from three to 100 percent, tunable from warm white (2700 K) to cool white (6500 K), features static and dynamic scenes for different light experiences (for example, wake-up and sunset), and provides a lifespan of approximately 25,000 hours. It can be controlled using any compatible connected device, or via a smart home ecosystem such as Amazon's Alexa, Apple's Siri, or Google's Assistant.

Using [Bluetooth LE](#) connectivity provided by the Nordic SoC, a screwed-in A19 Tunable White Bulb can be securely commissioned from a smartphone via a third party app. Once connected to the network, the smart LED bulb can be wirelessly controlled using Nordic SoC enabled Thread - a wireless protocol designed for low power, low bandwidth



network applications including mains powered devices such as smart lights. The smart bulb uses [Matter](#), an open source application protocol built on top of the mature Transmission Control Protocol (TCP) and User Datagram Protocol (UDP), as well as the mature Internet Protocol (IPv6) and other lower layer protocols including Bluetooth LE and Thread. "We selected Nordic's nRF52840 SoC for our A19 Tunable White Bulb due to the chip's powerful and reliable performance, as well

as its support for the Matter protocol which enables seamless interoperability with third party devices, apps and smart home ecosystems," says Kellen Yang, Global VP of Sales & Marketing, LEEDARSON. "Nordic's commitment to Matter also greatly supports our research and development." Nordic's nRF52840 SoC can concurrently run an application, Thread stack (OpenThread) and Bluetooth LE stack on its 64MHz, 32-bit Arm Cortex-M4 processor with floating point unit (FPU).

Design Services

Nordic Partner Program expands

Nordic Semiconductor has welcomed two new members to the [Nordic Partner Program](#) (NPP), an ecosystem of companies with experience of Nordic's solutions. The NPP will drive greater adoption of wireless technology and help Nordic's customers bring their wireless products to market faster.

IoT and ICT Cloud solutions company, A1 Digital and Cloud Location over Cellular (C-LoC) technology company, Polte, have both joined the program as solution partners. A1 Digital is part of the A1 Telekom Austria Group, a leading provider of digital services and communication solutions in Central and Eastern Europe. The partnership with Nordic will provide Nordic customers developing solutions based on its [nRF9160](#) low power SiP access to A1 Digital's expertise across hardware, firmware and cellular connectivity.

"As a key player in wireless tech for the IoT, Nordic is a great partner to A1 Digital," says Judith Pertl, Head of Digital Solutions and Platforms at A1 Digital. "Together we offer the complete toolchain, from the chip-to-the-Cloud with expert know how on top. This collaboration will ensure a great digital experience for our customers."

Polte and Nordic are providing a location solution leveraging Polte's CoreRes (CR) capability via the Polte Location API. Polte CR is a Massive IoT location service targeted at asset tracking solutions using the nRF9160 SiP. "We believe that achieving universal asset visibility should be simple," says Ed Chao, Polte CEO. "This partnership will provide Nordic customers with a Cloud based cellular location capability accessible through any cellular IoT device integrating the nRF9160 SiP."

NB-IoT keeps watchful eye on U.K. landslides

NB-IoT technology is being used in a pilot project in the U.K. to continuously monitor land stability and cliff movement at key points along the south coast in Dorset. Coastal landslides are common in the World Heritage Site.

The research conducted by Vodafone, telco service provider Neutral Networks, as well as experts in computer science from Bournemouth University and the British Geological Survey, will develop and trial a landslide and cliff monitoring system incorporating NB-IoT enabled sensors, edge computing, machine learning (ML) and AI. The system will comprise autonomous IoT sensing devices equipped with a suite of sensors to monitor ground movement, rainfall, water content and temperature. This data will then be relayed using Vodafone's NB-IoT network to the Cloud, where algorithms will process the data to provide valuable insights on cliff stability.

Wearables

Smartwatch delivers wearable Amazon Alexa voice control

A smartwatch incorporating Amazon Alexa Voice Service (AVS) functionality has been launched by Chinese smart wearables company, Shenzhen DO Intelligent Technology.

The ID206 smartwatch features a 43 mm LCD-HD color display screen, built-in microphone, heart rate and SpO₂ sensors, plus a three-axis gyroscope. The smartwatch can be used to remotely access the user's smartphone, for example, to receive call and text notifications or control music playback functionality.

The integration of Amazon's Alexa Built-In provides the user with total hands free control of smartwatch features, as well as remote control of other Alexa enabled smart home devices.

In addition, the waterproof ID206 offers a host of additional functionality including 14 sports modes, sleep and stress monitoring, steps tracking, calorie consumption as well as distance detection. The smartwatch is powered by the Nordic [nRF52840](#) SoC's

64MHz, 32-bit Arm Cortex-M4 processor with floating point unit (FPU), which provides ample computational power to allow the smartwatch to precisely track and calculate health and activity data.



From the VeryFit smartphone app, users can view their exercise history, fitness statistics and achievements in order to reach their goals more effectively. From the app, the user can also log into their Amazon account to set up their AVS. The smartwatch can operate for seven to 10 days between charges.

"Many of our products use the nRF52840 SoC because its software has been extensively verified, is stable, rich in resources and easy to develop with Nordic's SDK," says An He, founder and CEO of DO Technology. "Also, because battery life is such a key consideration when buying a smartwatch, the SoC's ultra low power consumption was key to ensure this device can operate for a long time between charges."

Toys & Gaming

Mouse supports very low latency PC gaming

U.S. gaming technology company, Glorious, has launched a wireless mouse designed for use with PCs supporting high performance gaming applications requiring reliable and fast response. According to the company, the Model O Wireless mouse has among the lowest wireless latency of any mouse in its class.

The ultra lightweight wireless gaming mouse features an ergonomic design for right handed users, six programmable buttons and a proprietary BAMF sensor. The company's newly developed pro-grade wireless sensor is made in collaboration with Pixart and is optimized for high performance 400 inches per second (IPS) tracking speed, 19,000 programmable dots per inch (DPI) and low power consumption.

The device integrates Nordic Semiconductor's [nRF52840](#) SoC with its 64MHz, 32-bit Arm Cortex-M4 processor with floating point unit (FPU) to provide ample processing power for the Model O Wireless mouse to support highly responsive advanced

gaming applications. The mouse connects to a user's PC via a USB adapter and a 2.4 GHz dongle integrating Nordic's [nRF52820](#) SoC as the receiver. Nordic's low-latency 2.4 GHz proprietary wireless connectivity enables a 1,000 Hz (1 ms) polling rate (or the frequency with which the mouse reports its position to the computer).



"Two of the most important features gamers look for in a wireless mouse are battery life and reliable low latency operation," says Shazim Mohammad, CEO & Founder, Glorious. "Nordic's nRF52840 and nRF52820 SoCs facilitate the Model O Wireless mouse's wireless and PC pairing functionality.

"Our product development and engineering teams recognized both Nordic chips as providing exceptionally efficient energy consumption while maintaining top level wireless performance."

Model O Wireless uses a 450 mAh Li-Ion battery providing up to 71 hours of play time in optimal configuration before recharge.

In Brief

NEARABLES, AIRABLES ADVANCE SLEEP TECH



Providing individuals with the tech tools they need to improve their sleep could influence global health outcomes, according to a company using AI to diagnose health conditions. Chris Fernandez, Co-founder of EnsoData said increasingly sophisticated sensors would enable wearables to gather waveforms like electrocardiograms, pulse oximetry and body movement with greater precision, while 'nearables' and 'airables' would also become commonplace in the sleep technology space. Nearables include devices that do not need to be attached to the individual, while airables use wireless signals from existing wireless transmitters and sensors to capture information about a person's sleep.

SWEAT TESTING PROMISES SIMPLER GLUCOSE CHECKS



Non-invasive glucose monitoring devices are not currently commercially available in the U.S., but a new device, created by Penn State University researchers and which can detect glucose in sweat, could see that change. While the concentration of glucose in sweat is about 100 times less than that in blood, there is a strong correlation. In a proof-of-concept test, the researchers used a skin safe adhesive to attach the reusable device to a person's arm one hour and three hours after a meal. A few minutes after collecting the sweat, the researchers found the detected glucose concentration dropped from the first measurement to the next.

SMART DISPLAYS SHOW THROUGH FABRIC



A [Bluetooth LE](#) connected display that shows information through clothes and other fabrics, has been developed by researchers at the University of Waterloo in Canada. The new technology, called PocketView, uses LED lights to display basic information. It can function as a standalone item or could be incorporated into smart devices. The display shines through fabrics to show notifications for email or messages, time, weather or other basic information. The researchers said the displays were deliberately designed to show minimal information, suitable, for example, to show simple navigation or weather conditions if the wearer is walking or cycling.

Sports & Fitness

Trampoline wearable provides activity and trick recognition

Sweden-based Wrlds Creations has launched a Bluetooth LE powered trampoline wearable that enables trampolinists of all skill levels to measure and track their activity. BERG AirHive is an unobtrusive wearable that straps to the user's right leg and combines a nine axis motion sensor and machine learning (ML) technology to accurately track their trampoline activity.

Designed for everyone from beginners to professionals, the wearable measures a range of movement data—for example, rotation speed—to allow the user to continuously record their progress and improve their skills. The company's AI software has been developed using data gathered from gymnasts performing jumps under real conditions to identify 15 different acrobatic tricks.

The ML algorithms enable the device to learn new tricks over time and provide feedback to the user based on learned data. The wearable is powered by Nordic Semiconductor's nRF52832 SoC.

The SoC's Bluetooth LE wireless connectivity enables the data to be relayed to the BERG AirHive app on the user's smartphone. The app includes minigames,



skill training, jump analytics and a 'social flow' function, which allows users to upload their latest tricks and create challenges for others in the community. "Strong processor performance and low power consumption were key requirements for this application," says Joakim Liljedahl,

Co-founder and Chief Revenue Officer, Wrlds Creations. "With the nRF52832, we were able to achieve the best of both worlds."

Employing a rechargeable 100 mAh capacity battery pack, the BERG AirHive product can achieve playing time of at least one week before being recharged, when in use for around two hours each day.

Smart Home

Bluetooth LE hob and cookware enables smart cooking

Appliances manufacturer, ASKO AB, has launched a range of Bluetooth LE induction hobs and smart cookware, designed to allow budding chefs to create dishes with precise temperature and timing control, thus eliminating challenges such as overcooking and boiling for too long.

The ASKO Celsius Cooking induction hobs use Nordic's nRF52832 SoC to wirelessly connect the hobs, smart cookware—including a fry pan, chef's pot and probe—and smartphone apps. In addition to built-in temperature sensors, the smart cookware employs motion sensors enabling the system to enter low power mode for extending battery life.

Each element in the solution is wirelessly connected via either Bluetooth LE or a

proprietary RF protocol. This system is enabled by the multiprotocol support capabilities of the integrated Nordic RF technology including the nRF52832 SoC. Temperature information is relayed from the smart cookware to the user's smartphone using the Bluetooth LE protocol. From there, the ConnectLife and Hestan Cue apps can be used to monitor cooking zones on the hob and follow the state of interactive recipes. The nRF52832 can also be used to wirelessly connect the hob to an overhead cooker hood enabling the hood to start automatically after the hob is activated, or allowing the user to, for example, change the hood fan speed from the hob.



Wearables

Alibaba pin ensures socially safe Olympics

Nordic Semiconductor collaborated with Alibaba to design a digital Olympic pin for the 2020 Tokyo Olympics. Based on a Cloud service platform and IoT technology, the Alibaba Cloud Pin wearable employs Nordic's nRF52840 Bluetooth LE SoC to provide the core processing power and wireless connectivity.

Built on the tradition of exchanging pins and buttons that dates to the first modern Olympic Games in Athens in 1896, the Alibaba Cloud Pin is said to be the first ever digital and Cloud connected pin, and was distributed to media working at this year's pandemic delayed Games in Tokyo.

The product has a 30 mm transfective LCD screen that acts as a digital name tag and personalized business card, displaying the wearer's name and unique artwork designs inspired by Olympic events. It also includes a step counting feature.

Smart Health

Biometric smart wearables predict illness before symptoms develop

Increasingly sophisticated wearable devices could detect illness in the wearer before symptoms develop, a new study published in *Jama Network Open* has found.

Researchers asked 31 people to wear a smart device that recorded information on the participants' heart rate, skin temperature, movement and how much electrical activity was on their skin. They were then infected with either the H1N1 influenza virus or rhinovirus. Once the study participants were exposed to their respective viruses, they were asked to report their daily symptoms, while the data collected by the wearables was used in an algorithm that predicted how likely someone would be infected and how severe their subsequent illness might be.

The researchers compared the participants' data after they were infected with their preinfection measurements and found the wearables were able to detect those who developed an infection and didn't develop an infection with 92 percent accuracy for those



who were exposed to H1N1. Those who were exposed to rhinovirus had an 88 percent detection rate with the wearables. The devices could even tell the difference between mild and moderate infections 24 hours before participants developed symptoms.

"Approximately nine percent of the world is infected with influenza annually, resulting in three-to-five million severe cases and 300,000 to 500,000 deaths per year," the researchers wrote. "This study suggests that the use of wearable devices to identify individuals with presymptomatic acute viral respiratory infection is feasible. Because wearable devices are common in the general population, using them for infection screening may help limit the spread of contagion."

Smart Health

Tech driven virtual care reduces patient readmission

Take home technology used by patients following non-elective surgery resulted in significantly greater detection and correction of drug errors, and reduction in patients' pain, according to a national study led by Canadian researchers from McMaster University. The study looked at patient outcomes from virtual care and remote automated monitoring (RAM) as well as self monitoring of vital signs using wearable devices.

"We began the study in the first months of the pandemic, when hospitals were challenged to drastically reduce non-emergency care," said P.J. Devereaux, co-principal investigator of the study. "Our study provides proof-of-concept that virtual care with RAM can improve outcomes after discharge following non-elective surgery."



Half of 905 post surgery patients were randomized and selected to use technology at home—a cellular tablet and RAM equipment to measure their heart rate, blood pressure, oxygen saturation, respiration rate, body temperature and weight—for 30 days after they left the hospital. These patients also took photos of any surgical wounds, and all data was sent via cellular communication back to the healthcare team.

The other half of patients received standard care, and were encouraged to reach out to their surgeon with any concerns. The study found fewer patients with the tech had to return to hospital for follow up care.

By the Numbers

\$148.5 million in revenue

Nordic Semiconductor has reported Q3 2021 revenue of \$148.5 million, a 24.4 percent increase over the same period the previous year. Gross profit grew by 22 percent on Q3 2021 to \$78.8 million. Revenue was roughly on par with the previous two quarters, as growth was capped by supply chain constraints. Bluetooth revenue amounted to \$124.3 million in Q3 2021, while cellular IoT reached revenue of \$5.3 million as the tech is in the early stages of commercialization.

12.3 billion connected IoT devices

Despite COVID-19's extended impact on the supply chain, the market for the IoT continues to grow according to market insight firm, IoT Analytics. By the end of 2021, the company said it expects the global number of connected IoT devices to grow nine percent to 12.3 billion active endpoints. By 2025, there will likely be more than 27 billion IoT connections. From a connectivity point of view, new technology standards such as 5G, Wi-Fi 6 and LPWANs are driving increased device connections, the firm said.

57% of Europe's electricity meters will be wireless by 2026

Wireless technologies will be used to connect 57 percent of European smart electric meters in 2026 with an installed base of 227 million units, according to IoT analyst company Berg Insight. This will be up from 25 percent in 2020. The company said much of the increase will be driven by the emergence of NB-IoT and LTE-M cellular IoT wireless tech for a second generation of smart electric meters, following the commercial breakthrough of cellular IoT technologies into the European smart metering market.

'World's first non-cellular 5G standard' promises high performance Massive IoT

Nordic is a key contributor to the ETSI DECT-2020 New Radio (NR) standard targeted at massive machine type communications demanding ultra reliable, low latency wireless networks

The European Telecommunications Standards Institute (ETSI) first developed the digital European cordless telecommunications (DECT) standard back in the early 1990s. Since then, the standard has evolved to encompass new technologies; the latest version has widened its scope still further to cater for 'Massive IoT'. [DECT-2020 New Radio \(NR\)](#) leverages the global license free 1.9 GHz band and is designed to support massive machine type communication (mMTC) wireless mesh and other types of network. These networks support IoT applications with very high deployment densities, and high reliability and low latency demands. (See sidebar next page: [What is DECT-2020 NR and how is it linked to 5G?](#))

"The reason why there are multiple wireless standards is because there's no perfect standard for every application," says Svein-Egil Nielsen, Nordic Semiconductor's CTO and EVP R&D and Strategy. "DECT-2020 NR will be a perfect fit for many existing applications and will no doubt trigger the development of a great many new ones. Applications that may not have been possible before."

Nielsen's interest in the standard comes because of Nordic's investment in its success. The company has played a key role in mapping the DECT-2020 NR specification. It is the main contributor to the physical layer (PHY) and a key contributor to the Medium Access Control (MAC) layer in the specification document. Nordic continues to serve as the editor for the PHY.

The initial DECT-2020 NR specification was published in July 2020, then amended in April 2021, with a new version (1.3.1) to be published in early 2022. The International Telecommunications Union (ITU) has included DECT-2020 NR as the first non-cellular 5G standard in [IMT-2020](#). IMT-2020 aims to specify the requirements for a global communications network for the coming decades that will incorporate IoT applications and key 5G use cases in its scope. Among these is a minimum requirement to support one million devices per square kilometer.

Enterprise IoT networks

DECT-2020 NR is particularly suited to the needs of enterprise IoT applications. Such applications typically need dense, decentralized deployments with low installation and running costs. Because the technology is based on the license free 1.9 GHz RF band, it is much easier for enterprises to easily set-up, manage and own a private wireless IoT network to connect millions of devices at very low cost of ownership. DECT-2020 NR employs decentralized mesh technology making it easy to add devices and eliminating single points of failure. If a node fails, communication is automatically re-routed via other nodes in the mesh network. Application examples include building automation, smart utility meters, manufacturing process automation, smart cities and logistics.



Tech Check

Nordic is working with Massive IoT solution firm Wirepas to accelerate development of a DECT-2020 NR capable version of Nordic's nRF91 Series SiP. The SiP, running Wirepas application firmware, will be targeted at massive machine type communications (mMTC) leveraging ultra reliable, low latency wireless mesh networks using the 1.9 GHz spectrum allocation

"Before now, building a private '5G' network required a lot of investment in infrastructure and so tended to only be the domain of larger enterprises," says Kjetil Holstad, Nordic Semiconductor's EVP for Product Management. "What DECT-2020 NR will effectively do is democratize the ability for any company or organization to build its own private network to run and optimize as they wish, free of a network operator. And do this using a license exempt and globally available frequency dedicated for this technology."

Holstad explains while indoor wireless coverage will likely be very high, the outdoor range of DECT-2020 NR will be restricted to around 2 km. Accordingly, Nordic places the technology in the new category of Wireless Neighborhood Area Networks (WNANs) rather than classifying it as an LPWAN like the cellular IoT technologies NB-IoT and LTE-M.

mMTC partnership

Nordic partner, Wirepas, is developing a "Private 5G" solution based on DECT-2020 NR that it describes as the "World's first non-cellular 5G connectivity product."

Wirepas is working with Nordic to accelerate the development of an nRF91 Series based DECT-2020 NR solution for mMTC applications. Because 1.9 GHz is recognized as a global license free band, a single product will be suitable in all regions, lowering costs.

"This new 5G IoT standard has been the missing piece in the wide-scale adoption of IoT," says Teppo Hemiä, CEO of Wirepas. "We know today only five percent of things that will be connected, are connected. To connect the remaining 95 percent, we need to let go of how things have been done in the past and dare to go [down] a different route."

What is DECT-2020 NR and how is it linked to 5G?

DECT-2020 New Radio (NR) is a "technology foundation targeted [at] local area wireless applications, which can be deployed anywhere by anyone in no time," according to the European Telecommunications Standards Institute (ETSI), the custodians of the standard. The technology enables autonomous and automatic operation with minimal maintenance effort. It supports point-to-point, star and mesh communication, with low latency links, enabling massive machine type communications (mMTC) for industry automation without the need for large infrastructure investments. The complexity of this technology is relatively low and use cases include asset tracking and industrial automation.

DECT-2020 NR doesn't rely on existing cellular infrastructure to operate. Because the technology is based on the license exempt 1.9 GHz RF band, private operators can set up a 'Massive IoT' network anywhere in the world without paying leasing costs. Within the network, each node can function as an access point with a direct backhaul connection to the Internet (in DECT-2020 NR terminology, nodes operating in this way are labeled "sink nodes"). Node autonomy enables the construction of a self-organizing and -healing mesh network. Reliability is increased because the lack of a centralized structure eliminates the chance that a single failure can paralyze the network. Traffic can be automatically and rapidly rerouted around any failed node or even back-up sink nodes. Every node in a DECT-2020 NR network can act as a relay node pushing traffic from a "leaf node" (a node on the edge) through as many router relay nodes as needed to get to a sink node. This functionality is automatically provisioned by the network.

DECT-2020 NR stacks up well against other wireless IoT technologies used for mMTC. When supporting node densities up to one million devices per square kilometer, existing technologies offer a maximum performance of sub-100 kbps throughput with sub-10 ms latency. In comparison, Nordic's nRF91 Series based DECT-2020 NR solution will offer up to 3 Mbps bandwidth with less than 1 ms latency. Such performance dramatically shortens on-air time, saving power, and supports advanced reliability and security measures without latency penalties.

Although DECT-2020 NR is not a cellular technology, its implementation shares fundamental similarities with cellular technology. Examples include a leading edge physical layer (PHY) with modulating and coding schemes that lean towards cellular technologies. Add self organizing network capabilities, and advanced interference avoidance and coexistence, and DECT-2020 NR earns its place in the 5G standards by being a leading radio technology. Reliability, security and performance at massive density scales are superior when compared with other existing non-cellular wireless IoT technologies. ETSI describes DECT-2020 NR as "the world's first non-cellular 5G technology".

DECT-2020 NR is the answer for next generation applications that are currently not viable because existing wireless technologies don't support the reliability and latency demanded when deploying networks at a million nodes per square kilometer.



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Education

Engineering education evolves to train tomorrow's IoT innovators

Hardware and software engineers are the lifeblood of tomorrow's connected world. Academia is looking at ways to ensure a steady supply

Former U.S. Secretary of Education Richard Riley's comments on the role of education in a rapidly changing world remain as true today as they did over two decades ago. "We are currently preparing students for jobs that don't yet exist, using technologies that haven't been invented, in order to solve problems we don't even know are problems yet." That puts pressure on governments, industries, companies and STEAM (Science, Technology, Engineering, the Arts and Mathematics) educators alike to come up with answers to tough questions. Questions such as: What does the engineering work of tomorrow look like? And how can education programs prepare young people and graduates for a future that's not entirely predictable, yet will likely revolve around technologies focused on big data, AI, machine learning (ML), edge computing and, of course, the IoT?

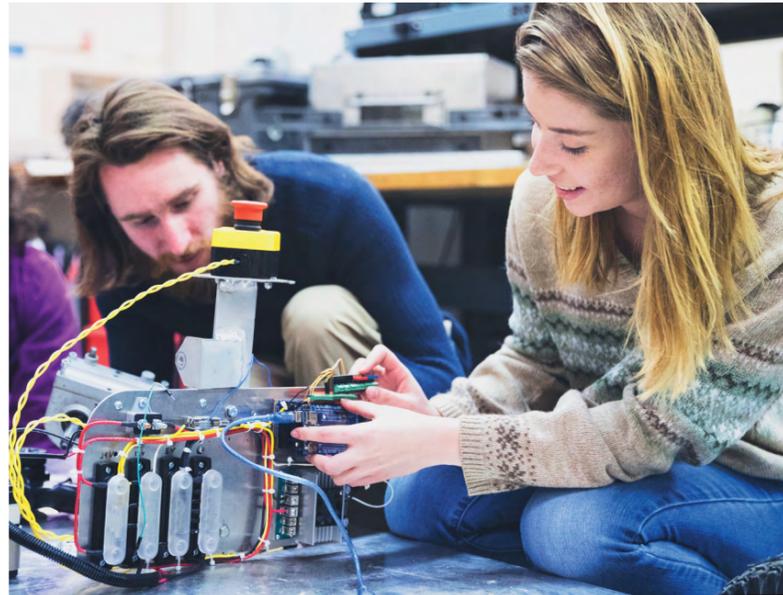
Society will need coders capable of leveraging advanced technologies to their full potential if innovation is to be relied upon to solve global challenges. To tackle climate change, aging populations, endemic diseases and sustainability we must build a pipeline for skilled engineering practitioners and make sure it flows continuously.

A 2020 study by the World Economic Forum (WEF) suggested the jobs of tomorrow will be based on seven key professional clusters that promise growth and prosperity in the future workforce. The study predicted data and AI, engineering and Cloud computing—disciplines which generally demand strong expertise in digital technologies—will be amongst the fastest growing professional clusters, with product development not far behind. For each of these clusters, skills described as 'tech disruptive' were found to be the most important, with 'tech baseline' skills also ranking highly.

The WEF study estimates the emerging employment areas are set to deliver 6.1 million new jobs within the next three years. And in the U.S., employment projections from the Bureau of Labor Statistics show 3.6 million computing-related job openings are expected by 2029. There appears little doubt the roles and responsibilities will exist, but will there be enough qualified people to perform them?

Breaking through the roadblocks

Industry insiders suggest that to meet future demand, the quality of engineering education must keep pace with technology. Moreover, by working to improve engineering education, institutions like schools and universities will better prepare students to fill looming digital and IoT skills shortages. Progress is good but challenges remain. One recent report, *Engineering Futures 2035: Engineering Education Programs, Priorities and Pedagogies*, by the Australian Council of Engineering Deans (ACED), listed the need for a greater focus on student engagement with



Tech Check

Unveiled in October 2020, the next-generation micro:bit is based on Nordic's nRF52833 SoC. It takes hands-on digital education to another level by combining a magnetometer, accelerometer and temperature sensors with a built-in speaker and microphone, while also supporting new complex functionality such as AI and ML applications



contemporary engineering practice and its sociotechnical contexts amongst seven key findings and 22 recommendations for the future of engineering education. Based on a 2019 national survey of undergraduates, the report states engineering students are less satisfied than students of all fields in engagement with skills development, teaching quality, student support, learning resources and overall quality of the learning experience.

Further, some education and technology stakeholders claim a lack of diversity in skills and ideas could stifle technological innovation as well as future career prospects. According to Bernadette Foley, General Manager Professional Standards at Engineers Australia: "What we need is diversity of programs, diversity of graduates and diversity of engineers, so that everyone can use their strengths differently and be successful in a range of career opportunities."

It's not only the nature and scope of the education itself to be considered; the demographics of learners matter too. In 1990, women represented 35 percent of the U.S. computer science workforce, but by 2017 this figure had fallen below 30 percent, while women accounted for just 16 percent of engineers, according to the country's National Science Board. When it comes to technology fields broadly, women are significantly outnumbered in both school programs and the workforce. They receive only 21 percent of computer science bachelor's degrees and hold only 25 percent of computing roles, says the U.S.'s National Center for Women & Information Technology (NCWIT).



By working to improve engineering education, institutions like schools and universities will better prepare students to fill looming digital and IoT skills shortages

In an attempt to close the gender gap and other imbalances in the technology sector, not-for-profit organizations like NCWIT, Girls Who Code, and AnitaB.org are providing wireless tech driven STEAM education resources to more women and girls, as well as underprivileged communities. The COVID-19 pandemic hasn't made this sizeable task any easier, but educators have adapted. At NCWIT, for example, Arduino kits—comprising development hardware for hands on tinkering as well as online lessons for electronics, programming and coding basics—have been used to continue teaching young students in the center's 'Code for Change' program.

Industry commitment

IoT wireless technology providers have a vested interest in the education of tomorrow's engineers. As the world's leading Bluetooth LE chipmaker, Nordic Semiconductor is committed to the objective of providing digital education opportunities for the coders of the future. This commitment is demonstrated not least by Nordic's partnership with the Micro:bit Educational Foundation—the not-for-profit organization behind the BBC micro:bit, a Nordic-powered, pocket sized computer and user friendly educational resource for teaching students about coding and how software and hardware work in tandem. The micro:bit could be helping around 100 million young people learn about technology by 2025. (*See WQ Issue 4, 2019 pg8*)

Companies are using the tiny computer as the basis for educational solutions that encourage an interest in coding. One example is Strawbees, a firm which provides a complete STEAM building and coding education solution to help teachers deliver curriculum aligned, class ready lessons. The STEAM Classroom Kit with Micro:bit combines physical building, robotics and electronics kits with web based development tools.

Nordic also recently joined global ICT leader, Nokia, and fellow fabless semiconductor company, MediaTek, in *establishing a new professorship* in SoC technologies for wireless systems at the University of Oulu, Finland. In sponsoring this professorship, Nordic further demonstrated its support for academia, education and research across engineering fields, particularly in relation to the advantages of low power wireless IoT connectivity. According to Svein-Egil Nielsen, CTO of Nordic, this type of cooperation with a leading research institution represents a great opportunity to contribute towards research and innovation for future wireless technology. "We believe the professorship will further enhance the interest in wireless education at Oulu University," explains Nielsen.

With industry stakeholders working together for better digital education, a healthy cohort of future coders will be ready to drive innovation.

Svein-Egil Nielsen
CTO/EVP R&D and Strategy



The IoT is no longer an emerging technology

If the COVID-19 pandemic has taught us anything it's that the Internet of Things is here and it's real

Just before the global COVID-19 outbreak in early 2020 I recall some members of the press still wondering out loud if the IoT was ever going to happen or if it was all just hype. Nobody is saying that now.

It was IoT wireless technology during the COVID-19 pandemic that played a pivotal role in keeping hospitals, organizations and businesses of all kinds functioning around the world. But the fact it took a once-in-a-lifetime pandemic to reveal a previously invisible revolution (except to professionals working in specific fields that employed the IoT) comes as absolutely no surprise to me.

Consider the arrival of the Internet in the mid 1990s, for example. Back then it was seen as an interesting new way to publish and find information, but not much more than that. And again some journalists wondered out loud if it would ever catch on. There was very little inkling of how the Internet would grow and evolve over the next 30 years, let alone fundamentally change our lives.

To me the IoT is in a very similar position today. Over the coming decades it is going to completely transform how we live, work and play in ways unimaginable to us today. And

I base that prediction on what the IoT is already doing: From crowd sourced prediction of infections, blood glucose monitoring, vaccine asset tracking, reducing greenhouse gas emissions and saving endangered animals in Africa – IoT wireless technology is at the forefront of saving the planet and making it a better, healthier and safer place to live. The current tech includes the increasing use of AI and machine learning that will bring a level of *autonomous 'intelligence'* to IoT applications that was unthinkable in the past. And most critically, in a commercially and technologically viable way at scale. The technology is affordable; the technology is useable even to those without a PhD in Mathematics or Computer Science.

These developments are vital. In fact I don't think we're going to stop climate change without the IoT. And we're certainly not going to ensure affordable patient care with an aging population and improve the treatment outcomes of chronic disease. There is a diabetes tsunami predicted for the world, for example, and lives will be destroyed and lost without the IoT. I can't state it more clearly than that. This is for real and it is here now.

And (as the current industry joke goes) if COVID-19 and the subsequent global chip shortage has done anything, it has at least educated the public as to what a semiconductor chip is. My hope is that they will come to know what the IoT is next.



Where in the World

Advancements in cellular tech, IoT and the Cloud promise to make location services viable for a greater number of industries

In Short

Location services are set to become more accessible to a broad spectrum of organizations

With a clearer and continuous view of the location of their assets, logistics companies can more efficiently manage their supply chains and more rapidly respond to issues

The benefits of asset tracking can extend beyond supply chains to other use cases including healthcare, construction, manufacturing and the consumer sector

The metaverse is coming. If the hyped forecasts of futurists are to be believed, we'll soon spend much of our lives in an online virtual world—comprising AR/VR, holographic avatars, video and more—moving effortlessly across vast and imagined geographies.

But for now, the physical realm remains at the forefront of our attention as we seek to marshal the planet's natural resources and manufactured products in a sustainable way. Ensuring sustainability lies in large part in understanding how many resources are available, how we're using them and, crucially, where they're located.

Addressing the last question has been a key driver behind the development of location technologies such as GNSS, which not only guides the layperson around their city but is increasingly being used to track the location of valuable commodities. The downside is that GNSS quickly drains batteries and relies on direct line-of-sight to the satellites.

Now, advancements in cellular technology, the IoT and the Cloud promise to complement GNSS and make 'location services' viable for an even larger set of asset tracking applications and make its benefits more accessible to a much broader spectrum of industries and organizations. In short, we are beginning to see the democratization of location intelligence.

The logistics industry in particular stands out as an arena in which better and greater use of location information is now being embraced, and where its application will have marked effects. Global supply chains are the critical arteries that connect and sustain the international economy. Fresh produce, household consumer goods, heavy machinery and medical supplies are a just a tiny sample of the vital items that criss-cross the globe daily, using a complex network of shipping routes, national highways and airspace.

SUPPLY CHAIN VISIBILITY

As critical as this global operation is, it is plagued with issues. Some estimates suggest companies lose \$2.4 billion annually to damage or loss of cargo at sea and more than \$30 billion to theft. To illustrate this point further, in one of the worst cargo



losses in history, 520 containers were lost overboard and 250 units damaged from a Danish container ship traveling between the Netherlands and Sri Lanka in 2014. In a similar vein, more than a fifth of items returned to retail giant Amazon are because they arrived damaged, according to Forrester Research. ([See WQ Issue 2, 2020 pg22.](#))

Given these figures, it's no surprise logistics firms and their customers want better supply chain visibility. An absence of data—on the whereabouts of assets and the conditions they encounter—creates sizeable blackspots that hinders the ability to detect and mitigate potential issues.

Asset tracking provides the answer. The technology monitors physical assets—be it shipping containers, pallets, or parcels—as they move from location to location. Tracking can be useful when the goods are in transit, or even when they are stationary at a site or facility. With a clearer and continuous view of the location of their assets, logistics companies can more efficiently manage their supply chains and more rapidly respond to issues and incidents. In fact, logistics giants contend that the use of asset tracking solutions in the global logistics sector could create \$1.9 trillion of economic value. Beyond the sizeable financial benefits, asset tracking can also help companies meet the expectations of regulators, who increasingly seek

to oversee shipping activity, and customers, who expect to receive accurate delivery information about their important goods.

The recent global supply chain crisis that continues to cause widespread shortages and delays has only made the need for asset tracking more pronounced. Disruptions due to the pandemic and transport labor shortages were among a number of factors that caused havoc with global supply chains. Over many years, these networks had been so heavily optimized that they were unable to cope with unplanned shocks—such as a shortage of shipping containers. ([See sidebar next page: Out of the box.](#))

"The same consultants who promoted the virtues of lean inventories now evangelize about supply chain resilience," wrote the *New York Times* recently. Operators now face a conundrum to "make their supply chains more resilient without weakening their competitiveness", says the *Harvard Business Review*.

Striking a better balance between ruthless efficiency and ensuring sufficient contingencies exist for unplanned shocks will arguably require logistics companies to have a clearer and more granular understanding of the movement of assets within their supply chains. In short, it will require better asset tracking.

LOCATION TECHNOLOGY

Ultimately, any asset or object considered valuable enough by its owner can theoretically be tracked, potentially opening the benefits of asset tracking beyond the optimization of supply chains. Clayton Hine, Business Development Manager at wireless IoT chipmaker Nordic Semiconductor, notes that providers in healthcare settings are already tracking critical medical equipment such as ventilators and beds to prevent valuable time and energy being expended searching for them. In construction and manufacturing, companies can track use of equipment and time spent at certain locations, allowing them to better understand how resources are used and how to optimize for future projects. Animal tracking similarly supports farmers to better manage their herds. Hine says the use of such tracking devices for domestic pets illustrates the potential of asset tracking for consumers. ([See WQ Issue 3, 2021, pg14.](#)) In that vein, food delivery also presents a compelling consumer use case.

A variety of asset tracking technologies have emerged over the years, but each is not equally suitable in every context. For example, barcodes and RFID have been used for asset tracking in factory and logistics contexts for some time,

By the Numbers

The use of asset tracking solutions in global logistics could create **\$1.9 trillion** of economic value

Source: Cisco and DHL

There will be **267 billion** IoT asset tracking devices deployed by 2027

Source: Reuters

165 network operators investing in NB-IoT

Source: Global mobile Suppliers Association

75 network operators investing in LTE-M

Source: Global mobile Suppliers Association

typically providing the last known location of freight items. However, in the case of barcodes, manual scanning is required while the use of RFID typically requires installation of additional infrastructure and only works over very short range. As such, these solutions don't commonly support real time tracking of assets.

THE POTENTIAL OF GNSS

GNSS is a widely recognized way to obtain accurate and real time location information and is particularly well known in cars, navigation devices and consumer electronics such as smartphones. The potential of GPS is also being exploited in the IoT and asset tracking context. [Cube Tracker's Cube GPS](#) is a prime example. The tracker uses the Nordic nRF9160 cellular IoT SiP's built-in GNSS capability to monitor and transmit the location of important assets.

But the use of GNSS for determining location involves notable trade-offs, particularly for battery-powered IoT devices that are required to operate over extended time periods in a variety of locations, says Hine. "GNSS can be very accurate for location, but it requires a direct line to multiple satellites—meaning the tracker only works outside—and it consumes enough power to quickly drain a typical asset tracker battery."

Fortunately, innovations have seen cellular trilateration now being used to determine the location of devices. This, and widespread cellular networks, mean asset tracking is becoming a viable option in a broader variety of contexts. "Cellular infrastructure is already deployed and covers most areas around the globe where assets need to be tracked," says Hine. "This means without spending any money on [expensive] infrastructure, you can get information about the location of an item almost anywhere."

Hine adds that cellular standards such as LTE-M and NB-IoT have been specifically developed for applications with lower data and lower power requirements, making longer-lasting battery powered asset trackers a reality. Location services that run over cellular networks also work indoors — another benefit over GNSS.

Cellular IoT asset tracking solutions can also deliver benefits beyond just location tracking. For instance, Norwegian company [Meshtech's environmental asset tracker](#)—based on the Nordic nRF9160—uses the SiP's built-in sensor support to determine not only the location of shipping consignments, but also to monitor temperature and whether a consignment has been dropped. This is beneficial for fragile or perishable goods such as food or medicines, with an estimated \$35 billion lost in waste annually in shipping perishable goods alone.

UP IN THE CLOUD

Cellular IoT appears to be following the arc of technologies such as PCs and smartphones, with the combination of growing sophistication of devices and falling costs fueling rapid uptake. But as companies add more trackable cellular IoT devices into their environments, new challenges emerge — namely, the need to manage a fleet of hundreds or thousands of devices and integrate and interpret the data they produce in quick time.



Tech Check

The [nRF9160 SiP](#) incorporates an Arm Cortex-M33 application processor, a full LTE modem, RF Front End (RFFE) and power management system. The modem supports both LTE-M and NB-IoT and can operate globally, removing the need for regional variants

Though some commercial IoT Cloud management solutions can support this, they can be clunky, making it difficult for young companies to integrate these products with their cellular IoT solutions. In response to this challenge, Nordic Semiconductor recently launched nRF Cloud Location Services. ([See WQ Issue 3, 2021 pg10.](#)) The service is designed to work with Nordic's cellular IoT solutions such as the nRF9160 and supports simplified configuration, management and maintenance of fleets of cellular IoT devices, says Ville-Veikko Helppi, Product Manager for Cloud Services at the company. Beyond supporting the management of devices, nRF Cloud Location Services also helps customers select a location service that optimally manages the trade-off between accuracy and power consumption. GNSS—while offering positional precision—consumes significant power, particularly in the 'time to first fix' (TTFF) when a GNSS device is searching for satellite signals and navigation data. As a result, it may not be appropriate for devices that need to run on low power for extended periods, such as during long periods of transit.

As an alternative, nRF Cloud Location Services offers single-cell and multi-cell location, which save power by not requiring a GNSS modem. Single-cell uses the nearest cell tower to provide a coarse location of the device, accurate to about a kilometer. "This is ideal where you need to track cargo or a container, but don't need to know precisely where it is. For instance, if you want to know the cargo is at Frankfurt airport and about to board the plane for South Africa, but you don't really need to know exactly which corner of the airport it's in," says Helppi. The multi-cell option uses a similar process, but determines location using multiple cell towers instead of one, with accuracy of a few hundred meters and a small power consumption penalty.

EXTENDING BATTERY LIFE

Where customers need more accurate location data than cellular services provide but would like to reduce the power drain of GPS (the U.S. version of GNSS), nRF Cloud Location



Services provides support for Assisted GPS and Predicted GPS options that help extend battery life. In Assisted GPS, 'assistance data'—that helps shorten TTFF and is usually obtained via satellites across a power hungry and slow radio link—is gathered via a fast and efficient cellular connection from a third party provider. This data narrows down the number of satellites a tracker device must look for and predicts their position, shortening the time taken to determine satellite location and thus extending battery life.

Predicted GPS builds on this technique, by using up to two weeks of predicted assistance data instead of just the few hours provided by Assisted GPS. "Consider a ship about to set sail that knows it will be at sea for five days. Using Predicted GPS, [a tracker] can pull down assistance data for those five days, [providing it] predictions about where to look for satellites during the time it is away from cellular networks or the Internet," says Helppi. By reducing the need to obtain new assistance data, Predicted GPS offers further power savings on Assisted GPS, while still providing precise location information.

The advancement of cellular infrastructure and tech, together with continued maturation of Cloud computing will result in even better location services. For example, [Polte's Cloud Location over Cellular \(C-LoC\)](#) promises highly accurate and continuous location for cellular devices, even as they roam. Solutions like Polte's integrate with nRF Cloud Location Services and the nRF9160 SiP, allowing Nordic customers to directly benefit from such advances. Polte has also joined the Nordic Partner Program as a solutions partner, cementing the relationship. ([See this issue pg6.](#))

With the criticality of supply chains as demonstrated by recent crises, and the continued intensification of cyber threats, the security of asset tracking solutions is also a priority. In addition to the well-known security of cellular networks, cellular IoT devices such as the nRF9160 provide additional layers of security through the use of Arm's TrustZone hardware—enforced isolation of critical components. Cloud solutions can add a further layer of security, with nRF Cloud Location Services employing authentication encryption for data that moves between devices and the Cloud. nRF Cloud Location Services

Out of the box

In the world of shipping, the most valuable item of cargo today is a box filled with air. Absurd as that sounds, a crippling shortage has turned the biggest boxes of them all—shipping containers—into a highly prized commodity. With shipments backing up in ports and factories, exporting nations have become desperate to get their hands on empty containers so they can meet the demands of customers around the world. Asian economies in particular rely heavily on exports to North America and Europe.

As a result, some countries have become rather "aggressive about trying to get empty containers back", a U.S. logistics executive, Mark Yeager, recently told CNBC. With China paying premium rates, it's now become more profitable to ship empty boxes than filling them, reports publisher Forbes.

With about 90 percent of the world's goods transported by ships, valued at around \$14 trillion each year, the stakes are high. One sizeable impact of the shortage of containers is a tenfold increase in prices for sending the metal boxes, which analysts say will eventually be passed on to customers.

The container shortage ultimately speaks to the difficulties of efficiently managing cargo movements at the immense scale of global trade. An illustration of this challenge is evident in the fact that, despite the intense scarcity of containers in some ports, empty containers have been found to be piling up at others. Yeager sums it up succinctly: There are 180 million containers worldwide but "they're in the wrong place".

Technology may offer answers. For example, improved asset tracking will provide improved data and visibility on the exact whereabouts of containers. Citing the shortage as motivation, Chinese tech giant Alibaba has recently launched a container booking service spanning more than 200 ports across 50 countries. A spin-off from Boston Consulting Group, xChange, also provides an online market of empty containers. Some call these developments the 'uberization' of container logistics.

It's all a long way from the invention of the shipping container. In 1956 American Malcolm McLean— then a truck driver, now dubbed the 'father of containerization'—had a simple idea: put cargo in standardized boxes to make more efficient use of space and enable the mechanized loading and unloading of ships. ([See WQ Spring 2019 pg14.](#))

Regardless of how the current shortage is resolved, it seems unlikely McLean could have foreseen his invention becoming such hot property and the crucial building blocks of a multi-trillion dollar global industry.

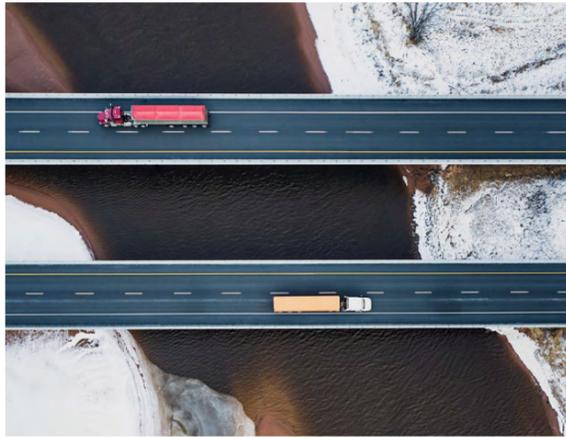


Nordic's nRF Cloud Location Services helps customers select a location service that optimally manages the trade-off between accuracy and power consumption, in line with their specific needs



Need to Know

The GPS system comprises a constellation of 31 satellites. Only 24 are needed for full global coverage but the additional satellites build in a degree of redundancy. Each satellite carries an atomic clock synchronized to within a few nanoseconds of the others in orbit and those at ground stations



simplifies this task with firmware updates over the air which, in addition to the security outcomes, also represents a convenience dividend for customers as the number of devices to manage grows.

LOCATING THE FUTURE

A more secure and integrated ecosystem comprising best-in-class SiPs, high quality cellular networks and the power of the Cloud not only makes location services more accessible, but also brings the opportunity to imagine new ideas and possibilities. For instance, the ability to access Cloud storage may enable users of nRF Cloud Location Services to identify new services and applications, says Helppi. "With cellular IoT combined with the Cloud, the asset tracking device is not the only option for storing data. We can capture more tracking data in Cloud storage, enabling us to view historical information about where an asset was and its condition at a particular moment." Helppi says this historical information could be useful for use cases such as insurance, investigations or route forecasting and optimization. In a similar way, cellular IoT tracking paired with Cloud location services might more readily enable leasing companies to pursue service based business models, by providing them Cloud based insights on time and distances traveled for leased equipment.

Smarter application of location services could also see the realization of a more automated supply chain. Silicon Valley-based IoT's combination of its **Pebble Tracker** with blockchain technology offers a glimpse of what's possible. The tracker uses Nordic's nRF9160 to send environmental and location data securely to blockchain based backend services and applications, which in turn determine if 'smart contracts' have been fulfilled. If an asset is lost or damaged, a blockchain contract can automatically penalize the transport company and compensate the customer.

The advent of Cloud location services is expected to spur more innovative applications like this, not least because companies will be relieved of the burden of managing and integrating their tracker devices. This enables them to focus time and effort on developing new ideas. By accelerating innovation like this, and forecasts by Reuters of 267 billion IoT asset tracking devices deployed by 2027, finding the future may be easier than ever.



“A more secure and integrated ecosystem not only makes location services more accessible, but also brings the opportunity to imagine new ideas and possibilities

Tech Check:
Smart supply chains keep cargo on track

An estimated 90 percent of the world's goods are transported by sea, the majority of it packed into steel shipping containers designed to ensure the estimated \$14 trillion of annual global cargo arrives safely at its destination. That may be the theory at least, but with some \$32 billion worth of sea cargo stolen or lost each year, wireless asset tracking is becoming a valuable tool for insurers and shipping companies alike to monitor the whereabouts of valuable goods

Illustration: Greg Bakes
<http://www.illustratorstralia.com/portfolios/greg-bakes/>



Ensuring containers are loaded and unloaded efficiently is complex. AI and machine learning software can reduce the 'dwell' time of each container on site, avoiding inflated storage fees and unnecessary stacking and restacking. AI can help prioritize which containers should be taken off the ship first (and therefore loaded last), and in what order they should be stacked to efficiently facilitate their onward journey

Low cost Bluetooth LE wireless devices, combined with sensors, can monitor and record forces and ambient conditions an individual box was subjected to during its journey, providing an audit trail if a shipment arrives damaged. Once it reaches the recipient, any impact events can be downloaded to a smartphone app enabling the recipient to demonstrate the damage likely occurred during the voyage and not once they had taken possession of the item

Wireless asset trackers provide perishable goods suppliers with end-to-end visibility of loads in transit. These devices regularly relay sensor data to the Cloud, alerting if a consignment of perishable goods exceeds its specified temperature. This allows the carrier to take immediate action to save the cargo, and provides traceability in the event of a compensation claim

Cargo theft is a problem estimated to cost the industry \$32 billion a year, and frequently it is criminals on land rather than pirates at sea responsible. For high value cargoes, cellular-based tracking technology allows the seller, shipper and customer to track its whereabouts across cities, countries or even the globe and be immediately alerted if the asset becomes separated from its shipping container

With ships at sea out of range of cellular coverage, smart devices can continuously record and store the location of cargo and whether it has been subjected to any knocks or water ingress, for example. Once back on dry land the device can be interrogated for this data to ensure nothing went wrong



Shanghai is home to the largest container terminal in the world, with a capacity to handle 43 million containers, and 514 million tonnes of cargo each year. The port covers an area of 3,619km² and employs more than 14,000 staff. To keep track of dockworkers is a formidable logistics operation in its own right, but wireless tech can help. Bluetooth LE-powered tags in combination with gateways enable employers to track staff across sprawling workplaces, as well as provide navigational information to any lost employees

Silver Lining

By leveraging pandemic proven wireless tech, industries are better equipped to track workers' safety and boost productivity

Back in the early 1970s the U.S. Department of Defense was desperate to identify a way for soldiers to inject themselves with an antidote in the event of a nerve gas attack. Drawing up a drug using conventional syringes and fragile glass vials was impractical. The solution came in the form of an invention which swiftly delivered medication by triggering a spring-loaded mechanism that pushed a needle into a muscle to administer medication. Invented by American Sheldon Kaplan, such was the practicality of the device that it was soon launched onto the commercial market and since 1980 has saved countless lives from anaphylaxis, a severe allergic reaction. Anaphylaxis is treated with epinephrine, which must be injected promptly by inexperienced users. Kaplan's EpiPen is the perfect solution.

In early 2020, authorities were desperate for a way to track-and-trace the movement of people stricken with coronavirus to slow the virus' spread. The solution came in the form of proximity monitoring—initially by leveraging Bluetooth in smartphones but later in purpose designed [Bluetooth LE wearables](#) and tags—a technology that enables detection of nearby wireless devices and records interactions for later download and analysis to help track infection. (See [WQ Issue 2, 2020 pg8.](#))

Over the past 18 months, wherever people and network coverage have come together, an implementation of proximity monitoring technology has mushroomed. Systems have been employed to ensure adherence to social distancing protocols and inform decision making by authorities on issues related to population movement and interaction. The latest global adversity has proven once



Proximity monitoring technology can ensure cleaning staff regularly attend high traffic areas

again that necessity truly is the mother of invention.

Now proximity monitoring is set to follow the EpiPen – first designed to mitigate a crisis but such useful technology it has much wider potential. Rigorously tested and proven-in-combat, to what purpose could proximity monitoring be put post-pandemic? How will it prove relevant and beneficial in the workplaces and domestic communities of tomorrow? These are questions being considered by stakeholders on both sides of the geofence, from IoT developers and wireless solutions providers to global industries and start-ups.

POWERING A NEW NORMAL

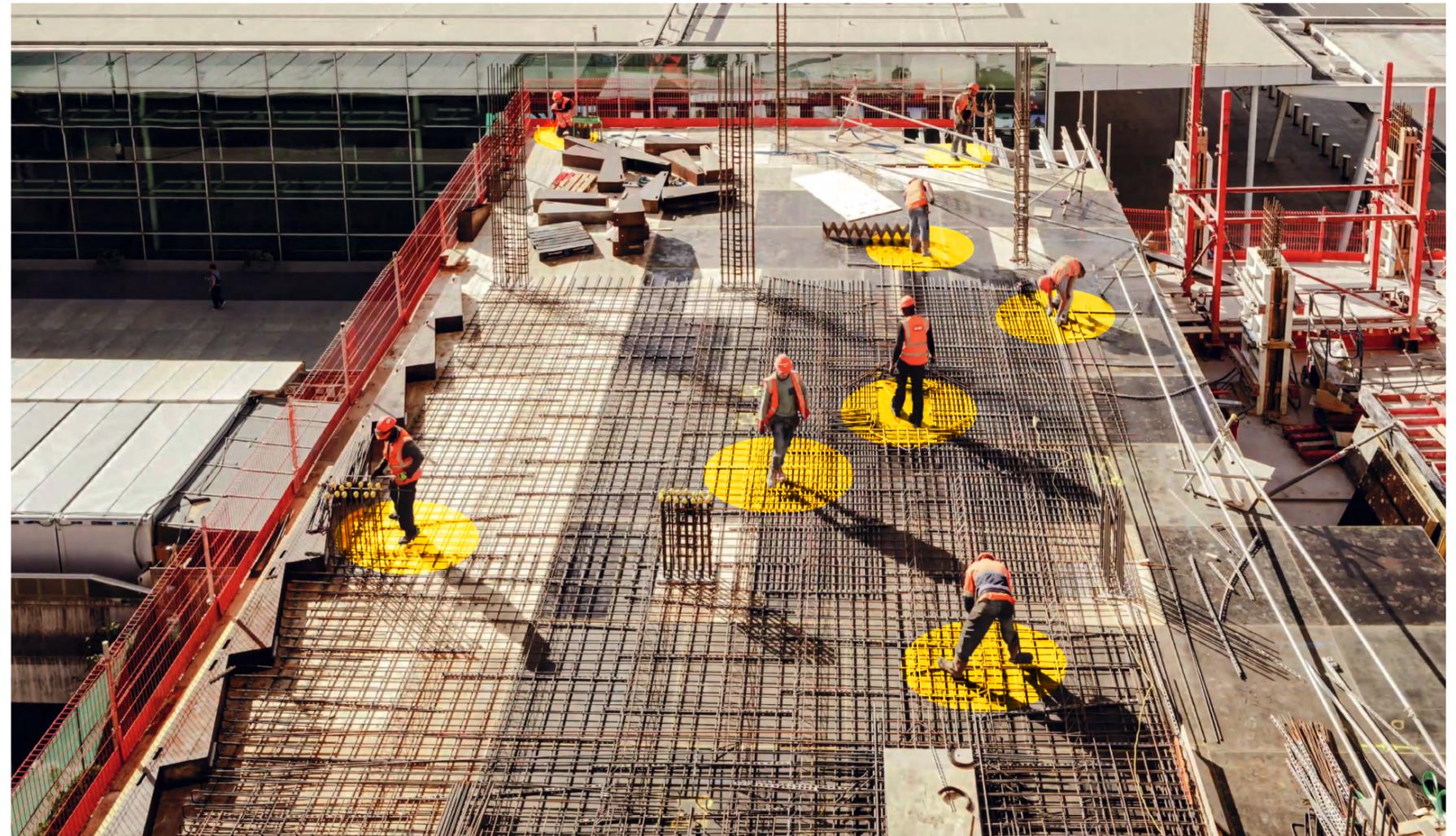
Proximity monitoring and detection solutions built during the pandemic have served a noble purpose and the world is now on a course to normalcy. And with the SARS-CoV-2 becoming endemic such technology will continue to be vital. But now, the technology offers many advantages for myriad other people- or asset-monitoring applications. Examples include tracking workplace health and safety procedure adherence, reducing the risk of workplace accidents and improving business efficiency and productivity via operational analytics.

Deployments could even stretch to emergency management, attendance automation and automated time-keeping. Industries as diverse as manufacturing, food processing, education, the military and even film production could benefit from technology that accurately tracks the interaction of groups of people and provides insights into their behavior. These are applications that were previously served by unwieldy and clunky technology before a highly infectious disease spurred the world to look at a better way of doing things.

Moreover, from a behavioral perspective, technology first developed for pandemic mitigation will make humans more aware of their actions in relation to others and in avoiding potential risks of sickness or infection from other illnesses such as the common cold or influenza.

A final benefit of proven proximity monitoring technology is that emerging applications can be rapidly deployed because the supporting infrastructure now exists.

One area of concern is that proximity monitoring applications record some personal information – but there is evidence that consumers are willing to cede some privacy if the value of the application is demonstrably beneficial. (See [WQ Issue 2, 2020 pg16.](#))



In Short

Developed as a contact tracing tool to combat the pandemic, proximity monitoring applications are now emerging in a diverse range of sectors

Rebooted industries are realizing the technology will improve efficiency by establishing a safer and more productive workplace

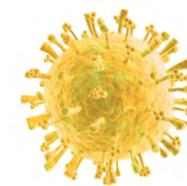
Familiarity with proximity monitoring has helped build industry awareness and created an appetite for wireless technologies in other use cases

BUSINESS REBOOT

Finland-based Wirepas, an IoT technology company and a Nordic Semiconductor partner, is a pioneer in proximity monitoring. The company's core technology is its proprietary Wirepas Massive connectivity software, a decentralized large scale mesh networking solution designed for a wide array of 'Massive IoT' applications. The solution enables smart devices to automatically connect to each other to form a mesh network and find the most efficient route to a gateway. In this advanced setup, every device is continuously capable of multidirectional wireless communication.

According to Youssef Kamel, SVP Ecosystem from Wirepas, post-pandemic industries are rebooting and as a result are realizing there are many operations that need to radically change to reduce business exposure and vulnerability. A key lesson from the pandemic is that the emergence of proximity monitoring technologies has improved efficiency by establishing a safer and more productive workplace for employees. (See [sidebar pg23: The new world of hybrid office work.](#))

"Contact tracing [using proximity monitoring] is one of the technologies that allowed employees to return to a safer work environment in a shorter timeframe," says Kamel. "And now, many managers who used contact tracing systems in the work environment realize the value



Need to Know

By using contact tracing tech to battle COVID-19, humans have also unwittingly culled the Influenza virus. In Australia, for example, in 2019 there were over 313,000 cases of flu. That dropped to 21,356 in 2020. Up until the end of October 2021 (which is well past the peak for the traditional Southern Hemisphere 'flu season) just 584 cases have been recorded.

Source: Immunisation Coalition

this technology will bring [across other applications]. "[Familiarity with proximity monitoring] helped build awareness and created more appetite for wireless technologies in other use cases like smart-tracking, -buildings and -factories," adds Kamel.

An example of this awareness comes from the construction, energy and manufacturing sectors, where 'digital' helmets allow workers to dispense with lengthy morning gatherings previously required to check they've turned up for work. Moreover, the helmets can ensure compliance with safety guidelines, in turn allowing project managers to remotely monitor the progress of their construction projects and plan accordingly.

A commercial implementation of a digital helmet is [WakeCap](#), which uses a Wirepas software powered network to enable safer working environments and enhance operational efficiency. Wirepas specified Nordic's [nRF52832](#) Bluetooth LE SoC to power the sensors, the network nodes placed throughout the worksite and the gateways used by the WakeCap wearable, which was developed and brought to market by San Francisco, CA-based WakeCap Technologies.

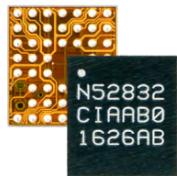
Designed to overcome the challenge of obtaining accurate visibility of employee flow and equipment location and with no additional worker training or configuration required, WakeCap enables near real time and 'real motion'

Feature: Proximity Monitoring

site reporting and information. WakeCap's analytics compare the onsite work crew timing with staffing and project management plans, highlighting unexpected problems early and avoiding delays or extra costs. For safety, the hard hat mounted sensors track the location of the wearer on a worksite and record any incidents of the hard hat being subjected to force. The decentralized Wirepas Massive network allows each WakeCap hard hat to relay important data forward to another hard hat or anchor node maximizing coverage across a large worksite and reducing the number of anchor nodes or gateways required.

The comprehensive site activity data generated by the wearable includes worker time, location and motion/shock analytics, and can be relayed via Wirepas Mesh to the Cloud. From there, site management can review the information and actionable insights via the WakeCap Analysis Platform. The platform provides a touchless automated attendance system, social distancing monitoring and contact tracing.

Elsewhere, the pandemic proved the catalyst for three London hospitals to deploy Wirepas' smart tracking technology to monitor thousands of assets across 90,000 m² of floor space. The system eased the treatment of sick patients—by, for example, making it simpler and quicker to locate critical equipment such as infusion pumps and oxygen masks as well as key staff—at a time when the system was under huge stress. Now the hospitals have weathered the storm, operational efficiency has been significantly boosted as authorities understand the value of tracking technology and how best to use it.



Tech Check

Nordic's nRF52832 is a general-purpose multiprotocol SoC. It meets the challenges of a broad range of applications that need advanced Bluetooth LE connectivity, protocol concurrency and a rich and varied set of peripherals and features

EMERGING APPLICATIONS

A demonstration of how proximity monitoring is enhancing other wireless technology applications comes from [Stratosfy Marker](#). The firm, which styles itself as a "connected service delivery monitoring company", is enabling business owners and operations managers to ensure the workforce carries out its activities on time and in the right place. The Canadian company's Nordic nRF52840 SoC powered solution combines proximity monitoring with mature beacon technology (see *this issue pg24*) to automatically register the presence of staff when they are close to wall mounted beacons or when they

unlock location based task lists. The equipment is used, for example, to ensure all the washrooms at a facility have been regularly attended by the cleaning personnel.

Once the location data has been relayed from the device to the worker's smartphone, an administrator or facility manager can monitor the activities being performed at predetermined locations from a proprietary Apple iOS or Android app.

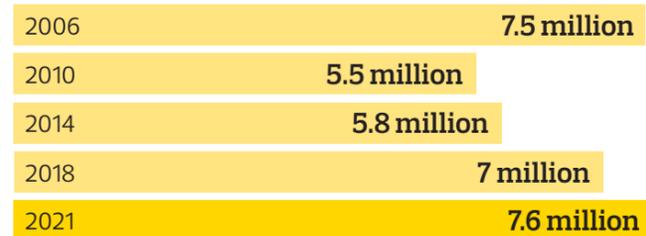
"Stratosfy Marker empowers commercial cleaning contractors [by providing near] real-time, granular and accurate reporting to the level of individual service points at a facility," explains Madan Kanala, Founder and CEO of Stratosfy.

A second Canadian company, I-SYST, is using Nordic technology to power its [BLUEPYRO-M3225](#) module. The solution provides plug-and-play motion/proximity detection capability, enabling users to quickly set up a system for wireless room occupancy detection for applications such as lighting control, security systems and smart thermostats. The unit cleverly combines both passive infrared (PIR) and proximity monitoring to maximize battery life.

Other proximity monitoring technologies are emerging for personnel tracking applications such as locating and identifying staff on industrial worksites. For example, French developer of wireless sensors and beacons, ELA Innovation, has designed a range of Nordic Bluetooth LE

Source: Deloitte, U.S. Bureau of Labor Statistics

U.S. construction industry employment



State of Play

Authorized personnel only

Construction sites will always be hazardous, but that doesn't mean they should be death traps. Wireless technology—built into safety clothing and used to monitor the whereabouts and health of construction workers—is just the latest aid aimed at cutting injuries and deaths. And it is desperately needed. Although things have dramatically improved since the U.S. Congress passed the OH&S Act in 1970, the construction industry still suffers from a disproportionately high rate of work related fatalities. According to the U.S. Department of Labor, about 20 percent (1,061 workers) of employee deaths in private industry in 2019 were in construction. Getting on top of the problem is vital because since the 2008 financial crisis and the pandemic, the industry is again a booming employer

Feature: Proximity Monitoring



The new world of hybrid office work

For millions of office workers, commuting is no longer a daily chore. As part of the new normal, many office jobs have skewed away from the central business district and towards the suburbs. That's forcing companies which previously have never seriously considered alternatives to full time attendance at a bricks-and-mortar workplace to investigate how it could be replaced by flexible, hybrid remote/onsite worker models.

After an initial shift to home working to damp down COVID-19 infection rates, twenty-seven percent of the American workforce remained working remotely during 2021, according to a survey by freelancing marketplace, Upwork.

That has its advantages and downsides. On one hand, productivity rises because workers have greater autonomy to manage their own workflows and concentrate on tasks while avoiding the distractions endemic to the traditional office. For example, one study looking at the call centers of a Fortune 500 online retailer found that the productivity of its employees working from home increased by 7.5 percent. And digital tools like virtual whiteboarding platforms, video conferencing, project management software and instant messenger channels will make face-to-face connections less essential. On the other, remoteness stymies creativity and decreases the effectiveness of collaborative processes. Part of that has to do with missing the company of friends, according to an article in the *Harvard Business Review*.

Ideal work arrangements of the future will likely combine home working with office life. Workers will be given much more flexibility, underpinned by proximity monitoring tools that will enable employees to come and go while keeping track of attendance hours and informing managers when staff members are in the office.

Companies are also using technology to ensure that when employees do venture to HQ, the experience is a lot more pleasant. For example, *The Business Times* reports that in Schneider Electric's offices in Kallang, Singapore, over a thousand sensors across nine floors track the occupancy of workstations and meeting rooms in near real time. The data helps the company tailor lighting and HVAC according to attendance.

Smart buildings that monitor air quality and adjust ventilation to suit are also increasingly common. A 2011 Danish study reported that people working in conventional open plan premises take 62 percent more sick leave compared with those that have their own enclosed workspace. Keeping the air fresher and cleaner could help reduce that figure.



“Managers who've already used contact tracing systems in the work environment realize the value this technology will bring”

SoC powered [wearable beacons](#). The solution was used to secure an underground construction site in Vancouver. In operation, tags were attached to the helmets of approximately 30 workers descending and ascending a well, with two RFID antennas used to track the whole workforce in near real time. ELA Innovation also partners with Wirepas for mesh networking capabilities.

TAKING THE NEXT STEP

Received Signal Strength Indication (RSSI) has long been exploited as a proxy for distance between two Bluetooth LE devices as a convenient application for locating a misplaced smartphone by using the wireless connectivity built into wearables. But at the outbreak of the pandemic some clever engineers realized that the ubiquity of those smartphones and the dual-mode (Classic Bluetooth plus Bluetooth LE) chips therein formed a ready made infrastructure for contact tracing. With the addition of some simple software, it became relatively straightforward to rapidly deploy a contact tracing system. The solution wasn't without its flaws—not all handsets have Bluetooth connectivity, it was incumbent on owners of compatible mobiles to download an app and make sure it was activated for the system to work, and there were privacy concerns—but its implementation was a stroke of genius and certainly saved thousands of lives.

Yet contact tracing alone is not the silver lining to the dark clouds of the pandemic. Rather, the real prize comes from the work of those pioneering companies that grasped the full potential of proximity monitoring technology. First, these firms made contact tracing globally available to less developed regions with lower smartphone penetration through low cost [Bluetooth LE wearables](#). And then they worked out how the technology could be applied to other sectors as the world returned to a degree of normalcy.

But things are only just getting started; the products described above represent just the first of what will be a tsunami of proximity monitoring applications. Now that engineers have got their hands on this fledgling technology, they will come up with thousands of applications that we can't even begin to guess at.

Inside Track

Supported by developments in beacon technology, wireless location services are making consumers' lives simpler

Beacons were envisaged as a key application of Bluetooth technology. So much so that Apple, with iBeacon, and Google, with Eddystone, introduced beacon profiles in the middle of the last decade to make it easier for developers to access the technology and supercharge the sector.

Early implementations made use of Bluetooth LE tech's three advertising channels to detect the presence of a nearby consumer's smartphone and trigger an associated app hosted on the handset. The app in turn could then offer contextual information based on the shopper's location. For example, if the customer was hovering near a particular product range in a supermarket aisle, such as breakfast cereals, the app could highlight a preconfigured special offer on the products in question, such as a discount deal on a cereal-and-milk combination. Or in a museum with beacon infrastructure, a visitor could listen to explanatory audio triggered on an app by a beacon near an exhibit.

But reality didn't quite meet the hype and beacons have been less of a hit than anticipated. Two challenges stymied adoption. The first was that the smartphone location was determined by Received Signal Strength Indication (RSSI) which is a proxy for distance between receiver and transmitter. However, other factors—such as attenuation due to obstacles—affect the signal strength too, limiting the precision of the distance calculation. So, a consumer might be looking at peanuts rather than cereal when they receive the combination offer. Second, because Bluetooth LE tech's advertising channels have limited data carrying capability (just 31 Bytes) the signal the smartphone receives informs it that the beacon is not soliciting pairing and solely provides the beacon's unique ID. The app then does the heavy lifting of associating that ID with the appropriate contextual information. The result is that if the app is not running, then the beacon is useless.

But now, changes to the Bluetooth Core Specification in versions 5 and 5.1 have addressed these deficiencies. Bluetooth 5, adopted in December 2017, not only increased the wireless tech's range and throughput, but also included an advertising extensions feature which increased the advertising channels' capacity to 255 Bytes. Now, a retailer can use advertising extensions to directly send bespoke information about a special deal or new product (think 'buy your favorite item, get a second half price' or 'hey, you looked at coffee machines; right now, you can get 10

In Short

Early beacons were basic devices using advertising packets to detect smartphone proximity and open a specific app

The updated Bluetooth 5 and 5.1 specifications included revisions that enhanced beacons' communication and indoor navigation capabilities

Retailers are now introducing proximity applications and location services to improve customer experiences and boost sales

Nordic powered beacon solutions are leading the way forward in retail, hospitality, healthcare and transport hubs



percent off the latest model') without the need for an app. (*See WQ Spring 2019 pg26.*)

Then, in early 2019, Bluetooth 5.1 added Direction Finding to the specification. The technology provides the basis for precision positional estimates in two or three dimensions—superior to that facilitated by RSSI—by adding support for Angle-of-Arrival (AoA) and Angle of Departure (AoD) location methods. (*See WQ Summer 2019 pg26.*)

These enhancements have changed beacons from a useful but constrained technology into one that offers comprehensive support for a range of advanced location services for the benefit of consumers and providers alike.

WHAT'S IN STORE?

Today's beacons support use cases that extend from proactive retail engagement offering customers real time contextual experiences, to indoor asset tracking and personal location devices. The technology is now operating in shopping malls, airports, hospitals and numerous other indoor venues where location relevant information can provide important advantages to create a better customer experience and improve business efficiency.

For consumers the technology makes it possible to access directory services providing information on nearby

points of interest such as restaurants; take advantage of indoor navigation or wayfinding services within large facilities like retail centers and airports; and receive personalized marketing directly to their smartphones.

By using beacons for location intelligence, retailers can collect customer footfall data and gather important insights into their behavior to help improve marketing strategies and campaigns; use customer location data to analyze trends and understand how a customer demographic is changing in a particular area; track the location of assets in real time and manage inventory; and push notifications about ongoing deals and special offers as customers enter or leave a geofenced virtual zone.

Increasingly sophisticated wireless enabled business models for consumer engagement are emerging on the scene. Retailers, for one, are introducing advanced location

services and proximity applications. One example is the DEVIO Beacon, a Bluetooth LE wireless product providing a targeted retail marketing solution. Developed by Thailand-based telecommunication provider, Advanced Info Service (AIS), DEVIO Beacon employs Nordic's [nRF52840](#) SoC to wirelessly push sales and marketing notifications to potential customers. The solution is designed for use in retail marketing and transport applications, offices or at major community events, enabling owners to broadcast sales and marketing information to a smartphone when it is within a ten to 25 meter radius.

DEVIO Beacon is compatible with LINE, a popular mobile messaging platform in South East Asia with more than 49 million active users in Thailand, and can, for example, be used to offer product discounts, advertise sales or promote complementary products via a LINE Official Account. Crucially, the solution does not require consumers to have a retailer's specific app installed on their smartphone. From a web based platform the business owner can easily configure their marketing campaign to set the length of the campaign period, determine the frequency of broadcast messages, create individual campaigns for different store locations and choose to send messages across as text, images, videos or links.

SMART TAGS DOUBLE AS BEACONS

Another Nordic-powered solution, the [Minew ESL](#) (Electronic Shelf Label) smart shelf labeling system—developed by China-based technology company and Nordic Partner Program member, Shenzhen Minew Technologies—is designed to replace traditional, manually updated price tags with smart tags for improved price visibility. The platform can also be used to enhance marketing and customer experiences. The electronic shelf labels use Nordic's [nRF52810](#) SoC to perform as beacons for marketing to consumers at the point-of-label via compatible Apple iOS and Android apps on the consumer's smartphone. The smart labels also report back to a Nordic [nRF52832](#) SoC powered gateway and a Cloud platform, allowing retailers to remotely monitor and manage their stock and the precise positioning of products on shelves.

"Location based beacons are increasingly being adopted in the retail sector to help cement a mutually beneficial relationship between retailers and consumers," says Melinda Huang, Vice Sales Director, Shenzhen Minew Technologies. "For effective 'proximity marketing', fixed



Need to Know

Advertisements are used by Bluetooth LE devices to broadcast data and information that can be discovered and processed by observer devices. This means information can be broadcast to multiple devices at the same time, as opposed to "connected" Bluetooth devices, which only allow peer-to-peer communication. Advertising extensions in Bluetooth 5 provide the capability to offload advertising data from the three traditional advertising channels to the full set of data channels for greater throughput and frequency diversity

Tech Check

DEVIO Beacon is used in retail marketing and can send messages as text, images, videos or links. It does not require consumers to install a specific app on their smartphone



CoreAIoT's base locator adds direction finding capabilities to existing wireless products such as third party tags and beacons, or other Bluetooth LE enabled devices such as asset tags and smart locks



BlueIoT, a Bluetooth LE AoA positioning system, enables customers and staff to navigate their way to a specified location or item via a partner app on their smartphone



By the Numbers

The global retail market is expected to grow from almost \$20.3 trillion in 2020 to **\$29.3 trillion** in 2025

Source: Research and Markets

During the 2021–2025 forecast period, the beacon market is poised to grow at a CAGR of about **56%**

Source: Research and Markets

The global smart beacon market is expected to reach **\$103.9 billion** by 2030 from \$3.3 billion in 2020

Source: Allied Market Research

136 million Bluetooth RTLS tags and trackers will ship in 2021

Source: Bluetooth SIG's 2021 Bluetooth Market Update

locators are capable of broadcasting continuous signals to Bluetooth LE and Wi-Fi enabled devices in range, delivering highly targeted messages to users within a precise area."

A final retail application comes from the draft beverage industry. Brewers, distributors and retailers are tapping into consumer purchasing behavior data using a smart tap solution and subscription based retail analytics platform developed by [TappTek](#). Beyond this solution's core ability to provide pour activity and volume dispensing analytics using Nordic powered wireless connectivity between sensor device and smartphone, TappTek can also be used as a beacon to provide contextual information and promotional deals for a product at the point-of-retail.

It's also possible to add direction finding capabilities to existing wireless products using Shenzhen-based CoreAlot's Nordic powered "[base locator](#)". The waterproof base locator can be wirelessly connected to third party tags and beacons, or other Bluetooth LE enabled devices such as asset tags and smart locks. According to the company, a single locator (equipped with the firm's proprietary software) can achieve two-dimensional positioning with a precision down to less than a meter by using AoA technology. The device is said to reduce the cost and complexity of deployment by minimizing the number of base locators required for a given application.

The data from the base locator is relayed to the Cloud from where the company's CoreLocation Positioning Assistant app can be used to monitor location information of the other devices discovered by the locator.

LEADING THE WAY

Advanced beacon technology is supporting a cautious return to normalcy as retail, hospitality, healthcare and transport hubs open-up post pandemic. People are returning to public places around the world, but protecting them has taken on a greater priority. It is now essential for shops and restaurants, for example, to ensure they're adhering to stringent occupancy standards. Monitoring foot traffic through stores is vital, as is knowing how many people have used the restrooms. At a larger facility like a shopping mall or airport, fixed locators make it feasible to implement dynamic digital versions of a whiteboard for cleaning staff, or to automatically indicate to people in transit that a particular area has been recently cleaned.

These examples are markers for a wider trend which indicates [Bluetooth LE beacons](#) will be the foundation for further advancements supported by location services, indoor navigation and direction finding technologies. This is good news for the sector's health; the segment is expected to exhibit good medium term expansion, with 32 percent compound annual growth rate (CAGR) in annual device shipments from 2021 to 2025, according to the Bluetooth Special Interest Group's (SIG) 2021 *Bluetooth Market Update*, based primarily on analysis by consultant ABI Research. The report suggests retail is the vertical taking the most significant advantage of Bluetooth Location Services, with 66 percent of all implementations currently supporting retail use cases.

The report also notes that 79 percent of Bluetooth



Beacon tech will help you get more out of a visit to your favorite art gallery

Location Services solutions include indoor navigation properties. This is perhaps of little surprise because [Bluetooth Direction Finding](#) capabilities allow for far greater functionality than previous versions of beacons could achieve. Now, since the latest generation of beacons know the precise position of smartphone owners, they can guide them effectively to specific indoor locations. For example, in the case of an airport, a traveler could use beacon infrastructure to confidently navigate from the security check to their designated gate. This could become more important as airports evolve following the pandemic. (See sidebar next page: *The changing face of airports.*)

BEYOND BLUETOOTH

The advent of GNSS has made it easier for people to find their way on the road. New location services promise to do the same for people on foot. For example, a visitor to an art gallery could use beacon infrastructure to move swiftly to the prize exhibit. Or shoppers could be guided to the sales items inside a large store. The result is the consumer experience is made far more convenient with the removal of frustrating searches.

Moreover, this technology gives companies providing products or services to consumers the ability to offer greater flexibility and then differentiate their offering based on the level of this convenience. One example is [BlueIoT](#), a Bluetooth LE AoA positioning system designed for indoor use in supermarkets, exhibitions and warehouses. BlueIoT employs Nordic [nRF52833](#) SoC powered tags placed in key locations throughout a facility or attached to items such as goods and shopping carts. It enables customers and staff to navigate their way to a specified location or item via a partner app on their smartphone. The user can navigate to any given tag within an accuracy of down to 30 cm, even in the case of non-line-of-sight applications. The application also helps retail stores gain in-depth insights into their customers' behavior and movement such that they can modify the store layout for optimum flow.

Bluetooth LE has some advantages for indoor navigation including long battery life and smartphone interoperability, but it's not the only game in town for location services.



Smart beer taps equipped with beacons can provide contextual information and promotional deals at the point of retail

For very precise location accuracy, down to just a few centimeters, engineers are turning to Ultra Wideband (UWB), an RF technology which calculates position by measuring the time-of-flight between transmitter and receiver, instead of using signal strength as a proxy for distance. There are already commercial solutions that complement the battery saving advantages of Bluetooth LE with the precision of UWB. Bluetooth Direction Finding locates the approximate position of the object, with the higher power consumption UWB switching in for a short period to enhance precision. (See [WQ Issue 3, 2020 pg22](#).)

For applications that require a lower degree of precision, Wi-Fi is an option, guiding consumers by detecting their proximity to routers sited in known fixed locations. While positional accuracy is lower than with Bluetooth, it is sufficient for many applications, especially those designed to give contextual information. The tech also has the advantage of accessing available infrastructure formed by millions of already installed smartphones and routers.

Finally, there are a swathe of applications, particularly in the asset tracking sector, designed to support location accuracy down to around a range of tens of meters. (See [pg14](#).) The primary function of these devices is to track goods as they move across a wide geographical area, for example a container on the back of a truck. Solutions employing Nordic's [nRF9160](#) SiP cellular IoT solution combine GNSS with cellular location services to allow for a trade off between location accuracy and battery life. But the same devices could also turn to indoor tracking by using cellular only when the GNSS signal is lost. Location accuracy is limited to a few hundred meters, but this is sufficient for a user to determine, for example, if a valuable pallet has arrived at its delivery destination deep inside a shopping mall.

As location services advance it's likely that tracking solutions will use a combination of short range wireless beacons, UWB, Wi-Fi and cellular to enable a trade off between cost, precision, battery life and interoperability. Developers making the most of technology will have the inside track in the race to success. And the result of their endeavors will be products that better engage consumers and boost the bottom line.



For effective proximity marketing, fixed locators are capable of broadcasting highly targeted messages to engage users within a defined area

The changing face of airports

From 2019 to 2020 international air departures fell by 71.8 percent (according to figures from GlobalData). With travel and border restrictions, airport footfall dropped alarmingly. However, abandoned airports are now returning to something resembling regular service and it won't take too much longer before international departures exceed pre-pandemic levels. That could be as soon as 2024, predicts analyst GlobalData.

Sadly, the dour airport experience we previously knew could become even more regimented and stressful. New stipulations around vaccine passports, temperature checks and COVID-19 rapid tests, not to mention social distancing and hygiene measures, will dictate just about every move a passenger makes. Just like the heightened focus on security measures in the wake of 9/11, the pandemic will leave a lasting impact on the process of arriving, departing and passing through the terminal.

But as airports evolve, some of the more challenging elements of the passenger experience may ease. Airports and airlines will look to minimize delays introduced by H&S screenings by implementing infrastructure and systems that speed up the process. For example, contactless technology will help smooth the flow of foot traffic around convoluted airport thoroughfares dotted with additional protocols and procedures.

Among the trend setters, London Heathrow Airport and Doha International Airport are using camera based technology and staff with state-of-the-art helmets to perform real time monitoring of passengers' temperatures. Meanwhile, Etihad Airways has installed advanced check in kiosks to identify virus symptoms, and Dubai Airport has invested in an AI powered security system to replace immigration officers.

And in the U.S., the Transportation Security Administration (TSA) has deployed credential authentication technology (CAT) scanners at many airports nationwide. These devices can access a traveler's specific flight information from their digital ID, thus mitigating the need for a boarding pass.

Beyond these streamlined screening and security processes, airports will use AI to work out the best way to route crowds from security to gate and will then incorporate indoor navigation services to ensure travelers are guided along that optimum path. In this way it just might be that the pandemic has kick started an airport revolution that could see flying evolve from a chore to a treat.



A Picture of Health

Wireless tech is helping Type 1 diabetics precisely control blood glucose and enjoy an uncompromised lifestyle

By the Numbers

8.5%
Prevalence of diabetes among the world's adult population in 2014

Source: WHO

43%
Diabetes deaths before the age of 70

Source: WHO

\$827 billion
Direct annual cost of diabetes to the world in 2016

Source: WHO

Global insulin pump market size in 2020: **\$3.62 billion**

Projected market in 2028: **\$11.86 billion**

Source: Fortune Business Insights

Back in 2006, Will Cross stood on the roof of the world. At 8,848 meters, the summit of Everest is well above the 'death zone' where the lack of oxygen can kill within hours and a slip within seconds. Since then, Cross has climbed the highest peaks on the other six continents. He's also led expeditions to unexplored regions of Patagonia, Greenland, Africa and India. And he's walked to the North and South Poles. It's an impressive list of achievements for even the fittest of athletes, yet Cross has suffered with Type 1 diabetes for over 40 years.

Type 1 diabetes is an autoimmune disease in which the body destroys its own insulin producing cells in the pancreas and as a result the body's ability to regulate glucose in the blood. (See sidebar next page: *The two faces of a silent killer.*) Before the development of treatment by insulin injections in the early 1920s, the disease killed sufferers within a year or two. And even as recently as the late 1970s, Type 1 diabetics faced a regimented life of carefully measuring their food, limiting physical activity, monitoring blood glucose using urine strips and injecting two different types of insulin multiple times a day. It was difficult enough to go to school or hold down a regular job, let alone climb killer mountains and trek across treacherous ice sheets.

A TREATMENT REVOLUTION

Since the 1980s, there has been a revolution in diabetes control. Deeper knowledge of how the body uses and stores glucose and the impact of different types of food, exercise and sleep has allowed physicians to refine treatment. Medical technology has also progressed rapidly. First came insulin 'pens' which allowed diabetics to inject insulin in carefully metered amounts from an injector with a large reservoir – saving them from having to draw up each dose from a vial and eliminating the danger of incorrect dosage. That was followed by portable electronic monitors which, together with a finger prick to release some blood, allowed diabetics to conveniently check their blood glucose anytime, anywhere.

Today, developments are focused on the 'artificial pancreas'. The term describes closed loop control of blood glucose using a system comprising a constant glucose monitor (CGM), a control algorithm, and an insulin infusion pump. Engineers and scientists are working hard to enhance and refine that positive feedback system. And wireless technology is proving the key to closing the loop.

Even patients without access to infusion pumps can take advantage of wireless technology. Nordic customer Diabnex, for example, offers its [Clipsulin](#) insulin injection

monitoring and recording device which features wireless connectivity powered by Nordic's [nRF52832 SoC](#). The device attaches to insulin pens and employs a vibration sensor to accurately detect insulin dosage, with the data then wirelessly transmitted to the user's smartphone. An app functions as a digital logbook for the patient, not only recording their insulin use but also enabling them to monitor blood glucose levels and physical activity.

Another Nordic customer, SiBionics, specializes in CGM sensors. The Shenzhen, China-based firm's [GS1CGM](#) System allows diabetics to continuously monitor and record their blood glucose levels for up to fourteen days before replacement. A sterile disposable electrochemical sensor—applied to the user's upper arm by a minimally invasive method—measures glucose levels in the interstitial fluid between capillaries and cells. Data is wirelessly sent to the user's smartphone via Nordic powered Bluetooth LE connectivity. This information can also be shared with medical professionals via a Cloud based dashboard for blood glucose management, either remotely or at the hospital.

South Korea-based EOFlow has introduced a low cost alternative to the insulin infusion pump in the form of its [EOPatch](#) insulin management system. The product—which can be worn for up to three-and-a-half days—is a wearable and disposable insulin delivery system which incorporates a Nordic nRF52832 SoC. The medical wearable includes a soft cannula for insulin delivery and an insulin reservoir. Once EOFlow has been attached and activated, the patient can use a smartphone to control and deliver insulin from the patch. The insulin requirement is calculated based on the user's current blood glucose level, amount of insulin already in the body and carbohydrate intake. (See [pg30](#).)

In addition to these examples, wireless technology is now a routine fitment to insulin pumps to receive RF signals from Bluetooth LE equipped CGMs (and blood glucose meters for sensor calibration purposes). The pump uses the CGM data to adapt and customize the infusion algorithm, and to ensure the user doesn't administer excessive insulin.

PLANNING THREE MOVES AHEAD

Next steps for the pump and sensors makers include mobile connectivity—such that family and carers can be quickly updated about the sufferer's blood glucose levels—sensors that can be worn for longer between changes and more compact insulin pumps with longer battery life.

But while pump and sensor technology has dramatically advanced in recent years, the optimum artificial pancreas is still some way off. Blood glucose control is a highly



complex physiological system and dozens of factors affect outcomes, including diet, hydration, exercise, sleep, stress and illness. Control systems also exhibit considerable inertia with insulin infusions taking tens of minutes to impact glucose levels. Worse yet, sensors introduce their own inertia because glucose levels in interstitial fluid can lead or lag that of the blood by five-to-fifteen minutes.

An article in the American Diabetes Association's Diabetes publication ([Artificial Pancreas: Past, Present, Future](#) by Claudio Cobelli et al) notes that the mechanical and electronic elements of the artificial pancreas are mature and the key to major improvements lies in the software algorithm that decides when and how much insulin to infuse. Future system will leverage machine learning (ML) and AI to not only consider data from a simple closed loop comprising sensor and pump, but also influential factors such as the patient's daily routine, and physiological factors such as temperature, heart rate and stress levels. Such data will allow an adaptive algorithm to plan the insulin infusion regime based on a 'chess' approach, planning three or four moves ahead and refining the strategy as the 'game' develops.

While the number of Type 2 diabetes sufferers is showing some decline in the developed world as health education encourages people to adopt better lifestyles, global numbers are increasing. Meanwhile Type 1 numbers are climbing everywhere; The U.S. Centers for Disease Control and Prevention (CDC), for example, reported 1.6 million American adults and children with Type 1 diabetes in 2020, up from 1.25 million in 2017. That makes diabetes a significant threat to global health.

But a fusion of precision mechanical components, wireless electronics and clever software offers hope. The wireless electronics, for example, include ever more powerful embedded processors with the capability to directly run ML software allowing for algorithm adaptation at the sensor or pump itself. That means diabetes sufferers will be able to discretely manage their disease while presenting a picture of rude health to the rest of the world.

The two faces of a silent killer

According to the World Health Organization (WHO), the number of people with diabetes rose from 108 million in 1980 to 422 million in 2014. The disease is a major cause of blindness, kidney failure, heart attacks, stroke and lower limb amputation, and between 2000 and 2016, there was a five per cent increase in premature mortality from diabetes. During the same period, the top killers (cardiovascular disease, cancer and chronic respiratory disease) decreased by 18 percent for people aged between 30 and 70. 95 percent of diabetes sufferers have the Type 2 version of the disease and one of the reasons for its escalation is because much of the world's population is putting on weight and doing less exercise.

The digestive system breaks down carbohydrates into glucose, a simple sugar. Some of it is stored in the liver while the rest enters the blood stream to provide a ready source of energy for the body's functions and movement. For healthy body function, the level of glucose in the blood stream must be tightly controlled; as blood glucose levels rise, the pancreas produces insulin, a hormone that prompts cells to absorb glucose for energy or storage. As the cells use up glucose, levels fall and the pancreas switches to releasing glucagon, a hormone that signals the liver to start releasing stored glucose.

Diabetes is the disease that upsets the mechanism. If the disease is unchecked, blood glucose can rise, eventually damaging eyes and organs. Or it can plummet to dangerously low levels which could result in coma and even death.

Type 2 diabetes develops gradually as the cells develop insulin resistance which causes blood sugar to remain stubbornly high. Treatment involves reversing resistance by improving overall health and/or medication. Long term Type 2 diabetes can irreversibly damage insulin producing cells such that the patient must inject insulin to control glucose levels.

Type 1 diabetes is much rarer and results from an autoimmune condition where the patient's own body destroys the insulin producing cells. The patient is faced with a lifetime of metered insulin injections to control the disease.



Need to Know

A diabetes infusion pump automatically delivers insulin whenever a wirelessly connected CGM detects a rise in blood glucose, and shuts off the medication when blood glucose drops. Users can also manually set the pump to administer additional 'boluses' of insulin to cope with rapid increases of glucose at mealtimes



Smart Health

EOPatch

Bluetooth LE insulin management system helps patients monitor diabetic therapy while maintaining an active lifestyle

An increasing incidence of lifestyle disorders such as diabetes and hypertension is leading to a reliance on devices that can constantly monitor physiological parameters such as blood glucose and blood pressure. Alongside wearables that support a healthy lifestyle, these devices will see the market expand to \$68.7 billion by 2027 according to Grand View Research



An active lifestyle makes your body more sensitive to insulin—the hormone that allows cells in your body to use blood glucose for energy—which in turn can help manage diabetes. Nor is the condition an impediment to athletic performance. Former U.S. swimmer Gary Hall Jr. has Type 1 diabetes but still claimed 10 Olympic medals in the pool, including five golds

António Laureano claims to have ridden the biggest wave ever at [Praia do Norte](#) in Nazaré, Portugal. In October last year, Laureano surfed a wave there estimated by the University of Lisbon's Faculty of Human Kinetics to measure an incredible 30.9 meters, equivalent in height to a 10 story building



EOPatch continuously delivers insulin under the skin via a soft cannula, helping control blood glucose levels in diabetic patients who need basal insulin and periodic injections of bolus insulin. The reservoir holds up to 2 ml. The insulin management system includes a controller that connects to the iOS and Android compatible EOBridge Cloud based diabetes data management program via the EOCloud server



Tech Check

The EOPatch provides continuous use for up to three-and-a-half days prior to disposal, thanks in part to the ultra low power characteristics of the Nordic nRF52832. The SoC has been engineered to minimize power consumption with features such as the 2.4 GHz radio's 5.5 mA peak RX/TX currents and a fully automatic power management system

EOPatch is a waterproof, tubeless, wearable and disposable insulin pump integrating a Nordic nRF52832 SoC. Once the EOPatch is filled with insulin, attached and activated, the patient can use either a smart touchscreen remote controller or app to control and deliver insulin from the patch. The controller enables the appropriate amount of insulin required based on the body's needs

Surfing is a sport that can be enjoyed by people of all ages, but [Baby Shave Roberson](#) was an early starter by anyone's reckoning. The now 13 year old created history when he surfed the world class point of Honolua Bay in Hawai'i at the tender age of just 4, and then 6 years later surfed the legendary 18 meter waves of 'Jaws' in Maui and lived to tell the tale

Industrial Automation

Industrial IoT gateway solution offers Cloud connectivity to wireless sensors

Developed by TZero, the Nordic nRF9160 SiP powered MachineMailbox tool uses LTE-M/NB-IoT to connect critical industrial systems

When factory owners and industrial process managers decide they need to improve productivity, a hired consultant will often point them straight to the IoT. After all, the IoT can help pave a way to enhanced data generation and Cloud connectivity that leads to better decision making. There's only one problem: The facility might be operating on wired systems that can't easily be converted. Fortunately, there is now a simple solution.

For those struggling with the perceived complexity of the Industrial IoT (IIoT), the ability to deploy connected sensor/machine-based solutions requiring zero configuration has the potential to be a game changer.

A machine connectivity tool

State College, PA-based technology company, TZero, has developed a cellular IoT gateway solution that enables wireless connectivity in critical industrial systems where network access is challenging – such as manufacturing equipment, robotics or chemical plant monitoring.

TZero's MachineMailbox connectivity tool is ready out-of-the-box to help industrial customers with remote compliance, equipment diagnostics and maintenance, and process optimization. Although vital, MachineMailbox is just one component of the overall IIoT solution. In addition to developing custom sensing solutions, such as the Sonic Density Sensor—used in fermentation monitoring or process chilling to monitor the health of fluid mixtures—TZero has built a data aggregating and processing backend that transforms the incoming sensor data into actionable intelligence.

"Very few people will purchase a drill for the sake of owning it; what one really wants is the hole. Likewise, raw sensor data is rarely the end goal in a complete solution," says Eli Hughes, CTO of TZero Research and Development. "Instead of simply visualizing raw sensor data on a dashboard, we strive to build solutions that contextualize information into asset-based intelligence."

In a brewery environment, for example, where critical level and temperature data would previously have to be collected manually, MachineMailbox can be deployed to enable fermentation monitoring. Using the solution, sensors in the brewer's tanks collect data that is relayed to TZero's proprietary gateway, and in turn to the Cloud using the LTE-M/NB-IoT cellular connectivity enabled by the integration of Nordic's nRF9160 SiP.

Hughes explains that for such a brewery solution, the company wanted the sensor and connectivity to "fade away" into the background. "The end user needs to know the status of the product in the tank," he says. "By using cellular connectivity and Cloud computing we can distribute the workload by doing high speed computations



TZero brings the IIoT to brewing and provides a fast and accurate picture as to what's happening inside fermentation tanks

at the edge, while calculating asset state and long term trends in the Cloud to give the user a true picture of what is going on in their process."

MachineMailbox connects to external sensors via a wired full duplex RS485 data port, which allows for flexibility in servicing different applications. RS485 has a large installed footprint in industrial systems so, whether for legacy or new systems, the RS485 based system means MachineMailbox can be used in many scenarios.

"The data rate of RS485 is well matched to LTE-M/NB-IoT networks so it's a good starting point for a general-purpose industrial connectivity tool," says Hughes.

Similar to placing items in a mailbox, the hardware can be configured to appear on an industrial network as a 'sink' where something else feeds in the data, or it can query attached devices. Using software configuration or a firmware change, MachineMailbox can then communicate using various wired protocols like Modbus (both client or server), BACnet, DMX or another custom protocol.

Once MachineMailbox sends information to TZero's Cloud platform (deployed on Microsoft Azure), applications can be customized with additional processing, notifications and remote visualizations.

Switching to cellular

The previous iteration of TZero's machine connectivity tool used Nordic's nRF52840 SoC coupled to an external modem. However, when the nRF9160 became available,



TZero favors cellular IoT over Wi-Fi because the service needs to provide reliable wireless connectivity, no security limitations and minimal complexity



Tech Check

Nordic's nRF9160 is a compact, highly integrated, low power cellular IoT SiP. The integrated modem supports both LTE-M and NB-IoT wireless connectivity. TZero employs LTE-M/NB-IoT in its MachineMailbox as cellular networks are ideal for connecting Industrial IoT systems to the Cloud

Chris Fryatt

Director of Product Management, Metasphere



Protecting freshwater and marine ecosystems

Cellular IoT tech can end polluting wastewater spills

Water pollution is seen as an unacceptable environmental and public health issue around the world. Ultimately, our target has to see zero pollution incidents to allow natural waterways to recover. Unfortunately, we are some way from achieving that. Today there are thousands of pollution events per year.

In the U.K., we have a combined wastewater network where rainwater, and domestic and industrial wastewater all ends up in the same pipes. That can cause the network to become overwhelmed and divert excess contaminated water into waterways, fields, woodlands and other designated spill areas.

In addition to these capacity issues, humans are causing more problems with network blockages (largely caused by sanitary wipes and fat) that can cause further spills, including into domestic property.

IoT and AI based, world first platform designed to protect freshwater and marine ecosystems from spill pollution. The solution is based around the Nordic nRF9160 multimode NB-IoT/LTE-M SiP.



Called ART Sewer, the platform targets utilities worldwide, provides network visibility and adds industry first intelligence to provide a proactive tool allowing utilities to take action and prevent spills. All that's required are battery powered, wireless cup-sized radar wastewater level sensors called Sense Level. These devices use radar to detect water levels and can be easily deployed in quantity. (See pg 4.)

We selected cellular IoT because it's the best LPWAN technology for the bidirectional communication required so the devices can be updated remotely over-the-air. Cellular IoT also brings security, reliability and global ubiquity.

The intelligence of the system comes from combining the monitored wastewater levels with rainfall data and using our machine learning model to predict wastewater flow across the network including sewers, pumping stations and treatment plants.

"We developed a world-first platform to protect freshwater and marine ecosystems

The plight of our natural waterways is increasingly coming into focus with campaign groups highlighting the impact these spills are having. Open water swimmers, for example, are experiencing the environmental damage and health hazards first hand.

Tackling this issue has been a challenge as most of the extensive wastewater network (over 500,000 km in the U.K.) is underground and existing wastewater spill monitoring solutions are expensive and limited. And large portions of the network are unmonitored leaving the utilities to react to spill events after they happen. Now, my company, Metasphere, has developed a cellular

The tip of the fat berg

The system is also able to detect partial blockages before they become full blockages. 'Fat bergs' are caused by an accumulation of things like cooking fats and sanitary wipes entering the sewer system. If detected early these can be cleared using high power jets when they are of a size that is easier to deal with.

The solution enables us to prevent flooding events in a way that wasn't possible until now. It also enables maintenance crews to be scheduled and deployed in an optimized way. The aim is to significantly reduce the amount of wastewater pollution which will lead to a cleaner and greener world for us all.

[Tech Zone]

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

Industrial IoT

Nordic & AVSystem collaborate on Lightweight M2M

Nordic Semiconductor will collaborate with Polish company, AVSystem, to ease the development and management of IoT solutions. The cooperation will ensure interoperability and optimization of cellular IoT development tools and device management platforms to accelerate emerging M2M applications.

The companies are initially working to ensure seamless interoperable Lightweight M2M (LwM2M) connectivity between Nordic's nRF Connect SDK and the AVSystem Coiote IoT Device Management platform when designing IoT devices based on Nordic's nRF9160 SiP. Further collaboration will make it easier for developers to use Nordic's cellular IoT technology for a wider range of emerging M2M applications in the logistics and industrial automation sectors.

"By working with AVSystem, we aim to give our customers a more complete and product-ready solution for their IoT applications," says Joel Stapleton, Principal Engineering Manager with Nordic. "The collaboration enables us to accelerate the development of application services and capabilities, for example, in asset tracking and machine learning applications, or delivering advanced device diagnostics."

The companies' work together has already resulted in an automated regression test framework to validate LwM2M client and server implementations, and ensure protocol optimization and interoperability for developers. Nordic uses remote interfaces to AVSystem's Coiote IoT platform to initiate tests and extract results to measure performance and meet quality criteria.



"The collaboration with Nordic means we have a device vendor counterpart with whom to validate protocol implementations," says Marcin Nagy, IoT Product Director with AVSystem. "This is the key for open standards, and ensures we can accelerate the product readiness of new capabilities."

Wearables

IMU delivers accurate orientation data

U.S. tech company, Sensor Maestros, has launched a wearable 'sensor fusion module' that integrates a nine-degrees-of-freedom (9DoF) IMU—including a gyroscope, accelerometer and magnetometer—to deliver accurate absolute orientation data, as well as pressure/altitude, temperature and humidity sensors.



Powered by Nordic's nRF52832 SoC, the SFM2 provides up to an 833 Hz sensor fusion output data rate (ODR) and up to an 1667 Hz ODR for raw accelerometer and gyroscope output. Five or more SFM2 devices can be used and synchronized by the firm's smSENSR-LOGR smartphone app.

The SFM2 uses the nRF52832 SoC's Bluetooth LE throughput capability to provide data rates approaching 50 kbps, which are demonstrated to be feasible on newer mobile devices, claims Sensor Maestros. The company says SFM2 is the smallest and lowest power wearable IMU on the market to provide both Bluetooth LE and USB connectivity.

New nRF21540 Development Bundle will provide developers range extension boost

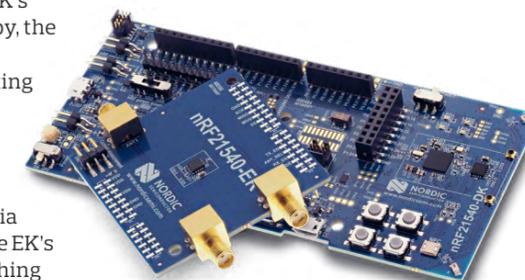
Nordic Semiconductor will soon launch the nRF21540 Development Bundle (DB) – design tools for verification and testing of applications that require the range extension or link budget improvements provided by its nRF21540 RF Front-End Module (FEM). The nRF21540 DB comprises the nRF21540 DK and the nRF21540 Evaluation Kit (EK).

The nRF21540 DK is the ideal tool for application performance testing of designs taking advantage of the extended range offered by the nRF21540 RF FEM. Based on Nordic's nRF52840 DK, the nRF21540 DK incorporates the nRF21540 RF FEM and has two chip antennas and ports for antenna diversity and additional SWF connectors for making direct RF measurements. The DK's RF FEM is connected to, and controlled by, the onboard nRF52840 SoC.

The nRF21540 EK is a shield incorporating the nRF21540 RF FEM and can be used for easy radio testing and development. The EK can be connected directly to an nRF52 or nRF53 Series SoC antenna output or to any of the Nordic SoC DKs via their Arduino Uno Rev 3 header pins. The EK's nRF21540's gain control, antenna switching

and operational modes are controlled via GPIO or SPI or a combination of both, accessible through the Arduino Uno Rev3 compatible headers.

"While the nRF21540 RF FEM will almost certainly extend the range and increase the link budget of any compatible 2.4 GHz radios ... it can be difficult for a developer to work out how to ensure their design gains maximum benefit," says Paal Kastnes, Technical Marketing Manager with Nordic. "The nRF21540 DB makes it simple for developers to experiment with the FEM such that they can become familiar with its capabilities and configuration and use the chip to its best advantage in their end product."



Nordic and Edge Impulse bring Machine Learning to cellular IoT

Nordic Semiconductor and Edge Impulse have introduced TinyML support for both the nRF9160 DK and the Nordic Thingy:91 cellular IoT prototyping platform. Following the introduction, both Nordic low power cellular IoT development tools are integrated into Edge Impulse's Edge Impulse Studio product.

The collaboration allows developers without TinyML programming expertise to quickly get started on fully supported standalone 'inferencing' projects based on Nordic's nRF Connect SDK. The example projects can then be run on the nRF9160 DK and Thingy:91.

"The introduction of TinyML for nRF9160 SiP based low power cellular IoT applications allows developers to quickly move beyond experimenting with ML code and building up expertise," says Joakim Tønnesen, Technical Product Manager with Nordic. "This means developers can focus on the best way to use their hard won data [for] innovative and exciting cellular IoT applications."

TinyML is a scaled-down form of ML



suitable for IoT edge devices such as wireless sensors. When using TinyML, Cloud based ML training and model synthesis is made simpler and faster compared with conventional techniques that rely on server training of increasingly large and complex models. The resultant lightweight models can then run efficiently on the optimized compute resources of the target edge devices.

All that's needed for developers to get started with TinyML projects is access to Edge Impulse Studio, an nRF9160 DK and some sensors, or a Thingy:91. Once the nRF9160 SiP based development tools are linked to Edge Impulse Studio it is straightforward to build and deploy a ready-to-go binary file of an industrial grade TinyML algorithm suitable for a low power cellular IoT application.

nRF Connect for VS Code accelerates wireless development

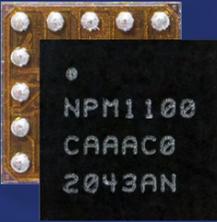
Nordic Semiconductor has launched nRF Connect for VS Code, an extension pack that allows developers to use the popular Visual Studio Code IDE to develop, build, test and deploy embedded applications based on Nordic's nRF Connect SDK.

Nordic's nRF Connect for Visual Studio Code turns VS Code into a complete IDE for developing applications on Nordic products and includes an interface to the compiler and linker, an RTOS-aware debugger, a seamless interface to the nRF Connect SDK and an integrated serial terminal among other valuable development tools.

VS Code is a lightweight, powerful IDE for macOS, Linux and Windows that combines the simplicity of a source code editor with powerful developer tooling. It has a strong ecosystem for extensions that makes it highly extensible.



Industry's most compact power management solution



Actual size
2x2mm



nPM1100 Power Management IC

The company that helped connect all those little things to the Internet is now helping you charge and power them – while keeping them small.

START YOUR DEVELOPMENT TODAY

nordicsemi.com/nPM1100



Inside Nordic's nPM1100 power management IC

Nordic's new PMIC perfectly complements the power demands of the company's wireless chips while also looking after battery charging

Nordic Semiconductor's nRF52 and nRF53 Series multiprotocol SoCs include embedded power supplies. The devices are efficient, able to serve multiple voltage rails and are powering millions of wireless products around the globe. So why has Nordic recently introduced the nPM1100 PMIC, its first discrete power management IC?

The company says the introduction was in part driven by a common customer requirement for an external voltage regulator capable of supplying both the SoC and charging the wireless device's battery. But it was also driven by the desire to free the company's analog power supply designers from the restrictions placed on them by having to work on the same piece of silicon that houses a powerful processor and high density memory. The wafer fabrication process node used for the [nRF52 and nRF53 Series SoCs](#) places some technical constraints on the power supply design that can be eliminated if that supply is fabricated on separate silicon.

Releasing Nordic's analog engineers from those design constraints has resulted in the nPM1100. The PMIC combines a USB compatible input regulator, 400 mA battery charger and 150 mA DC-to-DC step down (buck) voltage regulator. The product includes overvoltage and overtemperature protection. ([See WQ Issue 2, 2021 pg10.](#))

With the nPM1100, Nordic will help its present and future customers to not only wirelessly connect their devices to the Cloud but also power and charge those same devices. The PMIC is designed to be as compact as possible to meet the space constraints of tiny IoT devices. Examples include remote controls, wearables, personal medical devices and portable sensors; these are the types of products where the designer is required to equip the device with a lot of functionality while keeping the product dimensions small.

Battery charging functionality

The nPM1100 incorporates a Japan Electronics and Information Technologies Industries Association (JEITA)-compliant battery charger that can recharge the application's Li-ion or Li-poly battery-pack with a resistor-selectable charge current from 20 to 400 mA and a selectable termination voltage of 4.1 or 4.2 V. The charger includes battery thermal protection and automatic selection from three charging modes: Automatic trickle, constant current and constant voltage.

The nPM1100 system regulator draws its power from a 4.1 to 6.6 V USB input. (When the USB cable is unplugged, the wireless product's battery immediately switches from charging to becoming the power source.) The USB connection can supply a 3.0 to 5.5 V unregulated voltage to the application at up to 500 mA output current. The DC-to-DC converter element draws its supply from the system regulator output and can supply up to 150 mA to the wireless product (more than sufficient for typical target applications described above). It can regulate the

input voltage down to one of four voltages (1.8, 2.1, 2.7 and 3.0 V) with an efficiency of up to 92 percent. The supply voltage can be selected by the designer by setting two pins on the device high or low (either low/low, high/low, low/high or high/high). (*See schematic below.*)

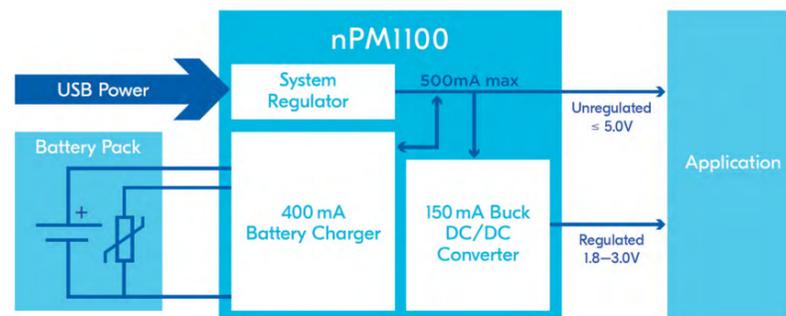
Depending on the application's requirement, up to 400 mA can be directed to the battery charger. (The application takes priority so if it demands more than 100 mA, the battery charging current will be decreased and the charging cycle time increased.) The charger can boost nominal 3.6 or 3.7 V Li-ion or Li-poly batteries up to the selected termination voltage. The charging regime follows a typical Li-ion profile (trickle charge (if needed) then constant current and finally constant voltage to top up the cell) to ensure there is no damage to the battery during charging. The charging rate is typically 1C (for example, a 400 mAh battery is fully charged in one hour). 2C rates are possible with smaller batteries. The charger offers thermal protection for the battery pack (via a third battery input) providing the battery pack features a negative temperature coefficient (NTC) thermistor. The nPM110's charger features its own thermal protection which will turn the device off if it gets too hot and then recommence charging at a reduced charging gradient once things have cooled down a little.

Higher efficiency or less space?

The choice of external components for a power supply based on the nPM1100 is influenced by whether the developer is looking for the longest battery life or to design the most compact product.

The nPM1100 achieves high levels of efficiency across a wide load range by employing dual-mode operation: Pulse Width Modulation (PWM) when supplying high currents and hysteretic operation when operating at low current loads. The PMIC automatically switches to the mode that offers the highest efficiency depending on the regulation requirement. However, when the SoC's radio is operational, the nPM1100 is switched into PWM mode to

“ The nPM1100 PMIC is designed to not only regulate the power in portable wireless electronics products but also to charge their batteries



The nPM1100 comprises a USB compatible input regulator, 400 mA battery charger and 150 mA DC-to-DC buck voltage regulator

Bigger batteries are not the only option

Designers are always under pressure to increase the battery life of their wearables to keep consumers coming back. One solution is to fit a higher capacity battery. That would certainly extend battery life, but is it the best answer? Let's consider an example. Imagine a fitness tracker with a 151mAh battery (typical for this kind of wearable). The display (which consumes a lot of power) is off for most of the time because it is only used when the user activates it. The result is a device that operates for 48 hours between recharges. The product uses a low drop out (LDO) linear regulator with an efficiency of 45 per cent and a space requirement of 12 mm². The average current draw is 3.14 mA (at 1.8 V) (151mAh/48 h). A new product specification demands an increase in battery life of at least 36 hours (preferably without making the product much larger). To achieve that specification the designer could fit a 275 mAh (3.14 mA x 84 h) battery. The downside is that this will increase the cost of the design by around \$0.31. Worse yet, it will increase the product volume by a whopping 960 mm³. An alternative design approach is to retain the original 151 mAh battery and replace the LDO linear regulator with the nPM1100 PMIC. In its smallest circuit configuration, the PMIC takes up 23 mm² and offers an efficiency of 88 percent. Because of the PMIC's higher efficiency compared with the LDO, the average battery current is lowered to 1.74 mA (at 1.8 V), extending the battery life to around 87 h (151mAh/1.74 mA). Compared to the larger battery option, the additional cost of \$0.13 and extra space requirement of 11 mm² are better design choices.



useful for consumers to be able to unbox the product and immediately switch it on without having to charge first. The nPM1100 can be switched to a low current consumption 'ship mode' to help meet these requirements.

When put into ship mode, the nPM1100's current consumption is 470 nA. Some competitive devices boast ship mode currents as low as 10 nA; that sounds advantageous but becomes much less important when compared with a Li-ion cell's self discharge current. The batteries self discharge at a rate of around three percent per month. For a cell in a typical wearable that equates to a current of 6 to 7 µA, far more significant than the PMIC's own ship mode current.

For example, consider a wearable with its battery charged to 50 percent before the product is switched to ship mode; after six months, the product fitted with the Nordic PMIC would have discharged to about 30.6 percent capacity. In comparison, the product fitted with the competitive device will have around 31.9 percent of its capacity remaining. The difference is irrelevant to the consumer. What is important to them is how long their wearable will run between charges, and that is determined by how efficiently the PMIC goes about its job when the wearable is in normal use.

What's next?

The nPM110 PMIC is just the first product in Nordic's PMIC range. Further chips are planned, with unique system management features that aren't available on competitive products. The introduction of these features will make it easier and less expensive to design highly-functional portable wireless products.

Another product in Nordic's PMIC range is targeted at non-rechargeable batteries such as the coin cells used in many wireless consumer products and IoT sensors. The device will ensure that the maximum possible energy is extracted from the battery, extending usable life and aiding sustainability by reducing the number of replacement batteries needed over the life of the wireless product. The PMIC design includes both step down (buck) and step up (boost) capability to extract the last of the capacity when the battery's output voltage has dropped. Nordic's PMICs for non-rechargeable cells will not need to include the charger element.

A Nordic technical webinar entitled *Introducing industry's most compact power management solution*, is available here: bit.ly/3ntv7Gj.

minimize any electromagnetic interference (EMI).

The designer has the option to trade off some efficiency for a smaller circuit footprint. The PMIC is a wafer level chip scale package (WLCSP) measuring just 2.075 (l) by 2.075 (w) by 0.5 mm (h). The chip has been designed such that it needs few peripheral components, but it does require an external inductor. To obtain maximum efficiency, an inductor about the size of the PMIC itself is needed and the circuitry will take up an area of about 27 mm² (following Nordic's reference design). To obtain minimum size, it is possible to choose a smaller inductor and sacrifice some efficiency. (Ultimate efficiency is largely related to the inductor's series resistance and saturation characteristics.) The result is a circuit measuring around 23 mm² with an efficiency of approximately 88 percent. (A Nordic whitepaper offering design advice on hardware design and inductor selection for the nPM1100 is available at bit.ly/3FuhzAt.)

It's important to remember that the more efficient circuit could allow the use of a smaller battery - gaining the space back that was sacrificed while still maintaining the longest battery life. Such a solution might also save money too. (*See sidebar above: Bigger batteries are not the only option.*)

Low current consumption shipping

Many months can pass between a wireless product's manufacture and the consumer's purchase; during this time, it's important the battery does not fully discharge because if it falls below a critical low voltage threshold it can be degraded or even ruined. Moreover, airline regulations require battery powered products to put into a low power consumption state before carriage. It's also



Tech Check

The nPM1100 PMIC is accompanied by an evaluation kit (EK) which allows testing of the chip's capabilities with existing applications without the need to create custom hardware. The [nPM1100 EK](#) features the high-efficiency (92 percent) implementation of the PMIC circuit. The EK works with nRF52 or nRF53 DKs. The EK can also be used with the [PPK11](#) to measure actual power consumption. ([See WQ Issue 1, 2021 pg36.](#)) Configurations that would normally be determined by board layout can be altered by DIP switches on the EK





Online expert panels expose the most important developments in wireless IoT

The WQ Live live expert panel discussions and audience Q&A sessions proved a success during 2021 and set the model for more events in 2022

At the beginning of 2021, Nordic Semiconductor introduced WQ Live events to bolster the company's virtual presence at a time when the pandemic made trade exhibitions no-go zones.

The events saw WQ's editors ask the questions and moderate proceedings. The first 40 minutes of each session comprised a debate between the moderators and an expert panel. The last 20 minutes addressed questions posted by the audience during the event.

The expert panels comprised Nordic management and engineers, and guest customers or external experts. The debates attempted to answer the tricky questions facing the rapidly growing wireless IoT sector via a lively, frank and informative discussion.

Back in January, when COVID-19 was at its height, a panel comprising Svein-Egil Nielsen, Nordic's CTO, Geir Langeland, EVP Sales & Marketing, and Kjetil Holstad, EVP Product Management, explained how COVID-19 had impacted Nordic and the tech business and what the long term implications of the pandemic were likely to be.

The conclusion was that COVID-19 had changed everything and the 'new normal' would be built on the IoT. (See WQ Issue 4, 2020 pg10.) Entitled *How COVID-19 has impacted the IoT and the IoT business*, the first expert panel can be viewed at bit.ly/394mBpm.

TinyML and location services in focus

The second WQ Live expert panel took place in April and featured Steve Roddy of Arm, Zach Shelby of Edge Impulse and Svein-Egil Nielsen of Nordic Semiconductor.

Entitled *When AI meets the wireless IoT: The impact of AI and machine learning on low power wireless IoT devices and their target markets*, the discussion explored how tinyML is enabling 'edge intelligence' - allowing resource optimized wireless IoT devices such as Nordic SoCs and SiPs to sift and analyze data before forwarding to the Cloud. (See WQ Issue 2, 2021 pg14.) The session can be viewed here: bit.ly/3w6izX3.

The third expert panel took place in September and



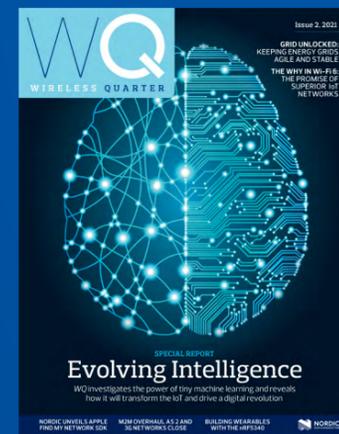
featured Nordic's Svein-Egil Nielsen, CTO, Chris Hansen, Director R&D USA and Ville-Veikko Helppi, Product Manager, Cloud Services. Entitled *From silicon to Cloud services*, the session looked at Nordic's addition of services to its silicon and development tools solutions and explained how the strategy has been driven by fundamental changes in the markets the company serves as the IoT spreads its reach.

During the debate, the participants discussed Nordic's launch of nRF Cloud Location Services. The platform has evolved from Nordic's nRF Cloud platform and assures Nordic customers access to a full commercial location services model once their cellular IoT products are deployed. (See WQ Issue 3, 2021 pg10.) The event is available to view here: bit.ly/3zgjUeU.

The WQ Live events during 2021 proved a success with around 2300 subscribers viewing the webinars across the year. For 2022 Nordic plans more WQ Live events designed to keep interested parties abreast of the most important developments as the IoT evolves.

To view all the WQ Live event recordings, go to: webinars.nordicsemi.com

“ TinyML is enabling 'edge intelligence' - allowing resource optimized wireless IoT devices to sift and analyze data before forwarding to the Cloud



ONLINE EXPERT PANELS NOW AVAILABLE TO STREAM:

THE IoT AND THE PANDEMIC

Exploring the business implications and opportunities in a COVID and post-COVID landscape

WHEN AI MEETS THE WIRELESS IoT

The impact of AI and machine learning on resource-constrained wireless IoT devices and markets

FROM SILICON TO CLOUD SERVICES

How Cloud-based support for location services and wireless IoT device management will revolutionize asset tracking



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Product Summary

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

	nRF9160	nRF5340	nRF52840	nRF52833	nRF52832	nRF52820	nRF52811	nRF52810	nRF52805	nRF51822	nRF51422	nRF51824	
WIRELESS PROTOCOL	LTE-M	●											
	NB-IOT	●											
	GPS	●											
	BLUETOOTH LOW ENERGY		●	●	●	●	●	●	●	●	●	●	
	BLUETOOTH 5.2		●	●	●	●	●	●	●	●	●	●	
	LE AUDIO		●										
	DIRECTION FINDING		●		●			●					
	2 MBPS		●		●			●		●			
	LONG RANGE		●		●			●		●			
	BLUETOOTH MESH		●		●			●					
	THREAD		●		●			●					
	MATTER		●		●			●					
	ZIGBEE		●		●			●					
	TYPE	SYSTEM-ON-CHIP		●	●			●		●		●	●
SYSTEM-IN-PACKAGE		●											
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	64 MHz Arm Cortex-M4	16 MHz Arm Cortex-M0	16 MHz Arm Cortex-M0	
FPU		●	●	●	●	●	●	●	●	●			
CORE SYSTEM	DSP INSTRUCTION SET	●	●	●	●	●	●	●	●	●			
	CACHE	●	●	●	●	●	●	●	●	●			
	MEMORY	1MB Flash, 256 kB RAM	1MB Flash, 512 kB RAM +256 kB Flash, 64 kB RAM	1MB 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	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	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), -155 dBm (GPS)	-98 dBm (1Mbps)	-95 dBm (1Mbps)	-96 dBm (1Mbps)	-96 dBm (1Mbps)	-95 dBm (1Mbps)	-97 dBm (1Mbps)	-96 dBm (1Mbps)	-97 dBm (1Mbps)	-93 dBm (1Mbps)	-93 dBm (1Mbps)	-93 dBm (1Mbps)
PERIPHERALS	ANTENNA INTERFACE	50Ω single-ended	Single-ended	Single-ended	Single-ended	Single-ended	Single-ended	Single-ended	Single-ended	Differential	Differential	Differential	
	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	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	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	nordicsemi.com/9160cert	CE, FCC	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 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	1.7 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 DK	nRF52840 DK, nRF52840 Dongle	nRF52833 DK	nRF52 DK, Nordic Thingy:52	nRF52833 DK	nRF52840 DK	nRF52 DK	nRF52 DK	nRF51DK, nRF51Dongle	nRF51DK, nRF51Dongle	nRF51DK, nRF51Dongle	
PACKAGES	10x16x1.04 mm LGA	7x7 mm aQFN94 (48 GPIOs), 4.4x4.0 mm WLCSP95 (48 GPIOs)	7x7 mm aQFN73 (48 GPIOs), 6x6 mm QFN48 (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), 2.53x2.53 mm WLCSP44 (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 (17 GPIOs), 2.48x2.46 mm WLCSP33 (15 GPIOs)	2.48x2.46 mm WLCSP28 (10 GPIOs)	6x6 mm QFN48, WLCSP48, Thin CSP	6x6 mm QFN48, WLCSP48	6x6 mm QFN48, WLCSP48	

Tech Profile

nRF21540

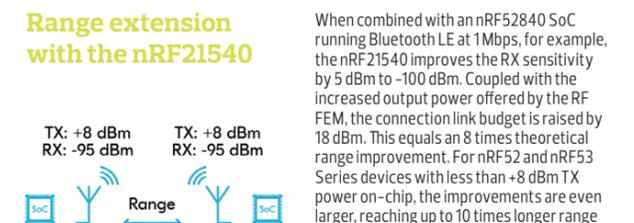


Description: The nRF21540 is an RF front-end module (FEM) that improves range and connection robustness for Nordic nRF52 and nRF53 Series SoCs. The nRF21540 is a complementary device operating as a 'plug-and-play' range extender with the addition of just a few external components. The nRF21540's 13 dB RX gain and low noise figure of 2.7 dB, coupled with up to +21 dBm TX output power, ensure a superior link budget boosting the range of the SoCs by between 6.3 and 10 times. The nRF21540 is supplied in a 4 by 4 mm QFN16 package and operates from a 1.7 to 3.6 V input supply range.

Operation: The nRF21540 supports Bluetooth LE, Bluetooth mesh, Thread, Zigbee and 2.4 GHz proprietary protocol applications. The RF FEM's TX output power is dynamically adjustable and can be set in small increments such that products can run with output power within 1 dBm of the allowable range across all geographical regions. The RF FEM's power consumption is 110 mA with TX at +20 dB and 38 mA at TX +10 dB. RX power is 2.9 mA and power use in power down mode is 45 nA. The RF FEM suits all applications that require increased range and/or robust coverage. In demanding RF environments, or where the application is operating close to the range limit, it can be more energy efficient to use the nRF21540 than continuously resend packets. The nRF21540 can operate across a -40 to 105°C temperature range, making the RF FEM suitable for use with Nordic's extended temperature qualified nRF5340, nRF52833 and nRF52820 SoCs in industrial applications such as professional lighting.

Development tools: The nRF21540 Development Bundle (DB) comprises an nRF21540 DK and an nRF21540 Evaluation Kit (EK). The DK incorporates the nRF21540 RF FEM and the nRF52840 SoC. The DK has two antennas with SWF ports for direct RF measurements. The dual antennas can be used in an antenna diversity scenario with, for example, Thread or Zigbee protocols to reduce multipath fading effects. The RF FEM is connected to, and controlled by, the nRF52840 SoC. The SoC supports all Bluetooth 5.2 features. The EK can link to lab equipment via SMA connectors to monitor the RF FEM's performance. The EK can also be used with nRF52 and nRF53 Series DKs, as well as other devices. The nRF21540's TX gain control, antenna switching and modes are controlled via GPIO or SPI or a combination of both, accessible through the Arduino Uno Rev3 compatible headers. The shield also features two additional SMA connectors hooked to the dual antenna ports from the RF FEM, to monitor the chip performance using the desired equipment. Driver support for the nRF21540 RF FEM is included in the nRF Connect SDK and nRF5 SDK for Thread and Zigbee.

Range extension with the nRF21540



Bringing nRF Connect SDK to your favourite IDE



nRF Connect for VS Code

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