WQ
WIRELESS QUARTER

Issue 2, 2021

GRID UNLOCKED:
KEEPING ENERGY GRIDS AGILE AND STABLE

THE WHY IN Wi-Fi 6:
THE PROMISE OF SUPERIOR IoT NETWORKS

SPECIAL REPORT

Evolving Intelligence

WQ investigates the power of tiny machine learning and reveals how it will transform the IoT and drive a digital revolution

NORDIC UNVEILS APPLE FIND MY NETWORK SDK

M2M OVERHAUL AS 2 AND 3G NETWORKS CLOSE

BUILDING WEARABLES WITH THE nRF5340

Welcome

Petter Myhre
Head of Product Marketing

Tens of billions of things are already connected to the IoT. Yet despite this impressive progress, the network is still very much an emerging technology. Many engineering challenges remain; one of these is where to do the computing using the data from all these connected devices.

Whether to compute at the edge or send all or most of the data to the Cloud remains determined by many factors including energy efficiency, privacy, latency and the actual cost of sending data. Nonetheless, edge computing is on the increase because in recent years it has become a practical choice for a greater range of products.

This is due in part to Nordic SoCs that are more energy efficient, and incorporate more powerful processors and greater memory support. In parallel, engineers at companies such as Edge Impulse have developed streamlined machine learning (ML) algorithms to extract key information from the sensors' raw data and which are optimized to run on Nordic's solutions.

Edge Impulse's TinyML is already powering edge intelligence in millions of IoT devices. But previously it was leveraged only by developers experienced with the technology. Now, with readily available development tools, non-experts can exploit the software and extend it to a far wider range of IoT end-devices.

These development in edge computing are set to give life to many more novel products that will run ML models locally more energy efficiently compared to sending all or most of the data to the Cloud. Batteries will last longer, energy harvesting will become more viable, and latency and subscriptions costs will go down. You can read more about TinyML and its far-reaching impact in *WQ*'s special report starting on page 14.

> “TinyML is already powering edge intelligence in millions of IoT devices and is set to give life to many more novel products

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News

The latest developments from Nordic Semiconductor

Internet of Things

Nordic Semiconductor launches Apple Find My network compatible SDK

Apple's Find My network enables consumers to easily find their possessions. Now Nordic Semiconductor has launched a Find My network compatible SDK which makes it easy for its customers to build Find My network-capable Bluetooth LE devices that maximize battery performance with Nordic's nRF52 SoCs.

The Find My network accessory program opens up the private and secure Find My network to third-party device manufacturers to build products utilizing the service. Their customers can then use the Find My app to locate and keep track of personal items.

"The Apple Find My network delivers a solution for helping consumers keep track of their important devices while fully protecting the owner's privacy," says Pär Håkansson, Nordic's Product Manager for Short Range IoT. "With Nordic's SDK, developers can create products which take advantage of the powerful Find My network. The end-products become part of the Apple ecosystem which ensures vast tracking coverage.

"While finding solutions have been on the market for a while, the Find My network's enhanced privacy and global coverage, made up of hundreds of millions of Apple devices, makes this sector an even better prospect for manufacturers. Companies such as Belkin, with its SOUNDFORM Freedom wireless earbuds, and Chipolo, with its Chipolo ONE Spot item finder, have already taken advantage of Nordic's technology for their Find My-enabled devices," adds Håkansson.

For Apple Made for iPhone (MFi) Program members only, Nordic has extended its software offering to include Apple Find My network technology options. In addition to new products, Find My network support can be easily added to existing Nordic Bluetooth LE-enabled devices. This means customers can incorporate Find My functionality into their wireless end-products without major changes to form factor or design.

"By using the Nordic Find My network SDK as a starting point ... we offloaded a lot of software work," comments Jure Zdovc, Chipolo's CTO. "This allowed us to complete the Chipolo ONE Spot in record time and to be one of the first companies to launch a Find My-enabled device."

Connected Health

Temperature data logger supports COVID-19 vaccine rollout

Shinyei Technology has launched a temperature logging unit that is being used in Japan for the rollout of the Moderna (mRNA-1273) COVID-19 vaccine developed by multinational pharmaceutical company, Takeda Pharmaceutical Company Limited. TempView monitors the Moderna vaccine to ensure it stays within a temperature threshold of -20°C ± 5°C—during storage and domestic distribution.

Low temperature storage is important because the vaccine's mRNA constituent quickly breaks down at higher temperatures, rendering it ineffective.

Designed to improve the reliability of vaccine transportation and logistics, the TempView GT002-T-DF is a compact and lightweight data logger using an external temperature sensor and employing Nordic Semiconductor's nRF52810 Bluetooth LE SoC to provide the wireless connectivity.

The device features two measurement modes: A storage mode for storage management in buildings such as warehouses, and a transport mode for transport management such as inside a truck or container. The product is suitable for monitoring and logging vaccine temperature throughout the distribution process from a wholesaler until it reaches the inoculation site of a medical institution.

Using the Bluetooth LE connectivity provided by the Nordic SoC, the temperature data is relayed from the device to a user's smartphone, from where the TH View app automatically generates analytics reports and graphs of the transport/storage temperature measurement data.

Nordic partner program aims to drive wireless technology adoption

Nordic Semiconductor has launched the Nordic Partner Program (NPP), creating an ecosystem of companies with experience of Nordic's solutions. The group aims to drive greater adoption of wireless technology and help Nordic's customers bring their wireless products to market faster.

NPP includes both design and solution partners that can assist Nordic customers by providing products, services and solutions that complement Nordic's portfolio of short range wireless and low power cellular IoT connectivity hardware, firmware, development tools and reference designs.

"Nordic has long believed in abstracting away all the complexity from the designer, and with the launch of the NPP this goal will be reinforced," says Geir Langeland, EVP Sales and Marketing, Nordic Semiconductor. "Wireless technology is disrupting many traditional businesses and enabling new applications, and companies without wireless solutions are going to be left behind. But many of them have no experience with wireless. NPP will help them overcome this problem."

During the pilot project phase of the NPP, eight leading IoT companies signed up to the NPP framework. These included Design Partners CA Engineering, Indesign, Sigma Connectivity, Shenzhen Minew Technologies, Meshtech, NORBIT as well as Solution Partner Telenor. German firm grandcentrix has joined both as a design partner and solution partner. Design partners are familiar with Nordic technologies and can offer design consultancy, design engineering or ODM services. They can assist with a specific aspect of a complex design or provide turnkey solutions, and can be used by Nordic customers to outsource or accelerate the design and launch of new products. Solution Partners can provide solutions that run on Nordic technology—for example third party protocols and development kits, or real time location services (RTLS)—and complementary technologies such as Cloud and cellular connectivity, as well as preproduction services such as programming, testing and certification. (*For more information go to: www.nordicsemi.com/npp.*)

Wearables

15 days of continuous health and activity data from smartwatch

Shenzhen Leadoys Technology has launched its Leadoys C16 Smart Watch, a Bluetooth LE-connected wearable capable of reporting health and activity data for up to 15 days of continuous use.

Developed by China-based technology developer Mo Young Ltd, the C16 Smart Watch is a stylish wearable providing users with an array of activity tracking functions including 20 sports modes, a pedometer feature, calorie and motion tracking, sedentary reminders as well as social media notifications and call reminders. In addition, the smartwatch provides health data including sleep- and 24-hour intelligent-monitoring of the user's heart rate and blood oxygen level.

Using Nordic SoC-enabled Bluetooth LE connectivity, this data is relayed from the C16 Smart Watch to the user's paired smartphone, from where a companion app can be used to customize the device, input personal information, and view graphical representations of current and past data from all sports modes and health functions.

The sensor and algorithm data processing capability for C16 Smart Watch is powered by the Nordic nRF52840 SoC's 64MHz, 32-bit Arm Cortex M4 processor with floating point unit (FPU). The Arm Cortex M4 processor is designed to support the Floating Point and Digital Signal Processing computations typical of high-end wireless applications.

The smartwatch is IP67 rated, making it waterproof for up to 30 minutes in one meter of water, and uses a 350 mAh battery for 45 days of standby time or between 10-15 days of operation before recharge, thanks in part to the low power consumption of the Nordic SoC.

In Brief

SMART LIGHTING COOPERATION AGREED

The Thread Group, together with the DALI Alliance (DiiA), the global industry organization for Digital Addressable Lighting Interface (DALI) lighting control, has announced that the alliance has adopted Thread as the first network technology that will be available with DALI+. The DALI+ specification, announced in early May 2021, brings DALI lighting-control commands to wireless and IP-based systems. DALI+ with Thread will be the first network transport to deliver DALI over wireless, IP-based networks. The DALI Alliance is now developing tests for DALI+ with Thread certification, with certified products and solutions available shortly.

IoT TECH WILL SAVE EIGHT TIMES THE ENERGY IT CONSUMES BY 2030

A new report from Transforma Insights and 6GWorld has shown IoT operations in 2030 will save more than eight times the energy they consume in production, eliminating one gigaton of CO_2 emissions. The report examined the impact of enterprise and commercial technologies on electricity, fuel usage, eWaste, CO_2 emissions and water usage. In terms of electricity, the report found the manufacturing of new IoT technologies will increase global electricity use by 34 terawatt-hours by 2030, but IoT solutions will also reduce electricity consumption by more than 1.6 petawatt-hours, enough electricity to support more than 136.5 million homes.

U.S. FIRM WEAVES TECH INTO TEXTILES

Nextiles, a U.S. National Science Foundation-backed textile firm, is weaving tech into textiles. The Brooklyn-based start-up has launched its patented smart fabric with built-in circuitry as a new way to capture biometric data. The first wave of the company's technology is embedded in sportswear. The idea is that it enables athletes to measure their velocity, force, momentum and other metrics that they can't get from today's wearable wristbands and smartwatches. The broader vision is for the advanced fabric to trickle down to mass market consumers to track heart rate and breathing through ordinary looking garments.

Logistics & Transport

Indoor and outdoor asset tracker achieves battery life of up to a decade

IoT technology company, Digital Matter, has released a cellular IoT indoor and outdoor asset tracking and management solution with a three-axis accelerometer to intelligently detect movement and impact events.

Based on Nordic's nRF9160 low power SiP with integrated LTE-M/NB-IoT modem and GPS, the Yabby Edge Cellular tracker achieves battery life of up to ten years with once-daily position updates, or two years of battery life at once-hourly position updates. This represents around five times the battery life of the product's previous iteration.

Yabby Edge Cellular is a compact, lightweight, cellular LTE-M/NB-IoT geolocation device. It features an IP67 rated weatherproof, ultra rugged housing and multiple installation options for covertly securing the product to the assets being monitored. The product uses the Global Navigation Satellite System (GNSS) including GPS and BeiDou, combined with Wi-Fi positioning in the absence of a GNSS signal. The tech enables continuous location tracking, traceability, loss/theft prevention and movement/impact detection of assets that frequently move between indoor and outdoor locations. The GNSS technology also offers assistance for quicker time-to-first-fix (TTFF) with the data downloaded to the device via the cellular network. When no GNSS or Wi-Fi signal is available, cellular IoT connectivity enables location/position monitoring of assets.

Tracked assets include pallets, containers, medical equipment and livestock. Nordic's nRF9160 SiP runs the proprietary software and algorithms that manage and perform the GNSS/Wi-Fi location lookups, and interfaces to the accelerometer for movement and high G-force (impact) events.

The Yabby Edge Cellular periodically transmits the whereabouts of the tracked item to Digital Matter's OEM Device Server Cloud-based platform via the cellular network. Stationary devices enter sleep mode until movement occurs to conserve battery life and limit data transfers.

"The nRF9160's unique low power features play an absolutely critical role in extending the incredible battery life of Yabby Edge Cellular at even more aggressive tracking parameters for our customers. We spent nine months evaluating cellular modules from six different vendors and chose the Nordic solution primarily due to its low power capabilities," says Ken Everett, CEO of Digital Matter.

Smart Health

Bluetooth device could help vapers quit

A device that attaches to e-cigarettes and can unobtrusively monitor inhalations and yield important information for research about how, when and where people 'vape' has been developed by researchers at Cornell University. The first-of-a-kind device, which can be attached to all types of e-cigarettes and other nicotine-delivery kits, can yield information about vaping that might help users curtail use, researchers claim.

"We wanted to figure out a way to map how people use e-cigarettes to determine what the triggers are," says Alexander Adams, a doctoral student at Cornell Tech. The device makes use of the e-cigarettes' own signals, as well as Bluetooth LE technology, to track the intensity, duration and frequency of inhalations. The data is then transmitted to a smartphone, which captures location, time and activity—such as walking, standing or driving—to help identify the circumstances that might be triggering people to vape.

"Correlating time of day, place and activity is important for understanding addiction," says Adams. "Research has shown that if you can keep people away from the paths of their normal habits, it can disrupt them. It creates opportunities for moments of intervention." For example, if someone skips or delays the first vape of the morning—shown in cigarette use to be critical in determining whether they'll smoke less over the course of the day—an app could send an encouraging message.

Cellular tracker monitors valuables

U.S. technology firm, Cube Tracker, has released a tracking device allowing users to remotely monitor the location of important items via mature cellular infrastructure.

Powered by Nordic's nRF9160 low power SiP, the C7004 Cube GPS tracking device can monitor the position of an object across the U.S. with a claimed accuracy of within 30 meters.

Enabled by the nRF9160 SiP's LTE-M connectivity and GPS—complemented by the tracker's built-in Wi-Fi capability for indoor and outdoor tracking, and Bluetooth LE connectivity for proximity monitoring—the product periodically transmits the whereabouts of the tracked item to the Cloud via the cell network. This in turn enables secure, reliable, and real time monitoring via the Cube Tracker app on the user's smartphone.

Wearables

Contact tracing for large groups at sports grounds and other venues

A wearable social distancing and contract tracing solution designed for environments where large groups of people gather has been unveiled by intelligent tracking and monitoring solutions company, Omni-ID.

Developed in response to the COVID-19 pandemic, Sense Shield is a wireless wearable beacon—available in a lanyard, belt clip or watch strap form factor—incorporating Quuppa's RTLS Intelligent Locating System, Wirepas Massive, a proprietary RF protocol firmware for short-range wireless mesh networking, and Nordic Semiconductor's nRF52832 SoC. The solution monitors and records the movements of the wearer which in turn enables social distancing management and contact tracing. The systems allows individuals, such as employees at a workplace or attendees at a sports event, to be tracked with a claimed positioning accuracy of less than one meter.

In September 2020, the platform was used as a key part of a U.K. government-endorsed trial examining possible ways for spectators to safely return to sports venues during the COVID-19 pandemic. The trial took place at The Kia Oval—a large and world-renowned cricket ground in London—and included 2,000 spectators who were each given a Sense Shield wearable device.

The nRF52832 used in the Sense Shield supports Quuppa's RTLS firmware. Quuppa's positioning engine enables the Sense Shield tags to be tracked and referenced to locators in known fixed positions.

Each Sense Shield forms part of a wireless mesh network enabled by the nRF52832's Bluetooth LE radio and Wirepas Massive. The SoC's support of Wirepas Massive enables wireless transmission of each wearers' location and movements across the mesh network to a Cloud-connected gateway. The aggregated data can then be used to determine, for example, if there are too many spectators in one area, or if spectators are not in their allocated seats. The data can also be used for contact tracing purposes if a subsequent infection outbreak is detected.

Smart Home

Project CHIP becomes Matter in CSA rebrand

The Connectivity Standards Alliance (CSA, formerly Zigbee Alliance) has rebranded the initiative formerly known as Project Connected Home Over IP (CHIP) to "Matter" – an industry unifying standard promising simplicity, interoperability, reliability and security as the foundation for connected things. To fulfill its vision of bringing Project CHIP to the market, CSA launched Matter as a brand for consumers and users to recognize and trust.

When originally launched, Project CHIP set out to formalize the effort to achieve smart-home interoperability. Now operating as Matter, the collaboration brings together ecosystems, device manufacturers and technology providers to address the barriers to IoT growth and adoption by creating usable and relevant standards. These barriers include interoperability and complexity, according to CSA.

Matter is guided by CSA and built on proven technologies and best practices.

Promoted by the 350 companies forming CSA, including Nordic Semiconductor, Matter aims to invigorate the smart home market and accelerate the smart home vision. Leading smart-home end product companies and trade associations representing various wireless technologies believe by creating a universal application protocol on top of the mature Internet Protocol (IP) and lower layer protocols, they can ensure interoperability between devices, platforms and ecosystems.

IP is ideal for delivering interoperability, end-to-end security, privacy and Cloud connectivity between a wireless device and another device, app or service.

Nordic has been involved in the development of OpenThread, a core technology in Matter, for several years. The company's nRF5340 SoC already incorporates everything needed to develop a Matter product.

In Brief

CELLULAR IoT TO DOMINATE ASSET TRACKING

More than 80 percent of OEMs in the asset tracking space are releasing products for cellular IoT LPWAN connectivity, with high growth in LTE-M trackers as mobile operators rollout LTE-M networks. Analyst ABI Research polled 43 major OEMs and found 82 percent of their asset tracking devices offer cellular LPWAN connectivity. It noted the pace of LTE-based and 5G-compatible NB-IoT and LTE-M deployments has accelerated, with 154 networks supporting one or other in operation to date. ABI forecasts the number of connections on cellular IoT LPWAN networks will overtake the number on proprietary LPWAN networks, from concerns such as LoRaWAN and Sigfox, after 2023.

NORDIC JOINS INDOOR LOCATIONING ALLIANCE

Nordic Semiconductor has joined the Indoor Locationing Group of the Precise Locationing Alliance. Founded in 2019, the Precise Locationing Alliance has more than 120 member companies including industry heavyweights such as CAICT, Huawei and ZTE. The goal of the Indoor Locationing Group is to bring together the collective resources of chip makers, developers and end users to create an open platform. The platform will boost the adoption of indoor locationing solutions based on technologies including Bluetooth LE, UWB, cellular, Wi-Fi, 4G and 5G across China. China Mobile Research Institute (CMRI) is the head of the Indoor Locationing Group.

BRAZIL REGULATORY CERTIFICATION FOR nRF9160

Nordic Semiconductor's nRF9160 low power SiP has received regulatory certification for Brazil. The certification by local authority Agência Nacional De Telecomunicações (Anatel), provides developers of nRF9160-based LTE-M and NB-IoT product designs with confidence the SiP has met the specifications for certification during the rigorous testing process, a condition for market approval in Brazil. The certification in Brazil follows worldwide GCF (Global Certification Forum) and PTCRB approval, as well as certification in the U.S., Europe, Canada, Australia, Taiwan, Singapore, Japan, South Korea, Mexico, South Africa, India and Thailand.

Audio & Music

USB microphone offers high quality audio for online applications

U.S.-based developer of media recording and monitoring solutions, Convergent Design, has developed a wireless, miniaturized audio solution designed for online meetings, livestreaming, webinars and podcasting.

Erika is an all-in-one microphone, transmitter and battery in a lightweight form factor. The device is magnetically attached to the user's lapel or clothing and eliminates the need for an additional body pack, wires or buttons. In operation, the user simply plugs a USB receiver into a host device—for example a desktop or laptop computer—to ensure wireless connectivity between Erika and the USB receiver. The wireless link uses Nordic's 2.4 GHz proprietary protocol with Enhanced ShockBurst (ESB) technology.

Both the microphone and the USB receiver integrate a Nordic Semiconductor nRF52833 SoC, taking advantage of its 64MHz, 32-bit Arm Cortex M4 processor as well as the SoC's Full Speed (12 Mbps) USB 2.0 capability. USB enables low-latency and high-bandwidth communication with a range of host devices, and makes device firmware updates (DFU)-over-USB practical.

Additional features of the USB microphone include an auto-mute function which mutes the audio when the user walks out of range, and automatically unmutes when they return. The addition of a USB hub provides the capability to use up to four microphones concurrently. A computer-based app supports firmware updates and the option to adjust the RF power level, volume control and microphone mute/unmute functionality. It also reports the current microphone battery level as well as audio volume.

The device employs a 75mAh Li-poly battery that provides a battery life of approximately 24 hours between recharge to create a wireless microphone ten times the power efficiency of competitive products, yet with 50 percent the size and weight, according to the company.

"Many hardware and software factors led us to choose the nRF52833, including PDM microphone and USB support, which were both 'must haves' for our product," says Mike Schell, President, Convergent Design. "The chip's radio sensitivity and power consumption were also critical features as they established our battery life and operating range, and without ESB, Erika would not exist."

Retail & Payment

Smart draft beer insights on tap

Technology startup, TappTek, has released a Bluetooth LE-powered smart tap that provides the brewing and beverage industry with insights on draft tap pouring data to help better understand consumer purchasing behaviors. Beverage manufacturers and venue managers can use the TappTek solution and subscription-based retail analytics platform to measure relative market share, waste and quality.

The TappTek device is designed to fit any draft beverage tap handle to monitor its activity and provide detailed information and insights such as a tap handle's location, start/stop times for pouring a beer, the volume dispensed and on/off tap events including brand changes. In addition, TappTek can be used as a beacon to enable consumer engagement at the point of retail. The device works either by being inserted into a tap handle at the point of manufacture, or by being retrofitted to existing tap handles using TappTek's universal enclosure.

Powered by Nordic's nRF52832 Bluetooth LE SoC, TappTek uses the SoC's powerful 64MHz, 32-bit Arm Cortex M4 processor for algorithm data processing and powering the device's built-in accelerometer, which is used to sense activity and wake the SoC from sleep.

Using the Bluetooth LE wireless connectivity, the sensor data collected by the smart tap device is sent directly to a user's smartphone, from where a sales representative or venue manager can view the event information through an associated app. In turn, the data is relayed to the proprietary Pour Data Cloud-based platform providing detailed analytics to TappTek subscribers.

Internet of Things

TinyML promises big future

Analyst ABI Research predicts the tinyML (machine learning) market will grow from 15.2 million shipments in 2020 to 2.5 billion in 2030, as the global base of IoT devices expands fourfold during the same period.

ABI Research says a growing number of devices are being developed to support AI at the network edge, but are underpowered for such a task, and TinyML could be the answer. In a whitepaper, *TinyML: The Next Big Opportunity in Tech*, ABI says TinyML can enable data analytics on low power hardware and software, using algorithms of 100 Kilobytes or less.

"AI processing at the edge minimizes the data traffic between IoT devices and gateways. Only data that is deemed critical to the system will be sent as an action point," the whitepaper said. It suggested the tech has benefits for data privacy.
(*See this issue pg14.*)

Smart Health

Bluetooth LE smart pen could monitor anesthetic levels during surgery

Scientists from Switzerland's EPFL research institute, the Lausanne University Hospital and the Polytechnic University of Turin have developed an experimental Bluetooth LE smart pen device that continuously measures anesthetic levels within a patient's bloodstream during surgery.

Anesthesiologists use a variety of methods to calculate the right dose for a given patient: clinical studies, medical databases and laboratory measurements, for example. However, every individual responds to anesthetics in a different way, and there's no way of knowing what that response will be until the anesthetic is administered.

"Scientists have been working for years to develop sensors that can instantly measure blood concentrations of compounds in anesthetized patients, so that doctors can personalize the doses," says Sandro Carrara, a professor at the EPFL School of Engineering. "Propofol is one of the main compounds used in anesthesia, but it's also one of the hardest to measure."

To attempt to solve the problem, sensors in the smart pen's needle—which is inserted into a vein—continuously detect concentrations of propofol in the blood serum.

The researchers' device looks like a large syringe. Its needle contains sensor electrodes that measure propofol concentrations in a patient's blood, while the electronics for the sensors are contained in a central control box. The sensors' measurements are analyzed using AI. The data is then transmitted via Bluetooth LE to a control unit, allowing the dosage of any supplemental propofol, if needed, to be adjusted automatically.

The device has been shown to accurately measure anesthetic concentrations in human blood samples. The next step is to measure concentration in actual patients.

Smart Health

Light therapy system provides non-invasive neuromodulation

An LED-based near-infrared (IR) light therapy system designed to improve human cognitive performance has been launched by health industry technology solutions company, CytonSys. In addition to cognition, the CytonBrite device can provide non-invasive treatment to patients for health issues such as poor sleep quality and mood regulation.

Based on research in the field of photobiomodulation (PBM), CytonBrite provides low-level laser (light) therapy (LLLT) on the brain to promote the neurons' energy performance at cellular level by irradiating photons on treated locations, according to the company.

Designed for small clinics or home use, the CytonBrite headwear features six light emission modules that can be simultaneously and flexibly secured at selected locations on the cap (according to the international 10-20 EEG mapping system), and a button interface box for controlling the therapy sessions.

A controller unit integrating Nordic's nRF52840 Bluetooth 5.2/Bluetooth LE advanced SoC controls the modulation parameters for the light therapy. The complex algorithm data processing capability for CytonBrite is powered by the Nordic SoC's 64MHz, 32-bit Arm Cortex M4 processor with floating point unit (FPU).

From an associated smartphone app, the user can configure settings for the controller unit – including the pulsing frequency and power density.

By the Numbers

$143.2 million in revenue

Nordic Semiconductor has reported Q1 2021 revenue of $143.2 million, more than doubling the $70.2 million reported in Q1 2020, and 13 percent above the previous quarter. Gross profit was reported at $71.9 million, an increase of 97.5 percent over Q1 2020. Order backlog meanwhile increased to a record high $803 million from $492 million at the end of 2020, while demand is solid across all end-user segments from both large tier-1 customers and the broader market, the company said.

16.7 billion by 2026

The global Bluetooth LE market is estimated to surpass $16.7 billion by 2026 growing at an estimated CAGR of more than 19 percent between 2021 and 2026, a report by analyst IndustryARC has claimed. The company said asset tracking and proximity marketing were two specific applications of the technology only made possible by the ultra low power consumption of Bluetooth LE SoCs, modules and chipsets.

1.1 trillion devices in 2021

The semiconductor market is set to shake off the COVID-19 pandemic with 13 percent growth in 2021 according to the latest report from IC Insights' McClean Report. Total semiconductor unit shipments, which include ICs as well as optoelectronics, sensor/actuator and discrete devices, are forecast to rise 13 percent in 2021 to 1.1 trillion units. This would set a new all-time annual record and would be the third time semiconductor units have surpassed one trillion units in a calendar year since 2018.

Tiny footprint and ultra low quiescent current define Nordic's first power management IC

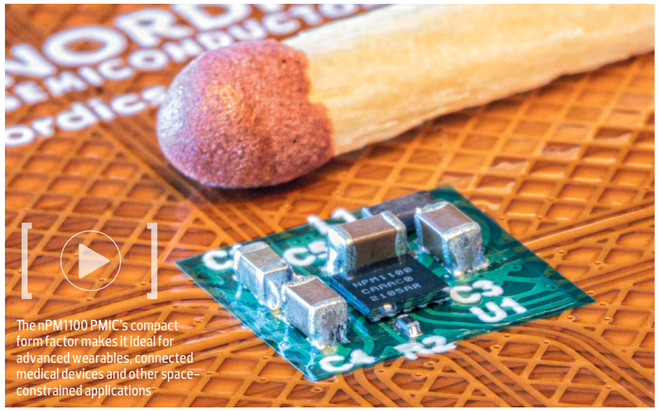
nPM1100 PMIC combines a USB compatible lithium-ion battery charger and highly efficient DC/DC buck regulator in a compact wafer level chip scale package

Nordic Semiconductor's ultra low power consumption wireless SoCs have proven to be a good basis for compact wireless products with long battery life. But developers must turn to an alternative vendor for a power management IC (PMIC) to both regulate the SoC's voltage supply and manage charging of the end-product's battery. While there are some satisfactory solutions on the market, they tend to be general-purpose devices that are not optimized either to extend battery life or save space in compact battery-powered wireless products.

Nordic has now reacted to customer demand with the launch of its first PMIC, the nPM1100. "Over the past decade, we have made it easy for the world to connect things to the Internet," says Geir Kjosavik, Product Manager for Nordic's PMIC range. "Now it makes sense that we help the same customers further extend battery life and charge the batteries in those same things."

The nPM1100 combines a USB compatible input regulator with overvoltage protection, 400 mA battery charger and 150 mA DC/DC step-down ('buck') regulator in a 2.075 by 2.075 mm wafer level chip scale package (WLCSP).

The PMIC ensures reliable power supply and stable operation for Nordic's nRF52 and nRF53 Series multiprotocol SoCs and maximizes application battery life. The product can also be used as a generic PMIC for any application using rechargeable Li-ion or Li-poly batteries. The PMIC takes up as little as 23 mm^2 of PCB area, including passive components (rising to 27mm^2 when optimized for performance). This makes it a much more compact solution than comparable competitive products.



The nPM1100 PMIC's compact form factor makes it ideal for advanced wearables, connected medical devices and other space-constrained applications

Maximizing battery life

"Our PMIC platform leverages Nordic's low power expertise by combining proven technology blocks to offer even more ways to conserve energy," says Kjosavik. "The first product in the family, the nPM1100, is a device that targets smaller applications by enabling charging of small batteries while providing efficient power management where physical space is at a real premium."

That low power expertise results in a device with an ultra low quiescent current I_Q of just 800 nA (typ.) which can be further reduced to 460 nA in 'ship mode'. Ship mode also disables power output – removing the need for an external power switch and ensuring minimum battery lifetime impact on products in transit.

The nPM1100's Japan Electronics and Information Technologies Industries Association (JEITA)-compliant battery charger will charge the application's Li-ion or Li-poly battery 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 -voltage.

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 EK can be powered by USB, external DC power supply or from battery power. It is designed for use with other Nordic DKs or to test out the PMIC's functionality with non-Nordic products

Applications based on nRF52 and nRF53 Series SoCs with multiple regulator stages, and using rechargeable Li-ion or Li-poly batteries, can take advantage of the nPM1100's battery charger to bypass the first regulator stage of the SoCs. The higher efficiency of the nPM1100's buck regulator, compared with the SoC's internal regulator, reduces overall system power consumption while its 150 mA capability increases the current available for other system components from around 10 to 100 mA.

High-efficiency voltage regulation

The product's DC/DC buck voltage regulator runs at more than 90 percent efficiency down to below 100 µA load current. It takes its power from the input system regulator and provides up to 150 mA current at a selectable 1.8, 2.1, 2.7 or 3.0 V regulated output voltage. The regulator features soft startup and automatic transition between hysteretic and pulse width modulation (PWM) modes.

The nPM1100 input regulator draws its power from either a 4.1 to 6.6 V USB input or from a 2.3 to 4.35 V connected battery input; it can supply a 3.0 to 5.5 V unregulated voltage to the application at up to 500 mA output current. The PMIC supports USB port detection. The input regulator includes overvoltage protection for transient voltage spikes up to 20 V.

While the nPM1100 has been optimized to complement Nordic's SoCs, the product can also be used as a generic PMIC for any application using rechargeable Li-ion or Li-poly battery batteries. The chip requires no configuration software to operate as all settings are pin configurable.

Nordic has published a webinar introducing the nPM1100 and how to use it. The webinar can be viewed here: bit.ly/2S3408b.

Manage power consumption for longer battery life

How long the battery lasts in a wireless device—particularly one with a small Li-ion battery—has a major influence on product acceptance. Clever design, the use of efficient wireless SoCs such as Nordic's nRF52 and nRF53 Series and power management using efficient devices like Nordic's nPM1100 will help maximize battery life. But to work out actual battery lifetime requires measurement of both peak current loading and average current draw.

Peak current loading—even if it is only for short durations—can have a significant impact on the coin cell's life. The designer should check the manufacturer's data sheet for recommended maximum peak current. Exceeding that current draw will significantly shorten battery life and may even damage the cell.

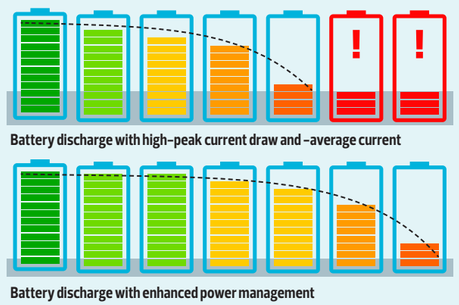
The developer should measure the current consumption of the application using appropriate equipment rather than relying on the component datasheet. Actual performance is often different to theoretical calculations. (*See WQ Issue 1, 2021 pg36.*)

Typical Bluetooth LE-powered applications only subject the battery to peak currents infrequently and then only for very short periods. If the design limits those instances of peak current draw to a safe level then it will be the average current over long durations that has the biggest impact on battery life.

There is much the designer can do to drive down average current. One of the easiest is to limit relatively high power transmissions by increasing the protocol's connection intervals; combining multiple small packets into fewer large ones; compressing data locally before transmission to reduce RF throughput, and identifying non-critical data that can be sent at a slower rate, or even not at all. (While some of these operations will save transmitter power, they will also increase the load on the microprocessor which will raise power consumption which must be taken into account when working out the total power budget.)

Because a Bluetooth LE device spends long periods in sleep mode, it's important to ensure the sleep-mode current is kept low to reduce average current. Nordic's SoC architecture makes it easy for the designer to trade off wake-up time against power consumption by selectively turning off peripherals and system blocks that don't need power when nothing is happening.

Tech Check: Extending battery life



Battery discharge with high-peak current draw and -average current

Battery discharge with enhanced power management

In use battery voltage gradually declines (dashed line) until it reaches the cell's functional end point (FEP - shaded area). Good power management can not only reduce peak current draw and average current but also lower FEP (bottom). The result is longer battery life and full use of the cell's energy

Internet of Things

2G and 3G network sunsetting changes the face of M2M cellular communications

As telcos prepare to shut down older networks to focus on 4G and 5G, legacy M2M wireless connectivity faces disruptive upgrades to take advantage of new cellular technology

> The sunsetting of 2 and 3G networks in the next few years will greatly accelerate the adoption of cellular IoT by encouraging replacement of legacy M2M systems

Today's machine-to-machine (M2M) wireless sector is largely based on cellular modems, integrated in appliances such as vending machines, fuel pumps, security systems and other infrastructure that quietly goes about its business behind the scenes. While the units are power hungry and expensive, when mains power is on hand and the information they provide is valuable, there is little problem justifying their cost.

But cellular networks are undergoing important changes, with network operators focusing their futures on 4G (LTE) and 5G services. These later forms of cellular technology use higher frequency (GHz) spectrum allocations than the older (MHz) networks and promise faster, more responsive services. That's a boon for smartphone users addicted to video streaming but it's also a huge performance boost for wireless IoT.

While today's M2M cellular wireless connectivity is largely based on 2G and 3G connectivity, tomorrow's will use these 4G and 5G services. This change is already afoot, with 'massive IoT' connections (using 4G-based NB-IoT and LTE-M cellular IoT technologies) doubling to almost 200 million during 2020, according to the *Ericsson Mobility Report November 2020.*

That means a problem is looming for modems that rely on legacy 2G and 3G technology. Licensed radio spectrum is a valuable asset and network operators are keen to 'sunset' older services and repurpose them for newer applications. Closing down decades old technology is hardly an issue for consumers who turn over mobiles every 20 months or so and last saw a 2G set in a science museum; but it is a serious issue for commercial users.

The benefits of disruption

To continue providing access to highly valuable—in many cases critical—real-time data and insights from machines, M2M cellular connectivity urgently requires upgrading to the next generation of technology.

Jan Willem Smeenk, CEO of SODAQ, a Dutch engineering and design specialist, refers to this change as akin to dealing with the millennium bug (a problem caused by computer programs representing years with only the final two digits, making the year 2000 indistinguishable from 1900) and says it is set to "truly disrupt the industry and also trigger a breakthrough in IoT."

It's a view echoed by Geir Langeland, EVP of Sales & Marketing with Nordic. "The sunsetting of 2G and 3G networks in the next few years will greatly accelerate the adoption of cellular IoT by encouraging replacement of legacy M2M systems," says Langeland. "While the change will be disruptive, the benefits of this newer technology—smaller, lower power, higher reliability modems and a more robust and secure communications link—will pay large dividends in the future."

Need to Know

While the global potential of 5G is currently restricted by current network infrastructure and coverage, communications service providers worldwide continue the build-out. By the end of 2020, over one billion people, or 15 percent of the world's population, were expected to live in 5G coverage areas, according to the Ericsson Mobility Report November 2020. Analyst McKinsey forecasts that will increase to 25 percent of the global population by 2030

Companies using older devices threatened by sunsetting don't have to search hard for the evidence to back Langeland's viewpoint. A major disruption in 2017 saw around 70 percent of San Francisco's buses and trains suddenly disappear from the system map responsible for real-time vehicle location tracking and arrival time predictions across the city. The hiatus came as a result of telco AT&T switching off its 2G network. It took weeks for the San Francisco Municipal Transportation Agency (SFTMA) to fix the problem by upgrading its legacy monitoring devices but the result was a more reliable and future-proofed system. And like the Californian transport provider, almost every industry has the potential to be transformed by embracing cellular IoT.

Pain now, gain later

The solution to the sunsetting problem is to upgrade existing M2M cellular wireless infrastructure to NB-IoT and LTE-M cellular IoT supported by 4G networks. The challenge is the rapid pace needed to ensure upgrades are in place before the 2G and 3G networks are switched off.

Things have been made much easier by the commercial availability of relatively inexpensive, compact and power-friendly cellular IoT modems. Examples include Nordic's nRF9160 SiP which not only incorporates the modem, but also an Arm Cortex-M33 application processor, RF Front End (RFFE), power management system and GPS. The nRF9160 is the most compact, complete and energy-efficient cellular IoT solution on the market. The SiP makes the latest LTE technology accessible and easy to use for a wide range of single device, low power cellular IoT designs and can support both 4G and 5G applications.

Devices like the nRF9160 take advantage of spaces in the cellular spectrum not used for consumer applications. This boosts reliability and security of the service and supports scalability; it also allows the cell phone companies to commercialize bandwidth they weren't previously using.

4G will coexist with 5G networks for at least another decade. And 5G is essentially an adaptation of 4G rather than a different technology so it shouldn't be too difficult or expensive to upgrade existing cellular IoT hardware to take advantage of the latest infrastructure when it's switched on. So while the change from 2G and 3G to 4G is a major upheaval, companies making the investment now will be over the worst for at least several decades. And cellular IoT purchased today will benefit from the continued major investment the network operators are making in 4G and 5G to meet their consumer and commercial customers' needs over the next several years.

But what of the old 2G and 3G licensed spectrum? Early cellphone services were based on 900 and 1800 MHz frequencies. The advantage of these frequencies is coverage; lower frequency signals travel further so fewer cell towers are needed to provide a good service – making things much cheaper. Where high throughput isn't a priority but coverage is, the old frequencies provide the answer. That's why many network operators intend to retain their megahertz bands and repurpose them to increase coverage of fully digital technologies such as voice-over-LTE (VoLTE).

Comment

Svein-Egil Nielsen
CTO, Nordic Semiconductor

The unseen IoT revolution becomes visible

The IoT's role in combating the pandemic has allowed users to witness its promise

It can be easy to underestimate the potential of new technology when it's first introduced. Consider, for instance, the mainstream arrival of the Internet in the mid 1990s. It was seen as an interesting new way to publish and find information, but there was no real inkling of how it would grow and evolve over the next 30 years, let alone how it would fundamentally change our lives.

Likewise, the IoT has experienced a lack of recognition, as the advantages were all but invisible to anyone outside of specific fields. However, its use in combating the devastating COVID-19 pandemic has brought to light many of the technology's benefits because the supported applications directly impacted the lives of many.

During the pandemic IoT solutions were used to minimize patient-to-staff contact by facilitating remote monitoring of patients and enabling more effective use of scarce hospital equipment and resources. The IoT suddenly become part of the front line battle against COVID-19.

Prime examples include battery-powered wireless pulse oximeters (that measure blood oxygen levels – a key indicator of serious deterioration in hospitalized COVID-19 patients) and AC plug-in wireless hubs and Bluetooth stick-on beacons that enable hospitals to track and quickly locate key equipment such as ventilators.

COVID-19 has also created a major issue for employers, who now need to convince their employees that it's safe to return to work. The IoT industry was quick to come up with various solutions, including a range of Bluetooth and UWB distance- and contact-trackers. These can be used to reinforce social distancing measures, as well as enable rapid contact tracing and testing should an employee become infected.

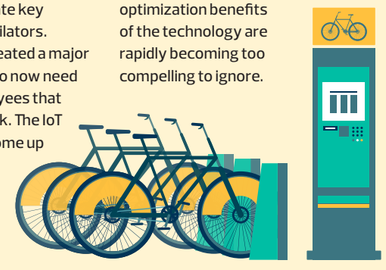
But as important as its proven to be in fighting the virus, the application of the IoT extends far beyond combating pandemics; the IoT forms a platform that can be used to solve many of the most pressing challenges the world faces right now.

For instance, IoT solutions have also been instrumental to reducing greenhouse gases and waste. In Portland in the U.S, for example, cellular IoT wireless technology is helping prevent an auxiliary coal-fired power station being fired up by streamlining local grid demand from domestic electric water heaters.

And share bikes and e-scooters have proven a great way to reduce car traffic. So-called micromobility has been made possible using the IoT to locate the vehicles (usually via GPS and/or cellular) and to allow people to easily rent one (usually via a Bluetooth LE-based app).

Another example of the use of the IoT to smooth electricity usage is technology for connected electric vehicle (EV) smart chargers that limit battery replenishment to off-peak hours only. This not only keeps electricity costs down but also limits spikes in power grid demand that could increase carbon emissions.

Today, we are beginning to see the IoT's true potential. There are still numerous privacy and security concerns that need to be addressed and resolved, but the efficiency, convenience, safety and optimization benefits of the technology are rapidly becoming too compelling to ignore.



Evolving Intelligence

More than the hyped developments with AI, the trend towards miniaturized machine learning will spur the wider IoT market and drive digital change at massive scale

In Short

Bandwidth limitations, latency demands and privacy concerns dictate that machine learning moves from the Cloud to resource-optimized edge IoT devices

The latest battery-powered IoT modules afford enough compute power to run simple algorithms – enabling real-time decision-making where data is generated and used

New software tools are stripping the complexity out of machine learning to help non-expert embedded system developers bring powerful intelligence to familiar everyday objects

Miniaturized machine learning (tinyML) in low-power IoT systems can help optimize energy usage, predictive and preventative maintenance, health and safety, and smarter society

Citius, *altius*, *fortius* goes the Olympic motto, capturing the eternal quest for sporting excellence. Faster, higher, stronger, it says. Was there ever a better tagline to promote competition and progress? It has been plagiarized and paraphrased to the point of cliché; its essence has been bottled by science and industry, in particular, to describe the march of technology. Cars, phones, televisions – each generation is more powerful than the previous.

Even the arts sector has robbed the message to talk about tech-life; think of sci-fi series *The Six Million Dollar Man* and electro-pop duo Daft Punk, both riffing on the same 'faster-stronger-better' motifs. Except, the tech industry has changed its mind. Everything we were told is wrong, it seems; progress is not just about power and speed. Because power and speed are limited, finite, problematic – in a way that cannot be solved by Olympian science.

To a point, this realization has caught the tech industry on the hop. Some Cloud-based version of 'artificial intelligence' (AI), an overused (and misused) term to describe all-knowing data analytics, was supposed to spur industrial revolution and raise the bar for tech advancement – meeting spiraling demand for bigger, faster, stronger data processing. But the vision outran the means, at least for massive-scale sensing (IoT) and sense-making (AI).

In the end, the physics tops-out because data networks cannot carry the load, the business case falters because wireless devices don't have the energy to constantly transmit and carriage is expensive, and the use case fails because AI applications will not tolerate delay. Plus, there are major issues with privacy. "You don't want open mikes and video streaming to the Cloud," says Steve Roddy, VP of Product Management at Arm's Machine Learning Group.

Chip design firm Arm was quick to observe the shifting market dynamics. The company accepts the design challenges for IoT devices extend lead times for the kinds of silicon blueprints it produces. Roddy explains: "You have bandwidth constraints, energy constraints, privacy constraints – not to mention response times. If your smart lighting relies on the Cloud to turn on a light when you enter a room, you are at the mercy of your Internet connection."

The line about power and speed no longer fits, then. Instead, the tech industry has been forced to rethink its forward march, and bring power closer to the action – to unburden WANs and remote data centers, and selectively load local infrastructure with practical AI. The real revolution is at the edge; the new tripartite mantra at the coalface of digital change should read: smaller, smarter, sharper – and altogether better.

MINDSET CHANGE

Nordic Semiconductor works closely with Arm, designing and supplying SoCs based on Arm processors. It has made its name by adding features to its chips that anticipate where the market is heading. "If you are producing hardware that is going to last ten years, you have to somehow bear to put stuff on – even if you don't know how people will use it," remarks Svein-Egil Nielsen, CTO and EVP for R&D and Strategy at the firm.

This has been the story with the company's previous nRF51 Series, present nRF52 Series, and new nRF53 Series Arm-based SoCs; each has been loaded from the get-go, with single Arm Cortex-M0 processor in the first generation to dual Arm Cortex-M33 processors in the latest. It is the same with its nRF91 Series of cellular IoT SiPs, also built on an Arm Cortex-M33 processor.

"You have to believe that if you give developers power, in terms of Flash and RAM, they will find a way to use it. We have been bold enough to do that – to prepare for things you can't quite predict," says Nielsen. Nordic's latest Arm-based SoCs are prime vehicles for the tech industry's migration towards smaller, smarter IoT systems, which enable AI at the very edge, in the home and workplace, where data is produced and used.

"If you look at the dynamics – sending sensor data over a wireless network to the Cloud – then, you know, it was just insane. It was never going to work. A change of mindset was enforced, almost – away from big computers to small computers. Because it is the only way that makes sense."

Nielsen is articulating the gist of the so-called tinyML movement, to place miniaturized machine learning (ML) into resource-optimized wireless IoT devices. ML is the

functional applied mathematics in nebulous 'AI' systems (*see sidebar pg20: Science fact and science fiction — what is AI anyway?*). The discipline turns on computer algorithms, implemented in code and exposed in data, that continually and automatically adjust and improve as they are exposed to data; this 'learning' process is achieved by compute-heavy training of ML models.

The training of ML models, too intensive to carry out in tinyML functions, cycles through ML algorithms on enlarged data sets in the Cloud, and issues pattern-making ML algorithms periodically to edge devices to filter live data points and calculate outputs. This last phase is called 'inference', and is the key to the puzzle for embedded IoT systems. This is what U.S.-based Edge Impulse is engaged with. The firm partners with Nordic, integrating tinyML functions into nRF Series Arm-based SoCs.

Zach Shelby, Co-founder and CEO at the firm, explains: "We have been able to make the training and models simpler, and focus on inference — as applied ML in the software on the device. That's what this whole field of tinyML has come out of — the ability to focus on inference in embedded systems at the edge, like sensors, audio and simple computer vision. Rather than on training larger and larger models for the Cloud."

The move to distribute and miniaturize functional ML decision-making has afforded a way for the low power end of the IoT market to dramatically cut down energy consumption. Roddy returns: "If you can send the event

information, the aberration, when it occurs, and only fire up the wireless connection when there is an anomaly—on the power line, in the refrigerator, wherever—then you minimize traffic on the network and battery power in the device."

FAMILIAR, BETTER

It is the only way most of the IoT market, hinged on inexpensive battery-powered IoT devices attached to LPWAN IoT networks, will get properly smart, Arm's Roddy suggests. "Millions of sensors sharing the same backhaul on some limited network couldn't send all that data back to the Cloud even if you wanted them to." Instead, the LPWAN connection is kept open for critical real-time alerts, and for updating algorithms and firmware.

Roddy explains: "The default with really low power battery envelopes will be to process data at the edge. The Cloud will be used sparingly — to collect metadata, aggregate activity and optimize the system." Roddy's employer has been talking about 'bite-sized' ML for years, even on entry-level Cortex-M parts with 64 KB of RAM. But Arm's new v9 architecture, to raise performance in the "next 300 billion Arm-based chips", places ML at the heart of 'things'.

The once-in-a-decade v9 release "sets out the next chapter" for Arm, and all the tech world running on its designs. It is geared for the move from general-purpose to "ubiquitous specialized" compute processing, from highest-power processing units in Cloud-based monster computers to lowest-power M-class systems running tinyML in fit-and-forget IoT units. "ML will touch every market segment; every class of product is being affected by this ML revolution," says Roddy.

"It is about making familiar products better — more responsive and more efficient. Look at the refrigerator, the prosaic everyday white box in your kitchen; all the billions of them in the world, in homes and restaurants and workplaces, account for 10-to-12 percent of global electricity consumption. If you can put smart ML into the motor controller to adapt to usage patterns, you can have a significant impact on global energy usage."

Indeed, the future is already here, chimes-in Edge Impulse; clever tinyML functions get around even limited Flash and RAM in existing Cortex-M based modules. "We can run tens of millions of math-operations per second on Nordic parts. Measuring temperature once per hour isn't all that interesting. But if you apply ML, you can make much better use of the compute and battery power that is there," says Shelby.

> "Sending masses of data over a wireless network was never going to work. A change of mindset was needed — away from big computers to small computers. It is the only way that makes sense.
>
> *Svein-Egil Nielsen, CTO and EVP for R&D and Strategy, Nordic Semiconductor*

The challenge, made acute in constrained IoT systems, is the ML module needs to share space with "sometimes 10 or 15" other components in the firmware. But real-time tinyML inference works with even 10-to-20 KB of memory, suggests Shelby. "We can handle all kinds of sensor applications — accelerometers, magnetometers, current sensors, heart-rate sensors — with the latest tinyML optimization techniques."

Increase the memory capacity to 50 KB, with the latest compiler techniques to compress parsing and analysis tasks, and the application set on the hardware can expand to include key operations such as real-time audio analysis, audio event analysis, and even human keyword spotting, he says. His firm has worked with Slovenia-based IRNAS to develop a tinyML solution to detect faults on power lines caused by environmental hazards such as "fires, wind and ice, branches hitting lines."

The challenge, even up a utility pole, was to get power to the sensors; overhead cables cannot be easily tapped. The team settled on a battery-powered NB-IoT unit, based on Nordic's nRF9160 SiP, with up to 20 years of battery life. "The utility can see the electric signal and detect errors from things like lightning strikes in real time, using a small ML model, and then fire up NB-IoT to send the events to the grid operator — and collect data to train the ML models," says Shelby. "It is just one example of many that developers are working on." (*See Case study pg18: Embedded machine learning makes smart electricity grids a reality.*)

DIGITAL CROSSOVER

But the developing challenge to popularize tinyML in embedded IoT systems is not just about optimizing the math; as with so much of digital crossover for developers and users of smart devices, there is work to abstract the complexity from the advanced analytics.

"When we started out, these ML tools were for data scientists; they weren't created for embedded engineers,"

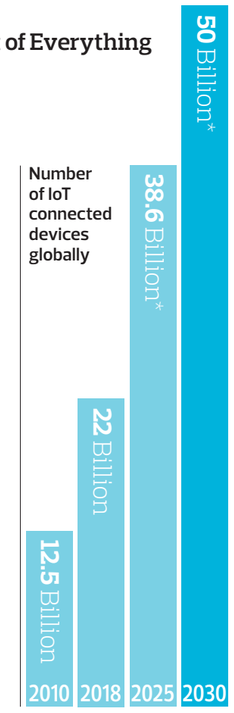
Need to Know

TinyML is not new and is all around us. It is, for example, a feature of digital services triggered by 'wake words' - such as virtual assistants Siri and Alexa. Using a smartphone's main processor to continuously listen for a wake word would be a major drain on the battery. Instead, a separate low power processing device remains continuously vigilant. A tinyML algorithm listens for the specific sound frequencies making up a wake word and, on hearing them, wakes up the smartphone

State of Play

Towards the Internet of Everything

Network equipment provider Cisco defines the birth of the IoT as the point at which the number of 'things' connected to the Internet outnumbered the people on the planet. That definition puts the IoT's genesis during 2009 when connected things first exceeded the 6.8 billion global population. Since then, the IoT has expanded dramatically. According to the online publication *Security Today*, some 127 new IoT devices were connected to the network every second in 2020, that's four billion for the year. Today, there are around 25 billion IoT connected devices and that's set to double by 2030. Next comes the Internet of Everything which melds the M2M communications of the IoT with machine-to-people (M2P) and technology-assisted people-to-people (P2P) interactions.



**Estimated. Source: Cisco, Statista*

Industry Viewpoint:

Zach Shelby
Co-founder and CEO, Edge Impulse

Artificial intelligence (AI) and machine learning (ML) are terms that are sometimes used interchangeably in everyday use, but within the industry they are understood very differently. For me, AI is a futuristic thing, it's an entire field of achieving a level of human-like intelligence from machines, and of course the reality is that we are nowhere near that today.

ML on the other hand is the practical, mathematical field where we use math to solve real problems with data. So ML algorithms are the real mathematical structures that we use to train and decipher patterns in all kinds of information. That means in wireless IoT devices we are talking about ML, not AI.

Traditionally you might think about ML as big Cloud-based workloads with a large amount of data, requiring huge amounts of training time and a huge amount of compute power to execute the model in production. A lot of time and energy in the industry has gone into this. But when we've looked at the technology and scaled it down for edge embedded systems—such as sensors, audio, simple computer vision—we've been able to make ML training and models simpler using inference (applied ML at the device level), rather than just training larger and larger models for the Cloud. That has many advantages including making much better use of available compute power, and doing so much more efficiently. As a result, ML routines can run successfully on constrained devices.

Steve Roddy
VP of Product Management, Arm Machine Learning Group

Arm CPUs are found in everything from the highest level supercomputers and Cloud servers to phones. When we look at future architecture changes we have to look at all the things that are going to drive evolution over the course of the next decade, but one of the key elements is machine learning (ML) and enhanced ML inferencing capabilities because we see it touching all of these market segments and every class of product being affected and modified by this revolution.

ML is really a mathematical universal problem solver. If you look at a typical application today, if the control loops are simple enough, the programmer can fully enumerate all the control, test it, validate it and he or she is good to go. But for more complex applications, ML comes into its own.

One of the classic examples is the traffic light controller. Can you write every specific rule about what you are supposed to do at a traffic light, with an intersection with protected turns left and right? That's something you can write all the code for. Scale that up to all the traffic lights in the city and it's impossible to write as a human, but with data and ML capturing patterns, suddenly you can have an adaptive system that can manage that far better, in a way the human software developer would never be able to completely code.

Virtually any functional application today can be made richer, better, more accurate or more adaptive by incorporating ML algorithms, and at Arm we see this impacting literally everything we touch.

says Shelby. "We pulled our hair out – it was just a horrible experience for the developer."

Roddy comments: "On one side, you have the ML world, which is the domain of mathematicians, most of whom work and develop algorithms in the Cloud, where storage and compute power are infinite. On the other side, you have specialist developers working on embedded edge systems. These sides have to come together; bridges have to be built. Because data scientists and embedded developers have different skill sets."

Shelby rejoins: "The question was how to fix that." Edge Impulse created one of the first open source projects for writing C/C++ based inference algorithms into embedded systems, combining with the TensorFlow Lite framework for microcontrollers. "It helped to create the tinyML movement," he says. All the heavy-lifting of "machinery and tooling" was moved to the Cloud, and wound into an integrated development environment with the Nordic hardware.

He explains: "You can drag-and-drop the tinyML client, flash the development board, and automatically stream sensor data [to the inference algorithm]. You go from data capture to data sets really easily, in a graphical way. The whole process is automated – to choose the right algorithms for the sensor problem, train them using the captured data, and test and iterate with live data. The system is integrated and efficient, and performance is maximized."

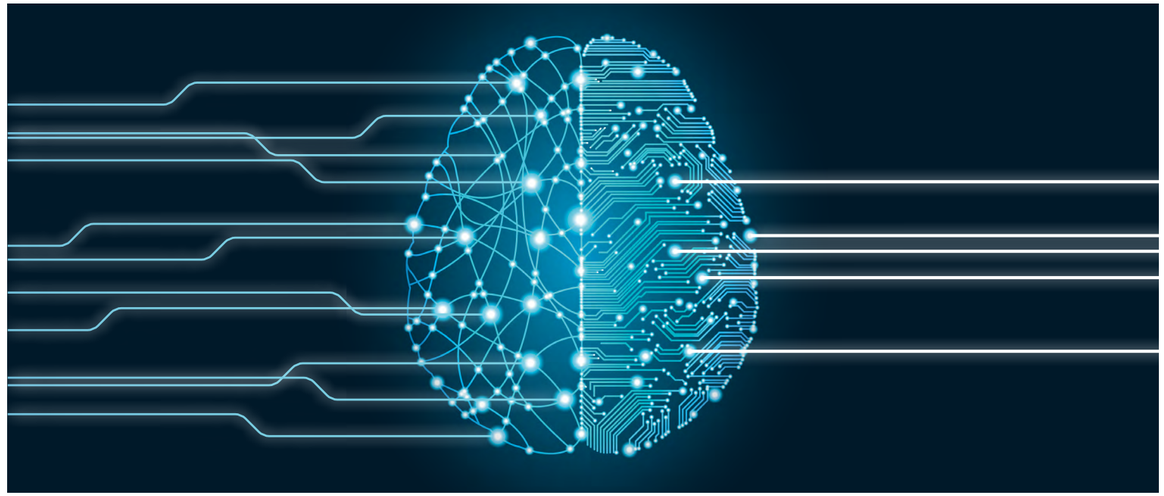
For Arm, "creating the building blocks to make it all come alive", this movement to democratize and popularize ML in even simple end-devices in the far reaches of the all-encompassing IoT ecosystem—like grabbing fingers in a digital version of the hundred-handed Hecatoncheires—is part of a wider trend towards what the company calls 'Software 2.0', where every single 'thing' becomes smart, as well as connected.

Roddy remarks: "It is one thing to make them interconnect, it is another to manage them as well. Not everyone understands all the arcane math that goes into these ML models. The whole field of neural architecture search (NAS), to automate the design of artificial neural networks (ANN), will be key to enable this concept of 'Software 2.0' – so you can have 10,000 different neural nets for 10,000 different sensor devices, each tailored for different ends."

Shelby agrees that Software 2.0 is a neat way of categorizing the future of coding. "When we started out, we thought, 'wow, we're going to help to solve all these amazing problems – with sensors, audio, computer vision'," he explains. "But it's much bigger than that. Because it's unlocking a data-driven approach to engineering problems. So just as we code today—as we write, test and iterate—engineers in all industries are starting to work with data, to develop, test and improve these ML algorithms."

Tech Check

Nordic's nRF5340 features dual Arm Cortex-M33 processors. One is a high performance application processor running up to 128 MHz and the second is a fully programmable, ultra low power network processor running at 64 MHz. Together with Nordic's nRF52 Series, the SoC is an ideal device to support tinyML at the network edge



DATA EXPERTISE

But this is the longer-term vision; as well as continued integration of edge-Cloud developer tools, and work to auto-tune signal processing parameters to further optimize power usage, the main job is just to animate IoT devices, one at a time, to bring tracking and monitoring into familiar everyday items like fridges, lifts and lampposts. Shelby references incoming audio applications, and "the [beginnings] of simple computer vision" in low power IoT units.

The latter will be helped along as Arm's v9 architecture takes hold, and new accelerometers are embedded in silicon. But developers should take advantage, now, he says. "You don't need to wait for some magical future. We can engineer algorithms today using any type of sensor, any type of audio input – on the entire range of Nordic Semiconductor parts. We can do that in a very small memory footprint, and we can do that in real time – which is huge." (*See Analysis pg21: Collaboration brings machine learning at the edge to non-experts.*)

Is there a 'killer app', to make the market jump? It's a trite question, in some ways, asked about every enabling technology since Apple unleashed the mobile internet with the first iPhone. But it is a question that usually elicits a telling response. "It is always wrong to predict," says Nielsen. "But I hope developers will [use ML] to help solve the world's big problems – climate change, energy efficiency, healthcare, social care, economic parity."

Case study:
Embedded machine learning makes smart electricity grids a reality

When a tree falls in a forest and no one is around to hear it, does it make a sound? This thought experiment has been disputed without conclusion for centuries. While metaphysicists theorize in search of an answer, the problem of unwitnessed falling trees is more than a philosophical conundrum for electricity grid operators.

In the U.S. the power transmission grid consists of about 300,000 kilometers of power lines and 180 million utility poles, and every day—through environmental conditions such as high wind and forest fires, the intervention of termites, or simply decay—trees fall on power lines causing disruption to the electricity supply for millions of consumers. In remote locations no one is around to see or hear or the falling trees, and pinpointing the location of the fault is notoriously difficult. Or at least it used to be.

Earlier this year, Slovenian innovation lab, Irnas, launched RAM-1, a device that once deployed on transmission towers throughout an electricity network enables utilities and energy companies to remotely monitor, locate, analyze and report a range of potential faults on the network. Not just problems caused by falling trees, but equally those occurring as result of fire, transmission tower collapse, power outage, as well as power surges. The device employs voltage, temperature, accelerometer and surge counter sensors to identify potential faults. RAM-1 also features LTE-M and NB-IoT cellular connectivity and GPS trilateration provided by Nordic Semiconductor's nRF9160 SiP to report the fault data and the device's location back to the network operator's control room.

RAM-1 distinguishes between significant and insignificant events, avoiding the cost of transmitting unimportant data

So far so good, but to capture large amounts of sensor data and report that to the Cloud over long distances and in 'real time' places unrealistic power demands on the device, and would require frequent battery replacement. Given the remoteness of many of these utility poles regular maintenance is impractical. Using tools developed by U.S. machine learning specialist, Edge Impulse, running on the Nordic SiP, Irnas has cracked the problem.

Machine learning advantage

TinyML, the name coined by Edge Impulse to describe its machine learning (ML) tools that run on resource-optimized devices, overcomes the limits of algorithm-based processing in low power and advanced sensing applications. By using TinyML, Irnas and Edge Impulse have trained the RAM-1 device to not report all the sensor data captured on the utility poles, but rather reliably distinguish between significant and insignificant events at the application level, avoiding the cost of transmitting unimportant data over the cell network and processing it in the Cloud. Instead the device sends an alarm only when an event requires human intervention. In doing so, the device can be made smarter at a minimal additional power consumption penalty.

> "RAM-1 has rapidly become a IoT device for remote monitoring, machine learning and advanced analytics of power grids

Nordic's nRF9160 SiP is ideal for TinyML applications. Its dedicated Arm Cortex-M33 application processor and memory provides ample computational resource to supervise on-device ML, while its low power capabilities—including support for PSM and eDRX power saving modes extend battery life. In the case of the RAM-1 device, its primary Li-MnO_2 cell can last up to two decades in the field between replacement.

Power optimized

"Using an ML model to detect [electricity grid] errors, then fire up NB-IoT to send that to the electric grid operator, and with the power optimization we now find in Nordic parts ... [Irnas] is able to do that with 10 to 20 years of battery life which is amazing," Edge Impulse Co-founder and CEO, Zach Shelby told the recent Nordic Semiconductor online expert panel debate entitled *When AI meets the wireless IoT*. "This is a product that is shipping to the market now."

An early adopter of the Irnas technology is Izoelektro, a Slovenian firm supplying utilities and energy companies with solutions that help set up, maintain and restore electrical energy systems. Jure Pungerčar, Izoelektro's Deputy CEO said the advent of RAM-1, and ML, had now made true smart grids a reality.

"From a device that originally reported the state of surge arresters, RAM-1 has rapidly become an IoT device for remote monitoring, machine learning, and advanced analytics of power grids," says Pungerčar.

"We are excited about the possibilities of a truly smart power grid and the ability to improve the operation, stability and reliability of electricity distribution."

It sounds simplistic, maybe; but talk about the potential of tinyML is feverish, and invariably reverts back to the future. The conversation turns to energy harvesting, and whether batteries might be eliminated from IoT devices altogether without compromising their newfound 'grunt'. Indeed, tinyML is compatible, with some tweaking of duty cycles, in devices scavenging solar, thermal or kinetic energy from adjacent supplies.

"[But] transmission is the killer," says Shelby. "The trick is to increase the on-board intelligence to do more processing on the device and reduce the amount of data to be sent. "That will open up the way to more energy harvesting, or smaller batteries. The holy grail is not to send any data at all, or as little as possible. That is the most energy efficient way to do anything," he adds.

The message from Nordic Semiconductor is to run the math, and move on energy harvesting when the numbers work. "You get to a point where you have to decide whether to put in a battery, which is very low cost, or spend on energy harvesting techniques. The calculation will certainly look more favorable in the coming years, but it will always ultimately come down to what you want to compute," says Nielsen.

More generally, the question for software engineers developing little solutions for big problems should rather be: what don't you want to compute? Because the answer is, nothing much at all, according to the companies providing the latest generation of development tools. "ML is not a passing fancy. It is here to stay. It is why we call it Software 2.0. It is the future of software," says Roddy.

Last word to Shelby, who restates that tinyML represents a giant leap in practical data-driven problem solving. "The big mind-change for developers is that it is not about experimenting with code anymore, or building up your code expertise. It is about building up your data expertise. Because this [practical tinyML market] is going to be huge — orders-of-magnitude bigger than the entire AI industry aimed towards data scientists today. It is super exciting."

A Nordic Semiconductor WQ Live webinar, entitled *When AI meets the wireless IoT: The impact of AI and machine learning on low power wireless IoT devices and their target markets*, featuring Steve Roddy of Arm, Zach Shelby of Edge Impulse and Svein-Egil Nielsen of Nordic Semiconductor is available for viewing here: bit.ly/3w6izX3.

Science fiction and science fact : What is AI anyway?

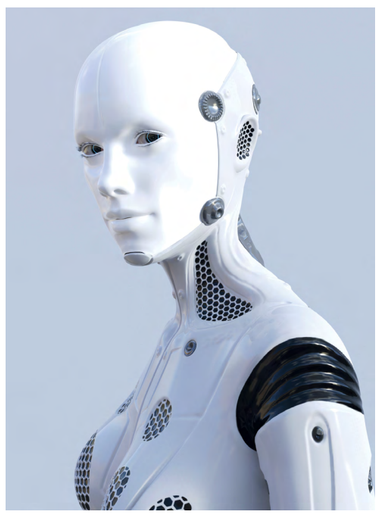
Purists scoff at usage of the term 'AI' in new technology. Modish number-crunching, pattern-sifting compute systems do not feature an 'artificial' form of intelligence, as such. The kind of AI conceived in mathematical theory and science-fiction writing is not directed by humans at all; instead, it thinks for itself, as a sentient machine. In the case of fiction, at least, it 'dreams of electric sheep', and invariably worries about a dystopian future.

Today's AI is just lazy marketing of clever analytics, the argument goes, giving way to industrial automation. But, actually, there are at least two classifications: 'narrow' and 'general' AI, distinguishing computer processes with limited and human-like ranges of abilities, respectively. Some have felt compelled to identify a third category, 'artificial super-intelligence', which, in dramatic terms, effectively imagines robots with laser guns and bad attitudes, set on Armageddon.

But that is so far removed from reality it can be left for Hollywood script writers. The point is practical AI, as we know it, does not get close even to this second notion of general AI. Instead, latest technologies deal with 'narrow' (or 'weak') AI, as a goal-oriented process marrying big data analytics and machine learning (ML). Narrow AI does not replicate human intelligence; it simulates human behavior based on a limited set of parameters and contexts.

In practical terms, think of speech recognition in home gadgetry, facial recognition in passport verification services, recommendations in search browsers and content platforms, augmented and virtual reality apps, intelligent transport systems, computer vision and predictive maintenance. These are powerful tools, which have accelerated in recent years, scoring major breakthroughs in fields like disease diagnosis and autonomous vehicles.

But they are not AI-proper — or, at least, the kind of 'general' or 'super' AI that sparks fear about a 'rise of the machines'. Any intelligence is pre-programmed. Even training data in machine learning is supervised and allocated, while neural deep-learning networks identify only limited rules and patterns. In the end, then, AI should be considered real, progressive and impactful, but controlled ultimately at every turn by human hands.



Analysis: Collaboration brings machine learning at the edge to non-experts

Once only for specialist coders, Edge Impulse and Nordic Semiconductor have brought ML for resource-optimized IoT devices within the grasp of developers with no previous experience

Machine learning at the edge will revolutionize industries ranging from logistics to health

Data is the lifeblood of the IoT and the numbers are staggering. Today, tens of billions of devices connected to the network collectively produce tens of zettabytes (ZB) of data. To put that into perspective, the contents of 250 *billion* DVDs is around one zettabyte. By 2025 connected IoT devices are expected to generate 79.4 ZB of data and that will continue to grow.

In the early days of the IoT, engineers struggled to find ways to deal with that data. Some early products proved unworkable because of the unsustainable energy, latency and subscription costs associated with sending all or most of the data to the Cloud.

Worse yet, moving most of the data to the Cloud proved inefficient because the majority of it proved worthless — confirming only the measured variable was unchanged.

The solution was to shift analysis to the IoT end-device (for example, a sensor) for it to decide what was of value and what should be transmitted to the Cloud.

At first, this edge computing was a challenge because many IoT end-devices were relatively energy inefficient and lacked computing resources to handle complex algorithms.

Today, things have changed; computing at the edge is getting progressively more energy efficient and powerful while algorithms are more streamlined and energy optimized.

For example, Nordic Semiconductor has enhanced the energy efficiency of its SoCs and SiPs with each new generation. On the software side engineers' efforts have resulted in 'tiny machine learning' ('tinyML') a type of ML that enables a low-latency, -power and -computational resource model powering 'inference' in end-devices.

Nordic-powered solutions can now run tinyML models locally and more energy efficiently compared to sending all or most of the data to the Cloud. In turn, edge-computing products have become more viable because

> "The development tools, hardware and software are in place and engineers are going to come up with many ground-breaking ML-powered applications

they can last longer on the battery (or use a smaller battery or even energy harvesting), have lower latency and attract lower subscription costs.

TinyML for non-experts

How effective is tinyML? The answer is "very". In addition to extending the battery life of end-products while running ML edge-computing applications, the adaptation of ML algorithms to run on small footprints has yielded stunning results. Some tinyML programs can now match the performance of conventional routines but run on memory footprints thousands of times smaller. For example, some tinyML algorithms can run on $5 microcontrollers with just 2 KB of RAM.

Compared to these devices, a Nordic nRF52 or nRF53 Series SoC has an embarrassment of riches. Nordic's chips are energy optimized, yet feature powerful Arm Cortex M-class processors and large capacity Flash and RAM. The nRF52840, for example, boasts a 64 MHz, 32-bit Arm Cortex M4 processor with 1MB Flash memory and 256 kB RAM.

However, exploiting that potential using tinyML has been reserved for those with a high level of knowledge and coding expertise. While there are plenty of examples of applications running tinyML on Nordic SoCs, the number has been restricted by a lack of skilled coders. But now a partnership between Nordic and Edge Impulse. (*See WQ Issue 1, 2021, pg4.*) makes it much easier for non-experts to take advantage of tinyML on Nordic SoCs.

"TinyML is already proving to be something of a revolution for edge computing but previously required expertise and experience to implement," says Petter Myhre, Head of Product Marketing with Nordic. "This collaboration brings together leaders in tinyML and wireless IoT with the aim of making ML at the edge accessible to all. The development tools, hardware and software are in place."

The collaboration brings together Edge Impulse Studio, Nordic's nRF Connect SDK and the nRF52840 and nRF5340 DKs. Developers can get started with fully-supported standalone inferencing example projects, based on the nRF Connect SDK and which run on the DKs. Raw data collected from accelerators, microphones and other sensors can be sent to Edge Impulse Studio—using the company's data forwarder tool—to acquire datasets, train and deploy models. Finally, developers can build downloadable binary images to run on Nordic SoCs at the edge.

A Nordic webinar about the technical benefits of the Edge Impulse/Nordic collaboration is available here: bit.ly/3gkeNCU.

Grid Unlocked

More agile and stable energy grids hold the key to a clean future. Wireless monitoring will be vital in realizing that potential

In Short

The aspiration for a cleaner energy future relies on electricity grids made more reliable through better use of data

The shift to renewable energy sources is bringing more complexity into already struggling electricity grids

The smart grid, in which IoT and sensor technology is integrated into the infrastructure, promises improved condition monitoring through concepts like 'self-healing'

More than 700 million people—at the time greater than the entire population of Europe—were plunged into darkness after widespread power cuts. It was the largest blackout in history.

The location was India, the year 2012, and it was the end of another brutally hot summer. For the citizens of the world's largest democracy, interruptions to air conditioning sadly only scratched the surface. Traffic lights cut out, surgical theaters shut their doors, miners were trapped in underground lifts and in a morbid twist, electric crematoriums ceased mid-activity. Never before had the *raison d'etre* of the power system—the reliable supply of energy—been brought into such sharp focus.

Months later, a review would find that poor visibility into what was happening in the grid was a key factor in the blackout. As operators struggled to maintain the health of a complex network, the lack of timely data about equipment failures and imbalances between load and supply would prove consequential.

It's a lesson that should ring loud for the global energy industry, which is rapidly shifting to renewable energy sources in pursuit of reduced carbon emissions — a transition sure to bring even more complexity into the electricity grid. To accommodate this complexity and fulfill collective global aspirations for a cleaner energy future, electricity grids will need to become smarter and more reliable through better use of data.

As it is, grids in many parts of the world are already struggling. Major interruption events in the U.S. have increased in frequency and severity since 2000 despite intense investment, according to McKinsey. It's not surprising when one considers that 70 percent of power transformers on the U.S. grid are 25 years of age or older, 60 percent of circuit breakers are 30 years or older and 70 percent of transmission lines are 25 years or older. Similar observations about aging infrastructure are also true of the European grid.

AN INCONVENIENT TRUTH?

Aging infrastructure must now cope with the introduction of renewable sources of energy. The change is necessary, propelled by a global shift in sentiment among political leaders, industry and citizens. U.S. President Joe Biden pledged in April that the country would achieve 100 percent carbon pollution-free electricity by 2035. The U.K. is also targeting net zero emissions by 2050, a target heavily underpinned by growth in renewable energy.

While the benefits for the planet are obvious, the shift to renewables does raise difficult questions for electricity grids, which were designed and built to support the one way flow of energy from baseload power stations to consumers via expansive transmission and distribution networks.

Now, the same infrastructure must accommodate distributed energy generation and even two way flows, as end users feed excess electricity back into the grid from rooftop solar panels.

Entirely new categories of devices—solar panels, electric vehicles (EVs) and their charging stations, heat pumps and batteries—also represent a radical shift in energy consumption patterns that grids must evolve to support. Consider EVs. While the increase in sales is unlikely to increase total power demand, it will reshape the electricity load curve, says McKinsey, an analyst.

"Beyond peak load increases (as people plug in their EVs at times of high demand), the highly volatile and spikey load profiles of public fast-charging stations will also require additional system balancing," the company reports.

This concept of 'system balance' may be where the challenge is at its greatest. Stability and reliability of electricity supply depends on a state-of-balance being maintained in the grid by operators between power generation and demand. Imbalances affect electrical AC frequency, which in turn can lead to collapse and blackouts.

In this context, renewable energy presents a tricky proposition. It can be highly variable – at times, clouds cloak the sun and winds die down. Increasing the proportion of renewable energy in the grid—as many nations are targeting—inherently increases variability of power generation. The shift to renewables makes energy operators' obligations to balance the grid (*see pg27*) and ensure reliable power considerably more challenging.

DATA IS THE NEW OIL

Upgrading the grid to meet the challenges will be a sizeable task. International energy authorities forecast that more than $300 billion in investments will be necessary through to 2030 to meet global grid modernization requirements, according to International Energy Agency estimates.

The phrase "data is the new oil" highlights the role that digital technology and data analytics will play in propelling societies forward. Given the phrase centers on hydrocarbons, it's perhaps no surprise that the concept has caught the attention of energy operators. Some operators in that sector believe greater use of computerization and data could pave the way for the industry to deliver cleaner and more reliable energy.

"Our data blind spots mean that grid operators, generators and networks are unable to fully see how new technologies such as rooftop solar are impacting reliable and safe supply," says Kerry Schott, an Australian energy sector policy maker. "It means networks put constraints on solar which are often unnecessary, to avoid risks to the security of the energy system, and makes it difficult to identify what, where and when additional generation, poles and wires are needed."

'Smart grids' are designed to eliminate these blind spots. But they are more than this; in the words of the European Commission (EC), a smart grid is: "An electricity network that can integrate in a cost efficient manner the behavior and actions of all users connected to it, including generators, consumers and those that both generate and consume, in order to ensure an economically efficient and sustainable power system with low losses and high levels of quality, security of supply and safety." More plainly, a grid that has more data about the operation of its components can be managed far more efficiently, reliably and sustainably.

Fortunately, this doesn't require wholesale replacement of the current grid, says Lorenzo Amicucci, Business Development Manager at Nordic Semiconductor. "Tomorrow's smart grid can be built by introducing IoT technologies such as sensors, connected meters and other equipment onto today's existing grid, and making

By the Numbers

70%
of power transformers in the U.S. grid are 25 years of age or older

(Source: U.S. Department of Energy)

More than
$300 billion
in investments will be necessary through to 2030 to meet the grid's modernization requirements

(Source: Boston Consulting Group)

Self-healing and distribution automation technologies have reduced the number of minutes that customers experience an outage by up to
51 %

(Source: U.S. Department of Energy)

Field workers required to fix network faults account for
40% of staffing costs for utility companies

(Source: Boston Consulting Group)

use of fast developing communications and data analytics technologies to harvest data and deliver new and meaningful insights and capabilities."

THE SELF-HEALING GRID

The first and perhaps most impactful change might be smarter grid condition monitoring and fault detection. Typically, faults in the grid become apparent to operators when consumers complain about power interruptions. Even where utilities themselves identify an outage in a network segment, isolating the fault to specific equipment requires a truck roll to dispatch a technician and lots of time to pinpoint the failure.

"This reactive approach costs time in detection and resolution, which translates to longer outages," says Amicucci. "Through the use of connected sensors, there is a better way forward."

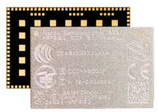
A Slovenian firm, Irnas, has developed a device for remote monitoring of power grids and surge arresters that can be mounted on utility poles. The 'RAM-1' device has integrated voltage, temperature, accelerometer and surge counter sensors that allow the monitoring of variables that might indicate a fault that could lead to a power outage. For example, the sensors could detect excessive temperatures that indicate a fire, while data from other sensors could indicate collapse of a transmission tower or a power surge.

With electricity networks covering thousands of kilometers, finding the exact location of a fault can also be difficult and require operators to shut down large sections of a grid to ensure safety. The RAM-1 device makes use of Nordic Semiconductor's nRF9160 SiP, which has in-built GPS capabilities that allow it to precisely relay the location of a fault. "The nRF9160's ability to perform edge processing also means only the most critical insights about the fault are transmitted, rather than running to the cost of transmitting all the raw data across the wireless link," says Amicucci. (*See pg18.*)

For connectivity, the nRF9160 supports LPWAN cellular technologies LTE-M and NB-IoT. These solutions are ideal for use in smart grids, as they leverage existing and future-proof network infrastructure (cellular IoT will be supported by future 5G networks (*see pg12*)) and consume low power. As a result, the RAM-1 can last up to 20 years in the field from just the power of a primary Li-MnO_2 cell, a welcome benefit given it is made to be mounted on utility poles distributed across geographically vast areas.

With more precise condition information from IoT sensors, grid operators can take steps to proactively detect and isolate faults and restore power in the event of an outage. This can include redirecting power to affected parts of the network using control systems and switching infrastructure such as automatic circuit reclosers (ACRs). This capability is being referred to as 'self-healing', and the benefits are already profound. Self-healing and 'distribution automation' technologies have reduced the number of minutes customers experience an outage by up to 51 percent, and reduced the total number of customers affected by up to 45 percent, according to a report by the U.S. Department of Energy.

Other utilities also stand to benefit from this approach. Gas and water pipelines often traverse large distances, and must contend with everything from the blistering heat of deserts to intense underwater pressure. Faults are common—liquid pipeline accidents cost $326 million annually in the U.S. alone—and can result from a range of events including structural failure, construction activities and freezing weather. In the case of gas, leaks affect not just reliability of supply but also entail obvious public safety concerns. Prompt detection and remediation of leaks is of course essential.



Need to Know

NB-IoT and LTE-M are cellular technologies specifically designed for IoT applications that require long battery life and reliable network coverage. NB-IoT is primarily designed for energy efficiency and good range. LTE-M offers higher throughput and suits mobile applications such as asset tracking. Nordic's nRF9160 SiP is a multimode cellular IoT solution offering both NB-IoT and LTE-M

Locating a fault in a pipeline—which like electricity distribution can also span thousands of kilometers—often requires expensive equipment and trial-and-error. Braveridge, a Japanese IoT solutions company, has developed a remote monitoring system to more rapidly identify faults. The system uses sensors to record air pressure inside and outside the gas pipe and determine if pressure differences indicate a leak. The system also uses Nordic's nRF9160 SiP, so calculations are performed locally and in-built GPS provides the precise fault location. Using LTE-M cellular connectivity, the data is relayed to a Cloud-based platform used by management teams who can direct repair crews to the precise location of the fault – speeding up repair and minimizing the hazard.

MAINTAINING A FINE BALANCE

Returning to the electricity grid, the introduction of sensor technologies and self-healing capabilities promises to increase network resilience. With the introduction of renewable energy, however, faults aren't the only contingency modern grids need to contend with to maintain stability. The ever-growing quotient of renewable energy sources means substantial variation in power generation. On the load side, growth in 'behind-the-meter' systems such as rooftop solar panels and batteries, which are typically beyond the visibility of utilities, also makes load forecasting more challenging.

Achieving balance in the grid of the future will require a more dynamic, agile and flexible approach, made possible by improved visibility of power flows across all parts of the grid, says energy consultant and author Peter Fox-Penner.

"The whole power system is engineered to balance demand and supply at every second, which means that control over generators is really important," he says. "But if you have really up-to-date information on all the flows on your grid, you can tolerate a little more variability. The smart grid will monitor everything at a very, very fine level of detail and reacts really fast, so operators will have time to fire up another plant if wind speed drops or a big cloud formation reduces solar output."

Amicucci says Advanced Metering Infrastructure—or 'smart meters'—will be critical here. "Smart meters can provide insights into how power is being used in a customer's home. But they can also measure the flow and output of energy through transmission and distribution, providing data that can greatly aid grid management," he says. Integrated smart meters may also provide insights into behind-the-meter systems.

While critical grid equipment such as switches and ACRs may continue to use wired connections, Amicucci expects increased use of LPWAN connectivity for transmitting data from devices like smart meters. "Millions of smart meters are being deployed around the world. If you want to keep pace and connect all these devices, it's difficult to do that with wired connections that require additional network and physical infrastructure," he explains. Operators are instead increasingly turning to established, secure long-range wireless connectivity options such as NB-IoT and LTE-M, which can scale and evolve.

As energy sources become more decentralized and distributed, edge processing capabilities become more critical to maintaining grid balance. It's feared by some that having data about surges and voltage fluctuations affecting distributed energy resources transmitted over long distances to centralized control systems for processing and actions to be transmitted back will take too long. That makes local solutions—where data is processed and decisions made at the edge—increasingly vital.

Cyber security is another critical consideration. Authorities were already looking intently at how critical infrastructure providers will account for growing cyber-attack risks when such a threat disrupted the Colonial Pipeline in the U.S. in May this year. The attack disrupted gas supplies for almost a week.

> "Our data blind spots mean that grid operators, generators and networks are unable to fully see how new technologies such as rooftop solar are impacting reliable and safe supply

Tech Check

In addition to incorporating a Nordic nRF9160 SiP, the IRNAS RAM-1 power grid monitor also features Bluetooth LE wireless connectivity provided by an nRF52811 SoC. The SoC enables commissioning, a method of collecting data in remote locations where there is no LPWAN coverage and a back-up channel for upgrading the device

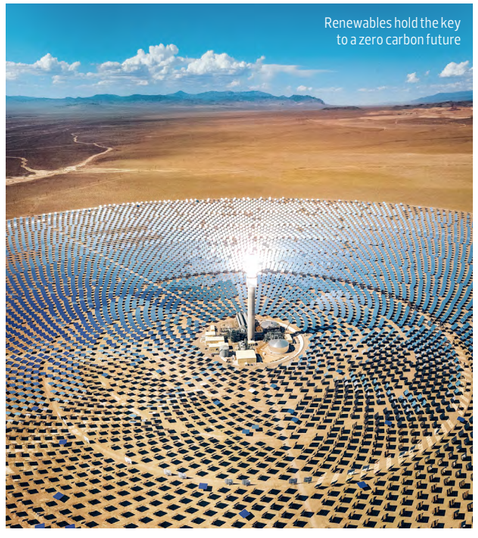
Who's got the inside track in the Race to Zero?

Since 2019, the number of participants has jumped tenfold in the Race to Zero, a global contest to hit net zero carbon emissions by 2050 featuring a coalition including businesses, cities and universities. The more players that cross the finish line, the better for the planet. Happily, the European Union and countries including Japan, the U.S., the U.K. and over 100 others have also fallen in behind the same net zero goal.

There's nothing like healthy competition to spur action, it would seem. The most competitive would have welcomed this handy race tip from International Energy Agency (IEA) head Dr Fatih Birol in May. "When we look around the world, we see that many governments from the U.S. to Europe, Japan and China want to have net zero emissions in the energy sector. This means we have to decarbonize how we generate electricity, how we run our cars, how we also run our industry," Dr Birol said.

In short, clean electricity could hold the key to faster carbon neutrality. The strategy is to make electricity generation cleaner, such as by adding renewables, while also electrifying parts of the economy currently dependent on fossil fuels, such as transport (by using electric vehicles, for example) and industry. For example, in April, U.S. President Joe Biden put a clean electricity standard and target for 100 percent carbon-free electricity by 2035 at the heart of his new $2.3 billion infrastructure plan.

Smart grids are fundamental to the strategy of hitting these more assertive clean electricity targets. Using data from the grid astutely will drive more efficient energy use, support the use of new devices like electric vehicles and batteries and—most critically—enable the integration of vastly greater volumes of renewable energy. The final challenge shouldn't be underestimated – between now and 2030, we will need to install the equivalent of the world's current largest solar park every single day to reach net zero, according to the IEA.



Renewables hold the key to a zero carbon future

In theory, integrating new technology into the electricity grid potentially introduces more cyber risk. The reality is that many technologies already used by utilities for fault detection and monitoring are based on aging and proprietary systems, making them more vulnerable to cyber-attack.

The shift to the smart grid is an opportunity to integrate modern IoT gateways whose components have been designed with security in mind and which use standards-based protocols more likely to be updated in light of emerging cyber threats. For example, Nordic's nRF9160 cellular IoT solution offers layers of security through the use of Arm TrustZone's hardware-enforced isolation of critical components and Arm CryptoCell.

AN INTERNET OF ENERGY

Perhaps the strongest selling point for a more connected and data-driven energy system—an 'Internet of Energy', as some have coined it—is that it stands to benefit many parties. For end users, a more reliable supply of energy is coupled with lower energy costs, particularly as smart grids better enable consumers to manage their own energy use and access renewable sources such as rooftop solar panels.

In addition to being better placed to manage the reliability of supply, energy operators and utilities will benefit from reduced maintenance costs, particularly through more proactive fault detection and use of remote monitoring, which lessens reliance on field workers (who now account for 40 percent of wages for utility companies) to fix network faults. In the longer term, utilities can also broaden and deepen relationships with their customers by better leveraging data about their use of energy.

Governments and policymakers will welcome the data generated and collected from the smart grid, which will provide insights into current and future energy consumption and inform planning for future grid infrastructure.

The enduring winner, though, will be the planet. Globally, the energy sector remains the largest source of carbon emissions. And though the path taken by electricity in a circuit may be well understood, the road to meaningful emissions reductions hasn't always been so obvious for the energy sector. With smart grids that pathway is clearer.

> Smart meters can provide consumer insights. But they can also measure the flow and output of energy through transmission and distribution, providing data that can greatly aid grid management

Tech Check:

What makes a smart grid so smart

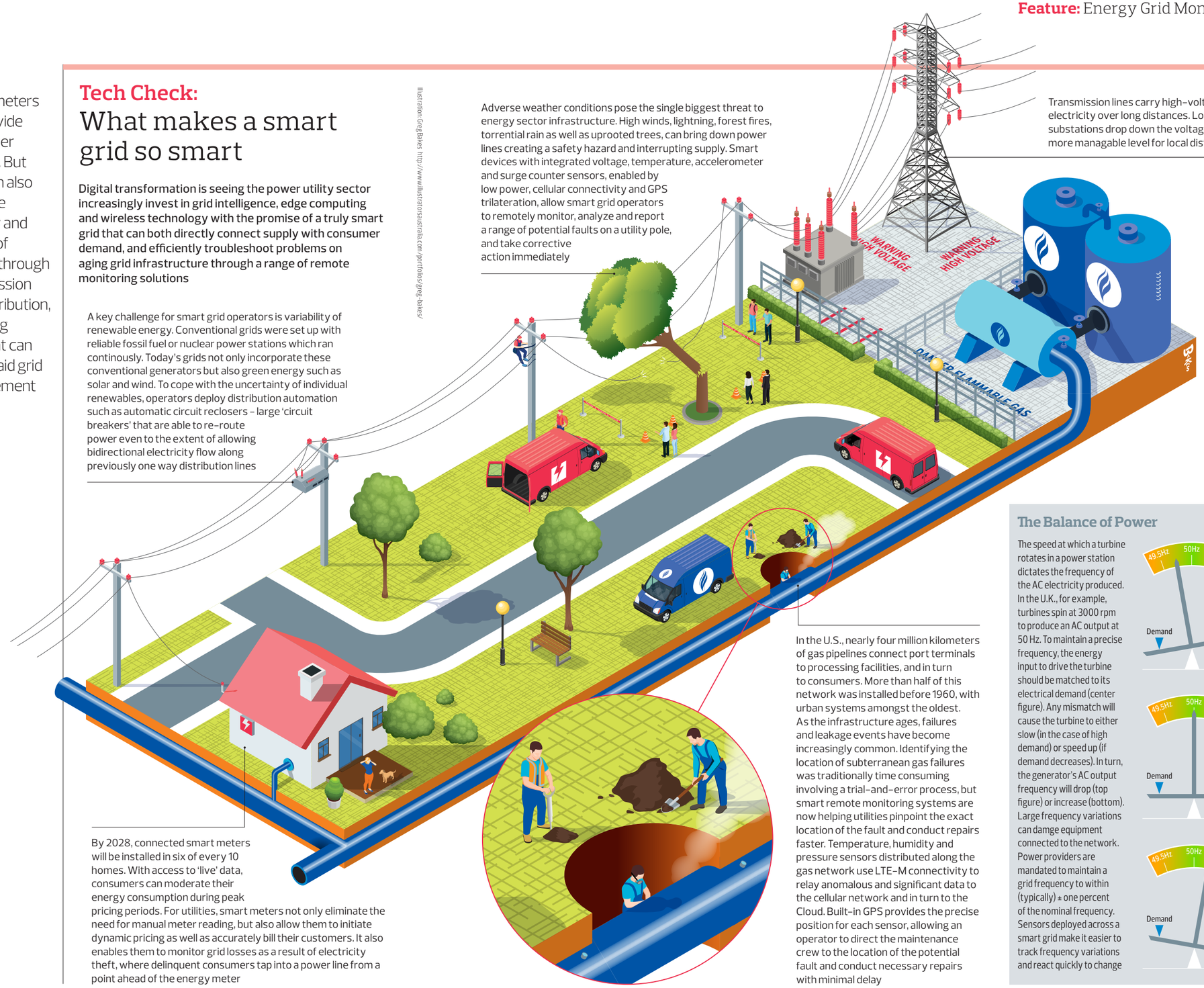
Digital transformation is seeing the power utility sector increasingly invest in grid intelligence, edge computing and wireless technology with the promise of a truly smart grid that can both directly connect supply with consumer demand, and efficiently troubleshoot problems on aging grid infrastructure through a range of remote monitoring solutions

Illustration: Greg Bakes http://www.illustratorsaustralia.com/portfolios/greg-bakes/

A key challenge for smart grid operators is variability of renewable energy. Conventional grids were set up with reliable fossil fuel or nuclear power stations which ran continously. Today's grids not only incorporate these conventional generators but also green energy such as solar and wind. To cope with the uncertainty of individual renewables, operators deploy distribution automation such as automatic circuit reclosers – large 'circuit breakers' that are able to re-route power even to the extent of allowing bidirectional electricity flow along previously one way distribution lines

Adverse weather conditions pose the single biggest threat to energy sector infrastructure. High winds, lightning, forest fires, torrential rain as well as uprooted trees, can bring down power lines creating a safety hazard and interrupting supply. Smart devices with integrated voltage, temperature, accelerometer and surge counter sensors, enabled by low power, cellular connectivity and GPS trilateration, allow smart grid operators to remotely monitor, analyze and report a range of potential faults on a utility pole, and take corrective action immediately

Transmission lines carry high-voltage electricity over long distances. Local substations drop down the voltage to a more managable level for local distribution



By 2028, connected smart meters will be installed in six of every 10 homes. With access to 'live' data, consumers can moderate their energy consumption during peak pricing periods. For utilities, smart meters not only eliminate the need for manual meter reading, but also allow them to initiate dynamic pricing as well as accurately bill their customers. It also enables them to monitor grid losses as a result of electricity theft, where delinquent consumers tap into a power line from a point ahead of the energy meter

In the U.S., nearly four million kilometers of gas pipelines connect port terminals to processing facilities, and in turn to consumers. More than half of this network was installed before 1960, with urban systems amongst the oldest. As the infrastructure ages, failures and leakage events have become increasingly common. Identifying the location of subterranean gas failures was traditionally time consuming involving a trial-and-error process, but smart remote monitoring systems are now helping utilities pinpoint the exact location of the fault and conduct repairs faster. Temperature, humidity and pressure sensors distributed along the gas network use LTE-M connectivity to relay anomalous and significant data to the cellular network and in turn to the Cloud. Built-in GPS provides the precise position for each sensor, allowing an operator to direct the maintenance crew to the location of the potential fault and conduct necessary repairs with minimal delay

The Balance of Power

The speed at which a turbine rotates in a power station dictates the frequency of the AC electricity produced. In the U.K., for example, turbines spin at 3000 rpm to produce an AC output at 50 Hz. To maintain a precise frequency, the energy input to drive the turbine should be matched to its electrical demand (center figure). Any mismatch will cause the turbine to either slow (in the case of high demand) or speed up (if demand decreases). In turn, the generator's AC output frequency will drop (top figure) or increase (bottom). Large frequency variations can damge equipment connected to the network. Power providers are mandated to maintain a grid frequency to within (typically) ± one percent of the nominal frequency. Sensors deployed across a smart grid make it easier to track frequency variations and react quickly to change

The Why in Wi-Fi 6

Wi-Fi is a stalwart of high-speed consumer connectivity. But the new Wi-Fi 6 version brings technical changes that see the wireless protocol offer greater support for IoT networks

The smart home is in transition. Not so long ago, short-range wireless protocols such as Bluetooth LE, Thread and Zigbee—plus a slew of proprietary technologies—were slugging it out for dominance. But no single tech looked like winning the war of attrition because each had its strengths and weaknesses. For example, while Bluetooth LE offered smartphone interoperability, Thread promised streamlined Cloud-connectivity and Zigbee looked like the most mature option for mesh networking.

Today the protagonists have called a truce among a growing realization that each can play a role in the burgeoning smart home sector. For example, the recently launched Connectivity Standards Alliance (CSA), formerly the Zigbee Alliance, boasts 350 member companies, including Nordic Semiconductor, all working together to harmonize IoT wireless standards. (*See this issue pg7.*)

This spirit of cooperation—fostered in part by the key role the IoT has played in battling the COVID-19 pandemic—makes it a good time for an IoT-friendly version of Wi-Fi to enter the game. Based on versions that were designed for high-bandwidth consumer applications and featuring a stack with baked-in Internet Protocol (IP), this new version of the wireless standard includes under-the-hood enhancements which promise to add much to the smart-home and -industry product developer's armory.

TACKLING SLOW WI-FI

Look far enough back into Wi-Fi's past and you'll see a story that combines a 1970s Hawaiian UHF radio network, the U.S. Federal Communication Commission's (FCC) 1985 decision to release the 2.4 GHz spectrum for unlicensed use, wireless cashier systems and an Australian project observing atomic particle-sized exploding black holes.

These disparate events fed into the formation of an Institute of Electrical and Electronic Engineers (IEEE) standards committee tasked with defining the physical layer (PHY) and media access control (MAC) for a WLAN or 'wireless Ethernet'. The first version of the specification, IEEE 802.11-1997, arrived in June 1997 and later versions used other frequencies, enhanced throughput and coexistence, and added IP layers to the PHY and MAC.

Fast forward to today and while Wi-Fi generally works satisfactorily, its ubiquity is putting pressure on networks which are in turn beginning to creak at the seams. Frustratingly slow Wi-Fi service in public places such as malls and libraries is now commonplace. IEEE802.11ax, marketed as 'Wi-Fi 6' and approved earlier this year, is touted as the solution; it is specifically designed to meet the requirements of so-called dense deployments. (*See sidebar p29: A short history of the IEEE802.11 standard.*)

Wi-Fi 6 combines enhancements to both throughput and spectral efficiency which should, according to the Wi-Fi Alliance, a trade organization charged with promoting the technology: "Enable good performance in even the most demanding Wi-Fi environments." These improvements provide support for many more devices from a single access point (AP) and will not only be a boon for YouTube and Netflix fans looking for a streaming fix in a public place but also for smart-home, -building or -factory owners looking to employ Wi-Fi 6 powered IoT sensors.

Wi-Fi 6's throughput and greater spectral efficiency not only enables faster response from connected devices but also allows for more network connections while still maintaining good service. While the previous version, 'Wi-Fi 5', could simultaneously support up to 250 devices from a single AP, Wi-Fi 6 boosts that support to 1024 devices.

Further improving Wi-Fi 6's suitability for smart-home and -industry applications is the addition of individual target wake time (TWT), a significant evolution over power-saving efforts of prior generations of Wi-Fi. Using TWT, client devices negotiate wake-up times with APs, so they do not need to stay awake to maintain the wireless connection. The result is that the AP is able to aggregate large groups of client requests into fewer triggered transmit opportunities. The benefits are more efficient, contention-free channel access and significant client device power savings. These are considerable, up to 80 percent in like-for-like applications, making IoT devices with long battery lifetimes more practical.

Finally, Wi-Fi 6 also brings improved security. The technology benefits from Wi-Fi Protected Access (WPA) 3 (although this was rolled-out separately to Wi-Fi 6) which uses the Simultaneous Authentication of Equals (SAE) protocol in place of the Pre-Shared Key (PSK) protocol common to older WPA2 protection. SAE boasts enhanced encryption technology compared with PSK.

BRIDGING THE GAP

While Bluetooth LE, Thread and Zigbee are leading short-range options for IoT sensor networks, cellular IoT and LoRaWAN offer practical options for the LPWANs needed to shift that sensor network data over much longer distances to the Cloud. Wi-Fi 6 adds something more.

"Wi-Fi 6 offers IoT sensors direct connection to the Cloud through routers without having to pay additional data subscriptions," explains Karl Torvmark, a Technical Product Manager with Nordic Semiconductor. "Moreover, better use of the RF spectrum makes Wi-Fi 6 powered IoT networks practical. Previous versions of the technology struggled to cope with more than a few sensors.

By the Numbers

4.5 billion
annual Wi-Fi device shipments by end of 2020, of which 1.6 billion were powered by Wi-Fi 6
(Source: IDC.)

82% of all IP traffic will be video based by 2022, more than half of which will be handled by Wi-Fi
(Source: Cisco.)

A typical family with a moderate number of smart home devices require at least **200 Mbps** bandwidth
(Source: Huawei.)

In April 2020, the U.S. FCC opened **1,200 MHz** of spectrum in the 6 GHz band for unlicensed use, securing bandwidth for Wi-Fi in the future
(Source: TechRepublic.)

"The technology's higher throughput [compared to other short range wireless tech] enables new use-cases like wireless security cameras and high-quality video doorbells. The additional throughput can also be used to complement Bluetooth to transfer large amounts of data – such as music streaming in wearables," adds Torvmark.

For its part, the CSA is backing Wi-Fi 6 as a foundation technology of the smart home; Matter, the alliance's unified IP-based connectivity protocol, is designed to run on the protocol (and older versions of Wi-Fi) – as well as on other mature networking technologies such as Ethernet and Thread (and for ease of commissioning, Bluetooth LE). The adoption of Matter will see a new type of device called a "Thread border router" which will be used to connect Thread/Matter devices using IEEE 802.15.4 as the wireless transport to the Wi-Fi network. (A Thread border router can also operate as a bridge from Thread networks to other networks such as Ethernet and LTE. Such a router won't be needed if the IoT device is connecting using just Matter over Wi-Fi.) (*See Need to Know right.*)

Nordic Semiconductor too sees Wi-Fi 6 as a key enabler for the IoT. The company acquired U.K.-based Imagination Technologies' Wi-Fi development team and associated IP tech assets at the end of 2020.

"As the global leader in Bluetooth wireless technology and the emerging leader in cellular wireless IoT, there has been a gap [in our product range] which our customers have been asking us to fill," says Svein-Egil Nielsen, Nordic's CTO. "Short range radio technologies are ideal for the IoT's sensor mesh networks, while cellular IoT is the answer for transmitting that sensor data to the Cloud. Wi-Fi 6 adds a low power, fast, secure and scalable version of the IP interoperable technology that can leverage routers to send information to the Cloud.

"We've now addressed the need for Wi-Fi with the acquisition of Imagination. We will be able to add Wi-Fi functionality to future generations of Nordic products," concludes Nielsen. (*See WQ Issue 4, 2020 pg7.*)

Need to Know

A border router isn't a new concept but until now vendors were forced to develop their own solutions. The device is a specific type of router that provides connectivity from an IEEE802.15.4 network to adjacent networks using other physical layers (such as Wi-Fi and Ethernet). Now the CSA Matter initiative plans to promote the concept more widely. This could see Thread border routers, for example, routinely embedded into items such as smart speakers and smart lights making Internet Protocol (IP)-based connectivity more convenient for both vendors and consumers

A short history of the IEEE802.11 standard

The first version of the Wi-Fi specification, IEEE 802.11-1997, arrived in June 1997. Then a 1999 amendment to the standard introduced the technology upon which today's versions of Wi-Fi are largely based. IEEE 802.11a leveraged the 5 GHz spectrum allocation and offered throughput up to 54 Mbps. And IEEE 802.11b offered an 11 Mbps alternative using the 2.4 GHz spectrum allocation. The Wi-Fi Alliance was formed to commercialize the technology.

The addition of an Internet Protocol (IP) suite to the IEEE802.11 PHY and MAC underpinned Wi-Fi's expansion. Then the IEEE802.11n and ac versions (now marketed as 'Wi-Fi 4' and 'Wi-Fi 5'), introduced in 2009 and 2013 respectively, cemented the protocol as the 'go-to' technology for high-speed consumer wireless connectivity.

While the b version is an exception (using direct sequence spread spectrum (DSSS) modulation), the a, Wi-Fi 4 and Wi-Fi 5 versions all use an orthogonal frequency division multiplexing (OFDM) modulation scheme. OFDM divides Wi-Fi's bandwidth into non-overlapping frequency bands each of which can carry separate information streams with limited cross-talk between the channels.

Wi-Fi 4 introduced multiple input, multiple output (MIMO), a technique which exploits multipath propagation to add more data channels. Wi-Fi 4 added four MIMO 'streams' while Wi-Fi 5 increased this to eight.

An updated form of MIMO is called multiuser (MU)-MIMO. The difference is that while conventional MIMO uses a single transmitter and single receiver, MU-MIMO employs several transmitters and receivers raising the potential throughput.

Wi-Fi also takes advantage of quadrature amplitude modulation (QAM). QAM improves spectral efficiency to enhance the volume of information carried over a given channel. The number associated with the QAM scheme is proportional to the throughput of the channel. Wi-Fi 4, for example, supports up to 64-QAM while Wi-Fi 5 raises this to 256-QAM.

Environment

Code of Conscience

This Proof-of-Concept hopes to help governments, NGOs and communities restrict the use of heavy vehicles in protected land areas

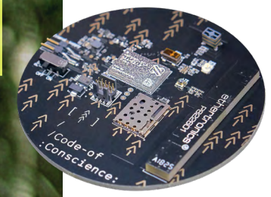
Protected areas are essential for biodiversity conservation and for the continued existence of culturally rich local communities. Today, despite its protective status, one third of the world's land reserves are under threat from human activity

Agricultural expansion, illegal logging, mining and urbanization continue to drive deforestation around the world. According to Conservation International from 2002 through 2019, global tropical forest loss averaged 33,600 square kilometers a year. Since the 1960s, more than half the world's tropical forests have been destroyed, with an entire soccer field worth of primary rainforest lost every six seconds

Chief Raoni Metuktire, the most prominent Native Brazilian leader, is the face of the campaign, which saw an invitation comprising the Code of Conscience chip embedded in a wooden sculpture of an endangered animal sent to the CEOs of the world's top-ten construction equipment manufacturers, with a vision for all new machines to leave the factory with the chip pre-installed

The Amazon rainforest contains around 10 percent of the world's known species. To date, at least 40,000 plant species, 427 mammals, 1,300 birds, 378 reptiles, more than 400 amphibians and around 3,000 freshwater fish have been found in the Amazon. These numbers are dwarfed by estimates for the smaller life forms. More than 100,000 invertebrate species have been discovered to date in Brazil

The Code of Conscience PoC was launched by a collective of designers, engineers and content creators led by global experience agency AKQA. To protect against illegal deforestation, open-source software uses publicly available cached and compressed mapping data in conjunction with existing GPS tracking technology installed in construction vehicles, to autonomously restrict crews from entering protected zones



The original hardware for Code of Conscience was based on the Nordic Thingy:91 multi-sensor cellular IoT prototyping platform. The open source software provides the GPS-based geofence capabilities which interlock with the fuel pump systems of heavy machinery, enabling automatic shutdown if the equipment moves into a restricted area. Integrated cellular connectivity enables notifications and audits of the machinery's position. (*See WQ Issue 3, 2020 pg10.*)

Tech Check

The Nordic Thingy:91 is an easy-to-use prototyping platform for cellular IoT using LTE-M, NB-IoT and GPS, ideal for creating PoC demos and prototypes. It is built around the nRF9160 SiP and is certified for a broad range of LTE bands globally, meaning it can be used just about anywhere in the world

Internet of Things

Cellular IoT transforms office water cooler into connected device for a new generation

Backed by Nordic cellular IoT connectivity, The Well Water is reinventing the multibillion dollar water cooler industry

> Connecting a water cooler to the Cloud has suddenly become viable in a way that wasn't technologically or commercially viable even a few years ago

The office water cooler as we know it has resisted innovation for the past 40 years, ever since cumbersome glass jugs were replaced by easier to transport and handle plastic alternatives. During that time they have earned a reputation as the place where colleagues stop and share gossip, entering the modern idiom as 'water cooler moments', where people discuss significant events of the previous day.

While water coolers remain a gathering place for talkative office staff, the device itself resisted change. A multibillion-dollar industry continued to rely on 'dumb' water coolers whose stock levels couldn't be monitored by anything other than the eye. As most organizations didn't want the hassle of having to regularly check themselves, water cooler delivery companies defaulted to restocking on a fixed schedule that bore little or no relation to actual consumption levels.

Technology to the rescue

But times are now changing, and technology is coming to the water cooler. Ireland-based firm, The Well Water, is launching what it claims is a new kind of Cloud-connected water cooler that continuously monitors stock levels down to individual water coolers on individual floors. In doing so it can rapidly detect changes in usage patterns and optimize delivery routes to not only keep coolers full, but completely eliminate unnecessary or emergency visits from delivery vehicles.

"With the advent of cellular IoT, connecting a water cooler to the Cloud has suddenly become viable in a way that wasn't technologically or commercially viable just a few years ago," says the firm's CEO, Kieran McKenna.

The Well Water iCooler employs Nordic's nRF9160 low power SiP with integrated LTE-M/NB-IoT modem and GPS. The unit is located in the front door of the cooler to communicate both cooler location and status info—for example if the cooler is on or off or the water is running low—using MQTT via NB-IoT cellular IoT connectivity.

"The water cooler also features two-way communication between the end user and supplier which supports not only the remote monitoring of stock levels but also industry-first maintenance status and alerts," says McKenna. "The latter makes it possible to spot a water cooler starting to fail in some way and fix it before the end customer even realizes they had a problem."

Given that water coolers are often located within busy reception areas and waypoints within a building, a large color touchscreen is also included on the iCooler which can be used to display general staff or visitor information, including QR-code driven marketing promotions.

"This brings new meaning to the proverbial 'water cooler chat'," adds McKenna.

The iCooler uses a SIM from global cellular IoT connectivity specialist and both The Well Water and Nordic Semiconductor partner, Arkessa. This enables the iCooler to operate anywhere in the world where there is a local NB-IoT network. "NB-IoT connectivity allows deeper penetration into buildings and supports low-cost deployment models, making it a great choice for static, low duty cycle applications located indoors or in hard-to-reach locations," explains Arkessa CTO, John Freeman. "And that pretty much describes the water cooler industry."

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. The Well Water employs NB-IoT in its iCooler application as it is better suited to low duty cycle applications, or those located indoors or in hard-to-reach locations

Clever by design

"We chose the nRF9160 SiP for several reasons," says Ian Mellor, Director of IMME Design, an embedded design consultant that helped The Well Water realize the technical design of its iCooler. "Not only is the nRF9160 SiP extremely small and highly integrated, but it also offers great power consumption and on-air performance, has a powerful internal Arm Cortex-M33 CPU core supported by loads of memory, and you get access to Nordic's excellent technical support which we have benefited from during numerous previous projects."

One of the key technical aspects of the iCooler design for Mellor's team was the decision to mount the cellular IoT PCB board with the Nordic nRF9160 SiP on the front door of the cooler.

"The theory here was that the door would most likely be positioned away from wireless signal attenuating walls," explains Mellor. "Also, the construction of the cooler body is mainly fabricated from pressed steel. This is another potential source of wireless attenuation compared to the door which is made of plastic with a glass front and only a small amount of steel around the frame – all well away from the antenna."

The water cooler also employs Nordic's nRF52833 SoC to assist in the set-up, remote monitoring and commissioning of the solution using the convenience of Bluetooth LE wireless connectivity, and its universal interoperability with the ubiquitous smartphone.

The water cooler is but one example of countless legacy 'dumb' products and applications that could be transformed by connectivity, and the iCooler illustrates just how transformative cellular and wireless IoT technologies are becoming.

"The evolution and enabling power of wireless IoT has also coincided with a reduction in size and cost of ancillary bolt-on technologies such as touch screens," says McKenna. "This has all served to make it entirely viable to add both intelligence and brand new interactive features in a way that was unthinkable in the past.

"With wireless connectivity, the sky really is the limit in terms of new innovation and possibilities."

James Keane
Chief Product Officer, TappTek

Raising a glass to smart wireless technology

The entertainment sector has been hit hard by the pandemic, but now the industry is primed for innovation

The retail sector as a whole has done a good job of embracing technology, but where beer and liquor is being poured it's a different story. Bars and restaurants have been slow adopters. It has a lot to do with mindset, cost and the fact that low tech does the job. For example, there has been little or no innovation in beer taps since U.S. prohibition in the 1920s and 30s. To successfully introduce technology to this sector you need to do it in a way that requires almost no behavior change from the venue or consumer. You must design around the industry rather than forcing technology on them in an unsustainable way, and that is what we've done with TappTek.

TappTek is a smart tap device designed to fit any draft beverage tap handle to monitor its activity (for example, volume dispensed, wastage and market share) as well as provide detailed information and insights via a subscription-based retail analytics platform that can help stakeholders better understand consumer purchasing behaviors. (*See pg8*).

The pandemic has seen lots of bars and restaurants suffer, many have closed and perhaps we'll see others close so when the industry does open back up it makes sense for them to use technology to be as profitable as possible. The same is true for brand owners. Bars and restaurants are important for brands, they are places where experiences happen, and people link experiences with brands and remember them. So I believe it's important for a brand to remain relevant—especially now—and wireless technology, data and analytics can help them do it.

From dumb to smart

If you add wireless connectivity to a beer tap you can turn it from a 'dumb' disconnected device into a two way connectivity point where you can dispense much more than just beer to the consumer – think songs, sports highlights, sales offers and the like. But beyond calls to action for the consumer, consider the data opportunity. Previously data was an afterthought, but what if at the same time as engaging the consumer you can provide meaningful data to the retailer, distributor and brewer to make them as profitable as possible? Who wouldn't want that?

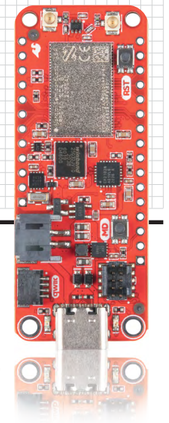
Connectivity was previously a hurdle. Wi-Fi in these venues tends to be fairly unreliable for a whole host of reasons and cellular doesn't work very well when you are surrounded by interior walls. But using Bluetooth LE solves a lot of these problems, and requires little or no behavior change from the venue or consumer.

> You must design around the industry rather than forcing technology on them in an unsustainable way

I believe that during my lifetime and probably a lot sooner, everything we buy will be connected. The cost, size and battery consumption of Bluetooth LE chipsets are all going down, while their capabilities are increasing. Over time it's going to be economical to include Bluetooth in everything, and the possibilities that will bring with it are unquestionable.

[Tech Zone]

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

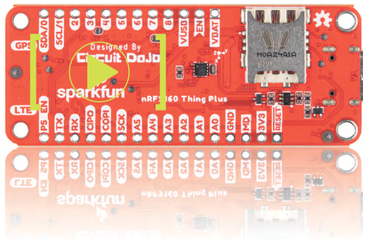


Cellular IoT dev board simplifies prototyping

SparkFun Electronics has launched the SparkFun Thing Plus – an nRF9160 development board based on Nordic's nRF9160 low power SiP with integrated LTE-M/NB-IoT modem and GPS. The board is designed for prototyping and Proof-of-Concept of cellular IoT-based devices for a wide range of applications using Nordic's nRF Connect SDK.

In addition to the Nordic SiP, the development board includes SparkFun's Qwiic connect system, an ecosystem of over 150 I2C sensors, actuators, shields and cables that make prototyping faster and less prone to error. All Qwiic-enabled boards use a common 1 mm pitch, 4-pin JST connector that reduces the amount of PCB space required for designs.

SparkFun has also teamed up with electronic design company, Circuit Dojo, to make the development board pin-compatible with Adafruit Featherwing accessory boards. The Adafruit Featherwing boards enable developers to easily add functionality to their product design by stacking additional 'Wings' to the development board, for example enabling precision motion sensing or air quality monitoring applications.



The development board supports Nordic's nRF Connect SDK. The nRF Connect SDK incorporates Zephyr RTOS which greatly reduces issues arising from firmware bugs or unforeseen events associated with embedded development of constrained, energy-limited and secure IoT products. It also offers flexible power options via Li-poly battery, micro USB and external power supply inputs.

"The combination of the Arm application processor paired with a cellular modem and GPS in a single package was the chief reason for using the nRF9160 SiP for the SparkFun Thing Plus development board," says Kirk Benell, Chief Technology Officer with SparkFun Electronics.

Module enables massive IoT mesh networks

Global positioning and wireless communication tech provider, u-blox, has unveiled its NINA-B4 Bluetooth 5.1 modules. The modules are optimized for Wirepas Massive (formerly Wirepas Mesh), a decentralized large-scale mesh network solution designed for a wide range of 'massive' IoT applications.

The NINA-B4 series includes the NINA-B406, which comes with an internal PCB antenna providing a low profile solution with high performance and good range, and the NINA-B400, which integrates a U.FL connector for use with an external antenna of the developer's choice. Both modules are based on Nordic's nRF52833 Bluetooth LE SoC.

The modules offer an open CPU architecture and can be supplied preinstalled with the Wirepas Massive software, reducing the time, cost and effort for developers integrating Bluetooth LE in their designs. The NINA-B4 series also comes with u-blox's u-connect development software.

Industrial IoT

Development platform accelerates solar energy-based cellular IoT designs

Netherlands-based Nowi B.V. has released a cellular IoT development platform designed to help companies rapidly develop and commercialize plug-and-forget cellular IoT sensor solutions powered by harvested solar energy.

The Blue Coral Energy Autonomous Sensor Fusion Platform combines Nordic's nRF9160 low power SiP with integrated LTE-M/NB-IoT modem and GPS alongside Nowi's NH2 energy harvesting PMIC. The product is targeted at end-use cases including smart meters, wearables and wireless sensor networks.

Despite its compact dimensions—the product measures 60 by 65 mm—the modular platform is designed to maximize development versatility for end users, offering both LTE-M and NB-IoT connectivity, eSIM and nano-SIM formats. The platform features a MikroE mikroBUS header enabling developers to select from over 200 off-the-shelf analog or digital add-on sensor boards to suit the requirements of their application.

Combined with Nowi's NH2 PMIC, the platform allows for simple and fast development of low-cost energy autonomous connected products.

"In comparison to other players in the cellular IoT market, Nordic's nRF9160 SiP provides a very low power solution which, for energy harvesting applications, is crucial in determining the feasibility and lifetime of a system," says Simon van der Jagt, CEO, Nowi B.V. "When paired with Nowi's energy harvesting power management technology this enables products to operate indefinitely without the need for battery changes.

"The SiP's support for Zephyr RTOS and the software features of Nordic's nRF Connect SDK creates an environment for very easy firmware development which is an important addition to Nowi's ease-of-use philosophy of our NH2 PMIC."

Nowi's NH2 PMIC comes in a compact 3 by 3 mm QFN package and incorporates an ultra-fast Maximum Power Point Tracker (MPPT) regulator.

Internet of Things

Platform brings cellular IoT applications to market in weeks

Nordic Semiconductor has partnered with Norwegian mobile network provider Telenor to provide developers using Telenor's Managed IoT Cloud (MIC) and SIM cards with the ability to test the platform using the Nordic Thingy:91 and the nRF9160 DK. MIC is an off-the-shelf Cloud based IoT platform and application toolbox that enables users to rapidly develop IoT solutions in weeks, without the time-consuming and expensive requirement to build their own infrastructure from scratch.

MIC not only collects and stores data from connected devices but also provides the tools to analyze that data using standardized dashboards and apps. Alternatively, users can easily build their own applications to visualize and track data using MIC's developer-friendly APIs. Using Nordic's sophisticated development tools these applications can be brought to market rapidly, without the need for high level programming skills or engineering expertise. Together with Telenor's NB-IoT/LTE-M networks, MIC is ideal for connecting devices that need small amounts of data, low bandwidth and long battery life, such as Nordic's low power cellular IoT solutions.

"The Nordic Thingy:91 is a cool prototyping tool, and its 'all-in-one' functionality makes it the perfect first step to test out the Telenor MIC platform," says Mette Kristine Kanestrøm, Head of Managed IoT Cloud - Telenor. "Developers can implement their MIC-ready code quickly and easily using Nordic's development tools and the Telenor Start IoT Cloud-ready development kit. Rather than spending years and millions [of dollars] building a platform from scratch, they can take a connected product idea to reality in just a few weeks."

telenor Start IoT

Toshiba launches world's smallest Bluetooth LE module

Japan-based multinational conglomerate, Toshiba Corporation, has launched a miniaturized Bluetooth module with Slot Antenna on Shielded Package (SASP) technology. The product comes in a tiny 4 by 10 by 1 mm form factor, weighs 0.09 g and is said to the world's smallest Bluetooth LE module of its kind. Based on the 2.48 by 2.46 mm wafer level chip scale package (WLCSP) version of Nordic's nRF52811 Bluetooth LE SoC, the module comes with an integrated antenna.

Toshiba's proprietary SASP technology minimizes the size of the module by using the shielded packaging to house part of the antenna. As a result, the amount of area the remaining length of antenna takes up on the module PCB is reduced compared to alternative solutions. This offers developers greater flexibility.

Getting creative with the nRF5340 SoC

Competitors in hackster.io's Dream Smart Wearables and Remote Patient Monitoring contests used Nordic's most advanced SoC to build their innovative applications

One of Nordic Semiconductor's guiding principles is to make its technology accessible to the widest possible audience. By abstracting much of the complexity away with user-friendly hardware and software development tools, developers are free to unleash their creativity. And when that happens, the wireless products they come up are amazing.

Just how amazing was demonstrated as a result of a recent competition organised by Nordic and hackster.io, an online innovators' community. One hundred successful applicants to the "Advanced Wearables for a Healthy World" competition were given the choice of two kits. For the "Build your dream smart wearable" option, the kit comprised an nRF5340 DK, Adafruit 2.8-in TFT Shield for Arduino and nRF52840 Dongle. The "Build a medical wearable for remote patient monitoring" option replaced the TFT display with Nordic's Power Profiler Kit II (PPK2). The challenge for both competitions was to "Showcase the processing capabilities and low power consumption of the nRF5340 SoC".

What's special about the nRF5340 SoC?

The successful applicants in the competition gained access to Nordic's most powerful SoC (as part of the nRF5340 DK). The device has been designed to meet the needs of the most complex short-range wireless applications.

Key to the SoCs high performance is its dual Arm Cortex M33 processor architecture. The dual processor architecture enables the SoC to overcome the trade-off between processing capability and power consumption.

The nRF5340 features a dedicated application processor and a network processor. A single Arm processor device such as Nordic's nRF52840 can find it a challenge to support the most complex applications—particularly those with real time processing needs—because the Bluetooth LE protocol software interrupts can make demands on the single processor at any time and divert it from application processing.

The nRF5340's application processor is optimized for performance and can run at either 128 or 64 MHz. The highest performance (510 CoreMark) is achieved at the faster clock rate, while running at 64 MHz offers greater efficiency (76 CoreMark/mA). This processor features 1 MB Flash, 512 KB RAM, a floating point unit (FPU), an 8 KB two-way associative cache and DSP instruction capabilities. The fully programmable network processor is clocked at 64 MHz and is optimized for low power consumption and efficiency (101 CoreMark/mA). It features 256 KB Flash and 64 KB RAM.

While entrants into the competition primarily used Bluetooth LE, the nRF5340 does allow developers to call on multiprotocol support for their end-product including Bluetooth 5 Direction Finding, all Bluetooth 5 features, Bluetooth mesh, Thread and Zigbee, NFC, ANT, IEEE 802.15.4 and 2.4 GHz proprietary protocols.

This is all possible with a radio sensitivity and power consumption superior to Nordic's nRF52 Series. The nRF5340's 0 dBm TX current is 3.2 mA, while the RX current is only 2.6 mA. Sleep current is 0.9 µA. The radio's RX sensitivity running Bluetooth LE at 1 Mbps is -97.5 dBm, 2.5 dB better than the nRF52840 while using 40 per cent less current. (*See WQ Issue 4, 2020 pg30.*)

Processor flexibility

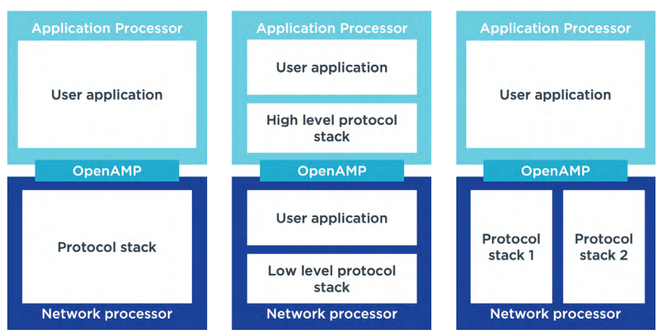
Unlike some competitive dual-core products, Nordic ensures that developers, such as those taking part in the Nordic/hackster.io competition, have access to both the application and network processors. And while the cores are labeled as such, the developer is free to split both the RF protocol ('stack') and the application software across either core. (*See panel below: Processor mix and match.*)

> By abstracting much of the complexity away with user-friendly hardware and software development tools, developers are free to unleash their creativity

Processor mix and match

Figure 1 illustrates how the developer can split the RF protocol software ('stack') and application code across the nRF5340's cores to optimize performance and power consumption. The left-hand schematic shows the simplest split with the application processor dedicated to the application code and the network processor looking after the stack. The right-hand illustration shows a similar arrangement but this time with the network processor running two protocol stacks (for example, Bluetooth LE/Zigbee or Bluetooth LE/Thread). An alternative approach is to split the application and protocol stack across both cores. A careful separation of the software could allow the higher power consumption application processor to be turned off more frequently to save power while less complex application code is run on the more efficient network processor

Figure 1



Software development on the nRF5340 is performed through the nRF Connect SDK. (*See below.*) The SDK includes the Zephyr real time operating system (RTOS) and RF protocol stacks, including an open-source full Bluetooth LE stack, an open-source Bluetooth LE Host and Nordic's own Bluetooth LE Controller (derived from its proven and stable SoftDevices). This selection of software allows the developer to, for example, run Nordic's Bluetooth LE Controller on the efficient network processor while running the Zephyr Bluetooth LE Host and the application software on the powerful application processor – optimizing performance and battery life for particular applications. The Bluetooth LE Host Controller Interface (HCI) runs over OpenAMP and provides the communication between processors. (The nRF Connect SDK includes a Bluetooth LE peripheral UART example that employs this software split.)

Development tools

The key tools contestants used to develop their projects were the nRF5340 DK, nRF Connect SDK and an appropriate Integrated Development Environment (IDE), such as SEGGER Embedded Studio, running on a PC or Mac. (The nRF Connect SDK includes a free SEGGER Embedded Studio IDE.) (*See WQ Issue 4, 2020 pg29.*)

The nRF5340 DK is the development kit for the nRF5340. It includes a SEGGER J-Link OB programmer/debugger (which programs the DK's resident nRF5340), 2.4 GHz and NFC antennas, pins for measuring power consumption using the PPK2 (or other measurement tools) and SWF connector for direct RF measurements. All GPIOs are accessible via connector headers. The DK can run from a 1.7 to 5 V supply from USB, Li-poly or CR2032 coin cell sources. The board also includes user programmable LEDs and buttons (four of each) and features external Flash which is connected to the SoC by QSPI. Because the nRF5340 DK is Arduino Rev3-compatible, it is simple to plug in compatible shields and items, such as the Arduino TFT display, without additional cables.

In addition to the DK and SDK it can be useful to have an nRF Connect for Cloud account (to send application data to the Cloud) and either nRF Connect for Desktop or nRF Connect for Mobile applications to emulate the Bluetooth LE application under development.

Finally, the nRF52840 Dongle can be plugged into a USB port on the PC running the nRF Connect for Desktop application to emulate a Bluetooth LE Central or Peripheral device which can then be wirelessly connected to the nRF5340 DK. (Note that the dongle is not a development platform in its own right, in part because it doesn't include a programmer/debugger.)

Getting started

Despite the nRF5340's sophistication, getting started with development on the SoC is relatively straightforward. The first step is to install the latest version of the nRF Connect SDK onto the PC or Mac and start it up within the Segger Embedded Studio IDE.

The nRF5340 with its dual Arm M33 processors powers the most sophisticated wearables while supporting extended battery life

Using the nRF Connect SDK the developer can select which of the nRF5340 cores' Flash memories he or she wishes to use to store their application code. When that's done, the nRF52840 Dongle can be wirelessly connected to the DK to ensure the application uses the wireless link as intended. (Alternatively, this check can be done using a smartphone hosting the nRF Connect for Mobile app.)

Competitors with the relevant kits were also able to periodically check the power consumption using the PPK2. A good design tip is to ensure logging is turned off on the network core and application core to obtain a true measure of power consumption for the app running in normal use. It's also a good idea to measure the power consumption at an early stage and then add each new feature rather than start with a complex application and then try to work out how to minimize power drain. (*See WQ Issue 1, 2021 pg36*).

And the winner is...

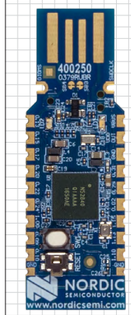
The competition closed in early July. Competition was fierce and resulted in many notable innovations. In the dream smart wearables category, the winner was 'Naveen' for the Posture Watchdog, a product that accurately monitors sitting posture and activities, and alerts the user about any bad stance habits.

In the remote patient monitoring competition the prize was awarded to Ed Oliver and Alejandro Sanchez for their Electrocardiology Holter Monitor (EHM). The device is a monitor of heart health (including an electrocardiograph (ECG)) and sends vital signs data to the Cloud.

The Grand Prize was awarded to 'xkimi' for the compact baby vital wearable with heart rate and SPO_2 monitoring and alerts.

The next edition of *Wireless Quarter* (Issue 3, 2021) will include more details about how the winners went about building their projects.

A Nordic webinar entitled Understand the nRF Connect SDK can be viewed here: bit.ly/3po2bi7.



Tech Check

The nRF52840 Dongle is a small, low-cost USB dongle that supports Bluetooth 5, Bluetooth mesh, Thread, ZigBee, 802.15.4, ANT and 2.4 GHz proprietary protocols. The Dongle functions as target hardware for use with nRF Connect for Desktop. It has a user programmable RGB LED, a green LED, a user programmable button as well as 15 GPIOs accessible from solder points along the edge

Online expert panel discusses expansion of commercial wireless IoT services

Nordic's wireless specialists and guest experts discuss the movement towards Cloud-based IoT device support products like Location as a Service, in a lively and frank debate

Now in its second decade, *WQ* uses print and digital media to inform how Nordic's technology is underpinning the IoT and what that means for the world. WQ Live events, a series of online expert panel discussions facilitated by members of the *WQ* editorial team and Nordic, extends that mission.

WQ Live events will be broadcast live each quarter and then made available on demand from the Nordic website. The events see *WQ*'s editors ask the questions and moderate. The first 40 minutes of each panel comprises a question-and-answer debate between the moderators and an expert panel. The last 20 minutes address questions posted by the audience during the event.

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

The second 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 pg14.*)(The debate is available to view here: bit.ly/3w6izX3.)

Unveiling Nordic's shift to services

Asset racking is booming. Drivers such as the growth in online shopping and shipments of fragile and valuable items such as COVID-19 vaccines are accelerating the trend. (*See WQ Issue 1, 2021 pg28.*)

But the millions of asset trackers criss-crossing the globe require configuration, management and firmware updates. While that's possible through Bluetooth connectivity and a smartphone it's hardly practical when the fleet numbers thousands.

Moreover, the trackers generate huge volumes of data. That data indicates things like current position and condition of the cargo being tracked and historical information about how it's been handled. But the data is only useful if it's carefully analyzed and presented in an easy-to-absorb format

Just as importantly, customers require services such as Assisted- and Predicted-GPS to reduce the tracker's GPS time-to-first-fix (TTFF) and save battery power.

The third WQ Live events expert panel, planned for mid-September, will center on a discussion about the critical role of Cloud-based asset tracking device management and support.

The session will also consider 'Location as a service' and will describe using the Cloud to support location determination and extend asset tracker battery life.

Attendees will also hear how these activities, and more, will be handled by commercial services including device management, location services and storage and presentation of trackers' historical movement data.

> This WQ Live event will center on a discussion about the critical role of Cloud-based asset tracking device management and support

For more information on this WQ Live events expert panel go to www.nordicsemi.com/wqliveevents

Product Summary

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

		nRF 9' SERIES	nRF SERIES 53	nRF 52 SERIES							nRF 5' SERIES		
		nRF9160	nRF5340	nRF52840	nRF52833	nRF52832	nRF52820	nRF52811	nRF52810	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		●	●	●		●	●					
	ZIGBEE		●	●	●		●						
	ANT		●	●		●			●			●	
	2.4 GHZ PROPRIETARY		●	●	●	●	●	●	●	●	●	●	●
	NFC		●	●	●	●							
TYPE	SYSTEM-ON-CHIP		●	●	●	●	●	●	●	●	●	●	●
	SYSTEM-IN-PACKAGE	●											
CORE SYSTEM	CPU	64 MHz Arm Cortex-M33	128 MHz Arm Cortex-M33 +64 MHz Arm Cortex-M33	64 MHz Arm Cortex-M4	64 MHz Arm Cortex-M4	64 MHz Arm Cortex-M4	64 MHz Arm Cortex-M4	64 MHz Arm Cortex-M4	64 MHz Arm Cortex-M4	64 MHz Arm Cortex-M4	16 MHz Arm Cortex-M0	16 MHz Arm Cortex-M0	16 MHz Arm Cortex-M0
	FPU	●	●	●	●	●							
	DSP INSTRUCTION SET	●	●	●	●	●	●	●	●	●			
	CACHE	●	●	●	●	●							
	MEMORY	1 MB Flash, 256 kB RAM	1 MB Flash, 512 kB RAM +256 kB Flash, 64 kB RAM	1 MB Flash, 256 kB RAM	512 kB Flash, 128 kB RAM	512 kB or 256 kB Flash, 64 kB or 32 kB RAM	256 kB Flash, 32 kB RAM	192 kB Flash, 24 kB RAM	192 kB Flash, 24 kB RAM	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	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	4 dBm
	RX SENSITIVITY	-108 dBm (LTE-M), -114 dBm (NB-IoT), -155 dBm (GPS)	-97.5 dBm (1 Mbps)	-95 dBm (1 Mbps)	-95 dBm (1 Mbps)	-96 dBm (1 Mbps)	-95 dBm (1 Mbps)	-97 dBm (1 Mbps)	-96 dBm (1 Mbps)	-97 dBm (1 Mbps)	-93 dBm (1 Mbps)	-93 dBm (1 Mbps)	-93 dBm (1 Mbps)
	ANTENNA INTERFACE	50 Ω single-ended	Single-ended	Single-ended	Single-ended	Single-ended	Single-ended	Single-ended	Single-ended	Single-ended	Differential	Differential	Differential
PERIPHERALS	HIGH SPEED SPI		●	●	●								
	TWI, SPI, UART	4xTWI/SPI/UART	4xTWI/SPI/UART +TWI/SPI/UART	2xTWI/SPI, SPI, 2xUART	2xTWI/SPI, SPI, 2xUART	2xTWI/SPI, SPI, UART	2xTWI/SPI, UART	TWI/SPI, SPI, UART	TWI, SPI, UART	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	3, 2
	TEMPERATURE SENSOR	●	●	●	●	●	●	●	●	●	●	●	●
APPLICATIONS	AGRICULTURE	●											
	ASSET TRACKING	●	●		●		●	●					
	AUTOMATION		●	●	●	●	●		●		●	●	●
	BEACON			●	●	●		●	●	●	●	●	●
	CONSUMER ELECTRONICS		●	●	●	●	●		●	●	●	●	
	DIRECTION FINDING		●		●		●	●					
	GAMING / VR + AR		●	●	●	●	●		●		●	●	
	HEALTHCARE & MEDICAL		●	●	●	●			●	●	●	●	
	INDUSTRIAL SYSTEMS	●	●	●	●		●						
	MESH NETWORKS		●	●	●	●	●				●		
	PC PERIPHERALS			●	●	●	●		●	●	●	●	
	PROFESSIONAL LIGHTING		●		●		●						
	SMART BUILDINGS	●	●	●	●		●						
	SMART CITY	●	●										
	SMART HOME	●	●	●	●	●	●	●	●		●	●	
	SMART METERING	●											
	SPORTS & FITNESS	●	●	●	●	●			●		●	●	
	TOYS		●	●	●	●			●		●	●	
	WEARABLES	●	●	●	●	●			●		●	●	
CERTIFICATIONS		GCF, PTCRB, CE, FCC and more: 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, nRF51 Dongle	nRF51DK, nRF51 Dongle	nRF51DK, nRF51 Dongle
PACKAGES		10x16x1 mm LGA	7x7 mm aQFN94 (48 GPIOs), 4.4x4.0 mm WLCSP95 (48 GPIOs)	7x7 mm aQFN73 (48 GPIOs), 3.5x3.6 mm WLCSP94 (48 GPIOs)	7x7 mm aQFN73 (42 GPIOs), 5x5 mm QFN40 (18 GPIOs), 3.2x3.2 mm WLCSP (42 GPIOs)	6x6 mm QFN48 (32 GPIOs), 3.0x3.2 mm WLCSP50 (32 GPIOs)	5x5 mm QFN40 (18 GPIOs) 3.175x3.175 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 (16 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

nRF52811

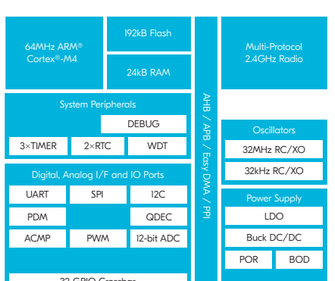
nRF 52 SERIES

Description: The nRF52811 is a Bluetooth 5.2 capable device with Bluetooth Direction Finding, Thread and Zigbee support. The SoC is a good choice for a transmitter in direction finding angle-of-arrival (AoA) or angle-of-departure (AoD) scenarios, with its low power characteristics and connectivity features. The nRF52811 SoC is also recommended for beacon applications where its support for Bluetooth Direction Finding or the Long Range feature introduced in Bluetooth 5 are an advantage. Long Range increases the link budget without adding costly components. The SoC supports Bluetooth 5's 2 Mbps high throughput feature and Channel Selection Algorith #2. In addition to Bluetooth 5.2, the device also supports 802.15.4, Thread and 2.4 GHz proprietary protocols.

SoC: The nRF52811 uses a powerful 64 MHz 32-bit Arm Cortex-M4 processor and includes 192 KB Flash plus 24 KB RAM. The multiprotocol radio offers up to +4 dBm power output and -97 dBm sensitivity at 1 Mbps Bluetooth LE for a link budget of 101 dBm. With Bluetooth Long Range, a link budget of 108 dBm is possible. The radio's peak power draw is only 4.6 mA TX (0 dBM) and 4.6 mA RX (1 Mbps) and the SoC's current draw is as low as 0.3 µA in System OFF (no RAM retention). The nRF52811 operates from a 1.7 to 3.6 V supply. Battery life is extended by using a sophisticated on-chip adaptive power management system. The SoC is available in 6 by 6 mm QFN48 with 32 GPIO, 5 by 5 mm QFN32 with 17 GPIO or 2.48 by 2.46 mm WLCSP with 15 GPIO.

Software: The nRF Connect SDK is recommended for nRF52811 software development. The SDK brings developers a wealth of varied examples, including Bluetooth LE profiles and driver support for all peripherals. The nRF Connect SDK supports applications using Bluetooth LE, Bluetooth mesh and Thread. The SDK also includes a migration of Nordic's Bluetooth SoftDevice Controller from the company's proven SoftDevices used with the nRF52 Series. The nRF5 SDK can also be used for development. The nRF52811's radio supports 802.15.4 PHY and MAC layers.

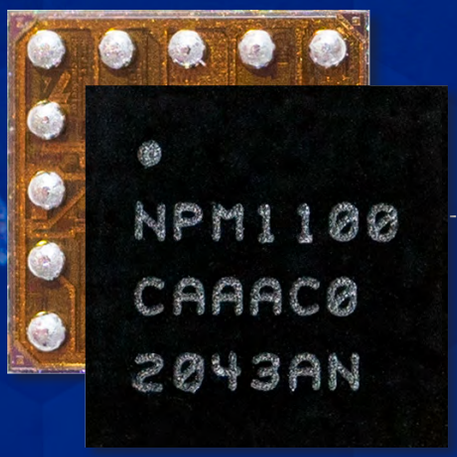
Development tools: The nRF52840 DK is the recommended development kit for the nRF52811. The DK emulates the nRF52811 and can be used as a starting point for development before moving over to a custom board. The nRF52840 DK is a versatile single board development kit and, when working with the nRF52811, can be used for Bluetooth LE, 802.15.4, Thread and 2.4 GHz proprietary development. Other development tools for use with the nRF52811 include nRF Connect for Desktop and Power Profiler Kit II.



The nRF52811 supports Bluetooth 5.2, 802.15.4, Thread and 2.4 GHz proprietary. The nRF52811 offers a good option for a network processor and when paired with a companion microprocessor is a high value proposition for smart home gateway and router applications

nPM FAMILY

Industry's most compact power management solution



Actual size

2×2mm

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.

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