WQ
WIRELESS QUARTER

Issue 1, 2021

WHAT LIES BENEATH:
IoT MONITORING KEEPS CITY INFRASTRUCTURE HUMMING

ON THE LEVEL:
CELLULAR IoT STOPS TANKS RUNNING DRY

THIS WAY UP:
ENSURING CRITICAL CARGO ARRIVES IN ONE PIECE

The Last Mile

Wireless tech is making micromobility safe and secure for post-pandemic commuters

ARE SEMICONDUCTORS IMMUNE TO COVID-19?

TRACK VALUABLES FROM ANYWHERE

POWER PROFILING MADE SIMPLE

Welcome

Alf Helge Omre
Business Development Manager – Transportation

At Nordic, we're close to many of the major changes the pandemic has enforced. That's because our tech has not only been used to fight COVID-19 but also to support other sectors that have transformed during these tough times.

Online buying is one example. It's booming and that has led to demand for tech such as wireless asset tracking to monitor the location of billions of packages as they speed across the planet. It is one change that looks like it's here to stay; one analyst, Research&Markets, forecasts the asset tracking market will double from $17 billion in 2020 to $34 billion by 2026.

Another area undergoing huge upheaval is micromobility. When the pandemic started, those that could worked from home. But as vaccines have started to be administered and people have returned to the factory, bank, shop or office, many have chosen to stay away from public transport and take to two wheels.

As a result, cycling—as well as skateboarding, scooting and other forms of human-powered transport—has boomed. Now cities like Leicester in the U.K. have followed cycling capital Copenhagen's example by closing streets to cars and introducing tens of kilometers of 'pop-up' bike lanes to make bike commuting safer.

Better yet, people on bicycles, instead of being in cars, buses and trains, go a long way towards cutting carbon emissions. That helps a lot if ambitious commitments such as the U.K.'s 80 percent reduction in emissions by 2050 and France's carbon neutrality by the same year are to be met.

Will cycle commuting continue to boom in a post-pandemic world? I'd like to think so, and wireless tech is already playing its part. Cycle sharing, safety, navigation and control are all served by Nordic customers. You can read more about how on page 14.

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Internet of Things

Nordic and Edge Impulse partner on AI and machine learning solutions

Nordic Semiconductor has partnered with U.S. company Edge Impulse to provide its customers with easy-to-use embedded machine learning features as standard for its nRF9160 low power cellular IoT SiP, as well as its nRF53 and nRF52 Series Bluetooth LE SoCs.

The partnership will make it easy for developers using Nordic technology to build and train tiny machine learning (TinyML) models in Edge Impulse Studio, and deploy these models across Nordic's wireless solutions. This will reduce development time and make the technology more accessible, especially to smaller companies without inhouse machine learning expertise.

"[This partnership] takes the application potential of wireless IoT technologies such as Bluetooth LE to a whole new level in terms of environmental awareness and autonomous decision making," says Kjetil Holstad, Nordic's Director of Product Management. "Although we have built and run TinyML applications on Nordic's Bluetooth LE chips in the past, this required a high level of maths and computer programming expertise using professional industry and academia software.

"Now, using Edge Impulse tools, Nordic customers could be running TinyML on their applications within hours. And at a power consumption level that still supports extended battery operation."

Prime engineering areas for TinyML include audio and vibration where it can be used to establish normal operating patterns and rapidly detect anomalies. Example applications include anti-poaching (listening for gun shots), predictive and preventative maintenance, and power line failure detection for utilities. But all applications stand to benefit from TinyML, from asset tracking to wearables.

"This partnership is bringing AI and machine learning to the wireless IoT masses," says Edge Impulse Co-Founder and CEO, Zach Shelby. "By leveraging the fact that Nordic's SoCs employ at least one powerful Arm core processor ... and are architecturally designed for ultra-low power battery operation, this partnership is democratizing access to TinyML within the Bluetooth market."

Smart Health

Wireless sensor offers continuous infection monitoring

Polish medical startup, Warmie, has released an intensive care-certified medical wireless temperature sensor. The sensor enables continuous infection monitoring of COVID-19 and post-operative hospital patients. And it facilitates localized continuous temperature and infection monitoring of post-operative surgical wounds both in and out of hospital, as well as of hospitalized COVID-19 patients. It also enables continuous monitoring of a large numbers of patients simultaneously.

"[Manual temperature checks] often miss critical changes that can signify an infection," says Professor Tomasz Banasiewicz, M.D. PhD. "Infections left untreated can quickly become more widespread within the body and thus much harder to treat.

"This means patients having to spend potentially several more weeks in hospital or being re-admitted if they develop an infection after returning home. This is extremely costly for hospitals and means that the potential cost savings of employing our device far outweigh the installation costs."

The battery-powered device uses Nordic Semiconductor's nRF52810 SoC and is the first device of its kind to be certified for use in hospital emergency rooms.

"Few industries have been more heavily impacted by COVID-19 than medical," says Geir Langeland, Nordic's Director of Sales & Marketing. "Shifts towards telemedicine and in particular continuous remote monitoring ... are being fast-tracked today. Continuous remote monitoring using wireless medical devices is set to become standardized within the medical industry over the coming years."

Smart Health

Wireless home test kit helps in fight against COVID-19

Digital diagnostic company Ellume has launched a COVID-19 home testing kit that enables individuals to check for an active infection in 15 minutes or less. The Ellume COVID-19 Home Test uses ultra-sensitive optics, electronics and proprietary software to analyze a nasal swab with the results automatically transmitted to the user's smartphone via Nordic nRF52810-powered Bluetooth LE connectivity. From the associated smartphone app, the results can be transmitted through a secure Cloud connection to healthcare professionals.

The test will help reduce the impact of the pandemic by providing a readily available and simple-to-use method to acquire the information needed to reduce risk of transmission. Users will be able to safely recommence group activities at work, school or on the sports field. Real-time reporting of test results to health authorities, employers and educators will enable efficient COVID-19 mapping and rapid reaction to outbreaks.

"The home test is the perfect example of how advanced digital diagnostics and the IoT can help address the worst impacts of the SARS-CoV-2 pandemic," says Geir Langeland, Director of Sales & Marketing with Nordic.

"Using the test, we can all enjoy the benefits of group activity safe in the knowledge that we present no risk to the vulnerable. That's a huge step towards a return to normality."

The antigen test has demonstrated 96 percent accuracy compared to an Emergency Use Authorization (EUA) molecular test in an independently-run, U.S. clinical study in five states. Ellume has received an EUA from the U.S. Food and Drug Administration (FDA) for its solution. The company plans to deliver 20 million Ellume COVID-19 Home Tests to the U.S. within the first half of 2021.

Smart health startup aims to automate public health diagnostics

U.S. smart medical and public health IoT and AI startup, NousLogic, has adopted Nordic-based cellular IoT connectivity across all its real-time monitoring and end-to-end diagnostics solutions. The solutions are designed to maximize scarce resources in the healthcare sector, not only by identifying problems but also automating diagnosis and remedy without the need for time-consuming and costly human intervention.

"We not only use IoT and data analytics to track who, what, where and when in remote monitoring for healthcare, but go one critical step further and provide the why and how," says NousLogic Founder & CEO, Hoang Nhu. "This enables both high accuracy, automatic diagnostics and advanced preventative care that spots problems and negative trends early and before they become more serious."

The Nordic nRF9160 SiP-based solutions include the The NousLogic Healthcare Real-Time Locating Services (RTLS) platform targeting infection control and compliance for hospitals, food outlets and the hospitality sector by reminding workers to wash their hands; a remote patient monitoring platform targeting the home health and assisted living market; as well as the NousLogic Smart Access platform that supports touch-free NFC video doorbell and door lock control. This enables users to screen visitors and grant them access from anywhere in their homes, including from beds. The company also offers an nRF9160 SiP-based cellular IoT adapter board that allows any third-party Wi-Fi health platform to transition to LTE-M or NB-IoT.

"Turning raw health data into useful and powerful health insights is a win-win for the industry and every individual it affects, which is all of us," says Nhu. "At the right economies of scale, the solutions could be delivered at a cost level that supports global adoption in both the developed and developing world that could improve the health outcomes of billions."

In Brief

AWARDS AT THE DOUBLE

Nordic Semiconductor, along with cellular connectivity partner, iBASIS, have been named IoT Partnership of the Year at IoT World 2020. The award recognizes how the companies have simplified global cellular IoT connectivity based on Nordic's nRF9160 SiP and iBASIS' Open eSIM technology. Nordic was also recently shortlisted by the Global Semiconductor Alliance (GSA) for the 2020 GSA Most Respected Emerging Public Semiconductor Company Award in the $100 million to $500 million annual sales category.

WILDLIFE TRACKERS GO WIRELESS

Two of the winning projects from the Hackster.io and Smart Parks backed ElephantEdge wildlife tracker challenge have specified Nordic's nRF52840 SoC for their elephant tracking collar designs. The challenge aims to replace traditional and manual methods of elephant monitoring to support conservation efforts in Africa. The challenge resulted in solutions which will be deployed onto 10 collars.

SHARE BIKE FIRMS LAUD NORDIC

Nordic has received awards from two of China's big bike-sharing companies. Nordic was recognized with a 5 Year Long Term Partnership award from Beijing Mobike Technology. Elsewhere Nordic received the Best Technology Collaboration award at the 2020 China Micromobility Industry Conference from Alibaba-backed Hellobike. The award acknowledges the company's leadership in low power, short range wireless technology.

MEDICAL WEARABLES RISING

The value of the global wearable medical devices market is expected to rise from $6.8 billion in 2017 to reach an estimated $29.6 billion by the end of 2026, according to figures from Transparency Market Research. The analyst said key advancements in R&D and the adoption of major innovations in the medical sector were key trends driving growth in the market. The collaboration between the medical sector and the electronics industry is also considered a major factor contributing to growth.

Smart Health

Wireless ECG heart monitor detects cardiac disorders

Norwegian medical tech manufacturer AppSens has launched a wireless wearable electrocardiographic (ECG) heart monitor. The wearable is designed to detect atrial fibrillation and other cardiac arrhythmias. Atrial fibrillation is the most common cardiac rhythm disorder and is a common cause of a stroke.

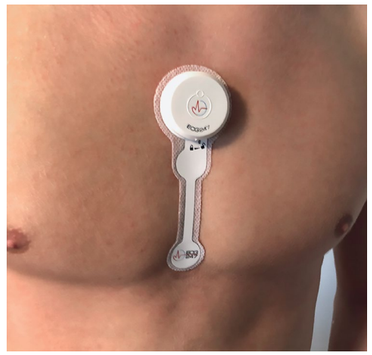
The ECG247 Smart Heart Sensor consists of a disposable electrode-patch to fasten the sensor to the patient's chest and a reusable electronic component to achieve reliable electrical connection for the measurement of ECG signals. The solution can be used by patients to self-test their own heart health, including during exercise, while also supporting remote patient monitoring and telehealth applications.

Medical professionals can use the platform to screen people who are at increased risk of strokes due to heart rhythm disorders or who have symptoms of rhythm disorders such as palpitations or fast heart rate.

The solution employs Nordic's nRF52832 SoC to enable a patient's ECG data to be sent from the wearable to a smartphone app via Bluetooth LE. The SoC's powerful Arm Cortex-M4 processor with floating point unit supports the wearable's integrated sensors and runs complex proprietary algorithms for continuously measuring and analyzing the electrical activity in the patient's heart for arrhythmia.

The device's CR2032 coin-cell battery mounted to the disposable plaster-patch supports continuous heart rate monitoring for up to 14 days before replacement.

From the iOS and Android companion app the patient can access their measurements and any detected arrhythmia conditions. The heart rhythm recordings are automatically transferred to and stored on a secure Cloud-based server. From there an AI-driven algorithm analyzes the detected arrhythmia episodes and either confirms the episode or rejects



it in cases of 'artifact disturbances' (electrical interference in rhythm monitoring). Medical doctors and cardiologists can then easily access the recorded ECG signals and detected arrhythmia episodes of their patients to provide a quick diagnostic evaluation.

"We selected the Nordic nRF52832 SoC for the ECG247 Smart Heart Sensor because it offers high radio sensitivity — which is important as RF signals are difficult to transmit in systems mounted close to the skin," says Tord Ytterdahl, CEO of AppSens.

Wearables

Proximity monitoring wearable combines Bluetooth LE and ultrasound

Atlanta, GA-based IoT software solutions company, M2MD Technologies, has developed a proximity monitoring wearable that combines both Bluetooth LE and ultrasound to track social distancing with one-to-three centimeter precision. Co-developed with its hardware manufacturer, Coolpad, a global consumer electronics company, the Coolpad Bubble is designed to help companies create a safer environment for their employees during the pandemic.

The compact wearable attaches to the user's shoulder, features four TDK ultrasonic transceivers and Nordic's nRF52840 Bluetooth LE SoC which together detect proximity to neighboring devices. Users receive visual, audio and haptic vibration alerts when another device is within a 1.8 m perimeter. Each device autonomously periodically transmits its unique identifier for receiving devices to monitor and then measure the difference in 'Time of Flight' (ToF) between the Bluetooth LE packet and an ultrasonic audio signal. The time difference is proportional to the distance between transmitter and receiver.

In addition to real-time proximity monitoring and alerts for wearers, the Bubble platform provides comprehensive data on contact interactions for tracking adherence to social distancing guidelines through the Cloud-based Coolpad dashboard.

Secure recording of non-personal data and intrusion alerts including device ID, distance, timestamp and event duration enables detailed reporting and analytics. This data is relayed from the device to the Cloud via Wi-Fi.

Wearables

Tracker and gateway monitors dependents

IoTBank, a Tokyo-based tech company, has unveiled an attachable and portable tracking device for monitoring the location of dependent or at-risk individuals, for example children or the elderly. The device is also designed for tracking industrial and commercial assets.

Enabled by LTE-M connectivity and GPS provided by Nordic's nRF9160 SiP—complemented by a built-in Wi-Fi triangulation capability for accurate positioning without requiring GPS—the Mamosearch 2 tracker periodically transmits the whereabouts of the tracked item to a proprietary Cloud-based platform and dashboard via the cell network. This in turn enables remote monitoring via a smartphone app.

AoA/AoD Direction Finding solution brings precision to location services

Californian tech company, IOSEA, has developed a proprietary real time location hardware and software platform that uses Nordic's nRF52833 SoC. The solution is claimed to offer an angular accuracy of two degrees precision down to a 10 cm range. The SEAgnal AoA/AoD Switched Antenna Array hardware, alongside the SEAgnal AoA/AoD 1.0 proprietary software, enables RF-based location finding for third party electronic devices.

The hardware, which integrates the Nordic nRF52833 SoC and the SEAgnal AoA/AoD 1.0 software, can be embedded into a third-party wearable device for proximity monitoring solutions including COVID-19 social distancing. IOSEA's SEAgnal provides Angle-of-Arrival (AoA)/Angle-of-Departure (AoD) solutions which aid positional accuracy. The technology uses advanced signal processing methods to mitigate the effects of multipath fading, and signal prefiltering to minimize signal processing algorithm errors and enable low bandwidth data transfer.

The nRF52833 SoC is used to control IOSEA's switched antenna array, sample Bluetooth LE packets and extract the in phase and quadrature phase information necessary for the AoA/AoD software's calculations. Using the Nordic SoC-enabled Bluetooth LE connectivity, the proximity data can also be wirelessly transmitted to a smartphone, from where the user can monitor and manage angular and location information using an iOS-compatible app.

IOSEA licenses its SEAgnal technology to chip manufacturers, wireless service providers, device makers, and other partners to make location finding affordable and convenient for end-users.

"IOSEA technology enables location services that are scalable, efficient, and precise," says Pål Kastnes, a Technical Marketing Manager with Nordic Semiconductor.

"Solutions like IOSEA's SEAgnal AoA/AoD proprietary hardware/software solution rely on Bluetooth Direction Finding, a powerful introduction to the Bluetooth LE protocol that will extend its use to widespread real time location applications such as asset tracking and indoor navigation."

Researchers airdrop sensors from insects

University of Washington (UW) researchers have developed a tiny sensor system that can ride aboard an insect and be airdropped at its destination using Bluetooth LE wireless connectivity. The system would potentially enable IoT sensors to be placed in areas where it is too dangerous or difficult for humans to go.

When the sensor is released it can withstand a fall of up to 22 meters—from about the sixth floor of a building—and land without breaking. Once in position the sensor can collect data, such as temperature and humidity, for almost three years.

"This is the first time anyone has shown that sensors can be released from ... insects such as moths, which can traverse through narrow spaces better than any drone and sustain much longer flights," says Shyam Gollakota, a UW associate professor in the Paul G. Allen School of Computer Science & Engineering.

While industrial-sized drones use grippers to carry their payloads, the sensor is held on the insect using a solenoid. To release the sensor, a researcher on the ground sends a wireless command using Bluetooth LE that activates the solenoid and sends the sensor on its way.

The sensor was designed with its battery, the heaviest part, in one corner. As the sensor falls, it begins rotating around the corner with the battery, generating additional drag force and slowing its descent. The researchers envision using this system to create a sensor network within a large scale study area, for example a forest or farm.

In Brief

ROBOT SOLDIERS ON THE MARCH

A quarter of British soldiers could be replaced by autonomous robot counterparts by the 2030s, according to the head of the British armed forces, Gen. Sir Nick Carter. A combination of robotics, AI and machine learning technologies could see robot soldiers gather data from multiple sensors and communicate with each other wirelessly to decide their next action with greater precision than humans. IoT-powered robots could perform nearly any kind of military operation.

NORDIC EXPANDS IN SOUTH AMERICA

Nordic Semiconductor has partnered with São Paulo, Brazil-based BP&M to provide third party sales representation and technical support throughout South America. The agreement covers sales and technical support for Nordic's entire portfolio of low power cellular IoT and short range wireless solutions. BP&M is among the leading sales representation and consulting firms in the region and has assigned a dedicated Field Application Engineer (FAE) to support Nordic customers in all project phases including design, development and prototyping.

SMART METERS FIND FAVOR IN ASIA

A study from the IoT analyst firm Berg Insight forecasts that 572.3 million smart electricity meters will be deployed in China, India, Japan and South Korea during 2021-to-2025. At the end of 2019, overall smart meter penetration stood at 69 percent in these markets, corresponding to an installed base of 653.3 million units. China has already completed its first-wave rollouts with Japan and South Korea next in line.

COVID-19 DRIVES SMART DEVICES

A third of all smart device owners in U.S. broadband households have increased their use of smart home solutions during the COVID-19 pandemic, including nearly half of smart door lock owners. According to recent research from Parks Associates, with consumers spending more time at home, they are finding more value in smart home and security use cases, driving new product announcements in these categories. In the connected health space, for example, the company said demand for virtual care solutions, telehealth and remote patient monitoring has boomed during the pandemic.

Cellular IoT keeps electricity smart grids humming

A combination of cellular IoT and Bluetooth LE connectivity is allowing electricity grid operators to remotely monitor smart power grids and take corrective action in the event of a network fault.

Slovenian innovation lab, IRNAS, has developed a device that once deployed on transmission towers throughout an electricity network, employs integrated voltage, temperature, accelerometer and surge counter sensors to monitor power grids and surge arresters for a range of potential faults. These include excessive temperature because of a possible fire, the collapse of a transmission tower, power outage or power surges. IRNAS developed the RAM-1 device for Izoelektro, a firm supplying utilities and energy companies with solutions that help set up, maintain and restore electrical energy systems. RAM-1 uses machine learning (ML) models built with Edge Impulse's technology. (*See pg4.*)

Incorporating Nordic's nRF9160 low power SiP with integrated LTE-M/NB-IoT modem and GPS in combination with the nRF52811 Bluetooth LE SoC, the RAM-1 device can be commissioned via a smartphone app using Bluetooth LE wireless connectivity. The nRF9160's SiP's multimode LTE-M/NB-IoT connectivity and GPS trilateration enables RAM-1 to periodically relay the data—and the precise location of the monitored device—to the proprietary RAM-CENTER web platform.

This allows operators to immediately fix any potential problems and improve the reliability and stability of the overall electricity network.

In addition to commissioning the RAM-1 device, the Bluetooth LE connectivity also provides a method of collecting data in remote locations where there is no LPWAN coverage, as well as providing a back-up channel for upgrading the device and applying different network settings if necessary. To avoid the need for regular maintenance, the ruggedized RAM-1 is powered by a primary Li-MnO_2 cell and is designed to last up to 20 years in the field.

"RAM-1 has rapidly become an IoT device for remote monitoring, ML and advanced analytics of power grids," says Jure Pungerčar, Deputy CEO of Izoelektro. "We are excited about ... the ability to improve the reliability of electricity distribution."

Smart Agriculture

Cellular IoT tech could fight food waste

Over one-and-a-half-billion tons of food is currently lost or wasted every year according to the U.N. Food and Agriculture Organization, equating to $1.2 trillion. However, this could be reduced by 20 percent by the year 2025, and by 50 percent before the end of the next decade by transforming supply chains through the use of cellular IoT technology, U.K.-based IoT company Eseye claims.

The U.N. has set a target of reducing food waste by 50 percent by 2030, however Eseye believes this could be achieved sooner were the industry to adopt cellular IoT-connected labeling technology and real time sensor-based data tracking.

The company says the labels, when placed on food items, would enable complete real-time visibility of the entire supply chain and provide instant monitoring of location, temperature and humidity data, while at the same time eradicating losses caused during transport and through farming inefficiencies.

"IoT has the power to overhaul the way we grow and transport food," says Nick Earle, Eseye CEO. "With finite resources we must become more efficient and end wastage.

"By connecting up the supply chain, we can produce and ship only what we need, and then better care for it to ensure it reaches the fork unharmed. IoT has traditionally been centered around big-ticket items, but new technologies are making smaller sensors economically viable on a massive scale."

Japan trials wireless tombstones

Bluetooth LE-powered tombstones that provide a more personalized experience for mourners visiting communal tombs have been introduced in the Yachiyo Yukyu no Sato Cemetery in Chiba Prefecture, Japan. Communal tombstones provide a cost-effective alternative for Japanese families who cannot afford to bury loved ones on their own plot.

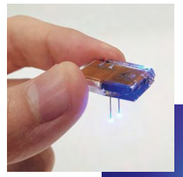
The tombstone, called Hikari, uses an electronic 'paper' screen and Bluetooth LE technology to detect who is approaching the tomb, before changing its display image on the headstone to match their family member. When approaching the site with a 'talisman'—in effect a Bluetooth-LE powered beacon—the screen on the tomb changes to display the name, date of death and photo of the loved one. Once the family member and their talisman exits Bluetooth range, the electronic screen returns to its default image.

Smart Health

Wirelessly rechargeable implant controls brain cells

A group of researchers from The Korea Advanced Institute of Science and Technology (KAIST) have engineered a tiny brain implant that can be wirelessly recharged from outside the body to control brain circuits for long periods of time without battery replacement. The new wireless charging technology addresses the limitations of current brain implants. The device is constructed of ultrasoft and biocompliant polymers to help provide long term compatibility with tissue.

Geared with micrometer-sized LEDs mounted on ultrathin probes, the device can wirelessly manipulate target neurons in the deep brain using light. The fully implantable, soft optoelectronic system can be remotely and selectively controlled by a smartphone using Bluetooth LE wireless connectivity.



Wireless implantable device technologies have recently become popular as alternatives to conventional tethered implants because they help minimize stress and inflammation during brain studies, which in turn enhance the lifetime of the devices.

To enable wireless battery charging and controls, researchers developed a tiny circuit that integrates a wireless energy harvester with a coil antenna and a Bluetooth LE chip. An alternating magnetic field can harmlessly penetrate through tissue and generate electricity inside the device to charge the battery. Then the battery-powered Bluetooth LE implant delivers programmable patterns of light to brain cells using an easy-to-use smartphone app for real-time brain control.

"This powerful device eliminates the need for additional painful surgeries to replace an exhausted battery," says Professor Jeong from KAIST who led the study.

"We believe that the same basic technology can be applied to various types of implants, including cardiac pacemakers."

Industrial IoT

Mesh-networked hard hat sensors track construction staff and assets

Designed to overcome the challenge of visibility of worker flow traffic and equipment location in industrial sectors, WakeCap Technologies has launched a mesh-networked sensor platform based on Nordic's nRF52832 multiprotocol SoC and Wirepas Mesh software.

The WakeCap solution comprises hard hat-worn sensors, network nodes and a gateway, and enables real time reporting highlighting unexpected problems early and avoiding delays or extra costs. The sensors track the location of the wearer on a worksite and record any impact incidents. The network nodes are placed throughout the worksite and together with the hard hats are wirelessly linked using the Wirepas Mesh powered by the Nordic SoCs. Data including worker time, location and motion/shock analytics can be relayed via Wirepas Mesh to the nRF52832 SoC-equipped gateway which in turn sends the data to the Cloud.

Site management can then review the information and actionable insights via the WakeCap Analysis Platform, through a web-based dashboard or an associated smartphone app, for operational purposes.

The platform can also be used to enhance COVID-19 safety and avoid site shutdown by providing a touchless automated attendance system, monitoring social distancing and contact tracing.

Wirepas Mesh can be used to connect, locate and identify lights, sensors, beacons, assets, machines and meters. The decentralized network allows each WakeCap hard hat to relay data to another hard hat or anchor node maximizing coverage and reducing the number of nodes or gateways required.

By the Numbers

$405 million in revenue

Nordic Semiconductor has reported full 2020 revenue of $405.2 million, representing growth of 40.5 percent over 2019 full year revenue. The result comes on the back of all time record Q4 revenue of $127.1 million, an increase of nearly 53 percent over Q4, 2019 revenue which was itself a record. The strong year-on-year growth reflects significant demand across all markets. Bluetooth LE dominated revenue growth, contributing $316 million.

6.6 billion connected IoT devices

At the end of 2020, 6.6 billion IoT devices were connected and active worldwide, with 840 million of them using a cellular network, just under eight percent of the total. According to market advisory firm, ABI Research, by 2026 cellular IoT devices will see near seven times growth, bringing the global total to 5.7 billion. To achieve this number the analyst said carriers would need to guarantee the reliability of networks through the use of global connectivity coverage solutions.

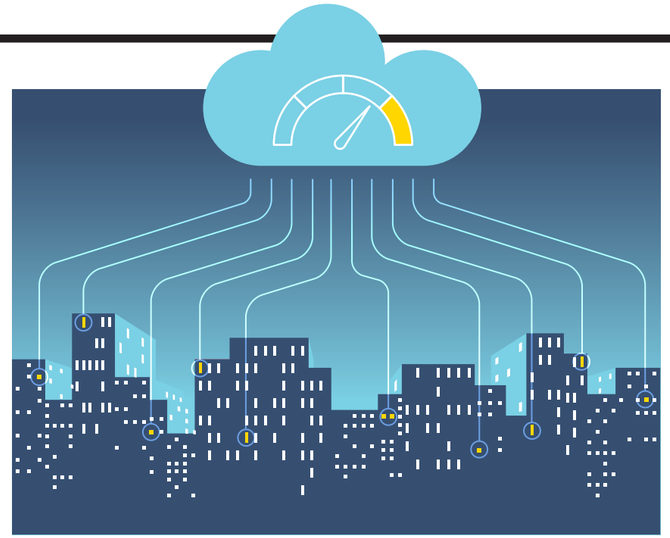
$81.5 billion in 2021

Global end-user spending on wearables will total $81.5 billion in 2021, an 18.1 percent increase from $69 billion in 2020, according to the latest forecast from Gartner. The rise in remote work and health monitoring during the COVID-19 pandemic has been a significant factor driving market growth. The analyst said the introduction of health measures to self-track COVID-19 symptoms presented a significant opportunity for wearables.

Smart City

Combining wMBus and LPWANs for Cloud connected gateways

With Lobaro's Wireless MBus Gateway, European utilities can choose from either cellular IoT or LoRaWAN to support their Advanced Metering Infrastructure



Smart meters aid both consumers and utilities. The devices provide both parties with real-time information about energy consumption enabling much finer control over production and usage. That boosts convenience while ensuring careful consumption of finite resources and limiting carbon emissions.

The European Union (EU) is at the forefront of smart utility meter deployment. EU member states are required to implement smart metering under EU energy market legislation. European countries have committed to deploying 200 million smart meters for electricity and 45 million for gas in the next few years at a total potential investment of €45 billion ($52.8 billion). When this phase of the program is completed almost 72 percent of European consumers will have a smart meter for electricity while 40 percent will have one for gas.

How well a smart meter performs is dictated in large part by how the data gets from the meter to the Cloud for analysis. Smart meters targeted at the European market typically incorporate Wireless Meter-Bus (wMBus) defined by the EN 13757-4 standard. wMBus is a mature and widely adopted technology, designed for short range connectivity between a local group of smart meters and a handheld reader, concentrator or gateway. (*See sidebar pg11, A standard for remote reading of smart meters.*)

Gateway to the Cloud

Utilities want to connect groups of smart meters to the IoT so that the data can be analyzed by powerful Cloud servers. That requires aggregating the data transmitted over wMBus from hundreds of smart meters and then forwarding that data over kilometer-range LPWANs to the Cloud.

German industrial IoT solutions firm and Nordic Semiconductor customer, Lobaro, has met this demand with its Wireless MBus Gateway. Lobaro says the gateway is a cost and energy efficient device that receives, caches and forwards metering consumption data from up to 250 wMBus enabled smart utility meters to the Cloud. The gateway sits close to where the utility meters are located, either in a basement or on every two or three floors of a large apartment building. Metering data is sent to the Lobaro Platform in the Cloud, were it gets parsed, displayed and made available for further processing. It is also possible to use the Lobaro gateway without the platform and instead connect it to a standalone backend (as long as the backend is capable of parsing and decrypting wMBus 'telegrams').

Lobaro uses Nordic's nRF9160 SiP in its Wireless MBus Gateway to provide LPWAN connectivity of European MBus utility meters using NB-IoT, LoRaWAN or a combination of both. Although the nRF9160 is capable of both LTE-M and NB-IoT connectivity, Lobaro says data is uploaded to the Cloud from the gateway using just NB-IoT. NB-IoT is better suited to fixed installations, especially those which are inside buildings or basements because it penetrates obstructions better than LTE-M.

While the nRF9160 is designed for cellular IoT, Lobaro is also using the SiP's Arm Cortex-M33 processor (and associated 1 MB Flash and 256 KB RAM) to support not only the cellular IoT firmware but also the company's own wMBus stack and LoRaWAN firmware. LoRaWAN is an LPWAN alternative to NB-IoT.

While open standard NB-IoT offers greater throughput and longer range than proprietary LoRaWAN,the latter's inclusion in the Lobaro gateway provides utility companies with fallback Cloud connectivity for smart meters used in areas lacking NB-IoT coverage.

"Cellular IoT and LoRaWAN are [often] regarded as complementary wireless technologies in the ... smart meter sector," says Theodor Rohde, Managing Director of Lobaro. "This is because LoRaWAN came to market first so there are a lot of existing installations where customers don't want to ... make a wholesale change to cellular IoT. At the same time, they don't want to be limited to just using LoRaWAN [for future installations]. Having the option of [two LPWANs] yields greater design flexibility and reliability in areas of limited coverage or poor signal strength.

"All the heavy lifting is done by the nRF9160 SiP so there are very few additional components required for the gateway," adds Tobias Kaupat, Lobaro's CTO.

Tech Check

The nRF9160 SiP's high level of integration, including RF front end, application processor and cellular IoT modem, reduces the number of components in Lobaro's Wireless MBus Gateway. The result is a full-functional wMBus/NB-IoT/LoRaWAN gateway that can support up to 250 smart meters in a form factor measuring 122 by 82 by 55 mm. The unit is powered by a 3.6 V (14.5 mAh) battery that, because of the low power design of the SiP, lasts for up to a decade when sending metering data once a day

A standard for remote reading of smart meters

Utilities look to connect their smart meters to the IoT to form the basis of Advanced Metering Infrastructure (AMI). AMI is defined as an integrated system of smart meters, communications networks and data management systems that enables two-way communication between utilities and customers. When integrated with consumer technologies such as smart thermostats, AMI lets utilities offer their customers time-based tariffs and incentives that encourage them to reduce peak demand and manage energy consumption and costs.

Wireless MBus (wMBus) is an RF technology that builds on the foundation laid by wired Meter-Bus (MBus) technology. wMBus is based on a European standard (EN 13757-4) which was developed for AMI networking and remote reading of smart meters across Europe. The most recent revision of the specification was adopted in 2013 and supersedes the 2005 version.

While other frequencies are used, notably a 169 MHz narrowband version which offers greater range, most wMBus smart meter deployments use the license-free 868 MHz band. This band offers reasonable throughput but better range (500 meters line-of-sight) and penetration (two to three building floors) than the popular 2.4 GHz license-free allocation. In addition, wMBus offers several operating modes, including "S" (meters send data once or few times a day), "T" (several times a day) and "C" (higher data rate version of mode T). The protocol is a low power, short range technology using Frequency Shift Keying (FSK) modulation.

wMBus has gained market share due to its simplicity. The software stack is lightweight and comprises just a physical layer (PHY), Date Link Layer and Application Layer. Security is underwritten by AES-128 encryption.

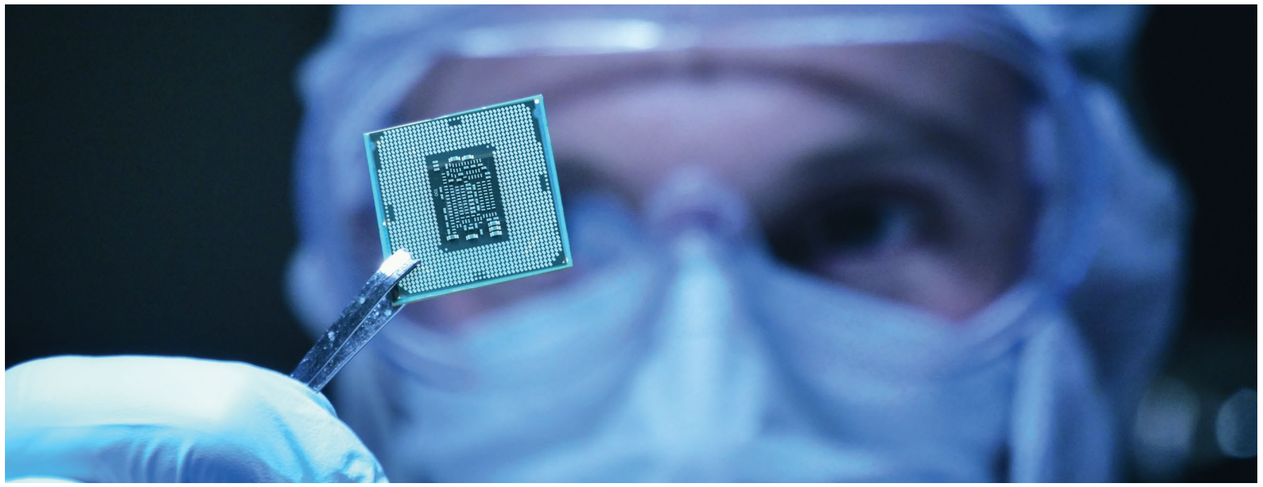
One downside is that wMBus supports star network topologies only which places restrictions on where the gateway can be placed. (Several competing protocols, for example, Zigbee, support mesh networking which boosts range and builds-in redundancy.) And, while wMBus is a standard, there is no independent certification authority like the Bluetooth Special Interest Group or Zigbee Alliance to ensure compliance and interoperability. Instead, interoperability challenges are resolved through lengthy field trials between equipment manufacturers. In addition—because there are multiple operational options—regions and countries pick-and-choose elements from the standard to optimize wMBus performance for their own operating environments. Such customization further undermines interoperability.

Internet of Things

Chip industry shows COVID-19 immunity but challenges lie ahead

As the pandemic negatively impacts economies, world chip sales have gone the other way but wafer supply constraints threaten to curb future shipments

> When the pandemic struck Nordic was already well positioned in most verticals and as a result we've seen good growth in all segments



The economic fallout from COVID-19 has been felt far and wide. Yet counterintuitively, the pandemic has at the same time accelerated key drivers of growth in the semiconductor industry, providing a fillip to chip sales that some market watchers may not have expected.

A February 2021 Semiconductor Industry Association (SIA) report details how much global chip sales ramped up during 2020. Based on World Semiconductor Trade Statistics (WSTS) data, the SIA report shows global semiconductor sales were $439 billion last year, an increase of 6.5 percent compared to the 2019 total of $412.3 billion.

Part of this growth can be attributed to the large number of IoT solutions that have emerged across sanitation, healthcare, COVID-19 testing, social distancing, contact tracing, vaccine tracking and other related applications – but other sectors have grown too.

However, headwinds are mounting, created by wafer constraints at the major contract chip fabricators such as TSMC, a supplier of components to Nordic Semiconductor and many other fabless chip vendors.

The road ahead for semiconductors

In 2021, while the global economy starts a slow recovery as vaccines roll out, the chip industry is leaping ahead. Just-reported January figures from the SIA show sales were $40 billion, an increase of 13.2 percent over January 2020 and 1 percent more than the December 2020 total of $39.6 billion. SIA is forecasting an overall rise of 8.4 percent for 2021.

According to *Global Semiconductor Industry Outlook*, a joint report by consultant, KPMG International, and trade body, the Global Semiconductor Alliance (GSA), the semiconductor industry has "proven resilient throughout the COVID-19 pandemic". The report also says the industry finished 2020 with "similar growth to pre-COVID-19 levels", and is "again illustrating the world's increasing reliance on advanced technologies".

Key findings from the KPMG/GSA survey of semiconductor companies suggest wireless communications (including 5G) and the IoT are tied as the most important application areas driving semiconductor revenue over the next year.

Seventy two percent of industry leaders (up from 50 percent in the previous year), believe 5G specifically will become a significant driver of industry growth, the report states. Although 5G buildout began well before COVID-19, the wireless tech is now supporting new IoT use cases based on powerful connected sensors.

The product category representing the largest growth opportunity for semiconductors is sensors/MEMS, with analog/RF/mixed signal ranking second, followed by microprocessors. "Respondents expect the growth opportunity for every semiconductor product category to increase in 2021 as the new reality drives demand for numerous kinds of connected technologies," says Scott Jones, a Principal with KPMG in the U.S.

Meeting the sales backlog will not be all plain sailing. Chip demand has put pressure on the fabs and *The Wall Street Journal* reports that suppliers have reached the limits of current production capacity. The newspaper reports that TSMC is upping its game adding that the chip maker's emphasis on capital spending will be necessary to capture growth opportunities. TSMC plans to raise capital expenditures to between $25 billion and $28 billion in 2021, at least a 47 percent year-over-year increase.

Need to Know

Of the 2020 chip sales annual total of $439 bn (up 6.5 percent on the year before), shipments into the Americas market increased annually by 19.8 percent. China remained the largest individual market for semiconductors, with sales totaling $151.7 bn in 2020, an increase of 5.0 percent. But annual sales did decrease in Europe by 6 percent. Logic ($117.5 bn) and memory ($117.3 bn) were the largest semiconductor categories. Sales of micro-ICs—including microprocessors—increased by 4.8 percent to $69.6 bn in 2020

Remarkable growth for Nordic

Nordic is one example of a semiconductor company which is not only surviving the uncertainty of a global pandemic but is thriving in the 'new normal'. The highlights of the company's recent performance include full-year 2020 revenue of $405.2 million (+40.5 percent compared to 2019), full-year gross profit of $213.9 million (+45.8 percent) and almost a fivefold increase in order backlog to a record high $492 million at the end of the 2020. The backlog reflects strong demand across the range of end-user applications as well as more contracts with tier-1 customers.

Geir Langeland, Nordic's Sales & Marketing Director, is pleased with the company's performance but noted growth could be restrained by supply challenges, saying: "Nordic commented in its Q4 2020 presentation that it had been notified of limitations in wafer supply that will limit production volumes in 2021."

During 2020, Nordic technology has enabled numerous solutions in direct response to the pandemic. For example, wirelessly connected health devices such as CWD Innovations' SmartTemp+ and Warmie's wireless temperature sensor support the frontline healthcare industry. Bluetooth LE proximity-monitoring wearable solutions like the Coolpad Bubble (co-developed by Coolpad and M2MD Technologies) provide contact tracing data and assists with social distancing. Elsewhere, Ellume's Nordic-powered and FDA-authorized COVID-19 Home Test is a safe and simple rapid antigen test allowing individuals to check for active COVID-19 infection within 15 minutes.

But according to Langeland, Nordic's success is not just down to the opportunities the pandemic has opened up for new technology. He said Nordic's success in the face of unprecedented global challenges can be attributed to the company's hard work, 'long-tail' business focus and strategic plan to 'democratize wireless' over a long period of time, many years before the current COVID-19 outbreak.

"You wouldn't ask a professional athlete that practices a thousand hours every year for ten years, and then wins the championship, if it's luck. It's similar for Nordic; we spent the better part of two decades building up a wide customer base—it ranges from small to very large customers and is very diversified—and we have spent an awful lot of time building up a portfolio of products [and] tools which are easy for our customers to use," Langeland asserted during a live Nordic Semiconductor senior management panel debate in January. "When the pandemic struck Nordic was already well positioned in most verticals and as a result, we've seen good growth in all segments."

Geir Langeland
Director of Sales & Marketing: Nordic Semiconductor

Coming of age for the IoT

After the pandemic we'll need to do much more with a lot less. Technology is the answer

It's hard to believe that at the start of this year some people were still openly questioning whether the IoT would ever realize its potential on any significant scale. No one is saying that now. And the primary reason is COVID-19. As this once-in-a-lifetime pandemic spread across the world, it was to IoT technology that governments, businesses and organizations turned.

As a result, mass scale IoT has become a global reality even in ultra conservative sectors such as healthcare. Upon realizing that technology was one way to take the fight to COVID-19, healthcare professionals rapidly adopted telemedicine, remote monitoring, key medical equipment asset tracking and a much increased use of medical wearables.

The key question is whether the end of the pandemic—still some way off but now closer due to large vaccine roll outs—will see a reversal of the IoT adoption trend. My prediction is the IoT-centered changes that COVID-19 forced on almost every industry are not about to significantly reverse. Instead, I believe that IoT-driven changes are set to accelerate.

COVID-19 was not only a health disaster for the world but also an economic disaster. It hammered finances across the globe, sky rocketed unemployment figures and increased government debt levels to unprecedented peacetime highs. That means even if the world does return to some degree of stability during 2021, it is going to have to operate a lot more efficiently than before. We're going to need to do ten times more with ten times less.

Technology will help us get there. For example, advances in AI and machine learning—particularly on resource-constrained wireless IoT devices powering 'tiny machine learning' or 'TinyML'—will bring new levels of local and environmental awareness, intelligence and basic decision making capabilities to even the most basic of products, applications and services.

I also predict a rapid rise in automation. A lot of the repetitive aspects of skilled manual labor and professions disappeared during COVID-19 and this might mean less market demand for that kind of work in the future as automation offers an alternative. But far outweighing any short-term job losses, I see a wave of new, higher quality job opportunities being created by the IoT, including designing, building and optimizing the use of increased automation.

At global economies of scale and thus affordability, the IoT, in combination with cutting-edge AI and automation, has the potential to genuinely make the world a much better place in which to live and work. A safer place. A sustainable place. Perhaps even a more peaceful and happier place.

An improvement to all our lives is my vision (and hope) for the new technical revolution that's beginning to gain traction in 2021. In the fullness of time COVID-19 is likely to be regarded as being one of the worst things to happen to the world during the 21st century. But there's a chance it might also be seen as one of the best things too – because it ushered in a new golden technological era.

The IoT is powering an automation and AI boom

The Last Mile

Last mile transportation through the use of micromobility solutions is on the rise as cities adjust to post-pandemic commuting

In Short

City residents and visitors are embracing the benefits of shared micromobility: Convenience, affordability, exercise and a reduced carbon footprint

The challenge of 'last mile' personal transportation—commuting from a public transit hub to a final destination—is that existing transport infrastructure doesn't take people door-to-door

Many bike sharing programs have proved to be not only effective, but sustainable, providing hope for cities in the fight against congestion, pollution and noise

Bluetooth LE and cellular IoT wireless connectivity is helping to grow the world's bike sharing population and with it the shared micromobility economy

The pandemic has seen commuting diminish as workers obey lockdowns and work from home. But in a post-COVID 19 world we'll all need to start traveling from A to B – and back again. How we choose to do so depends on how we prioritize factors like time, availability, reliability, cost, health, safety and environmental impact.

While urban mobility is both complex and critical, the difference after the pandemic is how the dominance of the internal combustion engine—a motive force that has dictated city layouts and lifestyles for decades—is under threat as millions of commuters turn to pedal-power. (*See sidebar pg17 Road to Recovery: Human-powered transport to drive post-pandemic commuting.*)

One example is the increasing use of share bikes. The concept has had a recent checkered history but the sector is consolidating and maturing and many cities are starting to resemble those from late American author Ernest Callenbach's influential 1975 semi-utopian novel *Ecotopia*. In the novel, the hero visits a breakaway society that favors a green lifestyle. This lifestyle includes a readily available bicycle sharing system, integrated into the public transportation of a society not reliant on fossil fuels. Over four decades later, the vision of efficient intracity transit supported by 'micromobility' has begun to pick up speed; even if the machines themselves typically max out at a steady 25 kilometers per hour. Micromobility encompasses shared-use fleets of small, lightweight, fully or partially human-powered personal vehicles such as bicycles, electric bikes ('eBikes') and eScooters. The difference between today and the mid-70s vision of the future is that wireless technology forms part of the foundation of micromobility's success.

Whether commuting to-and-from work, connecting to transit networks or riding for recreation, city residents and visitors are increasingly embracing the benefits of technology-driven micromobility: Convenience, affordability, exercise and a reduced carbon footprint among others. The global number of public-use bicycles soared from 2.3 million in 2016 to 18.2 million within two years (according to analyst Statista). In the U.S. alone, people took 136 million trips on share bikes, eBikes and eScooters in 2019, a 60 percent increase on the previous year, according to the National Association of City Transportation Officials (NACTO). Perhaps this is unsurprising, given the concerns about congestion and parking availability that come with driving a car from point-to-point.

For cities there's an important backdrop to the urban mobility revolution now underway. 'Last mile' personal transportation—when a person commutes from a public transit hub such as a railway station, bus depot or ferry berth, to a place of work, home or another final destination—fills the demand which transport infrastructure that doesn't take people door-to-door creates. That makes it vital for cities to establish a quality platform for bikes and bike infrastructure (for example, safe cycle routes, encouragement for share bikes and secure storage for those using their own machines) to provide a *bona fide* alternative to more carbon-intensive modes of transport. At the same time, the 'first mile' presents a problem because people have increasingly moved away from cities into the suburbs, and often live a considerable distance from a transport hub necessitating a walk to catch a bus just to reach the train that takes them into the city.

Beyond commuting, greater emphasis on micromobility would have a huge impact on conventional vehicle use considering that 35 percent of all U.S. car trips are under 3.5 kilometers (as measured by the National Household Travel Survey). Wider availability of alternatives would encourage travelers to make these short trips without relying on personal cars, taxis or ride-hailing vehicles that contribute to traffic congestion, urban sprawl and carbon emissions.

SHARE BIKE SHAKE-UP

Bike sharing initiatives, which have been successfully implemented in Europe, Asia and North America, will play a key role in alleviating the challenge of last mile commuting. Crucially, local authorities and communities as a whole are getting on board. In Amsterdam, for example, bicycle sharing initiatives have received more than €1 million ($1.17 million) in funding to help boost the city's smart mobility sector. Meanwhile in July 2020, Google Maps began including bike shares in its route recommendations.

Traditional bike sharing systems feature long rows of bikes parked in a fixed docking station—either staffed, coin deposit or automated—performing the roles of bike rack, digital bike lock and registration system all in one. The bikes are available for hire on a short-term basis for a small cost or subscription free, often via mobile payment. These systems feature smartphone mapping apps showing nearby available bikes and open docks, allowing people to borrow a bike from a dock and return it at another dock belonging to the same system. The arrangement isn't perfect, with one disadvantage being the inconvenience of locating a (relatively) nearby fixed docking station at both the start and end of journeys. Yet even as the number of dock systems in the U.S. decreased by four percent to 72 in 2018, total station-based bike share ridership increased 10 percent, says NACTO. It seems people are voting with their pedals.

To overcome the drawbacks of the fixed dock, 'dockless' smart bike systems have emerged. Pioneered by companies like Mobike (acquired by Chinese e-commerce company Meituan-Dianping in 2018), which now operates share bike schemes in over 200 cities and 19 countries around the world, these systems typically combine a smartphone app with GPS functionality and Bluetooth LE connectivity allowing users to locate a nearby bike and deposit it at their final destination. This removes the need to complete the last kilometer of a journey another way because of an inconveniently positioned bike dock. The concept clearly has wheels if NACTO's survey of ridership in six cities—which revealed 45 percent of users would make trips by personal/ride hail vehicle if dockless bike and scooter trips weren't available—is to be believed.

Both fixed dock- and dockless-bike sharing schemes have hit a few potholes on the path to widespread adoption. Images of share bikes vandalized and abandoned around cities, or grouped en masse to form urban bike 'graveyards', didn't exactly paint an eco-friendly picture to a skeptical public. That said, more accurate and reliable remote tracking of individual vehicles, enabling companies to send team members to check on the status of their bikes as required, has helped address community and government concerns about the eyesore of discarded machines.

The fact remains that share bike systems eliminate the hassle (not to mention expense) of buying, storing and maintaining a personal bike. Many bike sharing programs have proved to be not only effective, but sustainable, providing hope for cities in the fight against congestion, pollution and noise. And the longer these bikes are in use, the greater opportunity they have to save harmful carbon emissions. (Researchers claim a shared bike needs to be used for almost two years to create net carbon savings, based on an estimated carbon footprint of 34.56 kg of CO_2 over the bike's lifetime (*International Journal of Sustainable Resource Management and Environmental Efficiency*, Vol. 162).)

WIRELESS MICROMOBILITY

Wireless connectivity is helping to grow the world's bike sharing population and with it the micromobility economy. Without a reliable link between smartphones and networks of low-maintenance bikes, companies like Mobike, Hellobike (China), Citi Bike (U.S.), Nextbike (Germany)

By the Numbers:

An estimated **1,600+** bike sharing programs were operating worldwide in 2018

Source: Statista

342 million trips on shared bikes and scooters were taken in the U.S. between 2010 and 2019

Source: NACTO

Micromobility is predicted to be a **$300 bn-to-500 bn** market by 2030

Source: McKinsey & Company

and hundreds of other bike-sharing platforms across the globe wouldn't exist and couldn't expand. Bluetooth LE is currently used in most share bikes for communication between the bike and an associated smartphone app, while some systems are employing cellular IoT, an LPWAN technology, with Bluetooth LE as backup. Crucially, the low power consumption of these wireless technologies ensures the vehicles stay connected and can be located throughout a journey and beyond.

One example is the Meituan/Mobike dockless bike-sharing model, which allows its bikes to be parked anywhere and unlocked in an instant with a smartphone. The key to the system is a smart lock, permanently fixed to the bike and incorporating Nordic's nRF51822 Bluetooth LE SoC (or for newer share bikes Nordic's advanced nRF52840 multiprotocol SoC) to power a wireless link between smartphone and lock. When combined with GPS and QR code scanning, the electronics lets people conveniently locate, pay for and unlock a Mobike machine. At the end of a ride, users park the bike in any suitable location close to their destination. To secure the bike, the user slides a mechanical switch which causes the lock to engage around the rear wheel. This also triggers the Mobike smartphone app to log the ride as 'complete' and publicize the bike's location to the next user. The app tells users how long they have been on the bike, distance traveled and the fee charged.

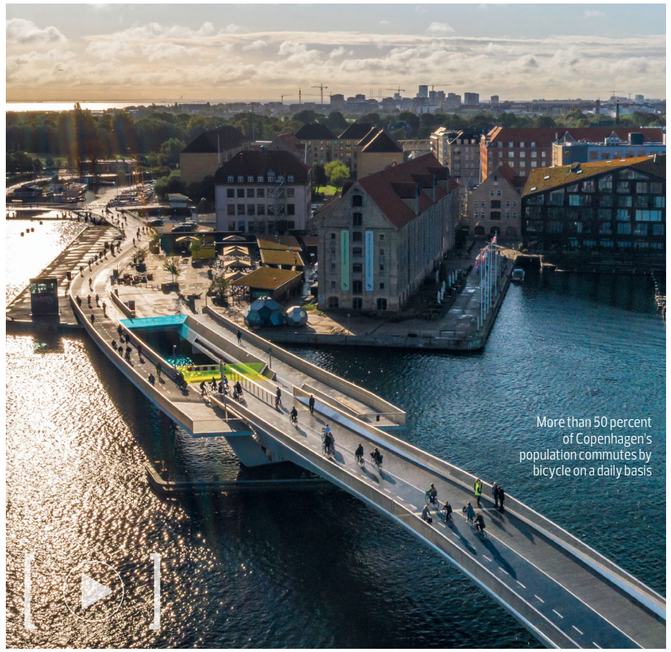
Backed by e-commerce giant Alibaba, Hellobike provides 230 million registered users in more than 200 cities with micromobility services, making it one of China's largest bike-sharing platforms. The beauty of Hellobike is its simplicity for all. From a smartphone app users can find a smart bike near them and then instantly unlock it using the integrated Nordic Bluetooth LE technology. The system works well in part because Nordic Bluetooth LE SoCs provide seamless interoperability with virtually all smartphones (unlike some competing Bluetooth LE products), making the Nordic technology ideally suited to consumer-facing applications such as bike-share platforms.

"Hellobike is a very technology-focused company that is using AI, big data, Cloud infrastructure and the IoT to integrate shared bikes into China's public transport ecosystem," says Damien Wong, Nordic's Sales Manager in China.

Low power wireless technologies also underpin other essential services supporting the micromobility sector, such as wireless bike/rider safety aids and bike trackers. For example, California-based cycling equipment company, Specialized, has developed ANGi (Angular and G-Force indicator), a sensor-based device that, when attached to a Specialized bicycle helmet, turns it into a live GPS tracking device, crash detector and safety beacon for cycle riders. ANGi uses Nordic nRF52832 SoC-enabled Bluetooth LE to wirelessly send alerts of potentially serious accidents, and the most recent GPS coordinates, to a rider's emergency contacts via a smartphone app.

Elsewhere, See.Sense AIR, the world's first NB-IoT cellular bike security tracker, uses Nordic's nRF9160 SiP, a cellular IoT solution with assisted GPS, to help users automatically locate and track their bikes from a smartphone. AIR works for up to three months on a single battery charge. Developed by Northern Ireland cycling start-up, See.Sense, the solution protects both bike and rider by identifying if the bike has been involved in a crash and by then sending an SMS of its precise location to the rider's assigned contact. On a broader scale, AIR can enhance cycling for riders by constantly and accurately monitoring the cyclist's experience on their ride, so that aggregated and depersonalized ride insights can be shared with partners to improve conditions for cycling. In action this means riders will be able to avoid the congestion, poor roads, steep inclines and other issues that reduce the appeal of cycling.

Meanwhile wireless gear changing, powered by ANT+ or Bluetooth LE wireless technologies and pioneered by the pro-peloton at the Tour de France, is making its way onto lower-price point commuter bikes, bringing faster and smoother sprocket jumps for tackling city hills. And into the future, low power cellular IoT could make use of mature city cellular infrastructure to enable operators to keep track of their bike fleet condition by remotely monitoring tires, drivetrain and brakes using a network of short range wireless sensors.



More than 50 percent of Copenhagen's population commutes by bicycle on a daily basis

Tech Check

The Unlimited eBike Kit is comprised of three key elements: A front motor wheel capable of generating up to 750W that replaces the regular wheel of an existing bicycle; a 'powerpack' containing the motor controller and battery; and a pedal sensor to detect the rider's pedaling motion and instruct the motor controller to engage the motor. Both the pedal sensor and the powerpack integrate a Raytac MDBT42Q Bluetooth LE module—employing Nordic's nRF52832 SoC—to provide robust wireless connectivity between the pedal sensor and the powerpack

Road to Recovery: Human-powered transport drives post-pandemic commuting

For the multibillion-dollar micromobility industry, the COVID-19 crisis has created an interesting dichotomy between immediate decline and unprecedented scope for progress. On the one hand the global lockdown, border closures and travel bans, strict social distancing measures and a transition to working from home, essentially ruined commuting. Declines in ridership and revenue sent previously accelerating micromobility solutions crashing back to earth. According to research by McKinsey, COVID-19 saw the number of shared and private micromobility passenger-kilometers traveled declining 50 to 60 percent worldwide.

Yet moving forward, the impact of COVID-19 could breathe new life into the micromobility sector as people prioritize healthy, hygienic, low-risk, affordable, greener and congestion-free commuting. The McKinsey modeling suggests micromobility is set to make a strong recovery, and by 2025 passenger-kilometers traveled are expected to rise 10 percent above pre-pandemic totals.

The pandemic has indirectly generated a renewed interest in the use of lightweight personal vehicles as a genuine alternative to cars. With the world in lockdown people simply stopped driving to work. Fresh air and fitness became higher priorities. Fewer cars on the road means reduced carbon emissions, but it also leads to people feeling safer about cycling to their destinations. Plus, the pandemic has made people more cautious about public transit options like buses and trains where effective social distancing is difficult to achieve.

In response to these factors, many cities have already started providing better and safer facilities to make micromobility more practical for commuters. And they don't have to look far for inspiration; for example, in Trondheim, Norway, up to 360 cyclists an hour can take advantage of a motorized aid that operates much like a ski lift, making it easy for riders to get their bikes up an intimidatingly steep hill. And intelligent traffic lights with dedicated signaling for bikes, installed at every downtown intersection in Denmark's capital, Copenhagen—where half the population commutes by bicycle daily—allow cyclists riding at a speed of 20 kilometers an hour to hit all green lights on their morning and evening rush hour commutes.

If the right cycling infrastructure and initiatives are in place, using human/electric-powered transport instead of carbon-intensive vehicles to get around cities could well become the new normal.

> "The pandemic has indirectly generated a renewed interest in the use of lightweight personal vehicles as a genuine alternative to cars

ELECTRIC DREAMS

Pushing the pedals unassisted is perhaps acceptable for short, flat journey or for longer trips by fitter riders, but it has its limits. eBikes, with their lithium batteries and compact, brushless electric motors, promise to not only extend micromobility to a wider audience but also promise to change 'last mile' trips to 'every mile' ones. eBikes and their two-wheeled cousins, eScooters, are now in high demand, particularly in China, where nearly 700 million rides are completed on a combination of conventional pedal bikes and eBikes every day, according to Hellobike. Plans are afoot to equip shared eBikes with a cellular IoT-based geofencing capability making it easier to manage the areas in which the bikes can be used and avoiding incidents of riders tempted to take their hired powered bikes well beyond city limits.

There is no need for riders to junk their existing machine to take advantage of electric power. Barcelona, Spain-based recreational electric vehicle developer, Unlimited, for example, has launched an eBike kit enabling a user to turn any bicycle into an electric bike in just a few minutes using low latency Bluetooth LE connectivity to activate the wireless electric power-assist. From a green perspective, although eBikes require lithium batteries to run, numerous machines can be manufactured for the same carbon footprint as manufacturing a single car. While many of today's machines are controlled by wires, it is not difficult to see all eBikes becoming wireless, with not only the gears, but also the motor being controlled by radio signals.

In the last-mile food delivery lane—where challenges include minimizing cost, ensuring transparency and increasing efficiency—eBikes and eScooters are increasingly being used by riders to speed around cities where cars are a poor option (or not an option at all) and deliver still piping hot food.

Could alternative modes of single-occupant transport supercharge the journey toward streamlined yet sustainable urban mobility? If technology can support micromobility devices to work for cities, citizens and service providers alike, the outcome will surely be positive. Backed by major advancements in wireless connectivity, GPS tracking, battery and electric motor advances, mobile payments and the ubiquity of smartphones, the micromobility market is on track to take commuters to their own version of *Ecotopia*.

By the Numbers:

About **60%** of car trips are less than 8 km

Source: McKinsey & Company

On average, the typical bike share annual/monthly pass-holder's trip lasts for 11-12 minutes and covers **1.5-to-2.5 kms**

Source: NACTO

What Lies Beneath

Reliable functioning of city infrastructure will become even more critical after COVID-19. That makes wireless condition monitoring essential

In Short

City denizens rely on an array of critical machinery and equipment to allow them to move up, down and across urban centers

COVID-19 has put even greater stress on this equipment, with social distancing requiring more trips and more uptime demands from elevators, escalators and their like

Powered by wireless sensor and network technologies, predictive maintenance is helping minimize equipment downtime

Wireless sensors can collect a variety of data such as heat, friction, noise, vibration and location and relay it using cellular connectivity to maintenance crews

City living was once replete with simple pleasures. A cup of coffee at a café with friends. Mingling among crowds in a vibrant town square. The excitement of exploring an immense urban metropolis.

Sadly, COVID-19 has radically reshaped city life, placing many of these pleasures on hold, at least for now. In their place, lockdowns and social distancing — the inhibiting but necessary precautions for containing a virulent disease. But now, vaccines are rolling out and residents are daring to dream of the old city life.

Yet it's not a given that cities can effortlessly resume normal function. Even before COVID-19, moving large numbers of people around was hard. Much depends on crucial machinery working reliably — on equipment like elevators, escalators, travelators and conveyors ceaselessly churning, turning and shunting crowds back-and-forth over sprawling geographies and up-and-down towering urban centers.

In a post COVID-19 world, this critical equipment will have to work even harder and smarter. Among other things, transit systems now must account for social distancing. There are more trips to make because of fewer people allowed per trip. More uptime demands. More wear and tear. And a shrinking pool of skilled maintenance specialists. Efficient and livable cities made possible by reliable, intuitive and connected equipment is no longer a vision, it's a mandate.

In some areas, change is long overdue. Take elevators. A pivotal force behind urbanization since their commercial introduction 200 years ago, reliability hasn't been their strong suit. The industry annually experiences over 24 million breakdowns and 190 million hours of downtime. (*See sidebar pg21 Elevator ride: From form to function.*)

The entire maintenance model is in need of repair. Elevator servicing today is largely reactive. Elevator components degrade towards failure, without intervention, resulting in sudden but inevitable breakdowns, disruption for passengers and heartache for building managers. Technicians are dispatched only after the fault is apparent. This approach does nothing for passenger convenience nor the elevator supplier's bottom line. It also creates a "reactive Murphy's Law situation" for elevator mechanics, says Chris Smith, Vice President for Service Innovation with leading elevator company, Otis. "[A mechanic will be] in the middle of a detailed maintenance routine at one building and get a service call [for a malfunctioning elevator elsewhere]. Now they have to leave, pack up their tools and drive—the most unproductive time you can have—to another building," Smith told the IoT Podcast.

Scheduled servicing, in which maintenance is proactively carried out at fixed times to get ahead of equipment failures, is only marginally better. It incurs high costs due to premature replacement and disposal of working parts and the operational costs of closing perfectly-functioning elevators for servicing. With only 18 percent of equipment failing due to age, scheduling maintenance based on fixed timeframes doesn't seem that smart.

Flawed maintenance strategies such as these translate to productivity losses of between five and 20 percent, according to Deloitte, to say nothing of the frustration it brings customers. "Customers tell us they want predictive, proactive and transparent [servicing]," says Otis' Smith. "[They say] 'I don't want things to break, I want the elevators to be up and running'."

Now, through a concept called predictive maintenance, the goal of radically extended uptime for critical equipment like elevators could be within reach. Powered by advancements in wireless sensor and network technologies, predictive maintenance lets service teams see the future state of their equipment and respond proactively.

Here's how it works: Wireless sensors placed on the equipment capture data about a spectrum of performance indicators. That data is locally analyzed by edge processors, and the critical information about the health of equipment is sent to technicians via the Cloud.

For example, for elevators, sensors might report on the distance an elevator has traveled. This could predict the elevator's need for service based on usage since the last service. But the analysis can be even more granular. Consider that issues with doors account for 70-90 percent of elevator breakdowns (perhaps unsurprising, given doors contend with everything from the dirt and grime of city streets being deposited into their tracks to impatient office-workers forcibly holding them open). With connected tech, engineers can monitor this problematic mechanical part directly. The number of times a door has opened and closed, changes in power consumed to close doors, noise and vibration generated by the moving parts — all of these indicators can be monitored by wireless sensors and, when run through clever algorithms, can proactively reveal signs of deterioration.

The same approach could detect disrepair in other critical elevator parts including sheaves, bearings and sliding components that guide the cabin. This approach extends beyond elevators to other moving machinery, such as escalators and travelators (also known as moving sidewalks). The City of London is there already, using sensors to identify unusual vibration patterns in escalators that might indicate mechanical issues in advance of a fault. They're also applying the principle to elevators, heating and cooling systems and communication networks.

MEANINGFUL INSIGHTS ONLY

For complex machinery with hundreds of parts—like elevators or escalators—wireless sensors can collect a large variety of data indicators such as heat, friction, noise,

By the Numbers

Each year, elevators are unavailable due to maintenance for

190 million hours,

that's 216 centuries

Source: Thyssenkrupp Elevator

New York City office workers spent a cumulative

16.6 years

waiting for elevators in 2010

Source: Thyssenkrupp Elevator

Flawed maintenance strategies reduce productivity by between

5–20%

Source: Deloitte

Spending on predictive maintenance is forecast to grow to

$12.9 billion

by 2022

Source: Gartner

Elevator sheaves (essentially grooved pulleys) are a key source of maintenance headaches. Worn sheaves wear cables, which in turn accelerate sheave wear. Technicians check sheave grooves at least annually to check how well cables mate

vibration and location. Transferring all this raw data to a service technician is cumbersome and impractical, not to mention costly in terms of bandwidth, says Lorenzo Amicucci, Business Development Manager at Nordic Semiconductor.

"A smarter approach is to perform edge processing, using machine learning to analyze the data locally and only send anomalies or patterns that reflect meaningful insights about the equipment," he says.

Capabilities to do this exist in IoT devices such as Nordic's nRF9160 SiP, which incorporates a powerful Arm Cortex M33 processor capable of sensor data acquisition, edge computing and basic AI data analysis. To get the data to remote technicians, the nRF9160 also supports the cellular IoT standards LTE-M and NB-IoT. These LPWAN technologies are ideal for predictive maintenance applications, because their low power consumption is critical for solutions using sensors that will run for years on battery power. The longer the batteries last, the easier the sensor maintenance becomes. In the future, low power wireless sensors might even be able to do without batteries at all by harvesting energy from the very vibrations they are monitoring.

While proprietary options exist, the value proposition of cellular IoT is compelling among LPWAN options. End users have immediate access to existing network infrastructure with global coverage. Mobile operators also continue to invest in cellular IoT networks, delivering solutions that are scalable and standardized. They're also building ecosystems and open application platforms around these networks to foster partnerships which will be critical for development of IoT and predictive maintenance solutions. It all breeds confidence.

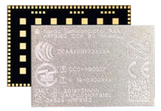
Moreover, in this connected age, malicious cyber actors have shown a willingness to disrupt cities by targeting critical infrastructure. Cellular is perhaps the most secure communications technology around. Says McKinsey of these low power cellular networks: "Ultra-low latency and strong security will create the confidence to run 'mission-critical' applications that demand absolute reliability and responsiveness—even in vital infrastructure systems and in matters of life and death."

But that's not enough by itself; connectivity devices that are secure-by-design are also vital. Nordic's nRF9160 SiP is one example; it makes use of Arm TrustZone's additional layers of security to provide high levels of protection.

A final tipping point for cellular IoT LPWANs has been the maturing of the specific low-power cellular technologies, LTE-M and NB-IoT. Global standards recognition of LTE-M and NB-IoT is no small thing. This recognition will spur their continued evolution, not to mention uptake. Global ICT company Ericsson predicts LTE-M and NB-IoT will comprise about 45 percent of cellular connections by 2026.

Choosing between LTE-M and NB-IoT depends on the application and coverage, says Amicucci. "LTE-M offers higher bandwidth and is designed for more complex devices. It suits the elevator use as well as predictive maintenance of complex industrial assets. That said, NB-IoT could suit the elevator use case when it is located in a deep indoor location beyond LTE-M signals' reach."

Amicucci notes that for predictive maintenance, the nRF9160 SiP's multimode support conveniently ensures industrial engineers can design solutions for both LTE-M and NB-IoT using the same component. He notes predictive maintenance will likely run on a dedicated specific comms module, while emergency calls services will be on different boards supported by, for example, LTE Cat1.



Tech Check

Nordic's nRF9160 is a low power cellular IoT SiP. The integrated modem supports both LTE-M and NB-IoT wireless connectivity. Arm TrustZone technology helps build solid and secure IoT applications that feature secure boot, trusted firmware updates and root of trust implementations without performance compromise

THE RELIABLE SMART CITY

Predictive maintenance has long been heralded the IoT's 'killer app'. It's easy to see why. Consulting firm McKinsey estimates predictive maintenance could reduce maintenance costs by 10-to-40 percent, equipment downtime by 50 percent and equipment capital investment by three to five percent by extending the useful life of machinery. The savings could translate to an economic impact of nearly $630 billion per year in 2025.

There are implications beyond the savings. Courtesy of predictive maintenance approaches, the green shoots of smarter, more livable cities may be starting to emerge.

In Japan, 34 million people ride the Yamanote Line around Tokyo each week. Trains leave every two minutes and run from early morning until late. Because breakdowns and *ad hoc* servicing won't suffice, the East Japan Railway Company is now using sensors and IoT technology to forecast failures and efficiently schedule maintenance.

Elsewhere, flights in and out of our major cities will soon again be the norm. But can an industry decimated by the pandemic afford to resume paying annual unplanned maintenance costs of $20 billion annually? A piece of the aforementioned savings of predictive maintenance may be essential for this vital global industry to revive.

Cities, which often own and run airports, can benefit too. Düsseldorf Airport is using cellular IoT paired with heavy-duty sensors to prevent fuel supply bottlenecks that could cripple flight schedules. Each day more than 120 heavy fuel trucks, each carrying 30,000 liters of jet fuel, travel along a critical access road. Averting erosion and damage is important, but preventative maintenance approaches can be disruptive. Using Deutsche Telekom's NB-IoT network to capture data on temperature, humidity and erosion from sensors in the road, maintenance crews now identify damage and schedule maintenance for the times when the trucks aren't rolling.

These are just some of the possibilities. But think of any critical service in the modern city—sewers, water tanks, bridges, ATMs, even vending machines and automated parking gates—and a maintenance revolution driven by sensors and cellular networks beckons.

The timing is just right. "Using sensor technology like this is not new," says Amicucci. "What is new now is the scale at which we can deploy these technologies, coming together with the emergence of low-power connectivity solutions to support our ambitions."

Wireless sensor-based predictive maintenance might also spur the uptake of infrastructure that's both more reliable and more environmentally sustainable. For example, Nordic's nRF9160 SiP is now supporting smart power grids, using sensors to monitor for issues such as fires or a power surge and relaying this data via the LTE-M/NB-IoT modem. (*See page 8.*)

Amicucci cites a further example: "Think about the emergence of electric vehicle charging stations – and you can see the role cellular IoT devices will play in safeguarding these and the health of other critical infrastructure in cities of the future," he says.

RELIABILITY AS A SERVICE

Beyond practical benefits and financial savings, the use of cellular IoT for equipment monitoring may open up a new commercial dynamic between the industry's suppliers and their customers.

Firstly, we might expect better relationships. The ability for suppliers to monitor equipment while in use creates a

> Through predictive maintenance, the goal of radically extended uptime for critical equipment like elevators may be within reach

Need to Know

LTE-M and NB-IoT are 3GPP standardized low power, wide area technologies designed for IoT applications and devices requiring low cost, long battery life, and ubiquitous coverage. Both technologies are formally recognized as 5G technologies, meaning investments in the technologies made by mobile operators will continue as part of the 5G roll out

Elevator ride: From form to function

"A sumptuous apartment ... with skylights, ventilators and chandeliers ... richly carpeted, with a large mirror and luxurious sofas around three sides. The sides and the domes overhead are finished throughout with panels, pilasters, brackets, carvings and moldings in richly variegated colors of bird's-eye maple, French walnut, tulip wood and ebony, lighted up with chaste and appropriate touches of gilding." It reads like a snippet from a magazine about luxury homes. In fact, this was the description of an elevator from an 1860s product catalogue.

Also known as 'sky parlors', elevators were markedly different in style and purpose to today's people-movers. They were not about speed – unsurprising given they had steam-powered engines. Manufacturers instead appealed to luxury, crafting lush interiors and selling them to fancy hotels.

The elevator's remaking as an efficient vehicle predictably aligns to the rise of industrial America. In the 1870s, New York boasted the first office building to feature elevators in its design – a milestone for a city that would become the home of skyscrapers.

The shift of elevators to commercial buildings brought demands for speed, reliability and easy maintenance. Innovations followed. In 1878, Otis introduced a hydraulic elevator. In 1880, Siemens came out with the first electric model.

Such developments continued the elevator's long history of evolution. The very first elevator, created in ancient Greece by Archimedes around 236 BC, was operated by men using ropes wrapped around a drum. Since then, they've been powered by slaves, animals, gravity, steam and electricity.

Today technology drives development as manufacturers compete for the tallest, fastest and safest elevator. Newer models use magnetic levitation instead of cables and pulleys. Computerization also features, as connectivity and data analytics deliver a more intuitive and intelligent service.

But as clinical as they are now becoming, the elevator's evolution alongside that of modern society ensures they remain tightly bound to the human story. From reflecting our own superstitions (no number 13 button) to a firm place in pop culture (countless elevator scenes in movies), elevators may always hold a special place in our hearts.

feedback loop for continuous improvement in equipment design and more tailored services. Customers get better products and suppliers can extract greater value from those products.

More profound is a shift in the very nature of the solution. With access to data on the use and performance of equipment, suppliers are sensing an opportunity to shift from selling equipment as a product to selling equipment 'as-a-service'. Picture elevator companies selling a number of elevator trips rather than elevators themselves, or transit companies selling rail miles traveled rather than rail cars.

For customers, this new business model converts large up-front capital expenditures into a 'pay-as-you-go' operating expense. Further, payments can be contractually linked to the meeting of performance metrics such as uptime, availability and efficiency.

For suppliers, the as-a-service model delivers stickier relationships, by focusing on better customer experiences. This creates "a more intimate tie with customers that competitors would find difficult to disrupt," says Mckinsey. Servicing is also more lucrative – in the elevator business, maintenance provides profit margins of up to 25 percent, compared with sales margins of five to 10 percent, according to *The Wall Street Journal*.

Shifting to these new models won't be easy. While the benefits are clear, McKinsey observes that connectivity solutions and predictive maintenance will require: "Technical skills and an organization that is prepared to embrace data-driven decision making".

Some say manufacturing and engineering companies may need to re-invent themselves as technology service providers. That may be overstating it. What does seem true for these solutions to flourish is strong collaboration across manufacturers, network operators, technology service providers, data analytics companies and others.

Ironically, there may be a silver lining to COVID-19. The pandemic shattered conventional molds for businesses, industries and economies. Those that survive have done so by being adaptable, resilient and determined, but perhaps more importantly, open to new ideas and collaborations.

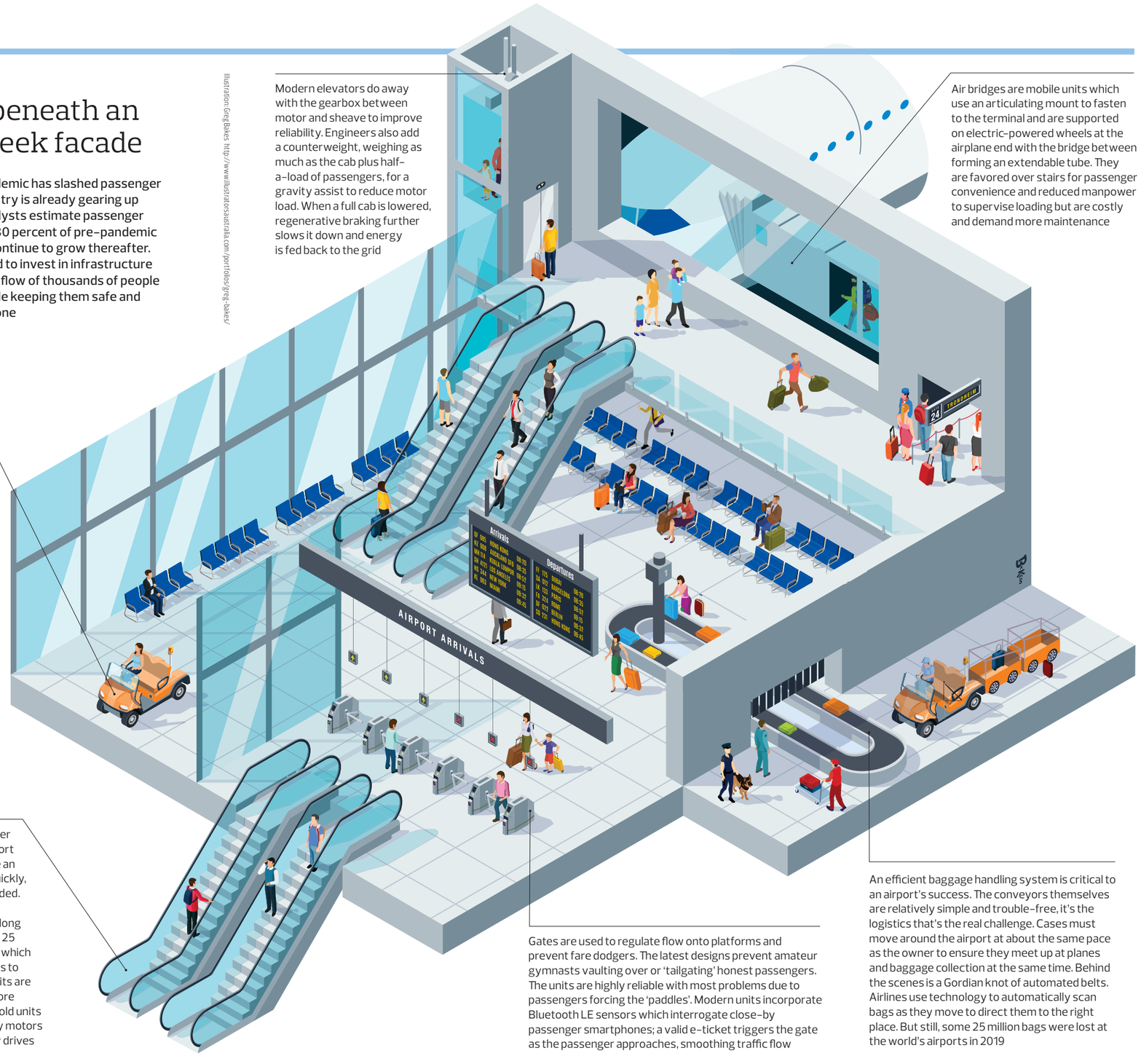
This may be exactly the spirit required to finally realize the dream of smarter, reliable and sustainable cities.

> The ability for suppliers to monitor equipment while in use creates a feedback loop for continuous improvement in equipment design and more tailored services

Tech Check:
What lies beneath an airport's sleek facade

While the COVID-19 pandemic has slashed passenger numbers the airline industry is already gearing up for a brighter future. Analysts estimate passenger numbers will recover to 80 percent of pre-pandemic levels by mid 2022 and continue to grow thereafter. That means airports need to invest in infrastructure to smooth and speed the flow of thousands of people through the terminal while keeping them safe and secure. Here's how it's done

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



Modern elevators do away with the gearbox between motor and sheave to improve reliability. Engineers also add a counterweight, weighing as much as the cab plus half-a-load of passengers, for a gravity assist to reduce motor load. When a full cab is lowered, regenerative braking further slows it down and energy is fed back to the grid

Air bridges are mobile units which use an articulating mount to fasten to the terminal and are supported on electric-powered wheels at the airplane end with the bridge between forming an extendable tube. They are favored over stairs for passenger convenience and reduced manpower to supervise loading but are costly and demand more maintenance

Airports invest in electric carts to move less able passengers around. Modern units can travel up to 80 km on a single charge, enough for a busy day at the largest terminal. The MotoEV 6, for example, boasts a 5.3 kW motor, enough for it to propel six passengers and a wheelchair around in style. While hardly needed, when fully loaded the MotoEV 6 can still climb a 20 percent grade or hum along at 40 km/h

An escalator is much better at moving passengers short distances because, unlike an elevator cab which fills quickly, it can be continuously loaded. Preventive maintenance sees escalators work for long periods, sometimes up to 25 years between upgrades which then take 10-to-20 weeks to complete. Modernized units are as much as 30 percent more energy efficient than the old units due to premium efficiency motors and adjustable frequency drives

Gates are used to regulate flow onto platforms and prevent fare dodgers. The latest designs prevent amateur gymnasts vaulting over or 'tailgating' honest passengers. The units are highly reliable with most problems due to passengers forcing the 'paddles'. Modern units incorporate Bluetooth LE sensors which interrogate close-by passenger smartphones; a valid e-ticket triggers the gate as the passenger approaches, smoothing traffic flow

An efficient baggage handling system is critical to an airport's success. The conveyors themselves are relatively simple and trouble-free, it's the logistics that's the real challenge. Cases must move around the airport at about the same pace as the owner to ensure they meet up at planes and baggage collection at the same time. Behind the scenes is a Gordian knot of automated belts. Airlines use technology to automatically scan bags as they move to direct them to the right place. But still, some 25 million bags were lost at the world's airports in 2019

On the Level

Cellular IoT and short range wireless tech is helping farmers, fleet managers and consumers monitor tank levels to prevent disruptive shortages

Europe's largest farm is an arable holding in Romania which at 570 square kilometers is roughly the same size as Singapore. Impressive certainly, but there's big and then there's enormous. The five largest farms in the world are located in China and Australia and between them cover 190,000 square kilometers, dwarfing their European counterparts. The largest, the Mudanjiang City Mega Farm in Heilongjiang, China, sprawls across 90,000 square kilometers and is home to some 100,000 dairy cows. To drive from one end of the farm to the other and back again would take 12 hours, which, despite the time of day dairy farmers rise, would leave little time for work.

Even for farmers managing more modest landholdings, scale can be the enemy of productivity. Every farm needs water and fuel, and depending on the type of operation, feed and fertilizer too. Whether generated on site or delivered, these consumables require storage in tanks and silos to ensure their availability year round. Running out of fuel, feed or water is not an option, so knowing precisely what stores you have at any given time is essential. But checking tank levels in multiple silos in person is a time consuming—not to mention potentially hazardous—exercise, even on a relatively small farm, let alone one on the scale of the appropriately-named Mudanjiang City Mega Farm. Previously the property manager would have to drive long distances to physically inspect each tank, in some cases putting themselves at risk by climbing high silos to inspect the contents from above. Now, thanks to wireless technology, things are changing and the ability to monitor tank levels remotely is opening new possibilities.

U.S.-based CoreKinect last year introduced a farm storage tank level monitor and asset tracker that it says completely eliminates the problem of farms running out of fuel or fertilizer. The CoreKinect TankTrack is a battery-powered wireless gauge reader that can be securely attached to any ammonia, propane or diesel storage tank using four permanent magnets. Both tank level and GPS location readings are sent via Nordic Semiconductor nRF9160-powered LTE-M cellular connectivity to a Cloud platform accessible from any smartphone, tablet or computer, allowing farmers to remotely ensure they don't run short of fertilizer or fuel essential for heating.

"These farms are huge and there's no way a farmer is going out to check on ten tanks each day unless they're working nearby," says Ali Kozlica, Executive Chairman at CoreKinect. "While this problem is nothing new in farming, before the advent of cellular IoT technology a commercially viable way to remotely monitor levels in fuel storage tanks simply did not exist.

"Lack of coverage and power requirements made such a solution cost prohibitive. With cellular IoT, all the major barriers are broken and the rules have changed. If you can eliminate just one unnecessary visit to a tank it pays for the entire cost of the solution."

In Short

Farms the size of countries and pan-continental trucking operators are turning to wireless technology to help them remotely monitor fuel levels

Running out of fuel and fuel theft is a multi-billion dollar problem that can be eliminated through the use of both cellular IoT and Bluetooth LE technology

Household users account for almost half of annual propane consumption and are driving the development of solutions that enable domestic wireless tank monitoring

DRIVING CHANGE

It's not only farmers reaping the benefits of wireless tank monitoring solutions. According to U.K.-based roadside assistance group, Green Flag, 70,000 U.K. motorists run out of fuel on the road each month. Despite the presence of a fuel gauge, warning lights and the digital display telling us we have 20 kilometers left in the tank, tens of thousands of us ignore the visual cues, including the signs on the motorway saying 'last fuel for 50 kilometers', and push on, taking pride in rolling into the next gas station with nothing but fumes in the tank. But while wireless technology probably can't save the public from itself, it is proving a valuable tool for remote fuel monitoring for both fleet managers and pan-continental logistics companies.

Fuel costs can amount to as much as one third of all fleet operating expenses, so to increase efficiency and cut costs, knowing exactly how much fuel is going into each tank in the fleet, and how much is coming out and when, is information worth knowing. Live access to this data enables management to reduce operating costs by optimizing routes, monitor potential causes of anomalous fuel consumption and assess potential breaches of protocol by drivers – not least the increasing problem of fuel theft.

Stealing fuel is one of the biggest problems faced by the trucking industry. How big is difficult to determine but according to an Australian fuel card comparison website, $10 billion worth of diesel is stolen each year at an average weekly loss of $125 per vehicle. Operate a fleet of 100 semi-trailers and that adds up to a potential $650,000 loss every year. The tricks of the trade are well known, usually involving either fuel siphoning or 'skimming', using the company fuel card to purchase fuel for other vehicles or to sell on for profit. "The biggest problem we see is not theft of the whole tank of fuel, but skimming, where 20-50 gallons [75-190 liters] are stolen in just a few minutes," says David Rogers, General Manager of FuelDefend Global, a company specializing in anti-fuel theft solutions. "Unfortunately, these incidents often go unnoticed by the fleet or owner-operator because quantities are small ... maybe 2-to-4 percent of fuel consumption. It's significant, but perhaps not enough to alert them to a theft problem."

Traditionally this crime has been difficult to detect as many factors can affect fuel consumption—road conditions, wind, driving habits and mechanical faults for example—but now technology is catching up with the thieves. Wireless, remote fuel monitoring systems can now ensure all purchased fuel was put in the tank, and identify where, when and how much fuel was drained from a vehicle, even providing live notifications should fuel levels drop beyond expected levels. Detailed fuel level and fuel consumption reports can document amounts at trip-start and -end, total fuel consumed, average fuel consumption as well as refueling and fuel draining events, putting managers back in control of their fleets.

One company pioneering such solutions is Escort Group, one of Russia's leading manufacturers of M2M and IoT equipment, who recently launched its Escort TD-BLE fuel level sensor claimed to be the world's first wireless capacitive fuel level sensor integrating Bluetooth LE technology. Primarily designed for the transport telematics market, once installed to a vehicle the device employs Nordic's nRF52832 SoC to wirelessly send the collected fuel level data to a Bluetooth LE- and GPS-enabled

Escort TD-BLE is the world's first wireless capacitive fuel level sensor integrating Bluetooth LE technology

Mopeka's Pro Check Sensor mounts underneath a cylinder and uses ultrasound to inform the user how much fuel is left

tracking device. Once the data is transmitted from the fuel level sensor to the tracker, it can then be transferred to the Cloud—typically via the GSM channel, or in rare cases via satellite—where the detailed information and insights can be viewed through a web-based dashboard by fleet management.

The Escort TD-BLE fuel level sensor also offers 'black box' functionality, collecting information on fuel levels or fuel 'events' that are then stored in the Nordic SoC's memory for 30 days, overcoming any deliberate attempts to disrupt data transmission. "It's not uncommon for heavy-duty drivers to intentionally jam the tracker's signal ... in doing so the tracker loses its connection to the fuel level sensor, and the satellite control system receives no information about fuel consumption," says Anton Turkin, CEO of Escort Group. "Drivers can continue jamming the signal and drain the fuel during this time [but] thanks to the fact that TD-BLE collects and stores data regardless ... you can always recover information about fuel events, no matter what happens earlier on the road."

KEEPING HOME FIRES BURNING

While commercial instances of fuel tank monitoring solutions are gaining plenty of attention, domestic applications are equally prevalent. Many rural homeowners who do not have access to natural gas pipelines rely on bottled propane for space heating, water heating and clothes drying, and according to the World LPG Association, household use of liquefied petroleum gas (LPG) accounts for approximately 44 percent of global propane consumption.

In the United States, 47 million households use propane to fuel an outdoor gas grill, while restaurants and caterers use propane for cooking and warming food, and also to fuel patio heaters for outdoor seating areas in cold climates. Because of its portability, propane is also popular with campers and RV owners to power appliances. According to University of Wisconsin-

Stevens Point research, approximately 70 million liters of propane are exhausted in domestic applications every day, providing a sizeable consumer market for tank level monitoring solutions that ensure fuel availability when it is needed.

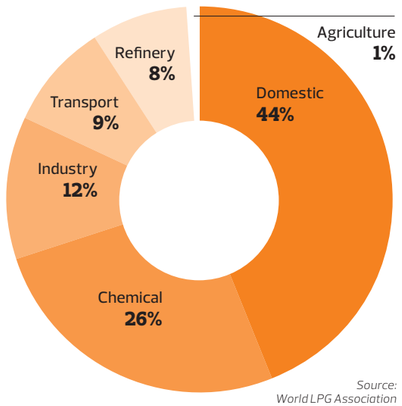
Mopeka Products, a developer of tank and cylinder management platforms, is one company that has built its business on meeting demand for such solutions, offering a range of wireless monitoring technology for propane, as well as water, heating oil, chemical and beverage tanks. For example, the company's Pro Check Sensor—a propane tank level sensor that mounts magnetically underneath a tank or cylinder—employs a combination of Bluetooth LE and ultrasound technology to let users know exactly how much fuel is remaining in their tank, rather than them relying on guesswork. The sensor employs the integrated Nordic nRF52810 Bluetooth LE SoC's Arm Cortex processor to measure the time of flight of ultrasound waves in the propane and then uses that information to calculate the fuel level in the tank.

CoreKinect TankTrack is attached to any storage tank with tank level and GPS location readings sent via LTE-M to a Cloud platform and enables farmers to remotely monitor levels in fuel storage tanks

State of Play

LPG and where it goes

First produced in 1912, propane has since found many uses in the home, industry, for transportation and on farms. Also known as 'bottled gas', propane is a colorless hydrocarbon that exists in both gaseous and liquid form. In its natural form propane is odorless, so a foul-smelling scent is added to alert users about leaks. Globally, the top five consumers of LPG are the U.S., China, Saudi Arabia, Japan and India. Nearly two percent of U.S. energy needs are supplied by LPG. Like natural gas, propane is one of the cleanest burning fossil fuel products, releasing negligible emissions



Source: World LPG Association Annual Report 2016

Using the Bluetooth LE wireless connectivity provided by the Nordic SoC, the fuel level data is relayed to a companion app on the user's smartphone or tablet, where they can view fuel level readings as well as set threshold alarms if the level is low, reminding them to refill the tank well before it's exhausted. A proprietary Wi-Fi bridge also allows the user to read the tank or cylinder level information remotely.

ANSWERING INDUSTRY'S CALL

Beyond the farm, fleet or family, remote level monitoring solutions are also proving valuable in a range of industrial applications. Wastewater, chemical and petrochemical, and mining industries all require intermittent observation of fluids to ensure tanks don't run out or overflow, and that the fluid is being drawn from the tank in line with expected usage. Overfills result in material and production loss or potential environmental damage, while running out of materials delays production and delivery too. Establishing a network of wired sensors around complex industrial facilities may require expensive and time consuming trenching of thousands of meters of cables that not only disrupts production but lacks flexibility should tanks require moving or if additional sensors need to be added to a network in the future. As such, wireless solutions are becoming a popular alternative.

"Wireless connectivity is flexible, cost-effective and much less hassle to deploy," says Alf Helge Omre, a Business Development Manager with Nordic. "With a long range and power efficient solution like cellular IoT, you can easily connect hard-to-reach assets using sensors operating on independent batteries that can last for years. What's more, when the required data rate is anything more than occasional, using the cellular network is easily the most economical solution."

Wireless tank monitoring solutions that provide complete insight into far-flung assets allow farmers, fleet managers and industrial operations to make informed decisions, reduce costs, and enhance operational efficiency and safety. Householders can also sleep easy, safe in the knowledge wireless tech is on hand to ensure the tanks that fuel our cars, grills and heating are always being watched.

> Before the advent of cellular IoT technology a commercially viable way to remotely monitor levels in fuel storage tanks simply did not exist

Tech Check

The nRF9160's modem and application processor were engineered for optimized power performance in IoT systems, enabling tank monitors to stay connected to a cellular network with unparalleled low power consumption, critical for sensors in remote locations where frequent battery changes are impractical

Keeping superjumbos stable

If you've seen the burners extinguish on your grill in the middle of cooking the family lunch, you'll know running out of fuel is annoying. Thankfully, it's unlikely to be a matter of life or death, other than the danger posed by a half-cooked sausage. For commercial airlines it is another matter. Certified to carry up to 853 passengers the Airbus A380 is the world's largest passenger airliner. Its four turbofan engines provide a range of almost 15,000 kilometers when fully fueled, but there it gets complicated.

The maximum take-off weight of an A380—depending on the airline—is around 569,000 kilograms, of which almost half of the weight is taken up by jet fuel. This fuel is for the most part stored in the aircraft's wings, but because the A380 employs a 'swept wing' design (where the wings point backwards at an angle of 33.5 degrees from the fuselage), the aircraft's center of gravity constantly shifts as the fuel is used. All planes have an optimum center of gravity to ensure stability, and to maintain this optimal balance point on the A380, a fuel tank in the horizontal stabilizer wing at the rear of the aircraft constantly transfers fuel to the other wing tanks. Each wing has five main tanks, including a feed tank on each side of the aircraft to supply fuel directly to the engines. The other tanks are for storage, releasing fuel to the feed tanks as required.

Moving 280,000 kilograms of fuel around an A380, to maintain the optimum center of gravity and ensure aircraft stability is completely automatic, is achieved using a network of pipes and valves known as 'galleries'. Shortly after take-off, fuel is transferred from the inner or midwing tanks to the outer tanks to reduce upward bending of the wing, after which the sequence of fuel transfer begins. The feed tanks are supplied by the inner tanks, followed by the mid tanks, then the trim tank, and finally the outer tanks when all the others are empty. The fuel transfer system keeps the fuel level in the feed tanks at the same level—give or take 1000 kilograms—to maintain the optimum center of gravity, until the trim tank in the horizontal stabilizer wing has been emptied.

With over 20 fuel pumps performing the complex procedure it is just as well the system is automated - but it wasn't always so. When the supersonic Concorde was still operational, the flight engineer had to execute all fuel transfer by manual switch and pump selection during the three hour transatlantic flight.

This Way Up

Asset trackers are already moving beyond location monitoring. The next generation of solutions include sensors to ensure fragile cargoes are well looked after

The roll-out of COVID-19 vaccines—apart from promising a return to normality—is proving a valuable stress test for the world's logistics systems.

While Russia, China and other countries are now immunizing their populations with locally-developed vaccines, many parts of the developed world have turned to messenger RNA (mRNA) vaccine products from U.S. companies Pfizer and Moderna. Each firm is ramping up production and distribution to meet an unprecedented demand. According to the International Air Transport Association (IATA) no less than the equivalent of 8,000 Boeing 747's is needed to shift the vials for just the first phase of delivery. And that's just the beginning – to protect the world's health, tens of billions of delicate doses need to be frozen and transported to every part of the globe. (*See sidebar pg29 A chilly Cargo: COVID-19 vaccine logistics.*)

To ensure timely delivery, safe handling and the correct cold-chain regime, logistics companies are increasingly turning to wireless technology.

COMBINING WIRELESS TECHNOLOGIES

Tracking and monitoring products based on Bluetooth LE—a mature and reliable technology for wireless sensors—offer a good solution for overseeing COVID-19 vaccine cold chains as well as many other industrial asset tracking applications.

Bluetooth LE wireless devices equipped with thermocouples and accelerometers can be placed in cold boxes and refrigerated containers to monitor and record temperatures and impacts. Because the sensors are relatively inexpensive, a monitoring device can be dedicated to each box. Bluetooth LE tech's smartphone interoperability allows the manufacturer to offer sensor configuration and monitoring from a mobile app. Impact and temperature excursions can be flagged and, for audit purposes, the data recorded during the delivery's entire trip from drug maker to healthcare provider can be downloaded to the smartphone (or other gateway device) and from there to the Cloud.

Bluetooth LE vaccine tracking does have limitations. For example, data can't be sent directly to the Cloud. "Cellular IoT overcomes that challenge," explains Geir Langeland, Nordic Semiconductor's Director of Sales & Marketing. "It completes what was a missing link for the IoT."

Cellular IoT is available in two versions, LTE-M (which is more suited to assets on the move) and NB-IoT (which is better for applications that demand the longest battery life). Together with direct Cloud connectivity, cellular IoT offers long battery life, kilometer range, reliability, quality of service (QoS), scalability and security.

By the Numbers

1.3 billion
doses of Pfizer COVID-19 vaccine for distribution in 2021
Source: Scientific American

500 million
to 1 billion doses of Moderna COVID-19 vaccine for distribution in 2021
Source: Scientific American

6 billion
Bluetooth chips forecast to be shipped in 2024
Source: Bluetooth SIG

Over **154** NB-IoT or LTE-M networks, managed by 123 operators in 59 countries, deployed by end 2020
Source: Global Semiconductor Alliance

Like Bluetooth LE, cellular IoT is on a rapid growth path. Introduced in 2016, the LTE-M and NB-IoT specifications have encouraged a multivendor ecosystem delivering chipsets enabling device makers to build wireless products that take advantage of this low power form of cellular.

Cellular IoT and Bluetooth LE are not interoperable, so cellular IoT monitoring solutions often include a Bluetooth LE SoC to communicate with the cargo monitoring network and which then passes on sensor information to the cellular IoT SiP via a wired connection.

Cellular IoT products tend to be relatively more expensive and use more battery power when operating than Bluetooth LE sensors, so a common strategy is to use one cellular device as a gateway to the Cloud servicing multiple sensors.

During transmission, the cellular device runs at a relatively high power consumption and there is a cost associated with data transfer across a cellular network. To minimize power and cost, the device's operation is typically limited to transmitting only when the conditions being monitored move outside set thresholds, or when it is remotely triggered for an update. Cellular IoT solutions have powerful processors for a degree of edge-processing and good Flash memory capacity allowing for long-term data storage when the device is in areas of sparse cellular coverage and can't upload data to the Cloud.

HELP FOR DEVELOPERS

Designing a cargo monitoring product that combines short-range wireless with cellular IoT is a tough engineering task. But prototyping platforms such as Nordic Semiconductor's Nordic Thingy:91 point the way. The Thingy:91 combines Nordic's nRF9160 low power SiP with integrated LTE-M/NB-IoT modem and GPS with the nRF52840 high-end Bluetooth 5.2 SoC. The product features an LTE-M, NB-IoT and GPS antenna connected to the nRF9160, and two antennas connected to the nRF52840 – one for Bluetooth LE and another for NFC.

The nRF9160 features a dedicated application processor and a multimode LTE-M and NB-IoT modem. The modem supports the eDRX and PSM power saving modes to extend battery life and includes assisted GPS.

Nordic designed the Thingy:91 to aid the rapid development of prototypes for cellular IoT systems such as asset tracking and environmental monitoring. The product includes sensors to gather data about movement, temperature, humidity, air quality, air pressure, color and light intensity. For rapid product development, the Thingy:91's standard application firmware extracts data from the onboard sensors and relays it securely to Nordic's

nRF Connect for Cloud, where the information can be displayed on an intuitive interface. The Thingy:91's cellular IoT communication can be interleaved elegantly with GPS positioning acquisition making it perfect for precision location and monitoring of valuable cargoes.

Nordic is not alone in offering developers combined short range wireless and cellular IoT tracking solutions. For example, Finnish firm, Ruuvi Innovations, has developed a product called the Ruuvi Node based on Nordic's nRF9160 and nRF52840.

The product houses a full range of environmental sensors, GPS positioning and NFC for securely reading device IDs and uploading configuration parameters.

The device can be used as an environmental sensing and asset tracking solution combining cellular IoT connectivity, GPS and NFC. But more than that, because the product includes a Nordic wireless SoC, it can operate as an IoT gateway for any nearby Bluetooth sensor beacons.

A third example of a reference design for wireless asset tracking solutions is Ericsson's ARDESCO – co-developed with Lund, Sweden-based connected solutions design firm, Sigma Connectivity. ARDESCO is offered to help enterprises developing cellular IoT solutions not only simplify and accelerate the design process and reduce development costs, but also efficiently deploy and manage devices over their complete life cycle.

The product again employs Nordic's nRF9160 SiP and nRF52840 SoC to provide LTE-M/NB-IoT and Bluetooth LE connectivity for a wide range of IoT designs. ARDESCO integrates an accelerometer as well as temperature, humidity, air quality, air pressure and light sensors.

"The ability to monitor and control 'things' independently of location or environment is a key asset of cellular IoT," notes Christian Johnsson, a Business Developer with Sigma Connectivity. It seems the technology has matured at an opportune moment – just when the world is relying on the efficient and safe delivery of the vaccines that could see an end to the pandemic.

Tech Check

ARDESCO is provided in a 45 by 80 by 12.7 mm form factor. The reference design is powered by a 1250 mAh battery, optimized for extended battery life thanks in part to the low power capabilities of Nordic's nRF9160 SiP. The nRF9160 supports PSM and eDRX power saving modes to keep current consumption low. For example, in PSM mode, uploading 1 KB every 12 hours, the average current is just 5.5 µA

A Chilly Cargo: COVID-19 vaccine logistics

The numbers are daunting, but that's just the beginning; the logistics challenge in moving vaccines around the globe is made much harder because they don't travel well. The medicines are stored in glass vials, and while the packaging is designed to absorb some knocks there is only so much it can do. According to an article in *Scientific American* magazine, each Pfizer tray, for example, holds 195 vials, each containing five doses, and a box can hold up to five trays. If that single box is dropped, nearly 5000 people will have to wait longer for protection from SARS-CoV-2, the virus that causes COVID-19.

In addition to their fragility, vaccines also need to be stored and shipped at low temperatures; Moderna's messenger RNA (mRNA) vaccine, for example, has to be kept at -20˚C. For the equivalent Pfizer vaccine, the storage temperature is a numbing -70˚C. Pfizer is using specially designed, temperature-controlled thermal shippers comprising an inner container holding the 5000 doses which is then slipped into an outer container. The space between the two containers is packed with dry ice to keep things cool and then the box is sealed with an insulated lid. Each container can maintain the recommended storage temperature for up to ten days if unopened. Every container houses a wireless temperature monitor and GPS locator.

Once thawed and kept in a refrigerator at between 2 and 8˚C, the Moderna vaccine can be used for up to 30 days. After the Pfizer vaccine is transferred to a refrigerator, it must be administered within five days or be discarded. If either vaccine is exposed to elevated temperatures at any part of the supply chain, even if quickly refrozen, they become ineffective. The reason is because the mRNA at the heart of the vaccines is very fragile and can easily be broken down by ever-present enzymes. Once the RNA strands are broken, the vaccine won't work, because the body doesn't recognize the RNA as part of the SARS-CoV-2 virus and therefore no protective immune reaction will occur. Low temperatures dramatically slow down the damaging enzyme reactions, in the same way that freezing food stops it spoiling.

Wearables

ArcX

This Bluetooth LE smart ring enables remote control of music and phone calls for people on the move

According to a 2019 survey by business news website, *The Manifest*, 56 percent of the population of the U.S.—approximately 183 million people—now own a connected wearable. The sophistication of these devices is also increasing, and the market is expected to grow to $27 billion by 2022

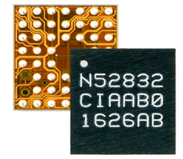
According to clinical research, music may exert an ergogenic (enhancing physical performance) and distractive effect during exercise. Music distracts people from pain and fatigue, elevates mood, increases endurance, reduces perceived effort and may even promote metabolic efficiency. When listening to music, people run further, bike longer and swim faster than usual – often without realizing it

The ArcX smart ring is designed to be worn on the index finger and, via its thumb-controlled micro-joystick, allows users engaged in sporting activities to remotely control a range of smartphone functions – for example shuffling music playlists, measuring split times or accepting incoming calls

While smart rings and other wearables are a relatively new innovation, the ring itself has been around a little longer. The oldest known examples are approximately 4500 years old and come from the Indus Valley in northwestern South Asia, home to a Bronze Age civilization from the third millennium BC

While exercise has increased in popularity since the fitness boom of the 1980s, the energy we expend during physical activity today is estimated to still only be a third of that of our ancestors living during the Paleolithic period. By walking long distances interspersed by high intensity animal stalking, hunter-gatherers effectively engaged in interval training, while lifting stones to build shelters, for example, was a primitive form of resistance training that promoted high levels of muscular fitness

The IP67-rated waterproof and shockproof device is supplied in a range of ring sizes, as well as a watch-strap form factor, enabling it to be worn either on the person, or attached to a handlebar, paddle or other piece of sports equipment. Using the nRF52832 SoC's wireless connectivity it can also connect with any other Bluetooth-enabled device, for example to act as a 'hands-free' controller for sports cameras or wireless speakers



Tech Check

Powered by a customized, rechargeable Li-Poly battery, ArcX provides a minimum of five days usage time between recharge thanks in part to the ultra low power characteristics of the Nordic SoC. The nRF52832 has been engineered to minimize power consumption, with features such as the 2.4GHz radio's 5.3/5.4 mA peak RX/TX currents and a fully-automatic power management system

Wearables

‘World’s most advanced’ personal tracker combines cellular IoT, GPS and Bluetooth LE

Supported by multiple Nordic Semiconductor wireless technologies, the AirBolt GPS asset tracker monitors valuable items from anywhere in the world

Keeping track of valuables like keys, bags, wallets, pets and even vehicles is an everyday task. But things get harder when you’re on the move because you also have to worry about leaving important items behind or having them stolen. Locks can help, but then you’ve got to keep track of the keys or remember lock combination numbers.

Recognizing that these solutions are yesterday’s technology, Melbourne, Australia–based company, AirBolt, started business in 2014 with a mission to help people overcome the frustration of using outdated products to protect their luggage and other valuables for stress-free travel. Following the initial successful release of a smart travel lock, the company recently took another step forward with the development of its AirBolt GPS, which it claims is the world’s most advanced personal tracker.

The lightweight and waterproof asset tracker is designed to monitor valuable assets across various locations including airports, train stations, gyms, entertainment venues and workplaces. The user simply attaches the AirBolt GPS to an item and tracks it from anywhere through the AirBolt App on their smartphone.

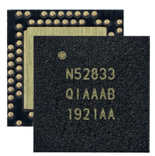
By combining low power LTE-M/NB-IoT cellular connectivity and assisted GPS alongside Bluetooth LE wireless technology, AirBolt offers both precise localized- and global-asset tracking functionality. One notable advantage of AirBolt’s solution, the company claims, is that the asset tracker provides up to one year of active tracking with global coverage on a single battery charge. While competitive solutions make similar claims, AirBolt says in reality most are either inconveniently large or can only deliver on their battery life promises when in standby mode.

For loss and theft prevention, AirBolt GPS uses geofencing technology and proximity/separation alerts to warn the user if someone tries to walk away with their valuables. Users can also grant live GPS tracking access to anyone from anywhere in the world, with various levels of permissions and security. And if it’s dark or the user’s possessions are hidden from plain sight, AirBolt GPS includes an LED status indicator and loud buzzer to help find misplaced items.

AirBolt GPS comes in a 37 by 37 by 16 mm form factor, making it the world’s smallest GPS, LTE-M and NB-IoT tracker, says the company. But despite the compact size, AirBolt GPS is far from a one-trick tracking device. The product employs multiple embedded sensors including a three-axis MEMS accelerometer for free-fall and motion detection, and a temperature sensor for remote monitoring of the environment, particularly in temperature-sensitive setups. The integrated LTE-M connectivity can then be used to send this information back to the user. “All the sensors allow us to use AirBolt GPS as a multifaceted product; we can use the technology to alert users about movement and falling objects or people,” says Mr. Kabir, CEO and Founder of AirBolt.

“For example, one of our partners deploys platforms exposed to extreme weather, so they came to us looking for a solution that can not only track their platforms but also alert them of platform movement or falls [due to high winds].”

AirBolt GPS also serves as a gateway to connect AirBolt’s range of Nordic-powered secure access and remote asset management products, such as its patented smart travel lock. This means users can remotely track their luggage or monitor and locate many other valuables. For example, if a user’s AirBolt Lock is near the AirBolt GPS and is opened without the user being around (whether by Transportation Security Administration or an unknown party), the lock will inform the tracker which will in turn alert the user. Alternatively, the solution can be used for enterprise level large-scale asset tracking deployments, enabling companies to secure and remotely monitor critical equipment.



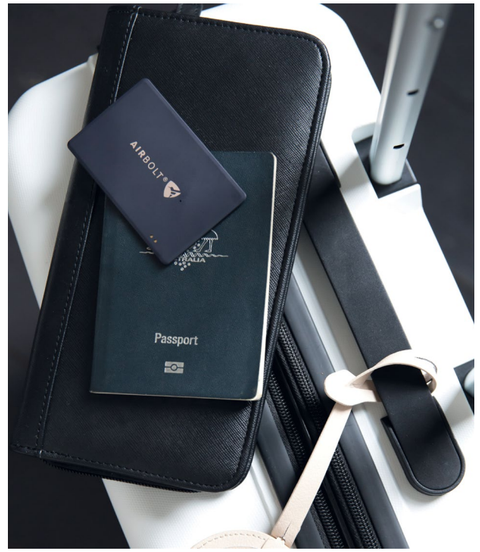
Tech Check

The nRF52833 is a multiprotocol SoC with a Bluetooth Direction Finding capable radio, qualified for operation at an extended temperature range of -40 to 105 °C. A generous memory allocation and dynamic multiprotocol support ensures the nRF52833 is an ideal device for commercial and industrial applications, including asset tracking and professional lighting

Combined connectivity

AirBolt GPS integrates two powerful and complementary Nordic solutions—the nRF9160 SiP, which combines cellular network location data with GPS trilateration for precise position monitoring, and the nRF52833 Bluetooth LE SoC with Bluetooth Direction Finding, for support of 2 and 3D indoor location services, as well as wireless connectivity between multiple AirBolt products and the associated smartphone app. Nordic’s cellular IoT SiP is certified for global cellular IoT applications and is designed for low power consumption.

> We selected cellular IoT because we wanted our application to feature reliable connectivity with a high radio link budget



The nRF9160 provides multimode LTE-M/NB-IoT capabilities in the same solution. The LTE-M version of cellular IoT is ideal for tracking moving objects in outdoor environments, while NB-IoT provides leading low power consumption, and good penetration into buildings.

For example, the integrated LTE-M modem provides a total link budget of 131 dBm, enabling the AirBolt GPS or any other asset tracking device to reliably transfer data over a long range.

The solution’s 350 mAh Li-Ion battery and other built-in power-management components provide the AirBolt GPS with its “best-in-class” 12-month battery life – a highly beneficial feature for an asset tracker used in settings and situations where regular recharging is often unavailable. The extended battery life makes the AirBolt GPS an “absolute game changer for the industry,” says Mr. Kabir.

“We selected cellular IoT over other LPWAN technologies to provide the connectivity for AirBolt GPS because we wanted our application to feature reliable connectivity with high link budget and no limitations of payload size.”

Jan Willem Smeenk
Chief Architect, SODAQ

Cellular IoT-based asset tracking ready to soar

Logistics is proving a key driver for mainstream adoption of cellular IoT, but there are still hurdles to overcome

The adoption of cellular IoT technology for asset tracking solutions has only just started. The solutions are out there, but the existing connectivity business model has been blocking growth as many of the telcos have been stuck in old school thinking when it comes to their pricing models and the IoT.

The business case for using cellular IoT for asset tracking is easy to prove. If you see how many drivers there are to earn money in logistics when you know where your assets are at what time, then you will understand why big corporations in particular are seizing the opportunity now. But slowly everyone will be pushed towards acceptance. A couple of years from now the telcos will shut down the 2G and 3G networks and we will all discover how many sensors and devices are out there monitoring industrial applications that urgently require upgrading to the next generation of communications solutions. At SODAQ we call this the next millennium bug, one that will truly disrupt the industry and also trigger a breakthrough in IoT.

As the industry matures there will be a handful of companies on the hardware side and many players on the data side. Everyone is jumping on data – software companies, dashboard platforms, telcos, as well as firms involved with data analysis, AI and machine learning.

Some won’t survive but there will be plenty of winners because the potential market is huge. On the hardware side those few manufacturers who can truly produce in the hundreds of thousands or millions—and at the same time deliver quality at the right price—will prevail.

A battery-free future

As the IoT deploys at a massive scale, another problem the industry will need to overcome is the use of batteries. The growth in IoT devices will simply not sustain it. Not just because the process of creating batteries is bad for the environment, and charging them with traditional power is equally bad, but also the sheer number of batteries we would need simply cannot be produced by manufacturers. The answer lies on one hand in making our devices ready for alternative power sources such as solar and kinetic energy and by buffering the energy in supercapacitors, and on the other by making these devices less hungry for energy. This is something SODAQ is pioneering with the launch of our SODAQ TRACK SOLAR device which is the first solar-powered cellular IoT asset tracker that can operate perpetually on harvested solar energy alone.

> The business case for using cellular IoT for asset tracking is easy to prove

Another answer may be found in producing different types of batteries that are printed and only consist of natural materials.

SODAQ is in a consortium with companies such as Varta and Elmeric developing these solutions. In the near future these batteries will be rechargeable and biodegradable as well. This is where innovation and technology are meeting to tackle real world problems.

[Tech Zone]

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

Internet of Things

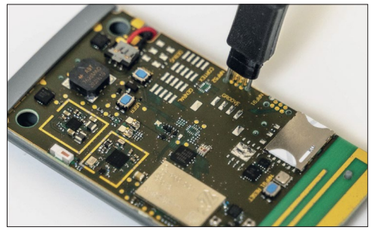
Cellular IoT reference design slashes costs

Sigma Connectivity has released a cellular IoT reference design to help enterprises not only simplify and accelerate the design process and reduce development costs, but also efficiently deploy and manage devices over their life cycle.

ARDESCO (Approved Reference Design for Ericsson and Sigma Connectivity) employs both Nordic's nRF9160 low power SiP with integrated LTE-M/NB-IoT modem and GPS in combination with the nRF52840 Bluetooth LE multiprotocol SoC, to provide a broad range of connectivity options for developers.

Suitable for logistics, environmental monitoring, metering and asset tracking applications, the design supports Ericsson's IoT Accelerator suite, providing Cloud-based connectivity and device management out-of-the-box. Developers also have access to hardware schematics, software development tools, software libraries and example code.

Designed for either indoor or outdoor use, ARDESCO is powered by a 1250 mAh battery and integrates an accelerometer as well as temperature, humidity, air quality, air pressure and light sensors. The inclusion of the nRF52840 SoC provides the capability to develop gateway solutions that can not only connect a short-range wireless network directly to the cellular network but also to a smartphone. The combination of the nRF9160's 64 MHz Arm Cortex-M33 dedicated application processor, and the nRF52840 SoC's Arm Cortex M4 processor provides ARDESCO with the processing power to comfortably handle even the most complex and processor-intensive applications.



"The main reason we chose to use the nRF9160 SiP and the nRF52840 SoC as part of the ARDESCO design was due to its versatility, low power consumption and security, which are all important aspects ... for cellular IoT," says Joakim Uddenfeldt, Technical Partner Manager with Ericsson.

nRF5340 enters volume production

Nordic's nRF5340 high-end multiprotocol SoC for complex IoT and LE Audio applications has entered volume production. The SoC introduces a new and flexible, dual-processor hardware architecture combining an application processor with a network processor.

For applications requiring a high level of security, the nRF5340 incorporates Arm CryptoCell-312, Arm TrustZone technology and Secure Key Storage.

The nRF5340 supports major RF protocols including Bluetooth 5.2/Bluetooth LE, Bluetooth mesh, Thread and Zigbee. In addition, the SoC has been designed to meet the requirements of LE Audio, enabling audio streaming over Bluetooth.

The nRF5340 can support Isochronous Channels, the Bluetooth 5.2 feature for audio streaming. LE Audio also introduces the Low Complexity Communications Codec (LC3), an audio compression codec that can run efficiently on the nRF5340. The audio data can be transferred to other parts of the system using the I2S and PDM audio interfaces, which employ the nRF5340's low-jitter audio PLL clock source.

Industrial IoT

Wireless access points enable multiprotocol network support

Beijing, China-based Waycloudshas launched two new wireless access points designed to equip smart buildings and offices with multiprotocol network support, while providing equipment access and management, video surveillance, AI image accelerated computing as well as other application services. The access points are said to significantly reduce the installation and maintenance costs of secure IoT deployments.

In addition to the Wi-Fi coverage capabilities provided by traditional wireless access points, the ceiling or wall mounted Wireless Access Point 300 Series (AP300) integrates Bluetooth LE, Zigbee and other IoT protocols for interconnecting smart devices. The product employs two Nordic nRF52833 SoCs with one acting as a dedicated Bluetooth LE gateway and the other as a Zigbee gateway to relay data from networks using either of the short-range wireless protocols to the Cloud. The Wireless Access Point 100 Series (AP100) incorporates a single Nordic nRF52833 SoC to provide Bluetooth LE or Zigbee connectivity. Both AP300 and AP100 also implement an infrared (IR) feature for IR connectivity.

Nordic's nRF52833 advanced multiprotocol SoC combines a 64 MHz, 32-bit Arm Cortex M4 processor with floating point unit, a 2.4 GHz multiprotocol radio (supporting Bluetooth 5.2, Bluetooth mesh, Bluetooth Direction Finding, 2 Mbps throughput, and Long Range plus Thread, Zigbee, IEEE 802.15.4 and proprietary 2.4 GHz RF protocol software) featuring -95 dBm RX sensitivity with 512 kB Flash memory and 128 kB RAM.

The Dynamic Multiprotocol feature uniquely supports concurrent wireless connectivity of the protocols.

Mesh network buildings automation platform launched

Finnish building automation specialist, Produal, has developed an advanced and flexible modular buildings measurement and control platform for measuring and controlling environmental parameters such as air quality, room temperature and humidity within buildings, using Bluetooth mesh networking.

Combining a Nordic Semiconductor nRF52832 SoC-based NINA-B1 Bluetooth LE module from u-blox and patented MiraOS mesh stack and embedded OS firmware from Sweden-based LumenRadio, the Produal Proxima platform supports up to 100 battery-powered wireless nodes under a single gateway with no need for signal-boosting wireless repeaters. The gateway securely routes data from the wireless nodes to a buildings management system or the Cloud.

Produal claims set-up and maintenance is made simple by the fact that each node can be commissioned and configured using an Android smartphone installed with the Produal MyTool app, while over-the-air-updates can be performed automatically and remotely. By eliminating the need for hard wired cables and unnecessary repeaters, installation costs are also minimized, while installation flexibility is maximized.

"The combination of LumenRadio's reliable and self-healing wireless mesh networking technology using patented cognitive coexistence together with u-blox modules based on Nordic's nRF52832 SoC is unique in this commercial space," says Petri Hakkarainen, Program Manager at Produal. "In commercial buildings you don't want to interfere with the local Wi-Fi network and with MiraOS running on Nordic chipsets we've got a solution that causes no interference. Something we have never seen before."

Tiny module supports multiple connectivity options

Avnet Asia has released what it claims is the smallest available module to support LTE-M/NB-IoT, Bluetooth LE and GPS. The 26 by 28 mm AVT9152 module includes Nordic Semiconductor's nRF9160 low power SiP with LTE-M/NB-IoT modem and GPS, as well as its nRF52840 Bluetooth 5.2/Bluetooth LE SoC.

The module is small enough to be integrated into a range of space-constrained embedded applications.

The nRF9160 SiP's Arm Cortex-M33 processor and the SoC's 64MHz, 32-bit Arm Cortex M4 processor with floating point unit equip the module with ample computational power to support complex and processor-intensive IoT applications. A high degree of flexibility means completing an IoT design can be as easy as connecting a power source, sensors and an antenna to the module.

Wireless application power profiling made simple

Nordic's Power Profiling Kit II is an inexpensive and flexible tool to help developers optimize the power consumption of their low power embedded designs without compromising performance

Nordic's short range wireless SoCs and low power cellular SiP are designed to offer high performance while maximizing battery life. But how the end-product actually performs is determined by the developer's hardware and software design. And while multimeters might provide an overview of average power consumption, they don't allow the developer to probe the instantaneous power consumption of their product to diagnose power anomalies. Instruments such as power analyzers do a better job of power profiling, but they are heavy and expensive making it unlikely that every engineer can have one on their desk.

Nordic's Power Profiler Kit II (PPK2) is an inexpensive, portable and standalone device which features an advanced analog measurement unit with a high dynamic measurement range. The PPK2 enables accurate instantaneous and average power consumption measurements for the entire range typically seen in low-power embedded applications, all the way from single microamps up to one amp. The resolution varies between 100 nanoamps and one milliamp depending on the measurement range and is suitable enough to detect the small power spikes seen in low power optimized systems.

Avoiding common problems

Wireless application design is complex but there are a few common problems that drain power and these are the first areas to consider when optimizing the power consumption of a design. The most common challenge is the SoC waking from sleep when not intended or expected or even not going to sleep at all. Good code ensures the SoC wakes up due to an interrupt, handles the event and then immediately goes back to sleep. But, if for some reason the SoC doesn't go back to sleep it can enter a waiting loop with the processor running flat out when what the designer actually intended was for the processor to do nothing at all. That makes the first rule of power profiling to check the current when the processor is supposed to be asleep to ensure that it's not actually operating. (*See panel below Test example: Checking sleep mode.*)

A second cause of excess power consumption is unnecessary event logging. Logging is convenient during the development and debugging stage of the application design. But it uses peripherals such as UART or the real time transfer module from Segger (which in turn uses the debug channel for communication) which consume power. This logging is not required for production devices but developers often forget to disable it to the detriment of battery life.

A third common reason for high power consumption is caused by the SoC waking up more often than intended. For example, a timer might wake up the processor to read some sensor data more frequently than the application requires. The developer should carefully consider how often sensor data needs to be read. For example, a design using a gyro and accelerometer to work out 3D position in real time will require frequent and fast sampling, but other applications might need only an approximate device position allowing the developer to slow down the sampling rate and extend battery life.

> No debugger is required, just a USB connection to a PC or Mac and a power profiling software package downloaded from Nordic's nRF Connect for Desktop

Figure 1: Normal operation

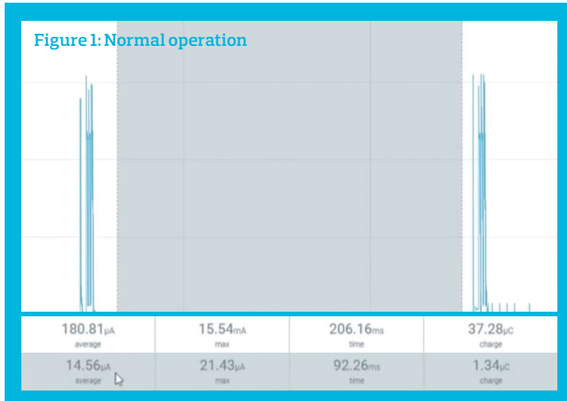
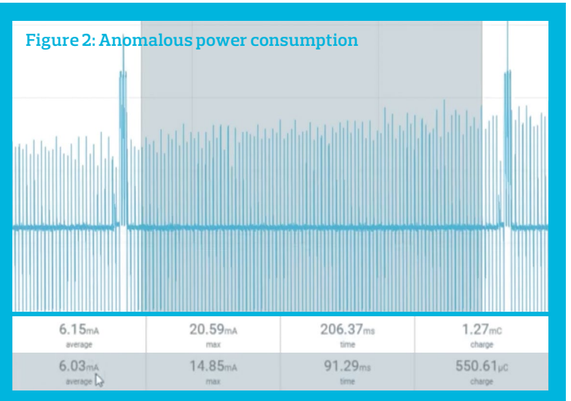


Figure 2: Anomalous power consumption



Test example: Checking sleep mode

The examples shown here come from an nRF52840 DK running a beacon application. The PPK2 is both powering and profiling the DK and is connected to a PC via a USB lead. The screen shots are taken from the power profiling software supported by nRF Connect for Desktop. In figure 1, the PPK2 measures the beacon power consumption while the device operates as intended. Between the periodic advertising transmissions, the SoC enters a low power sleep mode for around 100 milliseconds. Within the window, the peak current is measured as 15.54 milliamps (and occurs during transmission) and the average current is 180.8 microamps. During the sleep period (selected gray area) the average current is just 14.56 microamps. The situation in figure 2 is very different; instead of entering a sleep mode between advertising transmissions (gray area), the CPU is cycling round a waiting loop, burning power. The average current in this period is now 6 milliamps and the average current across the entire window is 6.15 milliamps, over 400 times greater than the designer intended and causing the battery to discharge very quickly.

The importance of hardware design

In addition to the SoC, a wireless design will comprise other hardware that could rapidly drain the battery if not chosen well and used correctly. For example, when selecting sensors such as accelerometers, the developer should choose devices with low quiescent current (current consumed when the device is idle). The developer should make sure the sensor does only what's needed and then goes back to sleep. For instance, if the application only needs to indicate when it's been inverted, then the developer should ensure the accelerometer only reports when inversion happens and save power by not reporting when the product moves in any other orientation.

Care is also needed in the selection of power management devices. Buck/boost voltage regulators and low drop out regulators (LDOs) all dissipate some power so it's important to select the most efficient components.

Another example where considered hardware design can save battery power is when a voltage divider is employed to ensure a component such as an analog-to-digital converter (ADC) receives the correct voltage. The voltage divider circuit should be constructed such that it dissipates the minimum amount of power through the shunt resistor. The designer should also carefully design signal pulldowns so that they pull the voltage to ground but minimize current leakage in order to save power.

Measuring power consumption

There are many ways to check how much power a design is using. One design tip is to plan the structure of software to make it easy to read through. That way it's easier to spot where parameters need to be changed to make sure, for example, that peripherals aren't switched on when they're not needed. And a developer can get a lot of information about power consumption from analyzing schematics, data sheets and source code.

Moreover, there are many tools to enable the developer to take a closer look at what's happening as the application runs. For example, if high power consumption occurs during a sleep cycle then it's a clear indication something is wrong. A debugger might then be helpful to determine the actual configuration of the device when it entered the sleep cycle to help diagnose the anomaly. One downside of a debugger is that sleep mode power consumption can't be measured while it's running. Another is that debug lines might not be accessible for measurement on the end product.

A multimeter is handy for measuring power usage and is easy to connect to almost any part of the circuit. But a multimeter always offers an average reading and without knowledge of the averaging window it is of little value for detailed measurements of, for example, a wireless product running Bluetooth LE.

A logic analyzer is useful to check event timing and to debug digital processing protocols like SPI and UART. The instrument is also a useful tool to show when and how traffic is exchanged with sensors.

The disadvantages of a logic analyzer is its expense, unsuitability for a production environment and the fact that it doesn't give direct information about current consumption.

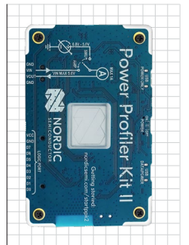
An oscilloscope can offer good information about power consumption with high accuracy and wide bandwidth. But it measures voltage rather than current. To make accurate power measurements the designer needs to measure the voltage drop across a resistor placed in the power path of the circuit board. This resistor must be constantly changed to set the range of measurements required and maintain power profiling accuracy. Another downside of an oscilloscope is that a decent model is very expensive.

Another option is a power analyzer. The device is very accurate and should be considered the benchmark for measuring a design's power consumption. But as noted above the units are heavy and expensive so there are likely to be very few within a single company.

Nordic's PPK2 is an inexpensive and lightweight alternative to a power analyzer yet is capable of comprehensive power profiling. The PPK2 can be used throughout the entire engineering cycle and can always be available on the developer's desk. It can support all of Nordic's DKs as well as external hardware.

No debugger is required, just a USB connection to a PC or Mac and a power profiling software package downloaded from Nordic's nRF Connect for Desktop. The PPK2 is also complemented by an online power profiler. The online profiler is based on theoretical power consumption levels of Nordic products so can provide a good estimate of the theoretical power consumption for a given design. The estimate can be cross referenced to that measured from the actual design by the PPK2 to highlight any anomalies.

For further information see Nordic webinar Become An Expert On Power Profiling Your Application (bit.ly/30LdJAL).



Tech Check

The PPK2 is able to dynamically switch its internal measurement circuitry so, for example, when working with the nRF9160 DK, the engineer can measure power consumption all the way from power saving modes up to GPS active states. The PPK2 is capable of continuously measuring 100,000 samples per second enabling it to reveal in high detail how the device-under-test is actually performing

Online expert panel discussions map the IoT's future direction

Nordic's wireless specialists and others feature in quarterly live debates answering the tricky questions about the challenges ahead for the IoT sector

Now in its second decade, *WQ* uses print and digital media to inform its readers about how Nordic's technology is underpinning the IoT and what that means for the world. The title is now further extending its reach with WQ Live events, a series of online expert panel discussions brought to the audience by members of the *WQ* editorial team and Nordic.

WQ Live events will be broadcast live each quarter and then made available from the Nordic website for subsequent viewing. The events see *WQ*'s editors ask the questions and moderate. The first 40 minutes of each panel comprises a questions and answer session between the moderators and an expert panel with the last 20 minutes addressing questions posted by the audience during the event.

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

The first expert panel took place in January and comprised Nordic C-level executives Svein-Egil Nielsen (CTO), Geir Langeland (Director of Sales & Marketing) and Kjetil Holstad (Director of Product Management). During the debate, the participants discussed how COVID-19 had impacted Nordic and the tech business and what the long term implications of the pandemic are likely to be.

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

The impact of AI and machine learning

The second WQ Live events expert panel is planned for the end of April and will consider what happens when AI and machine learning (ML) are combined with the IoT.

That the application of AI and ML to the IoT is a good thing is perhaps beyond debate. The data generated by billions of wireless sensors monitoring every aspect of society is far too great for humans to analyze. Today, Cloud servers absorb this data and clever AI and ML algorithms extract patterns and anomalies that can be used for forecasts and decision making. But the challenge for engineers is that as the IoT scales, the data increases exponentially. Sending all that raw data to the Cloud becomes too expensive and energy intensive to manage in the long term.

The solution is to process the data at the edge of the sensor network in order to decide what's important enough to forward to the servers. The challenge is that the AI and ML routines are intensive yet even the most powerful edge devices have limited computing and power resources compared to Cloud servers.

The next expert panel will debate this problem and will explore some solutions, including streamlined forms of AI and ML that are optimized for low power wireless IoT edge devices. These new solutions have the added advantage that they don't require a high degree of software expertise to incorporate onto edge devices.

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

> "The debates attempt to answer the tricky questions facing the rapidly growing wireless sector with lively, frank and informative discussion

Product Summary

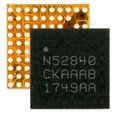
Full product details at: www.nordicsemi.com/Products

		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, nRF51Dongle	nRF51DK, nRF51Dongle	nRF51DK, nRF51Dongle
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

nRF52840

nRF 52 SERIES

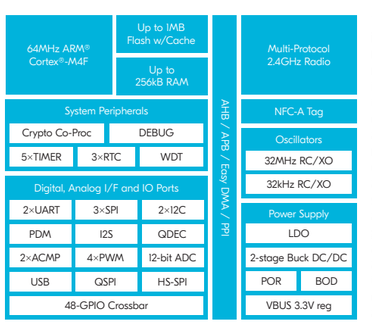


Description: The nRF52840 is a highly flexible SoC and is the most advanced solution in the nRF52 Series. It supports Bluetooth 5.2, including Long Range and high throughput (2 Mbps) modes. In addition, the nRF52840 supports Bluetooth mesh, Thread and Zigbee. The nRF52840 SoC adds best-in-class security for Arm Cortex-M processors with on-chip Arm CryptoCell cryptographic accelerator. CryptoCell builds security into applications from the ground up. The SoC is suitable for applications including smart home, industrial automation, advanced wearables and gaming controllers.

SoC: The nRF52840 uses a powerful 64 MHz 32-bit Arm Cortex-M4 processor and includes 1 MB Flash plus 256 KB RAM. The multiprotocol radio offers up to +8 dBm power output and -95 dBm sensitivity at 1 Mbps Bluetooth LE for a link budget of 103 dBm. With Bluetooth Long Range, a link budget of 111 dBm is possible. The radio's peak power draw is only 4.8 mA TX (0 dBM) and 4.6 mA RX (1 Mbps) and the SoC's current draw is as low as 0.4 µA in System OFF. The nRF52840 includes a full-speed (12 Mbps) USB 2.0 controller on-chip. An extensive range of peripherals are available with a number of high performance digital interfaces such as high speed SPI (32 MHz) and quad SPI (32 MHz) to allow direct interfacing to displays and external memory. An internal intelligent automated power distribution system ensures only system blocks that are required to carry out operations are energized. The SoC operates from a 1.7 to 5.5 V supply and offers a regulated ouput to power external components up to a maximum current of 25 mA.

Software: The nRF52840 uses the nRF Connect SDK for 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, Thread and Zigbee. The SDK also includes a migration of Nordic's Bluetooth SoftDevice Controller from the company's proven SoftDevices used with the nRF52 Series. The nRF52840 is a Thread certified component and as such is ideal for home networking products using the Thread mesh stack. The radio also supports 802.15.4 PHY and MAC layers which makes it suitable for additional stacks using 802.15.4 such as Zigbee. NFC, ANT and 2.4 GHz proprietary protocols are also supported. The nRF52840 boasts an over-the-air device firmware update (OTA DFU) feature.

Development tools: Applications can be evaluated using the nRF52840 DK. This is a versatile single board development kit for Bluetooth LE, Bluetooth mesh, Thread, Zigbee, NFC, ANT and 2.4 GHz proprietary development on the nRF52840 SoC. The DK is typically powered using USB but can be powered by a wide range of sources. Other development tools for use with the nRF52840 include nRF Connect for Desktop, nRF Connect for Mobile and Power Profiler Kit II.



The nRF52840 SoC is the most advanced member of Nordic's nRF52 Series SoC family. It meets the challenges of sophisticated applications that need protocol concurrency and a comprehensive set of peripherals and features. The generous Flash and RAM memory availability meets the requirements of innovative applications