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WQ Special Report

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Welcome

Finn Boetius
Product Marketing Engineer

N ordic is hardly a newcomer to the smart home and yet the company's decade of development of products for the sector is only a small slice of a much longer story.

Historians might place the genesis of the smart home with the ECHO IV, a home computer designed in 1966 by Jim Sutherland, a Westinghouse engineer. But I'd put the starting point to 1975 when Busch-Jaeger introduced their X10 network technology. This later evolved into EIB/KNX bus. Today, most electricians recommend a wired KNX-system to make a home smart.

But why use a decade-old, wired technology when you can have wireless appliances? Wireless would allow you to achieve a higher level of integration without the cost of cable but, unlike the KNX system, most wireless smart home product aren't interoperable.

Today smart speakers exist in no less than 33 percent of German and U.S. houses and more than a quarter of Australian ones. But the fully integrated wireless smart home is rare beyond the early adopter. Progress has been hampered by "walled gardens of technology" as Christopher LaPré, Head of Technology at the Connectivity Standards Alliance (CSA) explains it.

These walled gardens feature impressive smart home tech but lock consumers into a single vendor, limiting their options. The CSA is doing a lot to break down the walls by promoting Matter. The new standard is a wireless (and wired) specification that sees smart home products from any vendor happily playing together. Matter is backed by over 200 companies, including Nordic and major players in the consumer smart home market. It's a major collaboration between companies that otherwise spend their workdays fiercely competing.

Progress is good and Matter products, many powered by Nordic chips, are entering the market. A future where a robot butler prepares dinner while vacuuming the carpet is still some way off. But Matter will bring that time much closer. Read more about this smart home initiative in this edition's Special Report on page 14.

> " Smart speakers exist in no less than 33 percent of German and U.S. houses. But the fully integrated smart home is rare beyond the early adopter

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Rugged, cellular IoT geolocation device tracks and traces high value assets

Digital Matter's Oyster3 offers 10 years of battery life for tracking expensive assets in rugged environments

A geolocation asset tracker built for rugged environments and offering over a decade of battery life has been launched by IoT firm, Digital Matter. The Oyster3 product employs Nordic Semiconductor's nRF9160 SiP with integrated LTE-M/NB-IoT modem and enables telematics businesses to easily track and manage a range of powered and non-powered assets including vehicles, heavy equipment, tools, bins and containers.

Featuring an IP67-rated weatherproof, ultra rugged housing to survive in tough work environments, the battery-powered geolocation device includes an on-board temperature sensor and three-axis accelerometer for movement detection,

high-G events, tip detection and rotation counting.

Oyster3 uses the Global Navigation Satellite System (GNSS) including GPS, GLONASS, Galileo, BeiDou and QZSS, combined with cell tower location fallback in the absence of a GNSS signal. This enables continuous location tracking, loss and theft prevention, geofencing, asset use optimization and preventative maintenance, as well as optional movement-based tracking. The nRF9160 SiP's dedicated application processor runs the Digital Matter firmware that manages and performs the GNSS location lookups, and interfaces to the accelerometer to register high-G events.

When equipped with a roaming SIM,

Oyster3 supports automatic roaming between LTE-M and NB-IoT networks with minimal delay and marginal performance impact. The SiP also enables new early registration abort and location scan throttling options to save power and optimize the device for different use cases across varied network coverage.

The Oyster3 intelligently transmits the whereabouts of the asset via a cellular LTE-M or NB-IoT network. Digital Matter's OEM Device Server Cloud platform can be used to manage and update devices over-the-air. Location and other asset/device data can also be sent to any IoT or telematics platform with comprehensive documentation and a flexible and open payload format.

Internet of Things

Nordic and Nokia collaborate to simplify SEP licensing

Nordic Semiconductor and Nokia, have agreed a new approach to licensing the use of cellular IoT Standard Essential Patents (SEP). The deal will provide companies purchasing IoT hardware from Nordic with the opportunity to acquire licenses to Nokia's industry leading portfolio of cellular patents.

Nokia has defined many of the fundamental inventions used in virtually all cellular devices and LTE-M and NB-IoT technologies. In practice, this means any device connected to any cellular network automatically uses Nokia's intellectual property (IP).

The agreement, a first of its kind, will simplify and speed up the SEP licensing process and provide greater transparency and predictability to companies delivering IoT solutions. Licenses will be available at the end device level and companies will continue to have the option to license direct with Nokia.

"Nordic is all about making IoT easy for its customers," says Kjetil Holstad, EVP Product Management at Nordic. "Through this collaboration ... we have added transparency and predictability early in the design process, giving the increased clairty and certainty

Nordic cellular IoT customers [have sought]."

"Nokia has a history of working closely with industry to find effective licensing solutions and this innovative new approach is another example," says Jenni Lukander, President of Nokia Technologies. "It's a 'win/win' for Nordic's customers and Nokia, simplifying SEP licensing and making it easier for licensing agreements to be concluded amicably and efficiently. The move will support future growth of cellular IoT and ensure consumers benefit from a greater range of connected products and services."

Cellular IoT

Wireless Logic acquires Nordic's cellular IoT SIM partner Arkessa

Wireless Logic, which claims to be Europe's largest independent IoT connectivity firm, has acquired Arkessa, a Nordic Semiconductor cellular IoT connectivity partner.

"What Nordic cellular IoT customers really want is seamless global interoperability everywhere from a single SIM," says Kristian Sæther, Nordic Product Manager for Cellular IoT. "And next they want the ability to manage all their global SIMs in the field from a single portal. The Wireless Logic acquisition of Arkessa is a massive step in that direction."

Wireless Logic Group has over eight million IoT subscriptions active in over 165 countries, with collaborative partnerships that reach into more than 750 mobile networks across the globe. This includes direct access to 75 NB-IoT and LTE-M LPWANs in 45 countries in Europe.

Although the Arkessa brand and its LPWAN expertise are retained, Wireless Logic Group says the acquisition will give Nordic customers a "super-charged" expansion in global network access and an even wider choice of cellular IoT data and connectivity options.

"I would like to reassure Nordic customers that Wireless Logic Group is an extremely well-established, 20-year-old firm that organizations and businesses from governments to global enterprises trust to reliably and securely connect their IoT deployments," says Kieran Chury, Business Development Manager at Wireless Logic Group.

"A new 'thing', device or asset is connected to Wireless Logic's IoT connectivity platform, SIMPro, every 18 seconds of every day."

Environment

Nordic welcomes Norway's Minister of Trade and Industry in green initiative

Norway's Minister of Trade and Industry, Jan Christian Vestre, has paid a visit to Nordic Semiconductor's head office in Trondheim as part of the Norwegian government's efforts to accelerate green industrial projects, while creating jobs, strengthening investment and boosting the country's exports.

"We think it's great that the Minister takes the time to sit down with those who create jobs and is willing to hear what needs we have to grow a sustainable company," says Svenn-Tore Larsen, Nordic's CEO. "The important thing is to understand what's needed to strengthen our international position as a driving force for a green industrial boost.

"Our commitment to ESG [Environmental, Social and corporate Governance] goes far beyond the footprint we set ourselves. More than 80 percent of our investment goes towards innovation for the development of sustainable and energy efficient technology we will see in a few years' time."

Nordic holds a long-standing commitment to sustainability, and was recently recognized as one of the top 100 companies by STOXX Global ESG Leaders Index, the benchmark for

Jan Christian Vestre, Norway's Minister of Trade and Industry (l), meets with Svein-Egil Nielsen, Nordic's EVP R&D, and Nordic CEO, Svenn-Tore Larsen

sustainability champions. Nordic is also committed to the United Nations' Sustainable Development Goals. (*See* WQ *Issue 3, 2021 pg12.*)

"Sustainability depends on technology and innovation projects within the IoT that can contribute to the realization of the United Nations' sustainability goals," adds Larsen. "This will be decisive for the transition to

products and services that have significantly fewer negative consequences for the climate and environment than today."

Larsen welcomed the dialogue with the Minister as a positive step towards helping deliver a green shift.

"He had good questions, this was hopefully just the beginning of an important collaboration with the ministry," says Larsen.

Logistics & Transport

Anti-theft asset tracker for valuable goods

Designed to detect, record and notify within seconds any form of physical tampering, impact or attempted theft to valuable assets, the Bmmpr x Assets platform has been unveiled by U.S. startup, Bmmpr.

The anti theft, anti damage, high value asset protection platform integrates Nordic Semiconductor's nRF9160 SiP and nRF52- and nRF53-Series Bluetooth SoCs to provide dual Cellular IoT and Bluetooth LE wireless connectivity to the tracking devices.

The latest version of the Bmmpr hardware platform adds a host of new sensing capabilities including full range motion detection and tracking; detection of subtle environmental changes, and sound monitoring via a high sensitivity microphone.

In addition to the sensor enhancements,

Bmmpr x Assets also features new hardware-based thermal and watchdog protections that are suitable for industrial and mission-critical applications; a 30-pin board-to-board interconnect that offers unlimited expansion capabilities, and an onboard CAN bus controller and transceiver to support communication with a wide variety of external hardware. The unit can be powered from a supply providing anywhere between 3.7 and 30 V.

"The Bmmpr platform, which has been shipping for over two years to both consumer car owners and an increasing range of non-automotive industrial customers seeking to protect remote and/or high value assets, has now evolved into a full blown, state-of-the-art asset protection system," says Marko Mandaric, Co-founder & CEO of Bmmpr.

Environment

Leak detector harvests energy from water

A battery free, self powered leak detection device has been released by Canadian technology firm, AquaSensing. Leak Sensor 1.0 uses a proprietary sensor that acts as both power source and sensor for detecting water leaks.

Leak Sensor 1.0 harvests energy from any fluid ingress to power the Nordic nRF52832 Bluetooth LE SoC that then wirelessly connects to the user's smartphone. From there the user can receive alerts of active leaks via an accompanying app, or alternatively via a text/email notification.

Leak Sensor 1.0's small form factor makes it easy to install in any remote location. The maker says Leak Sensor 1.0 operates for more than 20 years, meaning the device can be safely hidden behind walls and in areas that are difficult to access.

Smart Agriculture

NB-IoT sensors help Australian farmers keep an eye on crops

A U.K. product design and technology innovation consultancy is helping roll out smart agricultural monitoring systems to some of the most remote farms in Australia.

42 Technology is working with Australia based software development and consulting company, Titan Class, to develop Farmify, a customized on-farm system. Farmify integrates existing farm systems with off-the-shelf sensors such as water level sensors, soil moisture probes, electric fence monitors, weather stations and livestock health monitoring equipment. The platform allows farmers to get a complete picture from all the sensors spread across their property, without needing to install costly infrastructure.

The solution employs Nordic Semiconductor's nRF9160 SiP—combined with a Rust programming language application—to transmit small LoRaWAN-style packets across the network. As a result, Titan Class has reduced the transmission costs by a factor of 100:1, leading to lower network charges and allowing the system to handle many more sensors than previously possible.

"Farmers say they pay around AUS50 [S36]

per month in network charges per device, whereas our initial trials suggest we can reduce this to around AUS0.58 [S0.42]," says Christopher Hunt, CTO of Titan Class. "Our approach is also more robust and reliable because we're getting a much higher range and penetration."

One of the challenges is that a sensor in a field could be up to 20 km from the nearest base station. As it's almost impossible to maintain full LTE-M duplex cellular communications across those distances, NB-IoT can instead be used to 'fire and forget'.

Beacons

Bluetooth LE beacons track service staff at work

Canada-based Stratosfy has released a suite of Bluetooth 5 beacons that enable business owners and operations managers to ensure a workforce carries out its activities at precise locations. The system works by either registering workers' presence or unlocking location-based task lists when they are within the device's communication range. The solution could be used in the commercial cleaning industry to ensure all the washrooms have been regularly attended by cleaning personnel.

The range comprises the Stratosfy Marker-I and Stratosfy Marker-IO devices. The Marker-I is designed for indoor service points such as lobbies, elevators, washrooms, meeting rooms and maintenance rooms. The IP65-rated water resistant Marker-IO is designed for both indoor service points as well as outdoor service points

such as parking lots and garbage bin areas.

The beacons can concurrently support Apple iBeacon and proprietary Stratosfy Telemetry formats, and once installed at a facility, can be used for distance calculations between a service point and an employee's smartphone to an accuracy of two meters. The calculation is based on RSSI using Bluetooth LE wireless connectivity provided by a Nordic nRF52840.

When the location data has been relayed from the device to the user's smartphone, an administrator can monitor the activities being performed by personnel at predetermined locations from a proprietary app. Alternatively, the location/activity data and corresponding timestamp information can then be relayed from the smartphone to a Cloud-based platform for viewing via a dashboard.

INSURERS USE TECH TO PREVENT CLAIMS

Insurance companies are increasingly making use of wireless IoT technology to help monitor potential water damage in homes, commercial properties and institutions. According to the *Insurance Journal*, Chubb, the world's largest publicly traded property insurance company, has embraced the technology and is deploying thousands of the hockey-puck-sized sensors around the U.S. The sensors can not only detect how much damage was actually caused by a water leak, but could potentially also stop the leak before it starts by instructing a shutoff valve to close the main supply line to the house as soon as a leak is detected anywhere in the home.

SIGFOX PLACED INTO RECEIVERSHIP

Sigfox, a proprietary LPWAN provider, has been placed into receivership in France, with a six month window to find a new owner. It cited a corporate slowdown as a result of the COVID-19 pandemic and global chip shortages for the decision. Sigfox operates in 75 countries, and covers 1.3 billion people and 6 million km^2. The firm is credited with pioneering LPWANs for IoT sensors, in the process paving the way for other LPWAN technologies such as NB-IoT, LTE-M and LoRaWAN, but was reported as having been in financial trouble for some time. The news was first reported in French publication *Notre Temps*, which quoted a "slower adoption cycle than expected" as the reason for the firm's financial crisis.

LIFE IMITATES ANTS IN LOGISTICS

A U.K. tech firm is helping logistics companies weather COVID-19 staff shortages using technology inspired by ants. Businesses that rely on complex warehousing and last-mile delivery are under pressure due to the pandemic, but could improve productivity by taking inspiration from the flexible behavior of ant colonies, according to Dr Niccolò Corsini, CEO and Founder of Logidot. Logidot is an industrial logistics firm. Corsini said the insects use distributed decision-making because they lack a central manager and this has the advantage of making their plans and execution more adaptable.

Retail & Payment

Smart shelf labeling system remotely updates product pricing

Shenzhen Minew Technologies, a China-based technology company, has released a smart shelf labeling system that enables an operator such as a retailer to automatically update individual shelf price labels across multiple stores, or in certain geographic locations, from a central point.

The Minew ESL (Electronic Shelf Label) solution comprises the proprietary ESL Cloud Platform, the G1 gateway integrating Nordic's nRF52832 SoC, and the electronic shelf labels of various dimensions each integrating the nRF52810 SoC. The dynamic displays can include pricing, product information, barcodes and QR codes, for example.

Pricing commands are sent wirelessly from the web-based dashboard on a PC to gateways located at a store. From there the commands are then relayed to the smart labels using the Bluetooth 5 connectivity provided by the Nordic SoCs.

Designed to replace traditional price tags that need to be manually updated, Minew ESL allows users to achieve benefits such as improved price visibility, reduction in pricing errors, promotional capabilities, labor cost reduction and an enhanced customer experience. In addition, the smart labels can be used as beacons for marketing to consumers in close proximity via compatible apps on the consumer's smartphone.

The labels also report back to the gateway and the Cloud platform, allowing retailers to remotely manage their stock and the positioning of products on shelves. Aside from the retail sector, the solution can also be used for applications across warehouses and logistics, healthcare and smart offices.

Smart Home

Nordic-powered smart lock reimagines the home entry experience

An Apple HomeKit– and Amazon Sidewalk–compatible smart lock that can be retrofitted onto almost any existing door has been launched by California based company Level Home. The Bluetooth LE Level Lock is powered by Nordic's nRF52840 advanced multiprotocol SoC and enables instant and secure keyless entry to authorized users.

The smart lock is paired to a user's smartphone where from the Level Home app users can automatically lock and unlock their door without the need for a physical key, and send digital keys to authorized guests, for example a tradesperson, friend or babysitter. From the app, users can also set specified entry periods for guests with a 'Party Pass' feature, create a single event pass for multiple people to use, as well as view a record of the smart lock's activity.
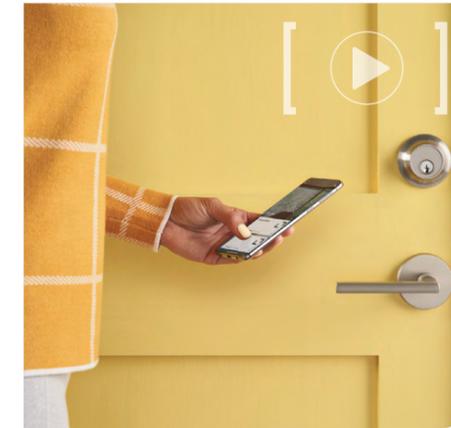
The Nordic nRF52840 SoC incorporates features that support a range of cryptographic services for secure applications, and support Level Lock's security requirements for the unlocking process.

Nordic-powered Apple HomeKit and Amazon Sidewalk compatibility provides the user remote connectivity to Level Lock via HomeKit hub or Sidewalk-enabled devices.

The ability to connect to other Apple, Amazon, as well as third party smart home devices allows consumers to perform automations or create linked events, for example turning off lights or activating security cameras once the door has been locked.

Smart Health

Reusable, wearable sensor records mask performance

Researchers have developed a lightweight, reusable sensor that clips onto a face mask to monitor how well it's working. The device, called FaceBit, senses leaks and records wear time while continuously measuring a wearer's heart and breathing rate. Its developers hope it will aid research and help health care workers and others who wear face coverings throughout the day to battle the transmission of diseases such as COVID-19.

Rather than developing an entire smart mask, which might be impractical to reuse, the team created a small electronic device that attaches to a face covering with a magnetic clip and contains several sensors.

A pressure sensor detects leaks, indicating how well a mask is fitting, and also enables the FaceBit to determine when the mask is over someone's face, so it can record wear time and can enter sleep mode when idle.

The FaceBit additionally monitors heart rate with a sensitive accelerometer that records minuscule facial skin movements caused by each pulse beat. It also measures breathing rate with a temperature sensor. A Bluetooth LE connection transmits the data to a companion smartphone app.

Smart Health

Wireless wearable targets overdose deaths

University of Washington researchers have developed a closed-loop wearable naloxone injector system they claim could help in reducing opioid overdose deaths.

Opioid toxicity is readily reversed with naloxone which rapidly restores respiration and decreases sedation.

The Proof-of-Concept solution comprises a pair of on-body accelerometers that measure respiration, and a Nordic Semiconductor SoC tracking the subject's body motion and respiration.

If cessation of breathing is detected, the device activates the injector that delivers the antidote to the individual.

Bluetooth LE wireless connectivity enables information to be relayed to a smartphone to notify first responders as well as family and friends.

Smart Home

Wonderlabs ecosystem wirelessly controls appliances

Tech company, Wonderlabs, has launched a smart home ecosystem for automated control of a range of Nordic-powered, sensor based smart home devices and peripherals.

The SwitchBot ecosystem includes the SwitchBot Curtain and SwitchBot Bot that can be used independently or in conjunction with each other using a proprietary Bluetooth-based mesh networking solution. The user can wirelessly configure and control the devices from a smartphone app.

SwitchBot Curtain is a motorized device that can transform an existing curtain rod and rail curtain into an automated smart curtain system controlled by the companion app, a remote controller device or a compatible smart home ecosystem such as Amazon Alexa, Apple Siri and HomePod or Google Home. Using the functionality of its built-in sensors, the device can be scheduled to close curtains at night and open curtains when it senses daylight.

SwitchBot Bot mechanically turns on or off appliances in a home or office that employ a button or rocker switch, for example a coffee machine. The device can be controlled using the companion app or via voice control.

Cellular IoT

Nordic and Acklio optimize live NB–IoT network

Static Context Header Compression will significantly simplify the deployment of NB–IoT LPWANs, optimize throughput and bring IPv6 to Non–IP Data Delivery

LPWANs are a fundamental element of the IoT. They form a critical link between short range wireless networks or a supported end device and the Cloud, bypassing a gateway. The cellular IoT technology, NB–IoT, is a leading LPWAN solution and offers up to 15 kilometer range together with low power consumption.

Further optimization of NB–IoT can be achieved by reducing data overheads, improving network capacity and lowering latency. To make it easier to implement this optimization the 3GPP Cellular IoT standard allows the cellular IoT device to eliminate all IP headers from the radio packet, and to send just the packet payload through the carrier network. This so–called Non–IP Data Delivery (NIDD) is an optional communication method available on a growing number of NB–IoT networks.

"LPWANs enable many processes and things to be measured in a smarter and battery–efficient way," says Afzal Mangal, Founder of IoT Creators, an IoT connectivity firm. "The various solutions that can be built on them are innumerable. But sometimes the LPWAN by itself is not enough. In cases like that, NIDD can provide the solution by reducing both data [traffic] and battery consumption."

However, NIDD does bring some disadvantages that have stalled its deployment. (See sidebar pg11 *Addressing the challenges of NB–IoT with NIDD*.) But now Nordic Semiconductor and Acklio, an IoT software company have collaborated to demonstrate a solution that overcomes these drawbacks. The solution combines Nordic's nRF9160 low power SiP and Acklio's Static Context Header Compression (SCHC) technology. The SiP combines an Arm Cortex–M33 dedicated application processor with integrated LTE–M/NB–IoT modem and GNSS and is a popular solution for cellular IoT products. The demonstration was made possible in a live NB–IoT network thanks to Deutsche Telekom IoT access provider, IoT Creators, with its IoT access management platform and integrated SIM.

Network optimization and security gains

For the live NB–IoT network demonstration, the Nordic SiP used NB–IoT with NIDD and then employed Acklio's SCHC to both compress and fragment messages exchanged over the network. This compression and fragmentation technique is tailored to the needs of LPWANs and is the key to the network optimization gains for network equipment using both SCHC and SCHC with NIDD compared to networks using NB–IoT alone. Crucially, SCHC also brings IPv6 interoperability between NB–IoT/
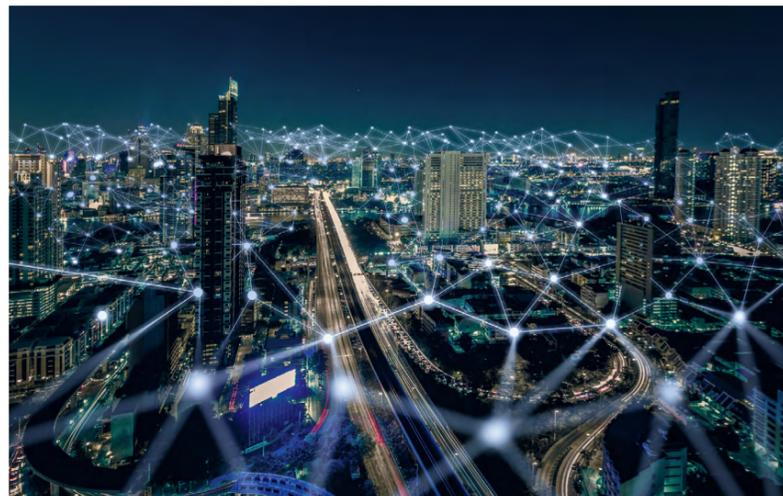
Tech Check

The compact nRF9160 low power SiP features a dedicated application processor and an LTE–M/NB–IoT modem in a compact 10 by 16 by 1mm package. The SiP supports both SIM and eSIM, PSM and eDRX power saving modes, NIDD and other NB–IoT 3GPP Release 14 features

NB–IoT with NIDD and other LPWANs, as well as the rest of the Internet.

"Once deployed at large scale, SCHC will unlock a technical barrier that has threatened to stall IoT traction by directly addressing the inherent limited throughput and capacity of NB–IoT and the lack of IP interoperability of some LPWANs," says Lorenzo Amicucci, Business Development Manager with Nordic. "LPWANs are critical to the success of the IoT and SCHC will significantly simplify their deployment."

Additional gains resulting from the use of SCHC include enhanced network security, lower power consumption, less complexity and increased end–device density.

"While SCHC has been successfully deployed on other LPWAN networks, this is a world–first demonstration of this leading edge technology on a non–IP cellular IoT network," says Amicucci. He noted that the demonstration's success relied on the combination of Acklio's expertise in SCHC combined with the Nordic nRF9160 SiP's rich feature set, high degree of flexibility, open nRF Connect SDK and easily accessible dedicated application processor. "The SiP's features made it easy for Acklio to customize its SCHC software to run seamlessly on the device," says Amicucci.

Acklio's engineers have been working on SCHC for years and played a key role in defining the specification for what is now an Internet Engineering Task Force (IETF)–adopted open standard. Now the technology is rapidly gaining commercial traction across a range of markets.

Addressing the challenges of NB–IoT with NIDD

While improving NB–IoT efficiency, Non–IP Data Delivery (NIDD) has some drawbacks that have slowed its deployment. These disadvantages include lack of interoperability with other LPWAN technologies, added complexity and lack of support for IPv6, User Datagram Protocol (UDP) and Datagram Transport Layer Security (DTLS). (IPv6 is the latest version of the Internet Protocol and provides the identification and location system for computers connected to the network plus traffic routing. UDP is part of the IP suite and minimizes latency for loss–tolerant connections across the network. DTLS provides security for communications using UDP.)

Static Context Header Compression (SCHC) is a compression and fragmentation framework tailored to the needs of LPWANs and was adopted as an open standard in 2020 by the Internet Engineering Task Force (IETF). French firm Acklio's founders played a vital role in the development of SCHC and formed a key part of the IETF IPv6–over–LPWAN working group that defined the specification.

SCHC tackles the challenges introduced when using NIDD by compressing and fragmenting messages exchanged by wireless networks. By adding SCHC, NIDD devices become IPv6 compatible, and can support UDP and DTLS communication. The result is an efficient network with low power consumption, but with dramatically reduced traffic compared to a conventional NB–IoT implementation. Further benefits include higher network security and simplicity.

Moreover, by enabling DTLS communication and optimization, engineers can solve some of the typical challenges caused by dynamic IP and frequent DTLS resumptions in cellular IoT networks, yielding even lower power consumption.

A demonstration of Acklio's SCHC running on Nordic's nRF9160 SiP with NIDD in a live European NB–IoT network achieved a 74 percent reduction in traffic when using SCHC with NIDD compared to conventional NB–IoT communications. The demonstration also showed a minimum 64 percent reduction in traffic compared to a conventional NB–IoT network without SCHC (or NIDD). (*See Figure below.*)
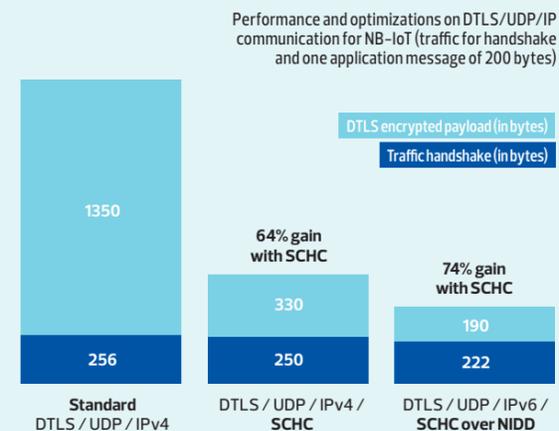
Performance and optimizations on DTLS/UDP/IP communication for NB–IoT (traffic for handshake and one application message of 200 bytes)

- DTLS encrypted payload (in bytes)
- Traffic handshake (in bytes)

Standard DTLS / UDP / IPv4	**DTLS / UDP / IPv4 / SCHC** 64% gain with SCHC	**DTLS / UDP / IPv6 / SCHC over NIDD** 74% gain with SCHC
1350	330	190
256	250	222

Environment

IoT forecast to save eight times more energy than it consumes

IoT detractors might point to the technology's upstream energy cost, but research suggests large net savings will be realized in the future

> Many enterprise applications are deployed to increase efficiency and those gains generally outweigh the energy footprints of the solutions themselves

Billions of battery-powered wireless IoT sensors are expected to connect and enhance tomorrow's world. But rolling out such ubiquitous connectivity will come at an energy cost. According to a new Transforma Insights and 6GWorld report, *Sustainability in New and Emerging Technologies In 2030*, building the IoT from now until 2030 will increase global electricity use by 34 terawatt-hours (TWh), with another 3 TWh equivalent in hydrocarbon fuel used to power assembly equipment to make the IoT's components. Further, water consumed during the manufacture of IoT-enabled solutions will reach 112 million cubic meters. The report also goes on to state that deploying the IoT will result in the equivalent of an additional 53 TWh equivalent of hydrocarbons used for distribution and deployment of solutions.
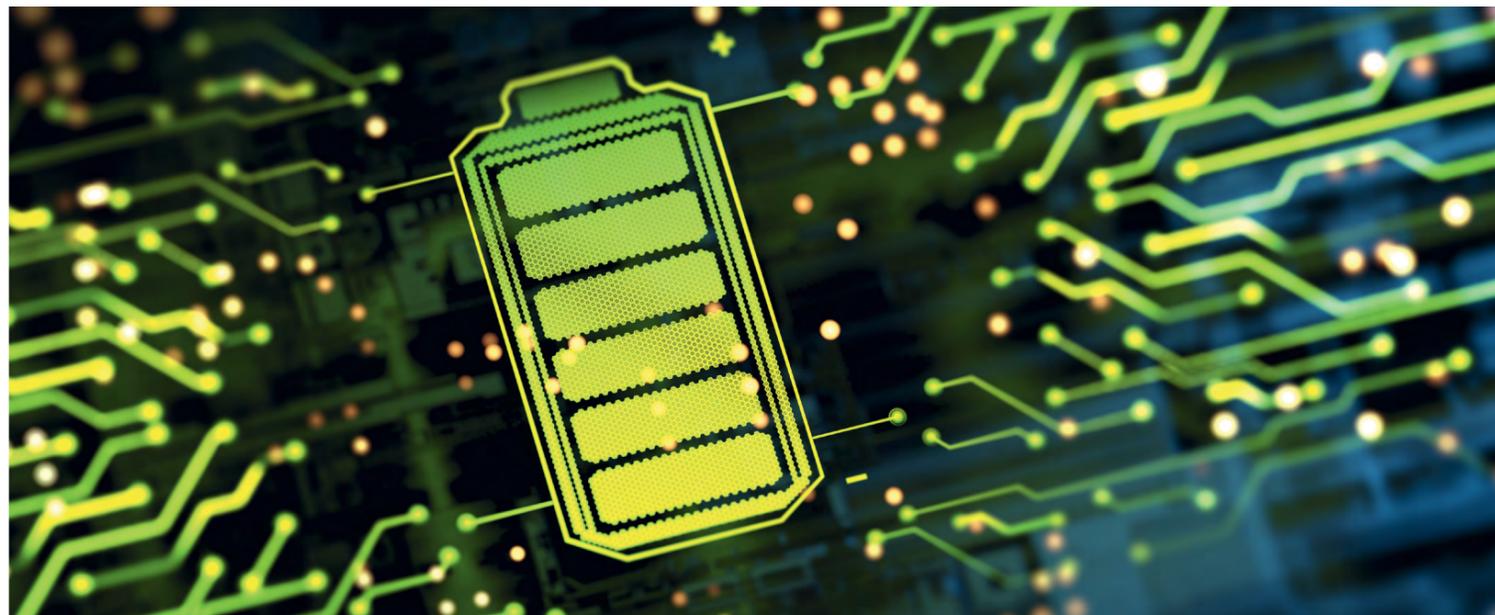
In addition to the up-front energy cost of building the IoT, the infrastructure will bring further environmental impact through the manufacture (and disposal) of batteries for IoT products that may need replacing several times during the life of the device. Finally, the energy consumed by the Internet and the Cloud infrastructure needed to support IoT applications must be taken into account. Overall it's a massive energy impact. But, the report concludes, the positive environmental impact of IoT applications will make the cost well worth the initial sacrifice.

Saving much more than it consumes

The Transforma report states the IoT will ultimately prove its worth and then some. For example, IoT applications will save over 1.8 petawatt-hours (PWh) of electricity in 2030, up from 0.6 PWh in 2020, plus the equivalent of an additional 3.4 PWh of hydrocarbon fuel use. This will result in total savings of around 5.2 PWh of energy. On the debit side, 653 TWh of electricity will be used to power IoT applications. The result is that IoT technology will soon generate enough savings to pay back the energy cost of its manufacture and deployment and from then on will save around eight times the energy it consumes.

IoT devices will also conserve nearly 230 billion cubic meters of water in 2030, the report says, with 35 percent of this impact coming from improved water grid operations and the balance boosted by IoT-enabled agricultural applications such as smart irrigation.

How will the IoT so resoundingly negate its development and deployment footprint? In part because IoT solutions are strategically designed to deliver power saving advantages, claims Jim Morrish, Founding Partner of Transforma Insights. "Many enterprise applications are deployed to increase efficiency, and those [gains] generally outweigh the [energy] footprints of the solutions themselves," he says.

Moreover, the benefits of big data are expected to be crucial. When combined effectively with ML applications, for example, the IoT will generate swathes of information to help people and organizations better understand energy costs, and subsequently to make better environmental decisions.

The benefits of enterprise IoT

The key environmental benefits from the IoT will largely come from enterprise solutions. This is because IoT consumer devices are intended to deliver an enhanced value proposition to consumers, while enterprise solutions are generally associated with some level of increased efficiency. These efficiency savings will often take the form of reduced electricity consumption, or reduced fuel or water consumption.

For example, by 2030 the most impactful electricity saving applications will be associated with smart electricity grid operations, the report predicts.

IoT applications could enable these savings to be made directly by enabling tasks to be completed more efficiently, or indirectly by saving consumption in related areas. An example of the latter is smart city traffic congestion mitigation where the savings come in part from vehicle fuel savings and in part from reduced health costs due to lower respiratory problems for citizens.

The report estimates that savings from enterprise IoT will account for 95 percent of electricity savings from all IoT solutions. However, there are notable exceptions, including building automation and smart lighting, which will generate significant sustainability benefits in both consumer and enterprise applications.

Utilities aren't waiting until the end of the decade to realize the IoT's benefits, they're already changing how they do things to enhance grid performance and maximize efficiency. For example, the Nordic nRF9160-powered Apricity Ara solution enables a domestic water heater to be controlled remotely across an LTE-M link, limiting electricity consumption during peak periods. Such management can help the utility avoid firing up costly and inefficient auxiliary power stations to meet extra load.

Elsewhere, Irnas is using Nordic cellular IoT tech in its RAM-1. The device is helping utilities monitor smart grids to enhance their efficiency and make it easier to connect renewable energy resources to the network. (*See* WQ *Issue 2, 2021* pg22.)

Need to Know

Cellular IoT devices like Nordic's nRF9160 SiP are helping limit the energy IoT devices consume as they go about their business. The SiP offers the developer the opportunity to customize the application to minimize power consumption while still ensuring good performance

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

Birth of a massive IoT standard

When established wireless technologies don't match the demands of novel applications, new specifications are created

Multiple wireless technologies exist because no single solution perfectly suits all use cases. But occasionally an engineer comes up with an idea that's not covered by any of the existing solutions.

One example of this is applications that demand high density, low latency, high reliability and long range like building automation, utility metering, process automation and logistics.

> Before now, building a private 5G network required a lot of investment

Nordic Semiconductor is a key contributor to the new wireless standard that targets these markets, ETSI DECT-2020 New Radio (NR). The standard describes a wireless technology that allows enterprise IoT customers to build their own low cost private mesh networks. In addition to high device density, reliability and low latency, the technology brings good indoor and neighborhood area coverage. The potential of DECT-2020 NR is such that the International Telecommunication Union (ITU) has included it as part of the 5G standard. Notably, DECT-2020 NR is the first non-cellular 5G standard included in the ITU's document.

The DECT-2020 NR standard will effectively enable enterprises to easily set up, manage and maintain a private 5G wireless IoT network that connects up to a million devices across every square kilometer of its coverage — while keeping the cost of ownership low. It uses the license-exempt and globally available 1.9 GHz frequency allocation which saves on data subscriptions.

By employing mesh technology, the network is decentralized making it very easy to add devices and eliminating any single point of failure. With an outdoor range of up to two kilometers, DECT-2020 NR will serve the needs of massive IoT and critical IoT applications. (*See* WQ *Issue 4, 2021* pg10.)

Before now, building a private 5G network required a lot of investment in infrastructure and tended to be accessible only to well-financed larger enterprises. But now, DECT-2020 NR makes it possible for even small companies or organizations to build their own private 5G network and run and optimize as they wish.

We're working with Wirepas, a massive IoT software specialist, to accelerate a DECT-2020 solution based on Nordic's nRF9160 multimode LTE-M/NB-IoT SiP. Once our customers get their hands on this product, I believe it will trigger the development of many new applications that weren't previously possible.

Living the Dream

Matter, a new unifying connectivity standard with support from the biggest tech companies in the world, stands to revolutionize the smart home

In Short

The promise of the fully integrated smart home has fallen short, with a disjointed and inconsistent consumer experience and manufacturers facing increased complexity.

Matter is a new open-sourced connectivity standard developed for the smart home to unite disparate ecosystems and bring the world of smart devices closer together.

Matter will drive improvements, by freeing device manufacturers from grappling with interoperability and allowing them to focus on their core competencies.

During the summer of 1959, the U.S. took the American National Exhibition to Eastern Europe, with the aim of showing communist nations the kind of advances made possible by capitalism. In one display was a demonstration kitchen featuring centrally controlled lights, a robot floor cleaner and a moving dishwasher that not only cleaned and dried dishes, but even put them away.

But the so-called 'Miracle Kitchen' was just that – a fantasy constructed less from technology than from trickery, with the primary aim of persuading the audience that the future belonged to the West.

Fortunately, genuine strides forward in home automation were not far off. Less than a decade after the Eastern European event, Westinghouse engineer James Sutherland designed the Echo IV, a prototype automation system that could control the temperature and turn on appliances in his home. And by 1984, the term 'smart house' had been coined by the American Association of House Builders.

Since then, a flurry of wirelessly-connected smart devices have rolled into the home, bringing automation and convenience to domestic life. Think of connected speakers, light bulbs and blinds, all able to be remotely activated by smartphones or dedicated home assistants. By some estimates, there are around 175 million individual smart homes in the world today and there will be more than 13 billion smart home devices in active use by 2025.

Though it sounds impressive, at least some of this progress is a mirage. While there's no doubt that individual connected products do provide homeowners with benefits, the promise of the fully integrated smart home has fallen short, with consumer experiences of the technology commonly disjointed, inconsistent and downright irritating.

The core issue is that smart home devices often don't work well together. Products built for one ecosystem won't always work as planned in another. For example, a digital voice assistant from one manufacturer often encounters issues when trying to configure and control smart lights or a home alarm system built by another vendor. It's a problem that's not going away as hundreds of brands operate across dozens of device types in the smart home space.

A LONG-STANDING PROBLEM

For modern homeowners, most of who are well-adapted to using technology but who have been groomed to expect 'plug-and-play' performance, the interoperability of today's smart home devices is a recipe for disillusionment. Frustrations commence early, even before buying the product. Prior to making a purchase, consumers must decipher which devices are compatible with which ecosystems, networks and home assistants.

Because that's far from easy, some resign themselves to staying within the one 'walled garden', solely buying products compatible with a single manufacturer, such as those targeted at Amazon's Alexa or Apple's HomeKit. But in doing so, they limit their choice of products and suppliers. Others opt for the ability to choose from a wider selection of manufacturers, but then take on the unenviable task of troubleshooting and seeking workarounds to the inevitable compatibility and interoperability issues that arise. And even where a device boasts compatibility with multiple ecosystems, it still may not support all features on all ecosystems to the same degree. These adventurous consumers learn to live with the disappointment of an unrealized dream – that of the fully integrated smart home.

The problems radiate beyond consumers. To minimize interoperability and fragmentation issues, product developers and manufacturers create largely identical versions of their products but tweaked to work with different ecosystems. This a duplication of effort, additional cost and unnecessarily increased complexity. Even retailers and distributors are affected, with display and storage space taken up by these duplicate versions of the same smart home product.

The issues with interoperability have been known and talked about in the smart home industry for years. Failure to overcome the challenge has seen a state of malaise set in, even amongst analysts and commentators closely tied to the industry. "The smart home is dead," declared renowned expert in all things IoT, Stacey Higginbotham, in her publication *Stacey on IoT*. "I thought that we would have solved interoperability challenges by now, and made the connected home easier for mainstream consumers to

"

By some estimates, there are around 175 million individual smart homes in the world today and there will be more than 13 billion smart home devices in active use by 2025

By the Numbers

12.2%
Global smart home penetration 2021

Source: Statista

$670 million
Bluetooth smart home device shipments in 2025

Source: Bluetooth SIG

$182.4 billion
Smart home global market value in 2025

Source: Digital Market Outlook

adopt ... I was wrong," she wrote. "Heck, even I sometimes struggle to get my devices to work with Google Home or the Amazon Echo and doing so is literally my job."

The impact of these struggles is an industry growing slower than had been hoped or forecast. "Although there have been studies about this technology in recent years, the adoption rate of smart homes is still low. One of the largest barriers is technological fragmentation within the smart home ecosystem," describes a research paper in academic journal *Sensors*. In a report last year, the Consumer Technology Association (CTA) observed that revenues in the smart home sector were "flat", and in a prior publication declared that the smart home was "not yet meeting its value proposition".

A RENAISSANCE COMING

But amid this gloom, a new hope for the smart home has arisen. A hope that tackles directly the issues of standardization and interoperability that are souring the experiences of smart home consumers and thwarting progress for the industry at large.

The name of this new initiative is 'Matter', a connectivity standard for the smart home. Developed by Connectivity

> Matter's level of support gives it immense credibility and momentum
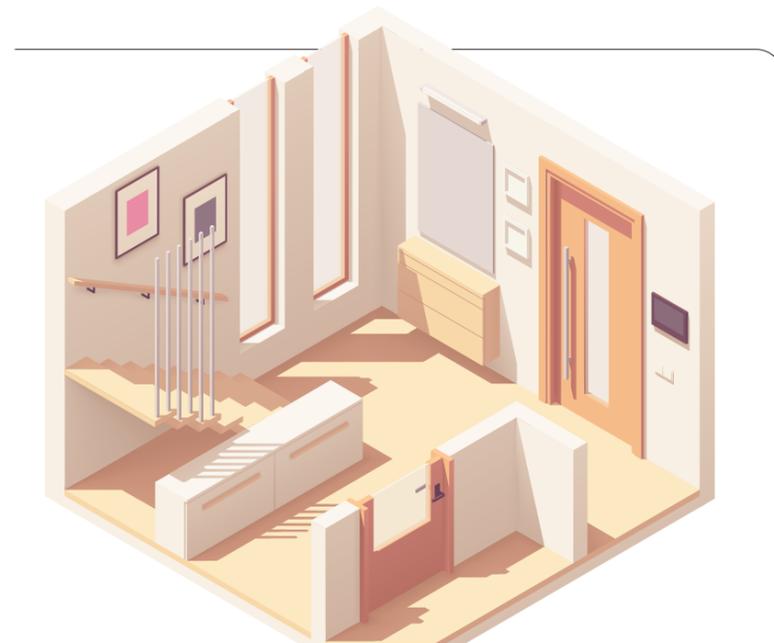
Access all areas: Around one in six smart home consumers consider security their highest priority. Smart locks ensure only those who really need access can do so. For example, temporary access can be remotely granted to tradespeople without handing over precious keys or lock combinations

Standards Alliance (CSA), and formerly known as Project Connected Home over IP (CHIP), Matter can be thought of as a 'common language' to unite disparate ecosystems and bring smart devices closer together. An open-source implementation of the standard is available.

Matter works by building on top of existing smart home wireless connectivity technologies Thread, Wi-Fi, Bluetooth LE, and the Ethernet wired protocol by providing a unifying application layer. By creating a standardized specification, Matter will give manufacturers a common data model to develop to, ultimately guaranteeing the compatibility and interoperability of their products.

For consumers, Matter promises greater simplicity. Instead of having to work out if a Nest thermostat is HomeKit compatible, or if an Echo device can control a third party smart lock, consumers can simply seek out the Matter seal of approval on devices they purchase and have confidence they will work together – from set-up through ongoing use. "All of the Echo devices will be able to control all of the Matter devices that are on your home network, regardless of what networking technology they happen to use," says Chris DeCenzo, principal software development engineer at Amazon. With a single standard to build to, the product development process for developers and manufacturers is also streamlined, while still enabling them to take advantage of integration with multiple smart home ecosystems. A standardized specification for connectivity also supports greater reliability.

One of the strongest selling points for Matter is the immense show of force and unity behind it. More than 200 companies have come together to develop Matter and solve the problems of interoperability. This includes major smart home technology platforms like Apple, Google, and Amazon, large and small device manufacturers such as Eve, Yale, Leedarson, Netatmo and Tridonic, and wireless connectivity specialists like Nordic Semiconductor.

A POWERFUL ALLIANCE

For a standard to have successful uptake and long-term viability it must have industry buy-in, and Matter's level of support gives it immense credibility and momentum. The stature and breadth of the alliance has rightly been described as an "unprecedented industry coalition". For many of the industry players involved, the incentives are plain to see. Having invested considerably in the smart home category, the prospect of a standard that could turbocharge the growth of the industry is highly appealing.

These companies have also realized the role they must

play in driving the change needed. "It's up to us to simplify the smart home, and to start we must change the way device makers build products," says Michele Turner, senior director at Google Smart Home. "There should be one standard that simplifies selection, setup and control, and makes it easy for our partners to create products and experiences for your home." Tobin Richardson, president and CEO of the CSA, goes further: "This is a Renaissance".

Matter is more than just a unifying language. It can also be thought of as a bringing together of world class approaches into a single specification, using an open source approach. "We use best-in-class contributions from market-tested smart home technologies, such as those from Amazon, Apple, Google, the Connectivity Standards Alliance, and others," says the CSA. "By leveraging these technologies' contributions, we are able to accelerate the development of the [standard] and deliver benefits to manufacturers and consumers faster."

A LOOK UNDER THE HOOD

Various connectivity standards have emerged as the home automation and smart home industry has matured over the years, among them Z-Wave and Zigbee, while protocols such as Bluetooth and Wi-Fi have also found prominent roles. Each has carved out a niche, yet none has successfully emerged as a default or primary standard for the smart home market. This is reflected in the fragmentation that consumers experience at device level.

Standard practice

King Henry I was among the earliest advocates for standards. According to some historical accounts, the 12th century English monarch tired of seeing varying and conflicting interpretations for measurements of length, so he arbitrarily redefined the yard to be the distance from his own nose to the thumb of his outstretched arm. It may not have been the most independent and objective way to define a standard of measurement, but it was a commendable attempt to bring order and consistency to human affairs.

Since the 12th century, standards have become widely accepted as a critical foundation for technological progress. The International Organization for Standardization (ISO) puts it this way: "When things don't work as they should, it often means standards are absent."

The folly of a world without standards is perhaps most famously illustrated by the example of the railways. Before railway gauges were standardized, different sections of rail adopted different gauges. This meant entire cargo loads had to be unloaded from one set of cars and loaded onto another at the point where these different sections came together.

Today, there are globally more than half a million published standards from over 1000 recognized standards development organizations. Having initially played a role in the industrialization of nations, over time the use of standards has spread across diverse areas such as consumer safety, construction and health.

As global trade expanded, standards too spread their wings and found their way into agriculture, logistics and even the development of weapons.

Now, standards are tightly coupled with the major human forays into the future – areas such as climate action, pandemic management, computer technology and the Internet. There are already standards for AI and non-fungible tokens (NFTs), digital assets that represent real world objects like art, music and videos.

At their heart, standards simply represent a consensus among experts in an area on the best way of doing something. With hundreds of thousands of standards now at play, the collective effort to keep them up to date and fit for purpose is such that ISO estimates there are around 26 technical standards meetings taking place somewhere in the world every single working day.

And perhaps most critical of all, there is a standard for the maintenance of standards.
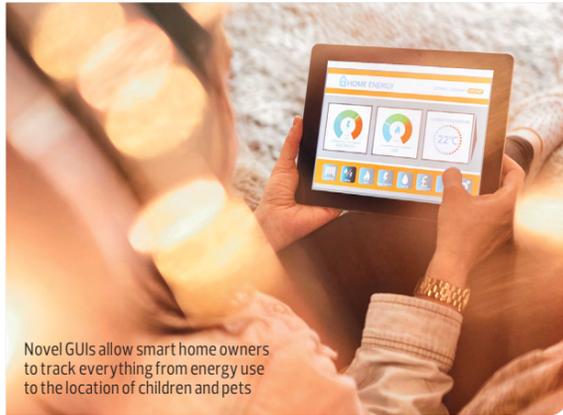
Novel GUIs allow smart home owners to track everything from energy use to the location of children and pets

Matter solves this by providing interoperability between existing connectivity protocols—specifically Wi-Fi, Thread and Ethernet. Moreover, since Matter is IP based, it provides developers with a common and well established foundation for communication.

Thread is one of Matter's primary connectivity protocols because it is a secure wireless mesh network specifically developed for the smart home by the Thread Group (which included Google as a founder member), and as a result it is tuned for reliability and low latency. Thread also works particularly well for lower power devices such as sensors and door locks — the kind that must run for several years on small batteries and are categorized as 'Sleepy End Devices' (SEDs). Lower power Matter devices will typically run across a Thread network, while devices with higher power and data bandwidth needs will use Wi-Fi. Thread border routers—key parts of the network which bridge from the Thread mesh to Wi-Fi, Ethernet or the Cloud—are also mainly mains powered.

Matter will initially support the Thread, Wi-Fi and Ethernet protocols for device-to-device communication with Bluetooth LE—primarily because of its mature smartphone interoperability—being used for commissioning new devices to the network.

Setting up new devices has long been a pain point for smart home users. Matter members are tackling this challenge with gusto; a key example is Amazon's Frustration-Free Setup (FFS). According to Amazon's DeCenzo, FFS is a "zero-touch" experience designed to enable consumers using Amazon's ecosystems to simply take a device out of the box, plug it in, and wait for automatic connection to the smart home network. Amazon says it is working with leading brands to launch FFS on its Matter-certified devices.

THE FREEDOM OF CHOICE

The 'Multi-Admin' feature of the Matter spec will enable connected devices to be easily controlled by multiple smart home ecosystems. Multi-Admin liberates customers from single-vendor walled gardens and gives them the freedom to mix-and-match according to preference — for instance,

Tech Check

Leedarson's A19 Tunable White Bulb employs Nordic's nRF52840 SoC for core processing power and wireless connectivity. Because it is Matter compliant, users of all popular smart home ecosystems can wirelessly dim, tune and trigger static and dynamic scenes for different light experiences from their smart home hub
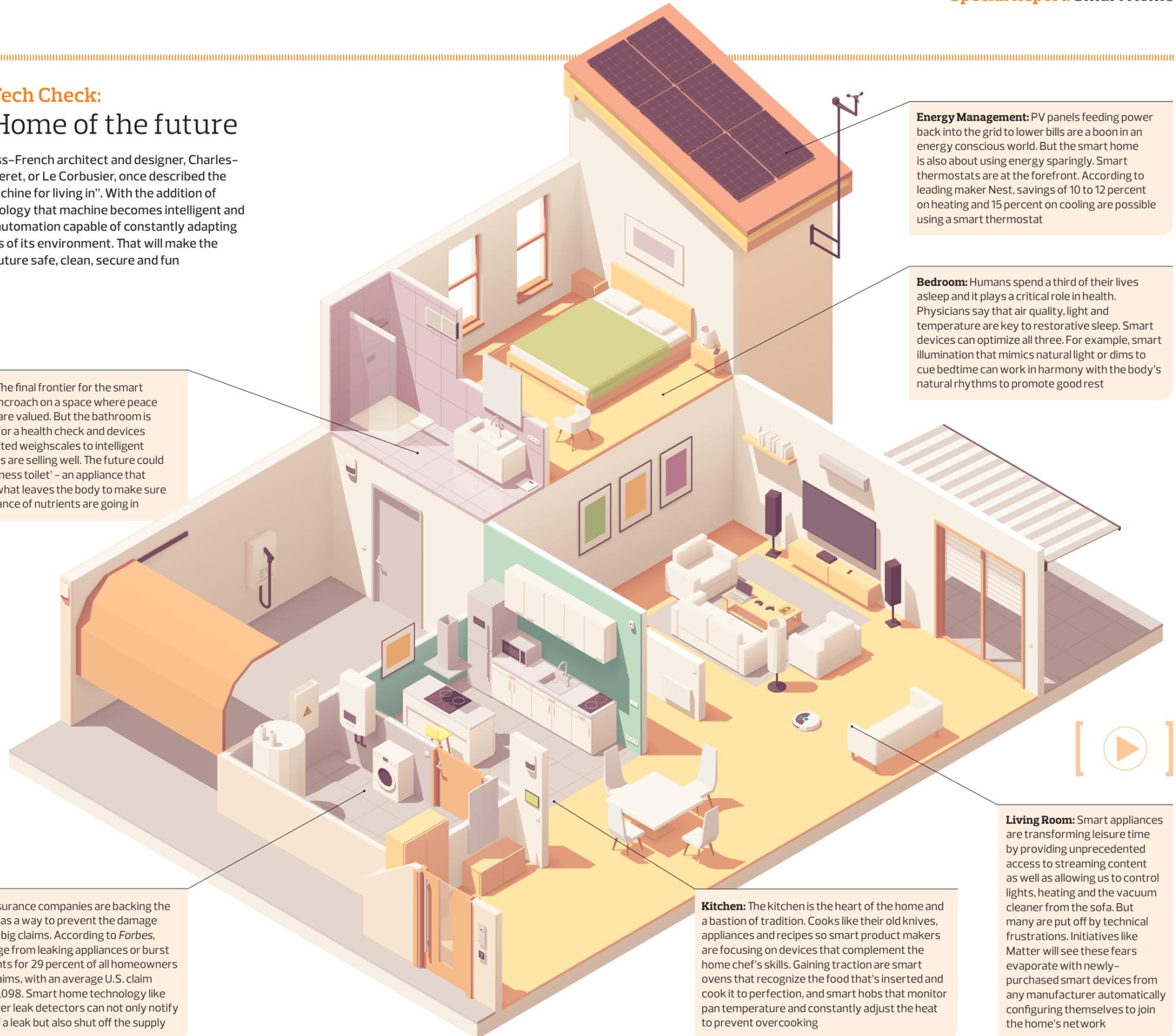
Tech Check:
Home of the future

Influential Swiss–French architect and designer, Charles–Édouard Jeanneret, or Le Corbusier, once described the house as "a machine for living in". With the addition of wireless technology that machine becomes intelligent and supportive of automation capable of constantly adapting to the demands of its environment. That will make the homes of the future safe, clean, secure and fun

Energy Management: PV panels feeding power back into the grid to lower bills are a boon in an energy conscious world. But the smart home is also about using energy sparingly. Smart thermostats are at the forefront. According to leading maker Nest, savings of 10 to 12 percent on heating and 15 percent on cooling are possible using a smart thermostat

Bedroom: Humans spend a third of their lives asleep and it plays a critical role in health. Physicians say that air quality, light and temperature are key to restorative sleep. Smart devices can optimize all three. For example, smart illumination that mimics natural light or dims to cue bedtime can work in harmony with the body's natural rhythms to promote good rest

Bathroom: The final frontier for the smart home, few encroach on a space where peace and privacy are valued. But the bathroom is a good spot for a health check and devices from connected weighscales to intelligent toothbrushes are selling well. The future could see the 'wellness toilet' – an appliance that checks out what leaves the body to make sure the right balance of nutrients are going in

Laundry: Insurance companies are backing the smart home as a way to prevent the damage that leads to big claims. According to *Forbes*, water damage from leaking appliances or burst pipes accounts for 29 percent of all homeowners insurance claims, with an average U.S. claim reaching $11,098. Smart home technology like wireless water leak detectors can not only notify the owner of a leak but also shut off the supply

Kitchen: The kitchen is the heart of the home and a bastion of tradition. Cooks like their old knives, appliances and recipes so smart product makers are focusing on devices that complement the home chef's skills. Gaining traction are smart ovens that recognize the food that's inserted and cook it to perfection, and smart hobs that monitor pan temperature and constantly adjust the heat to prevent overcooking

Living Room: Smart appliances are transforming leisure time by providing unprecedented access to streaming content as well as allowing us to control lights, heating and the vacuum cleaner from the sofa. But many are put off by technical frustrations. Initiatives like Matter will see these fears evaporate with newly-purchased smart devices from any manufacturer automatically configuring themselves to join the home's network

using either or even both Apple Siri and Amazon Alexa voice assistants to control a Nest thermostat.

The introduction of Matter is also influencing chip makers, with silicon and software being optimized for the new standard. The chip plays a critical role in the performance of a smart home solution, says Finn Boetius, a Product Marketing Engineer with Nordic Semiconductor. "In Matter applications, chips need to run the actual application—that is the switch, lightbulb or smart hub—as well as handle multiple wireless protocols at the same time," he says. "If you have a battery-powered smart home device you'll want it to be based on a chip that's optimized for low power but has plenty of power to handle the application."
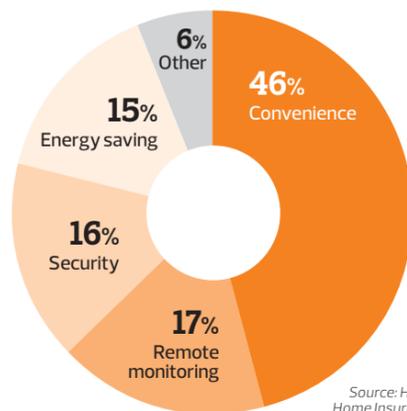
While the potential of Matter is clear, it is going to take some time before its realized — but not as long as you might think. Boetius says Nordic customers are actively developing Matter devices today using the company's nRF52840 and nRF5340 SoCs, which support Thread and Bluetooth LE. And with the company's recent expansion into Wi-Fi, future Nordic Wi-Fi products will also support Matter. Nordic has also integrated the latest Matter development tools into its nRF Connect SDK.

The company is playing a pivotal role in the continued development of the Matter standard and its promotion. Of the 200-plus companies involved in Matter, Nordic engineers are among those from only nine companies that can make changes to its implementation on code repository GitHub, says Krzysztof Loska, Technical Product Manager at Nordic. The company also prominently showcased Matter's interoperability capabilities at the recent CES 2022 exhibition, through a demonstration comprising a Google Nest Hub controller, Google Pixel
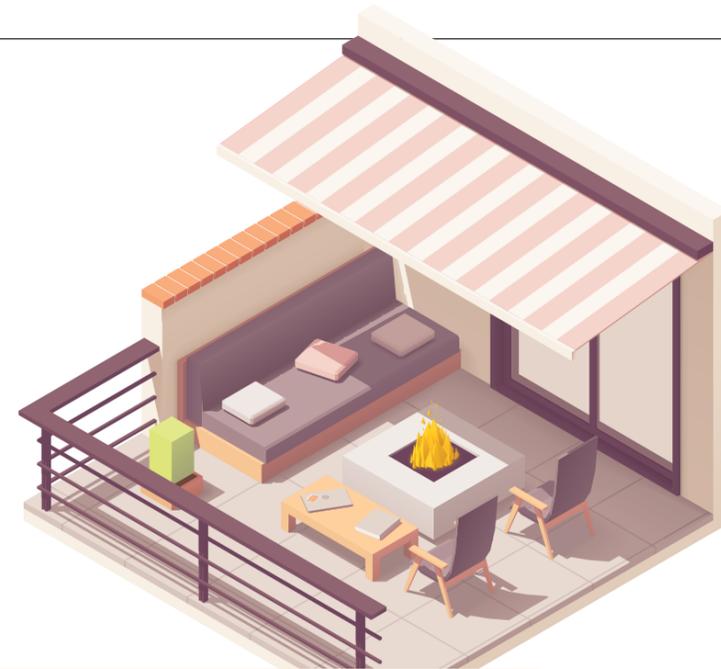
phone, Eve smart plug, Leedarson RGBW light bulb, Netatmo contact and occupancy sensor, Yale door lock and Nordic Thingy:53 'weather station', all running on the Matter standard across a Thread network. Loska also points out that the Nordic SoCs already in the field powering Thread devices can take advantage of an over-the-air software update to become fully Matter compliant. This means manufacturers that embraced Thread early and have already shipped thousands of units can seamlessly upgrade those products to the Matter standard.

STEPPING UP ON SECURITY

As the smart home market starts to boom, security will become ever more important. The expanding number of disparate device manufacturers entering the industry, each with varying commitments to product security, potentially creates unwelcome opportunities for cyber-attack.

But with Matter gaining force as the *de facto* smart home standard, it becomes easier to create a baseline of standardized security expectations. "We are secure by design, we take a zero-trust approach, we use specific industry-standard encryption technology, and every device gets authenticated before it joins the network," says Michelle Mindala-Freeman, head of marketing at CSA. "Every message is secured on the network, and Matter supports secure over-the-air updates."

As a standard, Matter will be continually inspected and strengthened. CSA says Matter's security is supported by a proactive community of members that perform activities such as threat modeling and mitigation.

Privacy also comes into sharper focus in a world of greater device interoperability, which will likely see

greater data sharing among devices. Matter has published a set of 'Matter Privacy Principles' that make clear its focus on privacy, particularly in its commitments to data minimization and ensuring data shared between Matter devices is restricted to the purpose of supporting the specific operation of those devices. The design of Matter, which allows devices to operate locally without needing to send data to the Cloud, is also a significant advantage in maintaining privacy.

Matter is scheduled to be completely rolled out in the middle of 2022 with the release of the final Matter specification, SDK and a certification program. Matter-certified devices should become available to consumers by the end of 2022. Previously published timeframes have been pushed back. The pandemic undoubtedly played a role, but the larger truth around these delays is the scale of the challenges involved. Creating a specification to support interoperability across several distinctly developed ecosystems involving large stakeholders understandably requires precise crafting and substantial testing.

Once the standard is bedded down, Matter is expected to drive improvements in the quality of smart home products. With the issues of interoperability resolved, device manufacturers will be free to focus on their core competencies, rather than on apps and architectures to support onboarding of devices to divergent networks and ecosystems. As walled gardens crumble, customer lock-in will also fade away, meaning manufacturers will need to work harder to attract customers.

When it does arrive, Matter will herald a new dawn. After being little more than a niche obsession for enthusiasts and a hope for the rest of us, the smart home finally looks set for the masses to live the dream.

Easy Living: Convenience is a key benefit of the smart home. A Matter-based network will encourage new applications to cover all our needs both indoors and out. For example, imagine the barbecue warming up, sunshade extending and favorite tunes playing through a wireless speaker as you focus on your guests

Power bank: By analyzing daily driving habits the smart home can decide precisely how much energy an EV needs for tomorrow, topping it up with just what's required. Alternatively the car can act as a power bank, supplying excess energy to the home or local grid to lower bills

State of Play
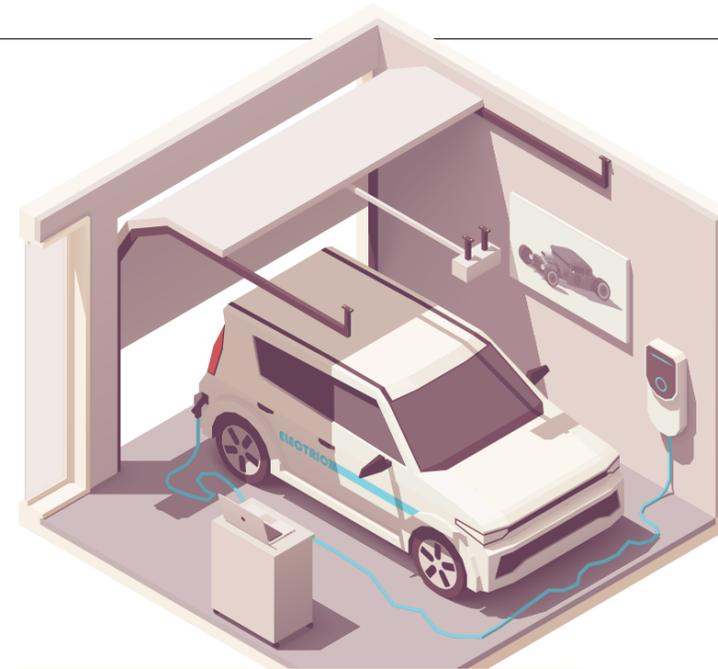## Why consumers choose smart home tech

The poster child of the smart home is the smart speaker. Apart from being convenient for playback of audio, these units act as digital assistants and increasingly powerful home automation hubs. Products from Amazon, Apple, Google and others will be found in 75 percent of U.S. households by as soon as 2025 claims Statista; popular yes, but not all there is to the smart home. Consumers are adding automation and intelligence to their homes for five key reasons: Energy savings; convenience (such as having the lights come on and blinds lowered); security and safety; automating household chores, and entertainment

- **46%** Convenience
- **17%** Remote monitoring
- **16%** Security
- **15%** Energy saving
- **6%** Other

Source: Hippo Home Insurance

Industry Viewpoint:

Christopher LaPré
Head of Technology, CSA

Kellen Yang
Global VP of Sales & Marketing, Leedarson

When technology comes to market it is the innovators that rule. They are nimble and experiment to see what works, and what doesn't. This can also often create walled gardens of technology.

Matter brings a single unified standard that will tear down the walled gardens and make it easy for developers to unleash their creativity and for consumers to build their smart home ecosystems of choice.

CSA has brought together the major vendors and brands into a collaborative environment which will be the catalyst for dramatic market growth. And it will make it easier to access and use smart home technology.

There is a lot of momentum around the initiative with well over 200 companies involved and around 2000 individuals participating. That includes firms like Amazon, Apple and Google and many others including Nordic Semiconductor. This wide adoption, together with IP interoperability, is a key advantage of Matter.

But this is just the start and we're already looking to the future. One key thing we're seeing is that many members are releasing products and silicon into the market that will be over-the-air upgradable to Matter. So those companies targeting the consumer don't need to wait to launch their smart home devices. They can build and release today and upgrade to Matter (and later Matter releases) in the future.

Leedarson is very committed to the Matter standard because as a global initiative that has the backing of most of the companies that are important in the smart home tech sector, we see the standard gaining momentum.

Moreover, because Matter is managed and promoted by an established industry body in the Connectivity Standards Alliance (CSA), Leedarson is confident Matter will become the widely accepted smart home industry standard.

A unifying standard such as Matter is particularly important to us because we are an ODM partner developing IoT products for many global well known tech brands. Matter allows us to design a single version for our customer that they then know will work with all the major smart home ecosystems. That's a major commercial advantage for all.

An example is our A19 Tunable White Bulb. The smart LED bulb is designed to replace a conventional bulb, enabling users to wirelessly control indoor lighting using any compatible connected device, or using voice control via Amazon's Alexa, Apple's Siri or Google's Assistant. We believe we were one of the first companies to launch a Matter compliant smart light.

Nordic was a natural partner for the A19 Tunable White Bulb and its membership of CSA Member Group China also gives us confidence of Nordic's future support for our R&D in the region.

Tech Check

Nordic is a leading supplier of Thread/Bluetooth LE multiprotocol SoCs. This is a requirement for Matter and Thread accessories, where Bluetooth LE is used to commission and Thread for data transfer. It is also possible to build a Thread-capable device now and include Matter support later with an update. The Nordic nRF52840 DK (pictured) and nRF5340 can be used to start developing Matter products

Alive & Ticking

Advanced wearables powered by sophisticated wireless tech are moving beyond fitness to deliver better health outcomes

In Short

Wearables have moved beyond step and calorie counting to offering valuable physiological insights to help prevent disease or medical emergencies

The COVID-19 pandemic fast-tracked the development of advanced wearables so healthcare providers could use them to monitor patients' vital signs remotely

The latest generation of SoCs offer powerful processors that can easily manage complex software algorithms and supervise the sensor hardware of high end devices

When 45-year-old Florida resident Jason Saucier woke up feeling unwell he did as many of us did before the pandemic, and brushed it off as nothing serious and went to work. When he later put on his Apple Watch it started making a sound he had never heard before. On looking at his smartwatch it told him he was in 'aFib' or atrial fibrillation, a type of heart condition that can increase your risk of stroke and other serious heart complications. Saucier wisely decided to head to the emergency room at his local hospital where the doctors confirmed what his smartwatch had been urgently trying to tell him – he was close to going into cardiac arrest.

Saucier is not alone. With an estimated 325 million people using wearables worldwide, you don't have to look far to find other examples of wearable technology that has saved lives. Be it smartwatches notifying emergency services when their fall detection sensor is triggered, or electrocardiogram (ECG) functionality detecting an irregular heart rhythm, increasingly powerful wearables have evolved from the activity trackers and calorie counters of a decade ago. Today these devices not only help keep their owners fit, they also notify them of potential medical emergencies and offer valuable physiological insights to help prevent disease.

In the last five years the take up of wearable technology has scaled faster than imagined. In 2016 in the fitness tracker and smartwatch sector alone, 89 million devices were shipped according to analyst, CCS Insight. At the end of last year, that number was around 300 million, with no end to the growth curve in sight. When asked what their number one expectation was from their wearable in a 2018 Pricewaterhouse Coopers (PwC) survey, 70 percent of respondents said they expected their device to help them live longer, albeit perhaps not in quite as dramatic a fashion as Jason Saucier's Apple Watch did for him.
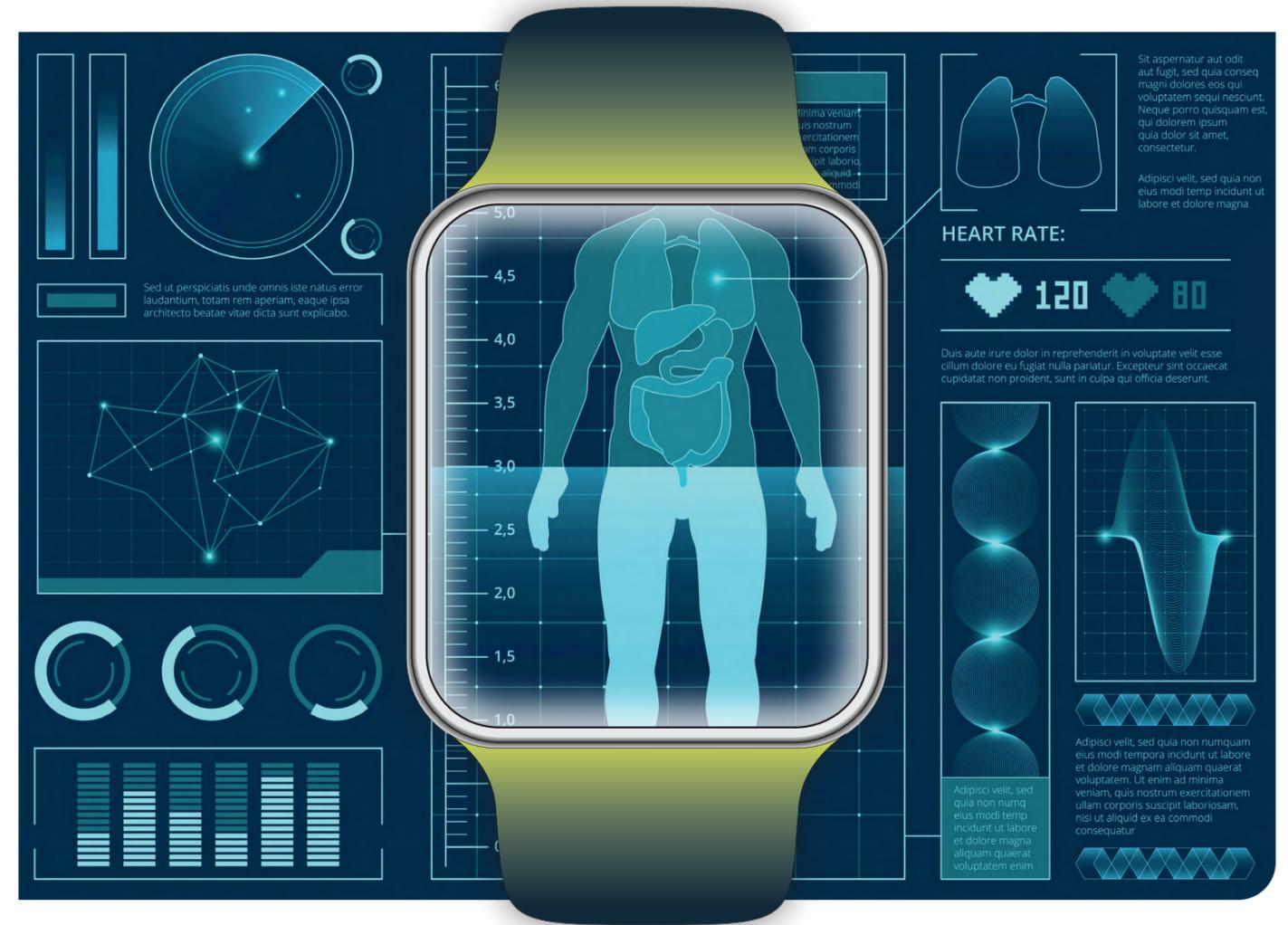
LIVE LONG AND PROSPER

Beyond consumer demand, other factors have also converged to drive the development and uptake of increasingly sophisticated wearables, not least COVID-19. The pandemic and the stress it placed on global healthcare systems saw the fast-tracking of countless IoT-based devices and 'ehealth' wearables. The U.S. Food and Drug Administration (FDA)—responsible for ensuring the safety and efficacy of medical devices in the country—grappled with how to regulate the new technology that blurred the lines between consumer gadget and medical device, but at the same time had the potential to reshape how the healthcare system managed the COVID-19 crisis. Ultimately the pandemic forced a rethink.

In March 2020 the FDA issued a new policy allowing manufacturers of certain FDA-cleared, non invasive, vital sign-measuring devices to expand their use so health care providers could use them to monitor patients remotely, including wearables that measure body temperature, respiratory rate, heart rate and blood pressure.

"Allowing these devices to be used remotely can help health care providers access information about a patient's vital signs while the patient is at home, reducing the need for hospital visits and minimizing the risk of exposure to coronavirus," FDA Principal Deputy Commissioner Amy Abernethy, M.D., Ph.D. said.

Such devices provided a key early warning system about the likelihood of COVID-19 infection by monitoring an individual's physiological data such as blood oxygen saturation, respiratory rate, heart rate and temperature. At the same time the devices used AI and deep learning for infection surveillance in different scenarios from screening to contact tracing. The FDA's seal of approval, while welcome, came too late for some.

"If health systems had accelerated the adoption of [wearable] technology available over the past few years, the magnitude of the current pandemic would likely have been much less severe," said Asma Channa, an early stage researcher from the Polytechnic University of Bucharest, in a paper titled *The Rise of Wearable Devices during the COVID-19 Pandemic*. "The potential of wearables in healthcare is enormous … [but] wearables must have multifunctional capabilities and be easily configurable."

TRANSFORMING HEALTHCARE

While the SARS-CoV-2 virus has helped accelerate the development of multifunction wearables, they are now equally playing a vital role in the prevention and management of a host of other diseases from the physiological—diabetes, hypertension and sleep apnea, for example—to neurocognitive disorders such as Parkinson's disease and Alzheimer's. They are also proving their worth for drug delivery applications.

In so doing they are driving a transition in healthcare from a conventional doctor–patient relationship, where diagnosis and treatment was previously based on a fragmented medical history and medical records, to a digitally mediated consumer-led model. That latter model makes it possible to generate rich data sets that enable health providers to offer more personalized health decisions, make earlier diagnoses, perform remote patient tracking and ensure prescription adherence.

The medical profession is largely in favor of the potential of wearables for patient care but advise caution, particularly if the onus will be on physicians to sort through the massive amount of data the devices collect. "The engineers have been able to give us all this data and create all these sensors for us," Dr Mohamed Elshazly, a cardiac electrophysiologist at the Cleveland Clinic told *The Verge*. "Now it's up to us to analyze that data and figure out how to make clinical sense of it." To do so, Dr Eric Topol and Lionel Tarrasenko, a biomedical engineer known for developing early-warning systems in critical care, said medicine needed to take a lesson from the aviation industry. (See sidebar pg25 *Aviation offers lessons for health monitoring*).

Writing in the international peer-reviewed medical journal, *JAMA*, the pair said jet engines with 100,000 individual parts are monitored constantly with readings taken on temperature, pressures, shaft speeds and vibrations. Machine learning (ML) is used to detect when readings veer from established patterns and produce early warnings that unscheduled maintenance is needed.

"The full potential of health monitoring for people will

> "Engineers have been able to give us all this data and create all these sensors … now it's up to us to analyze that data and make clinical sense of it

HEART RATE:

❤ 120   ❤ 80

only be realized when individualized models underpin the monitoring algorithms,'' the authors wrote. ''Prospective validation that it promotes health, rather than exacerbates false alarms, will be vital.''

WEARABLE AI AND ML

While they may not be able to supervise a modern jet engine, the SoCs and SiPs that power the latest generation of advanced wearables are well equipped to oversee the requirements of even the most sophisticated medical wearables. And that includes support for the ML algorithms that will be needed to sift huge volumes of data for signs that things are going wrong.

For example, Nordic Semiconductor's nRF5340 SoC provides developers with both a high performance application processor and a fully programmable, ultra low power network processor. The dual processors eliminate any trade off between processing capability and power consumption, while Arm CryptoCell-312, Arm TrustZone technology and Secure Key Storage enable advanced root-of-trust and secure firmware updates to help defend against unwanted hacking. A partnership with Edge Impulse, a specialist in TinyML (a scaled-down form of ML suitable for IoT edge devices), also allows developers to benefit from easy to use AI and ML features as standard.

''Computing on edge devices such as wearables is getting progressively more energy efficient and powerful while algorithms are more streamlined and energy optimized,'' says Petter Myhre, Nordic's Head of Product Marketing. Myhre says that in the future these developments will allow high-end SoCs and SiPs running ML routines to

Warmie is designed to integrate into other telemedicine systems so the body temperature of many patients can be reviewed simultaneously

rapidly establish data anomalies that could indicate underlying health issues. In so doing, the chips have the potential to allow wearable developers to explore ways to selectively provide doctors with just the information they need to make rapid clinical decisions.

MAKING SENSE OF MASSIVE DATA

Developers are already taking heed. In response to the pandemic, Polish medical startup Warmie developed a battery-powered, medical grade wearable wireless temperature sensor. The device is designed to rapidly detect changes in body temperature, providing localized continuous temperature and infection monitoring of post-operative surgical wounds in and out of hospital. It is designed to be easily integrated into other telemedicine systems so the body temperature of many patients can be reviewed simultaneously from a single web-based dashboard, without having to attend to the patient in person. It can also be used by consumers such as parents with young children, or patients themselves who want to ensure their own health after leaving hospital.

''Because temperature measurements are traditionally taken manually several times a day, they often miss critical changes that can signify an infection,'' says Warmie's Professor Tomasz Banasiewicz, M.D. PhD. ''And infections left untreated can quickly become more widespread within the body and thus much harder to treat.'' The Warmie Sensor is powered by Nordic Semiconductor's nRF52810 SoC and its 64 MHz, 32-bit Arm Cortex-M4 processor that enables the device to not only record single-point temperature measurements but also evaluate patterns of temperature changes that can be spread over several parts of the body, and alert clinicians or users of potential health risks.
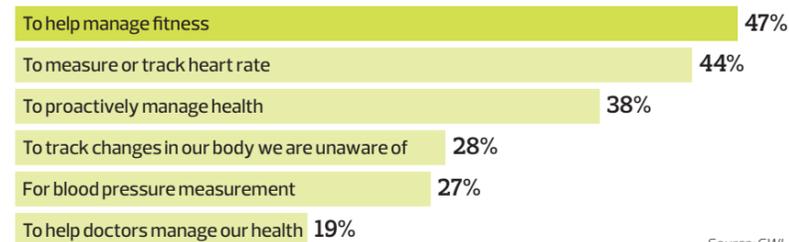
''Body temperature changes throughout the day … so it is more accurate to assess many time series measurements and perform pattern recognition in comparison to an individual patient's baseline,'' continues Banasiewicz. ''This gives significantly more accurate results compared to

traditional manual temperature measurement methods.''

Another company developing wearable products that offer benefits to both the medical sector and consumers is Norwegian tech manufacturer, AppSens. The company's ECG247 Smart Heart Sensor is a wearable ECG heart monitor designed to detect atrial fibrillation and other cardiac arrhythmias. Medical professionals can use the platform to remotely monitor and screen people who are at increased risk of stroke due to heart rhythm disorders or who have symptoms of rhythm disorders such as palpitations or fast heart rate. The solution can also be used by patients to self-test their own heart health, including during exercise or activity.

The device 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 integrated Nordic nRF52832 SoC's powerful Arm Cortex-M4 processor not only supervises the wearable's integrated sensors but also supports the complex computations necessary to run the proprietary algorithms for measuring and analyzing the heart's electrical activity.

''The uniqueness of the ECG247 is the capability for the sensor to analyze in real time for arrhythmia episodes and give both the patient and doctor an immediate result,'' says Tord Ytterdahl, CEO of Appsens. ''Patients obtain a quick medical response, at the same time clinicians gain remote diagnostics and telemedicine services.''

As wireless wearables transition to multifunction medical solutions, their ability to further disrupt healthcare will in part depend on the AI, ML, augmented reality and big data capabilities of the tiny chips inside, as well as the FDA's willingness to accept their role in a highly regulated sector. When this happens, researchers claim, the next step for wearables will be to provide the healthcare system with a value-added emphasis on diagnosis, treatment, tracking and prevention.

With healthcare consuming 18 percent of GDP in the U.S., equivalent to $3.6 trillion a year, the prize for developers of the technology will be huge.

AppSens' ECG247 Smart Heart Sensor is a wearable ECG heart monitor designed to detect atrial fibrillation

Tech Check

Nordic Semiconductor's nRF5340 SoC features ample overhead to supervise the constant stream of data generated by advanced wearables. Its dual processor architecture, security features and ML and AI capability make it ideal for the demands of complex IoT applications, including healthcare devices

Aviation offers lessons for health monitoring

Comprising 78 organs, 206 bones and a central nervous system that receives information from the organs and transmits it through the spinal cord before processing it in the brain, the human body is by any measure a complex piece of engineering. When something goes wrong, and a lot can, it takes a lot of time and sleuthing on the part of a physician to pinpoint the problem and find a fix. Spare a thought then for an avionics engineer.

A Boeing 747 is made up of approximately six million parts, with 100,000 odd in each jet engine alone. And there are four of those. Diagnosing problems can be an incredibly complex process, with end of flight summary reports potentially requiring maintenance engineers to sift through a myriad of data to locate a potential fault that can have equally grave consequences if left undetected as any medical issue.

To overcome this, avionics engineers employ advanced signal processing and machine learning (ML) algorithms to perform 'novelty detection' on flight data. This enables them to identify problems that fall outside of clearly defined vibration tolerances and performance parameters, without having to wade through gigabytes of non-essential data.

As advanced health wearables mature and bring with them the promise of doctors using these devices to support their diagnoses, the medical profession is faced with an even trickier predicament than their aviation counterparts. Engineers know what 'normal' is for a jet engine, yet with the human body normal is not so well defined. How then to best use the vast quantity of data wearables collect and ensure it can be used productively to validate a diagnosis and not generate false alarms?

According to researcher Dr Eric Topol, the key will be to follow aviation's lead and employ AI and ML algorithms to reliably extract clinically meaningful data from the rest.

The processors in today's advanced wearables make AI and ML easily accessible to developers, even on the optimized wireless SoCs that need to fit in a miniaturized footprint of a wearable. In so doing, wearables can help physicians more clearly determine what patient physiological data is normal and therefore not pertinent to a diagnosis, and more importantly what data is not, and thus justifies further investigation.

Why We Want Wearables

Wearable technology has come a long way in the last 10 years. In part driven by consumer demand, in part by the increased sophistication of the wireless chips that power them, today's wearables are multifunction devices that can not only provide fitness motivation and smartphone connectivity, but also have the capability to offer a valuable clinical role. While three in five smartwatch and fitness tracker owners still use their wearable for step counting, increasingly users are embracing their potential for advanced healthcare management. According to research by analyst GWI, this is why we use wearables:

To help manage fitness	47%
To measure or track heart rate	44%
To proactively manage health	38%
To track changes in our body we are unaware of	28%
For blood pressure measurement	27%
To help doctors manage our health	19%

Source: GWI

Making Waves

LE Audio is nearing commercialization and will deliver superior sound and longer battery life for both the hard of hearing and music lovers

In Short

LE Audio will not only enhance the lives of the hard of hearing and music listeners but will also enable many more use cases, including Audio Sharing

LE Isochronous Channels, a new codec and the latest generation of Bluetooth LE SoCs have come together to deliver on the promise of high-quality audio streaming

Leading audio brands are embracing LE Audio in soon-to-be launched consumer products

A pair of Moon Audio Opulence speakers will lighten the buyer's wallet by a cool $1.1 million, according to *What Hi-Fi*. The specialist magazine reports that just ten pairs of the speakers were produced, and each boasted a rather ominous-sounding 'Dark Star' feature. The maker noted the speakers offer "an optional second way of experiencing [sound] which delivers music into the listener's brain, bypassing the ears". The company also helpfully suggested that the speakers were "not meant for an ordinary living room". That's likely not a problem for prospective buyers.

Consumers without the disposable income to buy a pair of the Opulences and with conventional domestic facilities still crave decent audio quality. Wireless headphones, while perhaps lacking the essence of Dark Star, offer a considerably more affordable, convenient and discrete solution. And, while demanding the owner has some actual ears, the sound quality of reasonably-priced wireless products is perfectly acceptable for anyone bar the most demanding hi-fi aficionado.

But superior wireless sound is only months away. LE Audio, launched by the Bluetooth SIG back in January 2020 and with key specifications following during that year, is approaching commercialization and will start appearing in earbuds and headphones in late 2022.

"LE Audio represents one of those rare occasions where there's no technical trade-offs limiting what a designer can

do. It brings better audio quality, including True Wireless Stereo [TWS], more robust wireless connectivity and vastly improved battery life," says Vince Hagen, Business Development Manager for LE Audio with leading Bluetooth LE chipmaker Nordic Semiconductor. "An engineer can, for example, design earbuds with incredible sound quality and extended battery life by replacing Classic Audio with LE Audio. Alternatively, they can use smaller batteries to shrink their product's form factor and direct material costs, while still matching the original product's playtime."

Those use cases mean LE Audio will not only improve the pleasure of music lovers, but will also bring families closer through Audio Sharing by allowing each member to watch the same film through their own headphones. Attendees at plays and conferences will also benefit. "With LE Audio, places like theaters and lecture halls will be able to provide high-quality audio in multiple languages," said Peter Liu of Bose Corporation and member of the Bluetooth Special Interest Group (SIG) Board of Directors, in a statement.

WIRELESS AUDIO ORIGINS

The invention of Thomas Edison's phonograph—which used a needle to etch a groove which could then be played back by another needle following the groove's indentations—was among the first devices that allowed for the reproduction of recorded sound. Grooves, first on wax with mechanical playback and then on vinyl with electrical playback, continued as the mainstay of recorded sound until after World War II. Post-conflict, the German invention of magnetic tape became internationally available and was adopted as the preferred media for original recordings. Tape lasted until the mid-1970s when the analogue era was brushed aside by digital recording using technology pioneered by Sony.

Today, the benchmark for high quality digital sound is the CD. But while the high bitrate of CD technology is still beyond the capability of audio streaming, it turns out that most listeners don't care. They are perfectly happy with the quality delivered by the more modest bitrates supported by compressed audio formats that can easily be handled by wireless devices.

The Bluetooth SIG, custodian of the Bluetooth LE

Earbuds can be designed with incredible sound quality and extended battery life with LE Audio

specification, introduced its own low-complexity sub-band codec (SBC) to boost audio quality at low-to-medium bit rates with additional firmware to customize the Bluetooth protocol for audio applications, back in 2003. Called the Advanced Audio Distribution Profile (A2DP), it facilitated audio streaming between two Bluetooth devices.

However, the SIG's technology suffered from a few drawbacks. Among these was a channel limitation that only allowed the technology to stream audio to a single device such as the left-hand unit of a pair of earbuds. Engineers overcame the problem by processing the incoming Bluetooth audio stream in one earbud and then wirelessly retransmitting the second channel to the other earbud. The technique worked okay but was processor intensive and shortened battery life. Consumers demanded better.

A NEW LEASE OF LIFE

But it wasn't the music lovers that commercial outfits were really listening too, rather it was the hard of hearing that kick started the development of better wireless audio. According to consultant Nick Hunn, in his book *Introducing Bluetooth LE Audio*, hearing aid users have always wanted to connect to smartphones and other Bluetooth-equipped devices, but the relatively high power consumption of

> "LE Audio represents one of those rare occasions where there's no technical trade-offs limiting what a designer can do"

Classic Bluetooth proved challenging. Hearing aids are worn for many hours each day and only have space for small batteries so low power consumption is critical.

In his book, Hunn explains that Apple launched a proprietary solution based on Bluetooth LE in 2013 which was then licensed to hearing aid makers. Unfortunately, the system was unidirectional and only worked with Apple's own handsets. The Bluetooth SIG started work the same year on a Bluetooth standard for audio which would bring interoperability to the hearing aid ecosystem.

Today, the LE Audio specification features improved battery life compared with Classic Audio for all use cases. But because the technology allows engineers to further trade off audio quality against battery life, hearing aid applications where sound quality is not so critical as all day power, can gain a remarkable increase in battery life too.

Consumer audio companies soon realized that the hearing aid use cases were equally applicable to their market. LE Audio gained further momentum and the project expanded such that in the nine years since, the initiative has evolved into the Bluetooth SIG's largest ever specification development project.

Finn Boetius, a Product Marketing Engineer with Nordic explains there are three key elements that have come together to push LE Audio towards commercialization.

"First there was the addition of Isochronous Channels introduced as part of the Bluetooth 5.2 Core Specification, then the release of the Low Complexity Communication Codec [LC3] in December 2020, and finally the availability of highly efficient Bluetooth LE SoCs with powerful processors such as Nordic's nRF5340," he says. "And to help developers accelerate their LE Audio projects we've now introduced an nRF5340 Audio development kit which allows them to easily explore the technology's potential."

LE Isochronous Channels (*see WQ Issue 1, 2020 pg29*) enables isochronous communication. This in turn allows multiple devices (for example, a pair of earbuds) to each receive their own unique audio stream. The channels are 'time bounded' so that the left and right channels retain the original precise musical timing upon replay. The result is excellent stereo sound but without the processor overhead that plagued Classic Audio and hence lower power consumption. The Bluetooth SIG has dubbed the technology 'Multi-Stream Audio'. "It provides a better stereo imaging experience ... and makes switching between multiple audio source devices smoother," says Nick Hunn.
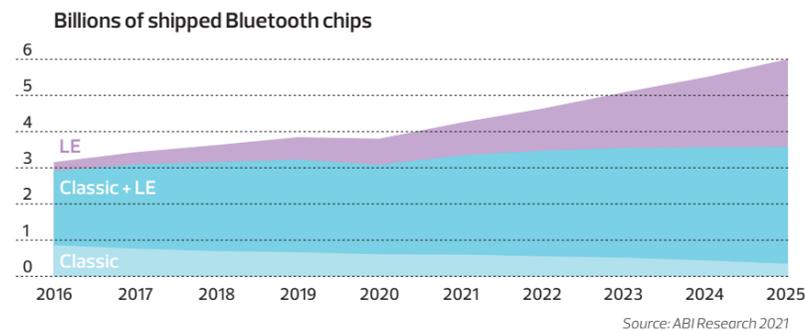
ENCODED AUDIO

While LE Audio benefits from Multi-Stream Audio for capabilities such as Isochronous Channels, it is LC3 that really underpins its striking combination of high audio quality and long battery life. In his book on LE Audio, Hunn notes that LC3 is one of the most advanced audio codecs available today, providing enormous flexibility and covering everything from voice to high quality audio. (See sidebar pg29, *Building an audio streaming codec*.)

That flexibility comes from LC3 being able to encode speech and music at various bitrates by supporting sampling rates of 8, 16, 24, 32, 44.1 and 48 kHz and sample resolutions of 16, 24 and 32-bits. It is this bitrate flexibility that allows developers to trade off sound quality against power consumption and in turn extend battery life or reduce battery size. Moreover, according to the Bluetooth

Tech Check

The nRF5340 Audio DK supports LE Audio applications with Nordic's powerful nRF5340 SoC and Cirrus Logic's CS47L63 high performance, low power audio DSP. The DK can function as a USB dongle to output or receive audio data to or from a connected PC. Or it can act as a headset with a microphone and speaker. Two DKs are required for True Wireless Stereo

[▶]

LE Audio allows hearing aid developers to trade off audio quality against all important battery life

SIG, extensive listening tests have shown that at all sample rates, the audio quality of LC3 exceeds that of SBC at the same sample rate, and provides equivalent or better audio quality at half the bitrate. Hunn explains that the practical benefit is the total size of LC3 encoded packets is around half of the size of those for SBC for the same audio stream, saving power. (There is an interactive listening demo powered by LC3 at bit.ly/3rDamtE.) Hunn says designers probably don't need to aim for the highest bitrates when striving for audio quality because other limitations in reproduction and the listening environment will likely mean few listeners will appreciate the quality gains they yield.

DEVELOPING WITH LE AUDIO

The LC3 codec is important to realizing the promise of LE Audio. Through highly efficient compression, the codec saves considerable energy while maintaining audio fidelity. But on the debit side of the ledger, the codec demands processing power to run the compression and decompression algorithms on each side of the link. Previously, that threatened to negate some or even all of the codec's operational gains, especially in compact products with correspondingly small batteries such as earbuds and hearing aids. However, a new generation of

embedded Arm processors used in leading edge Bluetooth LE SoCs offers greater computational overhead to deal with advanced codecs such as LC3 yet at a much lower energy consumption than previous generations of chips.

Nordic's nRF5340 is the definitive example of the leading edge in ultra low power consumption Bluetooth LE SoCs. Nordic has a hard won reputation for designing power efficient wireless SoCs and has taken this a step further with the dual processor architecture of the nRF5340. The nRF5340 features a dedicated Arm Cortex M33 application processor, optimized for performance and with ample overhead to look after high computational demands together with another M33 processor to supervise wireless connectivity. This second processor is optimized for low power consumption. The result is an SoC with the ideal combination of low power consumption and performance to meet the demands of LE Audio.

To accompany the SoC and to ease the development process, Nordic has released the nRF5340 Audio DK. The DK contains everything needed to get started with LE Audio projects. It can be used in different configurations, for example as an earbud in TWS applications or a broadcast receiver. For most use cases, for example wireless headphones, the designer needs to use two or more DKs, one to act as the headphone and one as the audio source.

LE Audio has taken years to reach commercialization, but now it is close. And it's gaining serious attention. For example, Sennheiser, one of the world's most renowned audio brands, says it will be using Nordic's Bluetooth LE Audio technology in selected future consumer products. "We were looking for a reliable short-range Bluetooth LE Audio wireless solution for some upcoming products," explains Stephan Lietz, Director Development Consumer Division at Sennheiser. "Through-wall range and reliability are very important to consumers, and was one of the many reasons we selected Nordic Semiconductor as our development partner."

The result of this partnership, and many others like it, will be LE Audio-powered products not meant for an ordinary listening experience.

> "
> LE Audio has taken many years to reach the market, but now it's close. And it's gaining serious attention

Building an audio streaming codec

Sound is an analog signal and must therefore be digitized for transmission by a packet-based wireless technology. The benchmark for digital audio is CD quality, whereby the original signal is sampled at 44.1kHz with 16-bit precision. The resulting data output rate is 1.41 Mbps which is sufficient to capture all the sounds humans are capable of hearing. (*See The science of digital sound, WQ Issue 1, 2020 pg17.*) But that's too great a throughput for a wireless link powered by modest batteries – so engineers turn to compression techniques to overcome the challenge.

It is the encode/decode (codec) algorithm that governs sound wave digitization The codec determines two parameters that determine the initial degree of compression: Sample rate (Hz) and bit depth (bits). The sample rate captures the sound's analog waveform amplitude at a specific time. Sample rate is a trade off; lower rates result in smaller audio files but decreased quality. The bit depth is the number of bits of information in each sample; again, there is a trade off between the number of bits and the audio quality. Common bit depths are 16, 24 and 32-bit. The sampling rate by bit depth by the number of channels (typically there are left and right channels in a high quality audio stream) determines the bitrate or the number of bits per second (bps). For acceptable music quality, the bitrate should be greater than 96 kbps. It is the job of the decoder to convert the digitized data back into the analog soundwave for reproduction by the loudspeaker.

Many codecs use additional compression to lower the demand on the wireless link, boosting reliability and extending battery life. These codecs use 'lossy' formats whereby before transmission, the encoder discards information considered not to affect how the listener perceives the decoded audio stream. The aim is to lower the bitrate as much as possible without compromising audio quality. The format is called lossy because the decoder can never reproduce the original signal due to lacking the information that wasn't transmitted. Developers are guided by psychoacoustic models which help them determine which information can be safely discarded by their algorithms. But not all psychoacoustic models are equal and compressed audio streams with the same nominal bitrate but competing lossy formats can exhibit very different perceived sound quality.

Survival of the Fittest

As Bluetooth LE evolves, Classic Bluetooth is destined for obsolescence bar the Classic + LE dual-mode chips used in PCs and smartphones. A key upgrade came with the introduction of Bluetooth 5, which introduced a 2 Mbps mode enabling developers to increase Bluetooth LE throughput near to Classic Bluetooth levels at the cost of a small range reduction. Wireless audio was the last bastion of Classic Bluetooth, but the introduction of LE Audio removed the advantages it held. All a consumer cares about is that Bluetooth works, is easy to set up, and doesn't drain their device's battery. Bluetooth LE does all that and then some

Billions of shipped Bluetooth chips

	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
6										
5										
4										
3	LE									
2	Classic + LE									
1										
0	Classic									

Source: ABI Research 2021

Sports & Fitness

BERG AirHive

Bluetooth LE–powered sensor enables trampolinists of any ability to measure and track their activity and skills

The global sports technology market is expected to reach $36.2 billion by 2028, registering a CAGR of 16.8 percent from 2021 to 2028, according to a new report by analyst Grand View Research. The growth is attributed to technical advances that have improved the accuracy, engagement and experience of both participants and spectators, and is empowering a data driven sports culture

Combining a nine–axis motion sensor and machine learning technology, WRLDS Creations' BERG AirHive straps to the user's right leg to accurately track their trampoline activity. The wearable measures a range of movement data—for example rotation speed—to allow the user to continuously record their progress and improve their skills. The company's AI software has been developed using data gathered from gymnasts performing jumps under real conditions

During World War II, the U.S. Navy Flight School developed the use of the trampoline in its training of pilots and navigators, giving them concentrated practice in spatial orientation that had not been previously possible. After the war, the development of the space flight programme again brought the trampoline into use to help train both U.S. and Soviet astronauts, giving them experience of variable body positions in flight

Ever since its invention, people have been setting trampolining world records for somersaults, the highest bounce and even backflips while riding a unicycle. If you want to get into the record books you will need to produce more than 3,333 consecutive somersaults or leap higher than 6.73 meters. The record for unicycle backflips is however more modest; the current world record stands at just two

While bouncing games have been around hundreds of years, trampolining as we know it is a relatively modern invention. George Nissen earned the first patent for a tumbling device in 1945, 15 years after he visited the circus and wondered if the safety net used by trapeze artists could be modified to not just catch the gymnast, but also allow them to continue to bounce

BERG AirHive developed by WRLDS Creations can achieve a playtime of at least one week between charges, made possible in part due to the ultra low power characteristics of the Nordic SoC. Jump data is relayed from the device to the BERG AirHive app on the user's smartphone using the SoC's Bluetooth LE wireless connectivity. The app includes minigames, skill training, jump analytics and a social flow function which allows users to upload their latest tricks and create challenges for others

Tech Check

The algorithms enabled by the nRF52832 SoC's Arm Cortex M4 processor with floating point (FP) unit enable BERG AirHive to learn new tricks over time, and provide feedback to the user based on learned data. The SoC's Arm processor has ample overhead to deal with the computations demanded of high end wireless applications

Drone Tracking

Drone tracker accelerates flight approval and monitors drone status

The Nordic cellular IoT SiP and Bluetooth LE SoC powered Dronetag Mini promotes flight safety and compliance with new European remote ID regulations

> " We opted for cellular IoT in part because we wanted the device to have long lasting battery life

D rone technology developed from the mid-1800s and took the form of balloons, torpedoes and aerial targets. Through the following 150 years, even as the inventions became increasingly innovative and robust, drones continued to be deployed almost entirely for military purposes.

That changed when the first commercial drone permits were issued around 15 years ago. Since then, government agencies and commercial organizations have been able to use modern drones—officially known as unmanned aerial vehicles (UAVs)—for a wide array of applications including emergency response, border and security surveillance, industrial site and pipeline inspections, crop monitoring, infrastructure monitoring, small item deliveries, mapping and more.

Today, flight approval for drone operation demands compliance with local regulations. These regulations came into force due to concerns over coordination and safety as the number of drones buzzing overhead escalated. In Europe, for example, the U-Space Regulation (EU) 2021/664 adopted by the European Commission, which comes into effect from January 2023, stipulates that all airspace participants must be able to remotely identify their drones and the operators.

These regulations, and the restrictions they bring, could present a compliance challenge for operators of existing UAVs and see the deployment of drones stall in affected regions. Fortunately, IoT innovation is helping to fast track the flight path to meeting compliance with new regulations and more effective drone monitoring.

A remote ID device for drones

Czech startup Dronetag—a company that works in conjunction with the European Space Agency (ESA)—has developed a compact and lightweight remote ID device for UAVs through the ASPIRE WITH ESA program. The program aims to encourage private enterprise to come up with solutions to space and aerospace problems.

The Dronetag Mini solution ensures a drone is detectable to all air traffic participants. Once attached, the device brings any drone from any manufacturer into line with the new regulations.

"The number of drones being used all over Europe has been growing [quickly], leading the EU to introduce new regulations which can be restrictive if operators don't have the right setup," explains Lukáš Brchl, CEO of Dronetag. "Our platform makes it easy to comply with these regulations and will help to enable a range of

Flight approval for drone operation demands compliance with local regulations

Tech Check

Dronetag Mini is powered by a 500 mAh rechargeable Li-poly battery, providing between eight and 14 hours of battery life between recharge. This endurance is thanks in part to the ultra low power characteristics of the Nordic chips which have been engineered to minimize power consumption

applications—such as delivery services requiring multiple concurrent trips, or drone shows and drone fleets where multiple drones are sharing the same airspace at the same time. We expect these to become increasingly common."

In flight, Dronetag Mini employs Global Navigation Satellite System (GNSS) signals to determine the exact position of the drone, and relays that data to the Dronetag web app via the Cloud using the drone's integrated Nordic nRF9160 SiP's cellular connectivity. This ensures the drone and its flight plan are visible both to airspace authorities and other pilots, and enables the user to track the drone in near real time.

Alternatively, the data can be transmitted to the Dronetag app on a user's smartphone using Bluetooth Long Range connectivity provided by Nordic's nRF52833 SoC. The high link budget provided by the SoC's 2.4 GHz multiprotocol radio enables Dronetag Mini to achieve an outdoor range of up to 1.5 km to the user's smartphone.

Connectivity for compliance

In addition to the drone's position, Dronetag Mini reports the UAV's speed and atmospheric pressure data using integrated accelerometer and barometer sensors, as well

as the device's battery level and LTE-M signal strength, and operator identification information.

From the beginning, Dronetag was looking for cellular IoT and Bluetooth LE wireless connectivity solutions that would complement each other to meet the requirements of the Dronetag Mini platform. "We integrated the nRF9160 SiP for Network Remote ID and the nRF52833 SoC for Direct Remote ID to guarantee compliance with the EU regulations," says Brchl.

Beyond the implementation of multimode connectivity for compliance purposes, Dronetag narrowed down its selection to Nordic solutions for a number of important reasons: "We selected the nRF9160 SiP because we needed the LTE-M modem and application processor in one package to save space and simplify the board design. And we opted for cellular IoT in part because we wanted the device to have long lasting battery life," he says. "We also appreciated the great support from Nordic during development and consider the Zephyr RTOS to be state-of-the-art in the IoT embedded world." Zephyr is incorporated into Nordic's nRF Connect SDK.

Ably supported by Nordic tech, the Dronetag Mini platform will ensure safe airspace coordination for the thousands of drones that will fill our skies in the future.

Miguel Lira
Innovation & Development Director, Urban Control

Lighting the path to the connected smart city

Street lighting combined with interoperable, scalable tech will bring the smart city vision to life

For the smart city vision to fulfil its promise at scale, street lighting will play a central role. The advantages of intelligent streetlights are well known. Their light output can be adapted to precisely what is needed, and they can respond dynamically to changes in pedestrian footfall or road traffic. In doing so, the lights reduce energy costs, carbon emissions and light pollution. They also report when they have a fault, which saves on maintenance costs. Not only does this make street lighting more efficient, but it also provides a physical infrastructure from which to run countless other

> " The challenge is to educate smart city operators and try to solve the problem they actually have

innovative smart city applications such as traffic counters and parking sensors.

Another key factor in bringing the smart city to life is selecting the appropriate connectivity technology. While short range technologies are well suited for mesh networking together sensors, they require a gateway to get the signal back to the Cloud. Cellular IoT solves this problem and is now disrupting the sector. Early non-cellular IoT smart city lighting installations were almost all based on proprietary tech that forced

city authorities to build their own wireless IoT networks and become expert wireless IoT network managers, neither of which they wanted. In contrast, cellular IoT leverages established infrastructure in towns and cities worldwide.

This is what Urban Control has set out to achieve with the launch of our Urban Node 324 city streetlight LED luminaire controllers. Each controller plugs into a standard LED lighting socket and connects via cellular IoT network using Nordic's nRF9160. It can then be remotely controlled by any smart city Central Management System (CMS). The product employs IoTerop's ALASKA Lightweight Machine to Machine (LwM2M) server which works with the two most widely used smart city standards — TALQ and uCIFI.

The need for interoperability

LwM2M, uCIFI and TALQ standards offer the promise of an interoperable and scalable smart city, where IoT devices and systems from different vendors can co-exist. This allows a single CMS to configure, control, command and monitor a smart city device network. Smart city platforms built on the LwM2M standard also offer edge processing capabilities and so can provide a solution for effectively managing the quantity of data smart city devices will generate, and reduce the volume that needs to be reported to the Cloud.

For now, the challenge is one of educating smart city operators, demystifying the complexity, and trying to solve the problem they actually have, not the problem they think they need to solve. It's not simply about gathering data – interoperability is key.
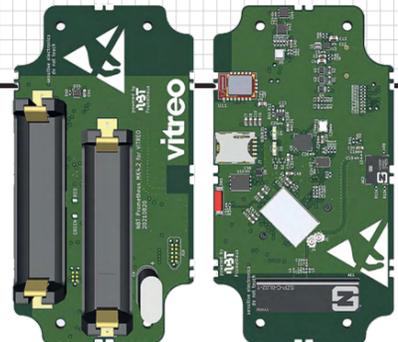
Development Platforms

LTE–M/NB–IoT dev platform aids cellular IoT prototyping

German venture studio, Next Big Thing AG (NBT), has launched an IoT sensor development platform designed to simplify prototyping and speed time to market for developers of cellular IoT– and Cloud–based solutions. The platform supports development across a wide range of industrial applications including manufacturing, pharmaceutical, and logistics sectors.

The Prometheus development platform is powered by Nordic's nRF9160 low power SiP with integrated LTE–M/NB–IoT modem and GNSS. The nRF9160 SiP's 64 MHz Arm Cortex–M33 dedicated application processor provides ample computational power to supervise the most complex cellular IoT product functionality.

NBT's IoT development platform comprises a hardware and embedded software platform (Prometheus); and the Cloud–based software platform (NBT Software Platform). The standard configuration of Prometheus consists of a range of sensors, for example temperature sensors (analog and digital), accelerometer, magnetometer, gyroscope, air quality sensor, ambient light sensor and humidity sensor. The extended version of Prometheus also includes Nordic's nRF52832 Bluetooth LE SoC to provide support for Bluetooth LE connectivity, as well as USB,

GPS, radar, an adjustable antenna tuner and extended temperature range.

In addition to the Nordic SiP and the sensors, the CE–certified development platform also features a stable embedded software stack, fully encrypted communication, mesh connectivity for short–range communication, automatic switching between NB–IoT and LTE–M cellular IoT connectivity, and advanced provisioning tools.

The solution is optimized for low power consumption and provides an industrial temperature range of –40 to +85˚C.

Modules

Tiny Bluetooth LE module supports complex applications

An ultra miniaturized module based on Nordic Semiconductor's nRF5340 high–end SoC has been launched by Insight SiP. The ISP2053–AX fully integrated module is offered in an 8 by 8 by 1 mm package size, and is described by the company as the world's smallest nRF5340 SoC–based module. It is designed for space constrained, processor intensive implementations, for example wireless audio, medical and high value consumer applications.

Nordic's nRF5340 SoC is the world's first wireless SoC to integrate dual Arm Cortex–M33 processors providing a high performance application processor alongside a fully programmable, ultra low power network processor. The module supports major RF protocols. The SoC also incorporates Arm CryptoCell–312, Arm TrustZone
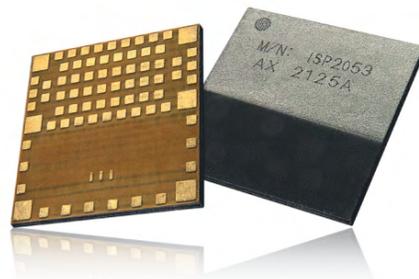
technology and Secure Key Storage for applications demanding high security.

In addition to the nRF5340 SoC, the ISP2053–AX module offers an integrated antenna, RF matching circuits, and will be precertified for global markets including Europe, the U.S. and Japan. As a result, developers access an out–of–the–box module for sophisticated short range wireless solutions without needing to understand the complexities of RF design.

The ISP2053–AX is designed to run on a coin cell battery, and can last up to several years between battery replacement. The ISP2053–AX Development Kit provides a complete hardware solution for prototyping, testing and programming with maximum flexibility.

Smart Home

Contest encourages smart home designs

Nordic has launched a contest to find the best cellular IoT design project for a smart home or smart city application in partnership with maker community website, Electromaker.

The 'Make it Smart with Nordic Thingy:91' design contest asks entrants to demonstrate their prototype or Proof–of–Concept using the Nordic Thingy:91 or nRF9160 DK, to send data from the application to the Cloud. Submissions can incorporate ML using Edge Impulse Studio.

The top 50 project ideas were issued with free Nordic Thingy:91 hardware from which to develop their design, with judging criteria covering creativeness, completeness and complexity. Winners of the $3000 prize pool will be announced on April 27, 2022.

Logistics & Transport

Gateway simplifies global Cloud communication

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

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

The SFM2 uses the nRF52832 SoC's Bluetooth LE throughput capability to provide data rates approaching 50 kBps, claims Sensor Maestros. The company says SFM2 is the smallest and lowest power wearable IMU on the market to provide both Bluetooth LE and USB connectivity.

Cellular IoT

Cellular IoT power controller monitors batteries on remote IoT equipment

A cellular IoT power controller that can monitor batteries on remote IoT equipment and turn connected devices on and off to maximize battery life has been launched by Dublin–based NEST iON.

Designed for applications where the ability to monitor battery levels is extremely difficult, the rugged IP67–rated IOT Power Controller uses a Nordic nRF9160 SiP to provide both NB–IoT and LTE–M connectivity.

"Our controller conserves battery life by only having remote sensors and equipment on when you need them to be on," explains NEST iON COO, Karl Peters. "By using intelligent sleep mode scheduling, for example, we can hugely extend battery operating life. And by monitoring battery levels remotely we can schedule battery replacements with precision to avoid outages being the only indicator that a battery has drained down, which is too late."

In operation, the IOT Power Controller searches for an NB–IoT signal first because it is the lowest power cellular IoT option. If it can't find a signal, it will use the dual–mode functionality of the Nordic nRF9160 SiP to automatically switch to searching for an LTE–M signal instead.

The IOT Power Controller can be configured to wake and connect to the cellular network from deep sleep mode if it detects motion using an accelerometer. The product also operates in underground locations such as car parks, basements or buried equipment locations.

A partner Android app gives critical battery data including percentage charge left and days of operation remaining, battery voltage, current and current used, plus the state of the IOT Power Controller's internal relay.
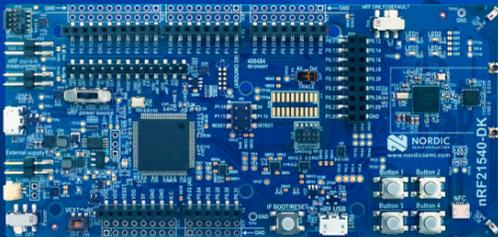
Boosting range with the nRF21540 RF FEM

Nordic's new RF front-end module enhances nRF52 and nRF53 Series SoC sensitivity and transmit power to extend range and increase link robustness in challenging radio environments

Nordic's nRF52 and nRF53 Series SoCs are designed from the ground up to minimize power consumption for long battery life. However, the SoCs are also frequently used for applications where extended range or coping with a challenging RF environment are more important than battery life. One example is asset tracking in a large warehouse where a tracker with longer range allows for fewer devices to cover the space, cutting costs. A second example is the smart home where other devices transmitting on the 2.4 GHz band—including those using classic Bluetooth and Wi-Fi, and cordless phones—make for a challenging RF environment for Bluetooth LE, Thread and Zigbee products. In such a situation it's common for interference to result in missed packets and subsequent retransmits which have a detrimental impact on battery life.

There are many factors that impact the range of a wireless connection, but the key determinant is the transmit power of the transmitter and the sensitivity of the receiver (that combine to offer the 'link budget' which is measured in dBm). In a like-for-like application, increasing the link budget will extend range. Moreover, for two products wirelessly connected over a set distance, the device with the greater link budget will be less prone to interference and lost packets. In particularly demanding RF environments, or where the application is operating close to its range limit, it can actually be more energy efficient to boost transmit power than continuously resend unreceived packets.

A proven method to raise the link budget of a wireless connection is to boost transmit power with a power amplifier (PA) and increase receive sensitivity with a low noise amplifier (LNA). The LNA boosts a weak signal without adding significant additional noise; its key attributes are gain (a measure of how much the signal is amplified) and noise figure (NF, a measure of how much noise is added during amplification).

An RF front-end module for Nordic SoCs

Nordic's nRF21540 RF front-end module (FEM) is a PA/LNA designed to complement the nRF52 and nRF53 Series SoCs. In addition to the Nordic SoCs running Bluetooth LE, Bluetooth mesh, Thread, Zigbee or 2.4 GHz proprietary, the FEM is also suitable for non-Nordic short range wireless SoCs running the same protocols. In addition to increasing the range of the wireless transmission, the Nordic FEM enhances the robustness of the wireless link – reducing packet losses and in turn lowering link latency, enhancing throughput and reducing power consumption.

The FEM's PA offers an adjustable TX power boost up to +21 dBm and the LNA provides +13 dB RX gain with a low NF of 2.7 dB. The FEM also supports antenna diversity for

> A proven method to raise the link budget of a wireless connection is to boost transmit power with a PA and increase receive sensitivity with an LNA

improvements to link robustness in static installations.

The FEM can be configured for ARIB, ETSI and/or FCC approval. There are interfaces for GPIO control as well as SPI control, and 50 Ω matched input and output. Supply range is 1.7 to 3.6 V and temperature range is –40 to 105 °C. The FEM is supplied in a 4 by 4 mm QFN16 package.
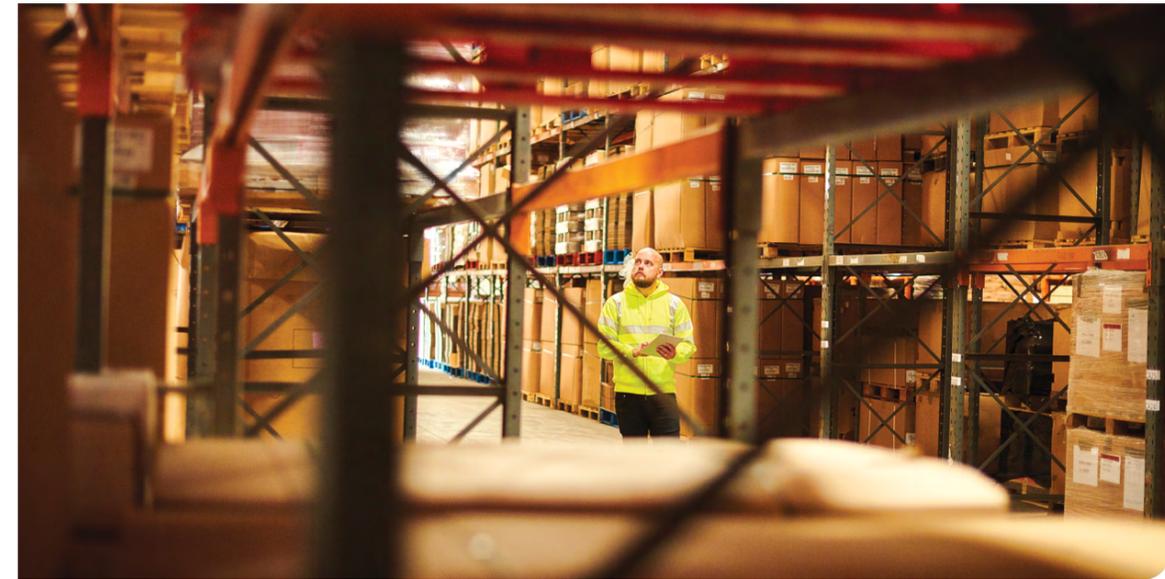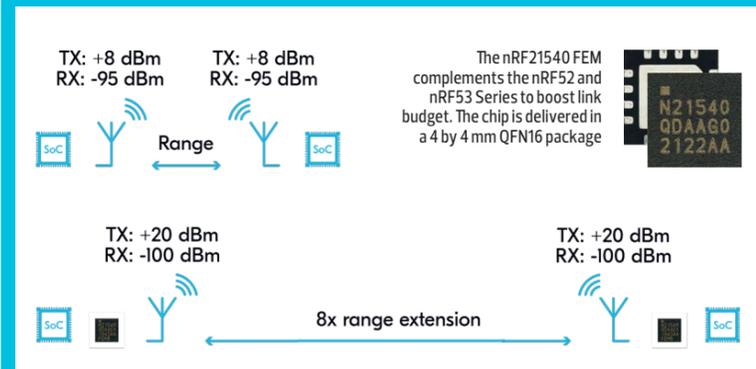
To accompany the nRF21540 RF FEM, Nordic has released the nRF21540 Development Bundle (DB), design tools for verification and testing of applications taking advantage of the FEM's capabilities. The nRF21540 DB comprises the nRF21540 Development Kit (DK) and the nRF21540 Evaluation Kit (EK).

The DK is based on Nordic's nRF52840 DK and features the nRF21540 RF FEM. The DK has two chip antennas with ports for antenna diversity plus SWF connectors for making RF measurements. The DK's FEM is connected to and controlled by the onboard nRF52840 SoC.

The nRF21540 EK is a shield which can be connected directly to an nRF52 or nRF53 Series SoC antenna output or to any of the Nordic SoC DKs via their Arduino Uno Rev 3 header pins. The EK's nRF21540's gain control, antenna switching and operational modes are controlled via GPIO or SPI, or a combination of both, accessible through the

Yes, I can hear you

The nRF21540 FEM is a PA/LNA that increases sensitivity of the receiver while boosting the output power of the transmitter. This graphic illustrates two scenarios: The top is a wireless link formed using two nRF52840 DKs while the bottom uses two nRF21540 DKs (which are based on the nRF52840 DK complemented by an nRF21540 FEM). For the symmetric link using the nRF21540 DK, TX power is increased +12 dBm and the receive sensitivity is boosted by 5 dBm compared with the nRF52840 link. This is a 17 dBm increase in link budget which offers a theoretical range boost of around 8x. The theoretical extended range depends on the base Nordic SoC's original link budget. When using the nRF52833 SoC with the FEM, for example, the maximum theoretical range boost is 6.3x, while the nRF52832 and nRF52810 plus FEM offer a 10x range extension.

TX: +8 dBm
RX: -95 dBm
SoC
Range
TX: +8 dBm
RX: -95 dBm
SoC

The nRF21540 FEM complements the nRF52 and nRF53 Series to boost link budget. The chip is delivered in a 4 by 4 mm QFN16 package

N21540
QDAAGO
2122AA

TX: +20 dBm
RX: -100 dBm
SoC
8x range extension
TX: +20 dBm
RX: -100 dBm
SoC

Arduino Uno Rev3 compatible headers. The EK features an SMA connector for connecting a radio or lab equipment and two additional SMA connectors attached to the FEM's dual antenna ports to connect lab equipment.

Nordic has released a single antenna reference circuit for the nRF21540 RF FEM (not including the companion SoC) which mirrors the EK layout. The reference circuit recommends a 50 Ω input into the TX port on the FEM. A second reference circuit illustrates a design using two antennas for applications requiring antenna diversity.

Range improvements with the nRF21540

The nRF21540 RF FEM offers a theoretical range increase of between 6.3 and 10x across a symmetric link (i.e. with both ends of the link employing the FEM and using the same SoC) compared with similar applications without the FEM. (*See panel left*.) Such range increases can only be realized outdoors and in line-of-sight applications. In practical applications, range will be compromised by obstructions, reflections, multipath fading and other environmental factors. Antenna and product design can also have a big effect. For example, highly compact modules for space constrained applications feature small PCBs. These have limited space for an antenna which can restrict its size, impact performance and decrease the module's RF range. (Several commercial compact modules using the nRF21540 RF FEM are now available. The FEM can be set to compensate for the lower gain of the small antenna for the benefit of space constrained applications.)

Nordic engineers have run comparison tests [▶] between a symmetric link using an nRF52840 SoC with its built in PA set to +8 dBm and a symmetric link with the same SoC complemented with an nRF21540 RF FEM set to +20 dBm. The original set up demonstrated an outdoor line-of-site range of 1.6 km; with the FEM the range was boosted to 4.3 km. Indoor range is dependent on many factors making direct comparisons difficult. However, the FEM will boost the link budget resulting in a more robust connection.

A key capability of the FEM is a highly adjustable output gain which can altered in 1 dB increments up to the

maximum +21 dBm level. This adjustability enables a high degree of design flexibility. For example, a single product design can be adjusted to meet the different maximum transmission power regulations across the globe. (The output limit for various regions can be found at www.nordicsemi.com/Products/Range-extenders.) Second, the adjustable gain allows a designer to trade off range against power consumption to ensure a robust link with the optimum efficiency.

The FEM enters a power down (PD) state when the radio is not being used. In this mode the product consumes just 45 nA. When demanded by the radio, the FEM enters a program (PG) state, consuming 1.1 mA, then reverts to either TX or RX modes. RX consumes 2.9 mA, while TX at +20 dBm is 110 mA (and 38 mA at +10 dBm). These currents are in addition to those consumed by the SoC. After radio operation, the FEM returns to the PG state then the PD state. From the PG state, the FEM can also enter a UICR program (UICR) mode to allow for PA gain configuration.

SDK development support

In addition to the DK and EK, development support for the nRF21540 FEM is integrated into Nordic's nRF Connect SDK (for projects using Bluetooth plus Thread and/or Zigbee). The support is built into the SDK's multiprotocol service layer (MPSL). Driver support is also included – allowing the engineer to run the FEM together with the various RF stacks during development.

Cycling through the FEM's operational states must be tightly synchronized with the radio's operation. Poor timing can lead to increased power consumption and potentially problems with regulatory compliance. Because of timing criticality, cycling is controlled by software delivered from Nordic as part of the SDK. Cycling is triggered via the PD, RX and TX pins. In the future version of the SDK, cycling will also be possible via SPI.

A Nordic technical webinar entitled *Introduction to the nRF21540 RF FEM for range extension*, is available here: bit.ly/3wVh3dQ

Modern warehouses can be cavernous, requiring a high density of wireless tracking devices to cover the space. Boosting range with the nRF21540 will allow fewer trackers to do the job, saving money

nRF21540-EK

Tech Check

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

Nordic Product Guide

This handy summary describes all of Nordic's IoT solutions

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

NORDIC SEMICONDUCTOR

Nordic's RF SoCs and SiP

	nRF9160	nRF5340	nRF52840	nRF52833	nRF52832	nRF52820	nRF52811	nRF52810	nRF52805
WIRELESS PROTOCOL									
LTE-M	●								
NB-IoT	●								
GPS	●								
BLUETOOTH LOW ENERGY		●	●	●	●	●	●	●	●
BLUETOOTH 5.3		●	●	●	●	●	●	●	●
LE AUDIO		●							
DIRECTION FINDING		●		●		●	●		
2 Mbps		●	●	●	●	●	●	●	●
LONG RANGE		●	●			●	●		
BLUETOOTH MESH		●	●	●	●	●			
THREAD		●	●	●		●			
MATTER		●	●						
ZIGBEE		●	●	●		●			
ANT		●	●	●	●	●	●	●	●
2.4 GHz PROPRIETARY		●	●	●	●	●	●	●	●
NFC		●	●	●	●				
TYPE									
SYSTEM-ON-CHIP (SoC)		●	●	●	●	●	●	●	●
SYSTEM-IN-PACKAGE (SiP)	●								
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
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
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
SECURITY									
ARM TRUSTZONE	●	●							
ARM CRYPTOCELL	310	312	310						
ROOT-OF-TRUST	●	●	●						
SECURE KEY STORAGE	●	●							
AES ENCRYPTION	●	●	●	●	●	●	●	●	●
LTE-M/NB-IoT/GPS MODEM	●								
CERTIFIED LTE BANDS	1–5, 8, 12–14, 17–20, 25–26, 28, 66								
RADIO									
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
MAXIMUM TX POWER	23 dBm	3 dBm	8 dBm	8 dBm	4 dBm	8 dBm	4 dBm	4 dBm	4 dBm
RX SENSITIVITY	-108 dBm (LTE-M), -114 dBm (NB-IoT), -155 dBm (GPS)	-98 dBm (1Mbps)	-95 dBm (1Mbps)	-96 dBm (1Mbps)	-96 dBm (1Mbps)	-95 dBm (1Mbps)	-97 dBm (1Mbps)	-96 dBm (1Mbps)	-97 dBm (1Mbps)
ANTENNA INTERFACE	50 Ω single-ended	Single-ended	Single-ended	Single-ended	Single-ended	Single-ended	Single-ended	Single-ended	Single-ended
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, 2xUART	2xTWI/SPI, UART	TWI/SPI, SPI, UART	TWI, SPI, UART	TWI, SPI, UART
QSPI		●	●						
USB		●	●	●		●			
PWM	4	4	4	4	3		1	1	
PDM	●	●	●	●	●		●	●	
I2S		●	●	●	●				
ADC, COMPARATOR	ADC	●	●	●	●	COMP	ADC, COMP	ADC, COMP	ADC
TIMER, RTC	3,2	3,2 + 3,2	5,3	5,3	5,3	4,2	3,2	3,2	3,2
TEMPERATURE SENSOR	●	●	●	●	●	●	●	●	●
CERTIFICATIONS	nordicsemi.com/9160cert	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
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
DEVELOPMENT KITS	nRF9160 DK, Nordic Thingy:91	nRF5340 DK, nRF5340 Audio DK	nRF52840 DK, nRF52840 Dongle	nRF52833 DK	nRF52 DK, Nordic Thingy:52	nRF52833 DK	nRF52840 DK	nRF52 DK	nRF52 DK
PACKAGES	10x16x1.04 mm LGA	7x7 mm aQFN94 (48 GPIOs), 4.4x4.0 mm WLCSP95 (48 GPIOs)	7x7 mm aQFN73 (48 GPIOs), 6x6 mm QFN48 (30 GPIOs), 3.5x3.6 mm WLCSP94 (48 GPIOs)	7x7 mm aQFN73 (42 GPIOs), 5x5 mm QFN40 (18 GPIOs), 3.2x3.2 mm WLCSP (42 GPIOs)	6x6 mm QFN48 (32 GPIOs), 3.0x3.2 mm WLCSP50 (32 GPIOs)	5x5 mm QFN40 (18 GPIOs), 2.53x2.53 mm WLC-SP44 (18 GPIOs)	6x6 mm QFN48 (32 GPIOs), QFN32 (17 GPIOs), 2.48x2.46 mm WLCSP33 (15 GPIOs)	6x6 mm QFN48 (32 GPIOs), 5x5 mm QFN32 (17 GPIOs), 2.48x2.46 mm WLC-SP33 (15 GPIOs)	2.48x2.46 mm WLC-SP28 (10 GPIOs)

Range Extender
nRF21540

Description: The nRF21540 is an RF front-end module (FEM) that improves range and connection robustness for Nordic nRF52 and nRF53 Series SoCs. The nRF21540 is a complementary device operating as a 'plug-and-play' range extender with the addition of just a few external components. The nRF21540's 13 dB RX gain and low noise figure of 2.7 dB, coupled with up to +21 dBm TX output power, ensure a superior link budget boosting the range of supported SoCs by between 6.3 and 10x. The RF FEM suits all applications that require increased range and/or robust coverage. In demanding RF environments, or where the application is operating close to the range limit, it can be more energy efficient to use the nRF21540 than continuously resend packets.

Operation: The nRF21540 supports Bluetooth LE, Bluetooth mesh, Thread, Zigbee and 2.4 GHz proprietary protocol applications. The RF FEM's TX output power is dynamically adjustable and can be set in small increments to comply with the allowable range across all geographical regions. The RF FEM can be use with Nordic's extended temperature qualified nRF5340, nRF52833 and nRF52820 SoCs in industrial applications such as professional lighting.

Tech Spec
Output power
Adjustable in small increments up to +21 dBm
Receive gain and noise figure ratings
13 dB receive gain. 2.7 dB noise figure
Input supply
1.7 to 3.6 V
Package
4 by 4 mm QFN16
Development hardware
The nRF21540 Development Bundle (DB) comprises an nRF21540 DK and an nRF21540 Evaluation Kit (EK)
Applications
Asset tracking, smart home, industrial, toys, audio

Power Management
nPM1100

Description: The nPM1100 is a dedicated power management IC (PMIC) with dual-mode configurable buck regulator and integrated battery charger. It is designed to work with Nordic's nRF52 and nRF53 Series SoCs. It offers reliable and stable power delivery, while maximizing battery life through high efficiency and low quiescent currents. The product can also be used as a generic PMIC for rechargeable applications. Its compact form factor makes it ideal for advanced wearables, medical devices, and other size constrained devices. When optimized for size, PCB usage is around 23 mm^2 including passives. This increases to around 27 mm^2 when optimized for performance.

Operation: The dual-mode regulator operates at up to 92 percent power conversion efficiency, prolonging battery life of Nordic SoC based applications using a rechargeable battery. Hysteretic mode reduces current consumption for low loads, while PWM mode allows for cleaner power operation and better performance for higher loads. The regulator can deliver up to 150 mA, providing ample current for the SoCs plus additional circuitry.

Tech Spec
Battery charger
JEITA compliant, 4.1 or 4.2 V selectable, 20 to 400 mA
Input regulator
Input 4.1 to 6.7 V, output 3.0 to 5.5 V (unregulated), USB current limit 100 or 500 mA
Buck regulator
Output 1.8, 2.1, 2.7 or 3.0 V, current limit 150 mA output
Package
2.075 by 2.075 mm WLCSP
Operating temperature
-40 to 85°C
Applications
Wearables, remote controls, medical devices, sensors

Cloud Services
nRF Cloud

Description: nRF Cloud is a versatile IoT connectivity enabler that can be directly used with Nordic's cellular IoT devices or with the nRF52 and nRF53 Series via a gateway. nRF Cloud services support Device-to-Cloud or Cloud-to-Cloud use cases. In the former, the device connects directly to nRF Cloud. In the latter, the device connects to a customer's Cloud that then connects to nRF Cloud's REST API.

Services: nRF Cloud Location Services are offered in nRF Cloud and include GPS and cell based location services. The product supplies accurate and rapid location data for customer connected devices. The A-GPS service can reduce time-to-first-fix significantly compared with regular GPS. The result is lower latency and improved power consumption. P-GPS downloads predictive data, extending validity of assistance data. Cell based services use base stations to predict location. SCELL uses a nearby cell tower, whereas MCELL uses multiple cell towers to triangulate a position. If power saving is more important than location accuracy, the cell based services are a good option. They are also useful for indoor positioning.

Tech Spec
Location services
Assisted GPS (A-GPS), Predictive GPS (P-GPS), Single-Cell (SCELL), Multi-Cell (MCELL)
Additional services
Supports Cloud-to-Cloud use cases for devices provisioned to a different Cloud provider
Supported products
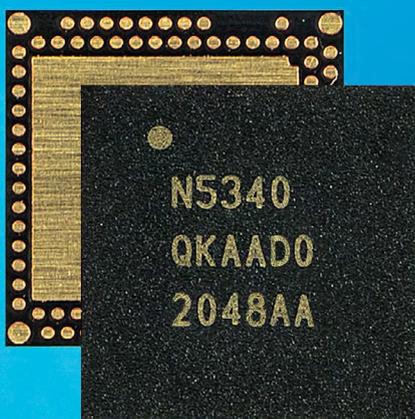nRF9160 SiP, nRF9160 DK, Nordic Thingy:91
Applications
Industrial, smart appliances, asset tracking, RTLS