WQ
WIRELESS QUARTER
Issue 2, 2022

CLAIM CHANGER:
IoT SENSORS HELP INSURERS MANAGE RISK

FEAST OR FAMINE:
HOW INDUSTRY PLANS TO COMBAT THE GLOBAL CHIP SHORTAGE

MAN vs MACHINE:
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The Missing Link

DECT NR+ promises to unleash M2M technologies and deliver massive smart city IoT

IS CELLULAR IoT THE LPWAN OF THE FUTURE?

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Welcome

Kjetil Holstad
EVP Product Management

Massive IoT describes a future where billions or even trillions of devices are connected. While today it remains a dream, here at Nordic we have embarked upon an engineering path towards realizing the vision.

According to Ericsson, a major telecom firm and an advocate for massive IoT, the two biggest challenges for the technology are cost-efficiently connecting a large number of devices over a wide area, and efficiently managing these devices over their complete life cycle. It is the first of these we're working hard to solve – while some of our key partners are focusing on the latter.

Being quick to embrace embryonic wireless tech with a view to commercialization is something for which Nordic has a good reputation. We were early to adopt 2.4 GHz ultra low power wireless, Bluetooth LE, cellular IoT and other now mainstream technologies. Today we are the leading Bluetooth LE company in the world and a primary supplier of 2.4 GHz and cellular IoT products. Now Nordic is backing the emerging technology of DECT New Radio (NR)+ as a major foundation for massive IoT.

DECT NR+ is the first non-cellular technology to be included in the International Telecommunication Union (ITU) fifth generation (5G) technology standards for mobile networks. It promises massive IoT for large scale M2M applications such as industrial, agriculture, asset tracking, smart city and smart energy.

Nordic's support takes the form of both engineering expertise and product development. Nordic's engineers have already played a key role in mapping out the technology's specification and the company is acting as the editor for the physical layer (PHY). And together with partner Wirepas, we're developing an nRF91 Series NR+ product.

You can read more about this massive IoT enabling technology on page 14 of this edition.

> Nordic is backing the emerging technology of DECT NR+, a non-cellular 5G solution that will form a major foundation for massive IoT

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The latest developments from Nordic Semiconductor

Industrial IoT

Solar-powered gateway offers utilities cost and sustainability benefits

Lobaro's solar-powered M-Bus Gateway helps utilities and consumers manage water and power consumption

A smart meter gateway that operates perpetually on harvested solar energy alone promises to deliver cost and sustainability benefits to European utilities.

German industrial IoT solutions specialist, Lobaro, that developed the Solar Wireless M-Bus Gateway, claims it is the first gateway of its type to not use either mains power or disposable batteries. The device is suitable for applications where metering data is needed at a higher frequency than is possible with battery-powered gateways – for example, in predictive maintenance and energy cost optimization applications, or billing use cases. The meter can record data from up to 500 commercially available meters including water meters, heat meters and heat cost allocators, the company claims.

The Solar Wireless M-Bus Gateway employs Nordic Semiconductor's nRF9160 SiP. The SiP supports both LTE-M and NB-IoT and brings NB-IoT connectivity to European wM-Bus (868 MHz) or Sensus RF consumption meters using NB-IoT and/or LoRaWAN. wM-Bus is a European short-range wireless standard for the remote reading of energy consumption meters. (*See WQ Issue 1, 2021 pg11.*)

By combining NB-IoT and LoRaWAN in a single gateway, the device ensures European customers are not restricted to a single LPWAN wireless technology. Users can choose between connectivity options based on local network availability and wireless signal coverage.

Nordic's nRF9160 SiP was designed to minimize power consumption and, depending on operational parameters, can operate solely off harvested solar energy, a feature that enables wireless cellular IoT sensors to deliver sustainability advantages. Energy harvesting is performed by Analog Device's ultra low power management unit, while the gateway uses a 3.8 V supercapacitor (LIC type) as an energy reservoir. The supercapacitor technology is similar to a Li-ion battery but can be recharged 10 times more frequently. The gateway remains in an energy-saving sleep mode for most of its operating time only waking up at pre-programed intervals.

Smart City

Cellular IoT-powered controller makes streetlighting smart

A new plug-and-play luminaire controller that can instantly convert conventional LED streetlighting into smart lighting, has the potential to save tens of thousands of dollars in energy costs, according to its developer.

The Urban Node 324, launched by leading smart city solutions provider Urban Control, plugs into an industry-standard Zhaga LED lighting socket and connects over the local cellular IoT network. From there it can be remotely controlled by any smart city Central Management System (CMS) based on the common TALQ smart city standard. Operators can remotely control brightness, dynamically respond to sudden changes in pedestrian numbers or road traffic, monitor energy consumption in real time, and preempt faults to precisely target maintenance crews. The device can be scaled from one streetlight up to millions, according to the company.

Urban Node 324 employs Nordic Semiconductor's nRF9160 SiP to deliver NB-IoT/LTE-M Cloud connectivity, as well as a LwM2M platform called ALASKA from IoT device management and security specialist, IoTerop. The LwM2M protocol minimizes on-air bandwidth and reduces power consumption levels low enough to support battery-powered smart city sensors and devices.

"Unlike traditional smart city lighting installations that require a specialized network, the Urban Node 324 works straight out-of-the-box just like a smartphone," explains Urban Control Innovation & Development Director, Miguel Lira.

"This makes it commercially and technically viable for any size installation because it doesn't require the operator to build their own wireless IoT network or become a wireless IoT network operator.

"Suddenly all the benefits of smart lighting are now open to small clusters of streetlights ... all the way up to massive, multimillion node capital city-sized installations. This is truly a game changer in the smart city streetlighting industry," says Lira.

Partner Services

Nordic Partner Program boosts cellular IoT ecosystem

Nordic Semiconductor has extended its Nordic Partner Program with four new design and solution partners. Joining the program are off-the-shelf antenna solution provider Ignion; AVSystem, a leader in IoT device management and LwM2M Cloud connectivity; Cloud-based remote debugging and monitoring specialist, Memfault; and antenna solution provider and IoT specialist, Taoglas.

Ignion's Virtual Antenna technology is deployed in millions of devices, including the Nordic Thingy:91 cellular IoT prototyping platform. (*See WQ Issue 3, 2021 pg36.*) Now Ignion's free Antenna Intelligence Cloud service enables Nordic customers in the early design phase to receive an antenna design and simulation report customized for their device. New Solution Partner AVSystem's iCoiote IoT Device Management platform offers out-of-the-box integration with Nordic's nRF Connect SDK LWM2M client and nRF Cloud location services.

Solution Partner Memfault's firmware observability platform allows IoT developers to remotely debug issues, deploy OTA firmware updates, and continuously monitor fleets of connected devices at scale. Nordic customers get free access to the Memfault platform via the nRF Connect SDK.

The addition of Taoglas to the program will provide Nordic customers with access to a portfolio of antennas as well as engineering expertise to optimize RF and antenna performance for their wireless design at any stage of development from initial system requirements to final optimized board design.

In Brief

NORDIC NOTED FOR ESG PERFORMANCE

Nordic Semiconductor has been included as one of 40 companies acknowledged for its demonstrated commitment to Environmental, Social and Governance (ESG) practices on the Oslo Stock Exchange's recently launched ESG index – the OBX ESG. The launch of the index is a result of growing demand for sustainable investment tools from investors, and follows the launch of similar initiatives in France, Italy and The Netherlands. To be included in the index, companies had to pass rigorous screening criteria provided by Sustainalytics, a leading global provider of ESG research, ratings and data.

CELLULAR IoT GAINING TRACTION

A total of 140 operators have already deployed or launched either NB-IoT or LTE-M networks in 64 countries, according to a recent report by the GSA. GSA's report stated that 166 operators around the world are actively investing in NB-IoT technology, of which 124 have deployed or commercially launched NB-IoT networks, 23 are planning, piloting or deploying NB-IoT networks and 19 are evaluating or trialing NB-IoT technology. The report also revealed that 74 operators are actively investing in LTE-M technology, of which 55 have deployed or commercially launched LTE-M networks, 10 are planning to launch, piloting or deploying LTE-M networks, while 9 are trialing LTE-M technology.

CONNECTIVITY KEY TO SUSTAINABILITY

Smart technology and connectivity will fundamentally transform our experience of the world in the next decade, according to a new report from Vodafone. *The Connected Consumer 2030* report predicts how innovation in sustainability, smart cities and transport, connected care, ethical connectivity and future technology will help solve once-in-a-generation challenges and improve everyday life. The study argues that connected nature could help reduce global emissions by up to a third and help meet 2030 targets. The report warned that there are fewer than 10 years to meet the target for limiting warming to 1.5°C.

Conservation

Wildlife tracker monitors at long distances

Long range animal tracking is made easy with iSiTech's iSi-TAG

A smart animal tracking and management system designed to combat livestock theft and wildlife poaching as well remotely monitor animal health and behavior, has been launched by South African company, iSiTech.

The iSi-TAG device is easily applied to the ears of livestock and wildlife and is equipped with temperature and movement sensors as well as GPS. Once attached to the animal's ear, the unit employs Nordic Semiconductor's nRF52840 SoC to not only supervise the on-board sensors but also to relay the data, using Bluetooth LE wireless connectivity, to a gateway. The gateway in turn transfers the data to the Cloud and a web-based platform where farmers or conservation agencies can review the data.

In addition to the nRF52840 SoC, the gateway also integrates an nRF21540 RF Front End Module (FEM), Nordic's power amplifier/low noise amplifier (PA/LNA) solution for applications demanding extended range. The The nRF52840 SoC's +8 dBm TX output power, and the +13 dB RX gain of the FEM enables the device to relay data from the tag to a gateway over a line-of-sight distance of up to three kilometers, iSiTech claims. A series of gateways can be mesh-networked to extend coverage further. The solution is also available in a LoRaWAN version with range up to 20 km.

From the web-based platform, users can set-up geofencing of feeding areas with 'go' and 'no-go' zones, as well as review captured sensor data to provide alerts if the animal's behavior is indicative of any issues. For example, low movement could indicate illness, or if it is outside of the set boundary, the animal may be lost or have been stolen. The system can be configured to provide customized 'real time' alerts to the user's smartphone, PC or tablet for rapid response to emergency situations.

The tags are powered by harvested solar energy, and can last for more than five days without charge even when transmitting data every two minutes.

Wearables

Health monitoring wearables offer cellular IoT Cloud connectivity

Consumer electronics firm, August International, has launched a pair of smartwatches that provide the ability to continuously monitor and record a range of key health metrics. The E2 and N2 wearables integrate pulse oximeter, temperature and IMU sensors to determine heart rate, blood oxygen, blood pressure and body temperature vital signs, for example, while the N2 also includes an ECG sensor to record heartbeat and rhythm, as well as providing GPS positioning and fall detection functionality.

Both watches are powered by Nordic's nRF9160 SiP and relay data directly to the Cloud using LTE-M or NB-IoT in the absence of a smartphone or gateway. The SiP also supervises the complex computational requirements of the on-board sensors. The SiP's wireless connectivity enables the user, family and friends, as well as medical professionals to review health data from the iCare server platform, or via the CareMate smartphone app. It can also provide alerts if any abnormal health events are detected.

"Due to COVID-19, there has been a need to reduce the frequency of face-to-face medical appointments," says Dr Keming Zhou, MD of August International. "The use of remote healthcare devices has become a key part of patient care and the E2 and N2 are designed as remote healthcare devices for family members, clinics, and care homes to monitor the health of the wearers.

"When doctors have access to the smartwatch data, they can obtain a more accurate insight into the wearer's condition, and adjust treatment as necessary, while embedded security ensures the protection of the user's privacy at all times," says Dr Zhou.

Smart City

Smart city vision takes shape in Korea

A $7.4 billion smart city experiment is underway in Korea, with the first 54 households, chosen by a lottery, taking up residence in the Eco Delta Smart Village. When completed, the development will comprise 30,000 homes across 11.8 square kilometers of coastal wetlands in the Nakdong River delta.

The project is now in the experimental phase, assessing not only how Koreans might live in but also how the government and the private sector might build more efficient infrastructure, as well as more energy-efficient appliances.

Residents in the 54 households of the smart village, which range from single-person units to three-bedroom homes, are living rent-free for three years, in exchange for data collected about them. Every tenant is required to wear a smartwatch synced to a smart home system which monitors the individual's health, food, exercise, what appliances are running and how much energy the home is using, for example. Each home's lighting and air filters are automated, as are the cleaning robots that patrol the village, and the drones that deliver mail.

"It's not going to be very soon, but in the future, we plan to have a standard model of a smart city and export that to the world," said Lee Jae Min, Deputy Director of the smart city project.

Maintenance

Maintenance alerts for commercial fridges

A smart plug for commercial chillers and freezers that detects a range of energy parameters and allows the user to remotely assess whether the unit requires maintenance, has been launched by SECO. The SECO Energy Sensor was developed by German IoT solutions company, Lemonbeat, a subsidiary of European utility giant E.ON, and a design partner of Nordic Semiconductor.

The smart plug employs a sensor to record energy, voltage, power and current variables, and uses Nordic's nRF9160 SiP to relay data to a Cloud-based platform, as well as supervise the smart plug's on-board sensors.

From the Cloud platform the health of the appliance and servicing requirements can be derived from its energy consumption.

Audio & Music

Audio transmitter pairs with up to 100 sets of headphones

Avantree Corp's Quartet audio solution enables multiple sets of headphones to be wirelessly connected to a single audio source. The base solution consists of four pairs of headphones and a transmitter base that can wirelessly relay audio to the headphones from any device that can output audio through an AUX or optical jack, such as a television, projector or stereo receiver.

Employing Nordic Semiconductor's nRF52832 SoC in both the headphones and the transmitter base to run the proprietary 2.4 GHz protocol for wireless audio transmission, the solution is designed for applications where multiple sets of headphones need to be connected to the same source. Examples include classrooms, aged care facilities or outdoor cinemas. Low latency eliminates any lip sync problems during TV or movie playback.

The nRF52832 SoC's multiprotocol radio enables Quartet to reliably transmit audio up to 100 meters outdoors, or 30 meters indoors.

The scalable solution enables up to 100 pairs of headphones to be connected to a single transmitter base, with each pair offering independent volume control so people with different levels of hearing can set their own desired volume.

The Quartet headphones are powered by lithium batteries and can last up to 20 hours between charges. "Having long battery life was very important when choosing a wireless chip for Quartet," says Howard Leung, Chief Product Officer at Avantree.

In Brief

SUSTAINABILITY GOES MAINSTREAM

Cloud sustainability, carbon footprint measurement and advanced energy grid management software are the three emerging environmental sustainability technologies that will reach early mainstream adoption within one to three years, according to Gartner, Inc. The analyst said the path to a net-zero future will create new opportunities for those developing the underpinning sustainable technologies. The analyst said sustainability had to be a global priority. It said the transition to a net-zero economy would be as disruptive as the industrial revolution, requiring new technologies, business models, strategies and processes.

ARM LAUNCHES NEW IoT HARDWARE

Arm has debuted a range of new products for its IoT portfolio, including its highest-performing Cortex-M processor yet. The new updates span Arm's Total Solutions for IoT roadmap and target applications such as Cloud-native edge devices and voice recognition. The new Cortex-M85 is said to offer a 30 percent performance uplift over the Arm Cortex-M7, and 20 percent for machine learning (ML) workloads. It also integrates Arm Helium technology to support ML and Digital Signal Processing (DSP) as well as Arm TrustZone security functionality with enhanced software attack threat mitigation. This helps achieve PSA Certified Level 2, a security baseline for IoT deployments.

TECH CHEATS NEVER PROSPER

A medical student in India has been caught cheating on his final exam using a Bluetooth LE device that was surgically implanted into his ear. According to the *Hindustan Times*, the unnamed student had been enrolled at the Mahatma Gandhi Medical College for 11 years and was attempting to pass the exam one final time, having previously failed to graduate on multiple occasions. He was collared after a smartphone, found during a search, was seen to be connected to a Bluetooth device. The would-be doctor admitted to having a microreceiver implanted in his ear by an ENT surgeon enabling him to obtain illicit answers.

Wearables

Smartwatch delivers advanced biometric data and insights

An advanced smartwatch designed to help users make informed lifestyle decisions by tracking their health, routines and biorhythms has been launched by eBuyNow, a subsidiary of Canada-based CE Brands.

Powered by Nordic Semiconductor's nRF5340 high-end SoC, the Moto Watch 100 and partner app provide biometric insights allowing users to see the 'real time' effects of exercise and their environment.

The compact, lightweight and water-resistant wearable integrates an accelerometer, gyroscope, heart rate monitor and SpO_2 sensor for measuring blood oxygen levels to track the body's response to exercise. The solution also provides health, wellness and lifestyle tracking features such as sleep pattern tracking, weight tracking, step counting and 26 different sport modes.

In addition, Moto Watch 100 comes with built-in GPS for location tracking without requiring the user to carry their smartphone.

Using Bluetooth LE connectivity provided by the nRF5340 SoC, the biometric data is relayed from the wearable to the user's smartphone, from where the app allows users to access their own health and wellness information, receive push notifications and analyze trends over time.

The smartwatch's wide range of features and processor-intensive functionality is supervised by the nRF5340, Nordic Semiconductor's most advanced SoC.

The SoC introduces a new flexible dual-processor hardware architecture featuring a dedicated, high performance Arm Cortex-M33 application processor, as well as a fully programmable, ultra low power Arm Cortex-M33 network processor.

The watch's rechargeable 355 mAh battery provides up to 14 days of full-time use from a one-hour charge, with an 'always-on' heart rate monitor and biometric tracking.

Education

Interactive teaching product enables remote learning

A handheld device used by students to answer test questions, record their attendance, answer surveys and provide class feedback has been launched by India-based technology company Chargtron IoT. The Real-time Assessment Frequency Transmitter (RAFT) employs Nordic's multiprotocol nRF52810 SoC to provide wireless connectivity between the device and an RF Receiver, which in turn relays the data to the Cloud for review by the teacher.

RAFTs allow teachers to capture student assessment data and receive a detailed breakdown of student performance via a web-based dashboard.

Each student is issued with a RAFT device—which includes 11 different buttons—that enables them to answer multiple choice questions, provide "yes" or "no" answers, 'virtually' raise their hand, or rate the learning experience, for example.

Responses are relayed to the RF Receiver in near 'real time' thanks to the Nordic SoC's low latency 2.4 GHz proprietary connectivity, and then to the Cloud. From the dashboard teachers can compile student test scores, keep track of attendance, as well as develop classroom sessions. When used in remote learning applications, the device employs Nordic Bluetooth LE wireless connectivity to connect with the RAFT app on a student's smartphone.

Logistics & Transport

NB-IoT tech tracks missing beer kegs

As bars closed during COVID-19, stainless steel beer keg use came to a standstill, leading to massive inefficiencies and a keg shortage as many kegs were simply forgotten in cellars or left on the street.

As lockdowns ease breweries are turning to tech to provide an answer to supply chain visibility issues. Australian IoT hardware maker, Binary Beer, and Canadian IoT software firm, Kegshoe, have teamed up to provide breweries with NB-IoT based KegLink trackers.

The arrangement sees Kegshoe combine its keg tracking software with Binary Beer's KegLink NB-IoT platform. The KegLink trackers screw under the rim of all-sized beer kegs in all geographic regions providing brewers with a solution to their traceability and waste concerns.

Wearables

Sensor bracelet gives back control to hand-impaired

People who lack the ability to use their hands from conditions like motor neurone disease and cerebral palsy may one day be able to play video games that normally require a handheld controller through the use of a customizable, wearable 3D printed bracelet.

The bracelet works by picking up tiny movements in the user's wrist when they move their fingers. These movements are sent wirelessly to a computer using Bluetooth LE, and are then interpreted, classified and adapted using machine learning (ML). The interpreted information can then be used to play a game, control a computer interface or communicate using a smart device.

The bracelet and program have been developed by a team in the University of Sydney's School of Computer Science, led by undergraduate student Stephen Lin under the supervision of Dr Anusha Withana.

"We have 3D printed a sensor bracelet that can be easily customized for individual users. It accurately detects subtle finger movements through vibrations in the carpal tunnel - an area of the wrist that contains the tendons which control the hand," says Dr Withana.

"These subtle movements are then transmitted from the sensors to a program using Bluetooth, which interprets an individual's movement patterns using machine learning. It then communicates this with the game."

It does so almost instantaneously, allowing the user to play games that would otherwise require the use of a handheld controller," says Dr Withana.

Stephen Lin adds: "We use machine learning to interpret an individual's movements, which vary from user to user. Currently, these signals are transmitted to a computer-based program, but we hope to progress this to a free phone app so it can be easily downloadable."

Wearables

Airbag 'helmet' protects cyclists from head injury

A wirelessly connected inflatable airbag that is said to provide greater protection for cyclists than a traditional bicycle helmet has been manufactured by Sweden-based company, Hövding. The Hövding 3 solution is designed to protect a rider's head and neck from injury in the event of an accident. The lightweight product is worn around the neck as a waterproof, adjustable fabric collar and hood.

The platform employs an accident detection system using built-in sensors and a proprietary algorithm based on AI technology to monitor movement 200 times per second and detect any abnormalities. When specific movement patterns relating to cyclists in accidents are detected, the airbag inflates in around a tenth of a second.

Hövding 3 uses Bluetooth LE connectivity provided by a Laird BL652-SA-01 module with integrated antenna—based on the Nordic nRF52832 multiprotocol SoC—to report an accident involving the airbag inflation to the user's smartphone.

From the smartphone, the Hövding app sends a text message alert including the location of the accident to the user's selected emergency contacts. Once the airbag has inflated, the companion app will wait two minutes before automatically notifying emergency contacts.

By the Numbers

$183.1 million
in revenue

Nordic Semiconductor has reported Q1 2022 revenue of $183.1 million, corresponding to growth of 28 percent over Q1 2022. Bluetooth LE revenue amounted to $150 million in Q1 2022, 82 percent of total revenue. Cellular IoT reported revenue of $7 million in Q1 2022, 11 percent above the previous quarter. The healthcare end product market recorded the largest percentage gain over Q1 2021, up 54.1 percent, the company announced.

$36.8 billion
from IoT services by 2026

Global revenues from IoT device management services is expected to top $36.8 billion by 2026, as increased demand for edge-based analytics, coupled with inherent complexity, scalability and security challenges drives the need for such services, analyst ABI Research claims. It said forward looking suppliers were preparing for a world where 41.3 percent of the connected devices will be using some form of LPWAN technology by 2026, on the back of a surge in NB-IoT and LTE-M connections.

90 million
device shipments in 2027

After years of slow but steady growth, VR is facing a market explosion over the next five years, says analyst, ABI Research. It said over 90 million Head Mounted Display (HMD) shipments in 2027 will power total VR market revenues to over $95 billion across hardware, software, and services. The increased capability of VR, combined with demand for immersive content presents a significant opportunity.

Cloud Connectivity

Cellular IoT gateway bridges connectivity gap

WiSilica's ENOR E-L/N uses Nordic's nRF9160 SiP to establish bidirectional NB-IoT connectivity between Bluetooth LE sensors and the Cloud

Bluetooth LE is a foundation technology of the IoT. It is widely used to build Bluetooth mesh networks based on point-to-point (one-to-one) and star (one-to-many) network topologies while minimizing power consumption. A further advantage of Bluetooth LE is its interoperability with smartphones which provides a familiar interface for configuring and commissioning nodes on the network.

However, a downside of Bluetooth LE is its lack of Internet Protocol (IP) interoperability, which means data can't be sent directly to the Cloud and end-devices can't be remote configured, managed and maintained.

"The data from Bluetooth LE end-devices is valuable, but that value can only be fully realized once the data is transmitted to the Cloud to be sifted and analyzed, and then used to make informed decisions," says Martin Lesund, Technical Marketing Manager — Cellular IoT with Nordic Semiconductor. "LPWANs bridge that gap between remote IoT end devices and the Cloud. The cellular IoT technologies, LTE-M and NB-IoT, are the leading LPWAN solution and offer up to 15-kilometer range together with low power consumption."

Now U.S. and India-based IoT platform and solutions provider, WiSilica, has introduced its ENOR E-L/N gateway to meet the demands of this market sector. The gateway transmits Bluetooth LE-network derived data across long distances using either LTE-M or NB-IoT. It also features an external antenna to boost GPS reception.

WiSilica's ENOR E-L/N gateway makes it easier to track the condition and location of valuable goods

Designed for logistics

The ENOR E-L/N is based on Nordic's nRF9160 SiP, a cellular IoT solution combining an Arm Cortex-M33 dedicated application processor with LTE-M/NB-IoT modem and GNSS. Supporting all major application protocols, the nRF9160 has also been engineered with power saving features such as eDRX and PSM to extend the life of battery-powered products. The SiP features a maximum output power (limited by regulations) of +23 dBm and a maximum sensitivity of -108 dBm in LTE-M mode or -114 dBm in NB-IoT mode.

The ENOR E-L/N can be wirelessly configured and controlled via a proprietary iOS or Android app. Key applications for the gateway include asset tracking, warehouse management and supply chain automation.

When used for asset tracking applications, the gateway monitors data from Bluetooth LE sensors attached to critical cargo and measures parameters such as temperature, humidity and vibration. Because the ENOR E-L/N provides uninterrupted Cloud connectivity, 'real time' data from the Bluetooth LE sensors can be transmitted even when assets are on the move.

The ENOR E-L/N gateway is complemented by ARIXA, WiSilica's IoT platform for unifying location, control and sensing. When combined, the gateway provides cellular IoT communication and continuous GNSS tracking while ARIXA supports a customized, scalable IoT solution for customer-specific requirements.

ARIXA also supports end-to-end security for all the data and communications exchanged between devices, applications and Cloud server using AES encryption, and well-defined TLS protocols.

Tech Check

WiSilica's ENOR E-L/N gateway uses Nordic's nRF9160 SiP cellular IoT solution. The SiP integrates a multimode LTE-M/NB-IoT modem with GNSS. The SiP features 700 to 2200 MHz LTE band support and is certified for global operation

The LPWAN of choice

Cellular IoT is rapidly gaining favor as the preferred LPWAN technology (*see this issue pg12*). LTE-M and NB-IoT now make up a larger market share of the sector than all other competing technologies combined. "The Quality of Service (QoS) and security of cellular IoT is far beyond competing technologies and it is supported by established global infrastructure," says Nordic's Lesund.

According to Vivek Pramod, SVP & GM — Smart Controls, WiSilica, this existing infrastructure was a key reason for selecting LTE-M and NB-IoT. "By choosing cellular IoT over other LPWANs, we ensured that our solution could be easily and quickly deployed using our partners' built-in infrastructure," he explains.

What's the difference between LTE-M and NB-IoT?

Cellular IoT's genesis can be found in the 3rd Generation Partnership Project's (3GPP)—a grouping of seven telecommunications standard development organizations—LTE specification Release 13. The specification defined a new low-complexity RF modem that supported the needs of a type of LPWAN that could link short-range wireless sensor networks to the Cloud. Before Release 13, M2M cellular connectivity was restricted to industrial modems that were inefficient, bulky and power-hungry.

When it was adopted in 2016, Release 13 specified three new technologies for LPWAN support: Extended Coverage GSM Internet of Things (EC-GSM-IoT), LTE for Machine-Type Communications (LTE-M) and Narrowband Internet of Things (NB-IoT). It's the latter two that have had the greatest commercial impact. So, if both LTE-M and NB-IoT support cellular IoT, what separates the two?

While LTE-M is based on stripped-down LTE technology, the technology still supports secure communication, ubiquitous coverage and high system capacity. LTE-M's ability to operate as a full-duplex system over a larger bandwidth improves latency and throughput compared with NB-IoT.

LTE-M features a bandwidth of 1.4 MHz, enhancing range at the cost of throughput. The raw data throughput is 300 kbps on the downlink and 375 kbps on the uplink, providing approximately 100 kbps both ways for an application running Internet Protocol (IP). The technology is suitable for TCP/TLS end-to-end secure connections and mobility is fully supported by the same cell handover as conventional LTE.

NB-IoT was primarily designed for energy efficiency and for better penetration underground, while multi-year end device battery life is possible. The trade-off is a relatively modest throughput. NB-IoT is not based on the LTE PHY. Instead, it is a new type of RF technology with modem complexity even less than that of an LTE-M modem. NB-IoT uses a narrow 200 kHz bandwidth. Due to the lower bandwidth and lower data throughput (60 kbps on uplink, 30 kbps on downlink), range is better than LTE-M without compromising battery life.

In summary, LTE-M offers higher throughput, supports voice and roaming, and is suited to mobile applications such as asset tracking or healthcare. NB-IoT offers lower data rates but longer range, and better penetration into buildings which suits static applications.

NB-IoT is suited to low data throughput, static and hard to reach applications such as smart energy meters

Cellular IoT

Is cellular IoT the LPWAN of the future?

As its competitors face challenges, cellular IoT is gaining increasing traction as the bridge between end-devices and the Cloud

> Positive news about LTE-M and NB-IoT, alongside the reported commercial difficulties for LoRaWAN and Sigfox, could see cellular IoT become the dominant LPWAN technology

New technologies tend to encourage competition. One only needs to look at how many automotive, aerospace and computing companies emerged in the earliest days of each industry. But commercial pressures take their toll, and it can be tough to turn a profit; as the market matures, companies go out of business and others are acquired by their more successful rivals until just a few giants remain. Ford and Toyota, Boeing and Airbus, Apple and Microsoft are examples of this market dynamic in action.

There is clear evidence the same forces are at play as the IoT matures. For example, take the technologies vying to become the dominant player for LPWANs. LPWANs bridge the gap between remote IoT end-devices and the Cloud and are a critical part of the IoT's infrastructure. So important are LPWANs that the global market is set to expand from $31 billion in 2022 to $61 billion by 2026, according to a recent study by analyst, Juniper Research.

Despite the impact of COVID-19 and the associated chip shortages (*see this issue pg24*), the LPWAN market has enjoyed steady growth to support a global installed base of 450 million LPWAN-enabled active devices in 2020, expanding to some 660 million by the end of 2021, according to analyst, IoT Analytics.

The low cost of connectivity is driving cellular IoT adoption across a range of remote monitoring applications

Network highs and lows

While the LPWAN market remains fragmented, cellular IoT technologies NB-IoT and LTE-M are taking a dominant market share. According to Juniper Research's *Cellular IoT: Strategies, Opportunities & Market Forecasts 2022-2026* report, the NB-IoT and LTE-M installed base is expected to grow by a dramatic 1,200 percent over the next four years. The analyst identifies the relative low cost of both connectivity and hardware as key drivers of cellular IoT adoption for remote monitoring applications.

According to IoT Analytics' report, NB-IoT (47 percent) and LTE-M (10 percent) already make up 57 percent of the global LPWAN installed base, compared to 43 percent for the combined LPWAN competition. The report suggests it's the support of a solid ecosystem—including major IoT vendors like Amazon, Arm, Cisco, Huawei and Qualcomm, plus network operators such as Vodafone, Orange and Telefonica—that has contributed to the success to date.

While growth of cellular IoT looks promising, what of the competition? IoT puts LoRaWAN at 36 percent market share with Sigfox on three percent and other technologies at four percent. However, recent business disruption in France suggests that, for now at least, the market share figures remain volatile. For example, leading French mobile telecom provider, Bouygues Telecom, is reportedly planning to close its LoRaWAN network in France from 2024 and shift its business to cellular IoT networks.

And LoRaWAN is not the only LPWAN technology evidently grappling to meet early ambitions. Sigfox—a French technology that, like LoRa, pioneered the use of license-free spectrum for LPWAN use—earlier this year filed for 'rehabilitation', essentially a period of creditor protection as the company attempts to restructure under crippling financial strain.

Need to Know

NB-IoT offers lower peak throughput than LTE-M but its better range is more suited to static devices. LTE-M offers 6.3 times greater uplink peak throughput but shorter range and is most suited to mobile devices. Shown here is Digital Matter's Oyster 3 asset tracker which uses Nordic's nRF9160 SiP

Platform for the future

Given the positive news about LTE-M and NB-IoT, alongside the commercial difficulties for LoRaWAN and Sigfox, cellular IoT looks set to become the dominant LPWAN technology. Cellular IoT offers flexibility and support for massive IoT that its competitors can't match.

LoRaWAN and Sigfox have some attributes that match some of the requirements for LPWANs. For example, each offers kilometer-plus range and low end-device power consumption. But both networks are incapable of giving connected devices true bidirectional connectivity capability. For example, both LoRaWAN and Sigfox require data to pass through Internet Protocol (IP) interoperable gateways and additional infrastructure to reach the Cloud. This adds complexity and potential network fault points.

And although LoRaWAN provides a degree of bidirectional communication, it is not always reliable and doesn't offer support for remote updates. Sigfox delivers even less functionality; 'things' can send data, but essential massive IoT requirements, such as remote configuration and management, is impossible. Other notable drawbacks of both technologies include the cost of rolling out the backhaul infrastructure, limited operational throughput, and potentially Quality of Service (QoS) issues stemming from the use of unregulated spectrum.

Cellular IoT offers end-to-end IP connectivity and as network infrastructure rolls-out throughout the U.S., Europe, China, Australia and other regions, the technology is rapidly gaining traction. Base stations can support up to 50,000 cellular IoT connections, the communications are fully bidirectional, robust, reliable and secure, and the technology is part of the 5G specifications (through the 3GPP's Release 15 document).

The investment in cellular IoT infrastructure has been enormous, but with support of a strong global standards body, powerful network operators and a large vendor ecosystem, it's beginning to look like money well spent.

Comment

Lorenzo Amicucci
Business Development Manager

IoT speeds deployment of renewable energy

Renewable energy is essential to address climate change, but it does bring grid challenges. Connectivity is the answer

The world is increasingly turning to renewable energy from the Sun and wind as it weans itself off a diet rich in fossil fuels. In the U.S., for example, wind, solar and hydro power made up about 13 percent of the nation's electricity generation in 2021 – over 4 percent up on the year before. For the world's largest hydrocarbon producer this is excellent progress.

Renewable energy is now mainstream. Anyone who calls it 'alternative energy' is living in the past. But renewable energy does bring headaches. Engineers tasked with feeding generated power into a delicately balanced distribution grid prefer steady and reliable sources. For all their faults, fossil fuel power stations are exactly that. And renewable power is not.

> Anyone calling renewable energy 'alternative energy' is living in the past

Sometimes the Sun doesn't shine, and the wind doesn't blow. And when they do it's difficult to predict precisely how sunny it will be and how much of a breeze will pick up. That introduces both unpredictability and variability into the power mix – which plays against the consumer wish for ultra reliable power on demand.

With more information about the sunny and windy spots around a country, power engineers can smooth out electricity variability by switching in power from wind and solar farms working at full tilt and switching off those that are idling because the Sun is hidden or the wind has dropped. And continuous data can also help them predict the need to deploy fast-to-fire up (and relatively low carbon emitting) gas power stations when renewables aren't going to cut it and the engineers don't want to add more coal or oil-fired power stations to the mix.

It's the IoT—which is putting the 'smart' into smart grids—that's enabling engineers to gather the information and then switch sources in and out to overcome the unpredictability and variability of renewable energy. And it's the IoT that will allow all nations to ramp up renewables and reduce the levels of carbon going into the atmosphere.

Challenges lie ahead. Chiefly storing power from renewable energy not needed right now but that might be tomorrow. Solutions include huge battery banks, pumping water uphill for later release, and separating hydrogen from water for use as clean fuel. It will again be the IoT that lets engineers develop, deploy and control these solutions. And that will make for a cleaner world for all of us and future generations.

The Missing Link

A new non-cellular radio technology forms the last piece of the puzzle for accessible, very large scale M2M IoT applications

> DECT NR+ will effectively enable enterprises to easily set up, manage and maintain a private 5G wireless IoT network that connects up to a million devices per square kilometer

In Short

The roll out of massive IoT lags because of the lack of a low cost, wireless M2M technology at the millions-to-billions-of-end device scale

DECT NR+ is the first non-cellular radio to be included in the fifth generation technology standards for mobile networks

DECT NR+ operates in the global and license-exempt 1.9 GHz band, which significantly cuts deployment costs by eliminating the need for frequency planning or certification

Viewed from space, the dark side of the Earth is covered with illuminated filaments. Some 326 million streetlights are the primary source of this light, and their number is set to grow to 360 million by the end of the decade. Streetlight density rapidly increases towards population centers to light the way for millions of citizens, cars and trucks going about their daily business.

But streetlights are becoming so much more than a beacon to light the darkness; 'smart' streetlights are the poster child for the smart city, high-tech solid state lighting leveraging established infrastructure to not only provide energy-efficient illumination but also a vandal-proof platform for a range of wireless sensors for measuring air quality, light levels, sidewalk occupancy and even things like audio sensors for public assistance in emergency situations. (*See WQ Issue 3, 2020 pg18.*)

According to U.S. market intelligence firm, Northeast Group, one quarter (81 million) of the world's streetlights have already been converted to LEDs and 10 million have become smart. Those numbers are set to expand to 263 million and 83 million respectively by 2029.

But what this optimism obscures is smart streetlighting's immaturity. To date, most installations have been little more than proofs-of-concept that employ any one of a wide variety of wireless technologies. Some use cellular IoT, others get by with open standards technologies using unlicensed radio spectrum, such as Wi-SUN, and still others use proprietary solutions such as Sigfox or LoRaWAN.

DEPLOYING SMART DEVICES AT SCALE

There has been little convergence on a single IoT technology because, according to Svein-Egil Nielsen, Nordic Semiconductor's CTO and EVP R&D and Strategy "there's no perfect standard for every application". For example, LTE-M and NB-IoT cellular IoT are geared towards providing long-range, LPWANs with reduced latency demand but using licensed spectrum and hence attracting data costs. LoRaWAN requires the build out of expensive infrastructure. The lack of a tailored wireless solution makes smart streetlighting complex, fussy and expensive – all things that keep city authorities awake at night. What's needed to make it quick and easy for cash-strapped city authorities to deploy smart lighting—and other smart city applications at large scale, think smart trash cans, micromobility (*see WQ Issue 1, 2021 pg14*), public transport, delivery tracking and many more—is a low cost, wireless M2M technology at the massive millions-to-billions-of-end device scale.

The solution is buried in the detail of a standard called International Mobile Telecoms (IMT)-2020 5G. (IMT-2020 5G is an umbrella document adopted by the International Telecommunication Union (ITU) and detailing the fifth generation technology standards for mobile networks.) DECT New Radio (NR)+ (originally called DECT-2020 NR) promises a technology for massive smart city IoT applications. It is a single, secure and reliable radio standard that supports a multivendor ecosystem, is future-proofed and scalable. Moreover, because it uses license-free radio spectrum allocation, DECT NR+ will incur no data charges making it cheaper to run than its licensed equivalents.

"DECT NR+ promises to democratize 5G wireless by allowing massive device deployments with all the benefits of cellular but at a much lower cost at massive IoT scale," explains Kristian Sæther, Product Manager – Cellular IoT with wireless IoT chip vendor Nordic Semiconductor.

MASSIVE (AND INEXPENSIVE) IoT

Massive IoT was a term coined to describe a future whereby billions and eventually trillions of small devices will be directly connected to the Internet. These 'things' are compact, often battery-powered devices with limited energy, computing and memory resources.

Ericsson, a major telecom company and IoT advocate, defines massive IoT applications as those "that are less latency sensitive and have relatively low throughput requirements, but require a huge volume of low-cost, low-energy consumption devices on a network with excellent coverage". The company says the growing popularity of IoT use cases relying on connectivity spanning large areas, and able to handle a huge number of connections, is driving the demand for massive IoT technologies.

Massive IoT connection density is something new. Existing cellular networks can't come close to the density required. Consider, for example, downtown Tokyo. There, the population density in the middle of a working day is some 6,000 people per square kilometer. The mobile network is designed to cope with perhaps a third of them simultaneously connecting to the network. That's impressive, but it's more than two orders of magnitude lower than the density of IoT devices that will require access to tomorrow's networks.

That future demand has been recognized by the standards-setting bodies when considering how to build 5G infrastructure. For example, the IMT-2020 document details how networks will meet the exacting demands of consumers and industry by offering capabilities such as one millisecond latency, an 'area traffic capacity' of 10 Mbps per square meter, and a connection density of one million devices per square kilometer. The specification details two elements: 5G LTE technology for consumers and NR for other use cases, including the unique demands of the IoT. And the 3GPP, a grouping of telecom standards organizations, has also added both 5G and NR elements to its IoT specifications starting with the recent Release 15.

Engineers call the 5G LTE and NR elements of the specifications 'radio interface technologies' (RITs). RITs fulfill all the technical performance requirements across five consumer and industrial use cases; two of these, 'urban macro' Ultra Reliable Low Latency Communication (URLLC), and urban macro (massive Machine Type Communication (mMTC)) are the RITs that primarily support IoT applications.

DECT NR+ has been adopted as a RIT (actually a set of RITs or SRIT) for both URLLC and mMTC. The standard was first published by the European Telecommunications Standards Institute (ETSI) in June 2020. It is also now recognized

By the Numbers

2,000 devices per km²
Maximum 4G base station capacity

1 million devices per km²
Maximum 5G base station capacity

Source: Antenova

35.8 billion
Number of IoT devices in 2021

75.4 billion
Number of IoT devices in 2025

Source: Statista

15%
Global 5G network coverage in 2020

75%
Global 5G network coverage in 2027

Source: Ericsson

Tomorrow's networks will offer a connection density of one million devices per square kilometer

within IMT-2020 5G requirements. It makes the grade for these specifications particularly for supporting one million devices per square kilometer.

"[DECT NR+ is a] technology foundation targeted [at] local area wireless applications, which can be deployed anywhere by anyone in no time," explains ETSI.

Need to Know

DECT is a standard primarily used for creating cordless telephone systems. It originated in Europe and uses the 1.88 to 1.9 GHz band outside the U.S. and 1.92 to 1.93 GHz in that country. DECT NR+ devices can co-exist with earlier DECT devices

UNDER THE DECT NR+ HOOD

DECT wireless technology has a long history dating back to the early 1990s where it became popular in single-cell home and small office cordless phones as a wireless extension to analog telephone landlines. It also found use in Private Branch Exchange (PBX) telephone systems used within many companies, as well as some home-security, automation and healthcare applications.

DECT NR+ continues that history because it is the first non-cellular 5G standard. However, its implementation does share fundamental similarities with cellular technology. For example, the physical radio layer (PHY) in DECT NR+ reuses known techniques from cellular radios, reaching the same level of reliability proven in billions of commercial devices already in service.

However, unlike cellular, DECT NR+ operates in the global and license-exempt 1.9 GHz band, which significantly cuts deployment costs by eliminating the need for frequency planning or certification. "The [technology] will effectively enable enterprises to easily set up, manage and maintain a private 5G wireless IoT network that connects up to a million devices per square kilometer while keeping the cost of ownership low," says Svein-Egil Nielsen. And because there's no requirement for cellular infrastructure, DECT NR+ has one of the lowest carbon footprints of any massive IoT technology.

Every node in a DECT NR+ wireless network can act as an access point (or a 'sink node') with a direct backhaul connection to the Internet. This decentralized setup and operation enables a self-organizing and -healing mesh network with all the associated reliability benefits. For example, in a DECT NR+ network, no single point of failure can bring down the entire system because traffic can be rerouted automatically and rapidly around the failed node.

In addition, every node in a network can act as a relay node - allowing traffic from one node to travel through as many other nodes as needed to reach a sink node.

DECT NR+ uses four network protocol layers—PHY, Medium Access Control (MAC), Data Link Control (DLC) and Convergence (CVG)—to manage most of its reliability, security and network management features, freeing up valuable resources at the application level. This architecture results in very low latency between network devices, even across kilometers of range. That makes DECT NR+ not only a robust wireless technology but also a practical alternative to wired networks for applications that demand low latency.

NORDIC AND WIREPAS PIONEER DECT NR+

Nordic has a history of early adoption of key wireless technologies with a view to rapid commercialization. 2.4 GHz ultra low power wireless, Bluetooth LE, cellular IoT and other now mainstream technologies were embraced by the company when they were embryonic. Nordic then pioneered the development of each through hundreds of millions of R&D dollars before then being among the first to market with commercial solutions.

And so it is with DECT NR+. Nordic's engineers have already played a key role in mapping out the technology's specification. The company is the main contributor to the PHY and a key contributor to the MAC layer and continues to serve as the editor for the PHY.

Nordic is also working hard to commercialize DECT NR+. The company's partner, Finland-based massive IoT software specialist, Wirepas, is collaborating to accelerate the development of a Nordic nRF91 Series- based DECT NR+ solution for mMTC applications. Because the DECT NR+ frequency allocation of 1.9 GHz is recognized as a global license-free band, a single Nordic and Wirepas product will be suitable for all regions, lowering costs. For its part, Wirepas is developing a '5G Mesh' solution based on DECT NR+ that it describes as the "world's first non-cellular 5G connectivity product".

> "Only five percent of things that will be connected, are connected. To connect the remainder, we need to let go of how things have been done in the past and dare to go down a different route

"We're working with Wirepas to accelerate a DECT NR+ solution based on Nordic's nRF91 Series," explains Svein-Egil Nielsen. "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."

Existing technologies for mMTC applications offer a maximum performance of sub-100 kbps throughput with typically seconds of latency. In comparison, Nordic's nRF91 Series- based DECT NR+ solution will offer up to three megabits per second bandwidth with less than one millisecond latency. Such performance dramatically shortens on-air time, saving power, and supports advanced reliability and security measures without latency penalties. (*See* WQ *Issue 4, 2021 pg10*.)

THE MARKET OPPORTUNITY

According to U.S. business publication, *Forbes*, there's already a big market for private 5G networks for M2M applications. As an example, the magazine points to the cost benefits the networks bring to manufacturing facilities by eliminating wires or cables. With a private 5G network, smart factories can configure robots and implement artificial intelligence (AI) and machine learning (ML) applications rapidly without disrupting the production line or supply chain.

The sunsetting of legacy 2G and 3G M2M networks is also proving a catalyst for private 5G networks. (*See* WQ *Issue 2, 2021 pg12*.)

But until this point, the rollout of these networks has stalled because of prohibitive cost. Building and licensing a 5G network is complex, time-consuming and expensive. For SMEs, that makes them a financial non-starter. Moreover, even for those that can afford it, existing technologies don't support million node per square kilometer density. "Before now, building a private 5G

Six generations of mobile telecoms

Mobile networks have followed a development path defined by leaps in technology. Their genesis is the retroactively applied 0G label describing mobile analog systems that predated the cellular approach.

The pace picked up with the combined analog/digital approach of the late 1970s and early 80s; 1G was based on cellular mobile communications that used analogue radio for calls but digital systems for backhaul. This was followed by the all-digital 2G in the early 1990s. Then, just before the turn of the century, 3G—building on enhancements introduced by 2.5G and 2.75G—was introduced and brought higher throughput to support the emergence of smartphones. Enhancements to 3G further boosted speeds such that networks could handle mobile Internet and streaming video.

4G introduced the Long Term Evolution (LTE) standard and was pioneered in 2009. It has since been deployed globally and is the mobile technology with which most consumers are familiar today. 4G betters 3G's 15 Mbps throughput by offering a maximum throughput of 100 Mbps – allowing it to support high-definition video, online gaming and video conferencing.

The 5G standard was introduced in 2016 and 5G networks continue to be built. Once deployed, 5G promises an impressive speed of 32 Gbps (downlink) and 13.6 Gbps (uplink). The technology is directly competitive with fiber networks for Internet broadband. It also offers lower latency, better coverage and improved spectral efficiency.

But 5G brings more than bigger and better 4G. While 4G does support LTE-M and NB-IoT cellular IoT, 5G is the first mobile standard defined with massive IoT in mind. The standard lays out technologies that suit consumers alongside those, such as DECT NR+, specifically designed for low latency million-device-per-kilometer connectivity.

6G is already in the works and will, of course, be significantly faster than 5G. The plan is to use frequencies ranging from 100 GHz to 3 THz and target applications that will extend from consumers and massive IoT to new sectors such as AI and fully immersive VR. Based on the decade-long beat rate for introductions of new generations of mobile wireless technology, expect to see the first 6G networks being built around 2030.

network required a lot of investment in infrastructure and so tended to only be the domain of larger enterprises," says Kjetil Holstad, Nordic Semiconductor's EVP for Product Management. "Now any company or organization can build its own private network and run and optimize as they wish, free of a network operator. And they can do this using a license-exempt and globally available frequency dedicated for this technology."

DELIVERING THE MASSIVE IoT PROMISE

DECT NR+ promises access to massive IoT for large scale M2M applications in markets such as industrial, agriculture, asset tracking, smart city and smart energy. And all at a low cost for each node and based on a robust, efficient self-organizing network.

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

But perhaps even more important than connecting up billions of devices that previously led a lonely existence, DECT NR+ is helping build a more sustainable planet. "New and emerging technologies like [5G for massive IoT] will be essential for an inclusive, sustainable future for all people, communities and countries," said the ITU's Secretary-General, Houlin Zhao in a statement. "Under the ongoing ... IMT programme, our diverse global membership continues its long-standing contribution to advance broadband mobile communications, furthering our mission to leave no one behind in connecting the world."

When that mission is complete, we will see the real promise of massive IoT.

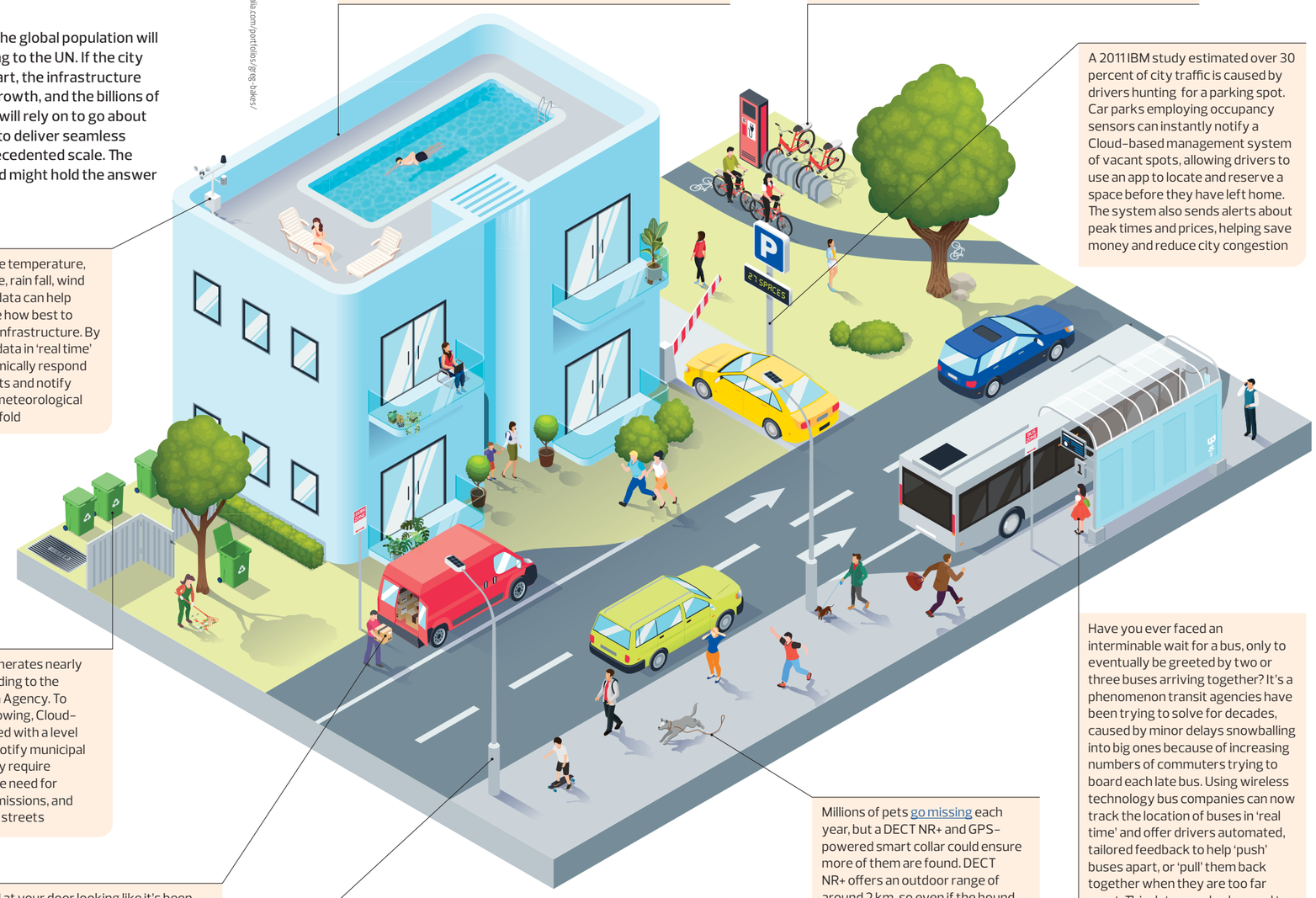
Further information: A Nordic webinar entitled Introduction to DECT NR+ is available from this link bit.ly/3zAmJv2

Tech Check:

Delivering on the smart city promise

By 2050, 68 percent of the global population will call a city home according to the UN. If the city of the future is to be smart, the infrastructure needed to service this growth, and the billions of wireless IoT devices we will rely on to go about our daily lives, will need to deliver seamless connectivity at an unprecedented scale. The DECT NR+ radio standard might hold the answer

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



Evaporation, leaks and boisterous children can dramatically reduce swimming pool levels in the summer. Wireless water metering allows utilities to remotely monitor water consumption, as well as provide owners with live data that can identify leak and flow issues in 'real time' and lower water bills

Wireless connectivity is helping grow the world's bike-sharing population. While Bluetooth LE is used for communication between the bike and an app, DECT NR+ could offer a cost-effective means of tracking an e-bike's whereabouts throughout its journey without cellular data charges

A 2011 IBM study estimated over 30 percent of city traffic is caused by drivers hunting for a parking spot. Car parks employing occupancy sensors can instantly notify a Cloud-based management system of vacant spots, allowing drivers to use an app to locate and reserve a space before they have left home. The system also sends alerts about peak times and prices, helping save money and reduce city congestion

Weather stations measure temperature, relative humidity, pressure, rain fall, wind speed and direction. This data can help city authorities determine how best to maintain roads and other infrastructure. By wirelessly delivering this data in 'real time' authorities can also dynamically respond to extreme weather events and notify customers of hazardous meteorological conditions before they unfold

In the U.S. each person generates nearly 3 kg of waste a day, according to the Environmental Protection Agency. To keep our bins from overflowing, Cloud-connected smart bins fitted with a level sensor and a compactor notify municipal authorities only when they require emptying. This reduces the need for collection visits, lowers emissions, and delivers cleaner and safer streets

If a parcel has ever arrived at your door looking like it's been mown down by an 18 wheeler, a DECT NR+ wireless asset tracker could provide answers. These trackers could give cargo companies and their customers end-to-end visibility of loads in transit, regularly relaying sensor data to the Cloud throughout its journey, notifying if a parcel has been subject to a fall or exceeded a specified temperature, for example

Streetlighting is an ideal platform for an array of wireless sensors monitoring everything from traffic flow to air quality in tomorrow's smart city. Every streetlight across a city could be networked together using a self-organizing and self-healing DECT NR+ mesh network, with each streetlight able to act as an access point with a direct backhaul connection to the Internet

Millions of pets go missing each year, but a DECT NR+ and GPS-powered smart collar could ensure more of them are found. DECT NR+ offers an outdoor range of around 2 km, so even if the hound strays beyond city limits, their collar could still be in range of other DECT NR+ devices which could pass information via a mesh network and a gateway to the Cloud then finally to the owner's smartphone

Have you ever faced an interminable wait for a bus, only to eventually be greeted by two or three buses arriving together? It's a phenomenon transit agencies have been trying to solve for decades, caused by minor delays snowballing into big ones because of increasing numbers of commuters trying to board each late bus. Using wireless technology bus companies can now track the location of buses in 'real time' and offer drivers automated, tailored feedback to help 'push' buses apart, or 'pull' them back together when they are too far apart. This data can also be used to notify fed up commuters of when they can expect their ride to arrive

Claim Changer

IoT sensors are enabling insurers to manage risks and mitigate claims by advancing accident prediction and prevention

In Short

Proactive insurance companies are looking at IoT solutions to help prevent catastrophes from occurring in the first place

Wireless tech is allowing occupants and insurers alike to monitor and detect water leaks

Using IoT devices to detect leaks before they become serious has the potential to save billions of dollars if rolled out country-wide

Insurers are providing discounts and benefits to customers willing to invest in certain monitoring devices

The history of insurance dates back to the beginning of civilized society. As early as 4000 BC, loans known as 'bottomry contracts' were granted to merchants of Babylon under the provision any shipment lost at sea would mean the loan did not have to be repaid. The insurance risk was covered by the interest on the loan.

By the 15th century, the marine insurance industry had become highly developed. But it wasn't until the 1600s, around the time exotic goods were being shipped back to the Old World from the New, that the practice of underwriting—taking on financial risk for a fee—emerged in London coffeehouses. One such coffeehouse, owned by Edward Lloyd, later of leading insurance market, Lloyd's, became the primary meeting point for merchants and ship owners, plus anyone else seeking to insure their valuable assets. (See sidebar pg23 *How fire brigades emerged from insurance companies.*)

While insurers were thriving in Europe, it was a different story across the Atlantic. There it took until 1752 for Benjamin Franklin to organize the first American insurance company which he called the Philadelphia Contributionship. While many of the early property insurance companies in the U.S. failed, from the early 1900s the U.S. insurance industry started to gather momentum. Fast forward to the 21st century and the business model for contemporary insurance providers is well understood – charge customers premiums in exchange for insurance coverage on their property, health, travel, and anything else you can name from cars and pets to weddings and special talents.

Now, the insurance industry is about to reinvent itself once again. The IoT is reshaping the way insurers assess, price and limit risks. Warning services and predictive maintenance of infrastructure and equipment, for example, could save billions of dollars each year for organizations and consumers, and consequently insurers. This is happening because wireless sensors enable early identification of a potential cause of catastrophe, for instance a leaking pipe, and by doing so prevent the large insurance claims that result from repairing the damages caused by flooding.

WASTING A VALUABLE RESOURCE

From the lead-lined Roman aqueducts of old to the intricate copper and PVC piping of today, getting clean water into people's homes has always been a feat of human ingenuity. But there are still significant challenges. Top among these is water leakage. Leaks can be caused by a variety of situations. For instance, a sharp drop in temperature can freeze pipes causing them to expand and crack. Disparities in water pressure levels, blockages and old or broken seals are other common causes of leakage.

While there are many simple fixes for household leaks, because pipes are hidden away the leaks often slip by undetected. Not only does that cause damage, but it also wastes a valuable environmental resource. In the U.S. alone, leakages in a single average property can waste up to 45,500 liters each year, says the U.S. Environmental Protection Agency (EPA).

Damage from leaking pipes is one of the most common insurance claims for domestic property, and is the third most common for commercial claims, according to Allianz Global and Corporate Security (AGCS). In the past decade alone, insurers in North America have lost $2 billion to water damage claims, says AGCS.

But imagine if, rather than relying on experts to assess the extent of losses and damage to property and assets following a serious incident, a proactive insurer could instead help prevent the worst from occurring in the first place. This scenario is now a reality for a growing number of insurance providers deploying advanced wireless tech-based solutions such as water monitoring sensors and leak detection systems across commercial, industrial and residential properties.

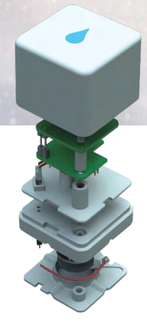
> Identifying a potential cause of catastrophe, is significantly less expensive than repairing water damage and paying hefty insurance claims

The introduction of unobtrusive monitoring devices for leak detection can help solve this otherwise hidden problem. Wireless leak monitoring devices mounted on walls or along pipes can detect leaks and frozen water, while building managers can use wireless water monitoring devices to discover liquid spillages, pump failures or floods over wide areas.

ATTENTION: LEAK DETECTED

IoT solutions use built-in sensors to detect any water outside of the pipes that could indicate a leak. An especially useful aspect of some of these devices is that some can detect the level of damage which can help with insurance claims and estimating the cost and scope of repairs.

In the first instance the sensors detect minor leakages that don't pose an immediate threat, allowing the user to schedule plumbing maintenance. The monitors break down into two versions: passive devices tend to be standalone battery-operated units that are easily installed and relatively cheap but do little more than notify that there's an impending problem, while active leak detection systems automatically shut off the water upon detecting the leak to minimize resultant damage.



Tech Check

The key feature of Nordic's nRF52832 SoC for AquaSensing's Leak Sensor 1.0 is the power optimization. The SoC's exceptionally low energy consumption is achieved using a sophisticated power management system

Some wireless leak sensors employ short-range wireless connectivity such as Bluetooth LE (to send information directly to the homeowner's smartphone) or Thread (which uses a gateway to a Cloud service which then notifies the consumer). Other models are increasingly making use of NB-IoT, the version of cellular IoT which is suited for use with stationary installations buried in walls or beneath floors. The transmissions from cellular IoT-equipped leak detectors are sent directly to the Cloud without the need for a gateway allowing consumers and insurance companies alike instant access to the information from a web interface. The range, penetration and battery-friendly nature of NB-IoT is allowing insurance companies to place leakage detectors in the most inaccessible locations.

SCALING-UP PROTECTION

When it comes to water damage, every second counts. This is especially true in large apartment complexes, commercial buildings and industrial facilities where a serious leak in one area can wreak havoc across the whole

site. Without the right detection systems, even free-flowing water may not be discovered before it's too late for a building's interior systems and its underlying structure.

A key issue for insurers is that water monitoring solutions have traditionally proved costly to deploy, preventing easy scaling of leak detection capabilities. But inexpensive IoT sensor solutions are changing all that. Now insurers can position fleets of detectors such that when a pipe bursts or plumbing fails, it is detected very quickly and insurers can send in rapid-repair teams to minimize the impact.

One example of a company that's moved fast is insurance giant, Chubb, which is installing thousands of water leak sensors around the U.S. to combat costly non-weather-related water damage. The sensors can not only detect how much damage was caused by a water leak but could potentially also stop the leak as soon as it starts by instructing a shutoff valve to close the main supply line to the house. According to *Insurance Journal*, a U.S.-based trade publication, customers that use such devices could see insurance discounts of up to three percent for passive sensors and eight percent for the active versions capable of shutting off the stopcock.

AIDING SUSTAINABILITY

Increasing the sustainability of water IoT sensors for water leak prevention, the Leak Sensor 1.0, developed by Canadian technology company, AquaSensing, uses the momentum of the water from the leak it detects to power its Bluetooth LE radio through energy harvesting circuitry. An alert is then transmitted to the user's smartphone using the leak detector's built-in Nordic Semiconductor nRF52832 SoC.

Because the leak detector doesn't use a battery, it can operate for extended periods without being replaced, thanks in a part to the ultra low power consumption of the Nordic SoC. The inert materials used in manufacture allow Leak Sensor 1.0 to remain operational for more than 20 years; this means during construction of the building, the device can be safely hidden behind walls and in areas difficult to access once the structure is complete.

The commercial sector represents an incredibly lucrative market. Having a solution that can effectively prevent water damage in such a setting is especially important, as the volume and complexity of the plumbing tends to be much greater than in domestic residences. Any water leakage issues can shut businesses down for extended periods compounding the cost of fixing the leak and the damage it has caused.

In addition to leak detectors, IoT devices can be home to other sensors that can detect impending damage. For example, complementing a leak detector with a temperature sensor could alert maintenance personnel to rapid temperature drops, averting potential damage from frozen and burst pipes. Other sensors supported by a single wireless IoT device could monitor the local environment and quickly detect smoke, carbon dioxide, mold or other damaging substances, send a notification as well as automatically adjust the building heating or ventilation to mitigate harmful effects on people or the building.

By the Numbers

4.9%
Growth in global insurance industry in 2019 over 2018

Source: McKinsey & Company

11%
Rise in global commercial insurance prices in the first quarter of 2022

Source: Marsh Specialty and Global Placement

$5.9 billion
The estimated size of the leak detection devices market by 2026

Source: Global Industry Analysts, Inc.

6% CAGR
Projected growth of the active leak detection system segment by 2026 (to reach $4.3 billion)

Source: Global Industry Analysts, Inc.


Natural climate events cause $15 billion in damage each year

IN CASE OF EMERGENCY

A burst pipe is one thing, but a *bona fide* environmental emergency is quite another. In an average year in the U.S. alone there are about 10,000 thunderstorms, 5,000 floods and 1,300 tornados, as well as widespread droughts and wildfires, according to the National Oceanic and Atmospheric Administration (NOAA). A staggering 23.7 million U.S. properties are at risk of flood waters, claims the Federal Emergency Management Agency (FEMA).

And the threat to lives and property is very real. NOAA estimates these natural climate events cause an average of approximately 650 deaths and $15 billion in damage each year. Flooding is the most expensive natural disaster in the country, costing over $1 trillion in inflation-adjusted dollars since 1980.

But greater access to real-time data can help improve situational awareness and mitigate the impact of natural disasters. As such, IoT solutions incorporating LPWANs such as cellular IoT, and advanced data analytics, are being pushed towards the forefront of emergency preparedness and response strategies.

While these solutions don't have the power to stop incidents altogether, investing in wireless technology could certainly help communities plan for and react to emergencies – hopefully minimizing the cost of damage in the process. The deployment of long range wireless sensor systems, for example, makes it possible to measure wind, rainfall and high temperatures to better understand not only the environment as a whole but how distinct areas are threatened differently by these dangerous conditions.

EXTRA SAVINGS

Potential savings for both insurance companies and their customers are not limited to predictive maintenance and environmental monitoring applications. Many insurers are providing discounts and benefits to customers willing to invest in monitoring devices and smart home security systems. For example, American Family Insurance has partnered with Ring to offer a discount to customers who purchase a smart doorbell solution, in the hope it will reduce the risk of home break-ins and theft, as well as help prevent fraudulent claims. This technology will continue to evolve alongside further advances in home and building automation, resulting in fewer related insurance claims.

In recent years, the use of 'black boxes' in cars has allowed auto insurers—who historically relied on indirect indicators such as the age or credit score of a driver—to set premiums based on actual driver behavior and use of the vehicle. Parameters such as routes, speeds, acceleration, or how often the vehicle is driven at night come into play. Insurers can customize premiums for drivers and offer better rates to those with safer driving records. This, for example, allows younger or less experienced drivers, who have demonstrated safe driving to avoid being charged a blanket, more expensive insurance rate.

Some insurers have also offered reduced life and health insurance premiums to those who use wearable devices to monitor their health and fitness or better manage existing health conditions. With discounted rates acting as an incentive for improving health, it's a win-win for both insurers and customers alike.

Moving forward, tech-savvy insurers leveraging the IoT will be able to determine risks more precisely, develop new products and services, and perhaps most importantly extend their reach to include prediction, prevention, and ultimately genuine assistance. While water leaks might be inevitable, wireless monitoring can help limit the damage to both pipelines and bottom lines. It seems the IoT is rapidly changing the claim game.

> “Investing in wireless technology could certainly help communities plan for and react to emergencies – hopefully minimizing the cost of damage in the process

Feature: Insurance and the IoT

How fire brigades emerged from insurance companies

In 2020, more than 4,700 full-time firefighters were employed at 102 fire stations across Greater London. But go back 350-odd years and fire brigades as we know them didn't even exist. Then, in England, the rapidly evolving insurance industry sparked the flame for what would become one of the largest firefighting and rescue organizations in the world – the London Fire Brigade.

It all started with the Great Fire of London in 1666 – an enormous tragedy directly preceded by the Great Plague that had already killed roughly 20 percent of the city's population. With a long dry summer and densely packed homes built with flammable materials proving a recipe for disaster, an inferno swept through London destroying more than 13,000 buildings and leaving around 100,000 survivors without homes. At a time when London's annual income was £12,000, the cost of the fire was estimated at £10 million.

In response to the ensuing outrage, groups of underwriters experienced exclusively in marine insurance decided to form companies offering fire and property insurance. However, by 1700 these same insurance providers concluded that putting out fires themselves would be significantly cheaper than paying for rebuilds. And so, they employed their own firefighting units and tasked them with preventing and minimizing fire damage to insured properties. Ultimately, the system proved both inefficient and fundamentally flawed. Despite reciprocal agreements, firefighting units were allowing buildings to burn if they were not covered by the affiliated insurance company.

To overcome this challenge, ten independent fire insurers united to form the London Fire Engine Establishment (LFEE) in 1833. Eventually, in 1865, when the LFEE expressed its unwillingness to remain responsible for London's fire protection, the British government created the Metropolitan Fire Brigade (renamed the London Fire Brigade in 1904).

These days the global fire insurance market is burning brighter than ever. The market was valued at $58.49 billion in 2019 and is projected to reach $120.49 billion by 2028 (data from Allied Market Research), with this forecast growth down to increased demand for insurance policies, the need for financial safety in uncertain times, and a global surge in property construction.

Feast or Famine

A global chip shortage is the product of skyrocketing demand and manufacturing challenges, but a solution is on the horizon

In Short

A critical global chip shortage has put the squeeze on a swathe of industries, from electronics to automotive and manufacturing

COVID-19 played an instrumental role, forcing a shift to working-from-home and fueling global demand for electronics, while also disrupting chip production facilities

Chip supply also experiences structural challenges, making it difficult to easily scale up in response to demand and highly susceptible to supply chain disruptions

During the late 1990s, a great amount of human attention was drawn to tending to small handheld 'pets' from Japan. The Tamagotchi—a tiny electronic gadget that mimicked a baby chick—had taken the world by storm. In 1997 alone, orders were placed for 70 million devices.

As it turned out the Tamagotchi was more than a digital chick in our hands – it was also the canary in the coalmine. A warning of a crisis to come, demand for Tamagotchis hit such heights in the 90s that it triggered a shortage of semiconductor chips whose impact would spill beyond handheld devices and impact a range of other sectors.

A quarter of a century later, the world is again reckoning with its reliance on silicon. Another critical global chip shortage has put the squeeze on a swathe of industries, from consumer electronics to automotive and industrial.

This shortage looks set to continue for years, but as manufacturers, vendors and policymakers take steps to relieve the crisis, it could force a reset that heralds a more sustainable and resilient approach to the production, distribution and consumption of silicon-based technology.

A BLESSING AND A CURSE

Like so many of today's challenges, COVID-19 plays an instrumental role in this story. At first glance, the pandemic appeared to be a boon. A forced shift to working-from-home, and an imperative to stay indoors more broadly, saw global demand for electronics such as computers and gaming consoles boom. Interest also spiked in wearables, seen as useful aids for social distancing and contact tracing. (*See* WQ *Issue 2, 2020 pg8*.)

Global chip sales grew in line with this rising demand for electronics, increasing 6.5 percent from 2019 to 2020. But the supply of chips was ultimately unable to keep pace with demand, with some key suppliers reporting having already sold-out production capacity through to 2026.

The resulting shortage has been felt widely. "It has become almost impossible to buy a PS5 games console," reported the BBC, a British broadcaster, in 2021. "Toyota, Ford and Volvo have had to either slow or temporarily halt production at their factories. Smartphone makers are feeling the pinch too, with Apple warning that the shortage could affect iPhone sales." U.S. automaker General Motors cited a drop in profit in 2021 by as much as 40 percent because of the shortage. Perhaps less visible, the lead times for chip orders to be fulfilled blew out to 15 weeks, according to Bloomberg. The shortages, and many of its impacts, persist into 2022.

Heightened demand for chips, particularly processors, had been rising strongly for years prior to the pandemic, powered by global demand for smartphones and buttressed by uptake of processing-heavy technologies such as Industry 4.0, 5G, AI and ML. Growing awareness of IoT also sees more industries seeking to embed wireless SoCs into machines to make them smarter and connected. Take cars – within a decade, automotive electronics such as displays and in-car systems will account for almost half a car's total manufacturing cost, says analyst Deloitte.

SUPPLY SQUEEZE

In addition to fueling demand, the pandemic hit key staff and proved highly disruptive to chip production and distribution, temporarily shutting down some factories and sowing chaos in supply chains. (*See* WQ *Issue 4, 2021 pg14*.) Severe weather events also affected production. In 2021, a fierce winter storm in Texas and a factory fire in Japan temporarily closed critical chip-making facilities.

If that wasn't enough, geopolitics also made its mark.

With trade tensions with the U.S. ongoing and, anticipating sanctions, Chinese companies in 2020 began stockpiling equipment needed to produce computer chips. "In the short term, stockpiling of whatever parts are available risks making the shortages worse for everyone else," noted *The Economist*, a British newspaper.

With a squeeze on wafer supply and ongoing rising demand for processors, semiconductor vendors like Nordic Semiconductor found themselves in the middle. "We've experienced demand from customers significantly above what supply constraints have allowed us to deliver," says Geir Langeland, EVP Sales & Marketing at Nordic Semiconductor. "This has lead to a sizeable order backlog." Langeland says Nordic is focusing on striking a balance between protecting its tier 1 customers while also supporting smaller firms and promising newer players.

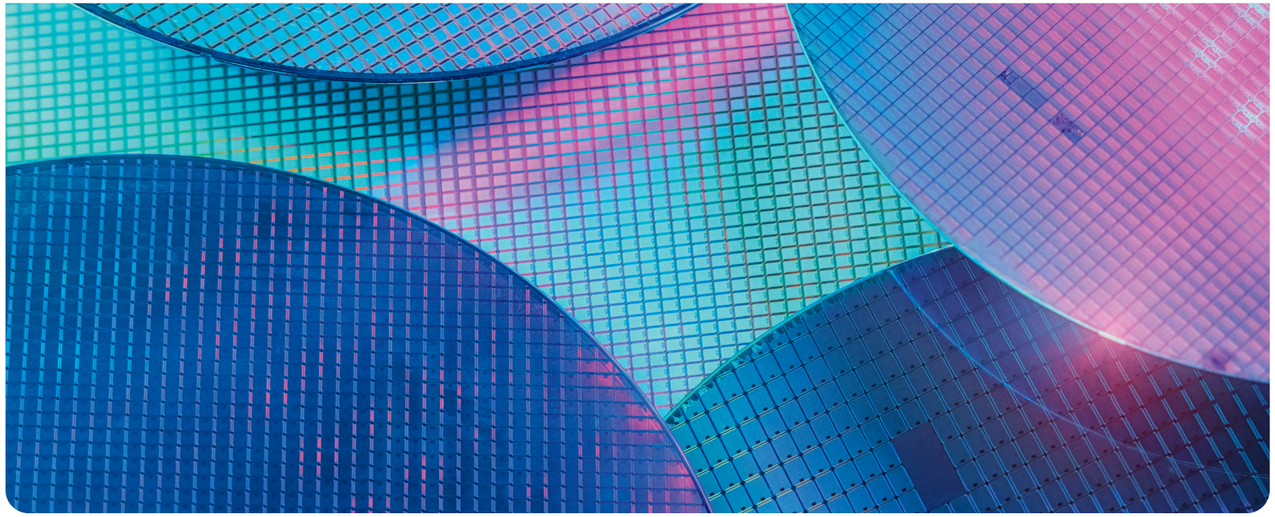
When analyzed, it's clear that while singular events like COVID-19 and geopolitical tensions did leave an indelible mark, these events merely widen cracks in the industry's foundations that were already there. To understand the underlying causes of today's shortages, we need to look more closely at the structural realities of the semiconductor industry.

Chip production is a complex and expensive exercise. The factories that make chips, known as wafer fabs (short for fabricators), are highly controlled and tuned facilities that must run round-the-clock and every day of the year to turn a profit. For such complex, precise and bespoke operations, scaling up production to meet demand spikes is difficult. "Typical lead times can exceed four months for products that are already well established in a manufacturing line," says analyst McKinsey. Switching products to another manufacturing site can add another 6-12 months, the company says.

Additionally, only a few players have the resources and capability to keep pace with the advances in technology necessary to be in the chip-making business. For this reason, most of the semiconductor companies that sell chips have also chosen to be 'fabless', focusing on design and development and turning to the giant fabs for supply.

These factors—which increase cost and encourage specialization—mean the manufacturing of chips is now concentrated in the hands of a small number of players. Just two fabs, Taiwan Semiconductor Manufacturing Company (TSMC) and Samsung Electronics Company, supply most of the world's advanced chips. Both are operating at full capacity so are unable to ramp production. The strain on the wafer fabs' ability to service all clients is also compounded by a marked imbalance between large and small production batches.

> "The flow of new chips will take some time. It takes up to two years to build a shell of a fab and install the required tools, plus another 18 months to ramp up to full capacity



Geographic concentration is another factor, with 91 percent of chipmaking businesses housed in Asia. This necessitates an expansive semiconductor supply chain—"one of the world's most complex" says IBM, a multinational technology company—to get chips into the hands of customers. "The production of a single chip often requires more than 1,000 steps and passing through international borders 70 or more times before reaching an end customer," IBM says. Any jolts or disruptions to global supply chains—and there have been many through the pandemic—have an outsized impact on chip supply.

A MULTI-FACETED RESPONSE

The first response to the chip shortage is to increase wafer production. Among key fabs, expansion plans are already underway. TSMC has announced it will invest up to $100 billion in new capacity over the next three years. Deloitte predicts investments by the three largest semiconductor players will exceed $200 billion from 2021 to 2023.

Still, the increased flow of new chips will take some time. "It takes about 12 to 24 months to build a shell of a fab and install the required tools, plus another 12 to 18 months to ramp up to full capacity," says McKinsey. The companies that supply critical equipment—such as lithography machines— to fabs are few and far between and face their own supply challenges. Meanwhile, demand is also predicted to keep growing, "roughly as quickly (or more)" than the planned growth in capacity, says Deloitte.

In the meantime, companies like Nordic, which sit between the fabs and customers building technology solutions, are doing what they can to smooth imbalances. "We took early and decisive action to secure additional wafer supplies from existing and alternate suppliers and have taken steps such as bringing forward delivery schedules from future quarters to try to meet immediate customer demand," says Geir Langeland.

Nordic has also increased dialog with suppliers, distributors and customers to improve awareness of supply constraints and future needs. *The Economist* describes the semiconductor industry as "notoriously cyclical: gluts and shortages are not uncommon". So improved demand forecasting and active management of wafer allocation is a significant focus area for the industry. With new chip supply likely to take time to materialize, it may be one of few realistic short-term options.

MORE RESILIENT, MORE SUSTAINABLE

Governments and policymakers are also now weighing in, having recognized a more resilient semiconductor supply chain is of strategic importance to national prosperity and security. Both China and the U.S. have made self-sufficiency in chips a national priority, with U.S. president Joe Biden last year signing an executive order targeting the shortage. After decades of shifting chip manufacturing abroad, the U.S. is now exploring incentives for greater U.S.-based semiconductor manufacturing. Multinational chipmaker Intel this year has already announced a $20 billion investment in wafer fab facilities in Arizona that will produce chips for other companies. Alongside these investments, the concept of industry 'clusters'—centralized locations where companies involved in the semiconductor value chain co-locate—is also catching on as a way to avoid the troubles of a complex supply chain.

These industry-level reconfigurations will take time to have an effect. Some argue rethinking chip-level design will make a more immediate difference. One approach is a shift towards greater integration on the chip. For example, Nordic's nRF5340—a highly integrated SoC that includes two embedded Arm Cortex-M33 processors, Flash and RAM, 2.4 GHz radio, power management and a host of peripherals—is designed to not only minimize physical size, but its high degree of integration means users are less reliant on having to source additional components in constructing a full connectivity solution.

Another more immediate way to alleviate shortages is to 'design for availability'. In a survey about the shortage, two thirds of design engineers said they are now making design choices based on availability of components rather than preference. This could mean potentially removing or deprioritizing non-essential features that rely on scarce components. Management consultancy, Bain & Company, predicts pricing could also become a prevalent tactic to steer customers towards readily available components.

These shifts in design approaches hint at a fundamental shift in attitude that may be necessary if constrained supply is the 'new normal'. BCS, a global IT industry body, argues that a primary driver of the chip shortage has been the demand for upgraded products every few years. "The underlying challenge that must be addressed is the very short life span of devices," says Alex Bardell from BCS.

This consumerist drive for ever-new gadgets has implications beyond the pressures exerted on chip supply. Today, mobile phone manufacturing has an annual carbon footprint equal to that of a small country, and smartphones comprise 10 per cent of global e-waste. The call from bodies like BCS is for products that are more durable, supported for longer and more suitable to repair, engendering an approach not only more sustainable in terms of chip supply, but also for the planet.

These environmental gains, if realized as an outcome of the response to the chip shortage, would come on top of improvements in global chip production capacity and distribution, more nimble and thoughtful design, and a more resilient supply chain. Perhaps, with hindsight, the chip shortage will be seen as the reset the industry needed.

> "In a survey about the shortage, two thirds of design engineers said they are now making design choices based on availability of components rather than preference

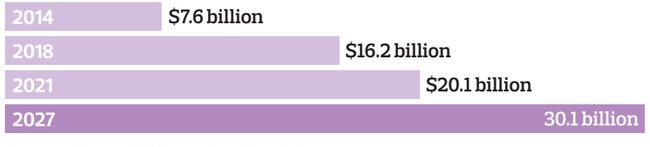
Tech Check

Nordic's nRF5340 includes two Arm Cortex-M33 processors, Flash and RAM, 2.4 GHz radio and much more. The SoC's high degree of integration means users are less reliant on having to source additional semiconductor components in constructing a connectivity solution

State of Play

How a pure-play wafer fab changed an industry

When Taiwan Semiconductor Manufacturing Company (TSMC) was founded in 1987 it transformed the semiconductor industry. That's because TSMC was the first chipmaker dedicated to manufacturing for others rather than making its own devices. Before then, companies wishing to enter the chip market were faced with either huge investment to build their own fab or chasing around for spare capacity from other manufacturers who were often already making competitive products. Most significantly TSMC encouraged the growth of Silicon Valley in California in the 1990s because it allowed single-product startups to get their production off the ground. Since then, the sector has consolidated and now just two major players remain, TSMC and Samsung Electronics Company in South Korea. Meanwhile wafer production has ballooned to $20.1 billion in 2021.



Source: Hexa Research, BCC Research, Future Market Insights

Made from sand

There's an irony at the heart of the semiconductor famine. Silicon, the base material of microchips, is actually one of the most common elements on earth. It's found in abundance in a wide range of highly common natural materials, including quartz, flint and even ordinary beach sand.

The shortage of chips, of course, has less to do with the scarcity of the raw ingredients and more to do with the specialized process and capabilities needed to transform these ingredients into silicon wafers and, ultimately, into the chips and integrated circuits (ICs) that power our smartphones, PCs and other electronic products.

The process of making silicon wafers begins by melting pure polycrystalline silicon. As silicon itself does not conduct electricity particularly well (in fact, it can almost be considered an insulator), 'dopants' such as boron or phosphorus are added during the melting process to alter the electrical properties of silicon to make it more conductive. The output of this process is the formation of a silicon ingot, a long salami-shaped block, that can be sliced into the wafers that will form the foundation of microchips and integrated circuits.

Wafers today come in a variety of shapes and sizes. When the term 'wafer' first came to be used around the 1960s, they were less than three inches in diameter, limiting the number of semiconductor devices that could be produced from each.

Today, following ongoing investment and innovation by the industry, wafers are commonly 300 mm in size. (Curiously, the shift to bigger wafers also saw a shift to measuring them in millimeters, rather than inches.) The next step forward will be 450 mm wafers, however the industry's transition to tooling and capability that will allow routine production at this size is still underway.

Before being packaged and distributed, wafers go through an intense cleaning and polishing process to remove scratches and impurities. When they eventually arrive at fabs, wafers are treated as highly precious objects. Air quality and temperature is highly controlled in any rooms that they pass through, while they are moved directly from machine to machine by highly sophisticated and gentle 'wafer handling robots'.

Such intensely careful handling seems highly appropriate for the crtical foundational layers of our modern digital world.

Silicon ingots can be sliced into wafers to form the foundation of ICs

Man vs Machine

IoT data and machine learning combined with human intelligence has the potential to improve decision-making

Thanks to long term evolution, humans have become sophisticated decision makers. We draw on our knowledge of the past and our conceptualization of the future, then, by using trial and error, intuition and pattern recognition, we make our judgement. We've become exceptionally good at it. Good, but not perfect.

The flaw with human decision-making is two-fold. Firstly, our ability to precisely process information is weak. We compensate with heuristics (using mental shortcuts, like rules-of-thumb), which frequently results in inaccurate conclusions. Secondly, we're human. And as such, our decisions are often bafflingly irrational. We focus on irrelevant information, rationalize bad decisions and, perhaps most worryingly, succumb to bias. For example, a 2011 research study found that during legal proceedings favorable rulings from judges fell to practically zero shortly before meal breaks, while immediately returning to 65 percent once they'd eaten. Food for thought.

Machines on the other hand 'think' differently. AI and ML are terms used interchangeably to describe how a machine processes information. But within the IoT industry the terms are defined more clearly. "AI is a futuristic thing, it's an entire field of achieving a level of human-like intelligence from machines," explains Zach Shelby, Co-founder and CEO of embedded ML specialist, Edge Impulse. "ML on the other hand is the practical, mathematical field where we use math to solve real problems with data."

IoT end-devices are increasingly being equipped with ML capabilities that aim to mimic the biological intelligence technique of looking for occasional deviations in an otherwise monotonous stream of data and then interpreting those patterns to aid decisions. What machine solutions lack are the human traits of instinct and intuition—or 'gut feel' if you will—but then what they don't do is make bad decisions shortly before lunch. There is much we could learn from such detached logic.

Tech Check

Thanks to Nordic's partnership with Edge Impulse, the Nordic Thingy:53 multisensor IoT prototyping platform, together with the Nordic Thingy:91 and nRF5340 DK, supports TinyML. This support allows developers to quickly get started with embedded machine learning

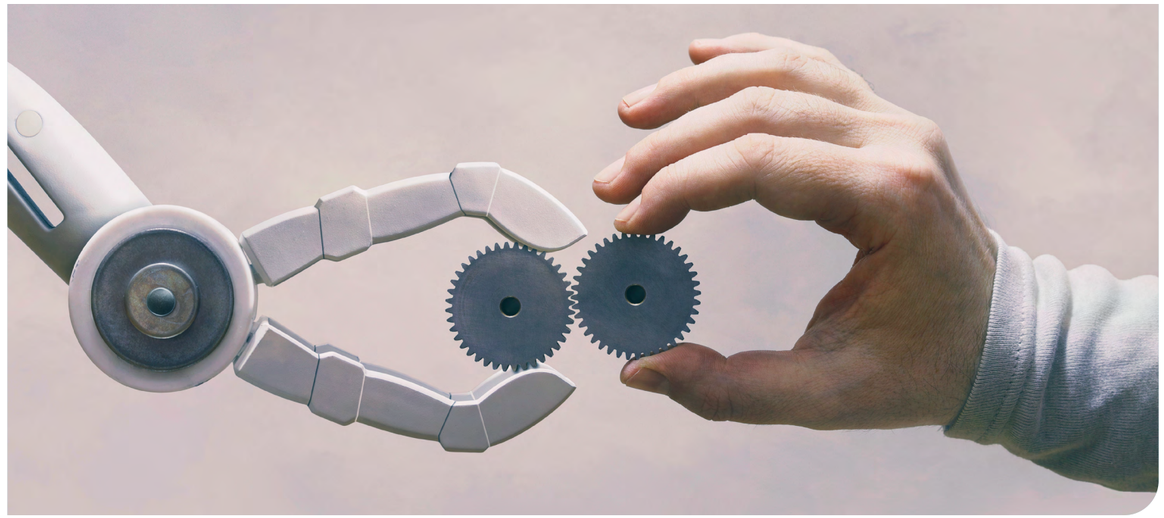
Advanced wearables such as eBuyNow's Moto Watch 100 could use ML to help make sense of the vast quantities of data they generate

AUGMENTED INTELLIGENCE

Whether human or machine in isolation is better at interpreting data depends on the task. "ML, natural language processing, data analytics and other AI applications can perform exceedingly well with large-scale data [input] and without human judgement," said Paul Pavlou, a Professor at the Data Science Institute, Temple University, Philadelphia. "Humans generally outperform machines when dealing with ambiguity, vagueness and incomplete information, and when requiring emotional intelligence and judgment." When it comes to games such as chess and Go, machines have now easily won out (see sidebar pg 29 *The struggle between human and artificial intelligence*). But beyond games, research suggests the human brain in combination with the silicon one—so called augmented intelligence—can deliver the best outcomes.

The opportunity for this augmented intelligence in the rapidly expanding IoT is large. As of 2021, there were more than 10 billion active IoT devices. If projections stand up this could multiply to 250 billion devices in the not-too-distant future. Without ML to spot changes, the data generated by the IoT would overwhelm. And yet, letting machines make all the decisions without some degree of human oversight is risky. "Organizations face multiple risks from AI in IoT, such as privacy intrusion, mechanistic decision-making and loss of managerial control," Pavlou said. "Can AI be trusted to fully circumvent human oversight?"

The answer for now, is no, the machines can't be trusted completely. For example, while advanced wearables are now widely used to enable healthcare providers to remotely monitor a patient's heart and respiratory rate, and blood pressure (*see WQ Issue 1, 2022, pg22*), we wouldn't want the devices to assume responsibility for diagnosis without the physician's oversight because of intangibles that are hard to spot in the data. But could ML be employed to sift through the vast amounts of data medical wearables generate to ignore the noise and reduce false alarms, enabling physicians to make more informed clinical decisions? Of course. But we're not there yet.



PROGRESS AT THE EDGE

To augment human decision using an IoT equipped with ML capabilities presents some formidable challenges. According to analyst IDC, the amount of data generated by the IoT will reach 73.1 zettabytes by 2025. Relaying that volume of data to the Cloud is untenable because the networks can't carry the load, the devices don't have the resources and the cost of carriage would be prohibitive.

However, today's IoT silicon can support TinyML, a scaled down version of ML (*see WQ Issue 2, 2021, pg14*). This, for example, enables edge devices to constantly monitor data from industrial machinery to predict if there's a risk of breakdown. Today the 'learning' is performed by powerful Cloud servers. The servers then 'retune' the predictive algorithm and reprogram the IoT device over the air.

The final step, for now still some distance in the future, will be for ML to directly augment human decision making. Advances in deep learning have enabled machines to achieve super-human performance for some tasks, but this not been reciprocated. However, according to the *Harvard Business Review*, that's not the point. The publication suggests we shouldn't waste time learning how machines make decisions, rather we should focus on directly leveraging their talents. The data generated by the IoT will ensure that machine prediction can substitute for the human version in many trivial situations. But when it comes to complex judgements, machine prediction will complement rather than replace humans. The machines will give us much more evidence on which to base decisions, but we'll always be the ones making the big call.

> We wouldn't want devices to assume responsibility for diagnosis without the physician's oversight because of the intangibles involved

The struggle between human and artificial intelligence

In 1997, then world chess champion, Garry Kasparov, famously lost a series against an IBM supercomputer called 'Deep Blue', a result seen by many as indicative that AI in harness with brute computer power had finally overtaken the mortal version.

25 years on, the pendulum has swung further in the direction of the machine, with today's commercial chess programs able to not only comfortably dispatch the strongest human players but also former supercomputer Deep Blue with relative ease. Unsurprising, because while it's estimated chess grandmasters can calculate up to 30 moves ahead, the best chess engines comfortably process 80 to 100 moves ahead. It's not a fair fight.

More recently, in 2016, a computer also beat the best human player at the world's oldest game, Go. It took longer to master Go because the game has unlimited possible moves that can't be precisely identified by brute force calculation alone. As such, elite human intuition and evaluation skills continued to trump machines until 2016, when advances in deep learning algorithms in AI won out. Instead of evaluating all possible solutions, the AI models used deep learning to reduce the potential moves under consideration and predicted sequential outcomes and winning probabilities. In essence, the computer recreated centuries of human trial-and-error from scratch to see if there was a better way to solve the game's problems than we had managed to come up with in the previous several thousand years. And it succeeded.

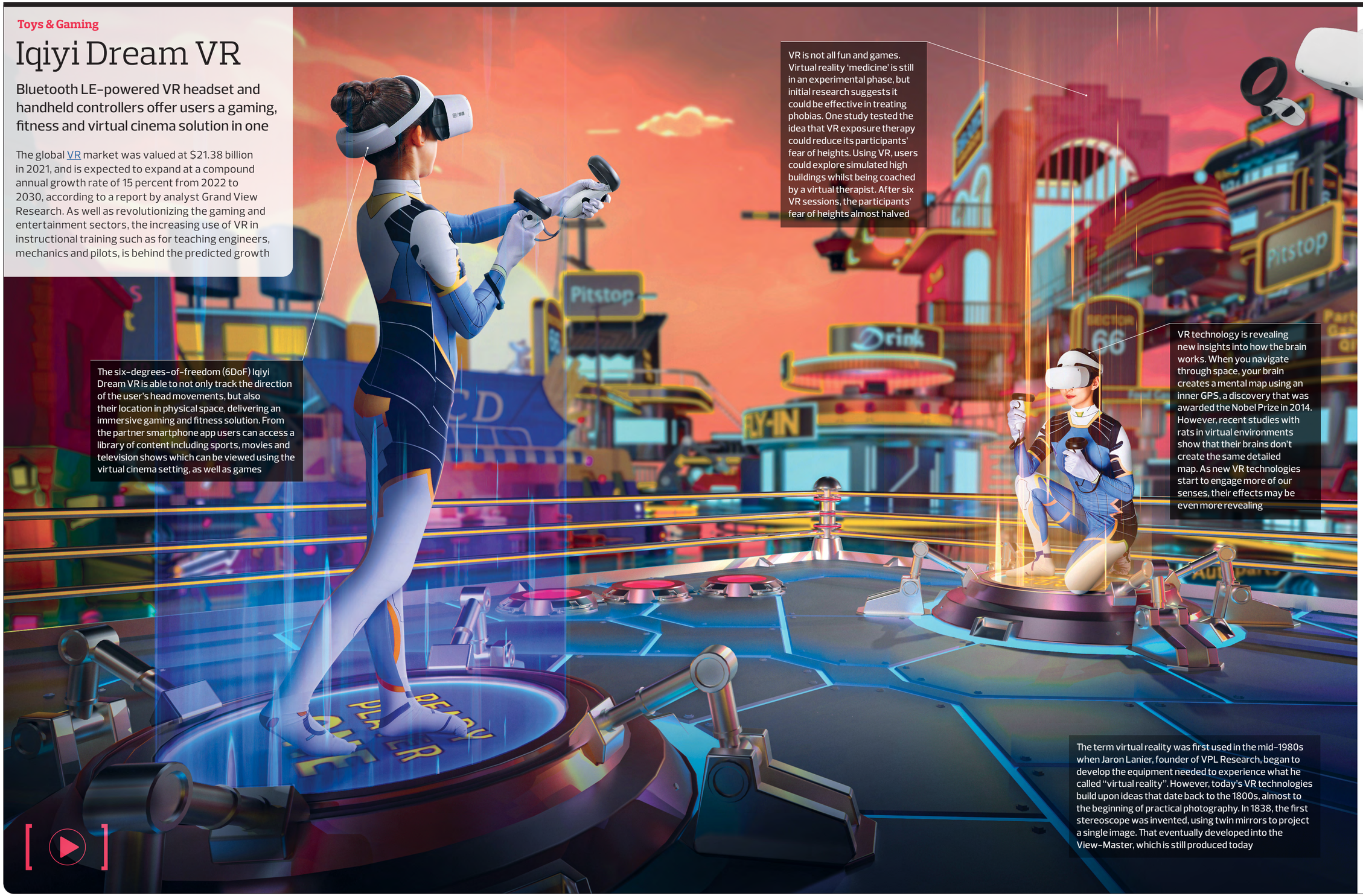
That could have been the end of the story, except it wasn't. Since that loss, research shows professional Go players have become much better at the game themselves, by studying the conclusions of the AI models, and attempting to simultaneously 'think' like both machine and a human. It hasn't yet reversed the superiority, but it has significantly narrowed the gap and demonstrated that when AI is better than humans, it can drag us forward.

Toys & Gaming

Iqiyi Dream VR

Bluetooth LE–powered VR headset and handheld controllers offer users a gaming, fitness and virtual cinema solution in one

The global VR market was valued at $21.38 billion in 2021, and is expected to expand at a compound annual growth rate of 15 percent from 2022 to 2030, according to a report by analyst Grand View Research. As well as revolutionizing the gaming and entertainment sectors, the increasing use of VR in instructional training such as for teaching engineers, mechanics and pilots, is behind the predicted growth



VR is not all fun and games. Virtual reality 'medicine' is still in an experimental phase, but initial research suggests it could be effective in treating phobias. One study tested the idea that VR exposure therapy could reduce its participants' fear of heights. Using VR, users could explore simulated high buildings whilst being coached by a virtual therapist. After six VR sessions, the participants' fear of heights almost halved

The six-degrees-of-freedom (6DoF) Iqiyi Dream VR is able to not only track the direction of the user's head movements, but also their location in physical space, delivering an immersive gaming and fitness solution. From the partner smartphone app users can access a library of content including sports, movies and television shows which can be viewed using the virtual cinema setting, as well as games

VR technology is revealing new insights into how the brain works. When you navigate through space, your brain creates a mental map using an inner GPS, a discovery that was awarded the Nobel Prize in 2014. However, recent studies with rats in virtual environments show that their brains don't create the same detailed map. As new VR technologies start to engage more of our senses, their effects may be even more revealing

The term virtual reality was first used in the mid-1980s when Jaron Lanier, founder of VPL Research, began to develop the equipment needed to experience what he called "virtual reality". However, today's VR technologies build upon ideas that date back to the 1800s, almost to the beginning of practical photography. In 1838, the first stereoscope was invented, using twin mirrors to project a single image. That eventually developed into the View-Master, which is still produced today

The head-mounted display of Iqiyi Smart's Iqiyi Dream VR employs Nordic's nRF52832 Bluetooth LE SoC, while the two handheld controllers use the nRF52833 general purpose SoC. The SoCs provide low latency Bluetooth LE wireless connectivity between the controllers and the headset to create a seamless VR experience

Tech Check

The nRF52833 SoC's radio provides +8 dBm TX output power and -96 dBm sensitivity (at 1 Mbps in Bluetooth LE mode) which helps ensure the connection between the controllers and headset is strong and reliable. The SoC is powered by a 64 MHz, 32-bit Arm Cortex M4 processor with floating point unit (FPU), designed to support the complex Floating Point (FP) and Digital Signal Processing (DSP) computations typical of high-end applications

Transport

Cellular IoT sensor detects wastewater tank problems on high-speed trains

The Nordic nRF9160 SiP-powered BeST SENSOR system monitors wastewater pumping to alert maintenance personnel of blockages or leaks

> Since their installation, these sensors have measured, evaluated and reported over 30,000 disposals of wastewater

When carrying large numbers of people across a continent, public transport must run in acceptable working order for a satisfactory customer experience. This not only applies to the engines, wheels and controls, but also the passenger facilities.

Take, for instance, the tanks of wastewater that need to be emptied from trains at specific locations along a route. To keep the train running on time, these tanks require maintenance according to strict schedules. And the demands are stringent; no tank can be missed, all tanks must be pumped sufficiently, there must not be any blockages or leaks that affect the pumping process, and no other pipe- or pump-related issues can be present.

Conventional wastewater dumping risks leaving these issues undetected. If there's a blockage, for example, the pump will automatically shut off, leaving the tank part-full. With the tank registering as empty, toilets might well be affected, leading to negative passenger experiences.

"These wastewater tanks need to be emptied in intervals of just a few days," says Oliver Völckers, Co-founder of BeST SENSOR, the German IoT technology startup behind a new smart sensor system designed to monitor the emptying of vehicle wastewater tanks.

"If there's an issue with the wastewater disposal from these tanks, the bathroom can become unusable. In the worst case, if multiple tanks are not serviced properly, the whole train might need to be taken out of service temporarily," says Völckers.

The BeST SENSOR Pump Monitor JROV2201 uses temperature, moisture, accelerometer, orientation and pressure sensors to monitor the status of the rail wastewater tanks

Wastewater tank management

German railway operator, Deutsche Bahn, undertook a pilot project using 36 BeST Sensor pump monitoring systems in Intercity Express (ICE) trains across four sites in Germany. The BeST SENSOR Pump Monitor JROV2201 devices use temperature, moisture, accelerometer, orientation and pressure sensors to monitor the status of the wastewater tanks.

Powered by Nordic's nRF9160 SiP cellular IoT solution, an integrated pattern recognition system detects any issues with the tank. The SiP's powerful 64 MHz Arm Cortex-M33 processor analyses the disposal flow. By using a streamlined machine learning (ML) algorithm, decisions are made on-chip about what data is important enough to transmit, cutting data costs and improving power consumption.

The critical information is then relayed to a Cloud platform via the SiP's LTE-M cellular IoT connectivity. An electronic report recording all the tank monitors on the train is then distributed by email to selected recipients.

Because the average Deutsche Bahn train contains at least 20 wastewater tanks, it is imperative the status of these tanks can be communicated quickly and efficiently with engineers and maintenance personnel.

JROV2201 provides full transparency about the quality and timing of the pump processes as well as potential problems with any pumps. The BeST SENSOR solution transmits the type of problem, time, place, and the direction and pressure of the pumped wastewater.

"Since their installation, these sensors have measured, evaluated and reported over 30,000 disposals of wastewater," says Völckers. "The results have been transmitted wirelessly for compilation by the server software part of the system. This helps to improve the service quality by ensuring that access to bathrooms and toilets is not compromised due to ... unserviced tanks."

Need to Know

Deutsche Bahn's core business is the German railway with more than 5.5 million customers and about 540 thousand tonnes of freight shipped daily. The company operates more than 40,000 train trips per day on its more than 33,300-kilometer rail network. Passengers embark and alight from 5,681 stations

Autonomous operation

The JROV2201 device can be retrofitted to any railway wastewater pump using the standard connector common to Central Europe. The ready-to-install capability of this device is key to its commercial viability, according to the company. Given the system must operate reliably at high speeds over long distances, connectivity using a continent-wide network also affords serious advantages.

"It's important the system works autonomously [using its battery and cellular IoT connectivity] as an add-on to the regular waste disposal system, meaning no modifications are needed to the train or the train depot," says Völckers.

"Cellular IoT was selected because it offers immediate and [low power consumption] transmission with full coverage practically everywhere in the target area of Central Europe. It operates independently from any existing local network and works both indoors and outdoors. The cellular connection makes it possible to deliver maintenance data to an MQTT broker and a server anywhere in the world, in real time."

Extended battery operation is a key feature of JROV2201. Using the nRF9160 SiP's low power consumption in standby (the SiP supports both PSM and eDRX) with instant wake-up after interrupt, JROV2201 can work for up to three months while sending data ten times a day. The device only wakes up when it senses the pump is turned on, making the most of low power standby mode.

"While the existing system is optimized to monitor wastewater pumps of rail wagons, it can be adapted to monitor all kinds of water pumps," says Völckers.

"The use of sensors in monitoring and maintenance will continue to assist in making train journeys as smooth as possible for staff and passengers," he adds.

Rohin Parkar
President and CEO, Spintly

The future of monitoring and controlling access

Wireless tech is modernizing the access control industry

For facility managers the ability to monitor and control access to restricted areas is becoming increasingly important. Commercial, industrial, residential and other verticals are turning to wireless access control for security reasons. And SMEs in particular are adopting these systems to improve the occupant experience through contactless building entry. Continued advances in technology are expected to help build the value of the global access control market even further over the next decade – up to $13.1 billion by 2026 (says *Fortune Business Insights*).

> The access control industry is on the lookout for new tech to address core challenges

As it evolves, the access control industry is on the lookout for new technologies to address its core challenges. Low power wireless tech fits the bill. That's because access control systems rely on a seamless user interaction and experience.

A robust connection becomes a necessity to provide quick response plus actionable feedback for facility operators. In the case of remote door opening, for example, network latency is a critical factor.

My company, Spintly, has a vision to make the built-world smarter and simpler by offering a frictionless access control experience. As part of our aim to transform the physical security industry, we developed a wireless, Cloud-based access control system called SMACC-UNO. The platform is designed to convert regular doors into smart doors. SMACC-UNO enables seamless smartphone-based access.

Nordic Semiconductor enabled us to integrate Bluetooth mesh networking into our product from the start. Nordic is actively working on adding support for technologies like Thread and support of advanced features like schedules and tamper detection.

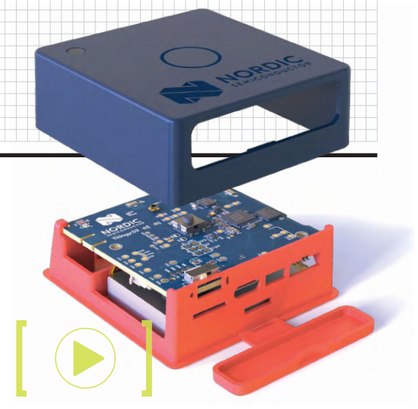
We believe tomorrow's wireless access control will use a combination of technologies including Bluetooth LE, Bluetooth mesh, Thread, NFC, UWB, Wi-Fi and more. It's not clear if one will emerge from the pack but we do believe direct Cloud connectivity through cellular IoT will greatly simplify access control services.

It would be premature to say the sector as a whole has successfully adopted wireless solutions, or that vendors have educated industries about the possibilities of wireless access control. However, there are positive signs the industry is moving in the right direction. The adoption of new wireless tech to make buildings smarter is providing substantial convenience to stakeholders. And by presenting the key advantages of wireless access control, vendors can put themselves in a position to align with prestigious projects.

Despite the potential, industry growth should not be taken for granted. The migration of systems to a more modern Cloud-based solution presents a challenge. Easy- to-install and retrofit wireless solutions are clearly needed for efficient and effective migration.

[Tech Zone]

An in-depth look at Nordic's wireless solutions



Prototyping

Nordic Thingy:53 delivers machine learning for IoT prototyping

Nordic Semiconductor has introduced the Nordic Thingy:53, a multisensor prototyping platform based on the nRF5340 dual-core Arm Cortex-M33 multiprotocol SoC. The product incorporates the company's nPM1100 Power Management IC (PMIC) and nRF21540 RF Front-End Module (FEM), a power amplifier/low noise amplifier (PA/LNA) range extender.

In addition, the Thingy:53 is equipped with a rechargeable 1350 mAh Li-po battery.

A key capability is the multiple sensor support. Thingy:53 is equipped with two accelerometers, a gyroscope, a magnetometer, an environmental sensor (measuring temperature, humidity, air-pressure and -quality), a light- and color-sensor, and a digital microphone.

Thingy:53 supports Bluetooth LE, Thread, Matter, Zigbee, IEEE 802.15.4, NFC and Bluetooth mesh RF protocols, and comes with preinstalled firmware for embedded machine learning (ML). The latter is thanks to a close collaboration between Nordic and Edge Impulse, a U.S.-based 'tinyML' specialist.

The sensors can all be used as part of an embedded ML application. The tinyML firmware collects training and test data from the sensors on the Thingy:53 and forwards it over-the-air using Bluetooth LE to the nRF Edge Impulse mobile app. The mobile app then forwards the data to Edge Impulse Studio (a Cloud-based development platform for ML) where it's used to build and test an embedded ML model. The ML model is then deployed to the Thingy:53 over-the-air using the same app.

The nRF Programmer app supplied with the Thingy:53 significantly simplifies prototyping by allowing the developer to select from pre-made firmware and then update the Thingy:53 over-the-air from an iOS or Android device.

This capability means new firmware can be deployed without recourse to a PC or Mac.

Internet of Things

Cellular IoT platform debugs network connection errors

Japanese IoT solutions company, Braveridge, has launched BraveLINK and BraveGATE, an automated network connection error solution and an IoT platform that together accelerate cellular IoT deployment for developers designing with Nordic Semiconductor's nRF9160 SiP.

Braveridge has conducted a program of extensive testing and debugging to generate a catalog of detailed error logs about a wide range of network connection problems. These error logs are easily accessible via common debug and interface tools directly from the nRF9160 SiP's Arm Cortex-M33 dedicated application processor. Using the information in the error logs, Braveridge has then generated a library of software fixes that resolve these common network errors, and compiled these fixes into the BraveLINK library which is available as a preprogrammed library in the nRF9160's application memory.

This solution is only possible because the nRF9160's dedicated application processor is embedded on the same package as its LTE-M/NB-IoT modem. This contrasts with competitive cellular IoT modems which typically use a system with 'built-in' applications and an external processor communicating with the cellular modem via a UART link.

A key advantages of the system is that BraveGATE needs no modification to suit the specific operation of the cellular IoT server, saving months and sometimes years of development time.

Industrial IoT

Thread Border Router supports mesh networking

The first industrial Thread Border Router certified by the Thread Group has been developed by China-based, HooRii Technology. The Hoo Max Industrial Gateway (Border Router) provides native support for OpenThread applications in commercial and industrial scenarios.

The product supports high-density and low-latency applications and provides wireless deployments for IoT scenarios with both massive and strict requirements.

The Hoo Max Industrial Gateway employs Nordic's nRF52833 SoC to support Thread connectivity. For example, in buildings with Thread connected lighting, sensors and controllers, the nRF52833 provides mesh connectivity between devices and the gateway. From the gateway the data can be relayed to the Cloud using Wi-Fi, Ethernet, and/or cellular connectivity.

Audio & Music

Nordic Semiconductor launches nRF5340 Audio DK

Nordic Semiconductor has released its nRF5340 Audio Development Kit (DK), a design platform for rapid development of Bluetooth LE Audio products. The Audio DK contains everything needed to get started on LE Audio development projects. It is based on Nordic's nRF5340 SoC.

The Audio DK is highly configurable, allowing it to function as an USB Dongle to send and receive audio data from a PC. It can also function as a True Wireless Stereo (TWS) earbud, or a headset and perform all Auracast Broadcast features.

The DK is typically powered via USB but also has a battery connector for a Li-ion/Li-po battery. The current consumption can be measured on the board and by using the dedicated current measurement pins.

In addition to the nRF5340 SoC, the Audio DK features Nordic's nPM1100 power management IC (PMIC) and Cirrus Logic's CS47L63 Audio digital signal processor (DSP).

Modules

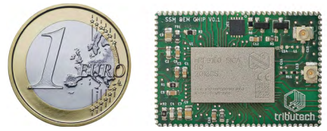
Cellular IoT OEM module accelerates development of scalable IoT solutions

A cellular IoT module integrating Nordic Semiconductor's nRF9160 SiP has been launched by Austrian IoT company, Tributech Solutions. The Tributech OEM module is designed to simplify the development of scalable and application-specific IoT devices with LTE-M or NB-IoT wireless connectivity.

The miniaturized 32 by 22 by 3 mm module is packaged as a System-on-Module (SoM) that provides all necessary core functionalities while also managing telemetry data, configurations, updates, provisioning, and security. This allows developers to design IoT devices that are optimized in terms of interfaces, form factor and costs for their use case, without the need to take care of all the complexity of a connectivity and data management platform. The product is also offered in an Arduino Shield variant for prototyping. The shield can be used with all popular hardware development platforms including Arduino Uno, STM32 Nucleo, and Infineon XMC Relax Kit.

The Tributech OEM module is fully integrated with Tributech's DataSpace Kit (DSK), an enterprise solution for creating 'dataspaces' and managing connected devices offering features including digital twin-based configuration and data management, high-end hardware security, blockchain-based data verification and audits, as well as built-in data sharing. The DSK creates dataspaces where data providers and data consumers can share selected data streams in a secure and trustworthy way and manage data assets through an integrated web portal.

Data verification technology guarantees the origin and integrity of data across systems and solutions for traceability and sustainability, while compliance can be implemented based on data audits.



Wi-Fi 6 Revision 2 brings even more to the IoT

Multi-user upload improvements and better power efficiency enables developers to design improved Wi-Fi IoT products. Here's the detail about Wi-Fi 6 Revision 2

Just three years have passed since IEEE 802.11ax was adopted. The product was marketed under the brand name "Wi-Fi 6". The new version of Wi-Fi was in part designed to enhance the wireless technology for IoT applications. Those enhancements included addressing power consumption and difficulties dealing with the dense deployments common to IoT networks as well as places like shopping malls and libraries.

Wi-Fi 6 solved those issues by bringing enhancements to both throughput and spectral efficiency. This proved a boon not only to consumers but also for smart-home, -building and -factory owners looking to deploy Wi-Fi IoT sensors. (*See* WQ *Issue 2, 2021 pg28*.)

The pandemic hit the year after Wi-Fi 6 was adopted, and its impact is in part responsible for a recent upgrade of Wi-Fi 6 (to "Revision 2") which is built on the foundation set by the original release. The upgrade was announced at the CES 2022 event held in January in Las Vegas.

As more people started working from home, there was a significant shift in the ratio of downlink to uplink traffic. Downlink data is the information moved to the user's computer from the Cloud and uplink is that which is moved the opposite way. Pre-pandemic, the ratio of downlink to uplink was 10:1. As people returned to work after COVID-19 subsided, that ratio has dropped to 6:1. The Wi-Fi Alliance, the group responsible for promoting the tech, expects it to approach 2:1 in the next few years.

This change in usage explains why Wi-Fi 6 Revision 2 includes upgrades for more robust upload support. Moreover, Revision 2 brings power efficiency gains which will make the technology even better suited to battery-powered IoT devices. The new features are supported across the 2.4, 5 and 6 GHz Wi-Fi bands.

Wi-Fi 6 Release 2 meets the growing demand for more data uploads with a feature called uplink MU-MIMO (multiuser – multiple input, multiple output). This is a natural extension of the downlink MU-MIMO that's already a part of the standard and which allows network devices to uplink at the same time on different streams. So much for the consumer, let's take a closer look at the Release 2 features which improve power efficiency for IoT devices.

Extending station battery life and range

The first new feature of Wi-Fi 6 Release 2 relevant to the extending the battery life of IoT devices is called Uplink Multi-User Data Disable OMI (Operating Mode Indication).

The initial release of Wi-Fi 6 offered two operating mode alternatives for synchronizing uplink transmissions among multiple users: Synchronized mode – whereby network connected devices (known as stations or STA) uplink transmissions are synchronized and controlled by the access point (AP); and non-synchronized mode – whereby STAs contend with others for their own transmission operations to send uplink packets to the AP. STAs can switch between the modes using transmit operating mode (TOM) signaling.

The enhancements added to Release 2 allows STAs to disable the synchronized mode for the actual data packets they send to the AP, while maintaining the synchronized mode for control and management of Wi-Fi frames. This can be considered a hybrid mode between synchronized and non-synchronized modes with the main benefit of additional device flexibility without compromising the efficiency of downlink synchronization.

The second enhancement to the standard is to the Uplink High Efficiency Extended Range Single-User PPDU (physical layer protocol data unit) and targets uplink transmissions between the STA and AP.

Typically, the AP transmits at a higher power than STAs which can result in a situation whereby under poor channel propagation conditions STAs at the edge of an AP's range can hear the AP transmissions, but the AP can't hear the STA uplink transmissions. In such a link imbalance situation an STA can fail to associate with the AP.

> Revision 2 includes power efficiency gains which will make the technology even better suited to battery-powered IoT devices

The Extended Range feature of Release 2 enables the AP to hear STAs located at maximum range even under bad channel propagation conditions, so these STAs can continuously associate with the AP. The feature generally offers an increased range for those STAs that implement it.

The third enhancement of Release 2 is Extended Sleep Time during the BSS (Basic Service Set) Max Idle Period. The BSS Max Idle Period is a measure of the time an STA can avoid sending transmitting frames to its associated AP without being disassociated.

During the Extended Sleep Time period an STA may remain completely idle, saving power and reducing unnecessary 'keep-alive' frames, without being disconnected. The idle period can range from one second to 18 hours. A side effect of Extended Sleep Time is that because fewer keep-alive messages are sent, the contention level decreases and throughput increases.

Improvements to Target Wake Time

Target Wake Time (TWT) was a power-saving feature introduced in the original release of Wi-Fi 6. It enables 'careful' scheduling of traffic exchanges between an STA and an AP so the STA can save energy by entering idle mode between the traffic exchange periods. The efficiency of duty cycling is controlled by the TWT service period, which is negotiated between the AP and the STA.

In Release 2, TWT information frames can be used to suspend or resume an existing TWT (negotiated) agreement or service period. This allows for more flexibility for the STA implementing TWT; the STA can now more easily update the TWT agreement and optimize the TWT parameters when it sees fit. Such a capability improves energy efficiency, because, for example, it removes the overhead associated with suspending and restarting a TWT negotiation with the TWT.

The final enhancement of Wi-Fi 6 Release 2 is Broadcast TWT. Broadcast TWT is a variant of the TWT feature that allows an AP to create Broadcast TWT schedules, assign the operational parameters and advertise their existence within transmitted broadcast management frames containing TWT Information Elements.

STAs receiving these broadcast management frames may participate in the Broadcast TWT schedules, with or without an explicit joining operation depending on whether the Broadcast TWT ID is non-zero or zero, respectively.

From the AP's perspective, Broadcast TWT schedules are simpler to manage (or 'enforce') compared to individual TWT agreements with STAs. This is because the AP dictates the schedules, without STAs being able to negotiate the 'offered' schedule. (Individual TWT negotiations are more prone to fail to reach an agreement over the actual parameters of the TWT.) As a result, the use of the Broadcast TWT variant is expected to increase the probability of the TWT feature being used by STAs wishing to implement power saving.

Nordic's Wi-Fi products

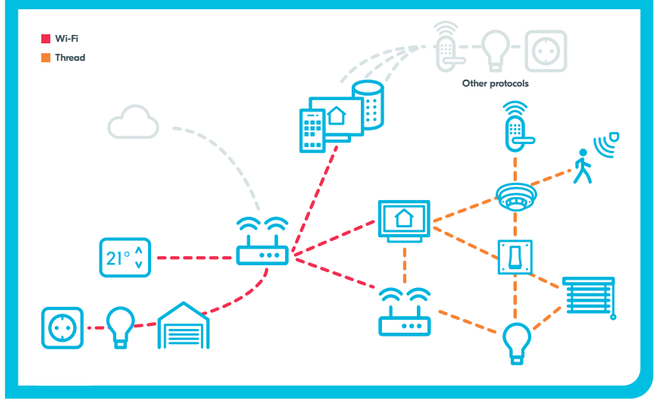
Nordic acquired U.K.-based Imagination Technologies' Wi-Fi development team and associated IP assets at the end of 2020 to bring Wi-Fi functionality to future products. While yet to announce Wi-Fi 6 products, Nordic is working on chips that will include some or all of Release 2 functionality.

Wi-Fi product development will be supported through the nRF Connect SDK, a unified software development kit for building applications based on the company's wireless products. The SDK includes all the software and firmware needed to develop Bluetooth LE, Thread, Zigbee, future Wi-Fi products and cellular IoT.

Wi-Fi's key advantages for the IoT are its native IP interoperability, enabling sensors to connect to the Cloud without having to pay additional data subscriptions, and, because APs are already everywhere, eliminating the need for new infrastructure. Those advantages will see the technology playing an increasing role in the burgeoning IoT. (See panel left *Wi-Fi's vital role in Matter*.)

Wi-Fi's vital role in Matter

Wi-Fi brings native IP interoperability to wireless networks. Such capability is being leveraged by Matter, which works by building on top of existing smart home wireless connectivity technologies Thread, Bluetooth LE and the Ethernet wired protocol by providing a unifying application layer. (*See* WQ *Issue 1, 2022 pg14*.) Matter devices will use either Thread or Wi-Fi for transport (and Bluetooth LE for commissioning). While Thread is the most efficient solution for low-power Matter devices, high-throughput applications like smart speakers will require Wi-Fi. In addition, the Matter application layer makes it simpler for Thread or Zigbee devices to communicate with a Wi-Fi network and from there to the Cloud. Matter devices using Wi-Fi for network transport won't need built-in support for mesh networking because Wi-Fi 6 range is such that a Matter device will always be able to connect. This is an advantage because non-mesh networking Matter devices will be more compact and use less power.



Wi-Fi 6 will extend smart home capabilities by providing higher throughput for applications such as security cameras and smart speakers

Need to Know

Wi-Fi can also be used for direction finding. Asset tracking devices can supplement GNSS when indoors by using Wi-Fi from local APs and referring to an AP database to determine location. The Yabby Edge Cellular asset tracker shown here uses GNSS to determine location, combined with Wi-Fi positioning in the absence of a GNSS signal

Nordic Product Guide

This handy summary describes all of Nordic's IoT solutions

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

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	1MB Flash, 256 KB RAM	1MB Flash, 512 KB RAM +256 KB Flash, 64 KB RAM	1MB Flash, 256 KB RAM	512 KB Flash, 128 KB RAM	512 KB or 256 KB Flash, 64 KB or 32 KB RAM	256 KB Flash, 32 KB RAM	192 KB Flash, 24 KB RAM	192 KB Flash, 24 KB RAM	192 KB Flash, 24 KB RAM
	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	●	●	●	●	●	●	●	●	●
RADIO	LTE-M/NB-IoT/GPS MODEM	●								
	CERTIFIED LTE BANDS	1–5, 8, 12–14, 17–20, 25–26, 28, 66								
	FREQUENCY	700–2200 MHz	2.4 GHz	2.4 GHz	2.4 GHz	2.4 GHz	2.4 GHz	2.4 GHz	2.4 GHz	2.4 GHz
	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, UART	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, Nordic Thingy:53	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), 5x5 mm QFN32 (17 GPIOs), 2.48x2.46 mm WLCSP33 (15 GPIOs)	6x6 mm QFN48 (32 GPIOs), 5x5 mm QFN32 (17 GPIOs), 2.48x2.46 mm 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 any 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. 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. Pricing for the different services can be found on nrfcloud.com.

Tech Spec

Location services
Assisted GPS (A-GPS), Predictive GPS (P-GPS), Single-Cell (SCELL), Multi-Cell (MCELL), Wi-Fi

Additional features
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

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