NEWS FOR THE ELECTRONICS INDUSTRY

element14
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eTECH JOURNAL

ISSUE 1

What is 5G?
EVERYTHING YOU NEED TO KNOW

+

WIRELESS CHARGER MODULES

BLUETOOTH FOR INDUSTRIAL IOT (IIoT)

IoT WIRELESS NETWORK PROTOCOLS

WIRELESS SELECTOR GUIDE

TOMORROW'S **WIRELESS TECHNOLOGY** TODAY

Wireless communication is a key aspect in the realization of the Internet of Things (IoT)

Data needs to flow from end equipment to other devices or to a cloud-based backend in order to provide meaningful use.

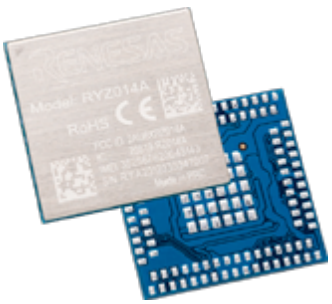
Renesas Electronics provides high-performance solutions for personal, local and wide-area networking covering Bluetooth Low Energy, LTE and many other technologies.

RA4W1
Bluetooth 5.0 Low Energy fully compliant with 2Mbit High-Throughput (HT) and Long Range (LR) support in a single chip MCU

LEARN MORE

RX23W
Fully compliant Bluetooth 5.0 LE module with ultra-small form factor (6.1 x 9.5 mm^2).

LEARN MORE



RYZ014A
All-in-one, single-mode LTE category M1 module with worldwide deployment and roaming capability

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WELCOME

Over the past few years, the wireless market has been booming as the number of wireless devices transferring data has grown exponentially. As a key enabler of the Internet of Things (IoT), the rise in interconnected devices is driving demand for low power, low-cost wireless solutions that enable applications never before possible.

For instance, wireless connectivity is attractive to manufacturing companies because it offers many advantages such as greater flexibility to reposition and reorganize equipment, the integration of factory-management systems, and the ability to scale operations by introducing new equipment without complicated planning and expensive re-cabling, just to name a few.

Additionally, other non-manufacturing applications such as home automation, autonomous vehicles, to smart industrial wearables are also driving the need for low-cost, low-power solutions that need to operate in a variety of environments.

However, in IoT, one size doesn't fit all. Wireless connectivity options for IoT applications are numerous and continually changing. Various applications may require one or multiple types of connectivity or configurations. Thankfully, designers now have an ever increasing choice of wireless technologies to choose from including WiFi, Bluetooth, 5G cellular, Zigbee, LoRaWAN and SigFox.

This e-Tech Journal provides the latest insights into the world of wireless connectivity solutions. You will learn about various IoT standards and their common features, to understanding the various types of wireless technologies available on the market today and how to identify the best fit for your applications.

We hope you enjoy this edition and welcome your comments and suggestions. Please feel free to drop us a note.

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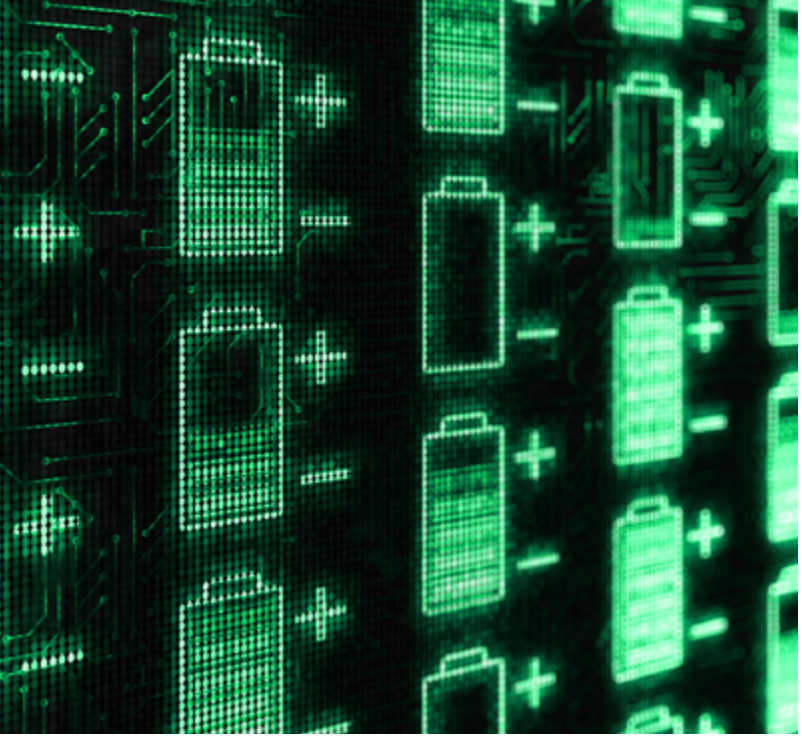

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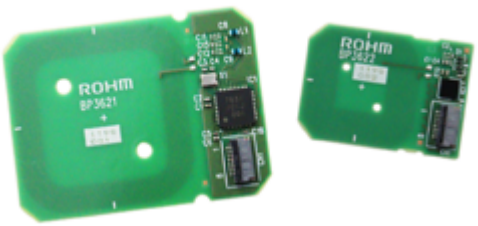
ROHM SEMICONDUCTOR

VISIT ROHM

WIRELESS CHARGER MODULES **BP3621/ BP3622**

COMPACT 13.56MHZ (NFC) MODULES ENABLE WIRELESS POWER SUPPLY FOR SMALL AND THIN DEVICES



The BP3621(wireless power transceiver modules) and BP3622 (wireless power receiver modules) are compact wireless charger modules with integrated compact antenna boards that easily enable wireless power supply functions in small devices such as smart tags and smart cards, as well as wearables. The new modules use the NFC13.56 GHz frequency range.

Wireless charging also known as wireless power transfer, is the technology that enables a power source to transmit electromagnetic energy to an electrical load across a determined air gap, without interconnecting cords.

This technology is attracting a wide range of applications, from low-power smart watches to high-power electric vehicles because of its convenience, design flexibility and better user experience. Nowadays, wireless charging is rapidly evolving from theories toward standard features on commercial products, especially smartphones and wearables.

The benefits of wireless charging compared to traditional cable charging:

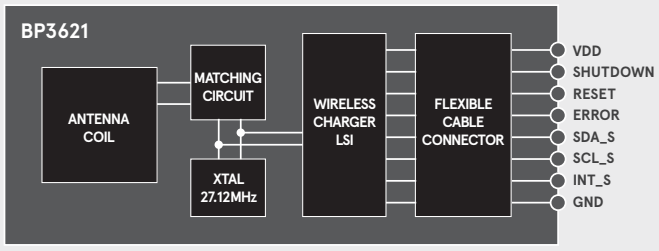
- ***It improves user-friendliness as the hassle from connecting cables is removed. Different brands and different models of devices can also use the same charger.***
- ***It renders the design and fabrication of much smaller devices without the attachment of batteries.***
- ***It provides better product durability (e.g., water-proof and dustproof) for contact-free devices.***
- ***It enhances flexibility, especially for the devices for which replacing their batteries or connecting cables for charging is costly, hazardous, or infeasible (e.g., body-implanted sensors).***
- ***Wireless charging can provide power requested by charging devices in an on-demand fashion and thus are more flexible and energy-efficient.***

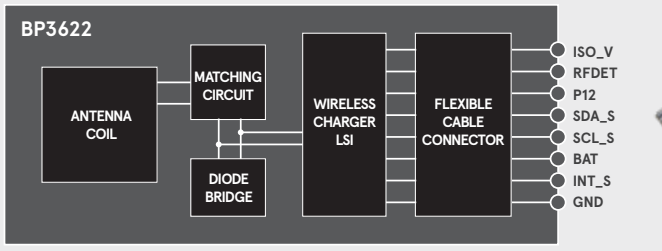
However, current Qi standard in wireless charging is based on low frequency at 110 kHz to 200 kHz and the size of antennas are too large to fit in miniaturized products. Therefore, there are increasing expectations for standards and methods that can be used more universally in small devices. In addition, the efficiency of the wireless power function varies depending on the shape, size, and distance of the antenna. Implementing this function requires repeated prototyping, adaptation, and evaluation on the part of the electronic device, which implies a high development cost for antenna and layout design.

With this in mind, ROHM has developed 13.56 MHz wireless charging modules that makes it easy to implement a wireless power supply function in compact and thin devices.

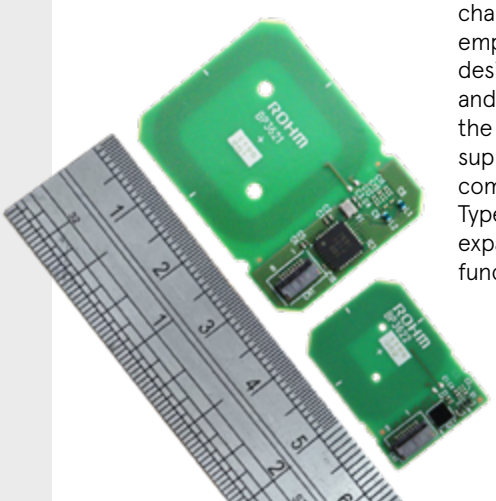
The BP3621 (wireless power transceiver modules) and BP3622 BP3622 (wireless power receiver modules) are small, board-integrated modules ideal for building wireless power supply systems using a high frequency band of 13.56 MHz. It can be easily used in very small equipment with flat limited back side size.

In addition, the power transmitter module and the power receiver module have built-in software related to wireless charging and NFC Tag communication and are optimized for efficient charging. By using these in pairs, it is possible to reduce phases such as prototyping, redesign, evaluation, etc. necessary for optimization of power supply efficiency.





The new products are small modules of approximately 20mm to 30mm square size that incorporate optimal antenna (coil) layout design technology to build a compact wireless power supply system capable of supplying up to 200mW of power.



In addition to facilitating mounting in small and thin devices, where wireless power supply has been difficult to achieve, the full-flat back side of the board structure contributes to greater flexibility in chassis design. By using ROHM wireless charger modules, you will empower your final product design with a validated plug and play solution. Furthermore, the built-in antenna can support bi-directional data communication and NFC Forum Type3 Tag, contributing to the expansion of communication functions for applications.

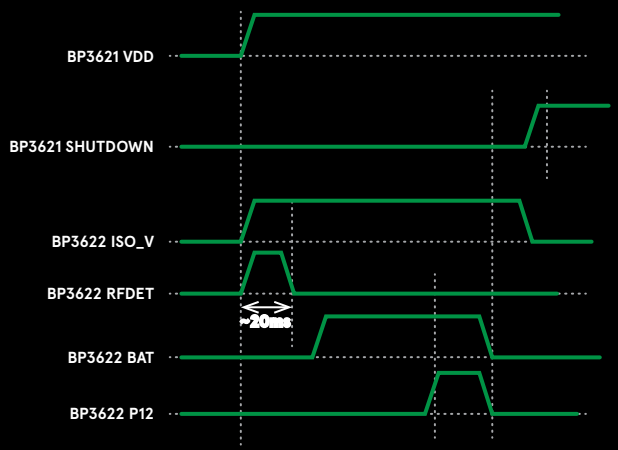
MAIN APPLICATION

Small devices such as smart tags, smart cards and ID cards, PC peripherals such as mice and remote controls, small devices for healthcare.

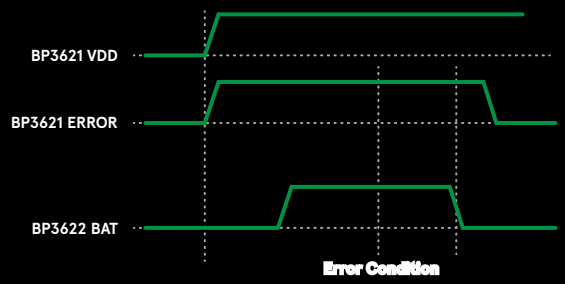
TIMING CHART

The timing chart is described for basic power supply operation. The power supply operation begins with the VDD input, and outputs from BAT.

The behavior of each terminal from the P12 opening at full charge to the charging stop and SHUTDOWN notification is as follows.



The behavior when an error occurs during charging is as follows.



EXAMPLE OF CHARGING FUNCTION

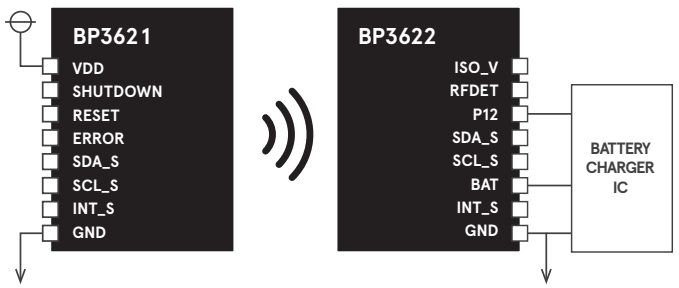
The BP3621/BP3622 each have a 0.5mm pitch, 8-pin FPC connector as host interface, which can be connected to the user's board via a cable. To start the charging process, the BP3621 must be switched on and the BP3622 placed at a distance of 10 mm. During power supply, charging is stopped about once every minute, and the status is checked between power transmitter and power receiver.

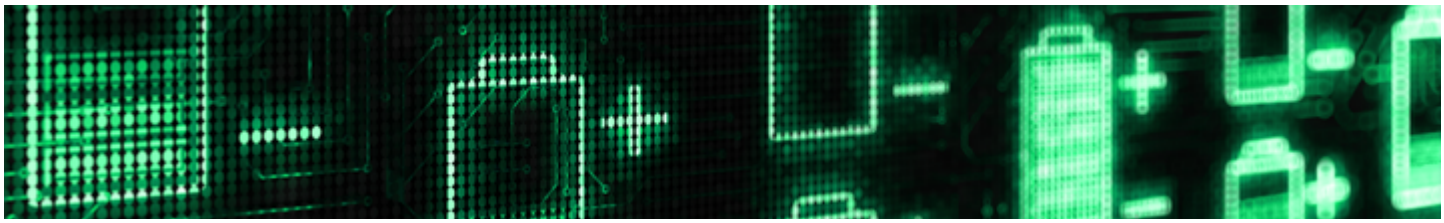
The BP3621 can be operated simply by connecting VDD and GND. When the opposing BP3622 is powered, it outputs a voltage from the BAT pin.

The connection with the BP3622 connects BAT, GND and P12, which is the status signal for charge control. P12 continues to output from the BAT pin for "L" and notifies BP3621 to stop powering when it reaches "H".

The product is adjusted so that power supply is most efficiently when both antenna centers are aligned and the distance between the antennas is 10mm. Please refer to the data sheet for the range that can be supplied with this product. Because the range of power can be supplied varies depending on the load, the distance between coils, the alignment and surrounding metallic parts.

It is important to carefully evaluate the received wireless power depending on the positional relationship in a full assembled system. The BP3622 defines the operating range with a load resistance value. If the load current is large (the load resistance is small), the output voltage may be less than the specified value. At that time, the power transmission from BP3622 to BP3621 will be adjusted. This behavior is called power supply adjustment, and it may be repeated multiple times until the output voltage stabilizes. In addition, if the output voltage is not stable even after multiple power supply adjustments are performed, the BP3621 stops power transmission and signal an error. In that case, the load current should be adjusted because it is not in a stable output state.





FEATURES OF THE NEW PRODUCT

1

Integrated Antenna Module Reduces the development phase and Facilitates Wireless Power Feed Function

The new products are modules with an integrated antenna board that incorporates ROHM's proprietary simulation-based antenna design technology, matching adjustment, and board layout design technology to reduce wiring loss. By using the power transmitting module and power receiving module in pairs, a maximum of 200mW of power can be supplied. Compared to the case where the antenna and control circuit are configured separately, the power feed characteristics are guaranteed, enabling product evaluation without antenna design and layout design or power feed evaluation. This significantly reduces development man-hours and the design load for board modification and makes it easy to implement a wireless power feed function.

2

Adoption of 13.56MHz high frequency band realizes module miniaturization and contributes to greater flexibility in chassis design

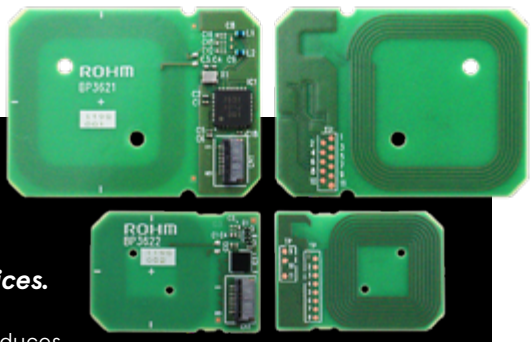
The new products use a 13.56MHz high frequency band magnetic field resonance method to reduce the size of the antenna for small devices such as smart tags and wearables. ROHM achieved a compact module with a built-in antenna, matching circuit and wireless charger IC, which was difficult to achieve with existing wireless power supply standards. In addition, as a wireless power supply product, it is not only waterproof and dustproof by eliminating contact terminals, but also contributes to simplification of the housing structure and improvement of design flexibility by facilitating attachment to the housing through a full-flat back side board structure with all mounted components on the surface.

3

The module's built-in antenna contributes to the expansion of data communication functions in applications

Since the new products use the same 13.56MHz high-frequency band as the NFC communication standard, the module's built-in antenna can support both power feeding and communication. The BP3621 and BP3622 are equipped with an I2C slave function. Data can be exchanged between them by issuing a command from the I2C master. The wireless communication speed of the modules is 212 kbps, and it is possible to transmit up to 256 bytes with one transmission. In addition, since BP3622 supports NFC Type3 tag communication, tag information can be read from NFC readers such as smartphones.

All this contributes to the expansion of data communication functions for applications such as firmware downloading, secure data transfer and rewriting of sensor data, device information, and authentication information, and transfer of battery output voltage values. It contributes to the expansion of data communication functions of applications.



SUMMARY

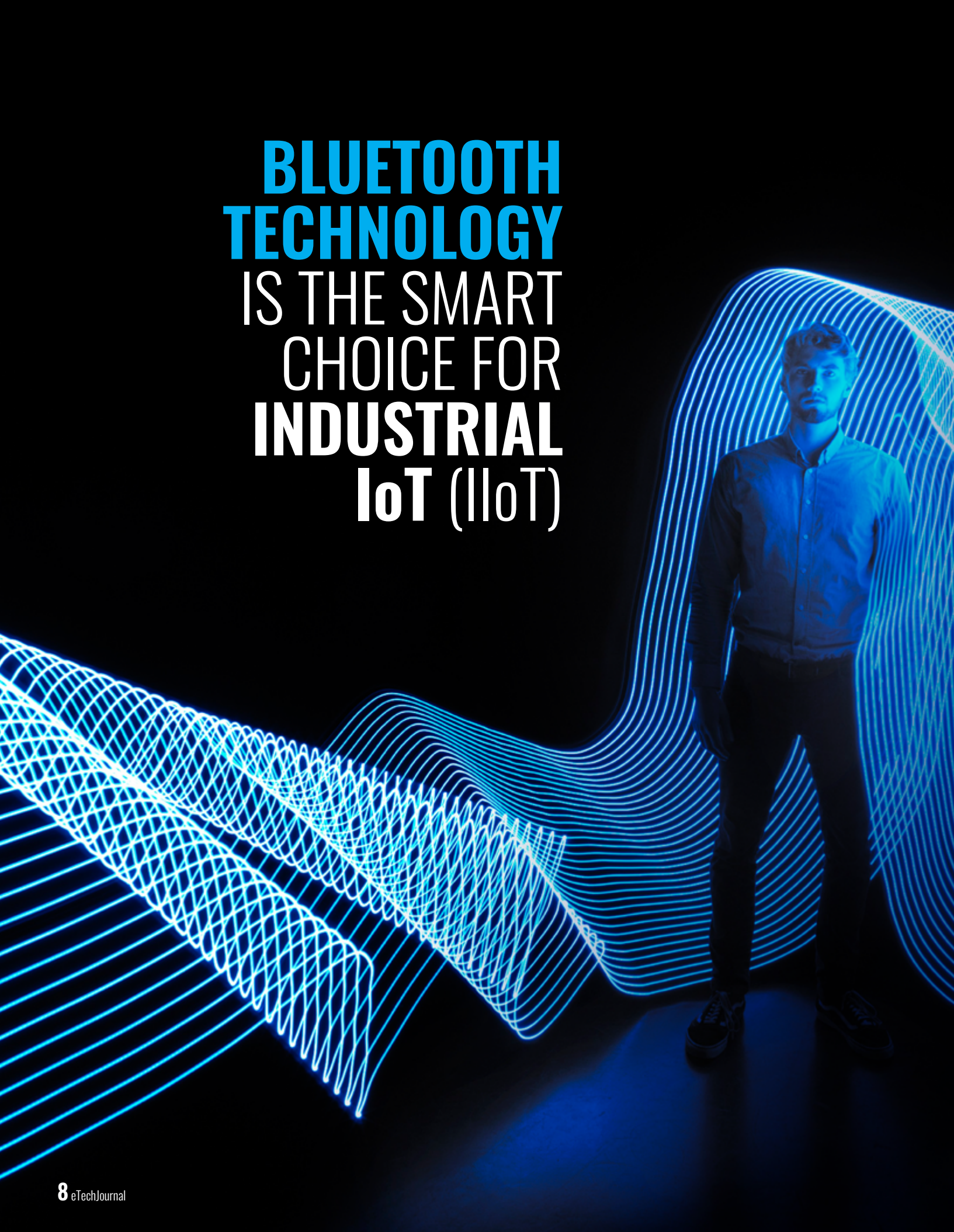
Wireless power technology offers the possibility of removing the last remaining cord connections required to replenish portable electronic devices.

This promising technology has significantly advanced during the past decades and introduces a large amount of user-friendly applications. In this article, we have presented the compact 13.56MHz (NFC) Charger Modules BP3621/BP3622 with integrated antenna boards that easily enable wireless power supply functions in small devices such as smart tags and smart cards, as well as PC peripherals. ROHM plans to continue to expand its lineup of compact shapes and high-power modules in order to expand the range of applications they can support.

BUY NOW

EXPLORE ROHM FULL RANGE

BLUETOOTH TECHNOLOGY IS THE SMART CHOICE FOR INDUSTRIAL IoT (IIoT)



Most people use at least one form of Bluetooth daily without giving it much thought.

Bluetooth enables us to stay connected to a seemingly countless number of devices including cell phones, headphones, smart speakers and automobiles. While the application and adoption of Bluetooth has been driven by the consumer market, there are many more practical applications of Bluetooth technology.

A few of the other markets that have seen broad adoption of Bluetooth technology:

Internet of Things (IoT)

- Smart home sensors, devices and controllers
- Industrial IoT sensors, devices and controllers
- Edge and Artificial Intelligence (AI) applications

Advanced computer peripherals

- Mice, keyboards, multi-touch trackpads

Interactive entertainment devices

- Remote controls, gaming controllers, headsets, game consoles

Advanced wearables

- Health/fitness sensors and monitoring devices
- Wireless payment-enabled devices

The possibilities for the application Bluetooth technology appear endless.

But where did it all start?

We'll review the beginnings of Bluetooth technology, its progression and current capabilities with a focus on IoT in industrial applications and security options for connected devices.

BLUETOOTH
1998 - 2022

BLUETOOTH CLASSIC PRE-LOW ENERGY (LE) PERIOD

LOW ENERGY (NOW REFERRED

1998

Bluetooth v1.0 is introduced as a replacement for physical cables

2004

Bluetooth v2.0 is introduced with Enhanced Data Rate (EDR)

2009

Bluetooth v3.0 is introduced with high speed over Wi-Fi

2010

Bluetooth v4.0 is introduced featuring Bluetooth Low Energy (Bluetooth LE)

TO AS BLUETOOTH LE) PERIOD

2014

Bluetooth v4.2 is introduced, addressing major security concerns for connected devices

2016

Bluetooth v5.0 is introduced with new Bluetooth LE features including long range mode with a new Physical Layer (PHY), a high-speed mode with a new Physical Layer (2M PHY) and extended advertisements

2017

Bluetooth Mesh is released as a separate specification and standard based on Bluetooth LE version 4.x allowing Bluetooth 4.x devices to support Bluetooth Mesh

2019

Bluetooth v5.1 is introduced with new direction-finding/location features for Bluetooth LE

2020

Bluetooth v5.2 is introduced with new features including LE power control, enhanced attribute protocol and LE Audio, the next generation of Bluetooth audio

BLUETOOTH 5.0 - 5.2
WHAT CAN IT DO?

BLUETOOTH 5.0 UPDATES

Bluetooth 5.0 delivered three main advancements over previous generations when introduced in 2016:

- ***Twice the speed***
- ***Four times the range***
- ***Eight times the advertising capacity***

2X FASTER

The on-air data rate for previous versions of Bluetooth (4.2 and earlier) was fixed at 1 Mpbs. Bluetooth 5.0 introduced a new mode with an on-air data rate transfer of 2 Mbps. The increase delivered important benefits. Among them was lower power consumption as the same amount of data could be transmitted in half the time. Another improvement was wireless coexistence with other wireless technologies that operate in the 2.4 GHz range.

Compared to other low power wireless protocols that include ZigBee, Z-Wave and Thread, Bluetooth LE offers the highest data rate, even at the original 1 Mbps data transfer rate. The addition of the 2 Mbps high-speed mode has made IoT applications more feasible. Examples include video streaming, audio streaming and short bursts of large data transfers such as images.

4X THE RANGE

Bluetooth 5.0 also introduced a long-range mode that employs error correction called Forward Error Correction (FEC). FEC enables the receiver to recover data from errors that occur due to interference and noise. Instead of requiring data to be retransmitted when an error occurs, the receiver can recover the original data transmission through data redundancy.

This long-range mode is referred to as the Coded PHY mode. PHY stands for physical layer radio and refers to the radio interface layer in network architecture. While PHY mode increases range, the trade-off is an increase in power consumption and reduced speed to 125 Kbps or 500 Kbps, depending on the coding level used.

Operating in Bluetooth long-range mode, achievable line-of-sight data transmission ranges from 1 mile (1,600 meters) to 2,600 feet (800 meters). This makes Bluetooth LE a good choice for applications that require communication with a device at a great distance or elevation. Examples include long distance remote-control devices, home automation and industrial applications.

8X THE ADVERTISING CAPACITY

In Bluetooth LE, there are three main operating states for Bluetooth devices. They are advertising, scanning or connected. To get Bluetooth LE devices to connect, one device needs to advertise and the other must scan for it, then initiate the connection. Advertising involves broadcasting data packets which allow another scanning device to discover them. The scanning device then decides to initiate a pairing connection if the advertisement device allows it.

Previous versions of Bluetooth capped the advertising data payload at 31 bytes. Bluetooth 5.0 introduced extended advertising mode. Extended advertising allows up to 255 bytes of payload data per packet and is used in all Bluetooth LE devices. The addition of increased advertising capacity allows for broadcasting audio to an unlimited number of recipients, something not supported with Bluetooth Classic Audio. Another capability that utilizes the extending advertising function are beacons. Beacon devices stay in the advertising state and broadcast data that other devices read. Through the increased advertising and data transmission capacity in Bluetooth 5.0, beacons can support new applications and use cases for IoT.

BLUETOOTH 5.1 UPDATES

Bluetooth 5.1 was released in the first quarter of 2019.

BLUETOOTH 5.2 UPDATES

Bluetooth 5.2 was released in 2020.

It contains several updates including Bluetooth LE Audio that enhances audio performance, adds support for hearing aids and the sharing of multi-channel audio streaming. Other key updates:

- ***LE power control (LEPC)***
- ***Enhanced attribute protocol (EATT)***

DIRECTION FINDING

It contained a number of improvements including advertising and caching enhancements, better state management and, most importantly, direction finding.

The revolutionary direction-finding feature that was introduced in Bluetooth 5.1 combines proximity and positioning data to identify approximate physical location down to a centimetre (.39 inches).

This feature utilizes two different methods for determining the angle that a Bluetooth signal is being transmitted from with a high degree of accuracy. The two methods are called Angle of Arrival (AoA) and Angle of Departure (AoD).

Each technique requires one of the two communicating devices to have an array of multiple antennae, with the antenna array included in the receiving device when the AoA method is used and in the transmitting device when using AoD. Direction finding offers numerous benefits including indoor asset tracking, wayfinding, employee monitoring, security and proximity-based applications like lighting and building control.

LE POWER CONTROL (LEPC)

In wireless communication, the Received Signal Strength Indicator (RSSI) can be used to estimate the distance of the receiver from a transmitter if the original transmission strength is known to the receiver.

A key benefit from LEPC is the conservation of output power used to maintain active connections. The foundation for this feature is created by setting output power to the lowest value where a stable link can be maintained within a given margin. This allows for minimum power consumption on both receiver and transmitting ends. The benefits are interference reduction and the ability to have more units in the same area. Cell phone service providers have applied this technology in their networks for many years.

With the new LEPC feature, a receiving device monitoring the level of the signal (the RSSI) from a connected device may request a change in the transmission power level used by its peer in either direction. A transmitter may also change the transmission power voluntarily and relay that information to the receiver.

Utilizing LEPC and keeping the RSSI within the optimal range of the receiver provides the following benefits:

- ***Better quality control of the signal***
- ***Reduced data transmission errors at the receiving end***
- ***Improved coexistence with other non-Bluetooth signals like Wi-Fi***

ENHANCED ATTRIBUTE PROTOCOL (EATT)

The original unenhanced attribute protocol used in previous versions of Bluetooth operates in a sequential manner. The new EATT provides the capability to perform parallel transactions between a Bluetooth LE client and a server. A benefit of this is the ability of the EATT protocol to help reduce the operational latency in applications. Instead of single transaction from an application being executed at one time, multiple transactions are now possible simultaneously.

The benefits of this are immense in industrial IoT, AI and Edge computing applications where sensor data is continuously being received, processed and often quickly acted upon with little human oversight.

BLUETOOTH IN **INDUSTRIAL IoT (IIoT)**

Bluetooth has received a lot of attention in consumer applications, but it's also incredibly well-suited for AI, Edge computing and smart industrial applications. Bluetooth is helping drive Industrial Internet of Things (IIoT) systems, which are shaping smart factories and the growth of Industry 4.0.

Connected Bluetooth devices and sensors at a single smart factory can gather up to 1.44 billion data points per day, even from legacy equipment. This raw data is extremely valuable in making business decisions once it is collected, secured and analysed.

One such benefit of this collected data is the reduction of equipment failure and downtime. Research by Deloitte has shown that poor maintenance can reduce a plant's productivity by 5 to 20 percent and cost manufacturers worldwide an estimated $50 billion annually.

5 WAYS BLUETOOTH IS WELL-SUITED FOR IIOT

1 BLUETOOTH IS HIGHLY RESISTANT TO INTERFERENCE

Adaptive frequency hopping helps ensure data successfully makes its way through the noise clutter. Individual messages are broken into small data packets, which are sent securely over different channels in a predefined sequence, known only to the transmitting and receiving devices. As many as 1,600 channel-switches can take place every second.

2 BLUETOOTH CAN OPERATE MANY WIRELESS DEVICES IN THE SAME SPACE

Bluetooth allows for the operation of large numbers of devices in close proximity, perfect for the smart factory environment. Short data packages, which are ideal for industrial measurement and control applications, only need to be briefly transmitted over the air. Bluetooth's automatic power control features ensure that data is broadcast at only the required strength, saving on power and reducing noise. These factors help free up airwaves for other devices to share.

3 BLUETOOTH CAN CORRECT ERRORS

When data is transmitted over long distances, in noisy environments or areas with physical interference the chance of errors entering the data stream increases. Bluetooth can automatically correct these by switching data channels or through Forward Error Correction (FEC) once data arrives at the receiver.

4 BLUETOOTH CAN BE INTEGRATED WITH EXISTING INDUSTRIAL SYSTEMS

Many industrial devices still rely on serial ports, but these devices can still be adapted to Bluetooth through a Universally Unique Identifier (UUID). Bluetooth LE provides for a separate UUID that identifies each device. The UUID is also used by the Bluetooth application to help process data. The code running on the connected Bluetooth devices can all be the same, the only difference would be the UUID.

5 BLUETOOTH HAS BUILT-IN SECURITY

In addition to secure programming and secure provisioning, three other security features make Bluetooth a great platform for sharing data wirelessly. The first is adaptive frequency hopping that transmits data on a random sequence of channels. The second is the LE Secure Connections feature in Bluetooth 4.2 and newer that prevents data from being intercepted in man-in-the-middle cyberattacks. The third is that Bluetooth devices can be made invisible, meaning hackers can't discover them. Device connections are only permitted between devices that have been previously paired. Regardless of the path chosen for security, redundancy is strongly recommended.

BUILDING THE RIGHT SECURITY FOUNDATION FOR **CONNECTED DEVICES**

Connectivity is vital for most modern devices. It's no longer just for computers, smartphones or tablets. Televisions, baby monitors, thermostats, medical devices, automobiles and even aircraft are all connected today.

With growing connectivity comes increased security concerns. Connected devices need to establish proof of identity and origin in order to reliably determine appropriate data sharing and control with other devices and service providers.

This process is defined as authentication.

Authentication is a key aspect of security that ensures robust access to trusted agents and easy identification of suspicious activity. With product-level authentication, clones and suspicious agents aren't validated so network and device access are denied.

This is especially critical in applications for automotive, industrial, medical and aviation where human and environmental safety is paramount.

With any connected device, serious security planning must be factored into the early stages of the design process. Waiting until the end of the design process risks project schedule delays, drives up costs and creates unforeseen vulnerabilities in device security. Well planned security delivers strong value by helping the device function properly from the start, avoid potentially expensive litigation and the detrimental effects to a company's brand image caused by hacking.

SECURE PROGRAMMING VS. SECURE PROVISIONING: **THE RIGHT SOLUTION**

What are the best ways to protect devices and software from intellectual property (IP) theft, cloning and malicious system hacking?

Two primary solutions are associated with device security: secure programming and secure provisioning. ***Which option is best for your application?*** While both solutions provide security solutions, there are key differences.

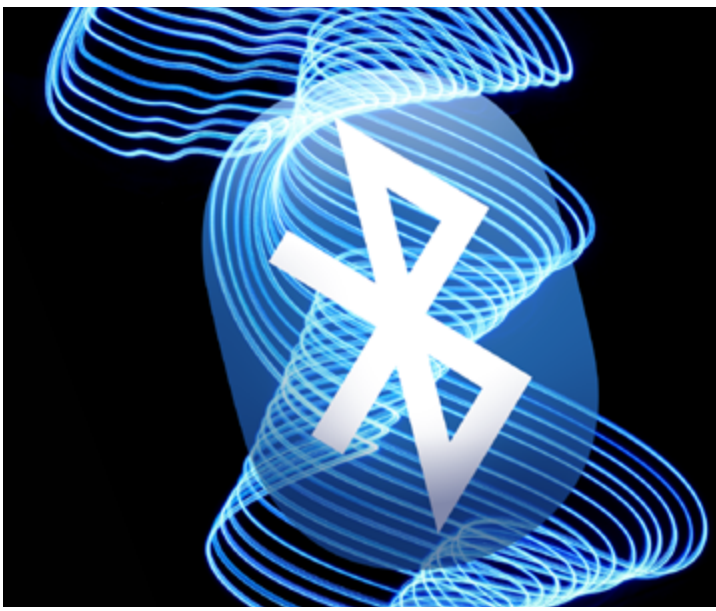
Secure Programming

First, secure programming requires all data be generated/obtained outside the device itself, increasing the opportunity for that data to be compromised. Except for certain field programmable gate arrays (FPGAs) and multiprocessor system on a chip (MPSoCs), secure programming provides security through software that resides on the device. This can protect firmware on the device but does not provide adequate protection from some cyberattacks like counterfeiting and overbuilding.

Software defects and bugs in programming are vulnerabilities continuously exploited by hackers. Once software-based security is compromised, system recovery becomes nearly impossible. Secure programming is suitable for low-level applications that don't require advanced security, or in cases where a malfunction won't cause injury or harm to a person or property. It's also suitable for devices specifically designed to provide security without requiring bidirectional communication with the programming system. Secure programming doesn't rely on additional hardware, which delivers some cost savings at the expense of more robust security.

Secure Provisioning

Secure provisioning employs added hardware in providing the best security protection for the complete lifecycle of the device. While the additional hardware will come at a financial cost, the prices are often very reasonable and can save a company expensive litigation and brand damage resulting from hacking. Secure provisioning also delivers firmware protection and prevents overbuilding, counterfeiting and protects against software programming vulnerabilities. By having the root of trust anchored to hardware, device software and operations are protected. Hardware-based security also protects against unauthorized code reading and is more resilient to physical attacks. Secure provisioning provides critical protection in devices that, if compromised, could cause harm to a person, property damage, loss of sensitive data or intellectual property.



TAKEAWAYS

By partnering with a trusted global technology partner, valuable resources can be better focused on intellectual property innovation and other areas that deliver a strong competitive edge.

We have partnered with industry leading suppliers to deliver progressive solutions in Bluetooth technology that provide best-in-class performance of system on chip (SoC) devices that support Bluetooth 5/Bluetooth Mesh/Thread/802.15.4/ANT/2.4GHz protocols.

BLUETOOTH DEVELOPMENT PLATFORMS

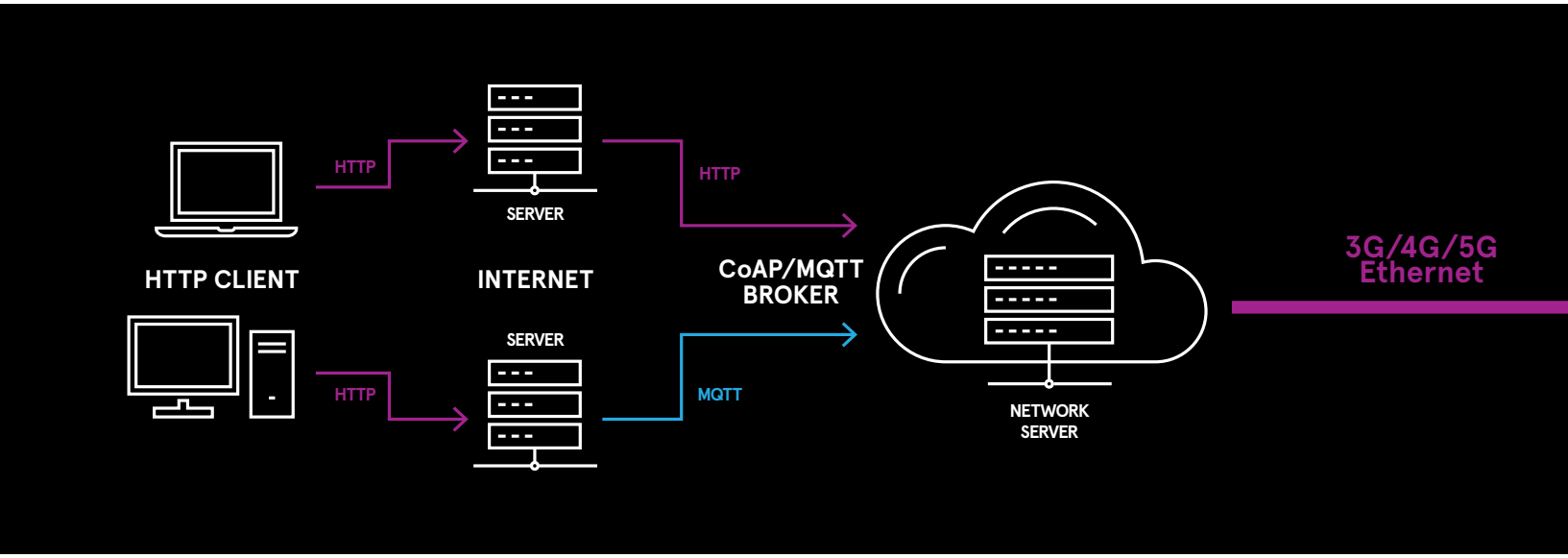
BLUETOOTH MODULES & ADAPTORS

INTERNET OF THINGS WIRELESS NETWORK PROTOCOLS

In the Internet of Things (IoT), the interchange of data among sensors, devices, gateways, servers, and user applications is enabled by network protocols like WiFi, Bluetooth, ZigBee, and many others. End Application requirements of range, data, security, power, and battery life dictate network protocol choice. This article explores some of these communication technologies and protocols.

An IoT ecosystem typically consists of nodes, data, connectivity, and application layer. The node layer is a coalition of smart devices such as microcontrollers, microprocessors, sensors, actuators, connectivity, and gateways interacting with a network. The data layer is concerned with the data collected, processed, sent, stored, analyzed, presented, and used in business contexts. The application or user layer is the component that allows humans to interact with IoT devices. We will discuss the connectivity layer, which is communication and IoT protocols.

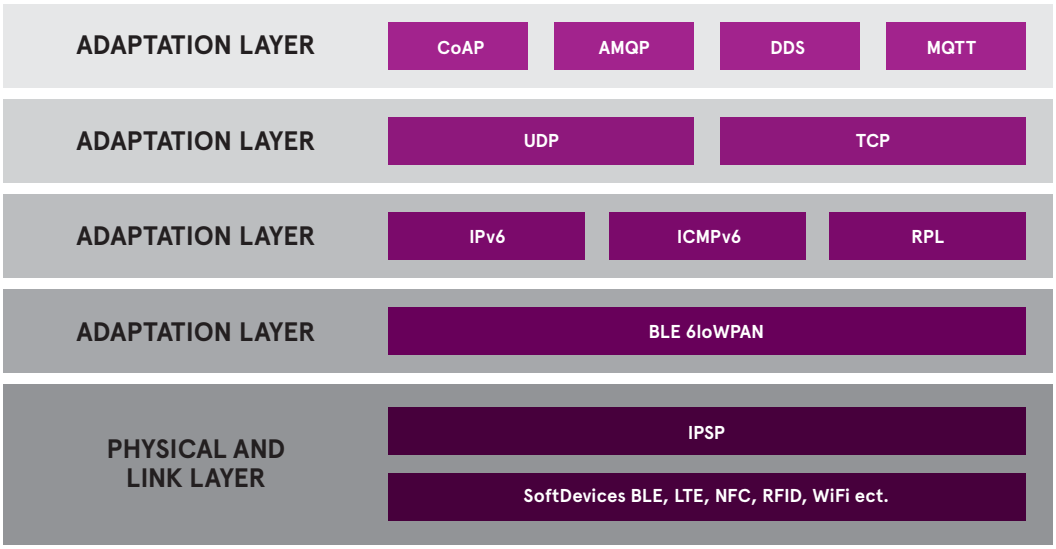
IoT ECOSYSTEM:

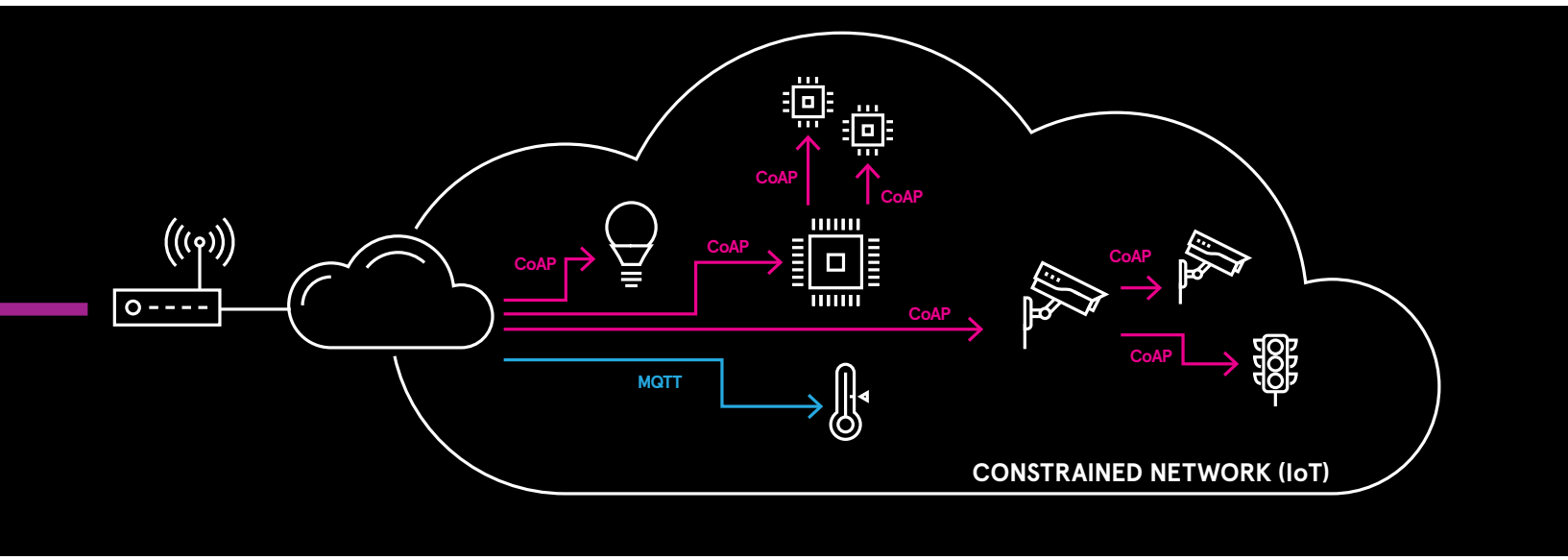


IoT PROTOCOL TYPES:

The Internet Protocol's (IP) inherent adaptable and dependable nature makes it an acceptable medium for procedural transmission among IoT modules.

The system architecture (through which the data must travel) determines the IoT protocol type. The Open Systems Interconnection (OSI) model delivers a map of the various layers that dispatch and accept data. Each protocol in the IoT system architecture enables device-to-device, device-to-gateway, gateway-to-data center, gateway-to-cloud communication, and communication between data centers.





KEY IoT PROTOCOLS USED IN THE DIFFERENT LAYERS OF THE IoT NETWORK:

Advanced Message Queuing Protocol (AMQP)

AMQP is an application (software) layer protocol that offers route and queuing for a message-oriented middleware environment. It is used for reliable point-to-point connections and supports the seamless and secure interchange of data between the devices and the cloud. AMQP has three distinct components, namely Exchange, Message Queue, and Binding. These three ensure a dependable, successful exchange and message storage. They also denote the relationship between two messages.

Constrained Application Protocol (CoAP)

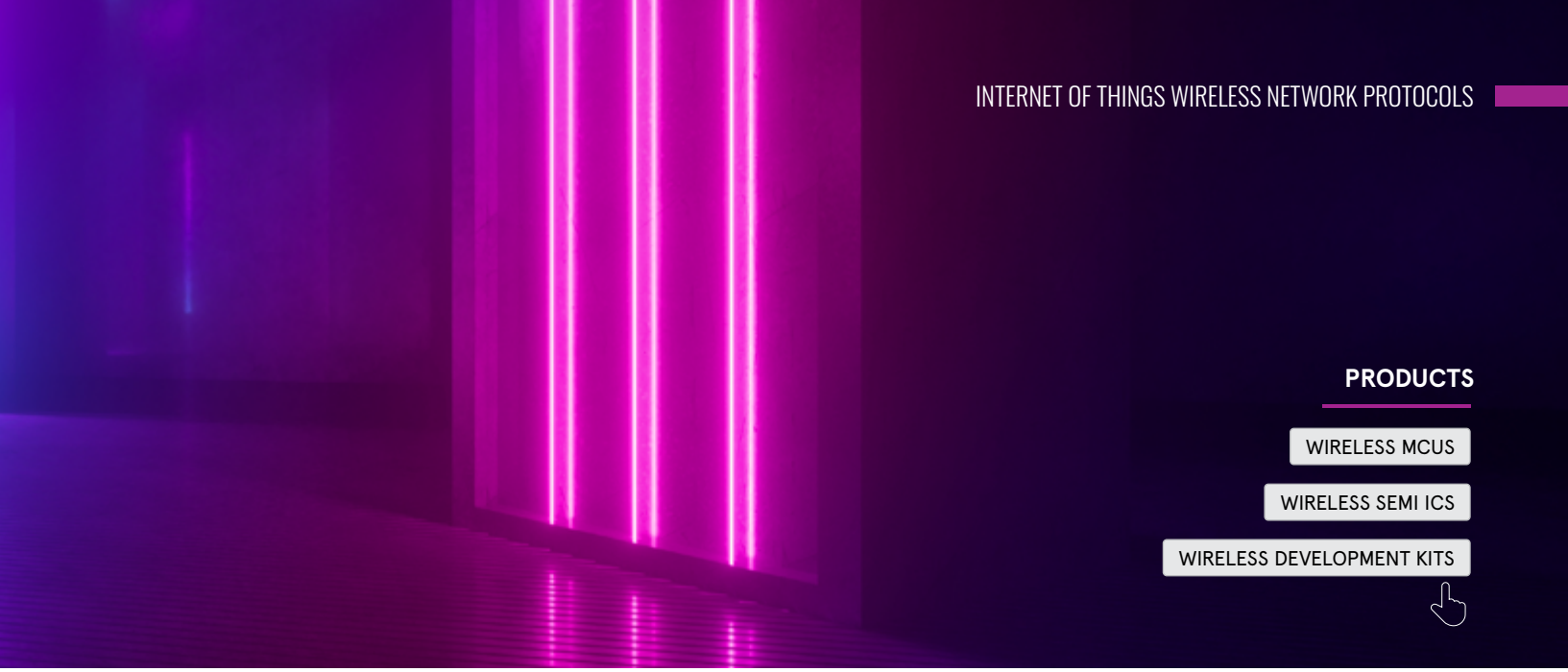
CoAP is a constrained-bandwidth and constrained-network protocol for limited gadgets. This protocol enables the client to send the server a request, and the server sends a response in HTTP back to the client. It uses the User Datagram Protocol (UDP) for lightweight implementation and minimizes space use. The protocol employs binary data format EXL. CoAP protocol is primarily used in automation, microcontrollers, and mobiles. The protocol dispatches a request to the home's application endpoint and returns the application's response to services and resources.

Data Distribution Service (DDS)

DDS is a flexible peer-to-peer communication protocol. It does everything from running tiny devices to connecting high-performance networks. DDS streamlines deployment increases reliability, and minimizes complexity.

Message Queue Telemetry Transport (MQTT)

MQTT, also known as subscribe/publish protocol, is a lightweight messaging protocol and the most preferred protocol for IoT devices. It collects data from various devices and supervises remote devices. It runs over Transmission Control Protocol (TCP) and supports event-driven message exchange through wireless networks. MQTT is mainly used in devices that require less power and memory. For example, in-car sensors and smartwatches.



PRODUCTS

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Machine-to-Machine (M2M) Communication Protocol

It refers to an open industry protocol. The M2M is created to manage IoT devices remotely. These cost-effective protocols use public networks. The M2M fashions an environment where two machines mutually communicate and swap data. Such a protocol reinforce machines to self-monitor and enable the systems to adapt as per the varying environment. It is mainly used for smart homes, vehicles, and ATMs.

Extensible Messaging and Presence Protocol (XMPP)

The XMPP has a unique design. It was developed using open XML (Extensible Markup Language). It employs a push mechanism to swap synchronous messages. The flexible XMPP can seamlessly integrate with any changes. XMPP functions as a presence indicator. It displays the servers' availability status. Other than WhatsApp, Google Talk, and other instant messaging apps, XMPP also finds use in online gaming, Voice over Internet Protocol (VoIP), and news websites.

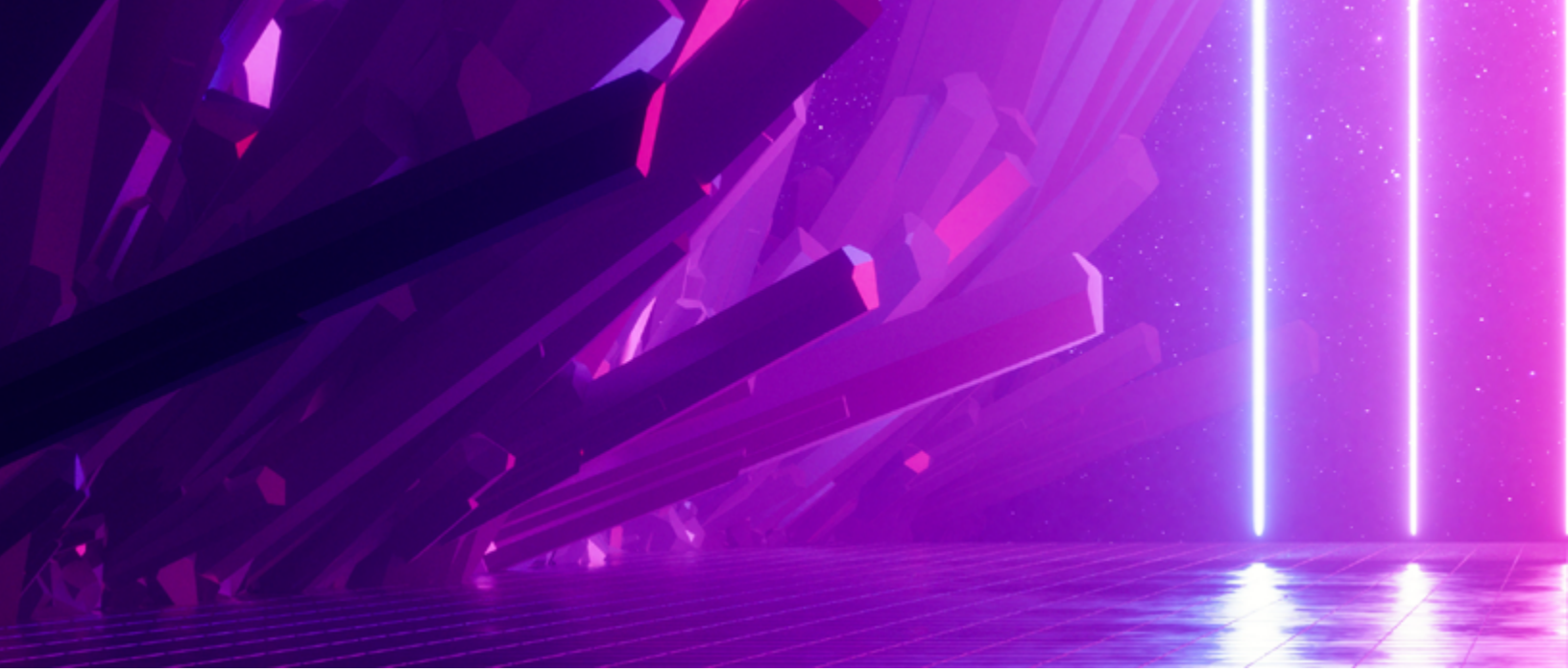
6LowPAN

IPv6 Low-power Wireless Personal Area Network (6LowPAN) is an Internet Protocol-based technology. It is a network protocol that defines encapsulation and header compression mechanisms. It has the freedom of frequency band and physical layer and can also be used across multiple communications platforms, including Ethernet, WiFi, 802.15.4, and sub-1GHz ISM. It is devised to dispatch IPv6 packets over the IEEE802.15.4-based networks and implement many open IP standards, including TCP, web sockets, UDP, HTTP, COAP, and MQTT. The standard provides end-to-end addressable nodes, permitting a router to link the network to IP. The 6LowPAN is a robust, self-healing, and scalable mesh network.

Thread

Thread, based on various standards, including IEEE802.15.4, IPv6, and 6LoWPAN, is a fresh IP-based IPv6 networking protocol directed towards the home automation environment.

It primarily complements WiFi and offers a resilient IP-based solution for IoT. Thread reinforces a mesh network utilizing IEEE802.15.4 radio transceivers. It manages up to 250 nodes with high authentication and encryption levels.



Zigbee

ZigBee uses IEEE 802.15.4 standard physical and link layer, operating at ISM 2.4 GHz band and provides a range of up to 300 feet. It supports mesh topology. Hence the network can be stretched over a longer distance using multi-hop operations. The protocol is highly interoperable and includes standard libraries of data models, security, and network management procedures. ZigBee has low power consumption, node discovery, duplicated packet detection, route discovery, sleep mode, and reliability. It is widely used in smart home and building automation applications.

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Bluetooth

Bluetooth is widely used for short-range communication and is a standard IoT protocol for wireless data transmission. Its low-energy version is Bluetooth Low Energy (BLE). The latest version, BLE 5.0, supports low data rate applications and an extended range of up to 150 meters. Features like beaconing and location services have helped deploy it in a wide range of fitness and automotive applications. It can support star topology. The latest versions support mesh topology, stretching the network using many-to-many device networking suitable for home automation applications.

WiFi

WiFi is a wireless communication protocol. WiFi uses the star network topology, and the access point can be used as a gateway to the Internet. Each access point can connect to a maximum of 250 devices, and most commercially available solutions support up to 50 devices. The 802.11-b/g/n operates on 2.4GHZ and provides 150-200 Mbps data rate in the home or office environment, typically at a range of 50 meters.

The latest 802.11-ac standard works on 5GHz and provides a 500Mbps-1Gbps data rate.

Cellular

Cellular networks, such as 3G and 4G LTE with 3GPP, are undesirable for IoT applications due to their high power consumption for IoT and M2M communication. However, 5G networks have a higher capacity than 4G networks for supporting communication between IoT devices. It employs many techniques such as huge Multiple-Input Multiple-Output (MIMO), full-duplex communication, heterogeneous networks (HetNet), millimetre Wave (mmWave), and networking slicing. According to The International Telecommunication Union (ITU), 5G network services may be divided into three categories: improved mobile broadband (eMBB), massive machine-type communications (mMTC), and ultra-reliable and low latency communications (uRLLC).

NFC

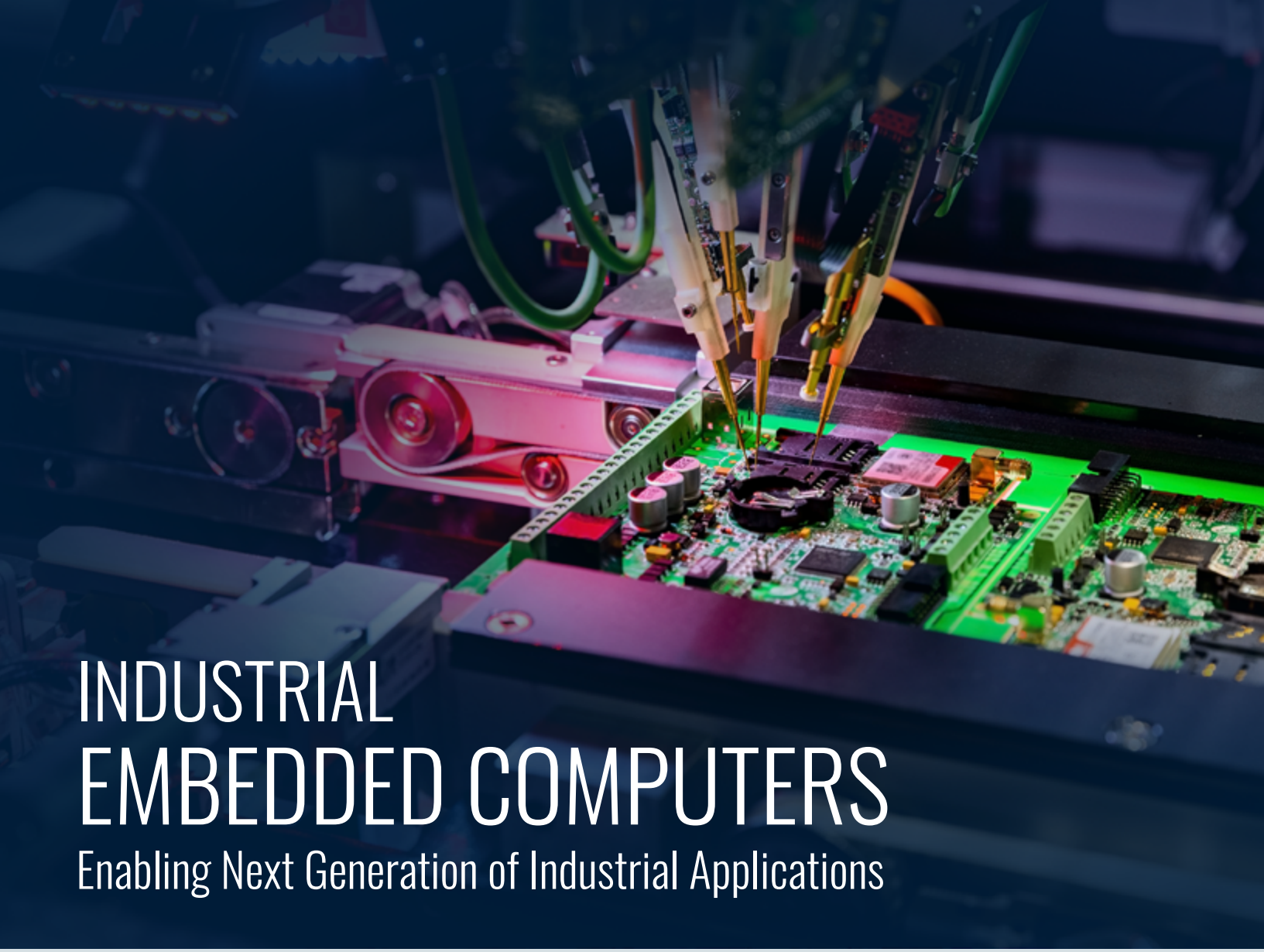
Near Field Communication (NFC) is an Ultra-Short Range Radio communication protocol. It uses the ISO/IEC 18000-3 standard and the 13.56 MHz ISM frequency band. It provides a data rate of 100-420 Kbps and a range up to 20cm. Some NFC devices can read (ISO 15693 compliant) passive high-frequency RFID tags, which also works on 13.56 MHz. NFC provides full-duplex communication over the detection range from metallic and non-metallic substrates. It is used for contactless payment, fast synchronizing, and digital content access applications.

Sigfox

Sigfox is a private network provider similar to telephony or cellular service providers, focused on serving customers in IoT. It uses sub-GHz ISM bands (868 to 869 MHz or 902 to 928 MHz) and supports a long-range (up to 50km) using the star topology. Although Sigfox communication is bi-directional, the payload from the base station to the node is meager. It is used for remote sensing, where low amounts of data have to be transmitted sporadically with high battery life requirements.

LoRaWAN

LoRaWAN is a Low Power Wireless WAN communication protocol in the sub-GHz frequency range (433/ 868/ 915 MHz). It has a typical data rate of 0.3-50 Kbps and can cover up to a 15km range. The higher distance is achieved by dynamically lowering data rates. It is designed to provide Low Power, low-cost, secure, and full-duplex communication for IoT, M2M, Smart City, and Industrial Applications.



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5G
WHAT IS 5G, ITS CAPABILITIES AND APPLICATIONS?

The twenty-first century is the "connected" century; wireless communication technology advanced at a rapid pace in succeeding years as a result of research and invention.

After the emergence of 4G wireless mobile technology, researchers and mobile operator industries began to look into the progress (technological) towards 5G communication technology due to certain major needs such as increased data rates, increased capacity, reduced latency, and improved QoS. (Quality of Service).

Fifth-generation (5G) wireless technology, which includes enhanced access technologies such as BDMA (Beam Division Multiple Access) and FBMC (Filter Bank Multi-Carrier Multiple Access), will easily replace fourth generation (4G) wireless technology.

5G will not only be faster than the current 4G, but it will also have the potential to revolutionize other sectors such as manufacturing, automotive, health care, and energy. It will allow the transition from wired to wireless connectivity in a wide range of industrial environments. This article explains 5G, its capabilities, and applications.

WHAT IS 5G & ITS CAPABILITIES?

5G Technology stands for Fifth Generation, which is the next generation of wireless network technology, designed to broaden the reach of mobile technology beyond LTE's capabilities.

It is the most recent version of cellular technology. 5G is distinguished by three key characteristics: faster speeds, lower latency, and the ability to connect many devices at the same time. Because of higher accessible bandwidth and new antenna technology, 5G enables a significant increase in data quantities sent through wireless systems. mmWave (millimeter-wave) technology powers these 5G networks.

5G technology will change the way cell phones are used in areas with very high bandwidth, such as 1Gbps or more. People will encounter unprecedented levels of call volume and data transmission when 5G is pushed over a VoIP-enabled device. 5G technology will provide services such as ubiquitous networks, radio resource management, high altitude stratospheric platform station (HAPS) systems, and so on.

5G wireless technology is a significant advancement over previous generations.

It solves all prior disadvantages, such as a lack of coverage, lack of performance at cell edges, and dropped calls. 5G promises better coverage and connectivity.

TECHNOLOGIES	1G	2G	3G	4G	5G
FEATURES					
Start / Deployment	1980's	1990's	2000's	2010's	2020's
Data Bandwidth	2kbps	64kbps	2Mbs	1Gbs	Higher than 1 Gbps
Technology	Analog Cellular Technology	Digital Cellular Technology	Broadband with CDMA, IP Technology	Unified IP & seamless combination of broadband, LAN, WAN & WLAN	Unified IP & seamless combination of broadband, LAN, WAN, WLAN & WWWW
Service	Mobile Technology (Voice)	Digital voice, CMS, Higher capacity paketized data	Integrated high quality audio video and data	Dynamic information access, Wearable devices	Dynamic information access, Wearable devices with AI Capabilities
Multiplexing	FDMA	TDMA, CDMA	CDMA	CDMA	CDMA
Switching	Circuit	Circuit, Packet	Packet	All Packet	All Packet
Core Network	PSTN	PSTN	Packet N/W	Internet	Internet

HOW **5G** WORKS:

The introduction of 5G technology has resulted in advancements in network design.

The 5G New Radio, hailed as the worldwide standard for a better 5G wireless air interface, includes spectrums that were previously unutilized in 4G. Massive MIMO (multiple inputs, multiple outputs) technologies are used for the new antennas, allowing many receivers and transmitters to transfer massive amounts of data at the same time.

However, 5G technology is not limited to New Radio. It strengthens a convergent and heterogeneous network that combines unlicensed and licensed wireless technologies. This increases the level of bandwidth available to users.

5G enhances digital experiences through machine-learning (ML)-aided automation. The requirement for fractions of second response times (for example, self-driving vehicles) pushes 5G networks to create automation with ML and, in the long run, artificial intelligence (AI) and deep learning (DL).

Active management and automated service and traffic provisioning improve the connected experience while also reducing infrastructure expenses.

5G TECHNOLOGIES AND TECHNIQUES:

Several technologies and approaches have been developed in consideration for the incorporation of 5G standards.

With these new approaches and technologies, 5G will be able to provide a dynamic and flexible service. Among the technologies being developed for 5G are:

Millimeter-Wave communications: These use frequencies that are considerably higher on the frequency range. It allows for the use of various new spectrums as well as a wide channel bandwidth of up to 2 GHz. This, however, introduces additional problems to handset development, since maximum frequencies and bandwidths are typically about 2 GHz and 10 - 20 MHz, respectively. Frequencies over 50GHz provide difficult challenges for 5G in terms of circuit design, technology, and system usage, as such frequencies do not travel far. They are completely absorbed by obstacles. Distinct countries allocate different spectrums to 5G.

Waveforms: New waveforms have elicited a lot of interest. OFDM is successfully as used in 4G LTE and several high data rate systems. It, however, suffers from limitations in a few circumstances. The other waveform formats discussed include GFDM, Universal Filtered Multicarrier, Filter Bank Multi-Carrier, UFMC, Generalized Frequency Division Multiplexing, and FBMC. A perfect waveform does not exist. OFDMA finds use as it brings superlative overall performance without leaning too heavily on the processing power.

Multiple Accesses: Several new access schemes are under investigation for 5G technology. The list of techniques under consideration includes OFDMA, IDMA, SCMA, NOMA, MUSA, and PDMA. The most probable format, however, is OFDMA.

Massive MIMO with beam steering: Even though MIMO is used in a range of applications from LTE to Wi-Fi, the antennas are fairly limited. The use of microwave frequencies makes possible the use of multiple antennas on a single piece of equipment due to the antenna sizes and spacing in wavelength terms. Such an arrangement would allow beams to be piloted to offer superior performance.

Dense networks: Cell size reduction makes for better overall effective use of that available spectrum. Techniques must be adopted to ensure that tiny cells present inside the macro-network and subsequently deployed as femtocells operate as planned. Considerable challenges are encountered during the addition of extra cells to a network, and methods are being created to avoid such a possibility.

5G TECHNOLOGIES AND TECHNIQUES:

The 5G technology will be an important component of the networked society.

5G will support huge numbers of connected devices and increase reliability in communication of mission critical applications. 5G will provide wireless connectivity for various applications such as smart homes, wearables, critical infrastructure, traffic safety/control, very high speed media delivery, industry processes etc.

IoT applications are well supported by LTE-M and NB-IoT based on 4G cellular networks but 5G will further enhance these Mobile IoT networks. 3GPP has incorporated LTE-M and NB-IoT into the 5G specifications, confirming their long-term status as part of future 5G standards. As the 5G technology evolves, the LPWAN (low power wide area networks) will become less complex and expensive. This provides a foundation for energy-efficient services.

5G-IOT ARCHITECTURE

This section introduces an architecture suitable for future IoT applications and services.

The new architecture provides a more reliable, scalable and sustainable mobile IoT system than traditional IoT architectures. It provides a 5G-based architecture called 5G-IoT, with specifications that are modular, efficient, flexible, scalable, simple and responsive.

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Physical Device Layer

This layer consists of wireless sensors, actuators, and controllers that are actually "things" of the IoT. Physical devices are a common layer across all architectures. Small components such as Nano chips are used in this layer to increase computing power and reduce energy consumption. Nano chips can generate large amounts of raw data which will be processed in the data analysis layer (Layer 7) suitable for big data.

Communication Layer

This layer consist of two sublayers.

Direct Device To Device (D2D) Communication Sub-Layer

Due to the increased computing power and intelligence, the physical device (node), has a unique identity and personality and generates its own data. To improve the performance and functionality of IoT systems, these devices must communicate with each other by forming a HetNet network. This lower layer uses the modern Wireless Sensor Network (WSN) communication protocol. A node can also choose a cluster head or cluster head.

One of the key technologies that powers this infrastructure is millimeter waves. 5G is also another alternative technology in this lower layer that can improve D2D connectivity. 5G networks are great candidates for connecting to MTC (Machine Type Communucation) devices. The high data rates of MTC and other high-quality media makes 5G-Plus-HetNet a powerful technical solution for the proposed 5G-IoT architecture.

Connectivity sub-layer

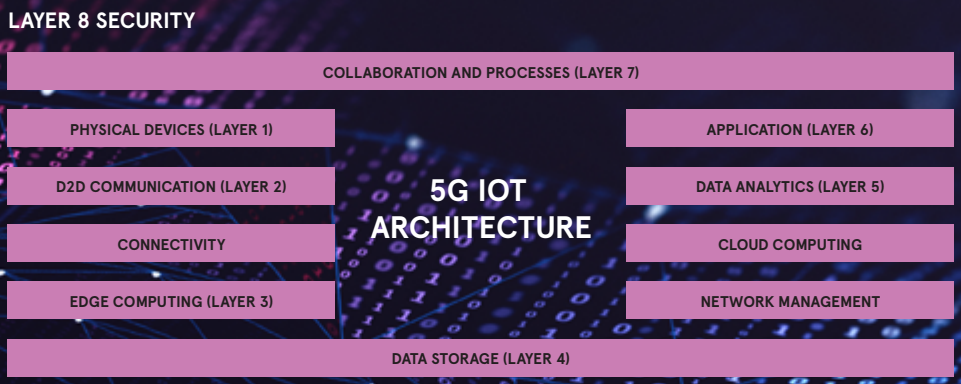
In this lower layer, devices are connected to the call center as BSs (Base station subsystem). It also sends and analyses data through the center via an intranet connection to the storage faci lity. Currently, this IoT sub-layer has some problems. It can only handle a limited number of device connections. In applications such as autonomous vehicles, data exchange does not apply to data types. High connection latency makes it difficult to process large amounts of data in real time. In the near future, 5G will significantly improve this foundation in terms of reliability, performance and agility.

Edge (Fog) Computing Layer

This layer processes data from the node or its leaders to make decisions at the edge level. With the advent of 5G technology and mobile devices (such as smartphones), MEC (Multi-access Edge Computing) technology will become more powerful, address challenges and contribute significantly to this level.

Data Storage Layer

This layer contains the data storage unit, which stores the information obtained from the edge processing of the physical devices, as well as the original data. This layer requires special protection in terms of security, and must also respond to massive amounts of data and traffic from future applications.



Management Service Layer

This layer consist of three sub-layers as follows:

Network Management Sub-Layer

Network management is changing the way devices and data centres communicate. The main technology of this subclass is WNFV (Wireless network function virtualization). WNFV can improve the quality of IoT architectures by simultaneously updating the network topology and communication protocol types such as 5G-IoT and ZigBee. Other technologies which are useful in these factories and smart cities include support for different types of data, support for many customers and requirements, and special features such as agility, flexibility, strong connectivity and low latency reliability.

However, architectures based on 5G communication technology can meet the above requirements and provide the following features: Easy management, reliability, reconfiguration, advanced security, fast and easy troubleshooting, comprehensive coveragewith a cost-effective 5G connectivity version.

Cloud Computing Sub-Layer

This sub layer reprocesses data and information from on-board computations in the cloud and retrieves the information to be processed. The implementation of 5G technology will allow mobile devices to perform this type of calculation, called MCC (MCC??), in real time. For example, computing activity is distributed in parallel between mobile devices, making IoT systems more efficient, reliable, scalable and faster.

Data Analytics Sub-Layer

This sub-level uses new data analysis methods to extract values (controllable information) from raw data. Improving big data algorithms improves data processing at this lower layer. Indeed, the role of this subcategory is likely to proliferate in the near future as the data collected by the integration of 5G and the Internet of Things increases. Application Layer: At this level the program communicates with the previous level and data in standby mode, so no network speed is required. Through application control programs, vertical and mobile applications, business intelligence and analytics can transform vertical markets and business needs. In fact, the application layer allows businesses to do the right thing at the right time with the right data.

Collaboration and Processes Layer

The IoT system and the information from the first few layers is useless unless it generates behavior. Applications that run business logic empower people. People use applications and related data to meet their specific needs. Sometimes, multiple people use the same application for different purposes. In fact, people must be able to collaborate and communicate for the Internet of Things to work.

Security Layer

Like many architectures, this layer is considered a separate layer. In fact, this layer covers and protects all the previous layers, but each part (the intersection of this layer and another) has its own function

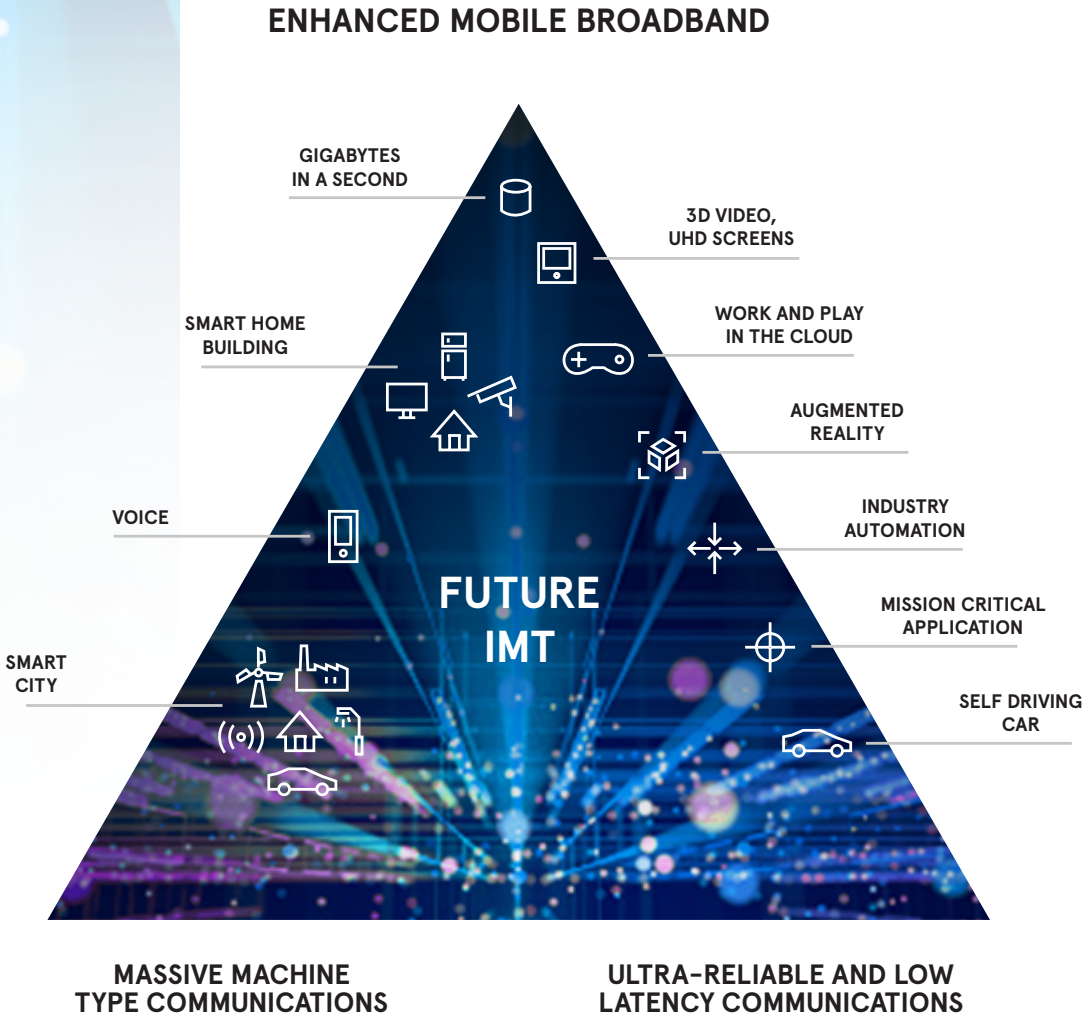
The security layer of the proposed architecture implies various security feature terms, including data encryption, user authentication, network access control, and cloud security. In addition, the security layer can also prevent and predict dangers and cyber-attacks, including forensics to detect and prevent the type of attack.

5G APPLICATIONS USE CASES

The goal of 5G technology is to enable new types of applications

It is not only an evolutionary update to the previous generation of cellular, but a breakthrough technology that is envisioned to eliminate the boundaries of access, capacity, performance, and latency on connectivity globally.

As illustrated in the picture below, the three major use cases of 5G are: Enhanced Mobile Broadband, Massive Machine Type Communication, and Ultra-Reliable Low Latency Communication.



eMBB

Enhanced Mobile Broadband (eMBB)

The growth of eMBB mirrors that of contemporary mobile broadband, allowing for bigger data quantities and a better user experience. A prime example is the support of higher end-user data rates.

Typical eMBB applications:

- ***UHD video (4K, 8K) 3D video***
- ***Tactile Internet, Cloud gaming, and Broadband kiosks***
- ***Remote classroom, Hologram***
- ***Virtual Reality (VR) and Augmented Reality (AR)***
- ***Real-time simulation and training***

mMTC

Massive Machine Type Communication (mMTC)

mMTC refers to services with a large device population, such as remote sensors, equipment monitoring devices, and actuators. Low device cost and efficient device energy usage are two requirements for such services. This allows for a longer battery life on the devices, which can last for several years. Each device merely receives and generates a limited amount of data. As a result, support for high data rates has become less important in this context.

Typical mMTC applications:

- ***Smart Home***
- ***Smart City***

URLLC

Ultra-Reliable Low Latency Communication (URLLC)

URLLC services need extremely low latency and tremendous high reliability. Examples include traffic safety, factory automation, and automatic control.

Typical URLLC applications:

- ***Industrial Automation***
- ***Self-driving vehicles***
- ***E-health, hazardous environments, rescue missions***
- ***Vehicular communication***
- ***Drones***

In today's 5G era, the automotive and transportation sectors are advancing toward intelligent transportation systems (ITS), which will provide numerous benefits such as enhanced safety, reduced traffic congestion, optimal fuel consumption, and a positive environmental impact. V2X communication is a key enabler of emerging ITS systems, allowing vehicles to communicate with one another, pedestrians, road infrastructure, and the internet.

CONCLUSION

With the advancement of the Internet of Things, the flexibility of 5G is becoming more and more important for businesses. 5G technology supports critical connections with more precise performance requirements.

With the advancement of the Internet of Things, the flexibility of 5G is becoming more and more important for businesses. 5G technology supports critical connections with more precise performance requirements. The high reliability and low latency of 5G will enable autonomous vehicles, smart grids, advanced factory automation and other advanced applications. Supporting the realisation of the global vision of IoT by supporting a variety of connected devices with diversity and accessibility.

We have partnered with many different suppliers catering to a wide range of industrial 5G components portfolio, such as Wireless module adaptors, Antennas, connectors, RF wireless development kits, Clock- timing development kits, IC modules, Debuggers emulators & JTag tool accessories, and interface communication development kits, and display development kits, are available to execute design, development, and projects on 5G Technology.

THE RIGHT WIRELESS TECHNOLOGY FOR EVERY APPLICATION

Compared to systems featuring cumbersome wires, wireless systems offer the very highest flexibility and convenience in networking applications. A huge range of technologies is available on the market, each of which is suitable for various applications with correspondingly diverse requirements. This table can at least provide a basic selection from among the most important wireless technologies

	CELLULAR 5G	CELLULAR - IOT	6LOWPAN	LORA
RANGE	A few hundred metres	5 km in urban area, 15 km in rural area	< 200 m, (> 1 km mesh)	2 - 5 km in urban area, 15 km in rural area
FREQUENCY BAND	Country-specific, frequency ranges, between 700 and 2600 MHz, 3600 MHz, 28 GHz, 38 GHz	Country-specific, frequency ranges between 700 and 2600 MHz; sub-1-GHz band usually used	868 MHz EU, 902–928 MHz US	868 MHz EU / 902 - 928 MHz US
MAXIMUM DATA RATE	40 Gbps	1 Mbps Cat M1, 50 Kbps NB-IoT	250 Kbps	0.3 - 50 Kbps
UPLINK/DOWNLINK	Yes / yes	Yes / Yes	Yes / yes*	Yes / yes*
POWER CONSUPTION	High	Low	Very low / low	Low / very low
STANDARDISATION BODY	3GPP	3GPP	6LoWPAN	LoRa Alliance
TYPICAL APPLICATION	Entertainment, Autonomous	IoT, Smart City, Metering	Industrial, Home Automation, IoT	Smart City, Smart Agriculture, Logistics

***According to ETSI regulations**

WIFI

- 10 - 100 m
- 2.4 GHz / 5.8 GHz / 60 GHz
- 1700 Mbps
- Yes / Yes
- High
- IEEE 802
- LAN, Internet

BLUETOOTH LOW ENERGY (BLE)

- 10 - 100 m (> 1 km mesh)
- 2.4 GHz
- < 2 Mbps
- Yes / yes
- Very low
- Bluetooth SIG
- Home Automation, Consumer

BLUETOOTH

- 5 to 15 m indoors, up to 100 m with line of sight
- 2.4 GHz
- 10 Mbps
- Yes / yes
- Medium
- Bluetooth SIG
- Connection of external devices, Data synchronisation between devices, Audio Streaming

ZIGBEE

- 100 m / mesh
- 868 MHz EU / 915 MHz US / 2.4 GHz
- 20 / 40 / 250 Kbps
- Yes / yes*
- Very low / low
- ZigBee Alliance
- Sensor Networks, Smart Metering, Lighting

SIGFOX

- < 10 km in urban area, 50 km in rural area
- 868 MHz EU / 902 MHz US
- 100 bps EU / 600 bps US
- Yes / limited*
- Low / very low
- Sigfox
- Smart City, Smart Agriculture, Logistics, Metering, Alarm backup

Z-WAVE

- 30 m / mesh
- 868 MHz EU / 908 MHz US
- 100 Kbps
- Yes / yes*
- Very low
- Z-Wave Alliance
- Home Automation

WM-BUS

- 50 - 100 m in buildings Approx. 3 km in urban area, 10 km in rural area
- 169, 433, 868 MHz
- 2.4 kbps
- Yes / yes*
- Low
- EC EN 13757-4
- Industrial, Smart Metering, Home Automation

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