



NB-IoT

The Future of IoT



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Preface

Downscaling the size of electronic devices has advanced significantly in the last two decades. Smart devices that are connected to the internet and communicate with one another have led to what we term the Internet of Things (IoT). Smart devices that communicate over the internet has found wide acceptance due to their reliability and performance. The majority of IoT applications involve taking cognitive decisions and then sharing those decisions over internet. These applications doesn't need a lot of bandwidth or transmission speed, and can be operated with ease using narrow band.

While earlier technologies resulted in higher power consumption and the waste of a significant frequency spectrum of bandwidth, therefore NB-IoT technology can help reduce power consumption and spectrum waste. Narrow band IoT (NB-IoT) is specifically introduced to achieve the least bandwidth utilization and for low spectrum wastage resulting in optimum resource utilization. Currently, NB-IoT is deployed in applications such as smart parking, smart street lighting, waste management and many more.

Bayslope's research aims to provide introduction to NB-IoT, information about market developments and patent activities in NB-IoT. An analysis of NB-IoT and patent data aligned with Bayslope's database has revealed valuable insights. This report will assist industry players and researchers in the field of NB IoT to promote further growth.

Introduction

What is IoT ?

The Internet of things (IoT) is a giant network of devices that are connected over the internet and communicate data to provide smart solutions with minimal human interaction. A decade ago, internet access was only limited to laptops, desktops, mobile-phones and tablets. But today, due to Internet of Things (IoT) we have TV remotes, fans, lights, alarms, cameras, refrigerators, health monitoring sensors and other similar smart devices connected over the internet to provide a smart technological solution.

Why IoT is required ?

The Internet of things is required to handle routine household and industrial activities efficiently and in a timely manner. And according to Statista, there were 4.66 billion active internet users worldwide on January 2021 i.e. 59.5 percent of the global population and hence today IoT is providing seamless communication between people, processes, and things. Here are a few of the merits of IoT that justify its adoption:

- Ability to gather large amount of performance data that provides opportunity for the organizations to analyze large trends in the data to better improve the device's capabilities.
- Ability to track and monitor necessary activities such as health monitoring, home security, industrial processes that helps Individuals to keep an eye on the state of functionality without having to inspect it on a regular basis.
- Cost reduction and optimal usage of resources. For example, if lights automatically turn themselves off the moment an individual leave the room, one can save a lot of money on the electricity bills. Likewise many industrial processes can be optimized for cost reduction can be achieved.



What is Narrow Band Internet of Things (NB-IoT)?



NB-IoT or Narrow band IoT is a low power wide area wireless communication network standard with a bandwidth of only 200KHZ. It has been developed especially for IoT applications that do not require higher data rates, power & computational resources and rather require longer transmission range and low bandwidth consumption. NB-IoT covers a range of 1 km in urban areas and 10 km in rural areas.

The device using NB-IoT remains disconnected from the network until it has some data to transmit. And once the connection is established, the device maintains it for a configured time until it becomes inactive and ends up disconnecting. NB-IoT also allows an immediate disconnection once the data confirmation is received.

How is Data Transmitted over the Internet?

A data carrier signal is required to transmit data over the internet. The carrier signal can be wide band, broad band or narrow band signal. And because of the wide range of IoT system applications in terms of data size, frequency of communication, power consumption, and network bandwidth utilization, selecting a data carrier network is crucial.





Communication Technologies used for IoT

IoT applications such as high-end driverless cars, complex computer vision-based analytics systems and adaptive smart systems based on artificial intelligence etc. desire extreme low latencies and ultra-high reliable connectivity requirements. Such IoT systems require transmission and processing of large data in almost real time to make critical decisions use **wideband carrier signal**.

If IoT applications require data to be transmitted at moderate transmission speed as in case of IoT based smart video surveillance, video communication over a distance etc., then it does not require a very high-speed internet and thus a **broad band carrier signal** can be used as data carrier for such applications..

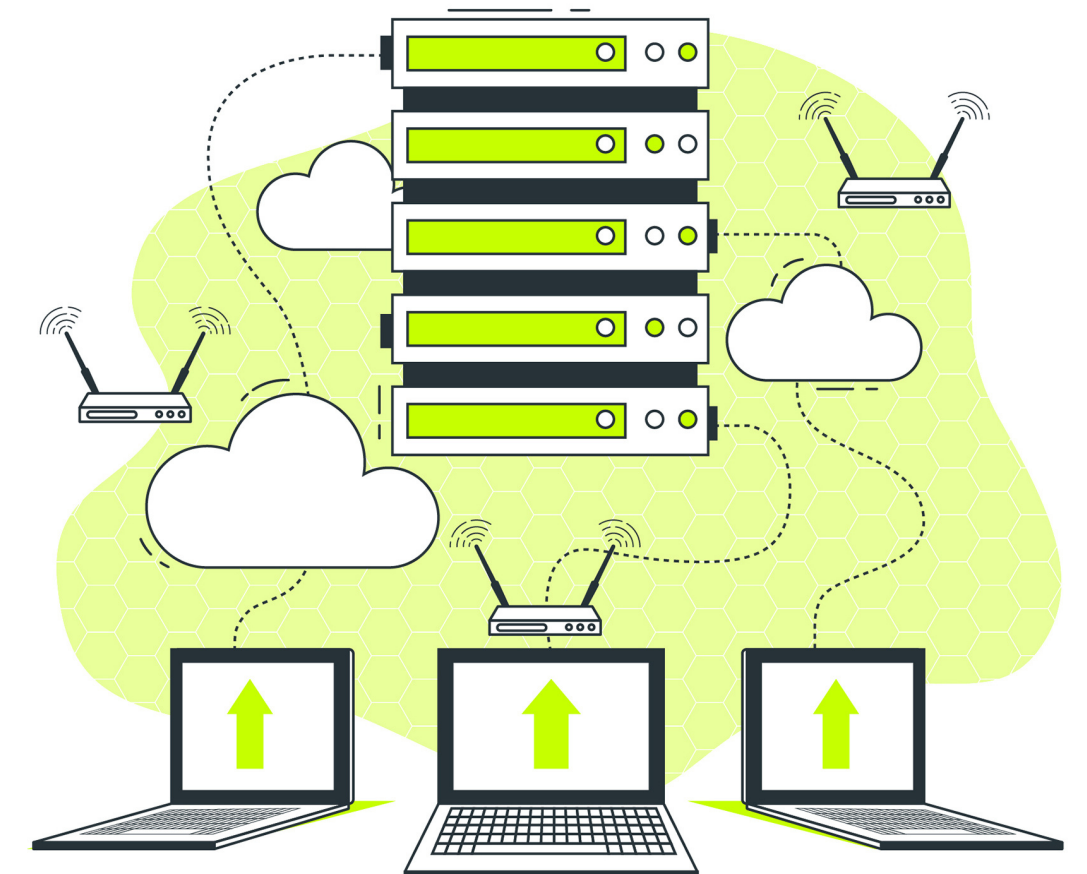
IoT applications such as smart cities, smart home appliances, smart agriculture monitoring, smart metering, transmission of industrial goods data etc. require small amount of data to be transmitted inconsistently with low power consumption. For such IoT applications, **narrow band carrier signal** is used and the broad field of such IoT devices is called **Narrow Band IoT (NB-IoT)**.

“NEED” of Narrow Band Internet of Things (NB-IoT)

Each smart device uses a channel of bandwidth for data communication. Therefore increase in IoT devices and usage of bandwidth, risks saturation of bandwidth in future and thus optimal bandwidth utilization becomes important for IoT.

Another important aspect is the power consumption. With tremendous downscaling of size of electronic devices in the past, their resources are also limited. With increasing processing and computational capabilities of the devices, optimum power consumption also becomes a critical aspect.

Many the IoT applications such as smart home appliances, smart agriculture monitoring system, smart meters, smart environment monitoring etc. demand a low data transmission rate or less frequent data transmission. And use of Wideband or broadband for such IoT applications would lead to loss of tremendous bandwidth and huge power consumption. Hence, the need for Narrow Band Internet of Things (NB-IoT) becomes critical.



Evolution of NB-IoT

Release 13

NB-IoT was first introduced in the **3rd Generation Partnership Project (3GPP) Release 13** standard in 2016 as LPWA (Low power wide area) technology in the licensed spectrum.

Release 14

The LTE Cat NB2 standard was established with **3GPP Release 14** in 2017. In 3GPP Release 14, NB-IoT and LTE-M were adopted to transfer data at a faster rate while using less power.

Release 15

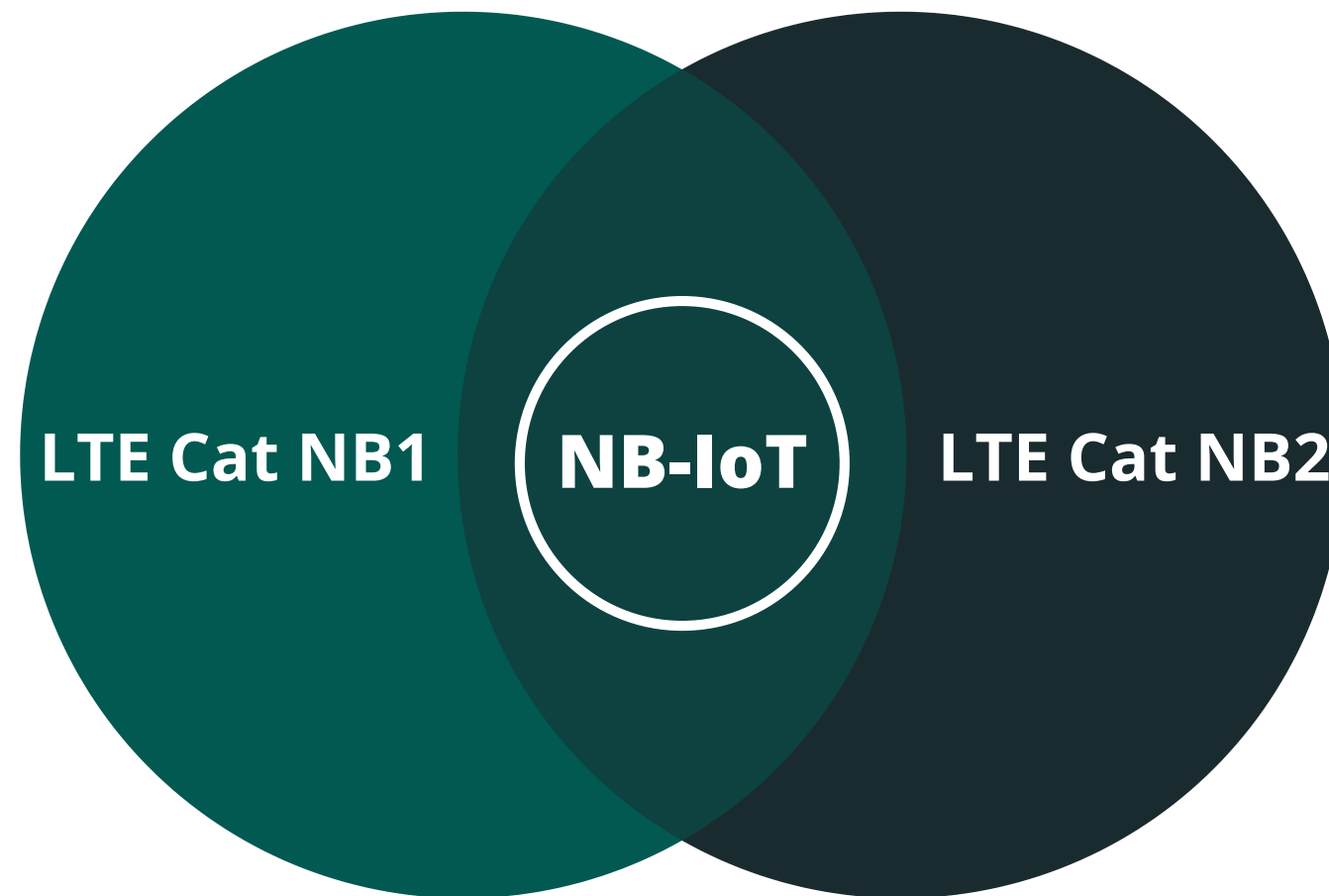
Interesting improvements were observed with the **3GPP Release 15** in June 2018. These include small-cell support for NB-IoT, and TDD (time-division duplexing) support for in-band, guard-band and standalone operation modes.

Release 16

3GPP Release 16 introduced in 2020, improved the capacity and operation of NB-IoTs existing features into new industry verticals such as transport industry, industrial IoT, manufacturing, enterprise, automobile (V2X), etc. It also featured enhanced channel capacity and improvement of operation efficiency.

NB-IoT Classification

NB-IoT can be classified as **LTE Cat NB1** and **LTE Cat NB2**.



LTE Cat NB1 refers to IoT devices based on the NB-IoT protocol standardized in the 3GPP Release 13 specification. It is a wireless cellular low-power wide-area connectivity protocol for IoT massive machine-type communications.

LTE Cat NB2 refers to devices which are based on the enhanced NB-IoT protocol as standardized in the 3GPP Release 14.

- NB1 devices support total downlink of 680 bits and uplink of 1000 bits with uplink data rate support of 62Kbps (max) whereas NB2 devices support total downlink and uplink of 2536 bits with uplink data rate support of 159Kbps (max).
- For example, CEVA launched Dragonfly 1 chipset with NB1 specifications and Dragonfly 2 chipset with NB2 specifications. NB2 provided multicast transmission, better mobility and higher transmission rate which were absent from NB1.

Competitor Technologies to NB-IoT

Sigfox and **LoRa** are the major competitors to NB-IoT and are designed for non-cellular Low power wide area network (LPWAN). Mobile network operators adopt their technology for IoT deployments over both city and nationwide LPWAN.



Sigfox is a France based narrowband (or ultra-narrowband) technology. It uses a standard radio transmission method called binary phase-shift keying (BPSK), and it takes very narrow chunks of spectrum and changes the phase of the carrier radio wave to encode the data. It allows the receiver to only listen in a tiny slice of spectrum, which mitigates the effect of noise. It requires an inexpensive endpoint radio and a more sophisticated base station to manage the network.

The base stations of SigFox are very expensive in infrastructure and maintenance. SigFox is an unlicensed communication technology with non-standard operating frequency which makes it difficult to utilize in many countries like in USA SigFox operates at 900 MHz which is susceptible to high levels of interference thus not suitable as LPWAN. Sigfox covers a range of 10 km in urban areas and 40 km in rural areas.

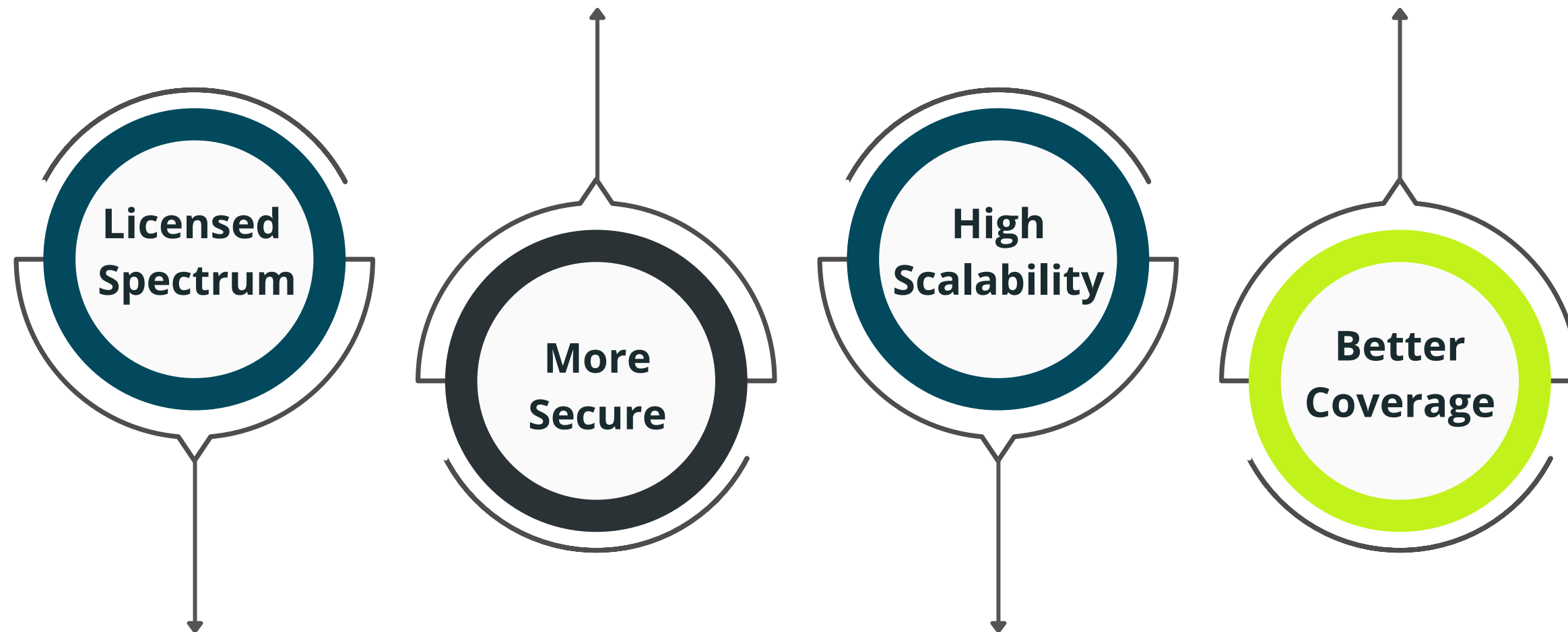
LoRa technology was developed by a company called Semtech and it is a wireless protocol designed specifically for long-range, low-power communications. LoRa stands for Long Range Radio and is mainly targeted for M2M (Machine-to-machine) and IoT networks. LoRa infrastructure is comparatively inexpensive and easy to maintain than SigFox. It has very wide coverage range about 5 km in urban areas and 20 km in rural areas.



Advantages of NB-IoT over other Technologies

NB-IoT technology is inspired by cellular 4G technology and thus data transmission has better encryption and thus **more secure**.

Coverage of NB-IoT is better than both LoRa and Sigfox and It work well indoors and in dense urban areas.



Sigfox and LoRa employ unlicensed spectra and asynchronous communication protocols whereas NB-IoT employs a **licensed spectrum** and an LTE-based synchronous protocol, which are optimal for quality of service at the expense of cost.

NB-IoT offers the advantage of very **high scalability** than Sigfox and LoRa. NB-IoT allows connectivity of up to 100 K end devices per cell compared to 50 K per cell for Sigfox and LoRa.

Application Areas of NB-IoT

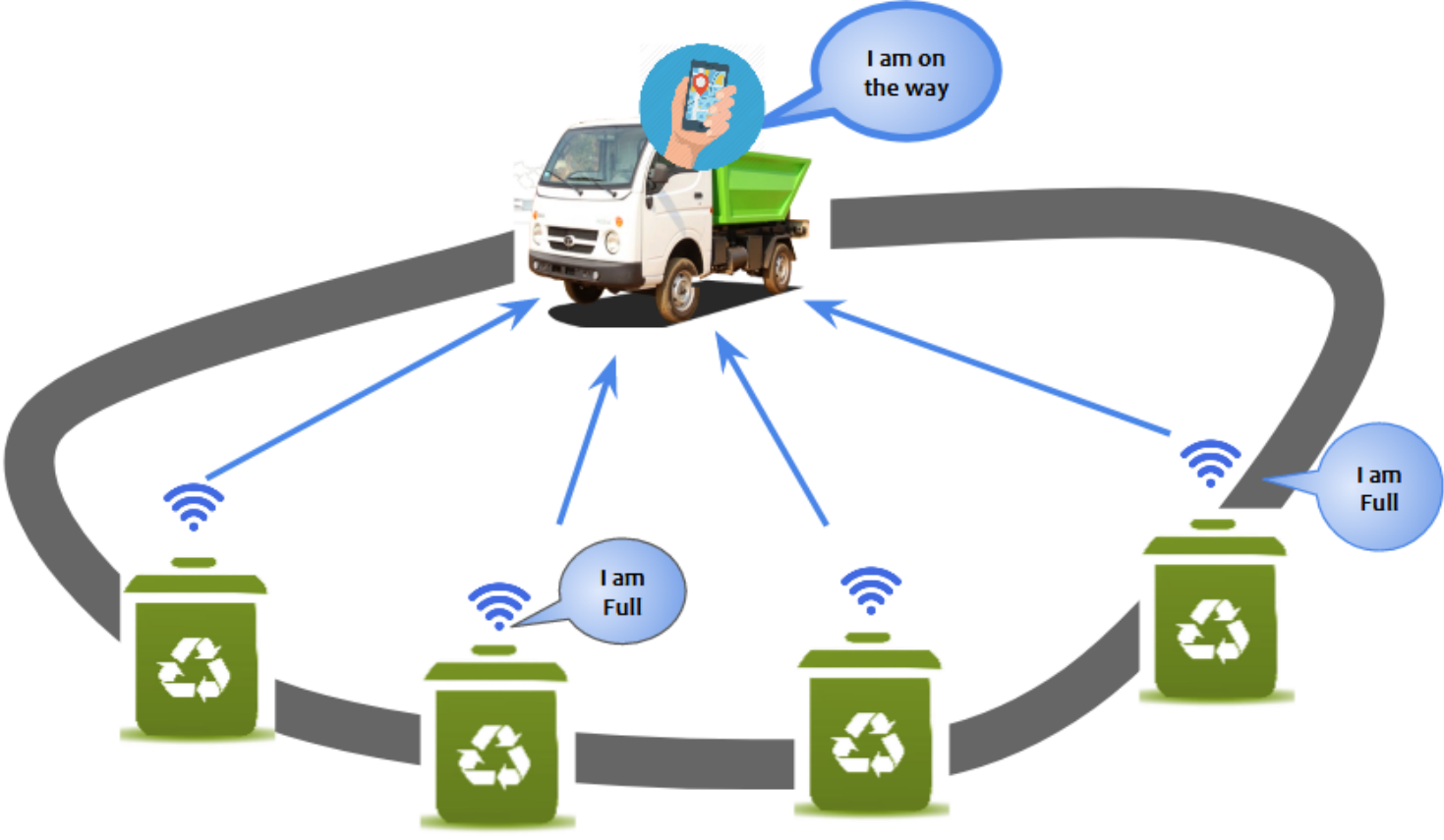
NB-IoT has been widely utilized in a variety of applications where data transfer size and frequency of data communication is low with minimal power and bandwidth consumption such as smart cities, smart healthcare, smart logistics, smart home appliances, smart metering systems and a variety of industries for keeping a track of goods and human resources. Few of the applications are discussed below.



Smart Lighting System: NB-IoT can be utilized for adopting smart lighting system. This system does not work according to the timers set for their operations. Rather this lighting system follows the ambient conditions through the sensors and accordingly takes actions to provide light when it is required.

Smart Parking Management System: Using NB-IoT, parking slots can be allocated logically. Smart parking system can help detect the reservations and sharing information of empty parking spaces present in the parking lot.





Smart Garbage Management System: A smart garbage management system contains sensors attached with the garbage bins which monitor the garbage loading level. Once the garbage bin is fully loaded, the attached garbage sensor transmits the data to the garbage collector along with the location address of the bin. The garbage data is only communicated once the bin is fully, thus NB-IoT helps in cost reduction for the process too.

Smart Traffic Management System: An NB-IoT based smart traffic management system provides flexibility in managing the traffic by measuring the traffic density in the cities. Traffic data is collected and analyzed using NB-IoT technology with better capabilities to provide the real-time traffic information. The data communication about traffic status is conveyed using NB-IoT network.





Smart Public Resource Management System: In most cities, efficient management of public resources such as water and electricity has been a big concern. Leakage in water pipelines and failure in electric grids etc. are frequent problems. A smart system is employed to detect faults and communicate the status of faults as soon as they are detected. And because the frequency of data transfer and the amount of the warning data are not large, NB-IoT is preferred for such a system.

Smart Meter System: Traditionally, meter reading has been done personally by a electricity retailer visiting the site where meter is installed. There may be a scenario when the location is unattended and the electricity retailer failed to take reading. In such scenario, smart NB-IoT based meters are deployed to measure and monitor the supply of electricity, gas and water in the cities. These smart meters can also be used to detect power theft and other illegal activity.





Smart Home Devices: A smart home application has been the widest application area of IoT utilizing NB-IoT. For example, Using NB-IoT, a security camera network capable of detecting abnormal activity & generating an alarm can be integrated with the alarm signal and could be communicated to the user from a remote location.

Smart Manufacturing: The production industry is dependent on both the quality and quantity of things produced on a regular basis. If a part or component of a machine fails mechanically, it can severely affect industry productivity if it is not identified and rectified immediately. Smart machinery based on NB-IoT contains sensors that detect component failure and trigger an alarm for the supervisor, as well as interact with other process components to ensure that product quality is maintained.





•**Smart Livestock Management:** Intelligent collars based on the NB-IoT are used to record the location, behavior, and vital signs of farm animals in real time in order to optimize livestock productivity. Such a system assists in refined breeding and reduction in livestock health risks.

Smart Greenhouse Farming: A set of NB-IoT-connected sensors are used to accurately monitor the climate inside a greenhouse. The same set of sensors can be used to track the moisture level in both the soil and the air, acidity level in water, light intensity, energy consumption etc. These trackings ensure consistent conditions and increased productivity. This system also provides notifications when specific parameters are breached, leading to an increase in farm productivity.



Top Contributors in NB-IoT Products

Several NB-IoT development organizations produce chipsets for MODEMS, SIM modules, and development kits that meet the NB-IoT technology's technical requirements. Here are the top organizations working in development of NB-IoT technology:



HiSilicon has been a leader in NB-IoT technology and a major promoter of NB-IoT standards within the industry. Huawei and Ericsson were the first organizations to start working with NB-IoT. Following the freeze of Release 13, HiSilicon released the Boudica 120, the world's first NB-IoT chipset, in 2016. This launch helped module vendors and industry customers to apply IoT solutions on a commercial scale.

Sanechips recently took part in the first large-scale field test of NB-IoT utilizing their pre-commercial RoseFinch chipset. With this test Sanechips demonstrated their commitment towards NB-IoT. The trial tested the network of the entire mobile chain including core network, terminals and apps and was reported to have been successful in every aspect.



The Qualcomm logo is displayed in a blue, sans-serif font. The letter 'Q' is significantly larger than the other letters, and the 'M' has a distinctive shape with a small gap at the top.

Qualcomm launched 212 LTE IoT Modem and claimed to be world's most power-efficient single-mode 3GPP Release 14 NB2 (NB-IoT) modem.

Altair has ultra-low power, smallest, most secured and highly integrated chipset for NB-IoT. Altair's ALT1255 is the most integrated, 5G ready, cost optimized NB-IoT chipset available in the market.

The Altair logo features a stylized blue 'a' followed by the word 'ltair' in a black, sans-serif font. Below the logo, the text 'A Sony Group Company' is written in a smaller, black, sans-serif font.

A Sony Group Company

The Mediatek logo consists of the word 'MEDIATEK' in a bold, sans-serif font. The letters 'MEDI' are in orange, and 'ATEK' is in blue.

For NB-IoT, **Mediatek** has its own platform, design optimization, and modem. The Mediatek NB-IoT platform has the highest temperament for connection quality, allowing NB-IoT devices to be installed in places where competing IoT connectivity standards are unavailable. This is especially beneficial for installing devices in remote or difficult-to-reach locations.



Nordic Semiconductors produces a low power SiP chipset known as nRF9160 SiP with an integrated LTE-M/NB-IoT modem and GPS. The nRF9160 is a compact, highly integrated System-in-Package (SiP) that makes the latest low power LTE technology.

The GR851x family by **Goodix** is a System-on-Chip (SoC) that integrates a powerful application and security subsystem with NB-IoT cellular communication functionality. It features ultra-low power consumption, high communications reliability, and outstanding application scalability, making it an ideal choice in a vast variety of Internet of Things (IoT) applications.



Cisco has launched its NB-IoT platform worldwide. The networking giant claims that its Cisco Jasper Control Center for NB-IoT is the first commercially available global NB-IoT platform.

Adoption of NB-IoT in India

When compared to other countries, India was late to adopt NB-IoT, hence there were dozens of NB-IoT modules available from every major cellular module manufacturer. There are interesting satellite-based deployments already being launched that provide pan-Indian coverage to sensors and other unconnected machines.



SAMSUNG

Reliance Jio's pan-India IoT network, based on NB-IoT technology, is already operational, which was launched in partnership with Samsung. In April 2021, Jio deployed its first commercial NB-IoT service for Tata Power Delhi Distribution's (Tata Power -DDL) smart meters. Jio aims to have a network of a billion IoT devices to its IoT platform, unlocking 20,000 crore annual revenue opportunity.



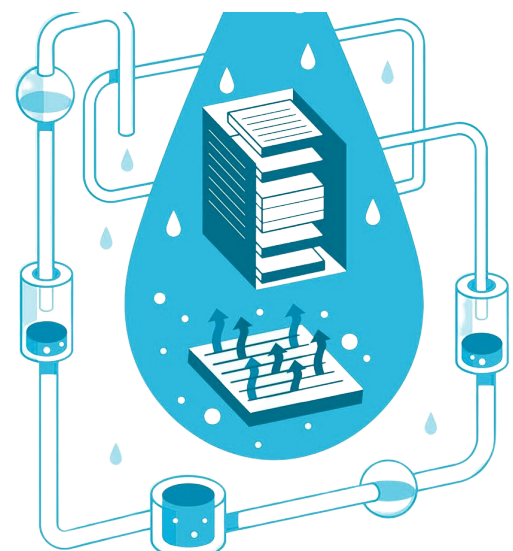
In 2020 Bharat Sanchar Nigam (BSNL) in partnership with Skylotech India launched its NB-IoT network which was world's first satellite-based NB-IoT network. With the help of NB-IoT network BSNL aims to connect machines, sensors, and IoT devices. The Skylo user terminal is a compact, smart, durable unit that communicates with sensors and transmits data to the Skylo network. This NB-IoT network has been successfully adopted in industries such as railways, fisheries and agriculture.

Recent Updates on NB-IoT



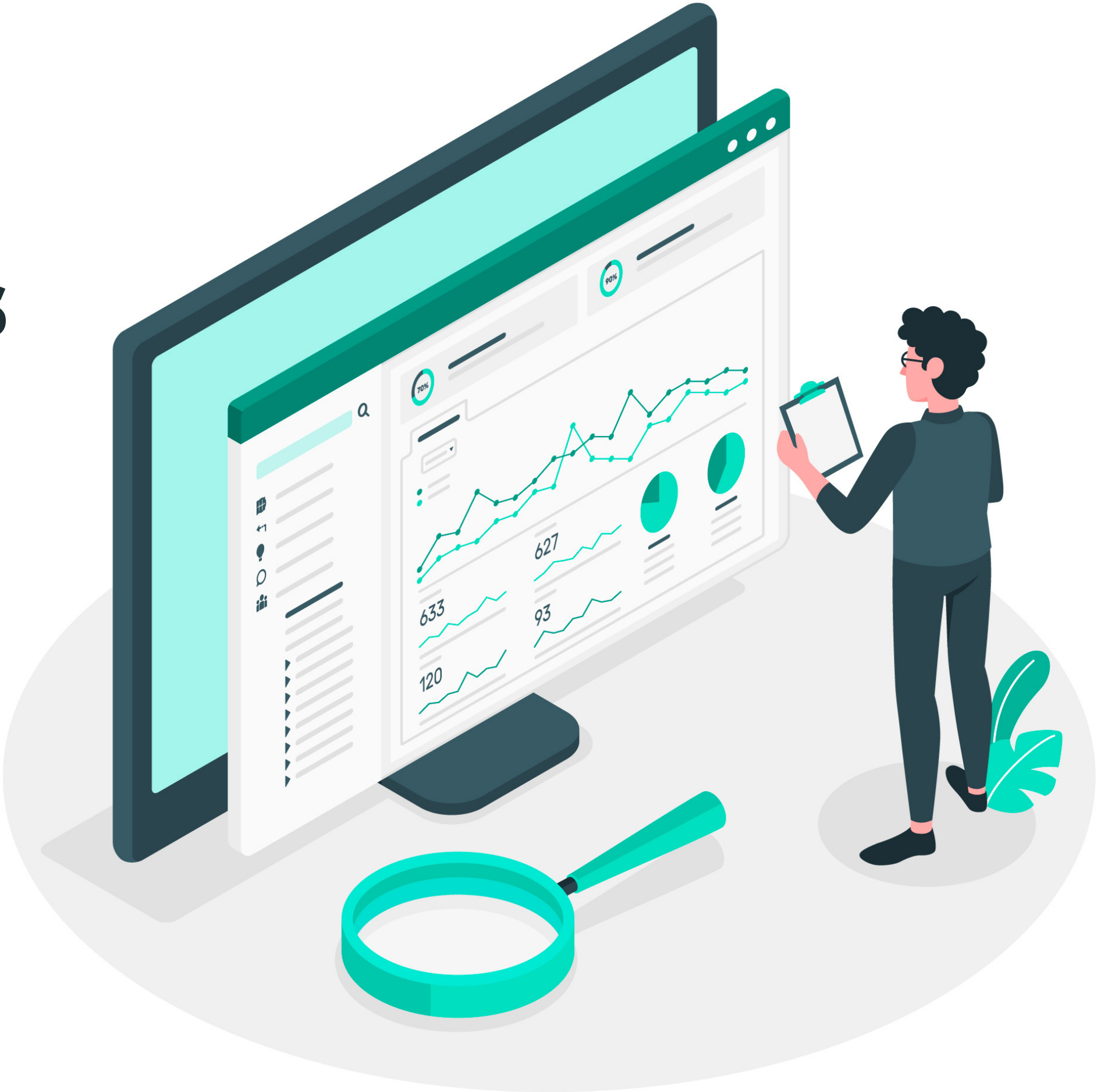
Telstra secured largest ever IoT deal by value and number of connections, an AUD100 million (\$71 million) contract with utility services company Intellihub. The 10 year agreement involves delivering up to 4.1 million IoT SIMs for Intellihub's smart meters, providing real-time insights to manage the different elements of an energy network. Telstra claims more than 5 million devices are connected to its IoT networks, with NB-IoT coverage of 4 million sq-kms and LTE-M coverage at around 3 million sq-kms.

·Recently, Taiwanese industrial IoT provider **Ubiik** has released a Release 15 level dual-mode LTE-M and NB-IoT unit that can operate as a small cell or access point. The new solution marks the firm's first entry into the cellular IoT market, and the first Release 15 small cell in the market.

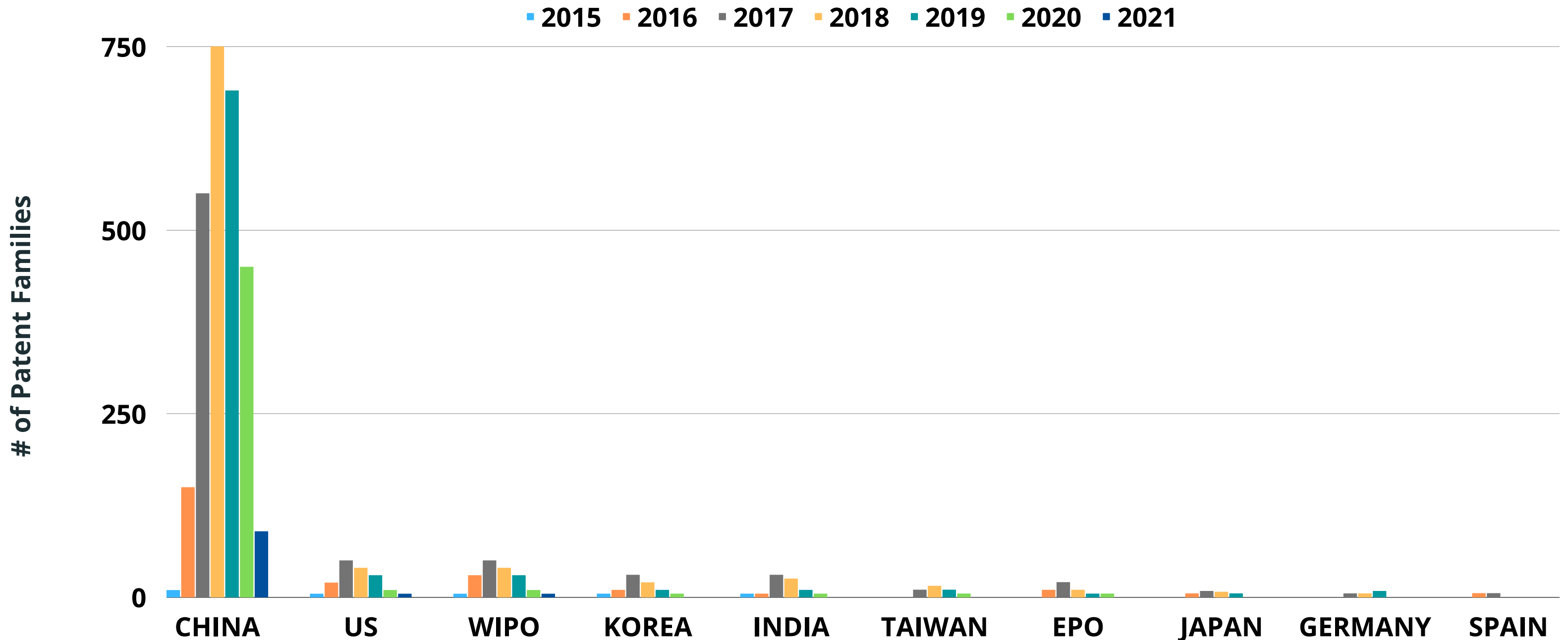


·Dundee-based **M2M Cloud** aims to launch its water monitoring device to European markets with IoT innovation centre CENSIS. By incorporating machine learning (ML) and allowing it to operate on Narrow Band IoT (NB-IoT) and LoRaWAN networks, the firm will be able to improve on its existing water monitoring device.

Patent Insights on NB-IoT

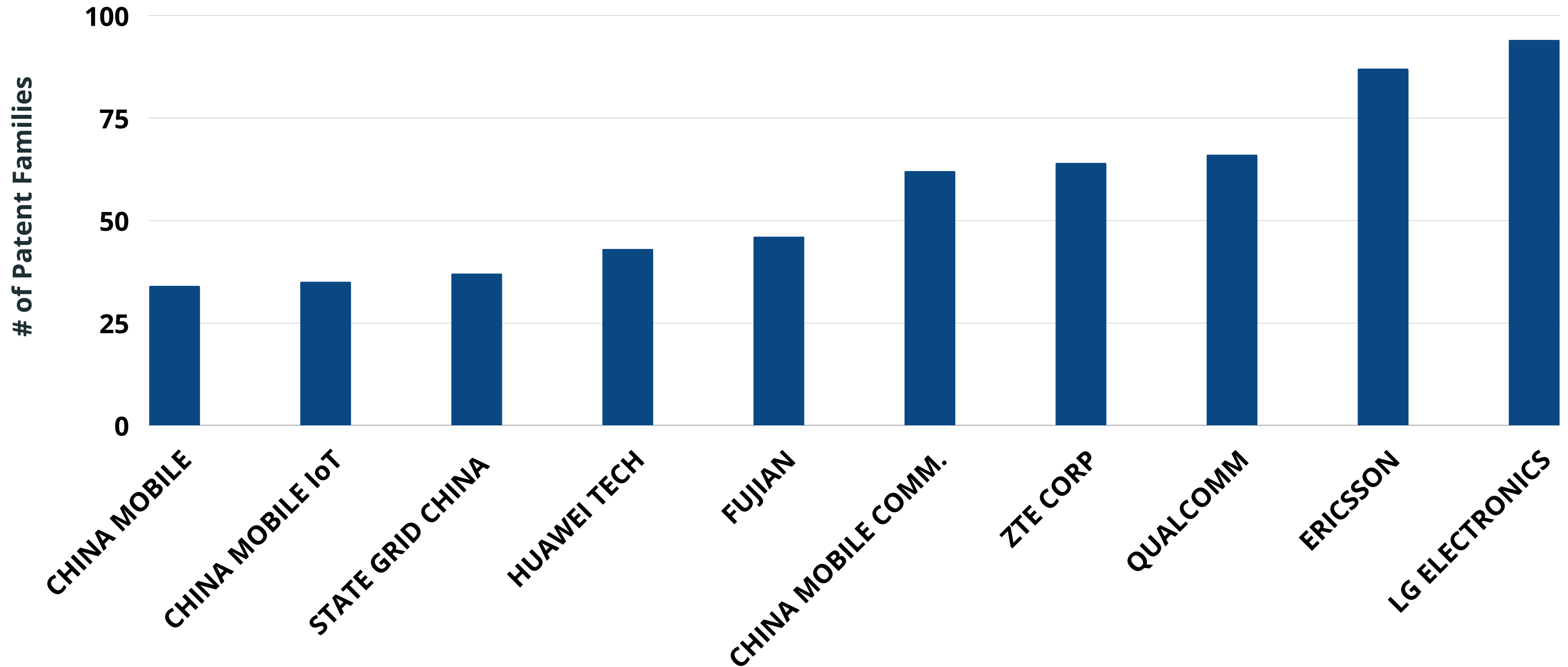


Patent Filing Trend



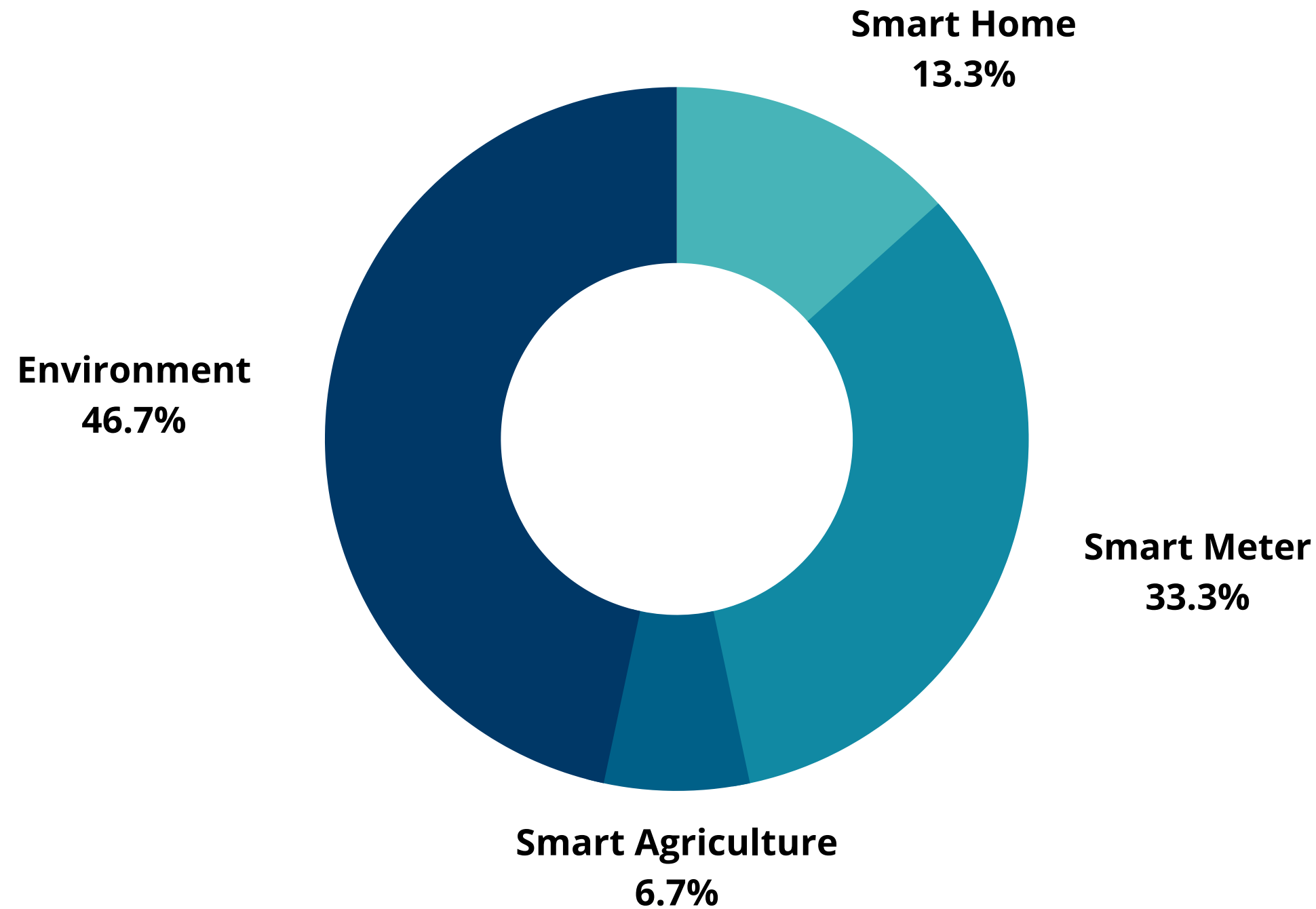
- In 2015 (CN106489246A), Intel proposed the downlink control channel of Narrow Band Internet of things.
- Motorola announced narrowband audio transmission in 2015 (DE112015002051T5).
- The patent filing breakthrough in the field of NB-IoT was first brought by HUMAX in 2016 when they proposed a machine type communication for NB-IoT.
- In the field of NB-IoT, China has been the global leader in patent filing, accounting for over 79 % of all patent filings.
- Most patents were filed in the year 2018 and 2019 in the field of Narrow Band Internet of things (NB-IoT).

Top Patent Assignees



- LG, ERICSSON, ZTE, QUALCOMM, FUJIAN, HUAWEI, NOKIA, CHINA MOBILE are the global leaders in filing patents for NB-IoT.
- Over 60% of the total patents are filed by QUALCOMM, LG, ZTE and ERICSSON.
- LG has filed the most patents for NB-IoT however, Ericsson holds the most rights for NB-IoT patents currently.

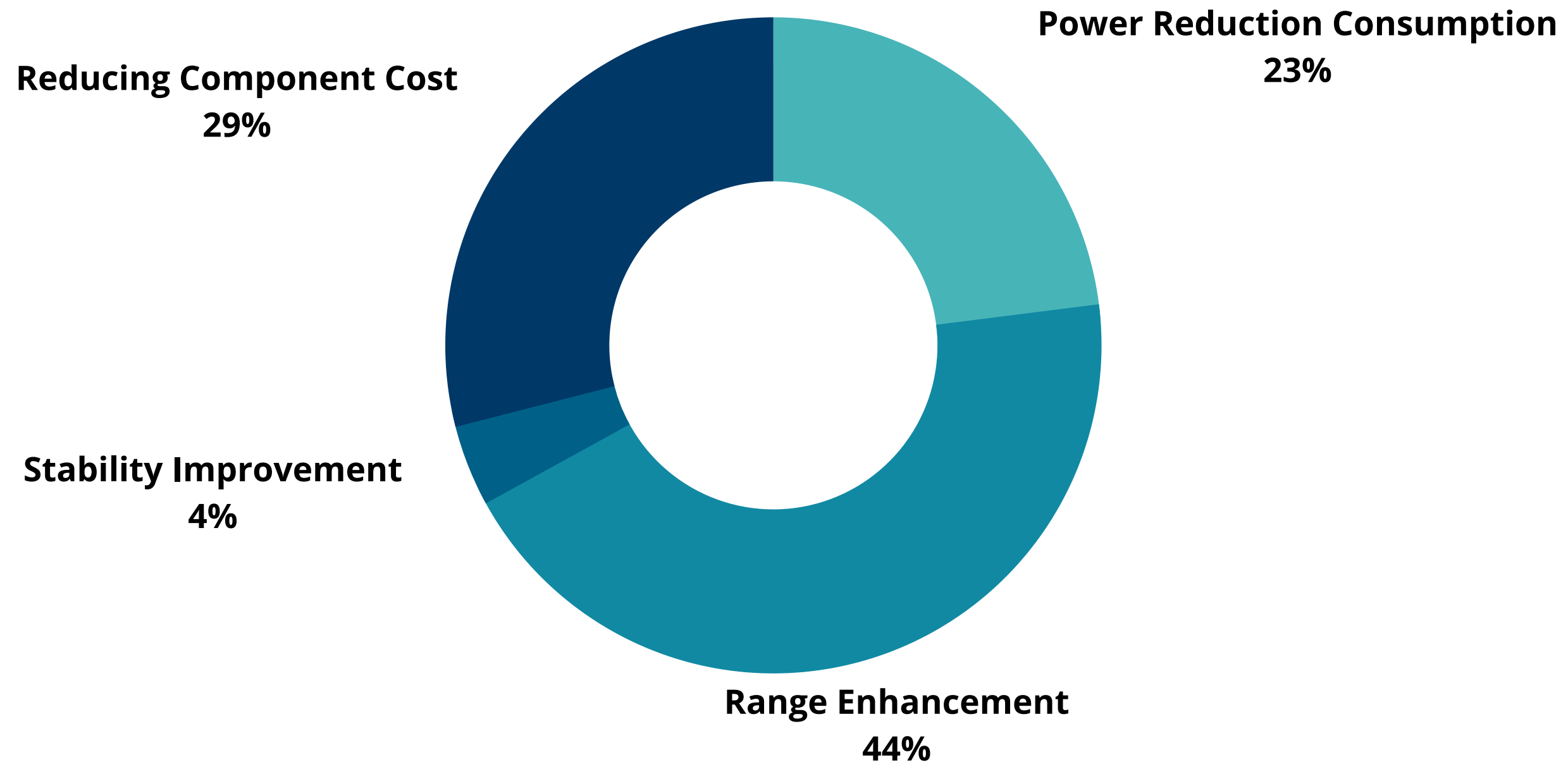
Major Application Areas in NB-IoT



- Major application areas of NB-IoT include smart home, smart metering systems, smart agriculture and smart environment sensing.
- Most patents on NB-IoT based applications for smart home appliances and smart cities were filed in 2018.
- Most patents on NB-IoT based applications for smart environment monitoring were filed in 2019.

- Most patents on NB-IoT based applications for smart metering were filed in 2018.
- Most patents on NB-IoT based applications for smart agriculture and cattle monitoring were filed in 2017.

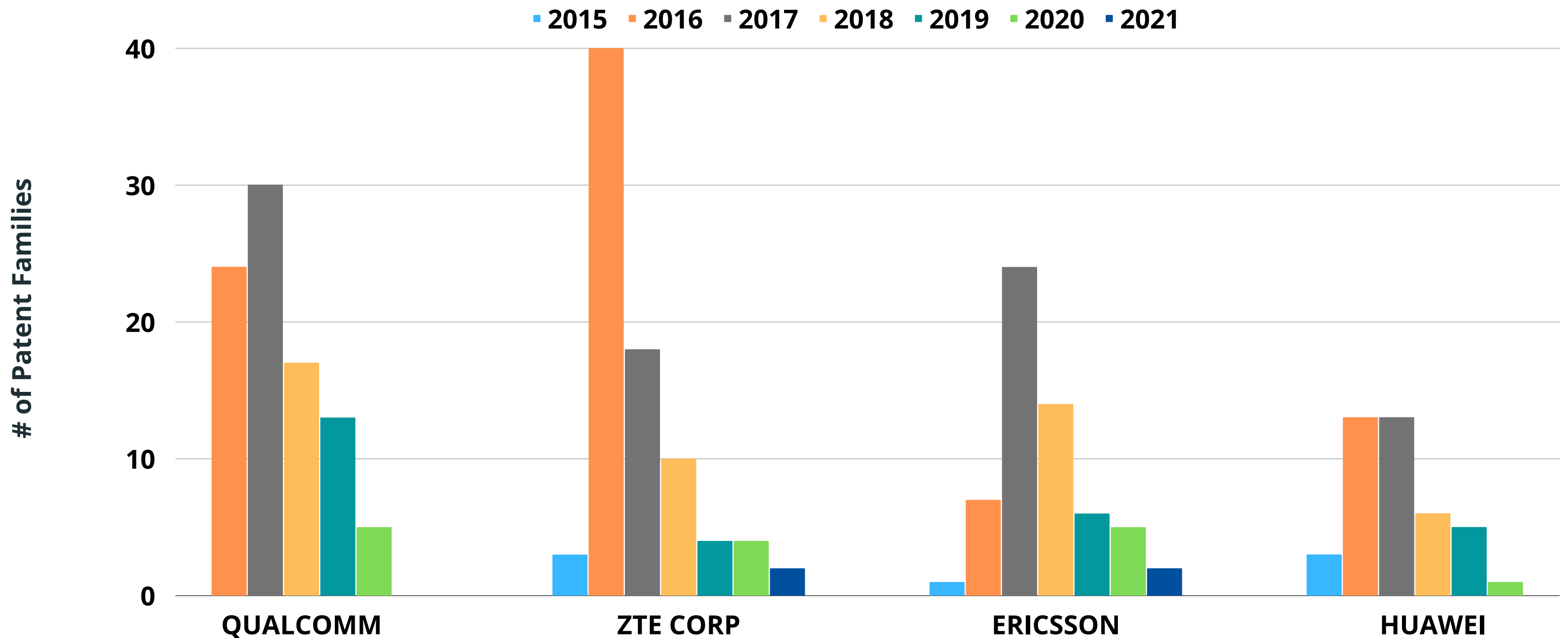
Development Areas in NB-IoT



- The major development areas in NB-IoT are power usage optimization, transmission range enhancement, improving network stability and reliability in terms of communication & architecture and reduction in component cost. Major focus is on range enhancement and reducing component cost.
- Most patents on power optimization of NB-IoT devices were filed in 2017.

- Most patents filed for component cost reduction of NB-IoT devices were filed in 2018.
- Most patents on Network Stability of NB-IoT devices were filed in 2018.

Filing Trend of Top Organizations Working in NB-IOT



Top 5 Startups Working in NB-IoT Domain



Hong Kong-based startup **Symphony** uses vibration sensors and cloud-based data analytics to enable predictive maintenance. The startup's magnetically attached plug and play (PnP) solution detects machinery faults, thereby decreasing downtime. The solution helps manufacturers and managers enhance machinery lifecycle management, boosting production and reducing capital cost.

Australian startup **EQUIPRISE** builds a connected equipment ecosystem for performance monitoring and machine control. The startup applies cloud computing, artificial intelligence and IoT solutions to define equipment performance metrics and design custom edge devices. The solution helps manufacturers to enhance machinery lifecycle management, boosting production and reducing capital cost.





·Estonian startup **IoTized** specializes in IoT connectivity solutions for digital transformation within industry. Through NB-IoT, applications such as wearables and smart parking, which rely on IoT and IIoT devices, benefit in terms of indoor data coverage, cost-efficiency, low-power consumption, and low connection latency.

Turkish startup **Smart Soil** develops IoT sensors that monitor weather, soil, and temperature conditions for agricultural applications. By monitoring leaf wetness and plant growth, the startup's solutions control plant health and susceptibility to disease. As a result, Smart Soil ensures better land utilization and crop yield.



Smartsoil



Indian startup **CLODPILABS** develops products in low power long range sensor data network communication, using technologies like LoRaWAN and NB-IoT. Their products include parking sensors, GPS tracker on NB-IoT technology, ClodPi Pro Hotspot and many more.

What Industry Leaders are Saying?



The organization is making 5G happen and Enhanced Mobile Broadband (eMBB) will be the first 5G business case, so that service providers can cope up with data traffic doubling in every 18 months. 5G will also bring in new capabilities in low latency and long battery life.

— **Mr. Borje Ekholm, CEO, ERICSSON**

It's been incredible to see the Qualcomm Smart Cities Accelerator Program grow to more than 300 global ecosystem members across multiple domains since its 2019 launch. Due to the requirements of the digital age, what we thought would take five years to achieve has expanded in months. The organization has been able to support the deployment of end-to-end solutions across vital sectors, including use cases across education, healthcare, and logistics using NB-IoT.

— **Mr. Sanjeet Pandit, Head of IoT Department , Qualcomm**



Quick Summary & Conclusion



Chinese and Koreans were the first to propose NB-IoT and it was developed to address high power consumption and frequency spectrum loss. NB-IoT brings several advantages over its competitors such as low power consumption, excellent range in buildings and underground, easy deployment into existing cellular network architecture, higher network security & reliability, lower cost. NB-IoT can be deployed in a wide range of applications, including healthcare, logistics, household appliances, metering systems, and many others.

NB-IoT was first introduced by 3GPP Release 13 as a competitor to unlicensed SigFox and LoRa narrowband technologies and was later improved in following releases. Number of leading organizations developed NB-IoT designed chipsets that were used in used in MODEMS, SIM modules and development kits.

In terms of patent activity, the majority of the patents applications were filed by QUALCOMM, LG, ZTE and ERICSSON in major applications such as smart appliances, smart metering systems, smart agriculture and livestock monitoring. Major objective was on the range enhancement and reducing component cost.

Currently, the application of NB-IoT in smart energy meters is being researched, with the goal of providing real-time insights to manage different aspects of an energy network. Also, integrating machine learning (ML) and allowing it to operate over Narrow Band IoT (NB-IoT) and LoRaWAN networks are driving innovation in water monitoring devices.

Although NB-IoT is not yet widely deployed, we may see more devices and applications in the future that require wireless transmission over a longer range at a cheap cost and with little power for long battery life, for which NB-IoT adoption is vital.



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