Beecham Research White Paper

NB-IoT: Enabling the Next Billion Connected Devices.

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Introduction.

The Internet of Things (IoT) is a rapidly developing market, involving connecting devices to the Internet to utilise the data they create. Forecasts indicate billions of connected devices within the next few years. So where are they and how are they being connected?

NB-IoT (which stands for Narrowband IoT) is a new cellular technology – part of the group of technologies known as Low Power Wide Area (LPWA) – that is now beginning to be launched by Mobile Operators worldwide. Its rollout will gather pace over the next year and with it comes opportunities to implement many IoT applications that have not been feasible before. This is because it offers low data (narrowband) rates at low power over long distances. Low power consumption is achieved by much simpler silicon in the device electronics with fewer components and this results in lower costs, adding to the appeal of NB-IoT for customers. It is also optimised for stationary or slow-moving applications, so in this respect different to all previous cellular technologies used for IoT connectivity which assume high mobility. NB-IoT offers superior Indoor and In Ground connectivity compared with existing cellular technologies, enabling many applications that have not been viable before.

With that timing in mind, Application Developers and Hardware Designers need to start thinking now about building for this new form of connectivity – it will literally be everywhere within the normal product development cycle time. Since its launch at MWC 2018, MVNO 1NCE (1nce.com) is establishing itself as an expert in low bandwidth connectivity, including NB-IoT as this technology rolls out and is already putting together a supporting eco-system for NB-IoT deployments. The 1NCE offer of €10 paid once for 10 years of connectivity opens-up a whole new way of thinking about how cellular connectivity payment can be made as simple as possible for the many narrowband applications that have yet to be connected.

Enabling new applications.

There are many more 'things' in the world that are stationary or not in constant motion than those that are moving. The vast majority of the many billions of stationary things that have the ability to create data are nevertheless not connected to the Internet. As a result, that data is lost and not converted into useful information having value and can therefore generate revenue, however small. The main reason why these many stationary things have not been connected is essentially down to cost versus the perceived benefit.

This is what NB-IoT and other LPWA technologies have been designed to address. As a result, the many billions of connected things that are often predicted for IoT are most likely to come from LPWA technologies in general, and NB-IoT in particular.

To get an idea of the breadth of applications enabled by NB-IoT, they can be characterised as either **Urban, Rural** or **Indoor/In Ground**, as illustrated in **Figure 1** (over).

Figure 1. Examples of NB-IoT applications in Urban, Rural and Indoor/In Ground locations.

Urban Includes applications such as street lighting, smart parking, waste collection, car/bike sharing services and air quality monitoring. These are typically stationary applications for monitoring purposes but assets being monitored may be changing location occasionally, or in the case of car or bike sharing, changing location frequently but stationary when these assets need to be located for a new share. These are all low data rate applications that are remotely located and where local power sources may not be easily accessible, making long battery life an important feature. **Figure 2** use cases provides more detail on some of these.

Rural Includes applications like crop water management for agriculture, farm equipment monitoring, tank monitoring, water leak detection. These are also all low data rate applications, usually far from any power source making long battery life essential and long range essential.

Indoor/In Ground Includes such diverse applications as home energy management, home security, vending machine management, commercial building space utilisation, personal health monitoring, vulnerable person fall monitoring and utility meter reading. NB-IoT has particularly good Indoor and In Ground coverage capabilities, making it very suitable for smart meters in basements, underground pipe leak detection for gas or water and other similar applications.

Figure 2. NB-IoT Example Use Cases Showing Connectivity Attributes and Benefits

Industry Vertical	App. & Description	Core Benefit	Benefits of Using NB-IoT
Water Utility & Industrial.	**Leak Detection.** Remote monitoring of pipelines for detection of leaks.	Real time alarm for operational response.	Superior Indoor and In Ground performance and long battery life.
Smart Meter.	**Electric/Water/Gas Metering.** Remote monitoring of usage for billing and resource management purposes.	Accurate and timely billing. Supply/demand optimisation	Superior Indoor & In Ground performance. Autonomy from power supply for gas & water applications where required.
Smart City.	**Smart Street Lighting.** Monitor and actively manage urban street lighting to optimise energy usage & maintenance.	Cost savings & safety after hours with proximity sensors to activate lighting in controlled pools.	Coverage in urban areas with option to be independent of lighting supply if required.
Smart City.	**Parking.** Detection of space occupancy using a surface mounted or buried sensor.	Provision of real time data on parking occupancy, optimising usage of spaces.	Long battery life, coverage in dense urban areas, In Ground penetration of signal. Widely available choice of compatible sensors.
Transport/ Logistics.	**Asset Tracking.** In conjunction with sensors detecting temperature and movement of goods such as perishable foods.	Location, status and condition of goods in transit.	Network based location finding with no need for GPS. Long battery life with National and International Coverage.
Environmental.	**Air Quality Monitoring.** Monitoring emissions of CO2, NO2 and other air pollutants.	More accurate reporting.	Low cost and reliable environmental monitoring in urban and rural locations. Supported by a growing range of compatible sensors.
Industrial/ Agricultural.	**Tank Monitoring.** Real time monitoring of fluid levels in tanks for utility, petro-chemical and agricultural applications.	Optimisation of stocks for refilling, fewer truck rolls required.	Autonomy from mains power with up to 10 years battery life. Widely available and reliable coverage paired with eco-system of monitoring devices.
Transport & Security.	**Transport & Security.** Stolen Vehicle Recovery. SIM and module hidden in the vehicle for independence from other vehicle systems. Vehicle is located using network triangulation, no need for GPS.	Rapid location of vehicle in the event of disconnection from main vehicle supply.	Long battery life with national and international coverage. Lower radio module costs.
Health & Lifesciences.	**Equipment Monitoring.** Remote monitoring of equipment such as transformers in low voltage electricity grid and pumps in water distribution networks.	Changes in temperature and vibration provide warnings of failure.	Indoor coverage and network based location finding.
Buildings.	**Buildings.** Sensors monitor utilisation of space using motion and temperature sensors.	Office building owners and their clients can maximise space utilisation.	Long battery life and Indoor coverage.
Buildings.	**Waste Management** Sensors detect when re-cycling bins reach a level for collecting.	Municipalities & waste management services can be optimised for travel costs.	Low cost modules and long battery life.

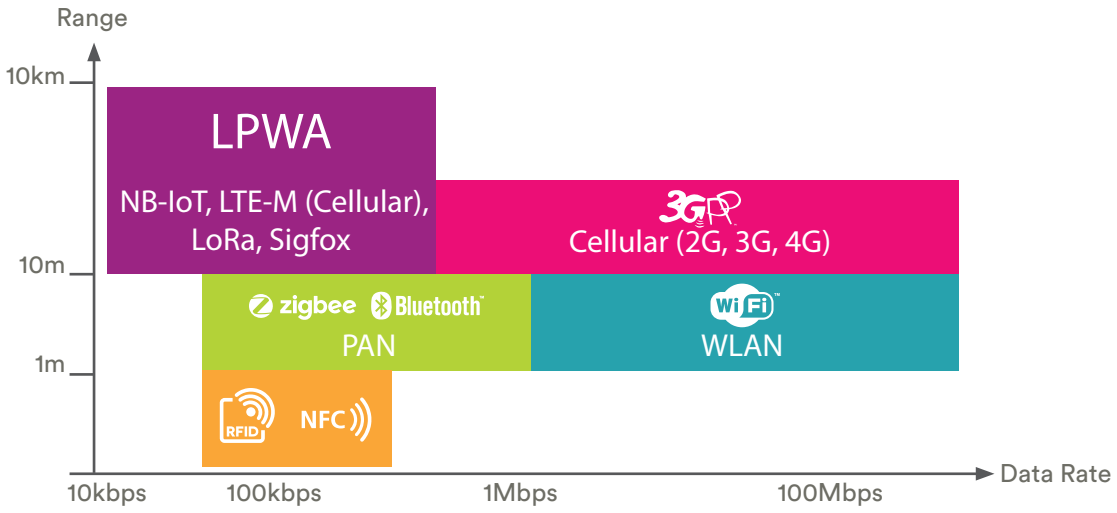
Figure 2 provides more detail on a variety of different applications for NB-IoT, including some of those mentioned above. As well as application descriptions, this identifies core benefits of the applications and why using NB-IoT is a good fit for these. Typical of these benefits are low cost, reliable, 'connect and forget' connectivity with long battery life, superior Indoor/In Ground performance, low latency and with extensive national and international coverage
See **Figure 5**.

These are of course mainly applications that have been identified and talked about before – they are not new. However, the diversity of opportunity offered by NB-IoT will encourage innovative thinking about applications that have not been thought of before, NB-IoT is a pathway to commercially viability.

What is new about NB-IoT?

Low Power Wide Area (LPWA) networks are currently being introduced to the IoT market, designed specifically for low bandwidth, low power IoT applications in wide area environments at low cost. There are two groups of these technologies – those that use unlicensed spectrum (such as LoRa and Sigfox) and those that use licensed spectrum that is cellular-based (such as NB-IoT and LTE-M). Their place in the market compared with other wireless technologies is illustrated in **Figure 3**. As this shows, while at the low-end RFID and NFC technologies have a range of less than 1 meter, Bluetooth, Zigbee and WiFi offer ranges of typically 10 meters and slightly higher, whereas LPWA offers up to 10km range and in some cases well beyond that. Some LPWA technologies have longer range than traditional cellular (2G, 3G and 4G) but generally offering lower data speeds, some offering well below 10kbit/sec as shown in **Figure 3.**

Figure 3. LPWA compared with other connectivity technologies.



The promise of IoT is a future where everything everywhere will be connected. Yet current wireless technologies do not fully meet this need. They either tend to be short range and low cost (such as Bluetooth and WiFi), or alternatively long range at higher cost (such as traditional cellular – 2G, 3G, 4G). What is different about LPWA technologies is the recognition that very large numbers of remote devices that would add value by being connected only need to transmit and receive small amounts of data. In addition, the vast majority of these are nowhere near any power source so need to operate on battery power over long periods. This is what LPWA is designed for – connectivity offering low bandwidth with very low power requirement over long distances.

This enables very low cost compared with other wide area technologies. As a result, LPWA is expected to provide the means for driving mass deployment of connected devices.

There are many products that immediately become more feasible to connect with the introduction of LPWA and this will be particularly attractive to OEMs. The remaining issues are then whether these will use licensed or unlicensed spectrum LPWA connectivity types. For licensed spectrum use, should the choice then be for NB-IoT or LTE-M?

The table in **Figure 4** compares the main licensed and unlicensed spectrum LPWA technologies.

Figure 4. Comparison of LPWA technologies

	NB-IoT	LoRa	Sigfox	LTE-M
Peak Data Rates	250 kbps	50 kbps	100 bps	1000 kbps
Typical Data Rates	75-200 kbps Down; 20-200 kbps Up	5 kbps (adaptive)	100 bps	375 kbps
Transmission Mode	Half Duplex	Half Duplex	Half Duplex	Half or Full Duplex
Typical Module Costs	$5-$10p	$5-$10	$2-$5	$10-$15
Typical Battery Life*	Up to 10 years	Up to 10 years	>10 years	Up to 5 years
Typical Range	1km Urban 10km Rural	5km Urban 20km Rural	10km Urban 40km Rural	1km Urban 10km Rural
Coverage	National & International	76 Network Operators in 43 Countries	Networks in 42 Countries	National & International
Indoor/In Ground Penetration	Very Good	Good	Good	N/A
Mobility	Cell reselection	Cell reselection	Cell reselection	Cell handover
Spectrum Governance	Licensed	Unlicensed	Unlicensed	Licensed

* 2 messages per day at 50 bytes/per message using 5Wh battery

As shown in **Figure 4**, peak data rates for cellular variants NB-IoT and LTE-M are 250 kbps and 1000 kbps respectively, while those for unlicensed variants LoRa and SigFox are lower, at 50 kbps and 100 bps respectively. Battery life varies from up to 5 years for LTE-M to over 10 years for SigFox. Regarding Mobility, only LTE-M caters for cell handover for moving assets while the other technologies rely on cell reselection. Connectivity device costs will decline over the next few years, with NB-IoT being comparable to LoRa, SigFox slightly lower and LTE-M being highest of the four. LTE-M can best be regarded as the natural successor to 2G and some 3G focusing mainly on mobile applications, whereas NB-IoT expands greatly on the ability of cellular networks to cover low data rate, slow moving or stationary applications.

The cellular versions of LPWA have several other advantages. The utilisation of existing cellular networks will see these services rapidly become available in many countries globally wherever 4G networks have been deployed (see **Figure 5** for expected European coverage by 2020). The transmissions are also highly secure and network quality is guaranteed due to being on restricted licensed spectrum. A further factor is that this technology is future proofed to 5G, ensuring it will be around for a long time with a widely established ecosystem with many suppliers.

Where will NB-IoT be available?

Rollout plans are developing quickly. **Figure 5** shows the countries in Europe that are already rolling out NB-IoT or conducting pilots prior to that. This is a constantly-changing situation with frequent updates.

As shown in the figure, there are many more networks committed to NB-IoT than LTE-M in Europe at this time. In addition, those committed to LTE-M are also committed to rolling out NB-IoT. It is clear from this that NB-IoT will become widely available in Europe over the next few years.

Figure 5. Cellular LPWA Technology expected rollouts by 2020 in Europe

NB-IoT

UK	Hungary	Switzerland	Norway
Spain	Greece	Croatia	Sweden
Ireland	Italy	Romania	Denmark
Netherlands	Austria	France	Czech Rep.
Germany	Slovakia	Poland	Finland
Portugal	Slovenia	Belgium	

LTE-M

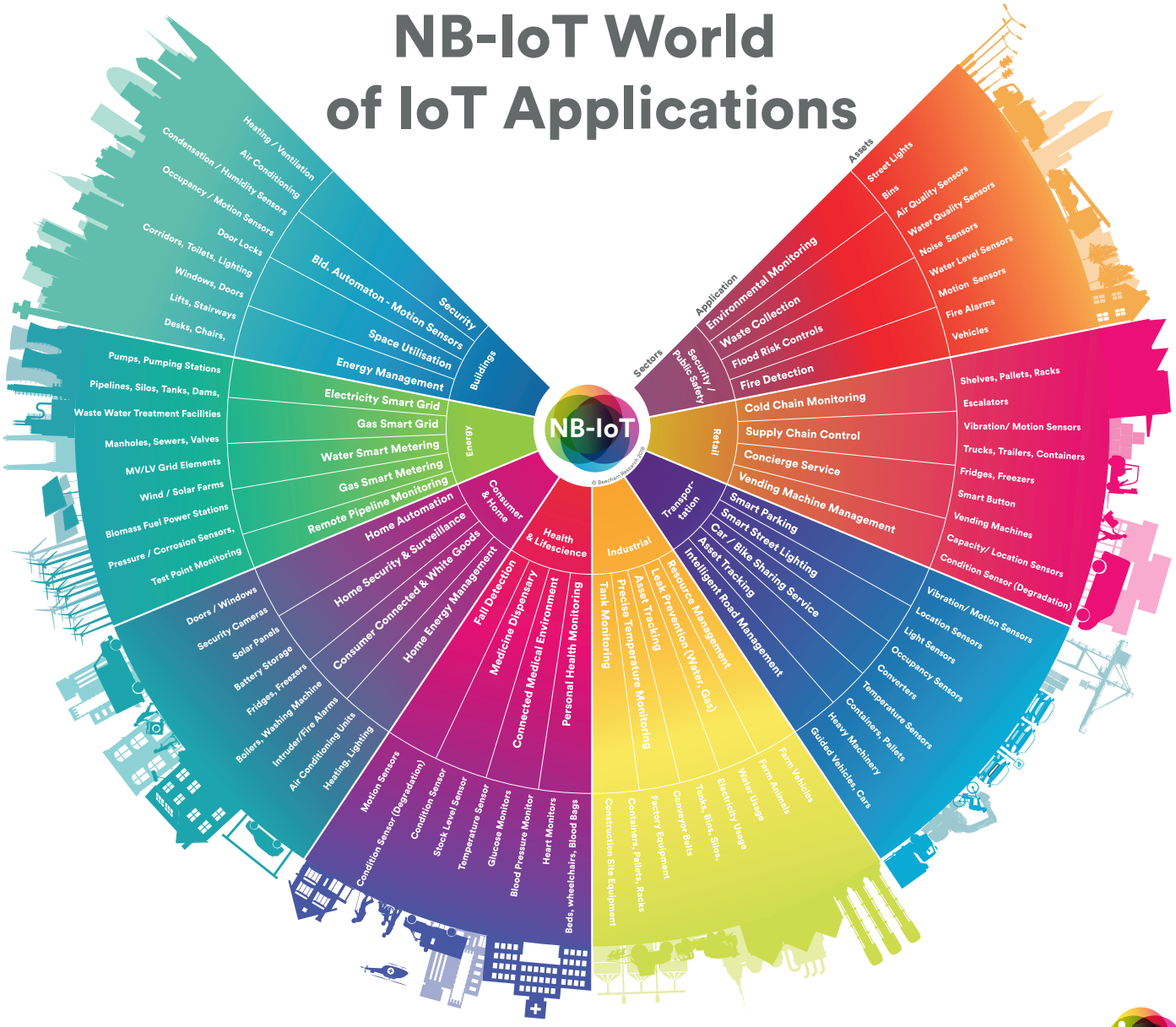
France	Denmark	Switzerland	Belgium
Netherlands			

Country rollout detail is subject to change with frequent updates

NB-IoT: Towards the full story

For each of the 8 sectors included in the chart, several application examples are identified. At the outer edge, over 70 different types of connected assets are also identified and there are many more possibilities. The sheer number of applications for NB-IoT suggests a much greater potential for the total number of connections than those for traditional cellular technologies. Since the beginning of the decade forecasters have predicted global connection volumes in the tens of billions, without specifying where the demand will come from and how this demand will be met.

Figure 6.



Taking just one sector from the NB-IoT Sector Map in **Figure 6**, namely Energy, along with some data from the World Bank suggests there are some 1.5 billion consumer meters connected to the world's electricity grids and many more gas meters and, potentially, water meters. All of them could be connected economically using NB-IoT, although this number is only the tip of the iceberg in terms of connection numbers. As electricity production and consumption becomes more distributed and bi-directional, the need to collect data grows. Connecting disparate sources such as small scale solar and battery storage onto the grid necessitates these devices are also capable of sending and receiving data to optimise their use. Such installations will add hundreds of millions of connections over the next decade, with low cost, reliable connectivity essential. Within every electricity grid sits a hierarchy of Low, Medium and High voltage control equipment such as transformers, switches and of course the power lines themselves. There are millions of these devices in the low and medium voltage grids, few of which are connected. This represents another big opportunity for connectivity using NB-IoT services.

Moving around the Sector Map it is possible to find other sectors and applications where many hundreds of millions of connections could be made, optimising the use of assets and minimising the costs of everything from public street lighting to the use of office space. Other applications ideally suited to narrowband cellular connectivity are connected pallets, smart buttons and environmental sensors. The potential connection numbers for some of these applications on their own is greater than the total number of M2M/IoT connections in use today. These connections only make economic and operational sense with LPWA technology. Cellular networks have of course developed over decades to meet the needs of mobile phones, 2G/3G and 4G technologies evolving to meet the growing demands from users for internet access. The market for high speed data will continue to grow with many IoT applications requiring high data rate technologies but NB-IoT is the first 3GPP standard optimised for connecting stationary and slow-moving things.

1NCE are positioned as experts in this technology, with a simple and compelling commercial offer, supported by a fully automated order and provisioning system. For customers looking to connect their assets costs effectively, 1NCE provide a connectivity service tailored to their needs.

Beecham Research is a leading technology market research, analysis and consulting firm established in 1991. We have specialized in the development of the rapidly-growing Connected Devices market, often referred to as M2M and IoT, worldwide since 2001. We are internationally recognised as thought leaders in this market and have deep knowledge of the market dynamics at every level in the value chain.

Our clients include component and hardware vendors, major network/connectivity suppliers, system integrators, application developers, distributors and enterprise users in both B2B and B2C markets.

We are experts in M2M/IoT services and platforms and also in IoT solution security, where we have extensive technical knowledge.

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