NB-IOT

The choice for NB-IOT as additional LPWAN protocol and the opportunities it creates for Sensolus customers.

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Introduction

In recent years a steady growth of the number of connected devices has been observed in the industry. In 2020 the worldwide Industrial Internet of Things (IIOT) market size is estimated to have been around 77 billion U.S. dollar (Statista[1], 2021), the foreseen growth in 2021 was slower than expected due to the worldwide COVID-19 crisis, but in 2022 a faster take-up is foreseen. Although the IOT market has been growing now for more than 15 years, and we could think it's not really a new thing anymore, there are still challenges and obstacles that ask for new inventions and innovations in the market.

In line with the growth of IOT roll-out in the industry, the **diversity of IOT use cases grows**. In order to fulfill the customer requests often a **diversity of technologies needs to be used or combined**. We are thinking of use cases that need tracking of assets deep indoor, in remote rural areas, asset tracking which needs worldwide coverage, the need for an extreme long battery lifetime of a location tracking device, the importance of data reliability, or the importance of security and privacy.

At Sensolus we closely monitor the technical trends and we always pursue to stay the best in offering tracking solutions for non-powered assets that travel around by using internet-of-thing networks that provide communication over long distance.

Sensolus is known for its delivery of end-to-end solutions. This means we provide (1) the applications for optimization of industrial processes and management of devices, (2) an IOT cloud platform that stores and processes the data, (3) the subscriptions to the communication networks and (4) the hardware devices with edge intelligence that are attached to the assets in the field. Although Sensolus develops its own devices, also devices and sensors from other providers can easily be connected to the cloud platform. The same counts for the network communication technologies and protocols we use.

Sensolus was one of the first to provide a solution for asset tracking using the LPWAN protocol Sigfox. Low-power, low-data rate communication over long distances together with a wireless tracking device that lasts up till 10 years without battery replacements is the strength of our solution. But we didn't stop there, we always look at new technologies, protocols and inventions that could fulfill the needs of new use cases, in new geographical areas, at an optimal price with the best user experience possible.

Different use cases can require usage of different technologies. And sometimes only combining different technologies can solve the problems. For example for location

[1] Statista (2021). Share of LPWA connections worldwide in the first half of 2020 and 2025, by technology. Original source: IoT Analytics; ID 1244778

tracking of non-powered assets inside a factory hall and while travelling outside, we combine Wi-Fi signals for indoor and GPS signals for outdoor location detection.

Sensolus can combine different communication network technologies and location tracking technologies at the back end of the system, but always with the goal to provide a seamless and unified user experience on top.

The low-power wide-area (LPWAN) network technologies are specialized in providing highly energy efficient solutions. They are specifically designed for combining very energy-efficient devices with wide transmission ranges. Until now Sensolus selected **Sigfox** as the LPWAN for their devices as Sigfox was, compared to the main competitor LoRaWAN, from the start the most energy efficient public network that existed in the IOT world. Nowadays we see a highly **fragmented LPWAN market whereby 16 LPWAN technologies are currently deployed** (see Figure 1). LoRaWAN is still the market leader. But a fast growth of NB-IOT is now seen and a surpass of LoRaWAN by NB-IOT is foreseen in the next months.

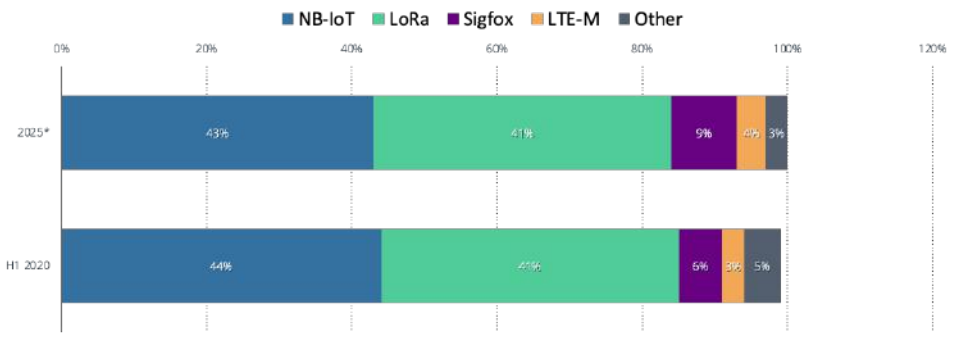

Figure 1: Share of LPWA connections worldwide in the first half of 2020 and 2025, by technology (source: Statista[2], 2021)

With the initial goals in mind, being to be able to provide solutions to more markets, to solve use-cases of more companies, in more countries Sensolus decided to launch a new tracking device using another low-power communication network. We choose the network communication protocol NB-IOT to reach these goals. With NB-IOT we believe that we can provide **the same or longer battery lifetime and a better user experience covering more challenging use cases and new geographical areas** .

[2] Statista (2021). Share of LPWA connections worldwide in the first half of 2020 and 2025, by technology. Original source: IoT Analytics; ID 1244778

Introduction to NB-IOT

What is NB-IOT

Narrowband Internet of Things (NB-IOT) is a low-power wide-area network (LPWAN) radio technology standard developed by 3GPP3 for cellular devices and services and is a subset of the LTE standard. NB-IOT is optimized for low-power IOT communications. China is the country with the largest NB-IOT deployments so far.

NB-IOT uses a single 200 KHz frequency band, which corresponds to one resource block in GSM and LTE transmission. NB-IOT can be deployed in three ways: in stand-alone operation by utilizing any available spectrum, in guard band operation utilizing the resource blocks within an LTE carrier's guard band and in-band operation utilizing resource blocks within a normal LTE carrier (see figure 2). The NB-IoT technology operates using resource blocks on existing LTE networks or in the LTE carrier's guard bands. It can also operate using unused 200 KHz bands that were previously used by GSM. It is also suitable for the re-farming of GSM spectrum.

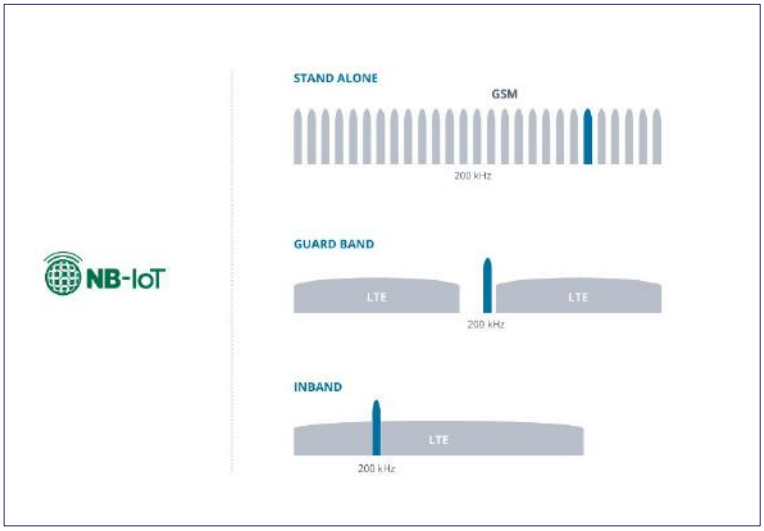

Figure 2: NB-IOT network spectrum

The overall technical specifications of NB-OT (also called LTE Cat-NB1) are listed in Table 1. The detailed protocol specifications can be read in the ETSI document on this release[4] .

Features	**LTE Cat-NB1**
3GPP Release	Rel.13, 2016

[3] 3GPP is the abbreviation of 3rd Generation Partnership project and is an umbrella term for a number of standards organizations which develop protocols for mobile telecommunications.

[4] https://www.etsi.org/deliver/etsi_ts/136300_136399/136331/13.02.00_60/ts_136331v130200p.pdf

Channel bandwidth	180 kHz
Duplex mode	Half
Transmit power	20,23 dBm
Downlink rate	~26kbps
Uplink rate	~62kbps
Latency	<10s
Voice/data	Data
Positioning	Cell ID
Cell capacity	200,00
Max. range	15 km (depends on a lot of factors)
Battery life	10-15 years (depending on use case)
Mobility	Limited/Idle

Table 1: Specifications of NB-IOT release 13

Roaming agreements

One of the reasons why it takes longer than expected to see asset tracking solutions on NB-IOT is the delay in roaming agreements between telecom providers. Since a lot of IOT applications are static applications (e.g., smart metering, smart parking spots) the negotiation of roaming agreements has long not been prioritized between telecom providers. Fortunately, providers are getting up to speed with roaming agreements and Sensolus believes this is on the right track in going from country level to regional and eventually worldwide roaming coverage.

Why did Sensolus choose NB-IOT?

Following IOT Analytics we see that, already in 2020, 44% of the global LPWAN connections is using NB-IOT technology. This is the biggest share of the connections, followed by 41% by LoRaWAN, 6% Sigfox and 3% LTE-M. Over the years they expect a growth of Sigfox towards 9%, so for sure our existing technology is future proof.

But why did Sensolus decide this is the right moment to launch a tracking solution using the NB-IOT communication network?

Important reasons why Sensolus decided to develop a tracker communicating over the NB-IOT network and to not only stick to Sigfox:

- The Sigfox network is still growing, but at a slower pace. This means the usage of another communication protocol for asset tracking is needed in areas where no Sigfox coverage is available. The NB-IOT rollout has also been slow but is backed by big telecom players which have the money to see it through till the end.
- Some important geographies for Sensolus customers are covered by Sigfox, but only very minimal, and it looks like they will never become fully covered.
- Sigfox is a proprietary standard, while NB-IOT is an open standard, making it easier and cheaper to build on this technology.

Enough reasons to extend our Sigfox portfolio with the NB-IOT technology.

A question that sometimes comes up, is **why Sensolus chooses NB-IOT above the other cellular system for IIOT, namely LTE-M** (Long Term Evolution for Machines) as an alternative network protocol to build their solution upon? LTE-M is another LPWAN radio technology standard developed by 3GPP.

It certainly has some advantages at first sight compared to NB-IOT. It supports higher data rates and seamless handovers between cell towers.

From a deployment perspective it is cheap to roll-out where LTE is already available and typically roaming agreements extend from already existing LTE roaming agreements.

However, for the use cases we target the absolute best battery performance and lowest cost are the two key drivers. In both those domains we see that NB-IOT has the edge.

For general background information on the different LPWAN networks we present the differences between the most important LPWAN technologies in Table 2

Technical data	**Sigfox**	**NB-IOT**	**LTE-M**	**LoRaWAN**
Technology	Proprietary	Open standards	Open standards	Proprietary
Public or private	Public	Public	Public	Private/public
Low or high bandwidth	Low	Low	Moderate to high	Low
Licensed or unlicensed spectrum	Unlicensed	Licensed	Licensed	Unlicensed

Roaming agreements in place	Yes	Discussions ongoing (getting up to speed)	Yes	Typical application is private
Max data rate (gross)	0,1 kbit/s	27 kbits/s	1Mbit/s	5,47 kbits/s (SF7)
Max. payload length (data per message)	12 B	>1000 B	>1000 B	51B(EU)/11B(US)
Downlink capacity	Very low	Unlimited	Unlimited	Very low
Latency	30s	1.6-10s	10-15 ms	1-16s
Voice/data	Data	Data	Voice & data	Data

Table 2: Wireless LPWAN technologies and their characteristics

NB-IOT and Sigfox for asset tracking?

Various sources mention that NB-IOT and Sigfox are no suitable protocols for location tracking of assets, and certainly not for assets travelling between different countries. The main reason for this claim is that the technologies cannot be used for fast moving assets (distortion of the wireless link). But we think this is not necessarily the case (and not only because it is our business).

Although Sigfox is used for smart metering, smart car parks, building monitoring and more, the biggest number of Sigfox connections are now used for asset tracking. Of course, certain obstacles had to be tackled before it worked properly, for example data integrity (a patented technology by Sensolus) and the most important one: **the mind-set on what 'asset tracking' of non-powered assets means**.

First, our customers learned us that **asset tracking is not per definition tracking of assets with an update rate of one position per second.** It is about delivering the relevant business insights at the right moment to the customer, There is no need to provide a real-time navigation experience as on Google Maps. It is about providing the location information that is needed to optimize the supply chain, and this in fact never requires an update rate of one per second.

Second, by now we know that **real-time is not always important for asset tracking**. For a lot of use cases customers are only looking one or two times a day to their asset fleet, so the real-time aspect of data transmission is not needed. Almost real-time is

just as good, or data can even arrive later if the data recovery algorithm is used, and then the Sigfox or NB-IOT networks are perfectly suitable.

Third, worldwide asset tracking is most often not needed. Very few assets are travelling over different continents all the time, so **no need for tracking devices with global coverage for all use cases**. A lot of assets circulate in the same loop all the time, between the same factory halls, warehouses or between supplier and customer and then back to the first location. This means we know very well where we need to have good network coverage to provide the optimal experience to the customer. So, no need for a wireless network technology that has worldwide coverage, but just the best coverage for the use case is needed.

Which asset tracking use cases? Which technologies?

Having explained why NB-IOT and Sigfox are good networks for most of the asset tracking use cases, we will explain the decision process related to network technology we select when proposing a solution to the customer.

Sensolus always aims at **finding the optimal balance between guaranteeing a long battery lifetime and gathering the necessary data at the best update rate to provide the insights needed for the assets**. The selection of the tracking device therefore depends on the **following characteristics** of the use case.

The first and most important criteria **is the country that assets are travelling in**, or the different countries the assets are travelling through. Some countries are only covered by Sigfox, some only by NB-IOT, some by both networks. Sensolus will always propose the tracking devices that are covered by the network of the use case. Sensolus looks to collaborate with different telecom providers for providing NB-IOT communication. Both the Sigfox and the NB-IOT network are still growing, due to roll-out in new countries or due to new roaming agreements. Currently Sensolus defined the following geographical areas covered with Sigfox and/or NB-IOT as depicted in Figure 3.

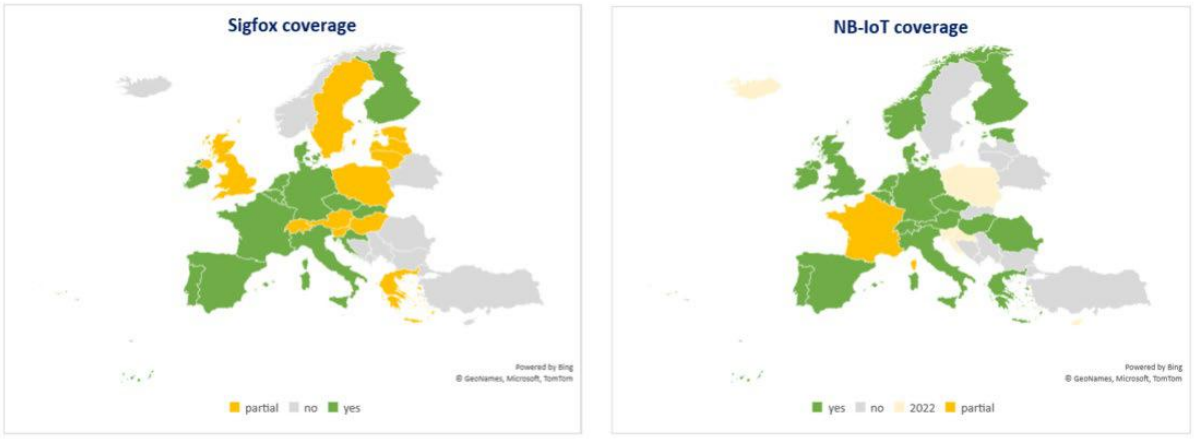

Figure 3: Sigfox and NB-IOT coverage maps

We can state that the further rollout of the Sigfox network is going slower than some years ago. The advantage of the NB-IOT network is that it is based on the 3GPTT LTE industry standard, and it can run on the same base station equipment currently used for the existing LTE network infrastructure. This means **the further rollout of NB-IOT can go much faster than the rollout of the Sigfox network,** as here the network infrastructure must be newly installed, and is most often not done by big telecom players. This means it will always take more time to cover a new area with Sigfox than with NB-IOT network infrastructure.

If the use-case takes place in a geographical area covered by Sigfox and NB-IOT Sensolus will take a closer look at the use-case to define which tracking device will provide the best experience.

We will discuss the following use case characteristics that will influence the decision we take to present a Sigfox or NB-IOT based solution:

- Deep indoor needs of use cases
- Assets travelling in closed or open loops
- Assets travelling on or often crossing country borders
- The importance of knowing the live locations of assets while they are travelling
- Tracker positioning on the asset and spreading of assets

Deep indoor use cases

Sigfox is known to be good at transmitting messages sent out by trackers under specific conditions like being **in basements or other deep indoor environments**. The level of reliability of message transmission is high and the transmission distance is

also high for devices using the Sigfox network for sending out messages to the internet. But because it communicates in an unlicensed band noise and interference can reduce the range, especially in dense urban environments.

NB-IOT performs even better in basements and indoor environments, because of its higher link budget (wireless sensitivity) and the use of the licensed band. On the negative side, compared to Sigfox the power consumption is in this case more unpredictable, while constant for a Sigfox message an NB-IOT message will autonomously compensate for the bad coverage by increasing transmission time (repetitions).

Assets travelling in open or closed loops

Optimizing the supply chain by tracking assets, or parts of assets over the supply chain is an important application of IIOT. Assets like returnable transport packages or manufacturing parts often travel from the factory hall of a supplier to another supplier or to the final producer of the product. Once delivered, the empty package travels back to the initial supplier. In such a case the **assets are travelling in closed loops** that are always the same. In areas **where no full coverage of Sigfox or NB-IOT is available** we have experienced that using the Sigfox network is often the best solution. This is because Sigfox remains a very cost-effective choice in places where the use case is a full closed loop because even without full coverage, the installation of local base stations can fill the coverage gaps. Installing one or more **local Sigfox base stations** is something that Sensolus can do, which is not the case for the installation of NB-IOT gateways.

If assets are travelling in half-open or open loops, which means that the location the assets are travelling to are not all known in advance, or are not always the same, then the most important selection criteria is the available coverage in the area the assets will be travelling.

Assets travelling on or often crossing country borders

The geographical location of the tracked assets, and the travel pattern of the assets are the most important criterion for selecting the communication network used. But if both networks are available another geographical criterion will be considered: **the proximity of national borders or the number of times an object must travel across national borders.** If assets are often crossing borders or reside in proximity of national borders, we will prefer the Sigfox network as communication protocol.

This is due to the technical implementation of the hand-over between network providers, which happens in a different way between the Sigfox and the NB-IOT

network and has a different impact on the battery consumption of the tracking device.

Sigfox uses Fire-and-Forget way of communicating, which means that the chance a message arrives is not guaranteed, but the tracker also does not have to listen until the proof of arrival arrives. Which means it can directly enter sleep mode, making the **battery lifetime predictable**.

The **NB-IOT** device will need to find a suitable cell tower in order to transmit its message. If the previous cell tower is found, the transmit happens efficiently. When a new tower is required, the device needs to reregister to that new tower. Depending on the configuration of the tower this can take some time, certainly if it needs to switch provider e.g., during a border crossing. Since the time taken is unpredictable it is **difficult to predict the energy consumption**. Sensolus has developed ways to reduce the amount of time the NB-IOT spends on network searching, but even then Sigfox still is the most battery efficient solution for use cases where assets are often crossing borders.

The importance of live location updates while travelling

Sometimes customers want to get live updates of the locations of their attest while they are travelling. With Sigfox, messages which are transmitted when an asset is moving fast will typically get lost. That is why our Sigfox devices always wait until the asset stops before any transmission will be attempted. In practice we see that for most logistics processes trucks will have a few stops as they reach their destination, so there will be an indication the destination is reached. But the messages will not follow a predictable periodic pattern.

On the NB-IOT side that limitation is not present, and transmissions are not blocked by the asset moving. The messages sent by the NB-IOT device to the cloud arrive some (milli)seconds later.

In both cases the devices will buffer and store messages until it receives confirmation by the cloud that they have correctly been processed. On Sigfox the system can check daily at most whether that transmission is complete, and this happens driven by a timer. With NB-IOT there are no constrains on the cloud to device communication and we will check on every stop if all messages are transmitted. Any message gaps will be restored much faster with NB-IOT.

Tracker positioning on the asset and spreading of assets

Typically for IIOT devices is that the intelligence is spread between the device and the cloud side. Some operations are executed on the device itself (firmware or sometimes referred to as 'edge computing'), some on cloud. It is carefully considered where an operation is carried out. The main tradeoff in this case is to reduce the amount of transmitted data. If a lot of computing power is required, it is more likely to be executed on the cloud side. If its computationally feasible, it can be beneficial to compute or reduce the collected data on the edge side.

As with all software, it is never finished. New feature ideas come up. And of course, there is the possibility of a defect in the firmware. Changing software on the cloud side is very simple. However, on the firmware of the asset tracker it is a lot more difficult to solve. Especially on Sigfox, with its very low uplink capacity, it is impossible to do a full firmware update over the air. Any firmware upgrade must be done over Bluetooth from a terminal which is near the device. From a practical perspective this is a complex logistics operation when assets are spread out in the field.

Because of the higher uplink bandwidth with NB-IOT it is possible to initiate remote firmware upgrades, called 'FOTA' (Firmware over the Air). Doing a FOTA will cost a bit of battery power but as this is a rare operation it shouldn't be considered an issue. This is a clear advantage of our NB-IOT tracking devices that are attached to assets on difficult to access assets, like assets that are spread at different locations or are difficult to physically access by a person.

A summary of the use case characteristics that influence the selection of the Sigfox or NB-IOT network and trackers is described in Table 3.

	Sigfox	NB-IOT
Deep indoor use cases		V
Use case where asset moves a lot between different countries	V	
Use case where assets are located on borders between countries	V	
Use cases where live updates while travelling are needed		V

Use cases where trackers are built into assets that are not very accessible (OTA firmware upgrades)		V
Use case where the asset moves in fully close loops in not so well covered Sigfox area (but local base stations can be installed)	V	

Conclusion

Sensolus' decision to design and develop a new tracking device using the NB-IOT network is the outcome of a well-considered strategy. The growth of the IIOT market comes with numerous new use cases and new requirements of which the extension of geographical areas for tracking of non-powered assets is the most important one.

As the growth of the Sigfox network is slowing down, Sensolus decided to add a tracker to its portfolio which covers areas not covered before. We chose NB-IOT as it provides the best battery life / cost tradeoff at this point.

In the paper we also explained why Sigfox and NB-IOT are protocols that are suitable for tracking of moving non-powered assets. Here the change in the mental model of geo localization and a better definition of customer needs are of high importance. In the final part of the paper, we described how at Sensolus we decide to present a Sigfox-based or an NB-IOT-based solution to the customer. Here the location of the assets (deep indoor, non-accessible for humans), the travelling behavior of the assets (in one country or between countries, in closed or open loops) and use case needs (delivery time) are the most important criteria.