WP2-D1: Review of available LPWAN networks and distribution models available to cities to support smart building adoption

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List of Acronyms

SRI	Smart Readiness Indicator
IoT	Internet of Things
LPWAN	Low Power Wide Area Networks
LoRaWAN	A LPWAN protocol in the 868MHZ spectrum
NB-IoT	A LPWAN protocol operated by licenced mobile operators under 3GPP standards

Executive Summary

This report evaluates competing technologies that can sustain the delivery of streaming data from buildings toward an SRI database. As a key plank of EU policy for delivering smart buildings, SRI implementation is crucial for managing the reductions in emissions and energy use within the built environment. SMARTLAB is a living lab funded by SEAI toward mapping the adoption of an SRI.

The SRI rates the smart readiness of buildings (or building units) in their capability to perform three key functionalities:

- optimise energy efficiency and overall in-use performance
- adapt their operation to the needs of the occupant
- adapt to signals from the grid (for example energy flexibility) (European Commission, 2022)

At the heart of the SRI framework is the assumption that data streams from buildings can be made available affordably and reliably to feed data models and underpin services. To achieve this, devices -- hardware sensors primarily along with actuators or controls -- will be installed in buildings to begin implementing an SRI locally.

Task 2.1 aimed to evaluate the correct set of technologies to rely on to implement streaming sensor data. It assessed that the most effective approach would be wireless data transmission limiting invasive wiring works. It was also assessed that avoiding use of tenant or occupant data networks was essential for security and data protection. This left a choice of LPWAN networks; LoRaWAN or NB-IoT.

Evaluation criteria for comparison of the two networks was laid out. These criteria are wireless transmission, wide area coverage, two-way communication, wide device support, long battery life, blackspot resolution and commercial models.

The evaluation criteria are intended to provide a useful reference for those at a national or policy level planning an SRI deployment as well as being suitable to the SMARTLAB context. Taking account of these evaluation criteria it is evaluated that LoRaWAN mitigates from of the major risks facing a large sensor deployment such as the occurrence of coverage blackspots and the existence of flexible funding models for network adoption.

Fig 1: Simulated LoRaWAN coverage from Cellnex Telecoms Ireland.

From the perspective of millions of sensors capturing data, there is a large overlap between LoRaWAN and NB-IoT. A crucial distinction is the delivery model where LoRaWAN has support for local private gateway devices while NB-IoT relies on broadcast base stations for delivery with limited scope for densification in a building.

A second crucial distinction is the scale of third-party vendors making equipment available on both networks. LoRaWAN has a significantly more advanced ecosystem and broader array of devices and vendors. This provides redundancy and security of supply for a national project.

These factors prompted the SMARTLAB project to adopt LoRaWAN locally for the project as well as present a recommendation that is offers best fit for a national rollout that will require reliable energy data as this data source is usually the most challenging to capture due to RF factors.

1 Introduction

The Living Lab project is assessing methods for implementing the Smart Readiness Indicator (SRI) within existing building stock in the project catchment area. The SRI standard is intended to support efforts to improve efficiency, comfort and performance of buildings and contribute to targeted reductions in carbon emissions across society. The vision for this project is mapping a process where ordinarily 'non-smart' buildings can be brought up to a basic level of 'smart readiness'.

Achieving this ambition is a data intensive process. One of the major milestones required to bring the building set up to a minimum SRI is to establish a flow of data between the building and the internet. A flow of data is the cornerstone of the SRI and a two-way data flow allowing for control and delivery of services remotely is at the top of the performance criteria for the SRI.

The SMARTLAB project will rely on technology enabled by IoT sensors to develop processes and recommendations for implementing the SRI and mapping out the way to an improved building stock. In order to achieve this, we need to evaluate the connectivity layer that lies between buildings themselves and the internet to evaluate the optimal route to enable smarter buildings.

Collection of building data is ultimately a physical endeavour and depends on a link between the data point within the building e.g. a meter and the internet of services that are supported. This creates a number of challenges that must be evaluated and overcome to successfully implement the SMARTLAB.

While the SMARTLAB zone is compact the ambition for the project is to generate nationally relevant use case and policy implications. Therefore, data collection has to be viewed from a national perspective. This could mean millions of devices streaming data essential to delivering the SRI nationally.

This deliverable examines the options available to the project to achieve this flow of data. The options ultimately resolve to a choice between competing LPWAN networks and the selection process for choosing between them in a way that is scalable in future.

2 Methodology

In order to select possible technologies to support wide area data capture from buildings a selection of high-level criteria was applied to contender technologies. It is conceivable that the deployment of an SRI would distribute hundreds of thousands of sensors within a region therefore the methodology evaluates network connectivity from the perspective of supporting very large device deployments. This deviates from the practical application in SMARTLAB but is ultimately what the overall project is evaluating.

The criteria reflect the project's need to implement sensor solutions simply and quickly and also to provide a nationally relevant roadmap for implementing SRI services. Thus, the criteria for evaluation along with their justification are:

- Wireless: Transmission of data from the data point should be wireless, this minimises the invasiveness to the building and the cost to end users for deployment. It increases flexibility over the long term.
- Wide Area Coverage: Network technology should cover a large area from the node, gateway or access point. This coverage should be measured in KM radius for urban and rural viability. This enables a single node to support hundreds or thousands of data capture devices from a single mast/antenna or gateway.
- Two Way Communication: The network should allow for communication between the data collecting device and the network for reporting. It should also facilitate instruction or activation messages to be sent from the network to the device to change parameters, check device health or trigger some behaviour/function remotely.
- Wide Device Support: The network should have a large body of supported devices in an eco-system of multiple vendors. Devices should be largely interoperable and supported allowing for expanded use cases and resilience in the event of a single manufacturer's failure or exit.
- Long Battery Life: Network choice should allow for battery life of devices to exceed five years and prevent significant maintenance or callout to remedy batteries.
- Blackspot Resolution: Working with energy metering is a challenge for radio networks. Metering takes place in cabinets that are often fully metal enclosures. This attenuates radio frequencies. Therefore a network has to support a 'plan B' backup to fill in any black spots in coverage with minimal additional cost and labour input.
- Commercial Model: The commercial model of network deployment has to be suitable for the procuring authorities who may be government, local authority and/or semi-state bodies or utilities. The model should be flexible allowing for capital investment or ongoing availability of network coverage 'as-a-service' analogous to a mobile phone network.

3 Network Options

A key challenge facing the project and examined in this deliverable is assessing the best means of capturing data from sensors across a wide area of coverage. The challenge – at a small scale for SMARTLAB and a large scale for cities and countries – is to smoothly ensure data can be captured to support SRI deployment e.g., energy usage data, comfort data, building performance information.

The collection of this data must be scalable in the following ways with few 'workarounds' or exceptions:

It must capture data relevant to SRI service provision in an accurate and acceptable manner. In reality this means having a wide ecosystem of third-party vendors capable of providing hardware that is compatible and interoperable.

It should be minimally invasive of the building fabric. In so far as possible data capture should be something that can be installed by tenants and residents and minimise intervention in the building fabric through cabling or wiring.

It should stream data automatically to a central database without requiring access to a local resident provided internet access point (e.g. Wi-Fi or Bluetooth hosted locally). This ensures continuity of performance if tenant leaves and reduces potential points of failure and dependencies in the system. It is also more secure for both parties to operate separate networks. This will ultimately require a city or national level network capable of covering large areas from a single access point.

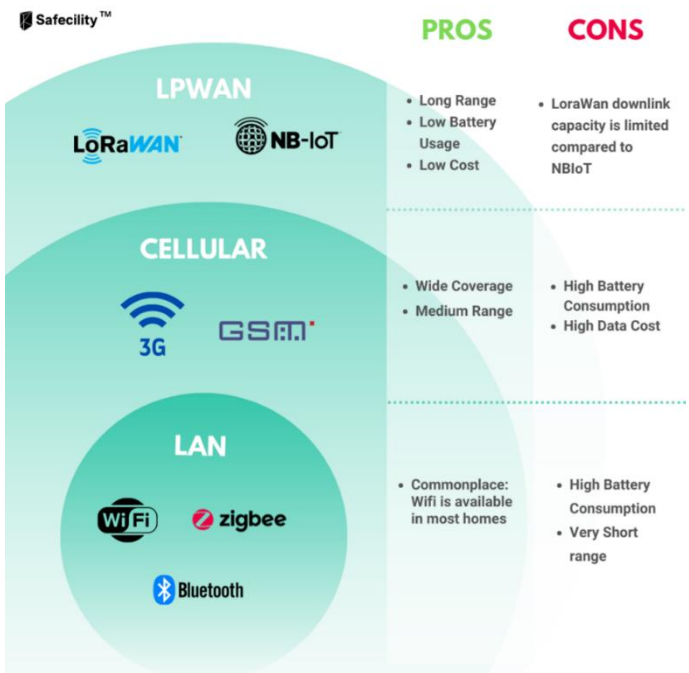

Fig 2: Comparison of available wireless transmission technologies.

It should have an optimal range of commercial models for deployment from private network through to accessing coverage as a service.

The technology that best fits this challenge is a group of wireless protocols referred to a LPWANs. These protocols are low powered (so devices have a long lifetime) and cover a wide area due to their low frequencies of use. The networks have the potential to allow wireless devices to transmit data over 5-10KM distances from the nearest access point – which may be a cell tower or gateway.

This section evaluates the two primary LPWANs that fit our model; LoRaWAN and NB-IoT. It also evaluates the criteria that best suits SMARTLAB in executing the project and scales to offer solutions at a national or regional level and describes our determination to move ahead with LoRaWAN provided on a carrier basis by a commercial coverage provider.

3.1 LoRaWAN

LoRaWAN is an open-source off-the-shelf communication protocol developed by Semtech. LoRaWAN uses unlicensed spectrums so anyone can set up their own network at a low cost using a gateway or hub while commercial operators can deploy networks to cover a wide area.

This flexibility makes LoRAWAN an excellent alternative to Bluetooth or WiFi for low power devices that need to be placed and connected throughout a building. It mitigates security concerns about allowing a third-party system on a local network by setting up local gateways to create a completely separate and secure network.

The big advantages are the low cost and low power consumption (which in turn leads to further cost efficiency), as well as the flexibility offered. The lack of location permanency means they can be set up quickly at a location and moved around later if needs be, as opposed to NB-IoT systems which are more set.

The downside is transmission success because these bandwidths are open to everyone, data can be slowed down (like traffic) or even experience interference from other data transmissions on the same bandwidth, resulting in data loss. For information like energy, temperature and humidity monitoring, delay in the transmission of sensor data is not the end of the world. However, for more critical data such as a fall monitor sensor in an elderly person's home – transmission delays can be an issue.

3.2 NB-IoT

NB-IoT was developed by the Third Generation Partnership Project (3GPP) as part of their goal to standardize cellular systems and IoT devices to be interoperable and more reliable. It operates on licensed spectrum bands and overall is a more sophisticated system meaning users get higher performance levels that allow for more advanced features like routing, multicast, firmware broadcast and more.

Furthermore, the 4G coverage means the devices work well indoors and in dense urban areas, with no interference or traffic issues like with LoRaWAN. This is dependent on the availability of a supporting cellular network, and it can be very difficult to fill in black spots in coverage as one cannot rely on private gateway devices.

The negatives include greater power consumption for devices and higher costs, and more difficulty in deployment than LoRaWAN devices.

NB-IoT will give you faster response times and better quality of service than LoRaWAN devices because it is usually backed by a commercial mobile operator agreement. However this comes with slightly higher licensing and operational expenses in the long run. There are fewer data collisions as the spectrum is regulated.

3.3 Evaluation

In order to assess the better network option for SMARTLAB and potentially for greater deployment of SRI related data services we will evaluate each against the criteria outlined above.

3.3.1 Wireless

Both network technologies are wireless and transmission of data between the sensor and the internet takes place over an RF network. They both operate in similar frequencies with slight variations from their status as regulated or unregulated.

3.3.2 Wide Area Coverage

These technologies are designed to offer long range communication between devices. LoRaWAN offers up to 5KM coverage in urban areas from nearest gateway access points while NB-IoT offers up to 1KM coverage in urban areas from the nearest access point.

3.3.3 Two Way Communication

Both network technologies support two-way communication which refers to the combination of reading data from the sensor devices and sending instructions or activating function (e.g. turn something on or off) by sending a message from the internet to the device. Two way communication in LoRaWAN is governed by the 'class' of the device. Most ordinary devices operate as 'Class A' and remain in a sleep mode until they transmit data to the internet. There is a window for receipt of any instruction messages from the internet only after a data transmission takes place, limiting the scale of two way communication. In some cases where devices operate as 'Class C' they are permanently active and listening for instructions, these devices consume greater power and are usually connected to a dedicated power supply.

NB-IoT supports two-way communication with very low latency. As devices join the local cell it is possible to send transmissions in both directions independently and at any time. This gives a maximum range of flexibility but at the cost of increased battery usage. NB-IoT transmissions consume more battery power than LoRaWAN so increased message volume reduces battery life.

3.3.4 Wide Device Support

A wide variety of devices that support the network is crucial to the successful deployment of an SRI. Devices vary in function (the data they monitor and collect or the systems they can control) and a wider variety of devices opens up a wider variety of SRI services that can ultimately be deployed.

LoRaWAN currently enjoys the advantage of a robust and established ecosystem of third-party device vendors that is mature and growing. These cover many of the major building functions including energy, water, gas, comfort and control as well as BMS bridging devices. LoRaWAN enables deployment of devices from multiple vendors without having to change each devices local settings during installation or commissioning. This lack of friction has increased adoption.

NB-IoT is a more complex technology and therefore offers a narrower range of supported devices from third party vendors. While the functionality is almost identical where it overlaps with LoRaWAN there are often differences in cost as lower volumes are in production. Some devices require a change of parameters in each device before deployment, such as setting the endpoint or APN address the device is to send data to once connected to the local network. This increases friction when deploying a large number of devices.

3.3.5 Long Battery Life

LoRaWAN Class A devices consume less power sending their messages than NB-IoT devices. The battery life of LoRaWAN Class A devices tends to be longer than NB-IoT devices as they require more peak current to send a message. As noted above the trade off for this advantage is in the higher latency and reduced transmission availability of Class A devices.

For applications insensitive to latency Class A LoRaWAN offers better battery performance (Mekki et. Al., 2019: 4).

3.3.6 Black Spot Resolution

Any SRI related project will deploy a large number of devices in buildings. These are unpredictable and challenging environments for wireless radio networks. Any efforts to track energy usage may require devices to be installed deep-indoors, in basement areas or within metal distribution board enclosures. All of these conditions lead to attenuation or loss of network performance. This results in a 'black spot' in coverage as seen from the perspective of the software monitoring the device data. Resolution of these black spots is crucial to ensure ongoing permanence of data flow and enabling technicians to resolve issues quickly and close to the problem site.

In this there is a clear difference between LoRaWAN and NB-IoT. LoRaWAN as an unregulated spectrum operator supports local private gateway devices. These can be as small as a standard broadband router and augment network coverage by 'boosting' signals indoors or in hard to reach places once plugged in. They bridge the LoRaWAN devices to the internet using either the local internet network, wifi or 4G cellular access. The LoRaWAN alliance have also recently published a new standard for relay devices which will amplify the ambient LoRaWAN signal into hard-to-reach areas extending coverage with lower costs.

NB-IoT as a regulated technology does not currently offer local devices to augment or bridge coverage. It relies on a high density of local antenna locations to ensures that coverage penetrates into difficult areas. Where a black spot is showing there is limited routes available to technicians to resolve this problem and they are installing an internal antenna system (or network booster) designed to amplify 4G LTE signals in the challenging area of the building. These require more time to commission and are more expensive to install without a guarantee of success. Alternatively the cellular operator can be invited to locate a base station closer to the challenging area to boost the signal performance. This is a painstaking process without any guarantee of success.

3.3.7 Commercial Model

A major consideration for a scale deployment of the SRI is the range of commercial network models available to a local, regional or national body that wishes to mandate SRI implementation. There are currently three delivery models for these networks operating in European markets.

- Commercial Service: An operator invests in network infrastructure across a broad geographic area and offers the connections to the network as a service to end users. This is the mobile operator model.
- Locally Owned Network: An authority (usually a council or government) decides to implement their own network and invest the capital required to design, deploy and maintain a robust network across a chosen geography. Access is provided locally as a service or for free depending on the service model.
- Hybrid: An area may be serviced by the commercial network operator (umbrella coverage) for either LPWAN but where gaps occur, or the project requires it, a local private network deployment can be put in place offering hybrid connectivity and better cost management. The trade-off is the requirement for more technical expertise internally to manage the deployments.

At this moment the only network technology that supports all 3 models is LoRaWAN in Ireland. NB-IoT is only delivered as a commercial service given the requirement for it to deploy in a cellular base station. This restricts somewhat the commercial flexibility available to bodies considering mandating SRI deployment.

An SRI deployment will deliver a large volume of devices to a network (counted in millions) which has an impact on the cost of each model. Ultimately there will be a focus on obtaining the lowest connectivity cost per device that is possible. While it may make financial sense in low volume to avoid investing in a network deployment and paying a connection fee instead, as device numbers rise the economics may change.

When the amount of connections reaches into the millions it may make more financial sense to operate a hybrid model where the connectivity cost per device can be lowered through partnership or managing a network locally to take significant device volume.

This is project dependent and requires planning and evaluation, but it suffices for this exercise to point out that only LoRaWAN offers the three listed options above. NB-IoT will restrict deployment to the commercial service model and resolve to negotiations on price per device traded against volume.

4 Conclusion

The SMARTLAB project will deploy smart devices to gather data from buildings and road map the implementation of the SRI within Ireland. To do these decisions need to be made around the technology that best supports device data travelling from each building or unit to the internet.

The above survey of options provides a set of criteria against which major competing technologies can be assessed and a determination made on the best option for SMARTLAB and for a broader national rollout. The project has a choice between LPWAN networks LoRaWAN or NB-IoT to standardise data collection.

From a risk perspective one of the largest risks facing the data collection function within SMARTLAB is the prevalence of 'black spots' across buildings. This would lead to a loss of visibility of our devices and the data they are streaming. At scale, black spots would ultimately negate the projects viability. Therefore a capacity to mitigate and resolve blackspots is of primary importance to the success of the project. It is also one of the primary mitigations that would need to be put in place nationally for any SRI deployment.

A second major risk is dependency on a sole device vendor for data collection, having little alternative options from the marketplace. Such a situation exposes the project and any wider SRI rollout to a major threat in the event the device goes out of production in future. Having a large pool of redundancy devices is therefore crucial to the long-term viability of SRI deployments.

On both these metrics the network technology best placed to mitigate is LoRaWAN as it empowers teams to implement black spot reduction independently, locally and with widely available devices such as micro gateways and it continues to enjoy a significant ecosystem advantage over competitors for devices.

While scale is not an operational challenge for SMARTLAB it will be a challenge for a national SRI programme. Delivery at scale and the commercials of network access are also important to consider. The cost per device for network access is a crucial metric that should be fully evaluated in a scale deployment before formally adoption a network standard or hybrid of network standards.

References

European Commission, (2022), What is the Smart Readiness Indicator, from https://energy.ec.europa.eu/topics/energy-efficiency/energy-efficient-buildings/smart-readiness-indicator/what-sri_en accessed 19-12-2022

Mekki, K, Bajic, E, Chaxel, F and Meyer F, (2019), A comparative study of LPWAN technologies for wide scale IoT deployment. *ICT Express, 5* pp.1-7 https://www.sciencedirect.com/science/article/pii/S2405959517302953