iENBL: The Ultimate Low Power, Wide Area Network, Rapid Development Platform

A Development Kit for Rapid IoT Application Prototyping and Field Testing

Introduction

To date, the machine-to-machine communication (M2M) business has been dominated by the owners of the wide area cellular networks (WAN), namely, the mobile network operators grouped under the GSMA and 3GPP associations. Only customers of these operators had wide area connectivity to their devices. The new wireless technologies operating in unlicensed Industrial, Scientific and Medical (ISM) bands are designed to provide low data rates, long-distance reach, deep building penetration, low energy consumption and low cost for connectivity services and end devices. During the past two years, these technologies have significantly changed the WAN connectivity landscape of Internet of Things (IoT) devices.

In the near future, a myriad of simple and ultra-low-power devices will permeate all aspects of our daily lives. They will be part of our homes, the buildings we visit, our modes of transportation, our apparel and more. Those devices will interpret our world by collecting data that will be used to provide valuable, actionable insights to help inform our decisions. Low Power Wide Area Networks (LPWAN) like LoRa and Sigfox, which are the two most widely deployed, are changing the "smartphone IoT hub" paradigm that allows IoT devices to connect to the Internet only when a smartphone is nearby. LPWAN enables us to sense our world by transforming everyday objects into smart objects, cities into smart cities, and workplaces into smart work environments.

Unlicensed, open and no-cost frequencies are good for consumers, but not for mobile carriers that have spent billions of dollars acquiring the exclusive use of licensed frequencies. The 3GPP association, and mobile network operators in particular, view LPWAN technology as a threat to their IoT businesses. In response, the 3GPP association reacted by defining and quickly approving the 3GPP Release 13, a specification of two LPWAN alternatives that can be deployed using existing cellular networks. These two new technologies are known as LTE Cat-M and Narrow band IoT (NB-IoT).

Although there is market competition among the LoRa Alliance (backing LoRa), network operator Sigfox (backing its own solution), and 3GPP (backing LTE-M/NB-IoT), they will likely coexist in the future. They can share the addressable market by focusing on applications in which their specific technology offers a unique advantage in price, energy consumption, network coverage or roaming. The characteristics of Sigfox technology, for example, are well-suited for static devices that only need to upload small amounts of data at long intervals, like smart metering or vending machines. If worldwide coverage, mobility and quality of service are required, LTE-M/NB-IoT would be an apt choice. Finally, static or mobile devices with a medium level of bidirectional data volume exchange needs would

Abstract - The recent eruption of wireless technologies operating on the unlicensed frequencies of the ISM bands, like LoRa and Sigfox, known as Low Power Wide Area Network (LPWAN) solutions, have significantly changed the WAN connectivity landscape for IoT devices. These technologies appeared to fulfill the "Four Ls" gap, providing IoT devices with Low data rates and Long-range communication capabilities while maintaining very Low power consumption and a Low cost for the silicon transceiver. In response to these initiatives, the licensed community grouped under the 3GPP organization released its own versions of LPWAN for their licensed frequencies, known as LTE Cat-M and Narrow Band IoT (NB-IoT).

Asset tracking and geolocation services are the main sectors that will benefit from LPWAN technologies, but other verticals including smart buildings, smart cities, agriculture and farming, are finding solutions to their connectivity problems in NB-IoT, Sigfox and LoRa. Many IoT applications require geolocation, and LPWAN technologies provide an additional benefit of location information at different levels of accuracy without using additional sensing elements (e.g., GNSS).

Bringing new communication technologies to market is a long process requiring sufficient network coverage, availability of devices and affordable costs. Hardware and connectivity costs decline with time and economies of scale, and networks are slowly and gradually being deployed. However, opportunities will be missed if no suitable devices meet the requirements of an IoT application in development.

Creating a new product to meet these requirements is prohibitive in terms of time and expense, as several iterations are necessary to produce an optimized IoT device that achieves the desired functionality and price objectives. Furthermore, IoT application development and field testing can only occur after the first prototypes of the new device are available.

One workaround to accelerate development is to enhance available development boards like Arduino or Raspberry Pi with the required sensors and the selected connectivity interface shields. This solution doesn't allow for application testing in the field on a small or medium scale (e.g., 10s or 100s of units), and requires the added step of porting the application to the final architecture once the appropriate device becomes available.

To address this problem, we at Flex have created the iENBL, which helps our customers develop, verify and test their IoT ideas in the field without spending time or money developing hardware. This paper analyzes and compares the main LPWAN technologies and introduces the iENBL, the ultimate LPWAN development platform for rapid IoT application prototyping and field testing.

Keywords - LoRa, Sigfox, IoT, NB-IoT, LTE Cat-M, LPWAN.

be good candidates for LoRa, which is an excellent modality for private/industrial IoT networks deployed and managed by the owner.

Asset tracking and geolocation services are among the most demanding IoT applications. LPWAN technologies present an advantage for these applications, as they offer location information with data communications by triangulating signal time-of-arrival measurements in a synchronized network. LoRa, Sigfox or Cat-M/NB-IoT location services are not reliable, nor do they provide accurate locations as they can be affected by a rural, urban or suburban environment and a limited or blocked line of sight between the end device and the network base station. Applying intelligent sensor fusion logic to LPWAN location information combined with GNSS data (outdoor), WiFi access point information (indoor), and other sensors (accelerometer, pressure, etc.), plus cloud intelligence and machine learning algorithms make it possible to create a low-cost tracking device to monitor anything or anyone that the device is attached to.

Although this paper focuses on the three aforementioned LPWAN technologies, there is another solution that merits mentioning. Sony has developed a LPWAN solution that is being tested in Japan. The solution features a reach distance in excess of 20 km in a dense urban area like Tokyo (1) and a modification of LoRa technology by the Israeli company Hoopo that provides accurate GPS locations in outdoor environments and can even detect directional movement (2).

LPWAN Technologies

Although there are several available wireless technologies offering both long range and low power-consumption transceivers – some open (such as Weightless N, -P and -W and DASH7) and some proprietary (such as Texas Instruments narrowband solution) – this paper focuses only on those with clear market penetration and that have network deployments and implementations in real world applications.

A. LoRa

LoRa is a chirp-based spread-spectrum radio technology initially developed by Cycleo, a company acquired by Semtech in 2012. Because of its spread spectrum nature, a LoRa signal looks like noise, which protects against eavesdropping. Due to the modulation technique and built-in forward error correcting capability, the LoRa signal can transmit data at a strength that's well below the noise floor. Also, due to an improved tolerance to frequency offsets, a temperature compensated oscillator (TCXO) is not necessary and only a 20 ppm to 30 ppm XTAL would be enough to clock the device.

LoRa transceivers for end nodes offer various selectable bandwidths over which to spread the signal (e.g., the Semtech's transceiver SX1272 can be set to a bandwidth of 125 kHz, 250 kHz or 500 kHz; the SX1276 bandwidth has broader range from 500 kHz to as low as 7.8 kHz). The spreading factor is also selectable between 6 and 12 bits. A higher spreading factor provides higher sensitivity and improves transmission performance for a given bandwidth, but also increases transmission time and lowers data rates. These can vary from as few as 18 bps to 40 Kbps. LoRa also offers the possibility to improve the noise immunity by means of a forward error correction (FEC) mechanism. The error correction code imposes an overhead on transmitted data to allow the receiver to recover data in the presence of errors.

In addition to the radio LoRa technology (PHY), the LoRa Alliance has defined an open protocol stack and a network architecture known as LoRaWAN. The open nature of the LoRa Alliance has facilitated an ecosystem where chip and modules providers, device and network infrastructure equipment manufacturers, and network management solution providers can co-create an easy and low-cost solution with connectivity to many IoT devices.

The network architecture enables a gateway or base station to cover hundreds of square kilometers. The achievable range depends on the environment and obstructions in a given location, but LoRa can provide link budgets in excess of 150 dB. Communication between end devices and gateways is spread across frequency channels and have different data rates. As the spreading factors are orthogonal to each other, communication at each data rate does not interfere with others and creates a set of "virtual" channels that effectively increase the capacity of the gateway. LoRaWAN network architecture typically has a star-of-stars topology in which the gateways are transparent bridges relaying messages between end devices and a central network server on the backend. All network management is completed from there. The gateways are connected to the network server via standard IP connections and don't implement any data processing on the payload of the end nodes. Instead, they add information to identify the gateway and the level of the RF signal with which the message has been received. This means that the end nodes are not assigned to a specific cell or base station, as is the case with cellular networks, and a message from an end node will be received by all gateways located in the transmission range of the sensor. The network server identifies duplicated messages and selects the most suitable gateway for the downlink path.

There are three different types of LoRaWAN classes, and each has its own way of receiving and transmitting signals (3):

- Bidirectional end devices (Class A): Class A end devices allow for bidirectional communications whereby each end device's uplink transmission is followed by two short downlink receive windows. The transmission slot scheduled by the end device relies upon its own communication needs with a small variation based on a random time basis. This Class A operation is recommended when the end device only requires downlink communication from the server shortly after the end device has sent an uplink transmission. Downlink communications from the server at any other time will have to wait until the next scheduled uplink.
- Bidirectional end devices with scheduled receive slots (Class B): Class B end devices open extra receive windows at scheduled times. This synchronization is provided from the gateways by broadcasting a beacon at regular intervals. Class B is recommended when the latency is limited.
- Bidirectional end devices with maximal receive slots (Class C): End devices of Class C have nearly continuously open receive windows; they are only closed when transmitting. Class C is only applicable to main power devices.

LoRa technology and equipment providers are now offering geolocation services in addition to data communication by using highly accurate timestamping of messages arriving to the gateways using the fine GPS clock. This process allows gateway synchronization within a few nanoseconds' accuracy. By feeding a Time Difference of Arrival (TDOA) solver with this timestamping information, the backend application server can accurately estimate the position of the end node. Such accuracy depends on the environment where the end nodes are deployed and on the line of sight to the gateways in their range. Direct signal paths from the end node cannot be accurately discriminated in a multipath environment, which introduces position estimation errors. Completed experiments to date show accuracies between 50 m and 500 m, but a specific accuracy level cannot be guaranteed. LoRa geolocations do not pretend to replace GNSS, but rather present another source of position information that can be very useful when combined with other sensor data and/or machine learning algorithms.

B. SigFox

Sigfox is the name of an ultra-narrowband radio technology and the company that promotes and deploys it. In a narrowband system, for a given output power, the achievable range of the RF link is partially determined by the bandwidth of the receiver: the smaller the bandwidth, the lower the receiver's noise figure (i.e., the sensitivity for the receiver is increased and the range extended). There is, of course, a tradeoff, since very narrow bandwidth also means very low data rates that result in longer air time and reduced battery life. Long telegrams also increase the probability of interference/collisions with other wireless systems. In practical installations, ultra-narrowband systems typically use a reasonably low data rate, generally down to less than 1 kbps (4) (5).

Typical narrowband systems are defined as having less than 25 kHz bandwidth, and a 12.5 kHz channel spacing with 10 kHz receive bandwidth is commonly used. This narrowband tuning of the receiver puts greater demands on the RF crystal. A frequency error there leads to an offset on the programmed RF frequency and, if the offset becomes too large, the signal will fall outside the channel and be eliminated by the receive filters. Legacy narrowband systems typically use temperature compensated crystal oscillators (TCXOs). While TCXOs have historically been more expensive than standard crystals, the cost differential has recently been drastically reduced.

Sigfox uses a bandwidth that is a hundred times narrower with a channelization mask in the uplink of 100 Hz in the EU (600 Hz in the US). For this reason, the technology is known as Ultra Narrow Band (UNB) and has an uplink data rate of 100 bps in the EU (600 bps in the US) using a DBPSK modulation scheme. For the downlink, the channel bandwidth is 1.5 kHz modulated with GFSK for a data rate of 600 bps. In Europe, the UNB uplink frequency band is limited from 868.00 to 868.60 MHz, with a maximum output power of 25 mW and a maximum mean transmission time of 1 percent. The downlink frequency band is limited from 869.40 to 869.65 MHz, with a maximum output power of 500 mW with 10 percent duty cycle. These duty cycles are defined by European regulation (6) to fairly share the spectrum in the ISM band. The same restrictions apply to LoRa technology, but they have a greater impact on Sigfox because of the fixed data rate. Because of these duty cycle restrictions, the maximum length of Sigfox's packet is 24 bytes, where the used data may occupy a maximum of 12 bytes. At 100 bps, each packet transmission takes about two seconds, and each transmission from the IoT Sigfox device consists of three of these packets transmitted on three pseudorandom frequencies.

Sigfox operates, deploys and manages its network. Actual coverage includes many countries within the EU, and Sigfox is being deployed in other continents as well. Being the only provider allows Sigfox to offer global coverage without roaming, which is an existing problem that still needs to be solved by the LoRa Alliance. Currently, Sigfox has a tiered option plan for the number of uplink transmissions allocated to a user each day, as well as the number of downlink transmissions received from the main network station to a device: Platinum (101 to 140 uplink messages + 4 downlink), Gold (51 to 100 uplink messages + 2 downlink), Silver (3 to 50 uplink messages + 1 downlink) and One (1 to 2 uplink messages + no downlink).

Although Sigfox signal modulation is a proprietary solution, several wireless transceivers providers like Atmel, Silicon Labs, ST Microelectronics and Texas Instruments, have made agreements with Sigfox to embed their technology as another modulation option in the transceivers. Table I summarizes the main features of these two unlicensed LPWAN technologies.

C. 3GPP (Cellular) proposals

The large number of new LPWAN technologies being deployed on the unlicensed spectrum has threatened the dominant position of cellular 2G technologies in the M2M market. New low power technologies provide long range access at very low connectivity costs. These advantages, combined with uncertainty about the future of 2G networks, have sparked great interest in these new technologies within the IoT community.

Some Mobile Network Operators (MNO) have invested in Sigfox, while others have supported LoRa from the beginning, using the technology to deploy nationwide networks. However, the possibility of connecting IoT devices directly to the cloud without going through existing networks was seen as a threat by the 3GPP organization and by the MNOs and cellular network infrastructure providers in particular. In response, the 3GPP developed three proposals to adapt existing technologies to reduce data rate requirements and improve coverage, power consumption and hardware costs. In doing so, the association seeks to improve upon the numbers offered by unlicensed LPWAN technologies for these performance indicators. These three proposals are known as Extended Coverage GSM (EC-GSM), LTE Cat-M (also known as LTE-M, LTE Cat-M1 or eMTC) and Narrow Band IoT (NB-IoT, also known as LTE Cat-M2 and LTE Cat-NB1). This paper briefly describes and compares only the last two, where the market of licensed LPWAN solutions will focus in the future.

	SigFox	LoRa
Band	868/915 MHz	868/915 MHz
PHA	UNB	CSS
Spreading factor	NA	27 - 212
Channel BW	100/600 Hz (UL/DL)	125 KHz to 500 KHz
UL data rate	100 bps	9– 50 Kbps
DL data rate	600 bps	27– 50 Kbps
Efficiency (b/s.Hz)	0.05	0.12
Doppler sensitivity	Unconstrained	Up to 40ppm
Max Tx power	EU:+14dBm US: +23dBm	EU:+14dBm US: +23dBm
Link Budget (Max)	156 dB	156 dB

Table I. Unlicensed LPWAN Technologies

- LTE-M: LTE-M is an evolution of LTE optimized for IoT in 3GPP RAN. It was first released in Rel.12 in Q4/2014 and further optimization is being included in Rel.13 with specifications completed in Q1/2016 (3 GPP 36.888, RP-150492). An LTE channel is comprised of Resource Blocks (RB) of about 180 kHz of spectrum (Figure 1), and LTE-M combines six of these RBs in a 1.4 Mhz block. LTE-M improves energy efficiency by extending the discontinuous repetition cycle (DRX), meaning that the endpoint agrees with the base station (eNodeB) and the network regarding how often it will wake up to listen for the downlink. A similar feature was previously implemented in the Rel.12 as part of the LTE Power Saving Mode (LTE-PSM), but the extended DRX was created specifically for LTE-M in Rel.13. The main advantage of LTE-M rollout is that it can work with a standard 4G network infrastructure simply by deploying the corresponding software upgrade. LTE-M has a higher data rate than NB-IoT, it is able to transmit fairly large chunks of data, allowing for the transmission of voice (VoLTE support), and it supports mobility. These last two features make LTE-M an appealing technology option for the next generation of wearable devices.

- NB-IoT: NB-IoT is the narrowband evolution of LTE for IoT in 3GPP RAN, included in Rel.13 with specifications completed in Q2/2016 (3GPP 45.820 7A). To reduce the price of the transceivers for battery operated IoT applications, the 3GPP merged two solutions into one: Narrow Band Cellular IoT (NB-CIoT) and NB-LTE. Huawei and partners (Ericsson, Qualcomm and Vodafone) promoted NB-CIoT as a solution that was defined by the Weightless interest group to promote the utilization of TV White Spaces (TVWS). That technology was promoted mainly by Neul from Cambridge, England, which was acquired by Huawei in September 2014 and subsequently adopted by the Huawai cellular network. This proposal was not a variation of LTE, but a DSSS modulation that makes the modem complexity simpler than a pure narrowband version of LTE and in turn allows for lower-cost chipsets. The problem with NB-CIoT in this implementation is that it does not support spectrum sharing with LTE networks and would need to operate either in a side band using different software at a higher cost to the MNOs, or be deployed in a deprecated GSM spectrum. The second alternative, NB-LTE, is a narrowband version of LTE that is designed to operate in a 200 kHz carrier refarmed from GSM, but with the advantage of being able to operate in shared spectrum with an existing LTE network. Therefore, no additional deployment of antennas, radio or other hardware (7) is required. 3GPP has combined both proposals in the NB-IoT specification, which can be deployed in-band, guardband or standalone (GSM bands) (Figure 1). Table II summarizes the more relevant characteristics of both proposals.

Figure 1: LTE-M & NB_IoT possible implementations

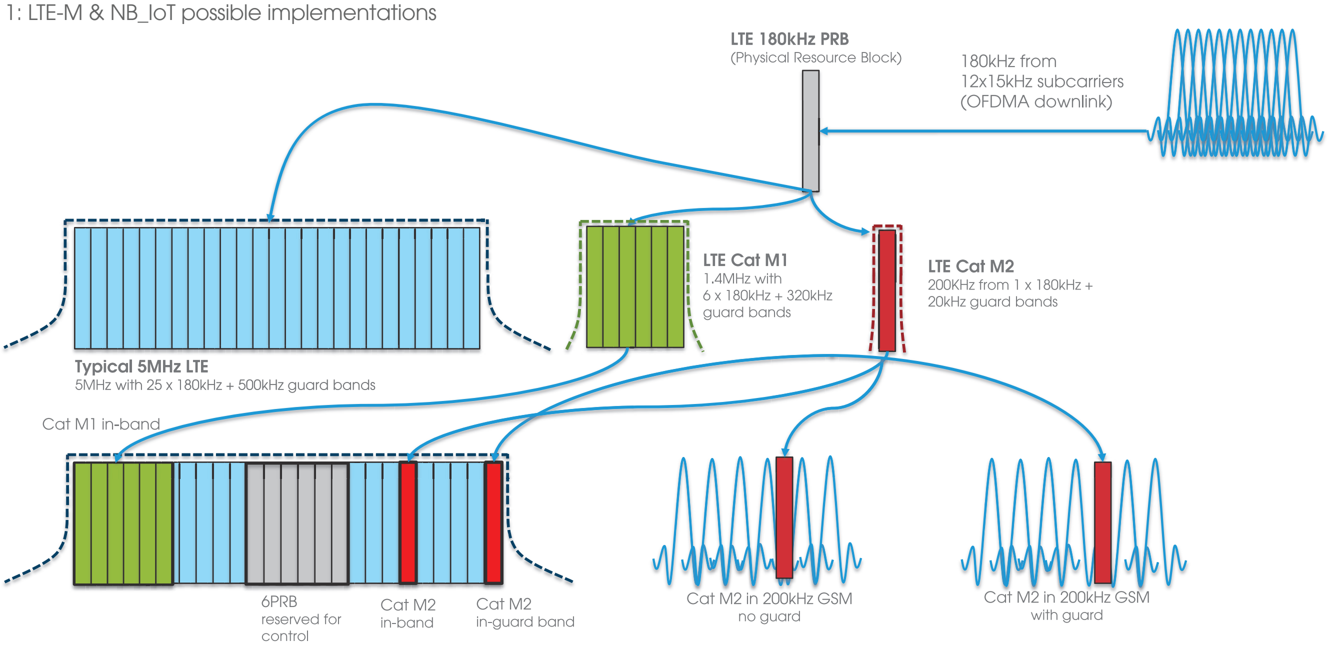


Table II. IENBL: 3GPP NB_IOT Proposals

	NB-CIoT	NB-LTE	NB_IOT
3GPP Release	Rel 13 Candidate	Rel 13 Candidate	Rel 13
Peak data rates	DL 360 Kbps, UL 48 Kbps	DL 128 Kbps, UL 65 Kbps	DL up to 250kbps UL single tone up to 20 to 64kbps, UL multi-tone up to 250kbps
Bandwidth DL	180kHz DL (48 x 3.75kHz) UL (36 x 5kHz)	180kHz DL (12 x 15kHz) UL (72 x 2.5kHz)	180kHz (12 x 15kHz)
Bandwidth UL	OFDMA	OFDMA	Single-tone 180kHz by 3.75kHz or 15kHz) or multi-tone (180kHz by 15kHz)
Multiple Access DL	OFDMA	OFDMA	OFDMA
Multiple Access UL	FDMA	SC-FDMA	Single-tone FDMA or multi-tone SC-FDMA
Modulation DL	BPSK, QPSK, optional 16QAM	BPSK, QPSK, optional 16QAM	BPSK, QPSK, optional 16QAM
Modulation UL	GMSK, optional BPSK, QPSK,8PSK	BPSK, QPSK, optional 16QAM	TBC π/4-QPSK, rotated π/2-BPSK, 8PSK optional 16QAM
Link Budget	+20dB better than LTE	+20dB better than LTE	~164 dB
Mobility	No	Yes	Nomadic
Max Tx Power	+23 dBm	+23 dBm	+23 dBm
VoLTE support	No	Yes	No
Duplex Mode	Half	Half	HD-FDD (TDD under discussion)

LPWAN: The IoT Enabler

The term "Internet of Things" (IoT) is sometimes applied broadly, encompassing every device connected in any way to the Internet, from smartphones to cars. For the purposes of this paper, the concept is linked to the original driver of the Internet of Things that dates back two decades: wireless sensor networks. Sensors, combined with advances in embedded computing, low power consumption techniques, and short-range and low power wireless communication technologies have opened a new world of applications to perceive the environment around us, the status of a machine, or the location of personal belongings. These sensors connect to the Internet through short range connectivity solutions (e.g.,Bluetooth, WiFi, Zigbee, ZWave, etc.) via a gateway like a home WiFi router or, as in the case of wearables and medical devices, the user's smartphone. The ultimate goal of connecting IoT devices directly to the Internet remained elusive until the advent of new wide area communication technologies working in low power modes. As depicted in Figure 2, IoT is about sensing, processing embedded data, and communicating the relevant measurements or results to the cloud where analytics will extract valuable information to aid the user's decision-making process.

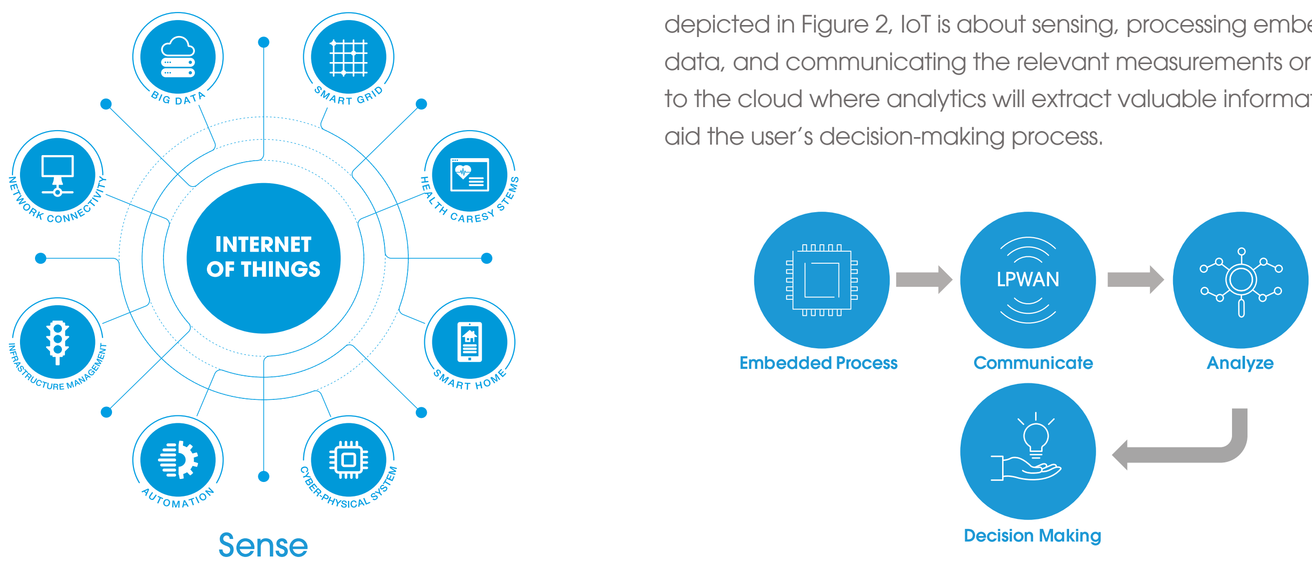
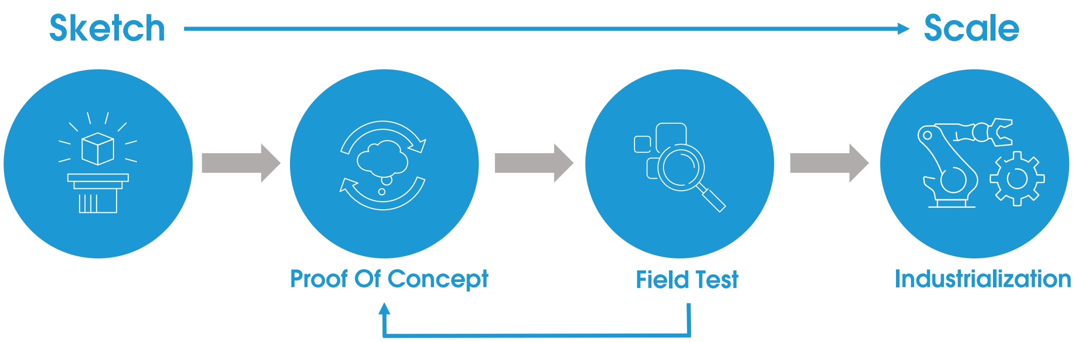


Figure 2: LPWAN enables IoT

The IOT Development Process

The IoT creation process tends to follow a common path that starts with a customer-focused idea for a device that can be used to acquire data. In most cases, the type of data or how this data can be used to benefit the customer is not clear. Therefore, before going from ideation to industrialization, or what we call Sketch-to-Scale®, the creation process is iterative. First, a prototype is created to provide proof of concept. Then field testing via a small- or medium scale trial establishes whether the device works as expected, ascertains whether the right data are being collected, and determines whether the data collection frequency and volume is sufficient. Finally, the prototype is adapted and perhaps redesigned to address any shortcomings. The end result is a solution optimized for cost, size, mechanical properties, battery size, and other variables that can then be taken to the industrialization phase (Figure 3).

Figure 3: The IoT development path



There are a few ways to approach product development for IoT hardware. Building a quick prototype is relatively inexpensive and easy to do using one of the multiple open and generic development platforms that are available on the market today. Connecting the required sensors and the selected LPWAN interface shield to an Arduino or Raspberry Pi development board should be sufficient to demonstrate that an IoT idea works, at least on the table. However, this operational prototype will not guarantee that an integrated solution, including case and battery, will perform similarly. It is also not possible to estimate the final device's real power consumption. Assuming a prototype succeeds in advancing to the next step of the development process, namely, a trial in small or medium scale, identical prototypes cannot be replicated and deployed for testing in the field. Each instance of the prototype will behave differently and provide inconsistent results. In addition, these field tests require the cumbersome task of assembling and handling the various prototypes, as there may be cables and separate batteries depending on whether the device is at a specific location or attached to a machine, for example.

Another option is to develop a hardware solution from scratch that meets the requirements for variables like the number of sensors, LPWAN technology choice, battery size, mechanics and industrial design. The development of this new product will likely involve one year of time and significant investment in electronic, mechanical and industrial designs, as well as validation, testing and certification. Prototypes will take six months to develop, during which time work cannot proceed on the IoT application. In this scenario, using a generic development platform to start the IoT application development can save some time, but unless the new development utilizes the same architecture of the development board, an application porting effort will be unavoidable. After the trial test, there will be adjustments and redesigns of the hardware to optimize performance and power consumption. The LPWAN technology initially selected for the device may prove unsuitable as well, prompting a larger redesign followed by another field test, which will increase development time and cost.

iENBL

iENBL (Figure 4) is an IoT development platform embedded in an IP65 ruggedized clamshell enclosure with focus in LPWANs. The highly integrated iENBL combines a high-performance ARM Cortex M4 microcontroller with 512 MB of memory, the sensors required for most IoT applications, the short-range communication WiFi and BLE solutions, a few actuators and the aforementioned LPWAN technologies. Table II summarizes all the features iENBL includes in various versions. Version 1 focuses on unlicensed LPWAN solutions LoRa and Sigfox, and Version 2 applies to licensed LPWAN solutions LTE Cat-M and NB-IoT. The iENBL also includes a microphone and an SD card slot for logging noise data in predictive maintenance applications. Any of the sensors can be utilized to record data. Should the IoT application need a sensor that is not included in the device, the iENBL is expandable, and required sensors can connect to and be powered by the expansion port (Figure 5). The expansion port is also used to program the device using a JTAG programming interface. The iENBL's USB port is able to download new firmware and also charge the included 1.320 mAh rechargeable battery. Figure 4 illustrates the iENBL's dimensions: 65 mm by 97 mm by 26 mm.

Figure 4: Flex's iENBL

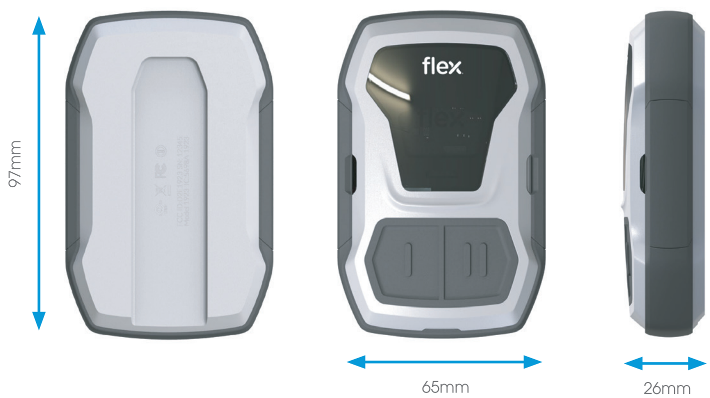


Figure 5: iENBL Mechancis

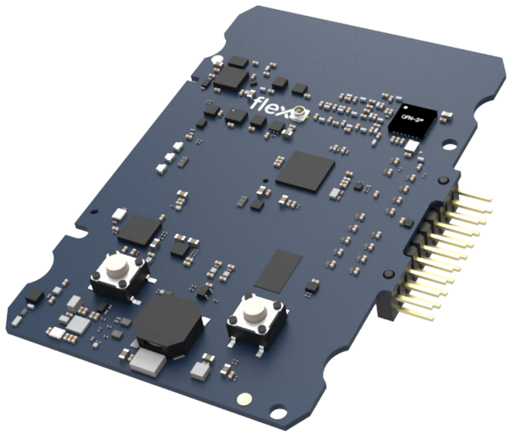


Table III. IENBL: What is inside?

Connectivity (Ver.1)	Connectivity (Ver.2)	Sensors	Actuators	HW Features	SW Features
LoRa	Cat-M (all Ver 2.x)	Accelerometer	RGB LED	MCU ARM Cortex M4 (STM32L4 — 512MB)	API Description
LoRaWAN 1.1	NB_IoT (all Ver 2.x)	Gyro + Accelerometer	Push Button (x2)	HW Secure Element (STSAFE)	C Examples
SigFox	GPRS (Ver 2.a)	Temperature	Buzzer	1.320 mAh Rechargeable battery	Instructions to install and Configure a Programming IDE based on TrueStudio
GNSS (GPS, GLONAS, GALILEO, BeiDou	GNSS (GPS, GLONAS, GALILEO, BeiDou	Humidity		SD Card Holder	
WiFi (802. 11b/g/n 2.4GHz)		Pressure		JTAG & USB Programable	
BLE 4.2		Light Sensor		IP65 Rated, Ruggedized Clamshell Enclosure	
		Hall Effect Sensor		ETSI & FCC Certification	
		Microphone			

As mentioned in the Introduction, asset tracking is one of the most demanding IoT applications, and iENBL is designed to account for that. iENBL features a GNSS unit which, when combined with the accelerometer, the pressure sensor, the WiFi and BLE interfaces, and the geolocation capabilities of LPWAN technologies, makes the iENBL an excellent platform to develop and test asset tracking IoT applications. The GNSS unit offers accurate position information outdoors, while the LPWAN conveys rough position information in both outdoor and indoor environments. The WiFi interface can leverage more precise WiFi location databases, like those from Google or Here, for indoor location information. The BLE unit also provides an indoor location/position if a BLE beacon infrastructure is available. The accelerometer can be employed as an energy-saving device, updating the position information only when movement is detected. Finally, the pressure sensor furnishes altitude informationas well.

A. iENBL Version 1

This version supports both LoRa and Sigfox operating in the unlicensed ISM band. Initially, we used two different RF front ends to serve both solutions, as LoRa requires a Semtech LoRa transceiver (we use the SX1276 for its flexibility), and Sigfox firmware implementation works with several off the shelf FSK transceivers from Silicon Labs, Atmel, STMicroelectronics, Texas Instruments, etc.). However, the LoRa SX1276 can also operate as a standard FSK transceiver. In collaboration with other partners, we succeeded in implementing both technologies using the same transceiver, RF circuitry and antenna. With the current configuration, the customer can test and/or use both solutions in the same device.

There are two SKUs for this version that have an optimized antenna tuned to EU (868 MHz) and US (915 MHz) frequencies. Nevertheless, both versions work in any region with a small antenna performance degradation. The need for two SKUs for the unlicensed LPWAN technologies may disappear in the future if the harmonization of the SRD spectrum used in the 874-876 and 915-921 MHz bands in the EU finally occurs as recommended by the ETSI TG28.

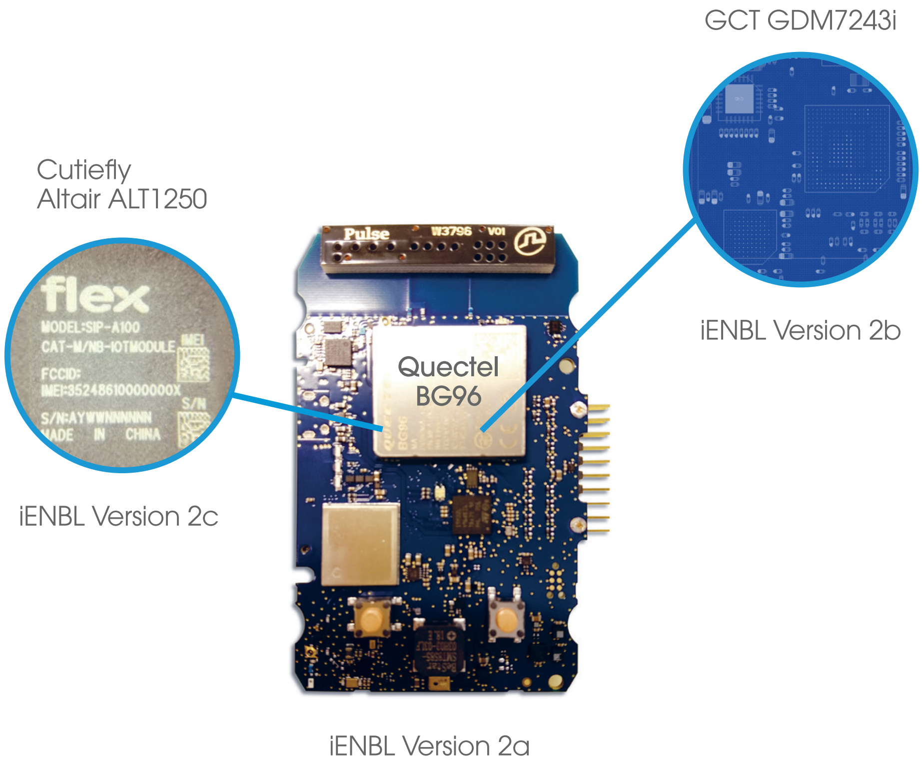
B. iENBL Verison 2

Version 2 of iENBL is focused on the licensed LPWAN technologies LTE Cat-M and NB-IoT. Unlike our first iteration, Version 2 offers as many implementations as there are silicon vendors offering chipsets for these technologies. We think this will be the largest market for IoT, although it will take some time before the required network coverage is available and the prices for hardware and connectivity decline to a cost at least close to that of the unlicensed LPWAN solutions. Also, although the 3GPP has defined a group of bands where LTE Cat-M and NB-IoT can be officially deployed, some carriers are acquiring nationwide spectra in frequency bands outside of that range supported by existing NB-IoT/Cat-M modules or that need specific channelization for nonstandard deployments in industrial private networks of smart cities. Examples of these bands are B71 (600 MHz) or B7/B38 (2.6 GHz FDD/TDD). Furthermore, each carrier has a preference for a specific chip, sometimes based on regionality. In China, for example, the HiSilicon Boudica NB-IoT chipset is the preferred choice for local mobile network operators.

To address different configurations and preferences, we developed a few variants of the iENBL Version 2. With adaptability in mind, we partially redesigned the iENBL electronics to define a common area of 25 mm by 22 mm where, by means of an interposer board, different NB-IoT/Cat-M implementations can be placed, keeping the rest of the iENBL the same for all the variants (Figure 6). The first variant (v2a) is using the Quectel module BG96, which incorporates the Qualcomm-MDM9206 chipset that supports Cat-M/NB-IoT and 2G fallback compatibility. This iENBL variant covers the LTE bands B1, B2, B3, B4, B5, B8, B12, B13, B18, B19, B20, B26, B28 in FDD and the band B39 in TDD for Cat-M only. In 2G, it supports EGPRS: 850/900/1800/1900 MHz.

The second version (v2b) is based in the chipset GDM7243i from GCT (Figure 6). This design supports the extended bands B71 and B7/B38 for Cat-M/NB-IoT, but also Sigfox and an additional BLE interface. The Sigfox and BLE features are already embedded in the GDM7243i chip, and we think there are benefits to including them in an IoT module. The Sigfox interface can be used to send very small messages, such as "still alive" updates once a day, to save energy for the more power-intensive NB-IoT modem or for basic geolocation

Figure 6: iENBL Version 2 variants a (Quectel), b (GCT), c (Altair)



without waking up the GNSS unit or the NB_IoT modem, which is helpful if, for example, a user needs to know if an item is in transport but not the exact location. Also, the BLE interface is very useful when a firmware update is required and the NB-IoT data rate available in a specific location, like underground or in cell edge areas, is not sufficient.

TThe variant v2c demonstrates the operation of a System in Package (SiP) that we have developed in collaboration with Altair Semiconductors. This SiP integrates the ALT1250 Cat-M/NB-IoT base modem and the ALT 1910 RF front end, which supports all the bands from 700 MHz to 2.2 GHz in only one SKU, with an ARM Cortex M4 microcontroller and a Sony GNSS unit in a 10 mm by 10 mm by 1.5 mm form factor (Figure 6). This SiP is targeted to enable Cat-M/NB-IoT connectivity in reduced form factor IoT devices that include wearables, medical devices and personal trackers. Incorporating this SiP into the iENBL enables customers to start IoT application development immediately, and offers the ability to test the VoLTE functionality embedded in the ALT1250 by using the microphone included in the iENBL.

iENBL: The Essence of Sketch-to-Scale®

The iENBL has successfully been used for its intended and designed purposes, as demonstrated by a recent customer developing hardware for an IoT application in monitoring construction machines. The customer was introduced to iENBL in April 2018. In May, the customer began developing the application with 10 units of iENBL V1 in May 2018 and by June, the customer had ordered 250 units for a field test (Figure 7). Over the course of two months, the customer gained enough information to optimize the IoT application software and the iENBL hardware for their specific needs – including redesigning the enclosure to hold primary batteries instead of rechargeable ones and removing components not critical to their application. After building test units with the customer's final specifications, the device was ready for production in high volumes. The entire Sketch-to-Scale® process was completed in only 6 months, without any additional development costs or engineering resources.

Figure 7: iENBL: The esence of Sketch to Scale®

CONCLUSION

LPWAN technologies open a new spectrum of business opportunities in the IoT space, but the selection and adoption of a new wireless technology is a slow process requiring extensive field testing of new developments and ideas. Testing in the field often involves the development of a prototype which can be expensive and time-consuming. Often, the need for a prototype stymies technological development because the market opportunity and ROI for an idea is unclear until after a medium size trial. These trials can't be completed by simply adding some sensors and a LPWAN connectivity shield to the traditional Arduino type evaluation boards that are on the market. This solution may be helpful for testing an idea on an engineering desk, but it is not adequate for a proof-of-concept field test. Furthermore, such tests are not reproducible in a small or medium scale, and this obstacle has slowed the development of new IoT applications and the adoption of LPWAN technologies – until now.

The solution is an integrated development platform including LPWAN connectivity and the sensors required for most IoT applications. In conjunction with the Connectivity Center of Excellence, Flex has developed a fully functional Development Kit that demonstrates and proliferates our expertise in IoT connectivity in general, and in LPWANs in particular. There are two versions of this multi sensor platform, including LoRa and Sigfox in V1, and Cat-M/NB-IoT and Sigfox in V2. Both versions also incorporate WiFi, BLE and a full GNSS unit. Our Sketch-to-Scale® LPWAN DevKit tool enables new and existing customers to enter the IoT space. Flex's platform's capabilities include rapid prototyping and field test deployments with a reproducible device that can be easily customized for scale manufacturing. By using our development platform to test an IoT business idea on a small and medium scale, customers can reuse their work on the application side in a final customized product with the same architecture.

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REFERENCES:

1. Seiji Kobayashi, Nabil Loghin et al., "A GPS synchronized, Long-Range Uplink-Only Radio Designed for IoT", 2018 IEEE International Conference on Communications (ICC).
2. https://www.hoopo.tech/
3. LoRaWAN Specification v1.1, N. Sornin, M. Luis, T. Eirich, T- Kramp and O. Hersent, LoRa Alliance, October 2017.
4. Long-range RF communication: Why narrowband is the de facto standard, white paper Terje Lassen Product Line Manager, TI Industrial Low Power RF, Texas Instruments.
5. Ultra Narrow Band Modulation, H.R. Walker, Pegasus Data Systems Published in: Advances in Wired and Wireless Communication, 2004 IEEE/Sarnoff Symposium on Date of Conference: 26-27 April 2004.
6. ERC Recommendation 70-03, European Conference of Postal and Tecommunications Administration (CEPT), Electronics Communciation Commetee (ECC), Editon of February 2014.
7. LTE Evolution for IoT Connectivity, Nokia, White Paper, 2016.

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