Saft White Paper

How to energize successfully your IoT project?

The choice of power source is critical to the success of any Internet of Things (IoT) project. In this white paper, Saft explores how choosing the right battery solution must go beyond looking at meeting criteria for technical performance. It must also support the business case for the specific IoT application, particularly in terms of reliability and long life. This white paper also highlights the crucial need to look beyond the data sheet to ensure that the selected power source meets the technical and financial requirements over the entire life of the IoT project.

IoT

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How to energize successfully your IoT project?

1. IoT market: background and history

1.1 IoT market – Background

A simple definition of the Internet of Things (IoT) is that it refers to the interconnection and exchange of data between devices/sensors. With the current explosion of IoT technologies, an increasing number of practical applications can be found in many fields including security, asset tracking, agriculture, smart metering, smart cities and smart homes (Figure 1).

1.2 IoT market – Some history

According to Gartner's Hype Cycle of emerging technologies published in 2011 (Figure 2), the IoT was then only at its very beginning. All its possible applications had not yet been imagined. While its ancestors, Machine to Machine (M2M) communications and Wireless Sensor Networks (WSN) were more mature and already into the phase of disillusionment.

Figure 1: IoT technology is now finding applications across many fields

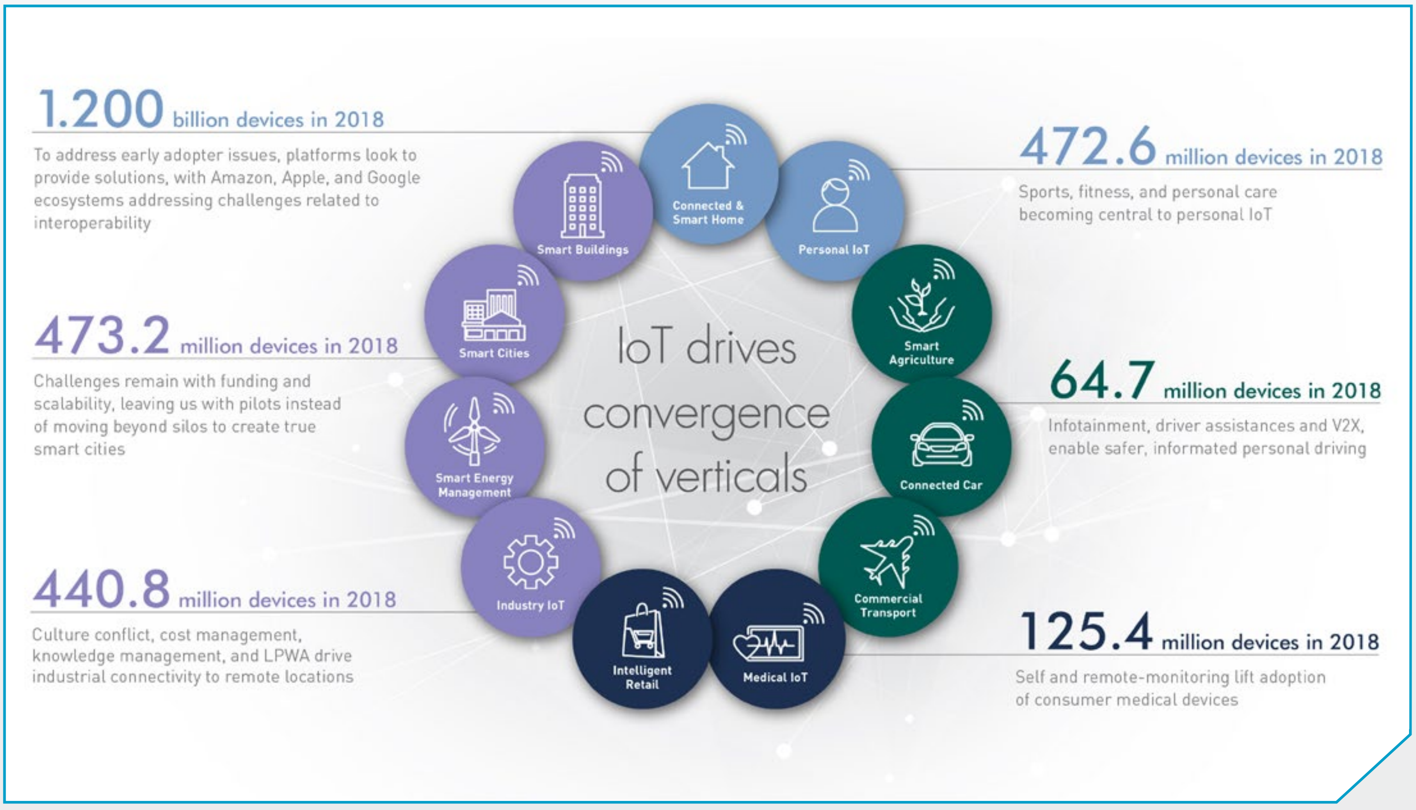
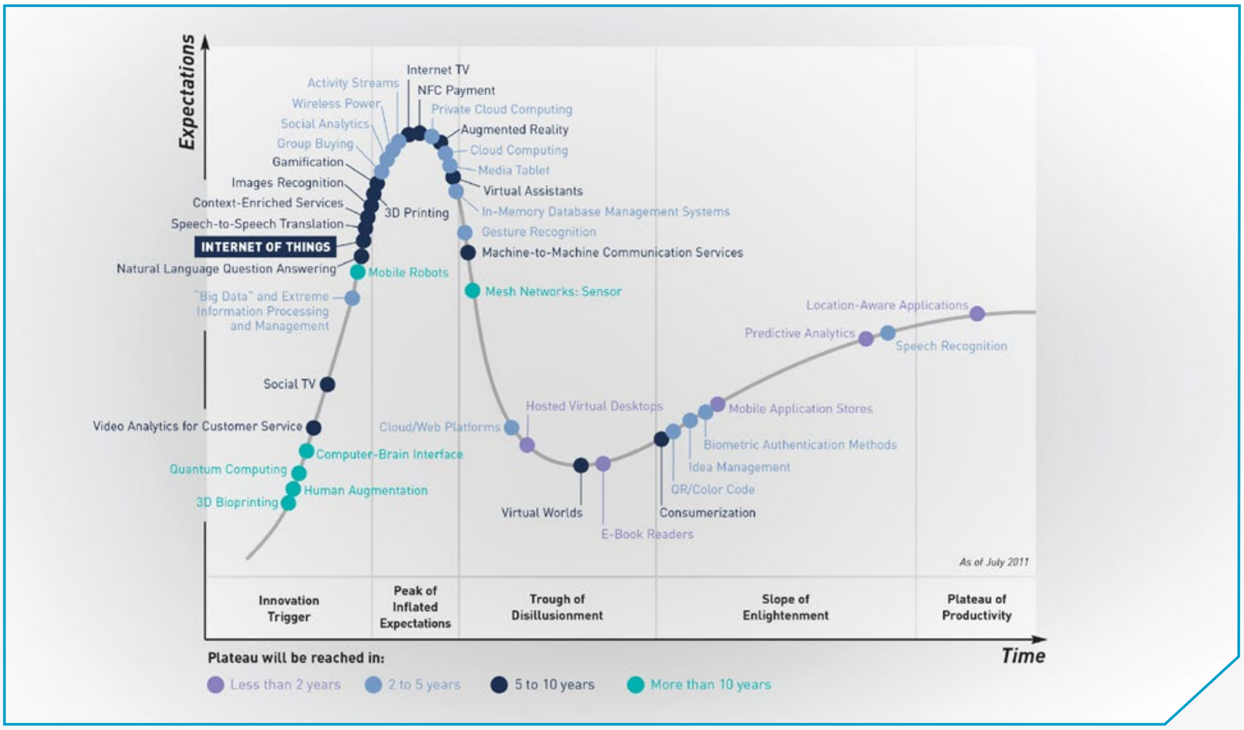
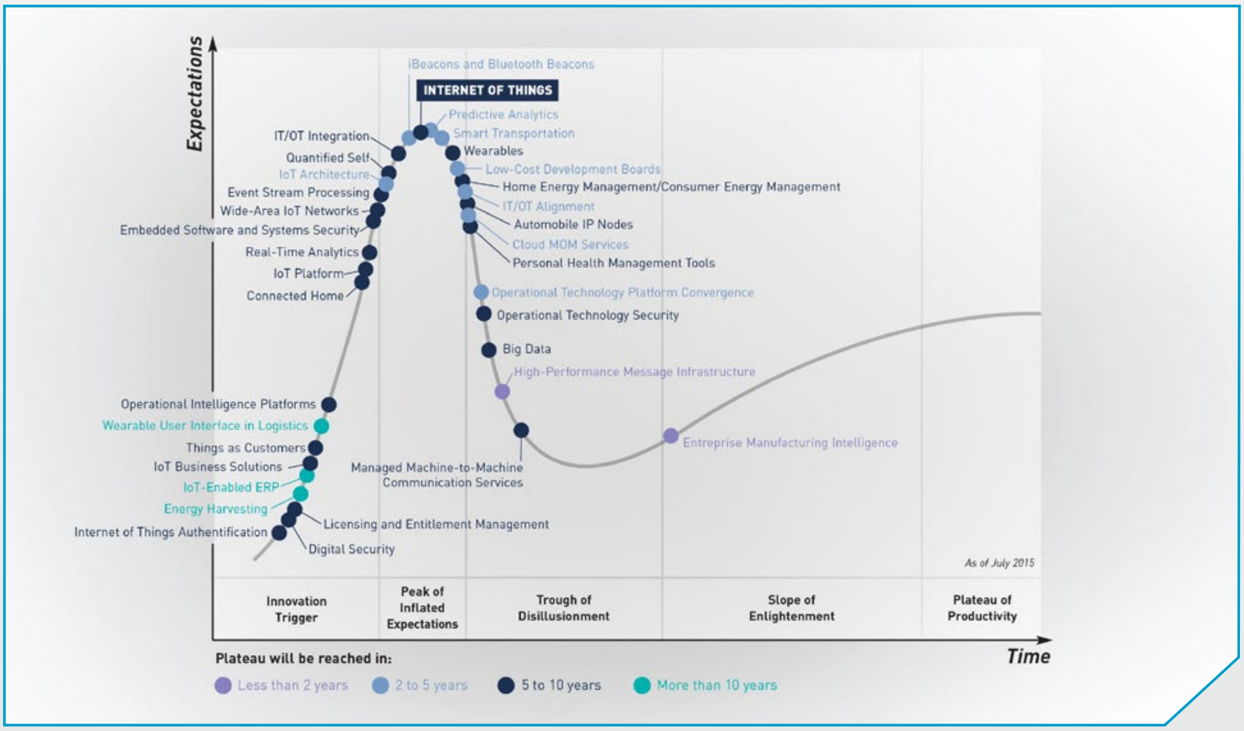


Figure 2: Hype Cycle for Emerging Technologies in 2011



Fast forward a few years, and the story was different. As shown in Figure 3, from 2015, on the same emerging technologies Hype Cycle, IoT was seen as its peak in terms of expectations, and it was now a 'buzz' word. IoT promised a multitude of interconnected devices equipped with embedded sensors and intelligent decision making. Many billions of web-connected sensors and other devices would be embedded into equipment, assets and the broader environment.

Figure 3: The Hype Cycle had changed - update by 2015



Today, IoT applications are a reality. This is made possible by the conjunction of three main factors:

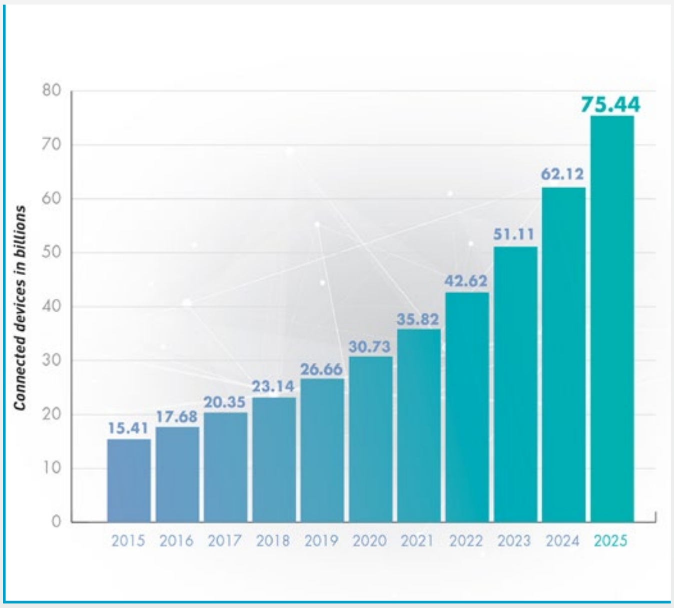
- the emergence and deployment of Low Power Wide Area Networks (LPWAN) and dedicated tele-communication offers for IoT applications,

- the development of IoT platforms, big data processing and storage capabilities,

- the drastic reduction in the energy consumption of electronics (communication modules, MCUs, etc…) combined with the increased lifetime and reliability of batteries, allowing communicating objects to be autonomous from external power supplies.

The rapid growth in the IoT will only continue. And according to IHS Markit (Figure 4) there will be over 75 billion connected devices by 2025.

Figure 4: Projected growth in the IoT



(Source: IHS Markit)

1.3 IoT network technologies and worldwide coverage

One way to segment IoT applications could be to discri-minate according to the end-user - between consumer and business dedicated applications. Another approach could be related to the mobility of the communicating device and the expected coverage of the communication. For example, an industrial sensor monitoring the condition of a machine will have to transmit data within the workshop or the factory. In contrast, a smart utility meter will need to transmit data over some meters or even kilometers depending on the network infrastructure. While, finally, a shipping container tracker must communicate on a global scale. This segregation could also be refined by segmenting according to the communication protocol that is used. Then, we can also classify use cases according to the expected lifetime, and/or the quantity and type of data that has to be transmitted.

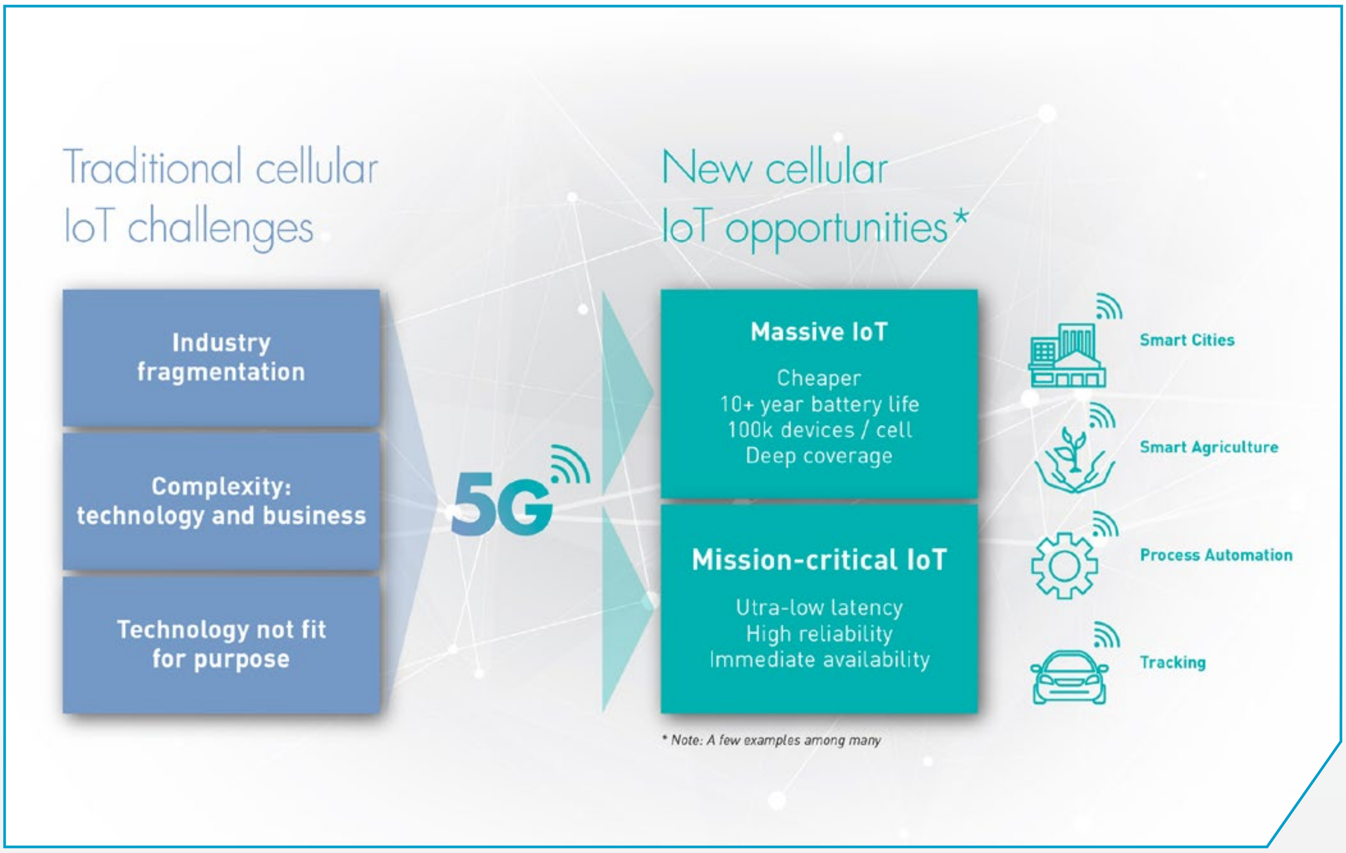
Many Business-to-Business (B2B) IoT applications have specific requirements such as long-range data transmission, low data rate, low energy consumption and cost effectiveness.

The widely used short-range radio technologies are not adapted for scenarios that require long range transmission. Solutions based on cellular communications can provide wider coverage, but their devices consume excessive energy. Therefore, the requirements of IoT applications have driven the emergence of a new wireless communication technology: LPWAN.

LPWAN is not a single technology, but a group of various low-power, wide area network technologies that take many shapes and forms. LPWANs can use licensed or unlicensed frequencies and include proprietary or open standard options such as Sigfox, LoRa, NB-IoT, LTE-M.

The next few years will see rapidly increasing deployments of IoT projects, especially large-scale ones based on cellular technology. The main drivers of this surge in IoT deployment are falling technology costs and the introduction of 5G cellular technology, which will open up new use cases for both mission-critical and massive IoT applications.

Figure 5: 5G addresses new opportunities across the IoT



5G technology (Figure 5) builds on existing investments in cellular M2M technologies and business models to deliver significant improvements in economies of scale. This will help drive adoption of the IoT across all sectors.

According to market analyst IHS Markit, by 2020 there will be around 31 billion connected IoT devices. As more advanced 4G and new 5G cellular technologies come on stream, wide-area IoT deployments will accelerate further as a result of falling costs and higher capabilities. Mobile network vendor Ericsson predicts that by 2023 there will be 3.5 billion cellular IoT connections (based on NB-IoT and Cat-M1), representing compound annual growth of around 30 per cent over the coming years.

Questions are often raised about protocols, such as which is best for energy saving or how to obtain the most accurate comparison between the different protocols on offer. Many experts agree that there is no absolute answer, as the selection of the protocol is highly dependent on the application. Indeed, not all protocols are available everywhere. For example, Figure 6 shows the global Sigfox coverage map as of January 2019, while Figure 7 shows the LoRaWAN network coverage in December 2018.

Figure 6: Map of Sigfox network coverage
(January 2019)

(Source: Sigfox)

Figure 7: LoRaWAN network coverage
(December 2018)

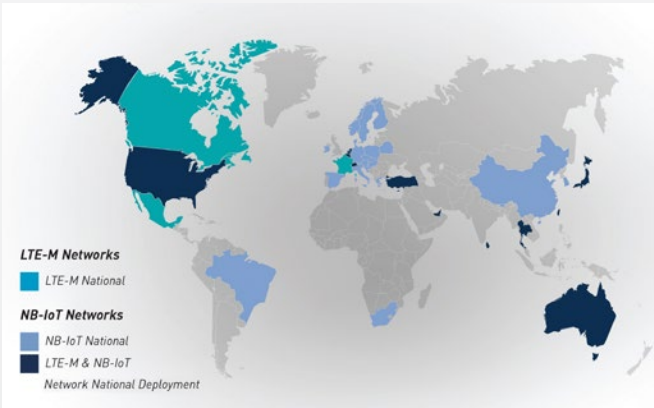
(Source: LoRa Alliance)

At Saft, we believe that solutions offered by several different networks will continue to exist at the same time on the market. This is because the availability of the hardware and the infrastructure, the energy requirements, the relevance regarding the application and the cost of connectivity are different from one application/one business case to the other. As of today, there is not one unique solution that would meet 100% of the functions required by the vast scope of IoT market applications.

A recently published article by LoRa Alliance and ABI research is drawing the same conclusion, stating that LoRaWAN and NB-IoT "will co-exist on the market, by competing in some vertical markets and complementing in other verticals based on cost, coverage, and bandwidth requirements of various IoT use cases" [1].

Mobile operators have been concentrating on their 5G offers and adapting them to IoT requirements to exploit this major new market. The GSMA, the association representing mobile operators worldwide, publishes a Mobile IoT coverage map on its website as shown in Figure 8. Before telecom operators release their 5G network solutions, they have launched 2 LPWAN protocols - LTE-M and NB-IoT - to answer the rising demand, based on the licensed spectrum of frequencies.

Figure 8: Mobile IoT deployment map
(January 2019)



(Source: GSMA)

2. The key success factors for an IoT project

2.1 Moving from a single dimensional approach to creating an ecosystem

In the past, when IoT applications were just emerging, there was a lot of discussion about network security/data security. It seemed that this was the major pain point to overcome. The IoT was often regarded in a single dimensional view from the IT application or the 'big data' crunching/analyzing perspective.

Later on, connectivity became the main concern: with the arrival of LPWAN in IoT territory, the major telecommunication players felt they were missing something. Therefore, connectivity, NB-IoT, 5G, LTE-M, etc… became the buzz words.

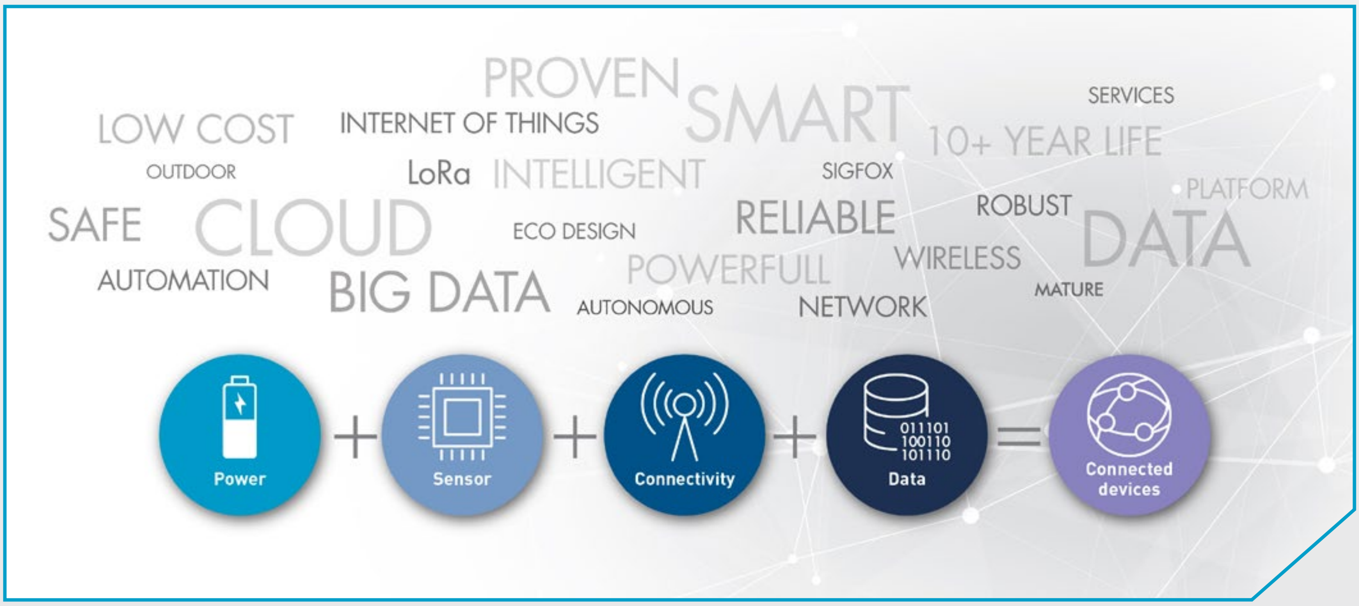
Finally, even though not all the issues have been solved for security, big data or connectivity, hardware has become a further critical aspect to be addressed. As a result, battery manufacturers like Saft have been approached by many IoT project holders or stakeholders to solve their power supply problem, as many IoT applications are meant to be wireless, autonomous and with zero maintenance requirements.

Where the power supply was once an afterthought, there is a growing consensus that it should be regarded as an integral element of a complete IoT ecosystem as shown in Figure 9. This is particularly the case for telecom operators, who have concluded that creating an ecosystem is the most efficient and successful way to develop projects with the right combination of competencies / technologies. This view is expressed in an article by Ericsson [2]:

"In the battle to establish leadership in the IoT, ecosystem will ultimately be the competitive unit [..]. The challenge for businesses is to establish an IoT ecosystem strategy that is holistic, […] and adopt an ecosystem mindset that moves away from vertical value chains with one set of customers at the end of it".

The creation and development of an ecosystem could, in the IoT world, only be successfully handled by companies or entities which have a sufficient size, footprint, and brand awareness, in order to be able to attract both end-users and more broadly, stakeholders representing all the IoT supply chain as partners. The broader and most relevant ecosystem will be then more likely to attract and serve IoT developers and end-users.

Figure 9: Power availability is critical to the IoT infrastructure



2.2 Reducing the time to market

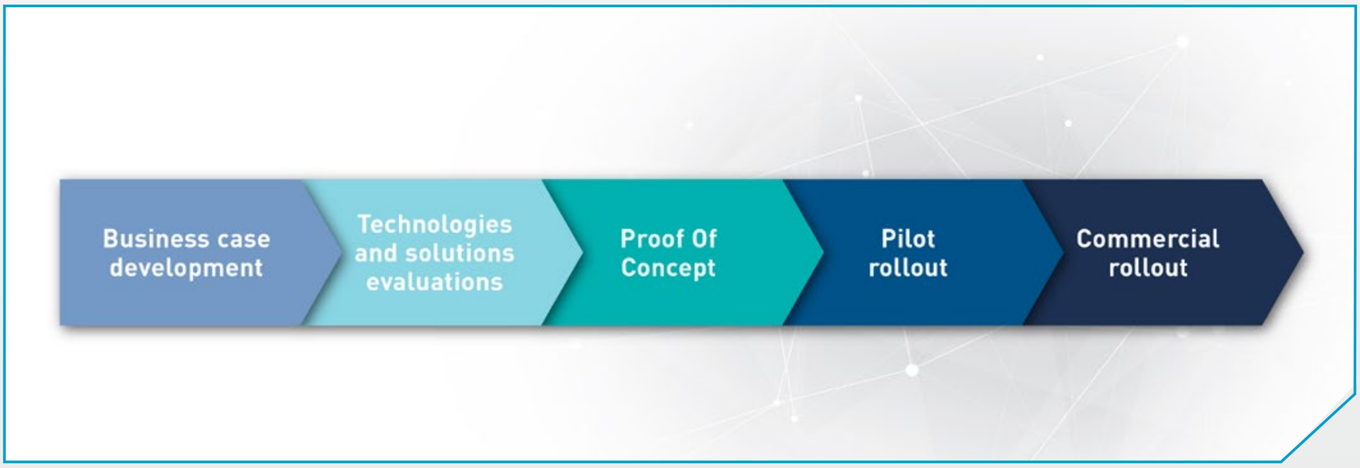
Time is money. Because IoT is a new technology, decision takers must establish complete confidence in their business case before investing in a massive rollout. Therefore, to accelerate the process and reduce the time to market, it is vital to shorten the time associated with some phases of the project development programs - Figure 10. Typically, the phases that can be shortened are the technologies evaluation and the Proof Of Concept (POC), especially if there is a pilot rollout phase in the project.

The key point is to be able to model a solution with real life parameters, to ensure the specified hardware and connectivity will function correctly under field conditions. This is driving the development and marketing of simulation tools.

A pioneer in this approach is Deutsche Telekom with its IoT Solution Optimizer. This is a scalable online tool that provides technical consultancy and customer onboarding services for reliable and cost-effective IoT solutions. It enables businesses around the world to model and optimize the performance of IoT applications in numerous vertical industries such as smart city services, security or asset tracking.

The IoT Solution Optimizer brings together the hardware, application and network feature elements necessary to assess IoT solution designs. Users can either model their own custom design or try a standard IoT offer off the shelf. The tool aims to create an ecosystem of IoT solutions and apps to serve any customer. It also pays particular attention to identifying batteries that can deliver the required performance, sometimes in harsh operating conditions, over a long service life.

Figure 10: The key steps in an IoT project development program



2.3 Building a successful business case

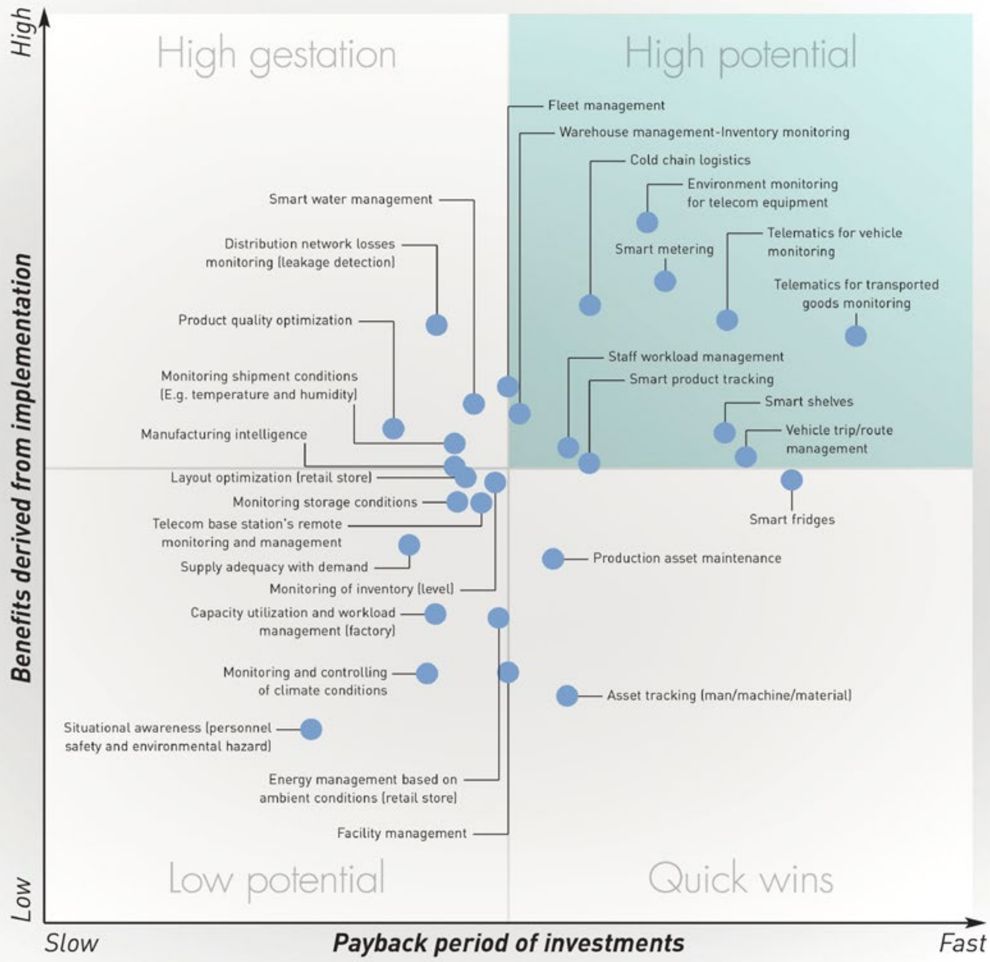
Only projects that will bring real value to customers will scale up successfully to deliver the desired return on investment. Capgemini addressed this issue in its report "Unlocking the business value of industrial IoT"[3] that focuses on the need to identify and prioritize use cases.

To help organizations choose optimal use cases, Capgemini segmented them by business value and the payback period. The high potential use cases identified combine higher benefits with a shorter payback time (Figure 11). By focusing on these use cases, organizations will be in a better position to drive greater value from their Industrial IoT (IIoT) investments and secure a competitive advantage.

However, this report found that many organizations across sectors are not currently focusing on the use cases that fall within the high potential quadrant. Telecoms is leading the way in this area. But many organizations are still missing out on opportunities available.

Clearly, the critical elements in creating a successful business case are detailed segmentation and prioritization at the early project stages. In essence, there must be a good level of certainty that the IoT project will deliver a cost-effective solution to a real problem.

Figure 11: Distribution of use cases by benefits and payback period



High = Greater than average benefit on a normalized range. **Fast** = Greater than average payback period on a normalized range.

(Source: Capgemini Research Institute, Industrial IoT survey, October 2017)

This type of segmentation is of course open to discussion. However, it is our view that any company developing a new IoT solution should consider mapping it along these two main factors: the payback period and the benefits for the end-user. This will certainly help assign the right resources for the project while defining a business model and a business plan, with the right price positioning. Therefore, if we go a little further, segmentation and positioning will also help define the expected lifetime of the solution, which will of course determine the selection of the appropriate power source.

3. The power source - a critical factor for the success of the IoT business model

Many IoT projects rely on battery power of some kind to ensure signals can be sent or received to transfer data when needed, whether or not there is main grid power and whatever the conditions. Whether in metering, monitoring or tracking, the choice of battery has a major influence on the long-term success of the project, both financially and technically.

Financially, battery choice directly impacts capital expenditure (CAPEX), operating expenditure (OPEX), total cost of ownership (TCO) and return on investment (ROI).

Technically, the battery must meet the specific performance needs of the IoT application and communications network over the whole lifetime of the project. It is equally vital that batteries capable of delivering the required performance are available commercially, in significant quantity, to ensure the shortest possible time to market and then support large scale roll-out programs.

3.1 Autonomous, reliable, long-lasting power

Virtually every IoT project needs an autonomous, reliable and long-life power source, whether its devices are completely off-grid, or if they need a reliable source of back-up power if the main power fails.

With many IoT devices located in remote, hard-to-reach or inhospitable areas, providing the power they need can be a challenge. Main grid power is often impractical due to the physical location or installation budget. This means many IoT devices will solely rely on batteries to provide the energy for a lifetime of operation.

Failure of the back-up battery is not an option either for most IoT schemes. At best there might be disrupted or missing data; at worst there could be a failure in a safety-critical system. Whatever the cause, or effect, IoT device battery failure will require a maintenance visit, involving additional operating cost.

Replacing a battery on a sensor embedded in a high ceiling could involve extensive scaffolding, a specialist access contractor and possibly downtime of critical equipment – making the cost of the change far greater than the initial cost of the battery. This means that for the vast majority of IoT projects, it is vital to select a battery that will deliver a long and reliable life with zero maintenance needs.

3.2 Typical IoT power requirements

A typical sensor device will draw just a few microamps (µA) of current in sleep mode, for example, when waiting for an external prompt to take a reading. Alternatively, in standby mode it might draw around 80 µA, for example running an internal clock between timed sensor readings. Data recording and processing might use 20 mA. Transmitting a few tens of bytes of data might call on up to 50 mA or more, depending on the protocol used, the topography of the network and the location of the device.

Typically, the LTE-M module will need peak currents that are in the range of hundreds of milliamperes, while the LoRaWAN module will only need tens of milliamps to transmit data. But the comparison between both technologies can't be limited to the power need, because LoRaWAN and LTE-M meet different connectivity needs. This is why some operators, such as Orange Business Services, are offering both technologies.

Figure 12: Typical power consumption of a LTE-M based module and a LoRaWAN based module

(Sources: Orange)

Other devices acting as IoT base stations or gateways will receive and relay data transmissions from numerous sensors. These types of devices demand higher currents and more frequent transmissions and so will consume more energy.

The required duty can combine with the operating environment to present specific challenges for batteries. For example, dormant periods at potentially elevated temperatures followed by high pulse currents can result in lower transient voltage readings. Ultimately, this can lead to early system malfunctions, and the need for maintenance if the cut-off voltage of the system (minimum voltage of the application) is reached.

There is also a trend towards higher current peak values (pulses) to achieve data transmission over longer ranges, even though newer LPWAN protocols have lower power requirements than GSM or GPRS. In addition, the trend is now to reduce the number of data concentrators deployed in the field, as this helps reduce the CAPEX of any IoT project.

3.3 Financial considerations

The battery selected for an IoT project has a significant influence on its overall financial performance. For example, in terms of capital expenditure (CAPEX), choosing a battery that can sustain high pulse currents enables signal transmission over greater distances. This reduces the number of transmission relays required and cuts overall capital expenditure. In addition, an autonomous power source which does not require a charging system further reduces installation and CAPEX.

When it comes to total cost of ownership (TCO), the cheapest power solution might not be the lowest cost in the long run. Selecting a high-quality battery, with lifetime calculated by product experts to match the lifetime of the IoT devices, can dramatically reduce the lifetime cost.

Operating costs (OPEX) and return on investment (ROI) can also be significantly influenced by battery performance. When IoT devices are deployed in remote areas or cover a large territory (such as in agricultural or meteorological applications), maintenance costs can become significant. Similarly, when the failure of the IoT system may lead to serious financial losses (such as in smart metering or security applications), a failure in the battery system will dramatically reduce the overall project ROI. A zero-maintenance, zero-replacement field-capable power source will both optimize OPEX and secure ROI. The lifetime of the power source has a direct impact on ROI and should at least match the lifetime of the IoT device, network or project.

4. How does Saft support customers in finding the right power source?

When selecting an energy source for their IoT project, the first step for an engineer is to decide if he will use a primary battery or a rechargeable battery operating in conjunction with some method of recharging - either from mains power or a renewable source such as a solar panel. This choice is governed by the energy requirements of the device and its application.

Finding the right battery for a new application can be a major challenge. Considering power and energy requirements needs is a necessary step. But this step alone is not sufficient to ensure the selection of the ideal battery, in terms of electrochemistry, design, size and configuration. In some IoT applications the battery is expected to operate in a potentially extreme and challenging environment for a decade or more. Therefore, its proven reliability, which is highly dependent on both the design and construction of its component cells and the quality of the production process, becomes a vital consideration.

But the key parameters influencing the battery lifetime are not only linked to its electrochemistry or environmental factors such as temperature and humidity conditions. The most significant factors are the discharge profile such as background current, pulse level, duration and frequency, and the cut-off voltage of the application.

Saft has developed a full range of solutions to cover the full spectrum of battery requirements for IoT applications as shown in Figure 13.

Figure 13: Saft has the capability to meet all the key requirements of the IoT market

4.1 A wide range of solutions

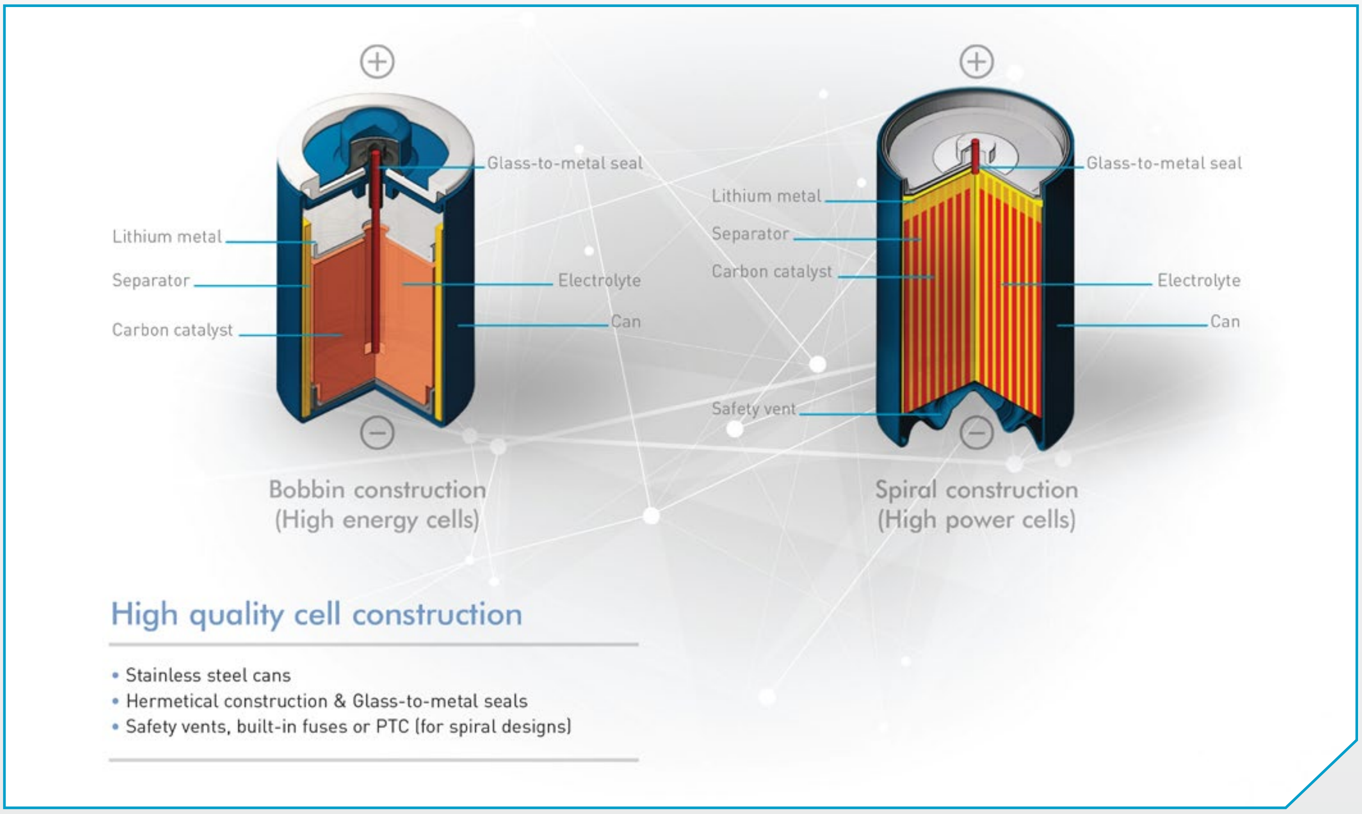
4.1.1 Autonomous, primary solutions

Its basic electrochemistry has a strong influence on how a battery will perform, as do other aspects including cell construction, quality of the raw materials and the manufacturing processes used on the production line. Delivering reliable power for IoT devices over a 10-year lifetime, and even longer, in demanding outdoor conditions, requires critical attention to both the electrochemical and mechanical design of the cell. Saft produces two different electro-chemistries for primary (non-rechargeable) cells, and many more for rechargeable batteries.

••• Construction types

Saft primary cells intended for IoT applications are based on a lithium anode: lithium-thionyl chloride (Li-$SOCl_2$), lithium-manganese dioxide (Li-MnO_2). Primary lithium cells differ in both chemistry and construction. Typically, primary cells are produced in a hermetically sealed cylindrical casing. Inside this casing, a cell can be constructed as a concentric bobbin to optimize energy density (measured by mass and volume) or as a spiral or coiled design to optimize power output – Figure 14. This knowledge is important in achieving the optimum match of battery and application.

Figure 14: Primary lithium cells feature bobbin or spiral construction



Bobbin cells provide higher energy density and lower self-discharge than spirally designed cells, but, can have limited current and pulse current capability, which is often required in IoT applications. In which case, an additional component might be used, such as an EDLC (Electrochemical Double Layer Capacitor) or a HLC (Hybrid Layer Capacitor), to take the current drain during the transmission phase.

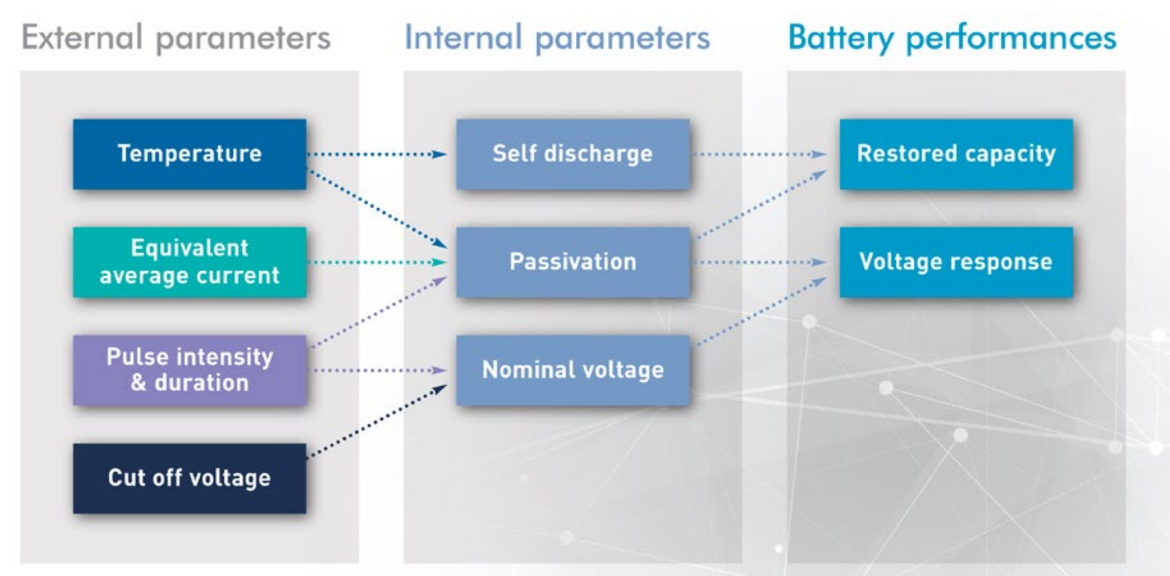
A spiral construction offers significantly more current capability, while showing a lower energy density compared to bobbin cells and an increased self-discharge rate.

For a primary battery, its end of service life can occur in two ways: the energy it contains has been totally consumed by the application or the battery voltage has dropped below the cut-off value for the application. Therefore, the two main performance factors to consider when selecting a primary battery are:

- the battery capacity (that depends on the construction, chemistry, the temperature and the average current drained)
- the battery voltage response (that depends on the construction, chemistry, the temperature and the pulse profile).

The key factors influencing battery selection are summarized in Figure 15.

Figure 15: Key factors influencing battery selection



Cell technologies

Saft lithium-thionyl chloride (Li-$SOCl_2$) cells have an exceptional reputation of reliability and long life in smart metering applications. However, the specifications for autonomous power supplies for new connected IoT devices may be challenging. Higher power pulse capability, for example to support the telecom protocols used in cellular networks, and a wider range of operating temperatures, while achieving a long, reliable and predictable lifetime, may be required.

These challenges have led Saft to develop a new range of hybrid solutions that feature a parallel combination of a lithium-thionyl chloride (Li-$SOCl_2$) bobbin cell and a pulse sustaining device such as an Electrochemical Double Layer Capacitor (EDLC) or a Hybrid Layer Capacitor (HLC).

The long-established track record of Li-$SOCl_2$

Among the different battery technology options available for IoT applications Li-$SOCl_2$ primary electrochemistry usually offers the best choice for such long duration applications. This is because it combines:

- high energy density (up to 700 Wh/kg)
- wide operating temperature range from - 60°C up to + 85°C
- low self-discharge (less than 1 % of capacity per year in storage at + 20°C - after stabilization - for a bobbin cell)
- high and stable nominal voltage of 3.6 V

When dealing with lifetime requirements of 20 years and more, the experience and track record established by the battery manufacturer is a critical consideration. Most of the slow and complex aging mechanisms involved at the battery level cannot be accelerated even for testing purposes. This means that a track record corresponding to the target lifetime is mandatory to anticipate and secure the performance of the battery over such a long installed life. Ultimately, it is experience that really counts.

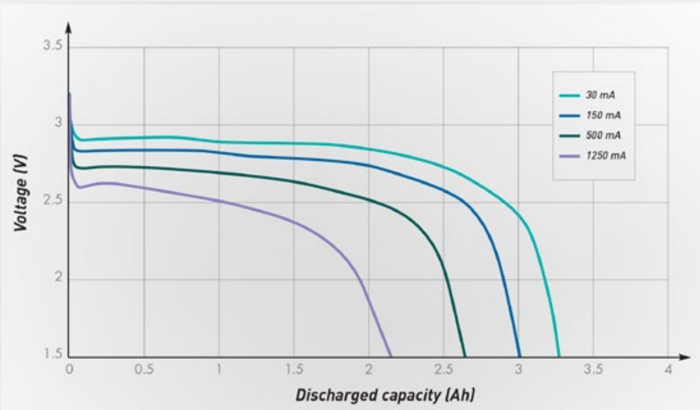
However, Li-$SOCl_2$ is subject to an intrinsic phenomenon that can limit battery performance in IoT applications. This phenomenon, known as passivation, occurs at the lithium anode in the cell and can lead to unwanted and unanticipated system malfunctions. (Refer to "Technical knowledge hub" section for more details).

Challenged by the power performances of Li-MnO_2

Saft also developed a new generation of cells based on lithium-manganese dioxide (Li-MnO_2) technology that, until recently, was not widely used for these types of applications despite its excellent performances.

Saft Li-$SOCl_2$ and Li-MnO_2 cells have in common a high energy density and a very low self-discharge rate. While lithium-thionyl chloride cells show a very flat and stable voltage during their lifetime when continuously discharged, Li-MnO_2 cells, under the same conditions, show a stable voltage throughout most of their lifetime and a slow voltage decrease at the end of life (Figure 16).

Figure 16: Saft LM 17500 continuous discharge curves at + 21°C show a slow decrease of voltage until end-of-life



This could be considered as a drawback, when looking at the power requirements of a device, but it might also represent the opportunity for detecting the battery end-of-life by monitoring the voltage of the battery, together with the battery external temperature, when the discharge profile is well known.

But the most remarkable physical property of this electrochemistry is the absence or very limited passivation phenomenon. This feature, combined with a spiral construction, allows Li-MnO_2 cells to power data transmission with high current pulses, hundreds of mA, if the cut-off voltage is compatible with its 3 V nominal voltage.

4.1.2 Rechargeable lithium solutions

For hubs, gateway devices or sensors that have both high energy and power requirements, rechargeable lithium-ion (Li-ion) batteries are a practical choice, to back-up a solar panel or a power grid solution when available. Because of their high cycling life and reliability in extreme temperatures, Saft's nickel manganese cobalt technology (NMC) is particularly interesting, as it was designed to operate reliably in outdoor conditions.

Saft MP xtd rechargeable cells can provide reliable power at temperatures of between – 40°C and + 85°C, which means they offer reliable power for devices installed anywhere from an arctic blizzard to a pipeline running through a desert or integrated into equipment in an engine room. It is for this specific feature that Thingenix has selected the MP xtd as a back-up solution for SenseHUB, an environmental monitoring smart sensor powered by a solar panel. The MP xtd battery was simply the only Li-ion solution to fulfill reliable operation within the temperature range specified by the customer.

In addition, Saft's unique lithium NMC based batteries do not degrade if left on float charge for long periods. They can be paired with a solar panel and left to charge day after day without losing performance – an advantage that could represent significant cost savings.

In conclusion, we can say that there is no universal battery solution that covers all the energy needs of IoT devices for all use cases. But, nevertherless, the lithium -thionyl chloride and lithium-manganese dioxide technologies show remarkable advantages over other battery technologies, both rechargeable or primary.

4.2 Accurate lifetime calculation and commitment to lifetime assessment

The major challenge that any battery manufacturer has to face when supplying batteries for an IoT application is to be able to advise on the correct sizing and appropriate battery configuration to meet customer expectations for performance, reliability, long life and return on investment.

An accurate evaluation of the battery lifetime in a given application requires a detailed understanding and evaluation of parameters that will affect it. For example, prolonged exposure at low or high temperatures can have a significant impact on the internal resistance of the battery, thus on its voltage response performance :

- low temperatures decrease the electrochemical conductivity
- high temperatures increase the passivation layer on the lithium anode leading to voltage drops and delays, and may also shorten the device lifetime.

Typically, key application parameters that need to be evaluated for an accurate lifetime prediction include:

- total system current consumption: base currents and pulses with duration and frequency information
- storage periods
- thermal environment
- equipment cut-off voltage.

Leading battery manufacturers have developed lifetime models that enable a battery's effective run time to be accurately predicted according to its specific utilization profile, by simulating the aging process of the battery. Based on such proprietary tools, lifetime prediction is generally part of the sophisticated services available to support IoT customers.

Saft itself has built on its long background experience and more than 40 years of research and development knowledge to develop a mathematical model to estimate the run time of primary lithium batteries. This model is already well established in helping meter manufacturers determine the optimum battery size for a specific application, and in helping utilities assessing life duration they can expect for meters based on representative field conditions. This approach translates readily to IoT applications.

4.3 Innovative solutions to optimize operational expenditures (OPEX)

Deploying a fleet of hundreds or thousands of connected devices, if not more, represents a tremendous investment (CAPEX) for a utility. Therefore, it is crucial for the end-user firstly to have a fully operational network of assets at any time, and then to be able to plan any maintenance operation in advance based on real data, not assumptions, in order to reduce OPEX.

To take battery life determination to the next level, Saft has developed an innovative service designed to extract real-life information from the field about remaining battery lifetime in operational meters. The service, which can be applied to any lithium based primary battery, starts by taking a representative sample of devices from the deployed fleet. The devices are then dismantled and the batteries removed for laboratory analysis including:

- mechanical integrity checks
- complex impedance measurement
- remaining capacity determination by a specific chemical analysis of the electrodes (destructive test) which makes it possible to determine:
  - actual State Of Charge (SOC) through measurement of discharged capacity and self-discharge
  - actual State of Health (SOH) by measuring the passivation state and using the complex impedance measurement of the batteries, previously achieved.

This data helps end users to determine their optimum deployed asset management strategy, provides a sound basis for the implementation of condition-based maintenance and ultimately helps secure the availability of end-user infrastructure. It is also giving IoT solution providers accurate feedback on the aging process of their devices in real-life conditions.

Saft has recently carried out this lifetime analysis for a number of utilities and meter manufacturers in Europe. These studies have enabled our customers to greatly improve their knowledge and expertise in battery technology. They also enable our technical and Research & Development teams to challenge the accuracy of our lifetime models by correlating the calculations made during the design phase with the actual remaining lifetime measured from cells collected after several years of service on the field.

Our main findings from these studies is that our initial lifetime calculation was either correct or slightly pessimistic.

5. Conclusion

In many cases, the effectiveness of an IoT solution is directly related to the quality of the battery. If it can't power up the device in the whole temperature range, if it can't deliver the pulse currents, if its life time is too short and it needs unplanned maintenance then the entire user experience is affected. And that will result ultimately in the project failing to deliver on its promised return on investment.

The key to success is that battery selection should never be an afterthought. Rather, it should be regarded as a vital component in the overall IoT ecosystem. And taking an holistic approach to every element will yield benefits in terms of performance, reliability and customer satisfaction.

There are battery solutions – both primary lithium and rechargeable – available for almost every IoT use case and new products are under continuous improvement.

Saft has successfully deployed many IoT projects that are available on our website and some of them illustrated in this white paper. From our experience we are able to confirm that the successful selection of an IoT battery depends on three critical factors:

- selecting a lithium primary battery technology that is the best match for the application, so that the battery will work in a predictable way over the expected service life,
- selecting a battery supplier with sufficient experience and a track record in IoT to be able to provide a fully documented accurate lifetime calculation that considers all the relevant environmental parameters,
- selecting a battery supplier with automated, highly controlled manufacturing processes, to ensure repeatable battery performance.

Technical knowledge hub

The passivation challenge

In Li-$SOCl_2$ cells, passivation causes the formation of a lithium chloride (LiCl) layer on the lithium metal anode by spontaneous corrosion reaction. Passivation is useful as it provides the cell with protection from self-discharge. But it is also a major challenge for pulsing applications, as a pulse current drain will cause the voltage to drop for the few milliseconds it takes to break down the passivation layer. Should the voltage drop below the system cut-off voltage it could interrupt the operation of the IoT device. Significantly, exposure to high ambient temperatures, especially above 40°C, promotes passivation. The result is that a Li-$SOCl_2$ cell will, under certain operational conditions, experience difficulties in meeting the voltage and current demands of the newer protocols used for IoT.

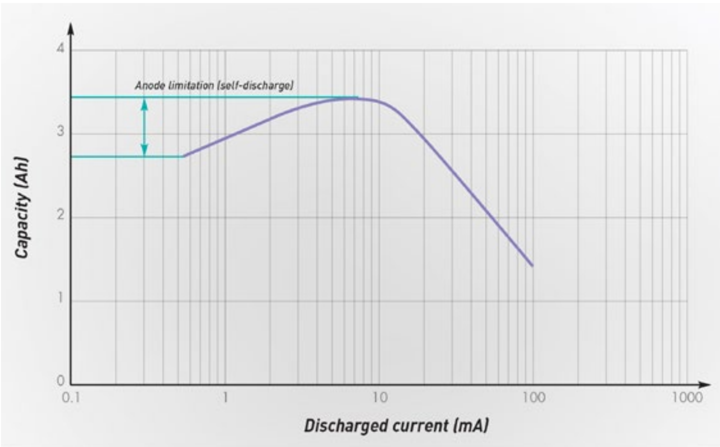
If passivation is not accurately controlled by an appropriate chemistry and a very repeatable and monitored production process, the voltage drop can be significant and may lead to an early end-of-life of the IoT device. One solution could be to add a pulse supporting device in parallel to the lithium -thionyl chloride. These solutions offer a great advantage in terms of the level of pulses delivered. But there are some disadvantages in terms of compactness, operating temperature range and cost. Moreover, depending on the type of device selected, the battery will have to support additional energy consumption, due to the leakage current of the "booster" device. This must be considered in the lifetime calculation.

The self-discharge challenge

Another parameter which has a major impact on the battery life is its 'self-discharge', which is closely linked to the passivation phenomenon for a lithium-thionyl chloride cell. Again, only an appropriate chemistry, full control of the cell's production process and strict quality assurance procedures can enable the cell manufacturer to achieve the lowest possible self-discharge levels.

Self-discharge is a critical factor in ensuring that sufficient capacity is available from the battery over the whole lifetime of an IoT device. Self-discharge is caused by a chemical corrosion reaction at the lithium anode surface, even when there is no load being supplied. The rate of self-discharge varies according to cell size or construction, as well as with ambient temperature. The development of a passivation layer on the cell's electrodes reduces the rate of self-discharge. Leading battery manufacturers have developed techniques to help minimize self-discharge rates over long operating lives. Figure 17 is showing the impact of self-discharge on restored capacity under low, continuous discharge rates, enhanced by the elevated temperature (+ 55°C) of the test.

Figure 17: Saft LS 17500 cell capacity vs current at + 55°C shows the capacity limitation at low rates of discharge by self-discharge



Case studies

Powering soil probes that help farmers work more efficiently and save resources

Climate change is a major risk for farmers in South Africa as conditions become drier than ever before. Traditional intensive farming methods are no longer efficient, and the country's farmers are turning to the IoT to improve their land's productivity.

Leading the way is DFM Software Solutions with highly specialized hardware and software solutions. These include soil moisture probes that monitor conditions round the clock, gathering a large volume of complex data at least once an hour. Armed with this detailed information on water levels, salinity, oxygen and plant root development, farmers can optimize the management of their crops and soil and use water resources more efficiently.

The probes rely on their batteries to deliver total reliability with a two-year service life in harsh conditions, where temperatures can vary between - 10°C and + 45°C. Saft LS primary lithium cells have proved to be the ideal "fit and forget" solution and have been installed in over 50,000 probes.

Smooth parking lot navigation for smart cities

Urbiotica is an expert in IoT, especially wireless sensor networks for smart cities. With a focus on optimizing urban spaces and reducing CO_2 emissions, the company's main focus is on providing an enhanced experience for car park users.

For a logistics center with more than 1,000 employees in Madrid, Spain, Urbiotica has deployed a fully integrated parking solution. It uses a network of sensors, routers and dynamic signage to guide drivers to unoccupied parking spots, saving time and improving the working environment.

A key success factor for Urbiotica was to find the ideal battery to provide autonomous power for its U-Flow parking space sensors. It had to offer the performance and reliability to help optimize the project CAPEX and OPEX and minimize the customer's total cost of ownership (TCO). Long-life was also crucial, as any need to replace failed batteries would lead to high operating costs. That's why Urbiotica selected Saft's LS 33600 primary lithium batteries due to their proven track record in even the most demanding IoT applications.

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Saft White Paper - IoT

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