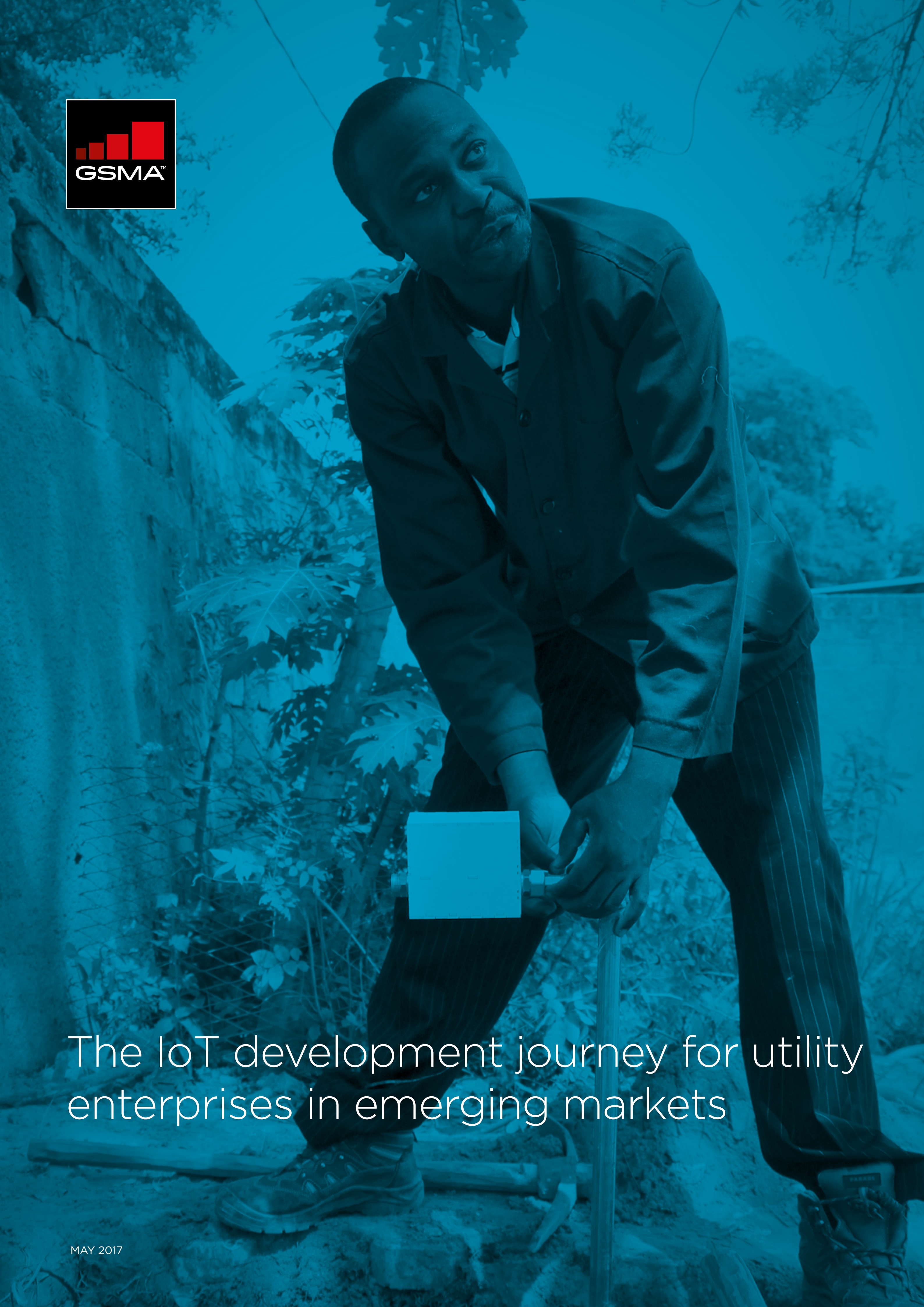

The IoT development journey for utility enterprises in emerging markets

MAY 2017

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Utilities

The Mobile for Development (M4D) Utilities programme promotes the use of mobile technology and infrastructure to improve or increase access to basic utility services for the underserved. Our programme focuses on any energy, water or sanitation services which include a mobile component such as mobile services (voice, data, SMS, USSD), mobile money, machine-to- machine (M2M) communication, or leverage a mobile operator's brand, marketing or infrastructure (distribution and agent networks, tower infrastructure). The programme receives support from the UK Government.

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1. Introduction

By enabling machines and infrastructure to be monitored remotely, the Internet of Things (IoT) and its applications can help deliver critical utility services in emerging markets, especially to underserved populations.[1] IoT and cloud computing will also likely play a major role in achieving the 17 Sustainable Development Goals (SDGs),[2] which aim to tackle some of the world's toughest problems by 2030. This, combined with the declining cost of computing power, sensors and connectivity modules, will make machine-to-machine (M2M) technology more easily accessible to entrepreneurs and enhance innovation in the utilities access space.

1. ITU and Cisco, 2016, 'Harnessing the Internet of Things for Global Development', http://www.itu.int/en/action/broadband/Documents/Harnessing-IoT-Global-Development.pdf
2. Sustainable Development Goals, https://sustainabledevelopment.un.org/?menu=1300

Written in partnership with Eseye Ltd and reviewed by PortMoni, this report aims to provide a high-level assessment of the journey of IoT hardware development that innovative enterprises undertake to create new connected utility systems and infrastructure. What are the main stages of the journey from prototyping to rollout? What types of connectivity enable machines to communicate? And how can mobile operators, as partners, support this journey? We base our analysis on emerging decentralised solutions, especially from GSMA M4D Utilities-funded projects,[3] rather than larger utility players, which face different constraints in terms of capacity, cost, operations, and volumes.

The GSMA Mobile for Development Utilities programme[4] focuses on how mobile connectivity and IoT can help tackle two SDGs in particular: SDG 6 for clean water and sanitation and SDG 7 for affordable and clean energy. In these sectors, the IoT could contribute in two ways: first, in retrofitting existing products to add connectivity where there are clear benefits to improving a service and/or reducing costs. Second, in developing new business models where connectivity and other services converge, such as mobile financial services (the foundation of the pay-as-you-go model). Most of the organisations selected for this research fall under the second category, as do most enterprises testing new ideas.

In both cases, keeping costs down while enabling new value to be created (by collecting data and/or remotely switching systems on and off) is critical for applications targeting populations at the bottom of the pyramid.

As IoT costs are a new expenditure for the business model to accommodate, both capital outlay for the circuit (cellular modem, short-range wireless, or similar) and the ongoing costs of service provision (network subscription or infrastructure maintenance) must be considered. However, the success of the two approaches are measured differently. The first approach is successful if operating costs fall and/or efficiency is improved, while the disruptive or innovative projects in the second approach are deemed successful when the new concept and business model flourishes.

The IoT is already evolving rapidly in the off-grid sector. Smart metering using cellular technology combined with prepayment is enabling a pay-as-you-go (PAYG) solar model for home solar systems and mini-grids. By monitoring systems remotely, this technology prevents usage if payments have not been made, and allows proactive maintenance to be performed.

In the water and sanitation sectors, IoT-enabled solutions are still in early stages of development. However, recent pilots and deployments have begun to demonstrate the impact of connected water infrastructure (such as handpumps) on system functionality, for which data visibility and accountability are key.

3. ITU and Cisco, 2016, 'Harnessing the Internet of Things for Global Development', http://www.itu.int/en/action/broadband/Documents/Harnessing-IoT-Global-Development.pdf
4. GSMA M4D Utilities Programme, http://www.gsma.com/mobilefordevelopment/programmes/m4dutilities

1.1 Recommendations to service providers and mobile operators

To Service Providers:

Build fast, fail fast – focus on an iterative approach to product development.

Test prototypes early in targeted locations – operating conditions, especially in underserved and hard-to-reach areas, are unique and will affect the development journey, especially in terms of connectivity.

Bring in external IoT specialists and have the right in-house capabilities – consultancies with experience in similar projects will help teams optimise the prototyping stage and limit the challenges that might arise in later stages.

To Mobile Operators:

Identify the common objectives of the mobile operator and the service providers. Engage early with partners to develop stronger partnerships and, in turn, reap more benefits over the medium to long term;

Support ideas with the greatest growth potential by ensuring prototyping, testing, and piloting are not hindered by faulty connectivity or SIM cards;

Establish clear business guidelines – the full benefits of early support will come after the pilot stage, and both parties will need to be engaged in clear business terms (e.g., connectivity, distribution, and marketing)

1.2 Ten enterprises leveraging IoT for utilities services[5]

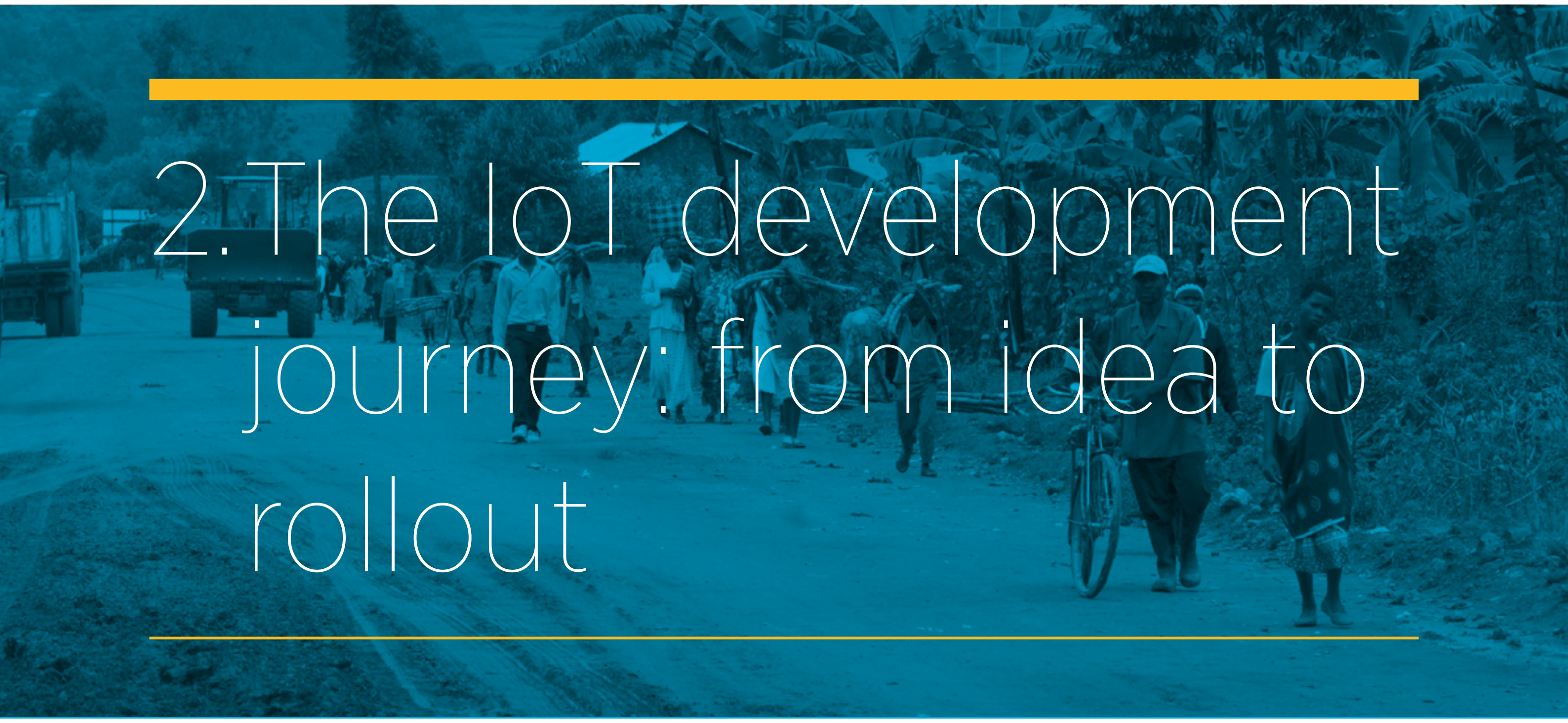
Table 1 below lists the enterprises which provided insights for this report. These enterprises are currently using IoT in either a pilot or commercial phase, and it should be noted that most are still proving their business concepts and how IoT will support them. These examples illustrate how technology can enable new businesses and how, coupled with other enabling technology, mainly mobile payments, they have the potential to unlock affordable and efficient services for underserved customers.

Table 1

Enterprises leveraging IoT technology for their utility projects

Sector	Projects	IoT technology	Usage of IoT
Energy	**Village Infrastructure Angels (VIA)**	Mobile-enabled PAYG monitoring system for solar agro-processing equipment in Vanuatu	Using the data it collects, VIA can efficiently plan the solar capacity of its micro-utilities and monitor customer usage. This data-driven model can help generate higher revenues and inform investors about its activities.
	KopaGas	Mobile-enabled PAYG meters for liquefied petroleum gas (LPG) canisters in Tanzania	The meter communicates with KopaGas' cloud servers to record payment transactions and to monitor and control canister units and gas consumption.
	ME SOLshare	Energy trading between households connected through mobile-enabled nano-grids in Bangladesh[6]	Data will improve the functionality of the grid and enable information exchange for electricity trading.
	Kamworks	Mobile-enabled PAYG solar home systems in Cambodia	Connected systems enable remote monitoring and control.
	M-KOPA	Mobile-enabled PAYG solar home systems in Kenya	Connected systems enable remote monitoring and control. Collecting consumption data and payment history allows M-KOPA to better customise products for their customers.
	SteamaCo	Smart metering systems using GSM and LoRa[7] connectivity in micro-grid architecture in Sub Saharan Africa	Connected meters monitor load availability across the micro-grid and control the architecture.
Water	**eWatertap**	Mobile-enabled PAYG water taps connected through LoRa in Gambia	Connecting taps enables the enterprises managing the taps to remotely monitor and control both the units and water consumption.
	Upande	Cloud-based app integrated with mobile-enabled sensors and data loggers for water utilities	Geographic information system (GIS) identifies isolated areas of the network and calculates water balances to identify where interventions will generate revenue the fastest. In the long run, utilities will save money and be able to connect more customers.
	CityTaps	Smart prepaid metering solution for water utilities in Niger	Smart household meters enable two-way communication between the water utility and its customers.
Sanitation	**Sanergy**	Mobile-enabled sensors for communal latrines in informal settlements of Nairobi, Kenya.	Sensors monitor the fill levels of waste cartridges to improve the logistics of waste removal.

5. See Appendix 1 for more information
6. This is the long-term objective of ME SOLshare, which is currently trading electricity between individual solar home systems, i.e. the system is a broker that permits the trading and calculates the balance on each households' account.
7. Long range, low power wireless platforms

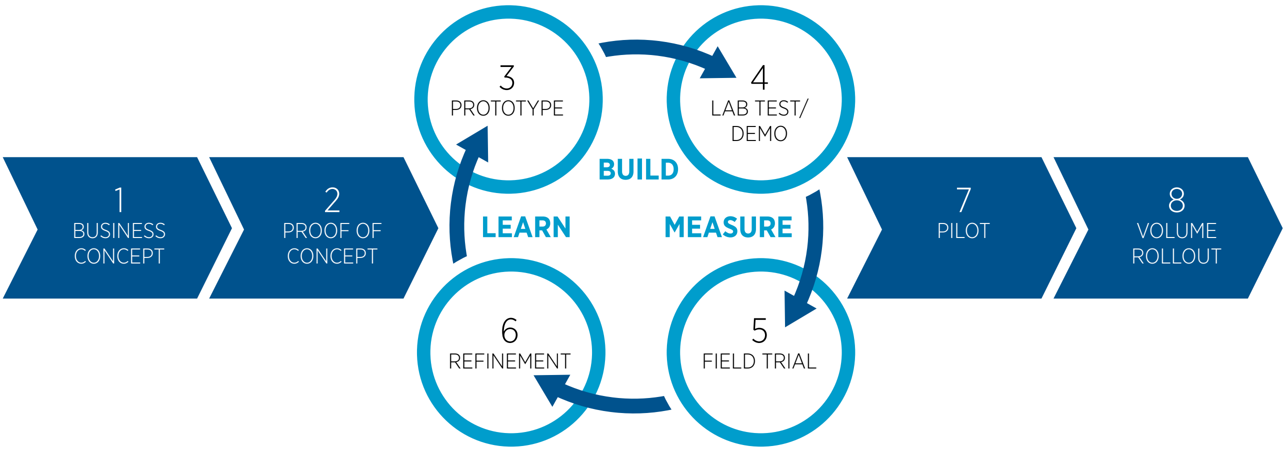


2. The IoT development journey: from idea to rollout

To model the IoT development journey of utility entrepreneurs, we looked at two approaches to product development. The first is a linear journey, capturing all stages of product development from early business concept to volume rollout (Figure 1). However, the journey also includes several iterations, especially in the intermediary stages, to improve and optimise prototypes. This approach is known as lean hardware development, which uses "build-measure-learn" feedback loops[8] to develop a minimum viable product to test business hypotheses and validate learnings from customers' usage before piloting and rolling out the hardware. Table 2 summarises each stage of the IoT development journey.

Figure 1

IoT hardware development journey



8. The Lean Startup Methodology, http://theleanstartup.com/principles

Table 2

Eight stages of the IoT development journey:

Stages of an IoT project	Usage of IoT
1. Business Concept	When an organisation identifies the potential for an IoT application to resolve a specific problem, it is essential to carefully consider the rationale for the project (why integrate IoT technology), the supporting business case, and the skills required to achieve the project's objectives. Entrepreneurs often look to integrate IoT connectivity to utility systems for the following reasons: • To monitor system operations remotely to improve functionality and transparency, and provide proactive maintenance using local teams. • To enable PAYG functionality (i.e., prepayment) by switching systems on/off remotely, and making utility connections and systems more affordable to low-income customers. • To support new local businesses that leverage the data collected (e.g., energy trading, management of waste collection, waterpump technicians)
2. Proof of concept	Proof of concept shows how the final IoT application will work for a given product or service. Typically, the proof of concept will not meet the final form factor and power budget requirements, and technical accuracy may be compromised to deliver it within an acceptable timeframe. Increasingly, 3D printing is enabling enterprises to quickly produce a starting product with an external power supply. At this stage, systems are often built using off-the-shelf components: • Single board computer that provides affordable, versatile and compatible systems, including a basic microprocessor/CPU, memory, and input/output; • Sensors that measure the desired functionalities (e.g. flow, battery charge, fill level); and • Connectivity modules appropriate to the operating context (wide area network such as GSM, local area network such as Wi-Fi).
3. Prototype	The prototype stage aims to deliver a completed unit that closely matches the proposed final product and meets its requirements (e.g., user interface, power consumption). Using an iterative process, the goal is to ensure that no technical problems arise in the following stages. While the look, feel, and operation of the device should be indistinguishable from the final product, modifications will be needed to operate the prototype.
4. Lab test / demonstrations	Lab testing will involve running through the expected use cases and other scenarios where the user may not operate the equipment in the prescribed or expected manner. Once all known issues have been resolved, the lab test phase can be extended to observe how users in the target market or in the field interact with the device. Feedback from users (as early as possible) and testing in real conditions is very useful for identifying issues that would be difficult to anticipate in a more controlled environment.
5. Small production run & Field Trial	The purpose of the small production run is to build a sufficient number of devices to prove the build process, test the distribution network, gather real, live data on usage and power consumption, and demonstrate service availability.[9]
6. Refinement	As the field trials progress, the development team collects information on device usage, operations data, and power consumption. While an assessment of communications costs should have been done at an earlier stage, the real costs of operating the device will only become fully clear once the devices have been operating for a while in the field. The output from this work is one of the most important steps on the journey.
6 bis. Certification and safety	All wireless devices will need the proper approvals and certifications. Ideally, these are obtained prior to the pilot phase, but can be issued simultaneously. Protocols and requirements are specific to the country of operation. Using a communication module within an IoT device that has already been certified by the module manufacturer will ease this stage of the process significantly.
7. Pilot	Typically, a pilot will include a production run of 1,000 units, which will be distributed using the final sales channel, but in a limited scope to allow detailed analysis of deployment, from logistics to customer experience and service delivery. The pilot could be considered the start of production and volume rollout, but a limited set of devices allow for better project control.
8. Volume rollout	Following a successful pilot with proven logistical capabilities and methods, technical excellence and service delivery, volume rollout may begin.

9. See Appendix 2 for more details on this stage of field trials

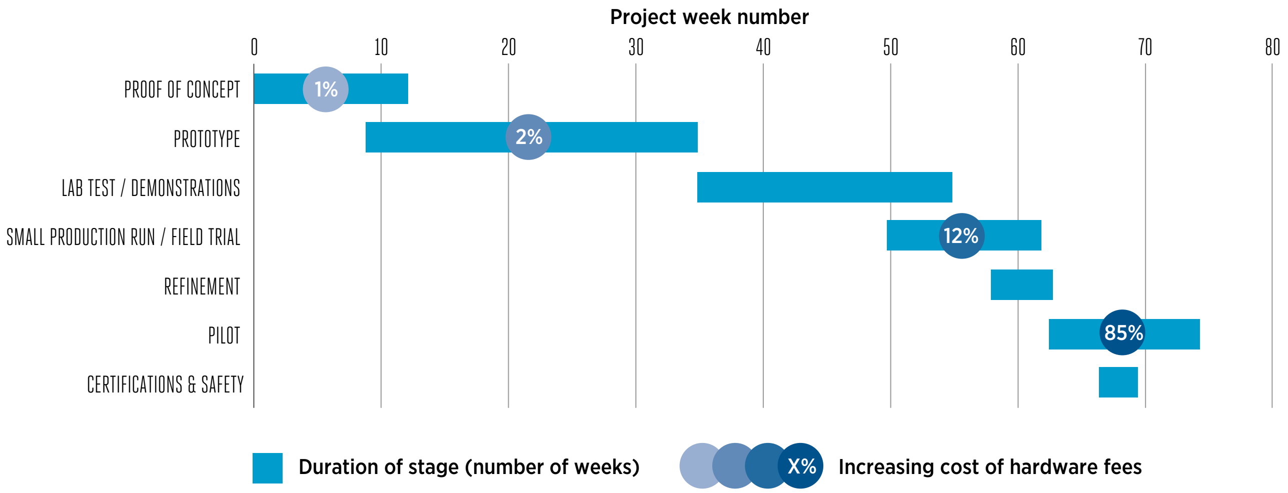
2.1 Five insights on the development journey

2.1.1 Estimated time and costs throughout the IoT development journey

Strong similarities exist in the IoT development journey for start-ups across the energy, water and sanitation sectors. What will differ however are the approaches taken at each stage to ensure technical and operational faults are solved in order to move to next stage (see Kamwork's testimony page 13). On average (and based on our reviews), the total length of the development journey is between 70 to 80 weeks from proof of concept to post pilot volume roll out phase. The most time intensive phases are the trio prototyping-lab testing-field trial.

Figure 2

IoT Project Development, duration and cost, by stage[10]



Note: Depending on the type of product, certifications will need to be secured before the pilot stage.

While the IoT development journey goes as far as volume rollout, most of the enterprises this report covers were still in the pilot stage. The experiences of GSMA grantees are similar and revealed common challenges arising along the journey. These issues spanned entire organisations and included the business process, technical integration, project management, production, testing, and an over-ambitious push to deploy quickly. Most costs were likely to be incurred in designing and implementing hardware and firmware, as illustrated in Figure 2.

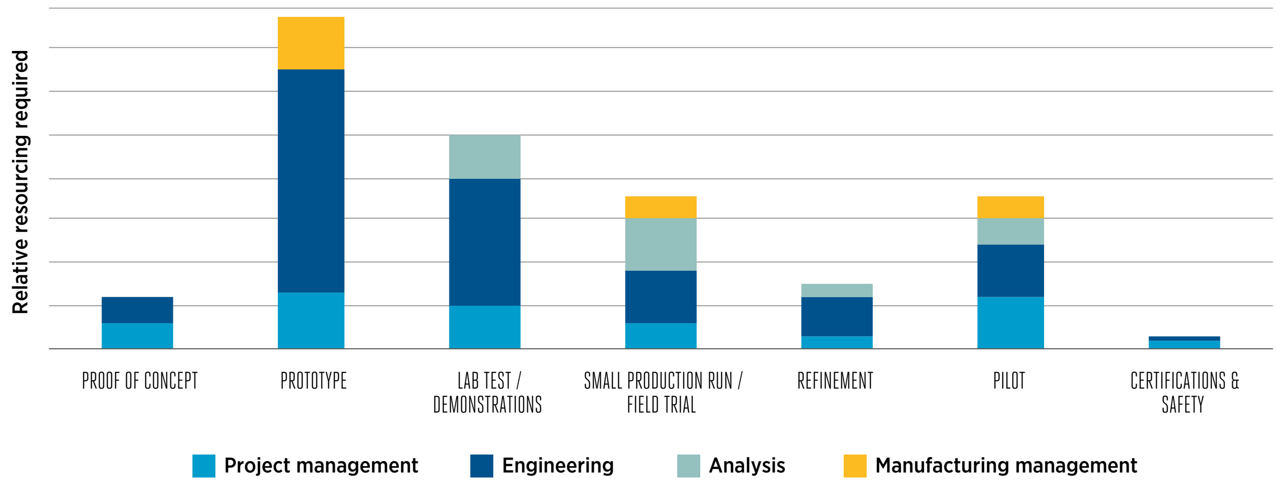
10. The duration of these stages is derived from a subset of Eseye's database of customer applications. As these projects have not yet reached volume rollout, it has been taken out.

2.1.2 Invest in your team's skills

Bringing in a hardware engineer, ideally with IoT experience, during this initial concept stage is critical to the enterprise saving time and money in the long run. IoT experts can explain how the features of a service (such as a location-based service) can be used to create a stronger and more compelling proposition. They can also catch incorrect assumptions and identify options in the technical solution that can affect service performance and operating costs, and reduce the likelihood of forced specification changes or scope creep. For example, assuming two-way communication by SMS for a utility to collect/send data to systems is instantaneous, when there is in fact a nine to 20 second delay in message delivery. This creates a 'round trip' time of up to 40 seconds, which may be unacceptable if the application needs to unlock a service.

Figure 3

Human resources for the development of an IoT project, by stage[11]



In this groundbreaking field, many entrepreneurs will integrate IoT in-house as it is perceived to be more cost-effective and customised to their needs. Others will engage third-party consultants and IoT specialists to build their product for them. When the core focus of the IoT project is not the communication layer, but rather the service running on top of it, working with third parties to develop an IoT network service and support team will save time and capital.

Although there is a heavy emphasis on engineering, project and business skills are also needed to help the concept evolve into a finished commercial product.

11. This figure is derived from an analysis of a subset of Eseye's database of projects. It does not include the full range of expertise needed in a real product development, such as procurement or finance. As these projects have not yet reached volume rollout, it has been taken out.

2.1.3 Improve prototypes based on connectivity challenges

What appears critical, from the proof of concept stage to the end of the pilot stage, is the need for in-country design and testing to evaluate the sensors and connectivity technology, and the robustness of the solution. In terms of connectivity, even though a standardised GSM connection is used, there may be differences across regions, and the product will need to be redesigned depending on the location. A key challenge, common in the off-grid energy sector, is system performance in hard-to-reach areas.

Developing and manufacturing new hardware is inherently risky, and unforeseen problems can cause significant delays, as illustrated by the three examples below.

BRCK, Kenya

For connectivity and IoT technology provider BRCK in Kenya, it was only near the end of the prototyping phase that it began seeing indications that the variable performance of the units may not be entirely due to development, but rather to larger infrastructure issues. To cope with network failures, BRCK had to develop a more robust General Packet Radio Service (GPRS) code.[12]

Portland State University (PSU), Rwanda

In Rwanda, after PSU performed laboratory testing on all its sensors before installing them in handpumps, it found the hardware needed to be improved due to certain issues encountered in the field.[13] The sensor and antennas had to be outside the handpump to operate, and battery life in extreme conditions was lower and difficult to predict, affecting how the sensor functioned. These discoveries led PSU to develop a new and more robust version of the sensor.

SteamaCo, Kenya

In SteamaCo's experience, prototyping was not the most time-consuming stage, rather, it was piloting and refinement. This was because so much of the design complexity and product architecture was based on operating in low-connectivity areas, so iterating and improving using real-world deployments was especially important.

12. Creating world-class hardware in Kenya: http://www.brck.com/2016/05/creatingworldclass/
13. GSMA Mobile for Development Utilities programme, "Portland State University: GSM-enabled sensors for monitoring handpumps to improve water services in Rwanda", March 2016, http://www.gsma.com/mobilefordevelopment/programme/m4dutilities/portland-state-university-gsm-enabled-sensors-for-monitoring-handpumps-to-improve-water-services-in-rwanda.

What type of mobile connectivity?

The connectivity requirements of IoT systems vary depending on the utility infrastructure. Is the location covered by GSM networks? What type of utility equipment is being used (solar home system, mini-grid, water kiosk or water pump, latrines, etc.)? What is the density of connected devices, and what are the cost constraints and plans for scale? Each technology has distinct characteristics, including the range of its signal, the extent of its data throughput (or bandwidth), and the power needs of the communications device (or battery life). Table 3 summarises the current connectivity solutions for utility models in both urban and rural settings.

Table 3. Main connectivity solutions based on the utility model

Type of Utility model	Decentralised systems	Decentralised clustered systems	Centralised systems
Types of applications	Solar home systems, handpumps, water kiosks, latrines	Smart household meter in micro-grids	Mini-grid and piped water connections for clusters of households
Technology	Wide Area Network (GSM, LPWA)	Wide Area Network (GSM, LPWA) and Personal Area Network (Zigbee)	Personal Area Network (Zigbee)

Source: ITU & GSMA

2.1.4 Benefits of building a demo at an early stage

Building a user interface early on, such as a prototype web platform that analyses data, can be used to educate and inspire investors, and help them to grasp the potential benefits and impact of the project quickly. The interface can also be used to demonstrate to potential customers/users how the product will work in real life.

2.1.5 Securing the network: an often overlooked step

While some enterprises do not seem concerned with security issues during the design phase, believing that encryption of their product data will suffice, not using a fully secure, licensed network may prove difficult in the long run as larger volumes of data is increasingly produced. Retrofit security, which is not optimal and very expensive, could affect the organisation's reputation. While entrepreneurs may not prioritise security due to lack of resources or time, the GSMA recommends that a full security and data privacy audit be completed by the prototype stage. This audit should address the possibility of a network side attack, physical modification to the unit, or an attempt to modify/overwrite the device firmware—all common threats in emerging markets.[14]

14. The implementation and review step described in section 7.4 of CLP.11 "IoT Security Guidelines Overview Document" goes into further details http://www.gsma.com/connectedliving/wp-content/uploads/2016/02/CLP.11-v1.1.pdf

2.2 The risk of under-testing: Seven tips

Some parts of an IoT system can be difficult to test or the results may be ignored in the interest of time or eagerness to begin field tests. However, justifying tests that were not 100% successful and ignoring the opportunity to find and resolve issues at this stage is a mistake, and will lead to delays in rollout and additional costs later in the project. Similarly, security tests should be undertaken at every stage of product development. Below is a list of top testing tips.

1. Test in multiple locations – If using a cellular network, performance will vary from one MNO's network to another and even from tower to tower, so test in multiple locations to help ensure a consistent signal. ME SOLshare's experience in this testing stage illustrates this point:

- ME SOLshare's Wi-Fi modules came close to the manufacturer-claimed range in the lab, but discovered in field trials that the building construction diminished this range significantly.

2. Do not proceed until test results are flawless – Because the device is in the lab, it is easy to reset or restart the device. The device should always recover from every test without any human intervention before moving to the next stage. SteamaCo insists on automated recovery from failure scenarios in its testing, even when failure is highly unlikely.

3. Test with defined error conditions – IoT devices differ from consumer applications in that it cannot be assumed a 'broken' unit will be restarted through human intervention. Defined error conditions are valuable for identifying weaknesses in the IoT component of the project. To ensure devices will always continue operating after data errors occur, where possible, devices using short-range wireless should be tested with bit errors introduced into the communications path before testing at the extreme end of the usable range.

4. Disrupt the service – Where cellular networks are involved, the operator should be asked to disrupt service by, for example, failing to allocate IP addresses, de-provisioning the SIM card and then restoring it, or providing partial service.[15]

5. Ensure faults are not hidden – Since the solution should always recover from unexpected situations, system problems may be hidden when the system recovers. There have been examples of fault tolerances hiding genuine design problems with communication systems. Typically, implementation errors that self-correct are related to message timing, with recovery taking place through a retry mechanism. Hidden errors degrade performance for end users and can increase connectivity service costs, so this should be a focus area.

6. Ensure the cost model works – While often disregarded during the testing phase, it is important to continue to check whether the cost model will work. If cellular communication is to be used, service provider charges must be understood, particularly in geographically dispersed deployments. It is more challenging to model costs if a private network is used. City Taps planned to use existing wired network connections to LoRa hubs and the data costs were presumed to be zero. However, the operating cost of monitoring and managing the connections was unknown.

7. Plan for scaling – While difficult to test at the prototype stage, the ability to scale at all levels needs to be considered. For example, the choice of connectivity channel is critical:

- City Taps planned to scale over wider areas, using LoRa base stations. The LoRa Protocol allows for this but sending credit responses to the correct base station in a timely manner may place a burden on the credit update server. CityTaps estimated a larger LoRa coverage for this project than the actual range available, which meant that the area covered by each base station was lower than anticipated;
- ME SOLshare successfully identified a problem with its Wi-Fi cellular gateway purchased as it did not support a connection from the internet into the gateway, through the cellular network. An IoT grade service was needed to allow this routing in a secure manner.

15. Additional examples of the testing the operator should provide are found at: http://www.gsma.com/newsroom/wp-content/uploads//TS.35_v3.0.pdf

- While reviewing various technologies to connect the eWATERtaps to the cloud, it was discovered that the most affordable off-the-shelf 2G products did not function in rural areas of Africa, so eWATERpay sought a tried-and-tested solution from ESEYE. eWATERpay licensed the technology, installed it on a few taps, and tested it in the field with positive results. eWATERpay also successfully trialled its own prototype, LoRa nodes and Hub, and is now developing a production-ready second version of the tap that incorporates LoRa, 2G AnyNet, and Bluetooth.

2.3 Focus on two energy and water enterprises' IoT journeys

For larger organisations, production runs are expected to use custom manufacturing tools and bespoke automatic test equipment, but enterprises will often use standard test equipment and less well-documented production.

Kamworks' IoT development journey

KAMWORKS

Kamworks sells PAYG solar home systems in rural Cambodia.

What has been your experience developing solar home systems, from prototype to refinement?

We have been working on what I would describe as a continuous rollout of our solar home systems since the beginning of the project. The hardware versions have stabilised over time, but development is still ongoing. This was not a linear process, as we were improving the design and features continuously.

What were the main enablers and hurdles to your IoT development journey?

The main enablers were our team and network. The team was already assembled, with good expertise in IoT – both on the software and hardware side. Kamworks also had a network for manufacturing and experience with the process. This saved a lot of trial and error.

The main hurdles were related to quality issues with the hardware and the difficulty in debugging those, for instance, the GSM chip on 75% of the delivered electronics boards for the second version of Kamworks systems turned out to be damaged. It took us time to understand the issue, and we had to replace all the chips. GSM connectivity also proved a challenge as it changes highly from one region of Cambodia to the next and we had not anticipated having such variations. This was, however, one of the lessons we wanted to learn from the project, so it was fine.[16]

How long did it take you to get there?

We went through three iterations, with three months to the first field test, another three months to the second field test, and a final four months to the third field test and version of the solar home system. From May 2014 through November 2015, Kamworks sold or rented a total of 505 solar home systems.

16. GSMA Mobile for Development Utilities Programme, May 2016, "Kamworks: Introducing GSM-enabled PAYG Solar in Cambodia", http://www.gsma.com/mobilefordevelopment/programme/m4dutilities/kamworks-introducing-gsm-enabled-payg-solar-cambodia

Sanergy's IoT development journey

Sanergy is a provider of low-cost sanitation centres for urban settlements in Nairobi, Kenya, testing the use of cellular sensors in its Fresh Life Toilets (FLTs) to collect information and improve the efficiency of its waste collection processes.

What were the main enablers and hurdles to your IoT development journey?

We decided to start our IoT development journey to evaluate the value of using data to make better decisions and improve our processes. We needed real-time data to learn more about the system and test toilet schedules, and we partnered with SweetSense to develop the appropriate GSM technology to collect this data. Partnering with a professional, experienced GSM-technology expert has greatly helped us along our IoT development journey.

Funding for the technology was a challenge; however, we were able to secure support from GSMA to make this project a reality. We had to implement a system of checks and balances to design our IoT systems. As the project is ending in March, we can say that IoT solutions still need cost reductions to justify their value at scale. The GSM-enabled sensor study was designed, in partnership with SweetSense, to support improved decision-making on collection planning.

At the beginning of our project, training and assisting our Fresh Life Operators with the use of GSM technology also required some adaptation from our customer support team.

What has been your experience developing the latrine sensors, from prototype to refinement?

In the first stage of our work with the GSMA and SweetSense, we tested three different types of sensors in nine locations to determine what type of sensor would work best for our larger pilot. Each type of sensor was installed in three locations.

We looked at the durability of each sensor in situ, as well as its ability to provide accurate information on the fill levels of the cartridges. As the pilot advanced, however, we updated the criteria to include toilet access, geometric variation between FLT versions, human concerns, and our existing weighing operations.

We found that while the Pressure Transducer (PT) sensors were useful for calibrating weight sensor data, they were too fragile to fit within our operating environment. While the Weight Sensor (WS) provided high-quality data, their design only worked for our newest toilets and couldn't be installed in older FLTs. The Passive Infra Red (PIR) sensors were the most practical to use within the network, and they have the potential to fit well into a hybrid model to collect additional information. We are currently working with SweetSense to modify the PIR sensors to better suit our needs, by installing RFID chips to provide us with additional data streams.

What is your plan to scale and will IoT enable you to achieve this scale?

IoT and remote sensor devices will be used in the future to understand toilet usage and the impact of new toilets on the overall usage of the network. Currently, there may be a risk that adding new FLTs to an area will hurt existing FLT businesses there. Occupancy sensors will be used to examine changes in user density before and after the installation of a nearby FLT. Because this concern extends to the entire network of toilets, this is an important study that delivers essential insights and focuses on customer concerns. Continuing to demonstrate a commitment to operational excellence will allow us to acquire more customers while maintaining lean operations.

What do you think IoT can do for the sanitation sector?

It can help keep companies accountable to their customers and challenge them to always be learning and iterating on their processes and services. Growing networks can no longer be managed from a few Excel sheets and require data to make informed decisions. Systems need to identify, track and solve issues, closing feedback loops and empowering customers to interact directly with sanitation service providers. Being able to test and change a system while receiving real-time data and feedback through devices on the ground can make all the difference in operational excellence. Sanitation organisations can improve their processes, customer support, and cost efficiency through IoT, making sure they are well equipped and guided by GSM technology partners.

3. The role of MNOs in the development of IoT solutions

There is an opportunity for mobile operators to seize in the IoT market, especially in emerging countries. Here, the market for advanced smart solutions is less crowded, mobile services are growing rapidly and mobile networks are becoming the the predominant infrastructure. From an early stage of development, MNOs are well positioned as enablers and partners for enterprises deploying IoT-enabled utility services. As IoT is combined to mobile payments in the case of the PAYG model, mobile operators will also benefit from increased levels of mobile money usage as well as new customer acquisition.[17] Working with governments rolling out smart city projects, mobile operators could establish their IoT strategies to lead the digitisation of large utilities.

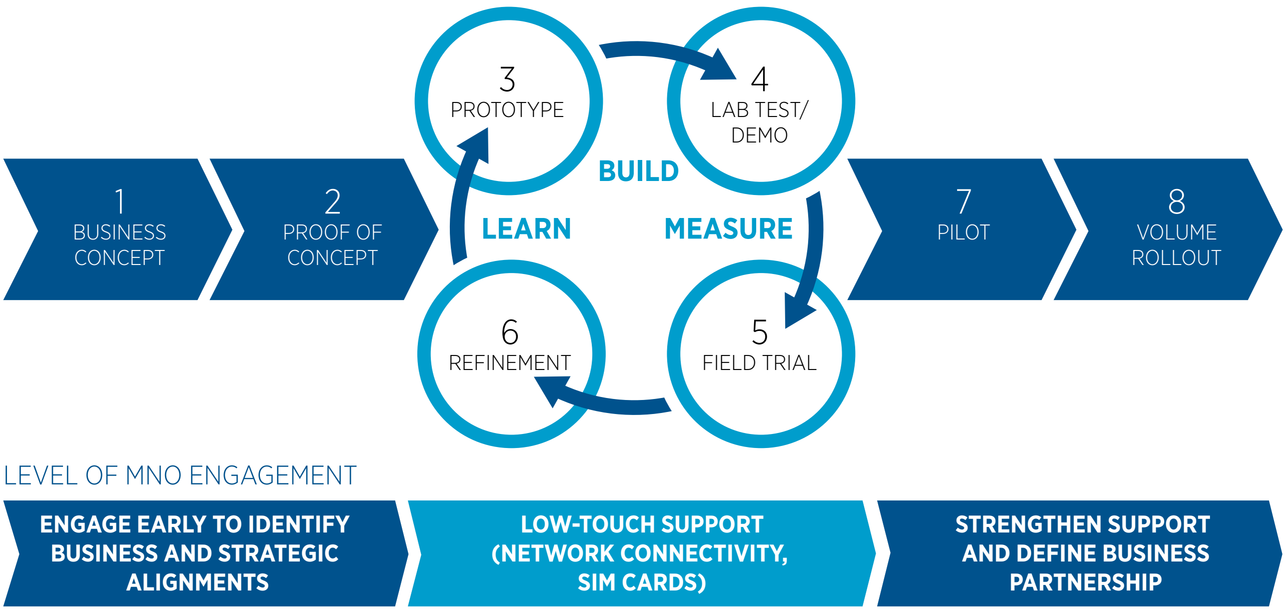
17 . GSMA, 2017, The use of mobile in utility payg models, http://www.gsma.com/mobilefordevelopment/programme/m4dutilities/the-use-of-mobile-in-utility-payg-models-four-key-lessons-from-our-new-report

3.1 MNOs' engagement at different stages of the IoT journey

The relationship between a service provider and an MNO strengthens along the IoT journey. In the first three stages, while the prototype is being finalised, tested in field trials and small production gets underway, the role of mobile operators will be limited. It is up to the entrepreneurs to think about how the solution will use mobile and work out the basics of the business model before field trial. However, one of the fundamentals is for the operator and the entrepreneur to have clear business and strategic alignments. Mobile operators will likely join the IoT journey from the pilot stage, when entrepreneurs will have more tangible results on their business operations and benefits to MNOs. The later stages, based on the positive outcomes of the pilot, will be to establish the terms of the business partnership, including data pricing.

Figure 4

MNO support throughout the Build-Measure-Learn stages



Based on interviews with GSMA Mobile for Development Utilities grantees, it appears that MNOs had limited inputs during the field trial stage, but were supportive of IoT deployment, helped resolve system faults, and troubleshot when necessary (see Box 1 below). As connectivity is a critical element of IoT-enabled services such as PAYG models, MNOs can ensure connectivity issues are addressed in a timely way. To reduce the costs of trials for the innovators, MNOs can also provide free SIM cards and preferential tariffs for data connections on a small number of connected systems.

Working with just one MNO in the pilot phase is usually advised, and entrepreneurs need to find the right partner based on mobile coverage and their interest in supporting the IoT deployment. In the case of M-Kopa in Kenya, working with one MNO (Safaricom in Kenya) enabled them to reach more customers faster because of Safaricom's high market penetration.[18]

18. Safaricom has a 69% market share in Kenya as of Q3 2016

Kamworks’ partnership with CellCard

For Kamworks, mobile connectivity was key to their PAYG solar business model, as it enabled the on/off switch on the solar home systems as well as the collection of data used for remote troubleshooting. Kamworks reached out to several MNOs in Cambodia and selected CellCard, which was the most responsive and had good mobile coverage. The initial agreement was purely commercial, in line with CellCard’s strategy to move further into the M2M area, and focused on connectivity plans for solar home systems (USD 2/month), as well as free SIMs.

The challenges faced in their collaboration with MNOs were:

- Finding the right contact within the MNO, a local champion who would support the project and help it overcome technical challenges while building stronger engagement at the senior level
- Securing access to SIM management tools
- Getting access to M2M-dedicated plans, for instance, offering aggregated data over a pool of SIMs instead of having to pay for each SIM.

However, after a year of operations and renegotiation, which included connectivity troubleshooting, CellCard offered better connectivity rates (USD 0.50/month) and formalised the partnership in April 2015, including co-branding of Kamworks’ solar home systems.[19]

After the pilot phase, as more units are deployed and connected to an MNO’s network, providing more than connectivity, for example, data analytics capability, would ensure MNOs reap the full benefits of the IoT opportunity. This model is especially relevant for organisations like large utilities with hundreds of thousands or millions of connections, but also for larger PAYG solar players, which add tens of thousands of customers every month.

19. GSMA Mobile for Development Utilities Programme, May 2016, Kamworks: Introducing GSM-enabled PAYG Solar in Cambodia, GSMA: http://www.gsma.com/mobilefordevelopment/programme/m4dutilities/kamworks-introducing-gsm-enabled-payg-solar-cambodia

3.2 How MNOs support the digitisation of utility services

Figure 6 below illustrate how MNOs can combine and analyse data from remote IoT devices monitoring the environment, water resources, and infrastructure, which in turn gives utilities more visibility and control over their water systems. A more comprehensive IoT service could create both stronger partnerships with enterprises and greater revenues for MNOs.

Figure 5

Smart water management value chain[20]

IoT DEVICES	COMMUNICATION SERVICES	IOT SERVICES	BIG DATA & ANALYTICS	ENTERPRISE APPLICATIONS
Sensors	2G/3G	Platform Hosting	Data Storage	Leekage Detection
Smart Meters	LTE	Divice Discovery	Situational Awarenes	Network Optimisation
Cameras	M2M	Data Aquisition	Predictive Insights	Asset Condition Monitoring
Controllers	Mobile IoT	Device Management		Environmental Monitoring
Actuators	VPN	Remote SIM Provisioning		Water Quality
Alarms				

END TO END PRIVACY AND SECURITY

To support the growth of this mobile ecosystem, MNOs could create IoT offerings specifically for entrepreneurs and developers. In 2016, mobile operators in the United States launched a series of new offerings and initiatives to spur innovation in IoT, including fixed annual data plans, a dedicated online programme for IoT developers, and starter kits with SIM cards, M2M modules, and data plans. Applying the same type of ecosystem support in developing markets and working with local partners, such as incubators, would help to create momentum for IoT.

20. GSMA Connected Living, 2015, 'Smart water management service development', http://www.gsma.com/iot/smart-water-management-service-development/

3.3 Next generation connectivity: Piloting Low Power Wide Area Network for utility applications

For utility services models, which operate primarily in rural locations, GSM remains the most widely used M2M technology for transferring data over long distances (Wide Area Network), due to its de facto standardisation and interoperability, ubiquitous coverage (about 90% of the world's population), wide availability of chipset, and relatively low price (USD 6–8/module). However, GSM has certain drawbacks when it comes to IoT applications compared to Low Power Wide Area (LPWA) connectivity using proprietary radio technologies on unlicensed spectrum, as shown in Table 4 below.

Table 4

Pros and Cons of GSM versus LPWA connectivity

Technology	Projects	IoT technology
Pros	Well established standard Extensive coverage	Low Power Consumption Low Cost
Cons	High Power consumption Network cost Coverage can be unreliable in some markets	Emerging Standard Need to set up own network or upgrade existing network Only low data rate

Given that most utility applications only require occasional connectivity with minimal throughput, novel technologies are likely to disrupt current applications relying on GSM connectivity in the next five to 10 years. In this light, MNOs are working to tackle the challenge of high cost and power consumption, expanding their IoT offering with new cellular LPWA technologies, known as the Mobile Internet of Things (Mobile IoT), to support a range of mobile network bandwidths and performance requirements suitable for many smart utilities applications.[21]

There are three standards that have been defined by the standard body 3GPP and are currently being deployed by several MNOs, with commercial availability starting in 2017:[22]

- **Extended Coverage GSM (EC-GSM-IoT)**
- **Long-Term Evolution for Machines (LTE-M)**
- **Narrow-Band (NB-IoT))**

These Mobile IoT technologies have been specifically designed to optimise power consumption (battery life of more than 10 years) and small data transmission, and operate at extended coverage (compared to traditional GSM networks). A few MNOs are beginning to explore these technologies for the utilities sector, as illustrated in examples below.

21. GSMA Connected Living, http://www.gsma.com/connectedliving/mobile-iot-initiative/
22. Additional information on these technologies can be found at: http://www.gsma.com/connectedliving/mobile-iot-initiative/

3.3.1 Mobile operators' NB-IoT pilots

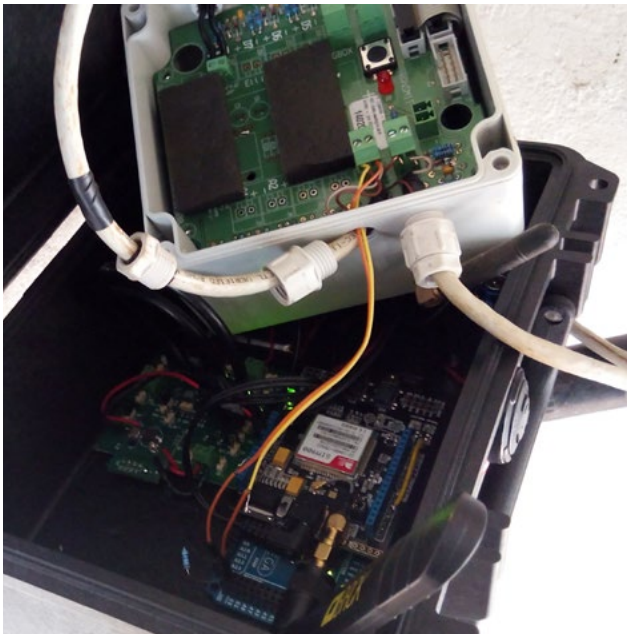
The NB-IoT Standard is emerging as the preferred M-IoT standard, backed by major mobile equipment manufacturers, and targeting applications in the utility sector, such as smart water management. New physical layer signals and channels are designed to meet the demanding requirement of extended coverage—rural and deep indoors—and ultra-low device complexity. The initial cost of the NB-IoT modules is expected to be comparable to GSM/GPRS.

In South Africa, MTN and Huawei have launched a smart water metering solution using the NB-IoT standard.[23] The data gathered will be used to control wastewater flows from each property, identify faults across the network, and improve health and safety outcomes.

In India, Reliance Communications announced a partnership with Cisco (through Jasper Technologies) to set up a dedicated and integrated IoT business unit, providing connectivity management platform and network capabilities.[24]

At the same time, alternative LPWA providers such as Sigfox announced the rollout of their network in South Africa with partner DFA. In such deployments, a local partner manages the deployment and sells connectivity services under a connectivity-as-a-service model. Alternatively, the entrepreneur itself could deploy its own network, with however higher capital cost associated.

It is unclear whether a clear winner will soon emerge in the LPWA technology race, but time to market will be a key element. Interoperability and the availability of an ecosystem upon which developers can build applications will be a core advantage for cellular IoT, as well as reliability and security via the use of licensed spectrum.



23. IT News Africa, 10 November 2016, "MTN, Huawei partner on IoT", http://www.itnewsafrica.com/2016/11/mtn-huawei-partner-on-iot/
24. Live Mint, 18 November 2016, "Reliance Group launches IoT services under venture Unlimit", http://www.livemint.com/Companies/qRSzdxJHCc7NaXM38DZxJJ/Reliance-Group-Cisco-Jasper-partner-for-technology-venture.html

Conclusion

In emerging markets, a new generation of entrepreneurs are looking to leverage IoT technology to make their products and services more efficient and unlock new business models for the utilities sector. As the examples in this report highlight, the IoT journey requires diligence, moving through the different stages of development to build a robust product. As Mobile-IoT becomes more widely available, there is an opportunity for entrepreneurs to leverage this new cellular LPWA technology to facilitate their IoT journey. At the GSMA, we continue to support IoT innovation applied to the utilities sector in emerging markets, through our support to mobile operators in the deployment of innovative IoT offerings and of strong partnerships with entrepreneurs as well as through our Innovation Fund.

Appendix 1: M4D Utilities Grantees using IoT

Geographical spread of M4D Utilities grantees and their MNO partners

Energy sector

Village Infrastructure Angels (VIA) in Vanuatu are developing a mobile-enabled monitoring system, coupled with a PAYG payment solution. The monitoring system (GPRS sensors and data loggers) will monitor the energy consumption of solar agro-processing equipment and households. Based on this usage data, VIA can efficiently plan their micro-utilities (increase or decrease the capacity of solar panels and relocate equipment if usage is too low). This data-driven model guarantees better revenues and is also used to inform investors on perceived risks and attract further investments.

KopaGas is deploying a PAYG meter installed on standard liquefied petroleum gas (LPG) canisters in Dar es Salaam, Tanzania, making clean cooking energy affordable to low- and middle-income households currently using dirty and expensive charcoal. The meter uses GSM-enabled M2M infrastructure to communicate with KopaGas' cloud servers, record payment transactions and activate the electronic prepayment valve, which allows the gas service to run until the credit paid is consumed. When the canister is nearly empty, the microcontroller sends a signal to KopaGas' servers and notifies the closest local vendor to visit or call the customer to arrange delivery of a new canister. The device also communicates alarm signals triggered by leakage or tampering. With the PAYG meter, customers can monitor their own gas consumption through the digital display on the meter.

ME SOLshare aims to facilitate the electricity trade between the nano-grid and its customers, allowing them to sell their excess electricity to other members of the community. Customers become entrepreneurs, increasing generation capacity in response to demand, thus allowing the nanogrid, itself comprised of several solar household systems (SHSs), to grow dynamically. To enable this trade, ME Solshare is developing a mobile-enabled data management system in which all data transmission between households and the ME SOLshare database are sent via GPRS/SMS. This data management will improve the functionality of the grid and enable information exchange for electricity trade. As this trade is directly related to the management of payment processes and money transactions, mobile payment will be integrated.

Water sector

The **eWATERtap,** designed by eWaterPay with funding from African Water Enterprises, provides a solution to inefficient collection of water payments in rural areas of The Gambia, and the subsequent failure to maintain water systems due to lack of funds. The tap is a low-power solar device that turns on a water supply and dispenses water. The tap is connected to eWaterPay's cloud-based dashboard using M2M technology. This allows Africa Water Enterprises and other NGOs to receive real-time data on water usage and remotely assess the health of the taps. The service offers sophisticated but easy-to-use facilities and customer management platform. Measuring performance in this way will allow local maintenance companies to exist and service rural communities efficiently and equitably.

Upande is developing a cloud-based application, WaSH MIS, integrated with GSM-enabled low-cost sensors and data loggers, which is being installed in areas where water utilities are experiencing heavy losses. A geographic information system (GIS)-based network model capturing isolated areas of the network, allowing for live calculations of water levels at the zonal and sub-zonal level. This helps identify where interventions will bring much-needed revenue most quickly. In the long run, the savings, along with comprehensive processes, will translate into higher revenues and more connected customers.

City Taps, in Niger, is building a smart prepaid water metering solution, currently being trialled by urban residents of Niamey, to increase the utility's penetration in underserved areas and reduce its non-revenue water losses (46%). Its smart household meters enable indirect two-way communication between the water utility and its customers, through an ultra-low energy ISM band radio from the meter to the gateway and from the gateway to the cloud via GSM/GPRS. Customers will also be able to pay their water bills through their handset using their mobile money account.

Sanitation sector

Sanergy is creating new businesses in the sanitation sector. Mobile-enabled solutions improve the logistics of waste removal in the informal settlements of Nairobi, Kenya. By installing sensors in toilets, Sanergy aims to improve decision-making on collection schedules by monitoring usage remotely and sending data over the mobile network to measure fill levels in toilet waste cartridges. This will allow Sanergy to monitor waste collection for timely and efficient service delivery and improve access to hygienic sanitation. These valuable insights will enable Sanergy to use resources more effectively and ultimately expand its network.

Appendix 2: Field trial stage: Four recommended phases and potential issues

Arrived at Stage 5, production devices must be of sufficient quality to be used for field trials and distributed to a small number of 'friendly' end users. With a small number of end users, it is possible to keep track of each unit and its usage and performance. However, as the number of units deployed increases, inevitable problems become difficult to manage. There are four recommended phases to a rollout of a small production run, with characteristics changing depending on how the project is managed.

Phase 1. Initially, with limited devices in the field, the development team observes each device and notes every anomaly in behaviour. During lab testing, any temptation to excuse issues with labels such as 'poor signal strength', 'network problems', or 'radio interference' must be avoided. The team should replicate, investigate, and resolve every issue they observe. First, the IoT communication is often new to a team with limited tools and newly acquired skills. It is therefore difficult for entrepreneurs to observe the communications path or draw on experience to reach a conclusion and resolution. Second, there is often pressure from management to continue to increase the size of the trial and demonstrate success.

In Phase 2, additional devices are deployed, still with a 'friendly' and engaged end user, but typically located further away from the development team, and therefore harder to access physically. Errors in device behaviour are still observed, but now a tool such as Excel is required to record device operation patterns. Often, we see IoT development teams presenting colour-coded spreadsheets, with notes and comments tagged to the cells. Pressure from management to keep the project on track often leads to continued deployment of units, often almost impossible to reach, as they are installed even further from the development team.

In Phase 3, additional devices are deployed and an inexperienced development team can become overwhelmed with the task of manually recording the performance of the growing deployments, and consequently have limited opportunity to make technical progress. Eseye has observed that, in this phase, management may perceive a crisis and halt deployment. No further devices are deployed and often the very viability of the project is called into question. Reasons cited are that "IoT is not sufficiently mature" or the project requires better performance than the cellular networks, or any other communications method, can offer. This plateau of deployment can only be overcome by examining each failed communication in turn and determining how to resolve it. Most often, this is related to complexities around firmware and modem or other radio circuit control.

There is usually pressure to exit the plateau of deployment as quickly as possible. Without causing unnecessary delay, it is essential that any changes made are tested across all the deployed devices for a sufficient period to ensure confidence in the system is restored, and at full deployment there are resources to detect, log, and investigate each communications failure.

When confidence is restored in all stakeholders, the final fourth phase is entered and the optimal number of devices deployed. As the scale of deployment increases, the team must continue to be vigilant and fully investigate every error.

Potential issues arising in the field trials stage

A state machine is needed to bring a modem from the power-off state to an open data session. Every error must be addressed, with timeouts to ensure the machine does not get locked waiting for an event that is not going to happen. There will normally be a successful exit to the next state, but unexpected conditions or modem responses will require the firmware to take alternative action.

In the case of cellular modems, the round trip time may change between lab and field. It is not uncommon for designs which communicated in the lab to fail in the field because the timing is now outside the thresholds set in the firmware.

Operating for extended periods is first tested with a small production run deployed to the field. Firmware engineers may find 'memory leaks', 'counter wrap', and 'buffer overflow' errors.

Environmental factors and tamper monitoring should be accounted for in the build specification of the first small production run. Temperature change, battery charge, signal strength, and cover removal are all vital.

The components used to monitor the environment may be removed from the final build, but at this stage they serve two purposes: first, knowing the environmental history of the unit leading up to a failure gives valuable clues when addressing the problem. Second, notification of tampering provides certainty there was no user interference with the device

For many enterprises specialising in a particular product or service, it is useful to have external support from a specialist IoT communications consultant. In the case of wireless applications such as LoRa or ZigBee, generic resources, such as costly test equipment, will push the budget beyond a single project. Where cellular networks are being used, a specialist will have access to components within the network infrastructure that can provide, for example, log files. They will also provide the skills to interpret these and many other issues, leading to robust resolution of any firmware issues.

For more information on the Mobile for Development Utilities programme visit:
http://www.gsma.com/mobilefordevelopment/m4dutilities

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