LPWA: Unlocking the Future of the Internet of Things

The Promise of the Internet of Things

Internet of Things (IoT) has, over the past few years, become the hottest buzz word in the technology industry – driving connected devices and the applications they enable firmly into the spotlight.

Anyone who has following IoT, even from the sidelines, can't have missed the huge projections being bandied about:

- In 2011, Ericsson famously predicted that 50 billion devices will be connected by 2020,
- More recently, economists at GE forecast a $15 trillion addition to global GDP in 20 years,
- Gartner believes the technology will contribute $300 billion in incremental revenue for companies adopting the technology by 2020, and
- IDC values the total IoT market at $1.7 trillion.

Although estimates vary widely, and debate about their accuracy remains spirited, one thing is absolutely clear, as analyst James Brehm puts it: "the IoT market is already big and poised to become huge."

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Why? Because the Internet of Things is creating new customer experiences and unparalleled economic value, while improving quality of life for countless people around the globe. By connecting "things" to the Internet, we gain a deeper understanding for businesses, governments, organizations and individuals, which will in turn transform the way we live and work.

Moreover, there is not a single industry that won't be affected to generate positive outcomes including: faster more effective emergency response; improved quality of life for the elderly or infirm; more efficient food production and distribution; safer, less congested highways, and a cleaner environment, among countless others.

So the only question that remains is: How? With what technologies? Leveraging what standards?

There are many ways to manage, control and collect information from assets. Some methods use wired and others, increasingly use wireless. Those technologies are either managed or non-managed.

Short Range Communication, Personal Area Networks and Local Area Networks have become extremely popular, particularly with individuals and enterprises as they are easy and cost effective to set up. There is no need to register their use in any kind of data base or purchase costly spectrum from local agencies or central government. Instead with a modest upfront CAPEX investment, equipment is bought, connected and administered to enjoy immediate economic, social or personal benefit.

Longer range wide-area technologies tend to be managed services, such as cellular, and as such involve a CAPEX-model upfront to connect the assets, with an ongoing OPEX expense to gain continued access to the network. The additional OPEX component often makes it difficult, if not impossible, to meet the business case of all assets that may benefit from connectivity.

The recent realization of LPWANs using ISM bands is disruptive, as it turns this paradigm upside down: those who are prepared to invest CAPEX similar to a LAN or PAN are able to gain long-range, wide-area device connectivity more akin to cellular for use cases where Short Range had been too costly, difficult to manage or unable to reach, such as remote sensor harvesting and control of industrial machinery.

This new wireless technology is poised to fundamentally change paradigms — driving not only the connection of heretofore unconnected things, but also new and innovative use cases previously unimaginable.

A look back at the past century provides easy evidence that seemingly minor technological advances can and have radically changed the way we live and work – in ways that we today take for granted. Who could have imagined the reality of our lives today back in 1916, or even in 1950 or 1970? Even technology pioneers like IBM's founder Thomas Watson had no idea. In 1943, he famously said, "I think there is a world market for maybe five computers."

So, before we take a deeper look at the connectivity technologies at play in today's IoT – let's first look back to see how we got here.

An Abbreviated History of the Internet of Things

Machine-to-machine (M2M) communications, the precursor to today's Internet of Things, has been around nearly as long as telecommunications itself. It predates personal computing, let alone the Internet, by many years. Addressing the need to remotely measure things like electrical distribution and weather, M2M was born as telemetry. Many agree, the first such system was rolled out in Chicago way back in 1912. It is said to have used telephone lines to monitor data from power plants.

Telemetry expanded to weather monitoring in the 1930s, when a device known as a radiosonde became widely used to monitor weather conditions from balloons. Though greatly advanced since then, radiosondes are still widely in use today with more than 800 registered launch sites around the world.

Whether used to monitor electricity, weather, pipeline throughput, air traffic information or environmental conditions, early telemetry had its limitations. First and foremost: communications were one way only – delivering remote data, but providing no return link to stave off disaster or send fixes over the communications channel.

In 1957, the Soviet Union launched Sputnik, and with it, the Space Race. What is likely less remembered and probably more transformational, is the entry of aerospace telemetry that created the basis of our expansive global satellite communications today. The same technology has since spread across a variety of industrial sectors from factory automation to pipeline monitoring to transportation and fleet management.

Broad adoption of M2M technology began in the 1980s with wired connections for SCADA (supervisory control and data acquisition) on the factory floor and in home and business security systems. Unfortunately, particularly for security, wired connections were easy to disable, ultimately leading to regulations requiring back-up communications channels for public safety-related applications.

In the 1990s, M2M began moving toward wireless technologies. ADEMCO, a leader in intrusion and smoke detection built their own private radio network to address this need, in part, because budding cellular connectivity was too expensive. Similarly Mobitex Technology built out a network of wireless monitoring stations in support of emergency response for police and fire services. In 1995, Siemens introduced the first cellular module built for M2M.

At this time, mobile applications began to take off, particularly fleet and container tracking, and even consumer telematics, with the introduction of OnStar in 1995. Simultaneously, there was extensive collaboration among phone companies like GT Mobile Net, Ameritech, Bell Atlantic, Bell South, Southwestern Bell, Airtouch and Alltel.

Of course, what makes IoT feel relatively new compared to its extensive history is the fact that the phrase wasn't used to describe this motley collection of applications as a group until after the year 2000.

A second large wave of adoption and development of cellular M2M solutions became necessary when the Federal Communications Commission mandated a shutdown of analog networks in favor of the more spectrum-efficient digital network technology. This was a major bump in the road for many early adopters who expected their M2M solutions (like previous, non-wireless or non-connected equipment) to survive in the field for as long as 20 years. All of a sudden, they all found themselves in a position where they would have to replace existing telemetry and telematics equipment. The good news was that reduced network costs and a more level playing field opened the door to many new entries.

75% of M2M and industrial IoT applications use less than 1MB of data per month.

We're now at the stage where cellular operators are voluntarily shutting down the earliest 2G networks and driving M2M/IoT customers to not only upgrade their physical devices, but also purchase bandwidth beyond what is generally needed for M2M and industrial IoT applications – 75% of which use less than one megabyte per month of data. The global carrier community is looking to variants of LTE and even years forward to 5G to address this disconnect. Unfortunately, from a practical perspective, these alternatives (LTE Cat-M1 and Cat-M2) are barely visible on the horizon in terms of commercial deployments.

This timing disconnect has created a window of opportunity for Low Power Wide Area (LPWA) networking. Commercial LPWA networks are being deployed globally today, assets connected to these networks will run for years on batteries and operate in locations other technologies simply don't reach. Plus, because most LPWA solutions operate on unlicensed spectrum, they deliver device connectivity at a fraction of the cost of cellular or even analog solutions.

What are the Connectivity Options?

A survey of available connectivity options can seem confusing, but can actually help tailor your IoT connection to your specific application and return-on-investment. There are four key criteria you should consider when evaluating which option is right for you: range; throughput; power and device management, and network topography.

On Range and Throughput

Personal Area Networks

Short-range wireless personal-area networks (PAN) are often well served with technologies like RFID, near field communications, Bluetooth, Zigbee and ZWave. With varying data throughputs and network topologies, these technologies provide limited range but reliable communications for very nearby sensor data harvesting. Centralized device management is mostly lacking in PAN implementations as the assumption is that the administrator is as nearby as the sensors are.

Local Area Networks

By far, the predominant communications technologies used in the Internet of Things today make up local area networks (LAN). These include wired connections including analog connections like Serial, UART, SDLC/HDLC, CAN, T1 and their evolution to Ethernet, as well as the now ubiquitous Wi-Fi local area wireless communications standards. Together these account for nearly 90% of all industrial IoT connections today and are projected to retain their dominance at 75% of all industrial IoT connections come 2020, according to James Brehm & Associates. Interestingly, wired connectivity, due, in part, to the cost associated with the required infrastructure, accounts for most of the drop off in dominance... and is the only technology likely to shrink its share of IoT connections in the next five years as the general move to wireless technologies continues to gain momentum.

When it comes to wired communications, users benefit from a dedicated, secure connection to the asset, however mobility is not possible as the asset is hard wired, an upfront cost that's often too costly and can involve bureaucratic legal contracts between building owners, their tenants and service providers. Wi-Fi, on the other hand, is quick and inexpensive to roll out and provides more- than-adequate bandwidth for most IoT applications, but suffers somewhat when it comes to security, range and power management.

Wide Area Networks

Clearly, when it comes to range and mobility, neither PAN nor LAN are sufficient to, for example, track a vehicle on a cross-country journey (not even across a small country like Luxembourg). Enter wide-area networking technologies like cellular, satellite and the new LPWA.

> "LPWA offers the opportunity to free industrial applications from the consumer-driven cycles of the public cellular networks."

Connecting mobile assets complicated the network picture. The benefits that cellular provided to the remote monitoring and asset tracking applications proved to be game-changing as well as cost saving. By leveraging public cellular networks, not only can you monitor assets on the move, but you can also eliminate the cost associated with building out and managing your own wired infrastructure.

These cellular networks were designed for person-to-person voice communications. Lucky for the network carriers, consumers were okay with replacing their cell phones every two years (at the most) and bringing failed systems back to the store for service, when needed – like battery replacement. Unfortunately, machine communications has more stringent requirements. When it comes to connecting utility meters, for example, power companies expect equipment to operate reliably, anywhere, for as long as 15 years, often times in harsh environmental conditions, and more often than not on battery power. These devices are expected to be available without changes for supply lifetimes of 10-20 years. However, since the introduction of LTE alone, there have already been multiple updates, causing updates to devices using those LTE networks. Just imagine the burden on equipment manufacturers to update product for each and every cellular network update, every regional spectrum difference, et. al. Moreover, these updates, focused, as usual, on consumer uses, often cost more than they were worth… offering unnecessary bandwidth for the five bytes of data sent daily from a typical backyard utility meter.

As the consumer market demands ever increasing bandwidth driving these updates, and given the cost associated with supporting legacy networks, service providers have found themselves driven to shutdown older networks in order to focus on the growing needs of their largest user base. As a result, the generational lifespan of any given generation is compressed over time – which is contrary to the needs of industries requiring as long as 20 years of consistent operation.

As the Internet of Things gained momentum, the cellular network operators took notice, and began their 5G standards building effort with machine communications in mind. Nevertheless, there are many years ahead of us before 5G standards are released, and even longer before global network ubiquity can be expected. In the interim, a variety of low-power, wide area technologies have emerged to fill the gap – addressing not only range, but also power management for IoT devices.

To better address those billions of IoT devices only transmitting a megabyte of data per month, and in most cases far less, LPWA offers the opportunity to free industrial applications from the consumer-driven cycles of the public cellular networks by providing the stability of public or private networks designed and built specifically for machines. These networks extend battery life and range and providing "good enough" connectivity for the large majority of connected device use cases.

Figure 1

Feature	LoRaWAN Now	Sigfox Now	RPMA/ Ingenu	LTE Cat-1 2016 (Rel-8)	LTE Cat-M1 2017 (Rel13)	LTE Cat-M2 NB-IoT 2018 Rel13+
Frequency Band	433/480/780/ 868/915 MHz ISM	868/915 MHz ISM	2.4 GHz ISM	Licensed Spectrum (700 MHz-2.5 GHZ+)	Licensed Spectrum (700 MHz-2.5 GHZ+)	Licensed Spectrum (700 MHz-2.5 GHZ+)
Modulation	DSS with Chirp	UNB / GFSK - BPSK	RPMA	OFDMA	OFDMA	OFDMA
Rx Bandwidth	125 - 500 KHz	100 Hz (EU) / 600 Hz (NAM)	1 MHz	20 MHz	1.4 MHz	200 KHz
Max Data Rate	293 - 50 Kbps	100 bps (EU) / 600 bps (NAM) 12 / 8 bytes Max	ACCESS POINT 624 Kbps DL 156 Kbps UL	10 Mbps	380 Kbps	~250 Kbps DL 22 kbps UL
Max. # Msgs/day	Unlimited (Some operators or service providers may have limits)	UL: 140 msgs/day DL Broadcast: 4 msgs/day	undisclosed	Unlimited (Single antenna restricted as low as 200KB/day)	unknown	unknown
Max Output Power	14-30 dBm	14-22 dBm	21 dBm	46 dBm	23 dBm	20 dBm
Link Budget	153-161 dB	149-161 dB	undisclosed	140 dB+	155 dB+ on DL	160 dB+
Communication Channel	Half Duplex	Limited Half Duplex	168-172 dB w/ diversity	Full Duplex	Half Duplex	Half Duplex
Power Efficiency	Very High	Very High	High	Low	Medium	High
Complexity	Very Low	Very Low	Medium	High	Medium	Low
Coexistence	Yes	No	undisclosed	Yes	Yes	Yes
Mobility	Yes	Yes	No	Yes	Yes	Limited to idle mode

Among LPWA options available today, although a leader has yet to emerge, multiple options are making names for themselves due to the anticipation of long lifetime and efficiency for machines. Options include LoRaWAN™, Sigfox and RPMA (marketed by Ingenu, formerly OnRamp Wireless). Each claims long range, long battery life and long network life, with important differences which impact their suitability to particular purposes. Moreover, there are new offerings coming out from the cellular carriers including LTE Category 1, M1 and M2 (NB-IoT), as well as 5G, targeted for deployment in 2020.

You can see a high-level comparison of these technologies in Figure 1.

Ultimately, we believe these technologies are very complimentary as each is suited to a subset of applications. Sigfox, for example, is ideal for simple sensor harvesting where its inherent limitations are acceptable due to the small size of the data being transferred and the need for optimal power efficiency. Ingenu offers a broader bit rate and tighter control, but requires antenna diversity at the edge due to the propagation of 2.4GHz creating an up-front CAPEX expense most suitable to very high-value assets where the additional complexity of integration can be effectively absorbed at the margin. LoRaWAN resides comfortable in the middle, providing higher bandwith and a faster data rate than Sigfox at a slightly shorter range and smaller link budget than Ingenue, but with a lower up front cost. And while Sigfox and Ingenue are both on the path to building ubiquitous nationwide networks, LoRa offers the ability, for those who prefer it, to deploy a private network to cover a campus, farm, refinery, etc. as well as the option to work with public network service providers.

On Network Topography

Connecting things also requires thought on how the network will be structured. Having an understanding of what types of conversations the things will have helps aid in the network architecture decision-making processes.

Wired networks have a higher CAPEX with limitations to their mobility. A wired network can be great for fixed assets that never move and are in an environment where a cable is easily run in, such as an office or server farm. These networks provide deterministic Service Level Agreements (SLAs) with more or less unlimited connectivity in both data rates and utilization at a cost per asset that is generally low per bit in high volume. Plus, wired networks are generally more difficult to listen in on or take control of from the outside due to the need to physically access the cable. Wired networks can be managed and optimized locally to changing needs and incremental additions of assets, which generally requires an IT team, leading to hidden or additional OPEX costs.

Cellular network structures are great for global mobility, with guaranteed quality of service (where connectivity exists). These networks are able to address a wide variety of use cases, from voice to data-only, where the frequency of interaction can be high or low and where data throughput requirements can be high. For example, transmitting HD video from a camera which in turn sets off an alarm system in the event of a break-in, notifying police or emergency responders. However, as anyone carrying a smart phone can tell you, power management can be a problem in situations where the end device must operate on battery power. Moreover, designing devices to communicate with cellular networks is more complex than most expect and requires extensive certifications and approvals. The cost of cellular end devices is also often higher than other options, increasing initial CAPEX needs. Finally, when deploying a high volume of devices to communicate with cellular networks, it can be difficult to stay ahead of device lifecycles as the carriers are continuously updating and fine tuning their networks and to manage far flung devices and their related subscription plans.

Wireless point-to-point networks generally have no ongoing operational expenses, however their range is often limited by technology as it is not a managed service. Nevertheless, it can be ideal for applications where cable installations are time consuming, costly or simply not viable, for example ship to shore communications or building control systems.

Wireless mesh networking leverages a complex and expandable, to a limit, topography to extend the reach of relatively short range end points through a limited number of hops through nearby or adjacent end points. By sending a signal in every direction for a short distance and bouncing that signal off other nearby devices again and again, mesh networking can carry small amounts of data over longer distances. This type of topography is most commonly used to transmit simple sensor data – for example, in building automation-type applications. Unfortunately the complexity of such networks result in fragile implementations that are difficult to deploy and manage. In addition, the ability of the network to route signals requires main "always on" devices dedicated to such routing, thus limiting locations where assets can be cost effectively connected, while increasing hardware overhead CAPEX costs and incurring greater maintenance-based OPEX costs.

Wireless star networks tend to be less complex to manage than mesh as there are fewer potential points of failure and less need for ongoing optimization. Moreover, star enables longer battery life as end points can go to sleep when not needed. As the end points are less complex, leveraging a star topography can be significantly more cost effective – opening the door to more, new and innovative use cases. Greater signaling efficiency as only one end point per connection = more payload or less time on air = better battery performance = remote asset locations and more end-point density per area.

As you can see, each available connecting technology has its pros and cons, but by understanding them, you are more likely to find the best for your specific purposes. In fact, as technologies evolve and use cases become more sophisticated, blended connectivity solutions are likely to predominate the IoT space. When connecting your devices to the IoT, you will need to get used to working with several technologies at once for any given solution.

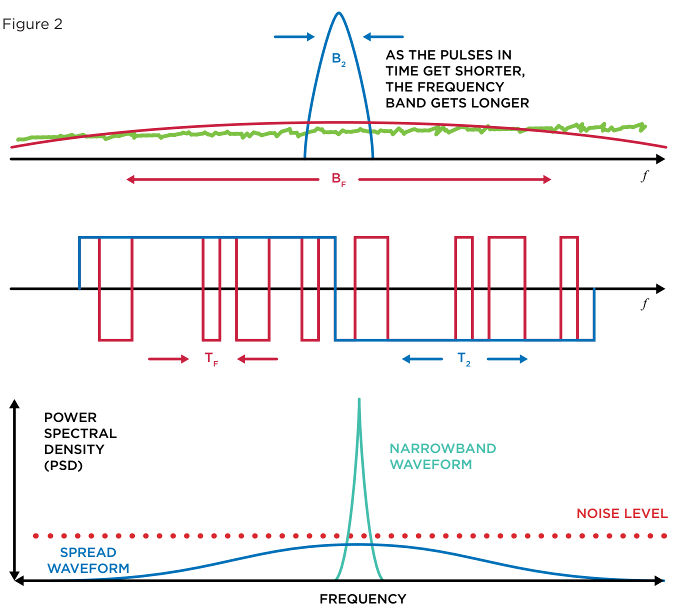
A Closer Look at LoRa™

LoRaWAN-based LPWA technologies, similar to other connectivity types, may not always provide the right connectivity for every application. Instead, LoRa works best for remotely deployed applications that require long-range or deep in-building communication between a large number of devices that have low power requirements and collect low or sporadic amounts of data. Created by the LoRa™ Alliance to standardize LPWANs, LoRa utilizes worldwide unlicensed spectrum such as those in the 433/470/868/780/915 MHz ISM bands, which is more cost efficient to develop and deploy assets into than the 40+ global LTE bands and experiences less interference compared to Wi-Fi (which operates at 2.4GHz and 5GHz) and Bluetooth.

Because LoRa utilizes sub-GHz spread spectrum (Figure 2), its signals can penetrate obstacles, such as concrete, more efficiently and travel greater distances while utilizing less power than other forms of connectivity. For instance, LoRa has an urban range of connectivity between 2-5 kilometers, while in a rural setting it can reach up to 15 kilometers. Its ability to provide such coverage is what makes LoRa so compelling for wide-area applications when deciding which connectivity type to choose. Unfortunately, the low-levels of power and the comparatively limited amount of data that can be transmitted limits the ability to apply LoRa to data-intensive applications, like mixed media and video streaming applications.

> "LPWANs like LoRa can drastically reduce complexities associated with traditional methods of connectivity and serve as excellent additions to cellular and satellite networks."

Figure 2



- Demodulate below noise floor
- Better sensitivity than FSK (better Eb/No)
- More robust to interference, noise and jamming
- Simultanious occupation on a single channel if different data rate
- Tolerant to frequency offset (unlike DSSS)

Because LoRa can travel over such long distances, utilizing very low levels of power, battery life can be dramatically extended, sometimes exponentially, whereas cellular connected devices over a sub-GHz spectrum are traditionally and severely constrained by battery life. Additionally, by utilizing LoRa, battery life can be extended even further by taking advantage of the ability of the connected devices to not have to be "on" continuously in order to transmit data. End nodes can turn on only when necessary transmitting critical data during emergency situations or during previously scheduled intervals. Plus, LoRa leverages a digital spread-spectrum strategy that transmits over several frequencies to the end nodes, allowing for gateways to optimize end node density despite operating on the noisy ISM band.

LoRa technology allows public or private single- or multi-tenant networks to connect multiple applications in the same space – coexisting to enable new IoT, M2M, smart-city, sensor-network, and industrial-automation applications. Leveraging a ***star topography,*** the sensors communicate with gateways. The gateways can then act as a transparent bridge relaying messages between end-devices and a central network server on the backend, which is ideal for public nationwide deployments, where gateways are connected to the network server via standard IP connections as well as for highly controlled private rollouts where security and control are essential.

Utilizing LPWANs like LoRa can drastically reduce complexities associated with traditional methods of connectivity and serve as excellent additions to cellular and satellite networks, significantly extending the range of those technologies deep into buildings, white spots and providing additional and backup coverage as needed. LPWANs can also stand on their own as dynamic connectivity solutions for large low-power deployments. Though LoRa may not fit the bill for every IoT deployment, it is another powerful tool in the growing catalog of connectivity solutions.

What is Right for Your Application?

As you can see, when it comes to choosing the right connectivity technology or mix of technologies, there is a lot to consider largely depending on what kind of application is going to be developed, how it will be implemented and where. Cost, complexity, distance, the amount of data that is transmitted, whether or not there could potentially be obstacles in the way of the signal, among others, can present unique challenges to connecting devices over long distances, particularly in rural areas and deep into buildings.

Here are a few applications for which LoRa technology is particularly well-suited:

Oil & Gas

Whether monitoring a well, a pipeline or a refinery, governments around the world are in agreement that understanding exactly what's happening in the production and distribution of fossil fuels is of paramount importance both for global continuity of energy production as well as for environmental protection. Moreover, as critical infrastructure, it is exceedingly important to protect this process from digital interference from those with technical know-how and malicious intent. Finally, many, if not most, of the production and transportation facilities exist outside traditional cellular coverage areas.

Until now, expensive satellite communications or difficult-to-deploy wired infrastructure has been the only means of monitoring much of the high-value assets in the oil and gas industry. More costly than cellular communications and with troubling latency issues, satellite communications has been the only way to reach these unreachable assets. In addition to cost, satellite modems require intensive power to operate effectively, creating issues in polar locals, for example, which lack adequate sunlight to operate on solar power for nearly six months of the year.

LoRaWAN provides an outstanding alternative for this market. Oil and gas companies can easily deploy their own, cost-effective, private networks on site – easily covering end-points up to ten miles, while taking an added step to prevent intrusion. Moreover, once the installation is completed, they can relax for up to five years without worrying about replacing batteries in far-away, distant places. And, they get all this for fractions of a cent compared to what they currently pay to communicate with their far-flung assets.

Agriculture

It is only natural that some of the globe's best places to grow crops and raise livestock are also the least likely to have complete cellular coverage. Still the Internet of Things holds a great deal of promise for agriculture, whether it's irrigation, soil management or ripeness: yield optimization for both horticulture and livestock is paramount to the farmers' success – and feeding the world for the next hundred years.

LoRaWAN technology offers a quick, affordable opportunity to network farms like never before. A single gateway covering endpoints within a ten-mile radius can monitor thousands of end points attached to things like tractors, irrigators, even animals. As a result, large agri-business, as well as small farmers, can improve efficiency and crop yield, while also improving their ability to respond to emergencies, whether overheated animals or injured workers.

Environment

Water availability, air quality, weather, natural disasters, industrial emissions, and more are capable of impacting our day-to-day lives in ways the industrial world often takes for granted. LoRaWAN technology is an affordable way to implement resource management in and around parks, reservoirs, production plants and busy intersections – all to provide the information we need to manage our environment and continue to sustain our post-modern lifestyles.

Smart Cities

Today's so called "smart city" consists of a set of unrelated, purpose-built applications. Parking, traffic signaling, ambulance or police car location monitoring, public utilities, HVAC at schools and government buildings… the list goes on and on. LoRaWAN offers a unique opportunity for municipalities to unify their countless machine-to-machine/IoT applications for the first time – and at prices often-cash-strapped town-ships can afford. Savvy city managers need more than local interest groups to inform them about how to spend and how to save, and the Internet of Things promises to provide the cross-departmental knowledge they need to optimize taxpayer spend as well as public services.

Conclusion

As we can see, the options for industrial connectivity are very broad. Applications which leverage multiple connectivity technologies can provide profound value with an improved return-on-investment, as they can be more flexible than strictly mobile or fixed applications. That's why MultiTech offers a variety of embedded devices as well as modems, gateways and routers that address connectivity across a variety of technologies including analog, Ethernet, cellular, PAN and LPWA.

The race is on to become the connection technology of choice, but we believe there is no clear winner takes all – as each available technology provides unique suitability for particular applications. LPWA networks seek to remove the inherent risk associated with deploying machine communications on consumer-driven networks as well as reducing cost and power draw and offers the promise of blended private and public networks for assets that are required to be deployed and running for many years in order to deliver solid ROI even on low cost assets.

MultiTech is committed to supporting the growth and development of the Internet of Things in order to create new customer experiences and unparalleled economic value, while improving quality of life for countless people throughout the world. By providing products and services to connect "things" to the Internet, MultiTech delivers deeper understanding to businesses, governments, organizations and individuals, which will in turn transform the way we live and work.

Technology that Transforms

Embedded Cellular System-on-Module

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Industrial Grade M2M Modems & Routers

Programmable Gateways for the Internet of Things

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