Keywords: Internet of Everything, water distribution and monitoring, ultrasonic flow metering

APPLICATION NOTE 5832

WATER AND POWER IN THE INTERNET OF EVERYTHING

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Abstract: The Internet of Things (IoT) will change everything about everyday life, once every thing is connected to the Internet! The networked toaster will send analytics to your favorite Internet company to track your gluten intake! But is this really what we should expect from the proliferation of sensors and network technology? Is this what we really want? In fact, the IoT is already here, but in a limited capacity. The IoT will continue to roll out, but not all at once in a glorious deployment of silicon and services The IoT will emerge in limited phases, in places and tasks where more intelligent real-time management of resources will improve our lives in meaningful ways. In this case, What resources, we all ask, will benefit the most from added intelligence? And what sensors and technology can bring this information to the IoT? This article will discuss how two of our planet's most vital resources, electricity and water, stand the most to gain from a much more intelligent sensing network. We'll also show that the energy smart grid is already an active IoT, but really just the beginning.… Examples of the next waves in the IoT are already underway to help us manage these our precious resources better.

A similar version of this article appeared in the June 2, 2014 edition of AXIOM, an Avnet publication.

The Internet of Everything Is Here…or Is It?

The next great age of technology is the Internet of Things (IoT),[1] if, that is, you believe everything that you read on the Internet. Supposedly, technology will be so inexpensive that we will connect everything. Smart sensors deployed throughout your home will let you monitor and control everything that happens there. Smart sensors deployed across a city will enable better managed communities. Yes, the Internet of Everything is just around the corner.

Or is it? Smart homes have been promised for decades, yet I still use three remote controls to watch a movie and a fourth to turn off the cable. The smart grid was supposed to be rolled out in much of the world by now, but it has seen continuous delays in deployment. Smart cities are supposed to be the next wave, but should I really expect a host of smart traffic sensors in every major U.S. city anytime soon?

The truth is that the IoT is here…sort of. We are only seeing early examples of a world connected with smarter sensors in discrete venues. Policy-driven initiatives like the smart grid are progressing, although slower than expected; consumer-driven sensors like those from NEST[2] or Belkin™[3] are finding a home, or are found in some homes. However, the ubiquitous IoT is, quite honestly, just hype. All that talk needs to be met with skepticism. Actually an Internet of Everything only makes sense where the return on the investment (ROI) makes *financial* sense, and that ROI will only make sense when there is a precious resource to manage.

What resources, we all ask, will benefit the most from smart sensors and systems managed with added intelligence? Perhaps more important, what sensors and technology can bring this information to the IoT? This article will discuss how two of our planet's most vital resources, electricity and water, stand to gain the most from a much more intelligent sensing IoT network.

A Policy-Driven IoT

Let's take a look at some IoT deployments that are driven top-down: machine-to-machine communication systems required by some government policy initiative. The most obvious example is smart power metering and the larger smart grid. There are many reasons for deploying smart grids and they differ from region to region, but the benefits of the smart grid tend to be more visible at the societal level.

Smart grids offer us better management of the planet's scarce energy resources through real-time pricing, demand-response signals to manage load levels, better control of nontechnical energy losses, and improved response time in power outages. In the face of eternally increasing electricity demand (**Figure 1**), smart grids promise a better way to manage the load; a better way to limit the amount of new and expensive energy generation required to power the world; a better way to educate, even train, consumers to be more responsible energy users. Note that it would almost never make sense for individual consumers to purchase and install a smart meter. There are very real safety issues with consumers possibly electrocuting themselves while installing an electricity meter. Moreover, the data from one consumer is not nearly as valuable to utilities and power generators as the data from all consumers in the region. In fact, the benefits of a smart grid only make sense when an entire region uses the technology and participates in the same IT network.

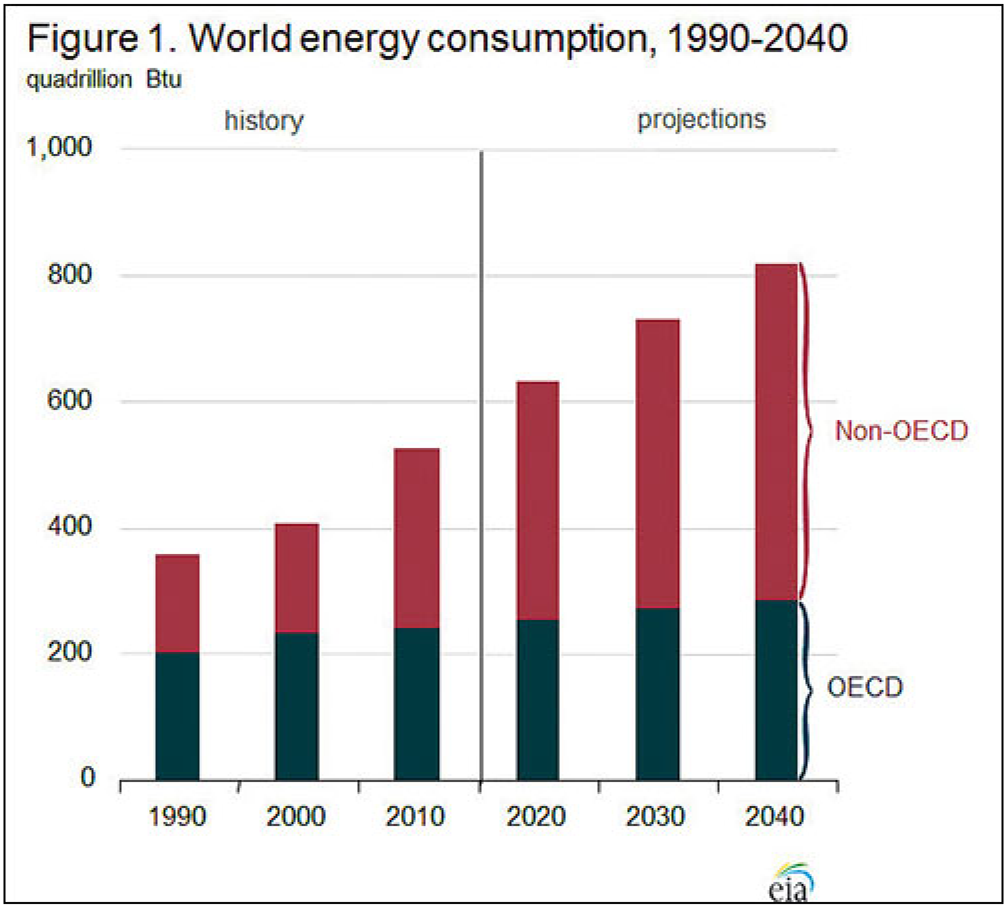

Figure 1. The world will be challenged to meet its energy needs over the next two decades. (Image courtesy of the U.S. Energy Information Administration.[4])

A similar example of a policy-driven IoT is found in smart water metering. Here again society's problem is not immediately manifested at the individual level. Yes, clean, treated water is a precious commodity to each of us and most of us probably use (read: waste) more than we need. But water losses at an individual level may not warrant attention. However, globally a significant amount of water is lost in the invisible: both in the water distribution system and around the home itself—and all this does warrant our attention.

Traditional mechanical water meters cannot detect the low flow rate associated with normal leaks inside the house, leaks that can lead to thousands of gallons of water "lost" every month and year after year.[5] In addition, mechanical meters are quite poor at detecting problematic sizable leaks. As consumers, we might not notice our leaking sprinkler system until several months later after multiple inflated water bills. What to do? We cannot really take control and improve the intelligence of our own water meters. Indeed, the replacement of these meters for a smart meter requires expertise and again, society benefits most when we have complete monitoring of water distribution throughout a region.

Note in both these examples that the government or utility policy drives the deployment of a smart IoT. The precious resources in question (here, electricity and water) are scarce, and smarter sensor IoT networks could better manage what we have without necessarily bringing new capacity online. The reality today is that consumers are largely decoupled from the utilities' capacity constraints…until, that is, there is a disastrous event like a blackout or drought. Consequently, the motivation for rolling out a sensor network likely needs to be policy driven.

A Consumer-Driven IoT

Governmental or agency policy is not the only force driving an increase in machine-to-machine networks. The emergence of a common wireless communication infrastructure (like our cell phones and the WiFi® system in our homes) has created opportunities for consumer-driven Internet-enabled devices: a bottoms-up machine-to-machine network compared to the top-down policy-driven networks mentioned above.

The NEST thermostat is one of the best examples of a consumer IoT device. No agency policy drove the introduction of NEST into the market. Instead we consumers are attracted to a nice looking, intuitive home appliance that promises to do a better job managing our heating and cooling costs; promises to give us a positive return on our investment in a short period of time. Perhaps most importantly, the ROI can be had with minimal interaction between consumers and the device. Taking the mantra, "don't make me think," NEST has developed a product that manages a precious resource in a way that provides an ROI manifested in lower monthly bills that an individual consumer can appreciate.

Belkin is taking a similar approach to deliver on the promise of a smarter house. Rather than ask consumers to deploy a big, complex home-control system, Belkin allows consumers to do it one piece at a time. Their WeMo® products include light switches, switched power outlets, and even an energy-measuring power outlet (**Figures 2** and **3**). Each product uses a simple interface on your mobile device to monitor and configure the network. Light switches and power outlet switches can be easily configured with simple commands like, "turn the light on at 5 p.m." The energy-measurement switch (WeMo Insight) shows you how much money (not energy!) your devices are consuming. These intelligent products[6] are giving us true "insight" to make decisions about powering our homes. Taking advantage of our home's WiFi network and a mobile device, Belkin products are making it easier for consumers to monitor and manage energy-consuming appliances.

Figure 2. The Belkin WeMo Switch wall unit. Provides wireless control of TVs, lamps, stereos, heaters, fans, and more. This smart switch features the energy-metering technology in the 78M6610+LMU from Maxim Integrated.[7]

Figure 3. The Belkin WeMo Insight Switch allows you to turn devices on or off, program customized notifications, and change device status—from anywhere.

A newer example of a consumer-driven IoT is smart parking systems. Pilot projects underway across the U.S. use a network of sensors to detect open parking spaces in dense urban areas. This data is then shared with your mobile device, and an application can navigate you to the best parking option. Certainly there is a commercial aspect to this deployment of sensors, because it could essentially act as "advertising" for parking spaces and potentially increase the utilization of lots implementing this technology. But the real resource managed here (and the reason we would be willing to pay for this service) is time. This IoT parking system would significantly reduce the time it takes to park in downtown Los Angeles, Chicago, New York, or any other bustling metropolis.

What Is the Challenge in Resources?

In all of these examples, there are some common themes. One is the need for network technology to connect real-world smart sensors to share information and/or make decisions. Secondly, all of these examples focus on improving management of critical and expensive resources: electricity, water, and time.

The fact that these resources are constrained is well supported with data. In 2010 the planet consumed 20,200 terawatt hours (TWh) of energy, while in 2040 the number is expected to be 39,000TWh, for an annual growth in energy demand of 2.2%.[8] If we assume a 300MW coal plant, that translates to about an additional 170 coal plants per year needed to appropriately increase the capacity for the planet.[9] If a coal plant costs about a billion dollars, this represents at least a $170B annual investment in energy capacity (not to mention ongoing maintenance costs). Note that we are simplifying the problem for this argument here, because it is the peak demand for electricity that really drives the new capacity demand and not the average power consumption. In any event, the data says that we need a steady addition of expensive energy generation to meet the growing demand. The smart grid promises to help us balance our consumption better to reduce peak demand, meaning that we can defer or save a significant portion of that capacity investment.

We can live without electricity for some time. But the constraints in water are perhaps more dire because gaps in the water supply would threaten our lives. As a planet, we certainly do have a challenge to deliver water everywhere it is needed. But the current water distribution system exacerbates this challenge because the delivery system leaks. From the time when water is cleaned until it is delivered, losses in the distribution system and in the home can be significant….over 50% in less developed parts of the world.[10] The EPA says[11] that the average house in the U.S. leaks 10,000 gallons of water a year. Better vigilance on the part of consumers could tackle a large part of this problem. But more importantly, better local and regional water-metering technology is needed to identify the original source of leaks.

The last critical resource that we are discussing here is time. It is certainly constrained since there is a limited amount of it in a day or even in a lifetime. While we drive around looking for a parking spot, we are wasting time and fuel. We are also causing more traffic, delaying the journey of other drivers, and wasting more energy (and time!).

The IoT: Helping to Save the World (One Constrained Resource at a Time)

Enter the IoT. It is here to save the world. Perhaps that is a bit grandiose, but in places with a clearly defined ROI—where precious resources have a significant opportunity for efficiency gains—a network of smart sensors can help us understand and react to the problem. That is how and when we will see the IoT roll out on a large scale.

So we need a network of sensors. On the network side, the options are already here. ZigBee®, Wi-Fi®, cellular, powerline, Bluetooth®—a host of technologies exist to give a "voice" to the billions of sensors that an IoT will demand. So the challenge turns to the sensors. To better monitor our electricity and water consumption, we need cost-effective, small electricity and water meters. True, but you've probably seen electric meters and water meters. Few would call them cost effective or small enough to be deployed at a large number of consumption points.

IoT and Energy Meters

For monitoring energy consumption, we do not need to replicate a traditional utility electricity meter. Instead we really need a ready-to-go measurement solution that can be added to existing applications. Energy measurement at decent accuracies (1% or better) is already a special discipline. So now we actually need turnkey solutions that enable us to monitor energy consumption. One possible solution is for sensor manufacturers to add a current transformer and a preprogrammed energy-measurement IC like the 78M6610_LMU to the outside of a communications module. While effective, the current transformer for energy measurement might not meet our "cost-effective and small" requirement.

While current transformers are the most common solution for sensing energy consumption, they can be heavy, big, and expensive. Shunts provide a much lower cost and lighter option, but they can be challenging to integrate with an existing system. Connecting to a shunt means a direct connection to the main AC powerline. Isolating with optocouplers then requires an additional power supply on the hot side where the measurement system is. This step then starts to work against the cost and size savings offered with the shunt in the first place. There are a few accurate measurement solutions on the market today like the MAX78615+LMU and MAX78700 chipset that solves the problem by providing isolation without the need to build an additional power supply for the measurement.

IoT and Water Meters

Expanding a network of water-consumption sensors is an even bigger challenge. A smart plug like the Belkin examples above can quickly become ubiquitous because they are very easy to install, and once installed are hardly noticed. But a smart water meter is going to be more obtrusive. Imagine a device about the size of a smart plug connected to your bathtub spigot, shower line, or sink faucet. Now the size of this device is likely to get in your way.

A larger deterrent to the growth of smart water metering is actually the market's use of mechanical water meters. Most water meters today use a turbine that rotates as water passes through. This physical device is bulky and inaccurate. Perhaps even worse, the flow rates associated with the "average leaky house" cannot be detected with these mechanical meters. Many so-called "smart" water meters simply use a small microcontroller to count the turbine rotations and then report the data over a wireless network. Fortunately, new technology exists that eliminates the mechanical component of a water meter, allowing newer robust smart water meters to shrink in size, increase measurement accuracy (especially at low leakage rates), and reach into more potential homes.

Ultrasonic flow-metering technology, once reserved for very expensive water meters used in the water distribution system or in industrial flow-monitoring systems, is now available for utility water meters and other flow applications. Ultrasonic flow-rate detection uses silicon connected to two piezo elements: a pulse is transmitted from one sensor to the other (and vice versa). A delta in the pulse times-of-flight indicates the flow of a liquid or gas. With ultrasonic metering technology, we can detect very low flow rates, even down to the "average leaky house". But this measurement is tricky, and we need special silicon sensitive enough to detect the average level of water leakage in a house.

It will likely take a long time for water flow sensors to become as prevalent as smart plugs. Nonetheless, society could benefit from even a handful of smart placements of a water submeter within a house. I would certainly be interested to know how much water each dishwashing cycle consumes. How much water does my pool need to maintain its level? (Perhaps I should buy an evaporation screen?). The benefits of wider scale deployment of water flow sensors in the water distribution grid are even more compelling. Maybe we can detect and fix the significant losses incurred delivering water to our houses.

IoT and Time

Unfortunately there does not seem to be an obvious one-to-one correlation between a sensor network and saving time. The parking problem described above could probably be solved with just a network of proximity or weight sensors—is there a car on top of me right now? But let's think about another troublesome situation that many of us have faced. What about the tens of minutes I spend trying to determine which smoke detector battery is bad when the "low battery" beep is bouncing off everything in the house and refusing to reveal its source? Of course, I am usually hunting for the suspect smoke detector at 3 a.m. In this case, adding a simple battery voltage detector to the network allows me to quickly identify which device needs attention.

The Challenge of Security

Sensors can save the world. Well, I guess that is debatable. But certainly smart sensor networks can make the world more efficient, less wasteful, and better managed. In some areas water and electricity networks are already underway. However, these networks face a new challenge, a force so devious and threatening that it could stifle and kill the IoT just as it begins. The issue is security.

As we deploy more smart sensors to gather data and as we allow more machines to start making decisions for us, the security threat increases dramatically. Imagine if a fraudulent signal induced thousands of consumers (or their smart machines) to increase electricity consumption by turning the air conditioner colder, starting the clothes dryer, running pool pumps, or just using every electrical appliance all at once. If the smart grid was already constrained on a hot day, the extra load induced by the fake attacker's signal could bring the grid down.[12]

Imagine a similar example with the smart parking application. Suppose that an attacker prompts the application to report a wealth of open parking at prime locations in a downtown metropolitan area. This might well prompt many drivers to converge in one location. What if the ensuing traffic jam makes it difficult for police to respond to a local bank robbery?

These are disaster scenarios, yet are they really that far fetched? Energy, water, time—these valuable resources are critically important to us, so wouldn't they be important to hackers? Hackers can be either mischievous pranksters or cold-hearted terrorists trying to disrupt those resources and our society. Ultimately, the greatest value of the IoT (managing precious resources) can also be its downfall (failing to protect those precious resources). With security such a pivotal concern for the IoT, embedded technology exists today to protect the smart grid and the networks of sensors that comprise an IoT. But still, having security available does not mean that it is automatically deployed. It will be up to the service providers to demand the highest level of security from, and for, the sensors in their IoT.

Summary

The IoT promises great things—a universe of abundant smart sensors monitoring our planet's most valuable resources. Water and energy are probably the first, best candidates for a widely deployed sensor network since everyone on the planet needs them. And if we have efficient and secure water and energy networks, then we will find ourselves saving time, effort, money, and the resources themselves. Improving our usage of time will continue to be a fertile ground for innovation and the impetus for additional sensor technologies to provide the data to help us save that time.

Regrettably, because of their intrinsic value, these IoT networks are especially attractive to cyber attackers. We must secure IoT data and operations or the many benefits of sensor networks in the IoT will collapse.

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Related Parts		
78M6610+LMU	Energy Measurement Processor for Load Monitoring Units	Free Samples
MAX35101	Time-to-Digital Converter with Analog Front-End	Free Samples
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