Executive Technology Brief

Powering Wearable Technology and Internet of Everything Devices:

What every product manager and designer needs to know

By Steve Grady Cymbet Corporation

Table of Contents

Introduction

Imagine a world where *everything* is smart and connected.

A world where every product – from washing machines to light switches, pacemakers to hospital gowns, wristwatches to running shoes – can provide useful data that make our lives better and easier...

Where thousands of wireless sensors networks help optimize crop planting and irrigation, monitor avalanche and forest fire conditions, regulate city water systems and automobile traffic...

That's the world of the Internet of Everything (IoE). And it's coming faster than most people think.

The driving technologies – ultra-low-power processors, tiny mobile sensors and wireless networking – are all available today. Industry leaders like Intel, Hewlett-Packard, Qualcomm, Bosch and Texas Instruments predict mobile sensor demand will rise from billions/year today to *trillions*/year by 2025.[i]

And according to Cisco, IoE growth will generate **$14.4 trillion** in value – across every industry – over the next decade.[ii]

Much of the first wave of this growth will be in wearable technology. From Google Glass and iWatch to fitness bands and patient vital sign monitors, the *body area networks* these devices will inhabit present fewer development obstacles and lower infrastructure costs than larger networks. Credit Suisse expects the total market value in wearables to increase ten-fold – from $3-5 billion to $30-50 billion – over the next three to five years.[iii]

But for this growth to happen, new power solutions will be required: power solutions that are small, thin, self-recharging, and never need replacement. Conventional batteries simply won't meet the requirements for most of these new products.

Fortunately, a highly efficient and effective alternative now exists: rechargeable *solid state batteries* combined with ambient energy harvesting or wireless charging.

This white paper will describe what product managers and designers need to know about powering wearable technologies and the many types of IoE devices

Internet of Everything vs. Internet of Things

Is it: “Internet of Everything" or "Internet of Things?" You've probably heard both terms. Is there a difference?

While many think of these terms as interchangeable and simply prefer one over the other, we at Cymbet feel each implies something different.

To us, "Internet of Things" (IoT) suggests stand-alone devices connected to the Internet. These devices include sensors, processors or controllers – often networked with other sensors – and consumer gadgets like Google Glass. They may be sharing data with other devices using Machine-to-Machine (M2M) or gathering data for users Machine-to-People (M2P).

"Internet of Everything" (IoE) suggests something much larger. It reflects the enormous potential of wireless sensors and actuators *so small*; they can "disappear" into any product. It embraces the idea that **everything can become smart**.

The functions of these tiny sensors become product *features*, rather than “gadgets.” They provide the user with useful data, and thereby add real value that customers can appreciate.

Thus, the Internet of Everything represents a much greater opportunity than the Internet of Things. IoE includes the IoT… and much more.

To put in another way, you could say the IoT is an electronics industry phenomenon, while the IoE will affect *every* industry *every* market and every person.

Cisco makes a similar distinction. They view the IoE as a stage after the IoT. They see the IoT as mature, while the IoE is just in its infancy – and offers 5 times the potential (Figure 1).[iv]

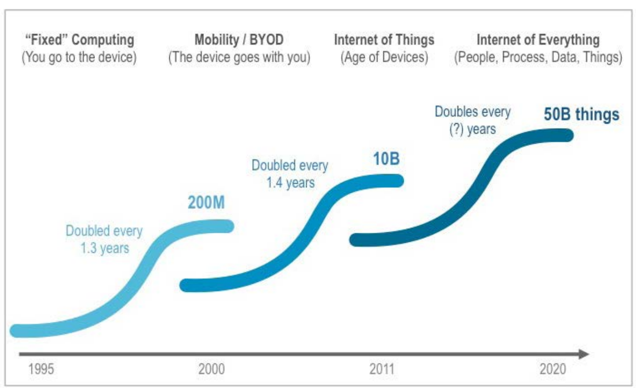

Figure 1: Waves of Internet Growth

Source: Cisco IBSG 2012[iv]

The Driving Forces of the IoE

What will drive IoE growth? What are the key enablers?

There are several. And they're already in place.

First and foremost is the proliferation of key "smart device" technologies including:

- Ultra-low-power processors
- Accurate, low-cost, ultra-low-power mobile sensors
- Low-power wireless connectivity (Bluetooth Smart, etc.)

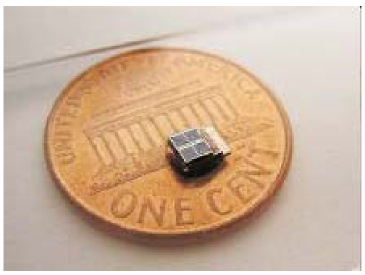

Fig. 2: A millimeter-sized solar energy harvesting sensor.

Continued device miniaturization is another key factor. Advances in IC fabrication and packaging now permit wireless sensor packages – including processor, sensor, network device and power source, like the ones we'll be discussing shortly – as small as one cubic millimeter (1 mm^3) in volume (Figure 2).

Cloud computing and Big Data analytics are other IoE drivers in that they make it possible to analyze data from massive sensor arrays. And they also drive demand for wireless sensors because of the new sensor applications they make possible.

Why You Must Prepare for the IoE (or get buried by it)

It's important to keep in mind that the IoE is not just the Internet. It's not "everything-connected-to-everything."

Instead, the Internet of Everything will spawn *billions* of new wireless network domains, large and small, across every industry. These will include:

- **Wireless Wide Area Networks** for monitoring environmental conditions, maximizing agricultural yield, regulating municipal water systems and traffic, and optimizing logistics.
- **Wireless Local Area Networks** for environmental control, lighting control and security in homes and buildings, and process monitoring and control in automated factories.
- **Wireless Room Area Networks** for automating hospital rooms, hotel rooms, dorm rooms, kitchens and entertainment rooms.
- **Wireless Personal Area Networks** consisting of handheld or wearable devices that link and control your immediate environment to your programmed preferences. Commands and key data are uploaded to the cloud for use later by your personal applications.

> *"Smart systems will drive a multi-year wave of growth based on the convergence of innovations in software architectures, back-room data center operations, wireless and broadband communications, and smaller, powerful, and numerous client devices connected to personal, local and wide-area networks."*
>
> \- Harbor Research [v]

- **Wireless Body Area Networks –** Wearable, patchable, or even implantable devices connected your smartphone or tablet, or a more specialized device like a hospital patient monitor, neurostimulator or sleep apnea system.

In short, the IoE will create a new global product landscape that product managers and designers need to embrace.

> *"Wearables are rapidly evolving from single function, hard to connect, dumb devices, to what we believe will increasingly become multifunction, always-connected, smart/aware devices.*
>
> *"We estimate a potential ten-fold increase in total annual market over the next 3-5 years, from $3-5 billion to $30-50 billion."*
>
> \- Credit Suisse [iii]

The First Wave: Wearable Technologies

Much of the initial growth of the IoE is likely to be in wearable technologies.

Credit Suisse points to the swelling install base of smartphones – already 1.1 billion and expected to reach 2.7 billion by 2017 – as an environment ripe for the adoption of wearables. They predict "smartphones will become the 'personal cloud' for wearables," and that "the average consumer will have at least one, if not two of these products close by at all times" within five years.[iii] This growth alone will account for more than 1.5 billion of those new sensor networks mentioned earlier.

These "personal clouds" will require less costly infrastructure and will be easier to secure than larger networks. In other words, they present fewer and smaller obstacles to development.

> *"By 2016, wearable technology will represent a minimum revenue opportunity of $6 billion."*
>
> \- IMS Research [vi]

As a result, technology research firms predict the wearable wireless device market will grow to $6 billion by 2016[vi], with annual shipping of 169.5 million devices by 2017[vii].

As the leading edge of the IoE's rise, wearables can serve as a springboard for understanding what you need to know about powering a wide variety of IoE devices in a wide variety of domains. Because the challenges of powering wearables are shared by a vast assortment of other tiny, inaccessible, or otherwise "invisible" devices, which will eventually join the IoE.

> *"The total market for wearable wireless devices in sports an healthcare will grow to 169.5 million devices in 2017, up from 20.77 million in 2011, a CAGR of 41%."*
>
> \- ABI Research [vii]

The Problem: How to Power Wearable Technology

Most customers – business customers in particular – are not going to buy smart devices just because they're smart.

For a product to gain acceptance in a world where *anything* can be smart, its' smart features must add real value. They must supply useful data to improve the user's experience in some way.

> *"Battery life is the MOST important aspect for a Wearable… The limitation to the number of sensors and amount of generated data is the battery life of the Wearable."*
>
> \- Credit Suisse [viii]

For this reason, most successful IoE products won't be "gadgets." They'll be smart versions of already useful products. Their smart features will be valuable *enhancements*.

"Enhancements" implies that the devices that provide them can't be seen as "extra baggage" by the user. They'll be practically invisible, blended into the product. As such, they will have to be small, lightweight and, for the most part, maintenance free.

That means their power supplies will have to be "invisible," too.

Power storage devices in most wearable IoE devices will have to last the life of the product. There will be no door for changing batteries. There will be no connector and no chord for recharging them. They will require wireless recharging.

These restrictions recently led Credit Suisse to state that, "battery life is the MOST important aspect for a Wearable… The limitation to the number of sensors and amount of generated data is the battery life of the Wearable." [viii]

Many other IoE devices will share these characteristics. Most won't be connected to the power grid, because of the expense that would entail. Many will be too small for a connector. Many will be too remote or embedded to be accessible for maintenance.

Conventional batteries don't wear well

Conventional batteries present a number of problems that make them unsuitable for wearables and similar IoE devices.

Drawbacks of Chemical Batteries

- Large size
- Require SMT sockets and hand assembly
- Low charge-cycle life
- Require external charge circuit
- Contain hazardous chemicals
- Possible explosion hazard

First, improvement in energy density is flattening. "Battery energy density for Li-Ion batteries, the predominant chemistry for mobile devices, has grown only modestly for the last decade," says Credit Suisse analyst John Pitzer. "iPhone 5 battery energy density of 142mAh/cm^3 is roughly 63% higher than the Li-Ion battery from 9 years ago – modest compared to CPU, cellular data, WiFi, capacity or camera improvements. Going forward, expectations are for battery improvement to significantly underperform the expected increases in other related mobile technologies through 2020." [iii] Without sufficient energy density, batteries will not last the life of the product.

Second, the hazardous chemicals in conventional batteries make them incompatible with many applications, and with automated SMT processes. Impact traumas, ambient temperatures above 60° C and repeated overcharging can all cause thermal meltdown (explosion or fire) in Li-ion batteries, a risk that increases with increasing energy density. Chemical leakage is also a risk.

Finally, chemical batteries require bulky packaging that prevents co-packaging with other devices, and which greatly reduces net energy density as total volume is reduced.

In short, coin cells and super capacitors do not possess the required characteristics. An alternative solution is needed.

The Solution: Solid State Batteries + Wire-free Charging

Fortunately, an alternative exists: solid state batteries combined with some form of wire-free charging.

Solid State Batteries are rechargeable energy storage devices manufactured on silicon wafers using semiconductor fabrication processes. They can be packaged as stand-alone components or co-packaged with other integrated circuits.

Solid state batteries are built on silicon wafers using standard semiconductor fabrication processes.

They can be packaged as standard components or bare die batteries can be co-packaged with other Integrated Circuits.

Solid state batteries are fully compatible with automated SMT and reflow soldering processes, and need no sockets or hand assembly for PCB surface mounting.

The advantages of solid state batteries make them a superior alternative to conventional batteries in most IoE applications:

- High energy density
- Low self-discharge rate
- High recharge cycle capacity
- Extremely small, thin dimensions (as low as 0.2 mm^3)
- Compatible with automated SMT and reflow soldering processes– as illustrated in Figure 2, below.
- Can be easily co-packaged with other devices
- No hazardous chemicals
- No sparking hazard (no fire or explosion risk)

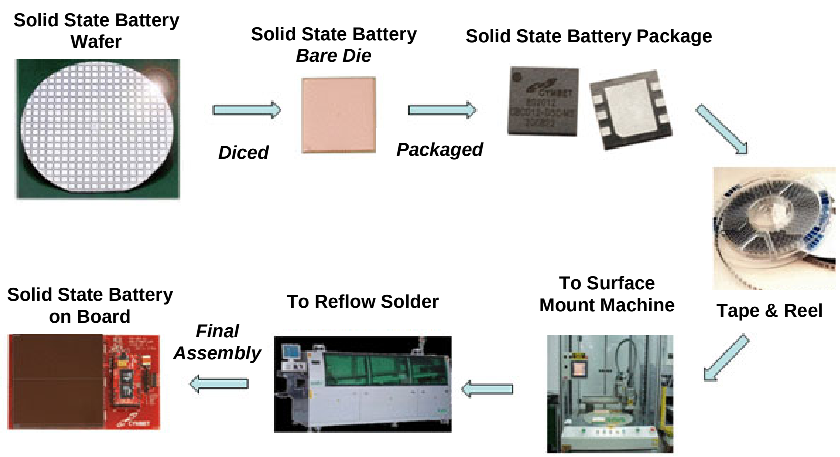

Figure 3: Solid State Batteries – from wafer to circuit board

Wire-free Charging is normally accomplished in one of two ways: *energy harvesting* (EH) or *near field charging* (NFC).

Energy Harvesting – also called power harvesting or energy scavenging – is the process by which ambient energy is collected for storage by means of a transducer, which converts that ambient energy to electrical power.

Near Field Charging operates in a *near field* condition, in which a transmitting coil produces a magnetic field that is picked up by a receiving coil in close proximity. Radio charging and induction charging are the two most common forms of NFC.

The new Qi standard[ix] will likely make induction charging a popular alternative for wearable technology. When not in use, Qi-compatible devices can simply be left on a Qi charging pad.

Note: Energy harvesting is the greener of the two solutions as it harnesses energy that is already present in the device's environment. Where that environment cannot be consistently relied upon, NFC may be the better choice.

Choosing Your Energy Harvesting Source

The following EH transducers are the most common for energy harvesting and near field charging applications:

- Photovoltaic: converts light to electrical power
- Electrostatic or Electromagnetic – convert vibrations
- Thermoelectric: converts a temperature differential
- Piezoelectric: converts mechanical movement
- RF and Inductive: convert magnetic power to electrical

Figure 4 compares characteristics of the most common transducers for energy harvesting and near field charging.

Energy Source	*Challenge*	*Typical Electrical Impedance*	*Typical Voltage*	*Typical Power Output*
Light	Conform to small surface area; wide input voltage range	*Varies with light input Low kΩ to 10s of kΩ*	*DC: 0.5V to 5V [Depends on number of cells in array]*	10µW-15mW (Outdoors: 0.15mW-15mW) (Indoors: <500µW)
Vibrational	Variability of vibrational frequency	*Constant impedance 10s of kΩ to 100kΩ*	*AC: 10s of volts*	1µW-20mW
Thermal	Small thermal gradients; efficient heat sinking	*Constant impedance 1Ω to 100s of Ω*	*DC: 10s of mV to 10V*	0.5mW-10mW (20°C gradient)
RF & Inductive	Coupling & rectification	*Constant impedance Low kΩs*	*AC: Varies with distance and power 0.5V to 5V*	Wide range

Figure 4: EH / NFC Transducer Comparisons

Fig. 5: The Amiigo fitness band tracks a variety of fitness activities and health parameters. It interfaces with IOS and Android devices and features wireless charging.[x]

It's worth noting that, especially with wearables, you may have a choice of energy sources for harvesting.

Take a fitness band, like the one shown in Figure 5[x], for example. It's on your wrist, moving with your arm. So motion harvesting is an option. It will probably be exposed frequently to light. So you may want to consider solar. And it can be left to recharge on a wireless charging pad overnight. So magnetic induction is another option.

Also keep in mind that multiple-source energy harvesting will complicate your system design and increase the cost of your device. As Figure 4 indicates, each type of transducer presents different impedance and voltage characteristics. In other words, you need a different front end for every energy source.

Your choice is going to come down to cost and practicality. You'll need to analyze your device's environment to determine which energy source will deliver the best combination of economy and reliability. (See also: *Key Design Considerations* on page 11.)

Putting it All Together: A Zero-Power Wireless Sensor

The most effective way to power an Internet of Everything device is to use ambient energy harvesting to recharge the device over its entire lifetime. Since all the energy to run the IoE device is "free", these types of sensors are known as Zero-Power.

A zero-power wireless sensor, as shown in Figure 6, typically consists of five basic elements:

- An energy harvesting transducer that converts some form of ambient energy to electricity.
- An Energy Processor to collect, store and deliver electrical energy to the electronic or electro-mechanical devices resident in the sensor node.
- A sensor to detect and quantify any number of environmental parameters such as motion, proximity, temperature, pressure, pH, light, strain, vibration, and many others.
- A microcontroller or variant thereof, to receive the signal from the sensor, convert it into a useful form for analysis, and communicate with the radio link.
- A radio link at the sensor node to transmit the information from the processor on a continuous, periodic, or event-driven basis to a host receiver and data collection point.

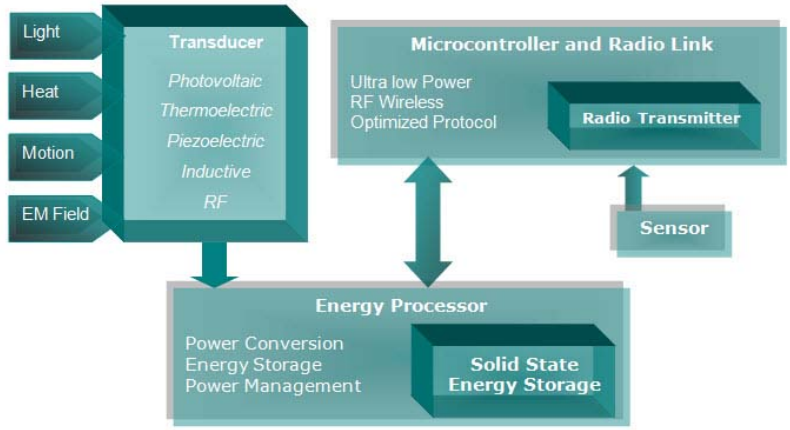

Figure 6: Zero-Power Wireless Sensor Diagram

Naturally, the harvested energy stored in the solid state batteries can also be used for other functions of your wearable device – display functions for example – not just the sensor. So your device can be sealed: no door, no battery disposal, no connector, no chord… no bother. It recharges itself.

Power Management: Making the Most of What's Available

In most wearable technology and other small IoE devices, energy storage volume will be extremely limited. A top design priority will be to make sure enough energy is always on hand, so the device will be reliable.

There are two ways to do that: (1) maximize storage device energy density, and (2) minimize energy consumption.

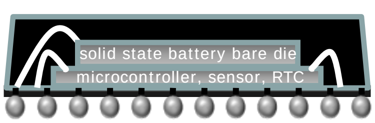

Fig. 7: A rechargeable solid state battery bare die co-packaged in a "wedding cake" die stack.

Maximizing energy density

One excellent way to maximize energy density is to use **solid state batteries**.

Packaged separately, solid state batteries provide an excellent combination of high energy density and low volume. And being reflow-solder compatible, they can be stacked with other chip-scale packages for 3D mounting to reduce device volume.

Further volume reductions can be achieved by co-packaging solid state batteries – in bare die form – with other components (Figure 7).

A Cymbet EnerChip 12µAh, 3.8V solid state battery, for example, in bare die form, measures 2.8mm x 3.5 mm x 150μm. The bare die battery stores the same energy as the packaged CBC012 battery, but takes up less than 1/15th the volume. By stacking that bare die solid state battery with other components, you get more than *15 times the energy density over discrete packaged parts*.

Minimizing energy consumption

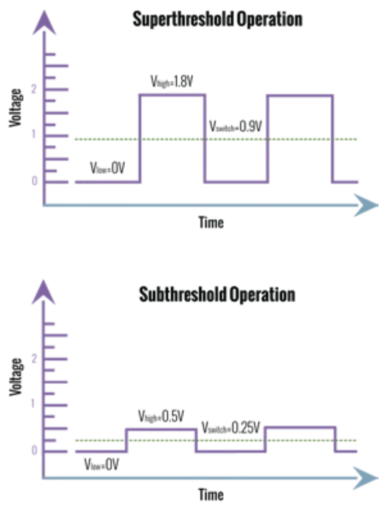

Fig. 8: Subthreshold switching operation significantly reduces the amount of charge (energy) used to run computations, thus extending battery life.[xi]

Power consumption in wearable and IoE devices can be minimized through careful system design.

New ultra-low-power components like those designed by Ambiq Micro for example, can significantly reduce power consumption. Designed to run at supply voltages at or below the transistor's threshold voltage (Fig. 8), these devices can provide a 7x improvement in energy efficiency – effectively making the system's energy storage look seven times bigger.[xi]

It's also important to analyze power profiles and take a hard look at how your code is written.

When does the device need to be powered? If it's only taking a reading and transmitting data, say, only once every sixty seconds, it doesn't have to be on all the time. Powering devices off when they're not in use can drastically improve efficiency.

With careful system design, you'll probably find energy harvesting more than covers the quiescent load of your device, and also keeps your solid state battery charged. Your solid state battery can then cover the load spikes during sensor sampling and wireless data transmission.

Cost Analysis: Energy Harvesters vs. Primary Batteries

At this point, you may be asking yourself, "What if my device is large enough for a primary battery and an access door? Is there a business case for using an energy harvesting solution instead? Will it really be worth it to save my customers the trouble of changing batteries? Can they also save money?"

Excellent questions, all.

To compare costs between a primary and an energy harvester on a $/mAh (dollar per milliamp hour) basis, you need first to calculate the lifecycle energy capacity of the energy harvester. This gives the total lifetime energy delivery cost.

Lifecycle capacity = #charge cycles x depth of discharge per cycle in µAh.

Then you calculate the cost of the energy harvester components that include the costs of:

- Transducer
- Interface components
- Conversion electronics
- Energy storage

An example calculation is given in the sidebar at left. It shows that, over the lifetime of the product, energy harvesting can be just as cost-efficient as using commoditized primary batteries.

But to make the best choice for a given product, your analysis needs to go deeper.

You must also consider – and assign $ value to a number of other design trade-offs, including:

- Primary battery change-out costs including: Device access costs and issues and Labor cost
- Product lifetime power requirement (200 mAh, 1Ah, 5Ah?)
- Product duration expectation (3, 5, 10, 20 years?)
- Energy storage cost in available space ($cost/mAh/mm^3)
- Relation of battery size to overall product size
  - Battery footprint vs. available space
  - Battery height vs. product thickness
- Physical design of product – reliability and warranty
  - Battery door removal
  - Power connector removal
- Required electrical characteristics
  - Flat voltage output
  - Fast recharge time
  - Low self-discharge
- Assembly issues and costs
- Aging characteristics
  - Chemical leakage
  - Seals drying out
- Transportation restrictions (air safety shipping laws)
- Safety and end-of-life disposal procedures and costs

Cost Comparison Example: Primary Battery vs. EH

Coin Cell (3.3V)

CR2032 + holder = $.36 (1K pcs on Mouser)

Output = 225mAh x 1 cycle

LC cost = **$0.0016 / mAh**

Alkaline

2 AAA + holder = $1.71

Output = 1000mAh x 1 cycle

LC cost = **$0.0017 / mAh**

Solar Energy Harvester

400 lux with 24/7 operation

Sanyo AM1815 4.9V solar cell (1K pcs) = $4.39

Output = 294µW

Simple electronic conversion components = $1.25

Rechargeable EnerChip batteries = $4.10

Current = 294µW / 3.3V = 89µA

Total capacity over 10 year 24/7 life = 7796mAh

LC cost = **$0.0013 / mAh**

(Note: Brighter light decreases LC cost - dimmer light increases LC cost. Normal sunlight: 100,000 lux, dim hospital room: 200 lux)

Conclusion:

Energy harvesters can be designed to be just as cost effective as primary batteries over lifetime.

Key Design Consideration for Energy Harvesting

The following checklist can help you design an optimized energy harvesting solution that's right for your application.

1. ***Determine energy available from your environment***
    a. Indoor solar: 10s to 100s of µW
    b. Thermoelectric: 10s to 100s of µW, based on ΔT
2. ***Harvest energy as efficiently and cost-effectively as possible***
    a. Design for maximum peak power point
    b. Avoid components with:
        i. Excessive current leakage
        ii. High Quiescent current
3. ***Calculate application power requirements in all operation modes and minimize power to fit available input EH power***
    a. Use sleep modes of components when possible
    b. Write energy-aware code:
        i. No polling loops, use interrupts
        ii. Check Vcc before running
4. **Size energy storage that matches EH Transducer output for times when ambient energy unavailable**

Some Energy Harvesting Application Examples

Cymbet has helped many companies develop products powered with an energy harvesting solution using EnerChip™ solid state batteries. We'll conclude this paper with a few examples.

Temperature and Humidity Wireless Sensor

The first is an application for the food industry shown in Figure 9. It's a re-design of a sensor to measure temperature and humidity in work areas in a food processing plant.

The original device used two AA batteries which had to be replaced on a regular basis. With a battery holder and door, the entire assembly was about the size of a pack of cigarettes.

In the new sensor, the AA batteries were replaced by an energy harvesting device employing a solar cell and Cymbet EnerChips.

Without primary batteries the wireless sensor is now a sealed unit that increases reliability and no access is required.

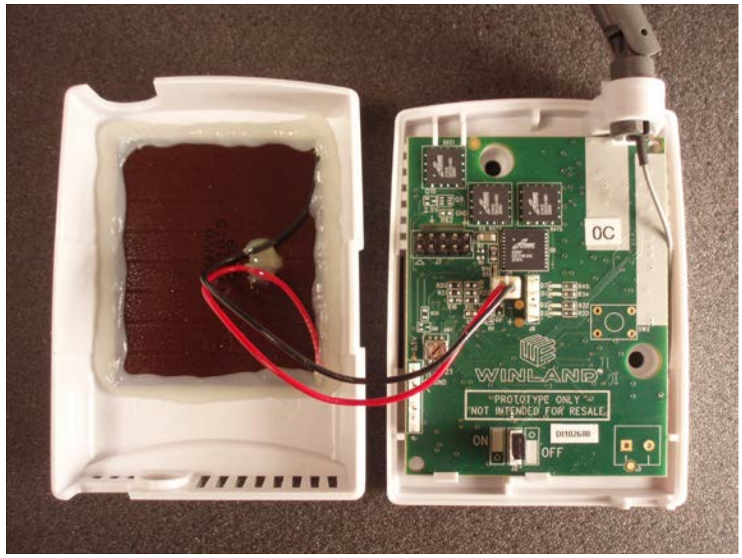

Figure 9: Solar Powered Environmental Sensor

EnerCard™ Energy Harvesting Power Modules

EnerCard™ energy harvesting modules are small footprint, high efficiency energy harvesting power modules. They can be used to provide a complete power supply solution for devices like wireless sensors, data logging tags, lighting controls, HVAC actuators and security devices.

The EnerCard not only supplies power. It also provides information on: input power, EnerChip charge state, and power management parameters – a vital capability when designing intelligent sensors that modify operational behavior depending on the power environment.

EnerCards can be configured with a variety of energy transducers. Figure 10, below, shows a double-sided, photovoltaic EnerCard. The photovoltaic cells would be exposed through a clear window in the device case. Also on this side of the board are LEDs to indicate the input power and battery charging indications.

The back side of the EnerCard contains a Cymbet CBC915 EnerChip EP Energy Processor which performs Maximum Peak Power Tracking (MPPT) and regulates the charge control for the 4 EnerChip CBC050 batteries (for a total of 200uAh of storage). The Energy Processor is a smart device and supports serial communication with the system Microcontroller. Input power levels and battery state of charge levels are supplied to the MCU so the entire system is "Energy Aware".

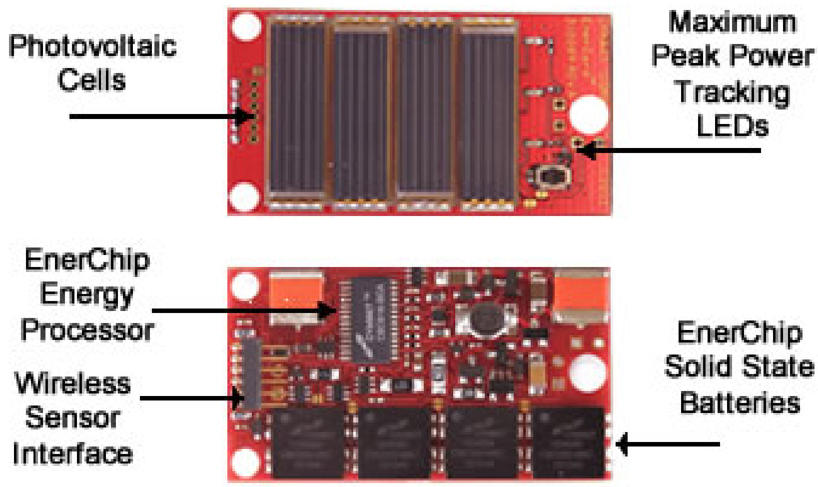

Figure 10: Double-sided EnerCard™ Energy Harvesting Module

You can find more information about the EnerCard at www.cymbet.com/products/enercard-modules.php.

EnerNode™ Wireless Sensor Concept

The EnerNode™ is a small footprint, high efficiency wireless sensor module the couples with the EnerCard. It provides the microcontroller, wireless radio and sensing functions required to create tiny EH-powered wireless sensors.

Figure 11 shows a wireless, 802.15.4-based temperature, humidity and pressure sensor EnerNode.

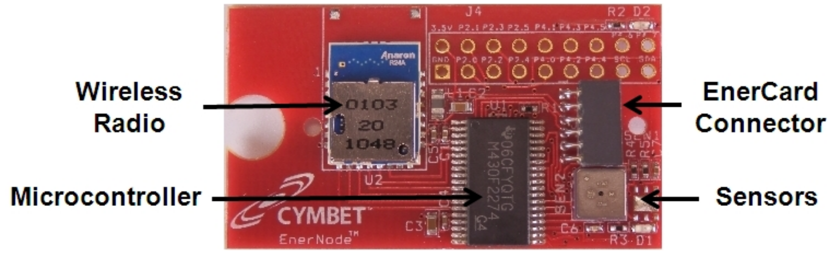

Figure 11: An EnerNode™ Wireless Sensor Module

EnerNode modules are designed to be paired with Cymbet EnerCard™ energy harvesting power modules to provide a complete, zero-maintenance, wireless sensing solution, as shown in the block diagram in Figure 12, below.

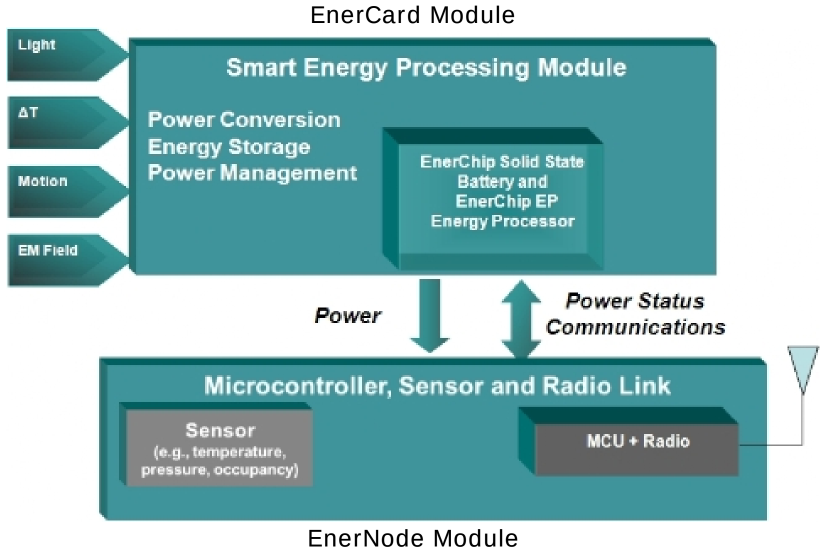

Figure 12: EnerCard™ / EnerNode™ Wireless Sensor Module

Figure 13 shows an EnerNode wireless sensor module paired in a sandwich configuration with an EnerCard energy harvesting module. Together, they form a zero-maintenance, zero-power wireless sensor, like the one described earlier, on pages 7-9.

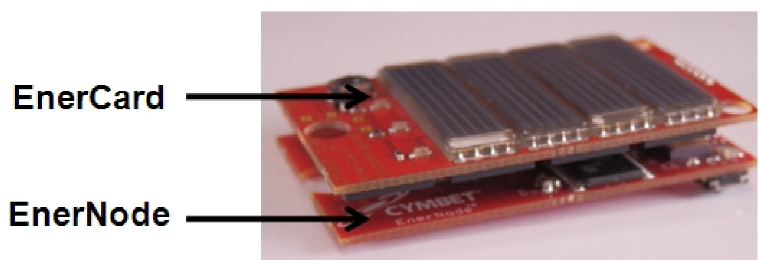

Figure 13: Paired EnerCard™ and EnerNode™ Modules

You can find more about EnerNode modules at www.cymbet.com/products/enernode-modules.php.

Intraocular Pressure Sensor

Finally, to demonstrate millimeter-scale energy-harvesting sensors, we present an intraocular pressure sensor, described in the case study at left.

Developed by the University of Michigan, it occupies a volume of only 1.5 mm^3 (0.5 x 1.5 x 2.0 mm^3), and can be implanted with

Case Study:

Intraocular Pressure Sensor

Solid state batteries made possible the creation of the millimeter scale intra-ocular pressure monitor (IOPM) shown in Fig. 9, below. It is used to monitor the eye health of glaucoma patients.

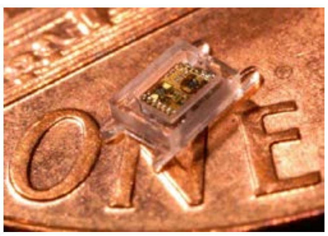

Fig. 14: Intraocular Pressure Sensor (courtesy of University of Michigan)

This tiny intelligent sensor uses ambient energy harvesting to power the device autonomously. Light is converted to electricity, stored in rechargeable solid state batteries and delivered to the sensor system. There are no traditional batteries to change out and the devices can be placed anywhere.

The IOPM contains an integrated solar cell, a Cymbet EnerChip™ solid state battery, MEMS capacitive sensor, and integrated circuits vertically assembled in biocompatible glass housing, as shown in Figure 14.

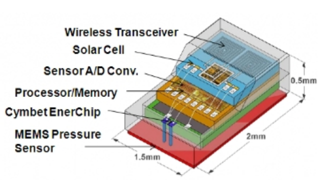

Fig. 15: IOPM Layers Block Diagram (courtesy of University of Michigan)

a minimally invasive procedure that is routinely used for cataract surgery.[xii] Commercialization is anticipated for 2016.

To read the Univ. of Michigan's paper on this sensor, presented at the 2011 IEEE International Solid-State Circuits Conference, click here: http://www.cymbet.com/pdfs/Millimeter-Sensor-ISSCC-2011.pdf

Conclusion

The Internet of Everything is going to happen. In fact, it's already happening: the key enablers are already in place.

And it's going to be HUGE. This next stage of Internet growth promises to be larger than all the previous stages combined. And as in those previous stages, most of the growth is likely come from technologies not yet envisioned.

You need to be ready.

IoE devices – and wearable technologies in particular – demand new power solutions. New enabling technologies like solid state energy storage and energy harvesting will make these devices possible.

You need to know about them.

For More Information…

Cymbet can help.

If you would like to discuss project requirements or explore options for including solid state energy storage and wireless charging in an upcoming project, Contact Cymbet, and ask to schedule a FREE applications consultation.

If your design team would like to gain hands-on experience with solid state batteries and wire-free charging solutions, Cymbet provides a number of evaluation kits aimed at energy harvesting, induction charging and wireless sensor applications. You can find out more about them at www.cymbet.com/products/evaluation-kits.

About the Author

Steve Grady has 30 years of experience in strategic planning, hardware/software engineering, networking and technical marketing. He has an MSEE and a BSEE from University of

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About Cymbet

Cymbet Corporation is the leader in solid state energy storage solutions for microelectronic systems. The company is the first to market eco-friendly rechargeable solid state batteries that provide electronic systems designers with new embedded power capabilities.

The company's EnerChip™ devices enable new concepts in energy storage application for ICs and new products for medical, sensor, RFID, industrial control, communications and portable electronic devices.

Founded in 2000, Cymbet has fabrication facilities in Elk River MN and Lubbock TX.

For more information about Cymbet and our EnerChip™ products, please visit our website: www.cymbet.com.

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