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Harvesting energy an sustainable power source, replace batteries for powering WSN and devices on the IoT

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Abstract. Harvesting energy from nonconventional sources in the environment has received increased attention over the past decade from researchers who study these alternative energy sources for low power applications. Although that energy harvested is small and in the order of milliwatt, it can provide enough power for wireless sensors and other low-power applications.
In the environment there is a lot of wasted energy that can be converted into electricity to power the various circuits and represents a potentially cheap source of power.
Energy harvesting is important because it offers an alternative power supply for electronic devices where is does not exist conventional energy sources. This technology applied in a wireless sensor network (WSN) and devices on the IoT, will eliminate the need for network-based energy and conventional batteries, will minimize maintenance costs, eliminate cables and batteries and is ecological. It has the same advantage in applications from remote locations, underwater, and other hard to reach places where conventional batteries and energy are not suitable.
Energy harvesting will promote environmentally friendly technologies that will save energy, will reduce CO2 emissions, which makes this technology indispensable for achieving next-generation smart cities and sustainable society.
In response to the challenges of energy, in this article we remind the basics of harvesting energy and we discuss the various applications of this technology where traditional batteries cannot be used.

1. Introduction

In the last period,it was a focus of attention on the Internet of Things (IoT). The rapid development of the Internet of Things (IoT) ,will mean that almost everything we can imagine can be connected to the Internet (Figure1).This technology refer to the wireless interconnection of the millions of “things” and devices through the Internet or local area networks, to increase efficient utilization.

Peter Middleton, research director at Gartner said that the development of IoT will far exceed the development of other connected devices.

By 2020, the number of smartphones and tablet PCs in use will reach about 7.3 billion units [1].

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Gartner says that 6.4 billion connected devices will be used in 2016 to 30 percent more than in 2015 [2].

Figure 1. Internet of Things (IoT) (Source Blue Sky Center)

2. IoT trends

Internet of Things (IoT) is one of the new technology in IT as noted in Gartner's IT Hype Cycle (Figure 2).

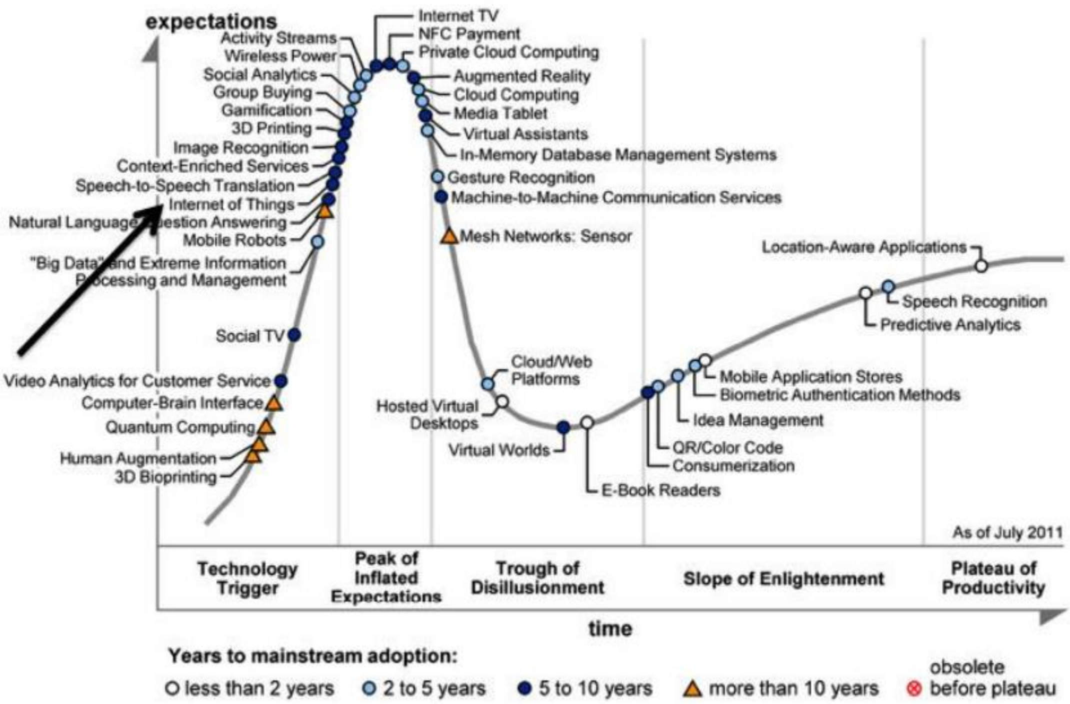

Figure 2. Gartner 2011 Hype Cycle of Emerging Technologies (Source: Gartner Inc. [3])

Hype cycle [3] is a method to represent the occurrence, maturity and impact of specific technology applications. IoT will take 9-10 years for adoption by the market. Web search popularity, as measured by Google search trends for terms in the past 10 years the IoT, computing and WSN are presented in Figure 3 [4], where:

A. Algorithms and Protocols for WSN Provides You with A Comprehensive Resource Market Watch - Nov 18 2008
B. IoT -- From Vision to Reality Market Watch - Apr 14 2010
C. CCID Consulting: China's IoT Industry Sees a Landscape Characterized by Clustering in Four Regions Market Watch - Oct 4 2011
D. China Hi-Tech Fair Highlights IoT Market Watch - Nov 21 2011
E. ARM unveils low-power chip for the (IoT)Reuters UK - Mar 13 2012 F. Web connected objects get a „voice" on the (IoT) Winnipeg Free Press - Apr 25 2012[4]

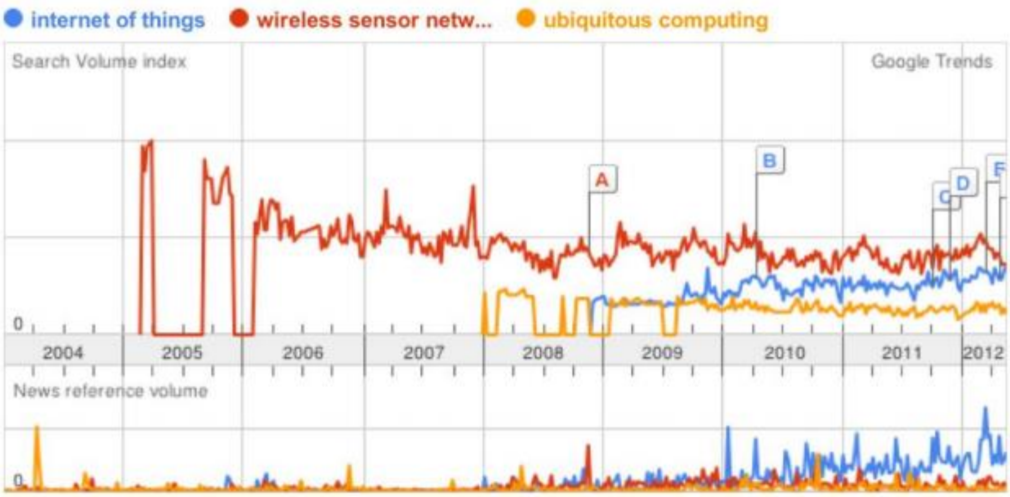

Figure 3. Google search trends since 2004: Internet of Things, Wireless Sensor Networks, Ubiquitous Computing. SPOT points are listed

We can seen, since IoT has come into existence, search volume is growing with the falling trend for Wireless Sensor Networks. This trend is to continue in the next decade as well as other generic technologies that converge to form a true Internet of Things.
From the Internet be observed that Internet of Things has started obtain popularity. This thing reflects the social acceptability of the technology.

3. Energy Harvesting or how can power IoT

With those millions of things come millions of batteries that must be purchased, maintained and disposed of. Unfortunately, battery innovation not increased proportionally with digital innovation. Battery disadvantages, threaten to limit growth across the entire Internet of Things (IoT) landscape.
Here comes the Energy Harvesting (EH) with technology innovations around ultra low power wireless sensor networks, network protocols and standards. EH soon becomes an important part of IoT ecosystem for many areas of industry but not only, it all comes down to manufacturing.

Energy harvesting (EH) represents a simple solution for easily powering those remote devices using clean energy. Energy-harvesting technologies it removes the need for batteries, and so eliminates an obstacle to the success of the Internet of Things (IoT).

Through things and devices on the IoT are included wireless terminals equipped with sensors which are connected to a network and will collect information about the environment around the terminal sensor.

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Miscellaneous sensor types are used by the wireless sensor terminals, such as the temperature, humidity, light, motion, pressure, stress, distortion, position, velocity, and gas flows.

Placement of many terminals will determine the variety and accuracy of data collected. This information, will help achieve control devices, monitoring and prediction that were previously impossible.

IoT development will have a big impact on our world, thanks to the evolution of semiconductor devices and wireless technology.

What is necessary for the Internet of Things, even mandatory, is the ability to place the wireless sensor terminals in all sorts of locations to collect the most important data. All are nice and good, but a problem arises when we installed power-distribution wires, or, when using the battery: life of the battery or battery replacement time.

Nobody would find this a problem with 10 or 20 batteries, but when there are 10,000 or a million or a hundred million, there are concerns not only for battery costs, but also for the enormous scale of maintenance expenses. This is one reason for debate the topics about wireless sensor terminals and is necessary to find urgent solutions.

Energy harvesting may provide this urgent solution. Energy harvesting isn't a new idea.

We have data on harvest light energy (photovoltaic) since the 19th century, when Alecsandre - Edmond Becquerel observed photoelectric effect in 1839 [5].

The techniques for harvesting energy use elements generators convert light (sun), heat (thermoelectric), vibration (piezoelectric), or RF energy (such as those emitted from cell phone towers) into electrical energy in a stably and without a great loss.

Energy harvesting allows designing systems capable of operating for years being fed to these energy sources in the environment, removing the battery change problem.

This does not mean that there is no use for a battery in these performant systems. After it gathered ambient energy , must then be stored to provide the current required at a time in which:

a. necessary (nodes have low duty cycles, meaning that an air temperature sensor can be active only a few milliseconds per hour and can be rest time in sleep mode)
b. when AC power is not available (sunlight, for example, are not present at night). Conventional rechargeable cells can be used in this way (semiconductor or supercapacitors).

4. Method that balances the power generation with the power consumption

When necessary energy harvesting, we must consider the necessary balance between power generation and power consumption. This is because the device will not work if it will generate less energy than can be consumed by the device. Although all of the power generating elements are continuously improved, it is difficult to produce enough power for a device that must operate continuously.

One way to solve this problem is to collect power generated in a fuel sensor capacitor and at times, resulting in a method that balances energy production with energy consumption. To achieve this, the designer must understand the perfect environment for generating power generator element, the power generated, the time needed, energy consumption and consumption device.

Figure 4 illustrates the important points using power generating time, power collecting time, and power consumption time to solve the balance of power generation, power collection, and consumption.

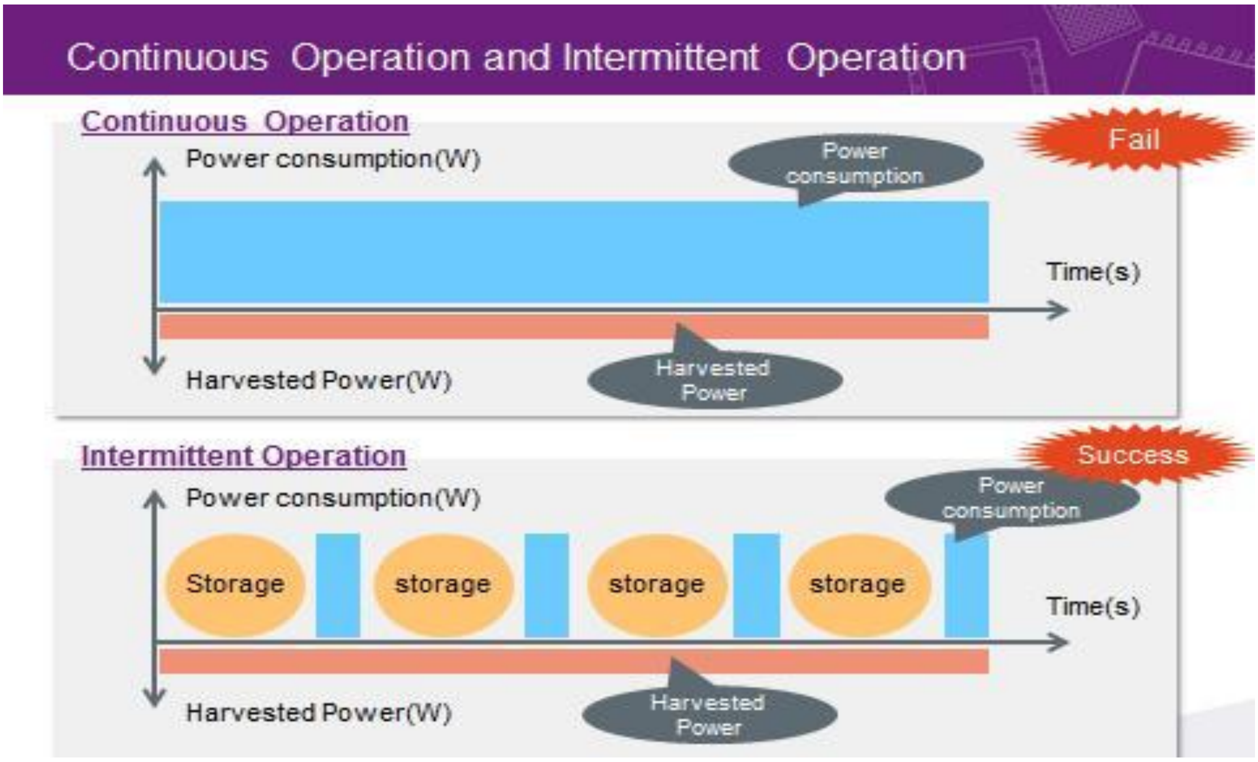

Figure 4. A way of balance the energy harvested power required by the device is to collect energy continuously, but wireless sensor terminal operation to be done at intervals

If we can harvest efficiently this energy we transform these relatively low levels of energy in an amount which can provide enough power for IoT node.

5. Elements of a wireless IoT node and categories of ambient power

In Figure 5 shows the main components of a system of wireless sensors including EH encoder processor energy (including energy conversion and storage) sensor, microcontroller and wireless radio.

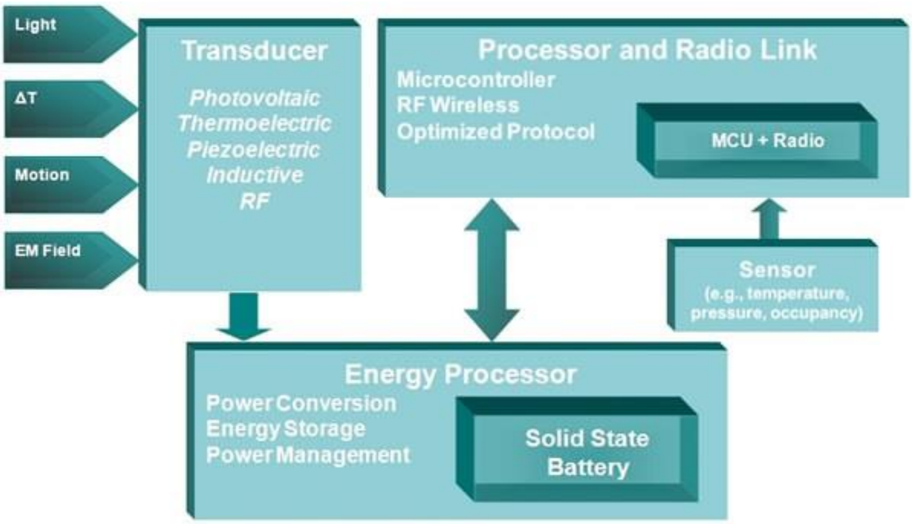

Figure 5. Elements of a wireless IoT node (Source: Cymbet)

We will talk a little about the four major categories of ambient power: light, temperature difference,vibration and RF.

Figure 6 shows the amount of harvested power available from these energy sources with solar (ambient outdoor light) and vibration (such as from industrial machinery) offering a considerable power advantage over the others; keep in mind, however, that not all applications will require that much energy.

Energy Source	Harvested Power
Vibration/Motion	
Human	4 μW/cm²
Industry	100 μW/cm²
Temperature Difference	
Human	25 μW/cm²
Industry	1–10 mW/cm²
Light	
Indoor	10 μW/cm²
Outdoor	10 mW/cm²
RF	
GSM	0.1 μW/cm²
WiFi	0.001 mW/cm²

Figure 6. Energy-harvesting sources.and harvested power. (Source: Texas Instruments)

5.1. The sun shine power

One of the newest technologies in permanent development and operation of energy is solar energy, which has been used for a long time to power small devices and, more recently, to provide back-up emergency power for mobile phones . Solar power collects and converts sunlight into electricity, but conversion efficiency is not very high. Regular solar panels are rated at 15% or 20% efficiency in optimal conditions.

Solar panels work in rain or cloudy (reducing production to 30% of the electricity generated in bright sunlight), in any season (solar intensity is reduced in winter), but changing the number of hours available light impact negative on the energy. To solve the problem semiconductor companies have developed controllers to optimize energy harvesting from solar panels.

These controllers use Maximum Power Point Tracking (MPPT). This technique optimizes the tranfer between the solar array (PV panels), and the battery bank or utility grid. The function of MPPT has described as analogous to the transmission in a car. When the transmission is in the wrong gear, the wheels do not receive the maximum possible power (Figure 8).

An MPPT algorithm monitors the input current and voltage and controls the duty cycle to maintain the MPP set point needed to maximize energy output from the photovoltaic module.
A controller IC verify the output of the panels, compares it to the battery voltage and then determines which is the best power, then the panel can put out to get the maximum Amps into the battery. Most MPPT's are around 95-97% efficient.

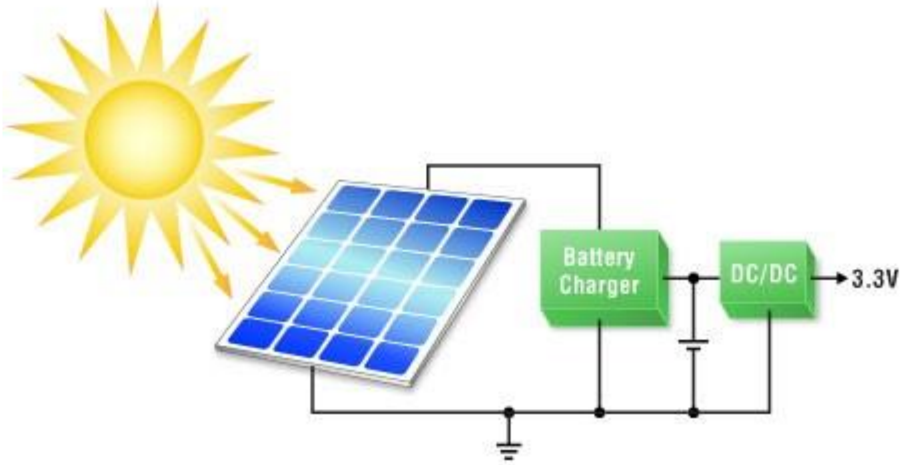

Figure 7. Solar Harvesting energy system (Source: Linear Technology)

5.2. *Thermoelectric energy*

Thermal energy can be used for the IoT by taking advantage of the available transducers and converter ICs.Using energy harvesting from thermal gradients, low-power circuits can operate many years without the need for battery replacement.

Two scientific "effects" are present here and we discuss for this. The "Peltier effect" is used to create a temperature difference by applying a tension between two electrodes connected to a sample of semiconductor material, usually to provide solid-state cooling. The "Seebeck effect" is a phenomenon in which a temperature difference between two dissimilar electrical conductors or semiconductors is converted into an electrical potential, or voltage. The simplest example, an energy autonomous sensor for measuring airflow temperature use copper to conduct warm air inside the tube where air is flowing, while a heat sink on the outside conducts the cooler ambient air, creating a difference in temperature between the sides of a Peltier element, and generating power for the sensor.

Residual heat from renewable plant equipment such as pumps and motors for industrial applications energy is converted into Internet objects (IIoT).

In the future, useable waste heat could be trapped and the human body to feed some of wearable sensors for medical implants developing (a harvester attached to a person's skin will be able to use a ΔT of up to 10°C).

5.3. Shake it for energy

The kinetic energy can be converted into electricity by piezoelectric effect; mechanically deforming a piezoelectric crystal (Micro Electro Mechanical System piezo MEMS) voltage or pressure to generate electrical charge, which can be measured as a voltage across the electrodes of the piezo element.

Piezoelectric vibration energy harvesters convert this mechanical vibrational energy into alternating electrical energy (AC).

This AC is then converted into DC electronic format that can be used to drive wireless IoT applications or recharge a battery.

Piezoelectric energy transducers supplies energy when operating at maximum resonance frequency of the vibration source, and when it works in a task designed to match the output impedance piezoelectric.

The secret for harvesting the vibrational energy with any piezoelectric material is to understand the vibration environment, and the best method to do this is to measure the vibration using an accelerometer.

5.4. RF harvesting energy

Due to the widespread growth of wireless communications and a concomitant increase in the number of radio transmitters, in particular mobile base stations, mobile phones, there is a lot of energy "free" RF around us.

Besides Wi-Fi sources, researchers can find sources of RF energy from short-range wireless technologies such as Bluetooth and ZigBee, and cellular services, long-range. A reception coil serves as an energy source, RF energy harvesting, generating a voltage in response to electromagnetic coupling with the RF transmitter.

The challenge in RF energy harvesting lies in maximizing the output from the transducer at a given ambient energy level (Figure 9).

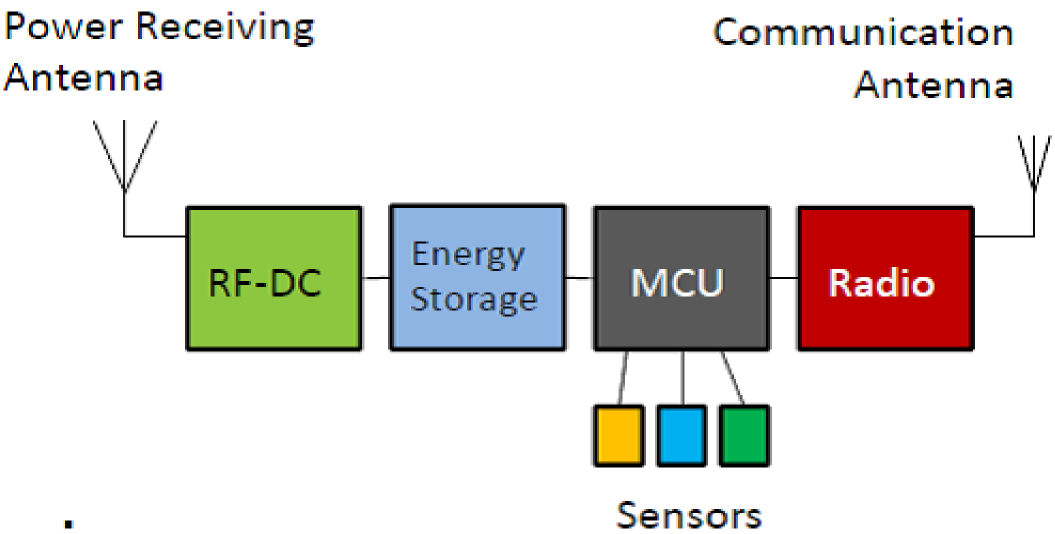

Figure 8. RF energy harvesting systems can provide renewable energy by converting radio waves to DC power for IoT applications (Source: Powercast)

6. IoT in Europe

Internet of Things activities is present, with numerous projects underway in industry, academic research and various levels of government.They will work together to achieve technological evolution in this area.

In Europe, is deposited a substantial effort to strengthen inter-domain activities of the research groups and organizations in a unified IoT framework.

Supported by the European Commission 7thFramework program (EU-FP7) this includes the Internet of Things European Research Cluster (IERC) and its objectives are: to establish a cooperation platform for IoT activities in Europe and become a contact point for IoT research in the world.

It includes projects such as CASAGRAS2, a consortium of international partners from Europe, the USA, China, Japan and Korea exploring issues surrounding RFID and its role in realizing the IoT IERC includes the Internet of Things Architecture (IoT-A) project established to determine an architectural reference model for the interoperability of Internet-of-Things systems .

IoT Initiative (IoT-i) is coordinated action formed to support the development of IoT European community. IO project bring together a consortium of partners to create a common strategic vision and technical IO Europe.

In the same time, the project SmartSantander is under way to develop a large city testbed IoT for providing research and implemented in the city of Santander, Spain, and at locations in the UK, Germany, Serbia and Australia [6].

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7. Conclusion

Development of actual devices that use energy harvesting power ICs is moving forward in many locations and applications. Sometimes energy harvesting feeds battery free wireless sensors terminals. In other cases, use of batteries and energy harvesting, together extend battery life.

In this way, there is an acceleration of the development of wireless terminals which incorporates sensors for energy harvesting.

In the next period, we should see the location of wireless sensor terminals with this technology in all manner of locations. Power management ICs designed for energy harvesting, as well as low-power MCUs, will help advance the growth of the Internet of Things.

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