ENERGY HARVESTING METHOD IN WIRELESS SENSOR NETWORK

Sutapa Sarkar , Bhavani.V, I.Hameem Shanavas, V.Nallusamy

Department of Electronic and Communication,MVJ College of Engineering,Bangalore, India

ABSTRACT

With the advent of modern micro mechanical system technology and wireless communication wireless sensor networks are finding a lot of application in modern day life. The design of the sensor network depends on the specific application. This paper gives a description of the components of the wireless sensor nodes used. It also describes how the lifetime of a wireless sensor network can be increased by the use of energy harvesting sensor nodes.

KEYWORDS

Wireless sensor networks, motes, energy harvesting sensor node.

1. INTRODUCTION

A wireless sensor network (WSN) is a wireless network that consists of a spatially distributed set of autonomous wireless sensor nodes. Nodes are commonly referred to as motes. The number of nodes in a sensor network can be up to hundreds of thousands. The nodes are tiny computing devices, each equipped with sensors (type of sensor depends on application), a wireless radio, a processor, and a power source. The sensor nodes can be considered as tiny battery powered computers. Nodes take the data from the attached sensor nodes and using the on-board processor perform simple computations and transmit only the required and partially processed data[1].Sensor networks consists of different types of sensors such as seismic, low sampling rate magnetic, thermal, visual, infrared, acoustic and radar.[1]Depending on the type of sensor it can have military applications, Environmental applications, health applications, Home applications and commercial applications[1].

According to Zigbee (IEEE 802.15.4) standards, commonly used in wireless sensor node communication, the wireless connectivity of the sensor is an application enabler. To build a wired network consisting is very costly and may be potentially impractical in target deployment environment. Bluetooth can be an alternative for interoperability with computer, cellular phone etc. But with Bluetooth power consumption is higher.

Wireless sensor network has attracted a lot of research attention due to its potential applications. But there are a number of challenges that are to be overcome. Sensor networks consist of a large number of unattended nodes working in harsh environment. One constraint is battery lifetime. This constraint can be overcome by using energy harvesting from suitable sources according to the application concerned. This paper describes the structural components of wireless sensor nodes, the possible methods of energy harvesting to improve the lifetime of the sensor networks and the possible applications.

2.WIRELESS SENSOR NODE COMPONENTS

The applications and capabilities vary for different sensor nodes. But essentially the basic building blocks of all the nodes consists of a sensor, wireless radio, a processor, and a power source.

2.1. PROCESSOR/COMPUTING SUBSYSTEM

The computing subsystem performs the required computation and controlling operation on the wireless sensor node components. It consists of the following parts: A microcontroller and a storage unit (optional in some of the commercially available WSN). Depending on the power availability and application a range of microcontrollers are used in different commercially available motes. Motes usually operate in Active, Idle or sleep mode. This is useful to save power. The range of microcontrollers can vary from low power 8 bit ones to powerful processors such as [4]: Atmel AT90LS8535, Atmel Atmega 128L,Atmel AT91FR4081A, PIC 18F452, 8-bit AVR-like RISC 4, Chipcon CC1010 (8051), PIC 16F877, TI MSP430F149, TI MSP430F149, nRF24E1 (8051), PIC 18F6720, TI MSP430F1611, Intel PXA 271, rfPIC 16F675, Cypress CY8C2764 etc. Microprocessors used can follow RISC or CISC architecture. Node contains a flash memory for storing the code and RAM for storing the sensed data. A node might also contain a separate storage unit.eg micro SD card interface in SHIMMER for storing off line data up to 2 Giga Byte. The main reason for avoiding computational complexity in wireless sensor nodes is the lack of available power. For similar reason writing to micro SD card is avoided as it consumes a lot of power.

2.2. RADIO/COMMUNICATION SUBSYSTEM

The radio or communication subsystem is required for communication between the nodes and also to transmit the sensed and processed data from the corresponding node. Sensor nodes mainly use broadcasting techniques for communication. Radio frequency communication is most popular for wireless sensor nodes. This type of communication does not require line of sight operation and also with the advent of technology available in different data rates and ranges based on applications. Unlicensed ISM bands are suitable for this type of communication.chk for licensed band from country to country.. The presence of such devices in the proximity of WSN can cause additional interference causing poor quality communication.

Table I. Specification of Microprocessors Used In Sensor Nodes

CPU	CPU structure(complexity)	FLASH	RAM	Operating voltage
Atmel AT90LS8535	RISC	8kbytes	512 Bytes	2.7-6.0V
ATmega128L	RISC	128k	4kB	2.7-5.5V
Atmel AT91FR4081A	RISC	8Mbits	136 k Bytes	2.7-3.6V
Atmel Atmega 163	RISC	256-2Kbytes	1024 bytes	4.0-5.5V
Dragonball EZ	CISC	_	_	_
PIC 18F252	RISC	32 Kbytes	1536 bytes	2.0-5.5V
Atmel AT91FR4081	RISC	8Mbits	135kbytes	2.7-3.6V
PIC 18F452	RISC	32Kbytes	1536 bytes	2.0-5.5V
PIC 16F877	RISC	8k x 14 words	368x8bytes	2.0-5.5V
TI MSP430F149	RISC	60kB	2kB	1.8-3.6V
PIC 18F6720	_	128Kbytes	3840bytes	2.0-5.5V
TI MSP430F1611	RISC	40kB	10kB	1.8-3.6V
Intel PXA 271	_	256kbytes	64kB	2.25-3.75V
TI MSP430F1232	_	8kB	256**B**	1.8-3.6V

Table II. Transceivers Used In Different Sensor Platforms

Radio Transceiver	BW(kbps)	Frequency(MHz)
RFM TR1000	10	916.5
Conexant RDSSS9M	100	900
National LMX3162	1000	2400
ZV4002 BT/ CC1000	1000	2400
Radiometrix	64	433
Chipcon CC1000	38.4	900
Ericsson ROK101007 BT	1000	2400
Zeevo BT	720	2400
Chipcon CC2420	250	2400
Nordic nRF903	76.8	868
Infineon TDA 5200	120	868
rfPIC 16F675	19.2	868
Chipcon CC2420	250	2400
Ember 250	250	2400
Nordic nRF24AP1	1000	2400
Nordic nRF24E1	1000	2400
WML-C46A BT/CC2420	250	2400
Atmel ATRF230	250	2400

2.3. SENSOR SUBSYSTEM

A sensor is a converter that measures a physical quantity and converts it into a signal that can be measured by an instrument. A sensor should be sensitive to the measured property only and should not influence it. Based on the application and the parameter they are sensitive to sensors are of different types, eg accelerometer, Barometer, Gyrometer, Hygrometer, Proximity Sensor, Temperature Sensor etc. From different companies different sensor platforms are available eg. WeC, Rene 1, AWAIRS 1, µAMPS, Rene 2,DOT, Mica, BT Node, SpotOn, iMote, Telos, MicaZ that use different softwares like TinyOs, MicroC/OS, Smart-its, Palos etc.

2.4. POWER SUBSYSTEM

Table III:.List Of A Few Types Of Sensors Based On Applicatio

Types of sensors	Description
Accelarometer	Measures the rate of change of velocity (aka Acceleration)in meters per second squared (m/s2) or g’s
ALS(Ambient Light sensor)	Measures visible light intensity in Lux.
Barometer/Pressure sensor	Measures atmospheric pressure in hecto-pascal (1 hPa = 100 Pa = 1 millibar)
Gyrometer /Gyroscope	Measures rotation velocity (aka angular rate),in

	degrees per second (dps) or radians per second (rad/s).
Hygrometer/Humidity Sensors	Measures environmental % relative humidity.
Magnetometer	Measures magnetic field strength, in Tesla (1 μT = 10 mG).
Proximity sensor	Measures object locality in cm.
Temperature Sensor	Measures environmental ambient temperature in Celsius (C), Fahrenheit (°F) or Kelvin (K)

The energy required to power a node should be dependable. Usually batteries are used to power wireless sensor nodes. The external battery pack usually contains AA batteries. The battery consists of a single electrochemical cell. The power supplied by the battery depends on the chemistry of the battery depending on application it might be difficult to replace the battery. Also it is difficult to replace the batteries if a very high number of nodes are required in that application.

Table IV. Chart On Sensor Parameters (Terminologies Adapted From Common Industry Practices [8])

Sensor type	**Applicable sensor parameters**
Accelerometer	Full Scale Range, Sensitivity Temperature Coefficient, Digital Bit Depth, Noise, Cross-Axis Sensitivity, Current Consumption, Integral Non-Linearity, Output Data Rate (ODR),Transition Time, Sensitivity, Filter -3dB Cutoff, Data Ready Delay, Internal Oscillator Tolerance, Zero-g Offset, Zero-g Offset Temperature Coefficient
Magnetometer	Full Scale Range, Sensitivity Temperature Coefficient, Digital Bit Depth, Noise, Cross-Axis Sensitivity, Current Consumption, Integral Non-Linearity, Output Data Rate (ODR),Transition Time, Sensitivity, Filter -3dB Cutoff, Data Ready Delay, Offset at Zero Magnetic Field, Acquisition Time, Offset Temperature Coefficient
Gyrometer/Gyroscope	Full Scale Range, Sensitivity Temperature Coefficient, Digital Bit Depth, Noise, Cross-Axis Sensitivity, Current Consumption, Integral Non-Linearity, Output Data Rate (ODR),Transition Time, Sensitivity, Filter -3dB Cutoff, Data Ready Delay, Internal Oscillator Tolerance, State to State Transition Time, Zero Rate Bias, Zero Rate Bias Temperature Coefficient,Internal Oscillator Tolerance, Root Allan Variance Parameters, Linear Acceleration Sensitivity, Mechanical Resonance
Barometer/Pressure sensor	Full Scale Range, Digital Bit Depth ,Noise, Current Consumption, Integral Non-Linearity, Transition Time, Sensitivity, Short Term Stability, Long Term Stability, Over Pressure Maximum, Pressure Temperature Coefficient, Pressure Accuracy, Acquisition Time,
Hygrometer/Humidity Sensor	Full Scale Range, Digital Bit Depth ,Noise, Current Consumption, Integral Non-Linearity,Transition Time, Sensitivity,Relative Humidity Accuracy, Long Term Drift, Response Time
Temperature	Full Scale Range, Digital Bit Depth ,Noise, Current Consumption, Integral Non-Linearity,Transition Time, Sensitivity,Long Term Drift, Absolute Temperature Error
Ambient Light Sensor	Digital Bit Depth ,Current Consumption, Transition Time, Sensitivity,ALS Conversion Time vs Maximum Detection range, ALS Measurement Accuracy,Normalized Spectral Response, ALS Noise, Responsivity vs Angle
Proximity Sensor	Digital Bit Depth, Transition Time, Sensitivity,sensing Current Consumption

From Table-V we can see that Lithium batteries are more efficient and have lower self discharge rate than Ni-Cd, Ni-MH or SLA batteries. For this reason Lithium batteries are better choices for energy harvesting wireless sensor nodes. Lithium based batteries need a high charging current pulse for charging whereas NiMH can be trickle charged that is directly connected to an energy source for charging.Efforts are there to recharge the battery by generating energy from the surrounding environment, by using thermal, vibration or RF energy sources.

Wireless sensor nodes are conventionally powered by batteries. But batteries have a limited lifetime. So once the power supply from the portable energy source

Table V. Few Rechargeable Battery Technologies [19]

Battery Type	**Nominal Voltage (V)**	**Power density (W/Kg)**	**Efficiency (%)**	**self Discharge (%/Month)**	**charging Method**	**Recharge cycles**
SLA(Sealed Lead Acid)	6	180	70-92	20	Trickle	500-800
Ni-Cd(Nickel Cadmium)	1.2	150	70-90	10	Trickle	1500
Ni-MH(Nickel Metal Hydride)	1.2	250-1000	66	20	Trickle	1000
Li-ion (Lithium ion)	3.7	1800	99.9	<10	Pulse	1200
Li-Polymer	3.7	3000	99.8	<10	Pulse	500-1000

(conventionally batteries) used in the sensor node is over the node becomes useless. In some applications it may not be feasible to replenish the battery if is embedded in a building or located at some place that is difficult to reach. This dependency on battery is inefficient and also it posses risk to the environment as the battery may leak its contents in the environment leading to pollution and possible corrosion of the surrounding medium.

To increase the lifetime of wireless sensor nodes two approaches are there: One approach is to design energy efficient routing protocols increasing the lifetime of the nodes.

Another approach is the idea of energy harvesting wireless sensor nodes that has gained considerable attention recently. Energy harvesting can remove dependency of wireless sensor nodes on power source.

3. ENERGY HARVESTING METHODS IN WIRELESS SENSOR NODES

Energy harvesting can be described as the process of capture, accumulation and storage of unexploited energy from circumambient environmental sources [2].The energy can be derived from solar, temperature, motion or electromagnetic.

RF wireless transmission of data is widely established in modern days, eg. Cellular networks, radio and television networks. Example: Even at a kilometer away from an FM radio tower, indoor power densities better than 0.5 uW/cm2 can be detected. Because of this wide availability of wireless network considerable amount of RF energy can be detected in the environment. With proper circuitry this ambient energy can be used to power autonomous sensor nodes. With the use of this technology wireless communication infrastructure becomes a source of power without any added cost to the wireless communication service provider. RF energy harvesting uses the power that would have otherwise been wasted and absorbed in the environment.

Short range(<2m) RFID applications focus on the industrial-science-medical(ISM) frequency bands around 0.9, 2.4, 5.8 Ghz and higher. With the increase of frequency, the wavelength decreases, making it suitable for wireless autonomous transducer systems (WATS).[2]

The EH (energy harvesting) circuit should remain always active to catch this small amount of energy. The power consumption of the harvester circuit needs to be very small as compared to the energy provided by the ambient sources. Also the EH circuit should be able to store the harvested energy with the minimum leakage.[6]

Energy harvesting or power scavenging is best suited for applications that need continuous supply of low power, or the applications that need high power for a small duration of time. Few possible energy sources for energy harvesting are as follows:

3.1. SOLAR

One of the most popular energy harvesting technique is the use of solar or photovoltaic cell. In this type of energy harvesters optical energy mainly from sunlight is converted into electrical energy. Hence it is best suited for applications that have ample exposure to sun. The output of solar cell depends on the sunlight as well as on the load attached to it. Solar cells have conversion efficiency upto 30%. Solar radiation yields around 15 mW/cm2 in full sunlight or 0.006mW/cm2 under bright indoor illumination.[6]

3.2.THERMOELECTRIC

The generation of electricity using a temperature gradient is referred to as thermoelectricity. A temperature difference between two junctions of a conducting material creates a potential difference. This potential difference is used by thermoelectric generators. With 100C temperature gradient 40 μW/cm2 of power can be generated.

3.3. MECHANICAL VIBRATION

If an inertial mass is subjected to some movement electrical energy can be generated using three mechanisms. piezoelectric, electrostatic and electromagnetic.[6]

- Piezoelectric: Converts mechanical (pressure, vibration) energy into electricity.eg. Piezoelectric shoe inserts can generate 330 μW/cm2.
- Electrostatic: The planes of initially charged varactors are separated by vibration and the corresponding mechanical energy is used to generate electrical energy. One dedicated voltage source is required for this type of energy generation to charge the capacitors initially.
- Electromagnetic: Electromagnetic induction is a useful method of energy harvesting which is free of the effects of mechanical damping. Permanent magnets, coils and resonating cantilever beam are used for this type of energy harvesting. But because of its large size these are difficult to integrate with wireless sensor nodes.

3.4. FAR FIELD RF ENERGY HARVESTING

Far field RF energy harvesting can be done in two ways: Active energy harvesting by using a dedicated energy transmitter or Passive energy harvesting using the ambient sources of energy present in environment such as propagating radio waves or sun light[9]. One possible method of RF energy harvesting is by using television broadcast energy. Energy from RF commercial broadcasting stations like TV or radio are used to supply energy to WSN. Energy is harvested using rectenna (rectifier +antenna) principle with the antenna connected to a tuner stage. The tuner selects one out of the possible commercial broadcasting channels. The selected channel is the more powerful one and to this the sensor node is connected.[5]

- RF energy harvesting using Rectenna: RF energy harvesting uses far field RF energy-transmission. The RF energy harvesting WSN consists of antenna that is matched with the desired frequency of operation. The antenna is connected to a rectifier. This antenna and rectifier arrangement together is called the rectenna system. The output of antenna is the usable DC power. This DC power is stored in a Energy Storage Device before being delivered to a load. The schematic of a general RF power transmission system is shown in fig1[3].

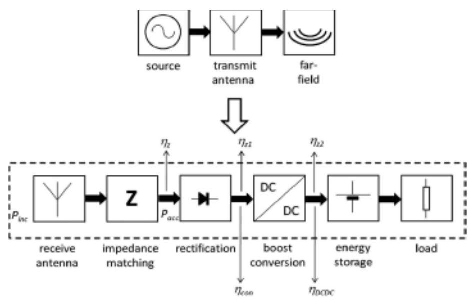

Fig. 1. Wireless RF power system, with the rectenna in the dashed box. Pinc is the incident power upon the receive antenna; Pacc is the accepted power after impedance matching; _z , _z1, and _z2 are the impedance matching efficiencies; _con is the rectifier power conversionefficiency; and _dcdc is the boost converter power efficiency

4. APPLICATIONS

Wireless sensor networks find a wide range of application in military, environmental, health, smart homes, space exploration and other commercial domains. They can be used for certain event detection or continuous monitoring of the target. Rapid deployment and fault tolerance feature makes it a attractive technique for military applications. In the domain of environment tracking sensor networks are used for monitoring bird or animal movements, monitoring environmental conditions that affect corps, flood detection, pollution study, chemical and biological detection etc. A few health applications of wireless sensor networks are diagnostics and drug administration in the hospitals, telemonitoring of human physiological data. Sensor nodes used in home appliances can interact with each other remotely. Air conditioners use sensors to centrally control the environment of an office building.

5. SUMMARY

This paper presents a review of currently available wireless sensor node structures. It describes the hardware specifications of different wireless sensor node platforms. The hardware cost and dependency on battery lifetime are the drawbacks that need to be overcome. Energy harvesting may give a possible solution to the reduced lifetime problem of sensor nodes due to battery dependency. With evolving technology a number of solutions for wireless sensor nodes are available. Using these techniques differently capable sensor nodes that are suitable for different applications is possible. Sensor node topologies are very stringent and specific to the application. With improved technology wireless sensor networks have started to find a wide range of applications in daily lives. Their flexibility, self organization and fault tolerance capability makes them suitable for wide range of applications.

REFERENCES

[1] I.F. Akyildiz, W. Su*, Y. Sankarasubramaniam, E. Cayirci, “Wireless Sensor Networks: A Survey” , Computer Networks, Vol. 38, No. 4, Pp. 393– 422, 2002.

[2] Mai Ali, Lutfi Albasha, Nasser Qaddoumi Department Of Electrical Engineering ,American University Of Sharjah ,Sharjah, United Arab Emirates, “Rf Energy Harvesting For Autonomous Wireless Sensor Networks”, Design And Technology Of Integrated Systems In Nanoscale Era(Dtis),2013 8th International Conference,Digital Object Identifier 10.1109/Dtis.2013.6527782.

[3] Hubregt J. Visser, Senior Member Ieee, And Ruud J. M. Vullers, Senior Member Ieee, “Rf Energy Harvesting And Transport For Wireless Sensornetwork Applications: Principles And Requirements”, Proceedings Of The Ieee, Volume: 101, Issue:6, Digital Object Identifier:10.1109/Jproc.2013.2250891.

[4] Michael Healy, Thomas Newe And Elfed Lewis, “Wireless Sensor Node Hardware: A Review”, Ieee Conference Publication,Digital Object Identifier10.1109/Icsens.2008.4716517,Publicationyear 2008,Page(S):621-624.

[5] T. Sogorbl, J.V. Llario2, J. Pelegri3, R. Lajara, J. Alberola, “Studying The Feasibility Of Energy Harvesting From Broadcast Rf Station For Wsn”, I2mtc 2008 - Ieee International Instrumentation And Measurement Technology Conference Victoria, Vancouver Island, Canada, May 12-15, 2008

[6] Mile K. Stojčev1, Mirko R. Kosanović2, Ljubiša R. Golubović3, “Power Management And Energy Harvesting Techniques For Wireless Sensor Nodes”, Telecommunication In Modern Satellite,Cable And Broadcasting Services,2009.Telsiks’09 9th International Conference: Digital Object Identifier:10.1109/Telsks.2009.5339410, Publication Year 2009,Page(S):65-72.

[7] Sravanthi Chalasani James M. Conrad, “A Survey Of Energy Harvesting Sources For Embedded Systems” , Ieee Conference Publication,Digital Object Identifier:10.1109/Secon.2008.4494336, Publication Year 2008,Page(S):442-447

[8] Www.Memsindustrygroup.Org/I4a/Doclibrary/Getfile.Cfm?Doc_Id=481.

[9] Triet Le, Karti Mayaram, Fellow, Ieee, And Terri Fiez, Fellow, Ieee, “Efficient Far-Field Radio Frequency Energy Harvesting For Passively Powered Sensor Networks”, Ieee Journal Of Solid-State Circuits, Vol. 43, No. 5, May 2008.

[10] Sujesha Sudevalayam And Purushottam Kulkarni, “Energy Harvesting Sensor Nodes: Survey And Implications”, Ieee Communications Surveys & Tutorials, Vol. 13, No. 3, Third Quarter 2011.

[11] Atmel Atmega128, Atmega128l Datasheet, Rev. 2467x–Avr–06/1

[12] Atmel At91fr4081 Datasheet, Rev. 1386c–Atarm–02/02.

[13] Atmel Atmega163, Atmega163l Datasheet, Rev. 1142e–Avr–02/03.

[14] Pic18fxx2 Datasheet, 2006 Microchip Technology Inc.

[15] Atmel At91fr4081 Datasheet, Rev. 1386c–Atarm–02/02.

[16] Pic18f6720 Datasheet, Microchip Technology Inc.

[17] Pic16f87xdatasheet, 2001 Microchip Technology Inc.

[19] Msp430f1611 Datasheet, Texas Instruments.

[20] Intel® Pxa27x Processor Family Datasheet.