A Survey on RF Energy Harvesting-RFEH- in WSNs

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Abstract : Lately, WSNs have attracted lot of attention due to their ubiquitous nature and their varied utilization in IOT, Cyber Physical Systems, and other emerging fields. The restricted energy related to wireless sensor networks is a considerable bottleneck of these networks. To surpass this serious limitation, the design and development of high performance and efficient energy harvesting systems for WSN environments are being inspected. We present a comprehensive taxonomy of the different energy harvesting sources that can be adopted by wireless sensor networks. We discuss also many freshly suggested energy prediction models that have the ability to boost the energy harvested in wireless sensor networks. To finish, we identify some of the challenges that still need to be addressed to develop cost-effective, efficient, and reliable energy harvesting systems for the WSN environment.

Keywords : WSN, energy harvesting , IoT.

INTRODUCTION

Power scavenging or (Energy harvesting) is without any ambiguity a very captivating method for a wide variety of autonomous-powered microsystems. Examples of such systems are WSNs, biomedical implants, military monitoring devices, structure-embedded instrumentation, remote weather station, calculators, watches, Bluetooth headsets. Recently power scavenging gets a huge attention and research report number has kept growing. The focus of this paper is to provide the research community with an update of the state-of-the-art of power scavenging from vibration, thermal, and RF sources. The principle of energy harvesting approaches can be found in Ref. [7].In the following; we list the energy harvesting sources (Section 2), a brief history of energy scavenging (Section 3), state-of-the-art based on the review of several recently published papers (Section 4) and Conclusion.

Motivations for energy harvesting in WSNs

It is a well-known that one of the main hitches WSNs face is energy[1-2]. When the power of a SN is ingested, it will no longer accomplish its role in the network except either the power source is changed or some harvesting techniques are introduced to stop the energy gap. The main existing power energy source adopted by the SNs is battery-power, but many issues are related to batteries. First, the current that flows ingests the battery even if not in usage. Second, severe climate conditions can cease to function of batteries, causing in chemical leakages that may provoke many environmental troubles[3]. Finally, the battery's energy capacity is restricted, and that can block or handicap the SN activity over a long time [4]. There are various wireless sensor network application scenarios where the lifespan of the SN varieties from months to many years based on the application necessities[5]. For that reason, the lifespan of the SNs should end many years before their power batteries get depleted and they become useless due to the deficiency of power supply. To operate continuously in most situations, SNs necessitate a uninterrupted power supply, either that supply is in an active mode to communicate and treat data or a passive mode when SNs go to sleep as presented in Fig.1.

Normally, deficiency of a few SNs is not a major problem for the appropriate functioning of a WSN, but the damage of those SNs undoubtedly affects performance and overhead. Ultimately, the network cannot surmount the loss of the nodes or fulfill the application's anticipated requests. Over time, the connected SNs will leak the energy kept in the storage components. The sensor nodes, treating, broadcasting, and data transfer frequency significantly influence the lifespan of the battery.

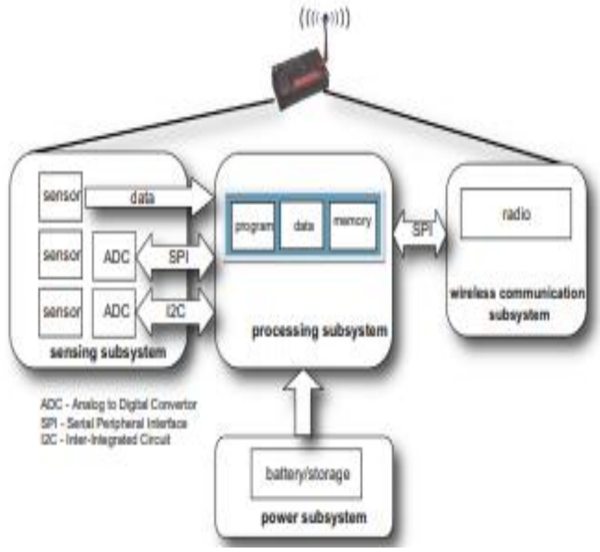

Fig. 1. Sensor node architecture with battery 1as main source[6].

All these features support the use of power harvesting in wireless sensor networks. A wireless sensor network must be self-powering, long lasting, and almost maintenance free. Thus, energy harvesting may be defined as a technique utilized to generate energy from networks ambient environments to afford a continuous power supply for a particular SN and for the whole network. Moreover, we can classify 2 types of energy scavenging systems: (1) where ambient energy is directly transformed to electrical energy to power the SNs (no battery storage is necessary as represented in Fig. 2(a)), and (2) where the transformed electrical energy is first stored before being supplied to the SN as presented in Fig. 2(b). For the time being, wireless sensor network applications will remain to use nonrefundable and life-long batteries. That being said, for applications demanding high power above the lifespan of the wsn, the energy scavenging mechanism will carry out the usage of rechargeable batteries. Power scavenging is ultimate for applications that must persist for longer time periods, i.e., those that are used once and then always accessible, such as environmental monitoring systems [7]. Other applications that may benefit from power scavenging are those that necessitate the carrying of large amounts of information to the base station, as is the case in multimedia applications in wireless sensor networks [8], operational monitoring data system [9], etc.

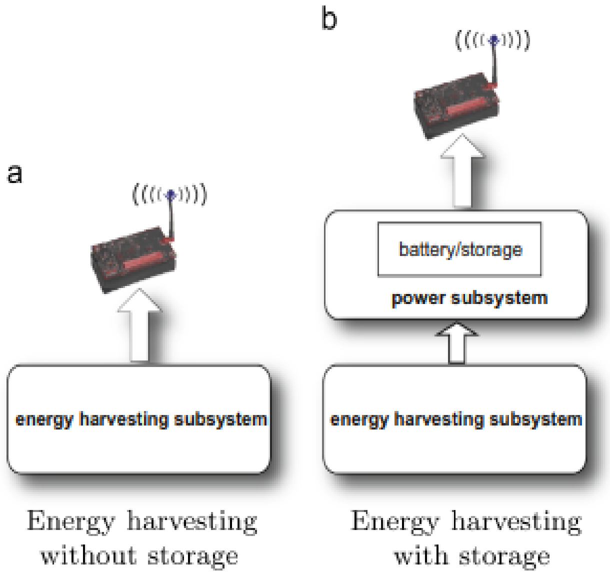

Fig.2. Architecture of energy harvesting wireless sensor node[6].

Basically, all types of wireless sensor networks uses can benefit from power scavenging techniques to elongate the lifespan of the WSNs.

Classification of energy harvesting techniques in WSNs

For Power scavenging several power sources have been deliberated. To select a power harvesting source, one of the leading standards is to define whether or not it can deliver the required energy level for the SN. Generally, power dissipates through voltage conversion and the dissipation growths as the input/output ratio of the voltage growths. Consequently, it is imperative to guarantee that the engendered power is at an appropriate voltage and current level. In order to attain the anticipated power level, whether the source of the energy is improved or the power scavenging device is surmounted accordingly. For example, in the case of Radio Frequency, raising the power of the source will satisfy the required demand. Also, growing the Photovoltaic (PV) cell region will assemble extra light, ensuing in the generation of extra power. Though, in certain environments, the sources/converters cannot be scaled so simply. For example, power resulting from industrial vibrations in general cannot be scaled up without growing the vibration effect on the machine, which may be undesirable. Therefore, while it may be promising to scale up the scavenging device, several wireless sensors network applications oblige sensors to be small sized and lightweight. Therefore, the power density parameter is used commonly by the scientist researchers to compare diverse power scavenging mechanisms [10].

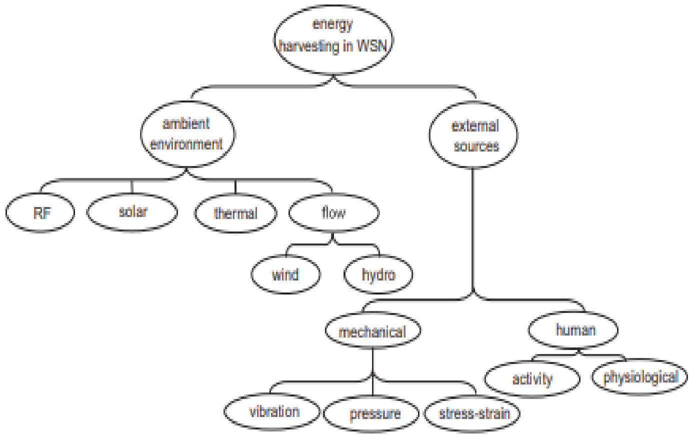

Fig.3. Taxonomy of energy harvesting sources in WSN

For that reason, developers need to keep this tradeoff in mind when choosing an appropriate power scavenging system for a specific use. We organize the power scavenging sources into two general classes: ambient sources and external sources. Ambient sources are readily offered in the environment at almost free. On the other hand, external sources are positioned openly in the environments for power harvesting purposes. These classes are auxiliary partitioned as presented in Fig. 3.

RF Energy Harvesting

Ambient Radio frequency energy is a 4^{th} source for energy scavenging fig.4. By ambient RF energy, we mean RF energy obtainable over public telecommunication services (e.g., GSM and WLAN frequencies). When harvesting power energy in the GSM or WLAN band, one has to deal with very low power density levels. For ranges of 25–100 m from a GSM sink, power density levels of 0.1–1.0 mW/m2 can be predictable for single frequencies [11]. For the entire GSM downlink frequency bands, these levels can be raised by a factor of between 1 and 3, contingent on traffic capacity. First measurements in a WLAN environment specify power density levels that are at least one order of magnitude lower [12]. Then, neither GSM nor WLAN is expected to harvest enough ambient RF energy for wirelessly powering tiny sensors, unless a big area is employed for harvesting. This was evidently proved by Intel [6] Energy diffused by an adjacent TV station (distance: four km) was used to power a temperature sensor (Fig.5.).

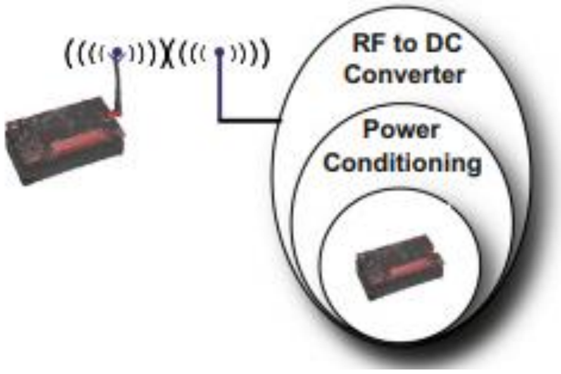

Fig.4. Generalized RF energy harvesting system for WSNs

With an antenna of around 30 cm by 20 cm, 60 µW of energy was harvested, which amounts to an energy density of 0.1 µW/cm2. Alternatively, one can use a dedicated RF source positioned close (a few meters) to the sensor node, thereby limiting the transmission power to levels accepted by international regulations. Consider an RF device with power PT transmitting and receiving at wavelength l at a distance R from the node. The received power PR is then described by the Friis equation [13] as PR 5 PTGTGRl2 14p22R2 , where GR and GT are the receiving and transmitting antenna gains, respectively. Such a commercial system, produced by the company Powercast, is currently on the market [14]. The system charges the internal battery of a device using the received RF energy. In ideal conditions, with no reflections and aligned polarization, 15 mW of power can be received at a distance of 30 cm, with a transmitted power of 2–3 W at a frequency of 906 MHz. There is still a lot of room for improvement in transmission (e.g., via beam steering), receiving (with improved antenna design), and conversion efficiency. As an example, at a transmission power of 100 mW, values of 1.5 mW at 20 cm and 200 µW at 2 m have been reported [15].

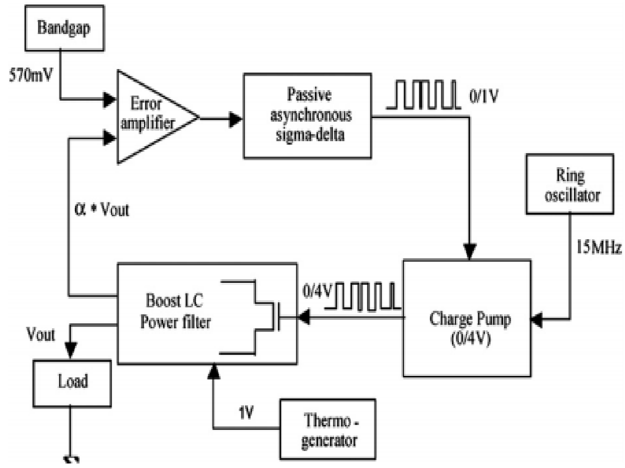

Fig.5. The DC/DC converter architecture[16]

CONCLUSION

1. Conclusion

This paper presented energy harvesting routing based and battery power based routing approaches in WSN. The state-of-the-art energy harvesting mechanism for WSN is discussed in details and the most recent energy-efficient data packet routing approaches are reviewed. Then comparisons of the studied methods based on the main features are made. According to the literature, balancing of the energy among the nodes is usually obtained in two ways, single-path, and multi-path methods. In single-path methods, the best path that can satisfy the required energy consumption. The load is divided amongst the paths, to ensure energy balancing among nodes in multi-paths methods

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