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RF Energy Harvesting For Ad-Hoc And Wireless Sensor Networks: A Survey

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ABSTRACT

Wireless sensor network and Ad-hoc networks are the most growing networks in every aspect of present systems. In the pool of Wireless Ad-Hoc Networks, Wireless Sensor Networks (WSNs) acquire a special category where these networks consists of low powered wireless nodes depending upon the specific applications to sense, collect the perticular event and transmit the same data to a main central node or network for further processing. Due to the well known fact that the wireless sensor nodes are low powered and have limited processing and storage capabilities, they are considered unreliable for use in critical systems. Due to this there is a huge requirement of eleiminating these drawbacks of WSNs an efficient, reliable and effective energy harvesting methods and techniques for RF signals need be designed and deployed for a network.
Keywords— Wireless Ad-Hoc Networks, Energy Harvesting , Wireless Sensor Networks (WSNs), Radio Frequency Signal.

I. INTRODUCTION

A significant research investigation is happening on various methods to extract energy and to save it from different sources and convert it into a form of electrical signal to directly energize or to power up the low powered mobile nodes or devices, or to store this energy for further usage. One such abundant energy source is Radio Frequency (RF) since it is transmitted from millions of radio transmitters all around the world. Harvesting energy from RF signal can enable wireless charging of low powered devices and which will give positive results on design of product and reliability of the system. The radiations from RF source will become a widely available source of energy if it can be effectively and efficiently harvested. Present techniques of RF energy harvesting have been considered as the best alternative and efficient methods to power the next generation wireless ad-hoc and wireless sensor networks, particularly low-power devices and systems.Sources of RF energy can be broadly categorized into two types:

A. Ambient RF

This type of energy is freely available, the range of frequency of this transmission is around 0.2-2.4 GHz, this range can includes most of the radiations like domestic appliances for example TV, Bluetooth devices, WiFi devices and mobile devices, and also different transmitting Base Stations. The figure 1 shown below gives the detailed circuit of ambient RF energy harvesting. Mainly there are three stages, Matching network, Voltage multiplier and finally Energy storage.

B. Dedicated RF

This is as an on-demand supply which has a higher power density and it is used to charge the mobile sensor nodes or mobile devices which require high energy. Since dedicated RF energy harvesting is fully controllable, it can serve applications which has constraints with Quality-of-Service (QoS). Since it is not freely available, the harvester must pay for this service.

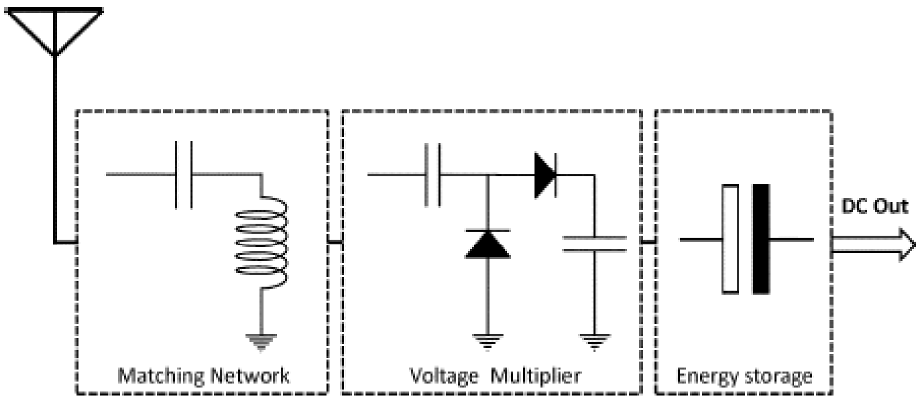

Figure 1: Energy Harvesting from ambient RF signal

II. LITERATURE REVIEW

[1] gives a review of various wireless power transfer (WPT) and a brief comparison between different ambient sources of energy. An overview of architecture and components of rectennas used for energy harvesting of RF signals. Since rectannas are comparatively cheaper and environment friendly, they are used for powering up low-powered sensors nodes and portable devices in remote and inaccessible areas. One such important concern about powering low power nodes is that where battery replacement is difficult frequently, if might not be impossible. A detailed comparisons of different rectannas and present challenges in the design of rectannas are briefed here.

A design of energy harvesting system [2] which consists of one stage and five stage voltage multiplier with a π type matching circuit for RF signal with a GSM-900 band standard where RF signal as input power is presented. ADS simulator is used to design and simulate the system and a 180KΩ load resistor is used to measure the output. The system design is mainly focused on specific input power range of -30dBm to 30dBm for a frequency of 915MHz. At five stages of design the output voltage of 9.6V at 0 dBm and a maximum of 33.9V at 20 dBm is achieved. Also there is a brief comparison between systems and techniques of RF energy harvesting on various voltage multiplier. And finally, the paper compared and concluded that the proposed π type matching circuit is better than any other matching circuits available.

A novel Self healing system [3] for Users equipment by using RF Energy transfer scheme is proposed and designed to heal and extend the battery life of a sensor node. This is done by incorporating energy transfer scheme for RF signal between a low powered battery users and network operator. This is achieved by sending a dedicated energy from various sources. This approach depends on the concept of Energy as a Service where the network operator delivers energy to battery starved users in the next generation networks. By using heuristic algorithms a mixed integer and non linear optimization solution is solved efficiently and formulated. The showed Simulation results can prove that required amount of energy can be transferred to starved users. Results also show that there is a minimal requirement of uplink power and a minimal data rate is guaranteed.

In [4], there is a summary of harvesting technologies of radio frequency (RF) power which gives a brief idea of existing technologies in the field of energy harvesting units. Also there is comparative analysis of various designs and discussions on their tradeoffs are also briefed. Finally, the authors have outlined the recent applications of RF power harvesting methods and techniques.

III. RF ENERGY HARVESTING TECHNIQUES

A. RF Energy Harvesting using Rectenna :

In this technique RF energy harvesting has done by converting EM waves to a useable DC voltage with the help of a special antenna that is rectifying antenna called rectenna. A simple system design comprises of one ore more combination of antennas, a band pass filter (BPF), impedance matching network, a rectifier and a low pass filter at the end of the output load. As an input to the system antenna is used for receiving the RF waves. To match the impedance of the antenna, an impedance matching network has been used at the rectifying circuit to transfer the maximum power of RF energy to the hardware of rectifier. In addition to this, between the rectifier and load a matching network has been used to avoid mismatching of impedance and a switch is used to limit the maximum power at the load. A brief discussion of rectanna is also done in the method used. State of the art rectennas is also explained in detail.

B. Single and five stage RF energy harvesting:

In this type RF energy harvesting is don with two different kinds of hardware. One is with a π type matching network and is of single stage. The other consists of voltage multiplier which is of multiple stages.

a. Single stage voltage doubler RF energy harvesting circuit with π type matching network : For a circuit to achieve maximum power, when the impedance of the circuit should match with the impedance of the antenna. Usually impedance matching will be done at the input power. Maximum power can be delivered with this impedance matching network. This design comprises of a π type matching circuit or network which is designed to operate at 915MHz and a 50Ω of input impedance also a 180kΩ load resistance. A comparison of bandwidth utilization gives that π type matching circuit requires higher and wider bandwidth than L type matching circuit. Therefore a π type matching circuit is used for all of the design to obtain a high output voltage with high voltage gain.

b. RF Energy harvesting circuit using 5 stage voltage multiplier: In the design of a five stage voltage multiplier, for RF energy harvesting schottky diodes are used namely HSMS 2860, HSMS 2852, HSMS 2850 and HSMS 2822. In the circuit design a capacitor at the load which will store and provides DC leveling of the output. A capacitor to charge to the peak value and a load resistor to discharge is used. Since the design contains 5 stages the output voltage which passes through the capacitor stage 1 will be double compared to input voltage. As there are 5 stages as the signal shifts from one stage to another, there is an increase in resistance in the discharge path of each stage across the diode and the capacitance is also increased due to the capacitors of each stage. Finally, due to the multiple stages of the design the results clearly show that the output is the multiplication of the input voltage of all the stages. A Comparison of output voltages for 1,7,10 and 5 stages harvesting circuit as been shown in figure 2. It clearly shows that as the number of stages increases, the output voltages also increases.

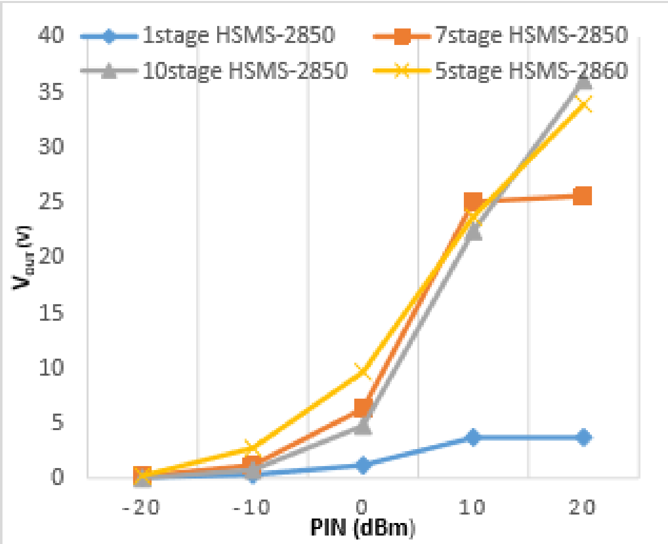

Figure 2: Comparison of Output voltages obtained for 1, 7, 10 and 5 stages of RF harvesting circuit by using diode HSMS-2850 and HSMS-2860

C. SURE Energy Harvesting:

This technique is developed from the previous work which is based on the fact that harvesting of ambient energy by User Equipments (UEs) received from Base Stations. The major problem of this previous work is that the received power will be too low to be harvested by user equipments the power from base stations is far away from UEs. So SURE algorithm is developed to overcome the above said issue by effectively using BSs and UEs which can heal the target user. Figure 3 gives details of SURE architecture comprising of all the components of the scheme.

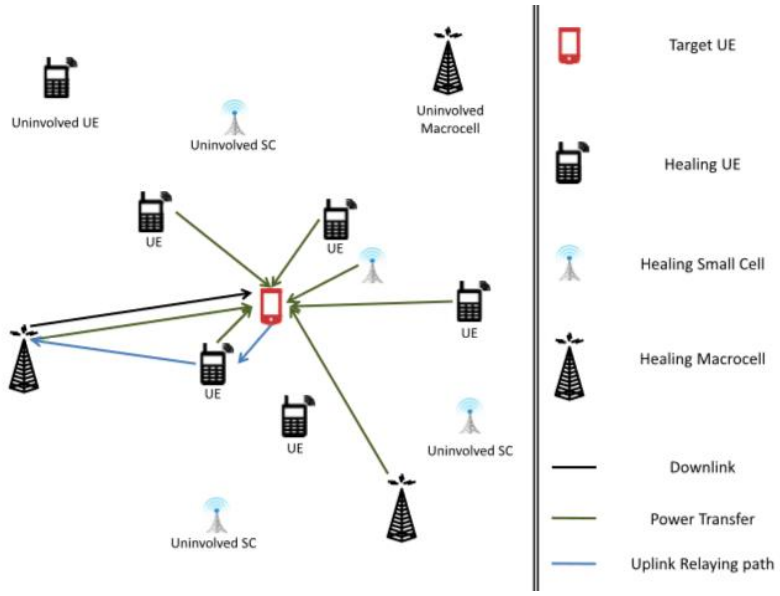

Figure 3: SURE Scheme Architecture

The operative UEs and BSs are the main components which decides theenergy harvested by SURE scheme. Figure 4 shows for different number os UEs and BSs the harvested energy by target UE's vs time.

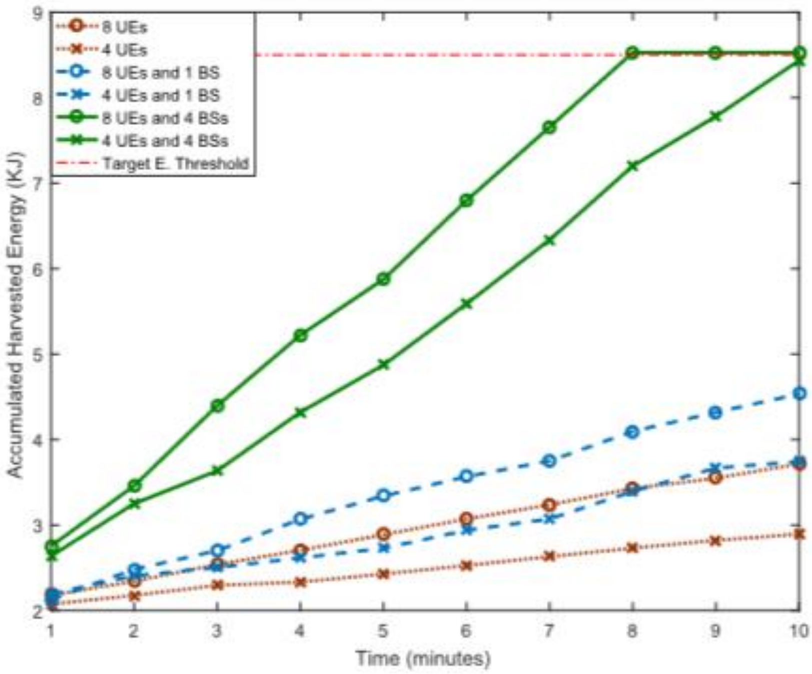

Figure 4: Energy Harvested for different number of UEs

IV. CHALLENGES FOR AMBIENT RF ENERGY HARVESTING

The main types of energy harvesting techniques have been discussed in the above section. However there are few challenges in the energy harvesting from ambient RF signals. The parameter 'energy' conflicts and faces trade offs between the other main parameters of the system, mainly input power, range, frequency, transmitter and reciever antenna gain. Another major challenge in rectenna based energy harvesting systems is the design of a robus rectifying antenna matching network. There is a requirement of broadband usage in impedance matching network and due to this for wider range of frequencies there will be a flat frequency response.

V. CONCLUSION

This paper gives a summary of RF power harvesting technologies developed in recent years. Since RF energy harvesting can be done for Sensor networks and Ad hoc networks, this technology can replace the urge requirement of batteries by any type of nodes in the near future networks. As discussed in all the sections of this paper, the basic RF energy harvesting system comprises of three main modules or blocks: the antenna, Impedance Matching Network, and finally a voltage multiplier. The integration of there modules will place an important role in the total efficiency of the system. The designs methods and operative principles of each and every module were also given importance in this paper.

Besides that there is a huge progress and accomplishment in the recent years, RF power harvesting technology needs further optimization in terms of many key factors such as increase in operation range, reduction of transmission loss, optimization of PCE, and minimization of system dimensions. Further, research on RF energy harvesting technology on harsh working environments is also attracting more attention to increase the capability of the system and network.

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