International Research Journal of Innovations in Engineering and Technology (IRJIET)

ISSN (online): 2581-3048

Volume 7, Special Issue of ICRTET-2023, pp 186-190, June-2023

International Conference of Recent Trends in Engineering & Technology (ICRTET-2023)

Analysis of Energy Harvesting for WSN in 5G

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***Abstract* - The Internet of Things (IoT) network used for gathering and efficient manage- ment of various information from wireless sensor network. As these sensor nodes are deployed at various remote region the energy source are more commonly battery, as per load of communication the nodes become dead node after drain out its energy. In such condition the replacing of battery is a crucial even impossible task. So to overcome such problems the Energy harvesting concept is used. The RF energy is harvested using large aperture power receiving antennae and this power is converted into DC power to recharge battery. Here a performance analysis of Energy Harvesting for IoT network namely packet loss and throughput is done by using discrete event simulator NS3. In this thesis numerical results are obtained for packet loss and throughput for various scenarios. The effect of variable energy arrival rate, number of nodes, variable packet arrival rate, mobility, on off application of nodes over packet loss and throughput of node is analysed.**

Keywords: IoT, WSN, 5G, Energy harvesting.

1. Introduction

Upcoming 5G Network are capable of connecting heterogeneous wireless and mobile system in each other as well as delivering Internet of Things (IoT) services along with device to device communication. The Internet of Things (IoT) networks widely used for gathering data from embedded sensors and controlling actuators in machines and similar physical objects. For implementation of IoT network Wireless Sensor Networks (WSNs), normally which are able to sensing, computing as well as wireless communication are well suited as per their special advantages such as wireless connectivity, lower energy consumption etc. and also widely used in many applications such as environmental monitoring, military surveillance, infrastructure and facility diagnosis and many other industry applications.

A special data gathering WSN are made up of large number of sensor nodes having battery as an energy source. These WSNs are used as a periodic monitor the area under coverage to detect any changes in parameters under observation and send the information to sink sensor node. Since the energy source of sensor node is battery powered, the energy consumption face scarcity and specially for the nodes deployed in unattended hostile area leads problem to convert that node to dead node [10]. Also, the same issue will crucial to prolong the network lifetime of WSN.

Introduction to Energy Harvesting

As energy consumption is exponentially increased as per communication distance according to energy consumption model, multi-hop communication is well suited to collect data with energy conservation. But due to this the nodes which are close to sink have burden to forward the data packets from other nodes, and these nodes lead to exhaust their own energy quickly as a result leading to an energy hole near the sink, causing the entire network will premature fail due to energy hole around sink [5].So energy efficient routing protocol can be use to avoid such energy hole sink [9].As this solution increases the node lifetime this is saved energy is not sufficient for further operations. However, the replacing of battery of dead node is a crucial part and sometimes impossible in harsh environment. In order to solve this problem Internet of Energy Harvesting Things (IoEHT) is proposed [1]. As there are various alternatives to collect energy and utilize as a secondary source or using super capacitor battery can be neglected but the presence of such energy depends on the environmental variables, ambient parameters, or another random external factors [1]. The ongoing power extraction limits affects the tradeoff between proper system operation and desired network lifetime. There are various energy harvesting techniques are available such as solar energy, artificial light, airflow, motion thermal, RF, etc. depending on the size, system complexity, energy availability, controllability, predictability one can choose better option for energy harvesting [1].

Electromagnetic Energy Harvesting Electromagnetic Energy Harvesting refers to collect radio frequency (RF) sig- nals from network routers, base stations, smartphones and other such devices by using large aperture power receiving antennae and utilizing such power of waves for further

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operations [12].Electromagnetic energy is available in environment due to large number of devices used by household, industry, and other applications. For low power network this energy is sufficient for its operation. Electromagnetic energy harvesting is predictable, availability is time independent, controllable if we use our own energy source within network area. Overall the electromagnetic energy harvesting is well suited for low power networks.

Energy Harvesting plays important role to predict network lifetime as well as to maintain the quality of service analysis of energy harvesting as well as energy consumption is important. Energy consumption can be minimize but it' s not a permanent solution hence energy harvesting came into existence. So we try to analyze the various parameters of IoT networks.

2. Energy Harvesting Methods

In order to achieve continuous monitoring and control, an auxiliary or even a completely distinct power source should be equipped to the sensors. However, even this option may or may not be applicable in some cases mostly due to size constraints or design restrictions. Hence, energy harvesting (EH) methods come into prominence to alleviate the problems of energy constrained wireless networks by exploiting a stray source or converting energy from one form to another [4].

There are numerous potential alternatives to collect energy, but their avail- ability depends on the environmental variables, ambient parameters, or other time- varying, and highly random external factors. The ongoing limits on the power extraction capabilities force wireless devices for an energy tradeoff between proper system operation and the desired network lifetime, whereby an upper bound is placed on the communication reliability. Due to this reason, hybrid energy scavenging approaches possess a great potential to extend the lifetime of wireless devices by operating in a complementary manner. A power supply fed by multiple available sources will eventually enhance the overall functionality, reliability, and efficiency of both the system and communication [1].

Energy harvesting (EH) enables sensor nodes to accumulate energy from sur- rounding resources such as high power line electromagnetic field [7] [8]. Energy may be harvested from various types of sources, such as solar and electromagnetic fields [1]. Through EH, batteries are recharged with the harvested external energy. Accordingly, integrating EH capacity with IoT networks empowers sensor devices to derive energy from renewable energy resources. Ideally energy is interminable in EH-enabled WSNs, but it can be harvested intermittently. Though its solution for avoiding replacing of battery, EH imposes many design challenges for IoT net- works [3].

3. Internet of Energy Harvesting Network

Efficient management and observation for Smart City concept can be perfectly realize using Internet of Things (IoT) [15]. And to achieve this large number of wireless devices are required. Replacing of such large number of batteries are tedious also even impossible. To overcome this problem, Internet of Energy Harvesting Things (IoEHT) is suggested by Ozgur

B. Akan [1]. Though the earlier study on IoEHT concentrate on energy harvesting (EH) as an alternate energy provisioning method, now self-sufficient and battery free systems are envisioned. Diverse sources of energy due to available concept of smart city give a way to appreciate capacity of EH [15].

RF Energy Harvesting

J.W. Matiko [16] reviews on the application of energy harvesting in commercial and residential building he proposed for available energy harvester and suitable energy harvester are discussed and potential energy is calculated. As due to large availability of radio frequency (RF) signals in surrounding the upcoming 5G technology and cellular network will be a room for IoT devices and supports integrating energy harvesting capabilities [16].Although the energy obtainable from RF harvest- ing is much lower compared with other sources, such as solar energy, the advantage is its anytime or anywhere availability (both indoor and outdoor, as well as day and night) [15].

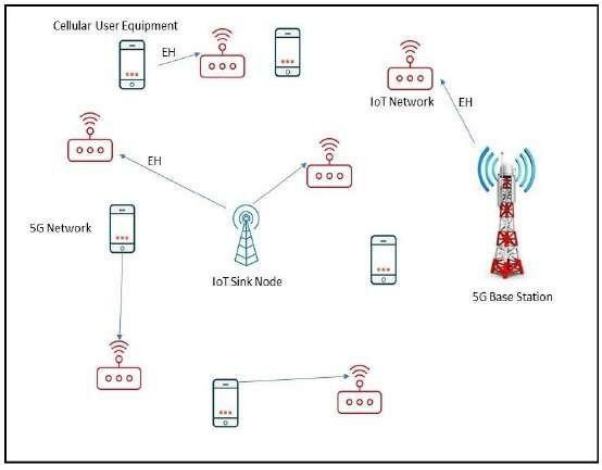

Figure 1: EH Enabled IoT Network

Figure 1 shows the network scenario for the Energy harvesting IoT Network. It includes;

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1) 5G Base station
2) Sink Node
3) Cellular user equipment
4) IoT sensor nodes

Basically IoT devices are surrounded by cellular user equipment as As well as 5G base station. Hence radio frequencies are available around IoT sensor nodes. So the Energy harvesting (EH) enabled sensor nodes harvest energy from available RF signals. EH enabled sensor nodes can harvest energy from sink node, cellular user equipment or 5G base station [2].

4. Assumptions for Simulation

1) All nodes contain rechargeable battery to store harvested energy.
2) Energy consumption is done using battery.
3) All nodes contain equal battery capacity and data packet queue.
4) Harvested power to all nodes will be assign periodically using uniform random variable.

An Overview of RF Energy Harvesting

In the envisaged IoT network, data packets arrive randomly to all nodes. At the same time, EH also occurs randomly based on the availability of energy sources. In order to transmit a packet, a sufficient amount of energy should be harvested by a node. As a consequence, even though there are packets available in the data queue of a node, those packets cannot be transmitted if there is not enough energy in the battery [14]. On the other hand, the EH process is independent of the packet arrival process. Once harvested, the stored energy can be used later when there is a packet arrival. In AEH [2], only those nodes that have at least one packet in the data queue and at the same time with sufficient amount of harvested energy behave as active nodes.

As illustrated in Figure 3.2, the active nodes compete for channel access [2]. A node which wins access competition transmits its packet (with or without collision) during the data period of that cycle. It goes to sleep right after finishing packet transmission. If a collision occurs, data exchange is not possible in the current cycle. The node will then try again in the next cycle. If there is no data or energy arrival to a node, then that node will not participate in access competition. However, it can check the status of its queue and battery in the next cycle and compete for channel access if both are available.

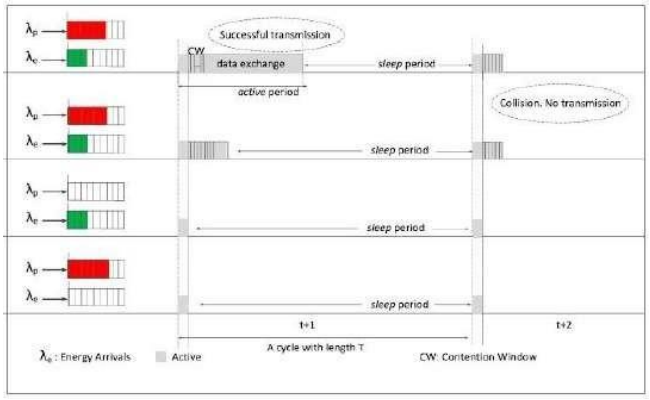

Figure 2: Channel Access for Transmission

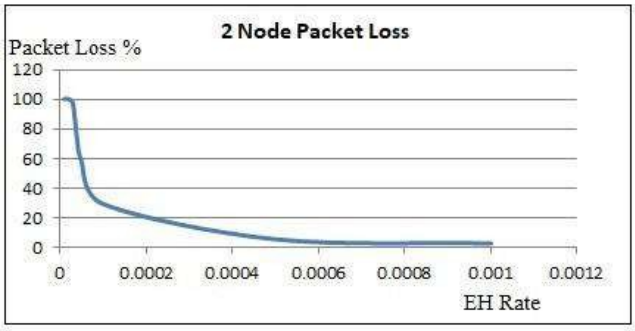

Figure 3: Packet Loss for 2 Nodes in Network

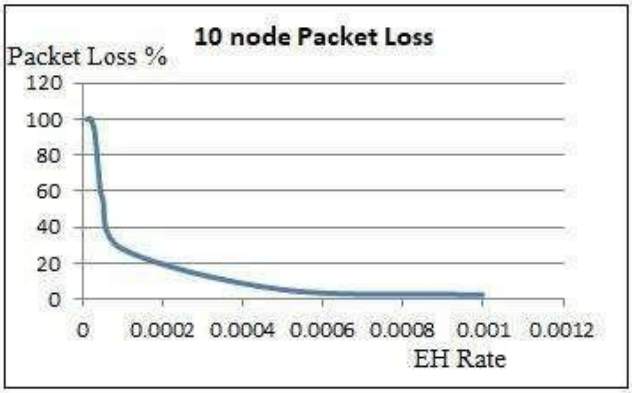

Figure 4: Packet Loss for 10 Nodes in Network

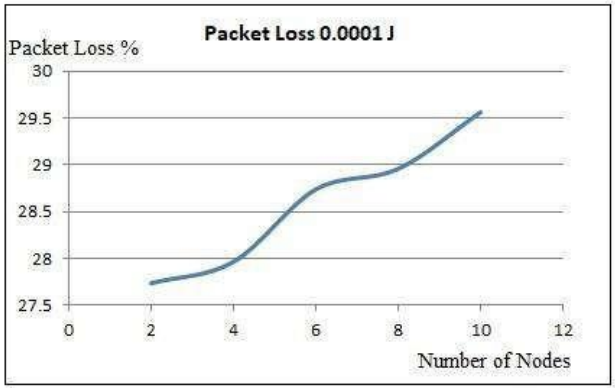

Figure 5: Packet Loss EH Rate 0.0001j in Network

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Volume 7, Special Issue of ICRTET-2023, pp 186-190, June-2023
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5. Conclusion

In this paper we have implemented Energy harvesting enabled IoT network, Energy harvesting for IoT network plays an important role to increase network lifetime. Depending on number of nodes, the packet loss get affected. When the energy harvesting rate is lower than the consumption rate then energy is drained soon and further communication stops till the sufficient energy is harvested. To maintain network in active state, sufficient energy should be harvested periodically. Number of nodes in network as well as mobility of nodes increases packet loss due to collision of packet in communication channel. Also periodically on off application of nodes saves the energy hence packet loss decreases above idea can be used for multiple energy sources for energy harvester to avoid dependency of a single energy source.

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ISSN (online): 2581-3048

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Citation of this Article:

Maske Ashish Mahadev, Dr. D.B. Salunke, Dr. Alok Agrawal, "Analysis of Energy Harvesting for WSN in 5G" in proceeding of International Conference of Recent Trends in Engineering & Technology ICRTET - 2023, Organized by SCOE, Sudumbare, Pune, India, Published in IRJIET, Volume 7, Special issue of ICRTET-2023, pp 186-190, June 2023.

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