NEW EFFICIENT ROUTING PROTOCOL FOR WIRELESS SENSOR NETWORKS IN PRECISION AGRICULTURE

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Abstract: Routing techniques in the WSN are different from the routing techniques used in the other wireless communication, because the architecture and the structure of the WSNs are different from that of any other network, and because WSNs can be applied in different types of application. Present research work has focused on deriving a better routing protocol for the precision agriculture applications. The work was carried out by using the technique of computer simulations and preparation of models of the WSN. Section 5 deals with design of solar panel. Section6 discusses the conclusion.

Keywords: WSN, Efficient Routing Protocols, Solar Panel, Precision Agriculture, Simulation Studies.

1. INTRODUCTION

Wireless Sensor Network was introduced by Defense Advanced Research Project Agency (DARPA) in the early 1980's [1]. It was called Distributed Sensor Networks (DSN) program where many low-cost sensing nodes were spatially distributed and they processed data collaboratively. These days powerful, smart and tiny sensor nodes are developed. The first miniature node was developed in the Wireless Self-Sustaining Sensor Network (WSSN) project [1] [2].

While designing WSN, one must consider following common design factors for WNS's such as reliability, scalability production costs, hardware constraints, network topology, operating environment, transmission and energy consumption [3].

WSN for precision agriculture broadly has scope in following areas:

- Sensor network for agriculture and water monitoring
- Provide data on local weather, soil moisture and water quality at high temporal resolution
- Develop automatic sensors and data services
- Develop agricultural applications and environmental monitoring
- Support new business initiatives
- Monitoring Local Temperature/ Humidity

But to work on the above points there are limitations and challenges for deployment on field ex. area, number of nodes, number of sensing parameters and interdependency. Energy requirement, energy efficient protocols for agricultural fields, sensor positioning, low cost model for real time adaptation, integration of cellular technology are the key challenges for employing WSN in Precision Agriculture [4].

Using wireless sensor networks in Precision Agriculture faces three challenges viz energy requirement, network availability and cost.

2. LITERATURE REVIEW

Routing techniques in the WSN are different from the routing techniques used in the other wireless communication, because the architecture and the structure of the WSNs are different from that of any other network, and because WSNs can be applied in different types of applications [5].

The main objective of the routing protocol in a WSN is preserving energy and reducing the power consumption rate. In other networks, the routing protocols are designed to achieve high Quality of Service (QoS) during data transferring [6].The architecture of wireless sensor nodes has many limitations such as a limited power supply, memory size, computation capability, and bandwidth of the wireless channels between the wireless sensors. WSN potentially contains a large number of sensor nodes, which may even sometimes reach thousands. Consequently, using global identification addresses to access each individual node may not be possible.

Recent Approaches

Andreas Decker [7], has discussed different solar cell materials and energy storage solutions are discussed and evaluated. He has estimated that for a continuous power consumption of an autonomous field device of 1 mW for a period of 10 years, a solar panel of 4 × 4 cm^2 in the outdoor case can deliver the required energy.

Hussein Mohammed Salman [8] has surveyed afresh the routing strategies for WSN. Various protocols are presented in this paper and further classified into many categories. This is done depending on set of metrics like infrastructure, functionalities, level of privacy and security or the application used. This paper studies the availability and the reliability of each class of these routing protocols and the energy consumption of each protocol. Depending on these criteria, this study can be used for improving the protocols and used them in another types of networks as well.

D. Antony Arul Raj et al [9], have suggested various research methodologies were proposed by researchers the area to reduce the energy consumption over the WSN. In this paper, computing paradigm which was a one bio-inspired and named Cuckoo Search Algorithm is used in research work. This was done for determining which path is the most energy efficient path and only then the routing action is performed.

Sridevi S. et al [10], have presented a review on the existing routing protocols for WSN by considering energy efficiency and QoS. They have focused on the main motivation behind the development of each protocol and explain the function of various protocols in detail. Protocols are compared based on energy efficiency and QoS metrics.

Songtao Guo et al [11] presented a framework of joint Wireless Energy Replenishment and anchor-point based Mobile Data Gathering (WerMDG) in WSNs by considering various sources of energy consumption and time-varying nature of energy replenishment is proposed.

Imad S. et al [12] [13] have proposed a new routing method for WSNs to extend network lifetime using a combination of a fuzzy approach and an A-star algorithm.

Jie Hao et al [14] have presented sleep scheduling brings great challenges to the design of efficient distributed routing protocols for multi-hop duty-cycled WSNs. This issue has attracted much attention and various routing protocols have been proposed. A survey of state-of-the-art routing protocols in this area is presented. The paper is organized as follows. Section 3 discusses the challenges, section 4 proposes new protocol and the results thereof.

3. CHALLENGES

WSN has evolved rapidly with applications in many areas. Possible applications of WSN are limitless. Innovators can think of different ideas and implement it to develop it as a new application area.

Precision-agriculture is an attempt to introduce the use of WSN for agriculture. While improve the production of the agriculture together with the quality. Using wireless sensor networks in Precision Agriculture faces three challenges viz. energy requirements, network availability and cost. Thus there is need to understand the challenges on the field. After identifying the challenges and to we narrow our research to develop the efficient routing protocols. Use of solar for the identified sensors will help to achieve energy source.

The problems identified can be stated as follows.

1. There is a need to make the protocols more energy efficient for the targeted wireless sensor network. There is a need to optimize the energy utilization optimally. No attempts were yet made to minimize the payload.

2. There are no attempts made to try exploring solar energy for improving the lifetimes of the network.

3. There is a need to develop the concise model for the optimized energy aware routing protocol.

These problems can be tackled using the following strategies.

1. The energy efficiency may be improved by introducing passive redundancy for the nodes.
2. The frequency of transmission of the message packets may be optimally controlled. The unused bits in the packet may be used for sending control messages or even the messages. This will reduce the payload.

Present research work has focused on deriving a better routing protocol for the precision agriculture applications. The work was carried out by using the technique of computer simulations and preparation of models of the WSN. Section 5 deals with design of solar panel. Section6 discusses the conclusion.

4. PROTOCOLS

The new protocol has 4 different sub parts discussed as follows. The Protocol-1 is suggested which is concerned with distributing the power consumption by balancing the assigned task to each node and distributing the responsibility of routing among the wireless sensor nodes.

This new energy aware routing protocol will have following features:

1. A passive redundancy is introduced. Instead of using just 21 nodes in the system, we scatter 42 nodes in the area under study. Out of these 42, we ensure that only half of them are active at a time. The energy of the nodes will decide, whether the node will remain active or inactive at that instant of time.

2. Two threshold levels viz. upper and lower thresholds are defined for the nodes. The energy levels of the nodes vis-à-vis threshold will be used to switch the node from active to passive state and vice-versa.
3. It is assumed that the active 21 nodes at any instant can cover the entire area of WSN. If any of the nodes goes inactive /dies, then the neighbouring node will take over the functioning of the previously active node.

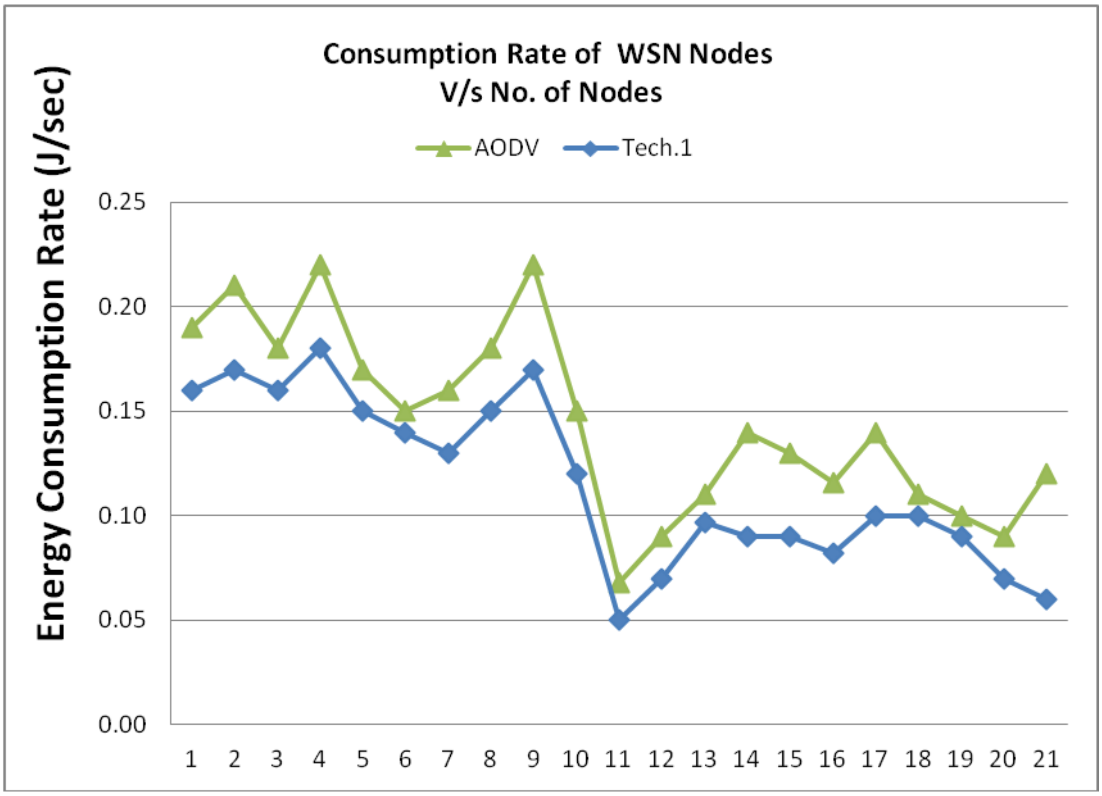


Figure 4.1 Energy consumption in the WSN nodes for Protocol-1

As shown in Figure 4.1, the energy consumption rates have been reduced for most of the sensor nodes. The average of energy consumption rate of the new Protocol is 0.116 joules per second, which is less than the average of the energy consumption rate of the original AODV routing protocol, which is 0.145 joules per second. We can observe that this routing protocol has about 20% less average energy consumption rate for its sensor nodes.

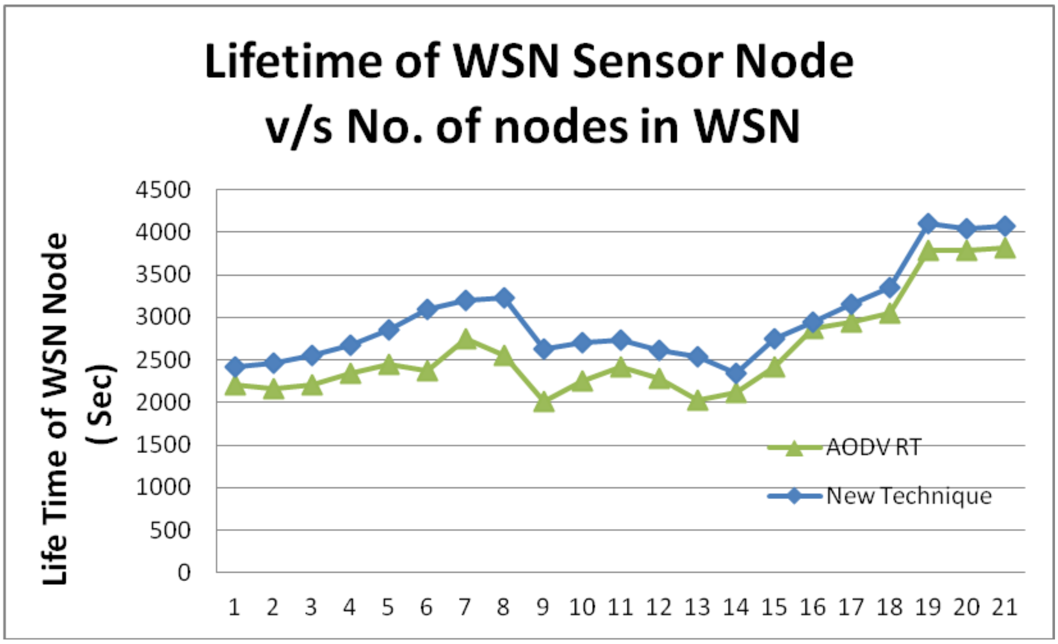


Figure 4.2 Lifetime of WSN sensor nodes v/s No. of nodes for Protocol-1

The result of the simulation of the lifetime of' the sensor nodes based on the original AODV routing protocol and the estimated power Consumption of the proposed new Protocol-1 are shown. While the lifetime of the whole network based on AODV routing protocol with the new proposed Protocol-1 for 21 nodes was around 4080seconds. This means that the lifetime of the network has been increased by around 270 seconds this is by about 7.1 %.

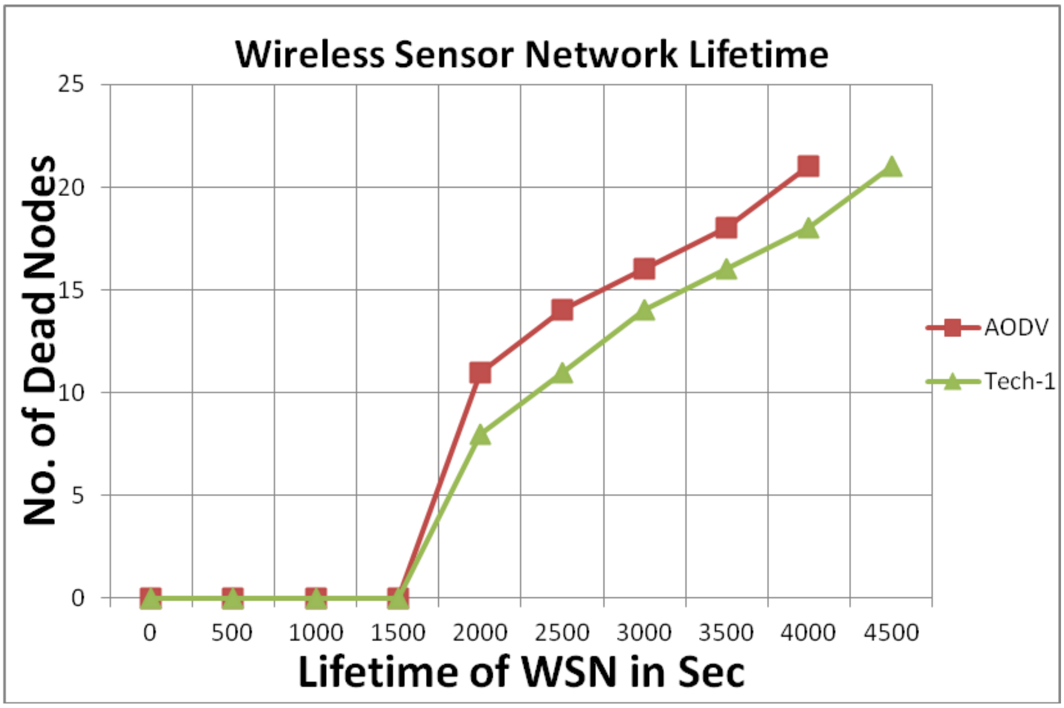


Figure 4.3 Overall Lifetime of WSN v/s No. of dead nodes for Protocol-1

The result of the simulation for the overall lifetime of' the whole network based on the original AODV routing protocol and the estimated power Consumption of the proposed Protocol-1 is plotted in the Figure 4.3. The overall lifetime of the whole network in the original AODV routing protocol was around 4000 seconds, while with the new proposed Protocol-1 for 21 nodes was around 4500seconds. This means that the overall lifetime of the network has been increased by 500 sec.

Protocol-2

In order to maximize the lifetime of the WSN, the new Protocol-2 modifies the MAC protocol to the tailor-made which is now specific to the particular network. Those unused bits in the IEEE 802.15.4 protocol are utilized for the purpose of sending the raw data to the controller. This Protocol ensures that pay load (data bytes from the sensor) is carried by this ***modified MAC protocol***. Thus we can reduce the pay load on the MAC protocol to zero. Bytes other than the first are used to send the raw data about the various sensor parameters present in the system. Following are the physical parameters associated with precision agriculture like soil moisture, soil temperature, water level, visibility, air temperature, air pressure, wind direction, image etc. The control packets are piggybacked on the data packets which reduce the number of packets to be transmitted. This further improves the efficiency.

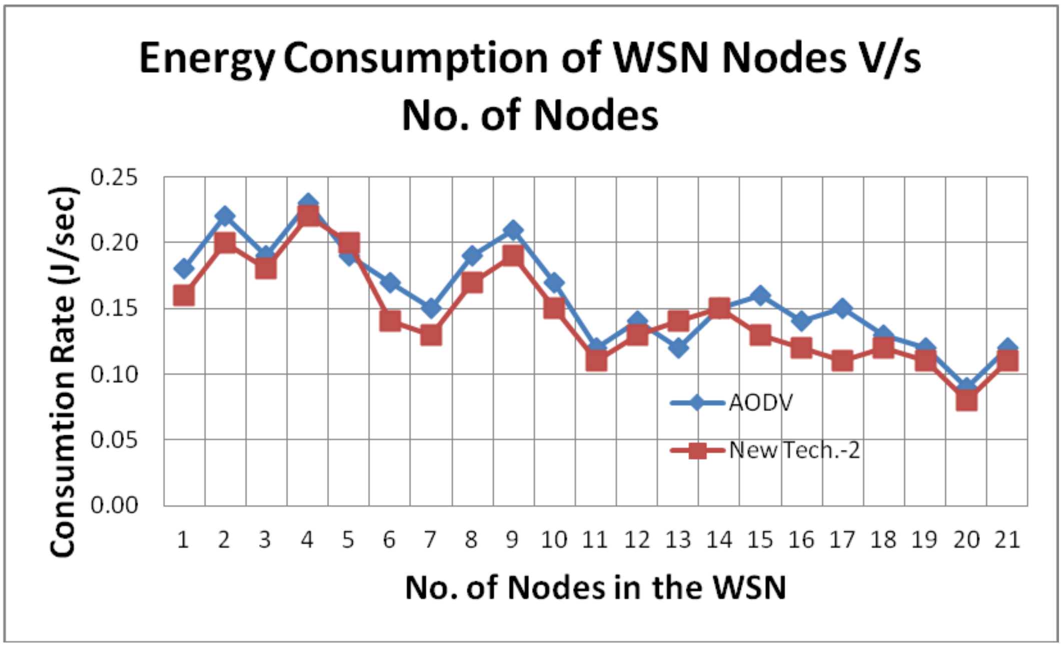
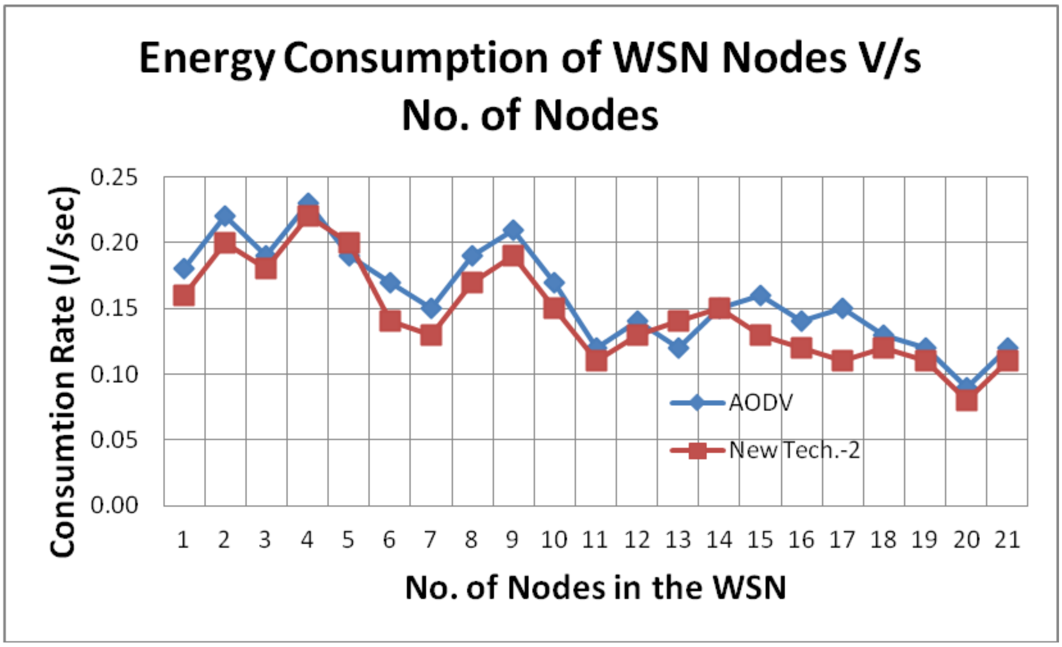


Figure 4.4 Energy consumption in WSN nodes for Protocol-2



In the simulation, three performance values are estimated in the comparison between the AODV and the new Protocol-2. These values are the energy consumption rate of the wireless sensor nodes, the lifetime of the nodes, and the overall lifetime of the whole network. The evaluation performance of these protocols has been carried out under the same traffic source, network loads, parameters, simulation environment and the same conditions.

Results related to the energy consumption rate of the nodes in the network shows the difference of the energy consumption rate of each wireless sensor node between the original AODV and the new Protocol-2. As shown in Figure 4.4, the energy consumption rates have been reduced for most of the sensor nodes. The average of energy consumption rate of the new Protocol is 0.145 joules per second, which is less than the average of the energy consumption rate of the original AODV routing protocol, which is 0.159 joules per second. We can observe that this new routing protocol-3 has about 8.8% less average energy consumption rate for its sensor nodes.

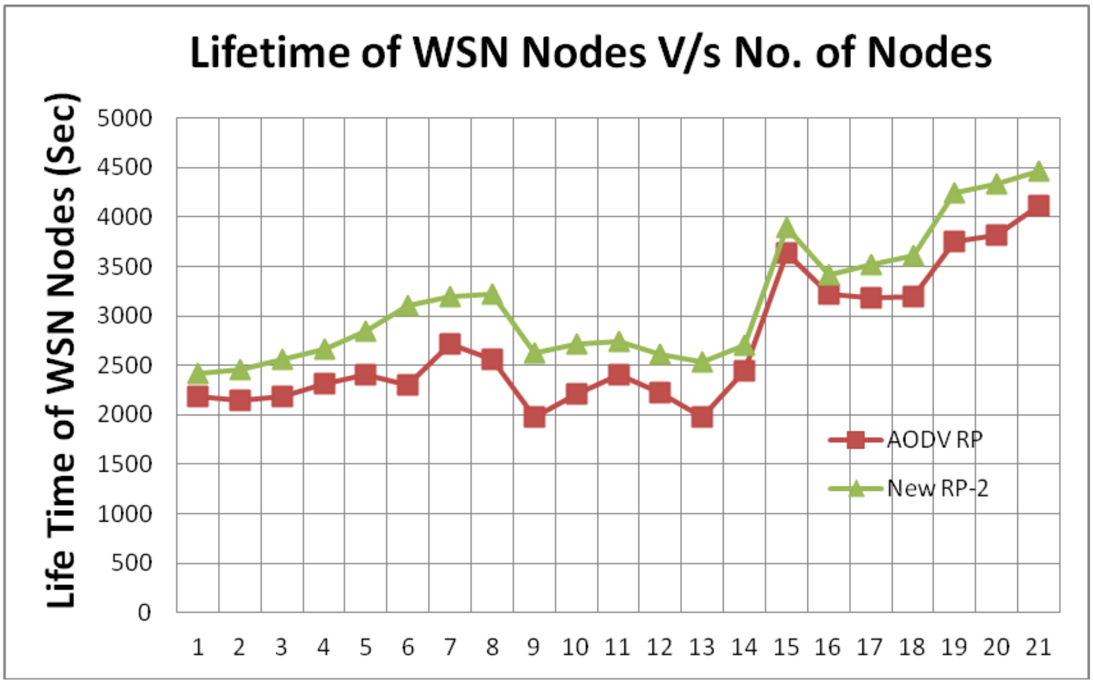


Figure 4.5 Lifetime of WSN sensor nodes v/s No. of nodes for Protocol-2

The result of the simulation of the lifetime of' the sensor nodes based on the original AODV routing protocol and the estimated power Consumption of the proposed Protocol-2 are tabulated in Table 4.5 and the same is plotted in figure 4.5. The lifetime of the whole network in the original AODV routing protocol was around 2713 seconds, while the lifetime of the whole network based on AODV routing protocol with the new proposed Protocol-2 for 21 nodes was around 3138seconds. This means that the lifetime of the network has been increased by around 270 seconds this is by about 15.7 %.

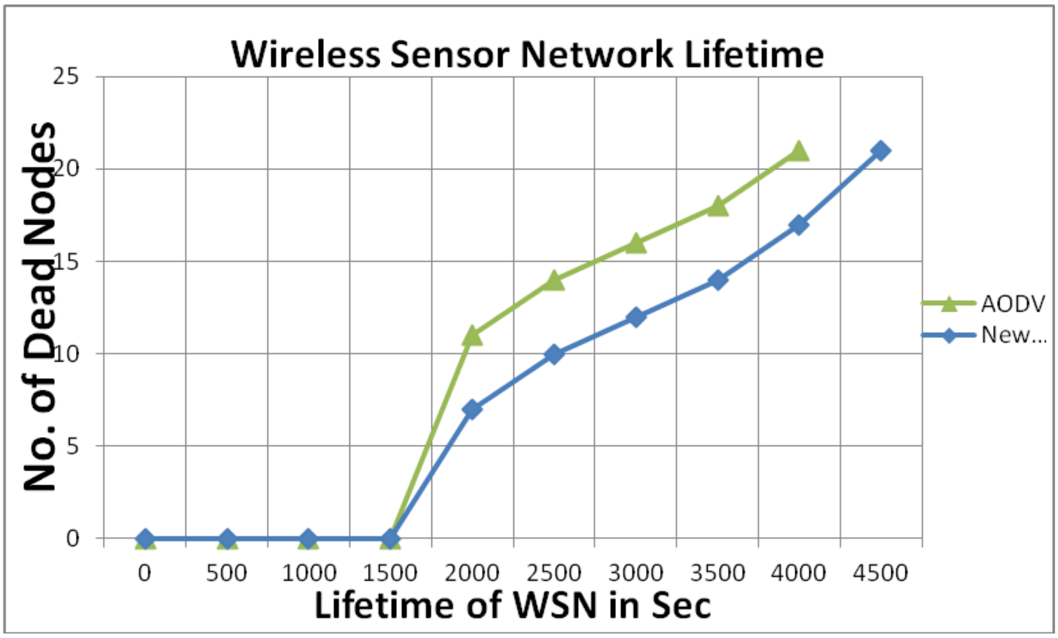


Figure 4.6 Overall lifetime of WSN v/s No. of dead nodes forProtocol-2

The result of the simulation for the overall lifetime of' the whole network based on the original AODV routing protocol and the estimated power Consumption of the proposed Protocol-2 are plotted in the Figure 4.6. The overall lifetime of the whole network in the original AODV routing protocol was around 4000 seconds, while the lifetime of the whole network based on AODV routing protocol with the new proposed Protocol-2 for 21 nodes was around 4500seconds. This means that the overall lifetime of the network has improved.

New Protocol-3

We can maximize the lifetime of the WSN by complementing the batteries in the nodes by the tiny solar panels whose size is computed separately. The proposed Protocol-3 modifies the hardware of the node circuit so as to add yet another energy source to boost the network life.

This approach does not help reduce the power consumption of the batteries in the nodes, but will provide continuous charging to the batteries in presence of sunlight. Since the application chosen for the present work happens to be precision agriculture, we expect it to be used in the outdoors, where there is abundant sunlight. This can play important role in the increasing lifetime which is the goal of the WSN designer. The suggested model for incorporating solar cell is shown in Figure 4.7.

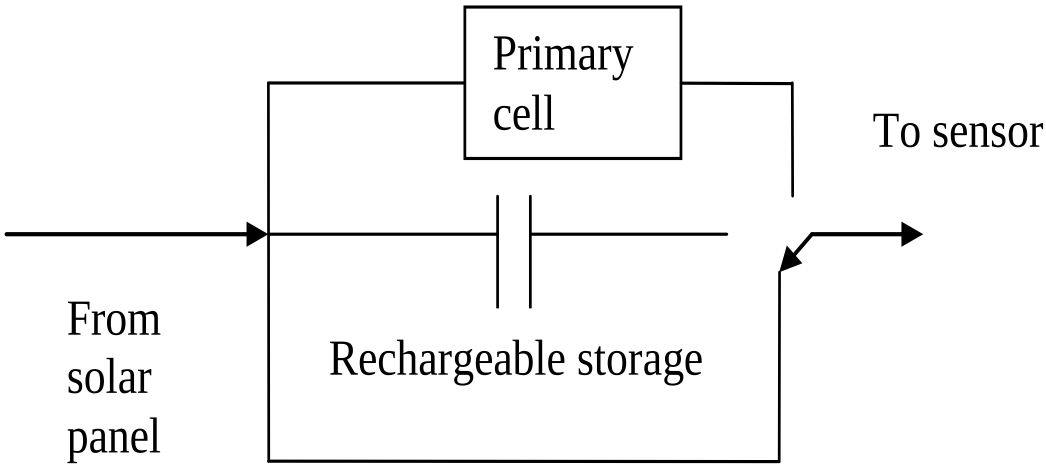


Figure 4.7 Suggested model for enhancing battery life of WSN nodes

The simulation model consists of 21 wireless sensor nodes in a square area of size 80X80 meters with Two Ray Ground as the radio model and Omni-Antenna as antenna model. The distance between any two neighbour nodes is 10 meters. The range of the wireless signal transmission is 16 meters. Table 4.7 lists the parameter values for the simulation model.

Table 4.7 Simulation parameter values

Parameter Name	Parameter value
InitEng	4.0 Joules
rxPower	1.0 Watts
txPower	1.0 Watts
Packet size	80 Bytes
Packet interval	15 milliseconds
Simulation time	50 Seconds
Number of nodes	21
Antenna type	Omni Antenna
Radio model	Two Ray Ground
Grid size	80x80 meter
Routing protocol	AODV
MAC protocol	MAC 802.15.4

Results related to the energy consumption rate of the nodes in the network are shown in Table 4.8, which shows the difference of the energy consumption rate of each wireless sensor node between the original AODV, and the new protocol-3.

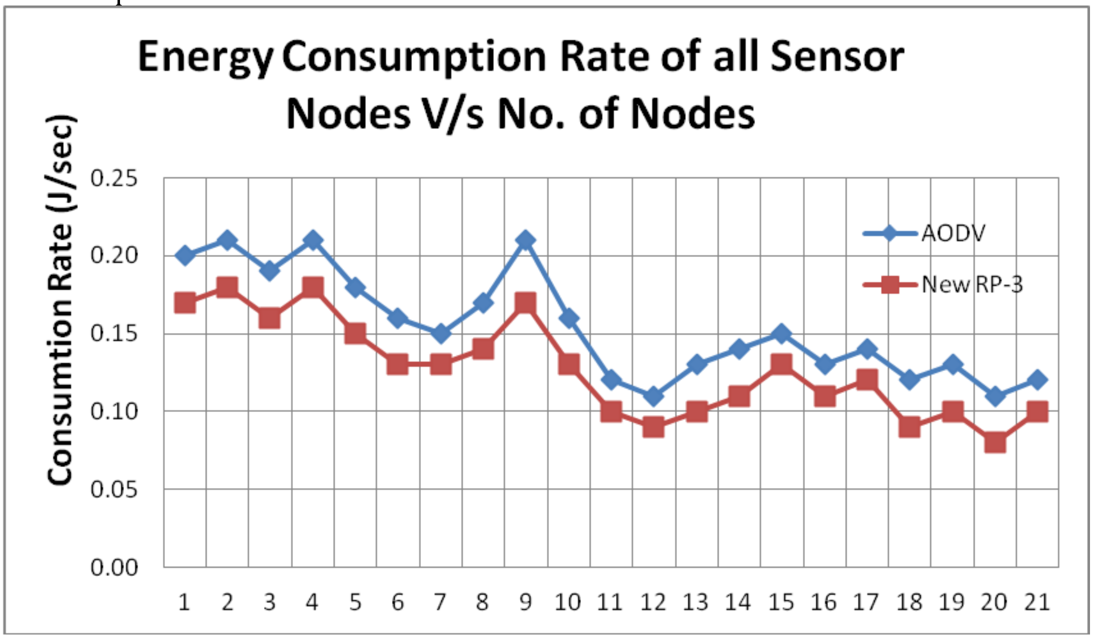


Figure 4.8 Energy consumption in WSN nodes for Protocol-3

As shown in Figure 4.8 the same results are plotted and it can be observed that the energy consumption rates have been reduced for most of the sensor nodes. The average of energy consumption rate of the new Protocol-3 is 0.127 joules per second. It can be observed that new protocol has 17.5% reduction in the average energy consumption.

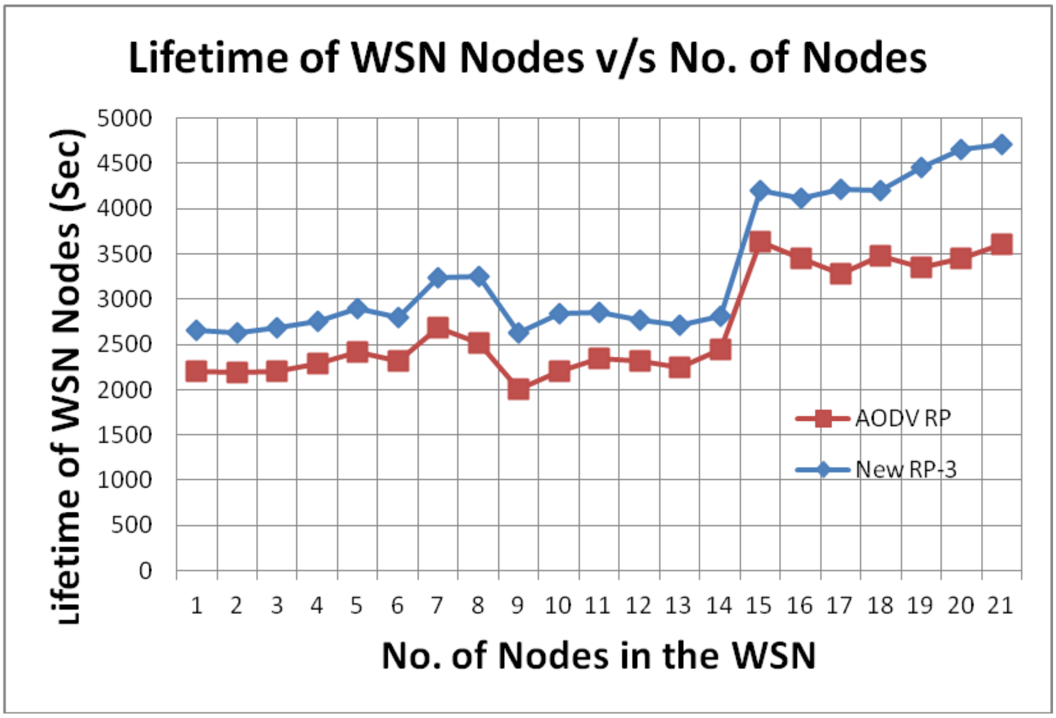


Figure 4.9 Lifetime of WSN sensor nodes v/s No. of nodes for Protocol-3

The results of the simulation of the lifetime of' the sensor nodes based on the original AODV routing protocol and the estimated power Consumption of the proposed Protocol-3 are tabulated in Table 4.9 and the same are also shown in figure 4.9. The lifetime of the whole network in the original AODV routing protocol was around 3610 seconds, while the lifetime of the whole network based on AODV routing protocol with the new proposed Protocol-3 for 21 nodes was around 4690seconds. This means that the lifetime of the network has been increased by about 29.9%.

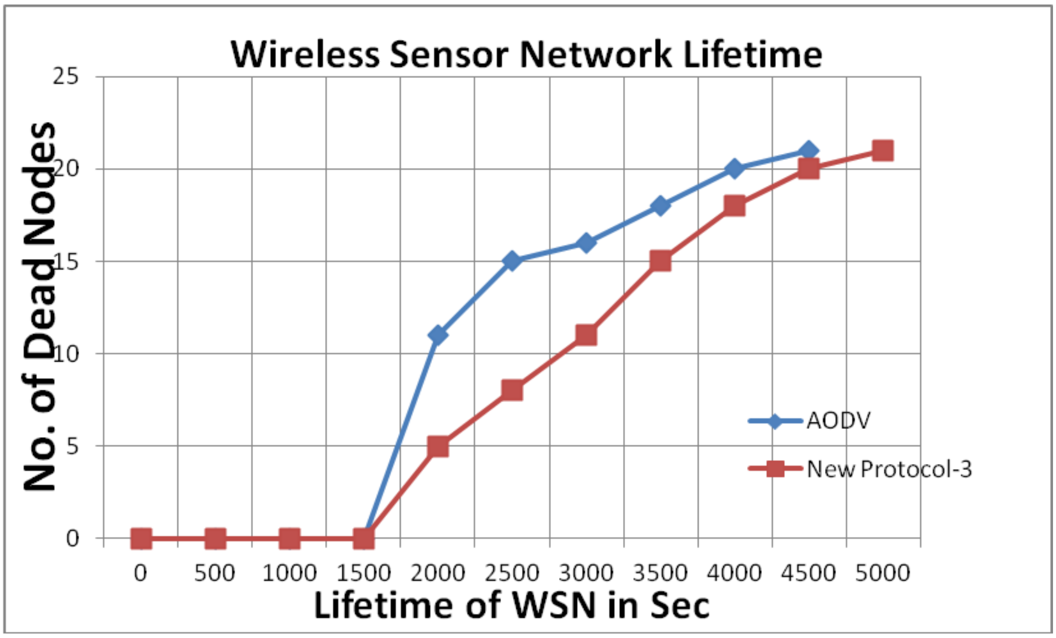


Figure 4.10 Overall lifetime of WSN v/s No. of dead nodes for Protocol-3

The result of the simulation for the overall lifetime of' the whole network based on the original AODV routing protocol and the estimated power Consumption of the proposed Protocol-3 are tabulated in Table 4.10 and same is plotted in the Figure 4.10. The overall lifetime of the whole network in the original AODV routing protocol was around 4500 seconds, while the lifetime of the whole network based on AODV routing protocol with the new proposed Protocol-3 for 21 nodes was around 5000seconds. This means that the overall lifetime of the network has been certainly improved.

New Protocol-4

In this method we have trying mixing and using all the three Protocols to maximize the lifetime of the WSN which are separately discussed above. The proposed Protocol modifies the hardware of the node circuit, changes the structure of MAC protocol as well as uses redundancy Protocol so as to make important boost in the network life.

The time between the two transmissions is controlled by the central computer (coordinator). This controller will compare the current parameter values with the previous ones and if the values differ by a margin less than the threshold the controller will ask the node to transmit the next values say after 1 hour instead of 0.5 hour before.

But if the values differ by a margin significant more than the threshold the controller will ask the node to transmit the next values say after 0.25 hour instead of 0.50 hour before. This will be conveyed to the sensor node by the controller.

The controller will hold the overall information map of the status of all the active and inactive nodes available in the system. This can be used by the user to understand if there is any critical need to replace or add more nodes in the existing WSN. All these efforts ensure longer uptime of the WSN.

Results related to the energy consumption rate of the nodes in the network are shown in Table 4.11, which shows the difference of the energy consumption rate of each wireless sensor node between the original AODV and the new protocol-4.

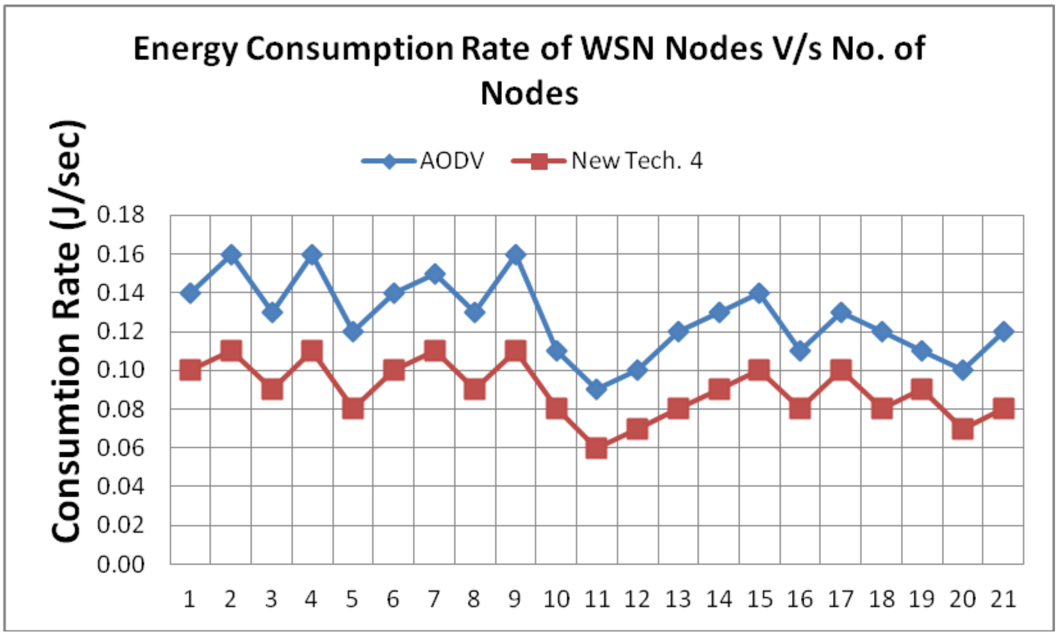


Figure 4.11 Energy consumption in WSN nodes for Protocol-4

The results of the simulation of the energy consumption rates sensor nodes based on the original AODV routing protocol and the estimated power Consumption of the proposed Protocol-4 are tabulated in Table 4.11 and the same results are also shown in figure 4.11. The average of energy consumption rate of the new Protocol is 0.090 joules per second, which is less than the average of the energy consumption rate of the original AODV routing protocol, which is 0.127 joules per second. Protocol 4 has 29.1% reduction in the average energy consumption.

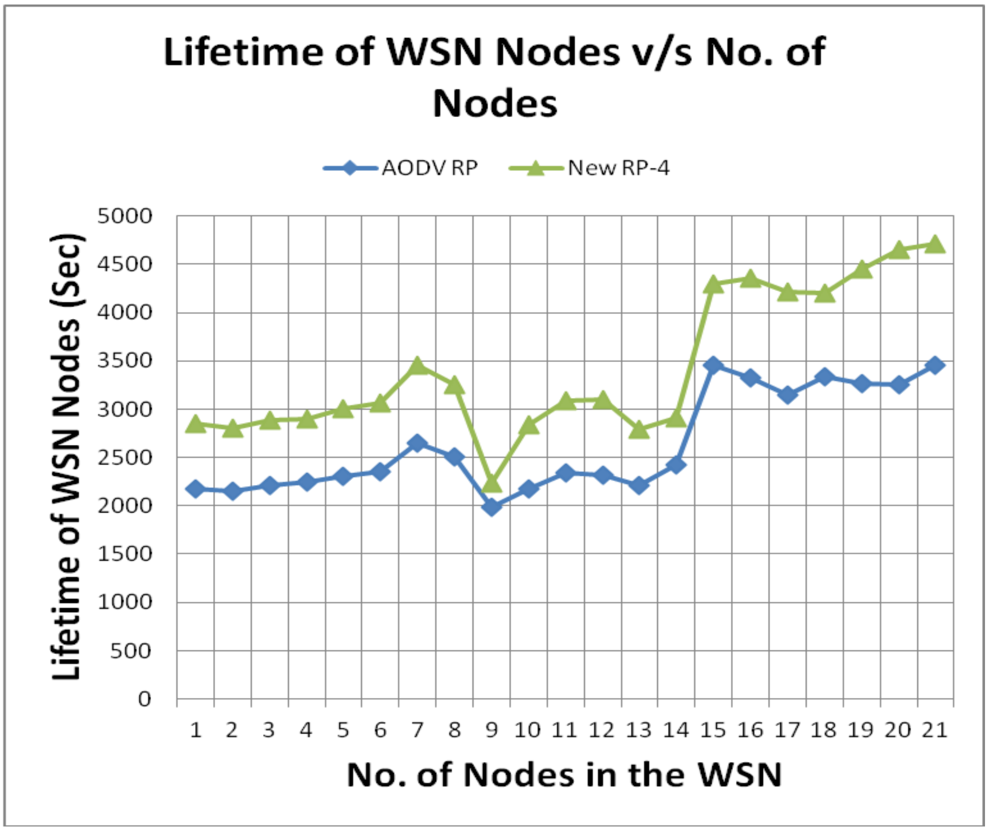


Figure 4.12 Lifetime of WSN sensor nodes v/s No. of nodes for Protocol-4

The results of the simulation of the lifetime of' the sensor nodes based on the original AODV routing protocol and the estimated power Consumption of the proposed Protocol-4 are tabulated in Table 4.12 and the same results are also shown in figure 4.12. The lifetime of the whole network based on AODV routing protocol with the new proposed Protocol-3 for 21 nodes was around 4710seconds. The lifetime of the network has been increased by about 36.5%.

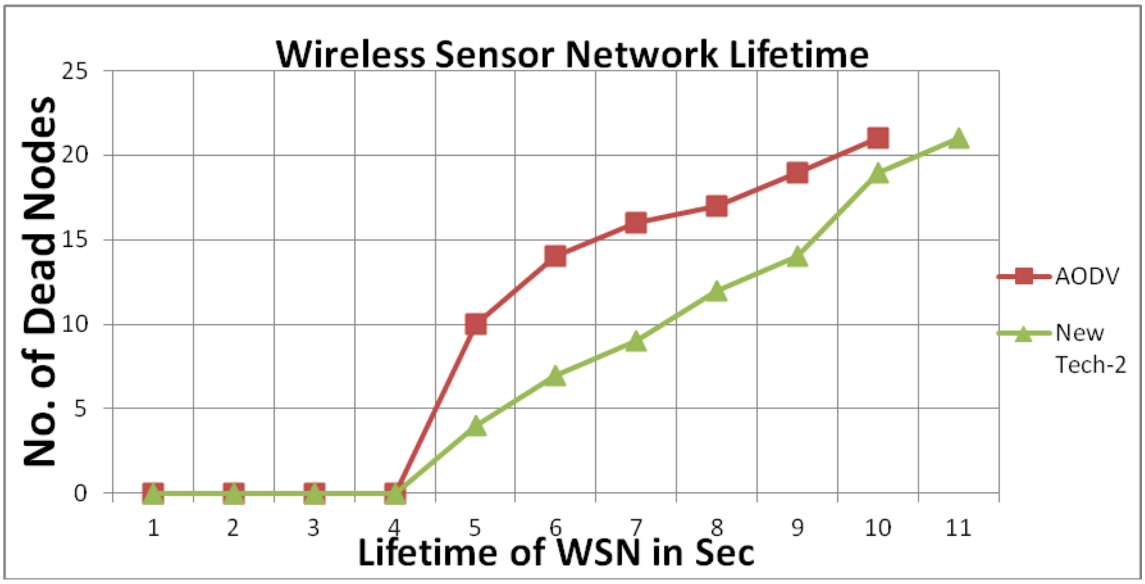


Figure 4.13 Overall lifetime of WSN v/s No. of dead nodes forProtocol-4

The result of the simulation for the overall lifetime of' the whole network based on the original AODV routing protocol and the estimated power Consumption of the proposed Protocol-4 are tabulated in Table 4.13 and same is plotted in the Figure 4.13. The overall lifetime of the whole network in the original AODV routing protocol was around 4500 seconds, while the lifetime of the whole network based on AODV routing protocol with the new proposed Protocol-4 for 21 nodes was around 5000seconds. This means that the overall lifetime of the network has been certainly improved.

5. SOLAR PANEL

For indoor use, this means that the rechargeable energy storage is used only occasionally. Since the solar panel is thought to provide power continuously, its size can be directly fitted to the powering needs, and extra energy for storage does not have to be taken into account as it can be charged when more light is available. Once the rechargeable storage is fully depleted, the primary cell can take over.

For the outdoor use case, the solar panel is thought to power the field device directly during the day and charge the rechargeable energy storage device at the same time, which then in turn can power the WSN nodes during the night time.

Sizing of Solar Cell Panels

The area of the solar cell panel A, which is needed to provide the electrical power P_{el} can be calculated as follows

$$\mathbf{A} = \frac{Pel}{Popt} x \frac{\mathbf{1}}{\eta pv} \qquad (1)$$

Here, P_{opt} is the incident optical power density and η_{PV} is the efficiency of the solar panel. To transform this ideal case into a realistic one this basic equation has to factor with many parameters.

Taking all these variables into account above equation expands to

$$\mathbf{A} = \frac{Pel}{Popt * (\mathbf{1} - L)} * \frac{(\mathbf{1} + \mathbf{S})}{\boldsymbol{\eta}\mathbf{pv} * \boldsymbol{\eta}\mathbf{age} * \boldsymbol{\eta}\mathbf{DC} - \mathbf{DC}} * \frac{\mathbf{1}}{\mathbf{w}} \qquad (5.2a)$$

for indoor use and

$$\mathbf{A} = \frac{Pel}{Popt * (1 - L)} * \frac{(\mathbf{1} + \mathbf{S})}{\mathbf{\eta pv} * \mathbf{\eta age} * \mathbf{\eta DC - DC}} * \left(\frac{\mathbf{24 - t}}{\mathbf{day}} + \frac{\mathbf{t}}{\mathbf{day}} * \frac{\mathbf{1}}{\mathbf{\eta PM}} \right)$$

(5.2b)for outdoor use

Determining capacity of Storage Device

Rechargeable batteries show different behaviour based on the depth of discharge (DoD) to which they are discharged. Taking into account all these variables together, the capacity of the storage device can be calculated as

$$\mathbf{C} = \frac{Pel * t * (\mathbf{1} + B)}{\mathbf{\eta} s * \mathbf{\eta} DC - DC * (\mathbf{1} - sdc * t) * \mathbf{\eta} deg} * \frac{\mathbf{1}}{\mathbf{U * DoD}} \quad (5.5a)$$

For rechargeable battery

$$\mathbf{C} = \frac{Pel * t * (\mathbf{1} + B)}{\mathbf{\eta} s * \mathbf{\eta} DC - DC * (\mathbf{1} - sdc * t) * \mathbf{\eta} deg} * \frac{\mathbf{2}}{\mathbf{U0 * U1}} \quad (5.5b)$$

For super-capacitor, capattery

where, U0 is the nominal voltage of the super-capacitor and U1 is the voltage up to which it is depleted.

The investigation of different solar cell materials lead to the conclusion that for the outdoor use case pc-Si solar cell panels would be of suitable. The calculated solar panel parameters seem acceptable and comply with the commercially available panels in the market. In the outdoor-use case, solar panel of the area of about 2.5 × 2.5 cm^2 would provide sufficient energy for the WSN nodes.

6. CONCLUSION

Following conclusions can be drawn from the study and experimentation work carried out during the course of research.
Based on the simulation results, the following conclusions can be drawn.

The New energy efficient protocol improves the lifetime of the WSN network to 4710 seconds because of passive redundancy provided for the nodes. Protocol 4 has 29.1% reduction in the average energy consumption.The suggestion of using tiny solar panels for the recharging of node battery,the suggested use of unused bits to further reduce the number of packets and distributing the role of routing among the wireless sensor nodes and making them participate in the communication process can increase the lifetime of these nodes, help increase the lifetime of the whole network. The controller holds the overall information map of the status of all the active and inactive nodes available in the system. This can be used by the user to check if there is any critical need to replace or add more nodes in the existing WSN

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