**CHAPTER VII**

**SENSOR NODE’S RESIDUAL ENERGY CALCULATION**

**B.S.DEEPAPRIYA1, G.SARAVANAN2**

1Assistant Professor, Department of Artificial Intelligence and Data Science, Erode Sengunthar Engineering College, Erode, Tamilnadu, India, 638057

2Associate Professor, Department of Artificial Intelligence and Data Science, Erode Sengunthar Engineering College, Erode, ,Tamilnadu, India, 638057

*1Correspondingauthor:E-mail:*deepapratheeb@gmail.com

**ABSTRACT**

One of the widely opened research area in wireless sensor networks still is the management of power. Management of power consumption is a non-trivial task directly from node architecture of low level to high level protocols of communication. To determine the energy consumption characteristic of a sensor node a particular model has to be considered. This model should focus on the architecture of sensor networks at node level and is very effective to determine the energy consumption characteristic of nodes of the network. Yet, it cannot serve as a platform to address problems like energy reporting, which aids in the replacement of depleted nodes. Building an energy distribution map is one technique to raise knowledge of the performance of the network's energy consumption. The difficulty, however, is in compiling a useful energy map without adding a substantial amount of network overhead. The remaining energy within the nodes of the sensor network after the entire routing process is completed is called residual energy of the networks.

**7.1 INTRODUCTION**

In a sensor network the level of energy in its nodes represents the energy model. This model has an early value of energy for nodes which is the level of energy the node has at the initial stage of simulation. This energy is called as the Initial Energy. The term “energy” is called as the simulation variable which represents the level of energy at any time specified. This value is passed as an input argument as any node initial energy. For every packet transmission and reception the nodes energy gets decreased by a particular amount and because of this the initial energy value of a node gets decreased. Moreover the residual energy is the current value of energy in a particular node after transmission and reception of routing packets. UDP agent and CBR traffic establishes data transmission between nodes. An internal variable in the process called "energy". Energy assesses a node's remaining energy at various time intervals. Furthermore, choosing a mechanism that enables a node to utilise its available energy efficiently is a basic challenge in constructing wireless sensor networks. A cluster head known as a monitoring node efficiently keeps track of each node's residual energy data. The network's SMAC protocol reduces the amount of time that passes between different frame transfers. As a result, listening caused by inactivity decreases. The time it takes to deliver SYNC messages when a frame begins transmission for synchronization is decreased by using the ASMAC protocol. Combining S-MAC with ASMAC improves network traffic. This mechanism determines the conclusion of the active period. The duty cycle adaptability thus reduces fluctuation in network traffic in terms of two properties such as time and space. This property helps in producing long sleeping time and improves the residual energy of the network. So the above protocols are sufficient for retaining residual energy of the network [2].

**7.1.1Residual Energy Concept**

To forecast the energy consumption rate, a Residual Energy Assessment method is used in the network. The performance of this model is measured based on the energy consumed by the process of transmission and reception of the number of packets send to the monitoring node by the other nodes at the lower level. Here an assumption is made that all the nodes are connected by means of a monitoring node. Also it is assumed that there is no change in the scalability of the network even if any numbers of nodes are added and connected with the monitoring node.

When energy consumption during packet transmission and reception is determined at the time of simulation, the calculation of each node's remaining energy in the monitoring node is more precise. Additionally, this computation enables us to determine the overall amount of energy used by network nodes connected to the cluster node. We can quickly determine the residual energy of a network node once the total energy utilised by the nodes has been computed. As a result, a group of network nodes will have access to the remaining energy after subtracting the energy used from the initial energy. Because residual energy is also taken into account in the simulation, the network's accuracy is improved. The main drawback of existing probability based approach is that, since every node involved in calculation of residual energy has to follow its current state at every time-step. So there is in need of more computation. However in order to accomplish this, there must be probability matrix along with every node which updates each node at every time-step. It is mentioned that none of the nodes in the network is capable of measuring their own residual energy than the node itself. Let that node be taken as N. However, only the neighbors of N can record the number of messages transferred from N and also compute a coarse estimate of the energy level of N. The neighboring node cannot reliably produce a result of remaining energy accurately with the help of initial energy of node N or the energy spent due to listening. Also these values are not precise to calculate the energy level. So the only way to calculate the amount of energy left within the nodes is to the node itself. So there is a need of head node called cluster. This can be obtained with the help of an algorithm called election algorithm. This election algorithm at the first round evaluates the energy of the every node itself and passes this value to the cluster head. When the cluster head receives the residual value of all the nodes, it selects the next head among the nodes based on highest residual energy among the ‘n’ neighboring nodes of N. Based on the above, they returns the n nodes with an information about selecting them as cluster head. This algorithm is also called as deterministic way of selection. This is a simple rule of selecting a cluster head. Here the nodes termed as cluster node consumes more energy than the surrounding because it listens to the nearby ‘n’ nodes most of the time [4]. A cluster based scheduling algorithm based on sleep-wake is proposed in[5] which compares the residual energy of nodes in the given sensor network. Here the working node is the node whose selection is based on the largest value in the remaining energy of the network. The remaining nodes of the network is capable of finishing the change of dormancy and delay states provided that they arrive at the predetermined dormancy period. The settings of each state of the node of this phase are concluded by a node knows as the provisional node which has the whole control. Both the selection of control nodes acting temporarily and sleep-wake scheduling are used here through the control of three dimensional topology(3D).This way of selection reduces the consumption of energy thereby guaranteeing coverage at utmost level in the network sensing and rate of connection of nodes which are active.

**7.1.2 Radio Energy Dissipation Model**

The model of radio energy dissipation shown in figure 7.1 represents the power essential to transmit a packet. This model has two components. They are essential power essential to route the radio electronics which is called as (Pe) and the power desirable by the power amplifier is assumed to be Pt = 0.1 m W. The summing up of Pe and Pt represents the total power to transmit or otherwise called transmission Power. In order to receive a packet, the power necessary is equal to the power dissipated by the radio electronics for packet reception or otherwise called as receive power or receiver power. Moreover, the energy is dissipated by the radio at the time of idle listening or idle power is set equal to the energy dissipated by the radio at the time of receive mode. Always the sleep power is set to be zero [2]. The figure below shows the simple energy model of transceiver for radio energy dissipation. The default values taken for the transceiver within the radio dissolution model is mentioned and tabulated in table 7.1 below.

**Table 7.1: Standard settings for transceiver within radio dissolution model**

|  |  |
| --- | --- |
| Radio Bandwidth in Kbps | 20 |
| Transmission Range of radio in meter | 22 |
| Range of Interference in meter | 139.6 |
| Length of the packet in Bytes | 50 |
| Power to transmit in mW | 24.75 |
| Power to receive in mW | 13.5  |
| Idle Power in mW | 13.5 |
| Sleep Power in mW | 0 |
| Height of antenna in meter | 1 |
| Signal Wavelength in meter | 0.69284 |

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**Figure 7.1: Radio Energy Dissipation model in sensor network**

**7.1.3. Calculation of Residual Energy of the Network**

Residual Energy of a Node=Initial Energy of the Nodes-The power consumed by the nodes.

The steps for calculating residual energy are as follows:

Step 1: Initialize WSN with the appropriate attributes first.

Step 2: If the supplied node is alive (has an energy value greater than 0), repeat the steps after it; otherwise, go back to step 2.

Step 3: The subsequent actions are carried out for each node n.

A random selection of the monitoring node is made from among the network's nodes using the self-head node selection formula. The network's nodes each generate a random number between 0 and 1. The node will employ itself as a header node if the generated random number exceeds the value determined using the formula given below (2.1). Additionally, that specific node extends an invitation to other nodes to participate in the cluster. Until the beginning of here.

p- suggested percentage of cluster heads

r- current round for selection of head node

G- Set of nodes in the network that has not been selected as cluster heads in the previous 1/p rounds.

Step 5 Find the total amount of energy spent by set of nodes during transmission of packets and reception of packets in certain period of time T. Let it be $∆$E.

Step 6 The remaining energy of each node I is updated.

Step 7 Evaluate energy dissipation and residual energy and then move to step 2.

Step 8 Continue the process with the selection of cluster head for next round

**7.2 ENERGY DISSIPATION OR CONSUMPTION OF SENSOR NETWORK**

The set of all nodes are considered as N to be there in the network. Let it be Sn = {sn1, sn2, sn3, ….snn}

To foresee how much energy the hub will scatter in the following T time-steps, the span the hubs engaged with the organization consumes absolutely ought to be anticipated first. The typical amount of energy consumed by all hubs in every one of the three states gives the complete energy spent or disseminated by a hub in the ongoing time step. The aggregate sum of energy consumed by a hub in a timeframe T is addressed. Allow it to be ∆E. The energy spent by the hub in a solitary state is addressed. Allow it to be ∆e. The connection among ∆e and ∆E can be communicated numerically as follows: utilization

 ∆E= ∑\_(i=1)^n∆ei (7.1)

The energy utilization in each state, ∆ei, can be determined utilizing the accompanying condition ∆ei=Qi\*ei (7.2)

where Qi is a steady which addresses the energy sum invested per time unit in a state I. The time term spent by a hub in a state I is addressed by ti. During each time span 'T', the energy dispersed in each state is straightforwardly corresponding to the time span t the hub remained in that state precisely predicts the period of time a hub spent in each state is significant. to have a powerful forecast. The length of the span a sensor hub spends in each state in a specific timeframe can be anticipated utilizing the collective normal of the deliberate length of the past time the hub spent in each state. This section describes formula for Average energy consumed

Energy consumed by a node Ec is given by equation

Ec = Ei – Er (7.3)

where, Ei = Initial Energy of a node and Er = Residual Energy of a node

Total energy consumed TEC is given by equation.

TEC = $\sum\_{i=1}^{n}[Ei-Er]$ (7.4)

Average Energy Consumption (AEC) is given by equation ().

AEC = $\sum\_{i=1}^{n}[Ei-Er]\* $𝑁𝑢𝑚𝑏𝑒𝑟 𝑜𝑓 𝑁𝑜𝑑𝑒𝑠 (7.5)

The simulation results shown below indicate that all nodes of the sensor networks are conscious of their physical location. There are two type of packets that can be considered while calculating the residual energy in the simulation. They are called message packets and energy packets. The sensor nodes use these message packets within the sensor network to transmit any information to the sink node. The second type of packet is called energy packet. This packet is used to send energy level information to the monitoring node of the network. In the simulation, each node periodically calculates the amount of energy it consumed during the transmission of packets and also the amount of energy consumed during packet reception time. Comparing the amount of energy consumed with the previously consumption rate, we get the average of the energy consumed during the packet transmission and packet reception time. T his average energy will give the total energy consumed during transmission and reception. To begin with, each and every node in the network launch their existing energy available and their energy consumption rate. If not an update is sent from the nodes, the node which acts as monitoring node of the network lessens the value of the nodes residual energy occasionally by the rate of energy consumption. This specified values are used in all of the simulations of the sensor network. To demonstrate the performance of the proposed prediction model, it has been implemented on a network with fifty nodes and one hundred nodes. Nodes in the networks are assumed to use a greedy routing protocol. The table 7.2 show the numerical values taken for simulation.

**Table 7.2: Tabulation of Numerical Values**

|  |  |
| --- | --- |
| **Parameters** | **Values** |
| Transmission Range | 15 m |
| Number of nodes deployed | 100 |
| Value set as initial Energy | 1000 mJ (1J) |
| Deployment area in x and y axis | 100 x 100m |

**7.3 SIMULATION RESULTS**

The simulation results show the comparison of network life time, Packets received by the sink node in two cases. One is when considering the network with residual energy and the other one is considering the network without residual energy calculation.

**Network Lifetime**

The definition of lifetime of the network is the time until the sink node is disconnected from other nodes; this happens when the nodes in the first level (neighbors of sink) are all dead. As the number of sensors is increased from 50, 100, 150, 200 the lifetime of the network increases. But when the residual energy calculation is involved and considered, the network lifetime is much better in this scheduling work when comparing without consideration of residual energy. The mean network lifetime of the proposed scheduling method under two cases i) nodes under transmission state ii)nodes under receiving state was shown below. Lifetime of the network when nodes are in transmitting state is shown below in table 7.3. The performance for the same is shown in figure 7.2.

**Table 7.3: Lifetime of the network when nodes are transmitting state**

|  |  |  |
| --- | --- | --- |
| **Number of Sensors** | **With the consideration of residual Energy** | **Without the consideration of residual Energy** |
| 50 | 1200 | 920 |
| 100 | 1337 | 1096 |
| 150 | 1559 | 1238 |
| 200 | 1690 | 1389 |
| 250 | 1720 | 1434 |
| 300 | 1801 | 1520 |
| 350 | 1903 | 1613 |

**Figure 7.2: Lifetime of the network when nodes are transmitting state**

When the nodes of the network are in receiving state they consume much less energy than during transmission state. But when comparing the energy spend with considering residual energy the nodes energy level of the network during reception is much better when considering the nodes of the network without residual energy. The below table 7.4 shows the energy consumption of the network during packet reception state. The nodes of the network are varied 50 to 350 and the lifetime of the network was tabulated with values during simulation time. The figure 7.3 below shows the lifetime of the network when nodes are in receiving state.

**Table 7.4: Lifetime of the network when nodes are in receiving state**

|  |  |  |
| --- | --- | --- |
| **Number of Sensors** | **With the consideration of residual Energy** | **Without the consideration of residual Energy** |
| 50 | 830 | 523 |
| 100 | 910 | 568 |
| 150 | 1005 | 673 |
| 200 | 1239 | 803 |
| 250 | 1310 | 910 |
| 300 | 1401 | 998 |
| 350 | 1503 | 1203 |

**Figure 7. 3: Lifetime of the network when nodes are in receiving state**

The table 7.5 below shows the energy consumption of the network during packet transmission based on 50 to 100 sensor nodes deployed in the network. The time taken for packet transmission is considered for various intervals in seconds as 5, 10, 15, 20, 25, 30 seconds. The comparison is made on various priority queuing algorithms is shown in figure 7.4 and the results tabulated shows that REDPQ algorithm is better compared to MPQ and WFPQ.

**Table 7.5: Energy Consumption during packet transmission**

|  |  |  |
| --- | --- | --- |
| **Number of Sensor Nodes** | **Time (s)** | **Energy Consumption during packet transmission(mJ)** |
| **MPQ** | **WFPQ** | **REDPQ** |
| 50 | 5 | 684 | 550 | 301 |
| 50 | 10 | 700 | 570 | 320 |
| 50 | 15 | 749 | 590 | 360 |
| 50 | 20 | 767 | 620 | 390 |
| 50 | 25 | 813 | 635 | 420 |
| 50 | 30 | 835 | 690 | 440 |
| 100 | 5 | 590 | 480 | 210 |
| 100 | 10 | 605 | 495 | 250 |
| 100 | 15 | 643 | 519 | 340 |
| 100 | 20 | 695 | 543 | 370 |
| 100 | 25 | 711 | 561 | 400 |
| 100 | 30 | 722 | 578 | 420 |

**Figure 7.4: Energy consumption during packet transmission**

As mentioned earlier, the nodes of the network consume less energy than during transmission, the values tabulated in table 7.6 shows the energy consumption of the network during packet reception based on 50 to 100 sensor nodes deployed in the network. The time taken for packet transmission is shown in figure 7.5 considered for various intervals in seconds as 5, 10, 15, 20, 25, 30 seconds. The comparison is made on various priority queuing algorithms and the results tabulated shows that REDPQ algorithm is better compared to MPQ and WFPQ at the packet reception time.

**Table 7.6: Energy Consumption during packet reception**

|  |  |
| --- | --- |
| **Number of Sensor Nodes** | **Energy Consumption during packet reception(mJ)** |
| **MPQ** | **WFPQ** | **REDPQ** |
| 50 | 415 | 315 | 215 |
| 50 | 420 | 320 | 220 |
| 50 | 440 | 340 | 240 |
| 50 | 460 | 360 | 260 |
| 50 | 500 | 400 | 300 |
| 50 | 510 | 410 | 310 |
| 100 | 390 | 290 | 190 |
| 100 | 410 | 310 | 210 |
| 100 | 430 | 330 | 239 |
| 100 | 450 | 350 | 255 |
| 100 | 470 | 370 | 275 |
| 100 | 495 | 395 | 295 |

**Figure 7.5: Energy Consumption during packet reception**

The table 7.7 below shows the average energy consumption for various scheduling methods. The average energy consumed during both transmission and reception for various nodes of the network as 50 to 100 nodes. From the figure 7.6 it is clear that the proposed algorithm consumes much lesser energy compared to the other methods.

**Table 7.7: Average Energy Consumption for various Scheduling Methods**

|  |  |
| --- | --- |
| **Number of Sensor Nodes** | **Average Energy Consumption(mJ)** |
|  **MPQ** | **WFPQ** | **REDPQ** |
| 50 | 550 | 433 | 258 |
| 50 | 560 | 445 | 270 |
| 50 | 595 | 465 | 300 |
| 50 | 614 | 490 | 325 |
| 50 | 657 | 518 | 360 |
| 50 | 673 | 550 | 375 |
| 100 | 490 | 385 | 200 |
| 100 | 508 | 403 | 230 |
| 100 | 537 | 425 | 290 |
| 100 | 573 | 447 | 313 |
| 100 | 591 | 466 | 338 |
| 100 | 609 | 487 | 358 |

**Figure 7.6: Average Energy Consumption for various Scheduling Methods**

The residual energy calculation shown in table 7.8 is based on the energy consumption and the initial energy of the nodes of the network. A value of 1000mJ is set as the initial energy for 50 to 100 nodes of the network for various processing rounds. The residual energy of the proposed algorithm shows better residual energy than the existing MPQ and REDPQ for number of nodes set as 50 as shown in figure 7.7.

**Table 7.8: Residual Energy for various Scheduling Methods**

|  |  |
| --- | --- |
| **Number of Rounds** | **Residual Energy for 50 nodes(mJ)** |
| **MPQ** | **WFPQ** | **REDPQ** |
| 100 | 450 | 567 | 742 |
| 200 | 440 | 555 | 730 |
| 300 | 405 | 535 | 700 |
| 400 | 386 | 510 | 675 |
| 500 | 343 | 482 | 640 |
| 600 | 223 | 450 | 625 |
| 700 | 113 | 313 | 535 |
| 800 | 87 | 251 | 482 |
| 900 | 78 | 101 | 333 |

**Figure 7.7: Residual Energy for various Scheduling Methods**

The residual energy calculation is based on the energy consumption and the initial energy of the nodes of the network as shown in table 7.9. A value of 1000mJ is set as the initial energy for 50 to 100 nodes of the network for various processing rounds. The residual energy of the proposed algorithm shows better residual energy than the existing FRED, and WRED for number of nodes set as 100. Figure 7.8 shows the residual energy graph for 100 nodes.

**Table 7.9: Residual Energy for various Scheduling Methods**

|  |  |
| --- | --- |
| **Number of Rounds** | **Residual Energy for 100 nodes (mJ)** |
| FRED | WRED | PQRED |
| 100 | 510 | 615 | 800 |
| 200 | 492 | 597 | 770 |
| 300 | 463 | 575 | 710 |
| 400 | 427 | 553 | 687 |
| 500 | 409 | 534 | 662 |
| 600 | 391 | 513 | 642 |
| 700 | 253 | 445 | 543 |
| 800 | 212 | 411 | 510 |
| 900 | 193 | 383 | 475 |

**Figure 7.8: Residual Energy for various Scheduling Methods (100 nodes)**

**Table 7.10: Overall Illustration of Simulation Parameters along with evaluation**

|  |  |  |  |
| --- | --- | --- | --- |
| **Parameter** | **MPQ** | **WFPQ** | **ARPFQ** |
| **Total Energy(mJoules)** | 1000 | 1000 | 1000 |
| **Average Energy during transmission(mJoules)** | 709.5 | 569.25 | 351.75 |
| **Average Energy during reception(mJoules)** | 449.16 | 348.5 | 250.7 |
| **Consumed Energy(mJoules)** | 579.7 | 459.5 | 301.41 |
| **Residual Energy(mJoules)** | 280.5 | 418.22 | 644.33 |

**Percentage of Dead nodes**

The overall percentage of residual energy is shown in table 7.10. The number of dead nodes can be identified for each simulation time based on seconds and the comparison is made based on various queuing disciplines used in the network. Out of the three comparisons made REDPQ has lesser percentage of dead nodes compared to the other queuing disciplines. This performance result in table 7.11 is based on the energy consumption and the initial energy of the nodes is shown as 1000mJ in the figure 7.9. Based on the residual energy calculated for the above methods the percentages of dead nodes are calculated. The table and figure shows the percentage of dead nodes at the end of simulation.

**Table 7.11: Percentage of dead nodes**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Simulation time(secs) | Number of nodes | MPQ | WFPQ | REDPQ |
| 100 | 50 to 100 | 10 | 5 | 5 |
| 150 | 35 | 19 | 15 |
| 200 | 56 | 28 | 19 |
| 250 | 75 | 38 | 28 |
| 300 | 90 | 59 | 36 |

**Figure 7.9: Percentage of dead nodes**

**Efficiency Measure of the Scheduling Algorithms**

Due to the lesser number of loss of packets, efficiency is increased for the REDPQ scheduling. The energy efficiency of the nodes of the network for various priority queue scheduling can be calculated using the given formula:

Efficiency= useful amount of output energy/ total amount of input energy\*100

The table 7.12 shows the efficiency variation of various algorithms in terms of residual energy remaining within the nodes of the network with the total energy as input. The figure 7.10 shows the efficiency of scheduling.

**Table 7.12: Percentage of Efficiency**

|  |  |
| --- | --- |
| **Scheduling Type** | **Percentage of efficiency (%)** |
| REDPQ | 64.43 |
| WFPQ | 41.82 |
| MPQ | 28.05 |

**Figure 7.10: Scheduling Efficiency**

**7.4 SUMMARY**

The residual energy calculation is one of the important phase in wireless sensor networks. The remaining energy within the nodes of the sensor network after the entire routing process is completed is called residual energy of the networks. The energy which is taken as the initial Energy is 1000mJ. This energy is named as “initialEnergy” in the calling procedure of the simulation code. During simulation, the variable “energy” signifies the level of energy in a node at any specified time and its value gets decreased. The rate of “initialEnergy” is passed as an input argument in the function for residual energy calculation. Losing of energy is based on the specific amount of energy transmitted and received for every packet. In this work the residual energy is calculated based on the number of nodes deployed for various time intervals and the current energy value is noted after transmission and reception. Evaluation of residual energy is based upon accessing of an integral variable “energy” in a function called “findEnergy” at different times. A special node called monitoring node saves the information of the residual energy approximately for each sensor node in the network. This residual energy is calculated for set of 50 to 100 nodes deployed within the network. The numbers of dead nodes are calculated at the end of simulation. The graph plotted for getting the residual energy information can be used as an input to other applications in order to improve their network lifetime.

# KEYWORDS

* Medium Access Control
* Network Animator
* Quality of Service
* Time To Live
* Synchronization

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