Energy Saving in Wireless Sensor Network using nodes Sleep/Active Strategy based on Bernoulli's probability distribution

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Abstract:

Wireless sensor networks (WSNs) are used widely due to its monitoring and reporting capabilities from different environments includes military, environmental monitoring,medical systems and industrial applications. The limited energy source is considered as the main constraint in the WSN. Because the energy exhaustion of sensor nodes of WSN affects the overall operation of the WSN.So, an energy harvesting system is introduced to extend the operational lifetime of WSN after the nodes deployed in the field environment. In this work, Exponentially Weighted Moving-Average (EWMA) based energy harvesting is used in WSN to charge the battery of the nodes. Hereclusterbased routing is accomplished in WSN to reduce the energy consumption among the sensor nodes of the WSN. The network is divided into several clusters by using the Recurrent Self Organizing Map (RSOM).Moreover, the RSOM based sleep awake routing is enabled to preserve the energy consumption of the sensor nodes. The sleep awake scheduling of WSN is used to minimize the energy consumption of the WSN by switching the modes of node that is either active or sleep. Also focuses on energy saving in nodes in WSN using sleep/active strategy based on Bernoulli's probability distribution. Hence, the RSOM-EWMA methodology is validated with the Markov chain model. The performance of the RSOM-EWMA methodology is analyzed in terms of number of alive nodes, number of dead nodes,energy consumption, throughput and total packet send. The performance of the RSOM-EWMA methodology is compared with RSOM without energy harvesting, RSOM only with sleep awake scheduling and NEEC.

Keywords: *Energy harvesting, Markov chain model, recurrent self-organizing map, sleep awake scheduling and wireless sensor networks.*

INTRODUCTION

WSN consists of more number of autonomous low power sensors which are organized in an ad hoc manner. These deployed sensors have the capability to receive the information from the surrounding environment, performing the simple computations and communicate with each other [1]. The sensors used in the WSN is used for monitoring the pressure, sound, level of pollutants, vibration and temperature [2].Due to the small size and low cost, the WSN is utilized in various applications such as healthcare monitoring, environmental monitoring, smart cities, medicine, military, etc. [3-4]. The main aim of the WSN is to receive the data from the desired environment and this data is transferred to the Base Station (BS). Generally, the BS is located far from the deployed sensors [5]. In WSN, the cluster based structure is developed to effectively collecting the information from the environment. In that case, the sensors are divided into various clusters. Here, each

cluster has one Cluster Head (CH) for monitoring the respective cluster and the information is transmitted to the BS by using the CH. Besides, the energy consumption of the sensors is balanced by altering the CHs in every round [6].

Additionally, the data aggregation schemes are used in the CH for removing the unnecessary or incorrect information from the gathered information. The data traffic, energy efficiency and topology are improved by using the optimum clustering in the WSN. Generally, the cluster based WSN contains two different types such as the network with temporary CH and the network with permanent CH [7]. The major concern in the WSN is the energy efficiency because the WSN is generally powered by non-rechargeable batteries with limited battery capacity [8]. So, the Energy Harvesting (EH) is used to enhance the lifespan of each sensors [9]. EH-WSN is defined as the WSN with the addition of rechargeable sensors. If the battery level of the sensor does not exceed its maximum capacity, then harvested energy is stored in the sensor's battery [10]. In EH-WSN, the electrical energy is generated from different environmental energy sources like atmospheric variation, wind, tree movement and solar [11-12].The difficulty over replacing/ recharging the exhausted batteries is eliminated by using the EH unit in the WSN [13]. Moreover, the sensors energy consumption is minimized to improve the network lifetime by utilizing the sleep scheduling in the WSN [14]. In sleep scheduling, the sensors cannot transmit or receive the information during sleep state. It can only transmit/ receive, when the respective sensor is in active state [15]. The major contributions of this paper are given as follows:

- The EWMA based energy harvesting is used for recharging the nodes which doesn't have any energy to transmit/receive the data through the network. This EMWA leads to increase the lifetime of the network.
- RSOM based sleep awake routing is introduced in the network to reduce the energy consumption of each sensor nodes.The active/sleep of MSN's are implemented using Bernoulli's vacation schedule concept.

The rest of the paper is organized as follows: Section 2 presents the literature survey. Section 3 presents the RSOM-EWMA methodology. Section 4 gives the analytical framework of the RSOM with sleep/awake scheduling & energy harvestingmethodology(RSOM-EWMA) and RSOM with sleep/awake scheduling & without energy harvestingmethodology(RSOM-WOEWMA). Section 5 presents the results and its discussion.

Literature survey

There are several existing techniques are related to the energy harvesting and sleep awake scheduling in the WSN. A brief evaluation of some contributionsto the existing literatures are given as follows:

The Novel Energy Efficient Clustering (NEEC) in the Energy Harvesting Wireless Sensor Network (EH-WSN) performs in a distributed and centralized manner. In this network, the energy harvesting is developed by using the exponentially weighted moving-average system and it considers the nodes are recharged by using the energy from the sunlight. The energy status and the quantity of harvested energy decides the probability of the nodes become Cluster Head (CH). The less delay time is achieved by the node with higher probability of becoming CH. Also, the CH is selected by considering the node with lesser time delay when compared to its neighbor nodes. After cluster formation, the nodes of the clusters transmit the data packets to the CH by using the energy-aware multi-hop routing.The CH selection used in this EH-WSN provides higher priority only to the energy left in the nodes[16].

The hierarchical routing protocol to identify the specific path among the source to the destination. This hierarchical routing protocol has two different phases.At first, the network map is generated without using the GPS for avoiding the increase in cost. For routing operation, the data aggregation algorithms and sleep–wake/load balancing are

utilized at second phase. The nodes sleep/wake states are determined by base station based on the energy level of the nodes. In data aggregation, the CHs are identified based on the distance from the BS and energy level. The energy consumption of the node high, when it has higher functionality in the network[17]. The Sleep-awake Energy Efficient Distributed (SEED) clustering algorithm is developed for the WSN. In that the sensing field of the network is divided into three different energy regions because of the direct data transmission from the cluster head to the BS. During the data transmission over large distance, the energy consumption of the cluster heads present in the high energy region are large than the cluster heads of low energy region. In each iteration, one node form sub clusters are in awake mode for data transmission and remaining nodes is kept in sleep mode for saving the energy. The unnecessary data transmission to the BS is reduced by thesub-clustering in SEED. The stability of the network is varied due to same energy levels of the advanced and normal nodes [18].The Novel Energy Aware Hierarchical Cluster-based (NEAHC) routing protocol is introduced for WSN. This NEAHC is the combination of a clustering approach and optimal relay selection algorithm. In clustering process, the energy consumption between the CH and BS is considered.There are three different values are considered in the NEAHC routing protocol which are high residual battery power, less energy consumption at multi hop path and optimal fairness between the nodes. The selection of next hop is designed as convex optimization problem that is easily solved in NEAHC. If the direct transmission is occurred in the WSN, it will lead to increase the energy consumption [19].Enhanced Energy Management (EEM) scheme is used in EH-WSN that utilizes the receiver-initiated communication for regulating the active/sleep periods over energy threshold policy. There are two different thresholds are used in the policy of energy threshold. In switching technique, the sensor node uses the first threshold for achieving the load balancing. In that the desired node is

handling its switching mode either sensing mode or relaying mode at wake-up period. The EEM-EHWSN uses the second energy threshold for calculating the sleep period duration by considering the Lagrange interpolation. Also, based on the residual energy their next wake-up time is adjusted dynamically with related to the EH condition. The energy and band width are wasted at the scenario of high latency in multi-hop scenario and moderate latency in single-hop scenario [20].

RSOM-EWMA methodology

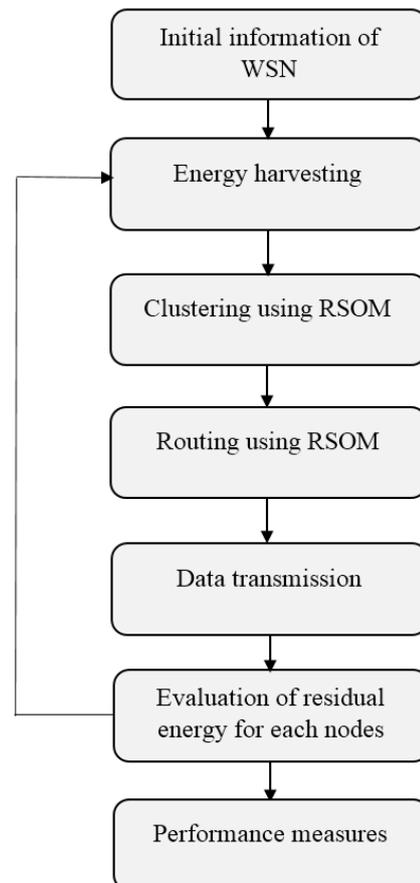The RSOM-EWMA methodology is shown in the following Figure 1.

Figure 1. Block diagram of the RSOM-EWMA methodology

- Initially, the sensor nodes are randomly deployed in the interested area. The source and the Base Station (BS) are fixed depends on the location of the sensor nodes.

- RSOM clustering is applied in the sensor

nodes to cluster the network into a number of clusters. Then the Cluster Head is selected from each cluster.

- The optimal route among the CHs are obtained also by using the RSOM.
- From the routing an optimized node is selected to form the route from CH to the destination (i.e., BS).
- If the selected node has required energy to transfer the data means, it delivers the data from one node to another node or else it selects another optimal node for transferring the information.
- After creating the path from source to destination, it sends the data to the destination.
- This RSOM-EWMA method predicted the optimal path for data transfer by considering three different parameters such as residual energy of the nodes, distance among the nodes and number of hops.
- The nodes present in the WSN losses their entire energy after some iterations due to the limited battery capacity nodes. So, the energy harvesting is required to decrease the dead nodes probability in the network.
- Besides sleep/awake scheduling is enabled in the WSN to reduce the energy consumption of the desired network.
- Finally, the performance of this RSOM-EWMA method is analysed in terms of energy consumption, throughput and total packet send.

1.1. Energy model

The network losses their energy in four different ways that are sensing, transmission, reception and aggregation. The equation (1) specifies the energy consumption of data transmission of k bits over the distance of d_0.

$$E_{tx}(k, d_0) = E_{elec} \times k + E_{amp} \times k$$
(1)

Where, energy consumption per bit at transmitter is E_{elec} and energy consumption of amplification process is E_{amp}.

The consumed energy during amplification is given in following equation (2) and (3). The equation (2) and (3) expresses the energy of amplification when the distance among the nodes less than and greater than threshold distance respectively.

$$E_{amp} = E_{fs} \times d^2 if \ d \leq d_0$$
(2)

$$E_{amp} = E_{mp} \times d^4 if \ d > d_0$$
(3)

Where, E_{fs} is energy consumption for free space model; E_{mp} is energy consumption for multi path fading channel and d_0 is the threshold distance $\left(i.e., \ d_0 = \sqrt{E_{fs}/E_{mp}}\right)$.

The amount of energy consumed for receiving the data is expressed in the following equation (4).

$$E_{rx}(k, d_0) = E_{elec} \times k \qquad (4)$$

1.2. RSOM model

Generally, the RSOM is a direct temporal extension from the Self Organizing Map (SOM). SOM is a two dimensional rectangular or hexagonal grid of units. The RSOM maps the data from an input space on low dimensional space and this RSOM uses a generation of selection of winner neuron and weights update rule. This RSOM algorithm removes the leaky integrator from the unit outputs. Here, the RSOM uses the pattern history (i.e., previous elements in the sequence) for obtaining the best matching unit and also this RSOM adapts the weights of the map. The following equation (5) describes the recursive differential equation which considers the weights of the map.

$$y_i(n) = (1 - \alpha)y_i(n - 1) + \alpha(x(n) - m_i(n))$$
(5)

Where, the leaked difference vector for unit i in step n is the $y_i(n)$ and the leaking coefficient is denoted as $\alpha (i.e., 0 < \alpha < 1)$. The leaking coefficient from the equation (5) is similar to the value of $1 - \lambda$ from the Temporal Kohonen map (TKM). But in the formulation of RSOM, the sum of factors is ensured

the stability when the leaking coefficient is positive but lesser than the one. Similar to the TKM, the formulation of RSOM contains a linear low pass filter in its each unit for preserving the trace of the previous samples. In the RSOM, the operators are moved from the unit outputs to inputs. The RSOM is treated like the normal SOM, due to the insertion of leaky integrators in the difference vector computation. The following equation (6) defines the Best Matching Unit (BMU) for obtaining the learning rule of the SOM.

$$b(n) = \text{argmin}_{i \epsilon M} \|y_i(n)\|$$

(6)

The corresponding error function are defined, once the BMU is selected from the desired samples. This error function is used for reducing the given input (x) in to leaked difference vector (y) which is given in equation (7).

$$E(n) = \frac{1}{2} \sum_{i \epsilon M} h(b(n), i) y_i(n)^2$$

(7)

Where, the neighborhood function is denoted as $h(b(n), i)$ and the error is calculated by selecting the neighborhood function with equation (6). The following equation (5) represents the differentiation of equation (7) with respect to $y_i(n)$.

$$\frac{\partial E(n)}{\partial y_i(n)} = h(b(n), i) y_i$$

(8)

Hence, the stochastic update rule is used for minimizing the error function. The following equation (9) shows the weight update rule.

$$m_i(n + 1) = m_i(n) + \gamma(n) h(b(n), i) y_i(n)$$

(9)

Where, the learning rate is $\gamma(n)$. Here, the discontinuities of the error function $(E(n))$ exists in the Voronoi cell's boundaries are avoided in equation (9).

1.3. Clustering using RSOM

The sensors present in the network are divided into clusters by using the RSOM algorithm. For clustering the network, the information of sensor locations is given to the RSOM. The optimal CHs are selected from the cluster by using RSOM. This CH has the responsibility to collect the information from the normal sensors of their respective clusters. Then the information about the cluster heads are given to the RSOM for enabling the sleep scheduling to transfer the gathered data by using the desired active nodes.

1.4. Sleep awake routing using RSOM

The sleep awake routing using RSOM is divided into two different phases which are given below:
- Sleep wake scheduling
- Event reporting

1.4.1. Sleep wake scheduling

After performing the clustering in the network, the information about the CH and sensors are given to the RSOM algorithm to switch the modes of the sensors like sleep to active and vice versa. The modes of sensor are switched for transferring the information to the desired location (i.e., BS) by identifying the optimal nodes from the network. The information given to the RSOM are residual energy of the nodes, distance from the sensors to the CH, distance from the CH to BS and number of hops. In sleep wake scheduling phase, the mode switching of sensors are performed based on the identified optimal nodes from the RSOM algorithm. Based on this the sleep wakeup pattern of each node is identified. In every sleep/awake cycle, the desired sensor wakes up and it senses the network to transmit/receive the information.

1.4.2. Event reporting

This event reporting phase has the responsible for transmitting the data from the source node to the destination (i.e., BS) in timely manner. Here, the data is collected from the sensor nodes and it is transmitted though the optimal path discovered from the RSOM algorithm. The wake interval of the respective nodes is increased, because that the event is occurred in sensor's proximity. The Time Division Multiple Access (TDMA) is assigned for the nodes which are in active mode to transmit the information

through the network. This TDMA schedule is broadcasted to the sensors and CH present in the network. In an event reporting phase, the sensors are in active mode transmit the sensed information to the desired CH in its own TDMA schedule. Since, the sensors in sleep mode does not participate in any activities like transmit or receive. Besides, the sensors in sleep mode saving their energy.

1.5.Energy Harvesting

Typically, the energy harvesting sensors have the capacity to harvest the energy from the surrounding environment. Sincethe renewable energy is varied with respect to the time. Then the sensor's harvested energy is stored in their battery. In this RSOM-EWMA methodology, the EWMA is used to develop energy harvesting. Consider, the solar energy is used as the renewable energy for energy harvesting to the exhausted nodes.

The following equation (10) expresses the energy model of an energy harvested node i.

$$E_{rem}(i,r) = \min\left(E_{max}(i),\left(E_{rem}(i,r-1) + E_{EH}{i,r-1}\right)\right) \qquad (10)$$

Where, the ith node energy in round $r$is $E_{rem}(i,r)$; the maximum battery capacity of the node i is $E_{max}(i)$ and the harvested energy of the ith node in the previous round is $E_{EH}(i,r-1)$.

The amount of harvested energy from the solar energy is expressed in equation (11).

$$E_{EH}(i,r-1) = \mu_i \Delta t \qquad (11)$$

Where, the ith node energy harvesting rate at $r-1$ round is denoted as μ_i and Δt represents the duration time.

Hence, the rate of energy harvesting is expressed in the following equation (12).

$$\mu_i = rand(P_{h,Min}(r-1), P_{h,Max}(r-1)) \qquad (12)$$

This μ_i is the random variable and it has the uniform distribution among the $P_{h,Min}(r-1)$and $P_{h,Max}(r-1)$. Where, the probable lowest and highest energy harvesting rate for all nodes at $(r-1)$th round are represented as $P_{h,Min}(r-1)$ and $P_{h,Max}(r-1)$ respectively. There are two types of thresholds are considered in the energy harvesting nodes such as low and high threshold. If the sensor's energy goes beyond the low threshold, that respective node will be blocked, and it won't participate at current round. Thus, the node cannot transmit the data and receive the data from the network. The node will be activated again, when the nodes energy level is greater than the high threshold.

2. Analytical framework

The analytical framework is based on Markov chain. The Markov model of sensor node is developed to set behavior of sensor node to active,awakeanddead mode according to the Bernoulli's process. We consider two Markov models for the RSOM-WSN and EWMA. The Markov model for single sensor node behavior for RSOM-WSN[21] and EWMA is described as shown in Fig 2 and Fig 3,respectively.This Markov chain is used for analyzing the probability of alive nodes and the dead nodes in the WSN.In awake state, the SN gathers, generates and transmit data, during sleep state remains in active. The model is designed to check with the remaining energy of sensor nodes periodically. Once the node remaining energy reaches the threshold parameter set then BS will make the status of node from sleep/awake to permanently dead status. The node now is said to be in absorption state because all its energy is consumed/absorbed completely. The BS now selects the other nearby node based on the Bernoulli's probability distribution. We assume that the SN can go from sleep/awake state to dead state and resumes back to sleep/awake state after some time by somehow recharging or by some triggering action. The probabilities of switching between active, sleep and dead is depicted in Fig 2. In this case, the node is assumed to resume its function at some point of time later. The node is now said to be in non-absorption state as the battery level of sensor node raised to more than threshold value.

We consider the system of N sensor nodeswhich are either awake or sleep state in the beginning. We assume that maximum one node can be dead in one slot.

Let$\boldsymbol{\pi}(n,t)$denote the probability that there are n dead nodes at time t and observing node either in active, awake or sleep state.

We consider an irreducible discrete-time Markov chain with state space active, sleep and dead.If at t-th slot the process is in state$i$, at $(t+1)$-th slot it moves to state$j$ with probability$(D_0)_{ij} + (D_1)_{ij}$.Here, $(D_0)_{ij}$,$i,j = active, sleep\ and\ dead$, represents a transition probability from state i to state j without node becomes dead, and $(D_1)_{ij}$,$i,j = active, sleep\ and\ dead$, denotes a transition probability from state i to state j with node becomes dead. Thus, the process of node becomes dead is completely defined by a stochastic matrix pair $(\boldsymbol{D}_0, \boldsymbol{D}_1)$, where $\boldsymbol{D}_0 = [(D_0)_{ij}]$and $\boldsymbol{D}_1 = [(D_1)_{ij}]$. Note that the elements of matrix $\boldsymbol{D}_0$are non-negative values in which the matrix $(\boldsymbol{I} - \boldsymbol{D}_0)$is invertible, and theelements of matrix $\boldsymbol{D}_1$are non-negative values with at least one positive entry, where $\boldsymbol{I}$ is the identity matrix of order 3.

Let us denote$\boldsymbol{D} = \boldsymbol{D}_0 + \boldsymbol{D}_1$ being a stochastic matrix corresponding to an irreducible, aperiodic and positive recurrent Markov chain. Let$\overline{\boldsymbol{\pi}}$ be the stationary probability vector of the Markov chain with the transition probability matrix$\boldsymbol{D}$, i.e., $\overline{\boldsymbol{\pi}}$satisfies $\overline{\boldsymbol{\pi}} = \overline{\boldsymbol{\pi}}\boldsymbol{D}$ with$\overline{\boldsymbol{\pi}}\boldsymbol{e} = 1$, where $\boldsymbol{e}$is a column vector of ones with order 3, and the j-th component of $\overline{\boldsymbol{\pi}}$ represents the stationary probability of the observing nodebeing in phase j.

LetY_t denote the number of nodes become dead in the first$t$ time slots, and$J_t$represent the state of the Markov chain afterthe same amount of time. Let$\boldsymbol{P}(n,t) = (P_{ij}(n,t))$, where $P_{ij}(n,t)$represents the conditional probability that the Markov chain$\boldsymbol{D}$ is in phase$j$ at time$t$ and that $n$nodes become dead in the interval$(0,t]$, given that the process was in phase$i$at time$t = 0$. Therefore, the probabilities

$$P_{ij}(n,t) = \Pr[Y_t = n, J_t = j | Y_0 = 0, J_0 = i], n \geq 0,$$

lead to the following forward Chapman-Kolmogorov linear matrix-difference equations

$$\boldsymbol{P}(0,t) = \boldsymbol{P}(0,t-1)\boldsymbol{D}_0, \qquad t \geq 1,$$
$$\boldsymbol{P}(n,t) = \boldsymbol{P}(n,t-1)\boldsymbol{D}_0 + \boldsymbol{P}(n-1,t-1)\boldsymbol{D}_1,$$
$$n \geq 1, t \geq 1,$$

with$\boldsymbol{P}(0,0) = \boldsymbol{I}$ and$\boldsymbol{P}(n,t) = \boldsymbol{0}$,$n > t \geq 0$. Thus, we write the system of equations in matrix form as

$$\boldsymbol{\phi}(t) = \boldsymbol{\phi}(t-1)\boldsymbol{T},$$

where

$$\boldsymbol{T} = \begin{pmatrix} \boldsymbol{D}_0 & \boldsymbol{D}_1 & \boldsymbol{0} & \cdots & \boldsymbol{0} & \boldsymbol{0} \\ 0 & \boldsymbol{D}_0 & \boldsymbol{D}_1 & \cdots & \boldsymbol{0} & \boldsymbol{0} \\ 0 & 0 & \boldsymbol{D}_0 & \cdots & \boldsymbol{0} & \boldsymbol{0} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ \vdots & \boldsymbol{0} & \boldsymbol{0} & \cdots & \boldsymbol{0} & \boldsymbol{D}_1 \\ \boldsymbol{0} & \boldsymbol{0} & \boldsymbol{0} & \cdots & \boldsymbol{0} & \boldsymbol{D}_0 + \boldsymbol{D}_1 \end{pmatrix},$$

and$\boldsymbol{\phi}(t) = [\boldsymbol{\pi}(0,t), \boldsymbol{\pi}(1,t), \dots, \boldsymbol{\pi}(N,t)]$.

In the steady-state, we have $\boldsymbol{\phi} = \boldsymbol{\phi}\boldsymbol{T}$, with $\boldsymbol{\phi}\hat{\boldsymbol{e}} = 1$, where $\hat{\boldsymbol{e}}$is a column vector of ones with order$3(N+1)$.Solving the system of equations, we get $\boldsymbol{\pi}(n)$ which represents that there are n dead nodes in the system.

For absorbing Markov chain, we have
$$\boldsymbol{D}_0 = \begin{pmatrix} 0.5 & 0.3 & 0.0 \\ 0.2 & 0.5 & 0.0 \\ 0.0 & 0.0 & 0.0 \end{pmatrix}$$
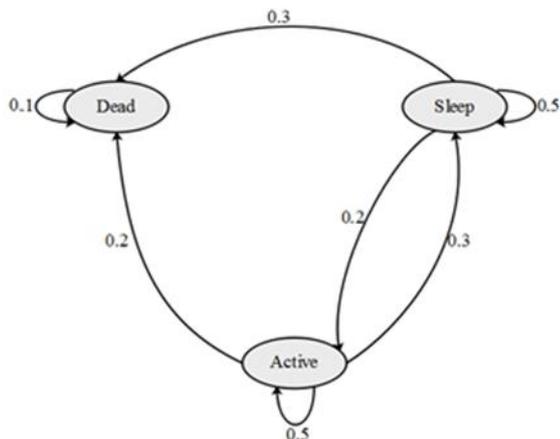$$\boldsymbol{D}_1 = \begin{pmatrix} 0.0 & 0.0 & 0.2 \\ 0.0 & 0.0 & 0.3 \\ 0.0 & 0.0 & 1.0 \end{pmatrix}$$

For non-absorbing Markov chain, we have
$$\boldsymbol{D}_0 = \begin{pmatrix} 0.5 & 0.3 & 0.0 \\ 0.2 & 0.5 & 0.0 \\ 0.1 & 0.2 & 0.7 \end{pmatrix}$$
$$\boldsymbol{D}_1 = \begin{pmatrix} 0.0 & 0.0 & 0.2 \\ 0.0 & 0.0 & 0.3 \\ 0.0 & 0.0 & 0.0 \end{pmatrix}$$

shows the simulation parameters used in the RSOM-EWMA methodology.

Figure 2.Markov model for Sensor behavior for RSOM-WSN

Table1. Simulation parameters

Parameter	Value
Area	1000*1000 m^2
Sensor nodes	100
Initial energy of sensor nodes	5 J
Number of simulation iterations	300
E_{elec}	50 PJ/bit
E_{fs}	10 PJ/bit/ m^2
E_{mp}	0.0013 PJ/bit/ m^4
d_0	87m
E_{DA}	5 nJ/bit
Packet size	4000 bits
Message size	200 bits

3.1. Performance analysis

The performance measures analyzed in the methodologies are given as follows

3.1.1. Alive nodes

The node which has an adequate amount of energy for transferring the information is named as alive nodes. Several alive nodes become high, for an effective data transmission in WSN.

3.1.2. Dead nodes

The nodes which don't have any energy for transmitting the information is called as dead nodes. It degrades the performance of the entire network, as well as the dead nodes, should be less for avoiding the packet loss. The following equation (13) expresses the dead nodes.

$$Deadnodes = Total\ number\ of\ nodes - number\ of\ alive\ nodes \qquad (13)$$

3.1.3. Energy consumption

The total quantity of energy required for each node to deliver the message through the path is extracted in the RSOM routing and the total energy consumption is given in equation (14).

$$E_c = E - (E_T + E_R)$$
$$(14)$$

Figure 3.Markov model for Sensor behaviorfor EMWA

3. Results and discussion

The RSOM-EWMA methodology is implemented by using MATLAB 2017a software tool (for the simulation purpose) through the i5 desktop computing environment with 8 GB RAM memory capacity. In that RSOM-EWMA methodology, clustering and routing is performed by using RSOM algorithm. Moreover, the sleep scheduling also considered in RSOM routing to preserve the energy consumption. The energy harvesting over the sensors are performed by EWMA. The following Table 1

Where energy consumption of the WSN is represented as E_c, E is defined as the total amount of energy, the transmitting and receiving energy is represented as E_T and E_R respectively.

3.1.4. Throughput

Throughput is described as several successful messages delivered to the destination as well as this value should be high for an effective data

transmission. The following equation (15) is given for measuring the throughput in a WSN.

$$T_H = N_T \times P_L (15)$$

Where, T_H is denoted as the throughput of the MANET, total number of rounds as denoted as N_T and the packet length is represented as P_L.

3.1.5. Total packet sends

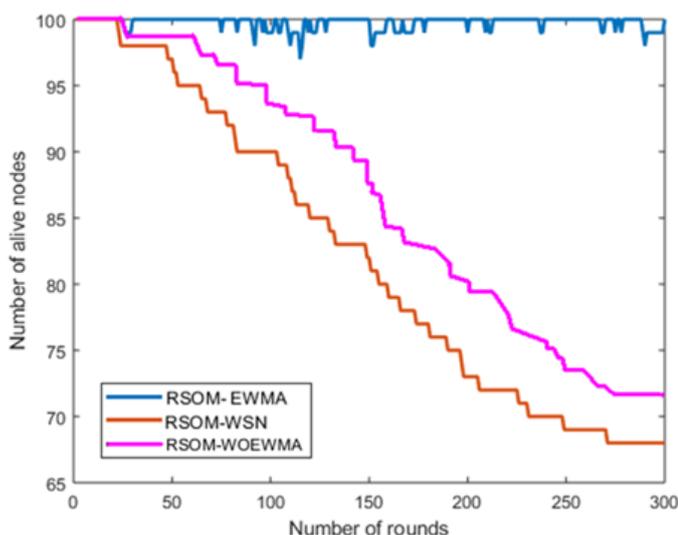The number of packets delivered to the BS is defined as total packet send.
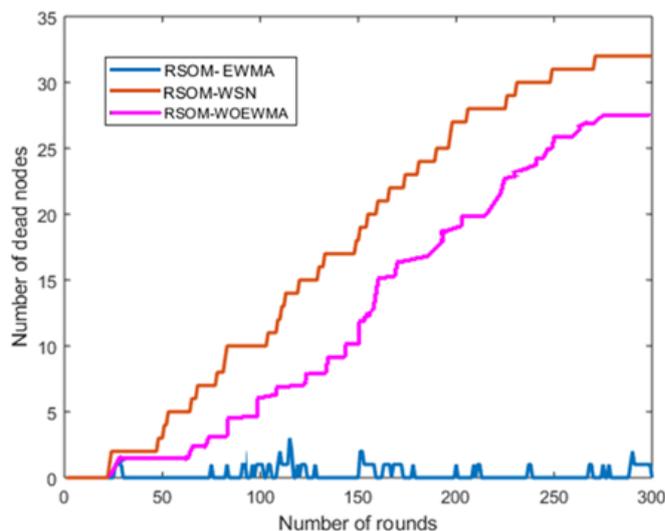
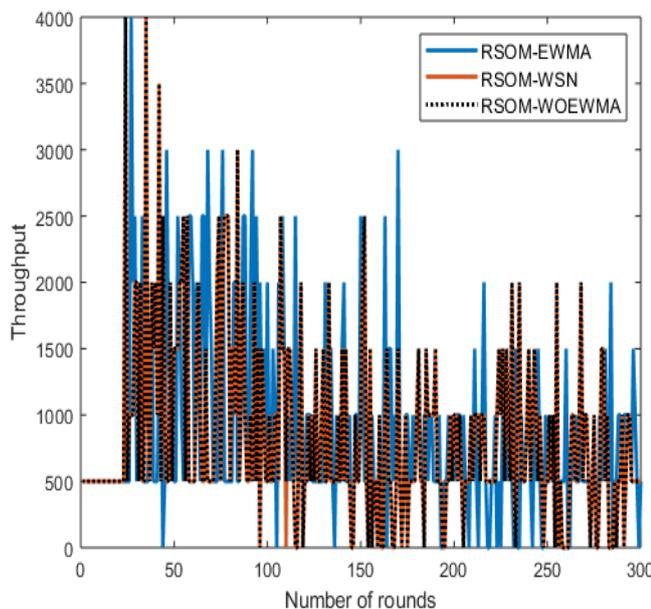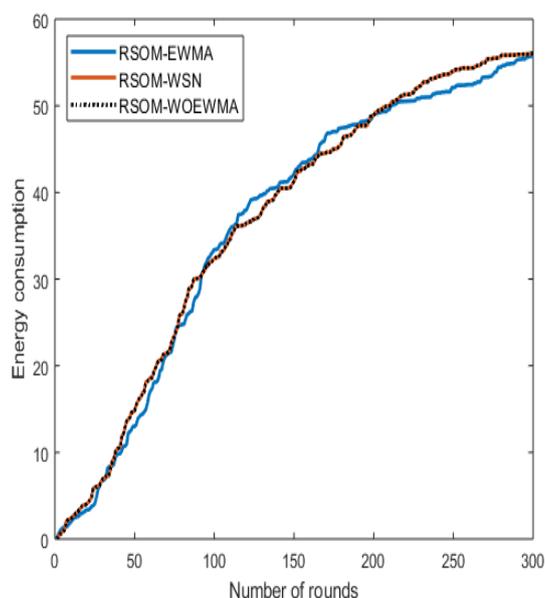Figure 4.Performanceof alive nodesFigure 5. Performanceof dead nodes

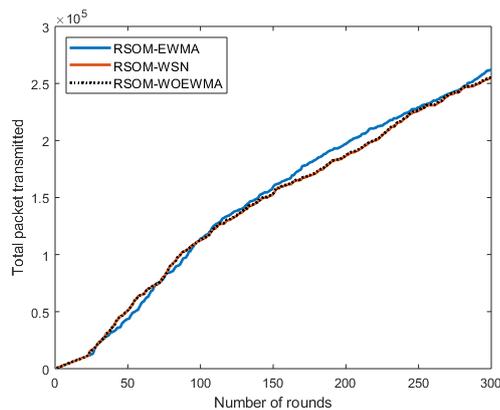Figure 6.Performance of energy consumption   Figure 7. Performance of throughput

Figure 8.Performance of total packet send

The performance of the RSOM-EWMA methodology is compared with RSOM without any sleep/awake scheduling and energy harvesting, and with RSOM only with sleep/ awake scheduling. Theabove Figure 4 to Figure 8 shows the performance validation of RSOM-EWMA methodology with RSOM-WSN and RSOM-WOEWMA. In that, RSOM-WSN defines the RSOM without any sleep/awake scheduling and energy harvesting, and RSOM-WOEWMA defines the RSOM only with sleep/ awake scheduling and without EH. Figure 4 shows the performance validation of RSOM-EWMA methodology with RSOM-WSN and RSOM-WOEWMA. From the Figure 4shows that the alive nodes of the RSOM-EWMA methodology are not decreased. Because, in this RSOM-EWMA methodology the EMWA based energy harvesting method recharges the dead nodes by monitoring the energy level of the nodes. So, the RSOM-EWMA methodology alive nodes are high when compared to the RSOM-WSN and RSOM-WOEWMA. Figure 5 shows the performance of dead nodes in terms of number of rounds. This Figure 5 illustrates the performance validation of RSOM-EWMA methodology with RSOM-WSN and RSOM-WOEWMA. The dead nodes of RSOM-EWMA methodology are converted into alive nodes by considering EMWA based energy harvesting method. In that case, the possibilities of the packet drop are decreased. So, the number of packets received by the BS is increased which improves the network performance. From the Figure 5, conclude

that the dead nodes of the RSOM-EWMA methodology is less than the RSOM-WSN and RSOM-WOEWMA.Figure 6 shows the energy consumption evaluation for the RSOM-EWMA methodology with RSOM-WSN and RSOM-WOEWMA in terms of rounds. In RSOM-EWMA methodology, the energy of each nodes is preserved by enabling the sleep awake routing using RSOM. In that case, the nodes which are sleep mode does not consumes any energy. So, the energy consumption of the entire network is less than the RSOM-WSN and RSOM-WOEWMA. Figure 7 shows the throughput evaluation of RSOM-EWMA methodology with RSOM-WSN and RSOM-WOEWMA in terms of number of rounds. The throughput of the RSOM-EWMA methodology is increased by avoiding the dead nodes in the discovered optimal path. The dead nodes are avoided by considering the residual energy of each node in the sleep awake routing of RSOM. Besides, there is only lesser possibility of the dead nodes due to the sleep/awake scheduling and EWMA. Figure 8 shows the performance of total packet transmitted to the BS at every iteration. This Figure 8 illustrates the performance validation of RSOM-EWMA methodology with RSOM-WSN and RSOM-WOEWMA. Similar to the throughput, the packet send of the RSOM-EWMA methodology is increased by avoiding the dead nodes in every iteration.

3.2. Comparative analysis of RSOM-EWMA methodology with NEEC

The performance of the RSOM-EWMA methodology is compared with NEEC [16] for knowing the effectiveness of the RSOM-EWMA method. In this comparison, there are 50 sensor nodes are taken for the simulation which is deployed over the area of 1000m×1000m.here, the initial energy of the nodes is fixed as 5J. The energy for transmitting and receiving the data is consumed up to 50 nJ/bit. Moreover, the energy consumption for the free space and multipath fading channels are 10

pJ/bit/m^2 and 0.0013 pJ/bit/m^4. The comparison between the RSOM-EWMA methodology and NEEC [16] are analyzed in terms of number of alive nodes, total packets send to the BS and average amount of energy consumed by the alive nodes. Further, the comparison is depicted as follows:

Table 2. Comparative analysis of RSOM-EWMA methodology with NEEC

Iterations	Alive nodes		Total packets		Average energy of the alive nodes	
	NEEC [16]	RSOM-EWMA	NEEC [16]	RSOM-EWMA	NEEC [16]	RSOM-EWMA
0	50	50	0	0	5	5
6	44	50	2500	3000	3	4.84
12	50	50	6000	6000	5	4.76
18	49	50	8500	9000	4.5	4.61
24	42	50	12000	12000	2.8	4.45
30	34	50	13500	15000	1.8	4.41
36	50	50	16000	18000	5	4.32
42	49	50	19000	26000	4.5	4.33
48	42	48	22000	36000	2.8	4.17
54	33	50	24500	41000	1.8	4.24
60	50	48	26000	46500	5	4.05
66	49	49	29000	56000	4.5	3.99
72	41	48	32500	67000	2.8	3.96

Table 2 shows the comparative analysis of RSOM-EWMA methodology and NEEC [16]. From the analysis conclude that the RSOM-EWMA methodology gives better performance than the NEEC [16]. Because, the NEEC gives high priority for energy in the CH selection. But in this RSOM-EWMA methodology, there are three different objective functions are considered such as residual energy, number of hops and distance among the nodes. The energy consumption of the network is optimized by considering the distance among the node to CH and distance among the CH to CH. Moreover, the energy consumption also reduced by using the RSOM based sleep awake routing over the network. The sleep awake routing activates only that the nodes which are in the optimal path. This leads to maintain the nodes except in the optimal path are in sleep modes and it minimizes the energy consumption through the network. The alive nodes in the network is maximized by reducing the energy consumption of the network and also the node drain their energy is again recharged by using the EMWA. The data packets transmitted to the BS is increased by avoiding the dead nodes in data transmission path.

3.3. Validation of RSOM-EWMA methodology with Markov chain model

The performance of the RSOM-EWMA methodology isvalidated with Markov chain model for knowing the effectiveness. This validation is analyzed in two different case one is absorbing case(i.e., the WSN without any energy harvesting) and other one is non-absorbing case (i.e., the WSN with energy harvesting).In that validation, the probability of the number of nodes being deadare evaluated through the network. Further, the Markov chain modelbased validation is depicted as follows:
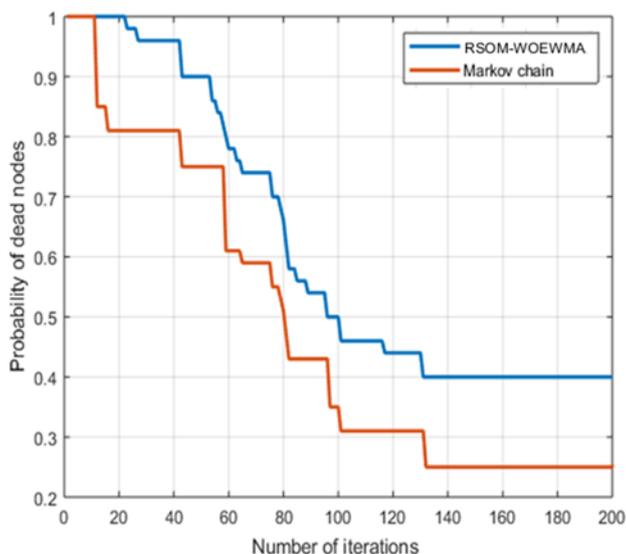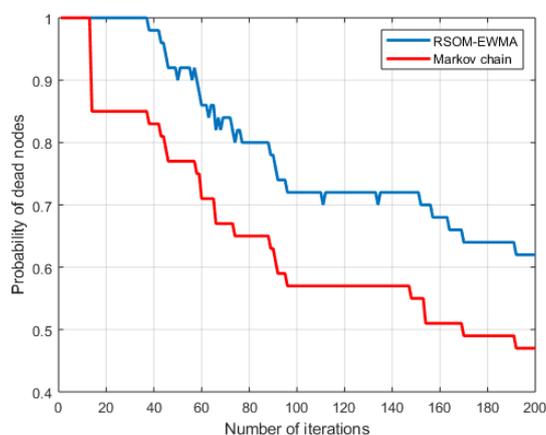
Figure 9.Probability of dead nodes for absorbing case

Figure 10.Probability of dead nodes for non-absorbing case

Figure 9 and Figure 10 shows the probability of dead nodes for absorbing case and non-absorbing case respectively. From the figures conclude that the performance of the RSOM-EWMA methodology is similar to the Markov chain model.

Conclusion

In this paper, the energy consumption of the sensor nodes is minimized by using the RSOM based sleep awake routing through the network. The nodes in the network are switched to the active mode only during the data transmission. This RSOM based routing leads to minimize the energy consumption. Moreover, the EMWA based energy harvesting is

used to recharge the exhausted nodes. This will increase the lifetime of the nodes. The RSOM-EWMA methodology is compared with RSOM-WSN, RSOM-WOEMWA and NEEC. Also, the RSOM-EWMA methodology is validated with the Markov chain model. The probability of nodes being dead of RSOM-EWMA methodology is almost similar to the Markov chain model.TheRSOM-EWMA methodology provides better performance than the NEEC in terms of alive nodes, average energy of alive nodes and total packet send to BS. For example, an alive node of RSOM-EWMA methodology at iteration 72 is 48, it is high when compared to the alive nodes of NEEC that is 41.

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