Applied Management Support for an Efficient WSN Infrastructure

Nilayam Kumar Kamila
Capital One, 802 Delaware Avenue, Wilmington, Delaware 19801 USA
United States
nilayam_kamila@yahoo.com

Sunil Dhal, Bhagirathi Nayak
Department of Business Administration, Sri Sri University, Ward No -3, Godi Sahi
Cuttack Odisha 754006, India
sunildhal@srisriuniversity.edu.in
bhagirathi.n@srisriuniversity.edu.in

ABSTRACT: *There are many management applications such as disaster management, air pollution management, weather management, traffic control management etc. which requires continuous attentions and prompt actions. Inclusion of theory of management support and timely decision to any un-managed system will improve the performance, usability and sustainability. Wireless Sensor Network is a self build infrastructure which deployed on the areas where there is no continuous power supply to the sensor nodes. There are many researches and approach has been proposed and protocols designed to address the network performance. We analyzed and identified the issue areas where management support and timely organized decisions improve the wireless sensor network performance. We categorized the system based on levels of management and presented our proposed protocols in all levels with process flow and performance comparisons through our simulation models.*

Keywords: WSN Management, Cluster Management, Hierarchical Cluster

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1. Introduction

In any management applications it requires the related data to take decisions and requires continuous attentions and actions. With the implementation of different levels of management concepts and best practices, the underlying system and organization performs in a better production manner. Every organization follow the below model of management as shown in figure-1.

1. Low Level Management

In this level, very short periodic/daily work execution level decisions are made. This level of management has very limited authority but have the responsibility to complete the work with smooth execution. It makes a link to the next level (middle level) management and the employees.

2. Middle Level Management

This levels of management provides support of coordination among all departments, and responsible in execution of plan and policies proposed by the top level of management. This level also prepare short term plans and provides the feed backs and suitable future proposal advise to the top level management for future actions.

3. Top Level Management

Top level management determines the objective, policies, plans. They mostly plan for organizing and forecasting the organization future path. They are responsible for long term plans and its executions. They decide to add/remove policies with future view of benefits.

Wireless Sensor Network is a self organized infrastructure where the sensor nodes are deployed on large amount in a specific area under the scope to sense the environmental properties. These sensor nodes could be deployed in battle fields, forests, mountains, green fields, watery areas to sense the different target properties under the scope. These devices are capable of

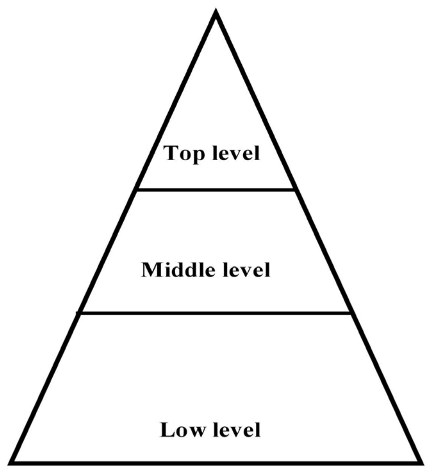

Figure 1. Level of Management

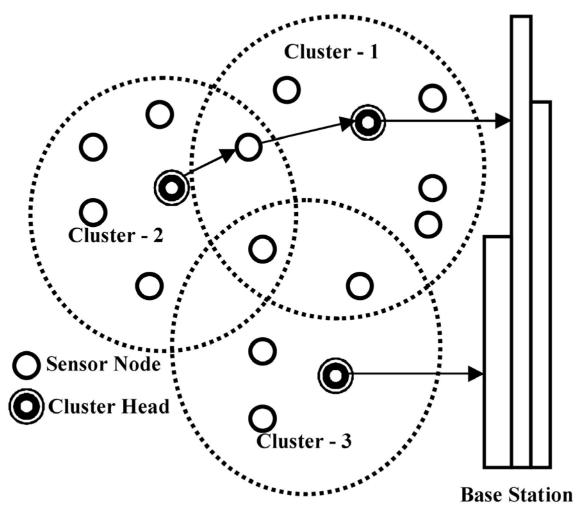

Figure 2. Wireless Sensor Network with cluster based Infrastructure

communication, computation, sensation and operated with battery. The sensor nodes sense the environmental target properties change and communicate the sensed message to the base station[1] directly or through intermediate nodes. Figure-2 shows a typical wireless sensor infrastructure which is cluster based. Each cluster associated with a cluster head elected by the cluster member sensor nodes and is responsible to collect the data from member nodes and send to base station. Due to a random deployment, this becomes very difficult to repair such devices or to supply continuous power to sustain the infrastructure for a very long period.

However with large number of nodes, the network management becomes difficult [3]. The infrastructure requires management support. This could be more organized and well managed through the applied management support and concepts which enable the sensor network infrastructure to sustain an extended period.

In this paper we'll discuss about the related work in next section. In section 3 we walk through different issues and our proposed management supported models and their process flows. In section 4, we present our simulation analysis and results followed by our conclusion section.

2. Review of Existing WSN Protocols

There are various WSN protocols have been proposed in relation to energy efficiency. As the sensor nodes are not having continuous power supply, so most of the protocols in this area have attempted to save the sensor nodes energy to extend their network life. Here, in this section, we will discuss few of such protocols in focus to review the related works.

Low Energy Adaptive Clustering Hierarchy (LEACH): LEACH [13] is a cluster-based protocol, which includes distributed cluster formation. The cluster head role is rotated among a few sensor nodes to evenly distribute the energy dissipation in the network. In LEACH, the cluster head (CH) nodes compress the received data, aggregate packet before sending to the base station in order to reduce the amount of information that must be transmitted to the base station. It has been found by the authors, based on their simulation model, to have a better performance in the extension of network lifetime only 5% of the nodes need to act as cluster heads.

Power-Efficient Gathering in Sensor Information Systems (PEGASIS): Power-Efficient Gathering in Sensor Information Systems (PEGASIS) [10] is a near optimal chain-based protocol which is proposed for an enhancement over LEACH protocol. The basic idea of the protocol is that in order to extend network lifetime, nodes need only communicate with their closest neighbors and they take turns in communicating with the base-station. When the round of all nodes communicating with the base-station completes, a new round will start and so on. This reduces the power required to transmit data per round as the power draining is spread uniformly over all nodes. Hence, PEGASIS has two main objectives. First, increase the lifetime of each node by using collaborative techniques and as a result the network lifetime will be increased. Second, allow only local coordination between nodes that are close together so that the bandwidth consumed in communication is reduced. Unlike LEACH, PEGASIS avoids cluster formation and uses only one node in a chain to transmit to the BS instead of using multiple nodes.

Reverse Transmission: Reverse Transmission [12] is another protocol to attempt minimizes the energy Consumption by avoiding the reverse path transmission. As shown in figure – 3(a), the node collect the information from neighbor node send the data to cluster head and cluster head again send the same message back to the same forwarding node as the node is on the cluster head path to the base station. RTRA proposes to avoid the reverse transmission and forward the collected information towards the base station instead of forwarding to cluster head. This protocol had shown a good performance improvement over the Flooding based LEACH & PEGASIS protocol.

3. Issues without Management Support & Remediation

There are various management support strategy could be placed in order to enhance the performance of the wireless sensor network infrastructure. Based on the different topology and wireless network functionality, we divide the infrastructure where the management support could be placed broadly into 3 different sections.

1. Low Level Management - At Node Level

2. Middle Level Management - At Network Topology Level

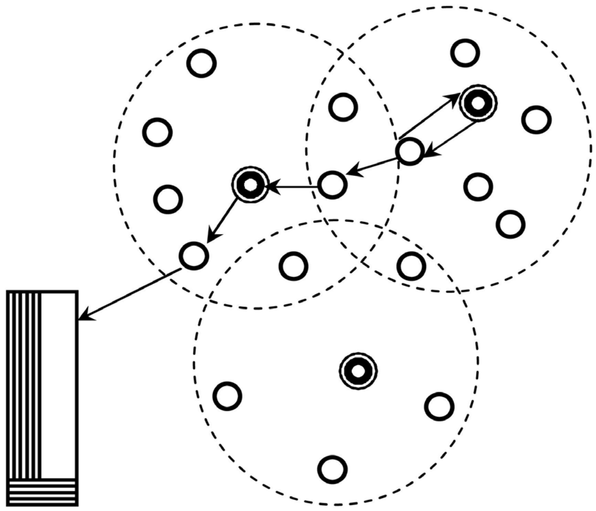

Figure 3(a). Traditional Approach for Data Transmission

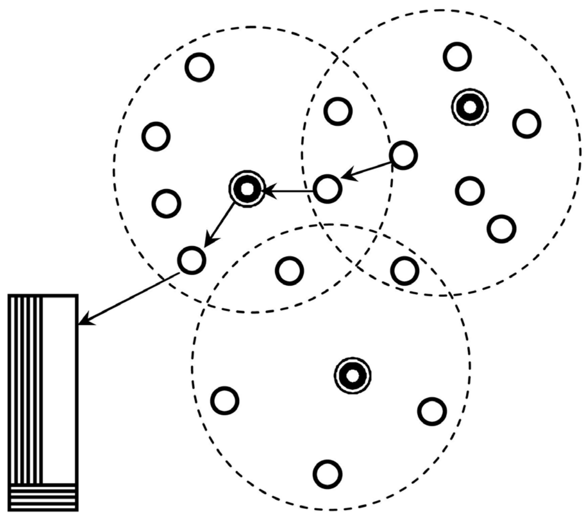

Figure 3(b). RTRA Approach for Data Transmission

3. Top Level Management - At Base Station Level

Low Level Management - At Node Level: Node level decisions could be compared with low level management where specific elementary decisions could be taken to optimize the network management cost. There are main issues associated with node to optimize the energy usage in order to enhance the network lifetime [2]. The performance of the network could also be optimized through optimizing the network topology and through the route path discovery decision. In this context the following two are two main areas where the power dissipation could be optimized.

Optimizing the Route Path: There are many protocols have been approached e.g. LEACH [13], PEGASIS [10], RTRA [12], where the route path could be optimized based on different approach and mechanism. However RTRA is a specialized model which fits to all clusters based network topology and enables the nodes to take decision to choose the optimized path. However, failure of correct routing protocol choice will lead to maximize the energy dissipation and will lead to reduce the network lifetime.

Avoid of Redundant Packet Forwarding: In this head, the nodes need to take elementary decision whether to forward the packets to the next neighbor node or not. As redundant packet forwarding decision will lead to dissipate more senders' amplifier energy as well as receivers' receiving energy. If the decision support in place to provide a decision whether to send the network packet to the neighbor or not, then it will save both senders' and receivers' energy and hence improve the network lifetime. In Delay-and-Forward mechanism will enhance the nodes' capability to take the decision whether to forward the packet or not.

There would be a situation where the individual node has two neighbors which are positioned in approximately same distance as shown in below figure. In such situations, we propose a Managed Neighbor Forward (MNF) approach which will saves the powers in redundant information sent to two neighbors.

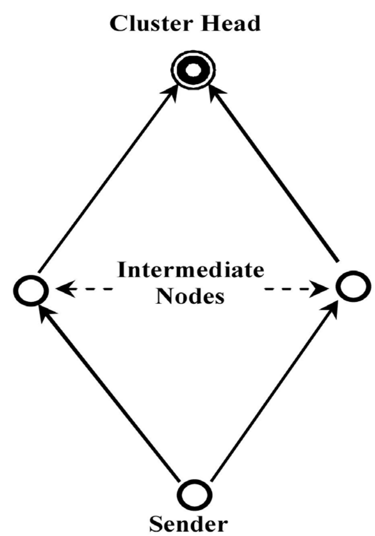

Figure 4(a). A scenario of Redundant Packet Forward

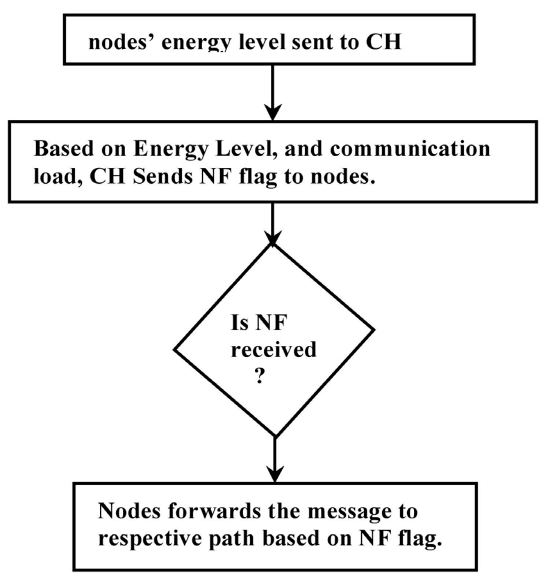

Figure 4(b). MNF Flow Process

The MNF Process could be followed as show in figure-4(b). In short, all nodes send their energy level to cluster head (CH). Cluster head also aware of the communication load on each intermediate node as it is receiving the data packets for few rounds of communications. The cluster heads based on the loads on intermediate nodes and their energy levels, will makes decision whether node to send in left neighbor or right neighbor and sends the flag to the nodes. Once receives this flag from cluster head, the nodes sends the data in that respective route and avoids the redundant data packet forward. In this model, if the cluster head is heavily loaded for making right decision, then base station could help CH to take appropriate decision.

The execution algorithm for MNF process flow is as follows.

Algorithm 1 : MNFExecution

```
Step 1. for each node do
            Send Residual Energy to Cluster Head
        done
Step 2. for each message_recvd do
            if hopCount>2 and  count(message_recvd) >=2 then
                Compare Residual Energy of Intermediate Nodes
                Compare Communication load of Intermediate Nodes
                Evaluate high Residual Energy with low communication load
                Send the NF Flag based on direction through above evaluated node to sender
            end if
        end for
```

Self – Silence: In wireless sensor network, nodes sometimes exhausted their residual energy(RE) due to continuous data transmission. But if data transmission is made a periodic delay especially when nodes are getting exhausted, then the network life time could be enhanced.

In this regard, instead of enforced from the management from being periodic stop from data transmission, it's better to adopt a self-silence for a certain interval. In this regard we propose a protocol named as Pre-Inactive Self Silence (PISS) model where each node should maintain two levels of threshold energy as follows.

Semi-Inactive Threshold

The nodes which reach to this level of threshold energy (SITh) should maintain silence i.e. they should adopt the strategy "No

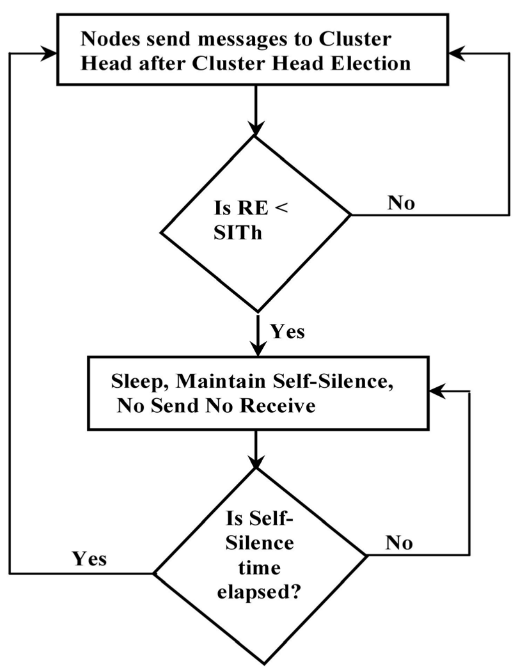

Figure 5. PISS Flow Process

Send, No Receive” for a certain interval. This would reserve some energy level and would utilize to extend the network life time.

Fully-Inactive Threshold

Once this threshold level (FITh) reaches, the node become inactive and will automatically out of the network communications.

The SITh and FITh value is set at the node level during network initialization step [RTRA]. Before each data transmission, the nodes are to verify their residual energy (RE) with the SITh value and if RE below SITh, the node will maintain self silent and will be again activated after the Self silence inactive time. The complete process flow is shown in figure 5. This model initially thought which provides the approach to extend the network life time and later based on this approach another enhanced model is designed which will be discussed in next sub-section.

The PISSExecution algorithm is briefed as below.

Algorithm 2 : PISSExecution

```
Step 1: Node Initialize, set SITh, FITh, self_silence_interval, elect ClusterHead. SITh > FITh.
Step 2: while(message_send) do
            if(RE > SITh) then
                Send Message
                else if(RE < SITh && RE > FITh ) then
                    Sleep(self_silence_interval);
                else if(RE < FITh)
                    Exit from Network Communication
            end if
        end while
```

Middle Management - Network Topology/Cluster Head level: Network topology i.e. cluster head level in case of clustered based network could be compared to a middle level management where managing the low level managed node will improve the resource utilization and reduction of network management cost by managing the set of nodes efficiently. In this purpose, the two important management theories could be applied.

1. Execute the plans & policies set by Top management

2. Supervise and coordination with the Low-level management

3. Short term plans & Implementations

All existing WSN infrastructures are lack of middle level management strategy which is a major disadvantage and failures of the network sustainability. Many theories have been attempted and implemented to reduce the energy dissipation at node level. Those protocols efficiency could be more enhanced if there a managed maintenance and nodes’ coordination plans in place. Here we identified some of the main pain areas in wireless sensor network infrastructure where the middle level management support system could be applied to manage the group of nodes and set of groups to improvise the overall sensor network infrastructure performance.

Lack of Node’s Routing Information: At the each node’s level, the routing information is maintained in their routing table. However, there is no updated routing or back-up information maintained in cluster head level or super cluster head level (a cluster head which capable to control multiple clusters heads). An alternate cluster head which has the same capability with the cluster head and acts as a passive cluster head, selected(not elected) by the cluster head would also be placed to take decisions in case the cluster head dies. This additional supervisory model provides more managed support to the network infrastructure.

Inactive Node Management: There are some nodes in the clusters which have low residual energy but still participate in network communications. This leads to make the node inactive after few rounds of communications. We propose a model named Node Inactiveness Recovery Management (NIRM) to recover each such node recovered from becoming fully inactiveness. The details management steps are as follows.

Algorithm 3 : NIRMExecution

Step 1: Cluster Head to maintain Residual Energy Level & Number of Communications made
Step 2: After certain number of communication node with less residual energy (semi-inactive node) self-stop to participate in next round communications.
Step 3: Cluster Head to decide when and which semi-inactive nodes to activate.
Step 4: send notifications to semi-inactive nodes to start transmitting the message
Step 5: The semi-inactive node starts sending information till it become inactive.

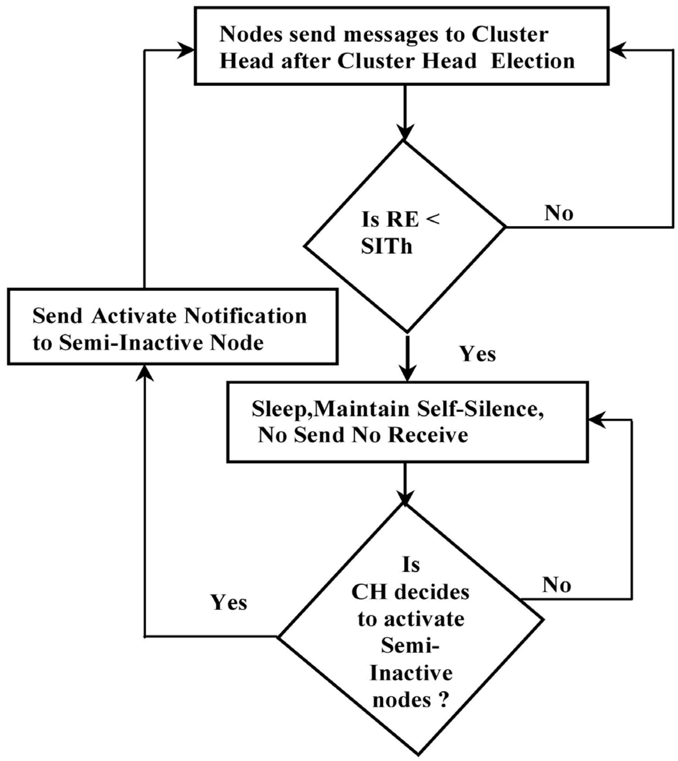

Figure 6. NIRM Flow Process

The CH needs to consider the following factors for the decisions,

• The CH starts receiving the data from very few number of nodes

• Out of all Semi-Inactive nodes, CH will choose those nodes which are falling under the sub-region from where it receives less or no information.

NIRM model process flow is shown in figure 6. This model is an enhancement over the PISS model where the cluster head takes the decision whether to activate the semi-inactive node unlike to PISS models self reactivation after self-silence inactive time.

Top Management – Base Station level: There is no management regulatory model in place for any of the proposed wireless sensor network infrastructure. If a regulatory model could be imposed then the network health could be monitored and remediated at a regular interval. Here we can discuss two cases which would be regulated through the implementation of regulatory model.

Supervised Maintenance: There are situation exists where a very few node (<~2%) of nodes remains active from a cluster and they are/or not providing any complete information (as they are non-periphery nodes). We can call such regions as semi-maintainable clusters. In such situation, there is absolute a decision model in place to take a decision whether to continue with this regions (if it may provide very important information in later periods)or we need to discard that regions which will enhance the network life time.

Semi-Active cluster Identifications: It's realized that if all nodes in a zone (set of clusters) became inactive then automatically there is no communications from the respective clusters and the network infrastructure will continue the communications with the active nodes. However, if this could be detected early where the energy level of the clusters approaching threshold level and the zones will be identified as Non-Active or semi-active zones, and hence there should be a decision to be taken whether to continue with the semi-active zones or need to discard for a certain time interval or completely discard from the network infrastructure future communications.

To address this un-attended behavior of the WSN infrastructure, we propose Cluster Activeness Identification and Remediation (CAIR) model which involves identifying the activeness of the clusters and based on decision logic, the cluster will become the part of future communications or will be discarded from the future communications. Once the decision is made, the respective information will be sent to the respective neighbor clusters.

As shown in figure 7(a), the Semi-Active cluster which has only two nodes active and to maintain a cluster and cluster head responsibility will be more cost effective. According to management theory, this Semi-Active cluster could become a part of the neighbor cluster and instead of two cluster head (in figure 7(a)), in new single active cluster only one cluster head as shown in figure 7(b). The active nodes of Semi-Active cluster will send their data through the neighbor cluster head, and managing an extra cluster head cost(residual energy) is reduced.

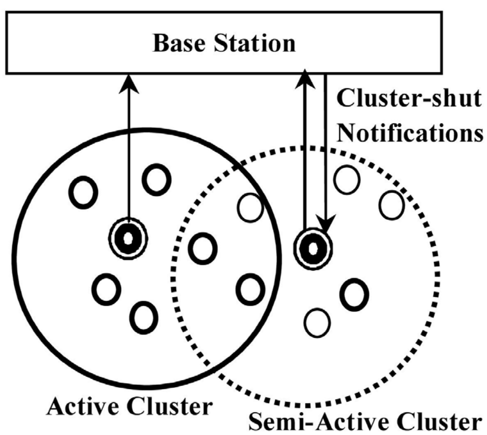

Figure 7(a). Existing Modeled Clusters, No Cluster Activeness Identification

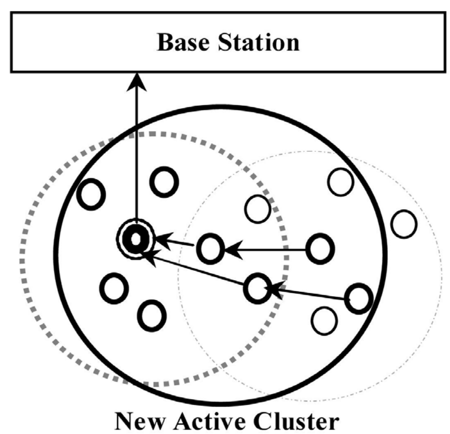

Figure 7(b). Cluster Activeness Identification & Remediation

The basic steps of this CAIR model is as follows.

Algorithm 4 : CAIRExecution

Step 1: Base Station receives all cluster head's information
Step 2: Base Station to evaluate the cluster strength and identify the cluster head which sends less information
Step 3: Base station sends the cluster-shut notifications to such identified cluster heads
Step 4: After receiving cluster-shut notification, cluster head to send re-elect notification.
Step 5: After receiving reelect notification, node will participate in a new election process or will rely to become part of another cluster by sending the data to another neighbor.

4. Simulations & Performance Analysis

We have taken all the above discussed proposed modes and have compared with existing protocols e.g. PEGASIS, RTRA. The following wireless sensor node and environment parameters have been taken during the simulation analysis.

• Each node has an initial residual energy of 200 J

• $\in_r$ = 50nJ/bit i.e. 50nJ receiver circuit energy requirement 1 bit information processing

• $\in_{ta}$ = 100pJ/bit/m^2 i.e. 100pJ transmitter amplifier energy requirement to brad cast 1 bit message in a 1m^2 area

• $\in_{te}$ = 100pJ/bit i.e. 100pJ receiving amplifier energy requirement to receive 1 bit information

• Location of base station (x, y) = (*random, random*)

• Data packets size p_d = 1024bits

• Wireless coverage of each node = 8.0 m

With the above wireless sensor nodes and environment's parameter we simulate our proposed models. In below figure 8(a), we found that the MNF protocol has a better efficiency over RTRA and PEGASIS protocols. Initially MNF protocol has consumed more energy due to the initial setup and initial communication with base station regarding the location and residual energy information. After few initial rounds (approximately 5 rounds) of communications, it found that MNF had better energy efficiency.

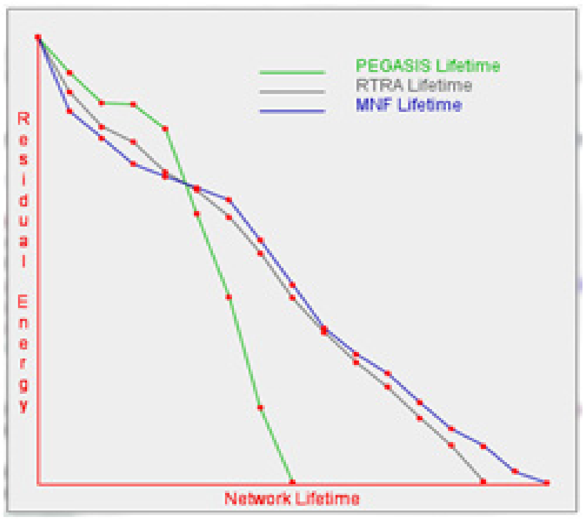

Figure 8(a). Residual Energy with life time for PEGASIS Vs RTRA Vs MNF Protocol

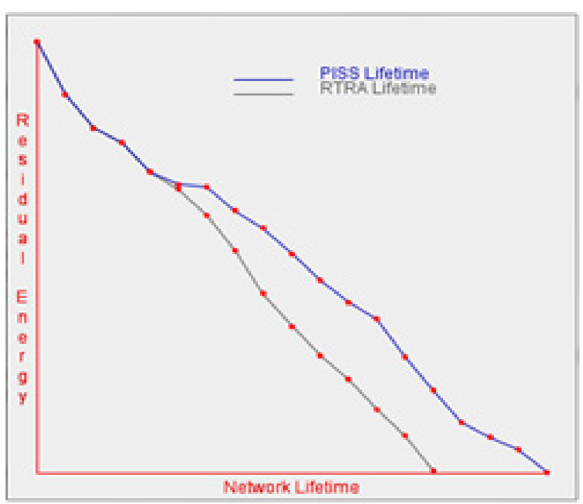

Figure 8(b). Residual Energy with life time comparison for RTRA Vs PISS Protocol

Similarly in Figure 8(b), the result shows that the PISS Lifetime has a better gain over the RTRA Lifetime. In this scenario, the PISS protocol have maintained same energy consumption as RTRA (As PISS algorithm is implemented over RTRA protocol), and after approximately 6 rounds of communications, the PISS based model adopted self silence and had started to save the energy consumption. We noticed that an approximate of 17.27% of energy saving occurred in case of PISS model over RTRA.

In figure 8(c), we again compared our newly proposed NIRM, PISS with RTRA protocol residual energy level with respect to network life time. NIRM protocol performed less during initial time as the cluster head to decide and send the activation and inactivation notifications to the respective nodes. However, the network performed well as soon the cluster head made the decisions and the network life time of NIRM has been extended as compared to PISS and RTRA based protocols.

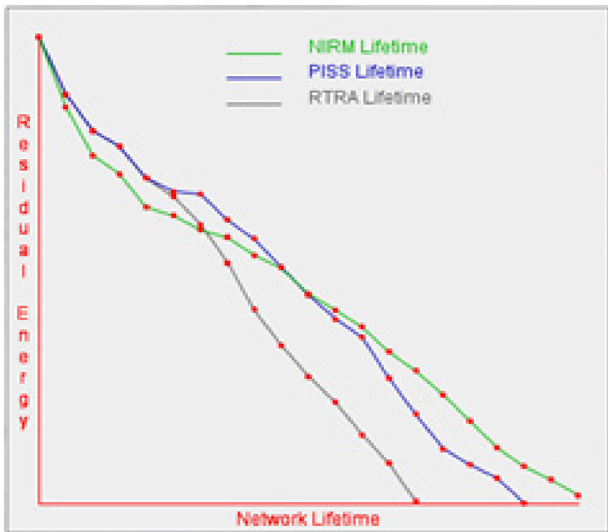

Figure 8(c). Residual Energy with life time for RTRA Vs PISS Vs NIRM Protocol

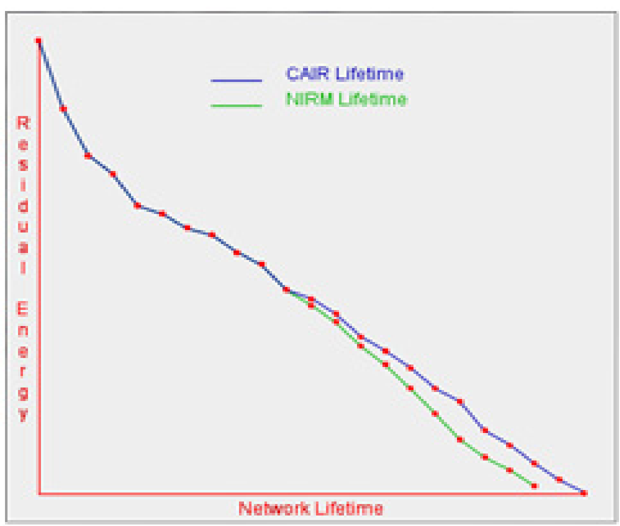

Figure 8(d). Residual Energy with life time for CAIR Vs NIRM Protocol

The CAIR Lifetime is compared with NIRM based model life time as shown in figure 8(d). It found that the base station takes a longer time to identify the inactive zone, and when it identifies, it dissipates more energy to re-cluster the network but at final rounds of communications it has a better energy savings (approximately 8.23%) over the NIRM protocol.

5. Conclusion

We have analyzed and identified the areas and issues that stay with the wireless sensor network infrastructure without management support model. There some management supported WSN models (MNF, PISS, NIRM and CAIR protocols) at different level of management has been organized and presented with their step-by-step process and flow. In this relation, we also simulated our work and compared the proposed models with other existing protocols. We have also compared our proposed model in one management level with other management level and found a good improved performance results and sustainability. The integration of all management level models and with other management support models is the future scope of this study.

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