DATA AGGREGATION IN WIRELESS SENSOR NETWORK

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Abstract

The fast advancement of hardware technology has enabled the development of tiny and powerful sensor nodes, which are capable of sensing, computation and wireless communication. This revolutionizes the deployment of wireless sensor network for monitoring some area and collecting regarding information. However, limited energy constraint presents a major challenge such vision to become reality. Data communication between nodes consumes a large portion of the total energy consumption of the WSNs. Consequently, Data Aggregation techniques can greatly help to reduce the energy consumption by eliminating redundant data traveling back to the base station (sink).This paper signifies the various data aggregation techniques in wireless sensor network and implementation of a data aggregation technique in wireless sensor networks. The main goal of data aggregation is to gather and aggregate data in an energy efficient manner so that network lifetime is enhanced. To provide energy efficiency we have designed energy efficient data aggregation method named E-BIN. We have considered a cluster-based wireless sensor network. Our method executes on each cluster independently and provides an energy efficient data aggregation in a cluster and hence maximize network lifetime for whole network.

Keywords- Wireless Sensor Network, Sensor Node, Data Aggregation, Sink, Surve, E-BIN.

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I.INTRODUCTION

WSNs Networked devices that are capable of sensing, computing & communicating. WSNs consist of many sensor nodes and one or more base station (BS) or sink. Wireless sensor nodes are very small in size and have limited processing capability with very low battery power this restriction of low battery power makes the sensor network prone to failure. It has also a sensing element and a transceiver. Sensor nodes sense the physical environment periodically, process it and send the data in the form of signals to the base station. WSN is a fast growing technology. These networks have huge application. Monitoring, disaster management, security and military etc. The frequency of data reporting and the number of sensors which report data usually depends on the specific application. Wireless sensor networks are new class of distributed systems that are an integral part of the physical space they inhabit [1]. WSN technology has the capability of quick capturing, processing, and transmission of critical data in real-time with high resolution. WSN is an emerging field with many applications in almost all walks of life. As soon as people understand the capabilities of a wireless sensor network, hundreds of applications spring to mind. Basic features of sensor networks are self-organizing capabilities, dynamic network topology, limited power, node failures & mobility of nodes, short-range broadcast communication and multi-hop routing, and large scale of deployment. The strength of wireless sensor network lies in their flexibility and scalability. The capability of self-organize and wireless communication made them to be deployed in an ad-hoc fashion in remote or hazardous location without the need of any existing infrastructure. Through multi-hop communication a sensor node can communicate a far away node in the network. This allows the addition of sensor nodes in the network to expand the monitored area and hence proves its scalability & flexibility property.

Figure 1 shows a typical sensor network deployment. Each of these sensor nodes has the capabilities to collect data and route data back to the sink. The sensors coordinate among themselves to form a communication network such as a single multi-hop network or a hierarchical organization with several clusters and cluster heads. While sending the data by its transceiver some amount of energy is consumed. Sensor nodes have less amount of energy so energy conservation is the important factor in sensor network.

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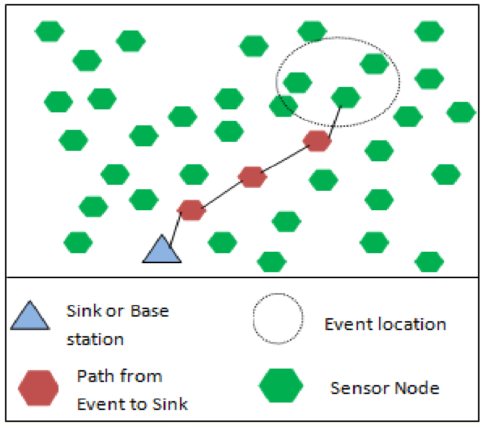

Figure1. A typical sensor network deployment

However, because sensors have severe resource constraints in terms of power, processing capability, memory and storage. It is challenging to provide efficient solutions to the data-gathering problem. Energy limitations have been an especially pressing issue that affects the design of WSNs at all layers of the protocol stack. There are various mechanisms such as shutting down the radio, eliminating control packets, and using topology-management algorithms to reduce energy consumption in WSNs. Data aggregation is also among those mechanisms utilized to save energy and achieve energy efficiency.

II .DATA AGGREGATION : AN OVERVIEW

Data Aggregation Technique explores how the data is to be routed in the network as well as the processing method that are applied on the packets received by a Node. Data Gathering or Data Aggregation is the process of systematically sensed data from the multiple sensor nodes to base station. For instance, WSNs may have a lot of redundant data because multiple sensors can sense similar information when they are close to each other. Therefore, there is no need to send the same information to the BS more than once when a summary of the readings from those sensors can be sent. Thus, data aggregation will decrease the number of transmissions in the network, eventually reducing the bandwidth usage and eliminating unnecessary energy consumption in both transmissions and receptions. Data Aggregation may help reduce the number of transmissions and hence energy consumption. It may adversely affect other performance metrics such as delay, accuracy, and security. These types of data aggregation are called In-Network data aggregation where packets are combined before reaching the base station. Data Aggregation in WSNs is done by the intermediate nodes en route to the BS incrementally. It is usually referred as in-network Data Aggregation [2].

They have a great impact on the energy consumption of nodes and thus on Network efficiency by reducing number of transmission or length of packet. Elena Fosolo *et al.* in [3] defines the in-network aggregation process as follows: "In-network aggregation is the global process of gathering and routing information through a multi-hop network, processing data at intermediate nodes with the objective of reducing resource consumption, thereby increasing network lifetime." Figure 2 shows effect of data Aggregation.

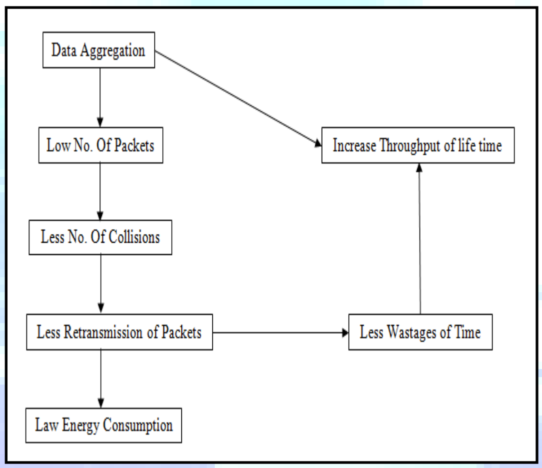

Figure 2. Effect of Data Aggregation

III.TECHNIQUES OF DATA AGGREGATION

The Techniques of Data Aggregation are divided into two parts: structure based and structure free. Structure based data aggregation can be further divided into four parts flat network based, cluster based, tree based and grid based. Figure 3 shows classification of Data Aggregation techniques.

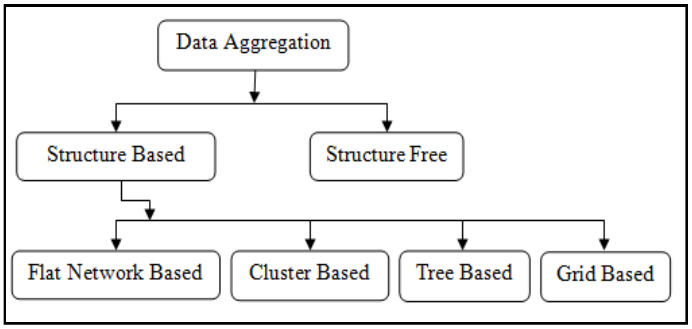

Figure 3. Classification of Data Aggregation Techniques [4]

Focusing on cluster-based approach, the existing protocols assume a sensor network which is divided in to several clusters. Depending upon the protocol operation, each cluster-head receives the data packets from some cluster-member or from all cluster-member nodes directly and then cluster-head perform aggregation operation. In a tree-based network, sensor nodes are formed into a tree where data aggregation is carry out at intermediate nodes along the tree and a compact representation of the data is transmitted to the sink node consider as a root node and source consider as a leaves node.

Taking the advantageous features of Tree-based approach, we have designed our method Energy balance in Network (E-BIN) which takes the merits of both cluster-based and tree-based approach. E-BIN assumes a cluster-based wireless sensor network and applies tree-based approach inside each cluster. When a cluster is formed and cluster-head selected, it consider cluster-head as root and construct an aggregation tree over cluster-m ember nodes. The process of aggregation tree construction requires the sensor nodes to reduce their transmission power as sensor nodes now have to send their data packets to the neighbor node which is selected as parent. Energy consumed in wireless transmission is directly proportional to the square of the distance between nodes in communication. Since cluster-member node now sends their data packets to the neighbor node instead of cluster-head, the transmission distance is reduced and hence the energy consumption of the sensor node. Likewise, overall energy consumption of sense or nodes in a cluster is reduced and so for the whole sensor network. Hence overall network lifetime will be increased.

Energy Balanced In-Network Aggregation is energy-aware as it has taken the residual energy of sensor node in to consideration while constructing the aggregation tree. This method also balances the network load by selecting different parent for a node according to the energy level remain in the sensor node during the aggregation tree construction process. Each parent node performs aggregation of data packet that it receives from its child nodes.

III.SYSTEM & ENERGY MODEL

Consider a homogeneous network of n sensor nodes and a base station or sink node distributed over a region. The location of the sensors and the base station are fixed and known priori. Each sensor produces some information as it monitors its vicinity. We assume that the whole network is divided into several clusters; each cluster has a cluster-head (CH). After the formation of cluster the transmission power of all nodes is adjusted in such a way that they can perform single hop broadcast. Single hop broadcast refers to the operation of sending a packet to all single-hop neighbors [7].

Energy model for the sensors is based on the first order radio model described in [5]. A sensor consumes Eelec = 50 nJ/bit to run the transmitter or receiver circuitry and E amp = 100 pJ/bit/m^2 for the transmitter amplifier. Thus, the energy consumed by a sensor i in receiving a l bit data packet is given by,

$$ERxi = Eelec \,.\, l \qquad (1)$$

While, the energy consumed in transmitting a data packet to sensor j is given by,

$$ETxi,j = Eelec \,.\, l + Eamp.\, di.j^2.\, l \qquad (2)$$

Where, di,j is the distance between nodes i and j.

IV. ENERGY BALANCE IN NETWORK

In cluster based wireless sensor network, the each cluster uses this algorithm independently. In a cluster, the nodes can be categorized as: one cluster-head (CH) and other cluster member node.

- Function of cluster-head (CH)

1. Receive a query from base station.

2. Cluster-head (CH) sends configuration packets to all single-hop neighbors.
3. Receive data packets from all single hop neighbors.
4. Finally aggregate the data packets received and route it to base station.

- Function of cluster member

1. Receive configuration packets from neighbor nodes.
2. Update and forward configuration packets to all single-hop neighbors.
3. Receive data packets from neighbor nodes.
4. Aggregate all data packets by applying redundancy factor and send it to selected Parent node.

The algorithm works in two phases: Configuration packet flow and Data packet flow that are described below.

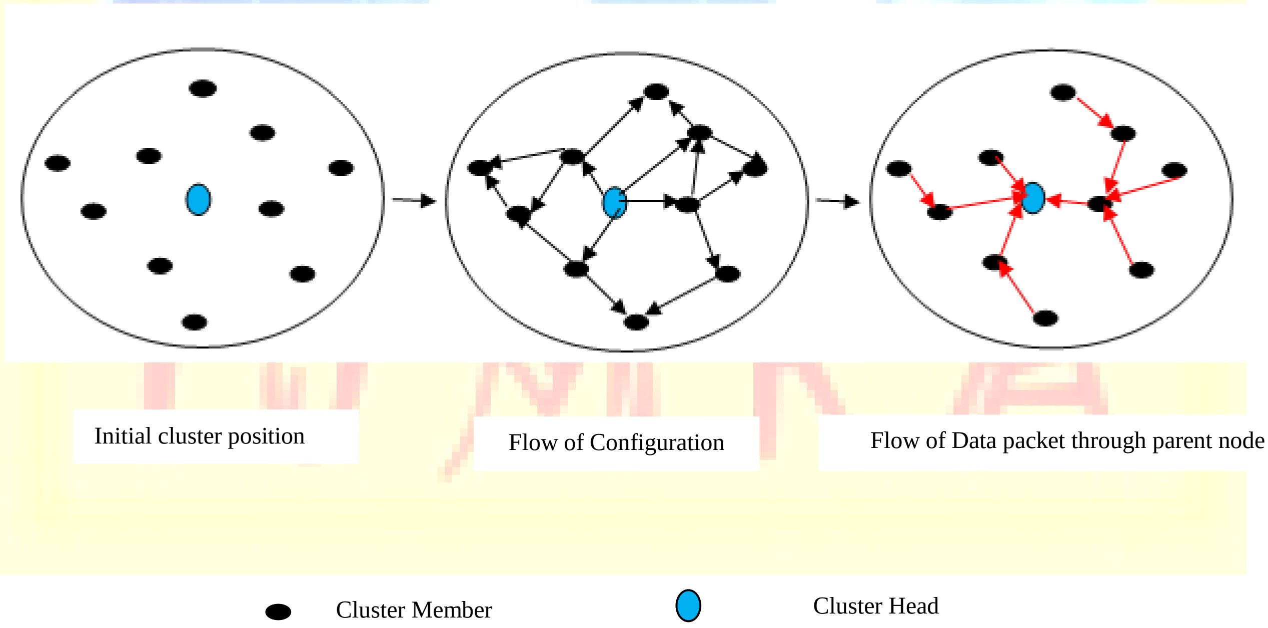

Figure 4. A typical scenario of Data Aggregation in a cluster

- **CONFIGURATION PACKET FLOW**

In Configuration packet flow phase, initially cluster-head broadcast configuration packet to all its neighbors. Configuration packet contains the following fields:

- Node Id -- location of node that each node knows in prior.
- Hop Distance -- distance from cluster-head in terms of hop count.
- Residual Energy -- current energy in node.

Each node upon receiving the broadcast configuration packet that is originated from cluster-head adds the sender of the packet in the list of its possible parents with its node id, hop distance, residual energy. After this the node again broadcast the configuration packet to all its neighbors by updating node id to its own id, incrementing hop distance by one and its own residual energy. This process continues until all the nodes in cluster receive configuration packet. All nodes that broadcast the configuration packet do so by predefined and common signal strength that is known to all the nodes.

- **DATA PACKET FLOW**

When all nodes receives configuration packets, each node now select the parent to which it can forward the data packet. Each node looks in to the list of all its possible parents. The neighbor node which has least hop distance, i.e. closest to cluster-head, is selected as parent by a node. In case when two neighbor nodes have the least but equal hop distance, the node checks the residual energy of two neighbor nodes. The neighbor node that has greater residual energy is now selected as parent. In both the cases, node also calculate the difference of residual energy of two neighbor nodes, which have least hop distance, and checks whether this difference is less than the threshold or not. If it is then the node selects the parent as usual. But if it is not then the node selects other neighbor node as its parent.

After selecting the parent node, each node now forwards its data packet to its parent. When a parent node receives multiple data packets from its neighbor nodes, it performs aggregation operation by eliminating redundancy in the data.

V. SIMULATION ANALYSIS

Many simulation tools are available for wireless sensor networks. Network Simualtor-2 (NS-2) [6], in particular NS-2.34 is chosen, as a tool to simulate the proposed method.

- A square field of 160 x 160 is taken where 10 nodes are randomly deployed. One node is designated as cluster-head (CH) and one node is designated data source.

The snapshot of node scenario in NAM is shown below. The three colors of node show the energy levels of nodes. The initial color of nodes is green. When energy drop to first threshold level the color turns to yellow and when drop to second threshold level the color turns to red. After this level a node is dead and color is red.

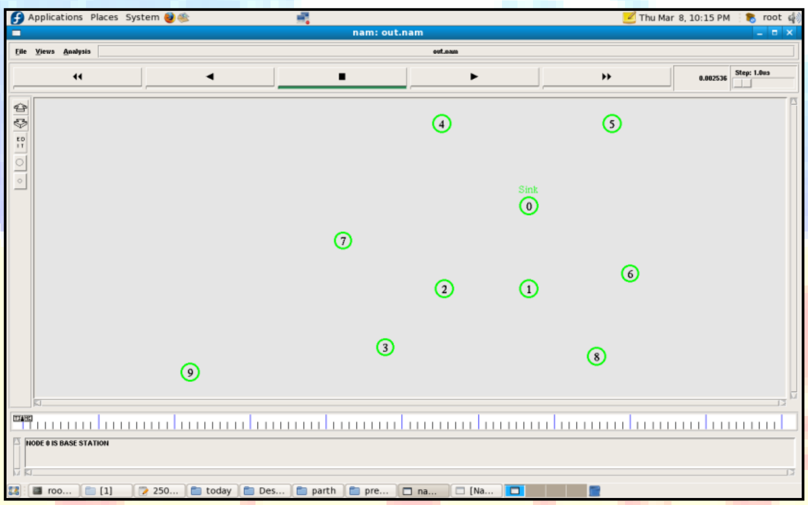

Figure 5. The snapshot of node scenario in NAM

- Energy model is ON. Transmit power, Receive power, idle power, Sleep power, Transition power, and Initial Energy of nodes is set accordingly. Also transmission range is set by controlling the transmit power and receiving threshold of antenna of nodes. All other parameters are taken default values. The value of RXThresh_ is obtained by executing threshold.cc.Snapshot is given below:

```
[root@localhost propagation]# ./a.out -m TwoRayGround -Pt 7.214e-3 100
distance = 100
propagation model: TwoRayGround

Selected parameters:
transmit power: 0.007214
frequency: 9.14e+08
transmit antenna gain: 1
receive antenna gain: 1
system loss: 1
transmit antenna height: 1.5
receive antenna height: 1.5

Receiving threshold RXThresh_ is: 3.65209e-10
[root@localhost propagation]#
```

Figure 6. Snapshot of console

- Some other parameters used are:

Parameters	Values
Channel Type	Wireless 802.11
Propagation Type	Two Ray Ground
MAC protocol	MAC – 802.11
Queue Type	Drop tail
Antenna	Omni Antenna
Queue Length	50
Routing protocol	AODV

- Parameters set for data transfer are:

Parameters	Values
Cluster head	Node 0
Source node	Node 3
Traffic type	CBR
Packet size	1000 bytes

VI. SIMULATION RUN

Case 1: Energy Balance In Network

For Energy Balance In Network, set transmission range of 100m such that a node sends its data to its single-hop neighbor and data is forwarded in a multi-hop fashion. Figure 7 shows the data transfer between node 3 and node 0. Node 1 and 2 are relay nodes. Since the transmission range is set to 100m, node 0 can only send its data to node 2 and so other nodes to its possibly multiple neighbors by exploiting the wireless medium characteristic. Hence data will flow from sources to sink along multiple paths and aggregation can be performed by each intermediate node.

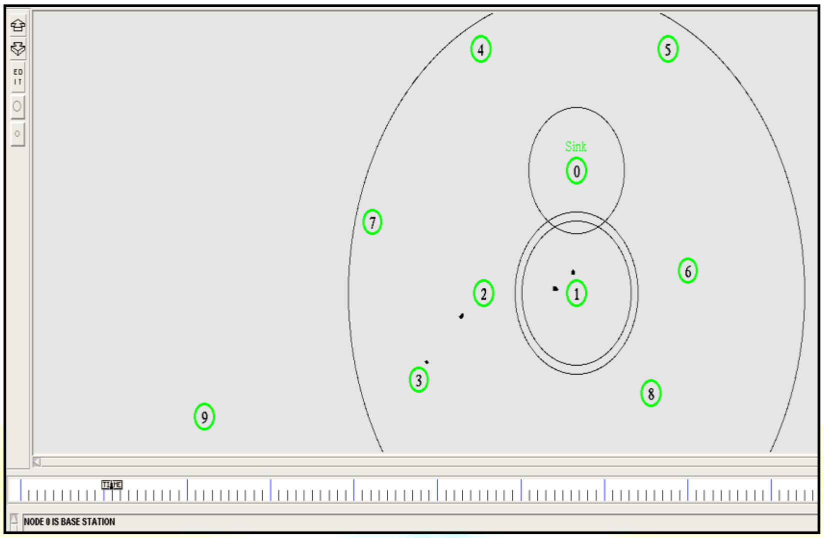

Figure 7. Data transfer between node 0 and 3 through node 1 & 2.

Case 2: Conventional Method

In conventional method, all nodes in a cluster send their data directly to cluster-head. For this reason set transmission range of nodes to be 250m so that source node 3 can send data directly to node 0. The data transfer start between node 3 and node 0 directly which is show in figure 8.

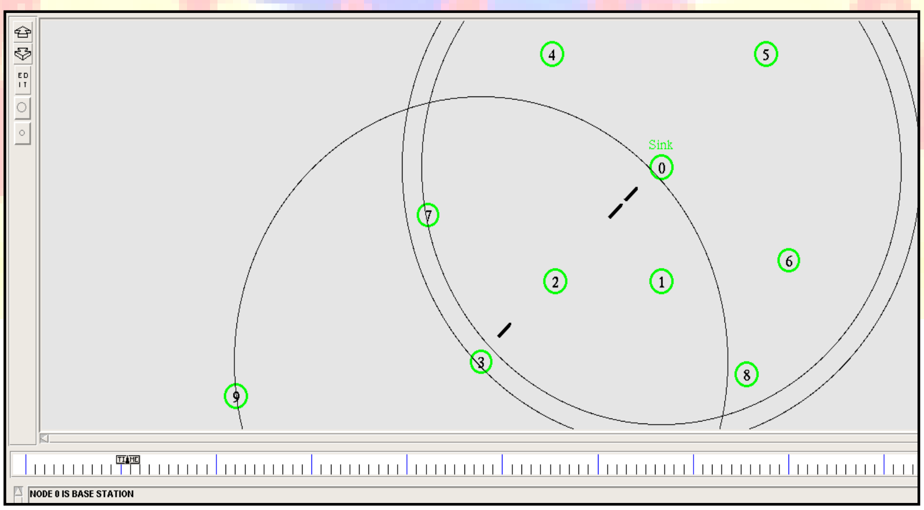

Figure 8. Data transfer between node 3 and node 0

As happened in last case, again after some time energy level of node 3 and node 0 decreased to first threshold level and color of nodes change from green to yellow and then energy level of both nodes go down to second threshold level and nodes turn to red.

VII. SIMLATION RESULT

A. CONSERVING ENERGY

Residual energy of the source node, which is defined as the remaining energy of a node and considered that as the metric to prove energy efficiency of Energy Balance in Network. Figure 9. Shows the significant reduction in energy consumption by using Energy Balance In Network when compared with conventional Method. This shows the benefit of sending data in a multi-hop fashion towards cluster-head.

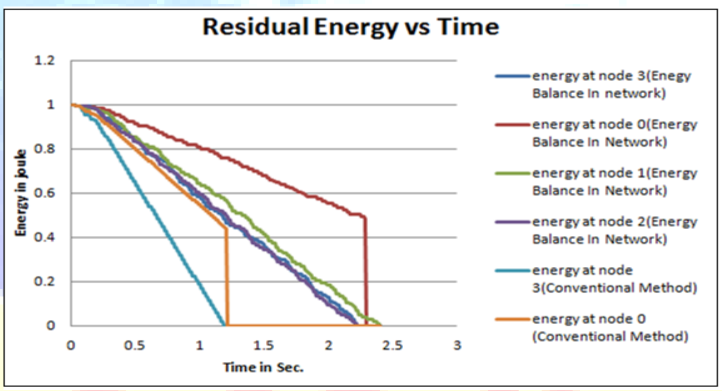

Figure 9. Residual Energy Vs Simulation Time

B. PACKET DELIVERY RATIO

Besides examining the network lifetime extension roughly via energy saving, we also evaluate the network efficiency influenced by E-BIN. Here, the efficiency in term of data delivery ratio, which is defined as the number of received packets divided by the number of sent packets for a certain time period. Simulation results illustrated in figure 10, Shows the stable performance of E-BIN. When the network energy is running out, the data delivery ratio collapses rapidly. This phenomenon probably can be taken as a sign of the network death.

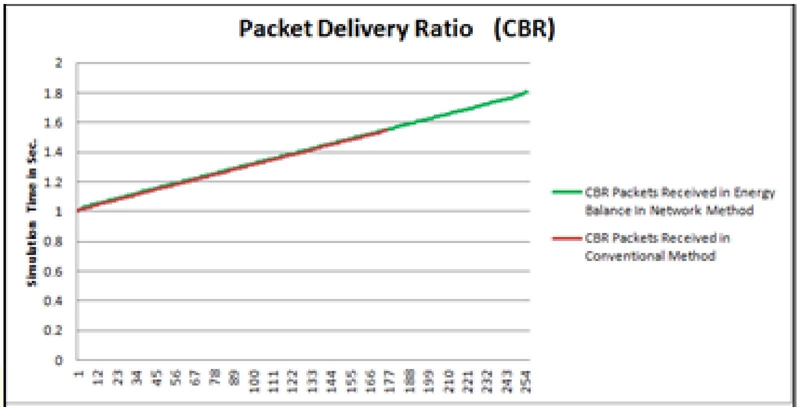

Figure 10. Simulation Time Vs. Packets (CBR) Received

C. NETWORK DENSTIY

By considering the changes in the network density, we also study the relationship between the network lifetime and network density. In our experiment we have considered the change in the residual energy of source node i.e. node 0 in the end of simulation. The density of network is calculated via equation [8]:

$$\lambda = N\pi R^2/A^2$$

Where, N is sensor number,

R is sensor range,

A is sensor area.

By keeping network area constant and increasing the number of nodes, we have increased network density. Due to increase in the network density, the hop count between source node and sink node also increases. When hop count increases node now transmit data to nearer node with less transmit power and hence consume less energy. Figure 11. Shows the increase in the residual energy when we increase the hop count. We have taken N as 10, 20, 30 and 40.

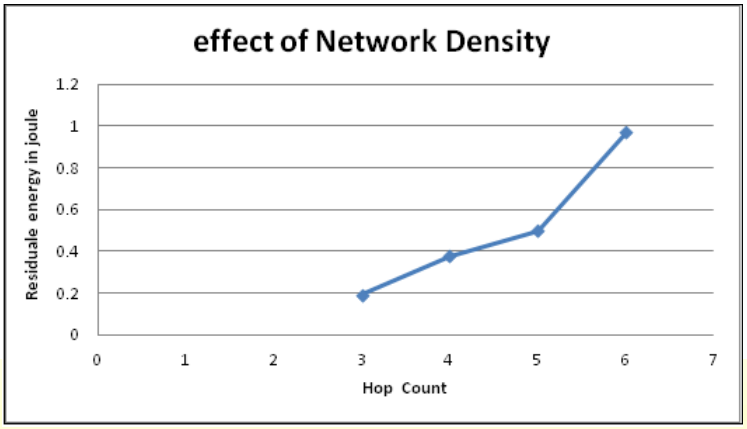

Figure 11. Residual energy Vs Hop count

D. NUMBER OF DATA PACKETS TRANSMITTED

Comparison of Conventional Method and Energy Balance in Network regarding energy optimization in sensor networks has shown that both the energy spent in transmission and reception of packets contributes significantly to the energy dissipation in the network. Hence reducing the number of packets transmitted and received results in significant network energy savings. Figure 12, shows no. of transmission Vs Simulation time.

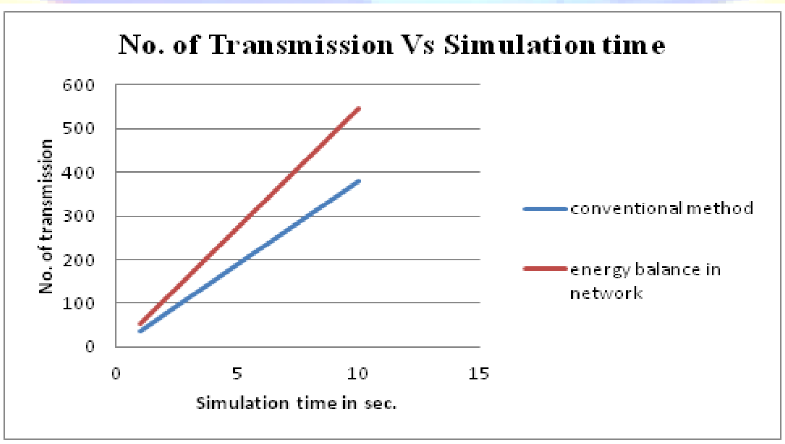

Figure 12. No. of transmission Vs Simulation time.

VIII. CONCLUSION

Wireless sensor networks are energy constrained network. Since most of the energy consumed for transmitting and receiving data, the process of data aggregation becomes an important issue and optimization is needed. Efficient data aggregation protocols not only provide energy conservation. There exist several protocols for data aggregation which uses different approaches to provide energy efficiency. Energy Balance In Network uses the advantageous features of cluster-based and tree-based approaches. It requires a wireless sensor network which is divided in to several clusters, each having a cluster-head. Each cluster then uses Energy Balance In Network approach independently and avoids aggregation only at cluster-head by constructing an aggregation tree rooted at cluster-head. The difference between Energy Balance In Network and other cluster-based approach lie in the reduction of transmission power of node as in Energy Balance In Network a node send data to its neighbor node instead of sending to cluster-head. This is the main performance improvement factor of Energy Balance In Network.

The simulation result shows that when the data from source node is send to cluster-head through neighbors nodes in a multi-hop fashion by reducing transmission and receiving power, the energy consumption is low as compared to that of sending data directly to cluster-head.

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