Improvement in End-to-End delay and Energy Consumption using Routing Algorithms in Wireless Sensor Network

Sunita, O.S Khanna, Amandeep Kaur

Abstract- ***The popularity of Wireless Sensor Networks has increased tremendously due to the vast potential of the sensor networks to connect the physical world with the virtual world. In wireless sensor network one of the main problems is related to energy issue because every node is operated by battery. In wireless sensor networks, sensors consume energy both in sensing data and in transmitting the sensed data to a base station. The power consumption for transmitting data is an exponential function of the distance from the sensor to the base station, while the power consumption for sensing data is determined by the type of sensor as well as the routing protocol. The problem in this paper is to increase the life time of the sensor networks. To have large network life time all nodes need to minimize their energy consumption. Node is composed of small battery so that the energy associated with this node is very less. So replacing and refilling of battery is not possible which is very costly. Hence some techniques are applied through which the energy associated with each node can be conserved. This paper proposes two algorithms, to minimize the energy consumption and end-to-end delay. Using both algorithm, there is improvement in energy consumption and end-to-end delay***

Keywords- ***Wireless Sensor Networks, Energy Consumption, Multi-path Routing, Lifetime of wireless sensor network, end- to-end delay.***

I. INTRODUCTION

The emerging field of wireless sensor networks (WSN) combines sensing, computation, and communication into a single tiny device. Recent advances in wireless communication made it possible to develop wireless sensor networks (WSN) consisting of small devices called micro-sensors, which collect information by cooperating with each other. These small sensing devices are called nodes. A sensor is any device that maps a physical quantity from the environment to a quantitative measurement. For example, in some military or surveillance applications it might be microscopically small. Its cost depends on its parameters like memory size, processing speed and battery [1]. The power of wireless sensor networks lies in the ability to deploy large numbers of tiny nodes that assemble and configure themselves.

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Usage scenarios for these devices range from real-time tracking, to monitoring of environmental conditions, to ubiquitous computing environments, to monitor the health of structures or equipment. While often referred to as wireless sensor networks, they can also control actuators that extend control from cyberspace into the physical world.

The most straightforward application of wireless sensor network technology is to monitor remote environments for low frequency data trends. For example, a chemical plant could be easily monitored for leaks by hundreds of sensors that automatically form a wireless interconnection network and immediately report the detection of any chemical leaks [2][3]. Unlike traditional wired systems, deployment costs would be minimal. Instead of having to deploy thousands of feet of wire routed through protective conduit, installers simply have to place quarter-sized device. The following steps can be taken to save energy caused by communication in wireless sensor networks.

- To schedule the state of the nodes (i.e. transmitting, receiving, idle or sleep).
- Changing the transmission range between the sensing nodes.
- Using efficient routing and data collecting methods.
- Avoiding the handling of unwanted data as in the case of overhearing.

In WSNs, the only source of life for the nodes is the battery. Communicating with other nodes or sensing activities consumes a lot of energy in processing the data and transmitting the collected data to the sink. In many cases (e.g. surveillance applications), it is undesirable to replace the batteries that are depleted or drained of energy. Many researchers are therefore trying to find energy-aware protocols for wireless sensor networks in order to overcome such energy efficiency problems as those stated above.

All the protocols that are designed and implemented in WSNs should provide some real-time support as they are applied in areas where data is sensed, processed and transmitted based on an event that leads to an immediate action. NEAP-Novel Energy Adaptive Protocol for Heterogeneous Wireless sensor networks is proposed in [4] that distributes load among powerful node. Power-Efficient Gathering in Sensor Information Systems (PEGASIS) protocol is proposed in [5]. 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. HEED protocol is proposed in [6], which terminates in a constant number of iterations, independent of network diameter. A general network lifetime model and a general deployment cost model is proposed in [7] to evaluate multiple sensor network deployment strategies [7].

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Different coverage-aware cost metrics for the selection of the cluster head nodes, active nodes and routers in wireless sensor networks are explored in [8], whose aim is to maintain coverage of a monitored space. A new routing algorithm Adaptive Load-balanced routing algorithm (ALB) is proposed in [9] which is a combination of cross-layer design and minimum interference routing algorithm to avoid link overload.

The remaining paper is organized as follows: Objective of paper is discussed in section II. Methodology is described in Section III. Proposed algorithm is explained in section IV. Result Analysis is discussed in Section V. Then, at last paper is concluded in section VI.

II. OBJECTIVE OF PAPER

In a Wireless Sensor Network (WSN for short), individual sensor nodes, or sensors, are constrained in energy, computing, and communication capabilities. Typically, sensors are mass-produced anonymous commodity devices that are initially unaware of their location. Once deployed, sensors should self-organize into a network that works unattended. Power consumption is always a problem in wireless sensor network. There must be less energy consumption to improve the quality of service of sensor network. The packet delivery should be reliable and scalable for the wireless sensor network for performing and better point of view. The objective of the thesis work is to develop

- An EQSR-based routing protocol
- Implement two algorithms in EQSR-based routing protocol to improve QoS in respect of end –to-end delay and energy consumption.

III. METHODOLOGY

The simulation is carried out using the Network simulator (version 2.35), which simulates the events such as sending, receiving, dropping, forwarding, etc. The wireless channel is used as the sensor nodes deployed communicate wirelessly with each other. The propagation models are used to compute the received power. When a packet is received, the propagation model determines the attenuation between transmitter and receiver and computes the received signal strength. The two-Ray ground Radio propagation model is used. An omni-directional antenna is employed for carrying out the transmissions which can transmit signal over a 360 degree angle. Omni-directional wireless sensor networks are modeled such that a bidirectional link is established between neighboring sensor nodes if they are within communication radius [10].

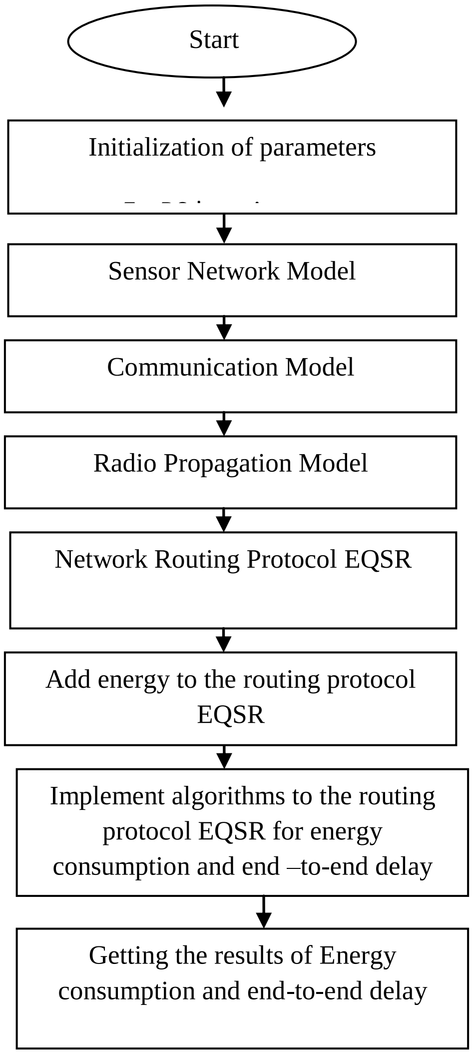

Fig.1.1 Methodology of the proposed work

A. Initialization of parameters

Suppose that there are 200 number of sensor nodes that are randomly deployed in the wireless sensor network of dimension 1000m* 1000m. Sensors have same transmission range of T of 25m. The parameter metrics are energy consumption E, transmission range of T, and end-to-end delay d. The parameters of network are shown in Table I.

Table 1: Parameters of Network

Parameter of Network	Description
T	Transmission range
d	End –to-end delay
E	Energy consumption

B. Sensor Network Model

The three main components of a sensor network are sensor nodes, sink and the sensor network as shown in Fig.1.2. The static nature of senor nodes are always assumed by the network based architectures. The end-to-end delay and the energy efficiency are the two out of main factors on which the lifetime of the whole network depends. The sensed event can be either dynamic or static depending on the application.

For instance, in a target detection/tracking application, the event is dynamic whereas forest monitoring for early fire prevention is an example of static events. Monitoring static events allows the network to work in a reactive mode, simply generating traffic when reporting

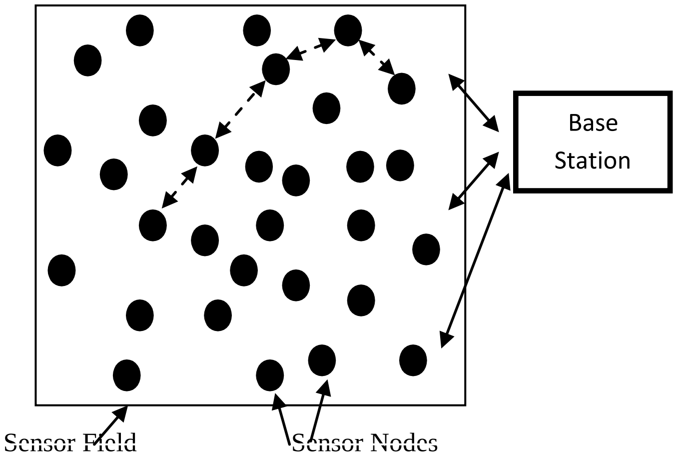

Fig.1.2. Sensor Network Model

To simplify the network model, a few assumptions [11] that are adopted as follows:

1. *N* sensors are uniformly dispersed within a square field *A*. The BS is deployed far away from the square field *A*.
2. All sensors and BS are stationary after deployment. Each node knows the location of BS. Each sensor with enough energy can communicate with BS directly.
3. Sensors can use power control to vary the amount of transmit power depending on the distance to the receiver.
4. Communication is symmetric and a sensor can compute the approximate distance based on the received signal strength if the transmission power is known.
5. All sensors are location-unaware and are homogeneous.

C. Channel Propagation Model

In order to compare different protocols, it is important to have good models for all aspects of communication. This section describes the models that are used for channel propagation, communication energy dissipation and computation energy dissipation [1].

In a wireless channel, the electromagnetic wave propagation can be modeled as falling off as a power law function of the distance between the transmitter and receiver. In addition, if there is no direct, line-of-sight path between the transmitter and the receiver, the electromagnetic wave will bounce off objects in the environment and arrive at the receiver from different paths at different times. This causes multi path fading, which again can be roughly modeled as a power law function of the distance between the transmitter and receiver. No matter which model is used (direct line-of-sight or multi path fading), the received power decreases as the distance between the transmitter and receiver increases [1].

In this thesis, both the free space model and the multi path fading model were used, depending on the distance between the transmitter and receiver, as defined by the channel propagation model. If the distance between the transmitter and receiver is less than a certain cross-over distance (d_0), the Friss free space model is used (d^2 attenuation), and if the distance is greater than d_0, the two-ray ground propagation model is used (d^4 attenuation). The cross-over point [10] is defined as follows:

$$d_o = \frac{4\pi\sqrt{L}h_r h_t}{\lambda}$$

Where

$L \geq 1$ is the system loss factor not related to propagation,

h_r is the height of the receiving antenna above ground,

h_t is the height of the transmitting antenna above ground, and

λ is the wave length of the carrier signal.

If the distance is less than d_o, the transmit power is attenuated according to the Friss free space equation as follows:

$$P_r(d) = \frac{P_t G_t G_r \lambda^2}{(4\pi d)^2 L}$$

Where

$P_r(d)$ is the received power given a transmitter-receiver separation of d,

P_t is the transmit power,

G_t is the gain of the transmitting antenna,

G_r is the gain of the receiving antenna,

λ is the wave length of the carrier signal,

d is the distance between the transmitter and the receiver, and

$L \geq 1$ is the system loss factor not related to propagation.

This equation models the attenuation when the transmitter and receiver have direct, line-of-sight communication, which will only occur if the transmitter and receiver are close to each other (i.e., d < d_o). If the distance is greater than d_o, the transmit power is attenuated according to the two-ray ground propagation equation as follows:

$$P_r(d) = \frac{P_t G_t G_r h_t^2 h_r^2}{d^4}$$

Where

$P_r(d)$ is the received power given at transmitter-receiver separation of d,

P_t is the transmit power,

G_t is the gain of the transmitting antenna,

G_r is the gain of the receiving antenna,

h_r is the height of the receiving antenna above ground,

h_t is the height of the transmitting antenna above ground, and

d is the distance between the transmitter and the receiver.

In this case, the received signal comes from both the direct path and a ground-refection path.

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Due to destructive interference when there is more than one path through which the signal arrives, the signal is attenuated as d^4.

If an omni directional antenna is used with the following parameters: $G_t = G_r = 1$, $h_t = h_r = 1.5$m, L =1 (no system loss), 914 MHz radios, and $\lambda = 3*10^8 / 914*10^6 = 0.328$m.

Using the above parameters, we have: d_o = 86.2m and on putting d_o = 86.2m, following equations simplify to:

$$\begin{cases} 6.82\times10^{-4}\,\dfrac{P_t}{d^2} & : d < 86.2\,m \\ 2.25\,\dfrac{P_t}{d^4} & : d \geq 86.2\,m \end{cases}$$

D. *Radio Energy Model*

There has been a significant amount of research in the area of low-energy radios. Different assumptions about the radio characteristics, including energy dissipation in transmit and receive modes, will change the advantages of different protocols. In this work, a simple model [1] is used where the transmitter dissipates energy to run the radio electronics and the power amplifier and the receiver dissipates energy to run the radio electronics. As discussed in the previous section,

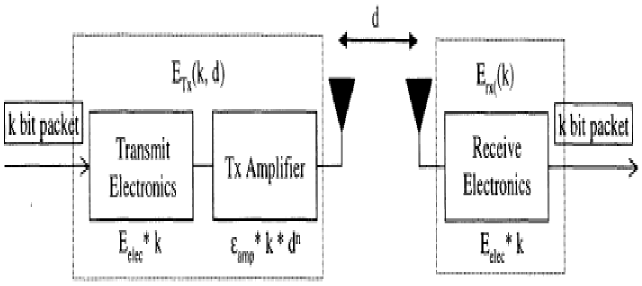

Fig. 1.3. Radio energy dissipation model [1]

The power attenuation is dependent on the distance between the transmitter and receiver. For relatively short distances, the propagation loss can be modeled as inversely proportional to d^2, whereas for longer distances, the propagation loss can be modeled as inversely proportional to d^4. Power control can be used to invert this loss by setting the power amplifier to ensure a certain power at the receiver. Thus, to transmit a k-bit message a distance d, the radio expends:

$$E_{Tx}(k,d) = E_{Tx\_elec}(k) + E_{Tx\_amp}(k,d)$$

$$E_{Tx}(k,d) = \begin{cases} kE_{elec} + k\varepsilon_{friss\_amp}d^2 & : d < d_o \\ kE_{elec} + k\varepsilon_{two\_ray\_amp}d^4 & : d \geq d_o \end{cases}$$

And to receive this message, the radio expends:

$$E_{Rx}(k) = E_{Rx\_elec}(k)$$

$$E_{Rx}(k) = kE_{elec}$$

The electronics energy, E_{elec} depends on factors such as the digital coding, modulation, and filtering of the signal before it is sent to the transmit amplifier. In this thesis, the energy dissipated per bit in the transceiver electronics to be set as: E_{elec} = 50 nJ / bit for a 1Mbps transceiver. This means the radio electronics dissipates 50mW when in operation (either transmit or receiver)

The parameters ε_{friss_amp} and $\varepsilon_{two\_ray\_amp}$ will depend on the required receiver sensitivity and the receiver noise figure, as the transmit power needs to be adjusted so that the power at the receiver is above a certain threshold, $P_{r\text{-}thresh}$. If the radio bit rate is R_b, the transmit power, P_t is equal to the transmit energy per bit $E_{Tx\_amp}(k,d)$ times the bit rate:

$$P_t = E_{Tx\_amp}(k,d)R_b$$

Plugging in the value of $E_{Tx\_amp}(k,d)$ gives:

$$P_t = \begin{cases} \varepsilon_{friss\_amp}R_b d^2 : d < d_o \\ \varepsilon_{two\_ray\_amp}R_b d^4 : d \geq d_o \end{cases}$$

Using the channel models described in the previous section, the received power is:

$$P_r = \begin{cases} \dfrac{\varepsilon_{friss\_amp}R_b G_t G_r \lambda^2}{(4\pi)^2} : d < d_o \\ \varepsilon_{two\_ray\_amp}R_b G_t G_r h_t^2 h_r^2 : d \geq d_o \end{cases}$$

The parameters ε_{friss_amp} and $\varepsilon_{two\_ray\_amp}$ can be determined by setting equation 5.10 equal to P_{r_thresh}:

$$\varepsilon_{friss\_amp} = \frac{P_{r\_thresh}(4\pi)^2}{R_b G_t G_r \lambda^2}$$

$$\varepsilon_{two\_ray\_amp} = \frac{P_{r\_thresh}}{R_b G_t G_r h_t^2 h_r^2}$$

Therefore, the required transmit power, P_t as a function of the receiver threshold and the distance between the transmitter and receiver is:

$$P_t = \begin{cases} \alpha_1 P_{r\_thresh} d^2 : d < d_o \\ \alpha_2 P_{r\_thresh} d^4 : d \geq d_o \end{cases}$$

Where $\alpha_1 = \dfrac{(4\pi)^2}{G_t G_r \lambda^2}$ and $\alpha_2 = \dfrac{1}{G_t G_r h_t^2 h_r^2}$.

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The receiver threshold P_{r_thresh} can be determined using estimates for the noise at the receiver.

E. EQSR Protocol (Energy Efficient and QoS multipath aware routing)

In wireless sensor network, the sensor nodes are randomly deployed. A network consists of a sink node, and other sensor nodes. The sensor nodes have limited energy, limited power and limited storage. The sensor nodes remain at their locations for sensing, once they are deployed. Depending on the available energy and signal strength of a node, it is selected to forward the data. The energy cost is calculated by data packet size, and radius of the transmission and energy cost model of transmitter and receiver. The energy cost for Sending k-bit packet to a node with distance'd' and receiving k-bit packet is shown as:

$$E_{Tx}(k, d) = E_{Tx\text{-}elect}(k) + E_{Tx\text{-}amp}(k, d)$$
$$E_{Rx}(k) = E_{Rx\text{-}elect}(k)$$

The Energy efficient QoS multipath routing protocol consists of two phases; Path construction phase and Data transmission phase. The path discovery phase consists of RREQ, RREP, and Second path discovery.

IV. PROPOSED ALGORTHIM

The following two algorithms leads to prolong the lifetime of the network. The first algorithm implemented for the energy consumption and the second algorithm implemented for the end-to-end delay.

In first algorithm, this paper first calculate the mean and then the variance depends on four parameter metrices payload, free buffer, SNR, residual energy. The mean and the variance is calculated two times to find the best optimum path. So that energy is not consumed by follow the wrong path for transmission

And its pseudo code is

Two_pass_algorthim(data):
K=0
SUM UP 1 = 0
SUM UP 2= 0
For K in data
K = K+1
SUM UP 1 =SUM UP 1 + K
Mean = $\frac{SUM\ UP\ 1}{K}$
For K in data
SUM UP 2 = SUM UP 2+ (x-mean)*(x-mean)
Variance = $\frac{SUM\ UP\ 2}{K-1}$
Return variance;

The second algorithm is implemented for end-to-end delay in which start time and end times are defined. By using this algorithm, this paper calculates the average end-to-end delay. This calculation of exact delay is acknowledged to the source node by the sink node. So that, the source node not send the packets. Sometime the delay is not exact known by the source node. The exact end-to-end delay is calculated by:

<u>Algorithm</u>

```
i = 0;
seqno = -1;
 count = 0;
#end-to-end delay
for(i=0; i<=seqno; i++)
{
     if (end_time [i] > 0)
{
    delay[i] = end_time[i] - start_time[i];
        count++
     else
          delay[i] = +0.5;
     }
  }
For (i=0; i<=seqno; i++)
{
     if(delay[i] > 0)
{
       end_to_end_delay = end_to_end_delay/2 +
delay[i]/2
 }
  }
end_to_end_delay = end_to_end_delay/count;

for (k=0;k<=50;k++)
 packetarrivalrate [k] = end_time[k], delay[k]/100
```

V. RESULT ANALYSIS

For analyze, the simulations have been done using Network Simulator version 2.34 (NS 2). NS-2 is scalable and open source used for the simulation behaviors of wired or wireless network functions and protocols [12]. The simulation network consists of 200 sensor nodes that are randomly scattered in the square field of 1000 * 1000. All nodes have same transmission range of 25m.

Fig 1.3 shows the graph between energy consumption and packet arrival rate. It is clear from Fig 1.3, the values of energy consumption are constant between co-ordinates (0,0) to (18,0). The values are slightly increases from co-ordinates (18,0) to (20,18) . the values again constant from co-ordinates (20,18) to (30,18) and the value increases. This process of conatant and slightly increment of values of energy consumption going on from co-ordinates (0,0) to (152,580). It is clear from the fig 1.3, that the values of energy consumption of nodes don't increase abruptly to diminish the energy consumption of the nodes.it leads to prolong the lifetime of the network. The values of energy consumption of nodes are generated by simulations done on NS-2 is shown in Table 1.2.

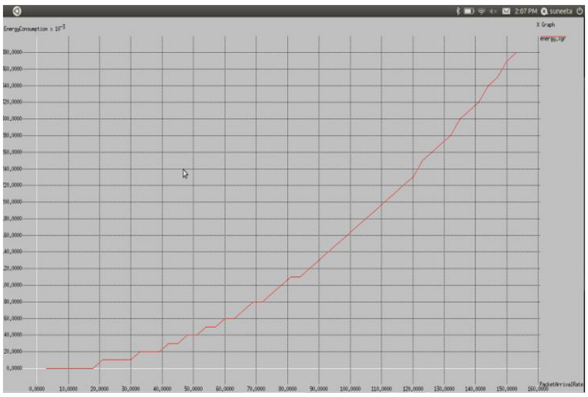
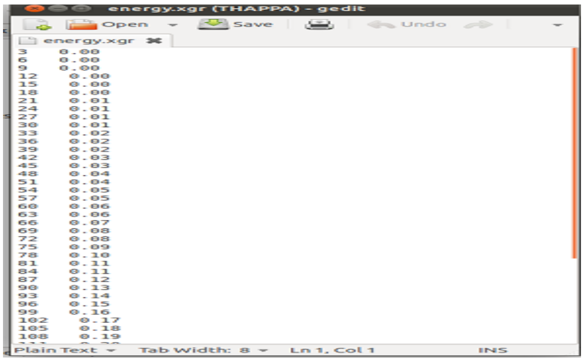


Fig 1.4. Energy consumption



energy.xgr (THAPPA) - gedit

3	0.00
6	0.00
9	0.00
12	0.00
15	0.00
18	0.00
21	0.01
24	0.01
27	0.01
30	0.01
33	0.02
36	0.02
39	0.02
42	0.03
45	0.03
48	0.04
51	0.04
54	0.05
57	0.05
60	0.06
63	0.06
66	0.07
69	0.08
72	0.08
75	0.09
78	0.10
81	0.11
84	0.11
87	0.12
90	0.13
93	0.14
96	0.15
99	0.16
102	0.17
105	0.18
108	0.19

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Table 1.2 Values of energy consumption

In Fig 1.3, the values of end-to-end delay linearly decreases from co-ordinates from co-ordinates (0, 50) to (120, 20). The end-to-end delay is in between three red lines in the graph. To find the average end-to-end delay, the average of the three values which are simulated at one time. At 10 sec, the values of end-to-end delay are 46, 46.5 and 46.9. So to find the average end-to-end delay, take the average of three simulated values. After calculation, the value of average end-to-end delay is 46.46 at 10 sec. so at different time intervals, the average end-to-end delay is calculated by same manner. The values of end-to end delay which are simulated from the simulator NS-2 are shown in Table 1.3.

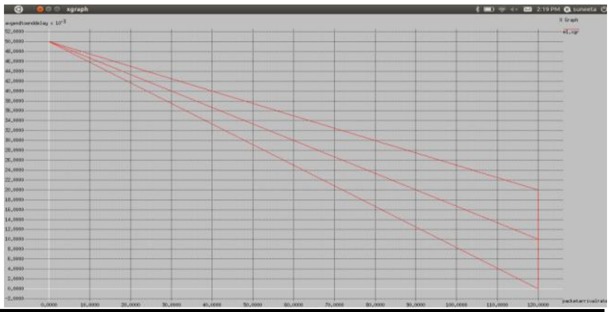
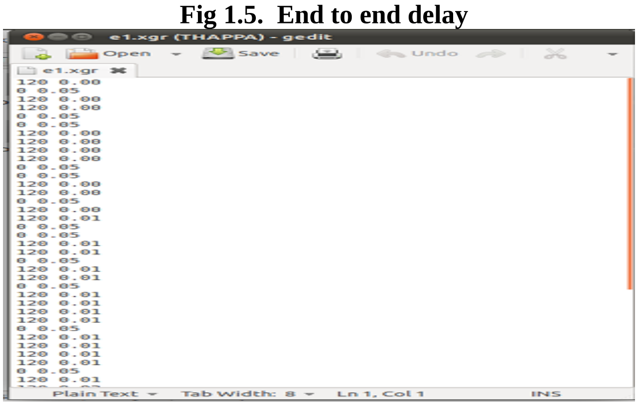


Fig 1.5. End to end delay



e1.xgr (THAPPA) - gedit

120	0.00
0	0.05
120	0.00
120	0.00
0	0.05
0	0.05
120	0.00
120	0.00
120	0.00
120	0.00
0	0.05
0	0.05
120	0.00
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120	0.01
120	0.01
120	0.01
120	0.01
0	0.05
120	0.01
120	0.01
120	0.01
120	0.01
0	0.05
120	0.01

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Table 1.3. Values of energy consumption

VI. CONCLUSION & FUTURE WORK

This paper analyzes EQSR protocol; An Energy efficient and quality of service aware multi-path routing protocol. The performance of EQSR is analyzed using NS2 simulator. At the initial point, there is less and constant energy consumption. After the passage of time, energy consumption increases due to usage of network which is shown by the increased sliding. , that the end-to-end delay is improved in modified EQSR as compared to existing EQSR. After analysis, it comes to know that EQSR has large energy savings and low end–to-end delay. Future work can be done further improvement in QoS parameters.

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