subsequent packets do not need to incur the idle delay at each hop, and thus the end-to-end delay for the subsequent packets is much smaller than that of the first packet [11].

1. Delay of SMAC over H hops

Suppose there are N hops from the source to destination. For node n, denote carrier sensing delay as tcs , transmission delay ttx , sleep delay ts , and a frame of listening and sleep cycle as Tf the average latency of S-MAC over N hops[1] is shown as:

$$E[D(N)] = NT_f - \frac{T_f}{2} + t_{cs} + t_{tx} \quad (1)$$

Now T_f is in general, much larger than (t_{cs}+t_{tx}). So the delay over h hopes is almost proportional to T_f.

T_f, is inversely proportional to the duty cycle. Then we have

$$E[D(h)] \propto T_f \propto \frac{1}{dutyCycle} \quad (2)$$

Let H denote the maximum possible number of hops of the network. Let ρ be the node density of the sensor network, the number of nodes h hops apart from the sink, N(h), is expressed by

$$N(h) = \rho(h^2 - (h-1)^2)\pi - \rho(2h-1)\pi \quad (3)$$

The main source of energy consumption is transmission and reception of packets, as well as idle listening. If the duty cycle is ideally configured with the finest granularity, the wakeup period is spent only for transmission and receptions. Then the energy consumption rate for each node h hops from the sink, E(h), is calculated as:

$$E(h) = \frac{E_{tot}(h)}{N(h)} =$$

$$\frac{\rho\lambda\pi((H^2 - h^2)E_{rx} + (H^2 - (h-1)^2)E_{tx})}{\rho(2h-1)\pi}$$

=

$$\frac{\lambda((H^2 - h^2)E_{rx} + (H^2 - (h-1)^2)E_{tx})}{2h-1} \quad (4)$$

E_{tot} , E_{tx} and E_{rx} denote total energy consumption, energy consumption due to transmission and reception.

By defining ε as the ratio of E_{rx} to E_{tx}, we express the delay of S-MAC over H hops as:

4. Simulation and Results

The simulation work is conducted by using ns-2.34 [8]. By default we use 20 mobile node topology forming a 5 X 5 grid. The other simulation parameter is shown in table 1.

Table 1: Simulation Parameters

Initial Energy	1000 J
Max. packet in interface queue	250 bytes
Radio Transmission Range	30 m
Data Rate(Radio Bandwidth)	2Mbps
Idle Power	0.2 w
Receiver Power	0.5 w
Transmit power	1.0 w

Simulation topology: The following diagram shows the topology used to simulate the procedure described in the paper.

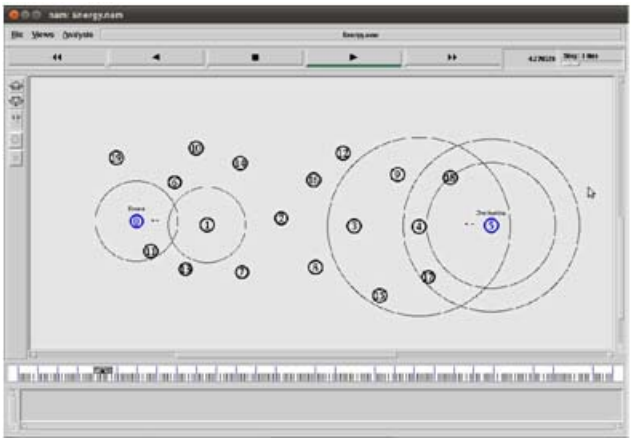

Figure 3: Simulation Topology

5. Simulation Results

The following graph figure 4 (a) shows the summation of energy consumed of all the nodes involved in process by using 802.11 MAC protocol and figure 4(b) shows energy consumed of the individual nodes involved in the communication while transferring data from source node to destination node.

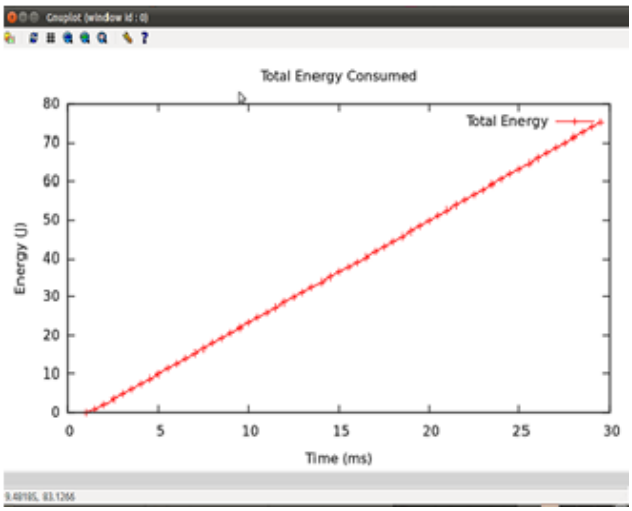

Figure 4(a): Total energy consumed

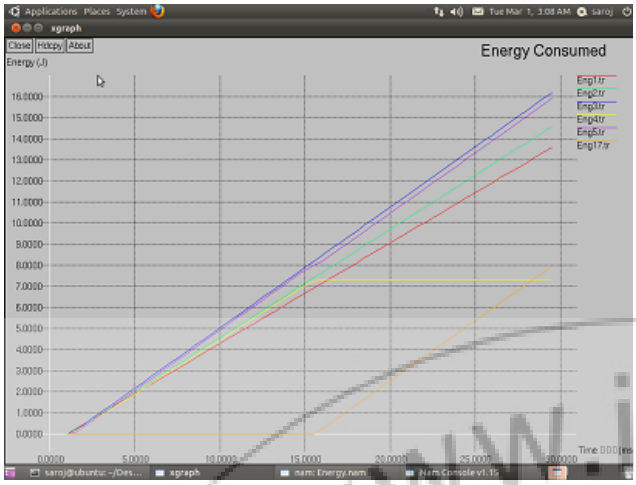

Figure 4(b): Energy consumed by used nodes

The following graph figure 5 shows the end-to-end delay of individual nodes involved in the communication process while transferring data from source node to destination node and figure 6 shows that the lifetime of sensor network based on delay while simulation time is 30 ms.

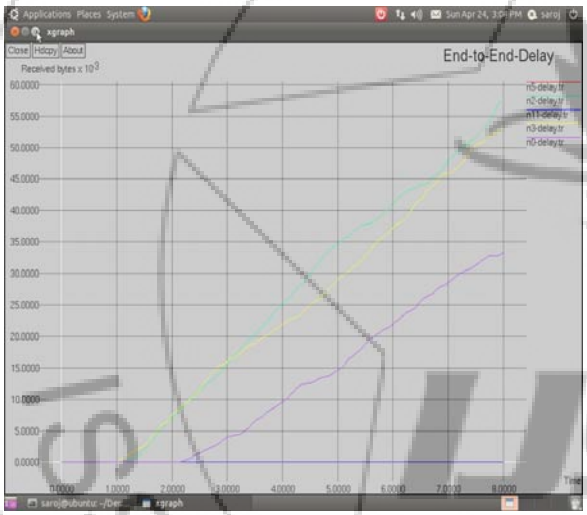

Figure 5: End-to-end delay by nodes

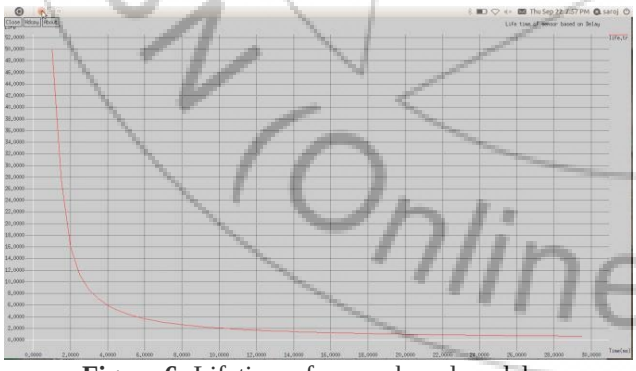

Figure 6: Lifetime of sensor based on delay

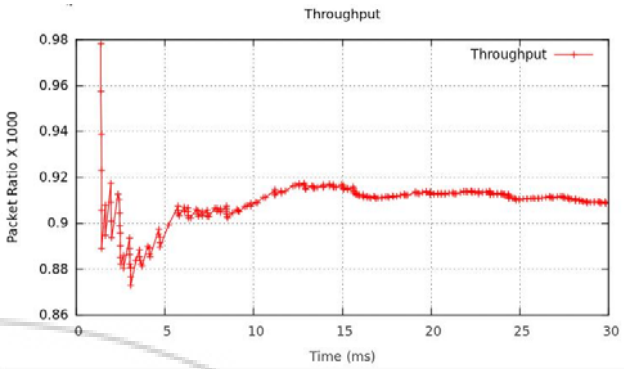

Figure 7: Throughput of the WSN

6. Conclusion

The minimization of the energy consumption is aimed to WSNs because the capacity of the power supply is limited of the sensor nodes. There is no single MAC protocol as universally minimized energy consumption for WSN, the need of protocols may vary depending on the network applications. The above paper shows the various results of energy consumption and their lifetime behavior of the various nodes of sensor networks the method applied in this paper can be extended to a bit more level to optimize the energy expenditure of the sensor network during the transmission of the data, implementation of this methodology to a more complex topology would be the future recommended work.

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