CHAPTER 3

TRUST BASED CLUSTER HEAD SELECTION ALGORITHM FOR WIRELESS SENSOR NETWORK

WSN is a network system comprised of spatially distributed devices using wireless sensor nodes to monitor physical or environmental conditions, such as sound, temperature, and motion. The individual nodes are capable of sensing their environments, processing the information data locally and sending data to one or more collection points in a WSN. Efficient data transmission is one of the most important issues for WSNs. Meanwhile, many WSNs are deployed in harsh, neglected and often adversarial physical environments for certain applications, such as military domains and sensing tasks with trustless surroundings. Secure and Efficient data Transmission (SET) is, thus, especially necessary and is demanded in many such practical WSNs.

3.1 Background of the proposed ENTM

Any node must be prepared to operate in a mode that need not immediately trust other nodes without their trust information. If the trust relationship amongst the network nodes is available for every cooperating node, it will be much easier to select proper security measures to establish the necessary protection. Moreover, it will be more sensible to reject or ignore hostile service requests. As the overall environment in WNS is cooperative by default, these trust relationships are extremely susceptible to attacks. To avoid the overhead of handling the network as a whole, nodes are grouped into clusters. Each cluster is a group of nodes which is headed by one or more nodes known as Cluster head(s) (TAs). The CH is elected by the member nodes to make the TA more stable depending upon some metrics.

The CH selection is entirely distributed and secured. The challenges can be handled by formalizing a trust relationship between the participating nodes within one hop distance away. To formalize the trust of a particular node, nodes monitor the behavior of other nodes and collect information from its neighbors and then finalize the decision about the node. A quantitative trust evaluation algorithm is used at each node to evaluate the direct trust of its neighbor nodes. The Enhance Node-based Trust Management (ENTM) scheme is based on a Clustered mobile sensor network with backbone; it introduces a trust of a node within local management strategy with the help from the mobile agents running on each node. That is, a node's trust-based information is stored as a history on the node itself and managed by the local mobile agent of the node.

3.2 System architecture of ENTM

The architecture of ENTM consists of three key segments: Node Initiators (NIs), Trust Monitors (TMs) and Trust Evaluators (TEs). Each node of ENTM consists of four components: wireless sensor, ID of the node, Trust Info-score and Context as shown in Figure 3.1. A TM is a mobile agent generated by the NI. It is designed to be distributed into every node and to provide its hosting node with a trust management service. Each node will hold a copy of the TM's current version. For an arbitrary node n_i, its copy TM, TM(n_i), locally maintains three data structures, (i.e.) a trust evaluation table TETBL, an interaction history buffer HB and a counter message COUNTR. The trust assessments that n_i recently made on other nodes are kept in TETBL, while the TEs issued to n_i by the local copy TMs of other nodes are also stored in TETBL. TETBL is composed of five fields: ID, CNTXT, EVAL, TSTMP and COUNTR among which ID and CNTXT together constitute the primary key of the table. Field ID contains the IDs of the evaluated nodes; field CNTXT implies trust contexts and field EVAL stores the trust evaluation values; field TSTMP holds the time when assessments are made. For any node n_i, field CNTXT means trust contexts. Field TSTMP contains the time when TEs are issued, while field COUNTR reflects the number of occasions a TE I acknowledged. A copy TM stays on its host until it is replaced by the copy of a higher-version TM and in the meantime, it offers its host the trust management service. When TM replacement takes place, the new local TM will take over all the data structures maintained by the old one and reset COUNTR to 0.

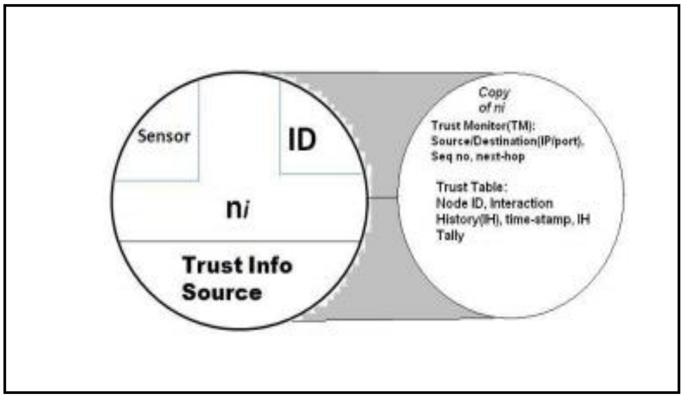

Figure 3.1 A node in ENTM

A TE is a segment of data that is organized with a particular structure and issued by the copy TM of a node (sender) to another node (receiver). It is stored in the TETBL on its receiver node. Considering any two nodes n_i and n_j the TE issued by TM (n_i) to n_j under context is defined in Equation (3.1).

$$TE(n_i, n_i, CNTXT) = EV\ ALSK(\mathrm{D}) \tag{3.1}$$

where

$$D = (ID(n_i), ID(\mathrm{n}_j), \mathrm{CNTXT}, \mathrm{T}, \mathrm{t}_{i,j})$$

T = time - stamp implying the time when the TE is issued.

TE implicitly indicates the temporal property of trust by the use of time - stamp T. TE is driven by transactions and it involves message transmission between the copy of TMs of the sender and receiver. The execution of ENTM includes three phases: network formatting phase, the trust management interaction routine phase, and the security analysis phase. As soon as ENTM starts, the network formatting phase is initiated. It is possible that some nodes do not yet have a local copy of TM when they are asked by other nodes for TEs. Apparently, the asynchronous execution may lead to the failure of the trust management service. The trust value acquisition service consists of three algorithms. In the trust management interaction routine, each intermediate node accommodates incoming TRUST-INFO in proper buffers (HBs). Upon receiving the first INFO, the node calculates the appropriate time duration for holding INFO in the buffer before forwarding it to the next node. ENTM classifies each incoming INFO as based on INFO's arrival time and adaptively determines a suitable due time for each INFO individually. The INFO is early, in time or late depends on its relative delay.

3.3 Design of the proposed ENTM

The entire network is divided into the hierarchical group of clusters. It is assumed that the nodes are location-unaware (i.e.) not equipped with Global Positioning System (GPS), they are left unattended at the beginning; therefore there is no need for battery recharge and all nodes are given initial trust value (i.e.) 0.5.

3.3.1 Cluster Formation

After deployment, the nodes broadcast their ID(n_i) and TRUST value to their neighbors along with the REQ/REP flag. When the participating nodes have discovered their neighbors, they exchange information about the number of one-hop neighbors. The node which has maximum one hop neighbors from the trust interaction table is selected as the TA. Other nodes become members of the Cluster or local nodes. The nodes update the trust values accordingly. A circle is formed with a fixed radius by selecting (either randomly or with highest cooperating neighbor density within one hop distance) a node as the center and an arbitrary small length as a radius. Center of the new circle is computed as the mean of the points within the circle while the limit is increased by the distance of two successive centers. The nodes reply back, and the clusters are formed in the network Algorithm. The entire WNS is hierarchical in nature, and the following sequence is observed network-group-Cluster-Cluster node.

Algorithm 3.1 Cluster Formation algorithm in ENTM

```
Input: Set of nodes
Output: Set of clusters
Begin Cluster = 1                    /* represent cluster number 1 */
Repeat
Select a node $n_i$ which is one hop distance apart from other participating nodes
with a small length $d_1$ randomly
do
$N = n_i ; d = d_1$
Draw a circle with $n_i$ as center and $d$ as radius
Compute new radius $d_1 = d + |n_1 - n_j|$
while $n_1 != n_j$
        Cluster-1 is formed with cooperating nodes lying within the circle
End
```

3.3.2 Cluster head selection algorithm

The selection of CHs is considered in a WNS of n nodes such that every node in this network is within distance h hops of a TA, for a given TRUST-VALUE. In ENTM model, the Cluster lifetime denotes the time from the point a node is selected as CH until the point a node changes its status to a normal node. It should be noted that the Cluster lifetime is dependent on mobility issues; the Cluster lifetime in WNSs depends on link stability. In ENTM model, a Clustering message is sent every 3 seconds. Thus, a neighbor node is kept in the neighbor table for 3 ∗ COUNTR seconds and discarded if there is no further Clustering message received. Initially, the Interaction History (IH) for all nodes has been considered as null or ≥ 1.

Algorithm 3.2 CH Selection algorithm in ENTM

```
$TA_{cur} \leftarrow 0$
$TA_{prev} \leftarrow 0$
$Time_{prev} \leftarrow 0$
now() $\leftarrow 0$
Time - OUTloop $\leftarrow$ 3*COUNTR
Interaction History(IH) $\geq 0$
while $Time_{prev} \leq$ now() or TRUST - VAL($TA_{prev}$) $\leq 1$ = true do
    $TA_{prev}$ remains as CH
end while
if TRUST - VAL($TA_{prev}$) = TRUST - VAL($TA_{cur}$) and IH($TA_{prev}$) = IH($TA_{cur}$) then
    both $TA_{prev}$ and $TA_{cur}$ remain as CHs
else
    select new CHs
end if
```

3.4 Simulation Analysis

The performance of the proposed method is analyzed by using the Network Simulator2 (NS2). The NS2 is an open source programming language written in C++ and Object-oriented Tool Command Language (OTCL). NS2 is a discrete event time driven simulator which is used to model the network protocols mainly. The nodes are distributed in the simulation environment. The parameters used for the simulation of the proposed scheme are described in Table 3.1.

Table 3.1 Simulation parameters of ENTM

Parameter	Value
Antenna Model	Omni Antenna
Type of Channel	Wireless Channel
Communication Model	User Datagram Protocol
Type of Interface Queue	PriQueue
MAC Type	IEEE 802.11
Type of Network Interface	WirelessPhy
# nodes	50 and 100
Routing scheme	ENTM
Simulation Area	1000×600
Simulation Time	100 s
Traffic model	CBR
Transmission range	250m

The simulation of the proposed scheme has 50 and 100 nodes deployed in the simulation area 1000×600. The traffic is handled using the traffic model Constant Bit Rate (CBR). Each and every node has the direct link with the nodes within the range 250 m. The initial energy is assumed as 10 J and the simulation time is 100s.The nodes are communicated with each other by using the communication protocol User Datagram Protocol (UDP). The radio waves are propagated by using the propagation model two ray ground. All the nodes receive the signal from all direction by using the omnidirectional antenna.

The performance of the proposed scheme is analyzed by using the parameters Packet Delivery Rate (PDR), Packet Loss Rate (PLR), average delay, throughput and residual energy. In ENTM, simulation can be performed using two types of analysis.

- Simulation of ENTM using 50 nodes.
- Simulation of ENTM using 100 nodes.

3.4.1 Simulation of ENTM using 50 nodes

Simulation analysis of the proposed mechanism is performed first using a 50 nodes scenario.

- **Packet Delivery Rate**

The PDR is the rate of some packets delivered to the destination to the number of data packets sent by the source. PDR is measured by the Equation (3.2).

$$PDR = \frac{\sum_{0}^{n} Packets\ Received}{Time} \tag{3.2}$$

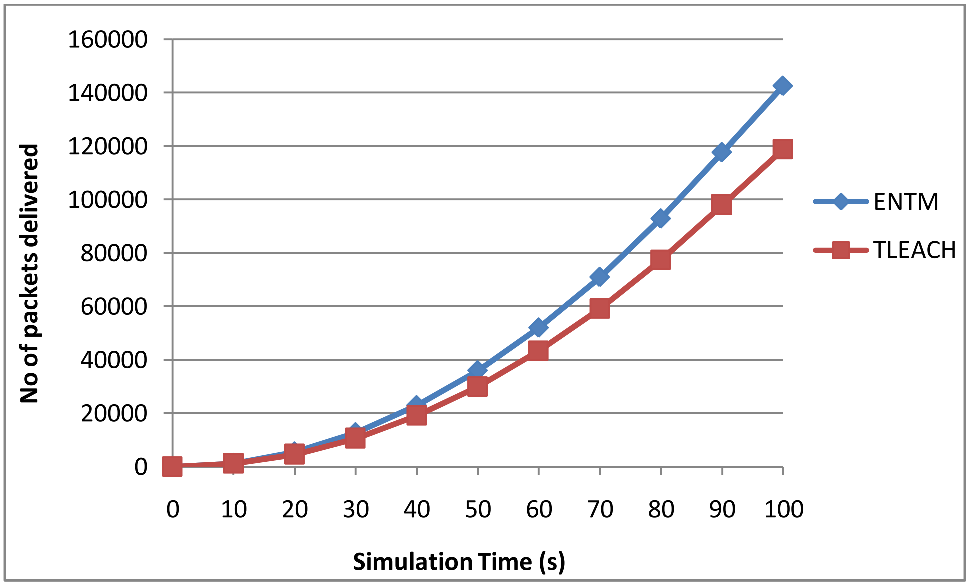

Figure 3.2 Packet Delivery Rate of ENTM and TLEACH for 50 nodes

Table 3.2 PDR values of ENTM and TLEACH for 50 nodes

Simulation Time (s)	PDR of ENTM	PDR of TLEACH
0	0	0
10	1310	1084
20	5573	4636
30	12776	10639
40	22919	19091
50	36002	29994
60	52025	43346
70	70988	59149
80	92891	77401
90	117734	98104
100	142606	118831

Table 3.2 shows the PDR values of ENTM and Trust based Low Energy Adaptive Clustering Hierarchy (TLEACH) during the simulation analysis for 50 nodes. The PDR of ENTM and TLEACH is plotted in figure 3.2. It shows that the proposed scheme ENTM has 83.32% better PDR when compared to the existing TLEACH.

- **Packet Loss Rate**

The PLR is the difference between the number of packets sent and the number of packets received per unit time and is measured using the Equation (3.3).

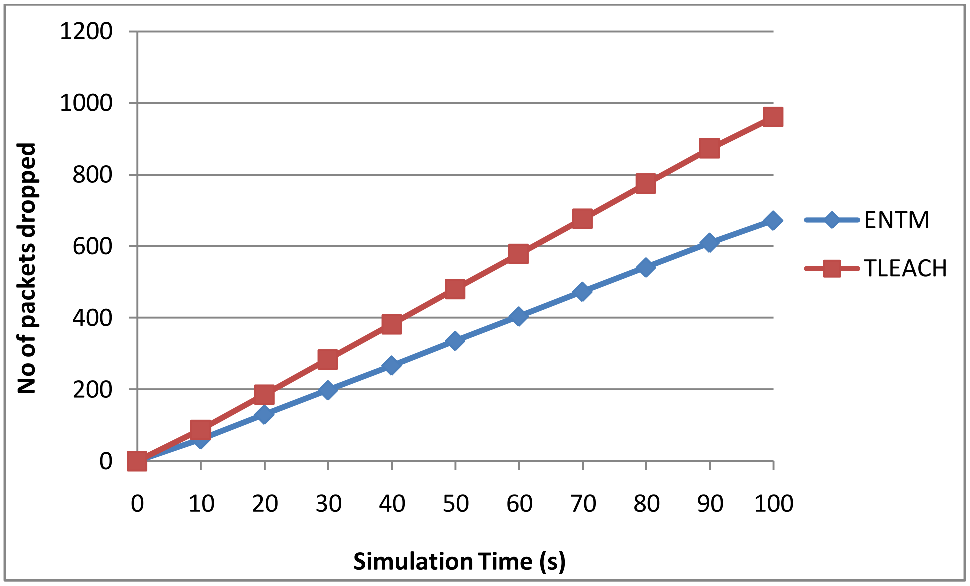

Figure 3.3 Packet Loss Rate of ENTM and TLEACH for 50 nodes

Table 3.3 PLR values of ENTM and TLEACH for 50 nodes

Simulation Time (s)	PLR of ENTM	PLR of TLEACH
0	0	0
10	61	88
20	130	186
30	198	284
40	267	382
50	336	480
60	404	578
70	473	676
80	541	774
90	610	872
100	672	960

$$PLR = \frac{\sum_0^n Sent\ Pkts - Rcvd\ Pkts}{Time} \tag{3.3}$$

Table 3.3 shows that the PLR values obtained from the simulation analysis of ENTM and TLEACH. Figure 3.3 indicates that the PLR of proposed scheme ENTM is lower by 70% when compared to that of existing scheme TLEACH.

- **Average Delay**

The average delay is defined as the time difference between the current packets received and previous packets received. It is measured by the Equation (3.4) where n is the number of nodes, here n=50.

Table 4.4 Average Delay values of ENTM and TLEACH for 50 nodes

Simulation time (s)	Delay of ENTM (ms)	Delay of TLEACH (ms)
0	0	0
10	0.184654	0.263971
20	0.715626	1.022732
30	1.589586	2.271494
40	2.806546	4.010256
50	4.366508	6.239015
60	6.269468	8.957778
70	8.51543	12.16654
80	11.10439	15.8653
90	14.03635	20.05406
100	16.96838	24.2429

$$Avg\ Delay = \frac{\sum_0^n (Packet\ \mathrm{Re}ceived\ Time - Packet\ Sent\ Time)}{n} \tag{3.4}$$

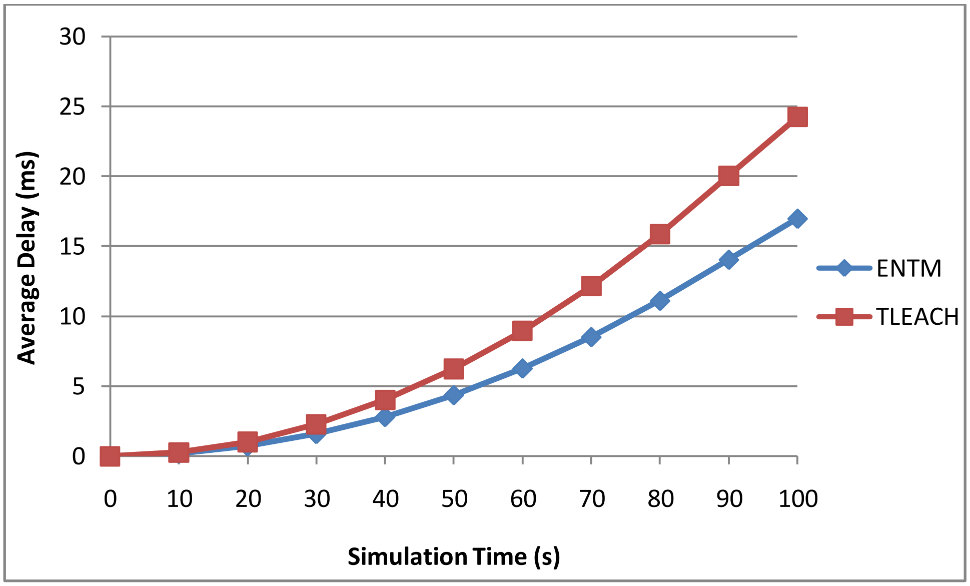

Figure 3.4 Average Delay of ENTM and TLEACH for 50 nodes

Table 3.4 shows that the average delay obtained from simulation analysis of ENTM and TLEACH mechanisms for 50 nodes. Figure 3.4 indicates that the ENTM has 69.99% lower delay for a node when compared to the TLEACH scheme.

- **Throughput**

Throughput refers to the total number of packets successfully delivered across the network for every 1000 packets sent. Throughput is obtained using Equation (3.5).

$$Throughput = \frac{\sum_0^n Packets\ Received(n) * Packet\ size}{1000} \tag{3.5}$$

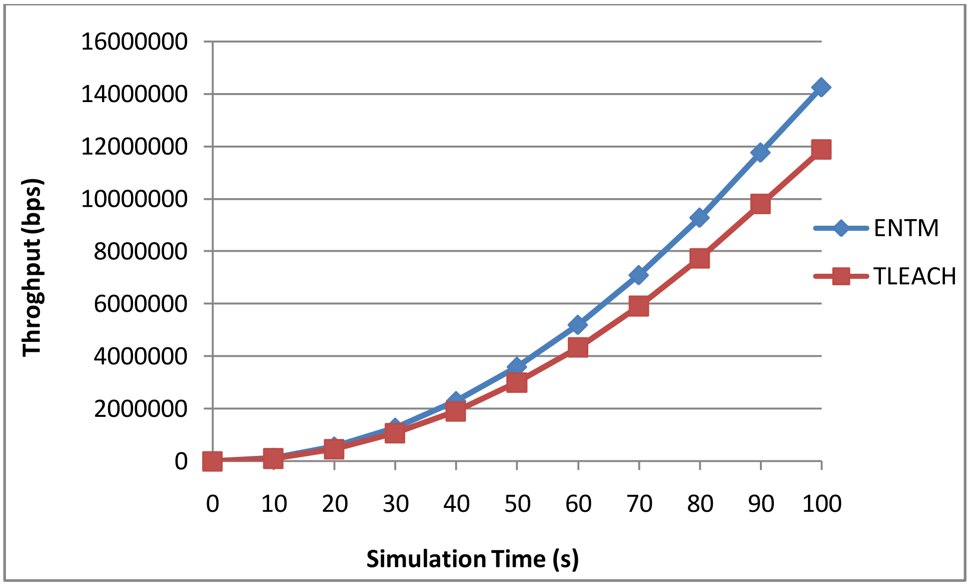

Figure 3.5 Throughput of ENTM and TLEACH for 50 nodes

Table 3.5 Throughput values of ENTM and TLEACH for 50 nodes

Simulation time (s)	Throughput of ENTM (bps)	Throughput of TLEACH (bps)
0	0	0
10	131050	108437
20	557350	463687
30	1277650	1063937
40	2291950	1909187
50	3600250	2999437
60	5202550	4334687
70	7098850	5914937
80	9289150	7740187
90	11773450	9810437
100	14260690	11883137

Table 3.5 indicates that the throughput values received throughout simulation analysis. It can be observed from figure 3.5 that the number of packets received successfully for every 1000 packets for ENTM is greater than 83.32% compared to that of the TLEACH mechanism.

- **Residual Energy**

The amount of energy remaining in a node at the current instance of time is called as Residual Energy (RE). A measure of the RE gives the rate at which energy is consumed by the network operations. Table 3.6 shows the RE values obtained during the simulation analysis.

Table 3.6 RE values of ENTM and TLEACH for 50 nodes

Simulation Time (s)	RE of ENTM (J)	RE of TLEACH (J)
0	10	10
10	9.91285	9.70285
20	9.82985	9.41985
30	9.74685	9.13685
40	9.66385	8.85385
50	9.58085	8.57085
60	9.49785	8.28785
70	9.41485	8.00485
80	9.33185	7.72185
90	9.24885	7.43885
100	9.17	7.17

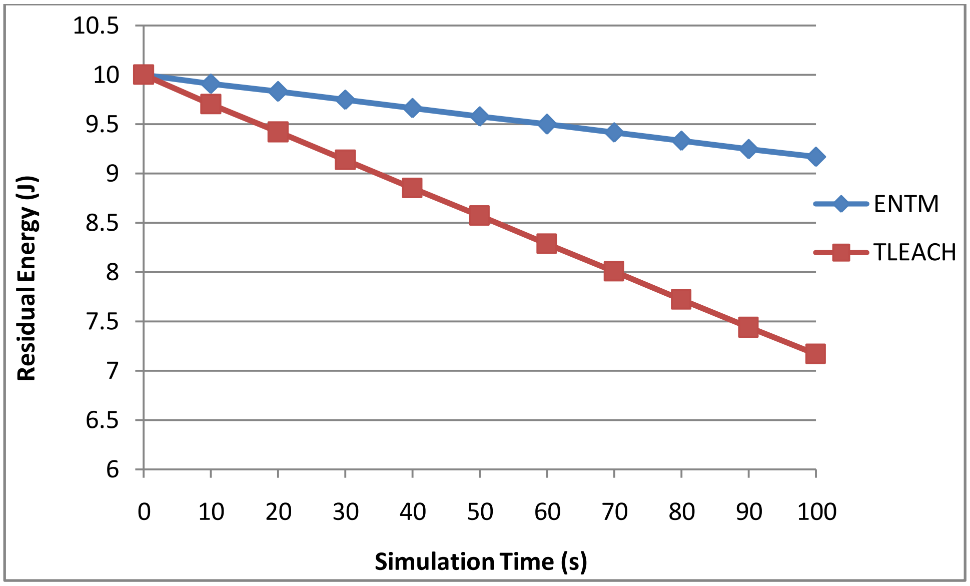

Figure 3.6 Residual Energy of ENTM and TLEACH for 50 nodes

Figure 3.6 shows that the RE of the network is better for the proposed scheme ENTM when compared with the existing scheme TLEACH. Around 78.18% of energy is saved per node by using ENTM protocol for routing.

3.4.2 Simulation of ENTM using 100 nodes

To study the performance when the number of nodes is increased, the value of N is increased to 100. The plots of the same parameters as that of 50 nodes are given below.

- **Packet Delivery Rate**

Similar to the PDR of 50 nodes, the values are obtained using equation 3.2 during simulations of the ENTM and the TLEACH protocols. These values are displayed in Table 3.7 and also plotted in figure 3.7.

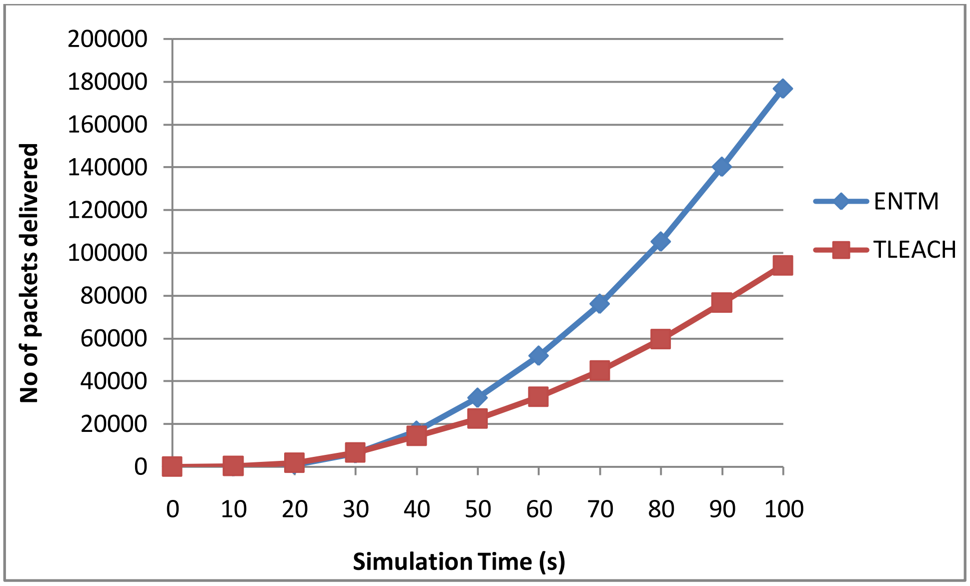

Figure 3.7 Packet Delivery Rate of ENTM and TLEACH for 100 nodes

Table 3.7 PDR values of ENTM and TLEACH for 100 nodes

Simulation Time (s)	**PDR of ENTM**	**PDR of TLEACH**
0	0	0
10	5	191
20	1000	1778
30	6153	6658
40	16728	14320
50	32181	22500
60	51872	32573
70	76174	44949
80	105308	59580
90	140325	76643
100	176918	94148

This shows that the PDR of ENTM is 53.21% greater than that of the TLEACH mechanism. The increase in the number of nodes increases the PDR values, which proves the efficiency of the proposed technique.

- **Packet Loss Rate**

The PLR is also estimated similar to the 50 nodes scenario using the equation 3.3 for 100 nodes. The PLR of ENTM and TLEACH for 100 nodes are plotted in Table 3.8.

The PLR of TLEACH is 67.96% greater than the ENTM mechanism. The PLR of ENTM and TLEACH for 100 nodes are plotted in figure 3.8.

Table 3.8 PLR values of ENTM and TLEACH for 100 nodes

Simulation Time (s)	PLR of ENTM	PLR of TLEACH
0	0	0
10	22	196
20	443	1331
30	1917	2931
40	3555	4901
50	5335	7120
60	7205	9829
70	9115	12786
80	11282	16003
90	13508	19479
100	15512	22823

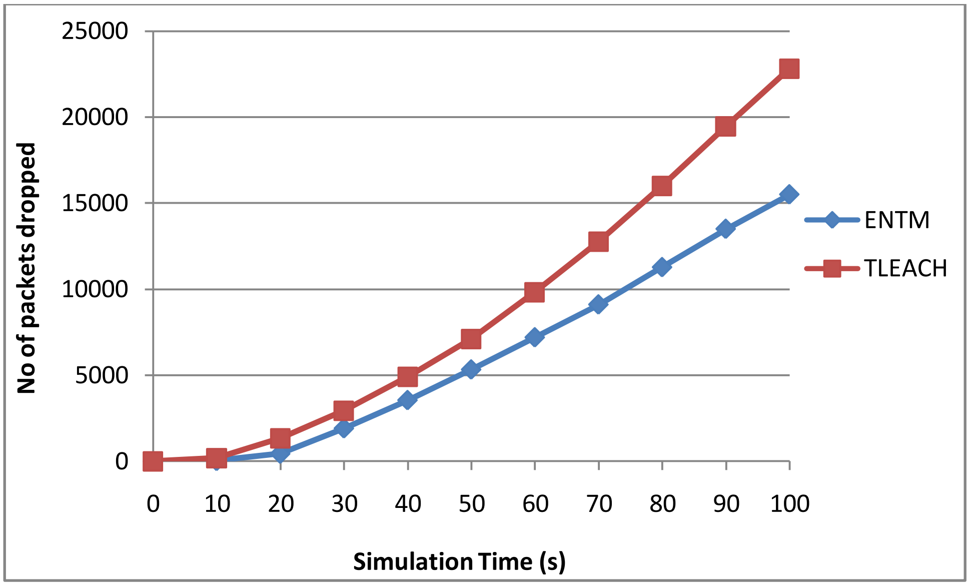

Figure 3.8 Packet Loss Rate of ENTM and TLEACH for 100 nodes

- **Average Delay**

Similar to all the previous parameters, the average delay is also measured using the equation 3.4. The values are tabulated in Table 3.9 for both ENTM and TLEACH.

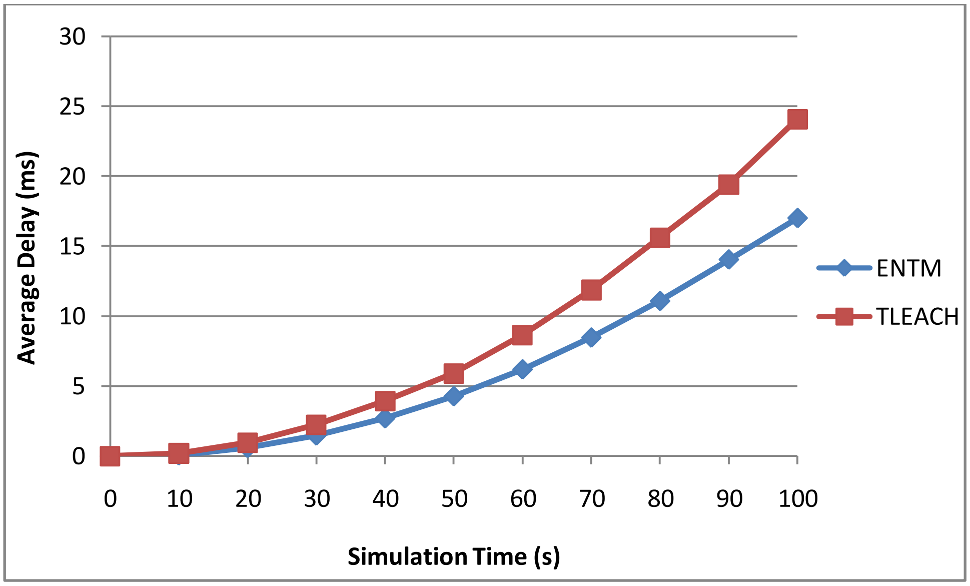

Figure 3.9 Average Delay of ENTM and TLEACH for 100 nodes

Table 3.9 Average Delay values of ENTM and TLEACH for 100 nodes

Simulation time (s)	**Delay of ENTM (ms)**	**Delay of TLEACH (ms)**
0	0	0
10	0.059223	0.201731
20	0.590174	0.964428
30	1.4724	2.225964
40	2.701847	3.923626
50	4.277942	5.884543
60	6.197664	8.630785
70	8.466482	11.86946
80	11.08189	15.60541
90	14.04379	19.39118
100	17.00577	24.06763

The average delay occurred for both the existing and proposed mechanisms is measured in ms. Figure 3.9 shows that the ENTM has 70.65% lower delay for a node when compared to the TLEACH scheme.

- **Throughput**

Throughput is also measured using the same equation used for throughput measurement in equation 3.5. The corresponding values obtained for throughput in ENTM and TLEACH are given in Table 3.10. The values of throughput indicate that there is greater throughput observed in the ENTM protocol.

On an average 53.21% increase in throughput is observed. This is also reflected in figure 3.10 showing the throughput plots of both ENTM and TLEACH mechanisms.

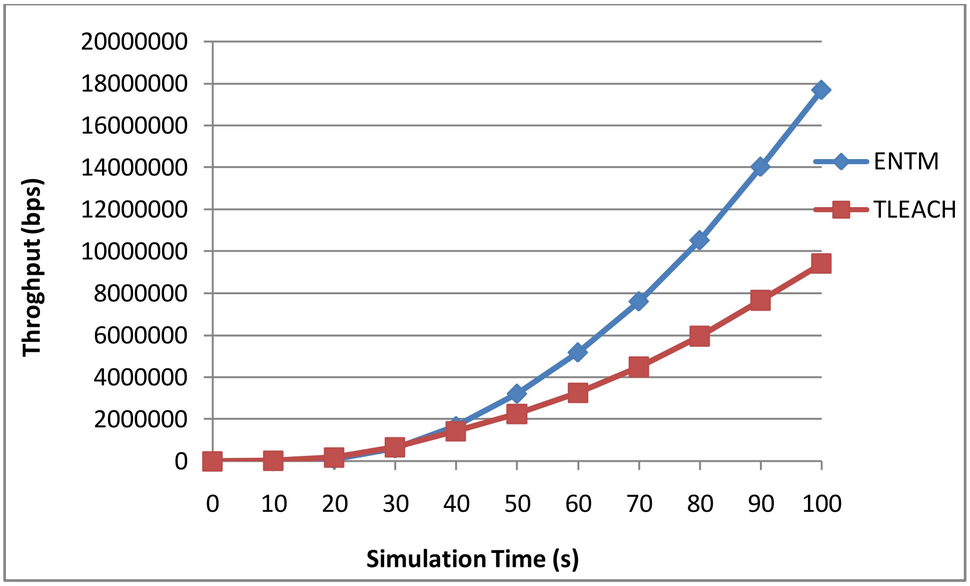

Figure 3.10 Throughput of ENTM and TLEACH for 100 nodes

Table 3.10 Throughput values of ENTM and TLEACH for 100 nodes

Simulation time (s)	**Throughput of TEEHC (bps)**	**Throughput of TMA (bps)**
0	0	0
10	594	19107
20	100088	177804
30	615383	665874
40	1672852	1432035
50	3218143	2250072
60	5187253	3257397
70	7617455	4494996
80	10530877	5958017
90	14032507	7664381
100	17691844	9414899

- **Residual Energy**

The amount of energy remaining in a node at the current instance of time is called as RE. Table 3.11 shows the RE values obtained during the simulation analysis.

Figure 3.11 indicates that the RE of the network is better for the proposed scheme ENTM when compared with the existing scheme TLEACH. Around 78.23% of energy is saved per node by using ENTM protocol for routing.

Table 3.11 RE values of ENTM and TLEACH for 100 nodes

Simulation Time (s)	RE of ENTM (J)	RE of TLEACH (J)
0	10	10
10	9.91495	9.70495
20	9.83395	9.42395
30	9.75295	9.14295
40	9.67195	8.86195
50	9.59095	8.58095
60	9.50995	8.29995
70	9.42895	8.01895
80	9.34795	7.73795
90	9.26695	7.45695
100	9.19	7.19

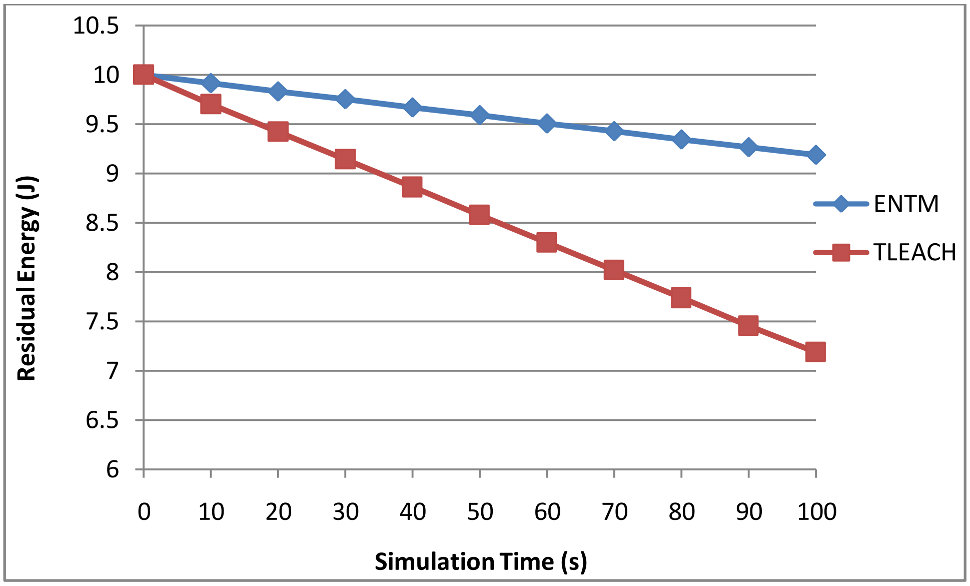

Figure 3.11 Residual Energy of ENTM and TLEACH for 100 nodes

3.5 Summary

The ENTM method has been simulated and analyzed using the network simulator, and the results have shown the efficiency of the ENTM mechanism over the TLEACH. The total packet delivery is increased by 68.27%, packet loss is reduced by 68.98%, the average delay is reduced by 70.32%, throughput is increased by 68.27%, and residual energy is saved by 78.21% in the proposed ENTM mechanism. Therefore this ENTM method is better used by the hierarchical topology thereby reducing the number of tasks in the WSN and increasing the efficiency.