CHAPTER 4

TRUST BASED ENERGY EFFICIENT SCHEME FOR HIERARCHICAL CLUSTERING IN WIRELESS SENSOR NETWORKS

WSNs contains a large number of spatially disseminated small devices that cooperatively examine and respond to environmental conditions and send the gathered data to the Base Station (BS) using wireless channels. Different security mechanisms, for example, cryptography, authentication, confidentiality and message integrity, are used to avoid security threats such as eavesdropping, message replay and falsehood of messages. These approaches still suffer from many security vulnerabilities, such as Denial of Service (DoS) attacks and node capture attacks. The traditional security mechanisms can oppose external attacks, but cannot resolve internal attacks efficiently that are caused by the captured nodes. To establish secure communications, all the communicating nodes are guaranteed to be trusted. This highlights the detail that it is critical to building a trust model allowing a sensor node to conclude the trustworthiness of another node.

4.1 Background of the proposed TEEHC

Trust model has been recently suggested as an efficient security mechanism for WSNs. However, most current research works consider only communication behavior to calculate sensor nodes trust value that is not enough for trust evaluation. The Communication Trust and Energy Trust are always used to evaluate the trustworthiness of sensor nodes. The Communication Trust is calculated based on the interaction behavior of the sensor nodes. Thus, the Energy Trust is required to improve the trust evaluation. Energy Trust is measured based on the residual energy and Geographical

Average Energy of each sensor node. Therefore, the source transmits the data to BS through the trusted Cluster Heads (CHs).

4.2 Design of the proposed TEEHC

Trust based Energy Efficient Scheme for Hierarchical Clustering (TEEHC) in WSNs is intended in this section. TEEHC aims to minimize the energy cost and maximize the security in WSN. This network consists of a BS, CHs and various sensor nodes that are grouped into clusters. Here all sensor nodes are stationary, and locations and communication range of nodes are known. The clusters of sensors can be formed based on the location. Each cluster includes the CH and a set of sensor nodes. Each sensor has two primary functions sensing and relaying. Sensors probe their environment and gather data. Then they transmit the collected information to the CH directly in one hop or by transmitting via a multi-hop path. A CH is in charge of its cluster. It is assumed that each CH can reach and control all the sensors in the cluster. Every CH receives the information from different sensors, processes the data to extract relevant information and then sends it to the BS via the multi-hop transmission. Therefore, the CH has higher computation power and memory when compared to other sensor nodes.

The information on a sensor node's prior behavior is one of the most important aspects of the communication trust. However, communication channels between two sensor nodes are unstable and noisy, thus monitoring sensor node's behaviors in WSNs based on previous communication behaviors involves considerable uncertainty. The communication trust is calculated based on successful and unsuccessful communication packets. The Communication Trust of every node is calculated in equation 4.1.

$$TC_i = \frac{2m+n}{2} \tag{4.1}$$

Where

$$m = \frac{s}{s+us+1}$$

$$n = \frac{1}{s+us+1}$$

s →Successful communication packet

us →Unsuccessful communication Packet

The Energy Trust is calculated based on the residual energy and Geographical Average Energy of each sensor node. Geographical Average Energy of node is computed by equation 4.2.

$$GAE(r) = \frac{\sum_{i=1}^{cn} RE_i(r)}{cn} \tag{4.2}$$

Where

r → Cluster round Number

$RE_i(r)$ → Residual Energy

cn →Number of nodes in the Cluster

The Trust Energy is obtained from the equation 4.3.

$$TE_i = p\frac{E_i(r)}{GAE(r)} \tag{4.3}$$

Where

$p \rightarrow$ Desired percentage of CH

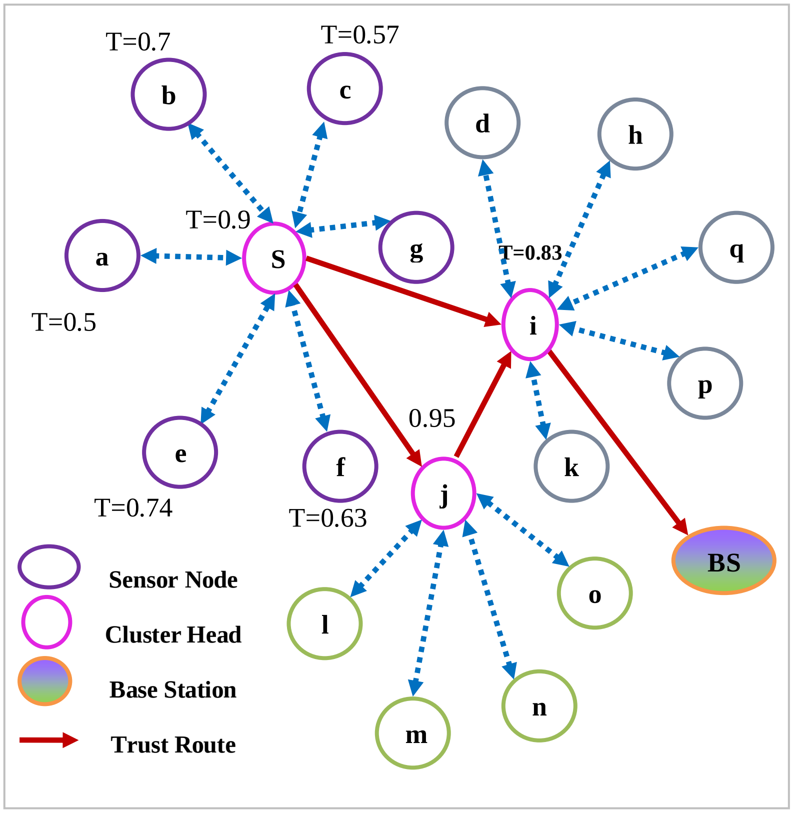

Figure 4.1 Illustration of Trusted Route

The overall Trust of each node is evaluated by equation 4.4.

$$T_i = \frac{TC_i + TE_i}{2} \tag{4.4}$$

TEEHC selects the CH based on the threshold that is calculated by the suggested percentage of CH for the whole network. In each round, the trust probability values range between 0-1. The Threshold value is determined in equation 4.5.

$$THi = \frac{T_i}{1 - T_i(r \bmod 1/T_i)} \qquad if\ i \in S \tag{4.5}$$

Where

S → Sensor nodes that does not select the CH in a previous round.

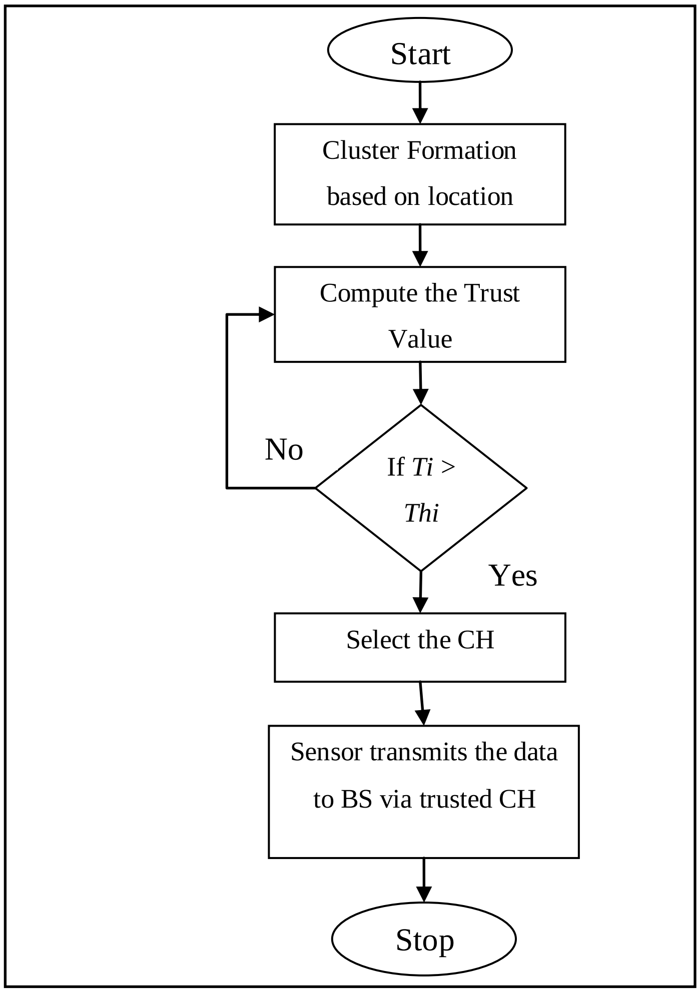

Figure 4.2 Flowchart of TEEHC

Figure 4.1 shows that the illustration of the trust routing in WSN. The CH is chosen based on Communication Trust and Energy Trust of each sensor node. If the Trust value is greater than the Threshold, that node is selected as a CH. The Source transmits the data to BS through the trusted CH node. The trusted path does not choose the untruthful nodes; therefore, the source transmits secure data to BS.

Figure 4.2 describes the flowchart of TEEHC scheme. In this scheme, the clusters are formed based on the location. Every sensor node computes the Communication Trust and Energy Trust. The Communication Trust value is calculated based on the successful and unsuccessful communication packets. The Energy Trust is estimated based on the Residual energy and Geographical Average Energy. If the Trust value is greater than the threshold, that node is selected as a CH. Finally, the sensor node transmits the data to BS through the trusted CH.

4.3 Simulation Analysis

The performance of the proposed method is analyzed by using the NS2. The NS2 is an open source programming language written in C++ and 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 4.1.

The simulation of the proposed system has 50 and 100 nodes deployed in the simulation area 1000×600. The traffic is handled using the traffic model CBR. Each and every node has the direct link with the nodes within the range 250 m. The initial energy is assumed as 10J and the simulation time is 100ms.The nodes are communicated with each other by using the communication 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.

Table 4.1 Simulation Parameters of TEEHC

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	TEEHC
Simulation Area	1000×600
Simulation Time	100 s
Traffic Model	CBR
Transmission range	250m

The performance of the proposed scheme is analyzed by using the parameters PDR, PLR, average delay, throughput and residual energy. In TEEHC, simulation can be performed using two types of analysis.

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

4.3.1 Simulation of TEEHC 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 4.6.

$$PDR = \frac{\sum_{0}^{n} Packets\ Received}{Time} \quad (4.6)$$

Table 4.2 PDR values of TEEHC and TMA for 50 nodes

Simulation Time (s)	PDR of TEEHC	PDR of TMA
0	0	0
10	2038	710
20	8187	3250
30	17392	7282
40	28755	12776
50	44787	20078
60	64637	29402
70	86514	40296
80	113321	52978
90	144804	67500
100	174783	81796

Table 4.2 shows the PDR values of TEEHC and Trust Management Architecture (TMA) during the simulation analysis for 50 nodes. The PDR of TEEHC and TMA is plotted in figure 4.3. It shows that the proposed scheme TEEHC has 46.79% better PDR when compared to the existing TMA.

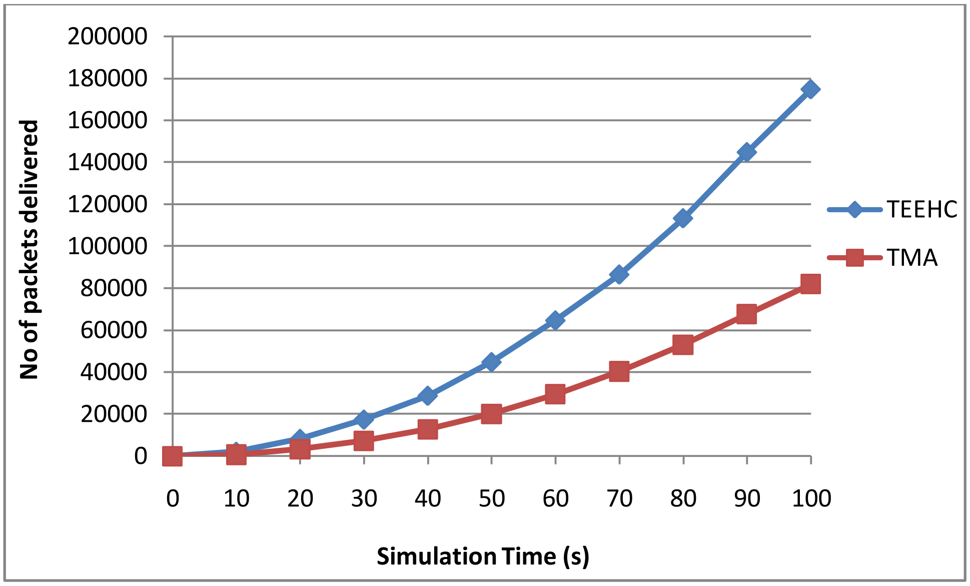

Figure 4.3 Packet Delivery Rate of TEEHC and TMA for 50 nodes

- **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 4.7.

$$PLR = \frac{\sum_{0}^{n} Sent\ Pkts - Rcvd\ Pkts}{Time} \tag{4.7}$$

Table 4.3 shows that the PLR values obtained from the simulation analysis of TEEHC and TMA. Figure 4.4 indicates that the PLR of proposed scheme TEEHC is lower by 12.39% when compared to that of existing scheme TMA.

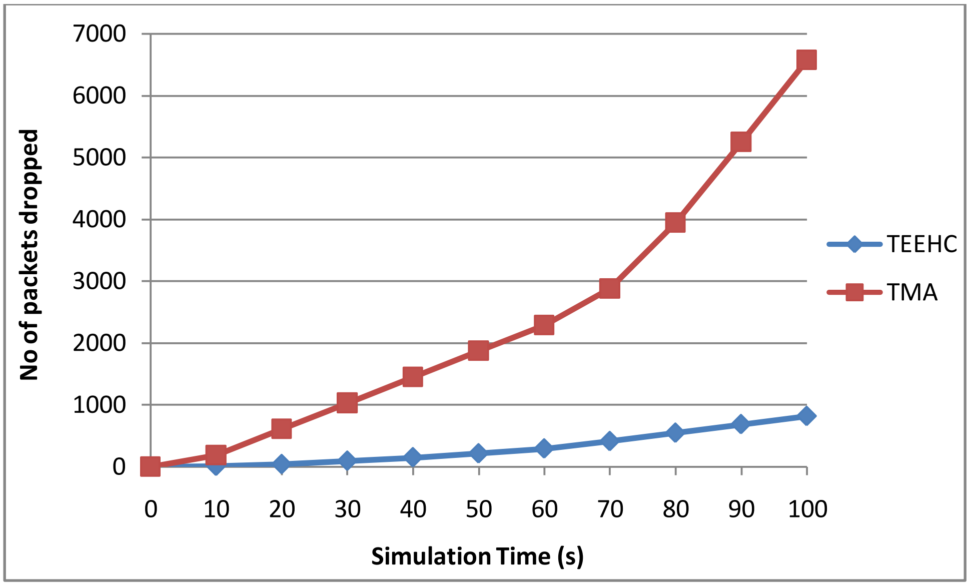

Figure 4.4 Packet Loss Rate of TEEHC and TMA for 50 nodes

Table 4.3 PLR values of TEEHC and TMA for 50 nodes

Simulation Time (s)	PLR of TEEHC	PLR of TMA
0	0	0
10	10	189
20	39	609
30	93	1029
40	149	1449
50	212	1869
60	291	2289
70	410	2877
80	545	3948
90	684	5250
100	815	6573

- **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 4.8 where n is the number of nodes, here n=50.

$$Avg\ Delay = \frac{\sum_{0}^{n}(Packet\ \mathrm{Re}ceived\ Time - Packet\ Sent\ Time)}{n} \tag{4.8}$$

Table 4.4 Average Delay values of TEEHC and TMA for 50 nodes

Simulation time (s)	Delay of TEEHC (ms)	Delay of TMA (ms)
0	0	0
10	0.007296	0.006369
20	0.039942	0.03592
30	0.110083	0.108952
40	0.232184	0.239178
50	0.42226	0.461782
60	0.655043	0.777635
70	0.953563	1.162662
80	1.363595	1.620308
90	1.838976	2.151091
100	2.28482	2.66157

Table 4.4 shows that the average delay obtained from simulation analysis of TEEHC and TMA mechanisms for 50 nodes. Figure 4.5 indicates that the TEEHC has 85.84% lower delay for a node when compared to the TMA scheme.

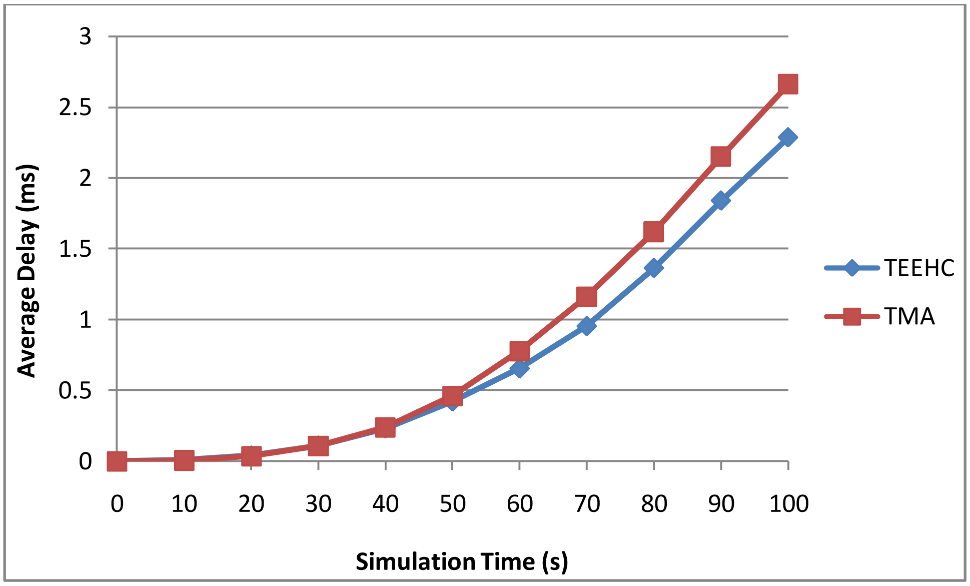

Figure 4.5 Average Delay of TEEHC and TMA for 50 nodes

- **Throughput**

Throughput refers to the total number of packets successfully delivered across the network for every 1000 packets sent. Throughput is obtained using equation 4.9.

$$Throughput = \frac{\sum_{0}^{n} Packets\ Received(n) * Packet\ size}{1000} \quad (4.9)$$

Table 4.5 indicates that the throughput values received throughout simulation analysis. It can be observed from figure 4.6 that the number of packets received successfully for every 1000 packets for TEEHC is greater than 46.79% compared to that of the TMA mechanism.

Table 4.5 Throughput values of TEEHC and TMA for 50 nodes

Simulation time (s)	Throughput of TEEHC (bps)	Throughput of TMA (bps)
0	0	0
10	203800	71000
20	818750	325000
30	1739250	728200
40	2875500	1277600
50	4478700	2007800
60	6463700	2940200
70	8651400	4029600
80	11332150	5297800
90	14480400	6750000
100	17478350	8179600

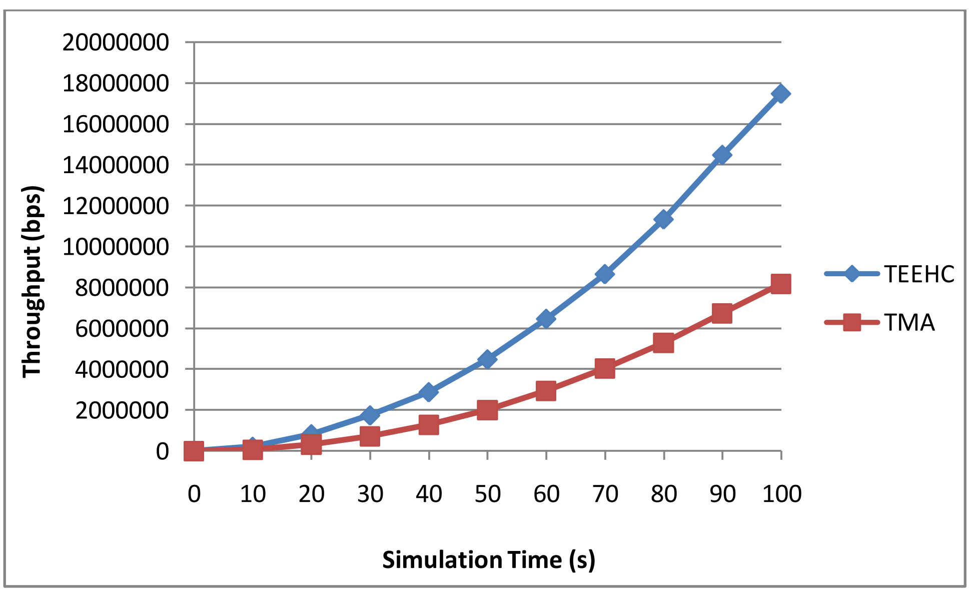

Figure 4.6 Throughput of TEEHC and TMA for 50 nodes

- **Residual Energy**

The amount of energy remaining in a node at the current instance of time is called as RE. A measure of the RE gives the rate at which energy is consumed by the network operations. Table 4.6 shows the RE values obtained during the simulation analysis.

Figure 4.7 shows that the RE of the network is better for the proposed scheme TEEHC when compared with the existing scheme TMA. Around 78.14% of energy is saved per node by using TEEHC protocol for routing.

Table 4.6 RE values of TEEHC and TMA for 50 nodes

Simulation Time (s)	RE of TEEHC (J)	RE of TMA (J)
0	10	10
10	9.91075	9.70075
20	9.82575	9.41575
30	9.74075	9.13075
40	9.65575	8.84575
50	9.57075	8.56075
60	9.48575	8.27575
70	9.40075	7.99075
80	9.31575	7.70575
90	9.23075	7.42075
100	9.15	7.15

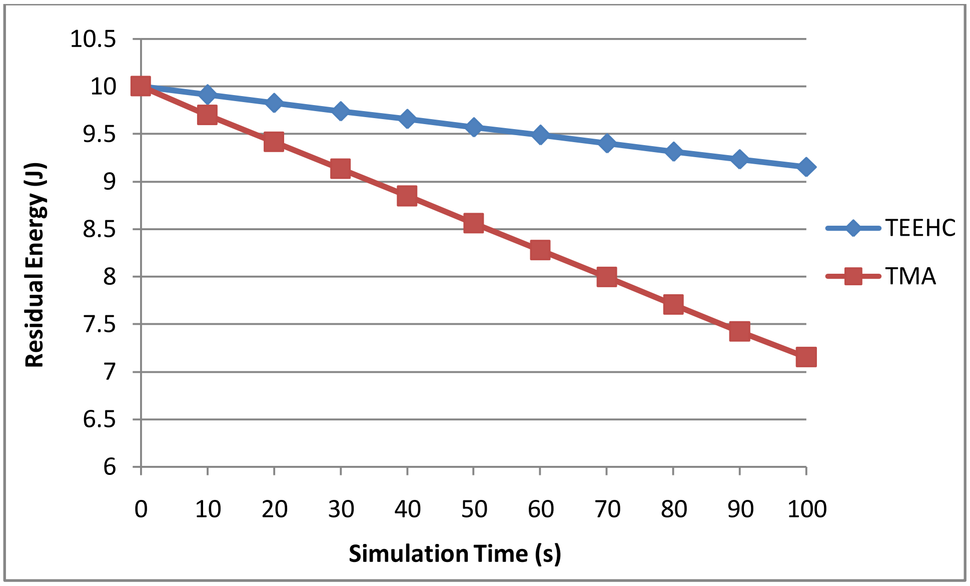

Figure 4.7 Residual Energy of TEEHC and TMA for 50 nodes

4.3.2 Simulation of TEEHC 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 4.6 during simulations of the TEEHC and the TMA protocols. These values are displayed in Table 4.7 and also plotted in figure 4.8.

This shows that the PDR of TEEHC is 60.53% greater than that of the TMA mechanism. The increase in the number of nodes increases the PDR values, which proves the efficiency of the proposed technique.

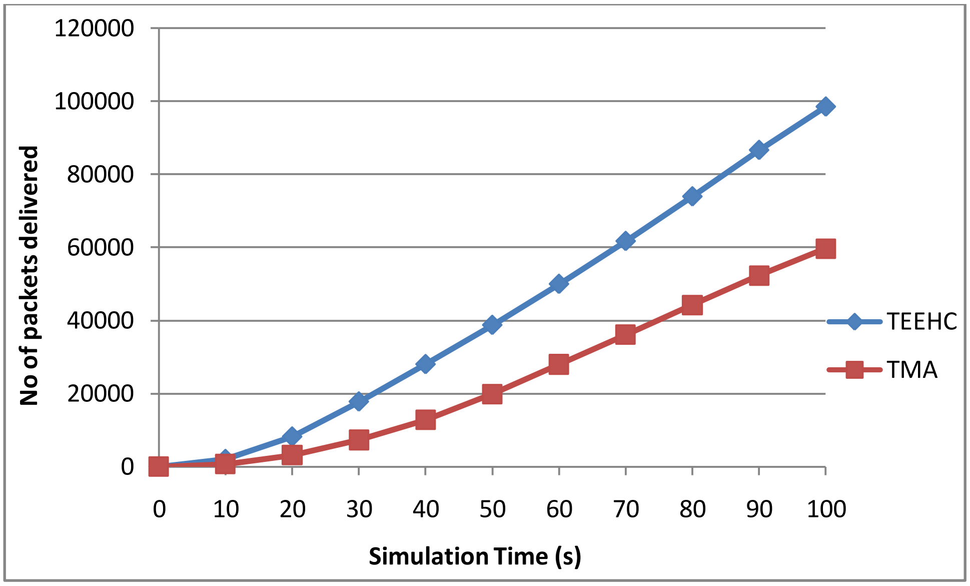

Figure 4.8 Packet Delivery Rate of TEEHC and TMA for 100 nodes

Table 4.7 PDR values of TEEHC and TMA for 100 nodes

Simulation Time (s)	PDR of TEEHC	PDR of TMA
0	0	0
10	2031	710
20	8197	3202
30	17789	7284
40	28029	12840
50	38769	19890
60	50009	28000
70	61752	36120
80	73972	44240
90	86688	52360
100	98571	59668

- **Packet Loss Rate**

The PLR is also estimated similar to the 50 nodes scenario using the equation 4.7 for 100 nodes. The PLR of TEEHC and TMA for 100 nodes are plotted in Table 4.8.

The PLR of TMA is 29.47% greater than the TEEHC mechanism. The PLR of TEEHC and TMA for 100 nodes are plotted in figure 4.9.

Table 4.8 PLR values of TEEHC and TMA for 100 nodes

Simulation Time (s)	PLR of TEEHC	PLR of TMA
0	0	0
10	10	105
20	62	343
30	147	623
40	234	903
50	321	1183
60	409	1463
70	496	1743
80	583	2023
90	672	2303
100	753	2555

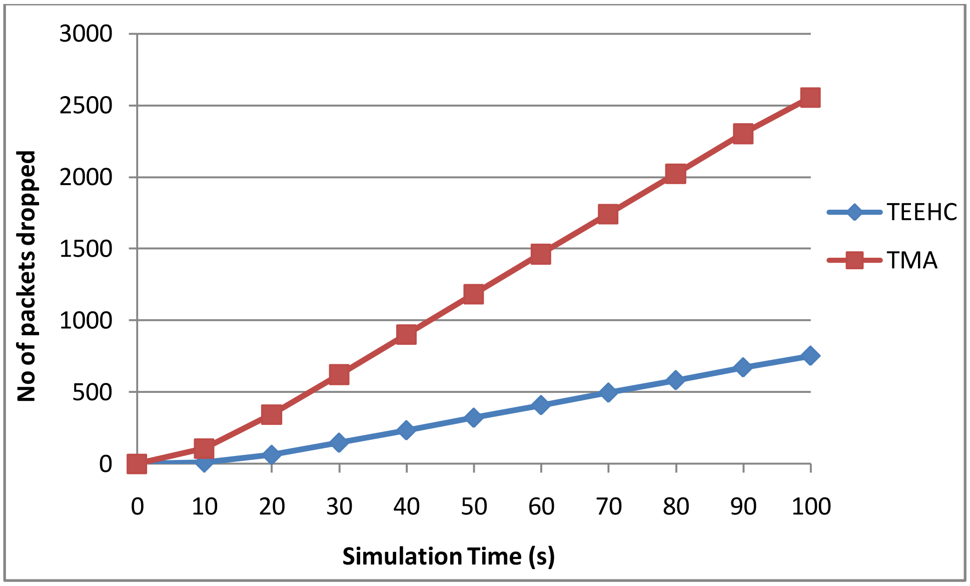

Figure 4.9 Packet Loss Rate of TEEHC and TMA for 100 nodes

- **Average Delay**

Similar to all the previous parameters, the average delay is also measured using the equation 4.8. The values are tabulated in Table 4.9 for both TEEHC and TMA.

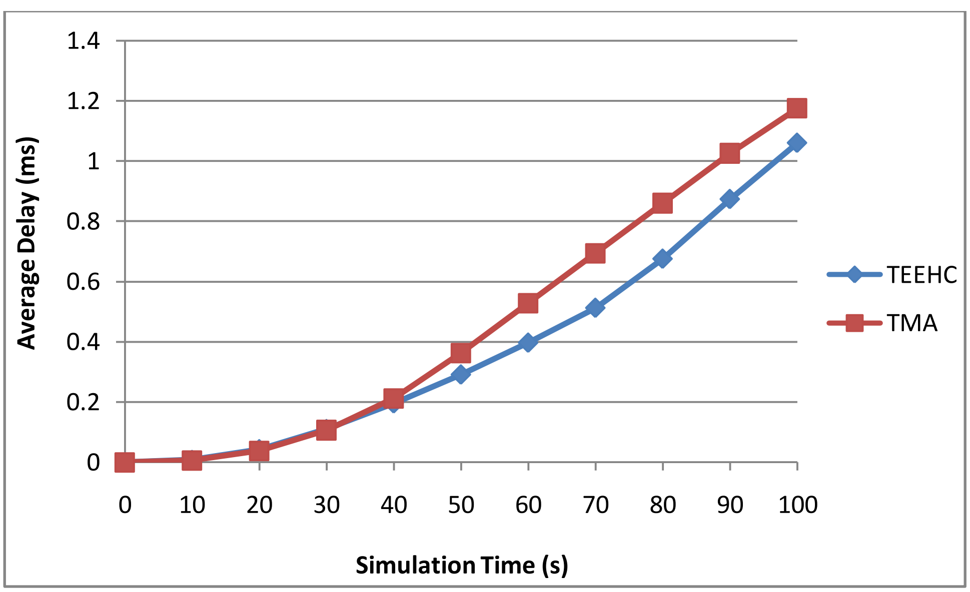

Figure 4.10 Average Delay of TEEHC and TMA for 100 nodes

Table 4.9 Average Delay values of TEEHC and TMA for 100 nodes

Simulation time (s)	Delay of TEEHC (ms)	Delay of TMA (ms)
0	0	0
10	0.007657	0.006372
20	0.043461	0.038859
30	0.110219	0.106996
40	0.195887	0.212281
50	0.291554	0.362851
60	0.397222	0.528617
70	0.51289	0.694433
80	0.675884	0.860249
90	0.873879	1.026066
100	1.060624	1.1753

The average delay occurred for both the existing and proposed mechanisms is measured in ms. Figure 4.10 shows that the TEEHC has 90.24% lower delay for a node when compared to the TMA scheme.

- **Throughput**

Throughput is also measured using the same equation used for throughput measurement in equation 4.9. The corresponding values obtained for throughput in TEEHC and TMA are given in Table 4.10. The values of throughput indicate that there is greater throughput observed in the TEEHC protocol.

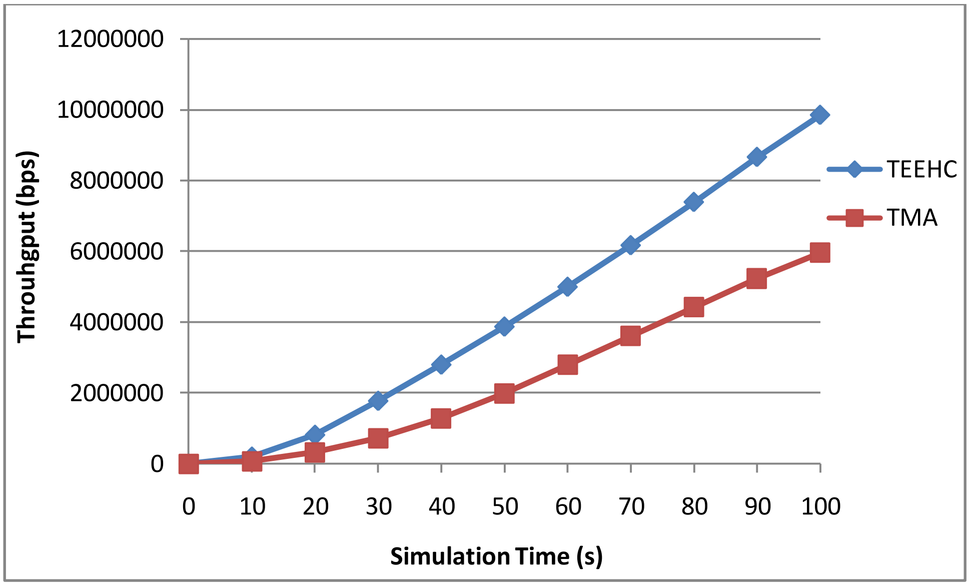

Figure 4.11 Throughput of TEEHC and TMA for 100 nodes

Table 4.10 Throughput values of TEEHC and TMA for 100 nodes

Simulation time (s)	Throughput of TEEHC (bps)	Throughput of TMA (bps)
0	0	0
10	203150	71000
20	819750	320200
30	1778900	728400
40	2802900	1284000
50	3876900	1989000
60	5000900	2800000
70	6175200	3612000
80	7397250	4424000
90	8668850	5236000
100	9857150	5966800

On an average 60.53% increase in throughput is observed. This is also reflected in figure 4.11 showing the throughput plots of both TEEHC and TMA mechanisms.

- **Residual Energy**

The amount of energy remaining in a node at the current instance of time is called as RE. Table 4.11 shows the RE values obtained during the simulation analysis.

Table 4.12 RE values of TEEHC and TMA for 100 nodes

Simulation Time (s)	RE of TEEHC (J)	RE of TMA (J)
0	10	10
10	9.70075	9.49075
20	9.41575	9.00575
30	9.13075	8.52075
40	8.84575	8.03575
50	8.56075	7.55075
60	8.27575	7.06575
70	7.99075	6.58075
80	7.70575	6.09575
90	7.42075	5.61075
100	7.15	5.15

Figure 4.12 shows that the RE of the network is better for the proposed scheme TEEHC when compared with the existing scheme TMA. Around 72.02% of energy is saved per node by using TEEHC protocol for routing.

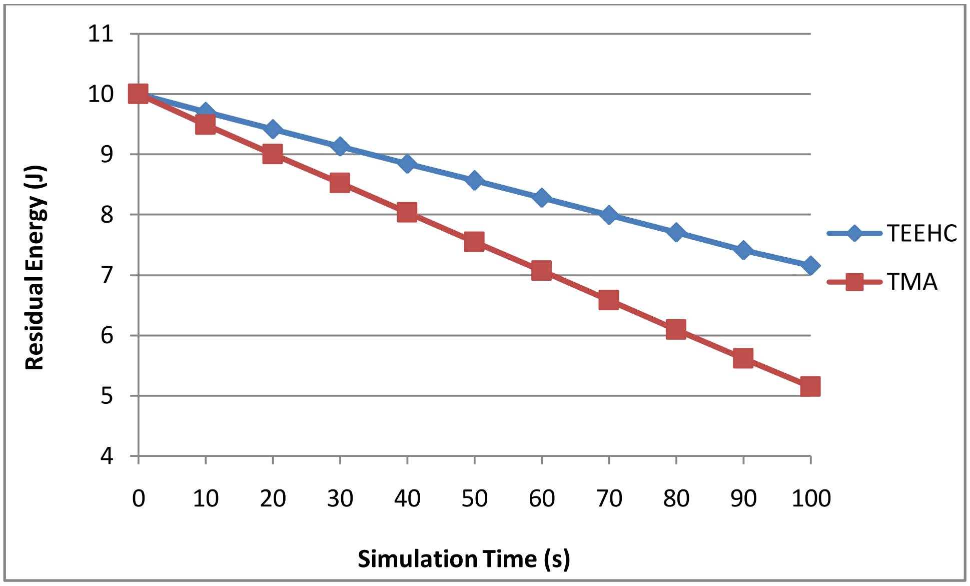

Figure 4.11 Residual Energy of TEEHC and TMA for 100 nodes

4.4 Summary

The TEEHC method has been simulated and analyzed using the network simulator, and the results have shown the efficiency of the TEEHC mechanism over the TMA. The total packet delivery is increased by 53.66%, packet loss is reduced by 20.93%, the average delay is reduced by 88.04%, throughput is increased by 53.66%, and residual energy is saved by 75.08% in the proposed TEEHC mechanism. Therefore this TEEHC method is better used by the hierarchical topology thereby reducing the number of tasks in the WSN and increasing the efficiency.