CHAPTER 5

DESIGN OF HIERARCHICAL TRUST BASED EFFICIENT CLUSTER HEAD SELECTION IN WSN (HTECH)

WSNs have been widely applied in various industrial applications, e.g., surveillance operations, an analysis of disease, monitoring of patient and equipment, source detection, fault prediction, pollution control, sea searching, tide follow-up to and report collected data to the sink by using multi-hp wireless communications. The nodes can collaborate and self-organize together to establish and maintain the network. Clustering means the grouping of nodes that are close to each other and the primary purpose is to reduce the energy consumption and routing overhead. However, the wireless and resource-constraint nature of a sensor network create it an ideal medium for malicious attackers to intrude the system. Thus, providing security is critical for the safe application of WSNs. To establish secure communications, it is to be ensured that all the communicating nodes are trusted. This highlights the fact that it is critical to develop a trust model allowing a sensor node to infer the trustworthiness of another node.

5.1 Background of the proposed HTECH

Due to limited computational power and energy resources, aggregation of data from multiple Sensor Nodes (SNs) secure routing is a significant problem because of very vulnerable in WSNs. Hence ascertaining trustworthiness of data is vital for WSNs. The Design of Hierarchical Trust based Efficient Cluster Head selection in WSN (HTECH) demonstrates the CH selection process based on Trust based routing in WSN. The trust evaluation relies on the SN cooperativeness, SN Unselfishness, SN honest and SN data transmission rate. This trusted route provides a realistic and secure approach to choose the shortest path in all trusted path.

5.2 Design of the proposed HTECH

The design of proposed method HTECH consists of two major phases: design of hierarchical trust phase and efficient CH selection phase.

5.2.1 Design of Hierarchical Trust

Trusted routing can kick out the untrustworthy nodes to obtain a reliable passage delivery route. Hierarchical Trust Design process considers four components such as node unselfishness, Node Cooperativeness, Node Honest and Node Data Transmission Rate.

- **Node Unselfishness Rate**

Node unselfishness refers to the rate of unselfishness. A node may become selfish to save energy. A selfish node may stop reading data and drops packets it receives. An unselfish node may turn selfish in every trust evaluation interval according to its residual energy and the number of unselfish neighbors around. The node Unselfishness Rate assessment is given in equation 5.1.

$$N_{USR} = \frac{E_{utlization}}{E_{IE}} + \frac{US_{neighbor}}{N_{\deg ree}} \tag{5.1}$$

Where

$E_{utlization}$ → Energy Utilization

$US_{neighbor}$ →Unselfish Neighbor

E_{IE} →Initial Energy

$N_{\deg ree}$ →Node Degree

- **Node Cooperativeness Rate**

Node cooperativeness refers to the experience of interaction between neighbor nodes. The Node Cooperativeness is calculated depending upon the difference between the number of Route Request (RREQ) messages to a particular node, and the number of non Route Reply (RREP) message to the RREQ message received. The node cooperativeness calculation is given in equation 5.2.

$$N_{CR} = \frac{RREQ_c - NRREP_c}{RREQ_c} \tag{5.2}$$

Where

$RREQ_c$ →Route Request Count

$NRREP_c$ →Non-Route Reply Count

- **Node Honest Rate**

A compromised node is that which performs some functions different from a legitimate node. Every node estimates by keeping a count of suspicious dishonest experience of the node based on the high discrepancy in the sensor reading, retransmission, repetition, and delay. The Node Honest Rate Computation is given in equation 5.3.

$$N_{HR} = \frac{N_{CN}}{N_{UCN}} \tag{5.3}$$

Where

N_{CN} →Node Compromised Neighbor

N_{UCN} →Node Uncompromised Neighbor

- **Node Data Transmission Rate**

Every node computes the Data Transmission Rate based on the packet sent during a time interval. The Node Transmission Rate computation is given in equation 5.4.

$$N_{DTR} = \frac{Packet\ sent\ Rate}{time} \tag{5.4}$$

The Trust Value of every node computation is given in equation 5.5.

$$T_N = \frac{1}{4}\left(N_{CR} + N_{USR} + N_{HR} + N_{DTR}\right) \tag{5.5}$$

5.2.2 Efficient Cluster Head Selection

Hierarchical Trust based Efficient Cluster Head Selection in WSN (HTECH) is designed in which the BS is placed at the corner of the field and SNs forms clusters. The cluster contains SNs and CH. CH is responsible only for receiving data from the CMs, perform aggregation process over the received data and then send to the BS. The

CH operations are transmitting, receiving and overhearing. In case the CH is wicked, all process will fail.

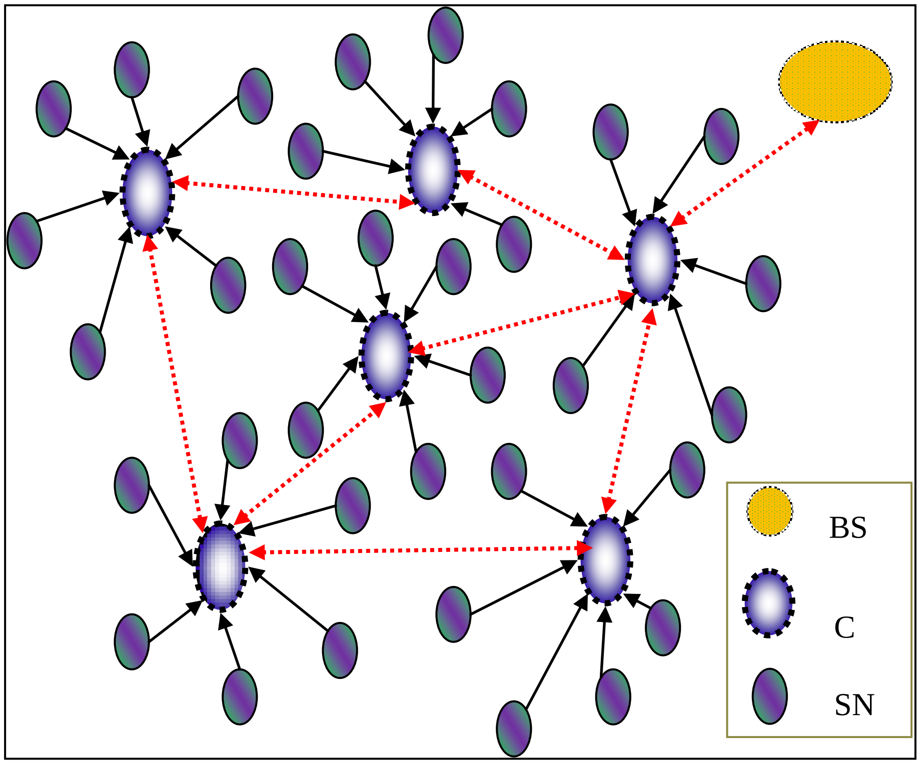

Figure 5.1 Illustration of HTECH

Therefore, the selecting CH becomes an important task. CH is selected based on the Trust Evaluation. If the trust value is greater than average trust, that node is selected as a CH. The CH collects the data from SNs, then aggregates the data and sends it to the BS. Figure 5.1 describes the diagram of the HTECH scheme.

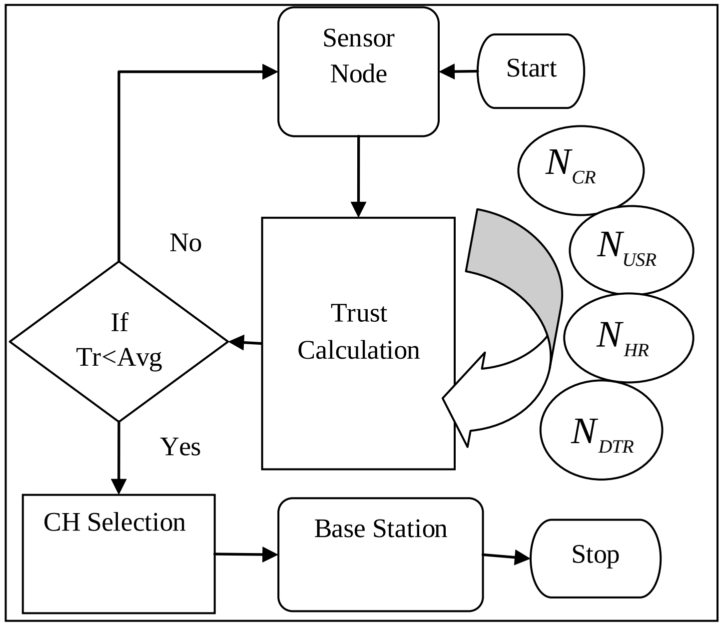

Figure 5.2 Working Flow of HTECH

Figure 5.2 shows the working flow of the proposed scheme in which CH is selected based on the SN Trust. The trust value computation depends on Node Unselfishness Rate, Node Cooperativeness Rate, Node Cooperativeness Rate and Node Data Transmission Rate. If the trust value is greater than the Average Trust, then that node is selected as a CH. CH receives the data from SNs, then aggregate these data and send it to the BS.

5.3 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 5.1.

Table 5.1 Simulation Parameters of HTECH

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	HTECH
Simulation Area	1000×600
Simulation Time	100 s
Traffic model	Constant Bit Rate (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 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.

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

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

5.3.1 Simulation of HTECH using 50 nodes

Simulation analysis of the proposed HTECH 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 5.6.

$$PDR = \frac{\sum_{0}^{n} Packets\ Received}{Time} \tag{5.6}$$

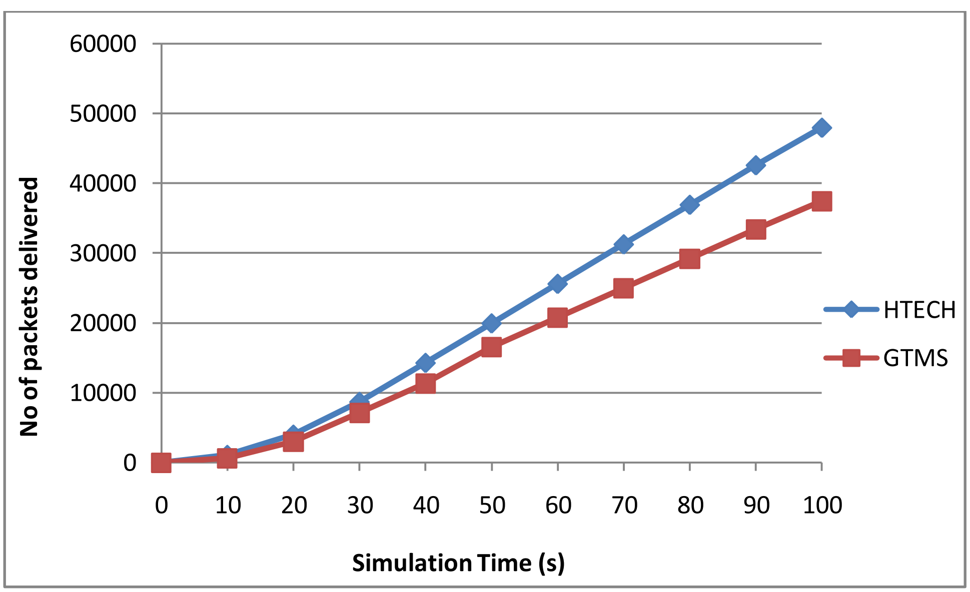

Figure 5.3 Packet Delivery Rate of HTECH and GTMS for 50 nodes

Table 5.2 PDR values of HTECH and GTMS for 50 nodes

Simulation Time (s)	PDR of HTECH	PDR of GTMS
0	0	0
10	1109	606
20	4013	3037
30	8702	7116
40	14292	11336
50	19952	16556
60	25612	20776
70	31272	24996
80	36932	29216
90	42592	33436
100	47969	37445

The table 5.2 shows the PDR values of HTECH and Group-based Trust Management Scheme (GTMS) during the simulation analysis for 50 nodes. The PDR of HTECH and GTMS is plotted in figure 5.3. It shows that the proposed scheme HTECH has 78.06% better PDR when compared to the existing GTMS.

- **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 5.7.

$$PLR = \frac{\sum_0^n Sent\ Pkts - Rcvd\ Pkts}{Time} \quad (5.7)$$

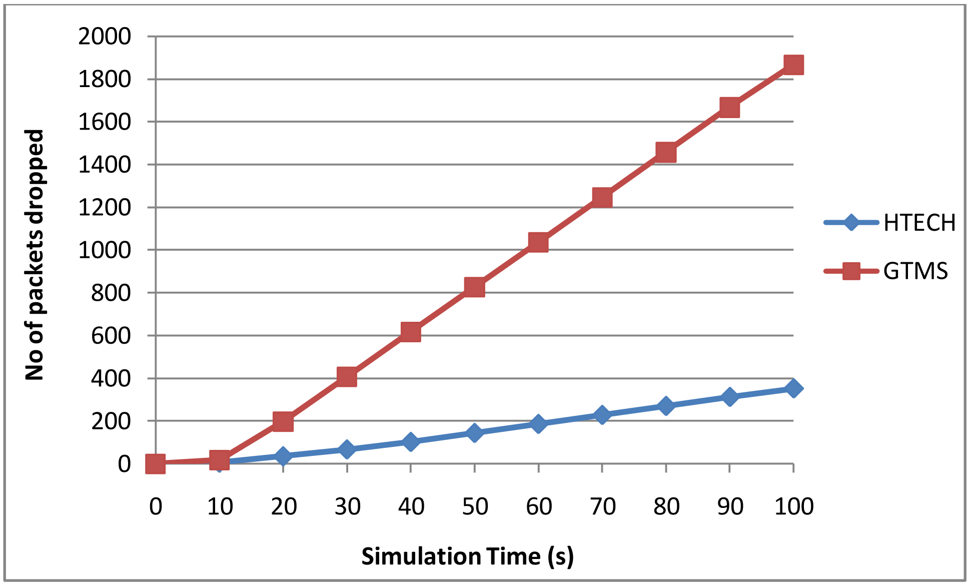

Figure 5.4 Packet Loss Rate of HTECH and GTMS for 50 nodes

Table 5.3 PLR values of HTECH and GTMS for 50 nodes

Simulation Time (s)	PLR of HTECH	PLR of GTMS
0	0	0
10	6	18
20	35	198
30	67	408
40	102	618
50	144	828
60	186	1038
70	228	1248
80	270	1458
90	312	1668
100	352	1867

Table 5.3 shows that the PLR values obtained from the simulation analysis of HTECH and GTMS. Figure 5.4 indicates that the PLR of proposed scheme HTECH is lower by 18.85% when compared to that of existing scheme GTMS.

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

$$Avg\ Delay = \frac{\sum_{0}^{n}(Packet\ \text{Re}ceived\ Time - Packet\ Sent\ Time)}{n} \tag{5.8}$$

Table 5.4 shows that the average delay obtained from simulation analysis of HTECH and GTMS mechanisms for 50 nodes. Figure 5.5 indicates that the HTECH has 53.28% lower delay for a node when compared to the GTMS scheme.

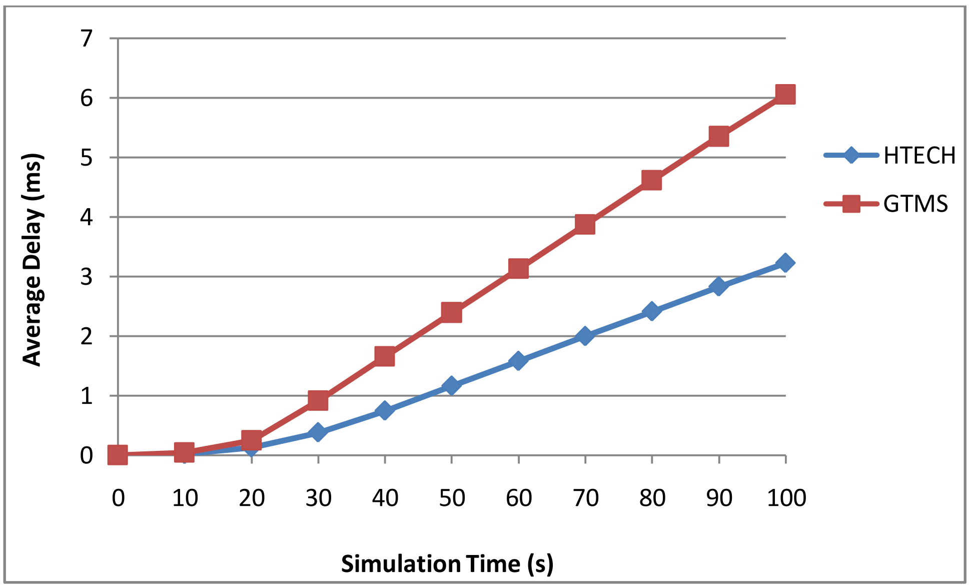

Figure 5.5 Average Delay of HTECH and GTMS for 50 nodes

Table 5.4 Average Delay values of HTECH and GTMS for 50 nodes

Simulation time (s)	Delay of HTECH (ms)	Delay of GTMS (ms)
0	0	0
10	0.018109	0.037923
20	0.128532	0.249347
30	0.379553	0.911868
40	0.744603	1.651622
50	1.161588	2.391377
60	1.578574	3.131131
70	1.995559	3.870886
80	2.412544	4.61064
90	2.82953	5.350395
100	3.225666	6.053162

- **Throughput**

Throughput refers to the total number of packets successfully delivered across the network for every 1000 packets sent. Throughput is obtained using equation 5.9.

$$Throughput = \frac{\sum_0^n Packets\ Received(n) * Packet\ size}{1000} \quad (5.9)$$

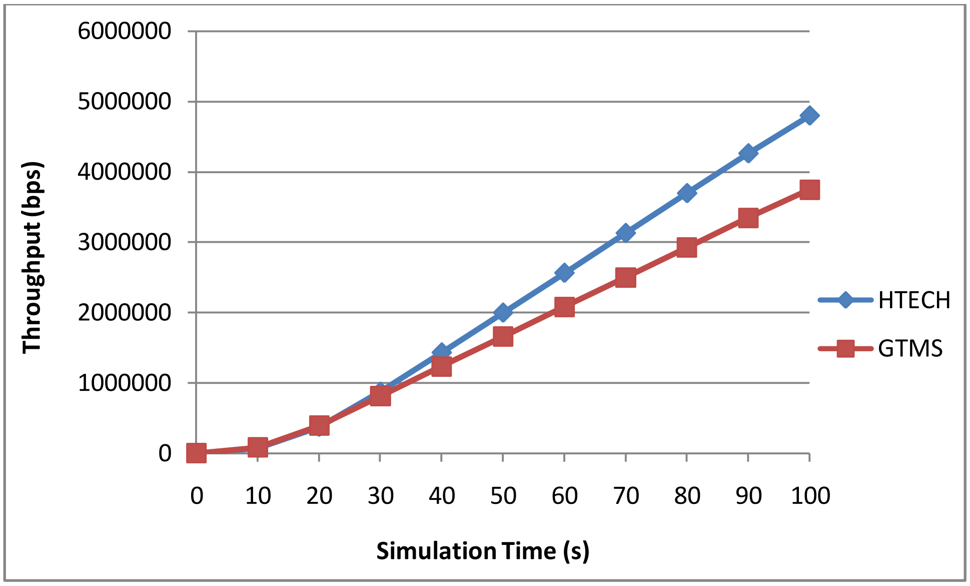

Figure 5.6 Throughput of HTECH and GTMS for 50 nodes

Table 5.5 Throughput values of HTECH and GTMS for 50 nodes

Simulation time (s)	Throughput of HTECH (bps)	Throughput of GTMS (bps)
0	0	0
10	70900	78600
20	371300	393700
30	870200	811600
40	1429200	1233600
50	1995200	1655600
60	2561200	2077600
70	3127200	2499600
80	3693200	2921600
90	4259200	3343600
100	4796900	3744500

Table 5.5 indicates that the throughput values received throughout simulation analysis. It can be observed from figure 5.6 that the number of packets received successfully for every 1000 packets for HTECH is greater than 78.06% compared to that of the GTMS mechanism.

- **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 5.6 shows the RE values obtained during the simulation analysis.

Figure 5.7 shows that the RE of the network is better for the proposed scheme HTECH when compared with the existing scheme GTMS. Around 97.99% of energy is saved per node by using HTECH protocol for routing.

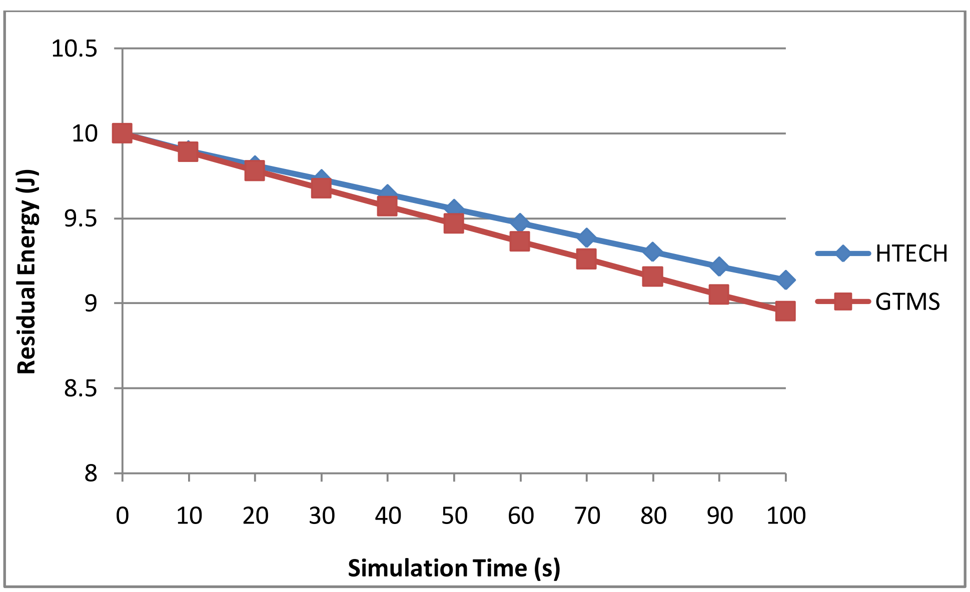

Figure 5.7 Residual Energy of HTECH and GTMS for 50 nodes

Table 5.6 RE values of HTECH and GTMS for 50 nodes

Simulation Time (s)	RE of HTECH (J)	RE of GTMS (J)
0	10	10
10	9.89675	9.8908
20	9.81175	9.7798
30	9.72675	9.6758
40	9.64175	9.5718
50	9.55675	9.4678
60	9.47175	9.3638
70	9.38675	9.2598
80	9.30175	9.1558
90	9.21675	9.0518
100	9.136	8.953

5.3.2 Simulation of HTECH 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 5.6 during simulations of the HTECH and the GTMS protocols. These values are displayed in Table 5.7 and also plotted in figure 5.8.

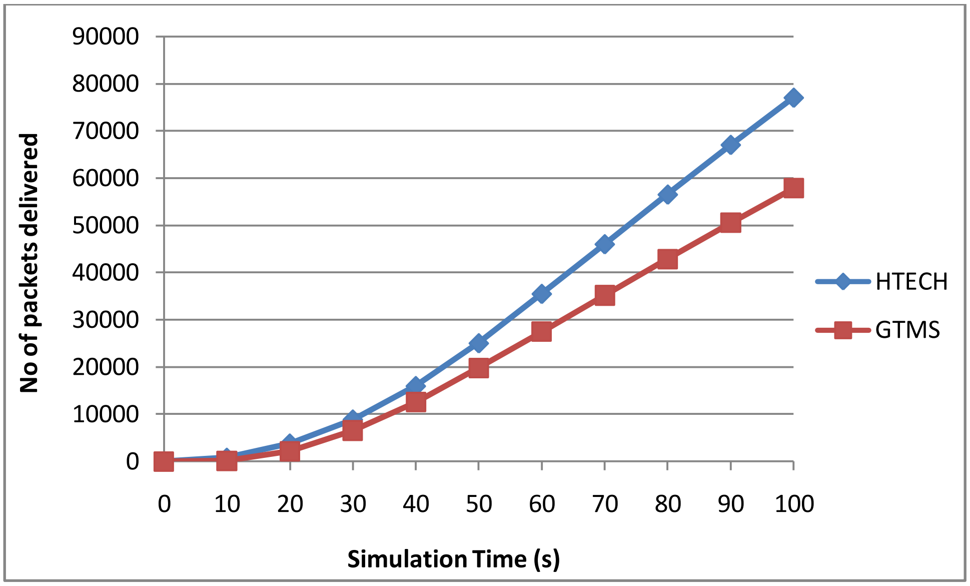

Figure 5.8 Packet Delivery Rate of HTECH and GTMS for 100 nodes

Table 5.7 PDR values of HTECH and GTMS for 100 nodes

Simulation Time (s)	PDR of HTECH	PDR of GTMS
0	0	0
10	768	129
20	3779	2192
30	8869	6562
40	15959	12553
50	25033	19779
60	35483	27479
70	46003	35179
80	56523	42879
90	67043	50579
100	77037	57894

This shows that the PDR of HTECH is 75.15% greater than that of the GTMS 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 5.7 for 100 nodes. The PLR of HTECH and GTMS for 100 nodes are plotted in Table 5.8.

The PLR of GTMS is 11.2% greater than the HTECH mechanism. The PLR of HTECH and GTMS for 100 nodes are plotted in figure 5.9.

Table 5.8 PLR values of HTECH and GTMS for 100 nodes

Simulation Time (s)	PLR of HTECH	PLR of GTMS
0	0	0
10	0	0
20	10	86
30	26	216
40	42	346
50	58	481
60	74	631
70	90	781
80	106	931
90	122	1081
100	137	1223

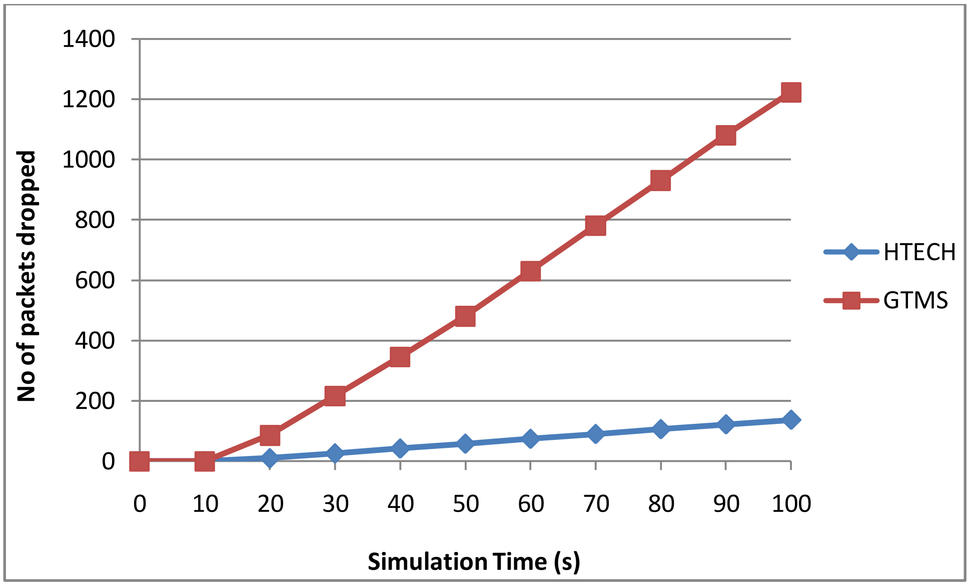

Figure 5.9 Packet Loss Rate of HTECH and GTMS for 100 nodes

- **Average Delay**

Similar to all the previous parameters, the average delay is also measured using the equation 5.8. The values are tabulated in Table 5.9 for both HTECH and GTMS.

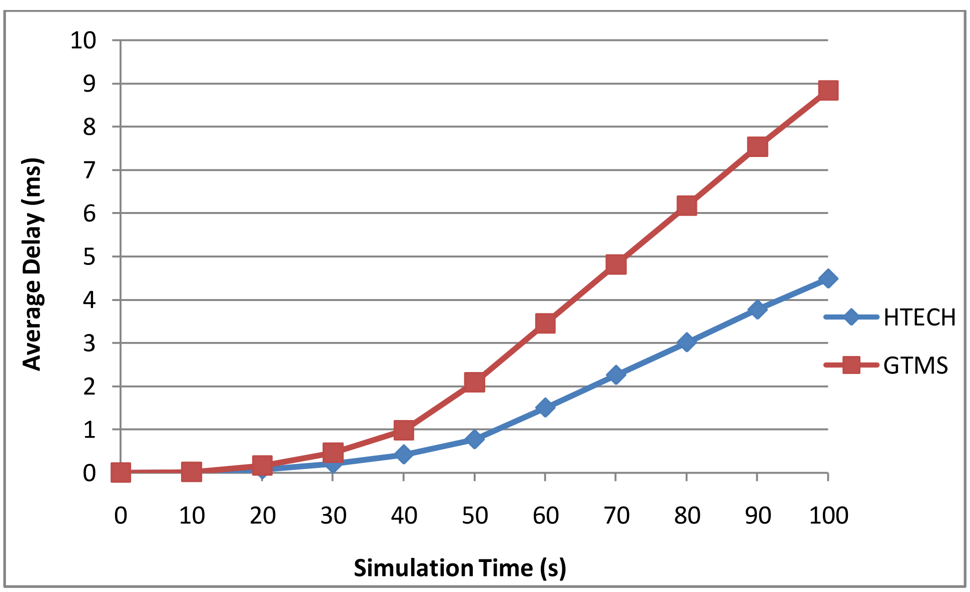

Figure 5.10 Average Delay of HTECH and GTMS for 100 nodes

Table 5.9 Average Delay values of HTECH and GTMS for 100 nodes

Simulation time (s)	Delay of HTECH (ms)	Delay of GTMS (ms)
0	0	0
10	0.012711	0.014024
20	0.075142	0.157214
30	0.204228	0.461664
40	0.416701	0.972485
50	0.76664	2.080516
60	1.500795	3.444239
70	2.256271	4.807961
80	3.011747	6.171684
90	3.767222	7.535407
100	4.484924	8.830944

The average delay occurred for both the existing and proposed mechanisms is measured in ms. Figure 5.10 shows that the HTECH has 50.78% lower delay for a node when compared to the GTMS scheme.

- **Throughput**

Throughput is also measured using the same equation used for throughput measurement in equation 5.9. The corresponding values obtained for throughput in HTECH and GTMS are given in Table 5.10. The values of throughput indicate that there is greater throughput observed in the HTECH protocol.

On an average 75.15% increase in throughput is observed. This is also reflected in figure 5.11 showing the throughput plots of both HTECH and GTMS mechanisms.

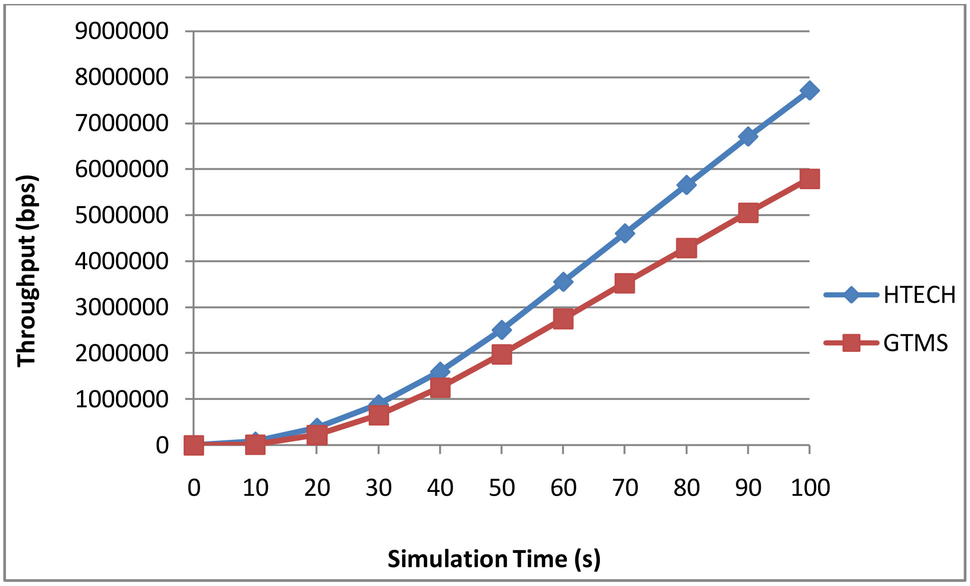

Figure 5.11 Throughput of HTECH and GTMS for 100 nodes

Table 5.10 Throughput values of HTECH and GTMS for 100 nodes

Simulation time (s)	Throughput of HTECH (bps)	Throughput of GTMS (bps)
0	0	0
10	76800	12900
20	377900	219200
30	886900	656200
40	1595900	1255300
50	2503300	1977900
60	3548300	2747900
70	4600300	3517900
80	5652300	4287900
90	6704300	5057900
100	7703700	5789400

- **Residual Energy**

The amount of energy remaining in a node at the current instance of time is called as RE. Table 5.11 shows the RE values obtained during the simulation analysis.

Figure 5.12 indicates that the RE of the network is better for the proposed scheme HTECH when compared with the existing scheme GTMS. Around 93.36% of energy is saved per node by using HTECH protocol for routing.

Table 5.11 RE values of HTECH and GTMS for 100 nodes

Simulation Time (s)	RE of HTECH (J)	RE of GTMS (J)
0	10	10
10	9.87575	9.81975
20	9.77075	9.65475
30	9.66575	9.48975
40	9.56075	9.32475
50	9.45575	9.15975
60	9.35075	8.99475
70	9.24575	8.82975
80	9.14075	8.66475
90	9.03575	8.49975
100	8.936	8.343

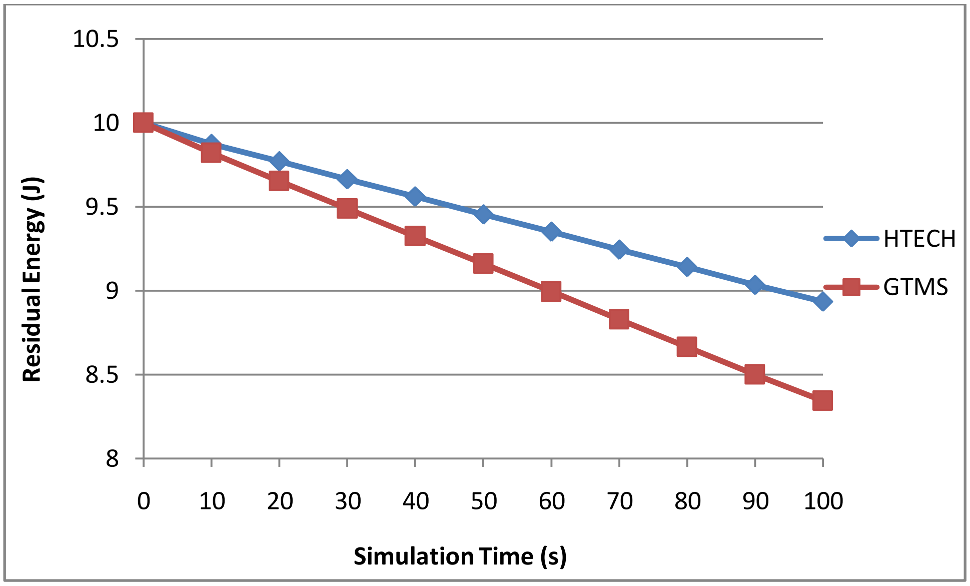

Figure 5.12 Residual Energy of HTECH and GTMS for 100 nodes

5.4 Summary

The HTECH method has been simulated and analyzed using the network simulator, and the results have shown the efficiency of the HTECH mechanism over the GTMS. The total packet delivery is increased by 76.6%, packet loss is reduced by 15.02%, the average delay is reduced by 52.03%, throughput is increased by 76.6%, and residual energy is saved by 95.68% in the proposed HTECH mechanism. Therefore this HTECH method is better used by the hierarchical topology thereby reducing the number of tasks in the WSN and increasing the efficiency.