CHAPTER 6

AN EFFICIENT DATA COLLECTION SCHEME BASED ON TRUST EVALUATION IN LARGE SCALE WIRELESS SENSOR NETWORKS

WSNs consist of hundreds to thousands of inexpensive wireless nodes with limited computational capacity and energy resources deployed in an unattended location. Most effective utilization of WSNs requires minimization of power usage through the design of energy efficient network protocols and algorithms to prolong network lifetime. Since sensor nodes are usually low priced hardware apparatus, they are very vulnerable and often become the fault. It imperils the reliability of data transmission and degrades the network performance. A single intermediate node can break a route; malevolent nodes can frequently break routes. When a route is broken, the nodes have to rely on cycles of time-out and route discoveries to reestablish the route. These route developments may incur network-wide flooding of route requests that use a significant amount of the network's resources. Thus, to create stable routes and continuous traffic flow, it is important to assess the nodes' competence and consistency in relaying packets to make informed routing decisions.

6.1 Background of the proposed EDCTE

In WSNs, trust management is necessary to evaluate the nodes trustworthiness, capability, and reliability in relaying packets. A node’s trust value is defined as the degree of belief about the node’s behavior that is the probability that the node will behave as predictable. The trust values are calculated based on past practices and are used to predict their future conduct. The majority of the trust systems in wireless networks compute a single trust value for every node. However, a single measure may not be significantly enough to depict a node's trustworthiness and capability sufficiently.

An Efficient Data Collection Scheme based on trust evaluation in Large Scale WSNs is developed. The main is to establish the reliable path and improve the network throughput based on trust evaluation. In this scheme, the nodes are grouped into clusters, and a node with substantial computing power and trusted node is elected as a CH. Establishing trust in a clustered environment provides numerous advantages such as to detect faulty or malevolent within a cluster.

6.2 Design of the proposed EDCTE

The trust mechanism can be used to ensure the security of data collection and data forwarding in WSNs. It can be used to detect the compromised and malevolent node to provide the trust relationship between nodes. An Efficient Data Collection based on Trust Evaluation (EDCTE) in Large Scale WSNS improves the reliability of data aggregation and energy efficiency. The EDCTE scheme consists of set-up phase and steady state phase. In the set-up phase, cluster formation, CH and Data Collector (DC) selection identifies the optimal path between Cluster Members (CMs) and BS. Then, the steady state phase is initiated to transfer the data from the CMs to the BS. Figure 1 shows the structure of the EDCTE scheme.

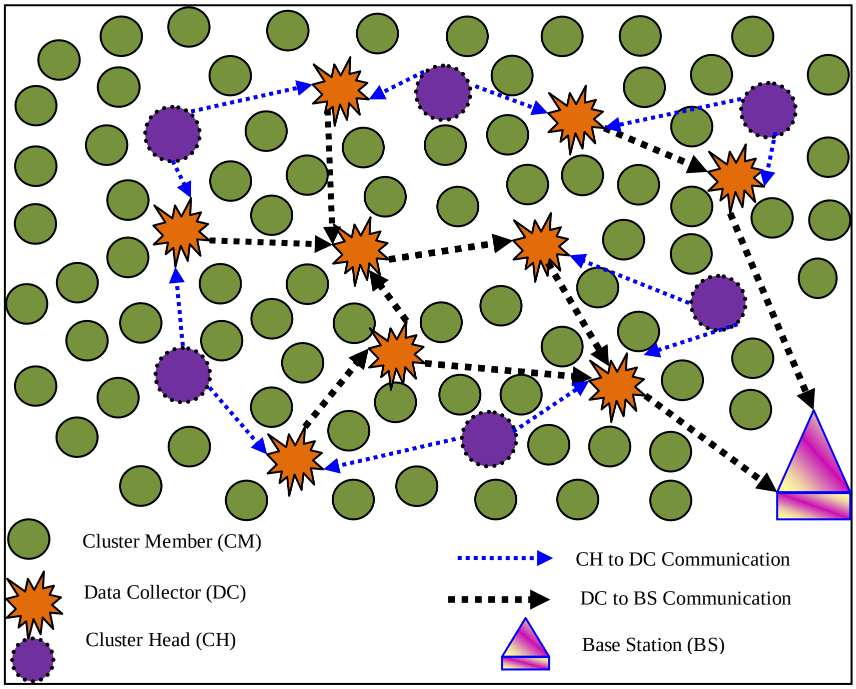

Figure 6.1 EDCTE Structure

6.2.1 Setup Phase

The set-up phase consists of CH election and DC selection. Every CH needs to enough energy for both the data gathering from CMs and forward the data to DC. Thus, the CMs elect the CH based on trust and residual energy. The trust value is determined according to the node behavior. The CH trust values are computed in equation 6.1.

$$T_{CH} = \frac{S_I}{S_I + US_I} \tag{6.1}$$

Where

$S_I \rightarrow$ Total number of Successful interactions

$US_I \rightarrow$ Unsuccessful interactions

The DC nodes are necessary to select the multiple paths to the BS. While selecting the data transmission path from CH to BS, the BS chooses the DC based on the trust value to ensure selecting the better communication path. The Feedback from the adjacent nodes serves as the dynamic information of the current network. This information is included in the acknowledgment without any usage of a special message for the consideration of avoids network congestion and is given in equation 6.2.

$$T_{DC} = \frac{F_F}{S_I + E} \tag{6.2}$$

Where

F_F → Feedback Factor

E →Energy

The feedback factor F_F is calculated in equation 6.3.

$$F_F = \frac{P_F + 1}{N_F + P_F} \tag{6.3}$$

Where

P_F →Positive feedback of Adjacent Node

N_F →Negative feedback of Adjacent Node

6.2.2 Steady State Phase

Once the set-up phase is completed, a steady-state phase is initiated. In steady-state phase, all the CMs send the collected data to the CH in an allocated time slot.

Then, the CH starts to gather and aggregate the data from its CMs. After the DC is initiated to collect the data from its CH, it then forwards the aggregated data packet to the BS. All the CHs are connected with DC and all the DC transmit the aggregated data to the BS. Here, the DC is responsible for collecting the data from the corresponding CH and transmitting the data to BS.

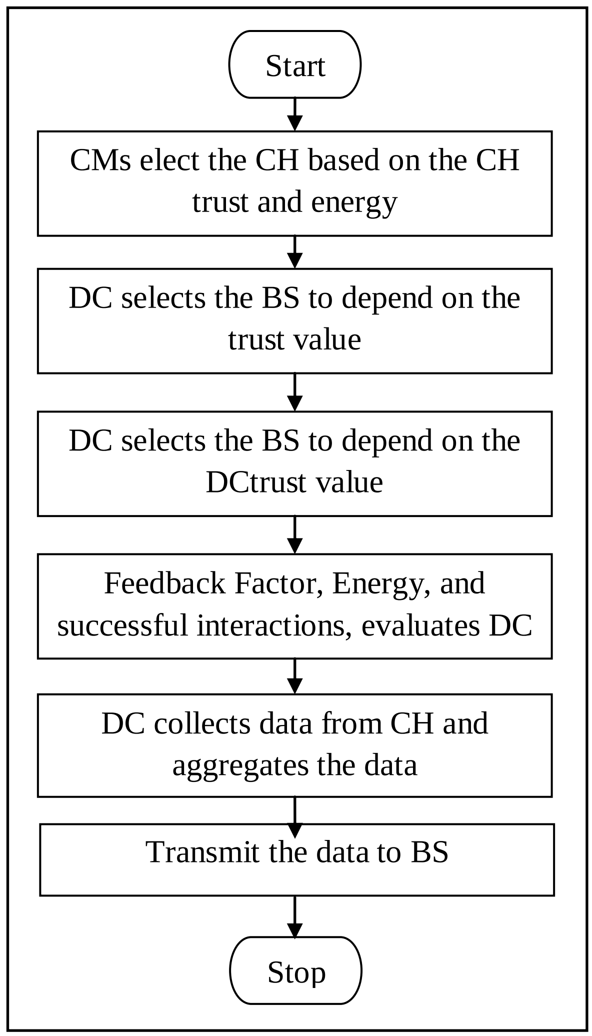

Figure 6.2 Flowchart of the EDCTE scheme

Figure 6.2 display the flowchart of the EDCTE that is a clustering method that uses the DC to collect the data from the CH and deliver it to the BS. The BS selects the DC based on the trust and CMs to choose the CH based on the trust and energy. The

CH gathers the data from CMs then aggregate the data. The DC collects the data from the CH and forwards it to the next DC. Once the DC reaches the BS, the process is stopped. EDCTE secures the multi-hop routing in WSNs against misdirecting the multi-hop routing by evaluating the trustworthiness nodes. EDCTE is also energy efficient, highly scalable and well adaptable.

6.3 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. The parameters used for the simulation of the proposed scheme are described in Table 6.1.

Table 6.1 Simulation Parameters of EDCTE

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

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 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 EDCTE, simulation can be performed using two types of analysis.

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

6.3.1 Simulation of EDCTE using 50 nodes

Simulation analysis of the proposed EDCTE 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 6.4.

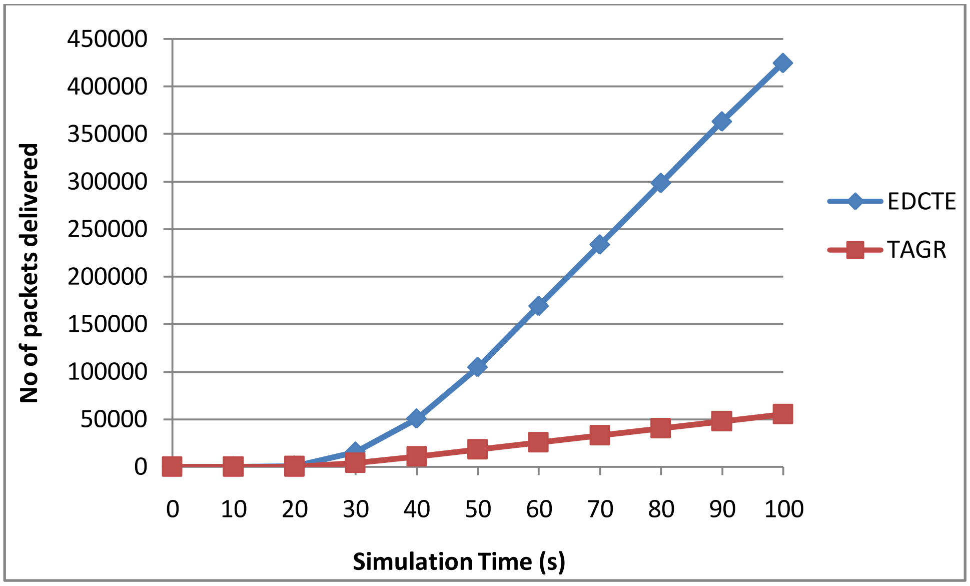

Figure 6.3 Packet Delivery Rate of EDCTE and TAGR for 50 nodes

Table 6.2 PDR values of EDCTE and TAGR for 50 nodes

Simulation Time (s)	**PDR of EDCTE**	**PDR of TAGR**
0	0	0
10	67	67
20	744	320
30	15526	3752
40	50503	10836
50	104687	18020
60	169016	25360
70	233730	32805
80	298518	40371
90	363318	47971
100	424878	55191

$$PDR = \frac{\sum_0^n Packets\ Received}{Time} \qquad (6.4)$$

Table 6.2 shows the PDR values of EDCTE and Trust-Aware Geographical Routing (TAGR) during the simulation analysis for 50 nodes. The PDR of EDCTE and TAGR is plotted in figure 6.3. It shows that the proposed scheme EDCTE has 12.98% better PDR when compared to the existing TAGR.

- **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 6.5.

$$PLR = \frac{\sum_0^n Sent\ Pkts - Rcvd\ Pkts}{Time} \qquad (6.5)$$

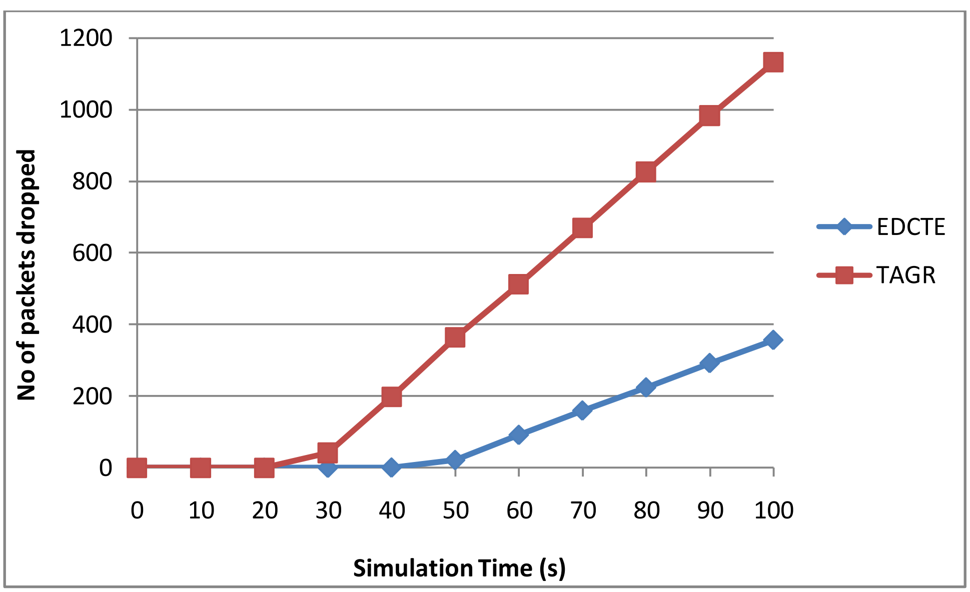

Figure 6.4 Packet Loss Rate of EDCTE and TAGR for 50 nodes

Table 6.3 PLR values of EDCTE and TAGR for 50 nodes

Simulation Time (s)	PLR of EDCTE	PLR of TAGR
0	0	0
10	0	0
20	0	0
30	0	41
40	0	198
50	21	363
60	91	512
70	159	669
80	224	826
90	292	983
100	356	1132

Table 6.3 shows that the PLR values obtained from the simulation analysis of EDCTE and TAGR. Figure 6.4 indicates that the PLR of proposed scheme EDCTE is lower by 31.44% when compared to that of existing scheme TAGR.

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

$$Avg\ Delay = \frac{\sum_{0}^{n} (Packet\ \mathrm{Re}ceived\ Time - Packet\ Sent\ Time)}{n} \tag{6.6}$$

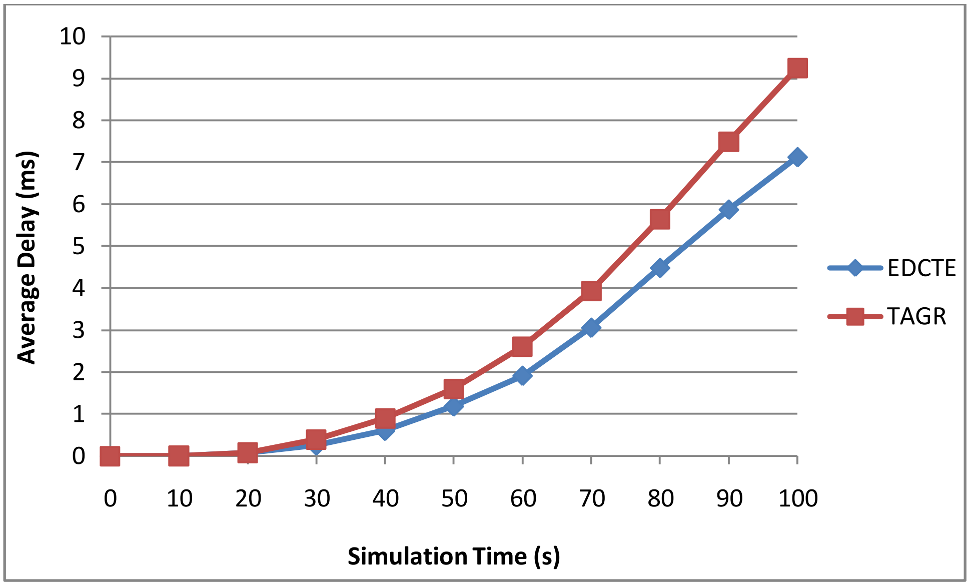

Figure 6.5 Average Delay of EDCTE and TAGR for 50 nodes

Table 6.4 Average Delay values of EDCTE and TAGR for 50 nodes

Simulation time (s)	Delay of EDCTE (ms)	Delay of TAGR (ms)
0	0	0
10	0.004535	0.005668
20	0.069428	0.082697
30	0.253601	0.390683
40	0.603124	0.898955
50	1.185717	1.596626
60	1.914899	2.615057
70	3.060829	3.932342
80	4.486044	5.651688
90	5.876244	7.496403
100	7.127424	9.248883

Table 6.4 shows that the average delay obtained from simulation analysis of EDCTE and TAGR mechanisms for 50 nodes. Figure 6.5 indicates that the EDCTE has 77.06% lower delay for a node when compared to the TAGR 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 6.7.

$$Throughput = \frac{\sum_{0}^{n} Packets\ Received(n) * Packet\ size}{1000} \tag{6.7}$$

Table 6.5 Throughput values of EDCTE and TAGR for 50 nodes

Simulation time (s)	Throughput of EDCTE (bps)	Throughput of TAGR (bps)
0	0	0
10	6700	6700
20	74400	32000
30	1552600	375200
40	5050300	1083600
50	10468700	1802000
60	16901600	2536000
70	23373000	3280500
80	29851800	4037100
90	36331800	4797100
100	42487800	5519100

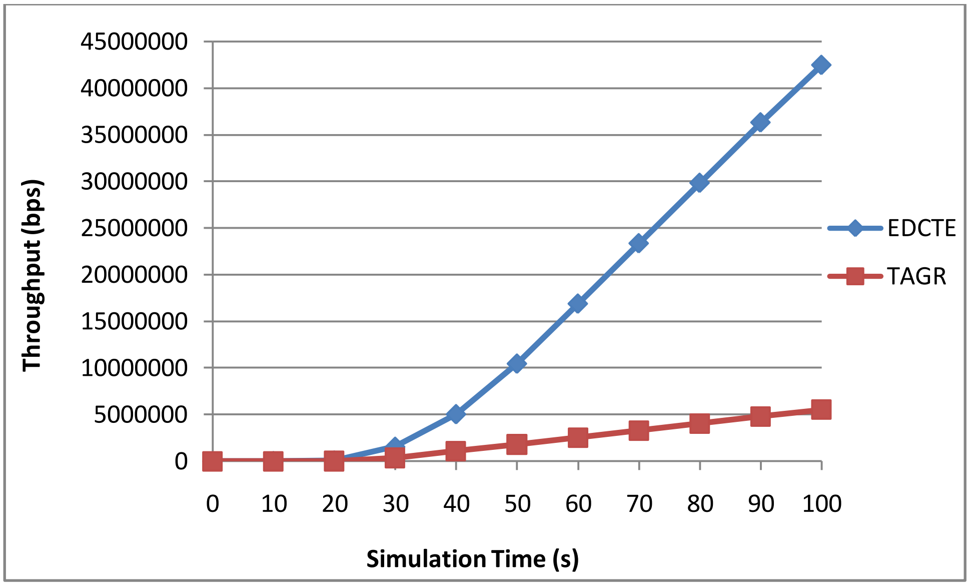

Figure 6.6 Throughput of EDCTE and TAGR for 50 nodes

Table 6.5 indicates that the throughput values received throughout simulation analysis. It can be observed from figure 6.6 that the number of packets received successfully for every 1000 packets for EDCTE is greater than 12.98% compared to that of the TAGR 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 6.6 shows the RE values obtained during the simulation analysis.

Figure 6.7 indicates that the RE of the network is better for the proposed scheme EDCTE when compared with the existing scheme TAGR. Around 98.97% of energy is saved per node by using EDCTE protocol for routing.

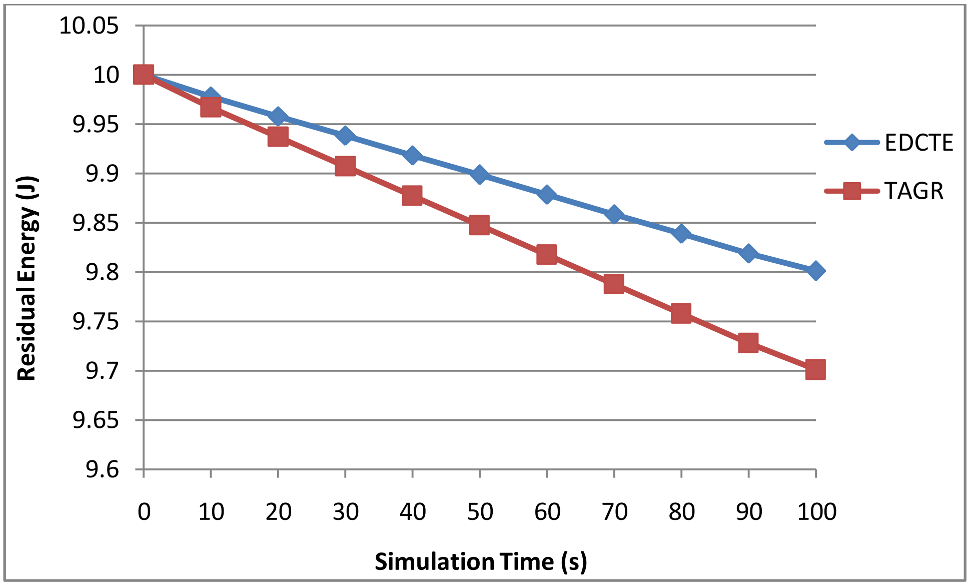

Figure 6.7 Residual Energy of EDCTE and TAGR for 50 nodes

Table 6.6 RE values of EDCTE and TAGR for 50 nodes

Simulation Time (s)	RE of EDCTE (J)	RE of TAGR (J)
0	10	10
10	9.97811	9.96711
20	9.95821	9.93721
30	9.93831	9.90731
40	9.91841	9.87741
50	9.89851	9.84751
60	9.87861	9.81761
70	9.85871	9.78771
80	9.83881	9.75781
90	9.81891	9.72791
100	9.801	9.701

6.3.2 Simulation of EDCTE 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 6.4 during simulations of the EDCTE and the TAGR protocols. These values are displayed in Table 6.7 and also plotted in figure 6.8.

Table 6.7 PDR values of EDCTE and TAGR for 100 nodes

Simulation Time (s)	PDR of EDCTE	PDR of TAGR
0	0	0
10	0	0
20	179	179
30	4819	2304
40	28314	7284
50	72099	16947
60	136456	27171
70	220698	37601
80	323008	48057
90	441874	58517
100	557926	68454

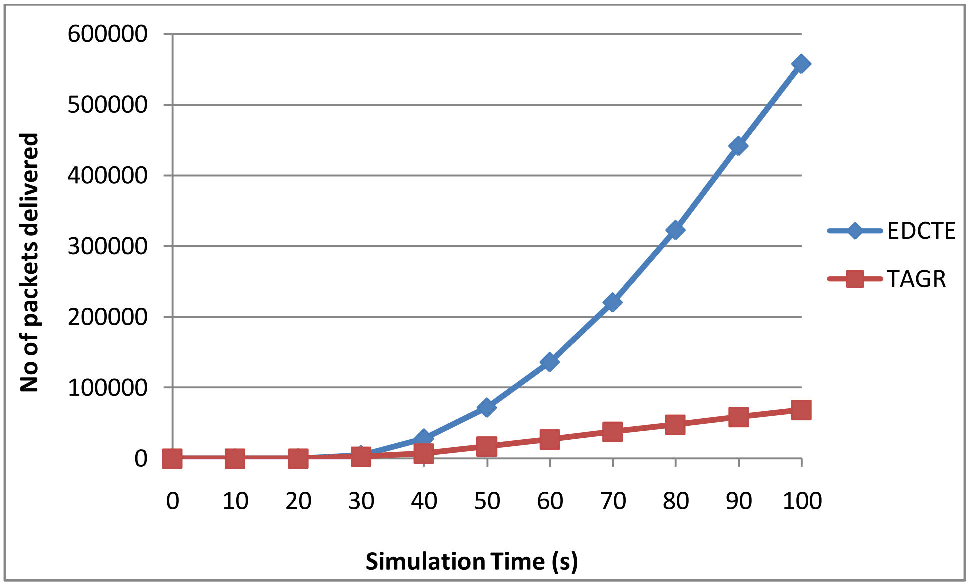

Figure 6.8 Packet Delivery Rate of EDCTE and TAGR for 100 nodes

This shows that the PDR of EDCTE is 12.26% greater than that of the TAGR 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 6.5 for 100 nodes. The PLR of EDCTE and TAGR for 100 nodes are plotted in Table 6.8.

The PLR of TAGR is 28.16% greater than the EDCTE mechanism. The PLR of EDCTE and TAGR for 100 nodes are plotted in figure 6.9.

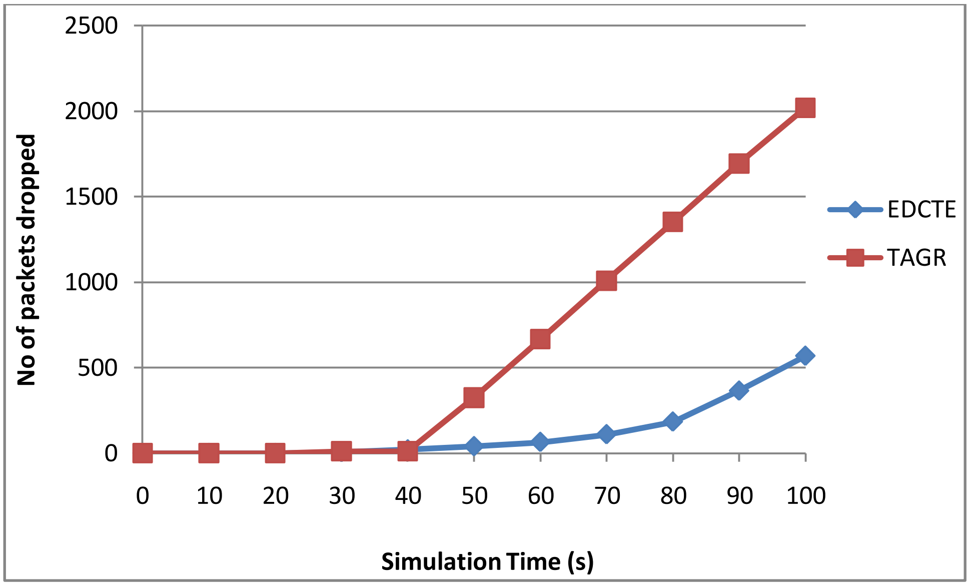

Figure 6.9 Packet Loss Rate of EDCTE and TAGR for 100 nodes

Table 6.8 PLR values of EDCTE and TAGR for 100 nodes

Simulation Time (s)	PLR of EDCTE	PLR of TAGR
0	0	0
10	0	0
20	0	0
30	6	10
40	21	10
50	40	324
60	65	667
70	110	1009
80	184	1352
90	365	1694
100	569	2020

- **Average Delay**

Similar to all the previous parameters, the average delay is also measured using the equation 6.6. The values are tabulated in Table 6.9 for both EDCTE and TAGR.

Table 6.9 Average Delay values of EDCTE and TAGR for 100 nodes

Simulation time (s)	Delay of EDCTE (ms)	Delay of TAGR (ms)
0	0	0
10	0	0
20	0.113157	0.141446
30	0.611279	0.818626
40	1.399907	1.969395
50	2.542234	3.565308
60	4.344104	6.048728
70	6.449259	9.101061
80	8.667769	12.22515
90	11.05612	15.36374
100	13.35257	18.3454

The average delay occurred for both the existing and proposed mechanisms is measured in ms. Figure 6.10 shows that the EDCTE has 72.78% lower delay for a node when compared to the TAGR scheme.

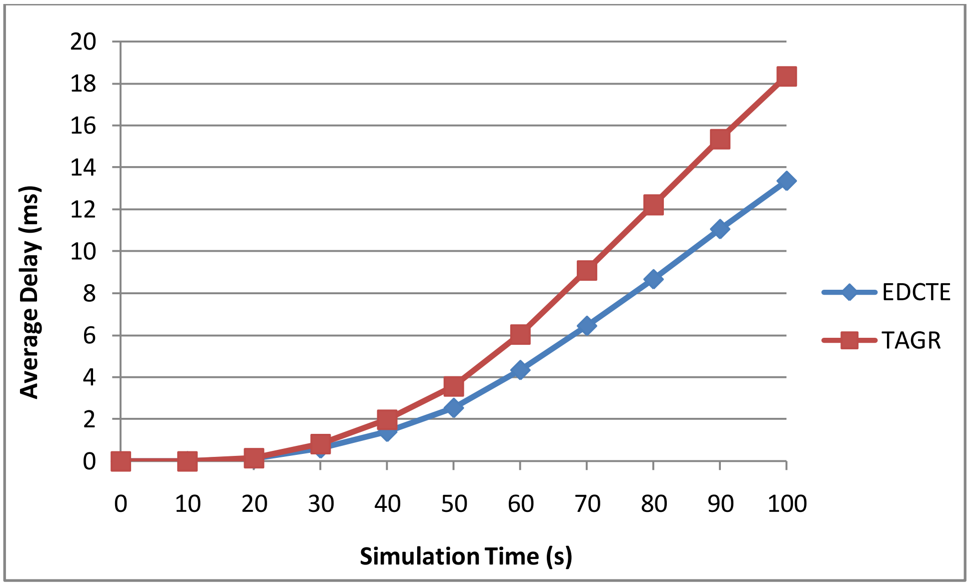

Figure 6.10 Average Delay of EDCTE and TAGR for 100 nodes

- **Throughput**

Throughput is also measured using the same equation used for throughput measurement in equation 6.7.

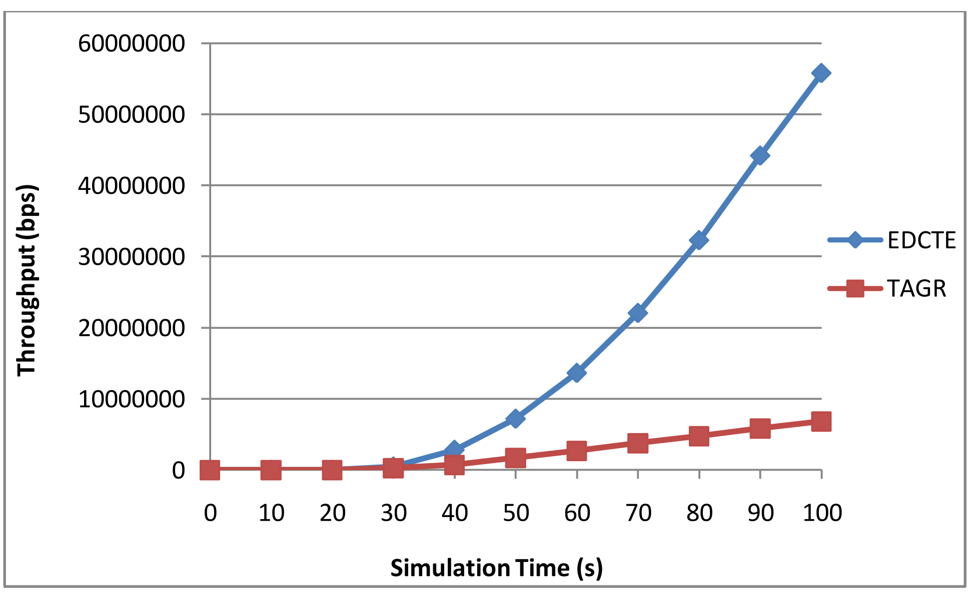

Figure 6.11 Throughput of EDCTE and TAGR for 100 nodes

Table 6.10 Throughput values of EDCTE and TAGR for 100 nodes

Simulation time (s)	Throughput of HTECH (bps)	Throughput of GTMS (bps)
0	0	0
10	0	0
20	17900	17900
30	481900	230400
40	2831400	728400
50	7209900	1694700
60	13645600	2717100
70	22069800	3760100
80	32300800	4805700
90	44187400	5851700
100	55792600	6845400

The corresponding values obtained for throughput in EDCTE and TAGR are given in Table 6.10. The values of throughput indicate that there is greater throughput observed in the EDCTE protocol. On an average 12.26% increase in throughput is found. This is also reflected in figure 6.11 showing the throughput plots of both EDCTE and TAGR mechanisms.

- **Residual Energy**

The amount of energy remaining in a node at the current instance of time is called as RE. Table 6.11 shows the RE values obtained during the simulation analysis.

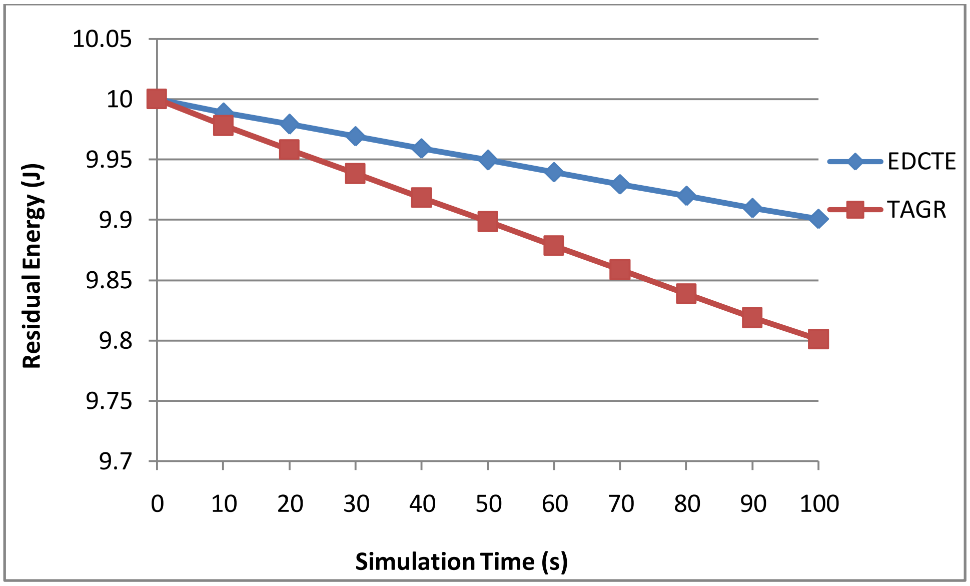

Figure 6.12 Residual Energy of EDCTE and TAGR for 100 nodes

Table 6.11 RE values of EDCTE and TAGR for 100 nodes

Simulation Time (s)	RE of EDCTE (J)	RE of TAGR (J)
0	10	10
10	9.98911	9.97811
20	9.97921	9.95821
30	9.96931	9.93831
40	9.95941	9.91841
50	9.94951	9.89851
60	9.93961	9.87861
70	9.92971	9.85871
80	9.91981	9.83881
90	9.90991	9.81891
100	9.901	9.801

Figure 6.12 shows that the RE of the network is better for the proposed scheme EDCTE when compared with the existing scheme TAGR. Around 98.99% of energy is saved per node by using EDCTE protocol for routing.

6.4 Summary

The EDCTE method has been simulated and analyzed using the network simulator, and the results have shown the efficiency of the EDCTE mechanism over the TAGR. The total packet delivery is increased by 12.62%, packet loss is reduced by 29.8%, the average delay is reduced by 74.92%, throughput is increased by 12.62%, and residual energy is saved by 98.98% in the proposed EDCTE mechanism. Therefore this EDCTE method is better used by the hierarchical topology thereby reducing the number of tasks in the WSN and increasing the efficiency.