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Chapter

Data Aggregation Scheme Using Multiple Mobile Agents in Wireless Sensor Network

Mohamed Younis Mohamed Alzarroug and Wilson Jeberson

Abstract

Wireless sensor networks (WSNs) consist of large number of sensor nodes densely deployed in monitoring area with sensing, wireless communications and computing capabilities. In recent times, wireless sensor networks have used the concept of mobile agent for reducing energy consumption and for effective data collection. The fundamental functionality of WSN is to collect and return data from the sensor nodes. Data aggregation's main goal is to gather and aggregate data in an efficient manner. In data gathering, finding the optimal itinerary planning for the mobile agent is an important step. However, a single mobile agent itinerary planning approach suffers from two drawbacks, task delay and large size of the mobile agent as the scale of the network is expanded. To overcome these drawbacks, this research work proposes: (i) an efficient data aggregation scheme in wireless sensor network that uses multiple mobile agents for aggregating data and transferring it to the sink based on itinerary planning and (ii) an attack detection using TS fuzzy model on multi-mobile agent-based data aggregation scheme is shortly named as MDTSF model.

Keywords: wireless sensor network, data aggregation, TS fuzzy, genetic algorithm and itinerary planning, firefly algorithm, minimum spanning tree (MST)

1. Introduction

Data aggregation signifies inspiring and well-researched topics in the wireless sensor network (WSN) [1–5] writings. The energy restrictions of nodes in a sensor network call for fuel-saving data aggregation approaches and encompass the nexus lifecycle. In addition, mobile agents (MAs) [3, 6] are projected to better the execution of data assemblage in WSNs. In these methodologies, schedules ensuing that traveling agents mainly control the total accomplishment of the collection of the data management. Gathering data effectively has always been of primary importance in a wireless sensor network. The mobile agent paradigm [7, 8] has made it possible to collect and aggregate data in a manner that is proper for real-time applications. Along this line, a number of heuristics have been scheduled to achieve effective itinerary planning for MAs [9].

2. Overview

Inside the complexity of the sensor, sensor nodes perhaps induce dispensable data; similar packets from various junctions can be accumulated to such an

extent that the several broadcasts could be condensed. Data aggregation [1] is the mixture of statistics from different origins by using utilities for example repression (eliminating copies), lowest level, highest level, and median. A few of these tasks can be achieved by the aggregator sensor node, by allowing sensory points to supervise data network depletion. Knowing that calculation would be less power absorbing than transmission, considerable reduction in energy can be achieved by data aggregation [10]. The potency of data aggregation can be deduced using many metrics [11].

3. Materials and methods

In recent times the concept of mobile agent (MA) was applied by researchers in wireless sensor networks (WSN) to reduce the energy consumption and improve data collection. Mobile agent paradigm has been adopted by researchers as an alternative to traditional client-server paradigm. Data aggregation in WSN is an active research area due to its importance in solving the main drawbacks of using WSNs. This research has the following contributions.

    i. An efficient data aggregation scheme by means of itinerary planning (DAS-IP) using ACO-GA was proposed using the concept of single mobile agent for data aggregation and transfer to sink.

    ii. A multi-mobile agent-based data aggregation scheme was proposed to overcome the desk delay problem encountered by single mobile agent itinerary approach.

4. Results and discussion

This section of the chapter offers a comprehensive and concise comparison of the implementation results of the proposed data aggregation schemes with existing ones in terms of the metrics say, delay, energy, drop rate throughput and finally overhead. The performance of the proposed data aggregation schemes are evaluated by contrasting with existing techniques [12, 13].

4.1 Performance evaluation of data aggregation scheme using hybrid based ACO-GA itinerary planning

The performance of the proposed data aggregation scheme using hybrid ACO-GA itinerary planning is contrasted with the prevailing techniques say, dynamic based data aggregation approach (DMA-DA). The comparison is done concerning the metrics say, energy, drop rate, throughput and overhead. The experimented was executed on NS-2. **Figure 1** shows the simulated WSN portraying the clusters along with their member nodes together with mobile agents and sink nodes.
The simulation parameters utilized for the experiment are offered in **Table 1**.

4.1.1 Results and comparative analysis of the data aggregation scheme using hybrid based ACO-GA itinerary planning

The performance analysis of the proposed method and prevailing DMA-DA results for the disparate metrics comparison is offered in **Tables 2** and **3** for the number of nodes 100, 200, 300, 400 and 500.
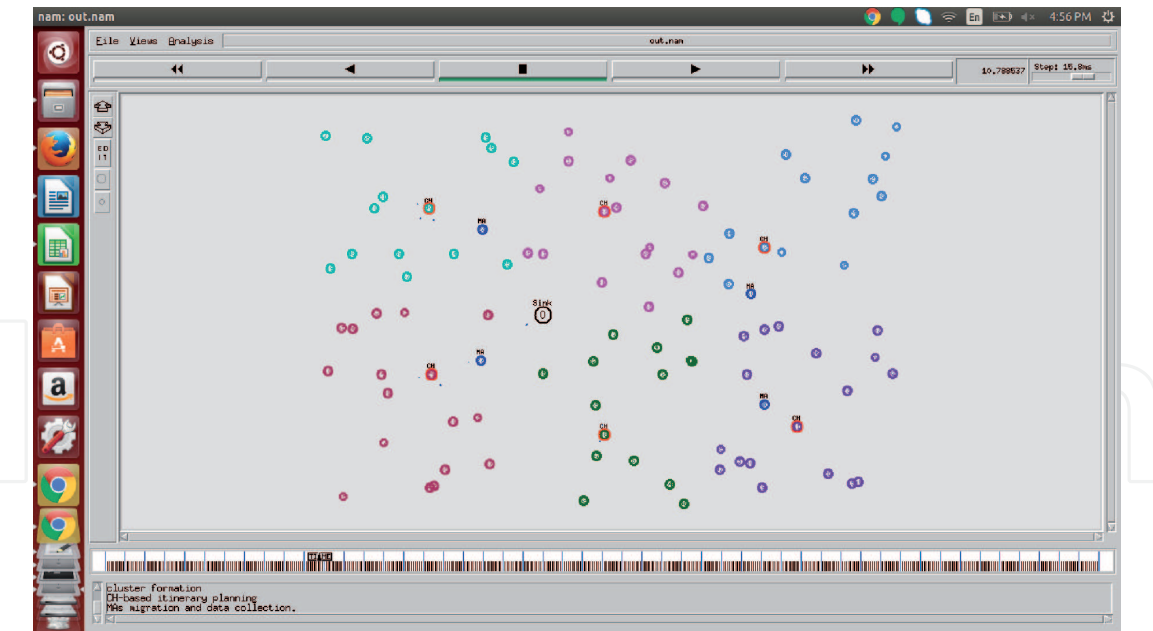
Figure 1.
Simulated WSN.

Parameters	Values
No. of nodes	20, 40, 60, 80, 100
Topology area	1000 m × 1000 m
Routing protocol	AODV
MAC type	MAC/802_11
Propagation	Two ray ground
Antenna	Omni antenna
Simulation time	50 seconds
Traffic type	CBR
Packet size	512 bytes
Rate	100 kbps
Channel bandwidth	2.0e6
Initial sending power	0.660
Initial receiving power	0.395
Initial idle power	0.035
Initial energy (Joules)	10.3 J
Channel frequency (Hz)	freq_ 2.4e9
Transmitter signal power (Watt)	Pt_ 0.28
Mobility speed	2–20 m/s

Table 1.
Simulation parameters.

4.1.1.1 Discussion

In **Figure 2** the propounded data aggregation scheme is contrasted to existing DMA-DA concerning the metrics say, delay, delivery ratio and drop rate for different number of nodes. From the above table the proposed method has a delay value

Metrics	Delay		Delivery ratio		Drop	
Number of nodes	Proposed	Existing DMA-DA	Proposed	Existing DMA-DA	Proposed	Existing DMA-DA
100	7.38156	15.308102	0.709117	0.386867	6	25
200	11.28197	17.303762	0.615861	0.272461	9	17
300	15.00316	17.269328	0.382883	0.172134	24	26
400	20.277569	22.16062	0.186749	0.078482	40	378
500	20.409008	25.571875	0.141381	0.058461	158	1034

Table 2.
Juxtaposition of the suggested DAS-IP and the subsisting DMA-DA in terms of metrics such as delay, delivery ratio and drop.

Metrics	Energy		Overhead		Throughput	
Number of nodes	Proposed	Existing DMA-DA	Proposed	Existing DMA-DA	Proposed	Existing DMA-DA
100	6.463972	13.61866	1909	2665	13,542	1031
200	7.80906	13.192729	1857	4775	11,439	1301
300	6.805129	12.490482	2828	6524	10,831	1123
400	6.309804	11.40279	5426	9620	10,133	755
500	5.750889	10.741787	6685	13,291	9452	777

Table 3.
Comparison of the proposed DAS-IP and the existing DMA-DA in terms of metrics such as energy, overhead and throughput.
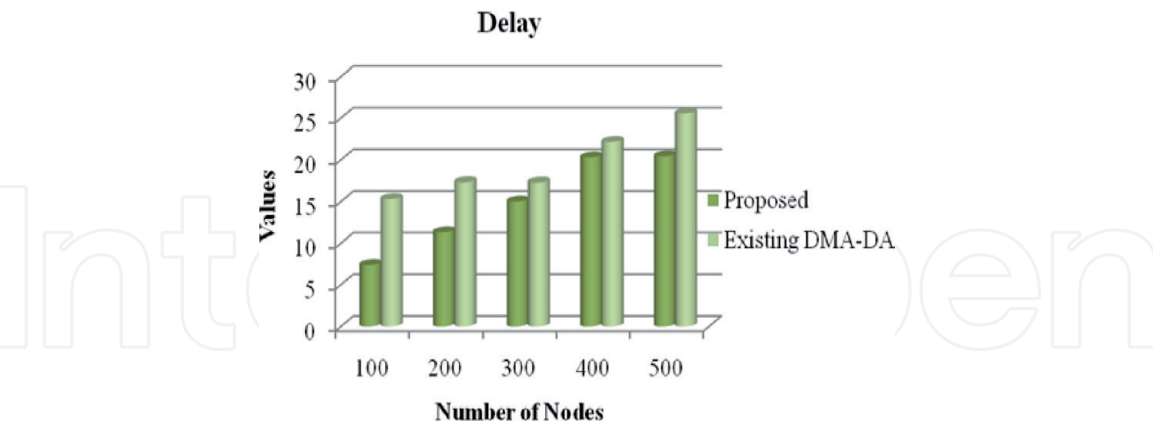

Figure 2.
Performance analysis of the proposed DAS-IP and the existing DMA-DA in terms of delay.

of 7.38156, 11.28197, 15.00316, 20.277569 and 20.277569 while existing DMA-DA data aggregation scheme offers delay values of 15.308102, 17.303762, 17.269328, 22.16062 and 25.571875 for 100, 200, 300, 400 and 500 nodes respectively. The proposed data aggregation scheme based on hybrid ACO-GA itinerary planning offers a delivery ratio of 0.709117, 0.615861, 0.382883, 0.186749 and 0.141381 whereas existing DMA-DA scheme offers 0.386867, 0.272461, 0.172134, 0.078482 and 0.058461 respectively. In terms of the drop values, the proposed scheme offers a value of 6, 9, 24, 40 and 158 while existing DMA-DA has drop values of 25, 17, 26, 378 and 1034 for 100, 200, 300, 400 and 500 nodes respectively.

4.1.1.2 Discussion

Table 3 above displays the experimental outcome of the suggested DAS-IP along with existing DMA-DA technique for 100, 200, 300, 400 and 500 nodes respectively. From the table it can be seen that for a simulation of 100 nodes the proposed DAS-IP offered energy of 6.463972 but the existing DMA-DA has 13.61866, for 200 nodes the energy is 7.80906 and 13.192729 for proposed DAS-IP and prevailing DMA-DA respectively. Similarly the energy for the proposed is 6.805129, 6.309804 and 5.750889 for 300, 400 and 500 nodes respectively while existing DMA-DA offers 12.490482, 11.40279 and 10.741787 for same number of nodes. The proposed data aggregation scheme based on hybrid ACO-GA itinerary planning offers an overhead of 1909, 1857, 2828, 5426 and 6685 whereas existing DMA-DA scheme offers 2665, 4775, 6524, 9620 and 13,291 for 100, 200, 300, 400 and 500 nodes respectively. In terms of throughput values, the proposed scheme offers a value of 13,542, 11,439, 10,831, 10,133 and 9452 while existing DMA-DA has throughput values of 1031, 1301, 1123, 755 and 777 for 100, 200, 300, 400 and 500 nodes respectively.

4.1.2 Delay for the data aggregation scheme using hybrid based ACO-GA itinerary planning

The delay of the proposed data aggregation scheme is contrasted with existing DMA-DA technique for 100, 200, 300, 400 and 500 nodes as illustrated in **Figure 2**. The vertical axis gives the delay value whereas the horizontal axis signifies the number of nodes. The bars in the graph represent the comparisons among the various techniques.

4.1.2.1 Discussion

Figure 2 compares the delay against the number of nodes for the existing DMA-DA and the proposed DAS-IP method. The delay for 100 nodes is 7.38156 and 15.308102 for proposed DAS-IP and existing DMA-IP respectively. For 200 and 300 nodes the delay varies by 6.021792 and 2.266168 values lesser than the prevailing DMA-DA technique. It can be inferred from the figure that the routing delay increases as the number of nodes increases. On considering 500 numbers of nodes, the delay is too high for the existing technique. But, the delay of the proposed technique varies by 5.162867 values lower than the existing one. Also, for any number of nodes when contrasted to the existing one, the proposed DAS-IP shows less delay for the routing data to the sink.

4.1.3 Delivery ratio for the data aggregation scheme using hybrid based ACO-GA itinerary planning (DAS-IP)

The data delivery ratio is given as the total number of data received at destinations (Sink) divided by the total number of data sent from the source node. **Figure 2** offers a comparison among the proposed and existing methods by varying the number of nodes from 100 to 500. In **Figure 3** the vertical axis shows the delivery ratio whereas the horizontal axis denotes the number of nodes used for running the experiments.

4.1.3.1 Discussion

Figure 3 compares the delivery ratio against the number of nodes for the existing DMA-DA and the proposed DAS-IP technique. It can be inferred that the delivery
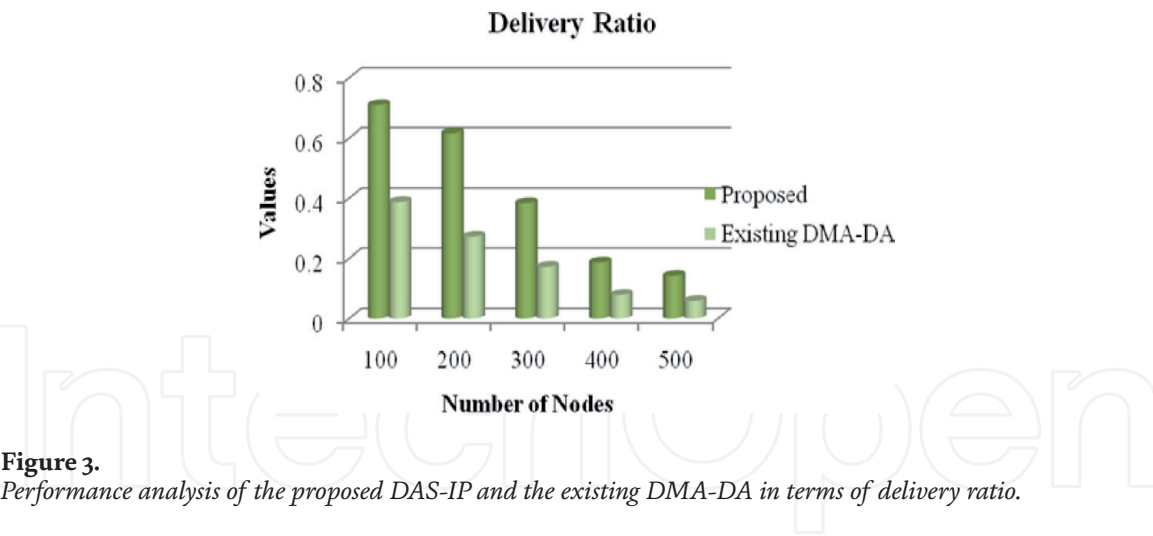
Figure 3.
Performance analysis of the proposed DAS-IP and the existing DMA-DA in terms of delivery ratio.

ratio decreases as the number of nodes increases. For lower number of nodes, say 100, the delivery ratio is too high for the proposed DAS-IP technique and its value is 0.709117, but the delivery ratio is too low for the existing one. For 200 nodes proposed DAS-IP offers a delivery ratio of 0.615861 as against 0.272461 for existing DMA-DA technique, similarly when the node increases 300 the delivery ratio is 0.382883 and 0.172134 for proposed DAS-IP and existing DMA-IP respectively. For higher number of nodes, say 500, the delivery ratio decreases when contrasted to the lower number of nodes. But, in terms of delivery ratio, the proposed technique shows improved results. It is obvious from the graph that the proposed technique exhibits superior performance in terms of delivery ratio.

4.1.4 Drop rate value for the data aggregation scheme using hybrid based ACO-GA itinerary planning (DAS-IP)

The drop value comparison is done on varying number of nodes from 100 to 500 as shown on the graph in **Figure 4.** The vertical axis specifies the drop values and the horizontal axis shows the number of nodes in running the experiment.

4.1.4.1 Discussion

Figure 4 demonstrates the comparison among the drop by varying the number of nodes for the existing DMA-DA and the proposed DAS-IP technique. Experimental outcomes confirm that the drop value rises for higher number of nodes. For 100, 200 and 300 numbers of nodes, the drop value remains constant
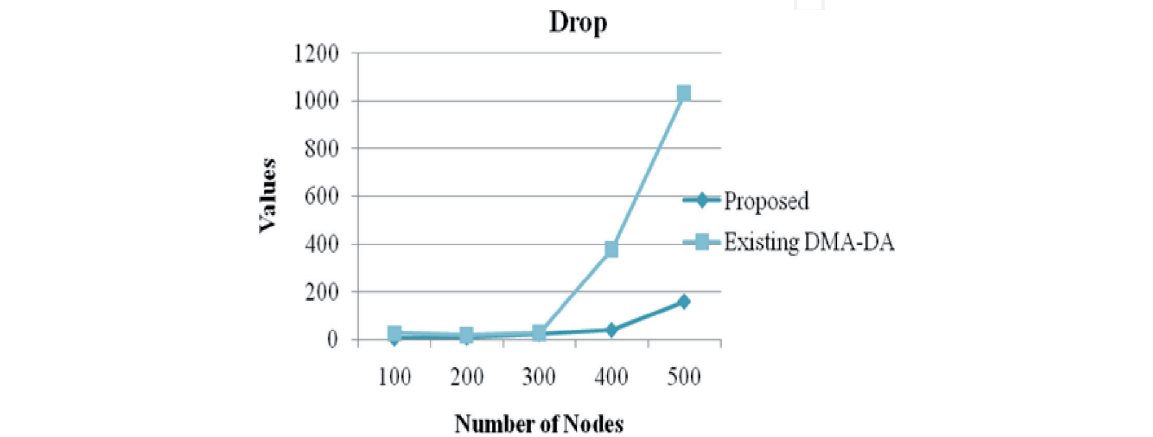

Figure 4.
Performance analysis of the proposed DAS-IP and the existing DMA-DA in terms of drop.

for both the proposed DAS-IP and the existing DMA-DA techniques and increases for 400 and 500 nodes. The existing DMA-DA technique displays the worst performance with drop value of 1034 for 500 nodes. But the proposed technique has the least drop value when contrasted to the existing one. This confirms the predominance of the proposed technique over existing ones.

4.1.5 Energy consumption for the data aggregation scheme using hybrid based ACO-GA itinerary planning (DAS-IP)

EC in the proposed data aggregation technique is contrasted with existing DMA-DA technique. The EC is given in the graph as illustrated in **Figure 5**. The vertical axis signifies the EC values in Kilowatts-hour (KWH) whereas the horizontal axis shows the number of nodes in running the experiments.

4.1.5.1 Discussion

Figure 5 compares the EC against the number of nodes for the prevailing DMA-DA and the proposed DAS-IP technique. For 100 and 200 nodes the EC for the proposed DAS-IP are 6.463972 and 7.80906 while prevailing DMA-DA offers relatively high EC of 13.61866 and 13.192729 KWH respectively. Interestingly for 300, 400 and 500 nodes the EC drops to 6.805129, 6.309804 and 5.750889 for the proposed technique. The compared existing technique consumes huge amount of energy for any number of nodes. The same is the case for existing DMA-DA. Therefore the proposed technique has the superior performance in comparison to existing DMA-DA.

4.1.6 Overhead for the data aggregation scheme using hybrid based ACO-GA itinerary planning (DAS-IP)

The Overhead value of the proposed DAS-IP technique is contrasted with existing DMA-DA. The overhead comparison appears in **Figure 6**. The vertical axis displays the overhead values while the horizontal axis shows the number of nodes in executing the experiment.

4.1.6.1 Discussion

Figure 6 compares the overhead against the number of nodes for the existing DMA-DA and the proposed DAS-IP technique. For 100, 200, 300, 400 and
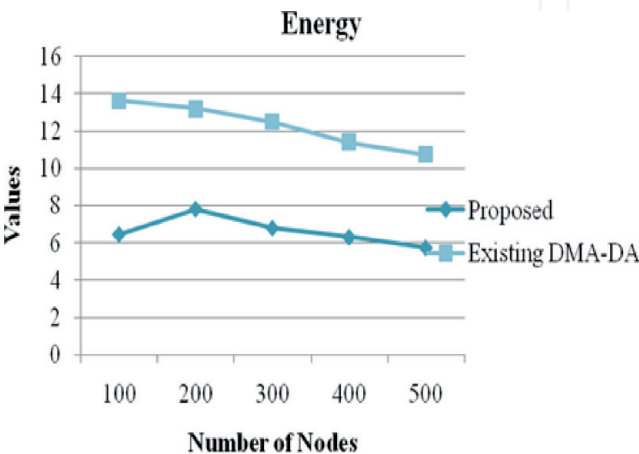

Figure 5.
Performance analysis of the proposed DAS-IP and the existing DMA-DA in terms of energy.
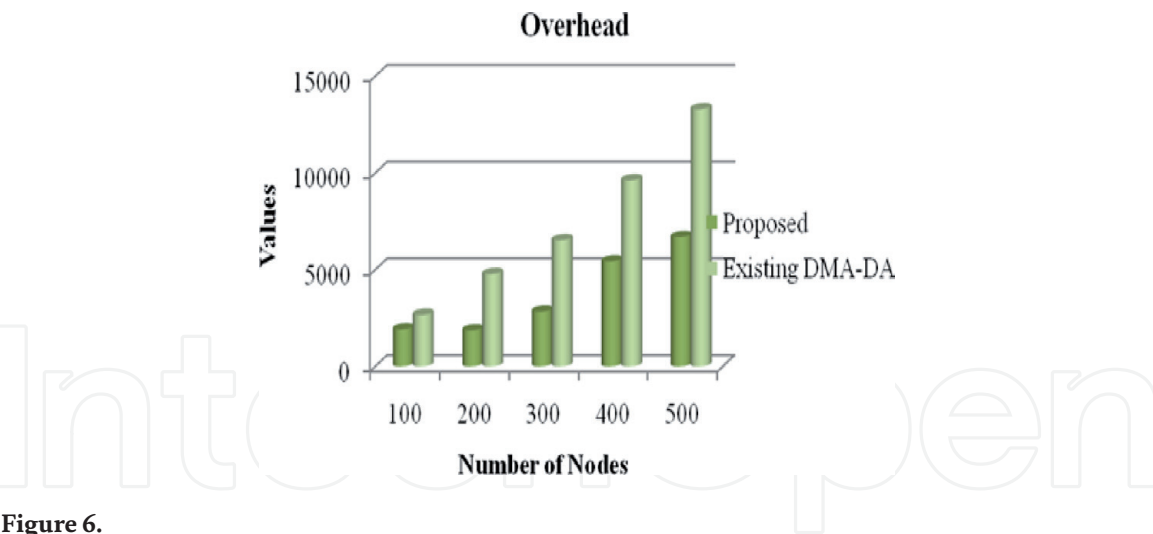
Figure 6.
Performance analysis of the proposed DAS-IP and the existing DMA-DA in terms of overhead.

500 nodes the overhead for proposed DAS-IP are 1909, 1857, 2828, 5426 and 6685 respectively while the prevailing DMA-DA offers 2665, 4775, 6524, 9620, 13,291 for same number of nodes. It is evident from the graph that, as the number of nodes increases, the overhead for the proposed and the existing also increases. The proposed technique has the least overhead in all the cases. Therefore, the proposed demonstrates superior performance on the basis of overhead as compared to existing DMA-DA.

4.1.7 Throughput for the data aggregation scheme using hybrid based ACO-GA itinerary planning (DAS-IP)

The comparison of throughput for the proposed DAS-IP and prevailing DMA-DA appears in **Figure 7**. The horizontal axis signifies the throughput in kbps while vertical axis signify the number of nodes in running the experiment.

4.1.7.1 Discussion

Figure 7 offers comparison of the output over the number of nodes for the prevailing DMA-DA and the contemplated DAS-IP process. Production is the amount of data groups triumphantly shifted from a starting point to a finish in a given time. For 100 nodes, the outturn is 13542 which is more for the recommended form and it lessens as the node escalates. For 200, 300, 400 and 500 nodes the proposed DAS-IP technique has a throughput of 11,439, 10,831, 10,133 and 9452 which is higher as compared to prevailing DMA-DA which offers 1301, 1123, 755 and 777 for 200,
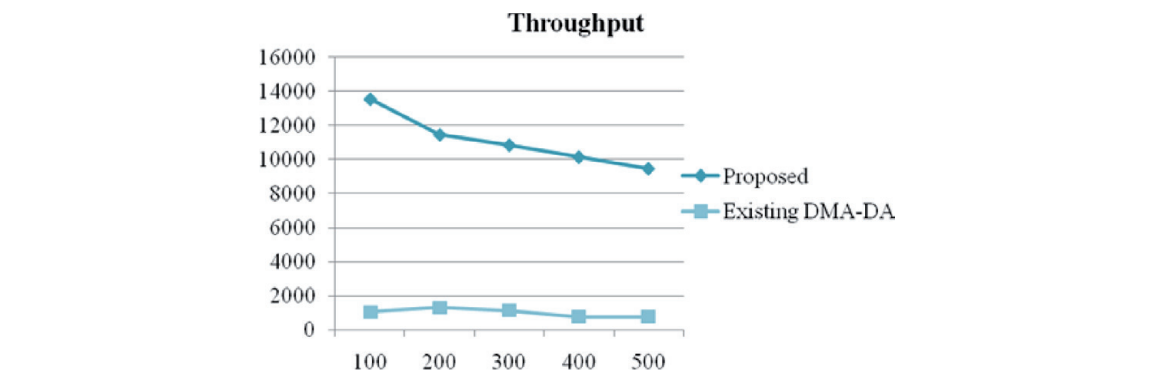

Figure 7.
Examination of presentation of the projected DAS-IP and the actual DMA-DA in means of throughput.

300, 400 and 500 nodes respectively. This proves the superiority of the proposed technique on contrasted to prevailing DMA-DA.

4.1.8 Performance evaluation of multi-mobile agent-based data aggregation scheme using TS fuzzy model (MDTSF)

The performance of the proposed multi-mobile agent-based data aggregation scheme using TS fuzzy model (MDTSF) is contrasted with the prevailing techniques say, LEACH and T-LEACH techniques. The comparison is done concerning the metrics say, energy consumption, end to end delay, packet drop rate, and throughput and network life time.

4.1.9 Results and comparative analysis of multi-mobile agent-based data aggregation scheme using TS fuzzy model (MDTSF)

The performance analysis of the proposed MDTSF model and existing LEACH and T-LEACH results for the disparate metrics comparison is offered in **Table 4** for the number of attacks 1, 2, 3, 4 and 5.

4.1.9.1 Discussion

Table 4 above displays the experimental result of the proposed MDTSF technique along with the existing LEACH and T-LEACH mechanisms for 1 to 5 attacks. The proposed MDTSF model uses energy of 6.25345, 5.8712, 4.9484, 5.2896 and 5.1357 for 1, 2, 3, 4 and 5 attacks respectively while existing LEACH uses 9.2384, 10.4587, 9.5647, 10.9874 and 11.2689 respectively. Similarly the energy consumption for existing T-LEACH is 11.2856, 12.8516, 10.2587, 9.2587 and 10.2658 for 1, 2, 3, 4 and 5 attacks respectively. In terms of end to end delay the proposed MDTSF, existing LEACH and T-LEACH offers 5.1458, 0.7548 and 0.6325 for 1 attack. It then rises to 12.2368, 0.4585 and 0.3547 when the attack increases to 5 for proposed MDTSF, existing LEACH and T-LEACH respectively.

4.1.10 End to end delay for multi-mobile agent-based data aggregation scheme using TS fuzzy model (MDTSF)

The end to end delay of the proposed MDTSF model is contrasted with existing LEACH and T-LEACH models for 1, 2, 3, 4 and 5 attacks as illustrated in **Figure 8.** The vertical axis gives the delay value (in seconds) whereas the horizontal axis signifies the number of attacks. The bars in the graph represent the comparisons among the various techniques.

No of attacks	Energy consumption (EC)			End to end delay		
	Proposed	**LEACH**	**T-LEACH**	**Proposed**	**LEACH**	**T-LEACH**
1	6.2534	9.2384	11.2856	5.1458	0.7548	0.6325
2	5.8712	10.4587	12.8516	7.5648	0.7122	0.5912
3	4.9484	9.5647	10.2587	8.1234	0.6145	0.5312
4	5.2896	10.9874	9.2587	10.2635	0.5587	0.3851
5	5.1357	11.2689	10.2658	12.2368	0.4585	0.3547

Table 4.
Performance analysis of proposed and existing techniques in terms of EC and end to end delay.
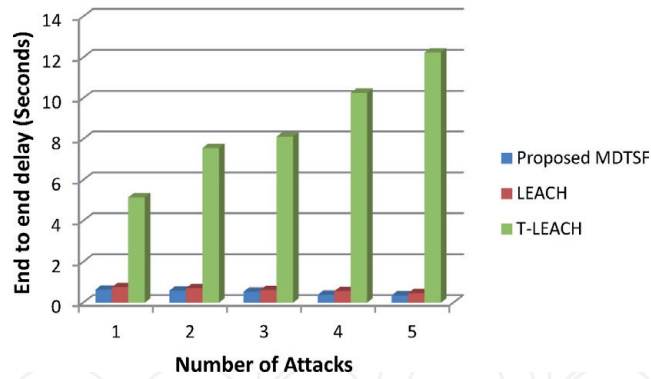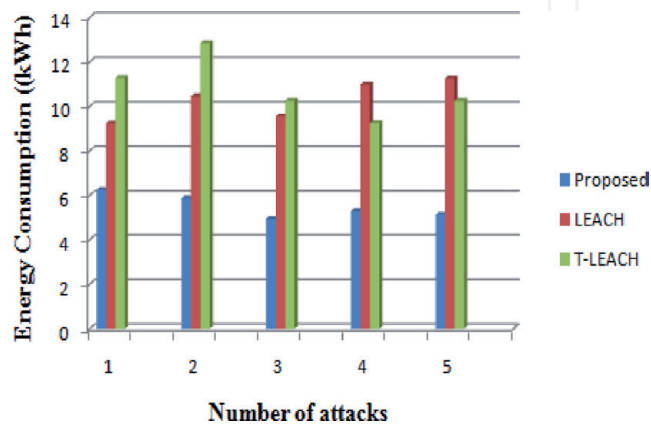
Figure 8.
End to end delay analysis of the proposed MDTSF with the existing methods.

4.1.10.1 Discussion

Figure 8 shows the end to end delay comparison of the proposed MDTSF model against existing LEACH and T-LEACH. The proposed MDTSF model offers a delay of 0.6325, 0.5912, 0.5312, 0.3851 and 0.3547 for 1, 2, 3, 4 and 5 attacks respectively whereas existing T-LEACH produces the highest delay of 5.1458, 7.5648, 8.1234, 10.2635 and 12.2368 for same number of attacks. The delay ratio increases marginally as the number of attacks increases. But the proposed method's delay is lower than existent methods for very attacks. The proposed work has a lower network delay contrasted with other existent methods.

4.1.11 Energy consumption for multi-mobile agent-based data aggregation scheme using TS fuzzy model (MDTSF)

EC in the proposed MDTSF technique is contrasted with existing LEACH and T-LEACH technique. The EC is given in the graph as illustrated in **Figure 9**. The vertical axis signifies the EC values in Kilowatts-hour (KWH) whereas the horizontal axis shows the number of attacks in running the experiments.

4.1.11.1 Discussion

Figure 9 shows the EC comparison graph of the proposed MDTSF model with the existing LEACH and T-LEACH. The proposed MDTSF model uses energy of 6.25345, 5.8712, 4.9484, 5.2896 and 5.1357 for 1, 2, 3, 4 and 5 attacks respectively

Figure 9.
Performance comparison of proposed and existing methods in terms of EC.

while existing LEACH uses 9.2384, 10.4587, 9.5647, 10.9874 and 11.2689 respectively. Similarly the energy consumption for existing T-LEACH is 11.2856, 12.8516, 10.2587, 9.2587 and 10.2658 for 1, 2, 3, 4 and 5 attacks respectively. The above graph signifies that the proposed model attained the lowest energy consumption. For the number of attacks, EC has increases and decreases gradually, but it is very low while compared to the existing LEACH and T-LEACH. For better communication, the value of EC should be low to prevent the node from network failure. The proposed method achieves this lower energy consumption for every attack.

4.1.12 Packet drop rate for multi-mobile agent-based data aggregation scheme using TS fuzzy model (MDTSF)

The packet drop rate (PDR) comparison of the proposed MDTSF and existing LEACH and T-LEACH is done by the varying number of attacks from 1 to 5 as shown on the graph in **Figure 10.** The vertical axis specifies the packet drop rate values and the horizontal axis shows the number of attacks in running the experiment.

4.1.12.1 Discussion

Figure 10 portrays the PDR by varying the number of attacks from 1 to 5. It is evident from the graph that the PDR has decreased in the proposed MDTSF model when contrasted to the existing methods. For optimal transmission of network, the PDR should be low. For first attack, the PDR of existing LEACH and T-LEACH are 0.8 and 1.12%, but the proposed method has 0.25% of packet drop rate. The graph confirms that the proposed method has the least PDR value than existing techniques for remaining four attacks. PDR of proposed method slowly increase son contrasting to other existing techniques. The least PDR of the proposed technique confirms its predominance over existing ones.

4.1.13 Throughput for multi-mobile agent-based data aggregation scheme using TS fuzzy model (MDTSF)

The comparison of throughput for the proposed MDTSF and prevailing LEACH and T-LEACH appears in **Figure 11.** The horizontal axis signifies the throughput in kbps while vertical axis signifies the number of attacks in running the experiment.
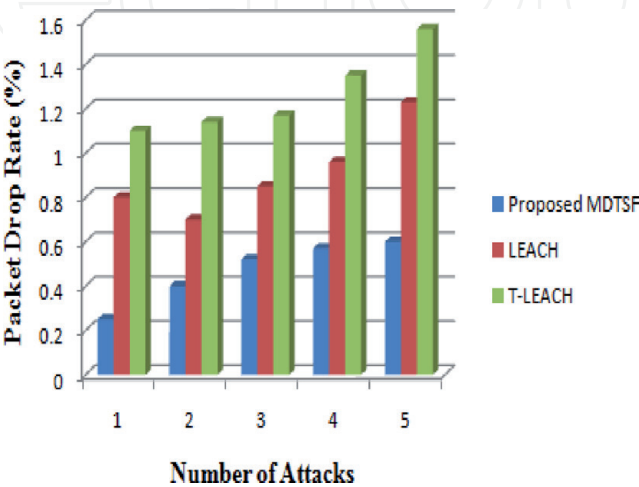

Figure 10.
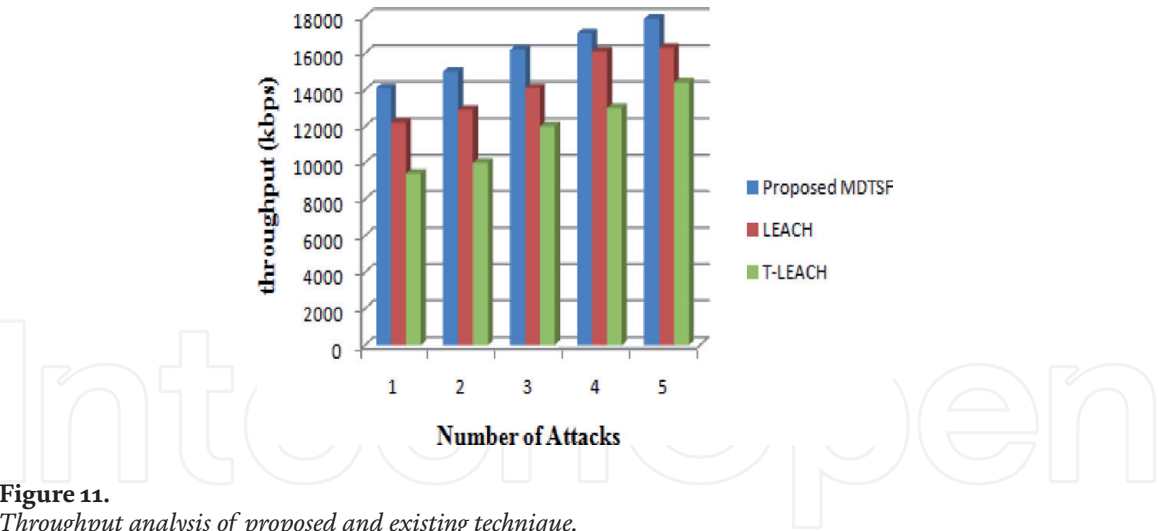*Packet drop of proposed and existing techniques.*

Figure 11.
Throughput analysis of proposed and existing technique.

4.1.13.1 Discussion

Figure 11 shows the throughput analysis of the proposed MDTSF and existing LEACH and T-LEACH methods. The graph clearly reveals that the proposed MDTSF has achieved the best throughput in comparison to other existent techniques. For the first attack, proposed MDTSF achieved 14,523 throughput values, while the existing LEACH and T-LEACH attains throughput values of 12,564 and 9568 for first attack. The proposed MDTSF has the highest throughput in all cases. Analysis of the techniques confirms the superiority of the proposed MDTSF model over existing ones.

4.1.14 Network life time of the multi-mobile agent-based data aggregation scheme using TS fuzzy model (MDTSF)

The network life time of the proposed MDTSF technique is contrasted with existing LEACH and T-LEACH. The life time comparison appears in **Figure 12**. The vertical axis displays the network life time values in hours while the horizontal axis shows the number of attacks in executing the experiment. The proposed and existing methods lifetime is compared as shown in **Figure 12**.

4.1.14.1 Discussion

Figure 12 shows the comparison of the proposed MDTSF and existing LEACH and T-LEACH in terms of network lifetime. Network lifetime should be high for achieving an optimum network performance. In this case, performance of the network is evaluated based on the number attack occurring in the course of data aggregation in the network and lifetime of the network diminishes linearly when number of attacks are increase as shown in the graph. But the lifetime of the proposed technique is higher than existing methods. Hence it is proved that the MDTSF has highest lifetime.

4.1.15 Packet delivery ratio of the multi-mobile agent-based data aggregation scheme using TS fuzzy model (MDTSF)

Figure 13 offers a comparison among the proposed and existing methods by varying the number of attacks from 1 through 5. In **Figure 13** the vertical axis shows the packet delivery ratio whereas the horizontal axis denotes the number of attacks used for running the experiments.
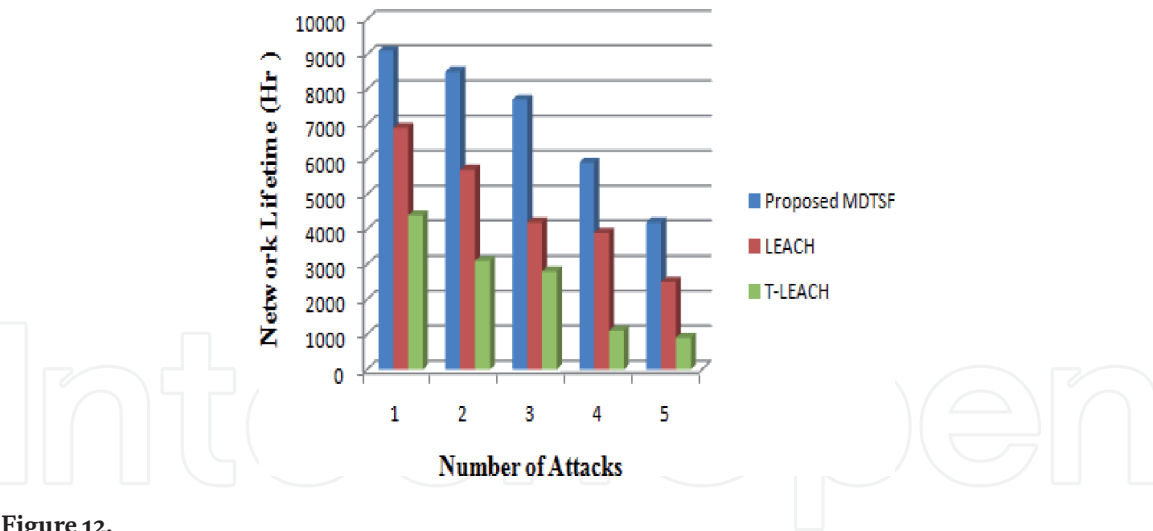
Figure 12.
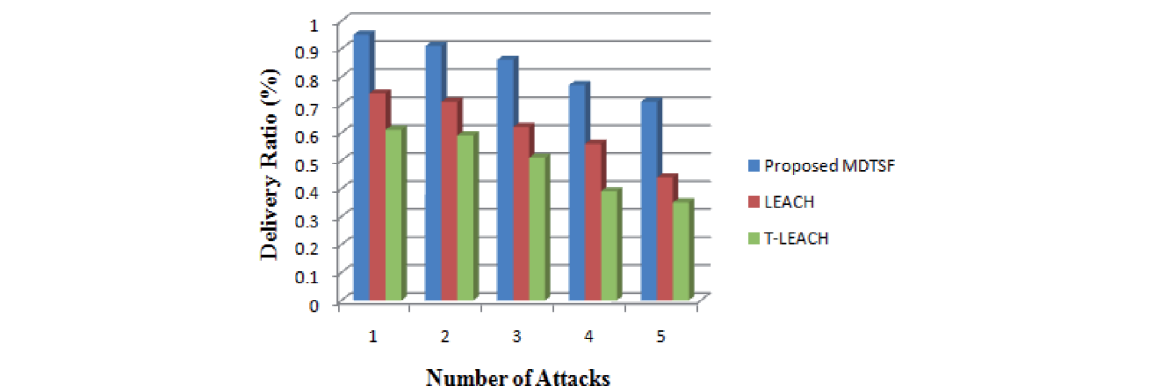*Comparison graph of network lifetime for proposed and existing systems.*

Figure 13.
Performance comparison of the proposed MDTSF with existing LEACH and T-LEACH.

4.1.15.1 Discussion

Figure 13 compares the packet delivery ratio performance of the proposed and existing techniques. For efficient data transmission in the network, packet delivery ratio should be high. If the packet delivery ratio has a highest value then, all the information are obtained at the receiver side without any data loss. From **Figure 13**, the graph clearly shows that the proposed MDTSF achieves the best value of 0.9485% but the existing techniques achieve less delivery ratio. Thus, it can be proves that the proposed MDTSF offers superior performance on compared to other existent methods.

5. Summary

In WSN, the communication cost is mostly greater than computational cost. Data aggregation is an ideal way of optimizing the communication cost. This can be achieved by accumulating the sensor readings. In this given thesis, an efficient data aggregation scheme based on itinerary approach is presented using multiple mobile agents aimed at accumulating and transferring data to the sink. Inside the proposed strategy a hybrid ACO-GA aimed at itinerary planning is engaged, cluster formation was done by aid of FCM algorithm. A progression of experiments is led and the outcome for the proposed data aggregation scheme is compared with existing ones. The experimental outcomes were compared with existing techniques to demonstrate the

predominance of the proposed data aggregation schemes over latest methodologies pertaining to the metrics say, end to end delay, delivery ratio, drop rate, energy consumption (EC), overhead and finally throughput.

Acknowledgements

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