ISSN (Print): 0974-6846 ISSN (Online): 0974-5645

# **Energy Efficient Collection Tree Protocol in Wireless Sensor Networks**

M. Pushpalatha<sup>1</sup>, Revathi Venkataraman<sup>2</sup> and K. Sornalakshmi<sup>3</sup>\*

SRM University, Kattankulathur, Chennai - 603203, Tamil Nadu, India; pushpalatha.m@ktr.srmuniv.ac.in, revathi.n@ktr.srmuniv.ac.in, sorna.anbu@gmail.com

#### **Abstract**

**Objectives:** Wireless Sensor Network (WSN) is a collection of sensor nodes which have limited resources like storage and power. To make the network energy efficient, data fusion becomes essential for reducing the number of transmissions. In this paper, we have implemented a data aggregated collection tree protocol (DA-CTP), an enhanced Collection Tree Protocol (CTP) and we compare its performance with the traditional CTP. **Methods/Statistical Analysis:** For every set of source nodes, the node at the next level will act as an aggregator to accept the packets from source nodes. The function of the aggregator is twofold. If the data packets sent by the source nodes are redundant, the average will be computed on the received data packets and sent to the destination, besides the received data packets will be merged to a single packet. Thereby minimizing the number of packet transmissions. **Findings:** Our experimental analysis shows that the DA-CTP consumes less energy than traditional CTP without any performance degradation. **Application/Improvements**: Betweenness Centrality concept can be introduced to minimize the latency.

Keywords: CTP (Collection Tree Protocol), Data Aggregation, TelosB Motes, Wireless Sensor Networks

#### 1. Introduction

The wireless sensor network is an on the fly network consisting of sensor nodes deployed in real-time environment. These sensor nodes sense environmental parameters such as sound, temperature, pressure, and humidity. In this resource constraint networks, battery power supplied to each sensor node is limited. Hence, energy is the main constraint of the wireless sensor network, and then it is necessary to incorporate energy awareness into every level of the network design<sup>1,2</sup>.

To maximize the lifetime of sensor networks, energy efficiency techniques need to be incorporated both in individual nodes and also into groups of cooperating nodes. A sensor node using its sensing mechanism generates data and can transmit the sensed data directly

from the source to the destination. Nevertheless, more energy will be consumed if the distance between origin and destination is too long. Hence, to overcome this, multiple-hop topology is considered as the best option for data transmission<sup>3</sup>. In summation, to bring down the power consumption during transmission, the redundant data sensed by two different detectors can be eliminated<sup>4</sup>.

An alternative approach to minimize the power consumption is to eliminate data redundancy packets using a well-known technique known as data aggregation. This technique combines redundant data packets into a single packet using aggregate function and provide this fused packet to the base station<sup>5.6</sup>. The common aggregation functions used to aggregate data are the sum, average, count, max or min. If data sensed by two different sensors

<sup>\*</sup>Author for correspondence

are of different types, they can be combined to reduce the count of data transmissions $^{7-9}$ .

Data aggregation technique in routing protocols has several advantages. It cuts the number of packet transmissions, which indirectly reduce the number of collisions, therefore cutting down the number of retransmissions. Due to these grounds, a considerable quantity of energy is saved, throughput increases, besides an end to end time delay of data transmission is cut down. The impact of data aggregation is also indicated in the Figure 1.

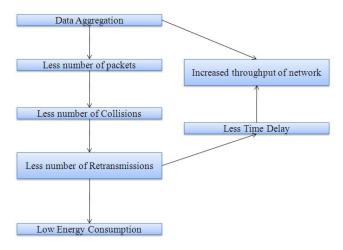


Figure 1. Impact of data aggregation.

Our work focuses on improvising a renowned routing protocol known as the collection tree protocol by implementing an aggregation technique where each source independently sends data to their best neighbors. These neighbors perform a consolidate function of the data originating from multiple sources and send it towards the base station.

The organization of the paper is as follows: Section 2 deals with associated works. Section 3 describes the proposed data aggregation scheme and Section 4 shows experimental analysis. Section 5 gives the finale and future directions.

The objective of LEACH<sup>10</sup> protocol is to form clusters with cluster heads. The cluster head in each cluster sends the aggregated (fused) data from some sensor nodes in its cluster to the base station. Cluster heads are selected based on any metric (residual energy, rotational policy, etc.). In LEACH protocol, each node can reach its cluster-head via single-hop routing. Dynamic clustering concept brings extra overhead which may decrease the gain in energy consumption.

PEGASIS<sup>11</sup> is a chain based type of data aggregation. Every node in the network receives data packet from its neighbors and performs aggregations along with its data. It checks its closest neighbor and sends the aggregated data to them. Base station will receive the aggregated data sent by the nodes along the chain. The challenges involved in PEGASIS are latency for distant node on the chain and single point failure.

To conserve energy, Sensor Protocols for Information via Negotiation (SPIN)<sup>12</sup> uses high-level descriptors or meta-data. These meta-data are exchanged among sensors before transmission using a data advertisement mechanism. If a node has new data, it will advertise the data to its neighbors and the neighbor nodes will send the request message to that node. SPIN does not guarantee data delivery.

Directed Diffusion 13.14 is a data centric protocol where sink broadcasts an interest message (Request) to each neighbor. This message propagates to the entire network to determine source node that can service the request. Every node on receiving the interest message sent a reply message as a gradient. The path will be established between sink and the source to send the requested data to the sink. Every node will maintain an interest cache and if they have the requested data, they will send the data. Otherwise, a new cache entry will be developed. The Directed Diffusion has the advantage of significant energy saving however limited to specific applications where continuous data streaming is not possible.

Our proposed model is an event driven model allowing multi-hop transmissions and reduces redundant packet transmissions. It uses the routing gradient ETX to find the next hop best neighbor. Hence, the knowledge of the whole network is not needed and the path taken for transmission of packets is also reliable. In gain, energy conservation in the intermediate nodes is also less since several packets are mixed and carried as individual packages.

# 2. Basics of Collection Tree Protocol

Collection Tree Protocol (CTP) is a tree-based collection protocol. CTP computes the routes from each node in the network to the root in the network. CTP is an address centric protocol since the source sends data to the sink

on the generated route. In the CTP, the nodes generate the route using a routing gradient. CTP uses Expected Transmissions Count (ETX) as routing gradient.

If a node transmits a CTP data frame, it must put the ETX value of its route in the ETX field.

ETX of a root is 0, and the ETX of a node is calculated as shown in (1).

$$ETX_{node} = ETX_{parent} + ETX_{linktoparent}$$
 (1)

Of all the valid routes, CTP chooses the route with the lowest ETX value.

CTP has three major components.

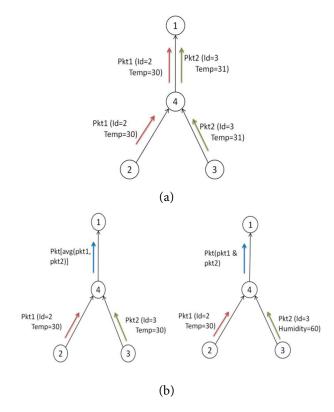
- 1. A link estimator is used to estimate the single-hop ETX of communication.
- A routing engine uses network-level information and link estimates to decide which node is the next routing hop.
- 3. A forwarding engine act as a waiting line of packets to forward them to the next level forwarder.

# 3. Proposed System

In this proposed method, a data aggregated approach is introduced into the traditional CTP to make the protocol energy efficient. The operation of the protocol is as traditional CTP by using ETX as the routing gradient to determine the next hop neighbor. However, the intermediate nodes (forwarders) on the routing tree will intercept for some time still it receives packets from all its neighbors. On receiving those packets, packets are aggregated based on their types.

The Figure 2 shows the operating mechanism of traditional CTP and proposed DA\_CTP. On both the figures node 1, is the sink, nodes 2 and 3 are the source nodes and node 4 is the forwarder and also designated as an aggregator. The Figure 2a represents CTP where the forwarder forwards the data towards the sink as soon as it receives from source nodes. As shown in Figure 2b, the forwarder waits for packets sent from node 2 and node 3 and based on their types; they are linked up as an individual packet and sent to the sink.

The following are two cases which deal with two types of data such as temperature and humidity generated by source nodes.



**Figure 2.** Sample Topology (a) CTP (b) DA-CTP.

Case 1: The first case deals with the same type of data. If source nodes lie in the same region, and if the sensed data are of the same type, the average of these values are calculated by the forwarder and combined as a single data packet.

Case 2: In the second case, aggregation is done by merging the data (payload) of the packets. This Case can be splitted into two categories.

If sensed data are of the same type, if the data deviates beyond the threshold then those packets can be merged.

If the sensed data from source nodes are of different types, the data can be merged to a single packet.

Following are the actions performed by the forwarder. Step 1: The forwarder receives the packet from one of its neighbors, it enqueues the packet and waits for a random delay to receive packets from its next neighbor.

Step 2: It dequeues the buffered data and its type and compared with the current data and its type.

Step 3: If both data are equal and are same type, it performs some aggregation function and sends the aggregated packet to the sink.

Step 4a: If both data are not equal and are same type, it performs merging and sends the merged packet to the sink.

Step 4b: If both data are not equal and are a different type, it performs merging and sends the merged packet to the sink.

Step 5: In the DA-CTP data frame, a new field named 'type' is introduced to indicate whether the packet is aggregated or not.

## 4. Experimental Analysis

The proposed routing protocol DA-CTP is implemented in TinyOS 2.1 using TelosB motes. Our experimental setup as shown in Figure 3 includes ten TelosB motes consisting of a sink node designated as 1 and sources nodes are numbered from 2 to 7 and remaining nodes 8, 9, and 10 act as forwarders or aggregators.

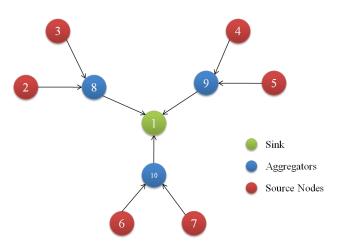


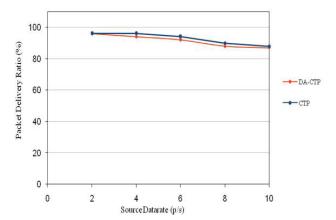
Figure 3. Experimental setup.

The following performance metrics are used to analyze the proposed protocol with conventional CTP:

#### 4.1 Packet Delivery Ratio (PDR)

PDR can be measured as the ratio of the total number of packets received at the base station to the total number of packets generated by the sources. The PDR for all sources is observed for every 100s for both CTP and DA-CTP protocols by varying the data rate and the results are shown in Figure 4. From the graph, it is observed that CTP has the PDR on an average of 97%, and our proposed protocol has 96% of PDR on an average. This

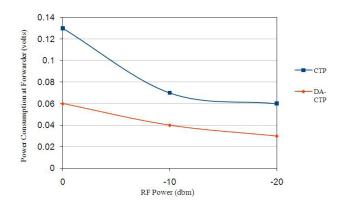
concludes that data aggregation does not affect the basic mechanism of CTP, and the packets are successfully destined for the sink.



**Figure 4.** Packet Delivery Ratio for different source data rates.

#### 4.2 Energy Consumption

Energy is considered as an important factor in the WSN. Due to data aggregation, the number of packet transmissions from intermediate nodes is reduced and thus leading to less consumption of energy. The graph in Figure 5 reveals the average power consumed at each forwarder at different experimental runs by varying the distance between the nodes. From the results, it is observed that 50 % of energy is conserved in packet transmissions.

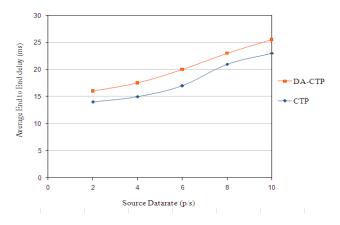


**Figure 5.** Power consumption of forwarder for different RF power.

#### 4.3 Latency

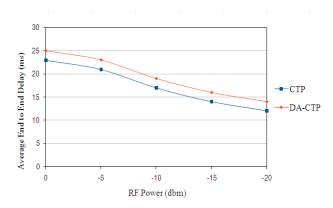
Latency is measured as the delay observed in data transmission from source to the destination. From the analysis,

shown in Figure 6, it is evident that when increasing the source data rate to 10 packets per second, our DA-CTP scheme can cause an average of 5ms delay as compared to traditional CTP. It is because the data from the source is held back by the forwarder to aggregate with the forthcoming packets. Hence, the latency is associated with the DA-CTP.



**Figure 6.** Average end-end delay for different source data rates.

Similarly, by varying the transmission power, average end-to-end delay is measured for each scheme. Results show that DA-CTP imposes 5ms delay than traditional CTP as shown in Figure 7.



**Figure 7.** Average end-end delay for different RF power.

#### 4.4 Memory Consumption

The graph from Figure 8 shows that the amount of memory consumed by DA-CTP code is higher than traditional CTP since extra components and interfaces are added in TinyOS code to implement aggregation of data packets.

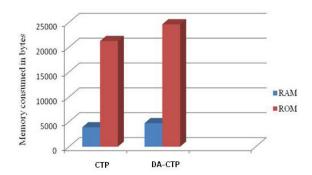


Figure 8. Memory consumption.

The performance metrics analysis of CTP and DA-CTP shown in Table 1.

**Table 1.** Analysis of CTP and DA-CTP based on the performance metrics in Wireless Sensor Networks

Performance Metrics	СТР	DA-CTP
Average packet delivery ratio	0.97	0.96
Average delay in ms	10	15
Power Consumed (volts)	0.12	0.06
Memory Consumed in bytes (RAM)	3903	5784
Memory Consumed in bytes (ROM)	22708	26687

#### 5. Conclusion

In this paper, we have presented data aggregated routing protocol known as DA-CTP, which is an enhancement of the traditional CTP. From experimental results, we observe that DA-CTP outperforms CTP regarding packet delivery ratio and energy consumption. However, the end to end delay in proposed mechanism is slightly high due to delay in aggregating the received packets by the forwarders.

To minimize the end-to-end delay, this work can be extended by selecting appropriate forwarders which lie close to both the source node and sink node by introducing a mathematical concept known as centrality.

# 6. Acknowledgement

The authors would like to thank Jesu Packia Devin and Meena Priyadharshini, SRM University for their continuous support in the testing process.

#### 7. References

- Yu Y, Prasanna VK, Krishnamachari B. Information processing and routing in wireless sensor networks. World Scientific Publishing Co. Inc: USA; 2007.
- Maraiya K, Kant K, Gupta N. Architectural based data aggregation techniques in wireless sensor network: A comparative study. International Journal on Computer Science and Engineering. 2011 Mar 3; 3(3):1131–8.
- 3. Akyildiz IF, Su W, Subramaniam YS, Cayirci E. Wireless Sensor Networks: A survey. Computer Networks. 2002; 38(4):393–22.
- 4. Akkaya K, Younis M. a survey on routing protocols for wireless sensor networks. Adhoc Networks. 2005 May; 3(3):325–49.
- 5. Pandey V, Kaur A, Chand N. A review on data aggregation techniques in wireless sensor network. Journal of Electronic and Electrical Engineering. 2010, 1(2):1–8.
- Sethi H, Prasad D, Patel R B. EIRDA: An Energy Efficient Interest based Reliable Data Aggregation Protocol for Wireless Sensor Networks. International Journal on Computer Applications. 2011, 22(7):20–25.
- Fasolo E, Rossi M, Widmer J, Zorzi M. In-network Aggregation Techniques for Wireless Sensor Networks: A Survey, IEEE Wireless Communications, 2007, 14(2):70–87.

- Sasirekha S, Swamynathan S. A comparative study and analysis of data aggregation techniques in WSN. Indian Journal of Science and Technology. 2015 Oct; 8(26): 1–10. DOI: 10.17485/ijst/2015/v8i26/81713.
- Saranya S, Bharathi N. Hierarchical approach to secure data aggregation in wireless sensor networks. Indian Journal of Science and Technology, 2015 Jul, 8(14):1–6. DOI: 10.17485/ijst/2015/v8i14/62529.
- Handy MJ, Haase M, Timmermann D. Low energy adaptive clustering hierarchy with deterministic cluster-head selection. 4<sup>th</sup> International Workshop on Mobile and Wireless Communications Network; 2002. p. 368–72.
- 11. Lindsey S, Ragavendra CS. PEGASIS: Power-Efficient Data Gathering Protocol for Sensor Information Systems. Aerospace Conference Proceedings. 2002; 3:1125–30.
- Heinzelmann WR, Kulik J, Balakrishnan H. Adaptive protocols for information dissemination in wireless sensor networks. Fifth ACM/IEEE MOBICOM Conference, Seattle WA, USA; 1999 Aug. p. 174–85.
- 13. Intanagonwiwat C, Govindan R, Estrin D, Heidemann J, Silva F. Directed diffusion for wireless sensor networking. IEEE/ACM Transactions on Networking. 2003; 11(1):2–16.
- 14. Azni AH, Saudi MM, Azman A, Johari AS. Performance analysis of routing protocol for WSN using data centric approach. World Academy of Research; 2009.