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A New Approach for Scheduling Periodic Aggregation Queries in Wireless Sensor Network with Aggregation Delay

Prasad C Mahajan

ME Student, CSE, Government Engineering College, Aurangabad, India

Abstract: Real Time System is a system in which each task has to be completed within a time called as deadline of task. In Real Time System scheduling the task set is an important task. For this various scheduling algorithms had been proposed. Wireless Sensor Network (WSN) is one Real Time System. Many queries are there in WSN for which sensor nodes of network have to response to sink node. In this paper a new approach for scheduling periodic aggregation queries has been proposed i.e. Vp-Rate Monotonic Scheduling (Vp-RMS) using Rate Monotonic Scheduling (RMS) and α-PCD Scheduling algorithm. A node probability factor (Vp) is used to schedule the queries using RMS. This algorithms helps to meet the deadline constrain of all queries as well as helps to take an aggregation delay into account while scheduling the queries. The results of proposed algorithm are verified through simulation.

Keywords: Aggregation Delay, RMS, α-PCD Scheduling, Vp-RMS.

I. INTRODUCTION

To observe physical or environmental conditions many sensors of various types are working together in a Wireless Sensor Network (WSN). In this WSN, there is one application called as control application or can say as node called as sink node which generates periodic queries. These queries are then transferred to the sensor nodes of WSN, for which sensor nodes have to response to these query requests. The sensor data or results generated by the sensors as a response to the query requests need to be streamed to the control application.

In the WSN aggregation plays an important role. This helps the system to reduce bandwidth as well as it avoids transfer of multiple packets on the network. This aggregation process aggregates data from all child nodes of a node into a single packet and then transmits this single packet toward the sink node [1].

For the scheduling of periodic aggregation queries, in the existing method, the aggregation delay is not considered while scheduling the queries [1]. But in a network which is a Real Time System this aggregation delay plays an important role [4]. Various methods have been proposed for this aggregation delay like transferring partially aggregated data. But this method degrades the performance by sending multiple packets on the network and may lead to bottleneck situation in the network or there may be a problem of packet loss due to the congestion in the network [4].

In this paper, author is going to propose a new approach for scheduling the aggregation queries in WSN with the aggregation delay taken into account. For scheduling the queries a modified RMS i.e. Vp-RMS is used, while TDMA is used for transmission of the packets. Dijkstra's algorithm is used to find shortest path from sink node to all sensor nodes before scheduling. The rest of the paper is organized as follow. Section II: Problem Formation. Section III: Related work. Section IV: Proposed System. Section V: Performance Analysis and Section VI: Conclusion and future scope.

II. PROBLEM FORMATION

A. System Model

Let W =(V,E) is a wireless sensor network.
V=Set of Nodes.
E=Set of bidirectional Communication Links.

Let v1 and v2 are the two nodes of G such that v1 Є V and v2 Є V, there exist a communication link $E_{1,2}$ between v1 and v2, iff v1 and v2 are in the transmission range of each other.

Let Vs be the Sink node.

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Vs Є V

Let S be the set of Sensor nodes.
S Є V
For wireless communication to avoid interference Protocol interference model is used. In this model, consider the transmission range is normalized to one and interference range as ρ.
By using this model we can say that, v1 is interfered by v2 iff

$$||v1v2|| \leq \rho$$

i.e., v1 is not an intended receiver of transmission from v2.
Assume that sink node Vs generate the set of periodic aggregation queries, say Q such that,

Q={Q1,Q2.Q3,..Qm}

For each query Qi Є Q
Pi=Period of Qi.
ai= release time of Qi.
di=end to end delay requirement.
S=Set of Sensor nodes.
S Є V
Each node v Є S will generate the data to be gathered at sink Vs.
Assumptions:
Clocks of different nodes are synchronized so that aggregation can be done on the data for a same period for a same query.
Aggregation can be done on multiple incoming data units into a single outgoing data unit of same size.

B. Problem Formation

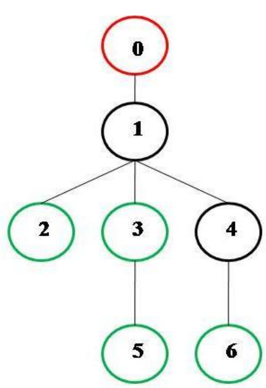

Figure 1: A routing Structure of Wireless Sensor Network

Given Q is a set of preemptive, independent and periodic aggregation queries in a WSN.
End-to-End Delay for a query Qi is the difference between time at which sink node received final aggregated data for query Qi and time at which the query Qi is released.
The two objectives are there 1) Design a routing structure and Transmission schedule 2) Schedulability.
Routing Structure Rs is a tree which helps to route the query in between sink node and sensor nodes. Here, Dijkstra's algorithm is used to find the shortest path between sensor nodes and sink node, which in turn gives a tree. This tree can be used as Routing structure.
Transmission Schedule Ts, consists of assigned time slot to transmit the packet at each node. Here, TDMA is used for transmission schedule. A transmission schedule is said to be schedulable iff the sink will get an response for each period of each query within a predefined time delay and every data is propagated in network via routing tree structure according to schedule.
Let us consider an example, Figure.1 shows a routing structure in a wireless sensor network. Node 0 is a sink node while nodes 2,3,5,6 are sensor nodes. A transmission schedule is proposed using TDMA.
Let if l be the current level in tree and L is Length of a tree and if nodes at level l are transmitting data the nodes at l-1 and l+1 are not able to send data. Therefore nodes 0,2,3,4 are able to send data simultaneously, while nodes 1, 5, 6 are able send data simultaneously.
Schedulability: Given set of periodic aggregation queries is said to be schedulable iff there exist a Transmission structure and transmission schedule that can answer all the queries within finite time [5].

III. LITERATURE SURVEY

A. Real Time Scheduling

Real time System is a system which has to produce the logically correct output within a time period [6].

Scheduler is a mechanism which to implement schedule, which is nothing but process which determine which task or job is to be assigned to a processor at a given time. For this scheduler various algorithms are there, such as Rate Monotonic Scheduling (RMS), Earliest Deadline First (EDF), etc. RMS is a fixed priority scheduling algorithm. It gives priority based on the periods of the tasks [3]. The task with lower period gets highest priority while task with larger period gets lowest priority. The processor utilization of RMS is given as

$$U = \sum_{i=1}^{n} Ci/Pi$$

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Where Ci is computation time and Pi is the period of task i and U is the Processor utilization for n tasks.
The Schedulability of RMS is given as follow,

$$U \leq n(2^{\frac{1}{n}} - 1)$$

RMS is a preemptive scheduling algorithm.

B. α-PCD Scheduling Algorithm

While studying α-PCD Scheduling algorithm, it is clear that, there is no need to execute the task for its whole computational time where it is not necessary. In [2],they find out α parameter and on the basis of this parameter, the computational time of a task is get divided into a mandatory portion and optional portion. Mandatory portion is compulsory execution time. Execution of mandatory portion of computational time gives the required output for system, so no need to execute the task for the total computational time at some instances [2].

C. PAQS with RM

In [1] author studied the periodic query scheduling for data aggregation with minimum delay. Proposed algorithm PAQS in [1] is based RMS and TMDA and suffers few limitations. PAQS algorithm assumed that aggregated packet is of same. Degree of aggregation may vary in practice. Extra aggregation delay was not considered by PAQS algorithm. This problem may be addressed by sending partially aggregated data without waiting for data from other child of a node.
But this method leads to draw of sending multiple packets on network and will increase the network traffic. This will again lead to delay due to traffic [7].

D. Conclusion from survey

In this paper, we are going to use the concept of α-PCD while transmitting the query on routing structure. The query is executed for mandatory portion on the internal node or non sensor nodes and on the other hand on sensor nodes, the query is executed for mandatory as well as optional portion of computational time. We are going to use RMS for scheduling the query while TDMA for transmission.

As a result of this, time which is remaining will be used to consider as time for aggregation on node where aggregation has to be performed.

IV. PROPOSED SYSTEM

Let us considered a Wireless Sensor network W such that W= (V, E) where V is the set of nodes in the WSN and E is the set of bi-directional communication link.
Let Vs be the sink node and S be the set of Sensor nodes. Then Dijktra's algorithm is applied on this W such that shortest paths between sink node and all sensor nodes are found out. This will gives a tree which is going to be used as Routing Structure Rs.
Now Vp factor will be used as α factor [2]. While scheduling the query with RMS, computational time of query get divided into mandatory as well as optional portion. Mandatory portion is nothing but difference of computational time and Vp factor. This Vp factor is find as follow.

```
I/P: Distances of all sensor nodes from sink node
  Tree Rs

1O/P: Vp Factor

Method:
    for (i=1 to number of sensors)
            Find the sensor with maximum distance.
        for that sensor from sink
                Find the number of intermediate nodes
    Calculate Vp:
```

$$Vp = \frac{Max\_Distance}{Number\ \ of\ intermediate\ \ nodes}$$

Figure 2: Vp Factor for Proposed Vp-RMS

To find out an aggregation delay time the following method is used.

```
aggre_delay (node, query)

    Find out the number of children of node.
```

$$aggre\_delay = \frac{number\ of\ children}{computational\ \ time\ of\ query}$$

Figure 3: Aggregation Delay

Let Tree.level be the height of level of tree Rs.
Let Tree.le be the current level of tree Rs.
Let us considered that when a node has a query and if it has child nodes then it must transfer that query to its child nodes and marks the visit of all the child nodes as 1. If that node doesn't have any child node then it must send response to its parent node or if it has child nodes and if data from all its child nodes has been received then it must perform the aggregation of data and send that data to its parent. If this

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node is sensor node it must add its own data to the aggregated data. After sending response node should mark its visit as -1 for that query.

```
do
 i=Tree.le
    while ( i>=1)
        pri=0;
        for all node at level i
        if any node with response for a query with higher priority
                then pri=1
        for all node in tree
            if a node at level i
        if a node has query to forward to child if has and pri==0
                mark visit of child for query=1.
                forward query to child.
            if the node has response and received data from all child nodes
                if it has aggregation to perform
                    Perform aggregation
                send response to parent node.
                mark visit of node for query=-1
        i=i-2
    check for all query if any visit =1
    flag=1
    if flag==1 and Tree.le= =Tree.level
        Tree.le=Tree.le-1
    else
      if flag==1
        Tree.le=Tree.le+1
while (flag==1)
```

Figure 4: Scheduling Protocol with Vp-RMS

While scheduling the query Vp-RMS is applied on every node. Vp-RMS works similarly to RMS. If node is non sensor node then execute only mandatory portion of computational time of query and if node is sensor node execute mandatory as well as optional portion of the query.

V. PERFORMANCE ANALYSIS

In order to evaluate the performance of the proposed algorithm, simulation is done for many case studies for the two periodic queries with computation time as 2 and 3 respectively. In each case study number of nodes are changed keeping the number of sensor nodes constant. Every case study is evaluated with RMS and Vp-RMS algorithm as below.

Case Study 1:

Number of Nodes: 10
Number of Sensor node: 4

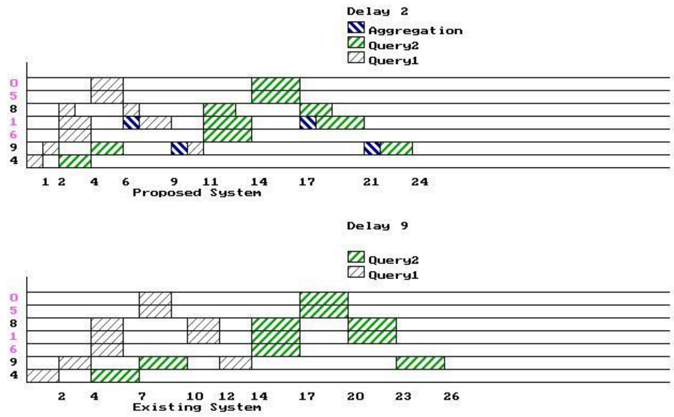

Figure 5: Case Study 1

Case Study 2:
Number of Nodes: 15
Number of Sensor node: 4

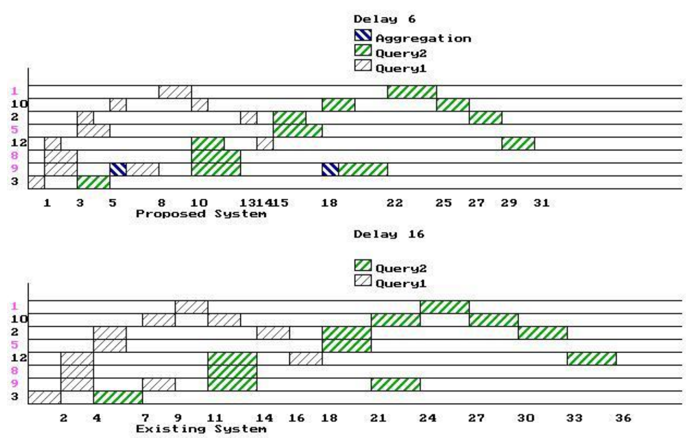

Figure 6: Case Study 2

Case Study 3:
Number of Nodes: 20
Number of Sensor node: 4

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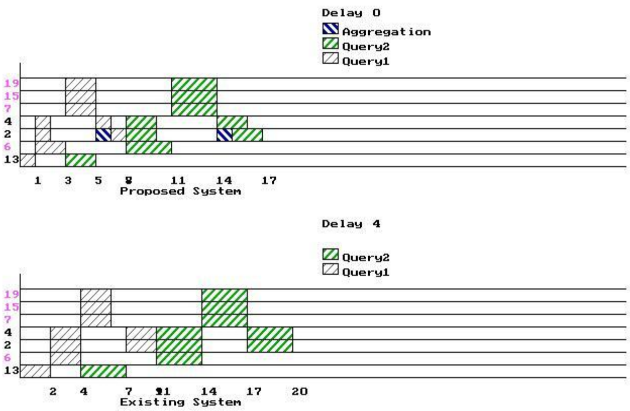

Figure 7: Case Study 3

Case Study 4:
Number of Nodes: 25
Number of Sensor node: 4

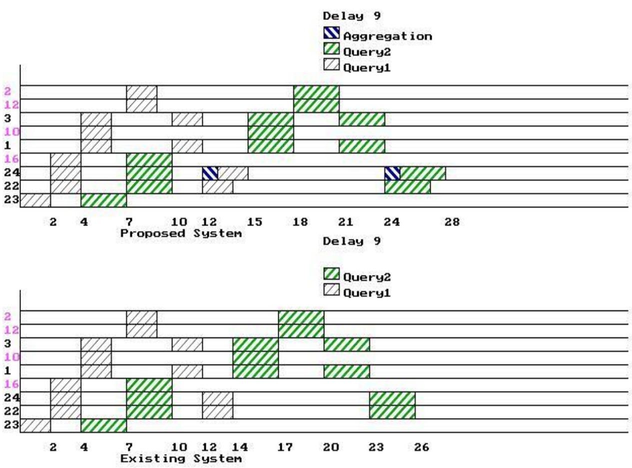

Figure 8: Case Study 4

Case Study 5:
Number of Nodes: 30
Number of Sensor node: 4

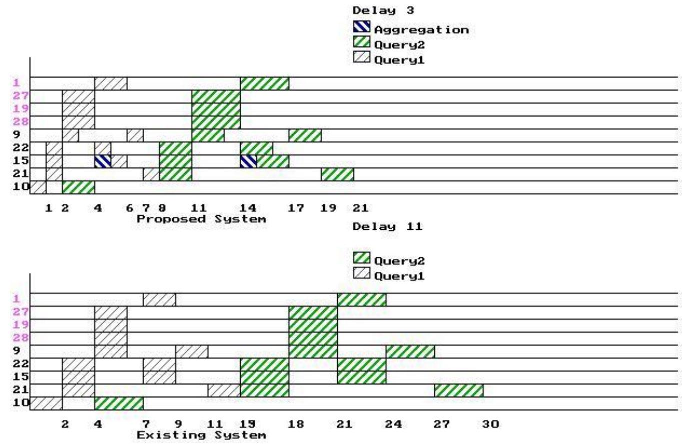

Figure 9: Case Study 5

After evaluation of all different case studies, it is clear that delay in Vp-RMS is less than that of in RMS. In Vp-RMS, queries get scheduled in such way that, sink node gets response earlier than that in RMS. The time saved in Vp-RMS is utilized for the aggregation delay effectively. Here if a graph is plotted for the delay then it is cleared that the performance of Vp-RMS are better than that of RMS. This graph is as shown in Figure 10. It is the graph between the number of nodes and delay.

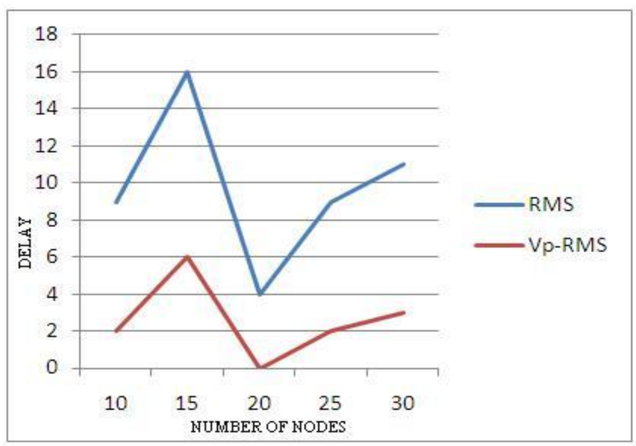

Figure 10: Graph for delay

VI. CONCLUSION

Wireless Sensor Network is a real time system and aggregation queries play an important role in it. Performance analysis shows that the simulation results obtained by proposed Vp-RMS are better than results obtained by RMS. Delay in Vp-RMS is less than that of in RMS. While transmitting query time remained or saved by minimizing the delay is utilized for consideration of aggregation delay. Vp-factor plays an important role in Vp-RMS. No partial aggregation is considered.

In the future, the work on degree of aggregation can be performed. As per the assumption of the algorithm in this paper, node aggregates different packets in a single packet of same size. In practice however, this degree may be different.

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BIOGRAPHY

Prasad C. Mahajan received the B.E. degree in Information Technology from Pune University, Pune in 2011 and currently pursuing the M.E. degree in Computer Science and Engineering at Government College of Engineering, Aurangabad.