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Spatio Temporal Correlated Buffered Data Aggregation For Maximizing Lifetime and Energy Saving In WSN

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Abstract : Enhancing network lifetime and saving energy are the most vital issues for WSNs. In this paper, a framework to improve network lifetime and ensuring energy saving termed, Spatio Temporal Correlated Buffered Data Aggregation (STC-BDA) is proposed, which is able to prolong network lifetime while efficiently minimizing the energy. In the STC-BDA, an energy efficient mechanism is designed by constructing Partition Spanning Tree that identifies the highest energy node and assigns it as the root node. In addition, a mathematical programming model, a Spatial and Temporal Correlated Point is identified for Data Aggregation. Finally, Buffered Data Aggregation algorithm is used to find the optimal solution of the proposed programming problem, through which the optimization of network lifetime is ensured.
Keywords : Wireless Sensor Network, Data Aggregation, Temporal, Partition, Spanning Tree.

1. INTRODUCTION

The main action of a wireless sensor network (WSN) is to monitor the network structure, processing of information being sensed by the sensor nodes and deliver the data packets or information to the base station nodes. Sensor nodes possess only minimum energy resource and hence, the main issue for this energy-constrained system is to design energy saving framework to improve the network lifetime.

2. METHODOLOGY

A. System model

Let us model the topology of a wireless sensor network in the form of an undirected graph 'G(N, L)', where is 'N' consists of the set of node, 'L' represents the set of link which is undirected l. A sink node '$S \in N$' is responsible for collecting the aggregated data from all most all other nodes in the network.

B. Spatial Temporal Correlated Point for Data Aggregation

In this section, the Spatial Temporal Correlated point for Data Aggregation is designed. As shown in the figure 2, each region records according to the event characteristics. The meeting point 'MP_t', 'MP_p' and 'MP_h' are identified via spatial and temporal correlated points.

Let us consider a random signal be represented as '$p_o(T)$, $q_o(T)$, T', where '$p_o(T)$, $q_o(T)$' denotes the sensor node coordinates at time 'T'. Then, the received signal strength 'RSS' by sensor node 'i' at location 'p_i, q_i' is mathematically formulated as given below.

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$$\mathrm{RSS}(p_i, q_i, \mathrm{T}) = (p_o(\mathrm{T})\, q_o(\mathrm{T})), \mathrm{T} - \sqrt{\frac{(p_i - p_o(\mathrm{T}))^2 + (q_i - q_o(\mathrm{T}))^2}{s}} \quad (1)$$

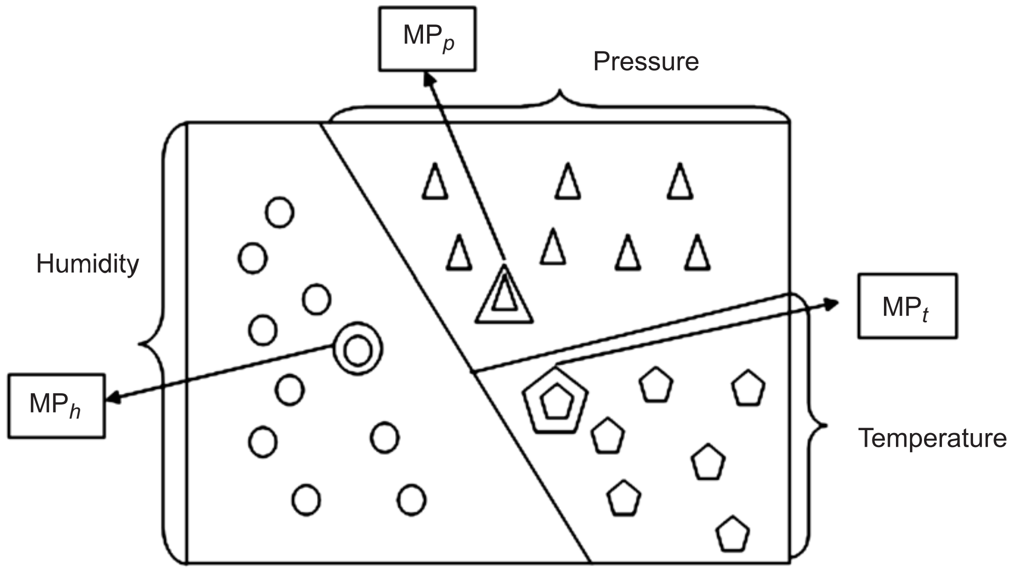

Figure 1: Spatial temporal correlation point detection to the event area

Spatial correlation 'SC' between the two sensors '(p_i, p_j)' and '(q_i, q_j)' at time 'T' is obtained from the mathematical formula given below.

$$\mathrm{SC} = \sqrt{(p_i - p_o(\mathrm{T}))^2 + (q_i - q_o(\mathrm{T}))^2} * \sqrt{(p_j - p_o(\mathrm{T}))^2 + (q_j - q_o(\mathrm{T}))^2} \quad (2)$$

From (1) and (2), the spatial correlation matrix 'SC_{mat}' is given as below.

$$\mathrm{SC}_{mat} = \begin{bmatrix} 1 & \ldots & \mathrm{SC}(1, n, \mathrm{T}) \\ \ldots & \ldots & \ldots \\ \ldots & \ldots & \ldots \\ \mathrm{SC}(n, 1, \mathrm{T}) & \ldots & 1 \end{bmatrix} \quad (3)$$

The spatial correlation point 'SCP' with discrete points '$d_i(\mathrm{T})$' at time 'T' by sensor 'i' and '$d_j(\mathrm{T})$' at time 'T' by sensor 'j' is mathematically obtained as given below.

$$\mathrm{SC}(i, j, \mathrm{T}) = \frac{d_i(\mathrm{T}) * d_j(\mathrm{T})}{\sigma_i(p_i, q_i) * \sigma_j(p_j, q_j)} \quad (4)$$

In order to obtain the temporal correlated point each source node, in the proposed Temporal Data Point selection algorithm, keep the last reading which is reported. And the current reading 'R_{curr}' is available, the new reading '$\mathrm{R}_{\mathrm{new}}$' is compared with the old reading '$\mathrm{R}_{\mathrm{old}}$'. The source node current reading is reported if obtained threshold 't' is greater than the temporal coherency threshold '*thr*'. It is mathematically formulated as given below.

$$t = \frac{(\mathrm{R}_{\mathrm{new}} - \mathrm{R}_{\mathrm{old}})}{\mathrm{R}_{\mathrm{old}}} \quad (5)$$

Algorithm 1 given shows the process involved in spatio-temporal data point selection.

Input : Sensor Node '$(p_i, p_j), (q_i, q_j), \ldots, (p_n, p_n), (q_n, q_n)$', temporal coherency threshold '*thr*'
Output : Optimized data aggregation time

Begin
For each sensor nodes ‘(p_i, p_j)’
Measure received signal strength ‘RSS’ using (1)
Measure spatial correlation matrix ‘SC_{mat}’ using (2)
Measure spatial correlation point ‘SCP’ using (4)
Measure temporal threshold point ‘t’ using (5)
If ‘$t > thr$’
Consider the point
Else
Discard the point
End if
End for
End

Algorithm 1 Spatio-Temporal Data Point selection algorithm

C. Buffered Data Aggregation

Subsequently, Buffered based Data Aggregation (BDA) mechanism is developed in the STC-BDA framework in which a subset of nodes serves. BDA approach combines the advantages of controlled mobility and network data caching to attain an immense level of balance between network energy saving and data aggregation delay and therefore increasing the network lifetime. Figure 2 shows the structure of Buffered Data Aggregation to be followed in WSN.

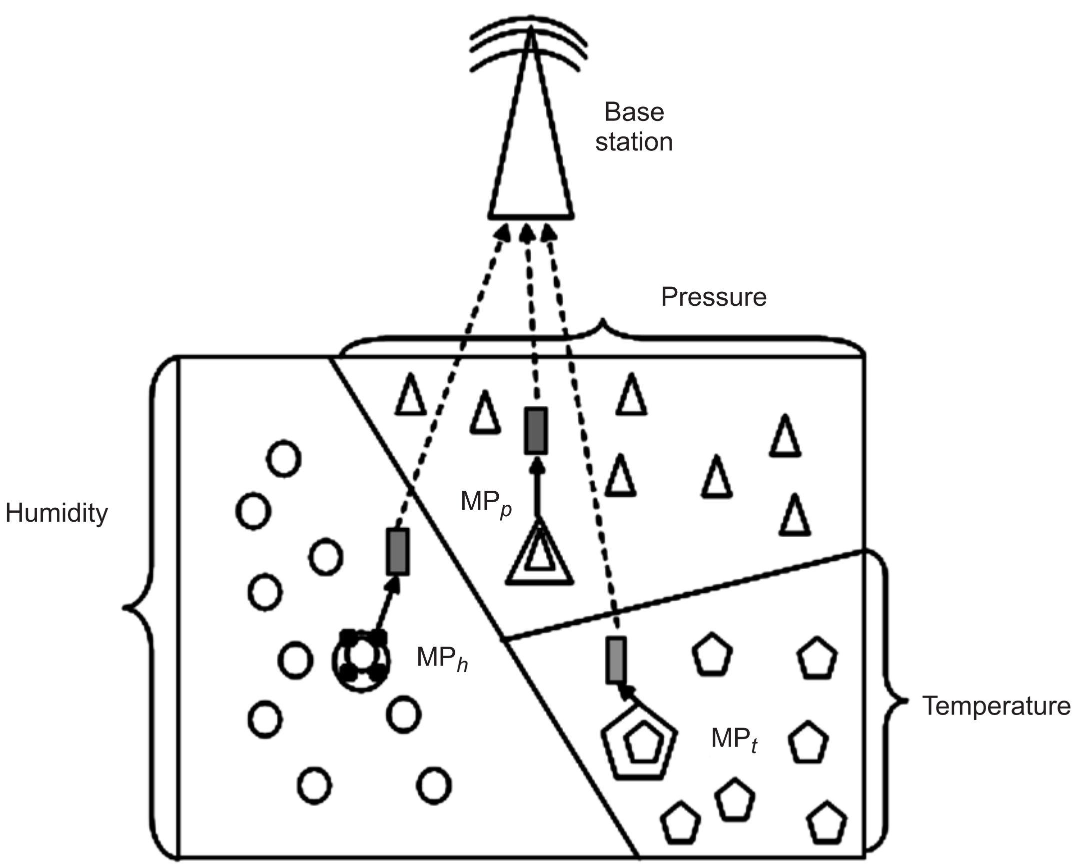

Figure 2 : Structure of Buffered Data Aggregation

In our problem, a set of source nodes generate data packets to be delivered to the base station ‘BS’ within time interval ‘T’. The objective of BDA algorithm lies in identifying a tour of the base station

'BS' that visits a set of nodes referred to as meeting points 'MPs'. The 'MPs ' buffers the data packets originated from sources and send to the 'BS' via short-range transmissions. The total delay incurred by the network to transmit the data packets from sources to the 'MPs' in the proposed BDA algorithm is said to be minimized under the assumption that all data packets 'DPi' are delivered to the 'MPs' before the deadline 'T'.

Let us further assume equal buffer size of '250MB' to three different objects being detected 'Temperature $\rightarrow t$', 'Pressure $\rightarrow p$' and 'Humidity $\rightarrow h$' respectively. Then, the allocation of buffer for each objects are as given below.

$$MP_t \rightarrow B(MP_t)\ 250 \rightarrow MB \quad (6)$$

$$MP_p \rightarrow B(MP_p)\ 250 \rightarrow MB \quad (7)$$

$$MP_h \rightarrow B(MP_h)\ 250 \rightarrow MB \quad (8)$$

This is performed for all the three objects being detected. It is mathematically expressed as given below.

$$\text{if } B\ (MP_t) > 250 \text{ MB then, PUSH } B(MP_t(DP_i)) \rightarrow BS \quad (9)$$

$$\text{if } B\ (MP_p) > 250 \text{ MB then, PUSH } B(MP_p(DP_p)) \rightarrow BS \quad (10)$$

$$\text{if } B\ (MP_h) > 250 \text{ MB then, PUSH } B(MP_h(DP_h)) \rightarrow BS \quad (11)$$

Algorithm 2 given below shows the process involved in data aggregation through the design of buffer model.

Input : Sensor Node '$(p_i, p_j), (q_i, q_j), \ldots, (p_n, p_n), (q_n, q_n)$, ', Time interval 'T', Base Station 'BS', Meeting Point 'MP_i, i = 3', Data Packet '$DP_i = DP_1, DP_2, \ldots, DP_n$ '

Output : Extended network lifetime

1. **Begin**
2. **For** each sensor nodes '(p_i, p_j)' with Data Packet 'DP_i' to be sent to Base Station 'BS'
3. Perform allocation of buffer for temperature using (6)
4. Perform allocation of buffer for pressure using (7)
5. Perform allocation of buffer for humidity using (8)
6. **If** $B\ (MP_t) > 250$ MB
7. Then PUSH $B(MP_t\ (DP_i)) \rightarrow BS$
8. **End if**
9. **If** $B(MP_p) > 250$ MB
10. Then PUSH $B(MP_p\ (DP_p)) \rightarrow BS$
11. **End if**
12. **If** $B(MP_h) > 250$ MB
13. Then PUSH $B(MPh\ (DP_h)) \rightarrow BS$
14. **End if**
15. **End for**
16. **End**

Algorithm 2 BDA

3. DISCUSSION

In our simulations, the energy consumption is computed by the average value of power consumed by each node.

$$E_{cons} = P * T \quad (12)$$

Lower energy consumption ensures efficiency of the framework. Fig. 4 shows the energy consumption of different sensor nodes in the range of 50 to 400 with an interval of 50 nodes within the observed phenomena area

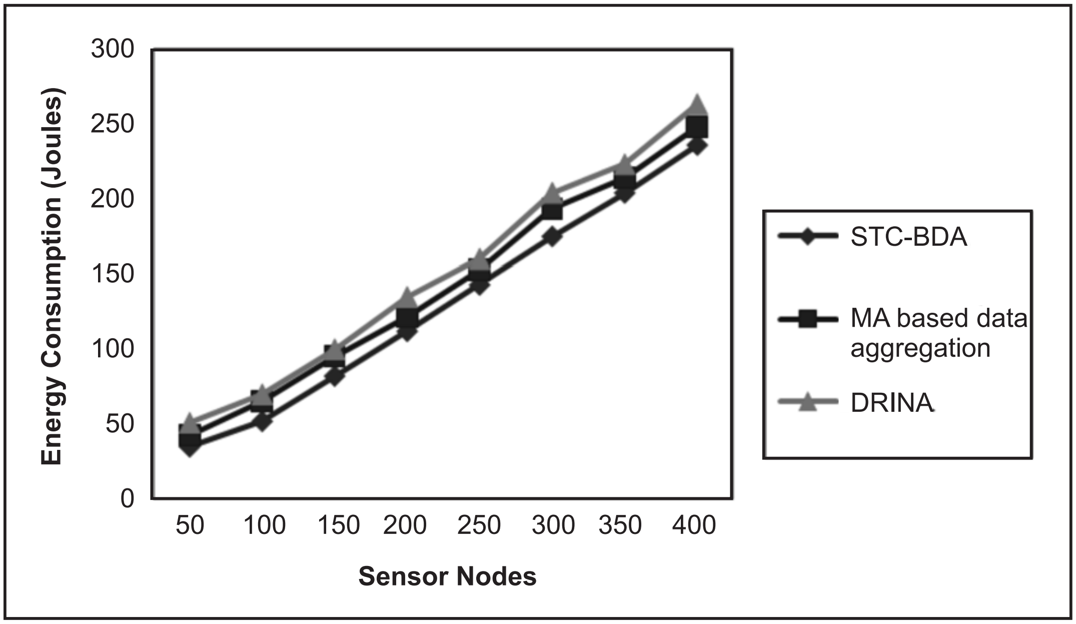

Figure 3 Energy consumption for different sensor nodes

Data aggregation time is the time taken to aggregate the data packets. It is mathematically formulated as given below.

$$T = \sum_{i=1}^{n} DP_i * \text{Time (Data Aggregation)} \quad (13)$$

From (13), 'T' is the data aggregation time, whereas 'DP_i' measures the data packets sent at a specific time interval. Data aggregation time is measured in terms of milliseconds (ms). Lower the data aggregation time, more efficient the method is said to be.

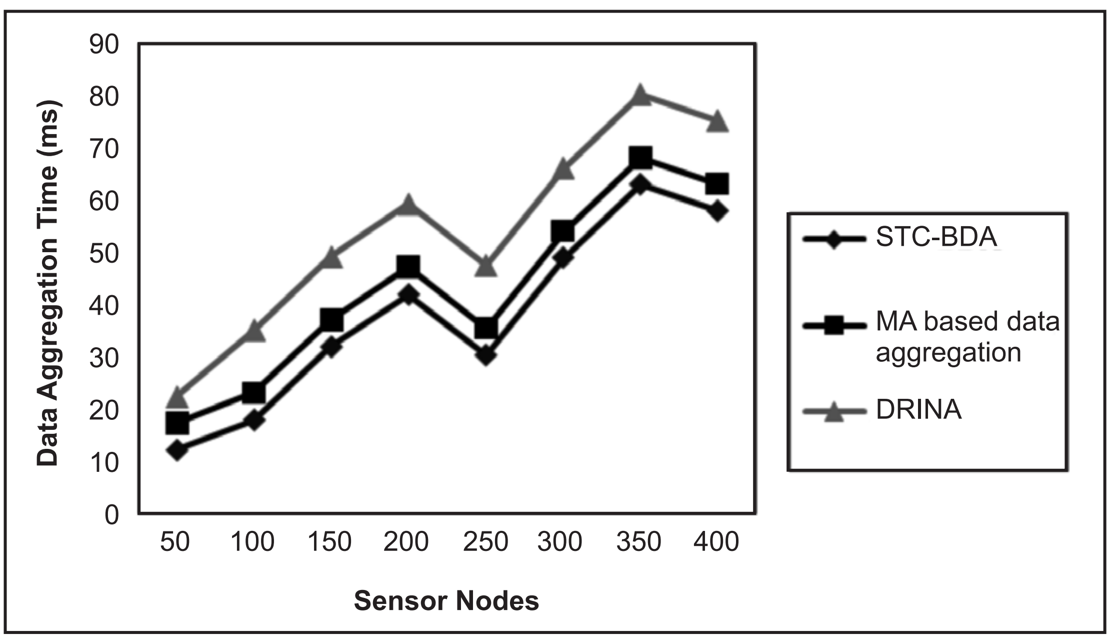

Figure 4: Data aggregation time with respect to sensor nodes

The lifetime of the network is determined by the number of sensor nodes in the network after repeated data aggregation in WSN. The network lifetime is mathematically formulated as given below.

$$NL = \left(\frac{SN_{addressed}}{Total_{SN}}\right) * 100 \quad (14)$$

From (14), the network lifetime 'NL' is measured using the total number of sensor nodes '$Total_{SN}$' in the network and the sensor node addressed '$SN_{addressed}$' for data aggregation in WSN. Higher the network lifetime, more efficient the method is said to be and is measured in terms of percentage.

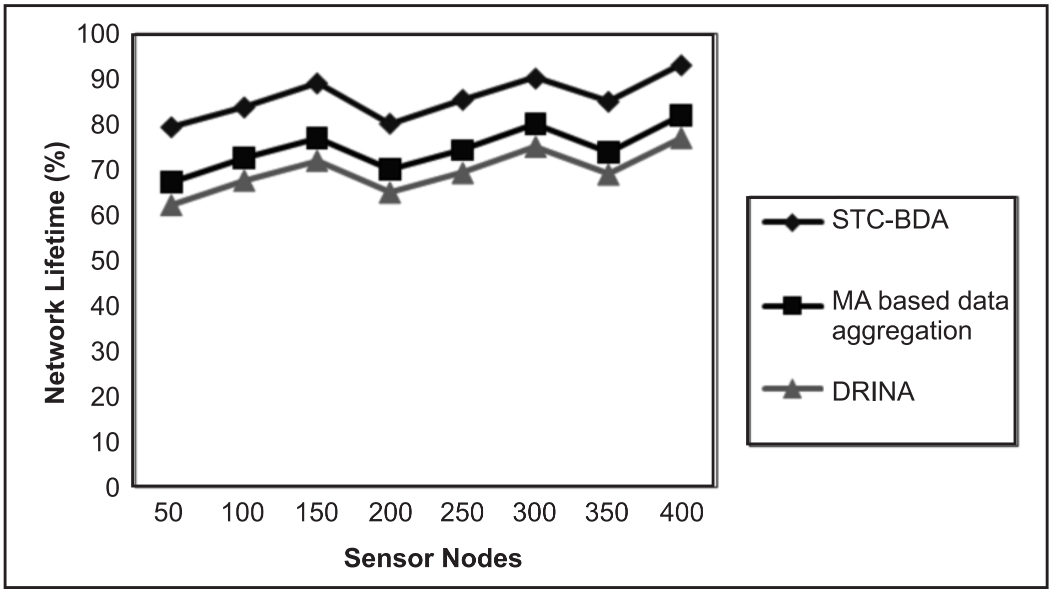

Figure 5 : Network lifetime with respect to sensor nodes

From figure 5, it is evident that the network lifetime is improved using the proposed STC-BDA framework. This is achieved by reducing the traffic across the network by Buffered based Data Aggregation mechanism, which in turn minimizes the power consumption of the nodes close to the base station node through buffer.

4. CONCLUSION

In this paper, Spatio Temporal Correlated Buffered Data Aggregation (STC-BDA) framework is provided based on the Spatial and Temporal Correlated Point with Buffered Data Aggregation algorithm for wireless sensor network. This framework minimizes the energy consumption between the sensor nodes by partitioning the occurrences of events. As the framework uses work Spatio-Temporal Data Point selection algorithm in a dynamic manner, it reduces the delay time to deliver the gathered data in WSN through efficient selection of meeting points. By applying the Buffered Data Aggregation algorithm, separate buffers are assigned to the corresponding objects and overcome the vulnerability of data aggregation in WSN. Different sensor nodes with varied events sizes on WSN using STC-BDA framework analyze the data aggregation to significantly improve the energy conservation and therefore the network lifetime in WSN. Number of cases are tested and the results are tabulated to measure the energy consumption, network lifetime and delay to deliver the gathered data and therefore to evaluate the effectiveness of STC-BDA framework. The simulation result over the various scenarios shows improvement over the state-of-the-art methods.

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