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Data aggregation of Moving Object with Dynamic Clustering in Wireless Sensor Network

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Abstract: ***In Wireless Sensor networks due to unfavorable environmental conditions that sensor nodes are placed into and some other reasons, power consumption of sensor node is the main constrained. Emerging in-network aggregation techniques are increasingly being sought to overcome this key challenge and to save precious energy. One application of WSN is in data gathering of moving object. In order to achieve complete coverage, this type of application require spatially dense sensor deployment, which under close observation, exhibit important spatial correlation characteristics. Rate distortion (RD) theory is data aggregation technique that can take advantage of this type of correlation to reduce network load with the help of cluster based communication model. In this paper we introduce a more realistic spatial correlation analysis that makes the RD theory based aggregation model to be more efficient.***

Keywords: Data aggregation, spatial correlation, Rate-distortion, Moving object.

1. Introduction

Wireless Sensor Network exhibit a Unique Property Such as self-organizing, multi-hop, low cost and data centric networking, thus, finding growing application in several domains in recent years. In these networks Sensor nodes observe a physical phenomenon, such as temperature in some areas. Although WSN continuously sense and report information in a dynamic environment, the energy supply for each sensor node is limited. Since WSN always operate in an unattended environment, it is infeasible or high costly to replace nodes batteries and more energy is consumed in data transmission in WSN. Since most of the time, the sensed information is redundant due to geographically collocated sensors. Most of this energy can be saved through data aggregation. Furthermore, data aggregation reduces collision due to interference.

To conserve resources for a sensor node, in-network aggregation techniques are commonly adapted. Which compact the data collected using sensor nodes during the routing process, and therefore significantly reduce the number of packets the network has to transmit. In order to achieve a complete coverage, WSN application requires spatially dense deployment of sensor nodes that leads to a single event being recorded by several nodes. This leads sensor observations to have a spatial correlation. This kind of data redundancy, due to the spatial correlation between sensor observations, enriches the research of in network data aggregation.

The cluster based communication model can provide an architectural framework for exploring data correlation in sensor networks. In this model, for each cluster, sensor nodes send their sensed data to one specific node, called the Cluster Head (CH). CH aggregates the cluster member's data and sends the results to the sink node.

For a physical phenomenon to be observed, it can be modeled either as a field source, as in the monitoring environment temperature, or as a point source, such as in target detection application. Suppose as shown in figure-1, an object that generates data is moving across the network.

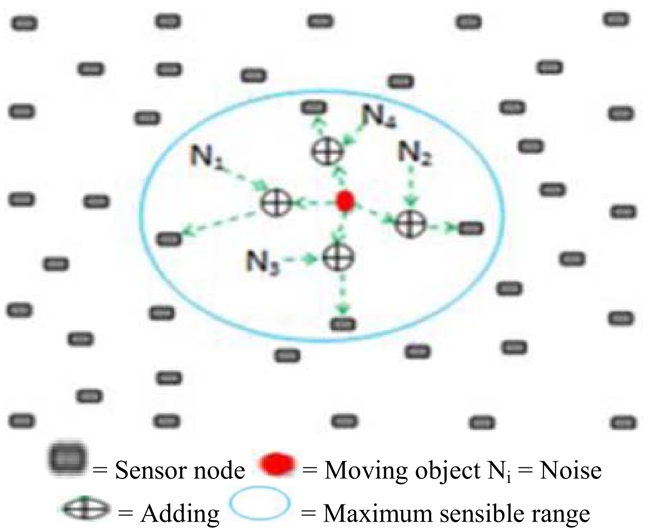

Figure 1. Moving object in the sensor network

We use the rate distortion theory for data aggregation of the moving object via cluster based communication model. Rate Distortion (RD) theory uses a spatial correlation for reducing the network traffic, provided that resultant distortion does not exceed a certain value defined by user. To achieve energy balancing and maximizing the network life time we use an idea of clustering and dividing the whole network into different clusters. Where clusters are refreshed periodically based on residual energy. Refreshing cluster minimizes workload of any single node and in turn enhances the energy conservation.

2. Literature Survey

In [2] spatial correlations are used for grouping of sensor nodes into the clusters. In [4], based on the notion of a spatial correlated region the Author maximizes the data aggregation along the communication route, and decreases the costs in routing discovery using YEAST method. In [6], the spatial correlation is used for the purpose of lossy data aggregation in aggregation point.

These all methods consider only field source phenomenon, but in the real world, the physical event may be mobile, so the communication protocol should support mobility in an energy efficient manner. In [7] the protocol is designed for the aggregation of moving object. Here a cluster of nodes is constructed and updated around the object by moving that object. This method does not use the correlation between data in the aggregation operation. Aggregation is done based on a maximum aggregator.

3. Problem Definition

In the previously proposed system, data is aggregated using static clustering w.r.t static event and this is not suitable in the real world, When the event is moving than this system fails to collect the data from the moving object and aggregate the collected data. To overcome from this problem we proposed data aggregation of moving object w.r.t dynamic clustering in wireless sensor network. One of the main key challenges of this system is gathering of data with respect to moving object and aggregating the collected data from sensor nodes thus reducing the number of packets the network has to transmit.

4. Methodology

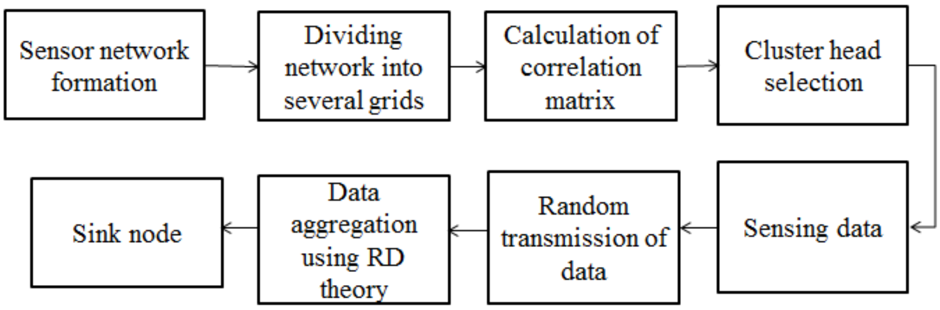

Figure 2: Block Diagram

Initially forming the sensor network and we assume that the entire area of a WSN is partitioned into a 2D logical grid. The centers of these grids are used for approximation of object position to pre-calculate correlation matrices. Our proposed protocols are not restricted to grid-based networks. These protocols only need a virtual division of the network to grids for approximation of object position, to reduce the high overhead of RD-based data aggregation of a moving object. Each grid is a square of size $d \times d$. Grids are identified (x, y) using the conventional *x-y* coordinate. This is well suitable for mobile event. For any given physical location, there should be a predefined mapping of a location to its grid coordinate.

4.1. Aggregation Model

4.1.1. Spatial Correlation

Assume an object generates a contiguous Gaussian random signal. This random signal is represented by $f_S(x_o(t), y_o(t)), t)$, where $x_0(t)$, and $y_0(t)$ denote object coordinate at time t. Suppose fS is Wide Sense Stationary (WSS), so μS(t)= μS and σS2(t)= σS2. We assume that μS=0 and the object movement before signal reaching sensor nodes is negligible. The received signal f by the sensor i with location(x_i, y_i) of is formulated as follows:

$$f(x_i, y_i, t) = f_S\left(x_o(t), y_o(t), t\,\frac{\sqrt{(x_i - x_o(t))^2 + (y_i - y_o(t))^2}}{v}\right) * e^{\frac{-\sqrt{(x_i - x_o(t))^2 + (y_i - y_o(t))^2}}{\theta_s}} + W_i$$

Where v denotes signal propagation speed, $\boldsymbol{\theta_s}$ is the attenuation constant and W_i is the Gaussian noise with zero mean and variance equal to σ_n^2. Spatial correlation between the two sensors, i and j, at time t is formulated as follows:

$$\rho(i, j, t) = \frac{E[s_i[t] * s_j[t]]}{\sigma_i(x_i, y_i)\sigma_j(x_j, y_j)}$$

Where $s_i[t]$ is used to express the discrete sampling values of $f_s(t)$ at time t by sensor i. We also assume that W_i and W_j are independent For i≠j the correlation matrix at time t can be obtained using equation:

$$Corr_{matrix} = \begin{bmatrix} 1 & \cdots & \rho(1, n, t) \\ \vdots & \ddots & \vdots \\ \rho(n, 1, t) & \cdots & 1 \end{bmatrix}.$$

After calculating the correlation matrix Cluster head is selected which is responsible for aggregating the collect data from cluster member nodes and sends to the sink node.

4.1.2. RD theory

Data correlation plays an important role in an efficient aggregation process. By collecting a correlated data at an aggregator point while using a Rata Distortion (RD) theory, we can reduce the load of the data transmitted to the base station by considering the maximum tolerable distortion by the user.

Let us suppose that a source point generates a signal, y, and that we wish to work out the minimum bits required to quantize it using an encoder, such that the distortion between Y and its representation ŷ, is less than the D_{RD} after decoding at the destination point. The minimum required number of bits to represent Y, such that E (d(Y, ŷ)) <= D_{RD} where D_{RD} is the bound on distortion, and is computed from
R(D) = min I(Y, ŷ)
f(Y|ŷ):E(d(Y|ŷ)<=D_{RD}

And E(Y, ŷ) = $||Y- \hat{y}||^2$ is a squared error distortion and I(y, ŷ) is a mutual information between y and ŷ. The above equation is solved for Gaussian sources. So for N $(0.\sigma_s^2)$ we have

$$R(D)= \begin{cases} \log \frac{\sigma_j^2}{D_j}, 0 < D_{RD} < \sigma_j^2 \\ 0, D_{RD} > \sigma_j^2 \end{cases}$$

If the source signal Y is a vector of N independent Gaussian Random Variable Each one with $N(0.\sigma_s^2)$, RD function is obtained as follows:

$$R(D)= \sum_{j=1}^{N} \frac{1}{2} \log \frac{\sigma_j^2}{D_j}$$

$$Dj= \begin{cases} \theta, \theta < \sigma_j^2 \\ \sigma_j^2, \theta \geq \sigma_j^2 \end{cases} \quad \text{and} \quad \sum_{j=1}^{N} D_j = D_{RD}$$

Where **θ** is chosen such that

$$\sum_{j=1}^{N} \min(\theta, \sigma_j^2) = D_{RD}$$

only random variables with variance greater than θ are described and no bits are assigned to other random variables with variance lower than θ.

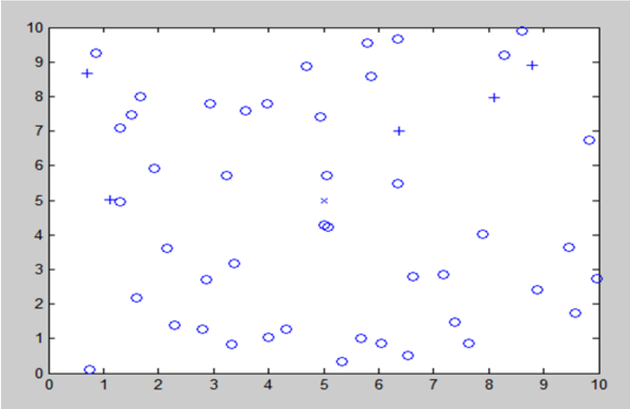

Figure 3: deployment of sensor nodes and CH selection

Nodes are randomly deployed in the network. The sink/base station, which is denoted by a x. Placing the base station at the center is convenient so that no node finds it out of its transmission range. Here, the CH nodes are shown by a plus symbol (+).

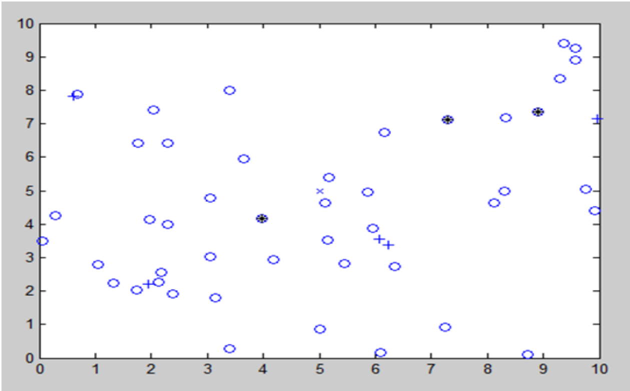

Figure 4: Moving object is introduced in the sensor network

When a moving object is detected in the sensor network, the non-CH (o)sensor nodes starts gathering of information of the moving object and gathered information is sent to the CH (+) nodes. Which aggregate the collected data and removes the distortion which is present in the signal using Rate Distortion theory and sends to the sink node(x).

5. Simulation Results and Analysis

We gather the data of moving object and by using RD theory we aggregating the collected data w.r.t moving object in MATLAB 2008. For the experiment, the CHs are selected randomly depending on the moving object in an area of (500 x 500). Maximum simulation round is set to 200. And packet size of 100 byte long.

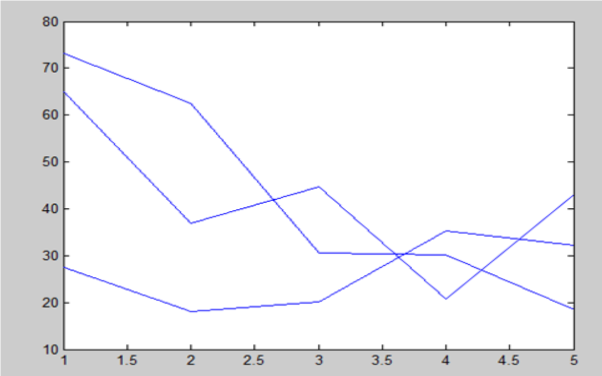

Figure 5: correlation b/w successive nodes

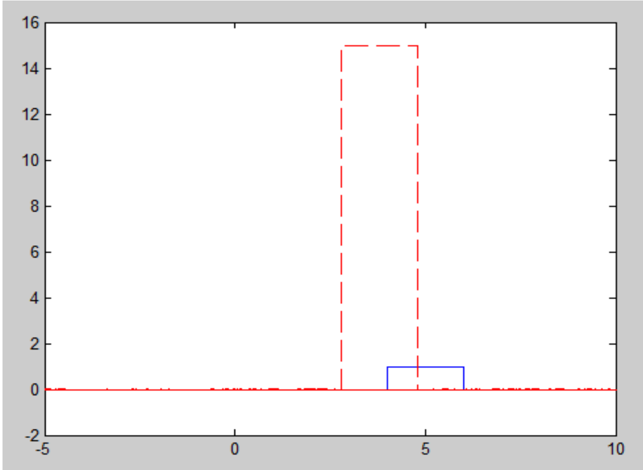

Figure 7: distortionless signal

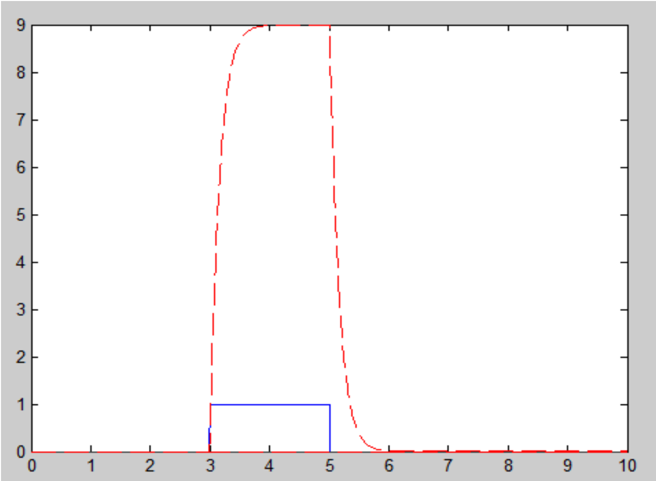

Figure 6: distorted signal

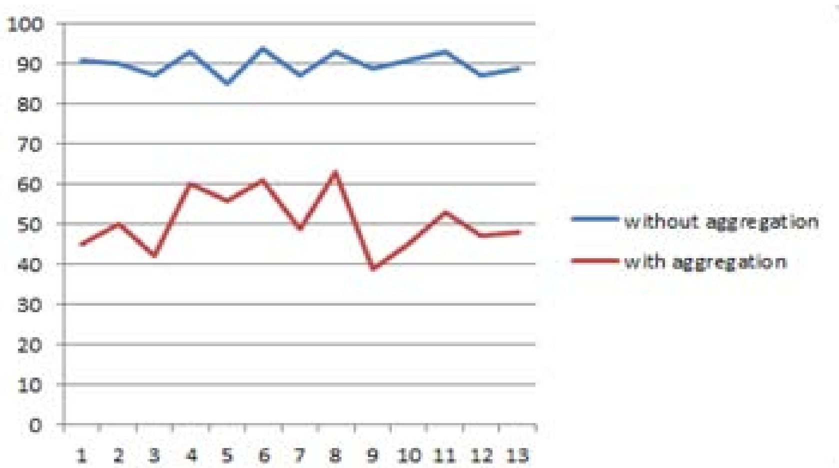

Figure 6: comparison of aggregated data (using RD Theory) and non-aggregated data

6. Future Scope

This technique can be further investigated on various aggregation techniques. It also includes implementing the algorithms in real sensor network using mobile event.

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