Cluster Based Clock Synchronization for Sensor Network

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Abstract

Core operations (e.g. TDMA scheduler, synchronized sleep period, data aggregation) of many proposed protocols for different layer of sensor network necessitate clock synchronization. Our paper mingles the scheme of dynamic clustering and diffusion based asynchronous averaging algorithm for clock synchronization in sensor network. Our proposed algorithm takes the advantage of dynamic clustering and then applies asynchronous averaging algorithm for synchronization to reduce number of rounds and operations required for converging time which in turn save energy significantly than energy required in diffusion based asynchronous averaging algorithm.

1. Introduction

The use of local processing, hierarchical collaboration, and domain knowledge to convert data into increasingly distilled and high-level representations or, data reduction is the key to the energy efficiency of the system. In general, a perfect system will reduce as much data as possible as early as possible, rather than incur the energy expense of transmitting raw sensor values further along the path to the user. Data reduction requires time specific similarity and ordering among the data generated by sensor network which strengthen the requirement of clock synchronization among the nodes. Sensor data fusion or coordinated actuation requires synchronized physical time for reasoning about events in the physical world. Energy efficient routing in ad hoc network is one of the challenging and flourishing frontiers of ad hoc network research. To accomplish this in sensor network some researchers proposed sleep and awake status of sensor nodes in a timely fashion for enlarging the life time of the network. Based on periodic control signals nodes determine their status. Transmission and reception of control signal should be well synchronized. Operations may be disrupted due to drifts in the clocks of different nodes.

Considering the above phenomenon many people have proposed clock synchronization technique for sensor network. In [2] Qun Li et al have proposed fully localized diffusion based technique for global clock synchronization in sensor networks with synchronous and asynchronous implementations. The technique is based on exchange and update clock information locally among the neighbor nodes. Synchronous rate based algorithm exchange clock reading values proportional to their clock difference in a set order. On the other hand, asynchronous method can synchronize with its neighbor at any time in any order. It is claimed that asynchronous algorithm can also adopt with node failure, broken link and node mobility. Keen observation about diffusion based method is it can achieve synchronization but it needs the participation of all the nodes in the network which in turn effectively reduce the life time of the nodes as the nodes consumes energy for the synchronization process. Also the time convergence requires large number of rounds and incurs huge amount of flooding overhead to exchange the clock collection and updates. Clustering can efficiently handle the flooding overhead by limiting the synchronization process in a manageable set and can reduce the node participation significantly which, in turn save energy and enlarge the life time of the nodes. Yet, clustering approach to be effective, we must consider the cluster creation and maintenance cost. Kwon and Gerla [3] has proposed a passive clustering for on demand creation and maintenance of the cluster substrate which can avoid potential long set-up time and reduce re-forwarding significantly.

In this paper we study how diffusion based technique can be benefited from a passive clustering based network topology to reduce its flooding overhead during [1]message exchange among the neighbors and

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thus make the synchronization process energy efficient.

2. Related Work

A lot of research works [4] [5] [6] [7] [8] available in the field of clock synchronization in distributed systems. However, techniques described for synchronization in distributed system do not take into account the limited resource availability for sensor networks and other dynamic constraints such as mobility

Three methods have been proposed for global clock synchronization in [2]. Those are (1) All-Node-Based, (2) Cluster Based and (3) Diffusion Based method. The idea of "All-Node-Based" method is impractical to implement due to its assumption of finding a single cycle which includes all the nodes at least once. To implement the idea of "All-Node-Based" method in a small manageable set they proposed "Cluster Based" method which create and maintain clusters and use "All-Node-Based" method to synchronize among the nodes of clusters. But still "Cluster Based" method is having a great amount of overhead for cluster maintenance which, ascertain its limitation to be implemented in energy constraint sensor network. Finally, the proposed fully localized "Diffusion Based" method for clock synchronization in which nodes can be synchronized at any time with its neighbor and also can adapt adverse communication channel and node mobility.

3. Diffusion Based Method for Global Clock Synchronization

Diffusion based method [2] achieves global synchronization by spreading the local synchronization information to the whole system. The method is based on two basic operations (1) for each collect the clock value of the neighbors and compare them (2) change them accordingly. Assuming n sensor nodes in the system they [2] modeled the network using graph G (V, E). Where V is the set of sensor nodes and E is the set of one hop connections among the nodes. Proposed rate based synchronous and asynchronous averaging algorithms are stated as follows:

Rate based synchronous diffusion algorithm:
Do the following with some given frequency
for each sensor n_{i} in the network do
Change n_{i}'s time to $t_{i} - r_{ij} (t_{i} - t_{j})$

All the nodes in the network will execute the above algorithm but requires the node operation to be done in a set of order. No node can perform the operation To make the algorithm a bit floppy, asynchronous averaging algorithm has been proposed operations can be done at any order.

Asynchronous Averaging Algorithms
for each node n_{i} with uniform probability do
Ask its neighbors the clock readings (read values from n_{i} and its neighbors)
Average the readings (compute)
Send back to the neighbors the new value (write values to n_{i} and its neighbors)

Asynchronous averaging algorithm can effectively solve the synchronization problem. But one of the factors that affects the convergence speed and energy is that, all nodes have the same probability to execute the average operation. The operation of node whose clock is similar to its neighbors does not contribute much to the convergence. We investigate this observation and came up with an implication that cluster based method can be useful to decrease the convergence time and energy consumption by involving the cluster head and gateway nodes for the averaging operation. At the same time we need to find a well suited clustering technique which is having the minimum cluster creation and maintenance overhead. Next section we articulate our idea of passive clustering asynchronous algorithm which can effectively reduce convergence time, number of broadcast and energy consumption due to synchronization process.

4. Proposal- Cluster Based algorithm for Synchronization:

To reduced operation and less overhead of cluster head maintenance of passive clustering, we change the asynchronous algorithm in the following way:

Like other traditional synchronization algorithms our algorithm is having two major operations:

1. Collecting clock information and averaging
2. Sending the new clock value to be updated

In our algorithm cluster head and gateway nodes are responsible for initiating clock collection, averaging and updating. All gateway nodes and cluster heads are having equal probability to execute averaging operation, while asynchronous diffusion in based algorithm all nodes are responsible for clock averaging operation. Synchronization process is as follows

Exchange clock times with n_i's neighbors
for each neighbor n_j do
Let the time difference between n_i and n_i be $t_i - t_j$
for each cluster head node hn_i and gateway node gn_i in the network {
if the node is a cluster head{
collect clock information from the member nodes of the cluster
compute the average of the clocks of the nodes in a cluster
send new clock to the members of the cluster }
if the node is a gateway node{
collect clock information from cluster head nodes within the gateways transmission range computer the average clocks of the cluster head nodes
send new clock information to the cluster head nodes
} }

5. Simulation:

Our experiment compares our algorithm with asynchronous averaging algorithm with in a roaming space of 200 x 200 under increasing number of nodes. Our proposed algorithm performs better both in terms of number of rounds and operations required for synchronization operation for increasing number of nodes. Our proposed algorithm significantly reduces the number of operation required for converging the clock with an error rate of 0.01%.

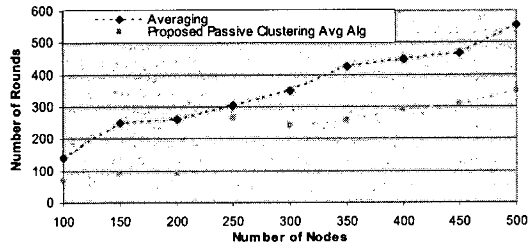

Figure: Number of rounds --- varying number of nodes --- Fixed transmission range

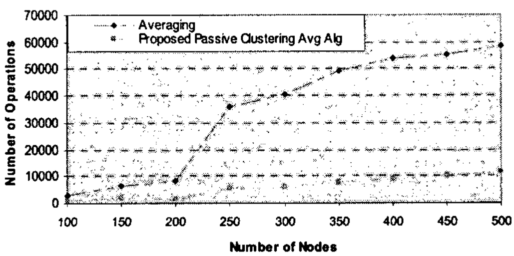

Figure: Number of operations --- varying number of nodes --- Fixed transmission range

6. Conclusion:

Diffusion based asynchronous averaging algorithm each node performs its operation locally and diffused to whole network to achieve the global synchronization. One of the factors that affects the performance of diffusion based asynchronous algorithm is all node have the equal probability to execute averaging operation. Our proposed algorithm takes the advantage of passive clustering (which is an on demand dynamic clustering method with negligible amount of cluster creation and maintenance overhead) which reduces the chance of executing averaging operation in all nodes. Rather our proposed algorithm executes averaging operation only in cluster head and gateway nodes which in turn improve the performance in terms of time and energy

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