TIME SYNCHRONIZATION STRATEGIES FOR WSN: AN APPRAISAL FOR SYNCHRONIZATION ERRORS, ALGORITHM

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Abstract - *Wireless sensor networks sometimes called wireless sensor and actuator networks, are spatially distributed self-directed sensors to observe environmental or physical circumstances such as temperature, sound, pressure etc. Wireless sensor networks are special type of ad-hoc networks. In ad-hoc networks we do not require an external infrastructure such as base station in mobile phone networks. In WSNs mainly focus on hardware prototypes and energy efficiency. WSNs used as a tool for improving the effectiveness of industrial process. Many wireless nodes are battery powered, so energy efficient protocols are necessary. Time synchronization is used to save energy. It allows the nodes to sleep for a given time and then awaken alternatively to receive a alarm signals. Time synchronization is used to determine exact location, proximity, energy efficiency and mobility.*

Time synchronization is a distributed task. Some intrinsic properties of sensor networks, such as storage, bandwidth computation and limited resource of energy combined with high concentration of nodes that is unsuitable for old synchronization methods in the network. For this reason we need to concentrate on the algorithms of synchronization specially for sensor networks. Synchronization algorithm required for precision, lifetime, efficiency and robustness.

It has been observed from literature survey that time synchronization mainly focus on two things. Firstly, drift from master oriented towards master less synchronization and secondly energy efficiency techniques.

In this thesis we have studied various time synchronization protocols for WSNs and their performance is discussed using various parameters. It is found that the performance of flooding time synchronization protocols is better than all other discussed protocols in terms of complexity and time delay.

***Key Words*: Wireless Sensor Networks, Time Synchronization, Energy Efficiency**

1. INTRODUCTION OF WSN

Research on wireless sensor network goes back to a number of US-based study projects, where the use of large networks of small wireless sensor devices was explored in a military domain. Initial work mainly focused on the development of hardware prototypes and energy-efficient networking protocols. These early efforts established a de facto definition of a wireless sensor network as a large-scale, wireless, ad hoc, multi-hop, un-partitioned network of homogeneous, small, mostly stationary sensor nodes that would be randomly deployed in the area of interest. Since then, the use of wireless sensor networks has also been considered for a number of civil applications. Wireless sensor networks have been suggested as a exact tool for better understanding real-world phenomena, as an enabling technology for making our daily life more at ease, as a tool for improving the effectiveness of industrial processes, and as a mechanism for dealing with issues such as environmental security and law enforcement. In these application domains, wireless sensor networks are deemed a promising technology with the potential for changing the way we live by bridging the gap between the real world and the virtual world of existing information technology.

The different set of potential applications has two important implications. Firstly, wireless sensor networks cannot any longer be characterized by a single, thin definition. Rather, wireless sensor networks span a broad design space with enormously varying requirements and characteristics. Secondly, wireless sensor networks have become a truly multidisciplinary domain, where close support between users, application area experts, software developers, and hardware designers is needed to realize efficient systems for specific applications.

1.1 NEED OF SYNCHRONIZATION SCHEMES FOR WSNS

Synchronization schemes are required in wireless sensor networks to satisfy the designs of algorithms that we used in time synchronization. It has less chance that each algorithm satisfies every requirement. There are some requirements that are essential for synchronization technique:

- Accuracy: Accuracy of synchronization technique is depends on the exacting application. The outcomes of accuracy maybe vary in microseconds.

- Robustness: If any node in the system is break down or go out of then it does not affect the functioning of other nodes in the system and schemes of synchronization.
- Scalability: Thousands of sensors might be deployed in some applications. Any synchronization procedure must work well with any number of nodes in the system. Number of nodes can be increased or decreased according to time.
- Energy efficiency: As we know Network nodes have limited resource of energy. All system protocols including synchronization ones should consider this restriction.
- Cost: Due to advanced technologies, network nodes are becoming so small and inexpensive. With this extended technology cost is not so affected and size of the system not so large.
- Scope: Time synchronization algorithm may provide an ordinary time to all nodes in the system. So it is expensive in huge network.
- Delay: Many applications, like detecting gas leak, necessitate an instant reaction. For those cases we require time synchronization as soon as possible [3-4].

2. PROCESS BEHIND TIME SYNCRONIZATION:

The basic requirement of time synchronization in wireless sensor network is computer clock, knowledge of sources of synchronization errors and needs of synchronization algorithms [6]. These basic requirements are as discussed below:

Computer Clock

Computer clock circuits consist of an oscillator and a counter. Depending on the oscillator's angular frequency, the counter increases its value to represent the local clock C(t) of a network node. In ideal situations, angular frequency is constant. The angular frequency changes and computer clocks drifts due to physical variations, like temperature, vibration and pressure. Approximation of local clock can be made as [11]:

$$C_i(t) = a_i t + b_i \quad (1)$$

Where a_i is the clock drift, and bi is the offset of node i's clock. Drift represents the rate of the clock, and offset means the difference in value from real time t. Using(1), local clocks of two nodes in a network can be compared, say node 1 and node 2 as in [12]:

$$C_1(t) = a_{12} . C_2(t) + b_{12} \quad (2)$$

We call a12 the relative drift and b12 the relative offset between the clocks of node 1 and node 2. If two clocks are perfectly synchronized, then their relative drift is 1, meaning the clocks have the same rate. Their relative offset is zero, meaning they have the same value at that instant. Few strategies are designed to adjust offsets of nodes.

2.1 Sources of Synchronization Errors:

The following elements contribute to the synchronization errors [6]:

1. Send time which is the total time of building the message and transfer it to the network interface to International Conference on Communication, Computing & Systems (ICCCS–2014) be sent. This time highly depends on the operating systems in use.
2. Access time which is the time needed to access the channel. Every network employs a medium access control (MAC) scheme.
3. Propagation time which is the time essential to propagate the message throughout the air from network boundary of the sender to the network boundary of the receiver.
4. Receive time which is the time spent in getting the message by system edge and transferring it to the application layer of the host.

2.2 NEEDS OF SYNCRONIZATION ALGORITHMS:

1. **Accuracy**: Either the spreading among a group of peers, or maximum mistakes with respect to an outdoor standard.
2. **Lifetime**: Synchronization lasts till the system operates, to nearly instantaneous (useful, for example, if nodes want to evaluate the recognition time of a single episode).
3. **Scope and Availability**: The geographic distance of nodes that are synchronized, and totality of coverage within that region.
4. **Efficiency**: The time and energy expenditures desired to accomplish synchronization.
5. **Cost and Form Factor**: It is important in wireless sensor networks that involve thousands of tiny, not reusable sensor nodes.
6. **Strength**: In case of insensitive environment, synchronization scheme should be functional.

7. **Longevity**: Synchronization must be able to work till the operation of the network works.

8. **Delay**: Time synchronization must be done in small time as possible for some critical applications such as gas leak detection.

2.3 SYNCHRONIZATION STRATEGIES FOR WIRELESS SENSOR NETWORK

A. Reference Broadcast Synchronization:

RBS [21] is a method in which receiver uses broadcasts to compare clocks. This method is different from old methods because mostly time synchronization techniques uses sender to receiver synchronization but RBS uses receiver to receiver synchronization. The Reference broadcasts do not contain an open time-stamp but it receives arrival time-stamp as reference point that compares their clocks and then formed a time scale in the network. RBS is used for high accuracy time synchronization that uses less energy. Its hardware is easily available and software is also existed in the wireless network.

B. Timing-sync Protocol for Sensor Networks:

TPSN [22] is a conventional sender-receiver based synchronization. It uses tree topology. TPSN is separated into two phases: level discovery phase and the synchronization phase. In level discovery phase, in the network a level is assigned to each node. At a time, one node remains at level zero, the root node. In second phase that is synchronization phase, pair-wise synchronization is done.

1. Level Discovery Phase:

In network operation, level discovery phase runs once at a time. The level 0 is assigned to the root node and initiates the level. It broadcast the packets. Then neighbor of root assigned itself level 1. Then level 1 also performs the same procedure and completed this phase when all nodes are assigned a level. This network is structured as tree topology.

2. Synchronization Phase:

Between the two nodes, two way communications is done through synchronization phase. As we already know this is a sender to receiver communication technique. As in level discovery phase, root node starts the synchronization phase and runs all the way in the network.

The synchronization broadcasted a time sync packet through root node. Till the two way messages initiated, the nodes will do wait. Then acknowledgment sent to the root again and clock synchronized by root node through level one node.

To hear the communication of nodes, it is necessary that between the two nodes one should be the neighbor of two nodes. After hearing this message two way message initiates till the level of two nodes. When all the nodes synchronized, process will be finished.

The whole process is same as the level discovery phase. Root node starts the communication and broadcast the information at level 1 node. This process is done through a tree and continuous till the level i-1 nodes are synchronized with the level i nodes and at last all the nodes synchronized through root node.

C. Flooding Time Synchronization Protocol:

FTSP [23] can be used to synchronize a whole network. In FTSP, the lowest node ID is chosen as the anchor whose local time serves as a suggestion for synchronization. If lowest ID node fails, then we could choose another lowest ID node of the remaining network.
Then we elected a new anchor to the network. The anchor regularly broadcasts a synchronization message that contains its current local time. Those nodes have no information about this message yet use the message contents to derive a constraint and broadcast the message to its neighbors. Each node collects eight such constraints and uses linear regression on these eight data points to estimate time offset and rate difference to the anchor. The algorithm is repeatedly executed to maintain synchronization over time. To minimize the delay variability, Time-stamping is performed in the MAC layer.

D. Lightweight Tree-based Synchronization: LTS

Lightweight Tree-based synchronization [24] is a synchronization technique that gives precision with little transparency, rather than determined for maximum precision. There are two algorithms: first one operates on demand for nodes that actually need synchronization and second one that itself synchronizes all nodes. Those algorithms that are out-of-band, contains at least one or more master nodes. Itself synchronized algorithm is constructed by spanning tree through the master node in the network and formed round-trip synchronization. The synchronization frequency is calculated from the depth of the spanning tree, from the requested precision and from the drift bound. One or more master nodes existed in on demand version. When a node needs synchronization, it sends a request to one of the masters using any routing algorithm. Then, along the reverse path of the request message, nodes synchronize using round-trip measurements. In order to reduce synchronization overhead, each node may ask its neighbors for pending synchronization requests. If there are any such requests, the node synchronizes with the neighbor, rather than executing a multi-hop synchronization with a reference node.

Tiny-sync and Mini-sync:

In order to attain synchronization protocol which Is more constrained to communication bandwidth, Mini-Sync and Tiny-Sync [25] was proposed which aims at minimal computational and storage complexity. In this algorithm, concept of data points is used which is the tuple of timestamps. In Tiny-sync some of the data points are used and others remain useless. It uses low storage space as only four data points and eight time stamps are to be stored. Mini-Sync improves the accuracy of Tiny-Sync at a low computational cost as it rejects only that constraint if newer constraint can eliminate the existing constraint. These protocols are suitable for sensor networks that are highly constrained in bandwidth and computational power providing tight, deterministic synchronization. No scalability and robustness is defined for these protocols. It is also tolerant of message losses.

3. CONCLUSIONS

In this paper we have surveyed the time synchronization strategies. In wireless senor networks, sensor ability, self configuration, energy efficiency and time synchronization is more challenging as compare to other wireless networks. In this paper time synchronization strategies **have been studied and major issues have been identified** that mainly include delay and efficiency. Each technique has its own superiority and limitations, so that we should be caution about selecting the strategy. From the literature it can be concluded that design innovations are needed to develop time synchronization strategies for energy efficiency and improved precision for hostile and challenging wireless sensor network.

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