Study, Analysis of Various Time Synchronizing protocols in WSN

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Abstract: In recent year's time-synchronisation plays a crucial part in WSN to preserve shared data among various sensor nodes observed in real world environment. Wireless networks consists of different types of sensors which are conjugate with each other to gather sensed data from the field such as temp, animal tracking and etc., the main goal of sensors is to maintain reliable information accomplished when nodes are time synchronized. The most common limitations of sensor networks such as security, bandwidth, storage, energy etc., in these prospect earlier researchers mainly paid attention on study of various protocols. Earlier effort and study in wireless sensor networks proposed different algorithms. The main aim of this paper is to investigate diverse time synchronisation algorithms and explore investigation based on qualitative and quantitative criterion. The analysis will help the researchers in studying various time synchronization protocols.

Keywords: *Time-synchronisation, WSN, protocols, synchronization.*

I. INTRODUCTION

In recent year's researchers showing keen interest time-synchronisation algorithms in WSNs as it acts a vital task in real world applications such as medical, military, environmental and industrial applications. Most of the wireless sensor networks are distributed systems with G-Clock operates independently with local clocks difficult to maintain synchronization with each other. It is very complicated to interpret and incorporate sensed data among nodes. Sensor nodes local clocks suffer drift and clock skews, which creates problem for synchronized notion of time in some applications, especially surveillance, weather forecasting and very difficult to have a common time stamp among all sensor nodes [1]. Some of the sensor limitations are energy optimization, cost reduction, security and quality associated with it. This paper focused broadly to analyze various protocols like GPS, TPSN, NTP, FTSP and RBS. The time-synchronisation problems have been considered comprehensively in Local Networks and in internet [1]. Most of the available synchronization protocols depend on the GPS clock information, where it is highly cost effective may not suitable for tiny sensor nodes. The cost effectiveness of sensor nodes motivated towards the development of software based schemes to accomplish internetwork clock synchronization.

This paper presents various sections as follows: Section II describes related work on various time synchronization methods, Section III describes existing time synchronization methods, Section IV describe comparative analysis of various time synchronization protocols, and final section concludes the paper.

II. METHODS OF TIME SYNCHRONIZATION

Synchronization of time in distributed sensor network systems is an vital parameter of a WSNs, intends to present a general timescale for localclocks of nodes in the network, which presents a detailed analysis. Many researchers described various existing protocols in which they focused to discuss on common challenges of synchronization and methods [2]. Hardware sensor nodes clocks are inadequate, localclocks of sensor nodes try to drift in time with each other and the observed clocks may vary for nodes in network.

- NTP

Synchronization plays a vital role in all the areas, network time protocol mostly utilized in regular networks of computers to maintain the synchronized clock. It uses UTC, where NTP utilizes clock-servers level to maintain time synchronization. Stratum known at each level assigned level value labeled as '0', label '1' is assigned to the next level and the same procedure is repeated for all the levels. Generally stratum'0' is a atomic-clocks or GPS-clock. Network Time Protocol client transmit multiples request to server and keeps pair of offset & delay for future computations. NTP's drawback is it needs to transmit multiple messages to the server for synchronization.

- TPSN (Timing-Sync Protocol for Sensor Networks)

Timing-Sync Protocol for Sensor Networks (TPSN) explores a S-R synch method which describes a 2-way message exchange method to achieve the time synchronization between 2-nodes, synchronization and level discovery phase, each node assigned a level, one assigned level-0 it is a root node. Second phase, node of level-*n* synchronizes to node of level-(*n-1*), finally at the end of this phase time synchronization is achieved. The 2-phases are described as follows: first phase (level discovery phase) in which selecting root node, other nodes are elect periodically the root node in the network and level-0 assigned to the root node. The root node connected to the reference clock (GPS). The root node sends level discovery packets to all the nodes, nodes which receive packets assign level-1, this process repeats until all the nodes in the network are covered. Second phase is synchronization in this root node initiates synchronization phase sending time synch packets, node-À of level-*n* synchronizes to node-Ɓ of level-*(n-1)* by 2-way message exchange. Every node is synchronized in the network to root node, this procedure is repeated until network clock synchronization is accomplished. In second phase pairwise synchronization is performed [4] as it performed along edges of the hierarchical structure by *level discovery phase*. Node- À sends a packet with its local time τ_1. Node- Ɓ receives packet at time τ_2 can be calculated as in [5].

$$\tau_2=\tau_1+\tau_d+\Delta \qquad (1)$$

τ_d is propagation delay, Δ is the relaitve clock drift among the nodes, Node-Ɓ stays for arbitrary clock and reacts to node-À during an ack packet at clock τ_3, it comprises the values of τ_1 to τ_3 and level-number. Figure 1 describes the message exchange among node-À and node-Ɓ. The figure 1 depicts how node-À and node-Ɓ exchanges message. As shown in figure τ_1, τ_4 indicates the measured time by localclock of node-À and τ_2, τ_3 present measured time by localclock of node-Ɓ. Node- À transmits synch packet to Node- Ɓ, it receives packet at τ_2 where τ_2 is sum of clock drift and propagaition delay, and at τ_3 Node- Ɓ transmit an ACK packet back to Node- À. Node- À can computes propagation delay and clock drift as follows

$$\Delta = \frac{(\tau_2 - \tau_1) - (\tau_4 - \tau_2)}{2}$$

$$d = \frac{(\tau_2 - \tau_1) + (\tau_4 - \tau_2)}{2}$$

Node-À able to correct its local clock when drift is computed, hence it synchronized to Node-Ɓ.

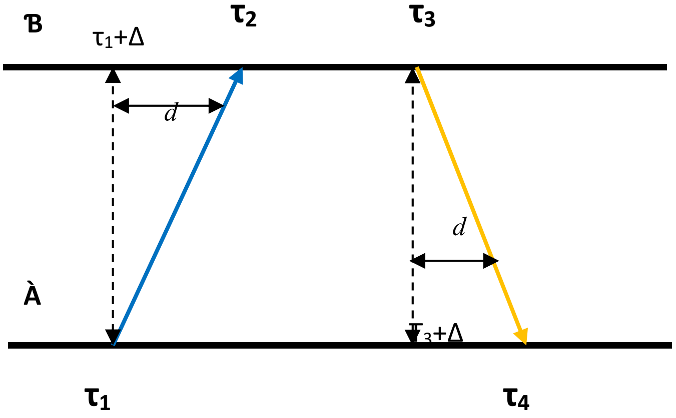

Figure 1: 2-way message exchange among nodes

- **RBS (Reference Broadcast Synchronization)**

The RBS algorithm as in[6] describes that a receiver-receiver synchronization is achieved, instead of sender-receiver synchronization. Here, beacons are transmitted by nodes and remaining nodes uses the time arrival of beacons as reference to calculate offset times among nodes. The aim of the algorithm is to eliminate non-deterministic of the transmit time. The propagation and time of receiving is the source of error in this protocol. The propagation delay errors ignored when the communication range is very short, so that all the nodes in the network receives the beacon at this time. When the message is received by the nodes, nodes record the arrival time of the message and evaluate the clock with each other. This procedure allows synchronizing at a high degree of precision. The figure 2 depicts the critical path analysis of traditional time synch and RBS algorithms respectively.

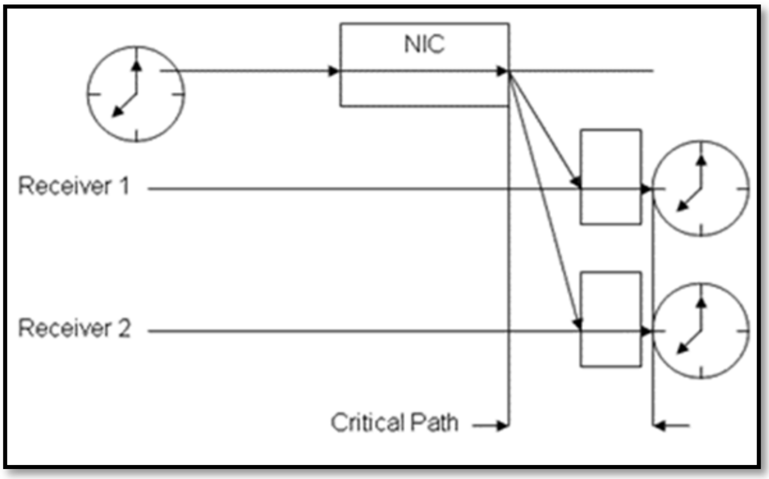

Figure 2: Critical path analysis of RBS

III. PROBLEMS AND PARAMETERS OF TIME SYNCHRONIZATION

- ***Computer Clocks****:* Most of the clocks associated with computer devices comprises of a counter and an oscillator. A computer local clock is represented by *C(t)* of real-time *t*

$$C(t) = x\int_0^t \omega(\tau)d\tau + C(t_0)$$

Where x is the proportionality co-efficient, $\omega(\tau)$ is angular frequency of the oscillator and t_0 initial value of the clock. For idyllic case, the rate of change of clock dC/dt =1. Depends on various substantial environmental alterations, the computer local clocks may drifts. Then, the computer localclock of node *i* can be associated to realtime *t* as [7]

$$C_i(t) = a_i t + b_i$$

a_i is the *clockdrift,* and b_i is the *offset* of the node *i's clock.* Here, drift represents the rate of the clock (frequency), and *offset* is the discrepancy in value from *realtime t,* by using the above equation, it can evaluate the computer localclocks of 2-nodes in a given network, state node1 and node2 as [7]

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

Considering a_{12} as *drift* and b_{12} the *offset* among the clocks of node1 and node2. The (2) two clocks are absolutely coordinated, subsequently their *relative-drift* is 1, means that the clocks have the similar rate. Their *offset* is zero, means that they have the similar rate at that moment [7].

- ***Synchronization Challenges****:* Most of the time synchronization protocols facing certain issues at different applications while they are implementing based on the requirements, and many of the protocols depends on message exchange between nodes with a time-stamp, delays like propagation times and access times etc.

The following four parameters are the sources of synchronization errors

- **ST**(*Sendtime)*: It is the time taken to assemble message from sender which consists of OS overhead and time to transmit to network interface.
- **AT***(Accesstime)*: It is the delay to access the transmission channel due to collisions and contention at MAC layer.
- **PT**(*Propagationtime)*: It is the time essential in propagating the message from S-to-Rxr. It vary based on the location of the receiver and sender.
- **RT**(*Receivetime)*: It is the time taken by the receiver node to process the message and responds with ACK to the sender. The receive time may or may not includes the overhead in the message.

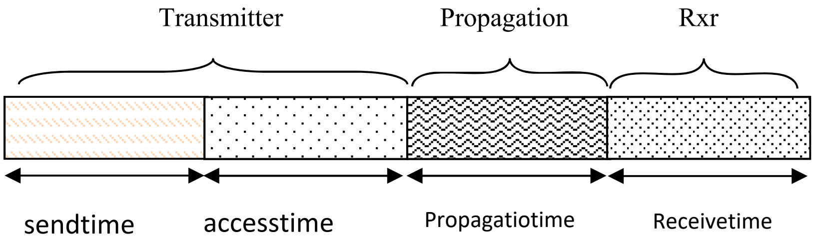

Figure 3: Packet-delay components

IV. TAXONOMY OF TIME SYNCHRONISATION

Time Synchronization schemes present a means for localclock synchronization of sensor nodes in a given network. These synchronisation algorithms can be categorized into the following types

a. *Master-Slave/Peer-Peer*: In *master-slave* initially a tree-like network hierarchy assigned one node as master and other nodes as slaves. All the slave nodes are tried to synchronize with the master node. In *peer-peer* type any node can synchronize with other nodes in the given network.

b. *Clock-correcting/untethered-clock:* In *clock-correcting* the local clock is corrected after every run of the synchronization process. In *untethered-clock* each sensor node preserves its individual clock as it is, and remains a time-translation table relating its local clock to other sensor nodes clocks.

c. *Sender-receiver/receiver-receiver/receiver-only*: Synchronization in S-R approach is obtained between 2-nodes, they are time synchronizing with each other, and transmits a time-stamp where other node receives it. In R-R approach reference-node sends synchronization message and other nodes receives the message records time-stamps. In *receiver-only* a set of sensor-nodes can be concurrently coordinated by listen to the message interactions of a couple of nodes.

d. *Pairwise/network-wide synchronization:* In the case of Pairwise time synchronization the algorithms are initially intended to synchronize 2-nodes, and can be extended to synchronize a group of nodes. In the case of *network-wide* synchronization are mainly used for large networks.

Table1: Time Synchronization algorithms classification

Time_Sync_Protocols	M-S/ P-P	S^{xr}-R^{xr}/ R^{xr}-R^{xr}	Sleep Mode	Internal/ External	Complexity
TPSN	M	S-R	Yes	Both	Low
RBS	P-P	R-R	Yes	Both	High
FTSP	M	S-R	Yes	Both	Low
DMTS	M	S-R	Yes	Both	Low
SLTP	M	S-R	Yes	Both	Low
TSRT	M	S-R	Yes	Both	Low
TDP	P-P	R-R	Yes	Internal	High

V. CONCLUSION

This paper mainly focused strictly on study and investigation of existing time synchronisation algorithms in WSNs. We found that based on the survey of various algorithms, and after careful analysis TPSN and RBS protocols exhibits good performance in terms of accuracy among other protocols. RBS and TDP are the traditional methods and easy to implement, but suffers with complexity compared with other protocols. After the detailed performance evaluation and analysis, from our survey we found and conclude that the detailed analysis is very useful for the future research aspirants for exploring the research work.

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