The Research of Time Synchronization Protocol for Wireless Sensor Networks

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Abstract—In this paper, we present a time synchronization protocol for wireless sensor networks. The aim of the time synchronization protocol is to improve the precision of time synchronization and to upgrade the efficiency on energy for wireless sensor networks. The work pattern of periodical awakening and sleeping for redundancy node is provided. The time to exchange the message on time synchronization, the work status, remainder energy of the node, is limited in the settled time slice. The time for the leader node to broadcast the message on time synchronization and network status is limited reserved time slice (the time slice is unlike for different layer). So the precision in the time synchronization and the efficiency in energy of the provided protocol in this paper are very well.

Index Terms—wireless sensor networks; time synchronization protocol; reservalization; NTP

I. INTRODUCTION

For distributed system, there is own clock, warp in the frequency of crystal oscillator for different node. The temperature is change. There is interfere of electromagnetic wave. The time of the clock for different nodes may be unlike. So the time synchronization between the nodes is need in wireless sensor networks. The time synchronization contained to make physical time or logical time synchronize. The global time is need for distributed system. The time synchronization is the key technology for wireless sensor networks.

The time synchronization is used widely in traditional networks. Such as NTP(Network Time Protocol) is time synchronization used in Internet. GPS, the technology of wireless range find, etc. are used to provide the global time synchronization in traditional networks. In wireless sensor networks, the position message of happening affair is most important. If the message does not contain the position of happening affair, the message is insignificant. The method and protocol to confirm the position of the sensor node are based on time synchronization of the wireless sensor networks. The time synchronization of sensor nodes is the base function, and play the key role in wireless sensor networks[1].

The node is low-cost and small in wireless sensor networks. The other instrument for time synchronization is not built in the wireless sensor node except the crystal oscillator and wireless communication module. The nodes must exchange the messages for time synchronization. The numbers of the messages to exchange between wireless sensor nodes is related to the consumed energy. The energy is limited for wireless sensor node. So the quantity of consumed energy must be considered in the time synchronization protocol.

To minimize error of time synchronization is used to maximum the precision of time synchronization, and the cost of the communication and computation is not considered in traditional networks. But the energy is limited in wireless sensor networks, the time synchronization protocol used in traditional networks is not applied to wireless sensor networks.

Usually, only a few sensor nodes built the instrument for time synchronization, such as GPS, the time synchronization for most wireless sensor nodes is based on exchanging synchronization messages real-timely. For the wireless sensor node, its resource is limited. So, the time synchronization protocol in wireless sensor networks must be considered the expansibility, stability, robust, astringency and efficient in energy, etc..

II. THE BACKGROUND OF THIS PROBLEM

A lot of network time protocols are provided for traditional network. C/S is the usual mode. In this mode, the time servers send the message of time synchronization to the clients periodically. If the typical delay time that the server send the message to client is less than hopes, the server send one message of time synchronization to the client only. Such as NTP[3]~[5], it is used to Internet.

A few of time synchronization protocols are put forward on wireless sensor networks, such as RBS(Reference Broadcast Synchronization), TINY/MINI-SYNC, and TPSN(Time Protocol for Sensor Networks), etc.[6].

A. RBS Protocol[7][8]

For the time synchronization protocol based on RBS(Reference Broadcast Synchronization), some node broadcast the message for time synchronization, a set of nodes receive the message, these nodes revise their self clock on the difference of the time received the message. But the protocol can not carry out time synchronization between broadcast node and the nodes received the broadcast message. The warp of delay created by different distance and circumstance is not considered. On RBS, it is not real to implement time synchronization the network is very busy when the some node takeout some affair is happening.

B. TINY/MINI-SYNC Protocol[9]

For the time synchronization protocol based on TINY/MINI-SYNC, the node can reduce the requirement...
in memory and calculation by discard some data. The protocol is applied to the fields in which the precision of time synchronization is not very high, and the period is not very long.

C. **TPSN [10][11]**

For the time synchronization protocol based on TPSN, it is like NTP. There is only one root node for the wireless sensor network. The root node can obtain the external time by some hardware instrument, such as GPS. In the first step, The nodes are compartmentalized different layers. A node is synchronous with its superior node. In the last, all of the nodes are synchronous with the root node.

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The keystones is show in Fig.1, the client wanted to synchronize time sends the message asked for time synchronization. The server return the ACK message to the client. T1 is the time (on the client’s clock) that client sent the request message to server. T2 is the time (on the server’s clock) that server received the request message from the client. T3 is the time (on the server’s clock) that server return the ACK message to the client. T4 is the time (on the client’s clock) that client received the ACK message from server. If \( \delta_1 \) is the transmission time of request message, \( \delta_2 \) is the transmission time of ACK message. \( \theta \) is the difference between the clock of server and the one of the client. We can get the expressions as follows:

\[
\begin{align*}
T_2 &= T_1 + \theta + \delta_1 \\
T_4 &= T_3 + \theta + \delta_2 \\
\delta &= \delta_1 + \delta_2
\end{align*}
\]

Usually, we can assume \( \delta_1 = \delta_2 \). then

\[
\begin{align*}
\theta &= \frac{(T_2 - T_1) - (T_4 - T_3)}{2} \\
\delta &= \frac{(T_2 - T_1) + (T_4 - T_3)}{2}
\end{align*}
\]

\[\text{Figure 1. keystone for TPSN}\]

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**D. DMTS**

For the time synchronization protocol based on DMTS, the node selected as leader one in some region broadcasts the message of time synchronization periodically. The other nodes in this region receive the broadcast message from the leader node. The broadcast message contains the sending time (on the clock of the leader node) sending the message. The node receiving the message records the sending time (on the clock of the leader node). The new clock of the node received the broadcast message of time synchronization is the value that the recorded sending time adds the delay time (the delay time was tested by the receiving node during its working time). So all of the nodes received the broadcast message are synchronized with the leader node in time. The precision of time synchronization is decided by the delay time.

E. **LTS**

LTS is a low cost time synchronization protocol. It is simply, and the energy used to synchronize time is less than the one used to synchronize time in other time synchronization protocol. But he precision of time synchronization is not very good.

**III. THE NEW TIME SYNCHRONIZATION PROTOCOL AND ALGORITHM**

The aim of the time synchronization protocol is to improve the precision of time synchronization and to upgrade the efficiency on energy for wireless sensor networks.

A. **The work pattern of redundancy nodes**

For extending the life-span, the work pattern of periodical awakening and sleeping for redundancy nodes is provided. During the awakening time of redundancy nodes, the upper-layer node (it is the leader node for the layer of the wakened node) broadcasts the message (it contains the information on time synchronization, network status, etc,) at special reserved time slice (the time slice is unlike for different layers). The redundancy nodes receive the message at the same time slice. After receiving the message, the redundancy nodes make their clock synchronize with their leader node, and send one message (it contains its status of energy, position, etc,) to the leader node at another special reserved time slice.

B. **The method to improve the precision of the time synchronization**

The precision of time synchronization is related to transport delay of the message. The transmission delay is composed of four parts as follows: sending time, accessing time, transmitting time and receiving time. To upgrade the precision of time synchronization, the reservation is used to assign the time slice of broadcast message of time synchronization for leader node, and one of send the message containing the sending time, status information, etc., to its leader node for under-layer nodes in this new protocol. The beginning time of reservation time slice for the leader node join in the broadcast message as the sending time. The sending time is precision. Because of using the reservation, the node can kwn the precision time of obtaining the channel, the influence of the accessing time is avoided.

C. **The algorithm to reduce the influence of transmitting time**

If the influence from transmitting time can be reduced, the precision of time synchronization is high. In
the new time synchronization protocol, the algorithm to reduce the influence of transmitting time is as follows:

On TPSN, if the T1, T2, T3, and T4 like in TPSN can be confirmed, the problem is resolved. The keystone is show in Fig.2., when the under-layer nodes send message (it contains its status of energy, position, etc.,...) to the leader node, the sending time T1 (on the clock of the under-layer node). The leader node records the received time T2 (on the clock of the leader node). During the working time, the leader node send the T1 and T2 to corresponding node, T1 and T2 was saved in its corresponding node. The values of T1 and T2 are updated during the working time of the wireless sensor network. The T3 produced by the leader node is the sending time (on the clock of the leader node) of the broadcast message for time synchronization. The T4 is the receiving time (on the clock of the under-layer node) of the broadcast message.

To upgrade the precision of time synchronization, the reservation is used to assign the time slice of broadcast message of time synchronization for leader node, and one of send the message containing the sending time, status information, etc., from under-layer nodes to its leader node in this new protocol. The beginning time of reservation time slice for the leader node join in the broadcast message as the sending time. Because of using the reservation, the node can kown the precision time of obtaining the channel, the influence of the accessing time is avoided.

The influence from transmitting time can be reduced, the precision of time synchronization is high. In the new time synchronization protocol, the algorithm to reduce the influence of transmitting time is

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IV. CONCLUSION

In this paper, we present a new time synchronization protocol for wireless sensor networks. The aim of the time synchronization protocol is to improve the precision of time synchronization and to upgrade the efficiency on energy for wireless sensor networks.

For extending the life-span, the work pattern of periodical awakening and sleeping for redundancy nodes is provided.