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Time Synchronization Method of Distributed System Considering Local Area Network

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Abstract: With the rapid development of society, whether it is a military control system or a civilian control system, various distributed systems have put forward higher and higher requirements for the real-time interaction of control information among various devices in the system. The purpose of this paper is to consider the research on the time synchronization method of the distributed system of the local area network, and study the extended Kalman filtering method based on the prior coordinate constraints to improve the PPP time transfer performance; for the PPP timing calculation, the ambiguity fixed reliability requirements are higher than the positioning calculation. According to the actual situation, the ambiguity fixing method based on the integer phase clock method is studied, and the ambiguity fixing and quality control strategy suitable for timing calculation is proposed. Quality control at each stage. Based on the average standard deviation results, this paper continues to calculate the average root mean square error of the above phase difference data in different smoothing times, and evaluates the synchronization accuracy of the terminal in different durations. The root mean square errors of scheme two in the duration of 60min, 120min and 180min are 0.13, 0.15, and 0.2ns, respectively, and the root mean square errors of scheme three in the same duration are 0.12, 0.14, and 0.18ns, respectively.

1. Introduction

With the rapid development of society, whether it is a military control system or a civil control system, various distributed systems have put forward higher and higher requirements for the real-time interaction of control information among various devices in the system [1]. Among them, military control systems such as integrated avionics systems and ship control systems, as well as civil control systems such as industrial control and high-speed train control systems, require the control information in the system to be completed in a very short time from generation to execution. Real-time execution is inseparable from time synchronization between devices. Therefore, how to construct time synchronization in distributed systems has become a hot issue to be solved [2].

At present, the application research of distributed system time synchronization method at home and abroad starts from many aspects. Gambuzza LV studies the problem of synchronizing an arbitrary subset of network nodes with a fixed coupling strength, ignoring the states of the remaining nodes. This question is inspired by the situation observed in many biological systems, where the function of the network is correlated with the presence of clusters of synchronized nodes, which, conversely, is lost when all nodes are synchronized. A distributed control is proposed, which introduces further interaction between oscillators to guarantee the onset and stability of the desired synchronization manifold. The controller is designed to create an appropriate set of symmetries in the network. Furthermore, it is shown that the stability of the synchronization pattern mainly depends on the degree of node synchronization, so it can be controlled by increasing it. Finally, numerical examples are provided to illustrate the results [3]. Szustak proposes an innovative strategy for data stream synchronization in shared memory systems. This strategy assumes that only interdependent threads are synchronized, rather than using a barrier approach - the opposite of our approach - to synchronize all threads. We show the adaptation of dataflow synchronization strategies to two complex scientific applications based on template codes. An algorithm for data stream synchronization was developed and successfully used for both applications. The proposed method is evaluated against various Intel microarchitectures released over the past 5 years, including the latest processors: Skylake and Knights Landing. An important part of this evaluation is the performance comparison of the proposed stream synchronization with OpenMP barriers. Experimental results show that using the proposed data stream synchronization strategy, the performance of the studied application can be improved by a factor of 1.3 [4]. Frost DF proposes a communication-free distributed battery management system based on a modular multi-level converter topology with distributed inductors and distributed controllers running on a local microprocessor. This configuration is referred to as a "smart cell". By sensing the voltage across the locally distributed inductor, each smart unit is able to: first, determine its optimal switching pattern to minimize output voltage ripple; second, adjust its duty cycle to its state of charge (SOC) is synchronized with the average SOC of the series-connected battery string. A decentralized controller is derived using the theory of Kuramoto oscillator, and the stability of the intelligent unit system is studied [5]. The existing research points out the direction for the research on the time synchronization method of distributed system considering local area network.

Relying on a scientific research project, this paper studies precision single point positioning technology and its application in the field of time and frequency, and proposes a GNSS time synchronization method based on precise single point positioning, which synchronizes the local time of distributed system nodes to a unified Time benchmarks to solve sub-nanosecond time synchronization problems in distributed systems. The research results can not only meet the dual requirements of time synchronization accuracy and flexibility in the field of national defense and military, but also provide scientific research such as cross-regional precise timing, fast backup of time scales, and Very Long Baseline Interferometry (VLBI). Provide reference for the time synchronization problem in. To sum up, the research on GNSS time synchronization method based on precise single-point positioning is of great significance for solving the current military needs and focusing on future scientific development.

2. Research on Time Synchronization Method of Distributed System Considering Local Area Network

2.1. Time Synchronization Process

(1) Synchronous host

After the synchronization host is powered on, it first enters the listening state, and starts the counter T0 whose duration is longer than one integration cycle to ensure that the synchronization network in the system can be heard. The standard value is two integration cycles. If it is detected that there is a synchronous network in the system, the synchronous host executes the restart service and directly joins the synchronous network in the system; if only a cold-start response frame is detected, the synchronous host executes the cold-start service and skips the The previous two handshake operations, which are performed in each state before entering the synchronous state, are due to the fact that a compressed host configured for standard integrity will only respond to a cold start frame from a synchronous host; otherwise, it will enter when the counter counts to the threshold Asynchronous state performs cold-start service [6-7].

(2) Compression host

After the compression host is powered on, it also first enters the listening state, and starts a counter T0 with an integrated cycle to ensure that the synchronous network in the system can be heard. If it is detected that there is a synchronous network in the system, the compression host executes the restart service and directly joins the synchronous network in the system; otherwise, after the counter counts to the threshold, it executes the cold restart service and enters the non-synchronized state [8-9].

(3) Sync client

After the synchronization client is powered on, it also enters the listening state first, and remains in this state until it listens to the synchronization network in the system. If it is detected that there is a synchronization network in the system, the synchronization client executes the restart service and directly joins the synchronization network in the system. After synchronization, the interaction of a certain number of integrated frames enters a stable synchronization state, and the number of interactions can be configured offline according to actual needs [10-11].

2.2. Distributed System

The so-called "distributed system" can be understood as a computer system based on computers connected to the Internet at the time of design and research, and the system will include many shared computers. Among them are many material or intellectual resources [12-13]. These resource units have a high degree of autonomy while cooperating with each other, which can better manage the resources within the system. On this basis, services or related activities can be strongly differentiated, and even multiple distribution systems can be carried out simultaneously. As a new type of multi-computer system, distributed computer system pays great attention to the overall allocation, management, operation and task allocation of resources. The resource part does not refer to a large number of physical devices, but to a large number of intellectual resources. It mainly covers communication interfaces, processors, backup memory and input/output devices. The latter consists of processes, databases, tables, files, and processes. These resources are allocated to each physical node, and the communication between each node is mainly through the network, so that a unified computer system can be created [14-15].

2.3. PTP Clock Synchronization Principle

(1) Offset measurement stage

Since the UDP protocol is used, the master clock sends out time synchronization packets randomly many times. The main function of this synchronization packet is to remind the devices in the same subdomain to synchronize the clock, although it contains the approximate time when it leaves the master clock, but this time is not the exact time when the message leaves, it is just an estimate by the system of the time when the message leaves. Therefore, in order to ensure the accuracy, the master clock then sends out its own follow-up message, the function of which is to send the precise time when the synchronization message recorded by the timestamp leaves the master clock" [16-17].

(2) Delay measurement stage

In order to measure the link delay between the master and slave clocks, after receiving the follower message, the slave clock actively sends a delay request message to the master clock, and at the same time uses the timestamp to accurately record the time when the message leaves. When the master clock receives the delay request message, it uses the timestamp to accurately record the time when the message arrives at the master clock. Next, the master clock sends a delayed response message, which has the same function as the follower message [18].

3. Design and Research of Time Synchronization Method of Distributed System Considering Local Area Network

3.1. Overall Hardware Framework

According to the index, the hardware design part is divided into two parts: the signal conditioning board and the main control board. By filtering and amplifying the original signal, the signal conditioning board enters the main control board for collection, packaging, and data buffering to realize data communication with the computer; the main control module includes a clock synchronization part, which makes the clock of the data acquisition module match the reference clock, so that the error is smaller when processing data from different data acquisition modules.

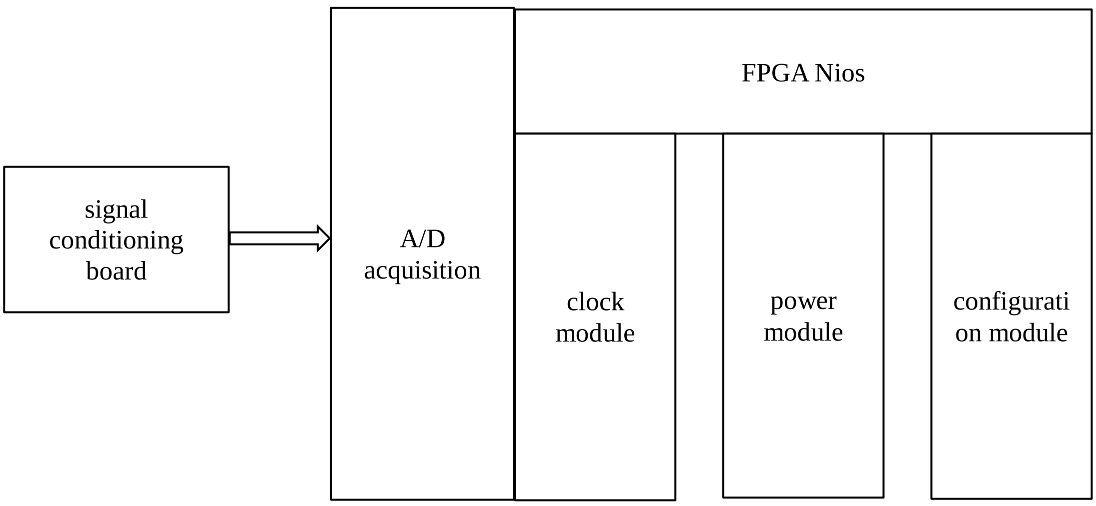

Figure 1. Overall system block diagram

The system block diagram is shown in Figure 1. After the hydrophone signal is conditioned by the signal conditioning board, it enters the main control module for AD acquisition. The KSZ8463 chip has the functions of a network chip and a clock synchronization chip. The main control module is connected to the host computer through this chip to transmit the collected data to the host computer. The clock synchronization part composed of the KSZ8463 chip is responsible for synchronizing the clock of the clock module of the FPGA with the reference clock.

3.2. Design Scheme of Time Synchronization Unit

(1) CM time synchronization unit

The time synchronization unit of the compression host mainly includes functional modules including receiving and listening module, analysis and solidification module, merge and collection module, branch cache module, confluence integration module, compression calculation module, optimal selection module, state management module, and group detection module., a framing sending module and a parameter configuration module, and an input distribution module upstream of the time synchronization unit and an output arbitration module downstream of the time synchronization unit.

(2) SM time synchronization unit

The time synchronization unit of the synchronization host mainly includes functional modules including receiving and listening module, parsing and curing module, optimal selection module, state management module, group detection module, framing transmission module and parameter configuration module. Like the CM time synchronization unit, The upstream is the input distribution module, and the downstream is the output arbitration module. The components of the SM time synchronization unit are part of the CM time synchronization unit, but the connection relationship between the modules and the functions of some modules are somewhat different.

(3) SC time synchronization unit

The time synchronization unit of the synchronization client mainly includes functional modules including receiving and listening module, parsing and curing module, optimal selection module, state management module, group detection module, cache management module, transparent transmission management module, framing sending module and parameter configuration. Among them, when the synchronization client is configured in the end system, the upstream is the input distribution module, and the downstream has no output, and there is no cache management module, transparent transmission management module and framing sending module. Except for the state management module, the functions of the other modules are related to the SM time. The module functions of overlapping modules in a synchronization unit are identical. When configured in the switch, the same as the upstream and downstream connections of the CM time synchronization unit, there are two functional modules in the time synchronization unit that the CM time synchronization unit does not have, and the functions of other identical functional modules are basically the same.

3.3. Architecture Design of Time Synchronization Scheme

The time synchronization system can provide timing through the network, and perform periodic time synchronization of distributed nodes according to actual needs. The introduction of time synchronization technology can make the connected nodes in the network achieve the same system time. In short, time synchronization is to use certain means to adjust the local clock in the network to complete the high-precision "matching table" process. In order to realize the time synchronization design, the time synchronization protocol should be defined first, and the content of the protocol should include the time recording format, hardware timestamp setting, time communication process and time correction algorithm. In the research of this subject, through the analysis of the clock network of the system, the architecture design of the time synchronization scheme is proposed, and the time synchronization system is introduced from the overall point of view.

In a distributed video system, assuming that there are n nodes (Pi), and they are interconnected through switches, the clock network of this system will be expressed as:

$$P = \{P_1, P_2, P_3, \ldots, P_{n-1}, P_n\} \tag{1}$$

Here Pi not only represents different terminal nodes, but also represents the local clock of each node. In a completely ideal time synchronization state, we believe that any two clocks Pi and Pj in the network should satisfy the following relationship:

$$C_i(t) - C_j(t) = 0 \tag{2}$$

Among them, t represents the time at a certain time, Ci(t) represents the time value of the local clock of the i node at the time t at a certain time.

4. Analysis and Research on Time Synchronization Method of Distributed System Considering Local Area Network

4.1. Time Base Selection

Table 1 shows the standard deviation of the station clock error relative to the GPST clock error. In order to eliminate the influence of the date boundary effect of the reference value of the clock offset on the evaluation results, the standard deviation of the single-day clock offset result relative to the reference value was calculated first, and then the average value of the standard deviation results of 5 days was calculated.

Table 1. Standard deviation (ns) of station clock error relative to GPST reference

	BRUX	NRCl	SPT0
IGS01	0.645	0.639	0.631
CLK10	1.775	1.764	1.776
CLK16	3.356	3.305	3.365
CLK53	0.283	0.274	0.275
CLK80	0.281	0.273	0.271
CLK93	1.276	1.299	1.273

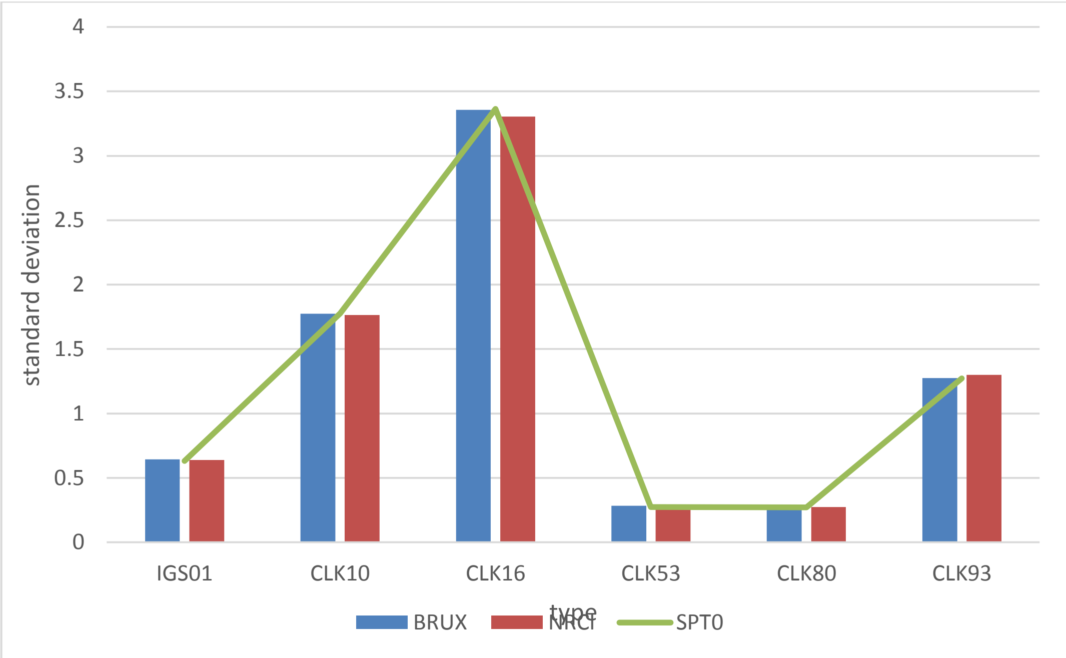

Figure 2. Comparison of standard deviation of station clock errors relative to GPST reference values

As shown in Figure 2, the standard deviation of the results of CLK53 and CLK80 is significantly better than that of other products, the standard deviation of the clock error of CLK80 is slightly smaller than that of CLK53, and the fluctuation of the clock error of CLK80 in the figure is smaller. In summary, this paper finally uses the CLK80 real-time orbital clock error product data stream for PPP time synchronization, and takes the time reference maintained by the CLK80 product as the time reference for PPP time synchronization.

4.2. Comparative Analysis of Three Groups of Experimental Test Results

In order to more intuitively show the phase deviation data distribution of the three groups of experimental results, the average standard deviation results of the PPP time synchronization phase deviation value series are shown in Table 2.

Table 2. Mean standard deviation results for sync phase difference value sequences

Time	Scheme 2	Scheme 3
0	0.13	0.12
1	0.15	0.14
2	0.2	0.18
3	0.24	0.22
4	0.25	0.22
5	0.27	0.23
6	0.28	0.24
7	0.31	0.25

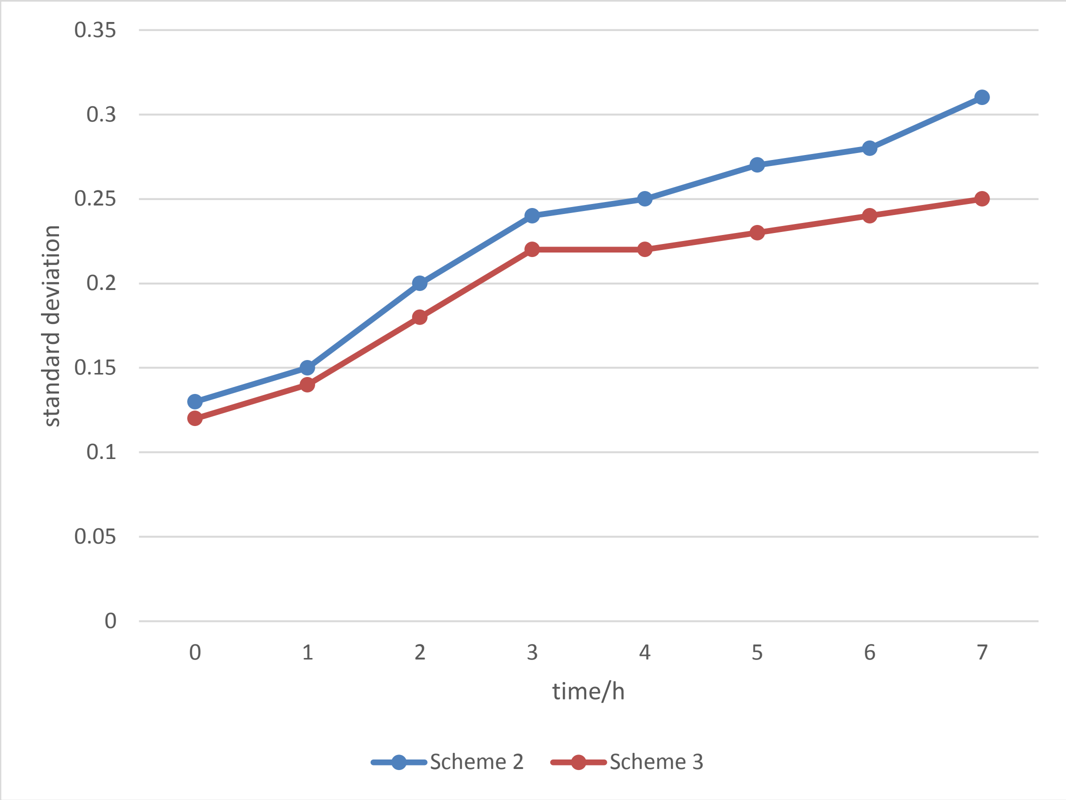

Figure 3. Comparison of mean standard deviation results for synchronized phase difference value sequences

As shown in Figure 3, based on the average standard deviation results, this paper continues to calculate the average root mean square error of the above phase difference data in different smoothing times, and evaluates the synchronization accuracy of the terminal in different durations. The root mean square errors of scheme two in the duration of 60min, 120min and 180min are 0.13, 0.15, and 0.2ns, respectively, and the root mean square errors of scheme three in the same duration are 0.12, 0.14, and 0.18ns, respectively. Therefore, first, the synchronization accuracy of the traditional GNSS time synchronization method in different durations is much lower than that of the PPP time synchronization method studied in this paper; second, the multi-mode GNSSPPP can significantly improve the reliability of time synchronization in practical engineering applications, the time synchronization accuracy is slightly higher than that of the single-system GPSPPP synchronization method.

5. Conclusion

This paper deeply analyzes the synchronization principle and summarizes the SDL flow chart of the three functional models of the AS6802 time synchronization protocol after power-on, which includes the running process of all possible situations after the initial power-on of each functional model. Secondly, in the synchronization process, the sending time point and the receiving time point of the synchronization frame interaction are monitored, and the response time interval is added to the newly defined reserved field of the response synchronization frame, so as to complete the transparency between the compression host and the synchronization host. The dynamic measurement of the clock value ensures the high accuracy of the transparent clock value, thereby improving the synchronization accuracy of each device in the system. Thirdly, the transparent transmission function of the synchronous client is designed to solve the problem of large-scale integration of the system, and on the premise of ensuring that no synchronization frames are lost during the transmission process, the transmission delay is minimized, thereby ensuring that the system is caused by synchronization. least. Since time synchronization can ensure that the system can maintain high-precision synchronization in complex application environments, it is of great practical significance to introduce time synchronization technology in distributed video display systems.

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Data Availability

Data sharing is not applicable to this article as no new data were created or analysed in this study.

Conflict of Interest

The author states that this article has no conflict of interest.

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