A NEW APPROACH TO TIME SYNC FOR TELEMETRY SYSTEM

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ABSTRACT

Instead of using a single data acquisition device, the distribute data acquisition system is broadly applied for onboard flight testing now. Therefore, the sync of data acquisition in varied devices and the real time data transportation have become the most important factors in a telemetry system. This paper presents a new approach to clock synchronization in a real time transportation network for a data acquisition system by using IRIG time code and an inner timer through network time recovery technique. This paper also illustrates how to keep the synchronization and continuity of a time tag used by each device through a precise estimation method for the difference of time resources and local inner timers.

KEY WORDS

Timing, Distribute Data Acquisition, Clock Synchronization, Full-synchronous

INTRODUCTION

There are two parts in the concept of time synchronization in a telemetry system, clock synchronization and absolute system time synchronization. The first refers to that both the clock frequency and the phase of the clock in all nodes are consistent. The other refers to that the count of year, month, day, hour, minute, second, millisecond and microsecond are the absolute same. In addition, the system clock should be consistent with an outer timing resource, such as IRIG time from a GPS.

In a traditional distributed system, the time tag of each data determines the time correlation of data acquired from different devices. The time correlation of data acquired in the same device relies on the sampling clock, while the control module often provides the sampling clock. This means that absolute system time synchronization should be achieved between the devices, and clock synchronization is required inside a device.

However, this time sync model is insufficient for a large-scale distributed data acquisition system. The correlation of data acquired from different devices will be lost if the sampling rate is high, as every device has its own clock, though the clock is updated by the system clock or an outer timing resource each minute. Therefore, the time sync is one of the most important factors for constructing a large-scale distributed data acquisition system, and both clock synchronization and absolute system time synchronization should be applied to the whole system.

IMPACT OF CLOCK CHARACTERISTICS

There are a lot of indices to describe the clock characteristics from different angles. Here we only focused on two of them, which can be used to analyze the impact of clock characteristics on the performance of a data acquisition system.

1) Frequency Accuracy

It is the relative variance of the actual frequency value from the ideal frequency, which is generally expressed by:

$$A = \frac{f_0 - f_x}{f_x}$$

Where f_0 is the frequency of nominal value, and f_x is the value of the actual frequency measured.

The frequency accuracy of a clock source cannot reach 1 in any circumstances; therefore, there must be a frequency variance within different clock sources. This variance will be accumulated into a phase difference between the clock sources over a period of time.

For example, if a system uses an OCXO (oven controlled crystal oscillators) with the frequency accuracy of 0.1PPM, which is the highest frequency stability that the internal clock source in an airborne data acquisition system can reach, the phase difference of the synchronization pulse used for sampling may reach 1ms or above after 3 hours of working without using any frequency tracking or compensation.

2) Maximum Time Interval Error (MTIE)

MTIE is the maximum phase change within a given window in a measurement cycle. It is a technical index used to constrain the phase change in peak-to-peak and frequency offset.

MTIE could be used to describe quantitatively the impact of frequency fluctuations (also called clock jitter), which are caused by the clock circuitry's internal or environmental factors in a period of time on the sampling synchronization variance between different channels under a same clock source.

SYNCHRONIZATION OF CLOCKS

There are four synchronization schemes of clock synchronization: full synchronous, pseudo-synchronous, quasi-synchronous, and asynchronous.

Full synchronization refers to that the entire system is synchronized to a unique reference clock to achieve the best synchronization accuracy. However, it is difficult to implement in a large-scale distributed network.

Pseudo-synchronization refers to that the system is composed of several parts, each of which has an independent reference clock (for this part) and all the internal corresponding clocks are synchronized by this clock. The clock frequency and nominal value of all the master clocks are consistent.

Quasi-synchronization refers to that every device or module in the system has an independent clock and all the clocks' frequencies and nominal values are the same.

Asynchronous refers to that there is no correlation in clock frequency and phase between any two nodes' clocks.

The most fundamental step of constructing a telemetry system is to choose which scheme out of the above four for the system. It depends on the sampling requirements for the performance of the system clock. In principle, it is required to determine the correlation between the parameters in time domain. As the clock determines the acquisition system's minimum resolution in the time domain, it could be a scale for a telemetry system as well. Therefore, nothing can be done if the clock performance indices do not meet the requirement of the system.

If the maximum sampling frequency of correlated parameters in a data acquisition system is F_{max}, the phase error of a sampling clock, introduced from frequency accuracy, should not exceed $0.25/F_{max}$, and MTIE in a period of $1/F_{max}$ should not exceed $0.25/F_{max}$ as well.

Therefore, a full-synchronous scheme must be adopted for each independent data acquisition subsystem in a telemetry system and all the main clocks of acquisition subsystems should be synchronized to an external reference clock, such as IRIG time resource from GPS.

For an independent large-scale distributed data acquisition system, it is impossible to provide a reference clock for every device in the system from the main clock source through an independent clock signal. It is better to synchronize the local clock of each device to a clock recovered from the transmission circuit.

The details of circuit clock recovery technique are not included in this paper, as it is quite mature. Here we focus on what regulation could be used to determine an appropriate clock recovery circuit. There are some standards for this in communication industry now, but some amendment must be made before they are adopted for a large-scale distributed telemetry system. For example, the power consumption of the circuit is large and the complexity degree is very high if the ITU-T G.813（Ref. 1） or ITU-T G8161/G8162 standard (Ref. 2, Ref. 3) is directly used in an airborne system. Currently, we are still working on establishing a standard, which is best for circuit clock recovery for large-scale distributed data acquisition system.

TIMING FOR A FULL SYNCHRONOUS SYSTEM

For a full-synchronous system, the timing protocol will be greatly simplified because the frequency accuracy of each node's clock is the same and the timing is more accurate as well.

A timing channel could be set up in a physical layer for a timing protocol, so that the impact of the data transmission delay caused by the transmission for the timing protocol could be avoided. As for establishing a timing protocol for a full-synchronous distributed system, the most convenient way will be simplifying from IEEE1588 protocol (Ref. 4), because IEEE1588 itself is a media independent timing protocol. The simplification and modification could be carried out from the following aspects:

1) Because a full-synchronous network itself has a master-slave characteristic in its system structure, the management communication in IEEE1588 protocol can be greatly simplified by implanting an outer timing receiver in the system main clock source.

2) Message response and delay estimation required for the PTP protocol could be completed by hardware. Then, the system factors influencing delay and fluctuation would be limited to the circuit clock fluctuations caused by external environmental factors. Thus, the timing accuracy could be further improved.

3) The node type could be simplified as the precision of the delay detection between nodes in a full-synchronous system is very high. Thus, only Ordinary Clock and Boundary Clock are needed to support in the system.

CONCLUSION

For a large-scale distributed data acquisition system, it is necessary to construct a full-synchronous network for communication inside the system. The clock recovered from the network circuit frequency could be used as the unique system clock, while a simplified IEEE1588 protocol can be applied to synchronize the local clock of each device with the system clock.

ACKNOWLEDGEMENT

A grateful acknowledgement to our colleague Mr. Chen, Yanping, whose advice on delay estimation and synchronization with an outer clock resource was very helpful.

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