

Performance analysis and simulation of RSI communication model for power line communication

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Abstract. The real-time of PROFIBUS field bus protocol is the key factor to evaluate its performance. Therefore, it is particularly important to study and calculate the real-time performance parameters. In view of this problem, based on the thorough analysis of the PROFIBUS bus access protocol, and the detailed analysis of the operation mechanism of the PROFIBUS-DP fieldbus access protocol, the communication performance test platform of the multi-master system of PROFIBUS-DP is designed, in order to derive and calculate various real-time performance indexes that affect the stability of bus communication and analyze the effect of multi-master token target cycle time on the queuing delay of high-priority packets, so as to provide practical application for field bus. Provide a certain theoretical reference. The real-time performance parameters such as packet information rate, transmission efficiency, average network utilization, network throughput, transmission delay and token cycle time are analyzed and calculated by the test platform. And we also calculate the relationship between the bus cycle time, number of master stations and packets, so as to make quantitative and qualitative analysis of the PROFIBUS-DP fieldbus real-time performance.

Key words. Fieldbus, Communication model, Efficiency, Application analysis, Bus access efficiency.

1. Introduction

PROFIBUS Fieldbus is an open fieldbus standard consisting of PROFIBUS-FMS, PROFIBUS-DP and PROFIBUS-PA. PROFIBUS-DP is mainly used in the manufacturing industries dominated by logic order control, and is a shop floor bus technology with an absolute market share [1–4]. At present, PROFIBUS bus is widely used in manufacturing automation, process industry automation, building automation, transportation and other fields of automation.

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In PROFIBUS field bus control system, real-time will directly affect the performance of the entire field bus system. The real-time nature of the PROFIBUS bus is mainly reflected in the efficiency of the bus access protocol (MAC). In recent years, many domestic and foreign scholars have systematically studied the real-time performance of PROFIBUS system. Foreign scholars have studied the operation period scheduling method and periodic characteristics of the PROFIBUS bus access protocol, while domestic scholars have studied the effect of token cycle time on the PROFIBUS periodicity [5–6]. Some scholars have also used the stochastic Petri net model or High priority packet queuing to delay model, studying the PROFIBUS system real-time performance [7–8]. The above research methods mainly discuss the effect of target rotation time on the real-time performance of the field bus. However, there are few researches on the influence of the parameters of the master and the slave on the system stability in the field bus system [9–13].

2. Profibus-DP

MAC layer protocol of Profibus-DP

2.1. Protocol Mechanism

PROFIBUS protocol structure makes ISO / OSI as a reference model, using the physical layer, data link layer, application layer, plus a user layer, thus greatly simplifying the protocol structure and improve data transmission efficiency, so as to adapt to the Real-time requirements of industrial automation. Data link layer defines the bus access protocol, including the structure description of the packet, security mechanism settings and services. PROFIBUS bus access protocol mainly includes three ways: transfer mode between the master token, master-slave mode between the master and slave, and hybrid configuration.

PROFIBUS-DP equipment is divided into the first type of master station, the second type of master and slave stations, the network structure can be single-master or multi-master structure, as shown in Figure 1. In the multi-master system, the master exchanges the token with each other. The set formed by the master is called Token Ring. The token is equivalent to a right, who holds the token, who uses the right to the bus, the one without the token has to wait, and the token rotates between the various primary sites [9–13]. When a master has a token, it can communicate with the slaves it controls, as well as with all masters; when the current master sends data or a specified amount of time, it sets the token as pre-set. The order is passed to the next master. Master-slave communication is always initiated by the master holding the token. The slave can only passively respond to the master's request but can not make a request to the master [14–15]. Since only one master has tokens at the same time, this avoids the disorder caused by the simultaneous issuance of commands by the master stations and solves the problem of network usage rights competition among nodes. In the meantime, the token cycle time of one week is prescribed in advance, which also ensures the real-time communication.

There are four ways for the transmission service provided by PROFIBUS [11]:

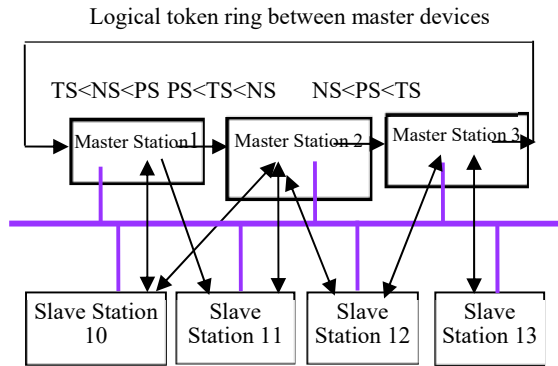


Fig. 1. PROFIBUS bus access protocol process

SDA (sending data to be confirmed), SDN (sending data no acknowledgment), SRD (sending and requesting data need to be answered), CSRD (sending loop and requesting data to be answered). PROFIBUS-DP can only use SRD and SDN services. These two service modes can ensure the real-time performance of PROFIBUS-DP to the greatest extent.

2.2. MAC layer operating mechanism analysis

PROFIBUS protocol packets have high and low priority, and also have their own send buffer and receive buffer. If there is a high-priority packet in the buffer, the master will process the high-priority packet first, and then process the low-priority packet as the case may be. Data access protocol message processing flow is shown in Figure 2.

When the field bus system is established, the data link layer first logically allocates the master to establish the token ring. During the operation of the system, the master station that has been powered off or damaged must be removed from the Token Ring. If a newly added Master station needs to add it to Token Ring. One of the major functions of the data link layer is to adjust the token target cycle time so as to ensure that each master station has sufficient time to accomplish the prescribed task. Token Actual Cycle Time TRR is the time from the time when the master obtains the token to regain the token interval length, and the token sets the cycle time to TTR. Token hold time $TTH = TTR - TRR$. The value of TTH is calculated at the start of each message cycle. Once this message cycle begins, the value of TTH is no longer changed. If the token hold time is greater than zero, it indicates that the token cycle is normal. The master with the token processes the high-priority packet first and then the low-priority packet within the allowable time, and if the token hold time is less than zero, The card cycle is delayed, the master with the token sends only one high-priority message, and immediately passes the token. This also shows that even in the worst case, high priority messages can be sent in real time. The prerequisite for low-priority packet transmission is that the token cycle time is greater than zero, and no high-priority packet needs to be sent

in the buffer.

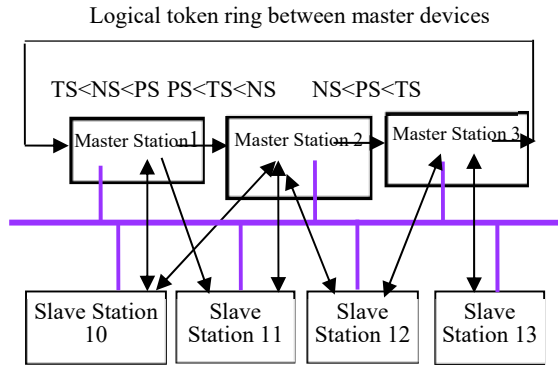


Fig. 2. PROFIBUS MAC layer message processing algorithm

3. Application and Examples

3.1. Hardware Configuration

PROFIBUS-DP multi-master field-bus communication performance test platform structure is as shown in Figure 3. In the field bus system network, CPU315-2DP is working as a class of master station, plug in the host computer with CP5611 field bus adapter is regarded as a second class master station, WAGO 750-833, BECKHOFF BK3120, HOLLIAS LM3107, SIEMENS ET200M, and ifm AC1305 are working as a slave station. Connect the network into a multi-master network structure via PROFIBUS cables and bus connectors.

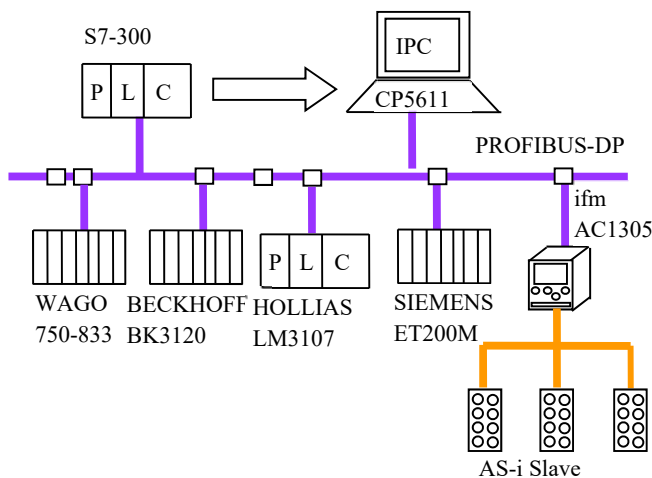


Fig. 3. The actual network configuration diagram

Test platform's specific hardware and software configuration is shown in Figure 4. PC is equipped with ProfiTrace fieldbus diagnostic software, from which you can view all the PROFIBUS-DP packets, parameter information, and parity or checksum error and other statistical information to complete the network configuration, on-site monitoring and analysis and diagnosis functions. Test platform makes ProfiCore hardware access to the PROFIBUS-DP system, together with dual-channel digital oscilloscope, you can trigger and display the signal waveform of each device to facilitate further analysis and diagnosis of the system. In addition, the ifm AC1305 is also plugged into the PROFIBUS-DP bus network and the oscilloscope can be used to test the phase modulation waveform of the AS-i network. Test platform can be used to simulate and simulate such as terminal resistance access is not correct, not using a standard cable, the transmission rate is too high and the distance is too long, unshielded or grounded, cable routing is not standardized, and the system configuration and parameter settings and other factors Influence the concrete degree of ROFIBUS-DP communication performance, so as to provide a certain theoretical reference for the actual engineering application of fieldbus control system.

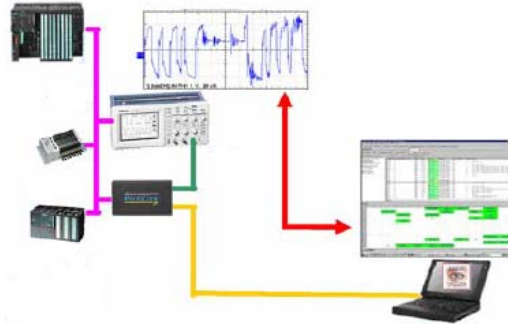


Fig. 4. PROFIBUS-DP communication performance test platform

4. Token could make the cycle time setting

Set the transmission rate of PROFIBUS-DP to 1.5 Mbit / s and the token target TTR parameter to 256, which artificially makes the token cycle time beyond a reasonable range. The ProfiTrace monitoring status display shown in Figure 5 shows that the communication on the fieldbus system was interrupted, the station was not ready and the slaves were still waiting for parameterization and configuration.

Analysis: After each master station of PROFIBUS-DP obtains the token, the TTR calculates the time it can hold the token, and then processes the packet within the specified token time. In order to be able to accomplish the task within the specified system reaction time, a wide range of situations should be considered to set a reasonable TTR value. The minimum token cycle time for a system depends on the number of masters and therefore on the token transfer cycle and the high priority packet transfer cycle time. In addition, the TTR shall include sufficient time margin for low priority messaging and for possible retransmission of messages. TTR

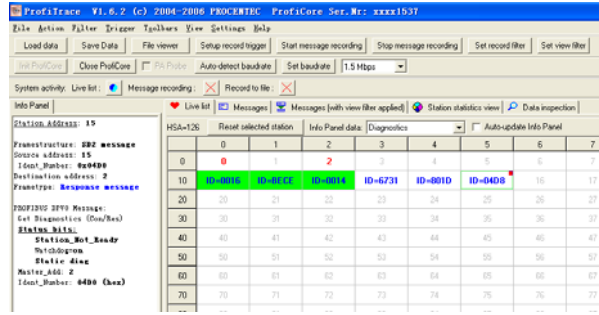


Fig. 5. TTR beyond the reasonable scope cause communication failure

choose a reasonable range, but not arbitrarily selected, otherwise it will lead to a part of the message will not be properly scheduled, resulting in greatly reducing the system reliability.

5. Real-time performance index analysis

1. Coding efficiency. It refers to the ratio of the effective data bits in the data packet and the entire data bits including the effective data bits, address bits and parity bits. PROFIBUS-DP physical layer use non-return to zero code, the data frame does not contain clock information, we have the other need to add start and stop bits, parity check code to ensure synchronization and transmission reliability, each 8-bit binary is transmitted in 11 bit order Therefore, the coding rate $ECE = 8/11 = 72.7\%$.

2. Transmission efficiency. Transmission efficiency is the ratio of the data length in the message to the total message length. Therefore, the service types of PROFIBUS-DP packets are different, the packet format is different, of course, the transmission efficiency is also different.

Table 1. The transmission efficiency of the message

Packet format data length			Data length	Transmission efficiency			
SD1	3	6	50%	SD2	Data_len	Data_len+6	Maximum 97.6%
SD3	3	6	50%				

3. Network Average Utilization. It refers to the ratio of the total data transmission time to the total time. PROFIBUS-DP uses token passing technology, if the TTR set is equal to about token average turnaround time, τ is the token delivery time, and the it can calculate the average network utilization of PROFIBUS-DP:

$$\bar{U} = \frac{TTR - \tau}{TTR} * 100\% \tag{1}$$

In a typical application, the average network utilization is 10% to prevent network

congestion.

Network Throughput. It refers to the average number of messages successfully sent per unit of time, that is

$$T_H = E_{CE} * \bar{U} * R = 72.7\% * \frac{T_{TR} - \tau}{T_{TR}} * R. \quad (2)$$

In the worst case, the token transfer time τ is negligible relative to the TTR. From equation (2), we can see that the network throughput of PROFIBUS-DP is about 1.09 Mbit / s when the transmission rate R is 1.5 Mbit / s.

Transmission delay. The delay time of PROFIBUS-DP high-priority packets is determined by the number of masters station and the length of the high-low priority packet. Suppose that the system has 5 masters, each of which has a size of 20 bytes and sends it every 10 ms. The size of the low-priority packet is 50 bytes and is sent every 100 ms.

The high priority packet size of PROFIBUS-DP on the bus transmission is $20 * 8 / ECE = 220$ bits, low priority packet size is $50 * 8 / ECE = 550$ bit / s, the transmission speed is 1.5Mbps, then there $T_{bit} = 0.67$ ns, $TTR = 5 * (33 + 220 + 550 * 0.1) + 110 = 1650$ Tbit.

Token Cycle Time. In a PROFIBUS multi-master system, the basic load is the bus load caused by media access control rather than by the messaging cycle, which is determined by the token cycle time TTR. The TTR consists of the token hold time TTH, the transmission delay time TTD, and the idle time TID1. Suppose $TTD = NTSD$, TSD is the time needed to send the token; the transmission time of the high-priority packet is THS, the number of the packets is M; the transmission time of the high-priority packet is TLS, the number of the packets is N, TTH into the available: (3)

$$TTP = [(M * 2048 + L * 3904N + 66) * N + 365]Tbit \quad (3)$$

In formula (3), the empirical value of TSD is 66 Tbit. Considering that the longest packet length of THS and TLS is 128 words and 244 words in the worst case, and the token maintenance time takes 365 Tbit, we can get:

$$TTP = [(M * 2048 + L * 3904N + 66) * N + 365]Tbit \quad (4)$$

Bus cycle time simulation

The relationship between the bus cycle time and the current number of active masters and the number of packets is shown in Figure 6. From the figure we can get the following conclusion: The relationship between the bus cycle time and the number of masters is linear. If the number of stations and the number of packets are unchanged, the bus cycle time is also approximately fixed, and the sending of high-priority packets Will be faster. If the number of packets increases, the bus cycle time also increases significantly. To ensure that all low-priority packets are sent, $N * (M + L)$ is the maximum number of packets that must be transmitted. The number of packets can affect the entire System's real-time performance.

The relationship between token cycle time and the number of packets; The relationship between token cycle time and the number of master

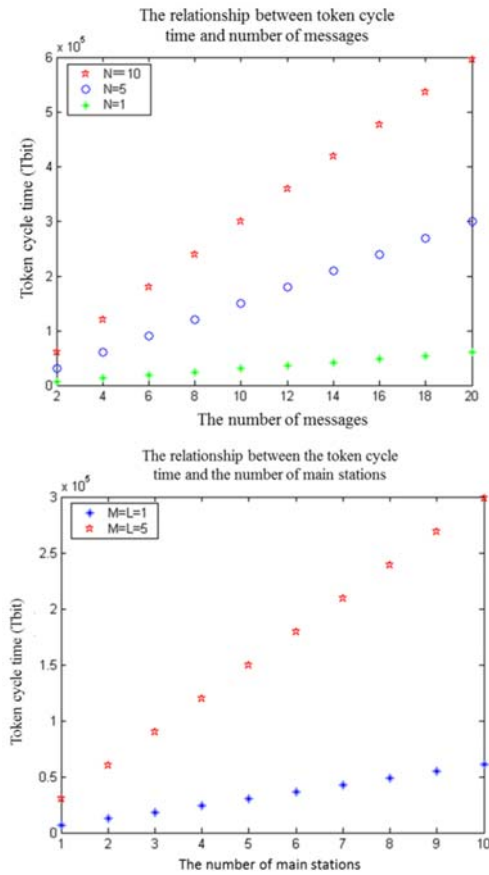


Fig. 6. The relationship between bus cycle time and master station number and message number

6. Conclusion

PROFIBUS-DP has high communication speed and simple coding rules, which is suitable for short-term industrial field devices for frequent periodic communication applications. In the field bus control system, this article has designed the PROFIBUS-DP communication performance test platform. Token cycle time and bus access efficiency, as a reference indicator of the overall network performance, can better reflect the real-time performance of the system. In order to meet the basic requirements of real-time communication, the token cycle time must be accurately calculated in order to reasonably set the token cycle time and improve the real-time performance of the fieldbus system.

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