

Research on the Construction Method of Real-time Scheduling Process and Bus Scheduling Table based on WorldFIP Fieldbus

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ABSTRACT

The WorldFIP protocol is the third part of the European standard EN-50150. It is particularly suitable for use in distributed computer control systems. WorldFIP provides data transfer services for variable exchange, and in order to cope with the real-time requirements of the system during variable transfer, the WorldFIP protocol provides communication services based on periodic and non-periodic identification exchanges, in which periodic exchanges have the highest priority and are scheduled cyclically according to the bus scheduling table at runtime. execution at runtime according to the bus scheduling table. Therefore, when constructing the scheduling table, the respective schedulability can be determined at pre-run time. For acyclic variable exchanges, the situation is different as they have a lower priority level and perform variable exchanges according to a first-come-first-served strategy. In this paper, from the perspective of variable exchange, we study the communication mode of the WorldFIP protocol, the process of cyclic and acyclic variable exchange, introduce a method for constructing bus scheduling tables based on microcycles and macrocycles, and finally give specific examples to prove the rationality of this method.

KEYWORDS

WorldFIP Protocol; Bus Scheduling Tables; The Process of Variable Exchange.

1. INTRODUCTION

In recent years, fieldbuses have become more and more widely used in the distributed industrial field due to their ease of management, low cost overhead and strong system robustness. In distributed communication, control applications, fieldbus is responsible for connecting field devices such as (sensors, actuators and controllers) and message transmission, and real-time is a must for industrial fieldbus, high real-time is to ensure that information can be transmitted in a timely manner to ensure the security.

WorldFIP is one of the most widely used fieldbus standard protocols and is part 3 of the European standard EN50170. WorldFIP provides two types of data transfer services: variable transfer and messaging. Real-time communication services reside in the Variable Transmission type, while Telegram Transmission is used to support Manufacturing Messaging Services (MMS) and is beyond the scope of this paper. The variable switching service mainly consists of cyclic and acyclic variable switching and is known as MPS service at the application layer. Cyclic variable exchanges are scanned and transmitted by the bus arbitration table according to the bus scheduling table and have the highest priority. Non-periodic variable switching, on the other hand, is carried out by dynamic requests through interrogation frames in the spare time of periodic variable switching.

This paper researches and outlines the cyclic and acyclic variable transmission process, proposes a method and program flowchart to build a bus scheduling table, gives specific examples, and obtains the corresponding bus scheduling table. The chapters of this paper are distributed as follows: the second part briefly outlines the WorldFIP fieldbus protocol; the third part analyzes the WorldFIP communication model, the process of transferring cyclic and acyclic variables as well as the structure and construction method of the bus scheduling table.

2. BASIC ANALYSIS OF WORLDFIP FIELDBUS PROTOCOLS

The WorldFIP fieldbus standard is a complete protocol which is part 3 of the European standard EN50170, a fieldbus technology developed by the WorldFIP organization with French companies as main members. The system constituted by WorldFIP is usually categorized into three levels, i.e. process level, control level and monitoring level. Meanwhile, corresponding to the ISO/OSI seven-layer model, the WorldFIP protocol hierarchy adopts three of these layers, i.e., the physical layer, the data link layer and the application layer, as shown in Figure 1.

(1)The physical layer is based on the IEC 1158-2 standard and is used to realize the connection between process-level physical devices and the bus, to provide mechanical and electrical interfaces for the connection of field devices to the notification medium, and to provide standardized physical signals for sending or receiving to or from the bus by fieldbus devices.

(2)The data link layer is located between the physical layer and the application layer, providing services for the application layer to access the bus media, bus communication in the link activity scheduling, data reception and sending, activity state detection, response, link time synchronization between the devices on the bus, are realized through the data link layer. The data link layer can provide two types of data transfer services: variable exchange and message transfer. In this paper, we will only discuss variable switching, as it is the basis of real-time network performance, and will not describe messaging.

(3)The application layer enables access to variables from each WorldFIP station and synchronization of user applications within each station. It can be divided into two groups: ABAS (Bus Arbiter Application Service), and MPS (Realization Periodic/Unperiodic Service).

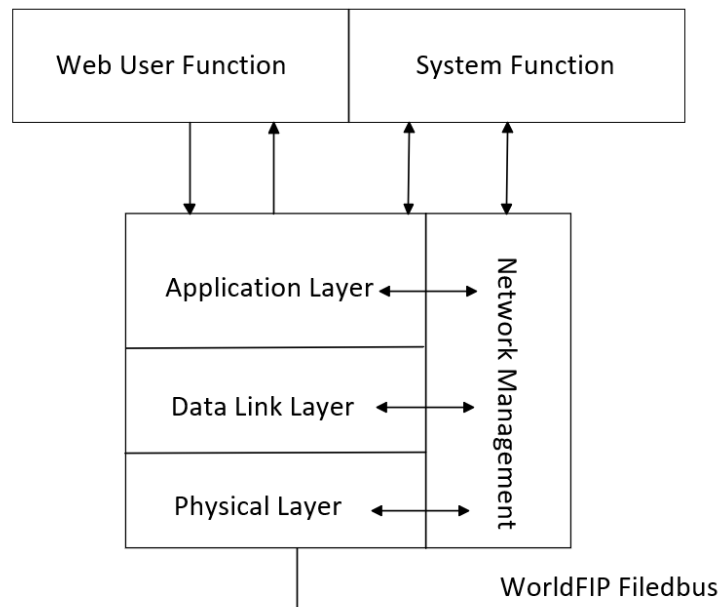


Figure 1. WorldFIP Protocol Hierarchy

3. RESEARCH ON REAL-TIME SCHEDULING MECHANISM OF WORLDVIP FIELDBUS

All communication scheduling activities on a WorldVIP fieldbus network are managed by the Bus Arbiter (BA). The BA is also known as the Link Activity Scheduler (LAS), which holds the link activity scheduling tables for all devices on the bus, and is in charge of the operation of the bus by each device on the bus segment. There is only one LAS in operation on each bus segment at any given time.

WorldVIP fieldbus communication scheduling activities can be divided into two categories: scheduled communication and non-scheduled communication. Scheduled communication is the communication activity initiated by the LAS periodically and sequentially according to a predefined scheduling timetable; non-scheduled communication is the communication activity that sends information by responding to the problem frames sent by the LAS at a time other than the predefined scheduling timetable.

3.1. Communication Mode

A WorldVIP network consists of multiple stations that have bus arbitration and producer/user functions, and any station connected to the WorldVIP network is capable of performing either or both of these functions, but only one station on the network is capable of performing effective bus arbitration at any given moment. The basic structure of a WorldVIP network is shown in Figure 2:

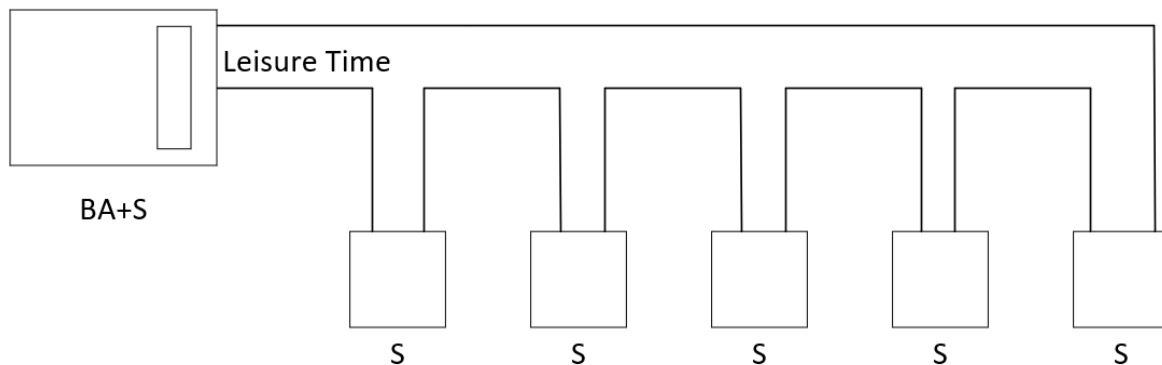


Figure 2. WorldVIP Network Infrastructure

In the Figure 2, S denotes the WorldVIP base station and BA denotes the bus arbiter.

3.2. WorldVIP's Real-time Scheduling Process

3.2.1. Periodic Scheduling of Variables

Due to the attributes of diversity and real-time scheduling of tasks in industrial processes, WorldVIP clearly distinguishes between cyclic and acyclic tasks and arranges different policies for these two types of tasks. WorldVIP adopts a centralized media control policy and manages real-time communication according to the Producer/Distributor/Consumer (PDC) model. PDC) model to manage real-time communication for periodic tasks.

In the PDC model, it is stipulated that each process variable has one and only one producer but can have multiple consumers. Any node that provides a process variable must provide the producer function and be able to transfer that process variable to the node where its consumer is located, coordinated by an arbiter. To work, first the arbiter grants access to the producer bus, and after getting access, the producer broadcasts the task that needs to be sent to the entire segment, and all the nodes in that segment receive that task. After receiving the task, only if the task is required by the consumers

on a node, this node retains this task, on the contrary, the other nodes discard this task, the specific process is as follows:

During the cycle scheduling phase, the LAS broadcasts the name of the identifier on the network bus using the problem frame ID_DAT in sequence according to the sorted contents of each entry in the bus scheduling table, and the problem is received at the data link layer of all device stations simultaneously connected to the bus, one and only one of which is recognized as a producer (P) of the variable identified by the identifier, and one or more of the other stations are recognized as consumers (C) of the variable identified by the identifier. After the LAS broadcasts the specified identifier using the problem frame ID_DAT, the LAS begins to wait one cycle for the appearance of the variable identifier answer frame RP_DAT on the network bus, as shown in the Figure 3:

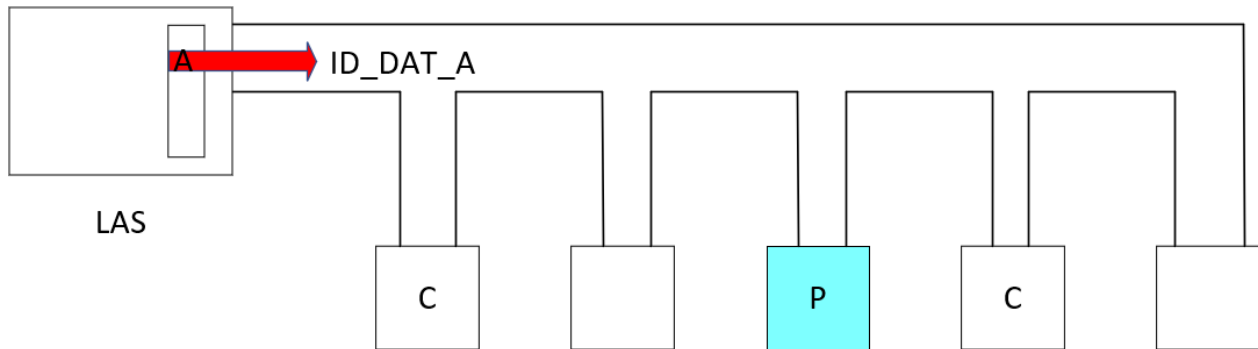


Figure 3. ID_DAT Frame Transfer

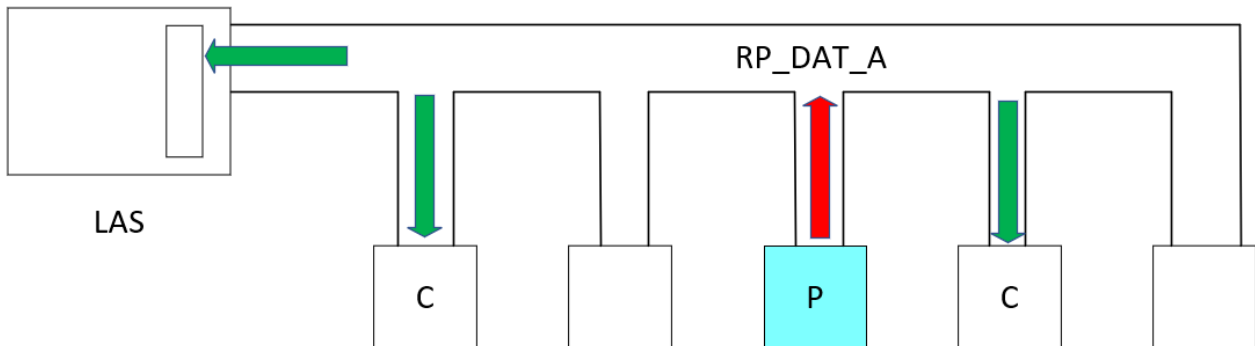


Figure 4. RP_DAT Frame Transfer

The producer of the variable then broadcasts the data for the variable identified by the identifier in the answer frame RP_DAT while all using stations get that data, and then the LAS proceeds to look for the next identifier in the bus scheduling table and repeats the completion of the question-and-answer cycle as described above, as shown in Figure 4.

3.2.2. Acyclic Scheduling of Variables

In distributed bus applications, it is not necessary to include all variables in the bus scheduling table of the bus arbiter, and some variables may be exchanged only occasionally. For the above application scenarios, WorldFIP provides an acyclic scheduling mechanism for variables in three phases:

Phase 1:

In the cyclic scheduling phase, the LAS broadcasts a question ID_DAT_A for identifier A. The producer of variable A answers using the corresponding variable and sets up an off-cycle request (RQ)

in the control field of the answer frame, i.e., using the frame RP_DAT_RQ. The scheduling of variables in the off-cycle phase can be categorized into two priorities: urgent and normal. There are two queues in the LAS for storing the requests issued by the Variable identifiers are stored in two queues in the LAS, one for each priority level. When the answer frame RP_DAT_RQ is received, the LAS stores the next identifier A in the request variable scheduling queue according to the priority level of the request, and so on, at the end of the cyclic scheduling and into the off-cycle scheduling phase, the LAS has collected all the variable identifiers that need to be exchanged in the off-cycle phase. The communication process in this phase is shown in Figure 5 and Figure 6.

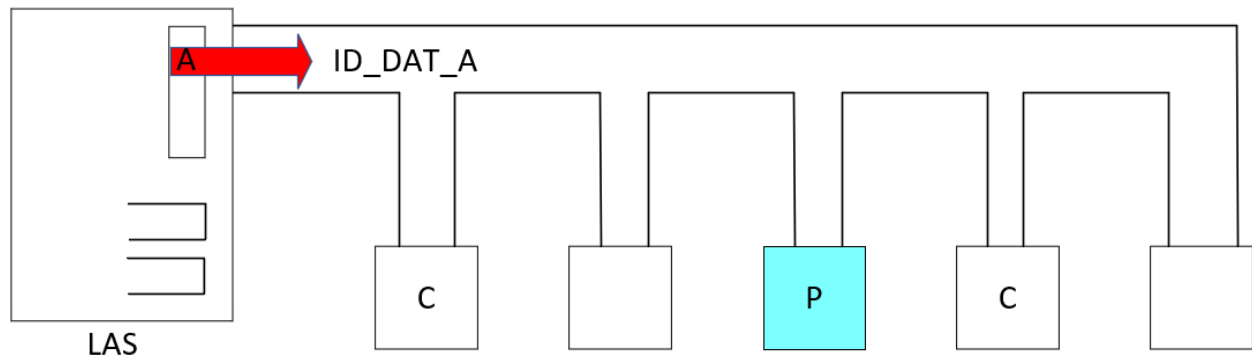


Figure 5. ID_DAT_A Frame Transfer

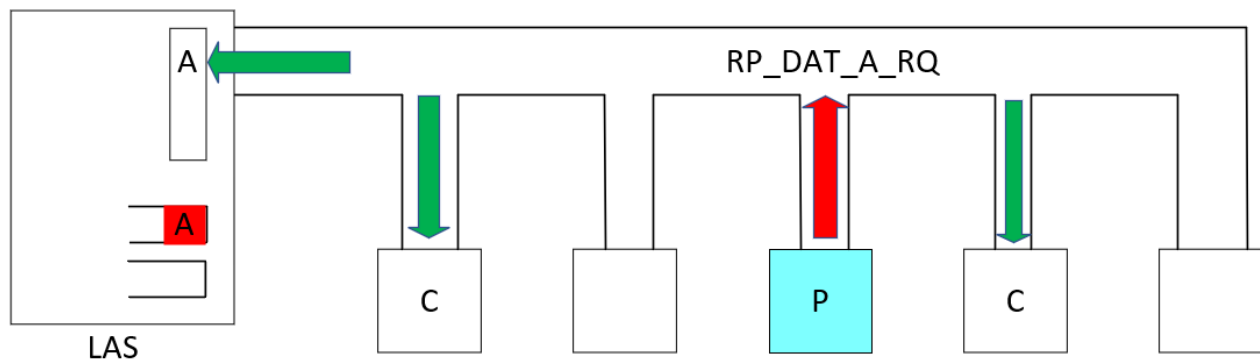


Figure 6. RP_DAT_RQ Frame Transfer

Phase 2:

In the off-cycle scheduling phase, the LAS takes the first identifier (set to A) from the "urgent" off-cycle transfer request according to the priority order of precedence, and if the urgent request queue is empty, then it takes the first identifier from the "normal" request queue (also set to A), then uses an identification request frame ID_RQ to ask the producer of the variable identified by identifier A to send its off-cycle variable exchange request, sets the waiting cycle deadline, and enters the waiting cycle. If the emergency request queue is empty, the first identifier is taken from the "normal" request queue (also set to A), and an identification request frame ID_RQ is used to ask the producer of the variable identified by identifier A to send its request for an exchange of the off-cycle variable, set the wait cycle cutoff, and enter the wait cycle waiting for an answer frame. the producer of the variable identified by A answers an RP_RQ frame containing a list of the identifiers of the variables for which data is to be transferred, which is processed by the LAS into another queue. another queue. The LAS processes this list of identifiers and deposits it in another queue, as shown in Figures 7 and 8:

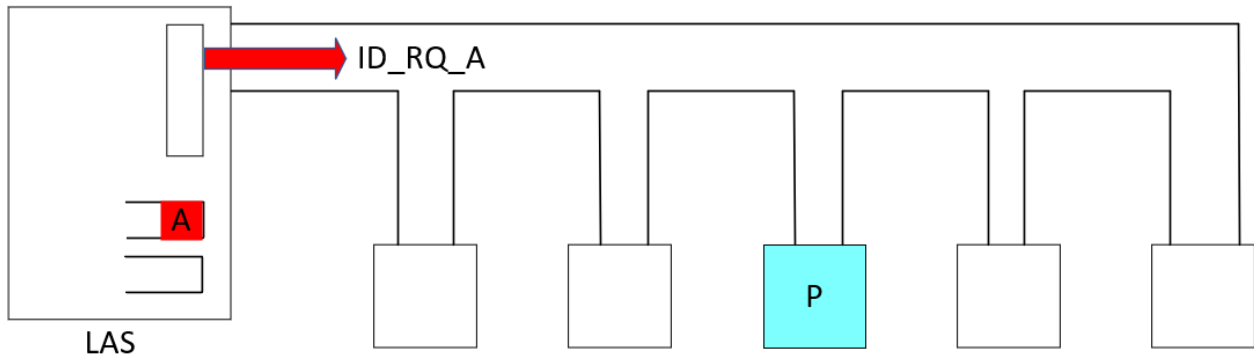


Figure 7. ID_RQ Frame Transfer

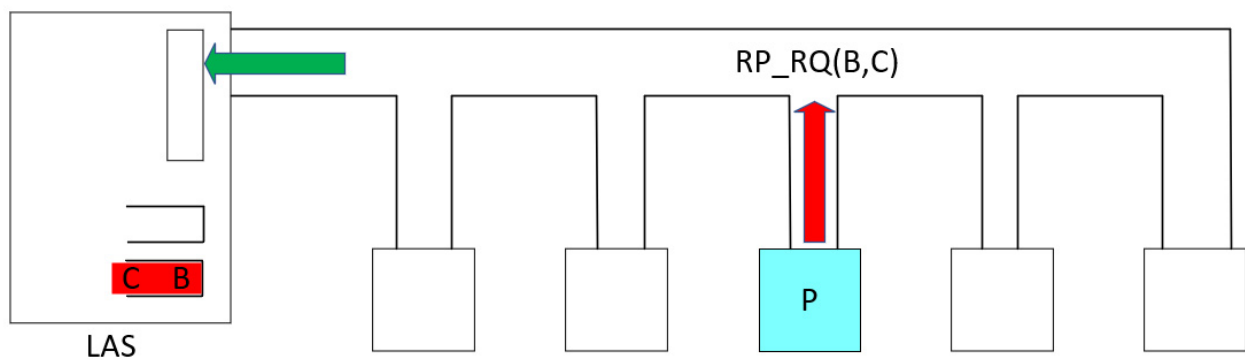


Figure 8. RP_RQ Frame Transfer

Phase 3:

In the second phase, the LAS enters the third phase after noting the identifier of the variable for which data needs to be transmitted and immediately starts sending the problem frame for the first identifier noted. The problem frames are sent faster or slower depending on the amount of cyclic information and the number of requests. The final phase of the non-cyclic variable exchange in the third phase occurs in the non-cyclic window and consists of a series of requests for non-cyclic transmissions that exist in the queue of the LAS. Depending on the time available within the basic cycle in this information traffic, the LAS fills one or more requests. The LAS uses the same transport mechanism in this phase as described above: broadcasting an identifier, generated by a single producer, that is received and used by multiple consumers. As shown in Figure 9:

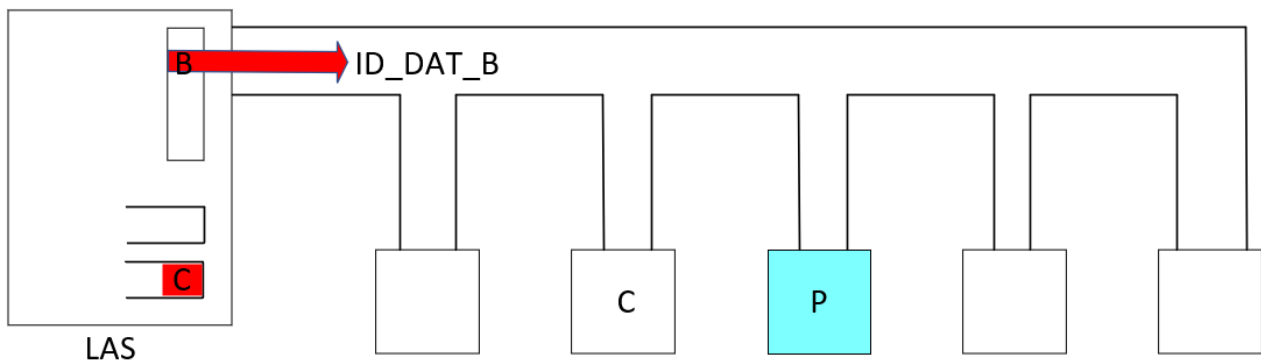


Figure 9. ID_DAT_B Frame Transfer

3.3. Bus Scheduling Table Creation

3.3.1. Structure of the Bus Scheduling Table

Network variable transfers and scans at the bus are controlled by the scheduling table. The role of the bus scheduling table is to ensure that the specified cycle variables are scanned at the proper time. The scheduling table structure is the basis for constructing the bus scheduling table, and it is also closely related to the system storage such as memory. The scheduling table structure mainly involves two parameters: the basic cycle (also known as microcycle), and macrocycle. Microcycle is the smallest scheduling unit in the bus scheduling table; macrocycle is the smallest interval in which all cycle information is repeated according to a certain law, usually composed of several microcycles.

3.3.2. Methods for Building Bus Scheduling Tables

Based on the definitions of microcycles and macrocycles, a basic method for constructing schedules can be obtained: the least common multiple (LCM)/highest common factor (HCF) method. That is, the microcycle is equal to the greatest common factor of cycles in all cycle information, and the macrocycle is the least common multiple of all cycle information. The basic relationship is:

$$\text{Macrocycle} = \text{Microcycle} \times \text{Number of basic cycles} \quad (1)$$

Expressing the microcycle in terms of Microcycle and the macrocycle in terms of Macrocycle, we have the following equation:

$$\text{Microcycle} = \text{HCF}(A, B, C \dots) \quad (2)$$

$$\text{Macrocycle} = \text{LCM}(A, B, C \dots) \quad (3)$$

In the formula: $\text{HCF}(A, B, C \dots)$ denotes the greatest common divisor of the refresh cycles of A,B,C..., $\text{LCM}(A, B, C \dots)$ denotes the least common multiple of the refresh cycles of A,B,C.

For example, there are 6 cycles of information to be transmitted on a bus network with the parameters shown in the Table 1 below:

Table 1. Periodic Information Parameters

Periodic Information	A	B	C	D	E	F
Periodicity	1	2	3	4	5	6
Execution Time	0.2	0.3	0.3	0.3	0.3	0.4

Then, for the cycle information in the above Table 1, it can be determined that its microcycle is 1 and macrocycle is 12. i.e., the minimum scheduling unit of the real-time scheduling table is 1 (time unit); and the scanning interval of each cycle is 12 (time unit).

Assuming that its 6 cycle messages are independent of each other, the worst case is taken into account, i.e., they arrive at their respective buffers waiting to be sent at the same time, which is the critical moment. The program flowchart for establishing the bus scheduling table is shown in Figure 10:

where i denotes the i th microcycle and $\text{Sum}[i]$ denotes the sum of the cycle messages owned in the 1st microcycle, i.e., the sum of the execution time of the cycle messages that need to be sent in this microcycle, j denotes the set of macrocycle messages, C_j and T_j denote the execution time and period of cycle message j , respectively, $P[j,i]=1$ means that the periodic message j can be sent at the i th microcycle, and $P[j,i]=0$ means that the periodic message j cannot be sent at the i th microcycle. Delay

then denotes the number of microcycles for which the cycle information j is delayed in a particular scheduling.

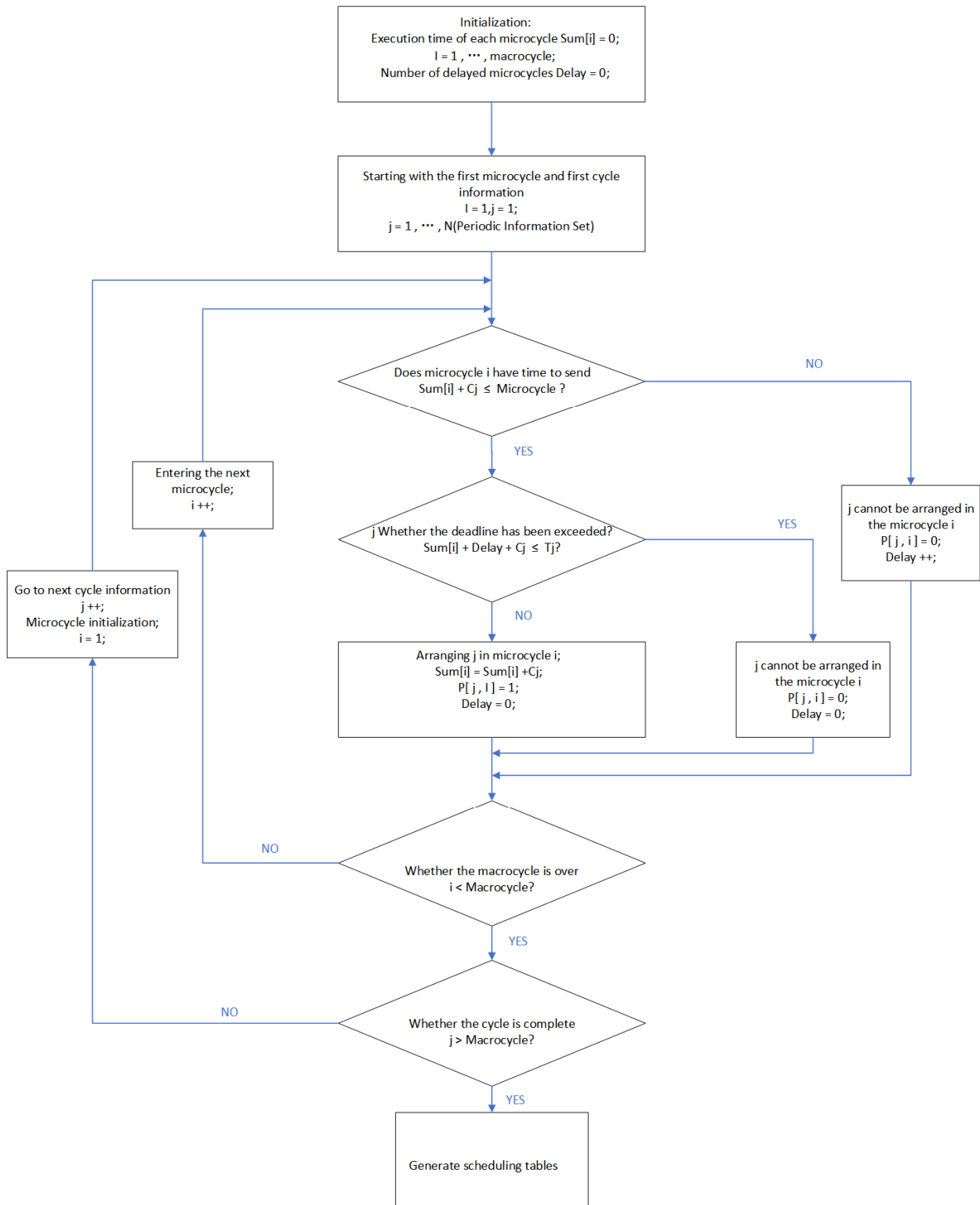


Figure 10. Program Flow Chart

Based on the method shown in Figure 10, a bus scheduling table is created for the cycle information in Table 1 and the results obtained are shown in Table 2:

Table 2. Real-time Scheduling Table For Instances

Microcycle/ Periodic information	1	2	3	4	5	6	7	8	9	10	11	12
A	1	1	1	1	1	1	1	1	1	1	1	1
B	1	0	1	0	1	0	1	0	1	0	1	0
C	1	0	1	0	1	0	1	0	1	0	1	0
D	0	1	0	1	0	0	0	1	0	1	0	0
E	0	1	0	0	0	1	0	0	0	1	0	0
F	0	0	0	1	0	0	0	1	0	0	0	0

4. SUMMARY

In this paper, on the basis of a brief overview of the WorldFIP fieldbus protocol hierarchy, we analyze and study the communication mode, cyclic and acyclic real-time scheduling process of WorldFIP fieldbus from the point of view of variable exchanges, and according to the concepts of microcycle and macrocycle, we give a basic method to establish a bus scheduling table, and at the same time, we give a specific example to construct a program flow chart of the bus scheduling table. The bus scheduling table of the example is obtained.

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