AVIONICS DATA COMMUNICATION NETWORK MODELING AND ANALYSING

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Abstract

In this thesis, the structure and dynamics of avionics system have been described and analysis using the theory of Petri nets. The purpose of this work is two fold. First, we attempt to find a way that the engineering theory can be applied to design, verify and assess avionic systems. Next, we plan to develop proper tools to demonstrate our application.

In the first instance the conceptions of Petri nets are introduced and the conventions are united. After the structure and principles of the system were summarized the objective to be optimized and the common features of the elements of the avionics system are then provided. Further the modeling method in detail and the Petri nets mathematic model of avionics is built. Finally, the optimized mathematical method of data transmitting provided.

In order to support the model building, the software is programmed. The results have been proved to be promising, in this technique can improve the overall performance of the illustrated system effectively.

1 Introduction

Developing of aeromechanics is depended on many new technological advances. Near twenty years, information engineering, computer technology, control technique and electronics progressed far enough. In these new technologies, it has large potential of advance plane operational capacity.[2][3] Avionics technologies emerge, as the times require.

It is one new-fashioned branch of technology that avionics technology. In fact, it is a sort of realize information collection, dispose, distribute and canned computer network. Also, it is one at harsh space constraint, rigid

authenticity requirement and specific real time peg，versus dense aviation electron subsystem and slather electron product gather proceed convergence of evidence and function integrative technology. So it has very impotent action, the multiplex bus assume network interface.[3][4][5]

Avionics system development usually broke into：System requirement, system definition, system design carry into execution, test and function for 6 ordered phases. How demonstration and appraise these engineering effort if it is rationality, validity and integrality of inter coordination，and thereof performance index whether meet the challenge the question is perforation to wholly development process issue as well of the costliness, intricacy even require harsh system development process，how general develop require and/or correlative definition grown system development.[3][5]

To solve these issue usually have two way at least. It is be up of many times specialist review, trial-manufacture differ physic prototype，with the help of special test equipment gradually implement system require that early way. Now popular way is that is made the most of figure technique of simulation to reduce prototype，only in step of early and detailing design, the document need specialist review，be on the special large-scale integrated emulation platform upper exploitation each phase and different kinds of functional simulation software， via emulation gradually syntheses each subsystem engineering prototype ，ultimately meet the system requirement.[2][3]

It was feasible，but，presence deficiency that

upwards am phi-way at engineering practice. Firstly，experts review sometimes suffer confine of individual knowledge extent and technicality familiar degree. Secondly， the exploitation prototype and different kinds of emulation platform and homologous simulation software so as to triturating not only cost high， but time cycle is too long as well.[3][7][8][11]

My work in this article is aim at avionics network system with "MIL-STD-1553 B" data transfer bus, to analyses and research，then establish systemic model that is the mathematical express，in turn raises pairing model proceed simulation run and the system analyses. To try through system model research，by way of system simulation and experimental supplementary means，supply worthy way and tools with system design, test and demonstration. To find the technology way witch is cost smallness, cycle short and plenitude mathematical theory. [6][10][13]

2 Theory tool and research technique

In many region，a sort of object or phenomenal research，it 's not that directly but through its model. One object 'model is its mathematical express. Such expression reserved the importance characteristic of structure and dynamic aspect. Through the model simulation and analysis, keep out of immediate observation by simulative object. As far as possible avoid hazard, cost and inconvenience, such as nuclear burst, chronometer, creature, society as well as avionics system and so on. [1][2][12]

Majority problem of modeling with to mathematics, many physical phenomenon and significance be able to use mathematics as expression. It is one discrete event object that whereas avionics network system. Its important characteristic is informational disposing and flowing. [4][5]

2.1 Theory tool select

It is precondition that select proper theory instrument to analyses and research avionics network system in this thesis. Theory implemental select should conform to several principle：

. It is accuracy，overcome the ambiguity of the description of human language.

. Facilitate to auto verify the validity of systemic description.

. Facilitate to utilize modeling proceed system simulation.

. Avail to adopt automated tool establish avionics development of system environment for.

Be able to serve for avionics data transmission network systemic engineering theory and way have got multiform. General broke into：transfer model，include different kinds of finite state （automatism）tools, different kinds of petri net and/or variable structure sequence tools； algebraic model，as communication calculus system； mixture model，as programming languages combination with model. By aggregate analysis, predicative ability, long-term potential and upper principle, The PETRI NET is considered as the ideal mathematical tool of expression avionics data transmission network systemic structure and dynamic characteristics.

Taking a wide view, PETRI NET develop and evaluative mechanism，could distinctly pick up，theory implemental select，must set a high value on thereof integrality for. That is to say，must select rounded system info for. As far as possible to keep out of appending or spreading for concrete problem convenience. If must to do so，with ought proceed rigid definition and deduce for expression and analytic overall process. Because，our aim to select tools of description system (namely modeling), is that through the model analyses, get some characteristic of system. Thus， destruction analysis methodological append and spread it must be inadvisable that. In this article, selecting rounded CPN system info by way of avionics data transmission network analyses and investing at theory tools. [1][2][9][13]

2.2 Research technique

This article use PETRI NET by way of avionics data transmission network analytic theory tools. Adopt three steps and research technique.

（1）On the foundation of study and grip PETRI

NET, my work is that to analyses, study and generalize the avionics with MIL _ STD _ 1553B for network system， then abstract transfer ， dispose and distribute information commonness. It is to construct the currency content PETRI NET model for avionics data transmission network system.

（2）Using petri net simulation，do with petri net by way of avionics system digital simulation 'information flowing load body. Be used to track, observe had a connection with count relate technical criteria up. It is as engineering practice routine design constructing systemic PETRI NET models that such approach. Avail petri net model function to realize track and viewing system information flowing instance. Combine be in action statistics relevant data， as on transmission time cost and transmission quantity. By these statistical data, can get some important technical criteria of.

（3）On the set model foundation upper，enter into some protocol. The system target is optimized; according to transmission time most province and load leveling.

Foregoing research need transmit between the system and petri net model time after time. Every time transcriptional intricacy degree and workload be sizable, to exploit modeling, operational analysis and optimize software，so as to avail petri net go with a swing of avionics system analyses and research. In this theses, with the avionics as an instance, using the modeling software establish the PETRI NET of the instance. Running and analyses the PETRI NET model, got system technical characteristics indices and optimized the bus timing information flow.

3 PETRI NET modeling approach research of the avionics data transmission network

3.1 Generalize & abstraction of the avionics data transmission network

In order to use PETRI NET description data processing and transmitting commonness for differ type avionics network system. Abstraction and generalize of the object is necessary， combine turn in some elementary hypotheses.

3.1.1 Single stage topology， oneness bus controller

Topology of avionics data transmission network system broke into single stage and multistage bus structure form. Multilevel bus topology broke into peer entity and hierarchy type. Yet，in essence of data transfer， any stair or any thickness in multilevel all have even only one terminal by way of local bus controller. Whereas, one local bus controller is a remote terminal of super strata bus or peer entity bus certainly. On the fact of that，any bus type avionics network system all is make up of one or more of single stage bus system witch possess oneness bus controller.

At control mode of variety of dynamic bus, the kernel question is main control power, that is to say the token transmission path and mode. Each terminal despoils token aim to precede high duty data transfer. Yet，at any one time，per local bus system none but one bus controller held token. Which is to say， none but one bus controller be in action.

Wherefore，when use PETRI NET modeling， have got as follows suppose.

[Suppose 1]The topology form of the avionics network system as figure1, It is single stage bus structure, only one bus controller (BC) and several remote terminal (RT).

3.1.2 Task determination character

Mission executive by avionics network system could resolve into four states: prepare, navigation, surveillance and attack. Each state again could more broke into different son state. It is predetermined, that the function or mission of each state and son state want to finish. It is bounded and could be prior estimate，that such mission foresee ability decided requirement of system serve time, required storage capacity and every other implicit shared.[3][4][5]

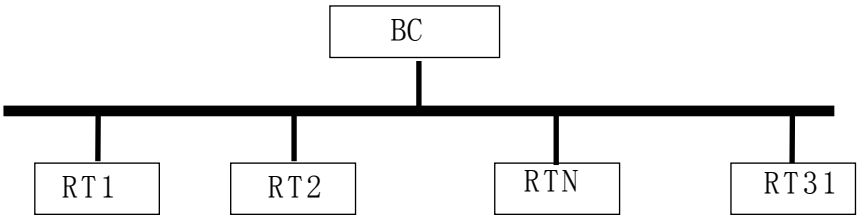

Figure1

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［**Suppose2**］It is bounded that the requirement of each terminal in avionics network system for time, storage capacity and so on. The data transfer requirement is prescient, resolvable and determinate.

3.1.3 The periodicity of the mission

When avionics network system design, according as mission foresee ability and real-time requirement, the sped of informational transmission in accordance with rate of change. In a great measure import and export course row become major cycle and minor cycle realize data transfer. periodic event insert to seasonal transmission queue by way of status word application. [7][8][12][13]

［**Suppose3**］Data transfer is in accordance with predetermined cycle in avionics data transmission network system.

3.1.4 Terminal

［**Suppose4**］Remote terminal（RT）on avionics data transmission network contain input system, export system and data processing unit. The bus controller（BC）not only contain the function unit of RT，but also has one command manager.

Above fictitious foundation， the data stream of avionics transmission network generalize describe as table 1.

Table1

purpose / Source	BC	RT1	RT2	…	RTj	…
BC		x01kz	x02kz		x0jkz	
RT1	x10kz		x12kz		x1jkz	
RT2	x21kz	x21kz			x2jkz	
…						
RTi	xi0kz	xi1kz	xi2kz			
…						

In the table: x--Express parametric title or message numbering. i--Express source terminal address number. At avionics data transmission network be system

with MIL _ STD _ 1553B as the bus, the span of "i" being 0，1，…,30.

j--Express purpose terminal address serial number，the span be like "i".

k--Express maximum-delay Generally, the multiple is risen by 2，for instance minimum delay hour for 20ms，those rest information 'maximum-delay time-value general derive as 40ms, 80ms, 160ms,…. Hour of parameter or information. Do so, not only facilitate analyses AND discuss， but possess actual application value as well thus.

z--Express information 'length or parametric word count.

3.2 Principle for establishing parallelism relation

Here the basic idea being of the petri net modeling is that， With place stand for event genetic condition; With transition stand for event; Or remark that with place representation state ， with transition representation change of state. Arc stand for event compartment 'relation； Token is flowing element that brings change of state.

3.2.1 Transition usage

With transition express two type of event. With transition name, icon and guard function describe a event， Only a matter of in order to constitute visualized PETRI NET chart，enhance the readability. Transition name be used to distinguish event what is affiliated with and sort. It is constraint of event that whereas guard function.

3.2.2 Positional usage

The place is used to express reside buffer of network system information（data, command or address）， As storage, register and so on. Each place has only title.

3.2.3 The usage of the arc

The relevance of event and condition of compartment are specified with arc. At CPN theory，arc has its expression function，could indicate token flowing quantity and condition restraint. With functional directed arc get position and transition join to form CPN chart. That is a sort of mathematical excretion of describes system.

3.2.4 Token usage

It is like as two peas that token reside &flow of PETRI NET and information flow & memory of avionics. It is objective that，on establishing model， with token to express information dynamic characteristics. In order to express parameter and command，ought bring token carry manifold information. In this way，so as to token and corresponding parameter or command parallelism. Parameter or command memory and carry，at PETRI NET respond to token reside and flow. In this way, using the token remove to realize avionics network system information flow dynamic emulation, analyses and research.

3.3 PETRI NET express means of net elementary of avionics network system.

With PETRI NET viewpoint, avionics network system centrally incarnate for two primitive concept： Event and condition. The event is activity occur by system. These behavioral occur by state of a system came control. Whereas, these state could with a set of condition came describe. Condition is the logical description of the system state. Occur of event may demand several condition also come into existence. This is the prior condition of the event. The occurring of event likely to do arrangement of condition for every other event occurs. Such conditions are reputed as the conditional subsequent of the event. In this section, PETRI NET expression of net element in avionics network system is based upon such idea.

3.3.1 PETRI NET model of transmit-receive mechanism in data terminal

In the avionics network system，it has two type terminal: BC and RT. Their key target is that data take over and dispatch. Wherefore，as the suppose， this article nothing but describe transceiver system. One typical terminal working process is constituted by a series of event and condition for event.

3.3.1.1 Receive mechanism of terminal

Receiver system inclusive event and condition for:

○Event

1．Information take over: tiB

○Condition

a．BC command terminal to take over: R

b．Existing data at bus: Pb2

c．Receive complete

Hereinto: It is receive event generation prior condition that a and b. It is receive event generation conditional subsequent that c.

3.3.1.2 Sending mechanism of terminal

Sending system inclusive event and condition for：

○Event

1. Terminal dispatch event: tiA

○Condition

a．BC command terminal to send over: S

b．Existing data in sending area: Si

c．Data has sent to bus: Pb1

Here: It is prior condition of terminal dispatch event generation that a and b. The c is conditional subsequent of terminal dispatch event.

One terminal key target except to data and dispatch besides，that is the data processing. When all required parameters have been received by terminal, data process could occur.

The conditional subsequent of event for such process is that it brings about the new data waiting to be transmitted. Wherefore， one rounded terminal data processing and sending-receiving PETRI NET model as in figure 2. In the picture, ti stands for data processing event.

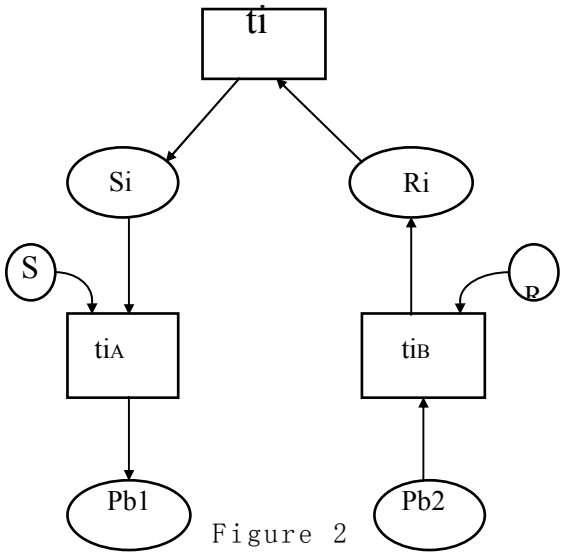

Figure 2

3.3.2 Establish PETRI NET model of instruction control mechanistic for bus controller

Event and condition include in the instruction generation and transmit-receive control in bus controller are as following：

○Event

1. Calling instruction sequence. t01

2 .Generating corresponding instruction. t02

3.Transmit-receiving control command given off. t03

4．Transmit-receive complete. t04

○Condition

a．Command sequence got ready. P01

b．Instruction generation module is all set. P02

c．Command sequence has been called out. P03

d．The control command by instruction sequence wait to be transmits. P04

e．Control command reach to corresponding terminal. P05

f．Transmit and receive finish. P06

Relation of upwards event and conditional as shown in the following table：

event	Premis condition	Conditional subsequent
1-t01	a-p01 f-p06	c-p03
2-t02	b-p02 c-p03	d-p04
3-t03	d-p04	e-p05
4-t04	e-p05	f-p06

According to this table, acquisitiveness PETRI NET model for bus controller instruction control mechanistic is as figure 3.

3.3.3 The petri net expression of the bus

Information transfer of the bus can use following event and condition relation to describe.

○Event.

1 Bus transmission event. tb

○Condition.

a. Sending end existing data. Pb1

b. Receiving terminal has received data. Pb2

It is prior condition of bus transmission event that the sending end exist data. It is conditional subsequent of bus transmission event that the receiving terminal has received data. So the PETRI NET model shown at figure 4.

3.3.4 The PETRI NET model of the instruction message format

In 1553B specification, it has 10 kind of message format. About data transfer message format include：

M1——BC to RT transmission

M2——BC to RT transmission

M3——BC to RT transmission

M4——BC broadcast

M5——RT broadcast

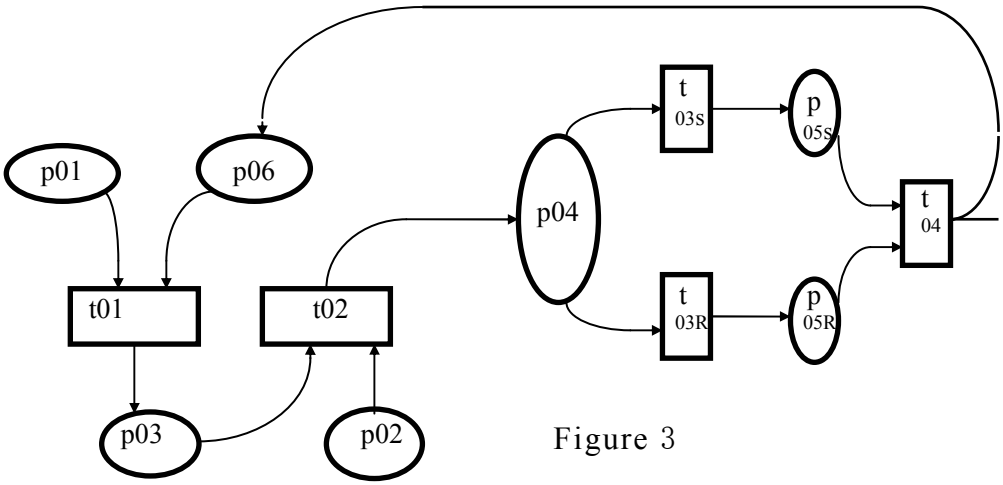

Figure 3

The rest 5 kind of are mode instruction，design to system management and maintenance. It is data link system discussion that these theses emphases. PETRI NET models of the data link system for correspondence with these 5 kinds of message format are given as following.

3.3.4.1 The PETRI NET expression of the instruction format M1-BC to RT is shown in figure 5.

3.3.4.2 The PETRI NET expression of the instruction format M2-RT to BC is shown in figure 6.

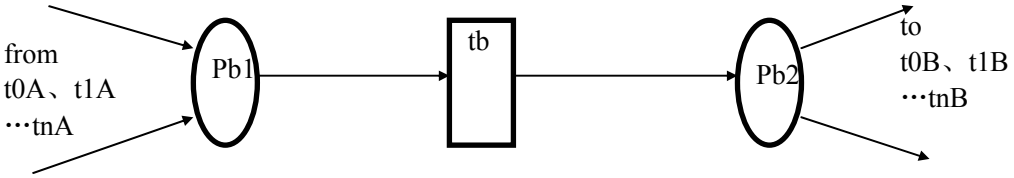

Figure 4

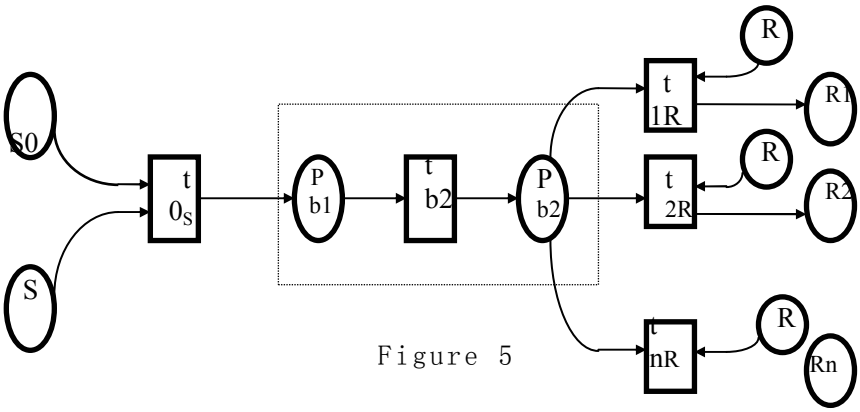

Figure 5

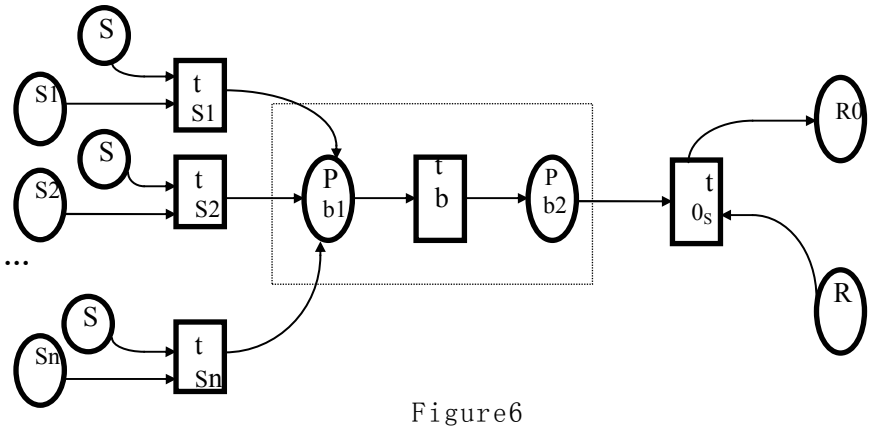

Figure6

3.3.4.3 The PETRI NET expression of the instruction format M3-RT to RT is shown in figure7.

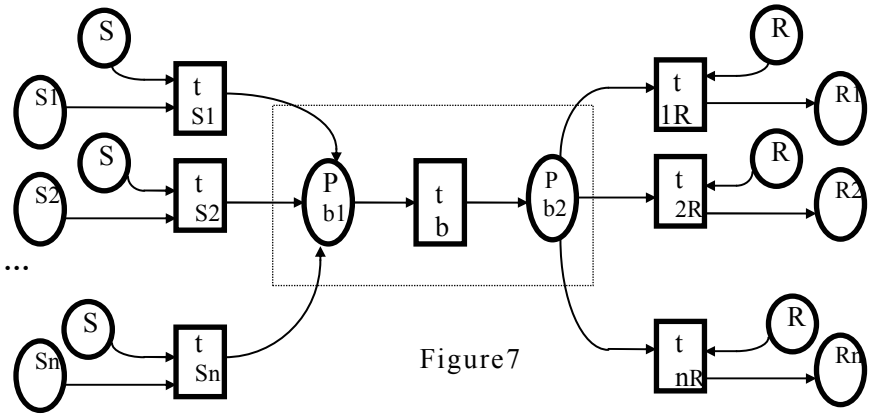

Figure7

3.3.4.4 The PETRI NET expression of the instruction format M4 _ _ BC broadcast is

shown in figure 5 .

3.3.4.5 The PETRI NET expression of the instruction format M5 _ _ RT broadcast is shown in figure7.

4 Control convention

4.1 Transmission time province convention

Convention is in order to economize transmission time. It is available approach to use as far as possible less token quantity for reducing the token flowing time.

4.2 The load leveling convention of the network system

Load leveling is that brought information stream pulls in avionics bus rectangular distribute by time in transmission cycle, to avoid period jam.

4.3 Time fold up convention

Time fold up leads terminal data processing and transmitting interlap in time.

5 The technical criteria analyses of the avionics network system

This article take 2 item of bus availability factor and bus load as example， To explanation how to use PETRI NET running to analyze avionics system technique exponential means. Calculation procedure of bus efficiency：

$$E=\frac{16*NDW}{20(NDW+CW+SW)+(TR+TG)}$$

Hereinto：

NDW——Amount of data word count

CW ——Instruction word count

SW ——Status word count

TR ——Instruction interval

TG ——Information interval

Calculation procedure of bus load：

$$L=\frac{act-bit}{sum-bit}$$

At PETRI NET running course, could statistic the parameter in upwards formulae. Seeing this article adopt with token carry time, that is to monitor and record both word length of token flowing and characteristic item，then convert become hour. Token flowing is through the initiation transition from one place flowing to alternate place. Token from source place to purpose place need for transit a series of place and transition trigger to complete single transmission. Each time such rounded transmission by way of once statistical unit.

This modeling and analytical procedure possess general-purpose sense. I have developed the corresponding modeling and analytical software. The analyze of the instance (see [13])

6 Conclusion

This article with PETRI NET for theory tools, with avionics network system for subject investigated, established PETRI NET model of avionics network system. And present some control convention and optimistic algorithm. The emulation of instance proven that the modeling method is feasible，the software has certain credibility. With the result that also show that， running convention and optimistic algorithm in this article really be able to improve the technical characteristics of avionics system.

References

[1]K • Jensen. A HIGH LEVEL LANGUAGE OF SYSTEM DESIGN ANALISIS. Adevances in petri nets 1990. *Lecture Notes in Computer Science* vol483.springer Berlin Heidelberg New York 1990.pp.342-416

[2]J • L • Peterson. *PETRI NET THEORY OF SYSTEM.* The University of Texas Austin 1989

[3]Lou Zhiqiang. *Aviation electron integration system*. For Peking aerospace university publisher. 1990

[4]LuYan. *Airborne fire control technology.* Defense industry publisher. 1992.

[5]Yiyang Chen. Dpendency Analysys —— A petri net Based Technique for Synthesizing Lange Concurrent Systems. *IEEE TRANSACTIONS ON PARALEL AND DISTRIBUTED SYSTEMS.* Vol4, No4.APRIL1993

[6]WuShiling. Z-mode consultative petri net describe, demonstration and random behavior appraise. *Computer engineering.* Vol20, No2.February 1994

[7]TianZengping. With petri net simulation two-stage

distribution scheduling algorithm. *Computer engineering*. vol21,No1.November 1995

[8]G • Balbo. An Example of Modeling and Evaluation of a Concurrent Program Using Colored Stochastic Petri Nets: Lamports Fast Mutual Exclusion Algorithm. *IEEE TRANSACTIONS ON PARALEL AND DISTRIBUTED SYSTEMS*. Vol3, No2, 1992

[9]Li Layuan. Communication protocol engineering headway. *Computer researc and develop*. 1993

[10]YingJing. Parallel shot system of ground on Petri net knowledge base. *Computer researc and develop*. 1992.8

[11]LOUIS E • ROSIER. Normal and Sickles Petri Nets. *JOURNAL OF COMPUTER AND SYSTEM SCIENCES*. 46, 1-26(1993)

[12]H • J Generich. SYSTEM MODELLING WITH HIGH LEVEL PETRI NETS. *Theoretical Computer Science* 13(1981)

[13]SongHailang. *Analyses and study of the avionics network system*. Master thesis in northwest industry university 1997