Application of Petri Nets in Computer Networks

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ABSTRACT— **In these days, several issues related to computer networks are faced. To evaluate and analysis these issues different kinds of modeling are available to find the best solutions to these issues. Petri Net is one of the most powerful and facilitates modeling that has crucial roles to offer a mathematically and graphically modeling framework for design, distributed, complex and performance evaluation of concurrent systems and have been used in the wide range of modeling applications. The main purpose of this paper, demonstrates some important features of the Colored Petri Net (CPN) and analysis several systems of networks that designed by using colored petri net.**

Keywords: Modeling, Petri Net, Colored Petri Net (CPN), Computer Network

I. INTRODUCTION

Nowadays, Computer Network has important roles to provide an interconnection Computer set with resource shares and autonomy. With the dilatation of network information and the expansion of network scale, the adaptive ability of traditional Network structure is being challenged. We need some new technology to adjust to the development of the near future. Distributed network get more attention for its higher fault tolerance, more reliability and parallel process potentiality. A typical distributed network consists of processing node with

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inclusion program and file resource and their intercommunicative links [17]. In the network, either node linked with other two nodes. And all nodes have equal position. Differ network nodes have no functional distinction but positional disparity. Every node of distributed network is sender, receiver and forwarder of information at the same time. The whole distributed network has no process and control center, but is functional by all network nodes working together. The entry and exit of network nodes change network, which also change the nodes themselves. So we need flexible network nodes design to insure nodes' entry and exit of the interconnection network, and scientific model methods to delineate, develop, analyze and upgrade network node design. Furthermore, the specification and development of communication protocols is a complex task. One of the reasons is that protocols consist of a number of independent concurrent protocol entities that may proceed in many different ways depending on when, e.g., packets are lost, timers expire, and processes are scheduled. The complex behavior makes the design of correct protocols a challenging task [11].

Petri Nets is a complete modeling tool. It has been used on various scientific research and engineering fields now. Petri Nets' nature makes it tightly couple with computer network, which becomes an important computer network research method. Petri Nets can find computer network's structural defects effectively and discover bottleneck of computer network, bring the future computer network new breakthrough [16]. In this paper we will concentrate on application of petri net in computer network. Colored petri net has important roles to provide an accurate model to design and analysis a wide range of systems. In this paper different types of routing protocols will be discussed that have used colored petri net to design and evaluate the performance these protocols. The rest of this paper is structured as follows. In section 2 provides petri net theory and colored petri net. Related work discuss in section 3. Section 4 gives some applications of petri net in computer network. The conclusion summaries of this paper provides in section 5.

II. RELATED WORK

In this section several researches have been demonstrated that using application of petri net in computer network.

In [1] Kristian L. et.al proposed using Colored Petri Net model to evaluate the performance of routing protocol is called Dynamic MANET On-demand (DYMO) protocol for multi-hop communication in MANETs. The internet Engineering Task

Force (IETF) has been attempting to develop the draft of this protocol. In this paper, Colored Petri Net model scenario based state space exploration of the DYMO has been used to authenticate important properties of the protocol. Their CPN modeling has been conducted on two revisions of the DYMO protocol specification and has had direct impact on the most recent version of the protocol specification.

Dahl in [4] presented detail information about using Colored Petri Net for modeling concurrency and attack progress. Furthermore, author gives some examples of attack modeling by using Colored Petri net. In [5], authors presented a Petri net based model and analysis technique for evaluating the risk induced by computer network attacks levied against industrial process control systems.

Dina I. et.al [2] proposed a method to evaluate the behavior for one of the common routing protocols Vector-Based Forwarding routing protocol in Underwater Wireless Sensor Networks (UWSNs) by using Colored Petri Net. In this paper authors conducted on this model based on two parts: First, by the state space statistics analysis which results that the proposed CPN model is liveness and free from deadlocks. Second, by the performance analysis in which demonstrates that the proposed model increases both the packet delivery ratio and the average end-to-end delay.

A study in [3] used Colored Petri Net to construct the model for the methodology of switched LAN. CPN tool has used to evaluate and analysis the model. This paper provides the solution to estimate LAN switch buffer size and network response time. Three components have been used to design the model such as Servers, Workstations and switches.

In [6] author used Colored Petri Net model to detect the problems in Ad hoc On-demand Distance Vector (AODV) routing protocol and analyze the State Space diagram of AODV routing protocol and before implementation resolve the issues. In this study to track the route from one node to another node on the network and detect the neighbors modeling in CPN tools require predefined input values to be incorporated in the states. In this model, author considered dead nodes and route breaks in the network also all nodes have sufficient energy. Furthermore, to identify the loops State space diagram are used. In this study, dynamic modeling of AODV routing protocol by using CPN have used with the help of NS2 and MATLab.

III. PETRI NETS THEORY AND APPLICATION

A. Classic Petri Nets

Petri Net was developed in 1962 by Carl Adam Petri. It is a graphical and mathematical model that able to deal with different kinds of fields. Petri net use a particular rule for transition enabling and firing. This rule seems very simple but it is very complex in petri net theory. Petri net consists of five tuple PN <P, T, A, W, M >. Each tuple has significant role to complete the structure of petri net. A Petri net is directly conduct on graph, each graph contains two types of nodes called places (p) and transitions (t). In addition, to connect these nodes from transition to a place or from place to transition arcs (w) are used. Arcs cannot be used directly from place to place or transition to transition. In graphical representation, transition and place has a particular shape. Transition are drawn as boxes or bars, places as circles and arcs are also labeled with the positive integer that called weight. Negative integer cannot use on the arcs. Also, each place contains a nonnegative integer is called token. The distribution of tokens over the places represents a configuration of the net called the marking [12]. The initial marking of places denoted by M0. A transition is also able to fire if each input place p of t contains at least one token and the number of token is not less than the weight of the arc from p to t. Sometimes firing may or may not occur while the transition is enabled. This case relies on whether or not the event actually takes place [13].

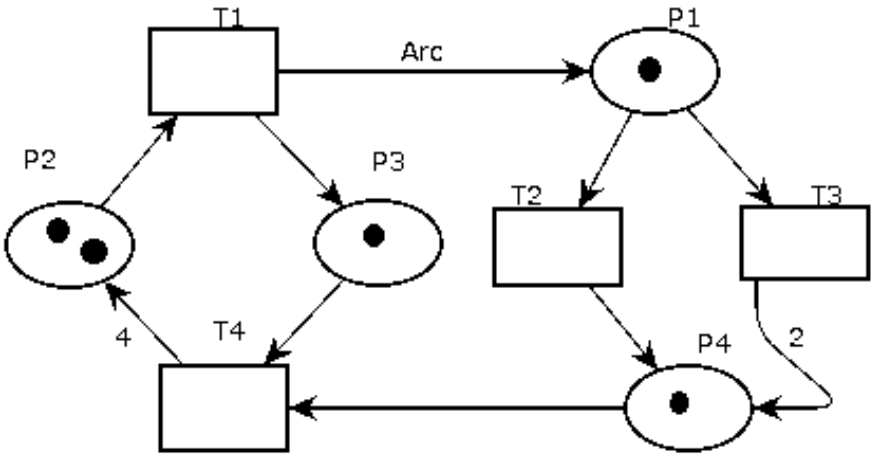


Fig. 1 Classical Petri Net

B. Colored Petri Net

In recent years, number of systems have been developed. Some of systems require several techniques and methods to develop. Especially, distributed and concurrent system is more complex because these systems need to use different ways to execute. This ways relies on whether how many packets of messages will be lost, how many times the system requires to receive the packet and the speed requires to process the system. Therefore, the designing and testing concurrent and distributed systems are difficult and complex.

Colored Petri Nets (CPNs) has the ability to provide a graphical language framework to design, simulation and verification concurrent and distributed systems. It is appropriate model for systems in which synchronization, communication and resource sharing are significant. CPN computer tool supports the design, simulation, performance analysis and functional of CPN models. In recent years, the number of organizations and companies the CPN graphical tools have been used [14]. Due to the ability of CPN model, it can be applied in a wide range of application areas, and many projects have been carried out in industry [15].

C. Petri Nets Application Fields

Petri Nets can be used in many various type of systems particularly suitable for the dynamic modeling and transition systems such as communication protocol analysis, evaluation and performance of System, distributed database system, distributed software system, multiprocessor system, flexible manufacturing and industrial manufacture system, , discrete event systems, data flow calculation, logic inference, neural networks and Decision Making Models, formal language, fault tolerant and fault diagnosis system, automation system. “Owing to the difference of engineering fields, Petri Nets needs abstract in varying degrees frequently and extend in different directions to acclimatize to the needs of application” [11].

D. Applications of Petri Net in Computer Network

Petri net can be used to design and implement various systems without considering the size of systems. It has the ability to provide accurate demonstration of the behavior and structure of modeling dynamic and transitional systems. They are particularly attractive for capturing features such as concurrency, non-determinism,

asynchronous operation, synchronization, and flow of control. Once a Petri net model of a system is created, it can be put to use in a variety of ways. In section gives some previous investigation of routing protocols and applications of computer networks that have been designed and analyzed by using colored petri net and Computer Petri Net tools:

1. Distributed Network Elements Based on Petri Nets

In the distributed network environment, different nodes are available on the network. Each node is be able to communicate with each other nodes at the same time. However, sometime setups and configurations of the network can affect the performance. Therefore, it is very important to understand when any problem occurs on the network. Several nodes work in the network as coordination and change information on an equal footing each other. All nodes have been maintained the whole network. When the new nodes want to entry the network and exit of exiting node. In this model demonstrates a problem that take palace when a new node wants to connect to the system of network and another node wants to leave the system. Two types of distributed networks have been used based on petri net. First model is called Distributed Network Model based on Petri Nets (DNMPN) to resolve the problem of new network nodes' entry and old network nodes' exit in interconnection network. The structure of the model consists of different elements. Elements are responsible for carry out their duty during the execute systems as shown in fig.2 network media was represented as 2S elements. The rest part is network nodes. Resource and logical of network nodes was represented under S elements.

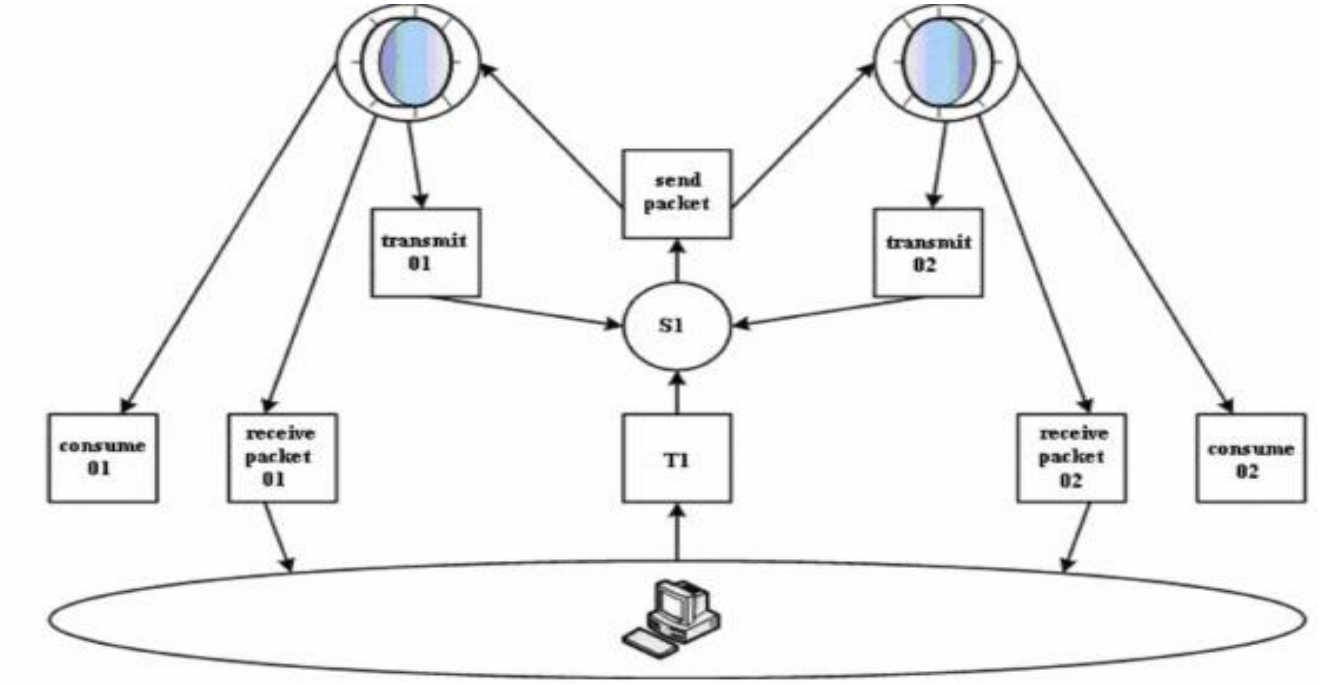


Fig.2 Distributed Network Model based on Petri Nets (DNMPN)

a) Analysis of Behavior and Complexity of DNMPN

In this system when network node wants to transfer packet to other nodes, T1 will be fired then the packet will received by S1. Now S1 has a packet that received from T1. After that T element (Send Packet) transition will be fired, and packet is sent to every backward S element (network media). In this system arch function cannot change the number of tokens only it has the ability to change the value of Token attribute. When network media needs packet Token that must be received, the network node fire (execute) receive packet2 as illustrate in the above figure to obtain the packet that needed. Moreover, consume2 is used by the network media to discard the old packet Token. By the way network can be reduced the load. When network has enough new packets Token but not intends to send it to this network and that packet is not sent by this network node, then this system is used to two elements to get rid of the packet. Firstly, transmit2 T element are used to send packet to the S1 and backward arc of transmit2 will make a lot of old packets in S1. Secondly, Send Packet T element will execute to transmit packet Token to other different network because S1 has received too many packet Token.

In computer network especially in large network there are many paths available to transmit data from one node to another. The problem in Distributed Network Model

Petri Net DNMPN is that when we take a packet from a network media to transmit, it will be transmitted back to the original network media directly. This problem makes unnecessary load on the network media and the performance of network will be decreased and cannot easily transmit data among nodes and

b) Distributed Network Model based on Petri Nets with Transmission (DNMPNT)

The previous model (DNMPN) has become waste of the network resource and generate many repetition packets that effect on the performance network. In order to solve this problem, another model has been proposed to block repetition packet in the network. This model is called Distributed Network Model based on Petri Nets with Transmission (DNMPNT). DNMPNT model as the previous model depending on the elements that have been used by DNMPN although DNMPNT model has different structure for transmitting packet Token. The network media will transmit all packets to other network media by transmit2 T element but not be transmitted to the source network media as shown in fig. 3. DNMPNT will save the network resources and resolve the high repetition rate problem. Furthermore, this method has sensible structure to prevent livelock and deadlock happen.

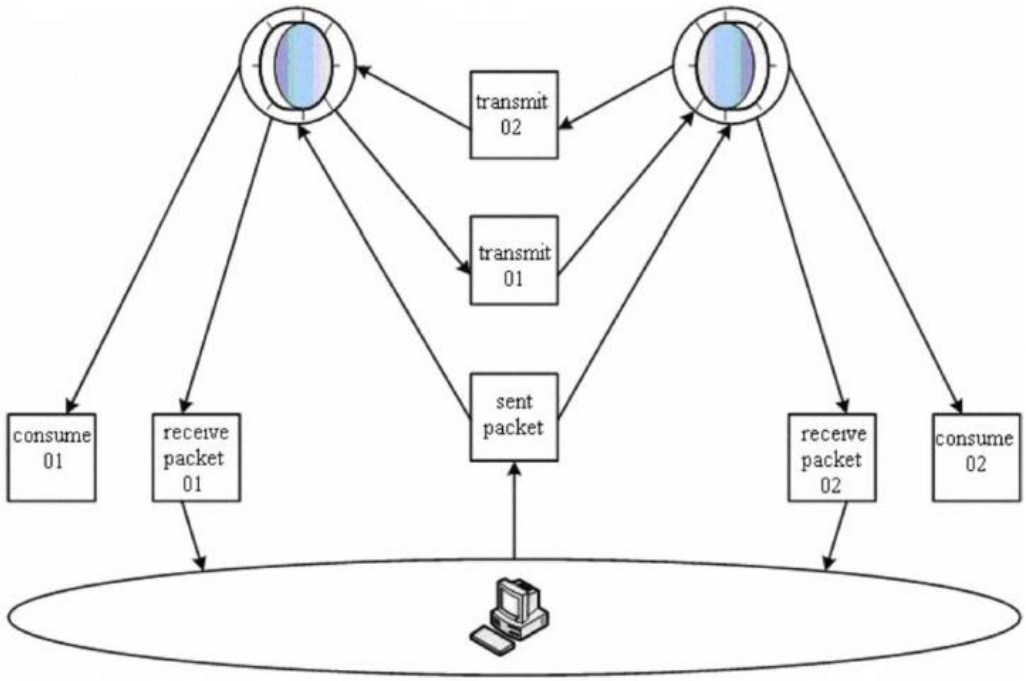


Fig. 3 Distributed Network Model based on Petri Nets with Transmission (DNMPNT)

2. *Edge Router Discovery Protocol (ERDP)*

ERDP is one of the router protocols that can be able to route packets between traditional networks and Mobile Ad-hock Networks (MANETs). This protocol presents an industrial project at Ericsson Telebit. Colored Petri Net has been used to specification and design of ERDP for mobile ad hoc networks. The routers that are used this protocol has the ability to provide and assign network address prefixed to gateways in MANETs. ERD protocol has been developed based on Colored Petri Nets and computer Petri Net tools. A CPN model has been constructed constituting a formal executable specification of ERDP. The behavioral of ERDP has been investigated depending on message sequence charts and simulation. Then state space analysis was applied to conduct a formal verification of the key properties of ERDP. Both the modeling simulation and subsequent state space analysis have important roles to detect and o has important roles to help in identify several errors and omissions in the design, demonstrating the benefits of using formal modeling and analysis in a protocol design process [8].

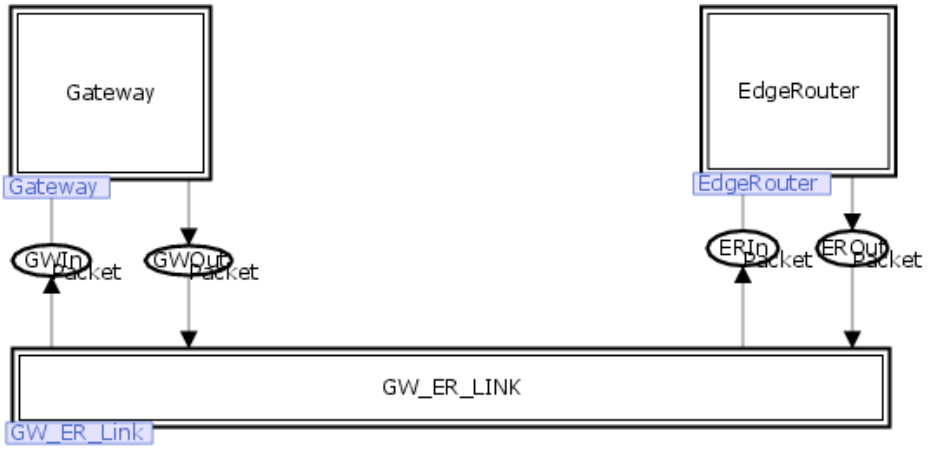


Fig.4 Edge Router Discovery Protocol (ERDP)

2. *Timed Protocol*

Another using of petri net in computer network is that timed CP Net. The timed CP Net can be able to deal with time and specify how long time single processes take and how long time the sender should wait before it makes a retransmission. During the individual operations, systems should produce different waiting times. CP Net has the ability to decide which one is the best to transmit the message fast without using the

network too much and without making too many retransmissions [9]. This example below shown that the structure of the timed net and untimed net are similar except that in the left-hand side a new place has been added is denoted by Wait. This place is responsible to specify how long time the transition SendPacket should wait before retransmitting a packet as illustrate in fig. 5.

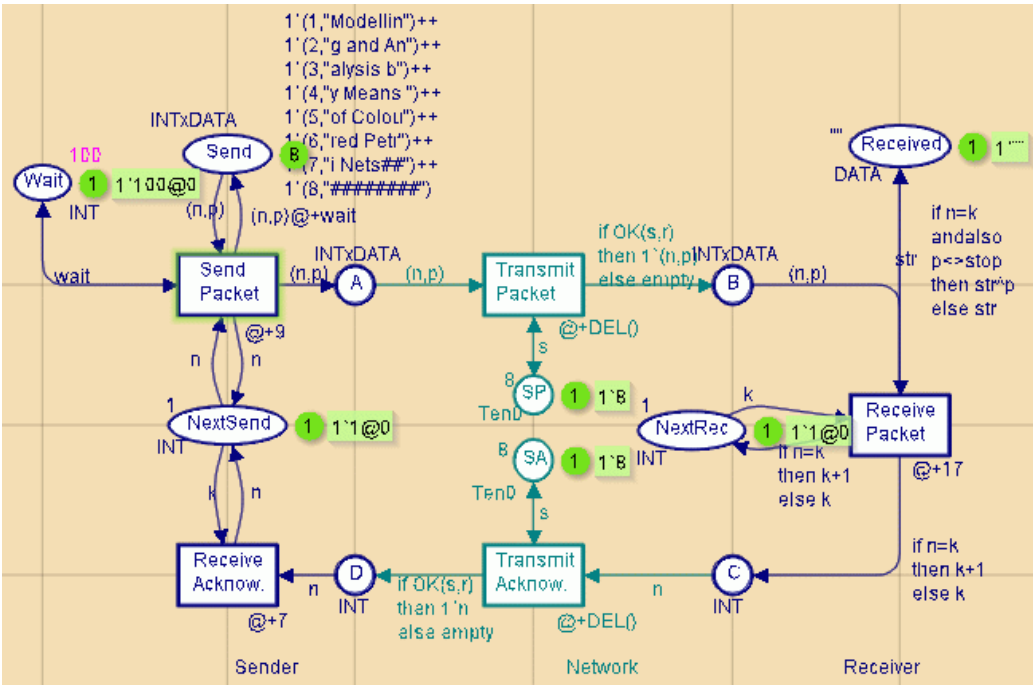


Fig.5 Time Protocol

3. Hierarchical Protocol

Hierarchical Protocol is another example of computer network that CP-net can be designed hieratical protocol with separate pages for the sender and receiver on the network. This example shows that a simple hierarchical protocol that consisting of one sender and two receivers but the design can be modified to accommodate multiple Receivers. The main idea of this example is that the messages send by the sender to the two receivers which the network broadcasts the messages to the receivers. The Receivers send acknowledgments which the Network transmits to the Sender. In this application, in order to the sender become enabled it should be received Acknowledgement from each of the two receivers network. Each acknowledgment is a pair where the first element is the contents, while the second element indicates whether it came from Receiver one or two. The packets are coming by means of broadcast,

Sender must wait the slower of the two Receivers. Hence next Send is updated to be the minimum of the two acknowledgment values as shown in fig. 6.

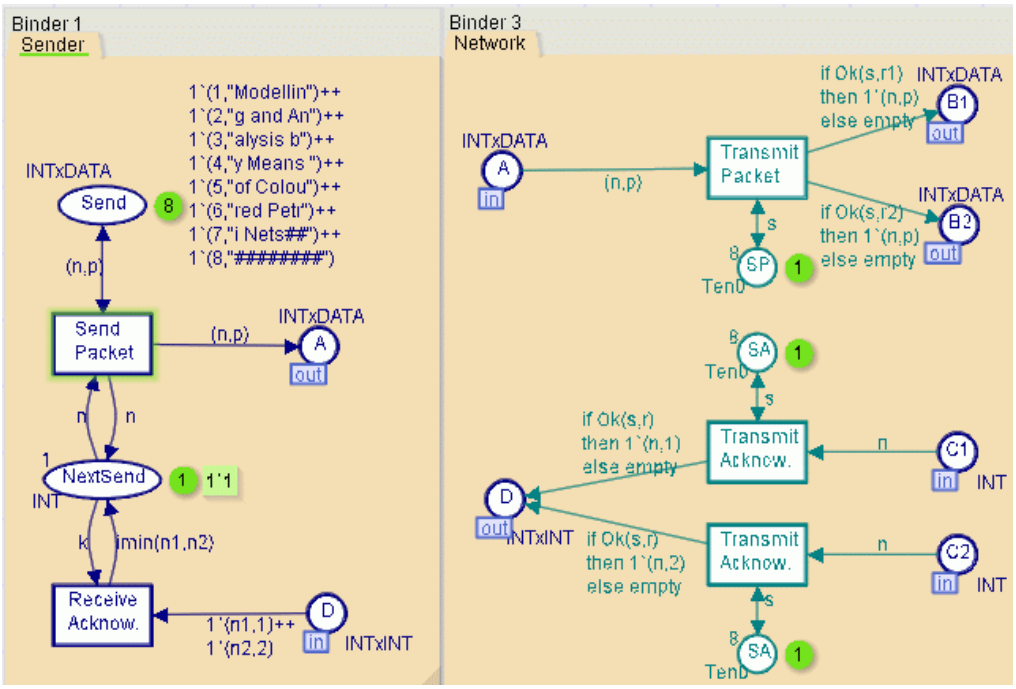


Fig. 6 Sender and Network Part

Furthermore, in this application we defined to two different kind of output places is called B1 and B2 as shown in fig.7 and transmit Packet produces packets at B1 and B2. The packets at B1 are for the first Receiver, while the packets at B2 are for the second. Furthermore, two kinds of variables are defined such as r1 and r2 to specify the packet at B1 and B2 are lost or not. This means that we model a broadcast in which one of the Receivers may get a packet while the other does not. If we replace r1 and r2 with a single common variable r, we get a broadcast where the two Receivers get exactly the same packets. Transmit Acknowledgment is divided into to two. The upper one handles acknowledgments from the first Receiver, while the lower one handles those from the second. Both of them modify the acknowledgment, by adding information telling where the acknowledgment came from.

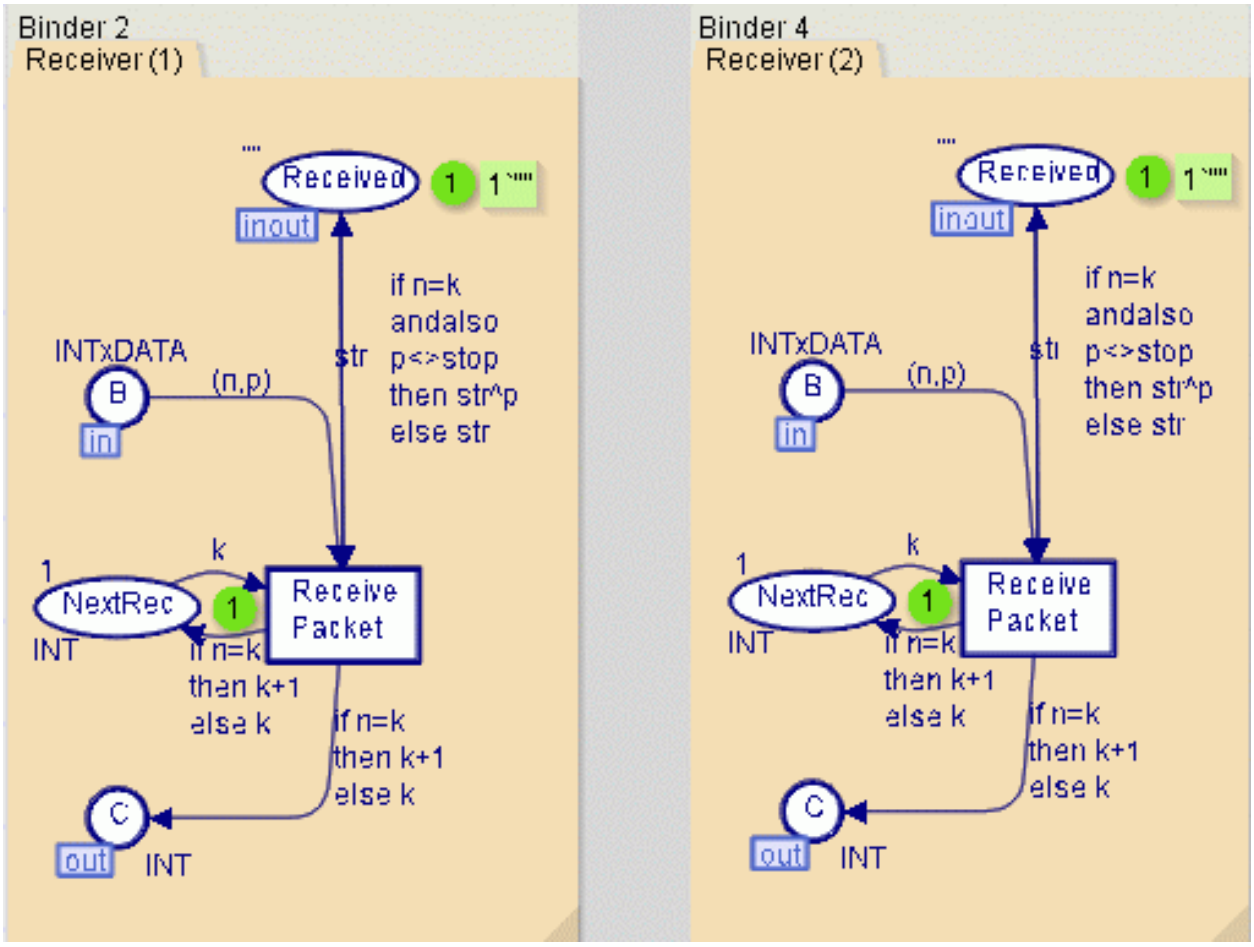
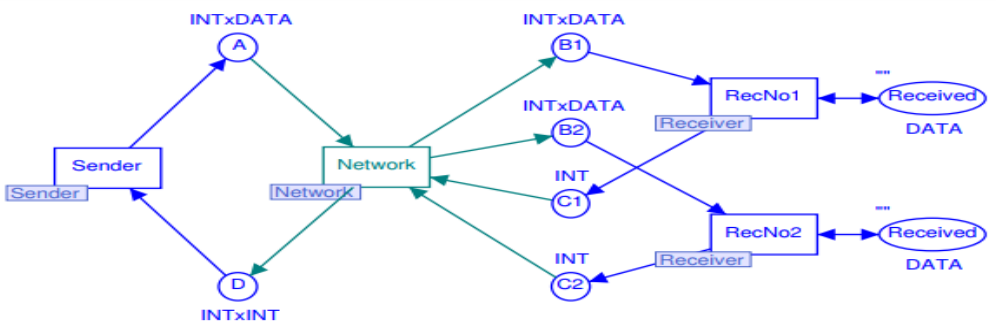


Fig. 7 Receiver Part




```
color INT = int;
color DATA = string;
color INTxDATA= product INT*DATA;
color INTxINT = product INT * INT;
var n,k, n1, n2: INT;
var p, str: DATA;
val stop = "#########";

color Ten0 = int with 0..10;
color Ten1 = int with 1..10;
var s: Ten0; var r, r1,r2: Ten1;
fun Ok(s:Ten0, r:Ten1) = (r<=s);
```

Fig.8 Hierarchical Protocol

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CONCLUSIONS

Petri Nets is one of the graphical and mathematical models that is able to evaluate and analysis the systems, especially appropriate for modeling and analyzing with conflictive discrete event and Concurrent system. This paper focuses on provides some theoretical of classical and Colored Petri Net. Furthermore, in this paper different types of protocols have been presented that Colored Petri Net has crucial roles to design and evaluate these protocols.

We have also explained a method to entry new node and exit old node in distributed network model based on Petri net (DNMPN). This model has generated the high level of repetition, waste network resource and decrement the performance of network. To solve this problem, we have explained another method is called Distributed Network Model based on Petri Nets with Transmission (DNMPNT) which has the ability to solve the problem of model DNMPN for repetition transmitting.

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