Design a Petri Net model for Wormhole routing packet

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Abstract

In order to check the reliability of moving the wormhole packet from source to destination in a communication network , we need a model that provide a dynamic behavior for this moving. The only one model having this facility is Petri Nets. The dynamic behavior provides by the Petri Net describe briefly wormhole routing packet as in real.

keywords

Petri net, wormhole, packet, liveness, bounded, place, token

1-Introduction

The implementation principle technique is how to choose a suitable modeling approach which can give a good view for the designer to operate (him/her) design as in real life. Petri Nets can be used for modeling many designs by their properties which can give to the design many facilities. ***Liveness*** one of the most properties can be used with communication protocols[Alb03].

Wormhole packet is one of the packet types, having a head, body and tail. This type of packed similar to the wormhole in it's moving. In this work we to design a Petri net model for the wormhole routing packet.

2-What are Petri Nets?[3,6]

A Petri net may de defined by five tuples , PN(P,T,F,W,M_0) where:

P={p1,p2,…,pm} is a finite set of places,

T={t1,t2,…,tn} is a finite set of transitions,

F (PXT) U (TXP) is a set of arcs (flow relations),

W: F $\longrightarrow$ {1,2,3,…} is a weight function,

M0: P $\longrightarrow$ {0,1,2,….} is the initial marking,

$P \cap T = \emptyset$ and $P \cup T \neq \emptyset$

A Petri net structure N=(P,T,F,W) without any specific initial marking is denoted by N.

A Petri net with the given initial marking is denoted by (N,M_0).

In order to simulate the dynamic behavior of a system state or marking in a Petri net is changed according to the following transition (firing) rules:

1- a transition is said to be enabled if each input place P of t is marked with at least w(p, t) tokens where w(p, t) is the weight of the arc from p to t.

2- an enabled transition may or may not fire (depending on weather or not the event is actually takes place).
3- A firing of enabled transition t removes w(p, t) tokens from each input place p of t, and adds w(t, p) tokens to each output place p of t, where w(t, p) is the weight of arc from t to p.

A transition without any input place called a source transition and one without any output place is called sink transition. Source transition is unconditionally enabled, and the firing of sink transition consumes tokens but does not produce any.

A pair of a place p and transition t called self-loop if p is both an input and output place of t. A Petri net is said to be pure if it has no self loop. A Petri net is said to be ordinary if all of its arc weights are 1's.

Example:

If we use well known chemical reaction:

$$2H_2 + O_2 \longrightarrow 2H_2O$$

Tow tokens in each input place in fig.(2.1-a   ) show that two unites of H_2 and O_2 are available, and the transition t is enabled. After firing t, the marking will change to the one as shown in fig.(2.1-b) , where the transition is no longer enabled.

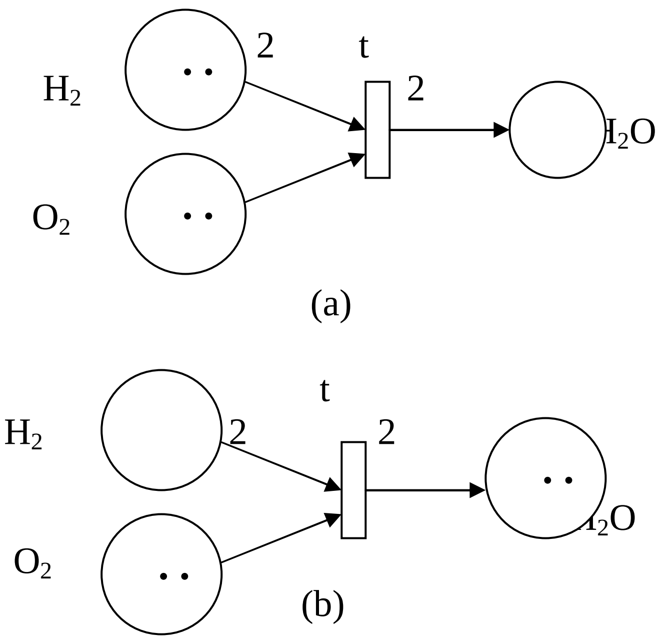


Fig.(2.1   ): An illustration of transition (firing) rules:
(a) The marking before firing the enabled transition t.
(b) The marking after firing t, where t disabled.

2-1 Petri nets behavior properties:

A major strength of Petri nets is their support for analysis of many properties and problems associated with concurrent systems. We can summarized the main Petri nets properties in the following[App97]:

2.1.1 Reachability

Reachability is a fundamental basis for studying the dynamic properties any system. The firing of an enabled transition will change the token distribution (marking) in a net according to the transition rules above.

2.1.2 Boundedness

A Petri net (N,M) is said to be k-bounded or simply bounded in the number of tokens in each place does not exceed a finite number k for any marking reachable from m0 i.e. M(p) <= k for every place p and every marking M R(M_0). A Petri net is said to be **safe** if it is 1-bounded.

2.1.3 Liveness

The concept of liveness is closely related to the complete absence of deadlock in operating system. A Petri net (N,M_0) is said to be **live**, if no matter what marking has been reached from M_0, it is possible to ultimately some further firing sequence.

A transition t in a Petri net (N,M_0) is said to be:

0- dead (L0-live) if t can never be fired in any firing sequence in L(M0).

1- L1-live (potentially firable) if t can be fired at least once in some firing sequence in L(M_0).

2- L2-live if, given any positive integer k , t can be fired at least k times in some firing sequence in L(M_0).

3- L3-live if t appears infinitely, often in some firing sequence L(M_0).

4- L4-live or live it t is L1-live for every marking M in R(M_0).

2.1.4 Reversibility and home state

A Petri net (N,M_0) is said to be reversible if , for each marking M in R(M_0), M_0 is reachable from M. Thus, in reversible net one can always get back to the initial marking state. A marking M' is said to be home state if, for each marking M in R(M_0), M' is reachable from M.

2.1.5 Coverability

A marking M in a Petri net (N,M_0) is said to be coverable if there exists a marking M' in $R(M_0)$ such that M'(p) >= M(p) for each p in the net.

2.1.6 Persistence

A Petri net (N,M_0) is said to be persistence if, for any two enabled transitions, the firing of one transition will not disable the others.

2.1.7 Synchronic distance

We can define the synchronic distance between two transitions t1 and t2 in Petri net (N,M_0) by:

D12=max| œ (t1)-œ (t2)|

Where œ is the firing sequence.

(ti) the number of items that ti, i=1,2,… fires in

2.1.8 Fairness

There are two basic concepts of fairness:

1- Bounded fairness. 2-unconditional (global) fairness.

Two transitions t1 and t2 are said to be in bounded fair (or B-fair) relation if the maximum number of times that either one can fire while the other is not firing is bounded. A Petri net (N,M_0) is said to be B-fair relation.

A firing sequence œ is said to be unconditionally (globally) fair if it is finite or every transition in the net appears infinitely often in œ. A Petri net is said to be an unconditionally fair net if every firing sequence œ from M in $R(M_0)$ is unconditionally fair.

3- Wormhole routing

Network faults can corrupt the local variables of any network processor. Thus, message flits and their wormhole routing paths can be spontaneously introduced, lost, or corrupted[AJO03].

Packets in a network can be transmitted in many ways, including one called wormhole routing. In wormhole routing, packets are divided into smaller parts of equal size called flits(flow-control digit), which are then transmitted one by one, instead of transmitting the packed as a whole. All the flits of the same packet follow the same path and cannot overtake each other. Furthermore, each node on the path of the packet can contain only one flit of that packet and will always try to transmit it to the next node. Because the movement of the packets resembles the movement of the worm, a packet moves through a network is gives in fig(3.1) [Ach95].

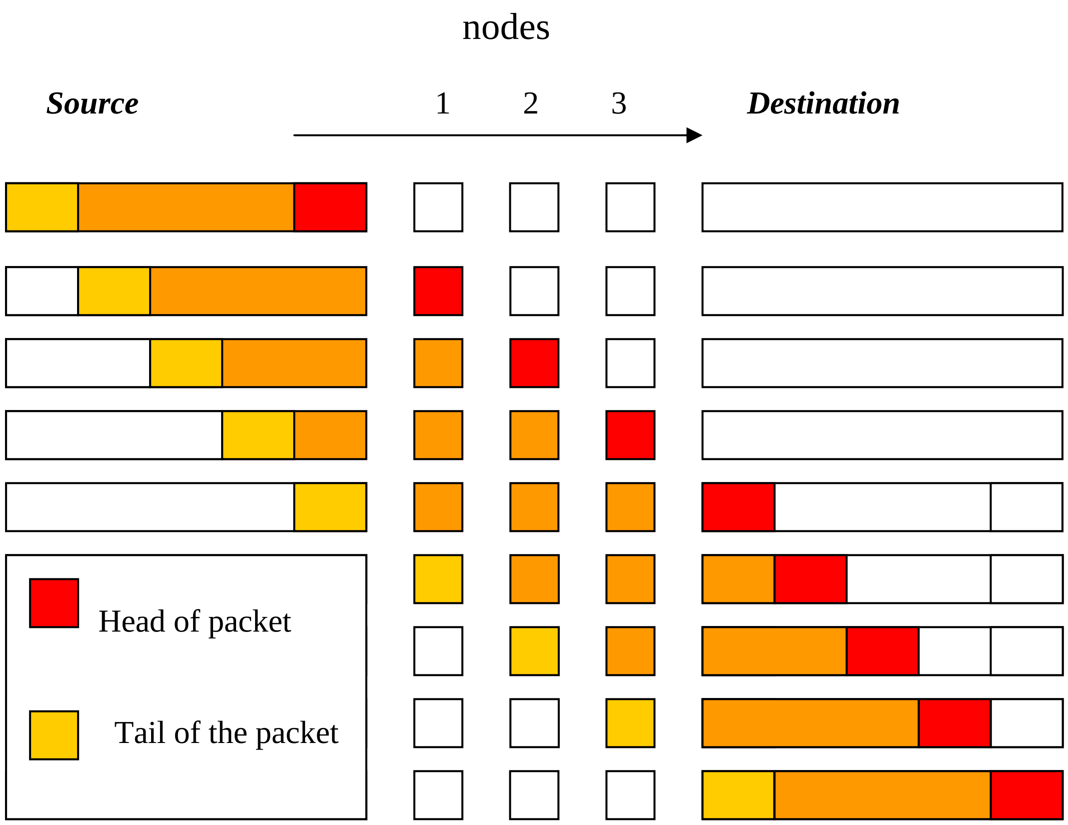
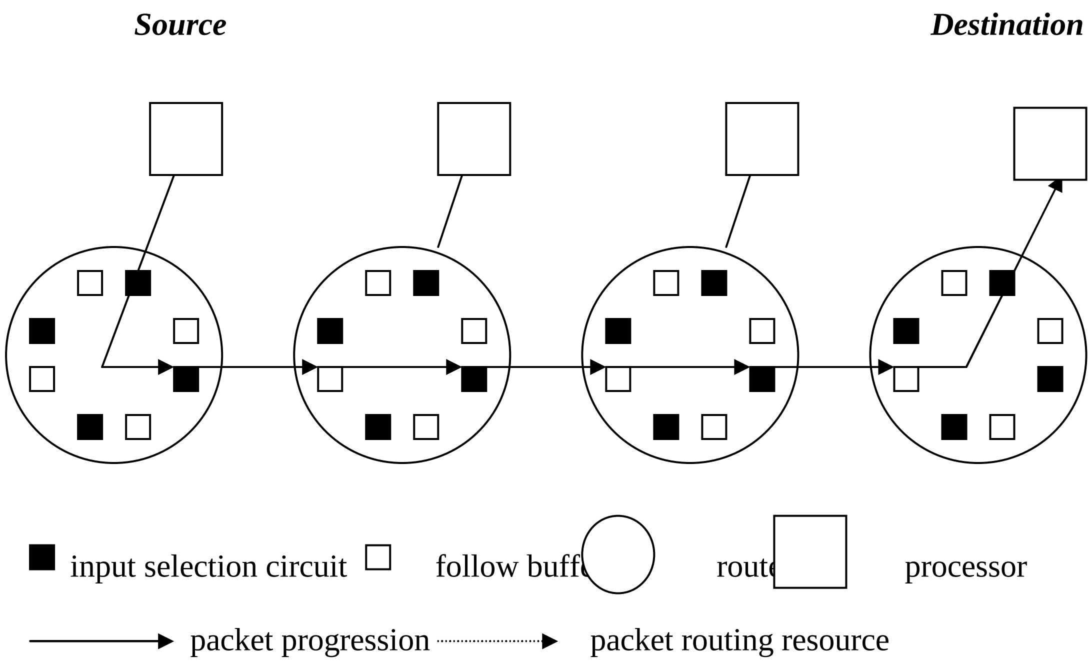


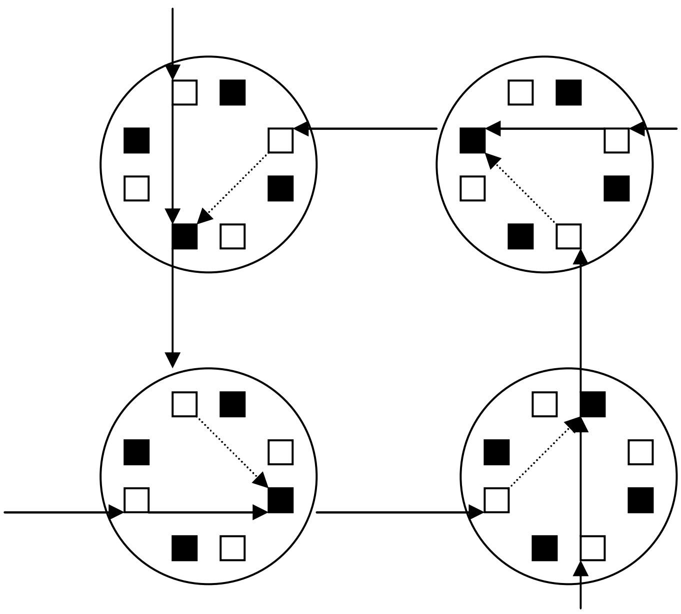
fig.(3.1) Transmission of the packet using wormhole routing

In the wormhole routing the following is done (see fig 3.1):
The source node starts transmitting the flits one by one to the next node, beginning with the head of the packet[Rli98], [AJO03].
The nodes on the path of the packet receive the flits, but can store only one flit at the time. If a flit is present in a node , other flits cannot enter this node, which means that the previous node cannot sent its flit.
A node always tries to send the flit which it receives on the following node , unless the node receives the flits one by one until the last flit of the packet has been received[Rbo96], [AJO03].
It must be noted that, in wormhole routing it is impossible for flits of another packet to cross the path of the current packet. This means , that even if a node is empty, flits of other packet cannot use this node, unless the last flit of the current packet has passed it. This characteristic of the

wormhole routing introduces a problem called deadlock, as shown in fig.(3.2) bellow.



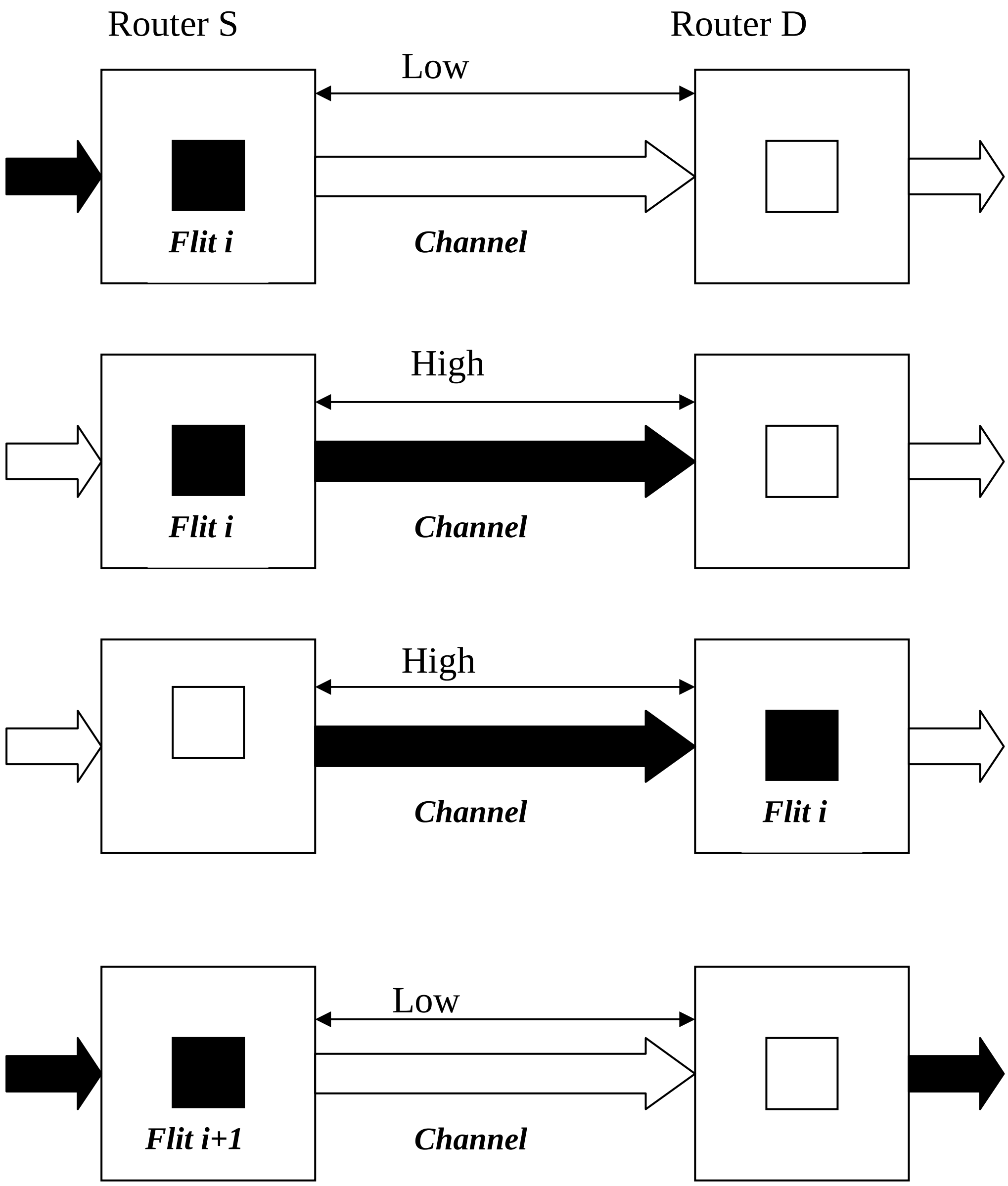
(a)wormhole routing



(b) Deadlock

fig(3.2) wormhole routing and deadlock

The packet transmitted from the router (s) to router (d) through the channel where the flits received by router (D) recursively (i.e. flit i, flit i+1, .., i+n) where n represent the flits number of the packet this can be represented in sequence of steps as in fig (3.3).



Fig(3.3) packet transmission through routers

4- The proposed model for the wormhole routing packet

Petri Nets can be used to represent and specify essential features of a system in communication protocol.
The liveness and safeness properties as described in sec.(2.1.3) of a Petri Net are often used as correctness criteria in communication protocols. The Petri Net shown in fig. (4.1) is a model to describe the communication between two processes (source and destination) and can describe how the wormhole packed routed from the source to the destination.

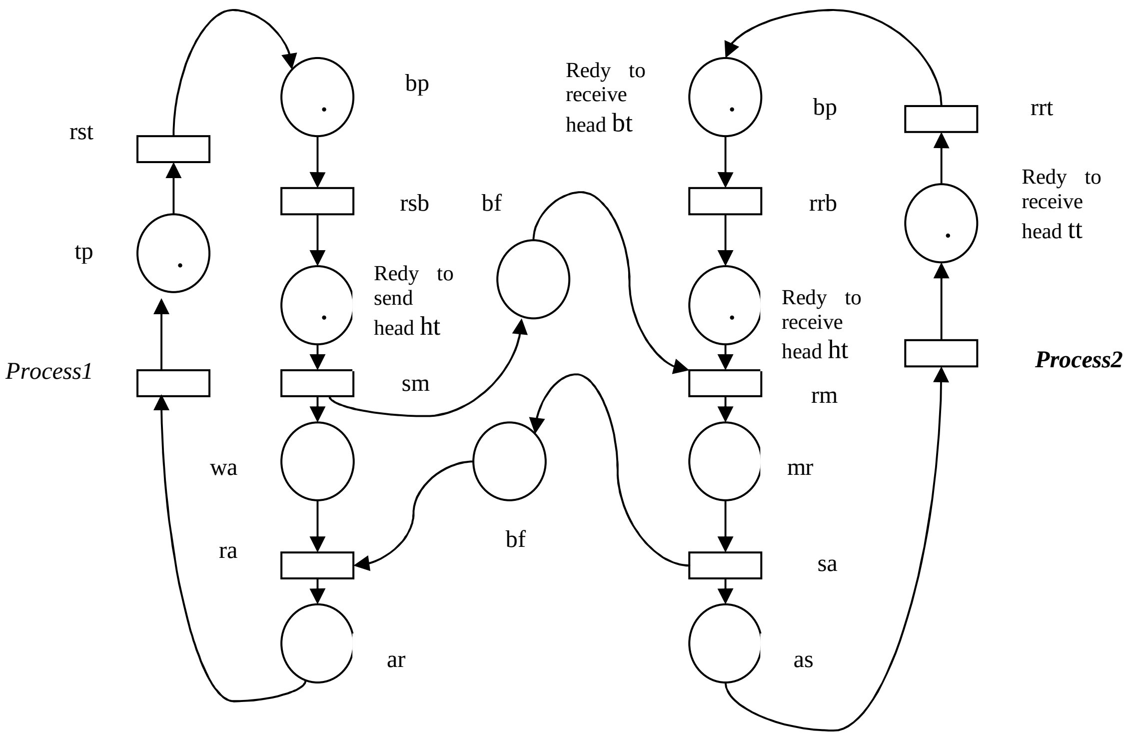


fig. (4.1) the proposed Petri net model for a wormhole routing

5.1 Model Operation

If the packet divide into head token(ht) in head place (hp), body token (bt) in body place (bp) and tail token (tt) in tail place (tp). The transition send massage (sm) become enabled and after firing this transition a token become in buffer full place (bf) and token in wait for acknowledgment (wa) ,at the same time the transition ready to send body packet (rsb) also become enabled and can be fired. The transition receive massage (rm) become enabled and after firing it a token moved toward massage received place (mr) after that send acknowledgment (sa) transition can be fired to transmit a tokens to each send (as) pace and buffer full(bf) place. In this case a transition received acknowledgment (ra) become enabled and can be fired, after firing it the process completed by receive the head packet at destination. The body token and tail token recursively received by the destination.

4-2 Model Properties

The model represented in fig. (1.4) having several properties can be summarized in following:

1- ***Live:*** The transitions in this model can be fired at least once at each marking $R(M_0)$.

2- ***1-Bounded:*** The number of tokens in each place of this model dose not exceed the finite (1) for any marking reachable from M_0.

3- Safeness: A Petri net is said to be **safe** if it is 1-bounded.

4- Reversibility: For each marking M in $R(M_0)$ in this net M_0 is reachable from M.

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