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Security of Grid Structures with Cut-through Switching Nodes

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Store-and-forward buffering of packets is traditionally used in modern network devices such as switches and routers. But sometimes it is a significant obstacle to the quality of service improvement because the minimal packet delivery time is limited by the multiplier of the number of intermediate nodes by the packet transmission time in the channel. The cut-through transmission of packets removes this limitation, because it uses only the head of packet, which contains the destination address, for the forwarding decision. Thus, the cut-through technology of packets transmission has considerable opportunities for the quality of service improving. Models for the computing grid with the cut-through forwarding have been developed in the form of colored Petri nets. The model is composed of packet switching nodes and generators of traffic; it can be supplied with malefactor models in the form of traffic guns disguised under regular multimedia traffic. The present work is the further development of methods of the rectangular communication grids analysis for nodes performing the cut-through switching. The methods are intended for application in the design of computing grids, in the development of new telecommunications devices, and in intelligent defense systems. Preliminary estimations show that the cut-through technology inherits some of the negative effects, which are associated with the traditional store-and-forward delivery of packets. A series of simulations revealed conditions of blocking a grid with its regular traffic. The results are applicable in the intellectual detection of intrusions and counter-measures planning.

Keywords: *computing grid security, cut-through switching, traffic attack defence, performance evaluation, colored Petri net, deadlock.*

1. Introduction

Intelligent Defense/Security Systems considerably relay on trustworthy models of networks and intrusion (malefactor). Colored Petri nets are prospective formalism for intellectual systems, because they allow simulating neural networks [2] and other facilities of knowledge representation. At the initial stage of research, models of underlying grid and intrusion of a specific (disgusted) form are developed [5] where an overview of the related work on the grid security aspects has been presented.

Store-and-forward (SAF) buffering of packets is traditionally used in modern network devices such as switches and routers. But sometimes SAF is a significant obstruction to the quality of service (QoS) improvement. Minimum time of the packet delivery for SAF is limited by the product of the number of intermediate nodes to the packet transmission time in the channel. The cut-through transmission of packets [3] removes this limitation, because it uses only the head of packet, which contains the destination address, for the forwarding decision. Thus, the cut-through technology of packets transmission has considerable opportunities for QoS improving.

However, preliminary estimations suggest that the cut-through technology can inherit some of the negative effects, which are associated with the traditional store-and-forward forwarding of packets.

The present work is the further development of methods for analyzing of the rectangular communication grid model, which nodes perform the cut-through switching. The methods are intended for application in the design process of computing grids [4], in the development of new telecommunications devices, and in intelligent defense systems. In [5, 8] the blocking of computing grids was studied. The prospects of grid models application lay in control tools and intelligent network security. The model is developed using a colored Petri nets (CPN) and modeling system CPN Tools [1]. CPN is a graphical oriented language for design, specification, simulation and verification of systems. This language is particularly well-suited to illustrate and simulate systems in which communication and synchronization between components and resource sharing are primary concerns. Telecommunication networks and different network technologies were modeled and investigated via CPN [6, 9].

2. The application of cuts-through packet switching

Two main methods of packet switching dominate in modern telecommunication systems [3]: the first is with the compulsory buffering of the packet or store-and-forward (SAF), and the second is without buffering or cut-through, another popular name is “on the fly”. Hybrid switches are also applied in networks; they can be automatically reversed from the cut-through mode to the SAF mode and vice versa. Switching between the modes is based on the determination of performance and the integrity of the package. Most of the modern switches support concurrently different packet rates.

The SAF technology is traditional for most networks. It provides the packet transmission to the sender only after receiving of the packet and the check the control sum (CRC). The packet is deleted if it shorter than 64 bytes or longer than 1518 bytes or the control sum is invalid. For the SAF method, the packet delivery time increases in proportion to the size of the packet.

The switching technology “on the fly” buffers the packet head only. The cut-through switches do not produce the packets selection; therefore they are the fastest in its class. The disadvantage of this switching is that it transmits any packets including with incorrect control sum. In some cut-through switches, ICS (interim cut-through switching – intermediate switching on the fly) method is used, which filters packets with a length less than 64 bytes. The cut-through switches [3] are primarily used in data centers, where it is necessary to ensure the continuous transmission of a large traffic value with minimal delays.

3. Model of grid structures with cut-through switching nodes

In telecommunication networks, one of the basic components is the active equipment such as switches or routers. Models of communication rectangular grids [4] with the basic element represented by the switch model with SAF method are studied in [5, 8]. Let us consider the construction of the node model with a direct transmission of a packet from port to port or the cut-through switching.

The used color sets, functions, variables and value are described in [5]. For construction of grid model we use two main models: node model with cut-through switching, as a communicational device, and model of a traffic generator, as a terminal device. All models were constructed in CPN Tools.

3.1. Node model with cut-through switching

The node model is based on the standard packing switching procedures [3] of the modern networks and grids which provide the model relevance. The model of the node with the cut-through switching is shown in Fig. 1. It is a model of network device for composition of the rectangular grid model. There are four ports in the node model which provide the full-duplex mode of work in two-directional mode for transmitting and receiving packets simultaneously. Each port consists of four places: output port buffer *po* and its capacity limit place *pol*, input port buffer *pi* and its capacity limit place *pil*. For specification of all ports, an index of port is added to the port name. The node ports’ places are situated on the sides of a square for a future composition of the grid: the upper port is the first port with places *po1, pol1, pi1, pil1*; the right port is the second port with places *po2, pol2, pi2, pil2*; the bottom port is the third port with places *pi3, pil3, po3, pol3*; the left port is the fourth port with places *pi4, pil4, po4, pol4*. According to the cut-through switching method, there is no buffer in the model. The ports places have a color set *pkt*, the limit places have a color set *cc*, and they are contact places for the grid composition.

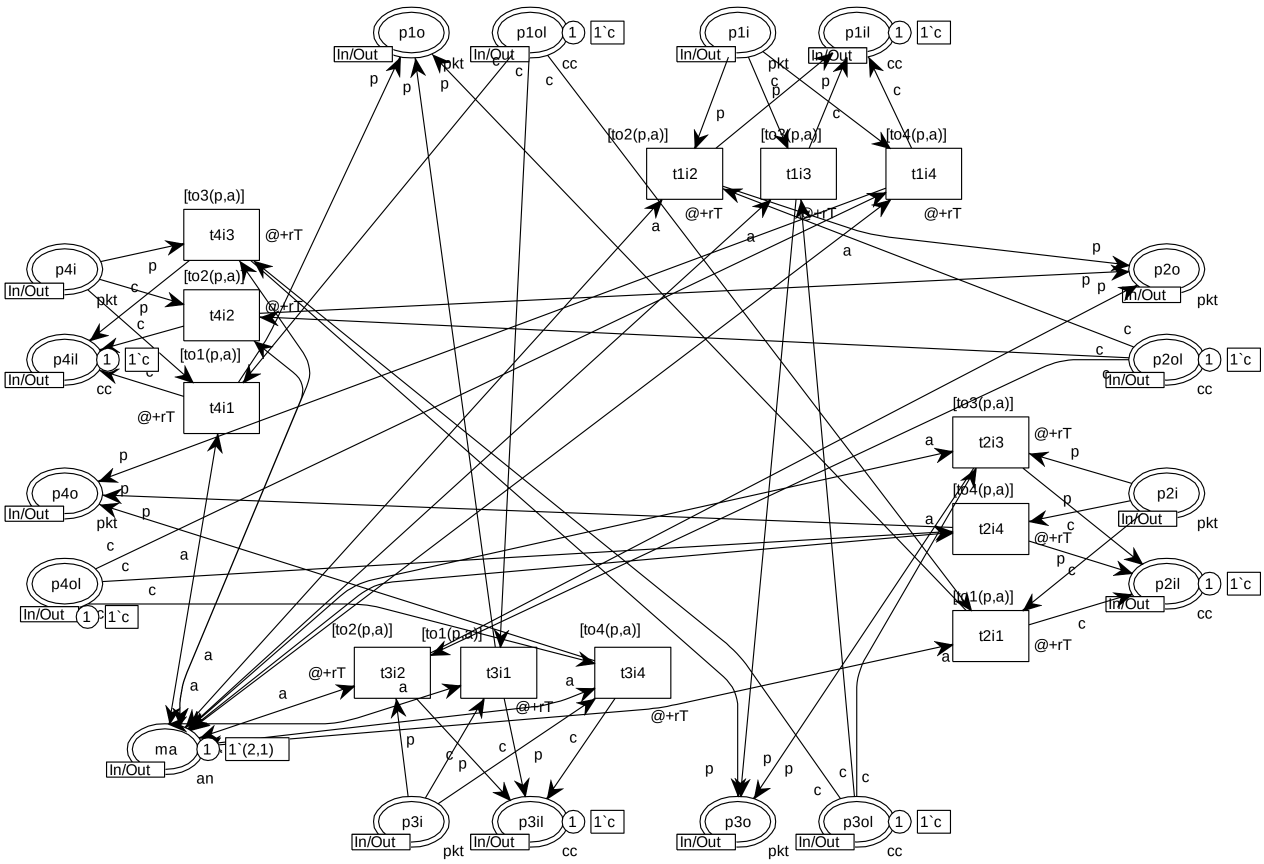

Fig. 1. Model of a communication node.

The system of nodes' addressing uses two integer numbers *(i, j)*, where the first number is a number of row and the second is a number of column in the grid. Contact place *na* contains address of the node.

The output channel of a port is modeled by the two places: *po* and *pol*. The input channel of a port is modeled by the two places *pi*, *pil* and three transitions for each possible direction of transmission (upper, bottom, left or right). The name of transition is *ti*; for describing the redirection from the input to output port, two indexes are added. For example, transition *ti34* transmits a packet from the input port *pi3* to the output port *po4*.

Each transition has a guard function for the packet redirecting and two timed parameters *rT*, the receiving delay time of a packet, and *chT*, the transmitting delay time of a packet.

According to the cut-through switching algorithm [3], a packet is redirected from an input port to an output port if the output port is free. In the node model, special predicates are used for definition of the destination output port [5], they are represented as the guard functions of transitions. For instance, the predicate *to3(p,a)* defines output port number three for a packet forwarding, were *p* contains the information of the packet (destination address, sender address) and *a* is address of a current node. Modeling of static switching and routing tables is studied in [6, 9].

In the initial marking, all the limit places of ports *pil** and *pol** contain a token *1'c* which defines the port capacity; all input *pi** and output *po** places of ports are empty, there are no tokens in the corresponding places. Communication node model has a name according to the number of row and column in the grid, for example node *n*2-1 is a first element of second row in the grid structure.

3.2. Model of traffic generator

For investigation of QoS parameters of the grid structure the model of the traffic generator was constructed. This model consists of the following parts: receiving, sending and computing [5] submodels.

The sending part describes the process of traffic generation, the intensity and type of the traffic function distribution, rules of packet sending. Each packet consists of a destination address, a sender address, a string with some content and timed stamp of the sending time.

The receiving part of the model does not process an incoming packet; all packets are used in the computing part for QoS parameters calculation. The model of the computing part is shown in Fig. 2.

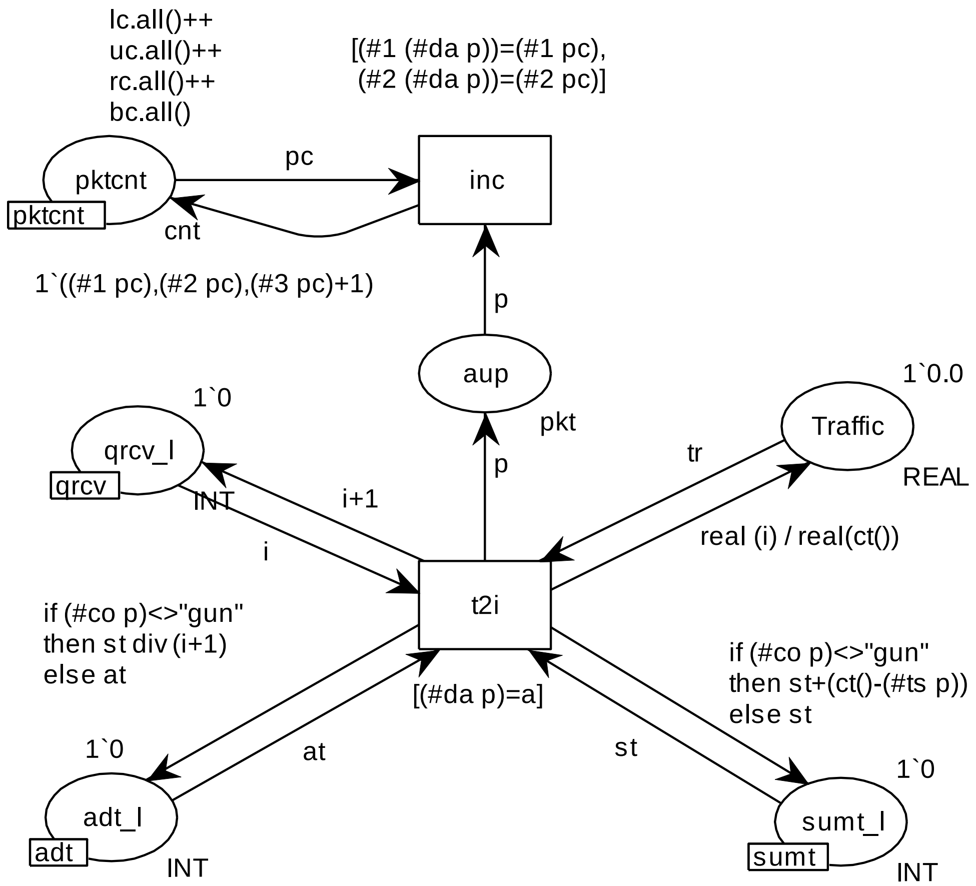

Fig. 2. Model of traffic generator: computing part.

Place *qrcv* contains a number of all received packets in the grid, place *pktcnt* contains a number of received packets for each terminal device, place *Traffic* describes a grid performance (packets/MTU), place *adt* is an average packet delivery time; abbreviation MTU denotes a model time unit applied for the time scalability. Terminal devices are named according to the first letter of border names, for example “right” border device has name *r*-indexes, *r*3-1 is a first right terminal device in third column of grid. Model construction for a measuring fragment (computing part of a model) was studied in [6, 7].

3.3. Model of grid structure

Model of grid structure is a composition of a communicational device models and a terminal device models [4, 8]. Device models are submodels and according to a hierarchical structure of CPN Tools [1], all submodels are represented as transitions; in our case they are supplied with address places situated in the main page of the grid model. Model of the grid structure with the cut-through switching is shown in Fig. 3. It is a model with current marking of the simulation process; there are three packets in the grid.

For example, the submodel of node with index (1,2) is represented on the main page as transition *n1-2* and address place *12a*. The submodel of bottom terminal device with index (3,2) is represented on the main page as transition *b3-2* and address place *32a*.

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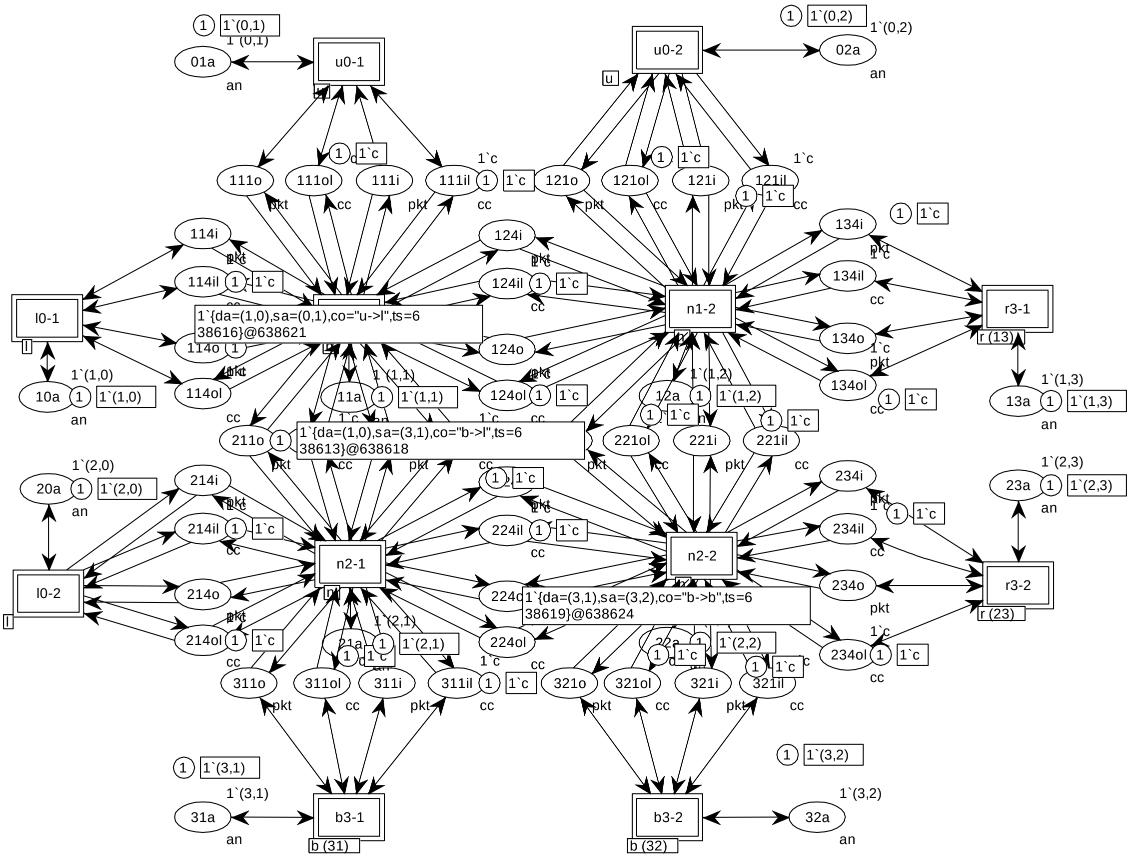

Fig. 3. Model of grid structure of size 2x2

Places with index (*) and suffix **o, *ol, *i, *il* are contact places, which describe output and input ports of the grid nodes and terminal devices. According to the composition rules [6, 8], all ports of communication devices have two description forms on the main page with respect to the enumeration in each of two connected nodes. The first and fourth ports of each node are represented with an index of this node; the second and third ports are union with the first and fourth ports of next nodes and have indexes of next nodes. For example, the place *221i* is the first input port of node *n2-2* and the third output port of node *n1-2*. The bottom row and right column contact places describe the first and fourth ports of nodes, which do not exist in the model. These places are used for connecting of bottom and right terminal devices. For example, the place *234oi* is the fourth output port of node *n2-3*, but there is no node with indexes (2,3) in the grid. This place is merged with the input port of terminal device *r3-2*. In the model, there are no contact places with indexes of border devices.

4. Simulation of Grid Workload

For QoS parameters estimation, simulation of the grid workload was implemented. The grid workload is obtained using the traffic generations, described in the previous section, attached to the grid border. Intensity of the workload and timed delay *rT* of sending packets are basic parameters of the model, whose influence on the grid behavior was estimated. For Poisson distribution with different intensity, a grid performance and an average packet delivery time were studied. The obtained results were compared with characteristics of the grid model having SAF forwarding. Buffer size in this model is supposed equal 10 packets.

Table 1 shows the result of the grid investigation via regular workload for SAF and cut-through switching modes.

Table 1. Grid characteristics under workload

Workload intensity (*wl*)	Type of switching	Average packet delivery time (MTU)	Grid performance *gp* (packets/MTU)
50.0	cut-through*	10	0,14
50.0	SAF	21	0,14
30.0	cut-through*	11	0,23
30.0	SAF	21	0,23
16.0	cut-through*	11	0,44
16.0	SAF*	22	0,42

Step=1000000, rT=5, bs=10, k1=2, k2=2; * *– the grid comes to a full deadlock – no permitted transitions.*

Workloads with *50.0* and *30.0* intensities are light workloads for investigated grids. The grid performance is equal for two switching modes; the average packet delivery time for SAF mode is twice greater than for cut-through mode. Workloads with intensity about *16.0* are middle workloads for the investigated grids. The grid performance of cut-through mode is greater than for SAF mode, the average packet delivery time for SAF mode is twice greater than for cut-through mode. For big size grids, the average packet delivery time for SAF mode will be a few times greater than for cut-through mode.

Cut-through mode switching works faster than SAF mode, but it has the important disadvantage: network with cut-through mode switching is blocked if destination ports are busy. Ports are cleared after executing a special system time procedure (TTL). Some incoming and outgoing packets are lost. Ports clearing function is not simulated in this paper.

An example of a full deadlock is shown in Fig. 4, where inscriptions on the arcs indicate the number of blocked ports in nodes.

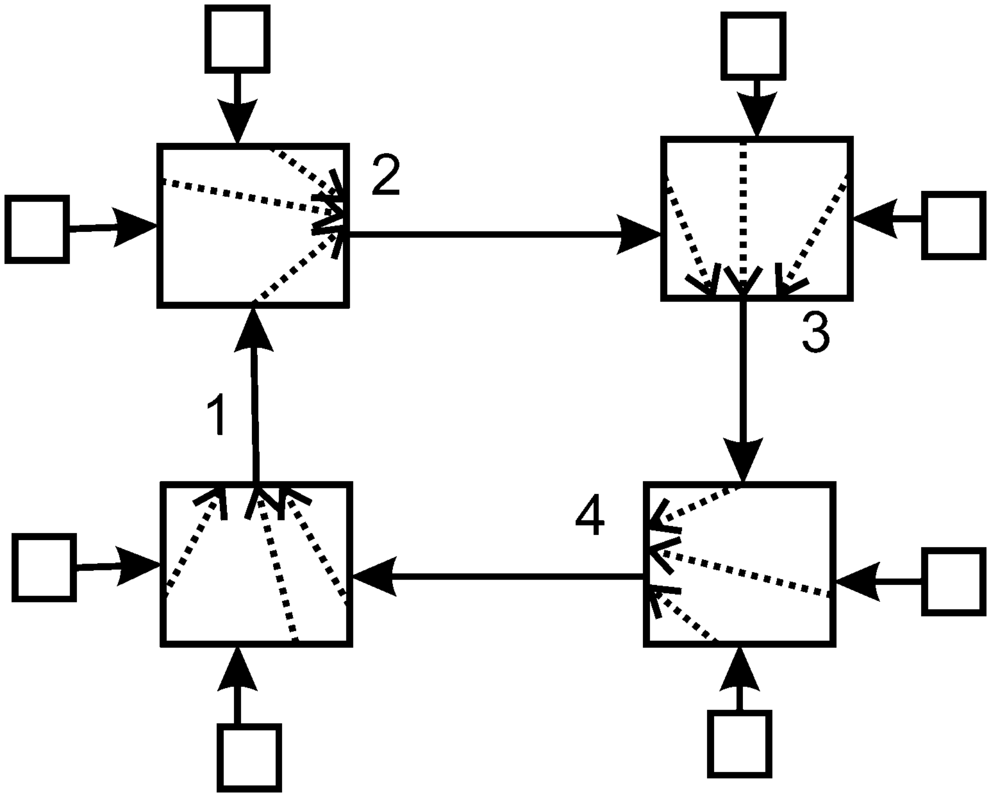

Fig. 4. An example of a full deadlock.

There are four packets in each node: one packet is in the output port, three packets are in the input ports and the destination ports of these packets are the same. The current node can not transmit the packet from output port to the next node, because the next node cannot redirect the incoming packet, because the destination port of this packet is busy. As a result of this clinch is the full deadlock of grid. Thorough explanations could be illustrated by a sequence of pictures from the first mutual blocking of a few nodes via extending the blocked areas to the complete deadlock shown in Fig. 4.

Grid behavior under traffic attacks and workload was studied for grid structures with store-and-forward mode [5, 8].

5. Conclusions

Models of grid structures with cut-through switching nodes were constructed in the colored Petri net form. Security of grid structures, in particular possibility of deadlocks, was investigated under workload in the environment of modeling system CPN Tools. The importance of obtained results for the grid computing domain consists in the conclusion that modern architecture of the switching devices does not guarantee the grid security. Special protocols which involve interoperability of a several nodes should be developed for the deadlocks detection and avoidance.

A future research direction will be to investigate the grid structures with cut-through switching nodes under a workload and traffic attacks; to study types of deadlocks and QoS characteristics of grid under disguised traffic attacks; to construct a re-enterable model [9] for investigation of grid structures with a big size, where initial characteristics of grid are model parameters.

The models are applicable in the intelligent defense and security systems of computing grids.

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