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(54) **METHOD FOR CONSTITUTING HYBRID NETWORK SPANNING TREES, METHOD OF REDUNDANCY, AND CONTROL SYSTEM THEREOF**

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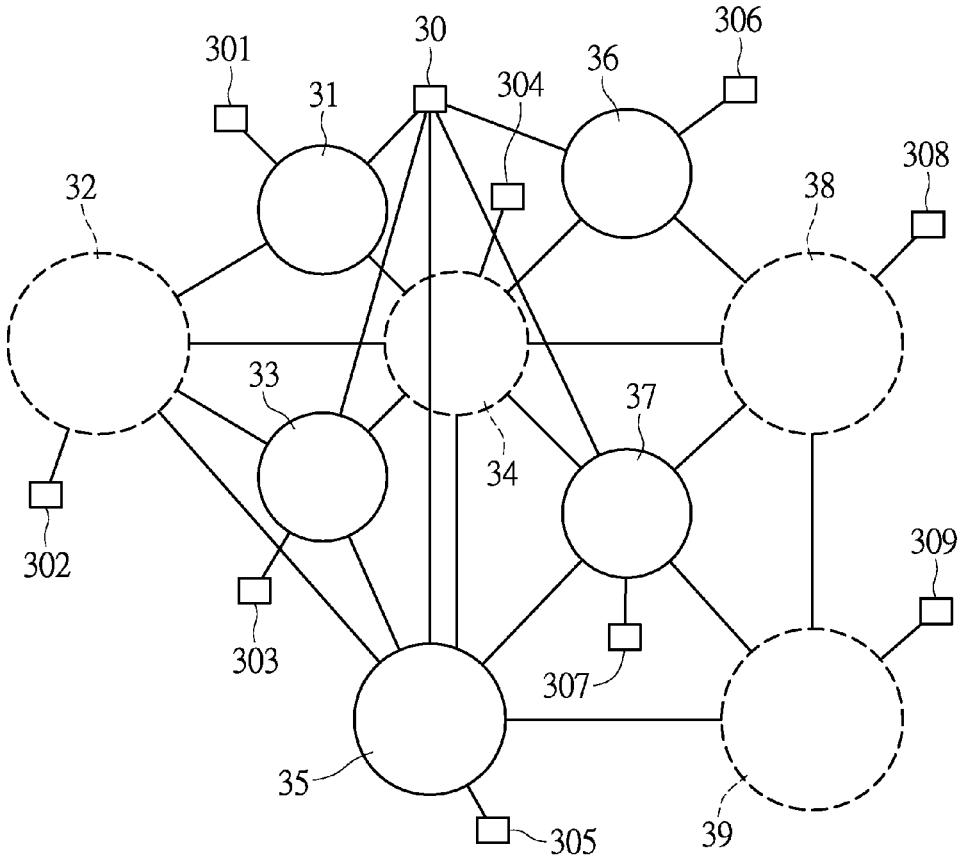
(57) **ABSTRACT**

The disclosure is related to a method for constructing hybrid network spanning trees, a method of redundancy, and a control system thereof. The method and system are adapted to a hybrid network system including at least one software-defined network (SDN) and at least one non-SDN network. In the method, a controller of the SDN is employed to collect network packets over the hybrid network. After analyzing the information carried in the network packets, the information relating to the topology can be obtained. Therefore, all the possible spanning trees can be constituted according to the topology. As well, the path delay and path bandwidth respectively for the SDN and non-SDN can also be obtained. The information allows the system to render utility function for every spanning tree. The most suitable spanning tree over the hybrid network system is applied. A mechanism of redundancy is also provided.



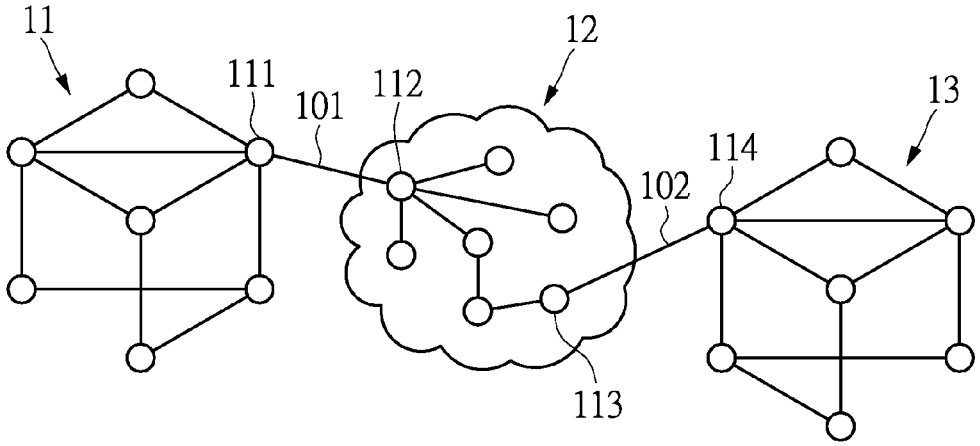

11
111
101
112
12
13
114
102
113

FIG.1A

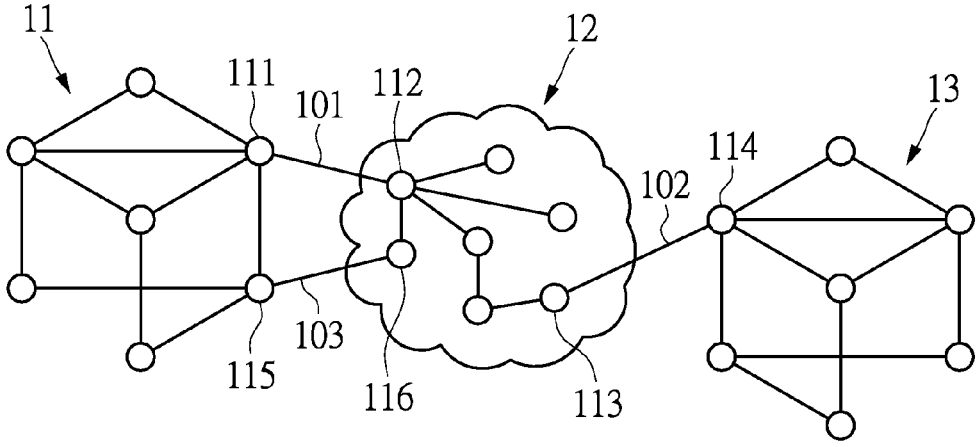

11
111
101
112
12
13
114
102
103
115
116
113

FIG.1B

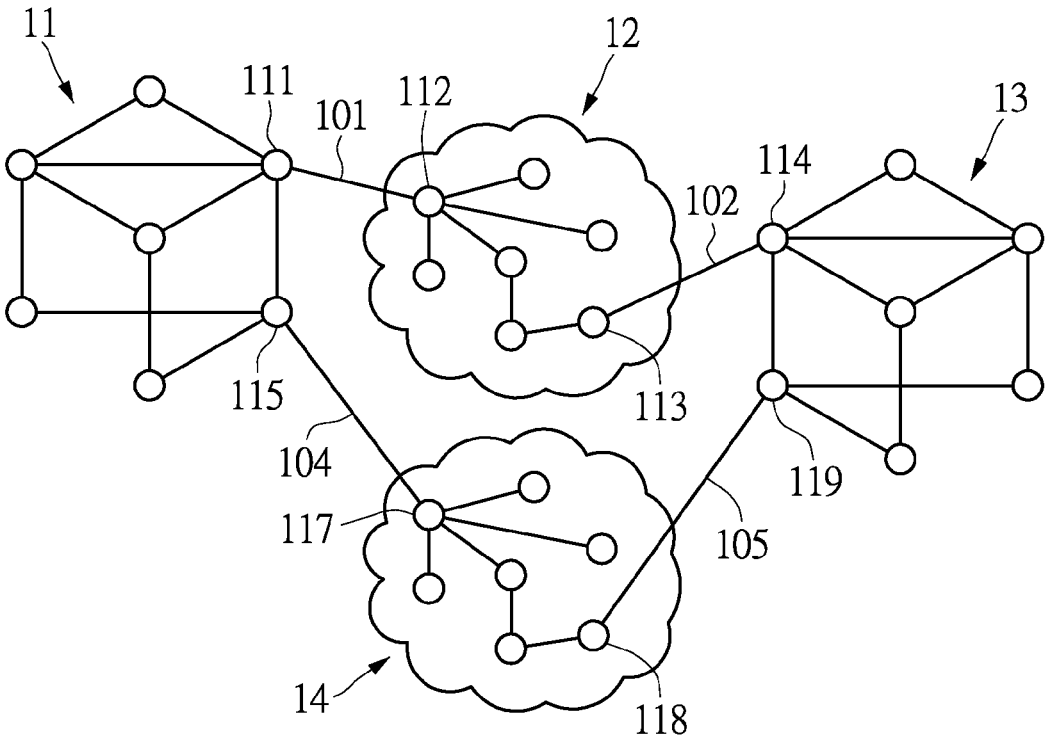


FIG.1C

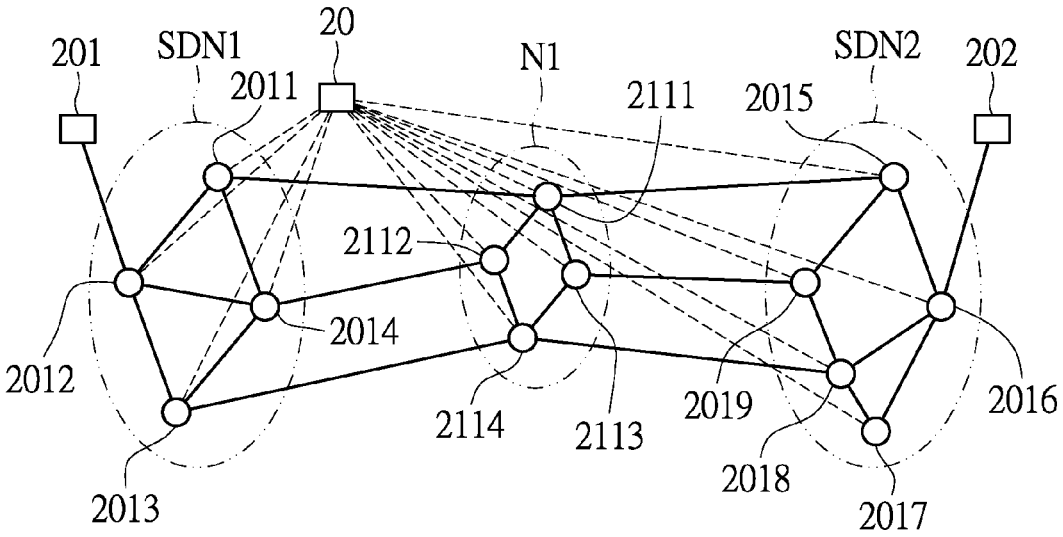

201
SDN1
20
2011
N1
2111
2015
SDN2
202
2112
2014
2012
2114
2113
2019
2016
2013
2018
2017

FIG.2A

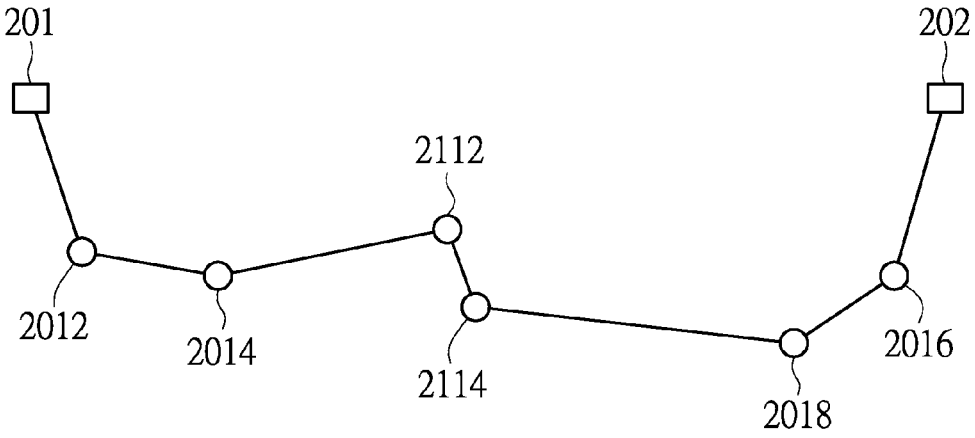

201
202
2112
2012
2014
2114
2016
2018

FIG.2B

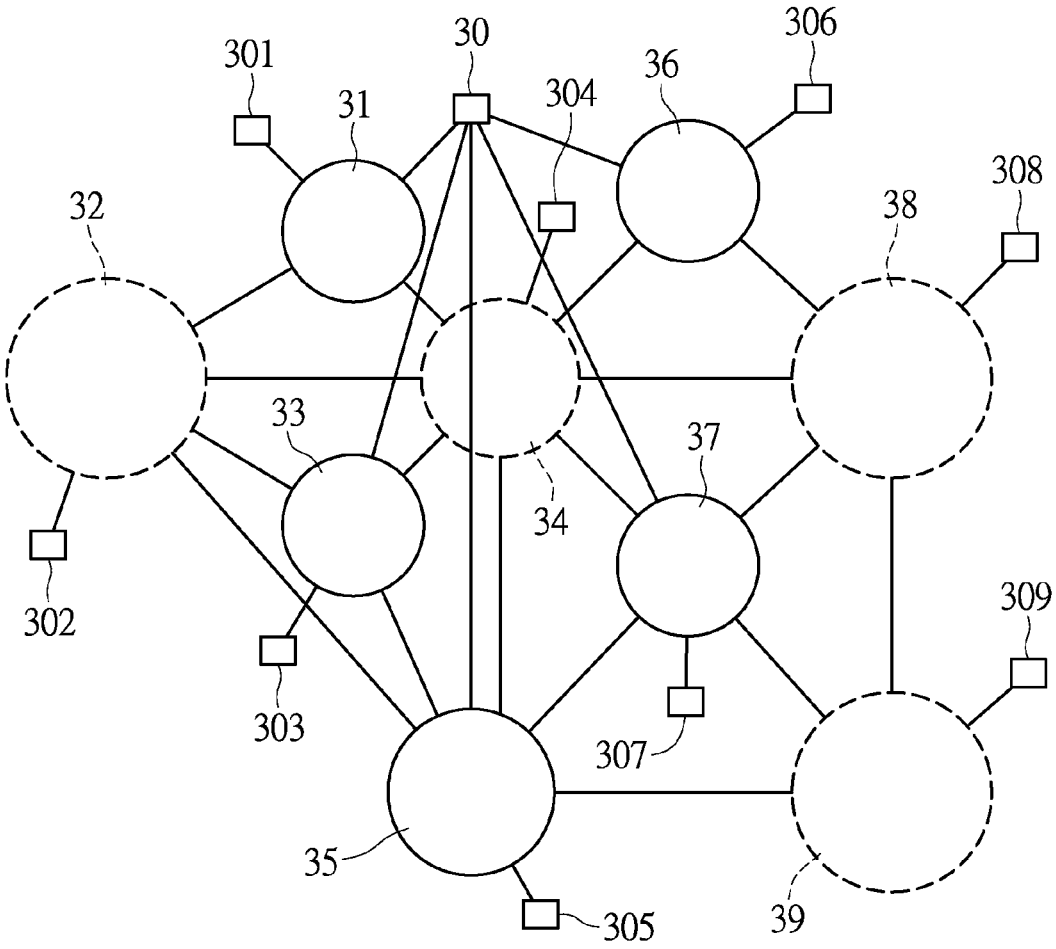


FIG.3A

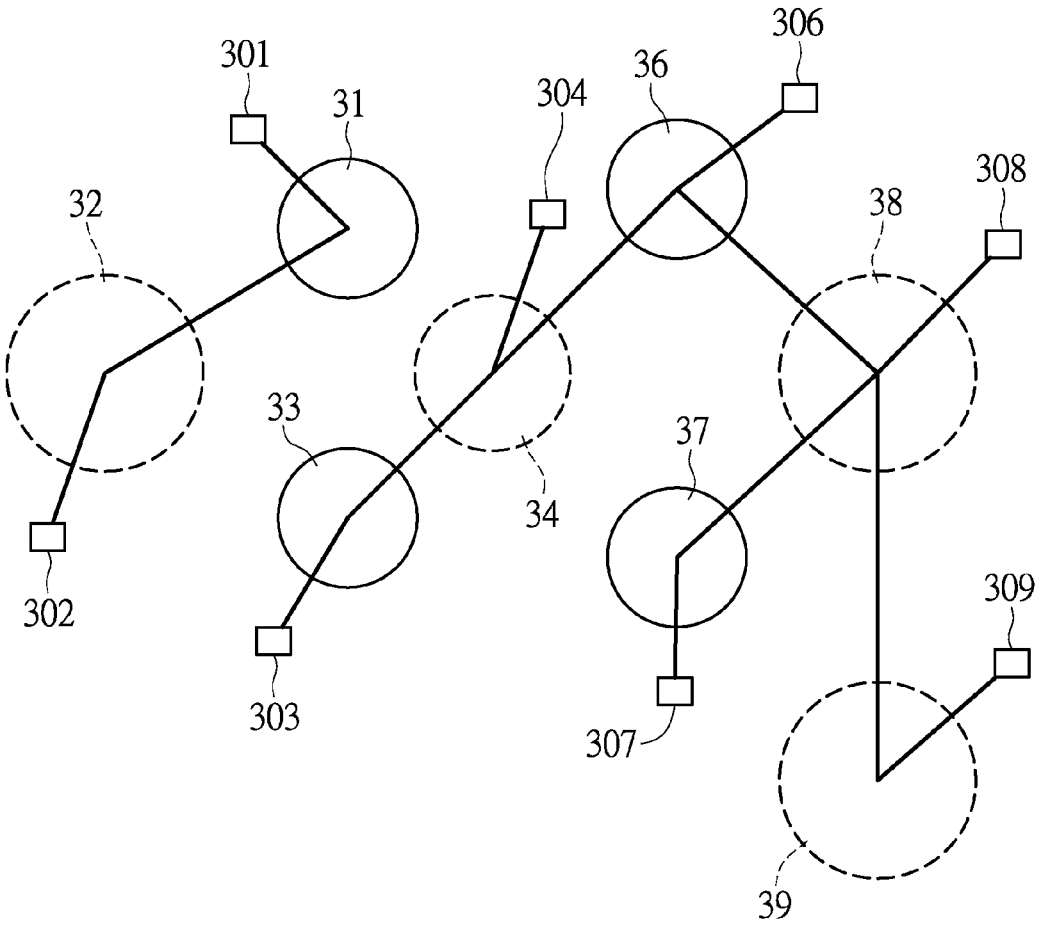


FIG.3B

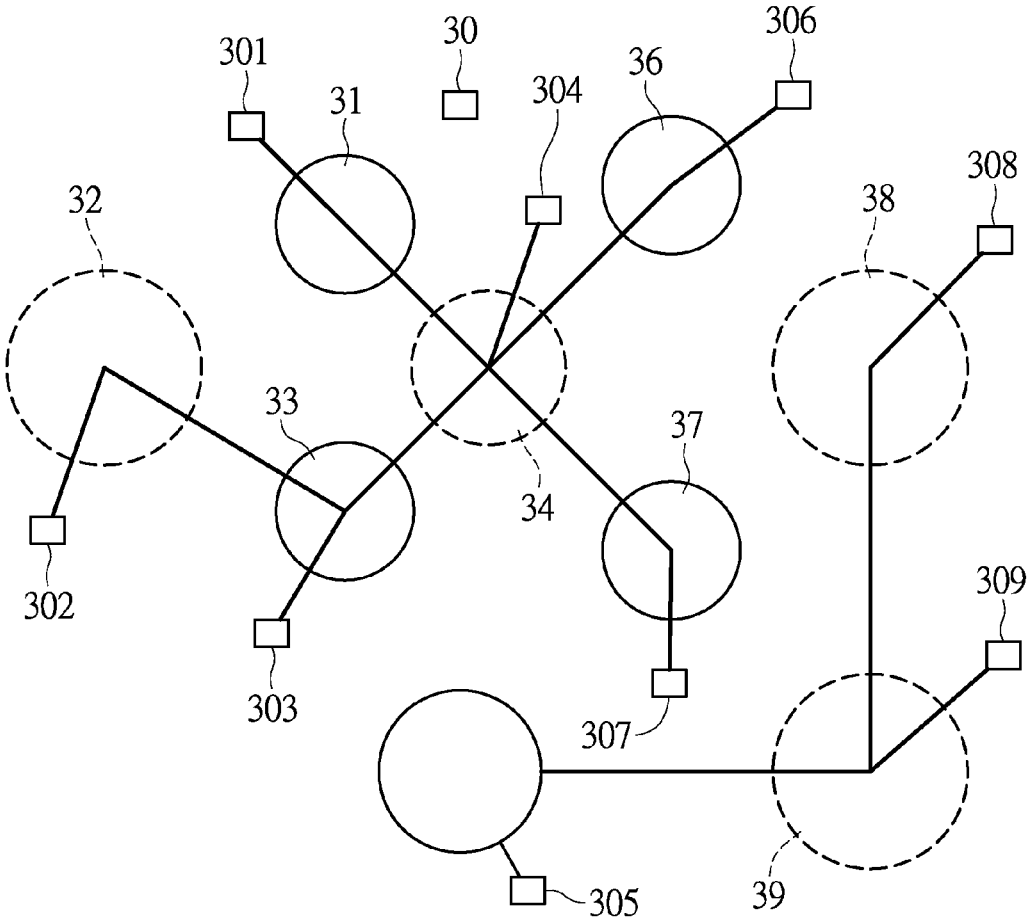


FIG.3C

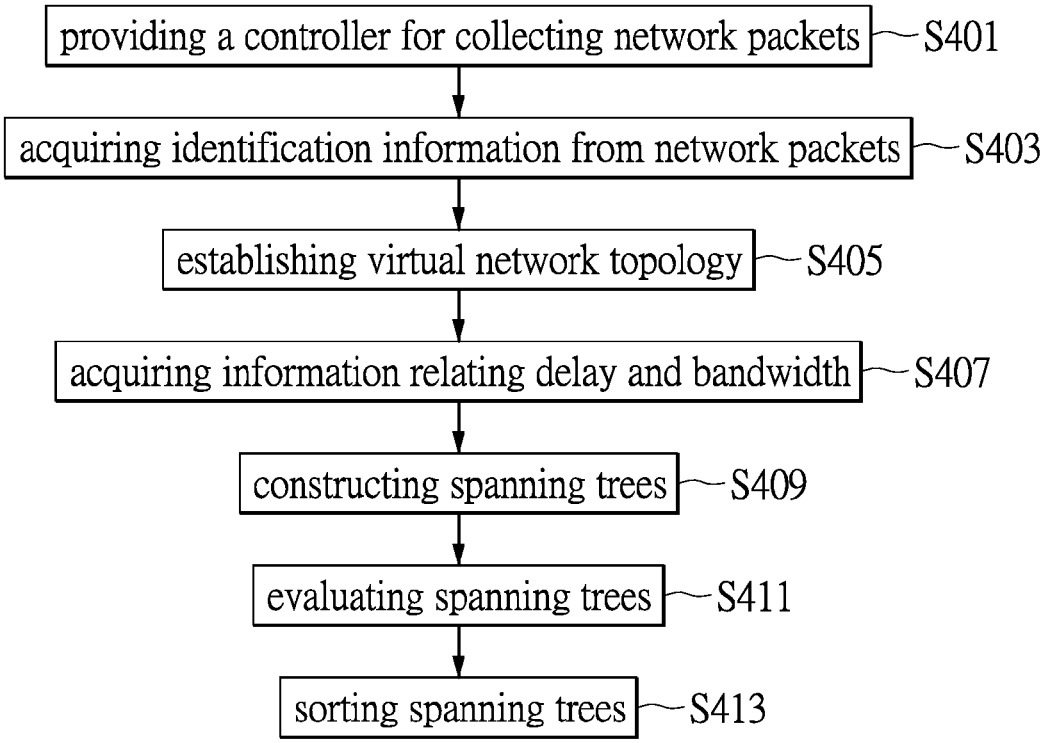

providing a controller for collecting network packets
S401
acquiring identification information from network packets
S403
establishing virtual network topology
S405
acquiring information relating delay and bandwidth
S407
constructing spanning trees
S409
evaluating spanning trees
S411
sorting spanning trees
S413

FIG.4

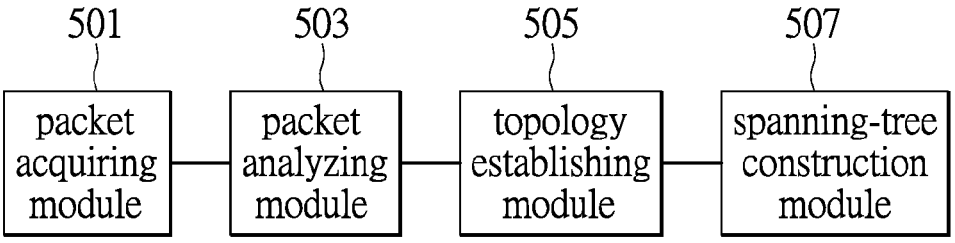

501
503
505
507
packet acquiring module
packet analyzing module
topology establishing module
spanning-tree construction module

FIG.5

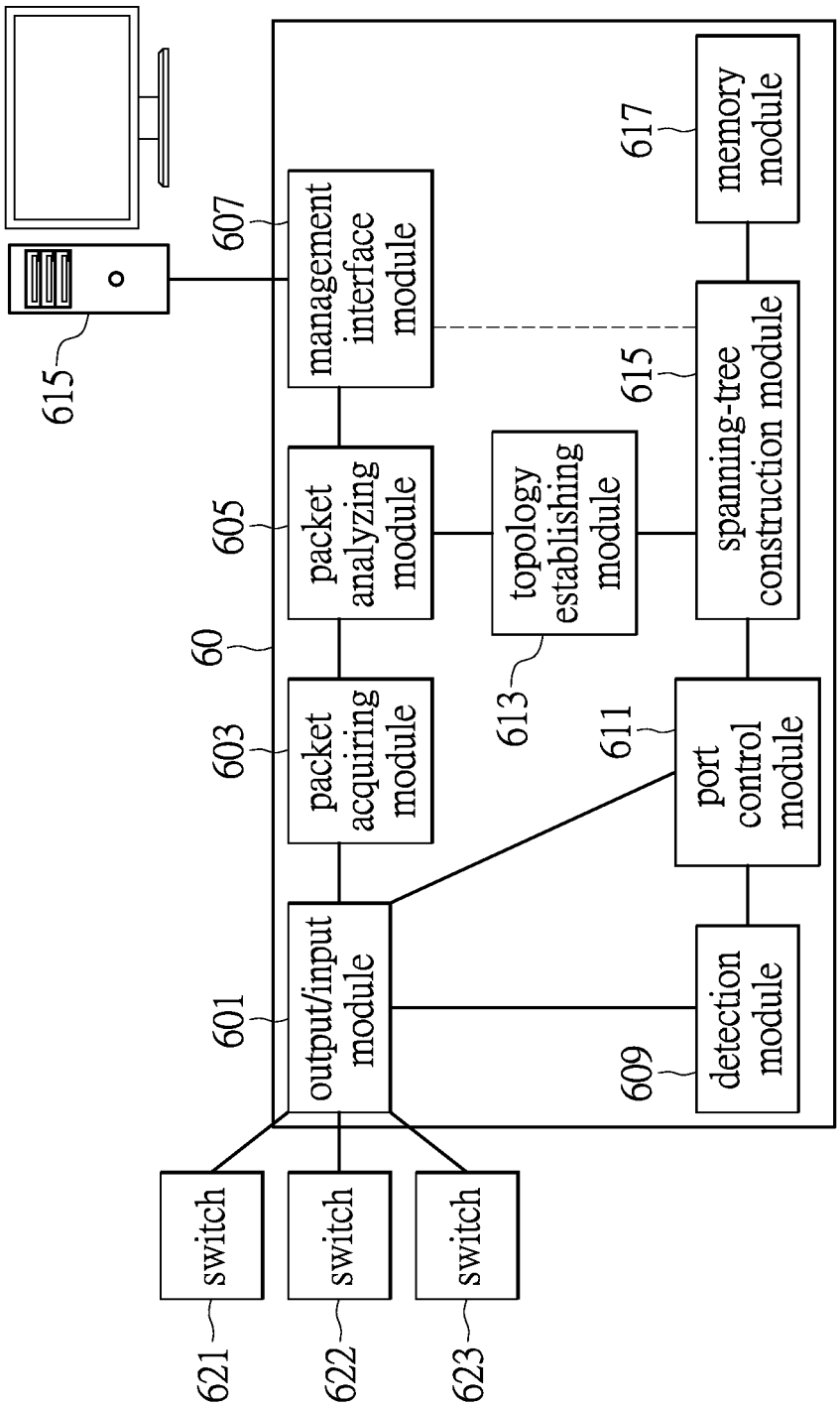

615
607
management interface module
617
memory module
605
packet analyzing module
topology establishing module
615
spanning-tree construction module
60
603
packet acquiring module
613
611
port control module
601
output/input module
609
detection module
switch
switch
switch
621
622
623

FIG.6

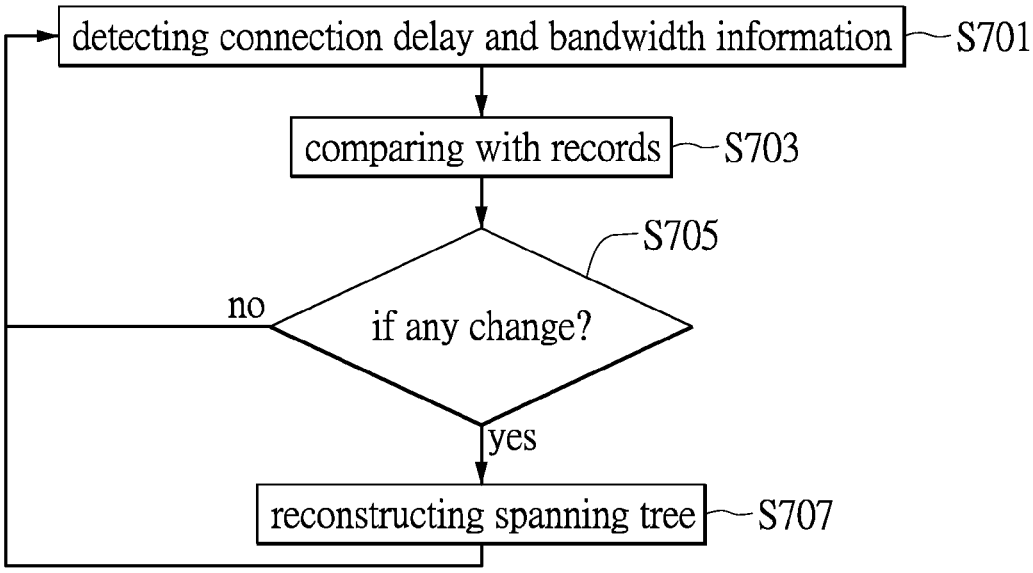

detecting connection delay and bandwidth information
S701
comparing with records
S703
S705
if any change?
no
yes
reconstructing spanning tree
S707

FIG.7

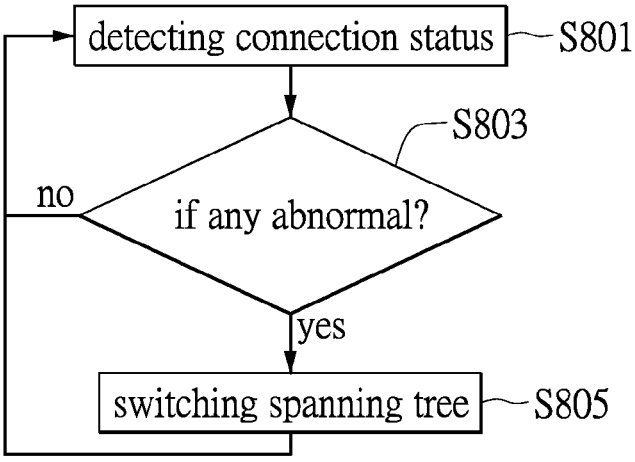

detecting connection status
S801
S803
if any abnormal?
no
yes
switching spanning tree
S805

FIG.8

METHOD FOR CONSTITUTING HYBRID NETWORK SPANNING TREES, METHOD OF REDUNDANCY, AND CONTROL SYSTEM THEREOF

BACKGROUND

[0001] 1. Technical Field

[0002] The present invention is related to a method for constructing spanning trees, a method of redundancy, and a system; in particular to the method for constructing optimal spanning trees in real time for a hybrid network system when abnormal condition occurs within the network system, and also to the method of redundancy and the control system.

[0003] 2. Description of Related Art

[0004] Software-Defined Networks (SDN) is a next generation network architecture that incorporates a centralized controller to act as a control plane of the switches of a traditional distributed network system. The architecture of the software-defined network allows the switches in the network to process the traditional data plane since the control plane is at the controller. The centralized controller provides the optimized control for the system.

[0005] The centralized architecture of software-defined network implements topology optimization and renders better routings by the controller. The communication between the controller and switches is made through standard and open protocols such as the OpenFlow protocol. The OpenFlow protocol allows the manufacturers to develop the compatible devices rather than using their own standards. The standardized architecture allows the network administrator to program or optimize applications of the controller due to the practical need. Therefore, the multi-functional application modules can be provided.

[0006] Thus, software-defined network is powerful and advantageous to the network development, and is able to dominate the future network systems. However, it is difficult to make SDN switches substitute for all the legacy network switches within a short period of time when the SDNs want to replace the legacy networks. The software-defined network may not be widespread so soon because the SDN switches are expensive and test for the substation requires great time. The centralized mechanism of management for the software-defined network may limit its network scale. Therefore, it requires a transition period for adjustment when the SDNs progressively substitute for the legacy networks. In the transition period, both the software-defined networks and the legacy networks coexist in a hybrid network.

[0007] In the hybrid network, the tangible network topology may exist loops due to fault tolerance is provided. The loops in the network may cause the notorious packet broadcast storm that will result in serious problem. Therefore, a spanning tree protocol is required to solve the packet broadcast storm problem. However, since the spanning tree protocol adapted to the software-defined network is not compatible to the spanning tree used in the legacy network, the spanning tree protocol for the legacy network does not function within the software-defined network. It is impossible to provide an overall spanning tree protocol over the topology of the hybrid network. The packet broadcast storm may still cause the problem in the loops of the hybrid network.

SUMMARY

[0008] For solving the problem of packet broadcast storm formed as connecting heterogeneous networks in the hybrid network, and providing management mechanism of the spanning trees, the disclosure is to provide a method for constructing spanning trees over hybrid network, method of redundancy, and a system thereof. The method and system are applicable to the hybrid network having at least one software-defined network and at least one non-SDN.

[0009] According to one aspect of the invention, in the method for constructing the hybrid network spanning trees, a controller of the software-defined network is utilized to collect network packets from both the SDN and the non-SDN. This hybrid network includes at least one node of SDN, and the node is connected with at least one node of the non-SDN. Next, the information of topology of the hybrid network can be obtained as resolving the identification data from the network packets. Therefore a virtual network topology can be created.

[0010] After that, the information of path delay and path bandwidth of the network for both SDN and non-SDN is obtained. The information is referred to when constructing all or part of the spanning trees for the hybrid network. Every spanning tree essentially attributes an average all-pair path delay and all-pair path bandwidth. A corresponding value with respect to every spanning tree is generated.

[0011] In another aspect, in the method, the OpenFlow protocol is incorporated in the software-defined network to collect information of topology of the software-defined network, further including information to the path delay and path bandwidth over every path. For the non-SDN, network packets of Bridge Protocol Data Unit (BPDU) issued by the traditional switch are referred to infer the spanning tree. The controller of SDN resolves identification information from the network packets of BPDU, and accordingly investigates the connections between the network sections of both the SDN and non-SDN. The controller also obtains the topology information of SDN. A whole topology for the hybrid network is generated.

[0012] Further, in a method of redundancy incorporating the method for constructing hybrid network spanning trees, it is firstly to sort the spanning trees based on the values corresponding to the spanning trees. When any abnormal condition occurs by detecting the network packets of the hybrid network, the sorting is referred to switch to the next spanning tree.

[0013] In a control system for the hybrid network, a packet acquiring module is one of the primary function modules and used to collect network packets from both SDN and non-SDN; a packet analyzing module is used to analyze the network packets obtained from the packet acquiring module so as to obtain the identification and path information; a topology establishing module is used to establish the topology for the hybrid network based on the information of topology obtained from the identification information retrieved by analyzing the network packets; and a spanning-tree construction module is used to estimate an average all-pair path delay and an average all-pair path bandwidth for every spanning tree in the hybrid network system. Every spanning tree has its corresponding value.

[0014] In order to further understand the techniques, means and effects of the present disclosure, the following detailed descriptions and appended drawings are hereby referred, such that, through which, the purposes, features

and aspects of the present disclosure can be thoroughly and concretely appreciated; however, the appended drawings are merely provided for reference and illustration, without any intention to be used for limiting the present disclosure.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015] FIG. **1**A shows a schematic diagram depicting a hybrid network system composed of SDN and the legacy network in one embodiment of the present invention;

[0016] FIG. **1**B shows a schematic diagram depicting the hybrid network system in one further embodiment of the present invention;

[0017] FIG. **1**C shows a schematic diagram depicting the hybrid network system according to one another embodiment of the present invention;

[0018] FIG. **2**A schematically depicts the framework of the hybrid network in one embodiment of the present invention;

[0019] FIG. **2**B shows a schematic diagram illustrating an exemplary spanning tree generated based on the topology of the hybrid network depicted in FIG. **2**A;

[0020] FIG. **3**A shows a schematic diagram of a topology of the hybrid network;

[0021] FIG. **3**B shows a schematic diagram illustrating an exemplary spanning tree generated based on the topology of the hybrid network depicted in FIG. **3**A;

[0022] FIG. **3**C shows a schematic diagram illustrating another exemplary spanning tree generated based on the topology of the hybrid network depicted in FIG. **3**A;

[0023] FIG. **4** shows a flow chart illustrating the method for constructing a spanning tree for a hybrid network in one embodiment of the present invention;

[0024] FIG. **5** shows a diagram illustrating function modules of the control system for constructing spanning trees for the hybrid network according to one of the embodiments of the present invention;

[0025] FIG. **6** shows another diagram illustrating function modules of the control system for constructing spanning trees for the hybrid network according to one further embodiments of the present invention;

[0026] FIG. **7** shows a flow chart depicting the method for reconstructing the spanning trees for the hybrid network in one embodiment of the present invention;

[0027] FIG. **8** shows a flow chart depicting the method of redundancy for the hybrid network incorporating the method for constructing spanning trees in one embodiment of the present invention.

DESCRIPTION OF THE EXEMPLARY EMBODIMENTS

[0028] Reference will now be made in detail to the exemplary embodiments of the present disclosure, examples of which are illustrated in the accompanying drawings. Wherever possible, the same reference numbers are used in the drawings and the description to refer to the same or like parts.

[0029] Before the software-defined networks (SDN) completely replace the traditional networks, i.e. non-SDN, a transitional period of time may be required during which the software-defined networks and the traditional networks need to co-exist. However, the mechanisms to construct spanning trees for the SDN and for the non-SDN respectively are different. That means the communication protocol adapted to constructing spanning trees for the non-SDN traditional network is inapplicable to the SDN and cannot solve the packet broadcast storm problem formed in the loop of the hybrid physical network topology. The present invention relates to the method for reconstructing the spanning tree instantaneously once any abnormal condition occurs, the method of redundancy, and their control system, and is also provided for a solution to solve the broadcast storm problem.

[0030] According to one embodiment in the disclosure of the present invention, the method for constructing spanning trees for a hybrid network is applicable to a network system combining two interconnected heterogeneous networks. The two different network systems are such as the software-defined network, hereinafter 'SDN' and others hereinafter 'non-SDN'. A control system of the SDN is able to collect the network packets from the various network sections, and construct new spanning tree after analyzing the information relating to the network packets. Accordingly, the new spanning tree solves the broadcast storm problem over the heterogeneous networks by disabling the redundant network links.

[0031] Reference is made to FIG. **1**A showing a schematic diagram depicting the hybrid network combining the SDNs (**11**, **13**) and the non-SDN (**12**) according to one embodiment of the present invention. In the diagram, a first SDN **11** is shown to have a network connection **101** to connect the non-SDN tradition network **12**. The network connection **101** bridges the nodes **111** and **112** respectively within two network sections. A second SDN **13** is connected with the traditional network **12** over another network connection **102** using the two respective nodes **113** and **114**. Thus, the topology formed over the two networks can successfully work without resulting in the packet broadcast storm problem.

[0032] FIG. **1**B shows another type of the network system. In addition to the mentioned system combining the first SDN **11** and the traditional network **12** using the connection **101**, another network connection **103** is used to link the nodes **115** and **116** respectively in the first SDN **11** and the traditional network **12**. Thus, the connections **101** and **103** may induce the packet broadcast storm problem between the two network sections **11** and **12**, and there is no way to avoid the packet broadcast storm problem under the conventional mechanism.

[0033] In one further embodiment, as shown in FIG. **1**C, the hybrid network includes two traditional networks **12** and **14** in between the mentioned first SDN **11** and the second SDN **13**. This more complex network system includes more network connections that may easily form the loops without intent. The possible network loops among the network sections may cause the packet broadcast storm problem.

[0034] Further, as shown in FIG. **1**C, no network loop forms over the network connections **101** and **102** among the first SDN **11**, the traditional network **12**, and the second SDN **13**. When a traditional network **14** is added and interconnected with two SDNs **11** and **13**, a network connection **104** is therefore established between a node **115** of the first SDN **11** and a node **117** of the non-SDN traditional network **14**. One the other end, another network connection **105** is formed between a node **118** of the traditional network **14** and a node **119** of the second SDN **13**. Those network connections **101**, **102**, **104** and **105** on this topology form a loop. Even though there is no loop formed within each network section, the whole network system now forms a

loop that may induce the packet broadcast storm problem. The packet broadcast storm problem may not be avoided since the broadcast network packets in the loop may still continue to loop over the whole topology.

[0035] With respect to the above-mentioned topologies that possibly form the network loops; the method for constructing hybrid network spanning trees is described in the disclosure. One of the objectives of the method is to construct a spanning tree for the hybrid network. In one embodiment, the spanning tree may be configured by an administrator. The spanning tree may be modified by the administrator who customizes the spanning tree based on the administrator's preference on the average path bandwidth or the average path delay.

[0036] Reference next is made to FIG. **2**A showing a schematic diagram depicting a framework of the hybrid network. The figure schematically shows a switch of SDN connected with another switch of non-SDN traditional network when the SDN**1** and SDN**2** interconnect with a traditional network N**1**. It is noted that the number of nodes and the topologies are not limited to the scope of the present invention.

[0037] The OpenFlow standard generally defines a communication protocol adopted by SDN, but fails to communicate with the traditional switch directly. Therefore, in accordance with the present invention, the switch within the SDN firstly broadcasts network packets over the network, and retrieves information from the received responsive packets. When the broadcast packets enter the traditional network, the packet broadcast storm problem may be induced once any loop is formed between the SDN and non-SDN. In the method for constructing hybrid network spanning trees in accordance with the present invention, an algorithm may be introduced to find out the redundant connections and disable these redundant connections in order to remove the loops. Therefore, the packet broadcast storm problem can be prevented.

[0038] At the left side of the diagram of FIG. **2**A, a software-defined network SDN**1**, hereinafter 'SDN**1**' is schematically shown; and the right side is another software-defined network SDN**2**, hereinafter 'SDN**2**'. Both software-defined networks SDN**1** and SDN**2** are connected with the intermediate traditional network N**1**. The circles shown within the network sections indicate the nodes such as switches. For example, the nodes **2011**, **2012**, **2013** and **2014** form the SDN**1**. The SDN**2** is composed of the nodes **2015**, **2016**, **2017**, **2018** and **2019**. The traditional network N**1** has the nodes **2111**, **2112**, **2113** and **2114**. The software-defined networks SDN**1** and SDN**2** are characterized by using a controller **20** connecting to the multiple nodes **2011**, **2012**, **2013**, **2014**, **2015**, **2016**, **2017**, **2018**, and **2019** in the software-defined networks SDN**1** and SDN**2** over a centralized topology. However, the non-SDN traditional network N**1** utilizes the mechanism of distributed management. Rather than the centralized management, the nodes, e.g. switches, in the traditional network N**1** exchange their messages for constructing routing table and exchanging packets.

[0039] According to the figure, there are loops formed among the network sections (SDN**1**, SDN**2**, and N**1**). A large loop is also formed over the whole network topology. For example, a first terminal node **201** located at the left side of the diagram is connected with the node **2012** of the SDN**1**; and a second terminal node **202** is connected with the node **2016** of the SDN**2**. When the first terminal node **201** issues packets, e.g. a "ping" command, to the second terminal node **202**, every node over this route for transferring the packets will re-generate broadcast packets under a specific network protocol, e.g. a learning bridge protocol. When these broadcast packets are generated, the simulation shows that the packet broadcast storm is instantaneously formed and almost damages the whole network system.

[0040] Next, in FIG. **2**B, when the method for constructing the hybrid network spanning tree is applied, the spanning tree constructed in the topology automatically removes the redundant routes and also destroys the loop. As FIG. **2**B shows, the packets will be delivered to the destination over a single route, that is, over the nodes **2012**, **2014**, **2112**, **2114**, **2018**, and **2016** in order as starting at the first terminal node **201** and ending at the second terminal node **202**. Thus no packet broadcast storm will be formed and spread over the whole network.

[0041] Under this topology, it shows that alternative routes exist between the first terminal node **201** and the second terminal node **202**. According to the method for constructing hybrid network spanning trees in accordance with the present invention, the controller **20** of SDN acquires the information relating to transmission delay and bandwidth from the network packets collected from network sections, and accordingly computes multiple spanning trees between the two terminal nodes **201** and **202**. The spanning tree automatically removes the redundant routes between the two terminal nodes **201** and **202**. Therefore, the packets can be efficiently delivered over the spanning tree, and avoids the packet broadcast storm problem. For example, the disabled network connections are such as the route between the node **2011** of SDN**1** and the node **2111** of the traditional network N**1**; the route between the node **2013** of SDN**1** and the node **2114** of the traditional network N**1**; the route between the node **2015** of SDN**2** and the node **2111** of the traditional network N**1**; and the route between the node **2019** of SDN**2** and the node **2113** of the traditional network N**1**.

[0042] In addition, since the network may suffer the situation of broken connection, in the method for constructing hybrid network spanning trees, a preferred alternate spanning tree can be prepared in advance for any possible broken connection. The method allows instantaneously switching to the alternate spanning tree when the switching is required. The network user will not be aware of the spanning tree switching. The process can be referred to the flow chart in FIG. **8**.

[0043] According to the above-mentioned embodiments, the method of the present invention is to disable the redundant network connections, and as well to construct an optimized spanning tree over the topology combining the SDN and the non-SDN. The optimization of the spanning tree is based on the requirements of average path bandwidth and average path delay as the network administrator's demands.

[0044] References are then made to FIGS. **3**A, **3**B and **3**C.

[0045] FIG. **3**A shows a schematic diagram of a hybrid network system. Several software-defined networks **31**, **33**, **35**, **36**, and **37** are directly connected with a controller **30**. The SDNs **31**, **33**, **35**, **36**, and **37** are also controlled under a centralized management mechanism using the controller **30**. The controller **30** employs a communication protocol defined by an OpenFlow standard. The controller **30** separates the control plane of the node of network, e.g. switch,

from its data plane. That means the controller **30** takes over the packet routing operation of the switch. The controller **30** manages the communication protocol between the controller **30** and the switch; computes the optimized route of the network; and controls data delivery of the switch through the OpenFlow standard.

[0046] FIG. **3**A schematically shows the topology of a network system combining the SDNs **31**, **33**, **35**, **36**, and **37** represented by solid-line circles, and non-SDN traditional networks **32**, **34**, **38**, and **39** represented by the dash-line circles. Every circle indicates a network section that includes multiple switches (not shown in the diagram). One or more connections may be used to link the adjacent network sections. In the diagram, all the solid-line-circled SDNs **31**, **33**, **35**, **36**, and **37** connect to the controller **30**, which manages packets transferring among the SDNs and constructs spanning trees thereof. The network system mixes the SDNs with the dash-line-circled traditional networks **32**, **34**, **38**, and **39**.

[0047] Every network section has one or more terminal nodes. For example, the plurality of terminal nodes **301**, **303**, **305**, **306** and **307** are the representative terminal nodes with respect to the SDNs **31**, **33**, **35**, **36**, and **37**. Each of the traditional networks **32**, **34**, **38** and **39** has its representative terminal node, such as the shown nodes **302**, **304**, **308** and **309**. As the network system operates, not only the controller **30** is in charge of processing packet transferring and path management among the nodes within the SDNs **31**, **33**, **35**, **36**, and **37**, but also managing the spanning trees constructed among the heterogeneous networks under the mechanism of the method of the present invention.

[0048] While the hybrid network is in operation, every terminal node **301**, **302**, **303**, **304**, **305**, **306**, **307**, **308**, **309** generates its own network packets. Performance of delivering the packets at every node may be influenced by each other. In the method for constructing the hybrid network spanning trees of the present invention, several parameters are introduced to the network system for evaluating the spanning trees created under different conditions. At least the information of source and destination regarding the packets can be acquired from the packets collected from network. Through the information retrieved from the packets, the path bandwidth and path delay for the network system can be obtained. In particular, in the method, a computation of average path bandwidth and average path delay is required. References are made to FIG. **3**B and FIG. **3**C to indicate forming the spanning trees based on different information such as average path bandwidth and average path delay respectively.

[0049] In an exemplary example, based on an administrator's configuration, the spanning tree for a network system may be made based on a more balanced requirement of higher average path bandwidth and smaller average path delay. The related spanning tree as shown in FIG. **3**B is such as the route arranged over multiple terminal nodes. It is noted that the diagram ignores the routing paths among the nodes within every network section.

[0050] Rather than FIG. **3**B, the spanning tree shown in FIG. **3**C requires different weights applied to the average path bandwidth and the average path delay. That means the construction of a spanning tree may only require higher average path bandwidth but ignore the average path delay. The spanning tree may also require smaller average path delay but without average path bandwidth requirement. Those requirements may be applied to various network systems. For example, the network system in charge of audio/video communication requires much smaller average path delay with high quality of network latency. Further, the network system with primary purpose of data transmission requires higher average path bandwidth since it uses high network bandwidth. Further, the network system may require balanced configuration of the average path delay and bandwidth since it provides comprehensive services. The flexibility of network system allows the administrator to tune ratio between the average path bandwidth and the average path delay, or their respective weights according to practical purpose.

[0051] The mentioned technology is to construct spanning trees among the heterogeneous networks according to the information relating to the path bandwidth and path delay in the network system. A control host of the hybrid network system is introduced to manage packet transferring over the whole network. The controller of SDN acts as the control host for managing the network system.

[0052] Reference is made to FIG. **4** showing a flow chart depicting the method for constructing the hybrid network spanning tree in one embodiment of the present invention.

[0053] At first, as in step S**401**, a controller is provided to act as the controller for the software-defined network. The controller is used to collect network packets from the network interfaces of the nodes within the network system periodically, for example, using a Link Layer Discovery Protocol (LLDP), such as in step S**403**. After inquiring identification information from the network packets, a topology of the whole network can be obtained. In step S**405**, the information for the whole network allows creating a virtual network topology.

[0054] The Link Layer Discovery Protocol (LLDP) is a protocol to establish network data link that allows the network equipment to acquire information of the adjacent equipment within the network system. The information is such as Internet Protocol address, and description of equipment and its functionality. In addition, the identification information with respect to the packets transmitted among the nodes is obtained, and also the other information such as delay and bandwidth related to the network can be obtained using the communication protocol operated in SDN, such as in step S**407**.

[0055] In an exemplary example, through OpenFlow command the controller of SDN can acquire the information relating to path delay and bandwidth over every link in SDN. For the traditional switches that are able to perform data transmission and instructions constituting the non-SDN, the controller of SDN retrieves the information regarding the traditional switches from the packets delivered to the switches of SDN using Bridge Protocol Data Unit (BPDU). These types of BPDU packets are the hello packets used by the spanning tree protocol. The BPDU packets are periodically delivered to exchange messages at the bridges within the network. The controller of SDN accordingly collects the information of traditional switches for constructing the spanning trees. The identification information such as Root ID with respect to BPDU packets can be retrieved for determining the connection status between all the SDNs and the non-SDNs. The BPDU packets allow the controller to receive the information between the network sections. The information between the network sections can be in combi-

nation with the topology information of SDN based on LLDP for resolving the whole topology for the hybrid network system.

[0056] Thus the controller of SDN is not only able to acquire information of path delay and bandwidth of SDN, but also acquire the information of network sections according to identification information resolved from BPDU packets. Next, in step **S409**, the information for the whole network system allows constructing spanning trees thereof.

[0057] The information with respect to the network section can be obtained from the identification information of BPDU packets. When the identification information from packets is determined as the same, the packets belong to the same network section. Therefore the controller of SDN can determine the connection status between the SDN and the non-SDN traditional network. Further, even though the controller of SDN is not allowed to explore the traditional network, the controller is still able to estimate connection status according to the path cost resolved from the BPDU packets. It is noted that the path cost of BPDU packets is used to estimate a path distance between the terminal node of the traditional network and the port of SDN switch receiving the BPDU packets. In the meantime, the controller periodically obtains information relating to the topology of the SDN under the Link Layer Discovery Protocol when the SDN switch explores the network topology under LLDP. The controller of SDN then computes the delay information as the packets are delivered over the traditional network using LLDP.

[0058] In the method, the information of connections among the heterogeneous networks is used to form the topology of the hybrid network, and accordingly construct all or part of possible spanning trees. The optimal spanning tree for the hybrid network system can be obtained by disabling the redundant routes. Further, a utility function is introduced to evaluate every spanning tree. Such as in step **S411**, the utility function is provided to compute a value corresponding to every spanning tree. The all or part of spanning trees can be sorted according to their corresponding values, such as in step **S413**. The optimal spanning tree is therefore obtained. Based on this rank, a redundancy for the spanning trees for the hybrid network system is achieved, one of the objectives of the present invention.

[0059] The utility function is described as follows. All the spanning trees for the topology of the network system are computed by an algorithm in the SDN controller. A conventional spanning tree protocol, e.g. a data-link layer communication protocol (the second layer) under an Open System Interconnection (OSI) network model, may be used to construct the spanning tree. The spanning tree guarantees that the network system has no loop to form the packet broadcast storm. Further, the algorithm performed in the SDN controller gives every spanning tree a corresponding value. The value is computed by referring to the numerical parameters such as the average path delay and/or average path bandwidth. The parameters are such as the path delay and path bandwidth over the route of the hybrid network using the OpenFlow protocol and BPDU packets. Thus every spanning tree can be evaluated according to one of or both the path delay and path bandwidth. It is noted that a conversion, e.g. normalization, may be applied to the two numerical values to be under the same grade since they have difference ranges of values.

[0060] For example, when the highest value of the average path bandwidth is set to 100 and the lowest value thereof is set to 0, the remaining values are calculated proportionally. The calculation allows every numerical value of the path bandwidth to be in between 0 to 100. Similarly, the lowest value of the average path delay is set to 100, and the highest value thereof is set to 0. The remaining values are calculated proportionally. Therefore every spanning tree can be evaluated by applying the two types of numerical values within 0 to 100. The spanning tree can be graded using the average path delay and average path bandwidth.

[0061] In addition, it is to weigh the average path delay and the average path bandwidth for every spanning tree according to one of the embodiments of the present invention. It is thereby to configure relative emphasis degrees of performance indexes respectively for the average path delay and the average path bandwidth for every spanning tree. Noted that the administrator can set the weighting to the numerical values via a management interface. In one embodiment, the administrator is allowed to set parameters to the SDN controller via an API, the application program interface. The approach allows the administrator to set a weight ratio. For example, 'x %' indicates a weight ratio; the utility function is formulated as (x %*grade of average path delay)+((100−x) %*grade of average path bandwidth). The highest score of the utility function in a rank derives an optimal spanning tree.

[0062] Reference is next made to FIG. **5** depicting the main function modules of the control system for implementing the method for constructing hybrid network spanning trees in accordance with the present invention. Those function modules may be implemented by software, firmware, or hardware. The function module is such as a packet acquiring module **501** which is used to collect network packets from SDN and non-SDN tradition network. The collected packets are resolved by a packet analyzing module **503** for acquiring at least the identification information and path information. Based on the identification information in the network packets, the information relating to topology for the hybrid network system can be obtained. The function module is such as a topology establishing module **505** used to establish the topology of the hybrid network according to the information obtained through the identification information resolved by the packet analyzing module. The information also allows estimating the path delay and bandwidth. The function module is such as a spanning-tree construction module **507** used to construct all or part of spanning trees for the hybrid network according to an average path delay and an average path bandwidth for every path estimated from the path information. A value with respect to every spanning tree is obtained.

[0063] FIG. **6** shows another schematic diagram describing the function module of the control system according to one of the embodiments.

[0064] The controller **60** indicates the SDN controller including the software, firmware, or hardware-implemented function modules. An output/input module **601** is used to connect with switches **621**, **622**, **623**. A packet acquiring module **603** is used to collect packets from the switches **621**, **622**, **623** located at the border between the network sections. The packet acquiring module **603** collects the packets from at least one SDN and the BPDU packets from at least one non-SDN. A packet analyzing module **605** is provided to resolve the information of network packets, such as root ID.

The identification retrieved from the packets allows the system to get the topology after exploring the whole network system. Further, a topology establishing module **613** is used to create a virtual topology that allows a spanning-tree construction module **615** to construct spanning tree(s) over the topology, especially all possible spanning trees for the whole network system that can be constructed. The information relating to the topology can be temporarily buffered in a memory module **617**. The memory module **617** is used to record the information relating to the topology, spanning tree, and delay and bandwidth over every route. The information regarding the construction of spanning tree is associated with the average path delay, the average path bandwidth, and the related weights. The information may also be used to compute the value with respect to every spanning tree. The corresponding value is the basis to sort the spanning trees and obtain the optimal spanning tree.

[0065] When the network system operates under a specific spanning tree, a port control module **611** of the SDN controller is used to conduct port control according to path information of the spanning tree. When a specific spanning tree is in operation, one or more ports may be specified to be disabled. The controller **60** is able to manage the port of a node of SDN, and thereby disabling redundant network routes for preventing loops. The controller **60** has a management interface module **607** which is provided for an administrator to manage the channel to the controller **60** and the control system thereof using a management computer **615**. The administrator can set weights to the spanning trees through the spanning-tree construction module **615**.

[0066] Because the network may meet some accidents such as line fault resulting in breaking communication, the method of the present invention renders a mechanism of redundancy. For example, the SDN controller periodically detects change of the network topology, and prepares one or more backup spanning trees ready for redundancy. The backup spanning tree replaces the current spanning tree once the network connection is broken or in congestion. In an exemplary example, the currently-used spanning tree topology can be rapidly switched to one backup optimal spanning tree once any line faults.

[0067] In an exemplary example, the controller **60** has a detection module **609** which is used to detect any abnormal connection in the network system from the packets retrieved by the packet acquiring module **603**. In the meantime, the method of redundancy using the hybrid network spanning tree is utilized to cure the fault caused by the abnormal connection. Reference is made to FIG. **8** showing a flow chart describing the method for constructing hybrid network spanning trees.

[0068] Firstly, in the method, the path information carried with the network packets can be used to detect the connection status, e.g. path delay, bandwidth, and any broken route (step S**801**). In step S**803**, it detects if any abnormal condition exists within the network system. In an exemplary example, the records in the memory module **617** or other storage medium, or a threshold set are used to determine if the path bandwidth is too small, the path delay is too long, or any change of the connection. The step of detection goes on, as shown in step S**801**, when the detection result is within a normal range as compared with the history records or a threshold. Otherwise, if any abnormal condition is found, e.g. broken connection, such as in step S**805**, a backup spanning tree is switched on according to the rank as evaluated based on the values of the spanning trees. It is noted that the detection process is performed periodically or constantly.

[0069] Moreover, the controller **60** performs the method of constructing spanning trees according to the path delay and path bandwidth, as referring to the flow chart in FIG. **7**.

[0070] In step S**701**, the detection module **609** of the controller **60** is used to detect the path delay and bandwidth. The detection result is compared with the records in the memory module **607** or storage medium, as shown in step S**703**. The controller **60** then determines if any change occurs to the average path delay or average path bandwidth within the network, as shown in step S**705**. The current spanning tree is still in operation when there is no change detected. The detection also continues. Otherwise, in step S**707**, the system will ask for re-constructing the spanning tree for maintaining the system operating using the optimal spanning tree.

[0071] Thus, disclosure in accordance with present invention is related to a method for constructing hybrid network spanning trees, a method of redundancy, and a control system. The SDN controller is especially incorporated to implement the method and used to integrate the network messages over SDN and the other network connected to SDN. The loops among the heterogeneous networks can be avoided when removing the redundant network connections, so as to avoid the packet broadcast storm problem. The spanning trees among the nodes over the heterogeneous networks are constructed by referring to the parameters such as the path delay and path bandwidth. An optimal spanning tree can be created over the hybrid networks composed of the SDN and the traditional networks, and therefore constructing the spanning trees over the hybrid network without any modification of the current systems and the traditional switches.

[0072] The above-mentioned descriptions represent merely the exemplary embodiment of the present disclosure, without any intention to limit the scope of the present disclosure thereto. Various equivalent changes, alternations or modifications based on the claims of present disclosure are all consequently viewed as being embraced by the scope of the present disclosure.

What is claimed is:

1. A method for constructing spanning trees over a hybrid network, applied to the hybrid network established by combining at least one SDN and at least one non-SDN, comprising:

providing a controller used to collect network packets from at least one SDN and from at least one non-SDN; wherein the SDN includes at least one node which is connected with at least one node in the non-SDN;

by resolving identification information from the network packets, acquiring information of a topology of the hybrid network, so as to establish a virtual network topology;

retrieving information relating to path delay and path bandwidth of the at least one SDN and the at least one non-SDN;

constructing all or part of spanning trees for the hybrid network, in which every spanning tree is attributed to have an average path delay and an average path bandwidth, and accordingly with a corresponding value.

2. The method according to claim **1**, wherein the controller originally operates for the SDN.

3. The method according to claim 2, wherein the SDN utilizes an OpenFlow protocol to retrieve information relating to path delay and path bandwidth for every path for the SDN.

4. The method according to claim 2, wherein the controller periodically obtains information relating to the topology of the SDN under a Link Layer Discovery Protocol.

5. The method according to claim 4, wherein the controller of the SDN collects network BPDU packets sent by traditional switches to a switch of the SDN, and resolves identification information, so as to determine connection conditions between the SDNs and the non-SDNs; in combination with the topology information of the SDN obtained by the controller through the Link Layer Discovery Protocol, information relating to the topology of the whole hybrid network system.

6. The method according to claim 5, wherein, a path distance between a terminal node within the non-SDN and a port of the switch of the SDN is estimated, wherein the path distance of non-SDN is estimated according to a path cost analyzed from network packets of the Bridge Protocol Data Unit.

7. The method according to claim 1, further comprising sorting the spanning trees based on the value corresponding to every spanning tree, so as to obtain an optimal spanning tree.

8. The method according to claim 7, further comprising weighting the average path delay and the average path bandwidth for every spanning tree, so as to configure relative emphasis degrees of performance indexes respectively for the average path delay and the average path bandwidth.

9. A method of redundancy for hybrid network spanning trees, adapted to a hybrid network integrating at least one SDN and at least one non-SDN, comprising:

utilizing the method for constructing spanning trees for the hybrid network to construct all or part of spanning trees for the hybrid network; wherein corresponding value of every spanning tree is obtained according to an average path delay and an average path bandwidth, and sorting the all or part of spanning trees; and

switching to a next spanning tree when any abnormal condition is detected from received network packets.

10. The method of redundancy according to claim 9, further comprising determining if the path has too small bandwidth, too long delay, or is broken according to path information carried by the network packets.

11. The method of redundancy according to claim 9, further comprising weighting the average path delay and the average path bandwidth for every spanning tree, so as to configure relative emphasis degrees of performance indexes respectively for the average path delay and the average path bandwidth.

12. A control system for hybrid network spanning trees, comprising:

a packet acquiring module used to collect network packets from at least one SDN and at least one non-SDN; wherein the SDN includes at least one node which is connected with at least one node of the non-SDN;

a packet analyzing module used to resolve identification information and path information from the network packets collected by the packet acquiring module;

a topology establishing module used to establish a topology of the hybrid network according to information of the topology obtained through the identification information resolved by the packet analyzing module; and

a spanning-tree construction module used to construct all or part of spanning trees for the hybrid network according to an average path delay and an average path bandwidth for every path estimated from the path information, so as to obtain a value with respect to every spanning tree.

13. The system according to claim 12, further comprising an output/input module connected to at least one switch of the SDN.

14. The system according to claim 12, further comprising a port control module used to conduct port control according to the path information of the spanning tree when the hybrid network operates under one of the spanning trees.

15. The system according to claim 12, further comprising a management interface module provided for an administrator to manage the control system using a management computer.

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