~~[DESCRIPTION]~~

~~[Title]~~

COMMUNICATION SYSTEM, CONTROL APPARATUS, CONTROL METHOD AND PROGRAM

TECHNICAL FIELD~~[Technical Field]~~

[0001]

(Reference to Related Application)

This application is based upon and claims the benefit of the priority of Japanese Patent Application No. 2012-221482 filed on October 3, 2012, the disclosure of which is incorporated herein in its entirety by reference thereto.

The present invention relates to a communication system, a control apparatus, a control method and a program. In particular, the invention relates to a communication system, a control apparatus, a control method and a program, where a network is centrally controlled by the control apparatus.

BACKGROUND~~[Background]~~

[0002]

In recent years, technology known as OpenFlow has been proposed (see Non Patent Literature (NPL) 1 and 2). In OpenFlow, communication is taken as end-to-end flow, and path control, failure recovery, load balancing, and optimization are performed on a per-flow basis. An OpenFlow switch as specified in Non Patent Literature 2 is provided with a secure channel for communication with an OpenFlow controller, and operates according to a flow table in which appropriate addition or rewriting is instructed by the OpenFlow controller. In the flow table, for each flow there are definitions of sets of match conditions (Match Fields) for collation with packet headers, flow statistical information (Counters), and instructions (Instructions) that define processing content (refer to "4.1 Flow Table" in Non Patent Literature 2).

[0003]

For example, when an OpenFlow switch receives a packet,

a search is made for an entry having a match condition (refer to "4.3 Match Fields" in Non Patent Literature 2) that matches header information of the received packet, from the flow table. As a result of the search, in a case where an entry matching the received packet is found, the OpenFlow switch updates the flow statistical information (Counters) and also implements processing content (packet transmission from a specified port, flooding, dropping, and the like) described in an Instructions field of the entry in question, for the received packet. On the other hand, as a result of the search, in a case where an entry matching the received packet is not found, the OpenFlow switch transmits a request for entry setting, to the OpenFlow controller via the secure channel, that is, a request (Packet-In message) to transmit control information for processing the received packet. The OpenFlow switch receives a flow entry determined by processing content and updates the flow table. In this way, the OpenFlow switch preforms packet forwarding using entries stored in the flow table as control information.

[0004]

Patent Literature (PTL) 1 discloses an optical network system provided with optical path establishing means, and configured from a plurality of optical edge routers that connect an external IP network to an optical network, and a plurality of optical cross-connect devices provided with switching means for connecting between the optical edge routers by optical paths on an optical path basis.

~~[Citation List]~~

~~[Patent Literature]~~

[0005]

[PTL 1]

International Publication No. WO2004/071033

~~[Non Patent Literature]~~

[0006]

[NPL 1]

Nick McKeown and seven other authors, "OpenFlow: Enabling Innovation in Campus Networks", [online], [Search performed on July 13, 2012], Internet <URL: http://www.openflow.org/documents/openflow-wp-latest.pdf>

[NPL 2]

"OpenFlow Switch Specification" Version 1.1.0. Implemented (Wire Protocol 0x02), [online], [Searched performed on July 13, 2012], Internet <URL:http://www.openflow.org/documents/openflow-spec-v1.1.0.pdf>

SUMMARY

~~[Summary]~~

~~[Technical Problem]~~

[0007]

It is to be noted that the respective disclosures of the abovementioned cited technical literature are incorporated herein by reference thereto. The following analysis is given according to the present invention.

[0008]

In a centrally controlled network as represented by the OpenFlow network of Non Patent Literature 1 or 2, detailed control is possible. At this time, if a destination to accommodate communication flows received by a communication apparatus belonging to a specific layer (for example, a network layer) is determined without giving consideration to a packet forwarding state of a lower layer thereof (for example, a data link layer), there is a possibility of communication flows in the lower layer being unevenly distributed. In the lower layer, if the communication flows are unevenly distributed, while adequate bandwidth is secured for the specific communication flows, efficient operation of the network is obstructed due to adequate bandwidth not being secured for other communication flows and the like.

[0009]

Therefore, it is an object of the present invention to

provide a communication system, a control apparatus, a control method and a program, which contribute, in a centrally controlled network where control targets are expanded, to efficiently operating the overall network.

[0010]

It is to be noted that, by providing functionality equivalent to an OpenFlow switch of Non Patent Literature 1 or 2, to an optical cross-connect device and optical edge router of Patent Literature 1, it is possible to build an optical IP network that may perform path control at a fine granularity level. However, Patent Literature 1 stops at disclosing technology for individual path control of an IP network and an optical network, and there is no disclosure of technology for realizing efficient operation of an overall network integrating both thereof.

~~[Solution to Problem]~~

[0011]

According to a first aspect of the present invention there is provided: a communication system comprising: a control apparatus that controls communication apparatuses included in a hierarchical network, and a first communication apparatus that forms links in a first layer of the network and also performs processing related to communication flows based on a first processing rule (i.e., packet handling rule, termed herein as "packet handling operation"); wherein the control apparatus determines a destination to accommodate communication flows specified according to the first packet handling operation, based on information related to a second layer that differs from the first layer.

[0012]

According to a second aspect of the present invention there is provided a control apparatus that determines a destination to accommodate communication flows via a first communication apparatus that forms links in a first layer of a

~~[Advantageous Effects of Invention]~~

[0015]

According to the respective aspects of the present invention, there is provided a communication system, a control apparatus, a control method and a program for the control apparatus, which contribute, in a centrally controlled network in which control targets are expanded, to efficiently operating the overall network.

BRIEF DESCRIPTION OF THE DRAWINGS~~[Brief Description of Drawings]~~

[0016]

[Fig. 1]

FIG. 1 is a diagram for describing an outline of an exemplary embodiment.

[Fig. 2]

FIG. 2 is a diagram showing an example of a configuration of a communication system according to a first exemplary embodiment.

[Fig. 3]

FIG. 3 is a diagram showing an example of a configuration of connections between OpenFlow switches 10-1 and 10-2 shown in FIG. 2.

[Fig. 4]

FIG. 4 is a diagram showing an example of an internal configuration of an OpenFlow switch 10.

[Fig. 5]

FIG. 5 is an example of a table set in a table DB 13 of the OpenFlow switch 10-1.

[Fig. 6]

FIG. 6 is a diagram showing an example of an internal configuration of a packet transport node 50.

[Fig. 7]

FIG. 7 is an example of a table set in a table DB 13 of a packet transport node 50-1.

[Fig. 8]

a TCP/IP flow of ID44 with respect to FIG. 26.

[Fig. 30]

FIG. 30 is a diagram summarizing maximum values and average values calculated for each pseudo line.

[Fig. 31]

FIG. 31 is a diagram showing an example of respective parameters for optical fiber cables configuring the network shown in FIG. 24.

[Fig. 32]

FIG. 32 is a diagram summarizing bandwidth estimated values for each optical fiber cable used by the respective pseudo lines.

PREFERRED MODES~~[Description of Embodiments]~~

[0017]

First, a description is given concerning an outline of an exemplary embodiment using FIG. 1. It is to be noted that reference symbols in the drawings attached to this outline are added to respective elements for convenience, as examples in order to aid understanding, and descriptions of the outline are not intended to limit the invention in any way.

[0018]

As described above, in a centrally controlled network in which control targets are expanded, a communication system is desired that efficiently operates the overall network.

[0019]

Thus, as an example, the communication system shown in FIG. 1 is provided. The communication system shown in FIG. 1 includes a control apparatus 100 that controls communication apparatuses included in a hierarchical network, and first communication apparatus 101 that form links in a first layer of the network and perform processing related to communication flows based on a first processing rule (i.e., packet handling operation). The control apparatus 100 determines destinations for accommodating communication flows specified according to

flows related to the optical fiber cable 7 corresponding to the optical path 7, is 2. The number X of TCP/IP flows related to other optical fiber cables is 1. The receive window W, round trip delay time R and packet loss rate P related to TCP/IP flows accommodated by the respective optical fiber cables are equivalent. Respective numerical values thereof are as shown in FIG. 31. Note that the link bandwidth of optical fiber cables 3, 6 and 8 is smaller than that of other optical fiber cables (1/10 of the link bandwidth of other optical fiber cables). It is to be noted that the values of respective parameters shown in FIG. 31 are exemplary, and there is no limitation to these values.

[0153]

The path/action calculation unit 24 of the control apparatus 20c calculates estimated values for bandwidth for each optical fiber cable used by respective optical paths, using information related to the respective optical fiber cables, as shown in FIG. 31.

[0154]

FIG. 32 is a diagram summarizing bandwidth estimated values for each optical fiber cable used by the respective pseudo lines. After calculating the bandwidth estimated values, the path/action calculation unit 24 calculates the total of bandwidth estimated values of the optical fiber cables used by the respective pseudo lines, for each pseudo line. Thereupon, as shown in FIG. 32, the total of the bandwidth estimated values for pseudo line 1 is 0.4; the total of the bandwidth estimated values for pseudo line 2 is 0.4; and the total of the bandwidth estimated values for pseudo line 3 is 3. The path/action calculation unit 24 determines pseudo line ~~3~~ 1 or 2 that has the smallest total of bandwidth estimated values, as a pseudo line to accommodate an unknown TCP/IP flow.

[0155]

In the communication system according to the present

embodiments and examples may be made within the bounds of the entire disclosure (including the scope of the claims) of the present invention, and also based on fundamental technological concepts thereof. Furthermore, various combinations and selections of various disclosed elements (including respective elements of the respective claims, respective elements of the respective exemplary embodiments and examples, respective elements of the respective drawings, and the like) are possible within the scope of the claims of the present invention. That is, the present invention clearly includes every type of transformation and modification that a person skilled in the art can realize according to the entire disclosure including the scope of the claims and to technological concepts thereof. In particular, with regard to numerical ranges described in the present specification, arbitrary numerical values or small ranges included in the relevant ranges should be interpreted to be specifically described even where there is no particular description thereof. It is to be noted that in the disclosure of the present application, elements represented in the singular form may also represent pluralities, as necessary. This point is based on the characteristics of the Japanese language.

~~[Reference Signs List]~~

[0159]

10, 10-1 to 10-3 OpenFlow switch

11 communication unit

12 table management unit

13 table database (table DB)

14 forwarding processing unit

20, 20a to 20c, 100 control apparatus

21 network configuration management unit

22 network configuration database (network configuration DB)

23 control message processing unit

24 path/action calculation unit

25 network path database (network path DB)