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CASCADE FAILURE ON SDN AS INTERDEPENDENT NETWORKS

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ABSTRACT

In conventional network science, we have considered the network as a single graph so that analyzed its characteristics. As a result, "scale-free" and "small-world" were discovered. However, it can be thought that the network exists not as a single, but as it is related to each other. The relationship between the networks makes a phenomenon that can't be explained by looking at a single network. A representative example of this phenomenon is the massive blackout that occurred in Italy in 2003. This is the incident that was caused by the mutual dependence between the electricity grid and the control network forming the electric power network. When constructing a network, it is common to make it resistant to failures. Therefore, we want to eliminate the possibility that the fault tolerance of the system will decrease due to the relationship between the networks. Then, in this research, we propose the model of occurrence and propagation of faults on interdependent networks, which is one example of networks that exist in relation to each other. Also, as an example of an interdependent network, we refer to software defined network (SDN).

KEYWORDS

Interdependent Networks, Software Defined Network, Cascade Failure

1. INTRODUCTION

Each network is also a component of a large system, and interaction exists between component networks. The interaction causes a phenomenon, which cannot be imagined if you look at only a single layer network. An example is a massive blackout in Italy in 2003. The Italian power system at the time consisted of a power grid comprised of power stations and substations, and a control network comprised of servers and routers. These were dependent on each other in terms of power and control. Failure of a node in one layer caused failure of a node in the other layer. As a result, a cascade failure occurred.

Since Buldyrev has dropped this large-scale blackout into a mathematical model, researchers on multilayer networks with interaction have been actively conducted. As the research progresses, the multilayer networks are divided into "multiple networks" whose relationships between networks are inter-network relations are the same as intra-network relations, "interdependent network" with the dependency between networks and "interaction networks" which defined a single layer network in another form. In this research, we focused on interdependent networks, because it has a property that cannot be convolved into a single layer network.

Research on interdependent networks has just started and there are many issues to be addressed. To elucidate such issues, we conducted a study on cascading failure on SDN. It can be said that SDN is one example of a real interdependent network because there is the dependency between controllers having the role of control and switches having the role of packet transfer. Furthermore, considering the implementation of SDN using Network Function Virtualization (NFV), which is a mechanism for implementing network equipment functions as a software on a general purpose server, the system can be said to be an interdependent network consisting of a physical network and a virtual network.

In this paper, we describe the interdependent networks in Section 2, and the basic concept of SDN in Section 3. Next, in Section 4 and 5, we propose a failure occurrence model and consider the cause of occurrence. Finally, in Section 6, we present a summary and problems of this research.

2. INTERDEPENDENT NETWORKS

In this section, we describe the multilayer network dealt with in this research.

Multilayer networks are a concept for discussing the relationship between networks proposed by Wang et al. Examples of multilayer networks include a power-based network formed by power stations and substations, and a communication-based network formed by servers and routers. Power stations and substations are managed by servers so that operate efficiently as a whole, and servers and routers need to be supplied with power from the power stations. Therefore, if either were missing, the whole system would not function.

In multilayer networks, single layer networks are called layer and the relationship between layers is expressed using inter-layer links representing the relationship between the nodes between the layers. Links in the layer are called intra-layer links. It can be classified as follows depending on the meaning of inter-layer links and duplication of nodes of each layer. Wang defined as follows.

Multiplex networks

Each layer has the same set of nodes (or an overlap of fraction nodes) but different links among them. An example is an airline network for each airline.

Interdependent networks

Each layer typically has different types of nodes, and there are dependency links (not physical connections) between the nodes in different layers. An example is the aviation network and its corresponding navigation networks in logistics.

Interconnected networks

Each layer typically has different types of nodes, and there are actual physical links between the nodes in different layers. An example is a network of protein interactions.

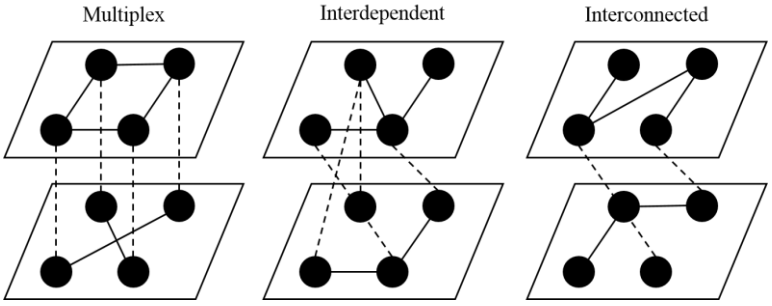

Figure 1. Type of multilayer network: The solid line represents an intra-layer link, and the broken line represents an inter-layer link

Among these networks, interdependent networks have the property that they cannot be convolved into a single layer network due to its inter-layer links.

In interdependent networks, a cascade failure, which is a phenomenon in which a chain fault spreads to the entire system due to local failure and interruption has already been observed. This is a massive blackout occurring in Italy in 2003. There was a dependence relation between the electric power network and the control network which is comprised of the electric power system. The failure spread in a form in which a failure on one side induced a failure in the other. Since both network structures had scale-free, fault tolerance was supposed to be guaranteed, but the fault tolerance was lost due to the influence of inter-layer links.

3. CASCADE FAILURE ON SOFTWARE DEFINED NETWORKS

Software defined networks (SDN) is an architecture that separates routing control and packet transfer functions. Since it is essential that both functions exist, SDN can be regarded as an interdependent network. A cascade failure occurrence model when this SDN is viewed as a single layer network has already been proposed. In this model, multiple controllers is placed for load distribution, and in the event of failure of a controller, the system will survive in the way the neighboring controller assumes control of the switch that the failed controller dominated. At this time, there is a possibility that the load of the controller that

underwent the load exceeds the capacity and fails. This failure can also cause overloading of another controller. In the model, we focus only on a connection between nodes.

In the interdependent network, an influence of the inter-layer link is significant, and there is possibility that it can cause unpredictable phenomena if we look at one layer. However, research on interdependent networks has only just begun, and the unknown part is still large. Also, although a cascade failure occurrence model in SDN has been proposed, SDN is regarded as a single layer network to the last. Then we cannot pay attention to the dependency relationship between the nodes, it can't be said that it is modeling the real network. Therefore, in this research, we propose a model of cascade failure occurrence which sees SDN as interdependent networks.

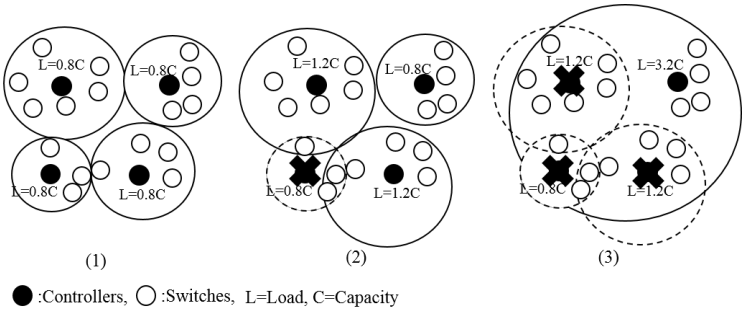

Figure 2. A cascading failure in a SDN: (1) the network runs normally with a load of each controller is 80% of its capacity; (2) one controller fails and the load is redistributed to other controllers, whose load are then exceeding their capacities; (3) the controllers whose load exceeds their capacities fail and the last controller takes all the load in the network and its load exceeds its capacities

4. PROPOSED MODEL

In this section, we propose a model of cascade failure occurrence on SDN using NFV.

4.1 Network Overview

We consider a network in which virtual controllers and virtual switches are arranged in data centers using NFV. The virtual device can exist only by providing a platform from the corresponding data center. Also, it can be said that the data center depends on the virtual controller. This is because packet transfers in the data center are performed by the virtual switches that depend on the virtual controller. Therefore, it can be said that there is an interdependence relationship between the virtual controller and the data center.

In addition, there may be multiple virtual controllers, which share topology information of networks managed by themselves and operate in an autonomous distributed manner. In order to realize this function, a single master controller is introduced. The master controller aggregates the topology information shared by controller and controls so that controller takes actions according to its policy. Therefore, all controller must have a path to the master controller. Also, master controller is also virtually placed on data center, but for load balancing, it is assumed that the master controller is transferred to another data center at regular time intervals. In this model, we do not think that a platform is provided from a specific data center.

We define a cascade failure occurrence model on such this network. In this research, consider the following points. The existence of a path the virtual controller to the master controller, and Data center and virtual controller dependencies. Therefore, in modeling, only data center, virtual controller, master controller, and physical or logical communication network connecting them are defined. Specifically, this model has two layers. One is a data center as a node, a link as a network representing a physical communication network, and the other as a logical network composed of a virtual controller and a master controller.

Explain the impact of node failure including faults and outages in our model. In this model, there are two possibilities: data center failure and virtual controller failure. If a failure occurs in the data center, a failure also occurs in the virtual controller from which the platform was provided. Next, a case where a failure occurs in the virtual controller will be described. If the data center that has been controlled by this virtual

controller has only one virtual controller, the data center will lose control and a failure will occur. When the data center has multiple virtual controllers, another controller replaces the control that the virtual controller in which the failure occurred. This is an only story within one data center, not the virtual controller in other data centers. Also, in order to reduce the load, new virtual controllers are not generated. In this case, it is possible that the load on the controller undertaking the control increased and it may be broken. Another influence caused by a failure of the virtual controller is that another virtual controller loses the path to the master controller and a failure occurs. The obstacles mentioned here are cascading failures because they can potentially be induced in a chain manner with each other.

From the above setting, the survival condition of the node in this model is as follows. The inter-layer order of the data center is 1 or more. The controller has inter-layer degree 1. The controller has a path to the master controller. Removes the node that violates this condition and removes the link connected to that node.

4.2 Failure Occurrence Model

Four failure generation models are shown. First, the first two are the simplest models. Although the initial states are the same, there is a difference that the node that fails first is the data center or the controller. Then, from the viewpoint that there is a possibility that the data center may hold multiple controllers, we propose a model that doesn't limit the inter-layer order of the data center to 1, and finally a model that considers the load of the controller is proposed. We represent data center with DC, controller with C, and master controller with MC. Additionally, intra-layer edge and inter-layer edge are represented each by a solid line and a dotted line.

a) Model due to data center failure

First, the data center breaks down. (1). Next, the controller loses the platform and fails, (2), and another controller loses the path to the master controller. (3). Finally, due to the failure, the data center loses control and fails. (4).

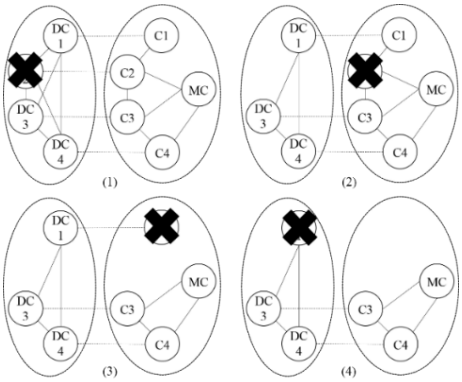

Figure 3. Model a

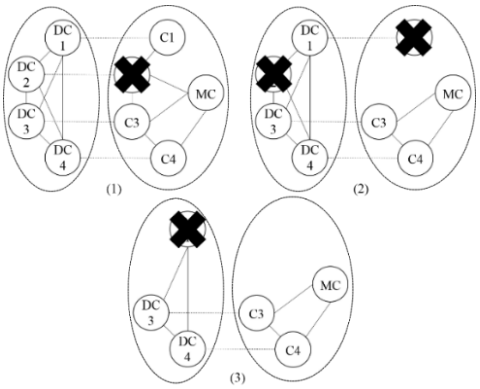

Figure 4. Model b

b) Model due to controller failure

The initial state is the same as the previous model. First, controller A fails. (1). Next, the controller B losses the path to the master controller and fails, and the control of the data center is lost due to the influence of A, and it breaks down. (2). Finally, the control of the data center is lost due to the influence of B and it breaks down. (3).

c) Model that doesn't limit inter-layer order to 1

The data center first fails. (1). Next, the controller loses the platform and fails, (2), and another controller loses the path to the master controller. (3). Finally, a data center that loses control fails. (4).

d) Model considering the load of the controller

In the past, we focused on only the survival condition of the node, but in this model, we also consider the load of the controller. A controller first fails. (1). Some controllers lose its path to the master controller and fails. (2). As a result, the data center that controls it fails and the controller has failed due to an additional load. Another controller loses its path and fails. (3). Finally, data center that loses control breaks down. (4).

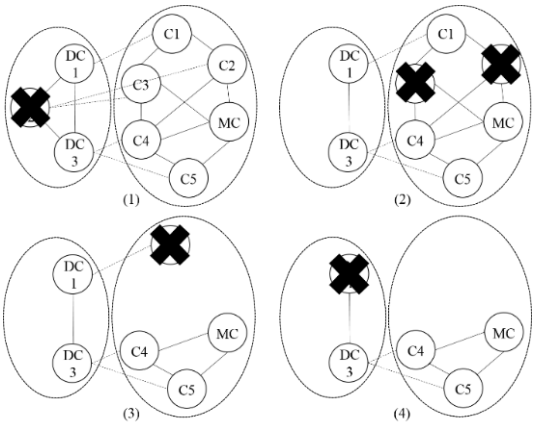

Figure 5. Model c

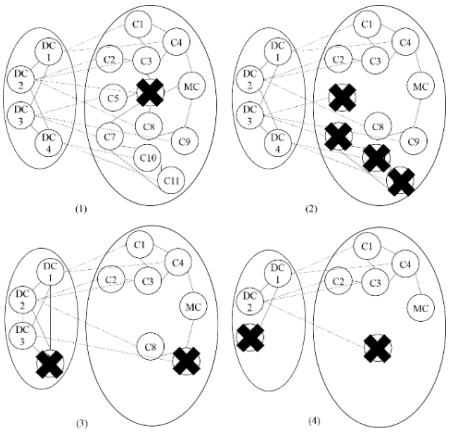

Figure 6. Model d

5. CONSIDERATION

From the fault models a and b, it can be said that whether the large-scale cascade fault occurs or not is largely related to the network topology of layer 2 and the node that fails first. If the controller that lost the path has a different path, or if another node has failed for the first time, a large-scale cascade failure does not occur. From this, it can be said that the network topology of layer 2 is not only scalable, it is easy to fail if it exists on the path from any node on the network to the master controller. If countermeasures are applied to this part, the node that fails first does not cause this failure.

The fault model of c allowed the data center to have multiple controllers, and it became a more realistic model. This indicates that there is a possibility that the failure will expand. This is because data center failures cause more controller failures. In order to suppress the damage caused by the failure, it is necessary to pay attention to the correlation between the inter-layer degree of the layer 1 layer and the intra-layer degree of the layer 2.

In the fault model of d, the fault due to the overload of the controller was considered. Specifically, although the controller 9 is faulty, such a failure does not always occur. However, there are examples like those introduced in Chapter 3, so you cannot ignore it.

6. CONCLUSION

In this research, we propose a cascade fault occurrence model with SDN as an interdependent network which is one of the networks with mutual network interactions and examined the cause. The fault propagation pattern is three, and the fault is attributed to the following three points. Layer 2 network topology. First failing node. Correlation between intra-layer orders of Layer 1 nodes and intra-layer orders of Layer 2 nodes

Future tasks include the removal rate of node necessary to cause failure of the whole system, the simulation of the correlation between the interlayer order of the Layer 1 node and the intra-layer degree of the Layer 2 node, and the proposal of another model.

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