Control and visualization system for managed self-organization network

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Abstract—We propose the managed self-organizing network concept considering the unexpected network changes caused by the future applications, and implement the control and visualization system for it. In the managed self-organizing network, multiple virtual networks are accommodated on a single optical infrastructure. Each virtual network is controlled based on self-organizing mechanism by attractor selection algorithm that models behavior where living organisms adapt to unknown changes in their surrounding environments. On the other hand, the physical resource management server dynamically manages the resource allocation for each virtual network to optimize the utilization of total network resources. Our implemented system efficiently visualizes the behavior of managed self-organizing network with time variability, and network filtering and clustering functions are implemented for visualization of large and multiple virtual networks.

***Index Terms*— managed self-organizing network, network virtualization**

I. INTRODUCTION

Future network should flexibly deal with the unexpected network changes caused by the diversification of the network services and applications, and economically accommodate multiple service networks.

In this paper, we focus on the managed self-organizing network for satisfying above future network requirements. In the managed self-organizing network, a physical network infrastructure consists of packet and optical-layer networks. Multiple service networks share a single physical infrastructure that is virtually sliced; each service networks has their allocated physical resources. To accommodate IP traffic over wavelength-routed WDM network, virtual network topology (VNT) [1] is configured on each allocated resources. VNT is consists of IP Router and IP links, and wavelength path. Wavelength path is established on a physical layer, and it corresponds to the IP link on IP layer. For adapting dynamic network changes such as failure and traffic variation, Each VNT is controlled based on self-organizing mechanism by attractor selection algorithm [2] that models behavior where living organisms adapt to unknown changes in their surrounding environments. On the other hand, the resource competition between service networks might not be avoided only by the individual VNT control. Therefore, the physical resource management server exists, and it dynamically manages the resource allocation for each service networks to optimize the utilization of total network resources [3].

In terms of the network operability, control and visualization of the behavior of managed self-organizing network is an important issue; it is controlled by the multiple algorithms with time variability, and single physical infrastructure should accommodate large and multiple virtual networks. Specifically, comprehending the physical resources sharing and competition between VNTs, physical resources allocation to each service network, and behavior of individual self-organizing mechanism with attractor selection becomes complicated. Moreover, our assumed network could be managed on a large scale (1000 nodes and/or 100—1000 VNTs).

We implement the control and visualization prototype system for operating large managed self-organizing network. Our system realizes integrated visualization of physical network infrastructure, allocated infrastructure to each service networks, and VNTs of each service networks. Especially, for visualizing large and multiple networks, we implement the filtering and clustering functions. By the filtering function, network operator extracts specific networks with their desired condition (e.g. share the specific physical link) from a large number of networks. The clustering function abstracts multiple nodes (edges) to a single node (edge). Our performance evaluation on 1000 nodes network shows that the drawing times with practical abstraction reduces to one seventh compared to it without clustering.

The rest of the paper is organized as follows. In Section II, we describe the concept of managed self-organizing network, and a problem statement. In Section III, requirements for visualizing the managed self-organizing network and overview of our system are presented. In section IV, we present our

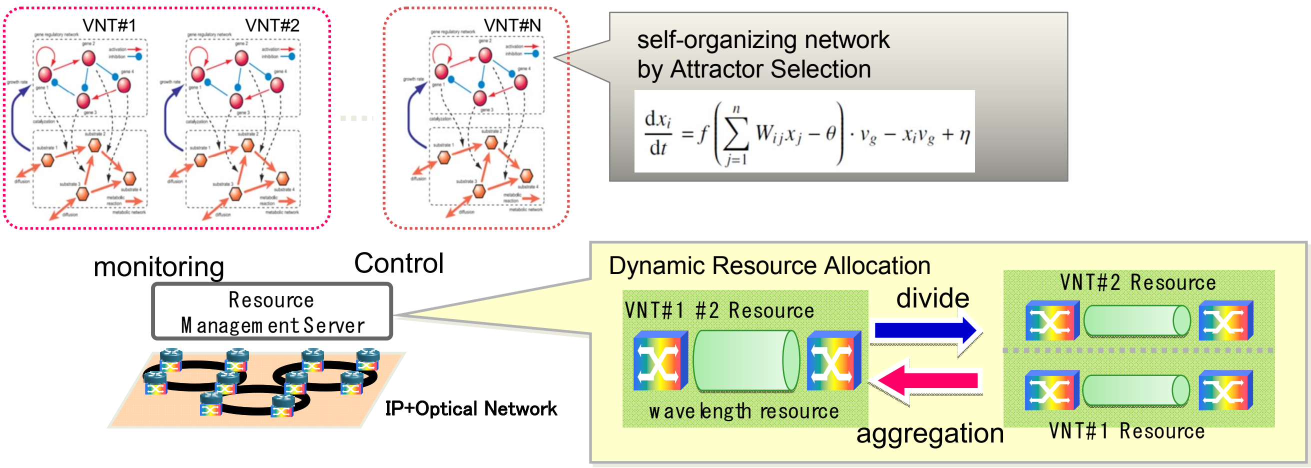

Fig. 1 Concept of managed self-organizing network

implementation and performance evaluation. Finally, we conclude our discussion in Section V.

II. MANAGED SELF-ORGANIZING NETWORK

Main control functions of managed self-organizing network consist of (i) self-organizing VNT control based on attractor selection, and (ii) dynamic resources allocation to each service networks (Fig. 1). In this section, we introduce the overview of them and state our problem.

A. Self-organizing based on Attractor Selection

For adapting unexpected and erratic network changes, rule-based approach, which assumes a certain set of network changes as rule, cannot necessarily work well. Instead, non-rule based approach, which mainly uses stochastic behavior for adapting to changes in environments, is required. In this paper, we focus on attractor selection [4], which models behaviors where living organisms adapt to unknown changes in their surrounding environments and recover their conditions. The fundamental concept underlying attractor selection is that the system is driven by stochastic and deterministic behaviors, and these are controlled by simple feedback of current system conditions. While rule based heuristic approaches cannot handle unexpected environmental changes, attractor selection has the capability of adapting to unknown changes since the system is driven by stochastic behavior and simple feedback of current system conditions. The VNT control algorithm, which interprets the gene regulatory network as a WDM network and the metabolic reaction network as an IP network, has been proposed [2].

B. Dynamic Resource Allocation

The dynamic resource allocation algorithm realizes the stable multiple VNTs accommodation on a single physical infrastructure by flexibly changing the resource attribute considering resource sharing and competition. The attribute of the physical resource includes the *dedicated* attribute and the *shared* attribute [3]. The dedicated resources are only used specific VNT, and the shared resources are shared by the multiple VNTs. Basic control is dividing physical resources (assigning the dedicated resources) when resource competition between VNTs occurs. On the other hand, a single direction from the shared attribute to the dedicated attribute causes the low utilization of total network resources. Therefore, aggregation of the physical resources (assigning the shared resources) is required and this operation utilizes the total physical resources. For example, if traffic matrixes of two VNTs have negative correlation that does not stochastically compete against each other, giving the shared attribute for them utilizes the total network resources as a result.

C. Problem Statement

The main issue of this paper is control and visualization of the behavior of the large managed self-organizing network. Our assumption is that network could be managed on a large scale (1000 nodes and/or 100—1000 VNTs). Some generalized studies for network visualization have been proposed [5,6]. In [5], visualization algorithms for large flat network were compared. In [6], it considering dynamic variation of network was proposed. In this paper, we propose the unique visualization system considering the requirements of the managed self-organizing network, and we also implement and evaluate it for practical use.

III. CONTROL AND VISUALIZATION SYSTEM

In this section, we first describe the requirements for visualizing the managed self-organizing network, and then introduce the overview of function structure of our prototype system.

A. Requirements for Visualization

The system should realize integrated visualization of physical network resources, allocated resources to each service networks (physical resources for individual service network), and VNTs of each service networks. On a view of physical network resources, network topology, available resources (e.g. wavelength), and resource attribute (dedicated/shared) should be drawn. On a view of allocated resources, network topology, available resources, and wavelength paths should be drawn. On a view of VNT, network topology (VNT), and utilization of

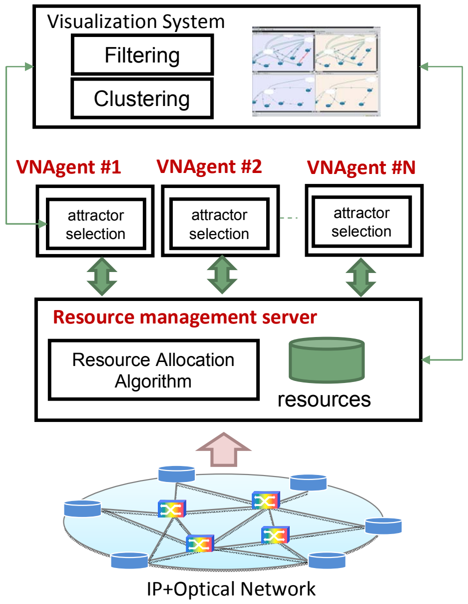

Fig. 2 Overview of interfaces and functions of our visualization prototype system

each IP links should be drawn. Especially, the links whose link utilization exceeds the threshold should be highlighted.

The managed self-organizing network is composed of multi-layer networks, and then the second requirement is visualization of the relation between the layers. As the relation between physical resources and allocated resources, the allocated volume from physical resources to allocated resources of each service networks and the resource attribute should be visualized. As the relation between the allocated resources and VNT, the correspondence relationship between the wavelength paths on physical layer and IP links on IP layer should be visualized.

The third requirement is visualizing the multiple networks: VNTs and allocated resources for multiple service networks, variability over time of single service network. For visualizing the relation of multiple service networks, the physical resource sharing and competition should be drawn. The resource competition means that the number of sharing of physical resources exceeds the threshold value.

The performance requirement is the scalability; the objective of our system is visualizing 1000 nodes and/or 100—1000 VNTs.

B. Overview of Visualization System

Our visualization system gets the physical resources information from resource management server, and gets VNT information from virtual network agent (VNAgent) that manages each service networks (Fig. 2). The resource management server has physical resource information (optical network topology, available resources, and traffic demand) and allocated resources information to each service networks. Resource allocation processes are dynamically performed by the resource allocation algorithm. The VNAgents exist with respect to each service networks, and computes VNT and IP routes over VNT on the allocated physical resources.

As the key feature of our visualization system for drawing large network, we introduce the filtering and clustering functions though our system has more detailed components (e.g. socket interface, drawing engine, and databases). With our assumption, a large number of VNTs (100—1000) exist, but visualization of them at the same time gives low visibility and is not practical. Meanwhile, operator interest is specific networks while multiple service networks exist. Therefore, by the filtering function, network operator extracts specific networks with their desired condition. We implemented some extract conditions: resource sharing and competition, control time, IP link utilization, physical available resources, and the number of nodes of VNT. For example, filtering function extracts VNTs whose maximum link utilization exceeds 80%, and it extracts VNTs whose links are physically shared or competed.

The second feature of our visualization system is clustering function that aggregates multiple nodes (edges) to single aggregated node (edge) (Fig. 3). The aggregated node is expanded by the operator manipulation such as a mouse click, and original set of nodes and edges are displayed. In addition, if the multiple links exist between the aggregated nodes, these links are abstracted as the aggregated link, and number of links (bandwidth) is expressed as thickness of line. The clustering function not only provides high visibility but also reduces the number of components for drawing, and then network drawing time is reduced.

IV. Implementation and Evaluation

In this section, we describe the operation example of managed self-organizing network using our implemented prototype system, and then evaluate the performance of our prototype in terms of the drawing time of whole network. The first operation example is (i) visualization of behavior of managed self-organizing network with attractor selection and resource allocation algorithm, and the second one is (ii) visualization of multiple service networks and filtering operation.

A. Visualization of Managed Self-organizing Network

Figure 4 illustrates the visualization of the behavior of VNT control based on the attractor selection and resource allocation algorithm. The left shows the service network #1 before network is controlled (phase 1), and the right shows it after network is controlled (phase 2). The bottom network is allocated resources for #1, and the top network is VNT for #1. From the VNT view on phase 1, the highlighted link between node 16 and node 17 is congested link. The attractor selection algorithm tries to solve this congestion, but it could not solve it because physical resources are restricted. In this example, the congested IP link is corresponds to the long length path that pass through the cluster 0 on the physical layer, and it actually

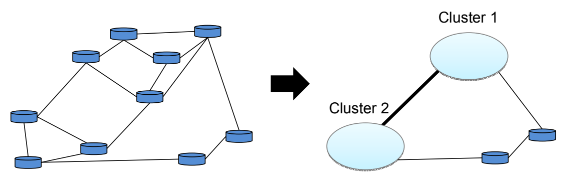

Fig. 3 Example of network clustering

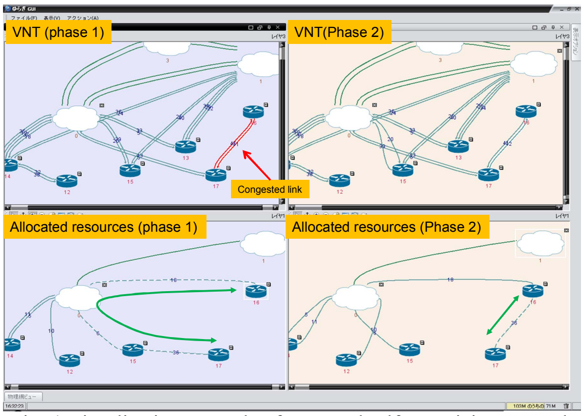

Fig. 4 Visualization example of managed self-organizing network (The top is VNT, and the bottom is allocate resources)

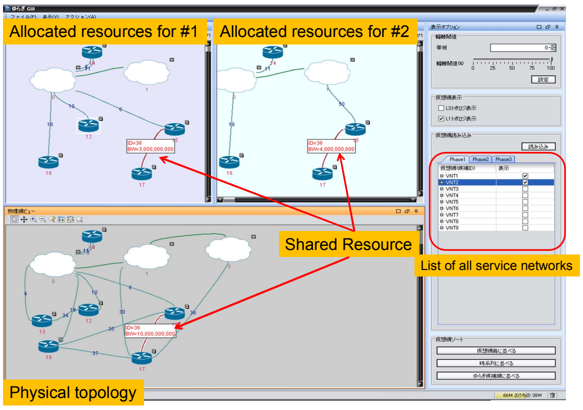

Fig. 5 Virtual networks extraction from multiple networks using filtering function

competes with other paths in the cluster 0. On phase 2, the resource allocation server assigns the dedicated physical resources from node 16 to node 17 to the service network #1. Then, attractor selection algorithm computes the new VNT. In this example, new wavelength path from node 16 to node 17 is established, and then congestion of IP link is resolved.

B. Multiple VNT View and Filtering

Figure 5 shows the example for visualizing multiple networks and filtering function. The right list shows the all service networks that exist on a single physical infrastructure. The bottom network is a physical network, and the top networks are allocated resources for service networks #1 and #2. In this example, multiple service networks exist, but the number of displayed service networks is restricted by the filtering function; only the service networks that share the physical link from node 17 to node 15 are displayed. Noted that an example of Fig. 5 only displays the allocated resources of each service networks, but our implemented system can also display the form of VNT at the same time.

C. Performance of Drawing Time for Large Network Visualization

Figure 6 shows the drawing time when the number of nodes and the number of clusters changes. When we draw the network over 800 nodes without a clustering function, drawing time

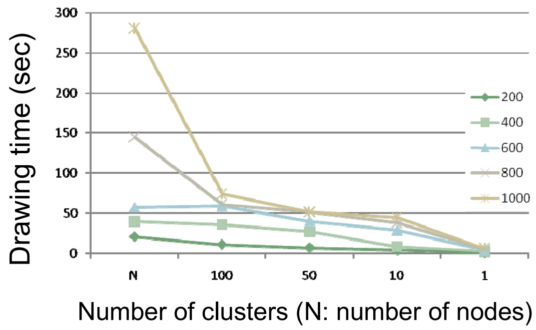

Fig. 6 Drawing time when number of nodes and number of clusters change (Intel Core2 Duo U7600 1.20GHz, 2Gbyte memory at 32bit windows OS)

extremely increases and it takes about 280 seconds to draw the 1000 nodes network. On the other hand, the drawing time for 1000 nodes network with 10 clusters is about 45 seconds. One cluster has 100 nodes, and then the time for expanding the aggregated nodes is assumed to be about 10 seconds; we believe this is practical.

V. CONCLUDING REMARKS

We presented the managed self-organizing network concept and the implementation to control and visualize for it. Our system can effectively visualize the behavior of the network that is controlled by the attractor selection and resource allocation algorithms. The clustering and the filtering functions are also provided for large and multiple network visualization, and our prototype can visualize 1000 nodes network in about 45 seconds.

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