Dynamic Topology Reconfiguration for Energy Efficient Multi-layer Network using Extended GMPLS with Link Power Control

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Abstract: This paper proposes an energy efficient multi-layer network using extended GMPLS with link power control. The experimental result shows that dynamic energy saving according to traffic volume is realized by layer-1 and layer-2 unified control.

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1. Introduction

Traffic flowing through the Internet is continuing to increase with the number of Internet users each year. Energy consumed by network equipments such as routers and switches has been steadily increasing. The worldwide energy consumption of ICT in 2008 was 168 GW and is predicted to grow up to 430 GW in 2020 [1]. Worldwide power consumption of network equipment is rapidly increasing at a yearly rate of 12%. Therefore, the reduction of energy consumption is an important issue. Several techniques have been studied to reduce the network energy consumption. We have proposed “MiDORi (Multi-(layer, path, and resources) Dynamically Optimized Routing)” network technology [2-5]. “MiDORi” achieves an energy efficient network by controlling the equipment port power and switching power. To realize the power control, a path computation engine (PCE) conducts traffic engineering (TE) for dynamically aggregating traffic on particular links. In order to improve the energy efficiency of networks, power consumption should be proportional to the utilization of the network. Because utilization of the backbone network is said to be less than 30% [6], our approach will be a very effective way.

To realize TE in the multi-layer network, GMPLS (Generalized Multi Protocol Label Switching) is a very powerful tool. GMPLS is possible to control multi-layer paths such as MPLS path, Ethernet VLAN path, SDH/SONET path, OTN ODU path, and wavelength path. To control the port power of equipment, extended GMPLS, which is called the MiDORi GMPLS, is proposed [3]. In this paper, experimental results of the equipment port power control (ON/OFF) capability and multi-layer TE capability by the MiDORi GMPLS is presented.

2. Proposed Energy Efficient Multi-layer GMPLS Network

Figure 1 shows the proposed MiDORi network architecture. The network consists of M-plane (management plane), C-plane (control plane), and D-plane (data plane). In the experimental network, the D-plane is conducted with Ethernet switches and optical switches. The M-plane, which consists of PCE and a network manager (NM) measures the traffic volume of all paths to calculate an energy efficient topology NM [3]. This topology calculation performs layer-1 wavelength path and layer-2 VLAN path together. The C-plane runs the MiDORi GMPLS which conducts path setup/teardown as well as link power control based on calculated topology results. The D-plane can be consisted with various layers equipment, because GMPLS is capable of controlling multiple layers.

3. MiDORi GMPLS Extension

We extended the GMPLS protocols (OSPF, RSVP, and LMP) [4, 7]. As an OSPF extension, a TE link power ON/OFF status in order to distinguish from non activated or broken links is added. Even if the link status in the D-plane is OFF, the logical link status is ON, so it can be included in the calculation in the PCE and signaling in the C-plane as shown in Fig.2.

The LMP extension makes it possible to control the power of neighbor switch ports by using channel status messages. Whenever a link is intended to be powered off, both end ports will be turned off as shown in Fig.3.
The extended RSVP adds power ON/OFF status of label switched paths (LSPs). LSPs that are in a power OFF state, cannot be used as a working LSP. Messages that are capable of controlling the power of data link ports are used to change the state of each LSP.

![Figure 2. Power-off state of the link.](image1)

![Figure 3. Link power on to off using LMP.](image2)

### 4. MiDORi GMPLS Implementation and Performance Evaluation

To evaluate an energy efficient network using the MiDORi GMPLS for controlling Layer-1 and Layer-2 switches, we constructed a multi-layer network as shown in Fig.4. In Fig.4, ID represents VLAN-ID of each LSP, and the number in each switch indicates the node-ID of the C-plane. A LSP is established by an explicit route using node-ID. This network consists of prototype Gigabit Layer-2 switches and a PLZT optical switch. The Layer-2 switch has a port level power control capability which saves nearly 1.4W per port and VLAN traffic monitoring capability. The PCE is set if call set up requires larger bandwidth than preset threshold, the PCE selects as much wavelength path switching route as possible. It is because wavelength path switching is energy efficient than frame switching if the call uses enough bandwidth and call duration time.

In this system, power consumption is evaluated in the condition where the amount of traffic changes to low volume or high volume dynamically. Traffic flow amount ratio of each LSP in this network is set as low traffic : high traffic = 1 : 5. Layer-2 switch link capacity is 1 Gbps, so low-traffic is set to 6% and high traffic is set to 30% of the link capacity per flow. Source and destination are set up arbitrarily. Two SmartBit are used as a traffic generator. Figure 5 shows a photograph of the demonstration system.

![Figure 4. Topology of the demonstration system.](image3)

![Figure 5. Photograph of the demonstration system.](image4)

In order to configure an energy efficient network dynamically, the following steps are repeated.

1. **Step 1:** The NM remotely measures the traffic of each LSP in all switches and calculates the average traffic rate.
2. **Step 2:** The PCE calculates the energy optimal LSP route and network topology [3] based on the traffic information.
3. **Step 3:** The PCE informs the calculated LSP’s explicit route to the LSP’s source node.
4. **Step 4:** The MiDORi GMPLS reconfigures (setup/teardown) each LSP and controls the power of port on the corresponding each D-plane switches.

Figure 6 shows a changing state from initial topology to the power-saving topology when traffic load is low. AS a result, more six ports can be power OFF. Figure 7 shows the MiDORi GMPLS RSVP PATH message example. This message contains information for explicit routes and VLAN ID of the LSP. The message was sent from Node50.50.50.1 to Node50.50.50.7 and had elements such as VLAN ID10 and explicit route (Node50.50.50.2, 50.50.50.4, 50.50.50.3, 50.50.50.7). VLAN ID10 path consist of a kind of traffic which use the PLZT to preferential. Consequently, it goes through the PLZT (node 50.50.50.4).
Figure 8 shows the amount of energy saved by setting different traffic loads. When traffic load is low, it is possible to reduce energy consumption of 19.6 W, while 11.2 W of energy still saved even at high traffic load periods powering off 8 ports. The reduced power of 8.4 W is not large. However, this result shows that the MiDORi network technology is potentially feasible in the high speed interface and large scale network environment.

5. Conclusion
This paper demonstrates the energy efficient network using the MiDORi GMPLS which is capable of controlling both Layer-1 and Layer-2 switches. We confirmed the reduction of power consumption by powering OFF unused links and the signaling messages by modified GMPLS. In this demonstration, we have confirmation that it is possible to further reduce power consumption when applying in larger networks which consists of large number of routers.

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References