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Energy-Minimized Routing Algorithm for Heterogeneous Network Environment

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1 Introduction

Due to increasing network traffic, many data-centers are built recently. One of the most serious problems is increasing electric power consumption of network devices. Ministry of Economy, Trade and Industry indicates that electric power consumption of network devices will increase 5.2 times from 2006 to 2025 in Japan. So many researchers try to reduce energy consumption of network devices, lines and cards. Shutdown of unused network devices in choosing a route is one popular method.

Open Shortest Path First(OSPF) is a network routing protocol to manage autonomous system area. OSPF uses shortest path first calculation with OSPF cost and Dijkstra algorithm. To reduce energy consumption, some network devices and lines aren't on the traffic route. Therefore, these devices and lines can be shutdown to reduce network energy consumption. But,traditional ways didn't consider different network devices. So past research on energy-minimized network design can not optimize to reduce energy power consumption in heterogeneous networks. In this paper, we propose a network design method and algorithm to optimize energy consumption in heterogeneous networks and devices. Considering each device's energy power consumption, and setting suitable OSPF cost value, we could optimize the network design. We compare our method with traditional methods and get 11.64 times better performance.

2 Energy-minimized network design

In the research on reducing electric power consumption, many researchers placed great importance on energy consumption, communication delay and compatibility with existing systems. Maestro proposed Energy Efficient Ethernet(EEE) for Transmitter to change to Low Power Idle (LPI) mode when packets don't arrive. EEE can reduce energy consumption of ports and lines in various network topologies. EEE has high stability and flexibility, but its reduction in energy consumption is very low. Considering this problem, Arai proposed ECO-RP with OSPF. ECO-RP can dynamically update OSPF cost with current traffic information. So network topology can be changed, and ECO-RP can eliminate devices in choosing a route. But ECO-RP doesn't consider energy consumption of each network device, and has problems of poor performance by using wrong network topologies. Traditional ways have

- Not considered energy consumption of devices in choosing route.
- Not considered information of neighboring devices in choosing route.
- Some OSPF costs are unsuitable when choosing correct route.

Therefore our research attempts to solve these problems. We propose this method of setting suitable OSPF cost, considering energy consumption of network devices and neighboring devices. We make a simulation of energy consumption, and compare our method with traditional methods by using average energy consumption rate, number of hops and over-flow rate.

3 Setting cost with energy consumption

In order to set energy consumption, our research proposed 3 methods; There are Define Cost with Performance(DCP), Define Cost with Neighbors(DCN) and Define Cost with Neighbors and Performance(DCNP) on OSPF. These methods can reduce network energy consumption to set suitable OSPF cost considering the energy consumption of network devices.
DCP multiplies initial OSPF cost of each line by average energy consumption of each connected device. This method can set suitable OSPF cost for calculation of energy-minimized network design (for example, if nodes A and B have high energy consumption, OSPF cost between A and B is high).
DCN considers neighbor node information to reduce energy consumption. If nodes A and B have high energy consumption, multiply initial OSPF cost of each line by α. α is the coefficient of increase in OSPF cost. If nodes A and B have low energy consumption, multiply OSPF cost by the coefficient β to calculate decrease in OSPF.
These methods can reduce energy consumption by changing network design, but DCP incurs huge OSPF cost due to large energy consumption value, and DCN doesn't optimize network design with small α, β. We propose DCNP to resolve these problems. This method merges DCP and DCN. DCNP uses normalization of energy consumption of network devices. Setting initial OSPF cost is optional, so if you don't want to include lines between edge nodes, set a high OSPF cost.

4 Comparison and evaluation

We performed an experiment of energy-minimized network design with our proposed methods, OSPF, ECO-RP and EEE, and compare average energy consumption, average number of hops, and average rate of overflow ratio (In this paper, overflow ratio is rate of overflowing lines due to data traffic). We use NSFNET T1 network topology, and create random network design topologies in our experiment. The experimental results showed that energy reduction rate of DCNP is the highest in both network topologies. The best reduction rate is 37.37 percent (4.41 times the reduction of ECO-RP,

12.25 times that of EEE) in NSFNET T1 topology, and 66.66 percent(2.44 times that of ECO-RP, 1.62 times that of EEE) in random network.
Average number of hops is not greatly different, but on average overflow ratio, result of DCNP is worse than any other method and 17.11 percent (ECO-RP is 0 percent and EEE is 5.73 percent) in both topologies. Generally, overflow ratio is low better than high. However, proposed method DCNP has high performance to concentrate network lines, and can reduce overflow ratio in combination with ECO-RP. Overflow ratio of DCNP plus ECO-RP is 0 percent (energy reduction rate is 54.91 percent). This reduction rate is close to that of DCNP. Also, we compare two different traffic models. This result doesn't show great difference in either traffic pattern.

5 Conclusion and future works

In this paper, we proposed DCNP to reduce network energy consumption, through energy-minimized network design considering energy consumption of network devices and adjacent node types. Result of DCNP is greater reduction than with any other method. The best values are 3.73 times the reduction of ECO-RP and 11.64 times that of EEE when using NSFNET T1 network topology. These results show that setting OSPF cost with DCNP is the best method for energy-minimized network design.
However, although we resolve DCNP's overflow problem with ECO-RP, the actual congestion occurred at a lower traffic threshold than the overflow point. Also, DCNP can't consider low-performance devices, because OSPF cost is set based on only energy consumption and adjacent node type. So an energy-minimized network design with DCNP, leads to errors, or the network will become unstable. Recently, network traffic increases more and more, so we need to modify DCNP practically. To solve these problems, we must implement a correction factor, and consider performance of devices through simulations. In addition, DCNP needs to concentrate network lines without congestion, and implement recalculations according to network traffic threshold.