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An improved energy efficient quality of service routing for border gateway protocol☆

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ABSTRACT

Global routing performance and saving energy are critical for Internet applications. Internet service providers use the internal Border Gateway Protocol for the distribution of external routes within the autonomous system. The balance between the trade-off relationship of energy efficiency and quality-of-service is necessary for autonomous systems in green networking. Past studies have shown that energy saving schemes exacerbate quality-of-service. However, the optimum use of resources balances the trade-off between energy efficiency and quality-of-service. Therefore, we propose a Green BGP model that balances the trade-off between energy efficiency and quality-of-service by optimizing the internal Border Gateway Protocol path selection policy. Border Gateway Protocol routers select a path considering the quality-of-service attributes and energy efficiency of the path within the autonomous system. The proposed model is compared with related techniques, and the results confirm the advantages of the Green BGP model that improves energy efficiency and maintains quality-of-service.

1. Introduction

Green networking aims to minimize the energy consumption and greenhouse gas (GHG) emissions in the environment. Due to the increasing size of ISP (Internet Service Provider) networks, energy consumption is growing and becoming a concern for the environment. Various studies have shown that information and communications technology (ICT) systems represent 2–10% of worldwide power consumption [1]. According to Ericsson [2], ICT solutions can decrease GHG emissions up to 15% by 2030 by using more energy-efficient devices. However, the energy efficiency of the device depends not only on the manufacturing of the device but also on their usage in operator networks. Eighty percent of ICT carbon emissions are attributed to the use of these devices and 20% result from manufacturing [1]. The underutilization of equipment wastes energy. Green routing recommends using the full capacity of equipment to save energy.

Reducing the energy consumption of the overall networks is challenging for green routing. Routing policies are responsible for the proper use of routers. The optimum use of the routers is essential for reducing the carbon and GHG emissions [3]. Green routing aims to reduce the energy consumption by selecting energy saving paths in the networks. The proposed model focuses on the Border Gateway Protocol (BGP) that has a very important role in saving energy in ISP networks. The

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BGP is a policy-based, path vector routing protocol for autonomous systems that define the Internet. The configuration of internal BGP routers using an energy saving policy significantly reduces energy consumption in networks.

The powering-down model is the most effective model for saving energy [4]. However, waking and putting the links to sleep in routing can exacerbate the quality-of-service (QoS) in the networks. The frequent transitions between sleep and active mode increase the convergence time of the topology. Therefore, the repeated changes in paths degrade the network's performance in terms of throughput, jitter, end-to-end delay, number of exchanged updates, and packet delivery ratio. Therefore, the trade-off between saving energy and QoS is an emerging concern for ISP networks. The optimized path selection policies in BGP can facilitate saving energy while preserving QoS in ISP networks.

A novel BGP model is proposed that reduces the overall energy consumption of the networks. It addresses the challenges of internal BGP and controls the trade-off between saving energy and QoS. The aim of this paper is to identify an effective strategy for green routing on internal BGP that uses the minimum number of active links to route the traffic with guaranteed QoS.

Our contribution in this paper is as follows: The Green BGP model proposes an energy-efficient internal path selection algorithm. The BGP model observes and monitors the queue and traffic flow for providing QoS. It adapts the dynamic changes in topology while balancing the trade-off between saving energy and QoS. BGP reroutes the traffic for lower power consumption. The BGP router selects an energy-efficient path by computing the QoS constraints such as delay, path uptime, maximum link utilization, and energy-bandwidth availability. The routing policy guarantees the delay and selects the path having the higher path uptime. The powering-down model is used to put lightly loaded links to sleep. Simulation results confirm that the Green BGP algorithm produces better results than related techniques [5,6].

The remaining sections are organized as follows. Section 2 describes the related work. The proposed Green BGP model is described in Section 3. This section formulates the problem and defines the QoS constraints used for an infrastructure-based energy saving technique in BGP. Section 4 illustrates the two algorithms used for Green BGP. The suggested Algorithm 1, discusses the energy-efficient internal path selection policy for balancing the trade-off between saving energy and QoS. Algorithm 2 presents the techniques used for putting to sleep and waking links. Section 5 defines the simulation setup. Performance evaluation of Green BGP is carried out in Section 6. This section compares our approach with the existing algorithms. This section also analyzes the effect of QoS constraints on energy efficiency. Finally, Section 7 concludes the paper.

2. Related work

Green routing has attracted the attention of the research community in the last decade. This paper relates to the three categories of energy saving algorithms, which are as follows: powering off the elements, infrastructure-based energy savings, and saving energy using traffic engineering. In the first category, the energy savings are achieved using the power of an individual element in the network. There are two types of power saving models (1) the powering-down model [3] and the (2) speed-scaling model [4]. The powering-down model is a widely used model for saving energy. The purpose of the powering-down model is to put the individual network elements such as routers, switch, and line cards in networks to sleep during idle time. The speed-scaling model adjusts the link rate according to the link utilization [3], uses a single threshold buffer policy, and dual threshold buffer policies. The authors of [7] implemented a power-aware algorithm and suggested that saving energy should be performed by monitoring each node in the network. In a case study, the suggested algorithm monitored the traffic between two networks, used local information of the node to avoid rerouting, and selected links for sleep mode. Similarly, the authors of [8] discussed a technique related to putting to sleep and waking links in the networks when dynamic changes occur in traffic.

In the second category, the research focused on infrastructure-based energy savings. The approaches determined the cost of each link in the topology and found the minimum links having the minimum cost to be active. The authors of [9] and [10] discussed different strategies to decrease energy consumption in backbone networks. The authors formulated a link weight assignment problem for saving energy and solved it using ILP programming.

In the third category, the energy in ISP networks was saved by applying traffic engineering rules in the networks. Rivera et al. [5] presented a technique called HotPlec that manages the interior gateway protocol (IGP). Similar to our work, HotPlec selects the minimum links to route the traffic using the collaboration of IR's (ingress routers) & ER's (egress routers), and idle links may go into sleep mode to save energy in the networks. The algorithm selects an egress router for a set of ingress routers. The IRs share the path information among the routers then each IR determines whether they should change their selected path to ER or not. The authors used equal capacitated networks and neglected the traffic flow. The algorithm required a significant amount of time to rebuild the path when any change occurred in the topology. Furthermore, the algorithm compromised the quality of a path selected by the IR that degrades network performance. The compromised quality of the path results in low throughput, higher end-to-end delay, higher convergence time and a low packet delivery ratio.

Chiaraviglio et al. [10] presented a technique that proposed to minimize the power consumption of the ISP networks. The approach used a capacitated multi-commodity minimum-cost flow (CMCF) network. The authors claimed that the strategy maximizes the energy savings and preserves QoS using a maximum utilization constraint. The QoS constraint (maximum utilization) ensures that the utilization of a link cannot exceed a given threshold value. The technique applied to minimize power consumption concentrated the traffic load to a minimum of physical nodes, links, and afterward switched idle nodes