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Multiple many-to-many multicast routing scheme in green multi-granularity transport networks

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ABSTRACT

Due to the ubiquitous use of the Internet and huge proliferation of network devices, the energy consumed by today's networks has increased significantly, implying the need for designing and operating green networks. In this paper, we propose a power-efficient Quality of Service (QoS) routing scheme for multiple many-to-many multicast requests with given static traffic demands in green multi-granularity transport networks, which comprehensively considers both the IP and the optical layers. A chosen probability model is devised to describe the probability of a link being selected when routing, and a heuristic routing algorithm is proposed to construct multiple many-to-many multicast trees in order to decrease power consumption, enhance QoS evaluation and improve resource utilization evaluation under QoS and capacity constraints. Results from simulation experiments demonstrate that our proposed scheme is more power-efficient with higher QoS evaluation and better resource utilization compared with others.

1. Introduction

Due to the rapid development of Information and Communication Technology (ICT) and a wide variety of networked applications, today's Internet consumes a significant amount of energy. In the US alone, Internet used 9.4% of the produced electricity and this Internet electricity cost keeps increasing every year [1]. Therefore, green or energy saving network is emerging as an active area of research on networking and communication [2]. Moreover, most of the current (wired) network resources are considered redundant in order to guarantee reliability; the maximum utilization ratio of the backbone network is often less than 30% even in the working state [3]. This makes it feasible to realize green networks.

There are a lot of researches and developments already existed in green networks based on the IP layer, for example, manufacturing energy-efficient routers [4], making networking devices sleep periodically [5], and so on. However, it is not enough to develop green networks just based on the IP layer. In fact, in the current Internet, the network traffic (in the IP layer) is transmitted on the fiber backbone (optical layer) in order that the flexibility of the IP layer and the huge bandwidth of the optical layer can be exploited [6]. Therefore, with the worldwide fiber deployment and advanced Wavelength Division Multiplexing (WDM) technologies, multi-granularity transport networks have been introduced [7]. By multiplexing many IP layer services into one wavelength and in turn multiplexing dozens of wavelengths into one waveband, and so on, bandwidth utilization is

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significantly improved. There is no doubt that multi-granularity transport networks should be green and energy saving.

The energy saving mechanism can be divided into node-wise type and network-wise type. The former achieves energy saving by adjusting the component's working status in the node and link and trying to make its energy consumption be proportional to its transferred traffic. The latter achieves energy saving by improving the existing or re-designing new network architectures, protocols or algorithms. As a network-wise energy saving mechanism, the green routing issue has attracted wide attention. However, most of the current researches have so far focused on energy-constrained networks, such as mobile/wireless networks and satellite-based networks [8–10]. Even for the backbone networks, existing energy saving routing mechanisms are often focused either on the IP layer or the optical layer [11–17]. However, in multi-granularity transport networks, energy saving should be considered not only in the IP layer but also in the optical layer, so that energy efficiency could be further increased compared with the case when only one single layer is considered. Therefore, a power-efficient routing scheme should be developed in green multi-granularity transport networks, taking both IP and optical layer energy saving into account in an integrated way.

With various kinds of new networked applications, especially multimedia based ones, emerged, and with user demands diversified, Quality of Service (QoS) support becomes critical to networks. For example, video conference often has tight requirement on the bandwidth, delay and delay jitter and relatively loose requirement on loss, while bulk data transfer often has tight requirement on the bandwidth and transfer reliability and relatively loose requirement on delay and delay jitter. Therefore, the QoS requirements of the applications, especially their requirements on bandwidth, delay, delay jitter and error rate, should be considered by the routing scheme, so that their users can get high Quality of Experience (QoE) [18].

Meanwhile, making energy consumption adaptive to the transferred traffic is an effective way to save energy in green multi-granularity transport networks. Traffic demands should be routed with guidance to promote traffic to traverse the already-in-use network components (such as routers, switches and links) as many as possible, and thus network resource utilization can be improved significantly. In fact, with traffic aggregated to certain network components, the unused components can be put into low-power sleep mode or even switched off [19], and then substantial energy can be saved compared with the situation under which network devices are active no matter whether there are traffics transferred by them. Therefore, to make network energy consumption be traffic adaptive, resource utilization evaluation should be used as an energy-saving indicator to guide the power-efficient routing.

When designing a power-efficient routing scheme in green multi-granularity transport networks, we also need to consider the application's communication type. According to the amount of participants, it can be classified into unicast, multicast and broadcast; and multicast can be further divided into one-to-many and many-to-many. Existing researches pay more attention to unicast, one-to-many multicast and broadcast. However, certain kinds of applications need many-to-many multicast support and their demands are often known in advance, for example, video conference, telemedicine consultation and cyber games, etc. As an example, consider a multinational corporation which holds a video conference among all managers from different regions for production plan every Monday at 9:00 am. For such kinds of given static traffic demands, the routes could be computed and the required resources could be reserved in advance with the QoS requirements satisfied.

In this paper, we propose a Power-efficient QoS Routing Scheme (*PQRS*) in green multi-granularity transport networks to support Multiple Many-to-many Multicast Requests (M^3R) with given static traffic demands, in particular, their QoS requirements are known in advance and they will be started up at the same time. The contributions of our work are summarized as follows:

(1) The *PQRS* not only takes IP and optical layers into account integratedly, but also optimizes power consumption, QoS evaluation and resource utilization evaluation simultaneously under QoS and capacity constraints. To our best knowledge, it is the first one which deals with all the above factors comprehensively.
(2) The quantitative models of power consumption, QoS evaluation and resource utilization evaluation for nodes, links, branches, and trees are devised respectively, which provide the basis for the optimized tree construction when routing is done.
(3) A Chosen Probability Model (*CPM*) is presented to describe the property of the link in the network comprehensively, and its value denotes the probability of a link being chosen enroute along the tree. With *CPM*, a link with good performance on power consumption, QoS evaluation and resource utilization evaluation is preferred when routing.
(4) A heuristic Routing algorithm based on the *CPM* (*RCPM*) is proposed to construct tree or trees for M^3R. In particular, a multiplexing phase is devised to promote traffics to traverse along the same routes and to use the same active components as many as possible, and thus help avoid newly activating components and reduce power consumption further.

The rest of this paper is organized as follows. The related work is reviewed in Section 2. The problem formulation is introduced in Section 3. The algorithm description is given in Section 4. Simulation study is presented in Section 5. Conclusion is drawn in Section 6.

2. Related work

For the node-wise energy saving mechanisms, some new energy saving routers have been proposed, such as green router [20], dynamic energy router [21], and green reconfigurable router [22], and so on. These newly designed routers achieve power efficiency mainly through adaptive rate processing or power-aware packet forwarding, etc. For example,

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