Chapter 5
Power-Aware Networking

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ABSTRACT

Energy consumption of networking infrastructures is growing fast due to the exponential growth of data traffic and the deployment of increasingly powerful equipment. Besides operational costs and environmental impacts, the ever-increasing energy consumption has become a limiting factor to long-term growth of network infrastructures. Operators, vendors and researchers have started to look beyond a single router or line card for network-wide solutions towards energy proportionality. Therefore, Power Aware Networking (PANET) has been proposed to improve network energy efficiency. A PANET-enabled network assumes that only a subset of devices will be involved in traffic forwarding when the network is lightly loaded, so as to improve global energy savings. PANET is introduced in this chapter. Promising solutions for PANET are also exposed. PANET features are also analyzed. The chapter also discusses the challenges and future work that needs to be done.

1. INTRODUCTION

Energy consumption of networking infrastructures is growing fast due to the exponential growth of data traffic and the deployment of increasingly powerful equipment. There are emerging needs for power-aware routing and traffic engineering (TE), which adapt routing paths to traffic load in order to reduce energy consumption network-wide. Today's Internet Service Provider (ISP) networks have redundant routers and links, over-provisioned link capacity, and sometimes enforce load balancing-based traffic engineering policies. As a result, routers and links operate at full capacity all the time with low average usage, typically less than 40% of link utilization (Guichard, Faucheur, & Vasseur, 2005). This practice makes networks resilient to traffic spikes and component failures, but also leaves networks far from being energy-efficient.

Power-aware routing and traffic engineering have been proposed to improve the energy efficiency of networks, for example, by aggregating traffic onto a subset of links and putting other

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links with no traffic into sleep. Observations have shown that line cards are a significant source of router's power consumption, accounting for 40% - 70% of total power consumption (Cisco, 2009). Most of the energy is consumed even if the router is in standby state, and forwarding packets at full speed only increases the energy consumption by a small percentage. This implies that being able to put links into sleep mode can potentially save a lot of energy. Designing practical protocols, however, has been challenging, because making routing protocols power-aware brings significant changes to the routing system and the entire network: it implies dramatic changes in hardware support, protocol design, network monitoring, and operational practices. These issues often depend on the specific network environments.

The Power Aware Networking (PANET) initiative has been proposed to investigate how network energy efficiency can be improved. The idea of PANET is that forwarding path computation can take into account the energy information for the sake of optimized, energy-efficient, network resource usage. For example, the design of a PANET-enabled network may assume that only a subset of devices will be involved in traffic forwarding when the network is lightly loaded. Those devices that are not involved in traffic forwarding operations can thus enter sleep state and save power accordingly, so that important energy savings can be achieved.

The chapter is organized as follows: Section 2 describes several PANET use cases. Section 3 presents the most representative feasibility studies of PANET conducted by the academic and industry, and which aim at addressing energy efficiency in networking infrastructures. Section 4 presents a set of requirements, and challenges for building a PANET-enabled network. Section 5 introduces PANET effort within Standards Developing Organizations (SDOs), such as the IETF EMAN WG (Internet Engineering Task Force Energy MANagement Working Group) and GAL (Green Abstraction Layer standard) of ETSI (European Telecommunications Standards Institute). Section 6 suggests some future work.

2. USE CASES

This section investigates PANET use cases which cover both backbone and data center networks. As for the energy efficiency of backbone networks, only intra-domain use cases are considered. Trying to be energy efficient at the inter-domain scale seems technically feasible, but it can easily end up with lack of business motivation. Inter-domain use cases are left for future study.

2.1. Power Awareness in Backbone Networks

The IETF EMAN WG focuses on the energy management of networking devices. For example, networking devices following the specification of the EMAN MIB (Management Information Base) can report their power states; the energy management of the network can therefore make use of these states. However, there is a gap on how to make use of this kind of data to achieve energy efficient networks. With a power control plane, it becomes possible to make use of these measurements and power control ability to achieve the energy efficiency of a whole network. This section lists several use cases for backbone networks.

For example, the bootstrapping time of a router may take several minutes and the stabilization of it (acquisition of the data to populate the topology database, for example) may take much longer. It is unrealistic to switch off and on a whole node in backbone networks frequently to achieve energy efficiency, so this section only investigates the cases in which links (i.e., links' attached components) are shut down or put into sleeping state for energy conservation purposes.

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