Energy Efficiency Using the Fast Reroute Technique

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1. INTRODUCTION

Today, the load of networks typically exceeds their long-term utilization by a wide margin (Reforgiato, 2013). Moreover, as shown in (Barford, 2010), current network nodes have a power consumption that does not depend on the actual traffic load they face. This implies an energy waste in today networks (Ipmon Sprint, 2007; Jardosh, 2007). The increasingly cost of energy led to a general concern about this occurrence. Today, in fact, 37% of the total ICT emissions are due to telecommunications companies infrastructures and devices. For this reason, addressing energy efficiency challenges in wireline networks is receiving considerable attention in the literature (Barford, 2008; Gupta, 2003; Mahadevan, 2009; Nedevschi, 2008). Moreover a number of research projects has been started on this topic (see for example Earth (2010), Chron (2010), Greentouch (2011), C2power (2010)). Some novel hardware devices that allow entering different energy power states are therefore expected in the near future (Cisco, 2009). Routers are device that forwards data packets between computer networks, creating an overlay Internetwork. Cisco (Cisco, 2009), the pioneer in home networking, has sold more than 70 million Linksys routers worldwide and is leading the charge in the next-generation connected home. A routing protocol specifies how routers communicate with each other, disseminating information that enables them to select routes between any two nodes on a computer network. Routers are therefore one of the core elements of computer networks. Moreover, Multiprotocol Label Switching (MPLS) is a mechanism in high-performance telecommunications networks that directs data from one network node to the next based on short path labels rather than long network addresses, avoiding complex lookups in a routing table.

Our idea builds upon several approaches that have been proposed to reduce the energy consumption in network components. For example, in (Nedevschi, 2008), the authors proposed a method based on putting network components to sleep during idle times, reducing energy consumed in the absence of packets. The rationale behind that was based on adapting the rate of network operations to the offered workload, reducing the energy consumed when actively processing packets (rate adaptation is usually achieved by scaling the processing power according to the data rate the router has to manage). Which energy aware technique to use in a green router (a router with novel hardware and software capabilities able to dramatically reduce its power consumption) is a challenging problem which depends on a number of parameters, including the role of the router in the network, the incoming traffic profile, the hardware complexity and the related costs with respect to the energy that can be potentially saved and the Quality of Service (QoS) to be guaranteed to the final users (Hu, 2011). In (Bianzino, 2011), a novel distributed algorithm puts into sleep mode links in an IP-based network. This solution is distributed among the nodes under the assumption that nodes do not know the traffic matrix, whose knowledge is indeed unrealistic in the current Internet architecture. Moreover, the switch off decision is taken considering the current load of links and the history of past decisions. One of the most common policies in network dimensioning is represented by resource consolidation: its goal is to reduce energy consumption due to devices underutilized at a given time. As the traffic in a given network follows a well known daily and weekly pattern, there is an opportunity to aggregate traffic

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flows over a subset of the network devices and links, allowing other devices to be temporarily switched off. This solution should preserve connectivity and QoS, for instance by limiting the maximum utilization over any link. On this direction, authors in (Bianzino 2011), (Kakemizu, 2009) proposed approaches that achieve energy efficiency in networks by controlling the usage probability of pre-defined multiple paths to bring about a situation where some nodes can transition to sleep state when the traffic volume is small. Moreover, stand-by modes have to be explicitly supported with special techniques to maintain the network presence of sleeping components. Last but not least, in (Bianzino, 2010) the authors analyze the design of green routing algorithms and evaluate the achievable energy savings that such mechanisms could allow in several realistic network scenarios.

In this article we face the problem of reducing power consumption in router networks adopting a Low Power Idle[1] (LPI) approach locally for each router. By sending a low-power-idle indication signal for a specified time the transmit chips in the system can be turned off.

We exploit the Fast Reroute mechanism, which is a technique, integrated in the MPLS protocol, that detects link failures at the hardware level (without Fast Reroute the OSPF protocol would require several seconds) and overwrites respective routing table entries with pre-computed routes, to minimize packet drops. An initial idea has been presented in (Reforgiato & Riccobene, 2013). We focus on wired networks and assume that interfaces have a certain number of LPI states: each of them is characterized by a maximum bit rate that can be supported and a given power consumption. The goal is to maximize the number of interfaces working in LPI mode (which corresponds to a certain amount of energy saving) in the network routers maintaining the reachability of all potential destinations and maintaining high the network QoS. More in detail, we have leveraged the Fast Reroute approach in order to detect the hardware interfaces, which can be set to LPI mode (therefore obtaining energy saving). The output traffic of the underlying router can be therefore deviated (depending on the current bit rate and a local control policy) towards other interfaces producing a non-negligible gain of energy saving. We have run simulations using NS-2 (a discrete event simulator targeted at networking research) to simulate the behavior of the nodes that use our approach within several network topologies. The results we have obtained showed us the amount of energy saving that is possible to achieve using our method. The results drove us to the development of such a technique on a real environment. In fact, we built our technique on top of a project based on the reference router of the NetFPGA platform (Gibb, 2008). The remainder of this article is organized as follows: in the next Section we described how we employed the Fast Reroute mechanism for energy efficiency. Then we will show how to detect the interfaces to be set to LPI mode. A result section will show experimentations, simulations with NS-2, and results. It follows an analysis on the NetFPGA platform, which is the case study we have been working on. Measurements relative to power consumption of the NetFPGA platform are reported, where we have estimated the amount of energy that could be saved using our approach and the NetFPGA power consumption analyzed in (Lombardo, 2012a). Finally we will show the future research direction before ending the article with conclusions and key terms definitions.

2. BACKGROUND

In a networking environment, a router must be able to forward packets to each destination. A common router keeps active all its interfaces in order to find the best path for each destination and minimize the cost of packet transmissions. Network operators tend to keep this cost as low as possible. Our goal is to maximize the number of interfaces set in LPI mode in the network routers maintaining the reachability of all potential destinations and maintaining high the network QoS. To know which interfaces can be set to LPI mode we need to understand how the network topology is characterized and how each router can forward packets to all destinations. Some of the information about the topology can be obtained by looking at the info provided by the routing protocol. For example, in the link state routing protocols, a router gathers information about the entire network topology, and the Djikstra's algorithm (Diestel, 2000) is performed using this information in order to calculate the best path for each destination. Moreover, if a given destination can be reached via multiple paths with the same cost, load balancing can be applied to improve the QoS of the communications. The reader notices that not all routing protocols implement the load balancing capability. Using this process

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