Design of a Temperature-Constrained Governor to Save Energy in an Open Multi-Frequency Green Router

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ABSTRACT

In the last years a new challenge turned out for both researchers and industries in telecommunications area is represented by green networks. Besides energy saving that is possible to achieve, another positive side effect of this is the reduction of the working temperature of internal components of telecommunications devices (switches, home gateway, routers, etc.). This idea is encouraging the development of routers of reduced dimensions as long as there is the knowledge that the temperature remains in a given range. For this reason the target of this paper is to propose a governor policy that provides the best trade-off between quality of service and energy saving in respect of a given target on the working temperature. More specifically, such a governor is in charge to manage the clock frequency of the Central Processor Unit (CPU) of the green router according to the traffic loading the router, varying the processing engine performance, the working temperature and the power consumption of the hardware at the same time. The proposed policy is then applied to a case study and evaluated by simulation to show how it can be used for the above purposes, and to allow green router designers to control the temperature statistics of a router and design the governor parameters to maintain the mean temperature below a given threshold.

Keywords: *Green Routers, Network Field Programmable Gate Array (NetFPGA), Performance Evaluation, Power Consumption, Router Governor*

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INTRODUCTION

Meeting Quality of Service (QoS) and network reliability has been the main target for telecommunications operators in the last years. This has been done completely ignoring energy waste introduced to achieve this target. In fact, today's most telecommunications networks are often provisioned for worst-case or busy-hour load, and this load typically exceeds their long-term utilization by a wide margin; Barford, (2008) shows that current network nodes have a constant power consumption that does not depend on the actual traffic load they face. Therefore, most of the energy consumed in networks today is wasted (Sprint, 2007; Jardosh, 2007).

The increment of the temperature of the places where network devices reside is a non-marginal side effect of high-energy dissipation. It derives a consequent further waste of energy used by cooling machines to maintain the temperature of the local environment below a certain threshold.

The constant rising cost of the energy and the need to reduce the global greenhouse gas emission make this occurrence unsustainable: today, 37% of the total ICT (Information and Communications Technology) emissions are due to telecommunications companies infrastructures and devices (The Climate Group, 2008). For this reason, addressing energy efficiency challenges in both wireline and wireless networks is an important matter and it is receiving considerable attention in the literature today (Gupta, 2003; Nedevschi, 2008; Lombardo, 2010a; Lombardo, 2012a; Chiaraviglio, 2010; Panarello, 2012; Lombardo, 2012b; Lombardo, 2010b); moreover many research projects (Econet website, 2010; Trend website, 2010; Greentouch website, 2011) have been started on this topic. Thus, some novel hardware devices, so-called "green routers", are expected in the near future to allow entering different power states (Cisco, 2009) according to the input traffic.

The energy aware techniques to be used in a green router depend on a number of factors, including the role of the router in the network, the profile of incoming traffic, the hardware complexity and the related costs with respect to the energy we can potentially save and the QoS we want to guarantee to the users (Hu, 2011).

Let us note that the introduction of green management techniques to make network routers green has an important consequence on the decrease of working temperature of the hardware device. As known, temperature is one of the major factors which must be considered and when designing electronic devices, (specifically routers), since operating at higher temperature degrades system reliability, causes performance degradation and leads to higher cooling and packaging costs (Pedram, 2006).

Moreover, "smaller and faster" are the chief demands driving today's electronic design. These issues translate into high power densities, higher operating temperatures and lower circuit reliability. Therefore, greening a router can be considered as a leveraging approach to move towards this direction. In other words, reduction of the average temperature in green routers due to the application of algorithms aimed at reducing energy consumption will allow designers to modify hardware, reducing its size and the size of the passive and active cooling systems, since a package designed for the worst case is excessive. However, the above hardware modifications can make again router circuits heat beyond their designed thermal limits. For this reason, the working range of temperature becomes again an important issue in green router design.

With all this in mind, the paper target is to propose a *router governor* policy for a green router with given requirements in terms of temperature, QoS and energy consumption, and to show some simulative results about that. The results allow the designer to determine in advance if the device will operate within the recommended thermal ranges when the green *router governor* uses the proposed energy saving policy. In addition, the same analysis can be used to evaluate the achieved amount of energy saving.

A case study based on the NetFPGA Reference Router (Gibb, 2008; Lombardo, 2011)