Dynamic Frequency Scaling Architecture for Energy Efficient Router*

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ABSTRACT

Recently, energy expenditures of the Internet have increased dramatically, raising energy issue of routers an urgent problem in relative research areas. In fact, much device surplus and redundancy are introduced during network planning for rarely appeared traffic peak hours and device failures, wasting energy most of the time. In this work, an energy-aware architecture is proposed for routers, which could trade system performance for energy savings while traffic is low by scaling frequencies of its inner components. We also explore multi-frequency modulation strategies to optimize the energy saving effect. The result shows that our prototype router could save about 40% of its peak power consumption.

Categories and Subject Descriptors

C.2.1 [**Computer-Communication Networks**]: Network Architecture and Design

General Terms

Design, Performance

Keywords

Energy efficiency, Frequency scaling, Router architecture

1. INTRODUCTION

Recently, many researches have been published on energy efficient technologies for networking devices, such as smart port sleeping, dynamic buffer adapting and green routing.

Maruti Gupta and Suresh Singh in [1] initially argued that network devices could save energy by putting idle ports to sleep. Later, their works on smart port sleeping led to the establishment of standard IEEE 802.3az. However, due to considerable time and energy costs for transitions, this method could only be effective while device utilization rate is under 10% [2].

A. Vishwanath *et al.* exam buffer usage of modern routers and develop scheme to dynamically turn on/off SRAM and DRAM buffers according to traffic demand [3]. Their results show that up to 10% of the total energy consumption can be saved at the cost of negligible traffic congestion and latency.

Green routing mainly focuses on concentrating traffic in a subset of network links, and create more opportunities for energy efficient behaviors of single network devices.

Based on our initially work [5], we propose an energy-aware router architecture, which could dynamically adapt lower frequencies for energy savings while being underused. The frequency scaling scheme has advantages in the following aspects. First, frequency scaling zones cover nearly all functional components, which consume more then 50% of the overall energy, much more than other methods [4]. Second, multiple energy states with different trade-offs between performance and energy efficiency are more flexible for strategic switching. Besides, frequency scaling scheme is a supplement, not a replacement, for current green networking technologies.

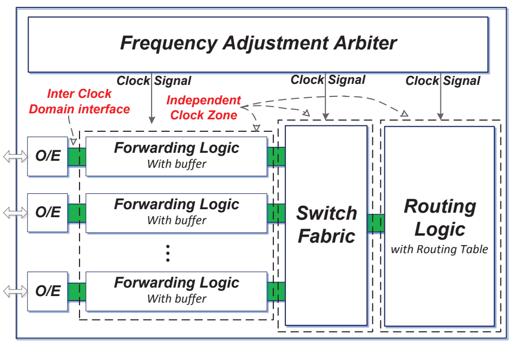

Figure 1: Block Diagram of Frequency Adjustment Router Architecture.

2. FREQUENCY SCALING ARCHITECTURE

As is shown in Fig.1, we regard functional components as elementary units for frequency scaling. In order to release clock constraints, *inter clock domain interfaces* are inserted before targeted components and turn them into frequency irrelevant and adjustable units. Generally, *inter clock domain interfaces* is an asynchronous FIFO based one-way data path, which could relay signals between different clock zones and capable of buffering packets. Frequency switchings are triggered by buffer occupancy of directly attached interfaces, which is regarded as a indicator of gaps between incoming workload and current performance. As a central controller,

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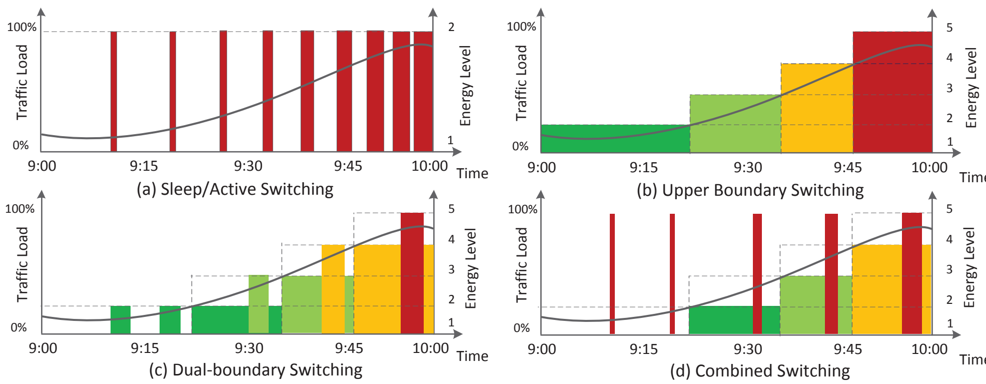

Figure 2: Energy State Switching Strategies.

frequency adjustment arbiter is introduced to monitor system information, such as buffer occupancies, module utilization rates and current energy states of each modules, and make frequency adjustment decisions.

3. DYNAMIC FREQUENCY SCALING STRATEGIES

Based on frequency scaling architecture, we propose several switching strategies distinguished by different buffer thresholds and preset cold down time between transitions to guarantee stay time in low energy states and reduce switches as follows:

Sleep/active switching: A two-frequency switch strategy as shown in Fig.2 (a) is proposed, which allows modules adopt very low frequency (as sleep) for energy savings, or active (in red) for packet processing. This scheme gains higher device utilization rate but causes frequent switching.

Upper Boundary switching: This scheme permits multi-frequency switching, and always adopts the higher frequency level that barely offering more capacity than necessary, which is shown in Fig.2 (b). Comparing to two-frequency switching, this method reduces frequency transitions at the cost of energy efficiency.

Dual-boundary switching: Fig.2 (c) describes a optimized strategy of upper boundary idea, which introduces a lower boundary to further reduce stay time in higher frequency levels with limited switches.

Combined switching: This strategy combines ideas of sleep/active and boundary switching, as shown in Fig.2 (d), treating low traffic time (such as nights) with sleeping strategy, and high traffic time with the aid of lower boundary for reducing transitions.

4. EXPERIMENT AND RESULT

We developed a software router prototype which supports 10-frequency adjustments range from 125 MHz to 12.5 MHz, corresponding to 1000Mbps to 100Mbps respectively in traffic capacity. We fed real traces for the experiments, which were captured from an office network of about 1000 users, spinning over a period of more than three hours and the loss rate was kept under 1% of the total traffic. The preliminary results are shown in Fig.3, by limiting switches with cold down time and processing buffered packets as fast as possible, our proposed combined strategy achieved the most significant savings.

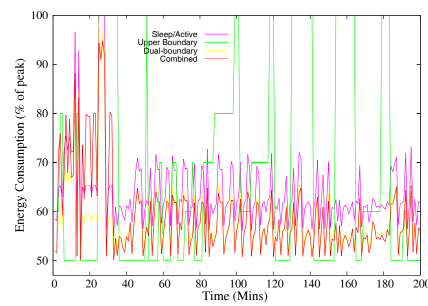

Figure 3: Frequency Scaling for Energy Efficiency.

5. CONCLUSION

In this work, we propose an energy efficient router architecture which allows inner components to adapt frequencies for energy savings. In addition, frequency modulation strategies for tuning various network environments are also introduced. Simulations on real traces show that our frequency adjustment router could save up to 40% of the total energy consumption.

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