Study on energy saving in network devices

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Abstract. A lot of studies on high efficiency energy for backbone networks, EPON (Ethernet Passive Optical Network), networking equipment and IDC (International Data Center) are being carried out by many Korean and foreign researchers. For EPON, research on the development of protocols for higher energy efficiency at the PHY/MAC layers and the enactment of standards, and the improvement of energy efficiency of EPON devices is being conducted, while for networking equipment such as routers and switches and IDCs, research on saving the energy consumed by devices and the management of energy efficiency using power monitoring, cooling devices and metering technologies is being conducted. Against this backdrop, this study is aimed to develop methodology for the improvement of network energy efficiency in existing home/ small and medium-sized office network environments and to develop, test and evaluate an energy saving prototype for L2 Switch.

Keywords: energy efficiency, network management, green ict

1. Introduction

Korea has been making active efforts to establish green growth and Green IT strategies in systematic ways and produce fruitful results from such strategies, for the purpose of emerging as one of the seven strong Green economies by 2020. Currently, Korea’s green growth strategies are being benchmarked by other countries around the world. In particular, on the basis of its world top class IT technology, Korea is supporting its Green IP sector for green growth. For example, Korea is making efforts to develop technologies for IT devices with high energy efficiency, environment-friendly lights and supporting new green growth engines, to create industrial infrastructure for green growth for the IT sector, and to develop a model for a new IT-based industry and create a market for green IT products. [1,2]

A lot of studies on high efficiency energy for backbone networks, EPON (Ethernet Passive Optical Network), networking equipment and IDC (International Data Center) are being carried out by many Korean and foreign researchers. For EPON, research on the development of protocols for higher energy efficiency at the PHY/MAC layers and the enactment of standards, and the improvement of energy efficiency of EPON devices is being conducted, while for networking equipment such as routers and switches and IDCs, research on saving the energy consumed by devices and the management of energy efficiency using power monitoring, cooling devices and metering technologies is being conducted.

Against this backdrop, this study is aimed to develop methodology for the improvement of network energy efficiency in existing home/ small and medium-sized office network environments and to develop, test and evaluate an energy saving prototype for L2 Switch.

2. Related Work

Due to the development of the IT industry and their popular use, the speed of increases in related energy consumption and CO2 emissions is getting faster and faster. CO2 emissions caused by IT devices are predicted to increase to 1.43Gt by 2020, which amounts to an annual six percent increase, with the consideration of that of 2002 (0.53Gt). 25% of the total CO2 is emitted during the manufacturing processes and the rest is emitted during the use of ICT devices (Source: Smart 2010 and NIA 2008). [3]

More specifically, we found out that there is a big difference in energy consumption patterns between individual devices. For servers, 75% of the total energy consumption occurs during the use of them, while for mobile devices such as cell phones, 80% of the total energy consumption occurs during manufacturing...
processes (Source: Gartner, "Green IT - A New industry shockware", gartner symposium/ITXPO 2007). The reason for this is that mobile devices running on battery is designed and manufactured with the consideration of low-power consumption, while servers and PCs is designed only with the consideration of device efficiency. [4,5]

3. Development of an L2 Switch-based proxying system

Generally, since all internal client traffic is transferred via L2 Switch to external networks, in the system designing for this study, L2 Switch carries out the function of proxing for internal networks.

First, an active L2 Switch analyzes the bandwidths and types of traffic that is transferred on the internal network all the time. By doing such an analysis, L2 Switch determines when it enters into standby mode. After shifting to standby mode, L2 Switch maintains standby mode until valid traffic occurs on the network to save power. However, in this mode, network protocols and dummy packets that are responsible for checking the state of network connection for individual applications are still transferred. Whenever such transfer occurs, the Switch goes back to operation mode to process packets.

50% of the traffic transferred within the Home is Dummy packets. This study describes the development of a proxying module that is able to process these dummy packets while L2 Switch is in standby mode in order to extend the time when L2 Switch is in standby mode for maximization of power saving.

As you can see from the below diagram, shift to Active or to Standby mode of L2 Switch is determined with the consideration of traffic flow, continuous traffic monitoring using libpcap occurs. In the case in which no traffic except one that can be discarded from L2/L3 layers or be proxied for a certain period of time (30 seconds), L2 Switch gets into Standby mode. If WOL (Wake on LAN)/ WOWAN (Wake on WLAN) traffic occurs on the local network or a direct IP packet is received via the WAN port, L2 Switch goes back to Active mode.

In the case in which a packet that can be discarded on the internal network is received, what L2 Switch should do is just discarding it. If the creation of a response packet such as an ARP request packet is required, proxying occurs. At the moment of shift to standby mode, packet proxying is supported by FPGA, and this is for making a network chipset support the function of proxying in the future. The below Table shows that for being processed, packets are classified into three categories—Proxying packets that create Acknowledge packets for Switch, Dummy packets that just drop received packets, and Active packets that make home gateway go back to Active Mode upon receiving applicable packets.

Proxying packets are the ones for ARP Request, which is L2 layer Packet transferred in advance for wired communication, ICMP Request such as Ping, TCP SYNC Packet checking TCP connectivity, and Netbios Name Service Packet used for Windows Explorer. For Proxying packets, Proxying is carried out only when the Destination Address of a received packet is one of the following:

- A MAC address of an IP address of a home device belonging to the home network
- A MAC address or the address of an IP layer broadcast packet
- One in the range of multicast addresses

To this end, L2 Switch during normal operation mode monitors traffic flows to collect information on devices on the home network and subnets and transfer such information through the FPGA Shared Memory when it enters into standby mode.

### 3.1. Development of L2 Switch, the hardware system supporting proxying

For the purpose of experimental evaluation of L2 switch supporting low-power mode, we have developed and have conducted experiments with a board, which you can see as below (<Fig x>). The hardware block diagram is as shown in <Fig. 4>. Peripheral devices are connected to the main processor, MPC8349E, and configuration includes typical wired and wireless Internet Access Points. In addition, for the management of power consumption on the network, which is not possible with conventional wired and wireless Access Points, a Switching Chip is used along with the main processor to make four LAN ports. The Switching Controller is connected to the main processor (Main CPU) through a PCI bus.

![Fig 4. Picture of the board](image)

For MPC8349E used for the system, a processor that has 533MHz as its Core frequency and 266MHz as CBS frequency was employed. Therefore, MPC8349E consumes an average of 3.3W when the system operates in normal mode, and the maximum power consumption is 3.6W. Also, MPC8349E has a power management control unit, so that it can provides the function of enabling a device to switch to low-power mode or to normal mode. There are three kinds of power saving functions that are delivered by MPC8349E:

### 3.2. Development of L2 Switch supporting proxying

1. **Proxying module operation flow**

   The operation flow of a proxying module is like the following.

   Once the Switch is shifted to standby mode, the proxying module of FPGA begins to start. After entering into the applicable mode, default settings of EMAC configuration is made and information on the client address and network addresses collected in Active mode is read by the Share Memory so that client address table settings are made for the management of proxying operations.

   Then, the system timer is defaulted to check if the system has entered into standby mode. If a packet is received, the counter within the timer indicates a given number +1, and if not, the counter indicates 0—the default value. If the counter indicates 0 for a specific period of time, the L2 Switch system is shifted to standby mode.
If a packet is received, the system analyzes the destination address and protocol of the packet and determines whether to carry out proxying or not. If the packet has been made for proxying, a response packet is created and transferred to the target system. If the packet is considered as a dummy packet, it is simply dropped by the proxying module. If the packet is an active one, PME PIN that is responsible for making L2 Switch shift to normal mode gets enabled so that the system goes back to normal operation.

4. Experiments and evaluations

In order to measure the amount of energy consumed by L2 Switch, which has been developed by our research team, we set up an experimental environment as shown below.

For power consumption evaluation, we connected a power measuring machine to L2 Switch, and connected Ethernet wires to each port, and then obtained measuring results as shown in below <Table 2>.

Table2. Measurements of power consumed by the L2 Switch platform

<table>
<thead>
<tr>
<th>Hardware configuration</th>
<th>ON Mode</th>
<th>Amount of consumed power (W)</th>
<th>Standby Mode</th>
<th>Amount of consumed power (W)</th>
<th>Power saving rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 WAN port used</td>
<td>5.4V 2.3A</td>
<td>12.42</td>
<td>5.4V 1.3A</td>
<td>7.02</td>
<td>43.5</td>
</tr>
</tbody>
</table>
As you can know from <Table 2>, the amount of consumed power significantly decreases when the system is in Standby mode. Whenever you use another one port, additional 4.3W is consumed, and the difference in the amount of consumed power between On and Standby mode is 5.4W. In this case, if you adjust the link speed and the data transfer mode of the Ethernet controller, you can save more energy.

It is expected that if the Ethernet controller chip in a WAN port which you don’t want to use is removed and the Ethernet controller chip in a LAN port is replaced with one consuming less power, more energy saving will be accomplished.

5. Conclusion

As of today, a huge amount of energy is wasted by network devices, and this phenomenon happens due to “permanent connectivity,” the unique feature of network devices—usually network devices have to be still connected even when they are idle. Recently, with the awareness of this problem, a lot of studies have been launched for the purpose of reducing energy consumption by these devices. In this paper, we proposed L2 Switch, an effective system which employs a proxying-based power management algorithm so that network connectivity is maintained and at the same time energy consumed by ICT devices on the network can be saved.

Nevertheless, given the fact that network integration service for various networks such as wired networks, WLAN, UWB-based wireless networks, IEEE 1394 and PLC is now popular, studies on energy efficiency for these various mediums should be conducted in the future. For this reason, additional studies on protocols for and electronic features of these various mediums for the purpose of developing an energy efficient algorithm suitable for technological requirements for various types of network devices will be conducted by our research team.

6. Acknowledgements

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7. References