Research on Web Server Application on Multi-core Embedded System

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Abstract

With the rapid progress of VLSI and Embedded Technology, it’s the time to integrate traditional data-acquisition equipments and web servers into an embedded system to get higher reliability, dependability and the real time performance. To this system, there are still exists some problems need to be solved effectively such as the implementation of multi-tasks running in concurrency mode. This paper presents a Web Server application based on multi-core embedded system for monitoring instance, the system was run on the eCos embedded Operation System and composed of the embedded Intel atom dual-core processor, a data-acquisition module and a web server module. We have carried out this multi-core embedded web server system to a Chemical Monitoring project in a Power Plant successfully, the practical result shows that this architecture can work better with higher performance than ever before.

keywords: Embedded Web Server, Multi-core, Intel Atom, eCos OS

1. Introduction

With the progress of semiconductor technologies and then the advent of multi-core processors at 2006 [1][2], multi-core era is coming and this novel architecture has imposed much influence on embedded system design ranging from ultra-mobile device to telecommunication server as well as the pervasive computing[6]. Especially with the announced of Intel Atom processor at the beginning of 2008, people were intrigued to integrate this processor to the embedded system to get high performance such as low response time in control or monitor system. The Intel Atom processor, was an embedded processor based on multi-core architecture and was built with the world’s smallest transistors and manufactured on 45nm Hi-k Metal Gate technology, the Intel Atom processor-based embedded system can offer better real time performance as well as simple interface.

Currently, most embedded web server system for monitoring were composed of two separated parts[3], an embedded monitoring device and a server with industrial field bus (IFB) joined each other, the monitoring device was commonly used to gather digital signals which were converted from many sensors’ analog signals, and then transmit these data to web server through IFB, the web server will broadcast these data on web after which were received and computerized normally. To most traditional web server system for monitoring the intermediate process between these 2 parts will greatly effect the system performance such as reliability, accuracy, stability, real-time performance, etc.

So, based on this new embedded multi-core technology, this paper presents a novel structure of the embedded web server system for monitoring, and eCos [9] embedded operation system was reconfigured as well to this system. In the system, different analog signals from sensors can be processed and stored in parallel, other processes such as sampling, A/D conversion, web broadcasting and so on can running in parallel mode as well to get high real-time performance. Managers of system can gather data from all monitoring fields and evaluate each equipment status to secure safety production process, and can browse relative information include history data in remote computer web browser. The paper also presents an application instance with high real time performance.

The remainder of paper was organized as following, section 2 illustrate the design of the system, include hardware design, software design, section 3 describe how many tasks in the system and how to deal with these tasks, section 4 presents some simulations results, finally, in section 5 we make some conclusion marks.

2. System Structure

The web server application system for monitoring based on multi-core platform was composed of two major com-
ponents, as shown in Fig 1, an Embedded multi-core Web Server for Monitoring (EWSM) and some remote monitoring terminals [4]. Plenty of sensors modules different areas will produce analog signals continuously with electrical current range form 4 to 20 mA and voltage range from 0 to 10 V, these analog signals will pass through the shaping circuit, filtering circuit, amplifying circuit, A/D conversion module in turn and it were finally convert to digital signals, the sampling digital signal data will be stored in local hard disk of web server. When a data request from remote terminals such as PC, Mobile Internet Device (MID), Pocket PC (PPC), smart phone etc, these web servers will arrange real time data dynamically and quickly to meet the coming request, system mangers of different level can browse these data information in all types of terminal browsers. Profit from the high parallel performance of the system with Intel Atom dual-core processor as its system CPU and embedded operation system eCos, the system performance improve significantly in parallel computing, storage procedure and web request response etc.

2.1. Hardware description

The hardware platform of EWSM was mainly composed of embedded multi-core processor (Intel atom 330), north bridge (Intel 82945GC), south bridge (Intel ICH7), display module(for local display), DDR system memory, Ethernet interface (Intel 82559), storage device, sampling card, and etc, as shown in Figure 2.

The multiplexing sensor signals were captured by sampling card and then converted to digital signals by A/D conversion module. These data were buffered and processed by the atom processor system (including Intel atom processor 330, Intel 82945GC north bridge chip, Intel ICH7 south bridge chip and etc) through PCI bus, and the ripe data will be stored into the storage device through IDE interface.

The sampling card was composed of the Cypress PSoC (CY8C26443), PCI 9052 and other Peripheral devices [12]. The CY8C26443 is a 8-Bit Harvard architecture Programmable System-on-Chip (PSoC) Micro-controller, its main components include a fast CPU, 16KB Flash program memory, and 256B SRAM data memory which could be configured to 12 channels for analog signal and 8 channels for digital signal peripheral blocks. The PCI 9052 is a 32-bit, 33MHz PCI Target I/O Accelerator for 32-bit, 40MHz Generic and ISA Local Bus Design, which provides slave PCI functions directly by joining the adapter’s I/O circuitry (control, address and data lines) and the CPU system via a 32-bit PCI bus.

In this system, with considering of the energy consumption and the parallel performance [10], Intel Atom dual-core processor 330 was selected as the CPU of this embedded system, not only for its high CPU frequency of 1.6 GHz , low power consumption of 8W which were appreciated for embedded system design, but also for its support of IA-32 and Intel 64 architecture. Intel Atom processor has a primary 32-KB instruction cache and 24-KB write-back data cache for each core, and a 533MHz source-synchronous FSB (Front Side Bus) which could improve data transmit rate. And multi-threaded programming was also supported on this type of dual-core processor based platform.

Here the display module was used to display local real-time sampling data.

The eCos embedded operation system was selected as the OS of EWSM [15] [14], and the Intel 82559 was selected as ethernet interface to communicate and transmit data between EWSM and intranet remote terminals.

Besides, USB 2.0 interface were mainly designed for system maintenance, data backup and exchange.

2.2. Software design

eCos is an open source, royalty-free, real-time operating system intended for embedded applications [10] [13]. The highly configurable nature of eCos allows the operating system to be customized to precise application requirements, delivering the best possible run-time performance and an optimized hardware resource footprint, it can support multi-threaded programming technology. And eCos was also designed to wide range of target architecture and platforms including 16, 32, and 64 bit architectures, MPUs, MCUs and
DSPs. Currently eCos can supports tens of different target architectures including ARM, Intel X86, MIPS, PowerPC and so on.

At the same time, eCos OS has been designed to meet applications with high real-time requirement [14] [17], eCos can provide nice features such as full preemption, minimal interrupt latency, all necessary synchronization primitives, scheduling policies, interrupt handling mechanisms. From the programming points, eCos also provides device drivers, memory management, exception handling, C, math libraries and etc to program embedded applications.

According to the eCos architecture, the software architecture of the embedded web server for monitoring was divided into three layers, the hardware abstraction and driver layer, the eCos operating system layer and the application layer, as shown in Fig 3.

<table>
<thead>
<tr>
<th>Sampling Application</th>
<th>Data Management</th>
<th>Web Server</th>
</tr>
</thead>
<tbody>
<tr>
<td>eCos</td>
<td>Hardware Abstraction Layer</td>
<td>Device Driver</td>
</tr>
<tr>
<td>Target Hardware</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Figure 3. Software architecture of Target Hardware**

Hardware abstraction and driver layer was composed of the eCos HAL (Hardware Abstraction Layer) and various drivers. The eCos HAL could be identified into three levels: the architecture HAL, the variant HAL and the platform HAL. The architecture HAL abstracts the basic CPU architecture and also includes mechanisms such as interrupt delivery, context switching, CPU startup etc. The variant HAL encapsulates some CPU variant features such as caches, MMU and FPU. It can also deals with some on-chip peripherals such as memory and interrupt controller. For architectural variations, the actual implementation of the variation is often in the architectural HAL, and the variant HAL simply provides the correct configuration definitions. The platform HAL abstracts the properties of the current platform and includes things like platform startup, timer devices, I/O register access and interrupt controllers. Generally there is a separate package for each of the architecture, variant and package HALs for a target.

The eCos layer was a operating system layer, which was composed of some related softwares, such as kernel, memory management, process scheduling, file system and network protocol stack, etc.

The application layer, which was the top layer of the software architecture and was mainly composed of data-acquisition, data management and storage and web server application. In this layer, parallel signal-sampling, conversion and transform control and the data storage were achieved. And the eCos http package provides a simple http server for use with applications in eCos. This server was specifically aimed at the remote control and monitoring requirements of embedded applications. For this reason the emphasis is on dynamically generated content, simple forms handling, a basic CGI interface and parallel request response.

### 3. Tasks decomposition

Besides the supports of the hardware and OS, the ultimate method for solving the multi-task processing was to achieve the data-acquisition task, data-storage task, web page create task and web request response task in parallel [8] [5] [7] [6]

As for Operation System, we have transplanted successfully the eCos operation system to Atom dual-core platform in order to make full use of the multi-core resource[17].

According to the application, tasks need to be decomposed into separated tasks which could be run in parallel or concurrency mode, these tasks include data-processing task (include data-acquisition and data-storage etc.), web-processing task (including web page creation and web request response etc.) don’t have any data race condition so that it can be paralleled well, also, we used a dynamic adjust mechanism to evaluate and adjust current system or cpu resources. When there has none web request, all system resources were used by the data-processing task, the Intel atom 330 processor has two cores, so one thread was designed to the data-acquisition control, and another was to store the data. In this process, data-acquisition processing was so faster than the data-storage processing, a buffer was needed to designed on local sampling card. When a web request was coming, one thread need to be assigned to arranged data and push response to the client, then the data-acquisition speed will adjust dynamically and more sampling data will be stored in the buffer.

### 4. Experiments

This type of EWSM has been realized in a power plant of Hunan Province in P.R.China, the remote web monitoring and configure interface was shown as Fig 4.

In the Experiments, three representative embedded web server were selected to compare their concurrency performance, the embedded platform based on Intel embedded PXA255 processor with eCos OS (abbr. PXA255 in the Table 1), an embedded web server base on Intel atom 330
Figure 4. An instance of remote web monitoring and configure interface

processor (working in only one core, abbr. Single core in the Table 1) with eCos OS, and the same embedded web server (working with none limited, abbr. Multi-core in the Table 1), different sampling points were imputed to the system to test time-consume for sampling of different platform, the result was shown as Table 1 and the scattered plot was shown in Fig 5.

<table>
<thead>
<tr>
<th>Sampling points</th>
<th>PXA 255</th>
<th>Single core</th>
<th>Atom</th>
</tr>
</thead>
<tbody>
<tr>
<td>200</td>
<td>0.95</td>
<td>0.98</td>
<td>0.52</td>
</tr>
<tr>
<td>500</td>
<td>2.50</td>
<td>2.52</td>
<td>1.31</td>
</tr>
<tr>
<td>1000</td>
<td>5.02</td>
<td>5.10</td>
<td>2.65</td>
</tr>
<tr>
<td>2000</td>
<td>9.55</td>
<td>9.98</td>
<td>5.36</td>
</tr>
</tbody>
</table>

Table 1. Time-consume for sampling

Table 2. Average response time for web request

<table>
<thead>
<tr>
<th>Web request</th>
<th>PXA 255</th>
<th>Single core</th>
<th>Atom</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>1.02</td>
<td>0.85</td>
<td>0.68</td>
</tr>
<tr>
<td>20</td>
<td>1.63</td>
<td>1.50</td>
<td>1.02</td>
</tr>
<tr>
<td>30</td>
<td>3.57</td>
<td>2.95</td>
<td>2.15</td>
</tr>
<tr>
<td>40</td>
<td>5.83</td>
<td>4.20</td>
<td>3.22</td>
</tr>
</tbody>
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Finally in order to test the response time of this embedded web server, the sampling points value was fixed at 2000, concurrent web requests from other local network terminals were sent continuously to get the different average response time. The result was shown in Table 2 and Fig 6.

5. Conclusions

The paper presents a novel embedded web server application based on Intel Atom processor, and the embedded operation system eCos was transplanted to support real time performance. From Table 1, 2 and Figure 5 and 6, we can see clearly that the system based on Intel atom dual-core 330 will work better with higher performance in parallel process oriented the application of embedded web server for monitoring than other two platforms. And this type of system can also be applied to some other monitoring systems which demand high requirements on real time data query, such as pumping station and water revisor information system and so on.

References


