

# DEVELOPMENT OF EMBEDDED SYSTEM FOR RUNNING EPICS IOC BY USING LINUX AND SINGLE BOARD COMPUTER

A. Uchiyama<sup>#</sup>, SHI Accelerator Service Ltd., Shinagawa, Tokyo, Japan  
M. Komiyama, M. Kase, RIKEN, Nishina Center, Wako, Saitama, Japan

## Abstract

The purpose of our development was to implement the EPICS (Experimental Physics and Industrial Control System) IOC (Input/Output Controller) box which has high durability, high reliability and high usability, in RIKEN RI-Beam Factory (RIBF) control system. The developed EPICS IOC box is consisted of a single board computer (SBC) installed embedded Linux. In the implementation test, we have confirmed the effectiveness of the IOC box. For this reason, PC-based IOCs were replaced with these embedded IOC boxes in November 2006 for the RIBF control system.

## INTRODUCTION

We constructed a control system based on the EPICS for the RIKEN RIBF. Nowadays, the PC-based EPICS IOC is used in many laboratories because it is available for use on the Linux x86 platform since EPICS was upgraded to version R3.14. Recently, a lot of network devices, such as the PLC (Programmable Logic Controller) and N-DIM (Network-Device Interface Module) of RIKEN's original device, are used in our facility for controlling the beam diagnostics and vacuum system [1]. These network devices must be controlled by PC-based IOCs, because it is available for simpler setup and lower cost than VME IOCs. When the number of device increases, the probability of troubles rises dramatically. Because some parts of PC, such as the fan, hard disk drive, and built-in power supply, is often broken for long term operation. Furthermore, if a large number of desktop PCs are used for running IOC, it is very hard to maintain them by small number of engineers. We expected we could solve the problems described above using a diskless and fanless embedded SBC for running IOC and managing IOC in the fileserver. For this reason, we developed a compact and simple embedded Linux specialized for running IOC and installed it in a SBC.

## TARGET BOARD

In our control system, the IOC box should be constructed by high durability hardware, and it should be kept to implement with simple maintenance for a long term. Furthermore, considering a development difficulty and cost performance, we chose WRAP (Wireless Router Application Platform) made by PC Engines GmbH. as a target board (see Fig. 1) [2]. The WRAP is one of the most suitable for our system using EPICS, because it is a SBC optimized in embedded system for network, such as router, VPN, and firewall. The characteristics of WRAP

are as follows.

- Disk less and fan less
- Low cost
- Operating system and software to be supplied by a lot of customer
- Cross compile environment is not necessary for development (x86 platform).

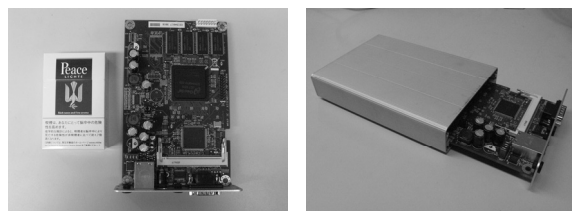


Figure 1: Photograph of the WRAP (left figure), the WRAP in the case (right figure)

We bought a WRAP for about US\$120 in Aug 2006 in Japan, and the total cost was about US\$150 which includes price of a 256MB compact flash (CF) and an AC adapter. The reasons for selection of x86-compatible platform CPU are as follows:

- It is not necessary to have the cross compile environment.
- We can use libraries and drivers implicitly from kernel source.
- It is effective method in order to shorten turnaround time for the system development process.

The hardware specifications are summarized in Table 1

Table 1: WRAP Specifications

CPU	233MHz AMD Geode SC1100
Memory	128 MB SDRAM
Storage	Compact Flash (256MB)
Connectivity	1 Ethernet channels, 1 Serial port
Power Supply	AC adapter

The WRAP does not have a VGA connector, so that the serial port is used for console.

<sup>#</sup>a-uchi@riken.jp

## SYSTEM SPECIFICATION

### Operating System

In the facility of RILAC/RRC in RIKEN before RIBF project started, namely RIKEN Accelerator Research Facility, EPICS was used in combination with Linux [1]. Therefore, it was natural that we considered using Linux for embedded IOC box's operating system. By contrast, major Linux distributions, for example Fedora core, Scientific Linux, and CentOS, were not suitable for WRAP's one, because system size is too big. At first, we tried to design the compact Linux minimized for embedded IOC box using the Fedora core. However, it was difficult to remove a lot of libraries and programs to resolve dependencies simultaneously. Consequently, we decided to develop the compact embedded Linux as own new distribution with the method of LFS (Linux From Scratch) [3]. This method is to build own Linux from kernel source and the necessary packages. In order to build the embedded Linux, we followed the procedure developed by administrator of "pochinet.org [4]" and build it on CentOS 4.2. On the other hand, the safety of system security in this operating system is not considered, because the network of control system is stand-alone in RIBF. The packages implemented into the embedded Linux are shown in Table 2. These packages, Linux kernel, programs and libraries for running IOC, are almost all in this embedded Linux. The Linux consists of small number of programs compared with those of the other distributions by using BusyBox [5].

Table 2: Packages of the embedded Linux

Package	Version
Linux kernel	2.6.13
GRUB	0.9.5
glibc	2.3.6
glibc-linuxthreads	2.3.6
BusyBox	1.10
Apache	2.0.58
bash	3.0.16
utelnetsd	0.1.9
NTP	4.2.2
PHP	4.4.4
EPICS base	R3.14.7

The characteristics of the Linux are listed as follows.

- Booting kernel 2.6 from 256MB CF
- Small and compact size Linux (about 120MB)
- Not available to change the physical disk by using RAM-Disk
- Optimized for running IOC
- Automatically running IOC process after booting

### EPICS Base

Before development of embedded IOC box, we used EPICS version R3.14.7 on desktop PC, and it was not necessary to upgrade EPICS version. The environment to compile EPICS programs and the environment to run EPICS IOC need to have same libraries. For this reason, we compiled the same version source code to EPICS programs on the PC used for operating system development. For managing IOCs, it is not necessary for all of the boxes to have EPICS programs in the CF. EPICS programs installed in the fileserver are shared by all of IOC boxes for managing IOC (see Fig. 2) [6]. In addition, we provided the function that IOC process runs automatically after turning on, in order to maintain more easily.

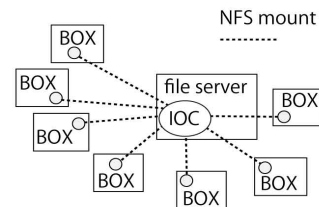


Figure 2: IOC shared with embedded boxes

### Web application

In implementation test, the following problems were found.

- It is difficult to watch the running process of IOC on the terminal, because the WRAP dose not has VGA connector.
- We would like to restart IOC process more easily.
- In trouble, the parameters in this system should be configured again by all accelerator operators as soon as possible.

To resolve the above problems, we developed web applications written by PHP language. The user interface (UI) of the web applications was designed like a router's one. Almost of router's UI can help to configure system easily for every user without knowledge of the system. Thereby, we expected that all accelerator operators can not only watch the running process, but also recover the system from some troubles using the simple manual. The screen shot is shown in Fig. 3.

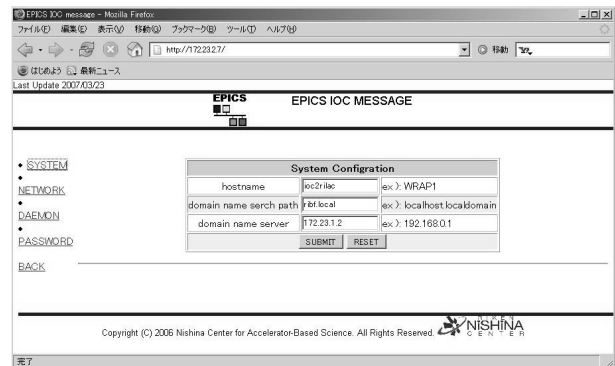


Figure 3: Screen shot of web application

## RECOVERY TEST

It is one of the most important concepts that all of accelerator operators can recover the IOCs quickly, if the system has rare hardware trouble. Therefore, the operator, who does not have the knowledge about system specification in detail, tried the recovery test alone with the simple manual and CF with operating system. The recovery sequence is summarized as follow.

1. Remove the SBC from the case of IOC box
2. Change with the CF
3. Put on the case
4. Turn it on
5. Configure the system parameters from the default value with browser.
6. Check to run the IOC after the system restarted.

As a result, the recovery test succeeded for about 10 minutes only with ease.

## SYSTEM SCALABILITY

Since February 2007, PC Engines GmbH. stopped to produce the WRAP due to the running out of AMD SC1100 as the CPU of this SBC. It might be a serious problem for our laboratory even though we had enough SBCs in stock at that time. We needed to check that our Linux was available for booting by other hardware, because in the future, we will keep using this system. For this reason, we tried to implement the Linux on the other hardware. The hardware were PFU AR2000 [7], and CC/NET [8] made by TOYO Corporation, both of them are embedded computer with x86-platform and available to boot from CF. As a result of unit test, the embedded Linux can boot and run IOC on these hardware, though it is necessary to rebuild Linux kernel and to edit “/boot/grub/grub.conf” and “/etc/inittab”.

## STATUS

In November 2006, we started implementation test of the WRAP installed embedded Linux of version 1.0. Afterwards, we repeated to upgrade the Linux many times and eight IOCs were implemented in RIBF control system without serious trouble till September 2007 [6]. Three WRAPs set in the case of 1U panel (see Fig. 4). The numbers of the EPICS record and the number of network device connected with the WRAP are shown in Table 3.

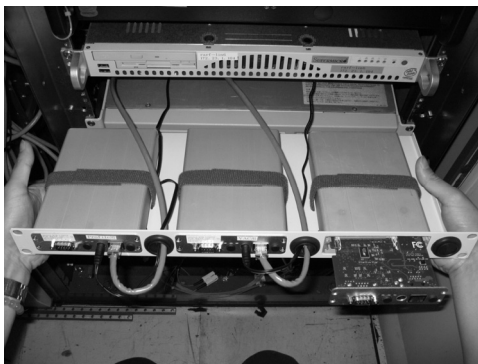


Figure 4: Three WRAPs set in the case of 1U panel.

Table 3: Devices connected with the WRAP and EPICS record in RIBF control system.

\* V: Vacuum system. B: Beam diagnostic system.

WRAP	Device	Number of device	Use	Number of EPICS record
1	N-DIM	14	V	112
2	N-DIM	21	B	454
3	N-DIM	37	V, B	960
4	N-DIM	27	B	491
5	PLC	5	V, B	363
6	N-DIM	34	V, B	1721
7	N-DIM	44	B	873
8	PLC	4	V, B	556

## CONCLUSIONS

The purpose of our work was to design high durability and easy maintenance system for running IOC, and to develop one using SBC and embedded Linux. As a result, it was successful to develop embedded Linux using method of LFS, to run IOC on SBC. By contrast, it will be difficult to implement the system using a lot of PC-based IOCs without trouble, because the system will be complicated to have a lot of network devices in RIBF control system. However, above problems are resolved by implementing embedded IOC with low cost. In this test, it was confirmed that our developed system was useful in RIBF control system. We expect it is not easy to be broken, even if it has some rare hardware trouble, almost all of accelerator operators can configure system to recover one quickly without administrator.

## ACKNOWLEDGMENTS

The author would like to thank J. Odagiri and N. Yamamoto in KEK for supporting the construction of system, and all of accelerator operators and RIBF commissioning members for cooperating with implementation test.

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