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Porting the Linux Kernel to Arm System-On-Chip And Implementation of RFID Based Security System Using ARM

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Abstract— This paper emphasizes on porting the linux kernel to an ARM board and thus implementing the RFID (Radio Frequency Identification) based security system using the ARM board.ARM system-on-chip is the best platform for reducing the risk and the cost of SOC designs and thus accelerating the speed, accuracy, flexibility.ARM boards are the combination of FPGA and ASIC technology and hence provides the optimal solution in terms of speed, cost and time. The embedded modules based on ARM delivers varied tasks such as process management, memory management and peripheral interfaces. Linux being an open source domain provides an additional edge to the embedded systems and as Linux can be freely downloaded thus it is being compiled for any system architecture including ARM. For new CPU architectures OS has to be configured, compiled burnt to the core and ported to the target platform. Building the linux kernel, bootloader and the file system are described in detail. This paper also describes the implementation of the widely emerging and matured technology i.e. RFID that has been widely deployed by various organizations. As the security issues are increasing day by day so, with the help of RFID sensors and ARM processors the RFID based security system is being implemented which is described in detail.

Keywords— Embedded systems, Linux kernel, RFID, ARM

1. INTRODUCTION

As embedded systems is gaining increased importance in every aspect due to various applications such as multitasking, multithreading, multiprocessing and the special attributes which are inherited by the embedded technology as reliability, flexibility, low power dissipation, cost, speed, time, software upgradation capability. Various sectors like biomedical, healthcare, automation, automobile, mobile communication, aeronautics, spacecraft, networking has increased the need of embedded technology. Various architectures are used for embedded systems according to their need such as ARM (Advanced RISC Machine) which is a reduced instruction computer (RISC) instruction set architecture. The combination of ASIC and FPGA in ARM platforms delivers an optimal and flexible solution in terms of cost, speed and time. Linux as an embedded operating system gives an added edge to the embedded technology[5,6] as Linux is an open source and has special attributes like multitasking, multiprocessing, multiplatform, multithreading, multiuser sharing, full memory protection. Real time operating systems are derived from the Linux kernel source which is being configured as per the requirements and specific to the application constraint. For the new design of the embedded technology the operating system must be modified accordingly to fit the target embedded board and the operating system thus configured and modified is then ported to the specific targeted board. After the porting part RFID security system is being implemented using ARM system-on-chip. As RFID i.e. Radio Frequency IDentification is a technology which includes wireless data capture and transaction processing. When RFID security system is implemented using ARM processor it gives added advantages in some broad areas such as asset management, access control, asset tracking, document tracking, healthcare, biomedical, networking, IT asset management, apparel tracking, tool tracking, banking, hospitality, tourism, shopping complexes. This paper describes the details of porting the Linux kernel and thus implementing the RFID based security system using ARM system-on-chip.

2. THE FEATURES OF EMBEDDED SYSTEM

An embedded system is a special purpose computer system designed to perform dedicated functions mostly with the real time computing constraints. As compared to a general purpose computer system it has some special attributes like low power dissipation, reduced cost, less time consumption, reliability, flexibility, portability. The embedded system is a combination of operating system, hardware and application programs. An embedded system focuses on available system memory, available processor speed and low power dissipation. In the sector of embedded technology ARM (Advanced RISC Machine) is the most popular and widely used. ARM is 32-bit instruction set architecture and is mostly used in real time applications. ARM is a full memory and full solution provider and thus supporting a broad range of applications. ARM is the industry standard embedded microprocessor architecture and is a leader in low power and high performance cores. ARM is a heart of advanced digital products and is leading intellectual property provider of low cost, high

performance, flexibility, power efficient RISC processors, peripherals and system-on-chip (SoC) designs[8,12]. The ARM subsystem constitutes of the ARM926EJ-S 32 bit RISC CPU which controls general system control tasks such as System initialization, Power management, Configuration, User Interface and User command implementation.

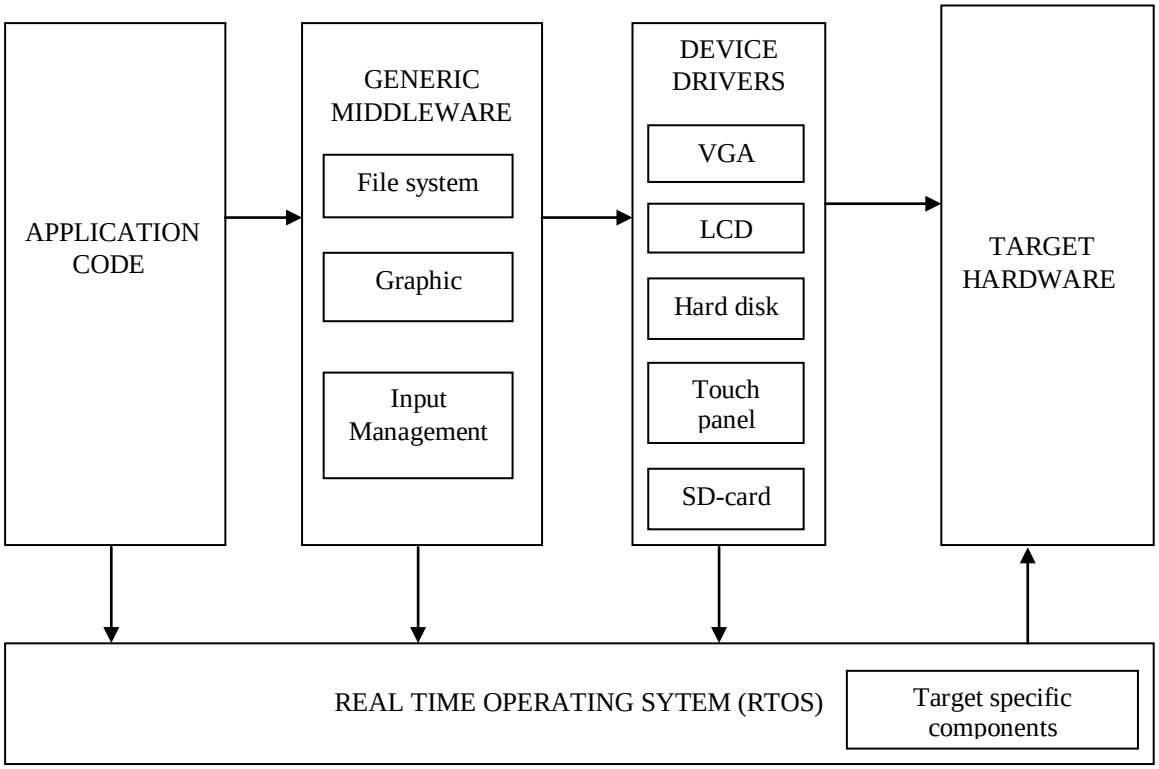

Figure 1: Embedded system architecture

3. BUILDING LINUX KERNEL

The Linux kernel has variety of CPU architectures. The method to port the linux kernel to ARM platform is thus architecture dependent. Say, PowerPC and ARM are very diverse. PowerPC relies on device trees to describe hardware details whereas ARM relies on source code only. In the source tree, every architecture has its own directory arch/arm for the ARM architecture [1,5].

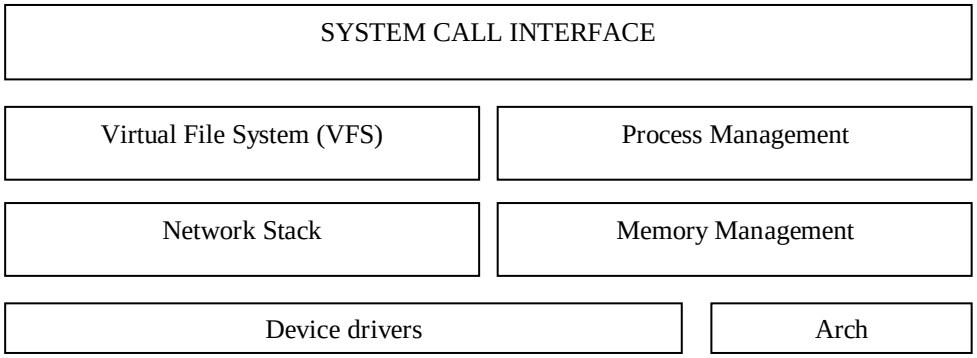

Figure 2: Linux Kernel architecture

3.1 Linux Kernel code

Linux being an open source and freely available can be downloaded easily.
The file name should be linux-x.y.z.tar.bz2, where x.y.z is actual version number. For example file linux-2.6.25.tar.bz2 represents 2.6.25 kernel version[6].
wget command is being used to download the kernel source code as shown below:

- $wget

3.2 Extract tar file

The tar file provides the ability to create tar archives and other various configurations. The command used to extract the tar file to the current directory is shown below:

- # tar -xjvf linux-2.6.25.tar.bz2

3.3 Kernel Configuration

To configure the kernel the development tools (gcc compilers and related tools) should be installed in the system. For the kernel configuration the following commands are used:

- $ make menuconfig: This is useful for the remote server and is useful for text based color menus, radio lists and dialogs.
- $ make xconfig**:** X windows (Qt) based configuration tool, works best under KDE desktop.
- $ make gconfig - X windows (Gtk) based configuration tool, works best under Gnome Dekstop.

To install the development tools (gcc compiler and other tools) the following command is being used:

- # apt-get install gcc

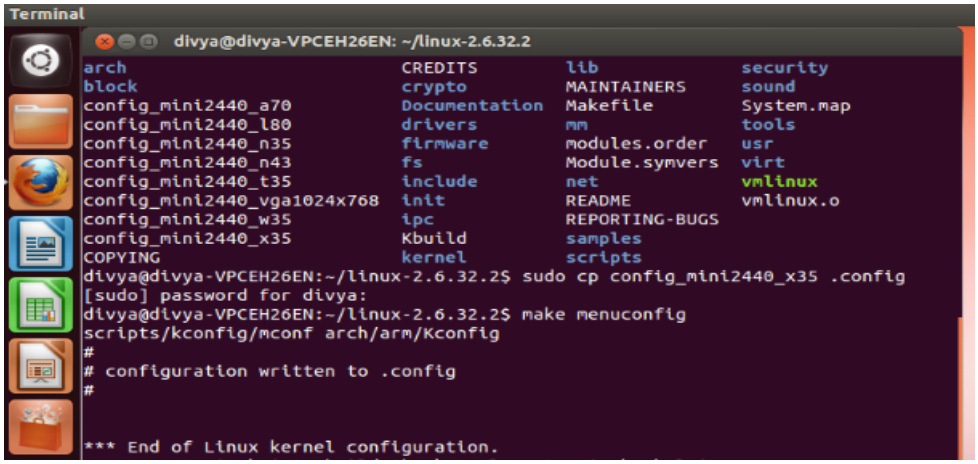

Figure 3: Configuring Linux kernel using make menuconfig

3.4 Kernel Compilation

The Linux kernel is dependent on CPU architectures. In the source tree, each architecture has its own directory arch/arm for the ARM architecture. To build the linux kernel, cross-compiler [6] should be made accessible on the execution path. Entering make command would start compilation and create a compressed kernel image. The resulting kernel image is placed in *arch/arm/boot directory.*

The commands are stated as following:

- $export ARCH=arm
- $ export CROSS_COMPILE= arm-none-linux-gnueabi
- $ make

4. Overview Of The System

Embedded system has become an important and core part of our life. For example say a mobile phone, a smartcard, microprocessor, electronic card, a music player, a router, or the electronics in an automobile. An embedded system is a combination of computer software, hardware, and other technical and mechanical components to deliver an optimal solution [12,5].

The core of embedded technology includes the following:

• Programmable processors including Microcontrollers / digital signal processors (DSP)
• Standard and custom hardware
• Concurrent software
• Integrated and inbuilt chips
• OS components including real time operating system (RTOS)
• Industry-related protocols and interface components
• Printed circuit development board assembly

Embedded system has some special attributes like high reliability, flexibility, low power dissipation, portability, low cost and high performance. In the technological advancement of embedded systems ARM (Advanced RISC Machine) is widely used. The ARM subsystem constitutes of the ARM926EJ-S 32 bit RISC CPU that controls and handles the general system control tasks such as System initialization, Power management, Configuration, User Interface and User command implementation. In this project ARM9 is being used which includes single processor solution for microcontroller, Java and DSP applications.ARM9 processors provides low risk, simple designs, low power dissipation, less power consumption, easy to use which reduces the cost and time and delivers the best solution. The ARM9 processor is the heart of advanced digital products across many applications.

ARM9 board adds a better edge over ARM7 which is shown as following [24]:

• ARM9 cores include "Enhanced DSP" instructions such as a multiply-accumulate, to support more efficient implementations of digital signal processing algorithms [24].
• ARM9 cores have separate data and address bus signals which the chip manufacturers use in many different ways.
• ARM9 has a Harvard structure with separate instruction and data buses which increases the speed of the system.
• Decrease heat production and low overheating risks.
• ARM9 includes cache which results in a simple software design.

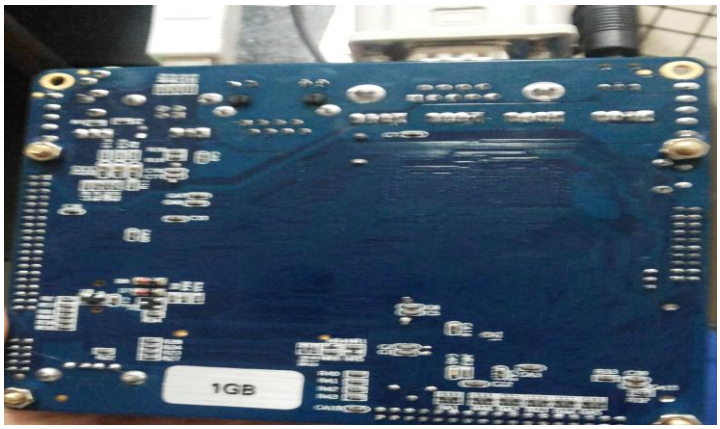

Figure 4: ARM9 development board

Embedded Linux is divided into the following steps: obtaining the source code; building cross compiler environment; porting Linux boot loader (Uboot or VIVI), then configuration and compilation of the kernel is done, porting and loading the embedded file system, developing and debugging of application program, program downloading. In this paper the porting technology of Linux kernel is being described. After the porting RFID based security system using ARM9 is implemented.

RFID (Radio Frequency Identification) is an ADC (Automated Data Collection) technology that uses radio-frequency waves to transfer data between a reader and a movable item to identify, categorize and track. It performs the functions using low cost components [18,19]. It attempts to provide unique identification and backend integration that allows wide range of applications. RFID is a micro-chip in a label used to transmit data when the label is exposed to radio waves to deliver an optimal and secure solution to a system.

The main core components of RFID system are as following:

- RFID tag
- RFID reader
- RF antenna
- Ethernet
- Workstation

ARM processor is used in this field because it is one of the powerful processor which is mending for such embedded works.

Figure 5: RFID receiver

5. Porting The Linux Kernel To Arm System-On-Chip

The Embedded technology based on ARM, can become very complex machines since these are meant to support optimal solution with varied tasks such as memory management, process management and peripheral interfaces. For seamless integration of these functional module OS has to be ported on ARM based CPUs. This OS porting is often the specialized work of third party vendors having expertise in this domain. For CPU architecture, the OS has to be customized, compiled and burnt into the core.

5.1 Algorithm for updating the boot loader

i. Update boot loader, kernel or file system images with customized images by using commands of uboot: install boot loader, install-kernel and install-file system [23]

ii. Update boot loader , Kernel and File system

iii. Make file system image by, Assume rootfs is the directory of your root file system on the workstation

iv. Load the boot loader image

5.2 Algorithm for porting the Linux kernel

i. Obtaining source codes
ii. Building cross compiler environment
iii. Porting Linux boot loader (Uboot)
iv. Kernel configuration
v. Kernel compilation
vi. Porting and loading the embedded file system
vii. Developing and debugging of application program

5.3 Tool chain installation

The GNU ARM tool chain is a programming environment which provides the workstation environments and tools for designing, developing, and testing on ARM simulators [23]. GNU tool chain includes the binary utilities (binutils), the GNU Compiler Collection (GCC), the GNU Remote Debugger (GDB), GNU make, and the GNU core utilities.
Algorithm for installing the tool chain is as following:
i. To download the GNU tool chain, from the Code Source download and choose the Linux TAR file.
ii. Extracting the downloaded GNU tool chain.
iii. Modify the PATH environment variable to access the bin directory of the tool chain, and the tools are ready.
iv. Set up symbolic links to ARM tools.

6. Steps For The Environment Setup

As Linux being an open source freely available. It can be downloaded freely. Embedded linux uses ARM processors for porting as ARM supports process management, memory management, peripheral interfaces and thus in result delivers a best solution in terms of speed, cost and time.
The steps for environment setup and porting the Linux kernel to ARM9 are as following:

- Install Ubuntu 12.04 version and all the other necessary softwares on the workstation.
- The basic hardware setup is installed which is necessary to start uploading and downloading data to and from the arm development board.
- DNW (donor network) is a variant of the software and it is used to transfer images to arm board but mostly serial port is being used to transfer the data.
- Configuration of the serial port when the device drivers are not being loaded.
- Setup minicom which is a terminal program that communicates with the serial port.
- Install the necessary software tools to access the serial port and to be able to communicate with the development board.
- Install minicom as:
  # sudo apt-get install minicom
- After setting up the hardware, there is a need of cross compile toolchain to build code for ARM development board.
- Build the bootloader.
- Configure and compile bootloader , Linux Kernel and file system.
- Port bootloader image , Kernel image and file system image using DNW .

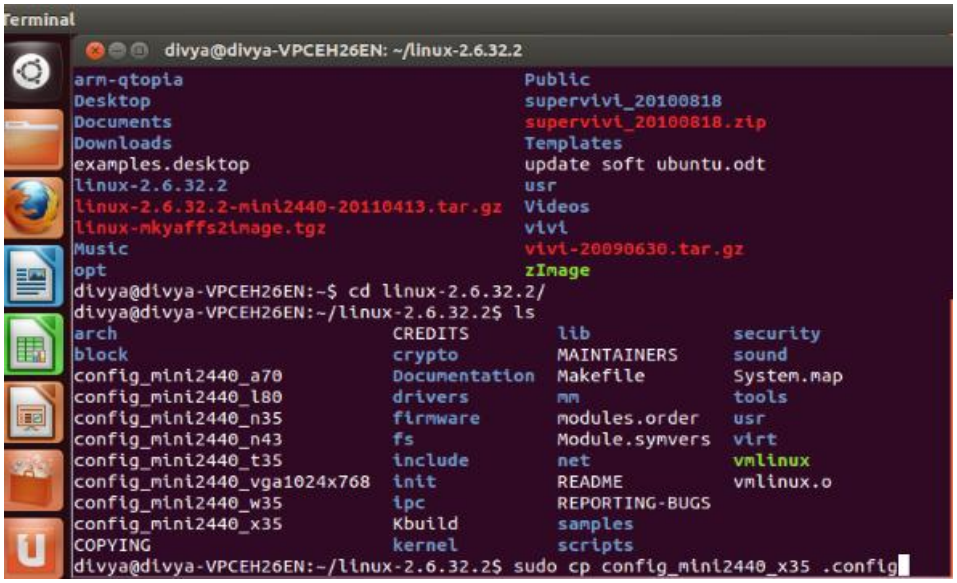

Figure 6: Kernel configuration

7. Rfid As A Security System

Radio Frequency Identification (RFID) is a micro-chip in a label used to transmit data when the label is exposed to the radio waves. When there are some critical issues as assembly process control, inventory management, supply chain integration and customer insight than RFID is the appropriate and optimal solution. It is an automated data collection (ADC) technology [19,20] that attempts to provide unique identification and backend integration for wide range of applications. This paper suggests building a RFID system using ARM processor to deliver an optimal solution in terms of security, cost, speed, performance, flexibility and time. In this paper RFID based security system is being implemented for the access approval and denial of the smart card with the help of ARM system-on-chip and the other RFID components to overcome the security issues and to deliver the optimal solution. In this paper RFID is taking advantage of ARM9 processor as it helps in the approval or denial phase of the RFID tag which has been received by the RFID receiver through mutual induction. The access is approved or denied with the help of ARM9 and RFID reader. Mutual induction between the RFID receiver which incorporates a coil in its inner part and ARM9 processor to improvise the security issues based on the various applications with an easy approval or denial.

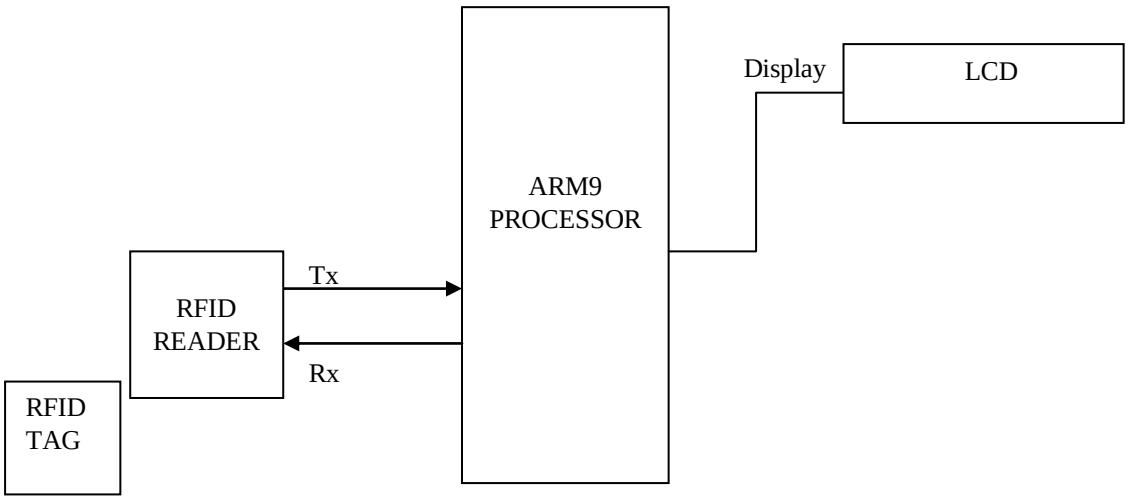

Figure 7: Block diagram of the proposed system

RFID is a wireless link to uniquely identify objects or people. It is called dedicated short range communication (DSRC). RFID systems include electronic devices called transponders or tags, and reader electronics to communicate with the tags. These systems communicate via radio signals carries data either uni-directionally or bidirectionally. When a transponder enters a read zone, its data is captured by the reader and can then be transferred through standard interfaces to a host computer, printer, or programmable logic controller for storage or action. As shown above RFID reader have RFID module and control module which communicates with the RFID tags through ARM9 processor [18]. This paper discusses about overcoming the security issues by uniquely identifying the identity through RFID tag as shown above. Mutual induction between RFID tag and RFID reader through antenna will lead to the approval or denial of the unique identity of the RFID tag.

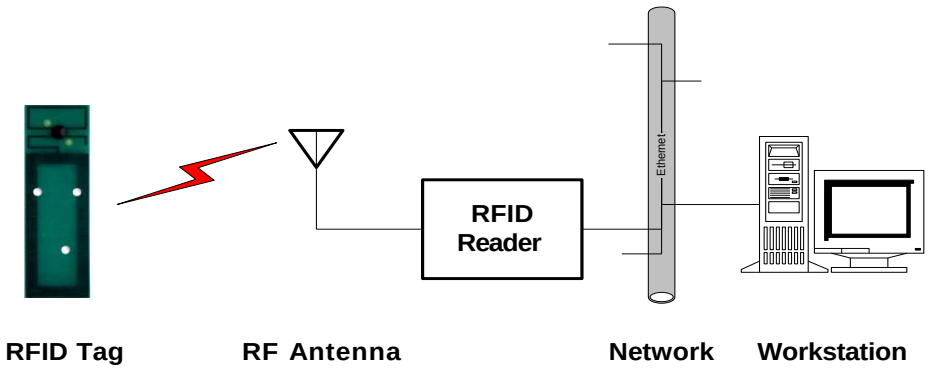

Figure 8: RFID system components

As shown in figure 8 are the system components of RFID which includes: RFID Tag, RF Antenna, RFID Reader, Network and workstation.

7.1 RFID Tags

RFID Tags can be attached to almost everything like items, cases or pallets of products, high value goods, vehicles, assets, livestock or personnel. There are two types of tags: Active tags and passive tags which are explained as:

Passive Tags:

- Do not require power – Draws from Interrogator Field
- Lower storage capacities (few bits to 1 KB)
- Shorter read ranges (4 inches to 15 feet)
- Usually Write-Once-Read-Many/Read-Only tags
- Cost around 25 cents to few dollars

Active Tags:

- Battery powered
- Higher storage capacities (512 KB)
- Longer read range (300 feet)
- Typically can be re-written by RF Interrogators
- Cost around 50 to 250 dollars

7.2 RFID Tag memory

RFID Tag memory includes the following:

Read-only tags:

- Tag ID is assigned at the organization during manufacturing
- They can never be changed
- No additional data can be assigned to the tag

Write once, read many (WORM) tags:

- Data written once, e.g. during manufacturing process
- Tag is locked once data is written
- Similar to a compact disc or DVD

Read/Write tags:

- Tag data can be changed over few span of time
- Part or all of the data part can be locked

7.3 RFID Reader

The functions of RFID reader are as following:

- They remotely power tags
- They establish a bidirectional data link
- These are inventory tags, filter results
- They communicate with networked server(s)
- They can read 100-300 tags per second

8. ADVANTAGES AND DISADVANTAGES OF PORTING ON ARM9 PROCESSOR

8.1 Advantages:

- High flexibility with fast synchronized operations.
- It supports dynamic power management and system- on-chip designs.
- ARM9 board supports dynamic design flexibility and portability. Thus it is dependent on C.P.U architectures.
- Optimal cost and performance with ARM9 boards.
- It supports a wide range of applications in real time embedded systems.
- ARM 9 supports on-chip buffers in case of linux porting. Thus helps in on-chip debugging [12].
- ARM9 cores have separate data and address bus signals which the chip manufacturers use in many different ways.
- ARM9 cores include "Enhanced DSP" instructions such as a multiply-accumulate, to support more efficient implementations of digital signal processing algorithms.

8.2 Disadvantages:

- The only disadvantage of using ARM9 board is that it is expensive in case of porting.
- The main disadvantage of using embedded linux is that there is large memory consumption i.e. root file system and kernel image [12].
- There is a complicated device driver framework in case of embedded linux.

9. APPLICATIONS OF RFID BASED SECURITY SYSTEM USING ARM PLATFORM

Few applications in major sectors of using Radio frequency identification based security system using ARM are as following:

Manufacturing and Processing:

- Inventory and production process monitoring
- Warehouse order fulfillment

Supply Chain Management:

- Inventory tracking systems
- Logistics management

Retail:

- Inventory control and customer insight
- Auto checkout with reverse logistics

Security:

- Access control
- Counterfeiting and Theft control/prevention

Location Tracking:

- Traffic movement control and parking management
- Wildlife/Livestock monitoring and tracking

The other arena of RFID based security system includes few more applications given as follwing:

Smart appliances:

- Closets that advice on style depending on clothes available.
- Ovens that know recipes to cook pre-packaged food.

Smart products:

- Clothing, appliances, CDs, etc. tagged for store returns.

Smart paper:

- Airline tickets that indicate your location in the airport.

Smart currency:

- Anti-counterfeiting and tracking.

RFID is an automated data collection (ADC) technology that attempts to provide unique identification and backend integration for wide range of applications as stated above.

10. Conclusion

This paper discussed about the embedded linux, porting the linux kernel to arm platform with the help of bootloader, file system and kernel images.ARM9 processor was used over ARM7 as ARM9 is the ideal platform for accelerating the development and reducing the risk of new SoC designs and ARM9 cores include "Enhanced DSP" instructions such as a multiply-accumulate, to support more efficient implementations of digital signal processing algorithms. OS has to be ported on ARM based CPU architectures. OS porting is done in three steps: Configuration, Compilation and Burnt onto the core platform. After porting the embedded linux using ARM9 RFID based security system is implemented using the same ARM9 processor. This radio frequency identification system is based on ADC (Automated data collection) technology that is being implemented using ARM9 processor for the access approval and denial of a RFID tag overcoming the security issues. This is widely applicable on various range of applications.

Acknowledgment

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