Design of a Power Meter for RISC Architecture Having Wi-Fi Wireless Communication Module

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Abstract

Energy problem is becoming one of the toughest issues nowadays. In order to meet the increased demands regarding energy awareness, we have been developing a new way of representing and interacting with energy in electric products, specifically home appliances. This paper presents the design and implementation of power meter. The design presents new methodology for preventing the high construction and maintenance costs with the existing meter reading technology, the applicability to different residential buildings and network infrastructure should be improved. Now wireless broadband network develops rapidly. At present, many cities in many countries are building or will build Wireless Metropolitan Area Networks by Wi-Fi, it provides the new connection ways to the this system. This system scheme using Wi-Fi technology and an ARM-Based PMWCM (Power Meter with Wi-Fi Communication Module) scheme. The ARM based hardware system is consisted of processor core board and peripheral board, and the software program is basing on embedded Linux. This paper also proposes the functions of wireless communication module and design detail.
Keywords: RISC Architecture, WIFI, PMWCM

I. INTRODUCTION

Rapid advances in electronic revolution not only transform our modern life, but also enlarge the world's appetite for energy, especially electricity. A strong motivation to meet the growing demands for energy is emerging recently. As a result, how to reduce energy consumption is becoming one of the hot spots for both industrial and academia. In this paper we propose a novel paradigm that is energy aware and smart enough to advise people how to reduce energy consumption according to the information it gathered, no matter where they are and when it is. And the result shows this prototype is effective and efficient in reducing the energy consumption. The traditional manual Meter-Reading was not suitable any longer. It also consumes more human and material resource and brings the some more problems such as the security of entering house. The power management department cannot collect the real-time data electricity being used. And with the power price reform, in order to make account rapidly, the power management department also needs more power parameters such as power requirement, time-sharing power quantity and burthen curve. Automatic Meter Reading can meet above demands.

II. THE PMWCM SYSTEM FUNCTIONS

The power meter with Wi-Fi communication module (PMWCM) system functions can be divided into Data Collection and Encryption Module, Wireless Communication Module, System Control Module, Remote Communication and Monitoring Module Remote Monitoring and Control Module, the System Security Module, Remote Software Upgrade Module, and so on. The functional modules are shown in Fig.1

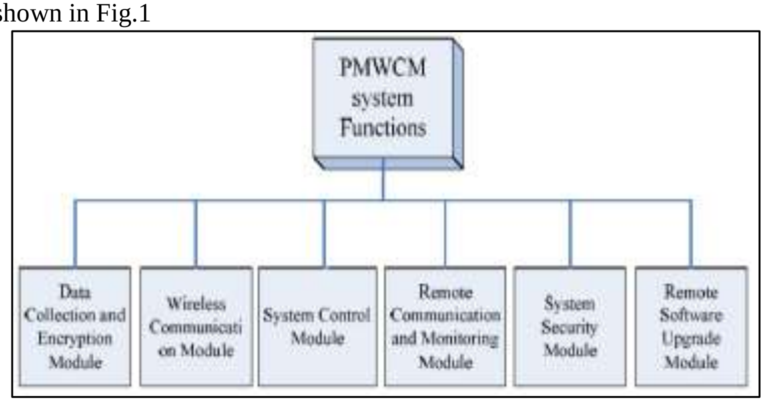

Fig. 1: The PMWCM system functions

To facilitate our implementation. We define these sub-systems as followings.

1) Data Collection System: Its mission is to collect accurate and real-time information about the energy consumption, and to be combined into smart meters.
2) Wireless Communication System: This sub-system takes charge of receiving and transferring data based on network reliably and timely. Wireless Communication System is one of main components of both smart meter and residential gateway.
3) Residential Gateway System: It links Wireless Sensor Networks (WSNs) with networks and Internet, so that a ubiquitous solution could be achieved.
4) Data Analysis System: We import Data Analysis System into our paradigm to add some intelligence behaviours. Throughout data gathering, classifying, integrating and modelling, this sub-system is supposed to make some helpful suggestions about how to reduce users' electric cost.
5) Terminal Application System: Any system should have its own interface with users. The ubiquity of web browser, and the convenience of accessing a web application without distributing and installing software on local client computer, introduces this way to our system.

III. THE PMWCM SYSTEM HARDWARE DESIGN

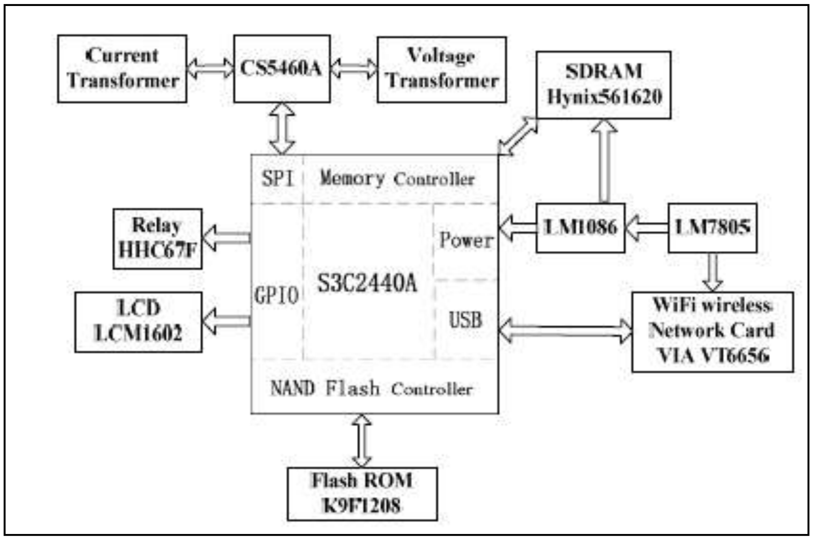

Fig. 2: The Hardware System of PMWCM

The hardware composed chart are shown in the above figure of PMWCM is consisted of Power ARM board, Data Collection Module, Wireless Communication Module, the Relay Control Unit, LCD Module, and so on. The ARM hardware system is consisting of the Core-Board and the Peripheral-Board. Here Core-Board of the PMWCM is composed of one 32bit ARM9 CPU (S3C2440A), one 64M Flash (K9F1208), two 32M SDRAM (Hynix561620).The Peripheral-Board is composed of the 3.5V and 3.3V power module, Voltage/Current Transformer (SCT254FK SPT204E), the LCD (LCM1602), the power measurement module (CS5460A),the Relay (HHC67) and the wireless communication module(VIA VT6656).

In this chart, the ARM9 CPU S3C2440A is the main controller in charge of the system and the data disposed, the 5V voltage which generated by LM7805 provided multiplied by the high-speed digital multiplier, and get instantaneous Active Power. Accumulated by the time, the average received energy E; Energy per unit time is the Active Power. After calculations, obtained instantaneous voltage and current, Active Power, etc., respectively, saved into the corresponding internal register, waiting for ARM processor to read.

A. The Main Controller S3C2440A:

SAMSUNG's S3C2440A 16/32-bit RISC microprocessor. SAMSUNG's S3C2440A is designed to provide hand-held devices and general applications with low-power, and high-performance microcontroller solution in small die size. To reduce total system cost, the S3C2440A includes the following components. The S3C2440A is developed with ARM920T core, 0.13um CMOS standard cells and a memory complier. Its low power, simple, elegant and fully static design is particularly suitable for cost- and power-sensitive applications. The S3C2440A offers outstanding features with its CPU core, a 16/32-bit ARM920T RISC processor designed by Advanced RISC Machines, Ltd. The ARM920T implements MMU, AMBA BUS, and Harvard cache architecture with separate 16KB instruction and 16KB data caches, each with an 8-word line length.

By providing a complete set of common system peripherals, the S3C2440A minimizes overall system costs and eliminates the need to configure additional components.

Fig. 2.1: ARM9 board

The integrated on-chip functions that are described in this document include: Around 1.2V internal, 1.8V/2.5V/3.3V memory, 3.3V external I/O microprocessor with 16KB I-Cache/16KB.DCache/MMU. External memory controller (SDRAM Control and Chip Select logic). LCD controller (up to 4K color STN and 256K color TFT) with LCD-dedicated DMA. 4-ch DMA controllers with external request pins.3-ch UARTs (IrDA1.0, 64-Byte Tax FIFO, and 64-Byte Rx FIFO).

B. The Power Data Collection Module:

The Power data collection module is consisted of Voltage/Current Transformers. Here CS5460A [15-16], is the power measurement module and in between them there is a resistor, 200 ~ 250kΩ 3W. The analog signal scale of voltage and current on the primary is proportionally transformed on the secondary via Voltage/Current Transformers. The sampled voltage or current would be chosen alternately by multiplexer and then converted into an equivalent digital signal by the A/D converter. The instantaneous voltage and current values are multiplied by the high-speed digital multiplier, and get instantaneous Active Power. Accumulated by the time, the average received energy E; Energy per unit time is the Active Power. After calculations, obtained instantaneous voltage and current, Active Power, etc., respectively, saved into the corresponding internal register, waiting for ARM processor to read.

C. CS5460A Communicated with ARM Processor:

CS5460A communicated with ARM processor through the SPI serial interface, SPI is a high-speed full-duplex synchronous serial communication bus, constituted by the 4- pin, SPICLK, MOSI, MISO and SS. SPICLK is common clock of the SPI bus. MOSI is the master output, slave input. MISO is the master input, slave output. SS is a sign pin from the slave machine, active-low. In the PMWCM system, ARM processor is the host machine, its external pin must be HIGH; CS5460A is the slave, the synchronous clock input from the host.

D. Wi-Fi Wireless Communication Module:

The Wi-Fi needs no wire and use the 2.4 GHz frequency, which can be used needing no application in advance, so it is generally considered the ideal scheme to resolve “the last 100meters connection”. Wi-Fi has relatively Lower cost. Only placing a Wi-Fi meter reading terminal in the hallway of a building. All the power meters in 100 meters will connect it by Wi-Fi, which is wireless. In other words, we do not have to spend money to lay the wires for network access by make holes in walls, thus saving a great deal of cost. At the same time, in the local reading meter, the PMWCM communication with vicinal ones can be local network, it’s free, and it can save money to circulate and maintain the system.

Wi-Fi Facilities the upgrade. Each of the Wi-Fi meter reading terminals supports nearly 100 wireless interfaces. So we do not have to re-wiring them in future. The meter reading terminals can communicate with the household appliances through wireless networking communications. So, the meter reading terminal can be added with some new functions such as IPTV, security control, remote Health care, information appliances, etc. and thus t realizes the true Digital Home which will be the future direction of development.

E. The Relay Control Unit:

A relay is an electrically operated switch.The Relay control unit is an interrupting device designed for shutting off or resuming the power supply control. Relays can switch AC & DC and can switch many contacts at once. When the power data is beyond the upper limit which the user buys in bank, the S3C2440A can control the Relay module to shut off the electric power supply. It is a better choice for switching large currents (> 5A).If the User pays the electricity bills in Bank, the S3C2440A can knows it by WiFi and other network, and can control the Relay module to resume the electric power supply. It is designed for fault interruption and load switching and also to protect the converter from exceeding current.

F. OPTOISOLATOR:

In electronics, an opto-isolator, also called an optocoupler, photo coupler, or optical isolator, is "an electronic device designed to transfer electrical signals by utilizing light waves to provide coupling with electrical isolation between its input and output". The main purpose of an opto-isolator is "to prevent high voltages or rapidly changing voltages on one side of the circuit from damaging components or distorting transmissions on the other side. Commercially available opto-isolators withstand input-to-output voltages up to 10 kV and voltage transients with speeds up to 10 kV/μs. We are using 6 pin Optoisolator in our project to isolate between the meter pulses and the input ARM board.

IV. THE PMWCM SYSTEM SOFTWARE SCHEME

The PMWCM system working principle is that circuit voltage and current values are noted by pulse circuit, and then the power obtained is output to ARM9 board, which is saved in its memory and output them when required. ARM9 board can also communicate with remote host system by using Wi-Fi module. The PMWCM system software flow is as follows:

A. The Hardware Initialization and Embedded Linux Operating System Initialization:

The system uses the S3C2440's NAND Flash boot mode. This mode uses a way of Stepping Stone implementation. First of all, it copy the first 4k code of NAND Flash to Stepping Stone at boot time, which are mapped to address 0x0 region in SRAM, then the copied code are run in SRAM to complete the system start-up. Stepping Stone is only 4K, unable to meet the requirements of booting systems, so the PMWCM system uses a phased booting strategy, namely: booting process is divided into phase 1) and phase 2).

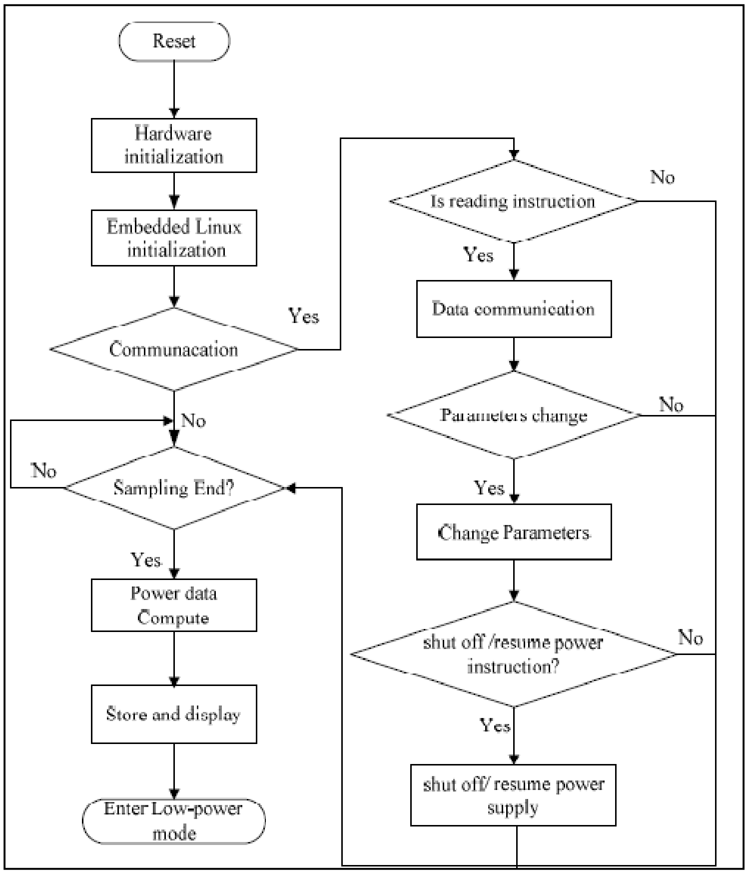

Fig. 3: The PMWCM system software flow chart

1) This Phase mainly includes hardware initialization code, which programmed by assembly language. Phase A includes the following steps.
   1) Hardware initialization
   2) Completion of SDRAM initialization, SDRAM is the RAM space which phase 2) required to run.
   3) Copy the phase B code of Boot loader to SDRAM space.
   4) Jump to the C program entry point of phase 2).
2) Phase B can be programmed by C language, this can achieve more complex functions, and the code has better readability and portability. Phase B includes the following steps:

1) Initializing the hardware device this stage uses.
2) Detecting system memory mapping.
3) Reading the kernel image from Flash to SDRAM..
4) Setting boot parameter for the kernel.
5) Calling the kernel.

B. When not received all Kinds of Interruption Request:

When not received all kinds of interruption request,
S3C2440A CPU implement watchdog program circularly, implement display program which shows the cumulative power of this month, determine whether the update time, read CS5460A instantaneous current and voltage Register value to determine whether it is the over-current or over-voltage or under-voltage shutdown protection. After complete the above programs, S3C2440A is prepared to accept external interrupts at any time.

C. When it received remote host computer communications interrupt request， it responds to the interrupt and calls the Wi-Fi communication program to deal with the request:

- If the meter reading orders are received, the power data stored in the Flash, the local MAC address information, and so on, will be sent to the remote host computer through WIFI wireless communication module.
- If it received the remote host computer to send the adjusting Real-time price such as instructions, then it calls the local procedures to adjust parameters such as electricity price.
- If it receives the instructions which remote host computer sends to shut off power supply or resume power supply, then call the procedure through the GPIO interface to control relay to shut off power or resume.
- It returns the main program after the above steps.

D. When the CS5460A's EOUT (energy output) pins and EDIR (energy direction indicator) pins output pulse, interruption program according with the time parameters stored in S3C2440A's clock, as well as the real-time clock value to determine the type of the current period, S3C2440A response to external interrupt to cumulate the power data, and the results is stored to the external Flash memory, then interrupt service routine exit into the above process B.

V. INTRODUCTION TO LINUX

Linux is, in simplest terms, an operating system. It is the software on a computer that enables applications and the computer operator to access the devices on the computer to perform desired functions. The operating system (OS) relays instructions from an application to, for instance, the computer's processor. The processor performs the instructed task, and then sends the results back to the application via the operating system. Linux is a modular Unix-like operating system. The Linux operating system is composed of four major sub systems:

1) User Applications - The set of applications in use on a particular Linux system will be different depending on what the computer system is used for, but typical examples include a word-processing application and web –browser.
2) OS-Services- These are services that are typically considered as part of the operating system (a windowing system, command shell etc); also, the programming interface to the kernel (compiler tool and library) is included in this subsystem.
3) Linux Kernel-The Linux Kernel is an operating system kernel used by the Linux family of Unix-like operating system. It is one of the most prominent examples of free and open source software.
4) Hardware Controllers- This subsystem is composed of all the possible physical devices in a Linux installations; for examples, the CPU, memory hardware, hard disks, and network hardware are all members of the system.

A. NAND Flash Controller:

In recent times, NOR flash memory gets high in price while an SDRAM and a NAND flash memory is comparatively economical , motivating some users to execute the boot code on a NAND flash and execute the main code on an SDRAM.
S3C2440A boot code can be executed on an external NAND flash memory. In order to support NAND flash boot loader, the S3C2440A is equipped with an internal SRAM buffer called 'Steppingstone'. When booting, the first 4 Kbytes of the NAND flash memory will be loaded into Steppingstone and the boot code loaded into Steppingstone will be executed. Generally, the boot code will copy NAND flash content to SDRAM. Using hardware ECC, the NAND flash data validity will be checked. Upon the completion of the copy, the main program will be executed on the SDRAM.

B. QT- Quasar Technology:

It is a cross-platform application framework that is widely used for developing application with a graphical user interface (GUI) (in which cases Qt is classified as a widget toolkit), and also used for developing non-GUI programs such as command-line tools and consoles for servers.

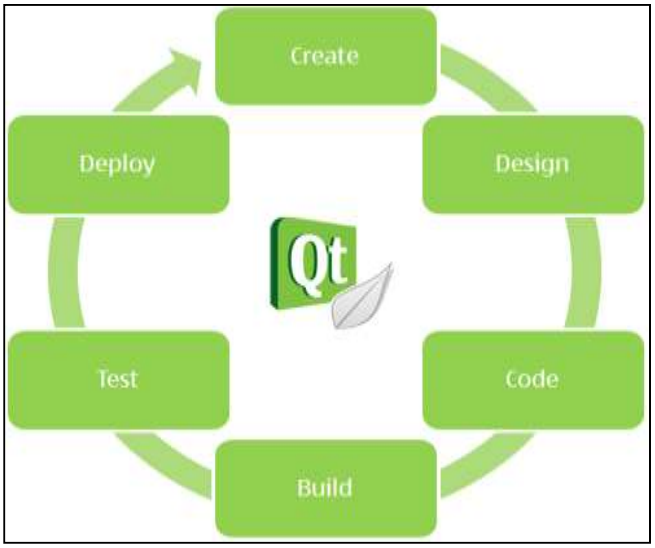

Fig. 4: QT builds flow diagram

Qt Creator deploy configurations handle the packaging of the application as an executable and copying it to a location developers want to run the executable at. The files can be copied to a location in the file system of the development PC or to a mobile device. Qt Creator allows us to create installation packages for devices that are suitable for publishing on other channels.

C. AMR Technical Requirements and Performance Metrics:

One missing aspect in the previously discussed design proposals is evaluation. An AMR network should meet certain quality requirements. Thus any new design has to be assessed according to a number of quality metrics as following:

1) Reliability: The AMR must guarantee the arrival of all meter readings as well as all utility server control packets. The success rate or loss rate performance metric shall give us a fair assessment of the given network.
2) Scalability: A designed network shall be assessed according to its ability to providing support to a large number of meters covering a large geographical area. Furthermore, the frequency of such readings should be high enough to support the desired AMR services (e.g. real time pricing).
3) Real time communications: Data reported from a given meter must arrive within a given amount of time. Traffic types (e.g. Fault detection) mandate a short time delay. A performance metric of end to end delay is required to provide a good evaluation of response time of the different traffic types.
4) Order: Packets representing different readings should be stamped with the time of measurement metric so that packet at the receiving station can be guaranteed.
5) Security: The level of security can be expressed in terms of the cryptographic tools implemented at different protocol stack layers and number of key bits used. Hop-by hop security is implemented at lower layers while end-to-end security is implemented at both ends of the AMR application.
6) Data collection mechanism:
7) All the previous work focuses on gathering power consumption information, in which the AMR data is pushed from meters into the network at certain fixed times. As utility providers are interested in a large variety of data with much high frequency, three modes of communications required to be supported: fixed scheduling, event-driven and demand driven. Each mode is more suitable for a certain kind of data and as such as the three modes must co-exist.
8) Fixed Scheduling: In this mode a meter reports data at fixed intervals. This is a straight forward mechanism with the advantage of guaranteeing a certain rate for energy meter under the knowledge of the available bandwidth. However, the traffic that results is significantly high. It may impact other Internet traffics at bottleneck nodes. As a result, packets will be dropped and data reports may not meet delivery deadline.
9) Event-driven: Data are generated as a result of events at meters. Examples of this mode include packets generated when consumption reaches a certain threshold value, power quality when it starts to degrade, and includes alarm data. This mode may cut down the amount of traffic though it will vary from time to time; however a trade-off must be considered as a connection overhead and possible delay will be introduced.
10) Demand-driven: Upon a request from the data collection centre, data packets are generated and transmitted back. A utility company uses polling to identify faults, or gets a consumption report at a certain time for a subset of meters. Polling requires extra messaging for the end parties to re-authenticate and set up other communication parameters every time. Demand-driven data typically require real time response. Therefore, such data should be distinguished from the rest and given a higher level of priority.

VI. Applications

- Automatic per day bill generation and monitoring of meter.
- Used for water meter control and monitoring system.
- Industrial electrical energy conservation.
- Used for distribution and maintains in supply sector.

VII. Advantages

- Less data collection cost.
- Faster and efficient meter reading.
- Faster and efficient billing process.
- Avoidance of human reading errors.
- Improved security.
- Ability to detect tamper events and outage occurrences.
- Remotely Connect/Disconnect power supply through meter.
- Calculate transformer loading and sizing from interval data.
- Consistent and granular data for improved accuracy.

VIII. Shortcomings

- The economical charges that must be satisfied in order to replace the old traditional meters with the new AMR devices.
- Communication patterns between levels can be complex.
- Algorithm complexity can be substantial.
- Increased security risks from network or remote access.

IX. Conclusion

This paper presents a new scheme using Wi-Fi technology and an ARM-Based PMWCM scheme, to reduce the energy consumption, as well as all the technologies ranged from hardware design to the implementation of application layer. The architecture together with a few core issues such as how to capture the information about energy consumption, how to achieve wireless communication, how to connect to internet, how to analysis data and give corresponding advices, and how to present those data to users conveniently and comfortably and the results address that our paradigm performs quite well in accuracy, stability and availability.

X. Result

- Once the code runs successfully the power meter starts reading the pulses
- Power is supplied according to the user's pre-recharge amount.
- Once the recharge gets over, relay will shut down the power supply.
- User has to make recharge again by using these steps:
- This is the window appearing on the remote user's system. It's developed using qtopia software.

User will get a message on his screen – "Recharge Successful".

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