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A Study on Anatomy of Smartphone

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Abstract: The latest smartphones are attributed with the quality graphics, portable size and user applications support and multimode connectivity features. Smartphone incorporatesthe capabilities of both computing and communication devices. The latest distributed computing models are focused on employing smartphone as a significant stakeholder for enabling complicated and ubiquitous applications in the changing mobile computing world. Therefore, it is necessary to understand the components of smartphone and its working behavior for operation in the cellular and data networks. In this paper we study the anatomy of the smartphone by discussing its major components such as application processor and baseband processor. We describe different subcategories of smartphone components and highlight the behavior and significance of each component for dual mode functionalities of smartphone. The paper provides tutorial for understanding the architecture of the smartphone and exploring the functionalities of the dual processors of smartphone which are used for accessing different types of wireless networks. It helps in developing optimal procedures for deploying the components of the smartphone while accessing cellular and data networks

Keywords: Smartphone, Application Processor, Baseband Processor, Anatomy

1 Introduction

Smartphone is a new generation high featured and multifunctional cell phone which has become universal replacements for Personal Digital Assistants (PDA's). A smartphone incorporates the functionalities of a handheld computer with the communication capabilities of a cell phone. It provides multimodal connectivity and user customized applications support for local and distributed services. Ssmartphones have high end features such as email, a mini browser, external USB options, large screen, GPS capability, and large memory capacity and basic PC functionality. Many third party applications, tools and programs are installed by the user to make the smartphone all in one device [1]. The latest smartphone has replaced different portable devices such PDAs, digital cameras, Internet browsing devices, and Global Positioning Systems (GPS) [2]. Users dependency on the latest smartphones is increasing rapidly in various domains such as e-businness, m-learning and m-gamming, m-healthcare and mobile management information systems[3]. Smartphones are predicted the dominant future computing devices.

Smartphone are quipped with two different processors for accessing communication network and performing computation. Baseband Processor (BP) is a dedicated processor which is used for employing GSM protocol stack, and Application Processor (AP) is a multicore general purpose processor which is used for providng user interface and running applications. AP and BP processor havetheir own memory (RAM and Flash), peripherals and clocking. However, due to the demands for portable devices with rich functionalities, highly integrated products are produced by

integratingthe AP and BP inside one physical package. Each processor is allocated isolated memory access by assigning separate portions of the integrated RAM and Flash memory to each of the two processors. Therefore each processor is provided access to its own memory address space [4].

The latest distributed computing models, such as Mobile Cloud Computing (MCC) and Cloud Computing are focused on employing smartphone as a significant stakeholder for enabling complicated and ubiquitous applications in the changing mobile computing world [5]. Therefore, it is necessary to understand the components of smartphone and its working behavior for operating in the cellular and data networks. This paper reviews the anatomy of smartphone by analyzing and modeling major components of the smartphone. We discuss the working of each component from different perspectives. The paper provides tutorial for understanding the architecture of the smartphone and exploring the functionalities of the dual processors of smartphone which are used for accessing different types of wireless networks. It helps in developing optimal procedures for deploying the components of the smartphone while accessing cellular and data networks.

The paper is organized into four sections. Section 2 presents the architecture of GSM model and the components associated with baseband processor. Section 3 discusses the architecture of application processor and models the anatomy of smartphone. Section 4 draws conclusive remarks.

2 Baseband Processor

Baseband processor employs GSM protocol stack for enabling smartphone to access different types of wireless network technologies such as WCDMA, EDGE, CDMA, Zifgbee, Bluetooth 4.0, Wi-Fi, or LTE. BP manages radio communications and control functions such as signal modulation, radio frequency shifting and encoding. Baseband processors were used earlier inordinary mobile phone technology for accessing cellular network,however, its architecture has evolved in several stages from analog to digital to 3G, and the latest development to LTE. Smartphone has a GSM modem which interfaces with the GSM network [6]. The GSM modem consists of the following parts.Figure 1, shows the block diagram of the parts of baseband processor associated with GSM.

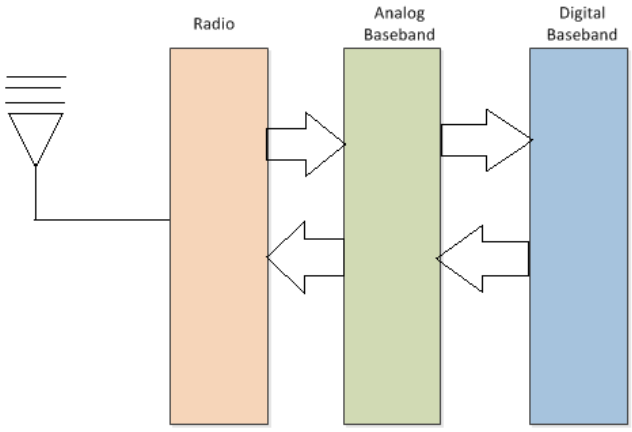

Figure 1.Block Diagram of GSM Modem components

The baseband processor is differentiated into two sections; analog functions and digital function;whereas the RF section remains as a whole circuit section.

2.1 Radio Frequency (RF) Section

Radio Frequency (RF) front end component of the BP is responsible for receiving and transmitting on different frequencies. RF is employed as the mode of communication for all types of wireless technologies; such as cordless phones, radar, ham radio, GPS, and radio and television

broadcasts. RF waves are electromagnetic waves which propagate at the speed of light, or 186,000 miles per second (300,000 km/s). The frequencies of RF waves, however, are slower as compared to visible light; for that reason RF waves are invisible to the human eye. RF component is responsible for the access of wireless cellular network and communication between smartphone and base transceiver station (BTS). RF section is composed of a transceiver for transmission and reception of signals and a power amplifier.

2.1.1 Transceiver

A smartphone employs transmitter and receiver circuits for correspondence with other mobile phone. A transmitter circuit transmits radio signals in the air and a receiver is used to receive transmissions (radiation) which are spread in the air by any transmitter on a specific frequency. The two way communication is made possible by setting two transmitters and two receivers synchronized in such a manner that a transmitter in a cell phone is synchronized with the frequency of other cell phone's receiving frequency; similarly the transmitter of second cell phone is synchronized with the receiving frequency of first cell phone. Figure 2, shows the basic operation methods of RF section.

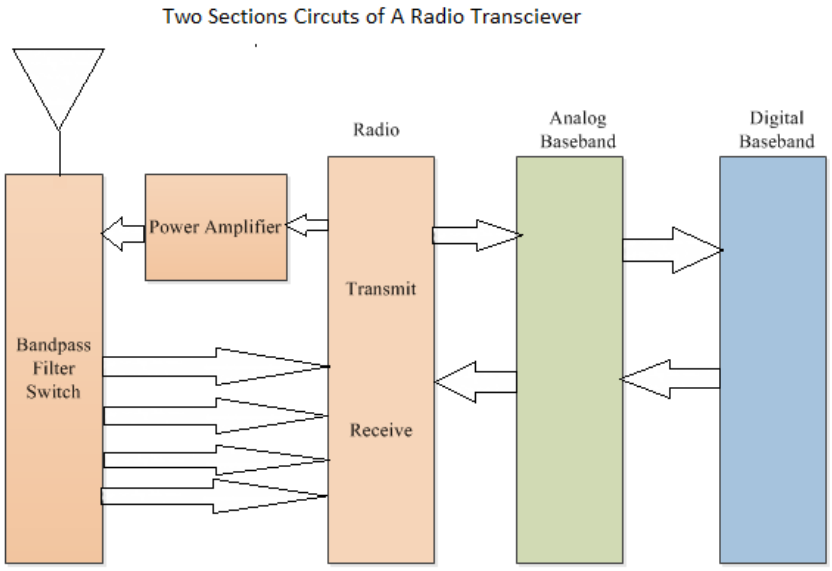

Figure 2. The Basic Operation Methods Of RF Section

2.1.2 The Analog Baseband (ABB)

The ABB part of a GSM modem is responsible to interface between the digital domain and the analog domain of the GSM modem. ABB consists of the following components.

A/D and D/A section: Analog to Digital (A/D) and Digital to Analog (D/A) component is responsible for modulation and demodulation; digital to analog and analog to digital conversions.

Control section: The control subsection acts as the controller of the input and output of any analog and digital signal.

Power Management: The power management subsection is responsible for the management of energy matter of the smart mobile devices. The power management subsections is composed of two components; power distribution and switching section and charging subsection.

*Power Distribution (PD):*The power distribution subsection of ABB is used for the distributionof desired voltage and current to the other sections of the smartphone. It takes power from a battery (commonly 3.6 Volts) and in some places it converts or step down to various volts

such as 2.8 V, 1.8V and 1.6V. On the other hand, PD steps up the voltage such as 4.8 V. Power distribution section is commonly designed around a power IC (and integrated circuit) which is used to distribute and regulate the voltage used in other components [12].

Charging Component: The charging component is responsible for charging the battery of smartphone. It is composed of a charging IC which takes power from an external source and gives it to battery of the smartphone. It uses 6.4 V, from an external battery charger and regulates it to 5.8 V while giving it to battery.

Audio Codecs Section: AudiCodecs is responsible for the processing of analog and digital audio signals received through microphone, earpiece speaker headset and ring tones and the vibrator circuits. Figure 3, shows operational structure of analog baseband processor component.

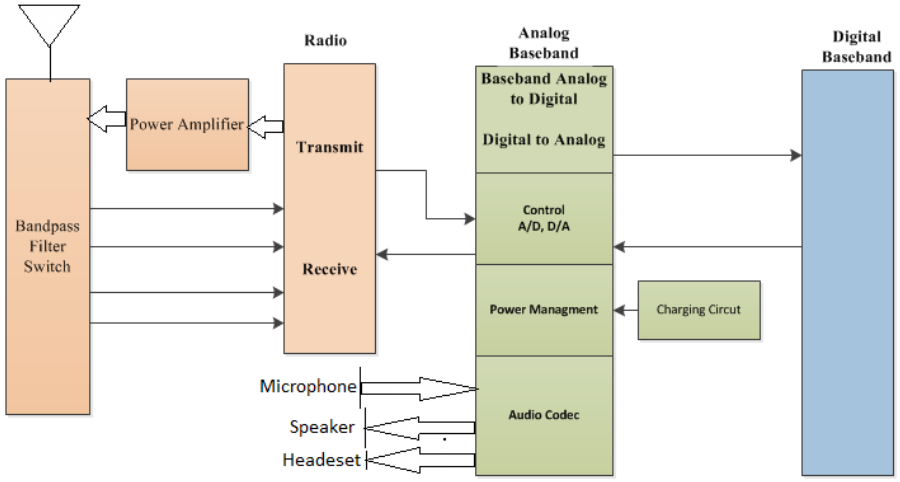

Figure 3. Functioning Diagram of Analog Base Band Processor

2.1.3Digital Baseband Processor (BBP)

A baseband processor (also known as baseband radio processor, BP, or BBP) is a chip or part of a chipin a smartphone that is responsible for managingall functions that require an antenna [7]. The digital BBPemploys the actual GSM protocols from Layer1 up to Layer 3 as well as higher layers; such as a user interface in the case of the feature phone. In a smartphone, the BBP employs a machine interface which is used by the AP. A normal BBP design includes a Digital Signal Processor (DSP) for the lower half of Layer1, and a general purpose processor (MCU) for the upper part of Layer1. DSP and MCU communicate by employing shared memory interface.

The shared memory contains both actual data, control information. The actual data is processed by application processor; whereas, control information and parameters describe the action to be taken with the respective data. The MCU instructs the DSP to perform decoding for a particular GSM burst type on the receiving side, after which the DSP receives I/Q samples from the ABB, and performs detection/demodulation/decoding and the result of the operation (including any decoded data) is reported back to the MCU. For the transmit path, the MCU presents the transmittable data and auxiliary information to the DSP, which then takes care of encoding and sends the corresponding burst bits to the ABB (remember, most ABB devices take care of the modulation to reduce DSP load) [4]. The Baseband Processor (MCU) cores have the typical set of peripherals of any Advanced RISC Machine (ARM 7) based microcontroller, such as RTC, UARTs for RS 232 and IrDA, SPI, I2C, SD/MMC card controller, keypad scan controller and USB device. The additional GSM specific peripherals are: GPRS crypto unit, GSM TDMA timers and smart card reader interface for the SIM card. The MCU generally runs a very small real time operating system

(RTOS) such as Nucleus, VxWorks or the L4 microkernel [2]. Figure 4 shows the components of digital baseband processor for mobile device.

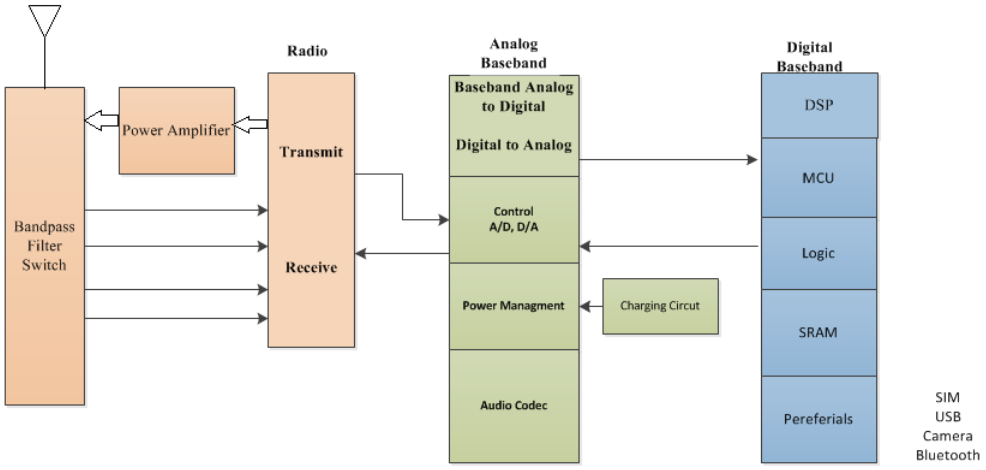

Figure 4. Components of the Digital Baseband Processor

Recently, a number of multi-SIM mobile devices entered the market such as Dual-SIM or Triple-SIM. Multi-SIM functionality of the smartphone is implemented in different ways. One way of implementing the dual SIM operating procedure of the mobile devices is that a multiplexer is employed on the mobile device, which allows electrical switching between multiple SIM card slots. This is technique is similar to replacing the SIM card in a phone, just without the manual process of mechanically removing/inserting the card. As a result, mobile user can use one of the two SIMs at any time. The second method of implementing dual SIM functionalities on the smartphone is by employing two complete phones in one case. Mobile device contains two full GSM phone chipsets, i.e. 2 antennas, 2 RF frontends, 2 analog basebands, 2 digital basebands. Dual sets are implemented in such a way so that one of the two basebands does not have keypad or display and is simply a GSM modem connected via serial line to the other baseband processor. A smartphone is a GSM modem connected to a PDA in one case, similarly a Dual-SIM phone is a GSM modem connected to a ordinary phone in one case [4].

3 Application Processor

Smartphone is equipped with a dedicated Application Processor (AP) for performing computation. The AP is a special type of System on a Chip (SoC) which supports a number of multimedia related features such as web browsing, email, multimedia entertainment and games. Application processor enables smartphone to run autonomous operating systems [13] and employ customized user applications. The application processor provides additional processing capabilities for performing such taskswith minimal power consumption [8]. A smartphone runs different types of operating system such as Android, Windows Mobile and Symbian [9, 13]. Application processor processes The multimedia contents which are either delivered to the consumer's multimedia device, or produced by the consumer’s multimedia device are processed by the application processor with the intention of sharing the content with others or storing it for later use [10]. The application processor is comprised of the following vital components.

1. Processor Core (ARM926EJS)
2. Multimedia Modules
3. Wireless Interfaces
4. Device Interfaces

3.1 Processor Core

Smartphone application processor is Advanced RISC Machine (ARM) based RISC processor which is specially optimized for application for minimal power consumption (measured as joules per instruction).

3.1.1 Multimedia Modules

Multimedia modules perform multimedia related computation; for that reason, they are hardware implementation of one or more multimedia standards. Multimedia related operations are often time consuming; therefore, single purpose hardware is generally better than general purpose hardware in order to save power. Application processor is composed of the following modules.

1. JPEG module for decoding pictures for viewing on the LCD screen, and encoding pictures taken with the camera, for later viewing or for sending out on the network.
2. MPEG module decoding streaming live video, video on demand, and incoming video conferencing data, and encoding video taken with the video camera for later viewing, or for sending out via the network (for video sharing or conferencing)
3. Audio modules allow the device to act as an MP3 (music) player, or encode/decode voice data.

Smartphone contain Graphics Processing Unit (GPU) for rapidly manipulating multimedia functions. It is a specialized electronic circuit which is designed to speedily operate and change memory for accelerating the creation of images in a frame buffer which is intended for output to display. The highly parallel structure of modern GPUs make them highly effective than general-purpose CPUs for algorithms wherein large blocks of data is processed in parallel [14]. The role of the GPU is to manage 2D and 3D graphics, video capture, playback, deliver mobile gaming, and provide a rich user interface.

3.1.2 Wireless Interfaces

The wireless modules found within an application processor enable the smartphone to communicate with the cellular network and data network (internet). The digital components of the wireless communication scheme are integrated into the chip as part of the application processor, whereas the analog parts are placed off-chip. A smartphone employs the following wireless modules.

1. Bluetooth Module allows for communication with peripherals such as headset, or other nearby mobile devices.
2. WiFi module enables smartphone to communicate with local 802.11 network.
3. GSM modules enable smartphone to communicate with the cellular network for both vice communication and access to internet.

Figure 5 shows smartphone device wireless network interfaces.

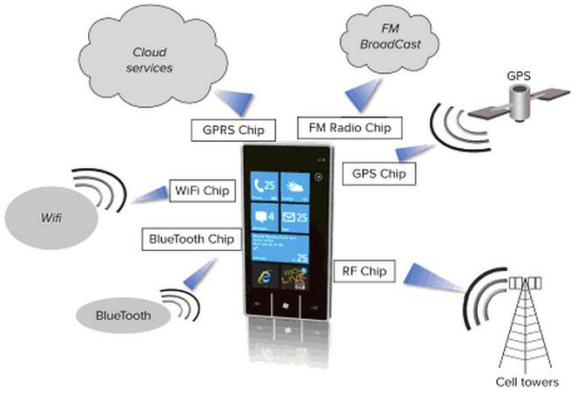

Figure 5. Smartphone Network Components

3.1.3 Device Interfaces

Devices interfaces enable the smartphone to communicate with any peripheral device. Examples of the peripheral devices attached to an application processor include; LCD screen, keypad, camera, Universal Serial Bus (USB), Secure Digital (SD), Multimedia Card (MMC). Each type of peripheral device is connected to application processor through a separate interface. For example display controller interface allow for convenient communication between the display and other modules. Similarly camera interface allow for interaction between the camera and other digitial modules integrated with SoC. USB interface facilities the connection of external devices on USB port. SD/MMC interface enables smartphone to connect external memory devices. Examples of the application processor are ARM Cortex-A9, Samsung S5PC100, and TIOMAP4 Platform, Apple A4. Figure 6 shows the anatomy of smartphone.

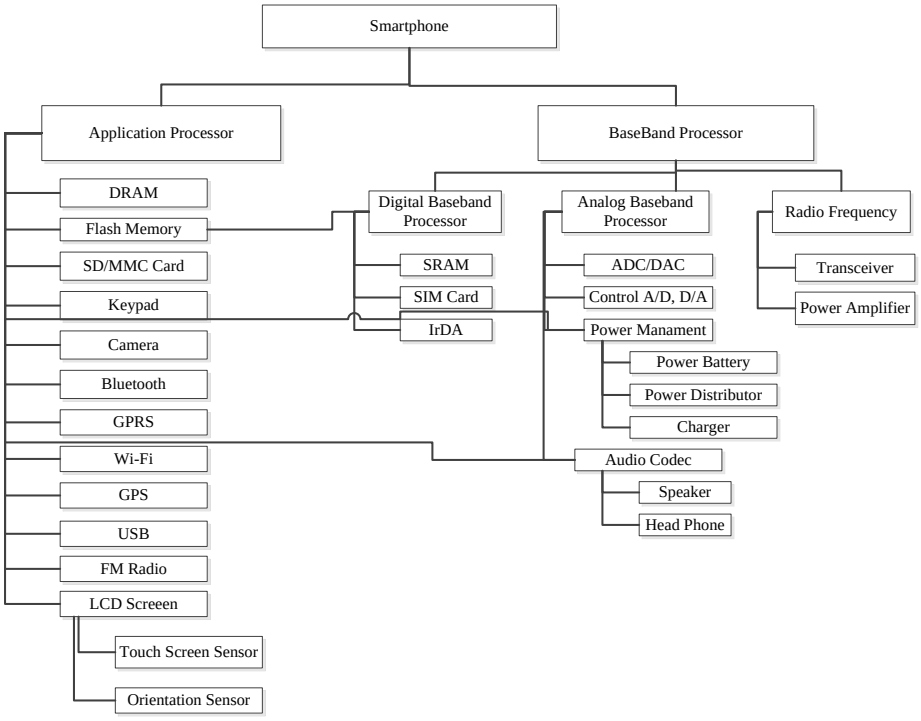

Figure 6. Anatomy of Smartphone

Smartphones contain highly integrated computing and communication components. For instance, main chips include the CPU, GPU, other specialized coprocessors, motherboard buses, memory controller, LCD controller, sound chipset, CMOS camera interface, on-board memory, and several peripheral devices (such as Cell, Wi-Fi, and Bluetooth radios). The application processor is the chip responsible for general processing (like a CPU and motherboard chipset of desktop computer) and can have several other functions built into it; whereas, the baseband processor is responsible for cellular wireless communications [11] which include all functions that require an antenna.

4 Conclusion

Smartphone is a portable device that encapsulates computing capabilities and cellular network access functionalities in a single integrated multicore processor. In modern smartphones, dual core processor is composed of two processors; each one with a separate RAM and flash memory access

and distinct objectives. The baseband processor is responsible for radio access of the wireless network environment and the application processor is specially designed for the execution of software stack on smartphone. Application processor is assisted by some specialized multimedia modules in the execution of multimedia functions such as audio, and video with optimal computing resources consumption. A hardware interface bridges the functionalities gap between application processor and baseband processor.

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