Smartphone Architecture

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Smartphones

• 182 million active smartphone users in the US
  • That’s 74.6% of the total population
• Apple has the largest market share
  • 41.6% of total subscribers
• Gaming
  • Worldwide mobile gaming revenues are expected to overtake console games in 2015
  • North America and Western Europe mobile gaming is growing at ~50% year after year
• Average Mobile digital media time is greater than Desktop digital media time in the US
Cellphone vs PDA vs Smartphone

Cellphone:
- Calling and texting features
- Very few other features

PDAs (Personal Digital Assistants):
- Web browsing, personal organizer
- Traditionally did not include calling / faxing / emails

Smartphones:
- Combined the PDA and Cellphone functionality

Many Similar Devices:
- Pocket PC, Tablet, “smartphone” vs. “Smartphone”
Challenges for Mobile Devices

Power Consumption:
- Battery life and device efficiency must be optimized
- Device must conserve power when idle or suspended

Networking:
- Most mobile devices designed for on-the-go computing
- Need to handle internet / calls / SMS reliably

Security:
- Devices can be easily lost or stolen
- Important personal information must be protected
Anatomy of a smartphone

- Smartphone
  - Application Processor
    - DRAM
    - Flash Memory
    - SD/MMC Card
    - Keypad
    - Camera
    - Bluetooth
    - GPRS
    - Wi-Fi
    - GPS
    - USB
    - FM Radio
    - LCD Screen
  - Baseband Processor
    - Digital Baseband Processor
      - SRAM
    - SIM Card
    - IrDA
    - Analog Baseband Processor
      - ADC/DAC
      - Control A/D, D/A
      - Power Management
        - Power Battery
        - Power Distributor
        - Charger
      - Audio Codec
        - Speaker
        - Head Phone
    - Radio Frequency
      - Transceiver
      - Power Amplifier
System on Chip (SOC)

- Single chip solution for application processor
  - Processors (CPUs and GPUs)
  - On-chip memory
  - Accelerating function hardware
  - All analog components
- Coordinated software and hardware
- Smartphones use SoC instead of connecting separate chips on a PCB because:
  - Reduces cost, power, and size
  - Increases performance
The iPhone

• Design features
  • One of the first phones with a GPU
  • Accelerometer (automatically rotates screen)
  • 2 megapixel camera
  • Proximity sensor (dims screen during calls)
  • Ambient light sensor to automatically change brightness

• Problems:
  • exclusive to AT&T
  • low battery life (due to GPU and new sensors)
  • No removable battery or SD card…did not please power-users

• Resulted in more “Average” users entering smartphone market
SoC design challenges

• Very complex designs
• Much more expensive than alternatives
• Performance requirements: (must do well for all)
  • Size limitations
  • Power usage (affects battery life)
  • Heat dissipation is more difficult
  • Performance with images, sound, video of all varieties
  • Performance with networks of all varieties (Wifi, cellular, etc.)
• Smartphone sales can drop if even one aspect is sub-par
Solutions to SoC problems

- Multi-core processing and Hyperthreading
  - Run task in parallel for more speed
  - Rotate between cores for temperature management (sort of like a minigun)
  - Non-linear increase in performance when adding cores
- Rely more upon GPUs
  - Better performance for specialized tasks
- Move analog functionality do digital domain
  - Analog tech growth rate doesn’t follow Moore’s law
- Use ARM processors (over 95% of market share)
Baseband Processors

- Secondary processors functioning as modems
- Originally used in cellphone networks
  - Have since evolved to handle Digital, 3G, LTE, etc.
- Most employ an ARM design for very low power usage
- Processors contain their own micro OS and memory
  - Allows the processor to function on its own
  - Increases reliability by isolating functions from main system
- Handles device functions when device is idle
Baseband Processor Design

In the diagram, the flow begins with the Bandpass Filter Switch. It is connected to the Power Amplifier, which in turn is linked to the Transmit module. The receive module contains the Radio and Analog Baseband components. The Analog Baseband further includes Baseband Analog to Digital, Digital to Analog, Control A/D, D/A, Power Management, and Audio Codec sections. The charging circuit is connected to the Power Management section. The output from the Analog Baseband is directed to the Digital Baseband, which contains DSP, MCU, Logic, SRAM, Peripheral, SIM, USB, Camera, and Bluetooth sections.
Power Usage - Idle vs Suspended

A device is considered IDLE when:

- The device is fully awake, with the SoC running
- SoC is powered but not performing tasks
- Power consumption is fairly stable and can be benchmarked

A device is considered SUSPENDED when:

- The SoC of the device is in low-power mode
  - Android devices power off main SoC by saving current state to RAM
- Only the low power baseband processor is active
- Most of a device’s time is spent in the suspended state
Power Consumption: SPEC2000 Benchmarks

- Performed on an Openmoko Neo Freerunner with Android (2008)
  - Similar to the Google Nexus One (2010) and HTC Dream (2008)

![Power consumption in Suspended State](image1)

![Power consumption in Idle State](image2)
Power Consumption: SPEC2000 Benchmarks

- Power consumption playing a 5 minute video with no sound
- Power consumption during a 77 second phone call
- Notice the power consumption bottleneck
Power Consumption: SPEC2000 Benchmarks

Power consumption handling emails with wifi and GPRS (2G and “old” 3G)

Power consumption handling web browsing with wifi and GPRS
Future Challenges

- Users desire ever-increased computing power
  - Results in higher power consumption
  - Will require a more aggressive power conservation method

- Baseband Processor Designs
  - Very closed source hardware
  - Unknown security risks
  - Power consumption bottleneck during device suspension

- Battery technology
  - Not advancing fast enough to relieve power consumption issues
  - Consistent increase in smartphone costs until major battery tech breakthrough
Links

Baseband and SIM Card Secondary Processors on smartphones:
http://www.androidauthority.com/galaxy-s4-att-update-3.1.78.18/

Network Challenges and Architecture for Smartphones (look at pages 9+):

Smartphone Power Usage Analysis (performed on Openmoko Freerunner):

Mobile game revenues set to overtake console games in 2015

Mobile Marketing Statistics 2015
http://www.smartinsights.com/mobile-marketing/mobile-marketing-analytics/mobile-marketing-statistics/

System on chip (SoC) for mobile phones
http://www.slideshare.net/Funk98/system-on-chip-soc-for-mobile-phones

iPhone original
http://www.imore.com/history-iphone-original