SMARTPHONE HARDWARE: ANATOMY OF A HANDSET

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MOOC on M4D 2013
Outline of topics

• What is the hardware architecture of a smartphone?
• How does communication take place in a smartphone?
• Where does a user application execute in a smartphone?
• What are the important peripheral devices in a smartphone?
• Which processors are commonly used in a smartphone?
• What is ARM TrustZone?
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Smartphone hardware architecture

- GPS
- Display/TS
- KBD
- Camera
- μphone
- Speaker

Main memory (DRAM)

Application processor

- Operating system and drivers
- Run-time system
- Middleware

Application software

Transmitter/Receiver

SIM Card

Modem processor

Operating system and baseband radio interface

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Smartphone hardware architecture

• A system-on-chip architecture with three primary components
  – An application processor executing the end-user’s application software with assistance from the middleware and operating system (OS)
  – A modem or baseband processor with its own operating system components responding to the baseband radio activities (transmission and reception of audio, video, and other data contents)
  – A number of peripheral devices for interacting with the end-user
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Communication mechanism

• Reception
  – The receiver hardware (part of the modem) senses incoming signals and generates interrupts for the radio interface logic of the operating system
  • The radio interface and the operating system software run on a baseband or modem processor
  – Once the reception begins (after a physical layer handshake), the incoming audio, video, and other data are processed by the modem processor
  – The radio OS components talk to the peripheral device drivers to present the incoming data to the user through appropriate devices (display, speaker, etc.)
Communication mechanism

• Transmission
  – The data to be transmitted are collected by the radio OS components from memory regions populated by the device drivers
    • For example, audio data captured by the microphone driver or an image or a video captured by the camera or a position information captured by the GPS device
  – These data can be further processed by the modem processor to suite the transmission protocol
  – A transmission is initiated by the radio interface logic through the modem transmitter hardware

• The subscriber identification module (SIM) plays an important role in reception and transmission
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User applications

• Application processor executes the user applications and the related OS services
  – Applications include audio/video codec and players, games, image processing, speech processing, internet browsing, text editing, etc.
  – Application processor takes help from graphics accelerators as and when needed
    • Most handheld applications are graphics-intensive
  – Handhelds come with reasonably large amount of storage in the form of volatile SDRAM (1-2 GB) as well as non-volatile compact storage (10+ GB)
  – The OS is mostly a traditional one, stripped down and optimized to cater to smartphone applications
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Peripheral devices

• These are the I/O devices through which the end-user interacts with the handheld
  – The OS needs to have the driver software installed for each such device
  – Typical peripheral devices
    • LCD and touchscreen
    • Keyboard
    • Camera
    • GPS
    • Speaker and audio output for headset/earphone
    • Microphone
    • Bluetooth and Wifi
    • HDTV
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Processors in handhelds

• Need to balance performance, power consumption, and cost

• ARM-based processors are very common
  – Optimized for battery life as well as performance
  – Remarkably low area and transistor count
    • Important for small form factors and low energy drain

• Modem processor is either a separate ARM core or a DSP extension of the application processor ARM core
  – Some architectures use a modem accelerator along with the application processor core
Processors in handhelds:
A typical ARM-based smartphone hardware

Photo courtesy: www.arm.com
Processors in handhelds

- Modern handhelds include multiple application processor cores (two, four, or eight)
  - Samsung Galaxy S4 i9500 comes in two possible configs
    - 1.9 GHz quad-core ARM Krait + Qualcomm’s Adreno GPU
    - 1.6 GHz quad-core ARM Cortex-A15 + 1.2 GHz quad-core ARM Cortex-A7 + Imagination’s PowerVR GPU (only four cores out of the eight app. cores can be active at a time)
  - Apple iPhone 5
    - 1.3 GHz dual-core Swift (ARMv7-based) + PowerVR GPU
  - Nokia Lumia 920T
    - 1.7 GHz dual-core Qualcomm Krait + Adreno GPU
  - Lenovo K900
    - 2.0 GHz dual-core Intel Atom Z2580 + PowerVR GPU
Processors in handhelds

• Modern handhelds include multiple application processor cores (two, four, or eight)
  – Samsung Nexus 10
    • 1.7 GHz dual-core ARM Cortex-A15 + ARM Mali-T604 GPU
  – Asus Nexus 7
    • Nvidia Tegra 3 platform with 1.2 GHz quad-core ARM Cortex-A9 + ultra-low-power Nvidia GeForce GPU

• These multi-core app. processors can deliver excellent performance although low-power remains a primary goal for longer battery life
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ARM TrustZone

• ARM TrustZone is a hardware-software solution for security in handhelds
  – Important pieces of information such as various encryption keys must be protected
  – TrustZone hardware allows the application processor to execute in one of the three modes: normal, monitor, and secure
    • Normal to secure transition happens through monitor
  – TrustZone software offers a set of secure OS services and the capability to add new user-defined secure services through TrustZone APIs such as SIM-locking
ARM TrustZone

• ARM TrustZone is a hardware-software solution for security in handhelds
  – TrustZone hardware adds a “non-secure” or NS bit to every address space to distinguish between secure and non-secure information
    • Registers holding encryption keys would be mapped to secure address space
  – If an application tries to access a data residing in a secure address space while the processor is not executing in secure mode, an error is returned
  – In secure mode, the secure OS services and the secure device drivers are invoked

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Questions

• What is your smartphone?
• Which processors does it use? Does it have a dedicated graphics processing unit (GPU)?
• How much storage does it have?
• What peripheral devices does it have?

• Question to ponder about: Can a cluster of smartphones be used some day to do energy-efficient high-performance computing (e.g., weather modeling)?
  – Era of extreme green computing
Thank you!