SMARTPHONE HARDWARE: ANATOMY OF A HANDSET

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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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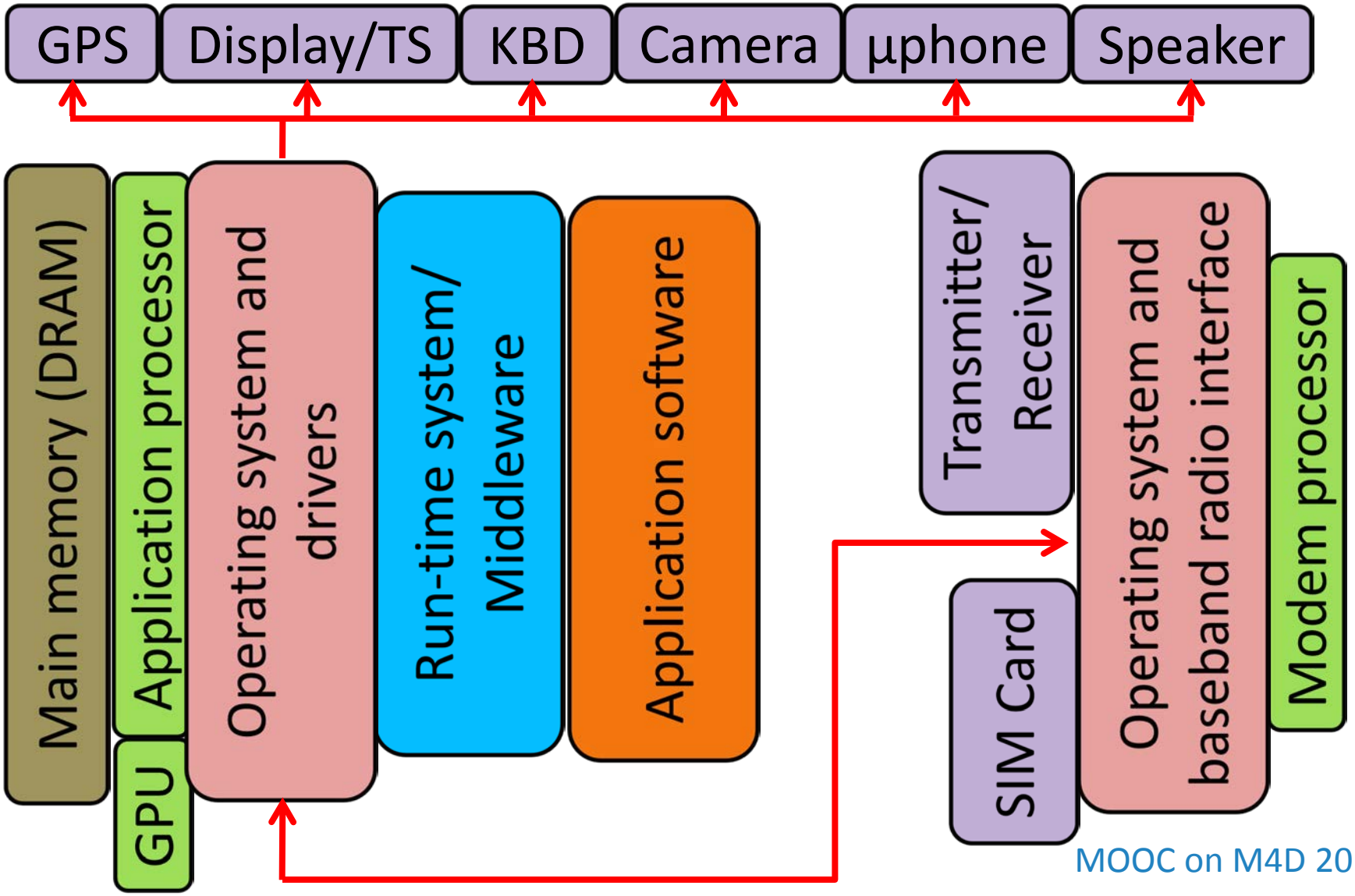
Smartphone hardware architecture



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

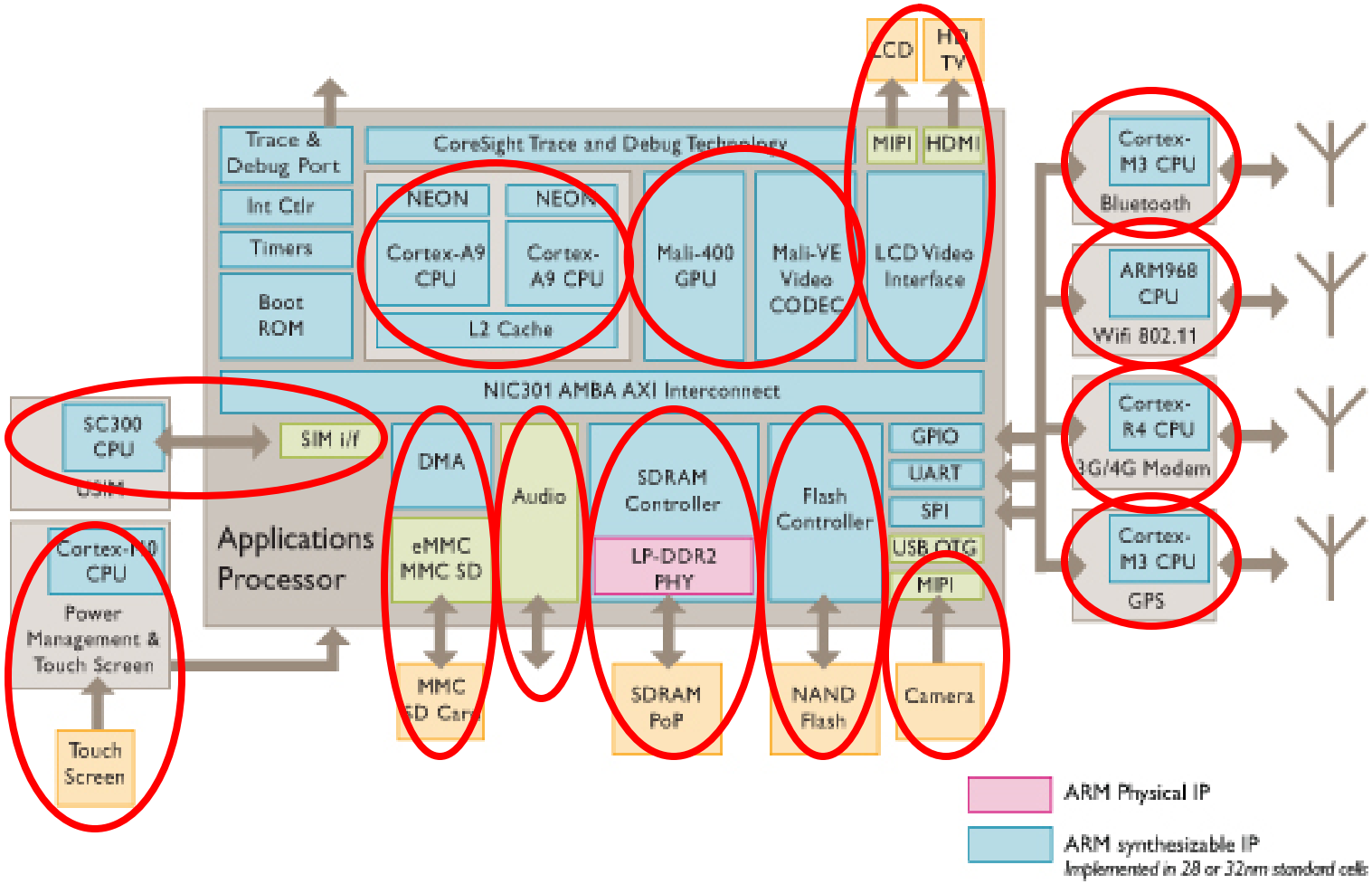

Photo courtesy: www.arm.com

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

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!