National Technical University of Athens
Microprocessors and Digital Systems Laboratory

ARM®

TODAY

Masouros Dimosthenis
Manolis Katsaragakis
Ioannis Oroutzoglou
Aggelos Ferikoglou

Before we start

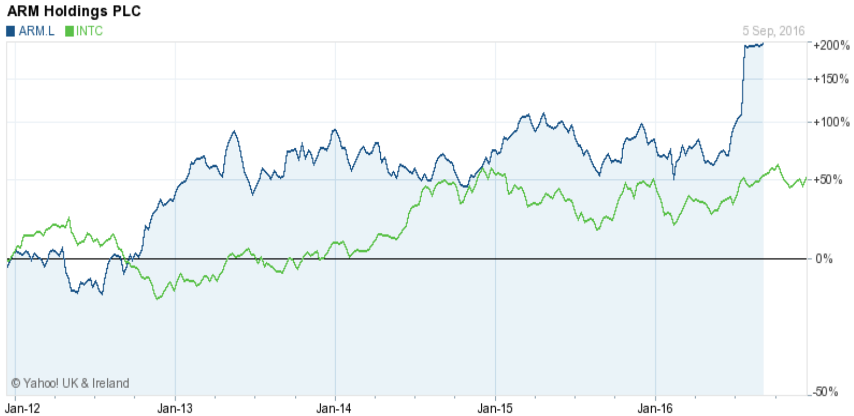
- **helios ->Έγγραφα -> Lab_Material -> ARM material**
- Install and open QEMU
- Replace **/etc/apt/sources.list** file inside qemu vm!!!!!
- Then **apt-get update**
- Install **gcc, vim , build-essential** ...
- Ready to code!

ARM ltd

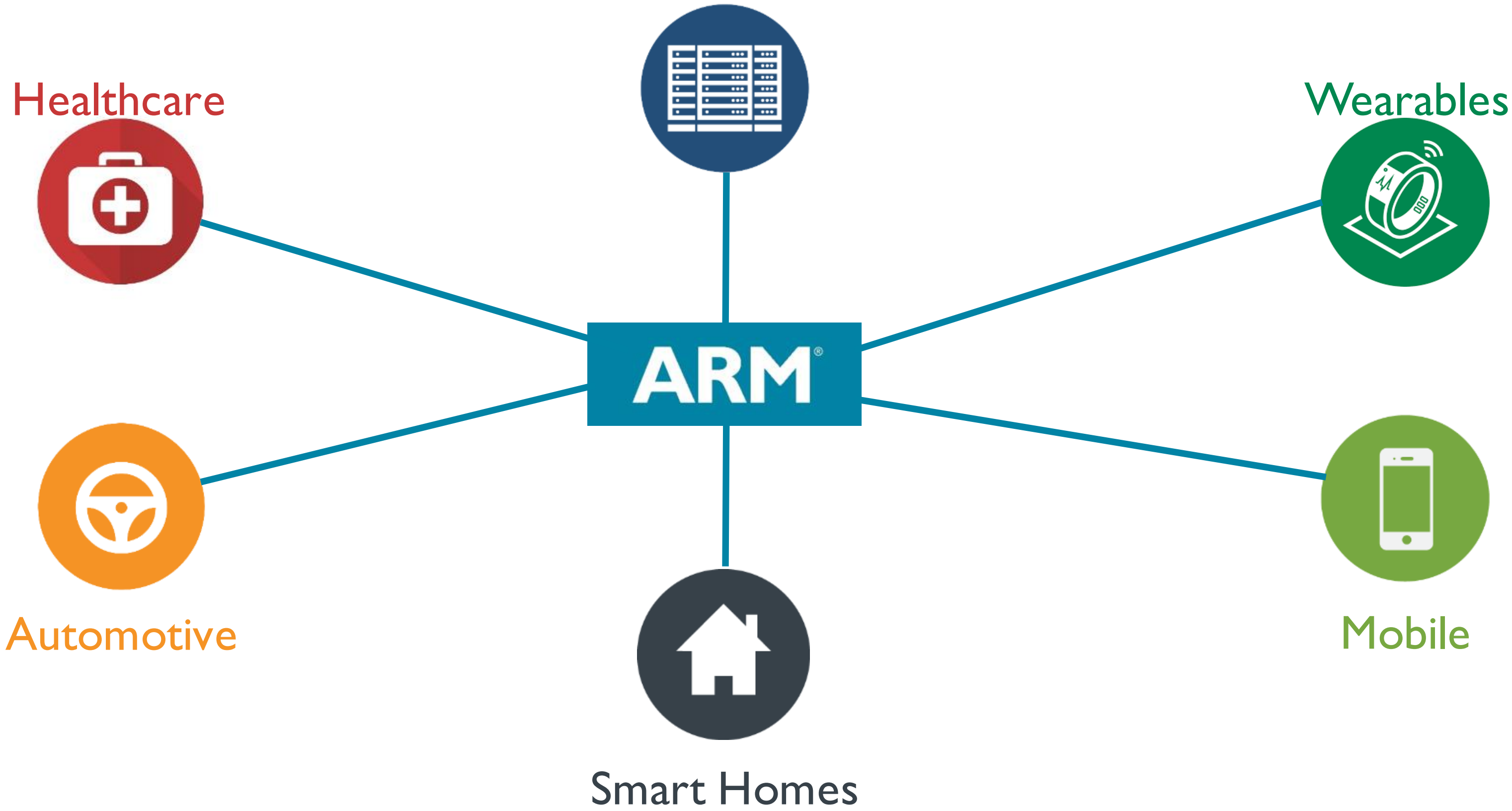
- Founded in November 1990
- Designs the ARM range of RISC processor cores
- Licenses ARM core designs to semiconductor partners who fabricate and sell to their customers
  - ARM does not fabricate silicon itself!
- Also develop technologies to assist with the design of the ARM architecture
  - Software tools
  - Boards
  - Debug hardware
  - Application software
  - Graphics
  - Bus architectures
  - Peripherals
  - Cell libraries
- Bought by Softbank in 2016 for $31.4 billion!

ARM Business Today

- More than 40 million ARM-based chips shipped every day
- Nearly 15 billion ARM-based chips shipped last year alone
- More than 86 billion ARM-based chips shipped in total
- Processor Licenses : 1379
- Semiconductor Partners : more than 450
- more than 4500 patents in total
- ARM technologies reach 80% of the global population!



ARM Markets



ARM Markets

arm

Products

Why Arm

Support & Training

Resources

Company

Solutions ›

Technologies

Artificial Intelligence
Transform lives through machine learning solutions.

Internet of Things
Compute power built into everyday objects and physical systems.

Security
Security for billions of devices through Arm technologies.

5G
Connect anything anywhere with faster, low-latency 5G networks.

Industries

Automotive
Autonomous driving is the next frontier for car manufacturers.

Retail
Leverages IoT for insights into shopper engagements to improve customer experience.

Logistics
Technology that brings end-to-end visibility for transport goods.

Smart Cities
Transform cities to be more responsive to events and changes.

Smart Spaces
Modernize indoor space operations using IoT devices to realize significant savings.

Smart Homes
The power of home automation through always-on IoT devices.

Healthcare
Improve healthcare with proactive, and advanced treatment solutions.

Storage
Power to meet the growing needs of HDD & SSD storage applications.

Industrial
Industrial and operational practices become increasing efficient with connected IoT devices.

Wearables
Secure, flexible processing for wearable electronics with small silicon footprint.

Utilities & Energy
Data management for the spectrum of critical infrastructure for IoT Utilities.

Mobile Computing
Mobile technology for always-on, always-connected devices with AI.

Infrastructure
IoT, cloud and 5G are driving the transformation from datacenter to devices.

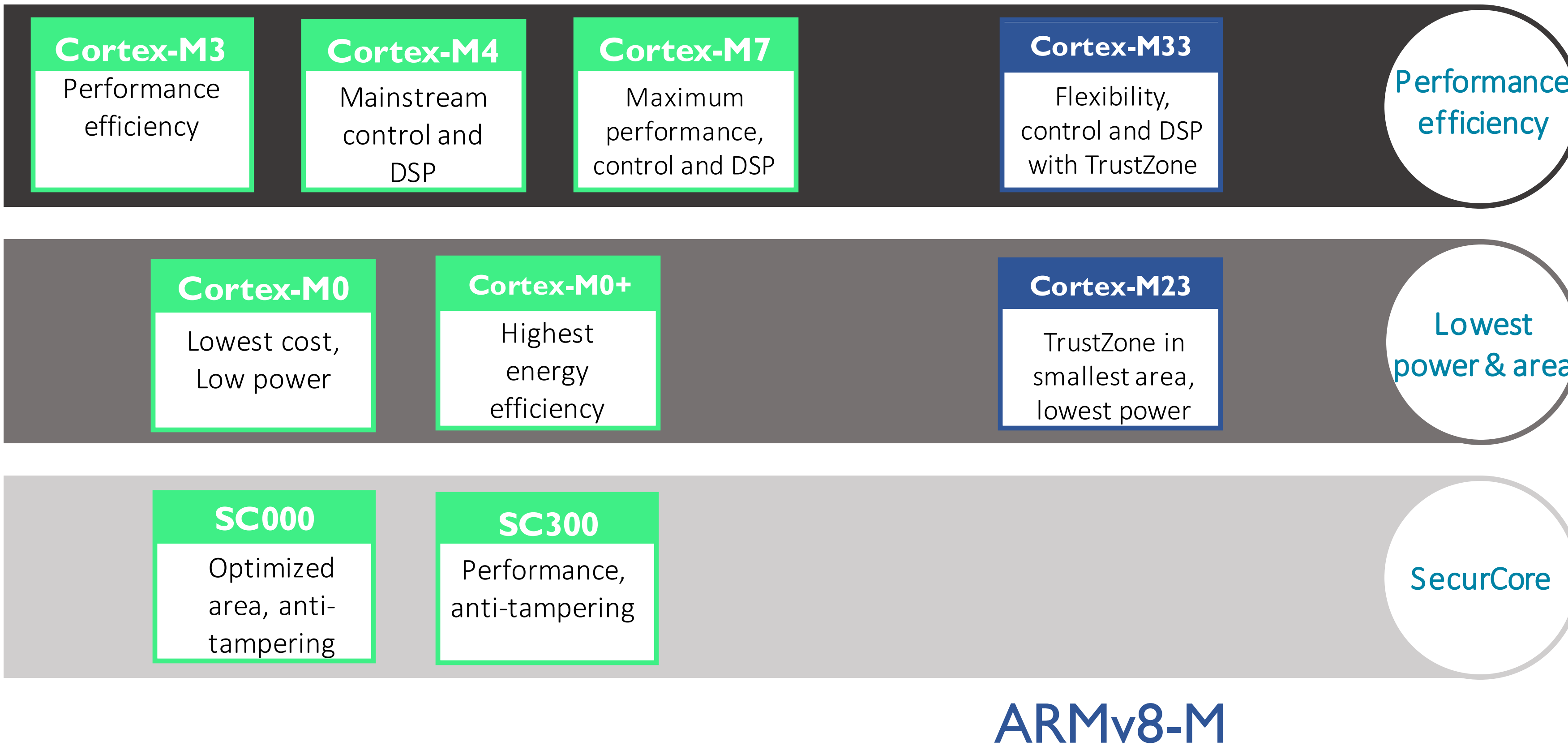
Companies utilizing ARM architecture

ARM

	System-On-a-Chip (SoC)	Products Containing	Type of ARM processor	Number of Cores
Apple	A4	iPhone 4, iPod Touch (4th Gen), iPad (1st Gen), AppleTV (2nd Gen)	Cortex-A8	1
	A5	iPhone 4S,iPad 2, AppleTV (3rd Gen)	Cortex-A9	2
	A5X	iPad (3rd Gen, Retina Display)	Cortex-A9	2
Samsung	Exynos 3 Single	Samsung Galaxy S, Samsung Galaxy Nexus S	Cortex-A8	1
	Exynos 4 Dual	Samsung Galaxy SII, Samsung Galaxy Note	Cortex-A9	2
	Exynos 4 Quad	Samsung Galaxy SIII	Cortex-A9	4
	Exynos 5 Dual	N/A	Cortex-A15	2
Nvidia	Tegra	Microsoft Zune HD	ARM11	1
	Tegra 2	Samsung Galaxy Tab 10.1, Motorola Xoom, Dell Streak 7 & Pro, Sony Tablet S	Cortex-A9	2
	Tegra X1	Motorola ATRIX, Asus Transformer TF101, Microsoft Kin One	Cortex-A57	4
Texas Instruments	OMAP 3	Barnes and Noble Nook Color	Cortex-A8	1
	OMAP 4	Amazon Kindle Fire, Samsung Galaxy Tab 2, Blackberry Playbook, Samsung Galaxy Nexus	Cortex-A9	2
	OMAP 5	N/A	Cortex-A15	2

ARM Cortex processors - Cortex®-M and SecurCore® portfolio

- Smallest and lowest power Cortex processors
- Optimized for deterministic real time embedded processing
- Microcontroller applications



ARM Cortex processors - Cortex®-A portfolio

- Efficient application processors for every level of performance

High performance

- **Cortex-A15**: High-performance with infrastructure feature set
- **Cortex-A17**: High-performance with lower power smaller area
- **Cortex-A57**: Proven high-performance — 64/32-bit
- **Cortex-A72**: 2016 Premium Mobile, Infrastructure, Auto — 64/32-bit
- **Cortex-A73**: 2017 Premium Mobile, Consumer — 64/32-bit

High efficiency

- **Cortex-A8**: First ARMv7-A processor
- **Cortex-A9**: Well-established mid-range processor used in many markets
- **Cortex-A53**: Balanced Performance and efficiency — 64/32-bit

Ultra High efficiency

- **Cortex-A5**: Smallest and lowest power ARMv7-A CPU, optimized for single-core
- **Cortex-A7**: Most efficient ARMv7-A CPU, higher performance than A5
- **Cortex-A32**: Smallest and lowest power ARMv8-A — 32-bit
- **Cortex-A35**: Highest efficiency — 64/32-bit

ARMv7-A

ARMv8-A

big.LITTLE compatible

ARM Cortex processors - Cortex®-R portfolio

- **Fast response - optimized for high performance, hard real-time applications**

Cortex-R7
High performance 4G modem and storage

Cortex-R8
Highest performance 5G modem and storage

Storage & modem

SC000
Real-time performance

Cortex-R5
Real-time performance with functional safety

Cortex-R52
Most advanced processor for functional safety

Functional safety

ARMv7-R

ARMv8-R

ARMv8-A Architecture

ARMv8-A introduces **64-bit architecture** support to the ARM architecture and includes:

- 64 bits general purpose registers
- 64-bit data processing and extended virtual addressing
- Two main execution states:
  - **AArch64** : The 64-bit execution state
  - **AArch32 :** The 32-bit execution state
- The execution states support three key instruction sets:
  - **A32 (or ARM)**: a 32-bit fixed length instruction set enhanced through the different architecture variants.
  - **T32 (Thumb)**: Thumb-2 technology provides a mixed-length 16- and 32-bit instruction set.
  - **A64:** a 64-bit fixed-length instruction set that offers similar functionality to the ARM and Thumb instruction sets.

The big.LITTLE Technology

What is big.LITTLE?

- Complex multicore CPU architecture combining…
  - Several high performance “big” cores
  - Several lower power “little” cores
- Cores should be architecturally compatible
- Cores may be…
  - Of 2 different architectures
  - Of the same architecture but with different highest frequency or cache size

Why big.LITTLE?

- Targeting optimal power saving / performance balance
  - Real life CPU load is bursty
    - big.LITTLE allows for running power hungry cores only when bursts are coming
  - Peak performance only when it’s needed
  - Power optimized cores run most of the time
- More options for fine-tuning compared to standard Symmetric Multiprocessing (SMP)

The big.LITTLE Technology

What is big.LITTLE?

- Complex multicore CPU architecture combining…
  - Several high performance "big" cores
  - Several lower power "little" cores
- Cores should be architecturally compatible
- Cores may be…
  - Of 2 different architectures
  - Of the same architecture but with different highest frequency or cache size

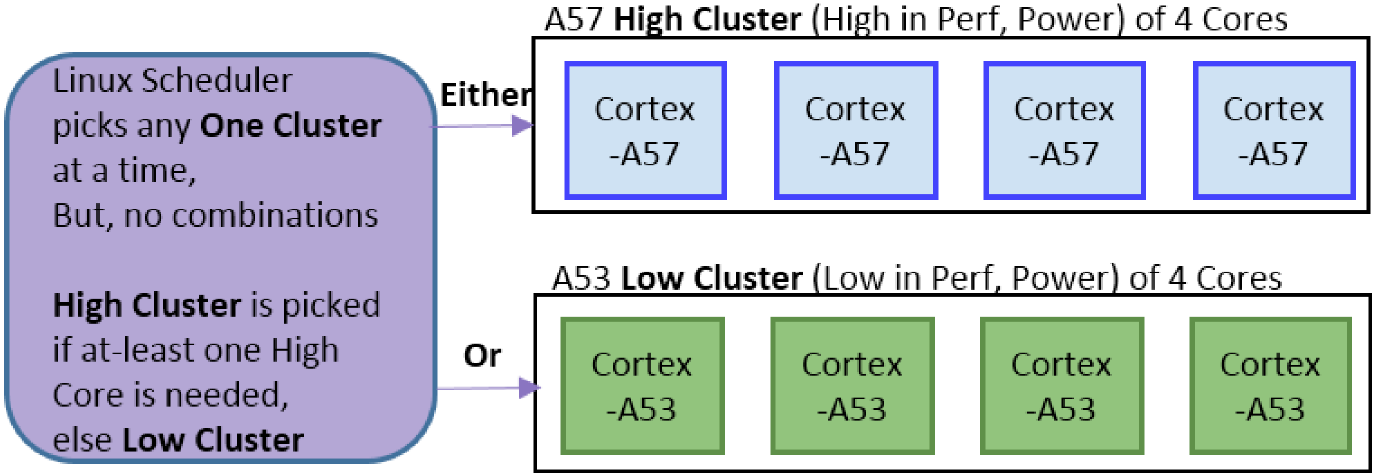
Which ones would you choose?

Why big.LITTLE?

- Targeting optimal power saving / performance balance
  - Real life CPU load is bursty
    - big.LITTLE allows for running power hungry cores only when bursts are coming
  - Peak performance only when it's needed
  - Power optimized cores run most of the time
- More options for fine-tuning compared to standard Symmetric Multiprocessing (SMP)

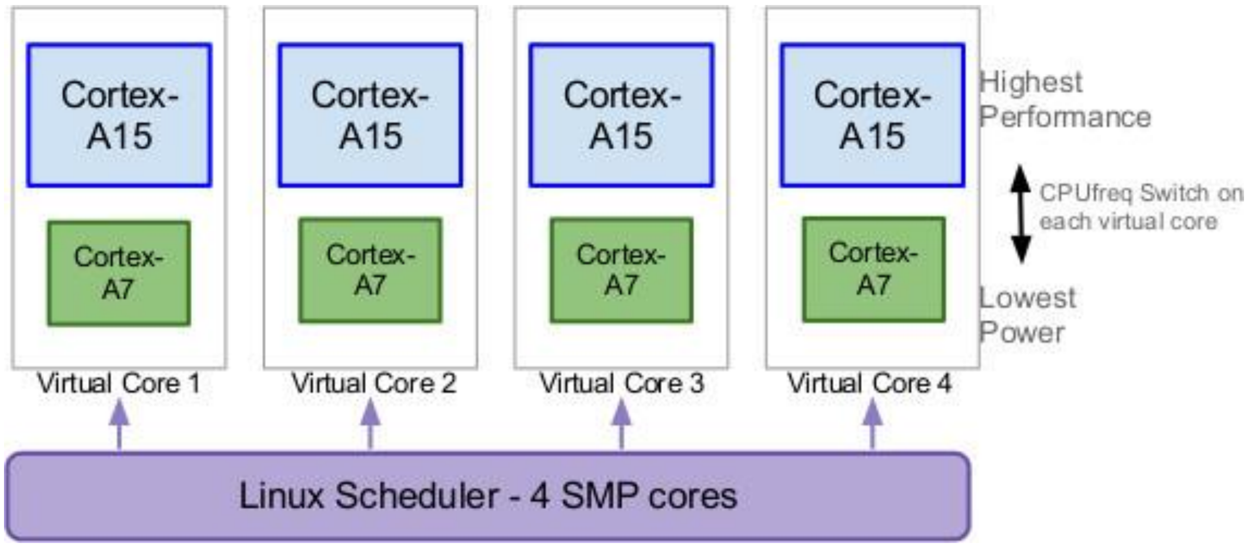
Clustered Switching

- Simple implementation
- Identically-sized clusters of “big” or “little” cores
- The operating system scheduler can only see one cluster at a time
- No combinations
- High cluster is picked if at least one High core is needed, otherwise Low cluster



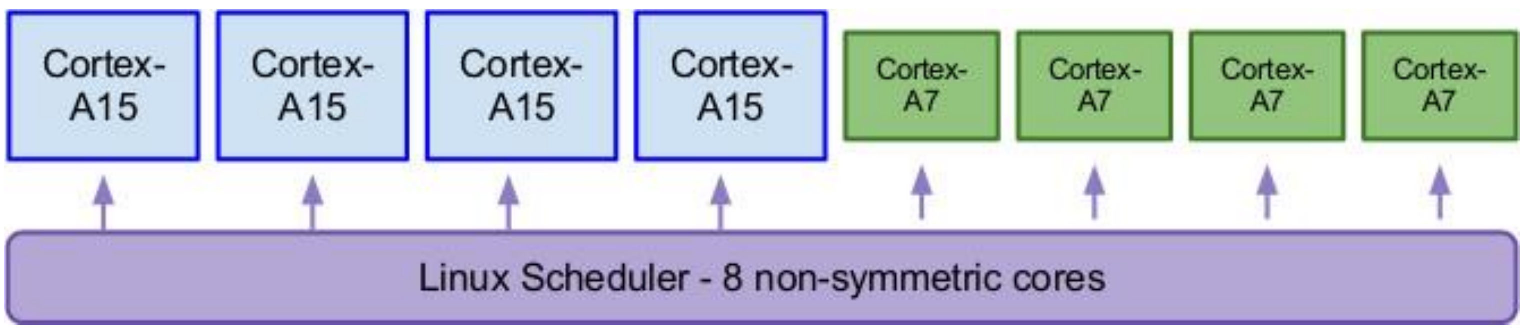
In-kernel switcher

- Pairing up a “big” core with a “little” core
- Each pair operates as one virtual core
- Only one real core is (fully) powered up and running at a time
- 'Big' core is used when the demand is high
  'Little' core is employed when demand is low



Heterogeneous Multi-processing

- Most powerful use of big.LITTLE architecture
- Use of all physical cores at the same time
- Threads with high priority or computational intensity are allocated to “big" cores, rest in “little” cores



The big.LITTLE Technology

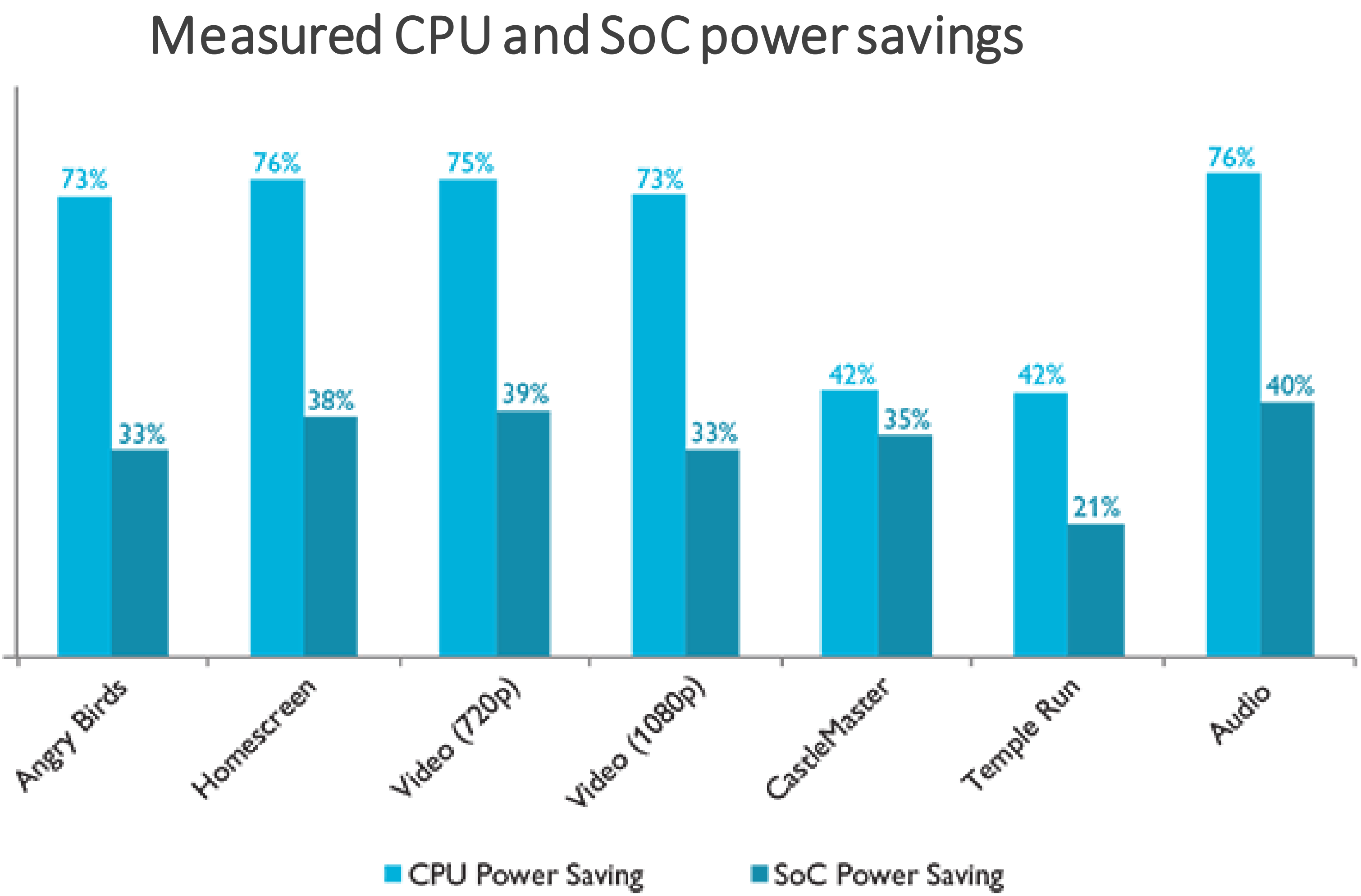


Fig. 2: Measured CPU and SoC power savings on a Cortex-A15 MP4·Cortex-A7 MP4 big.LITTLE MP SoC relative to a Cortex-A15 MP4 SoC

The big.LITTLE Technology

DVFS Frequency States: Web Browsing with Audio Playback

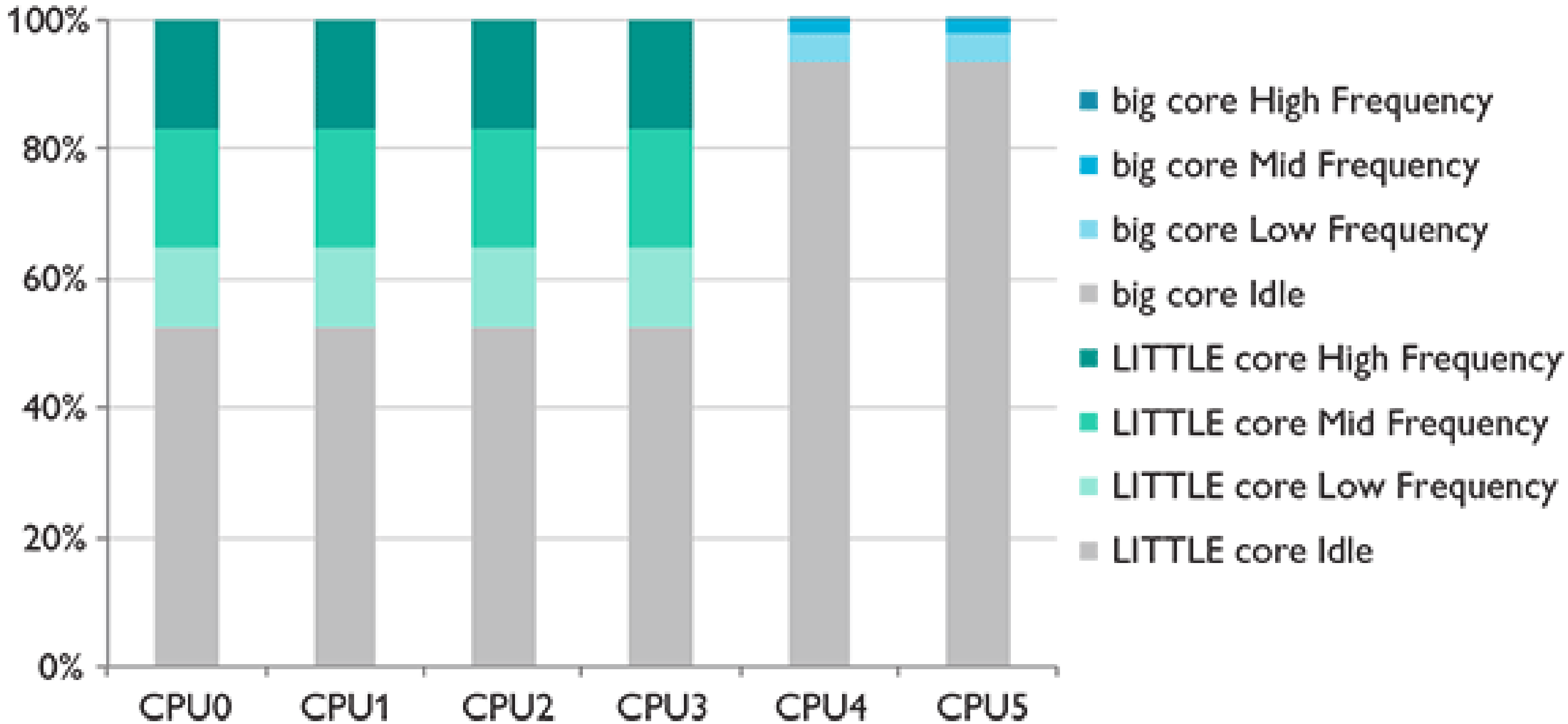
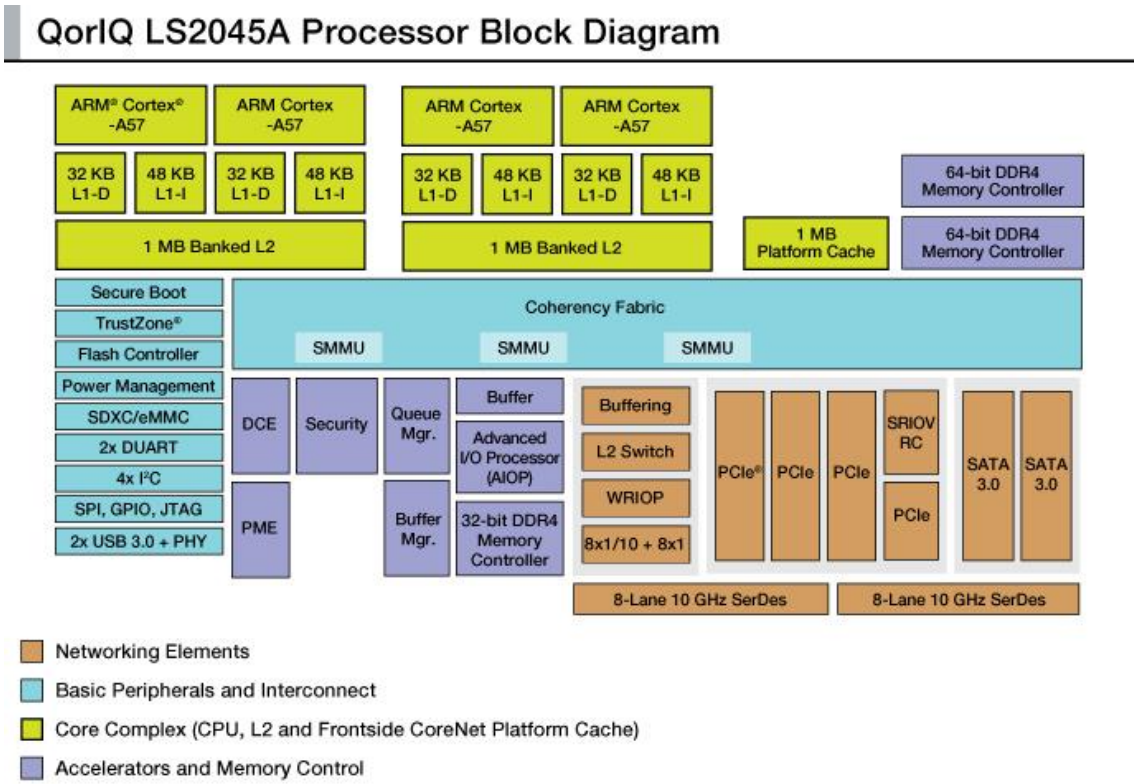


Fig 1: The distribution of per-core DVFS Frequency States during Web Browsing with Audio Playback

MultiProcessors System on Chip (MPSoC)

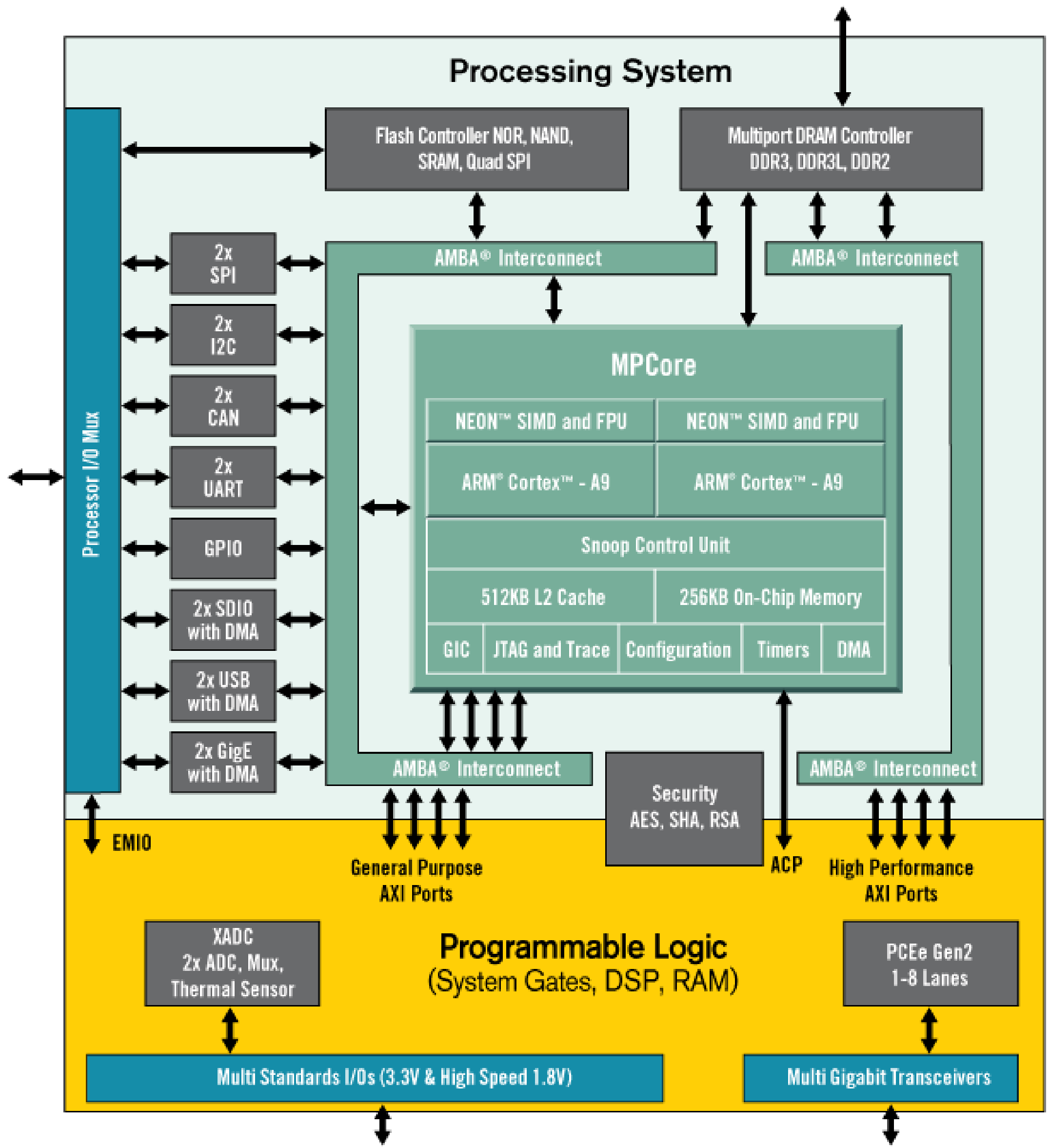
- QorIQ LS2045A and LS2085A multicore processors combine up to eight ARM® Cortex®- A57 cores
- Advanced, high-performance datapath and network peripheral interfaces
- Use case applications:
  - Networking
  - telecom/Datacom
  - wireless infrastructure
  - aerospace applications



All Programmable System on Chip (APSoC) – Zynq 7000

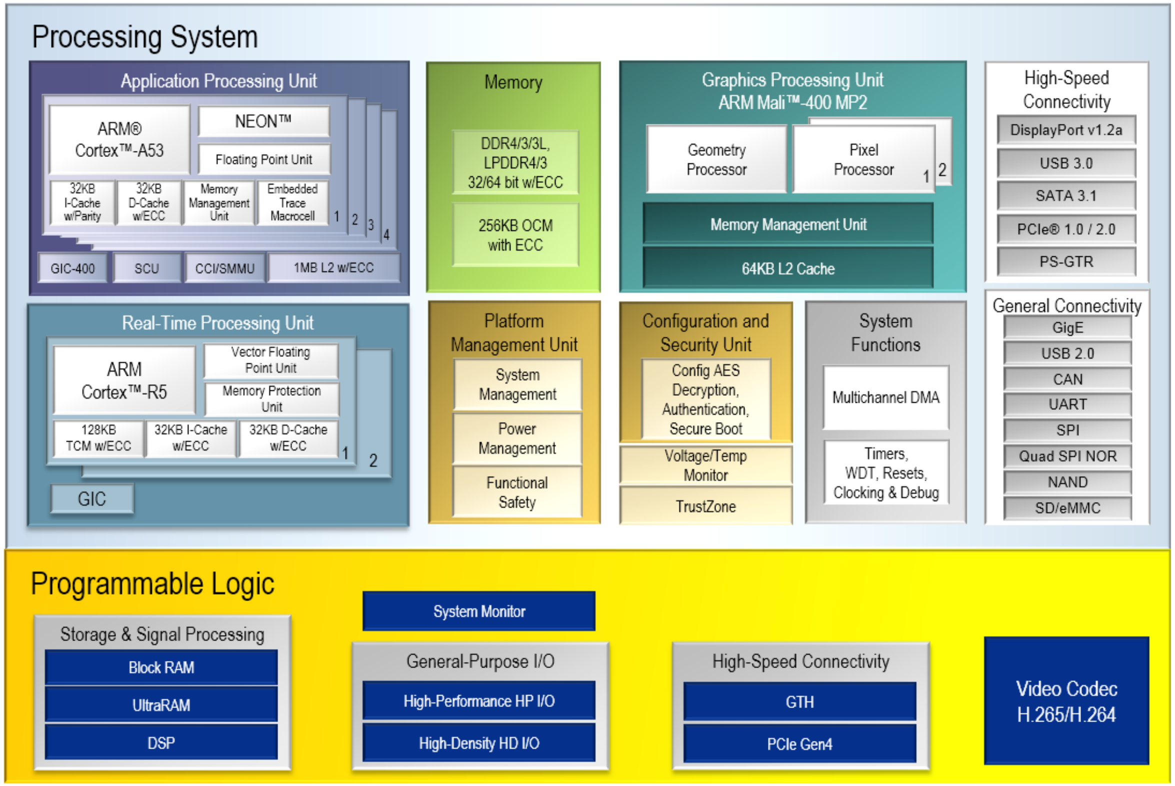
ARM-based Processor + FPGA

- Zynq-7000 devices are equipped with dual-core
  ARM Cortex-A9 processors
- Integration with 28nm Artix-7 or Kintex®-7 based
  programmable logic for excellent performance-per-watt
  and maximum design flexibility
- Use case applications:
  - Professional Cameras
  - Machine Vision
  - 4K2K Ultra-HDTV



ARM-based Processor + FPGA

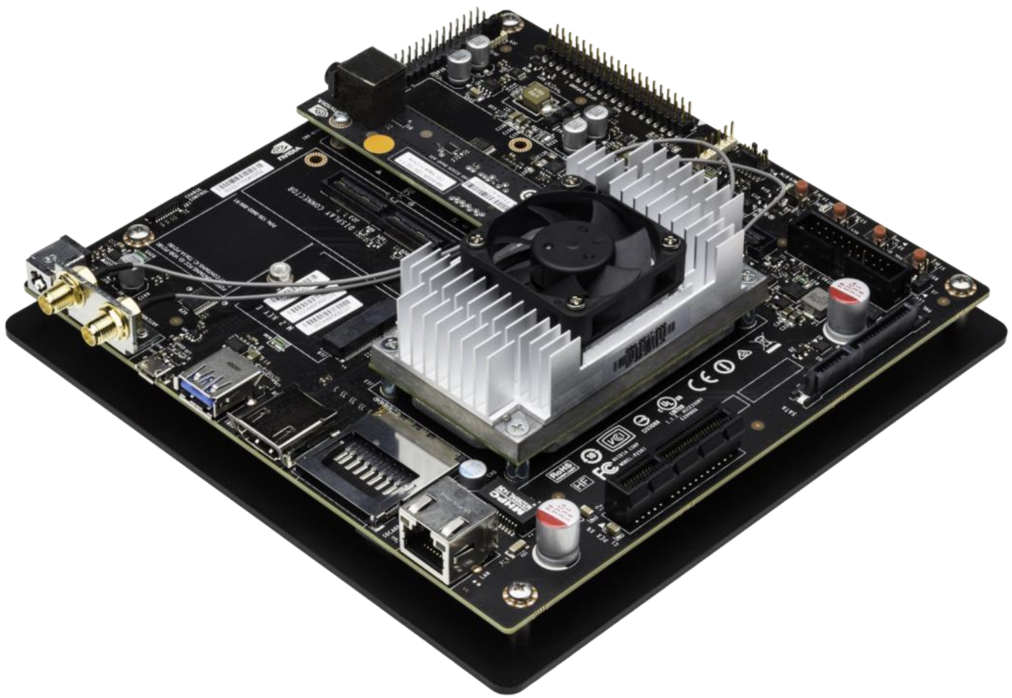
- Zynq UltraScale+ MPSoC devices are equipped with:
  - 4 ARM Cortex-A53 64-bit processors
  - 2 ARM Cortex-R5 32-bit processors for real-time safety critical operation
  - 1 ARM Mali 400 GPU for rendering processes
- Integration with 14nm Kintex® or Virtex® based programmable logic with about 4x the FPGA resources of Zynq-7000
- Use case applications:
  - Professional Cameras
  - Machine Vision
  - 4K2K Ultra-HDTV
  - Camera-based Advanced Driver Assistance Systems (ADAS)



ARM-based Processor + FPGA

- 4 CPU-cores, 64-bit ARM
- 2MB shared L2 Cache
- 256 GPU cores
- < 10 Watts power consumption

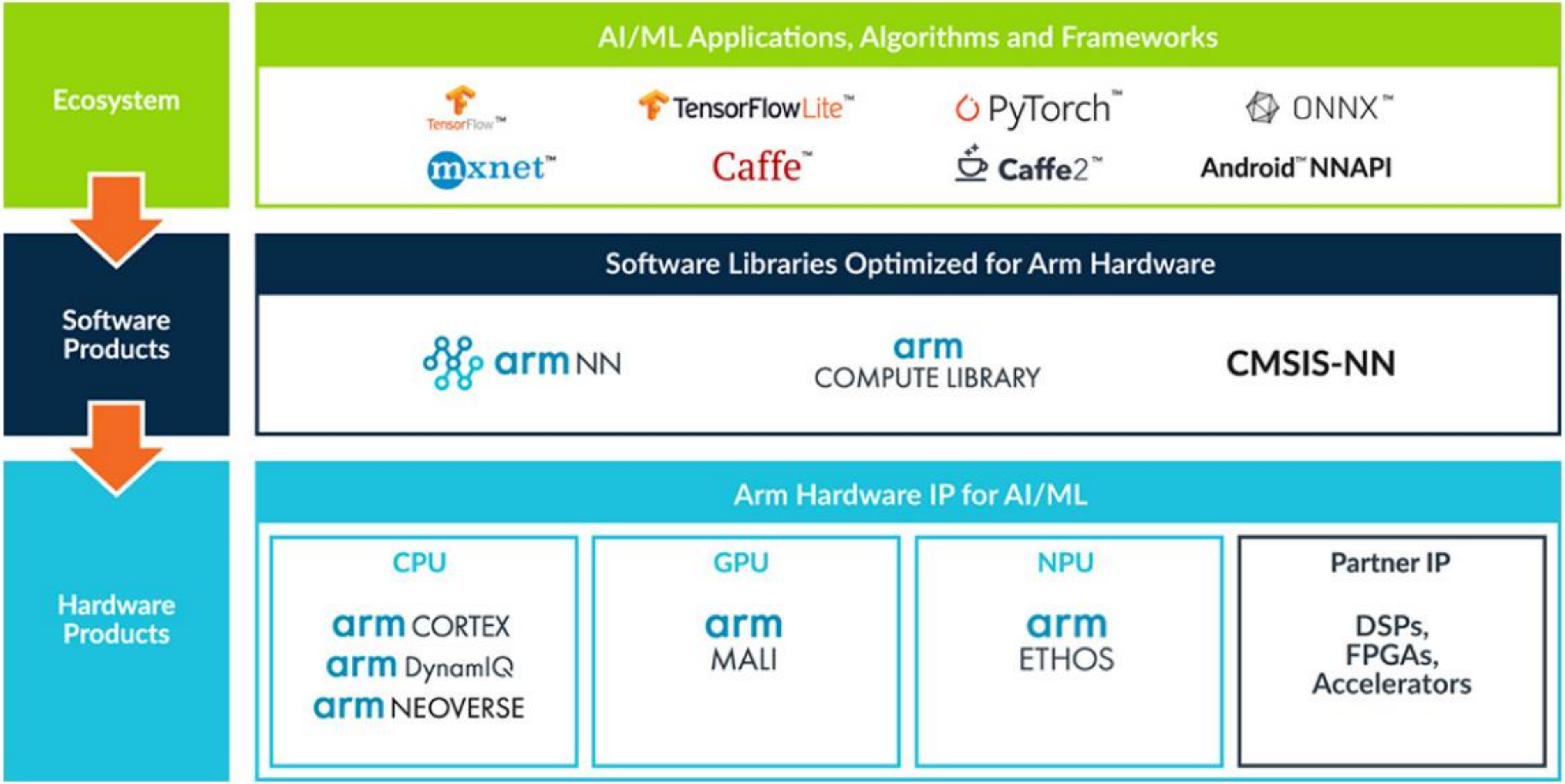
- **Use case scenarios**
    - Cell Phones
    - Self-Driving Cars
    - Neural-Networks



Is ARM only about VLSI?

- Open source embedded OS for IoT

ARM for machine learning



Q & A

Questions?