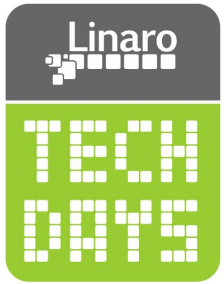
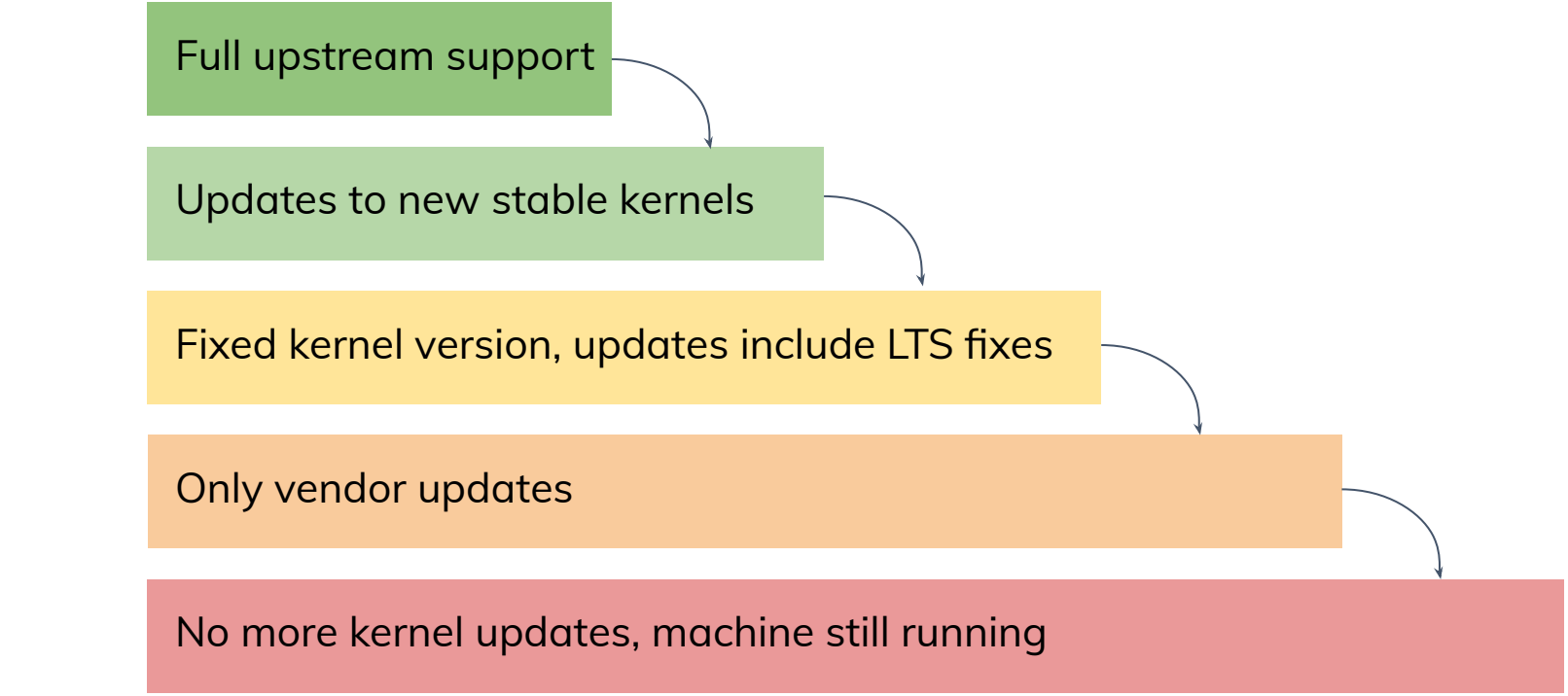
SoC support in the kernel

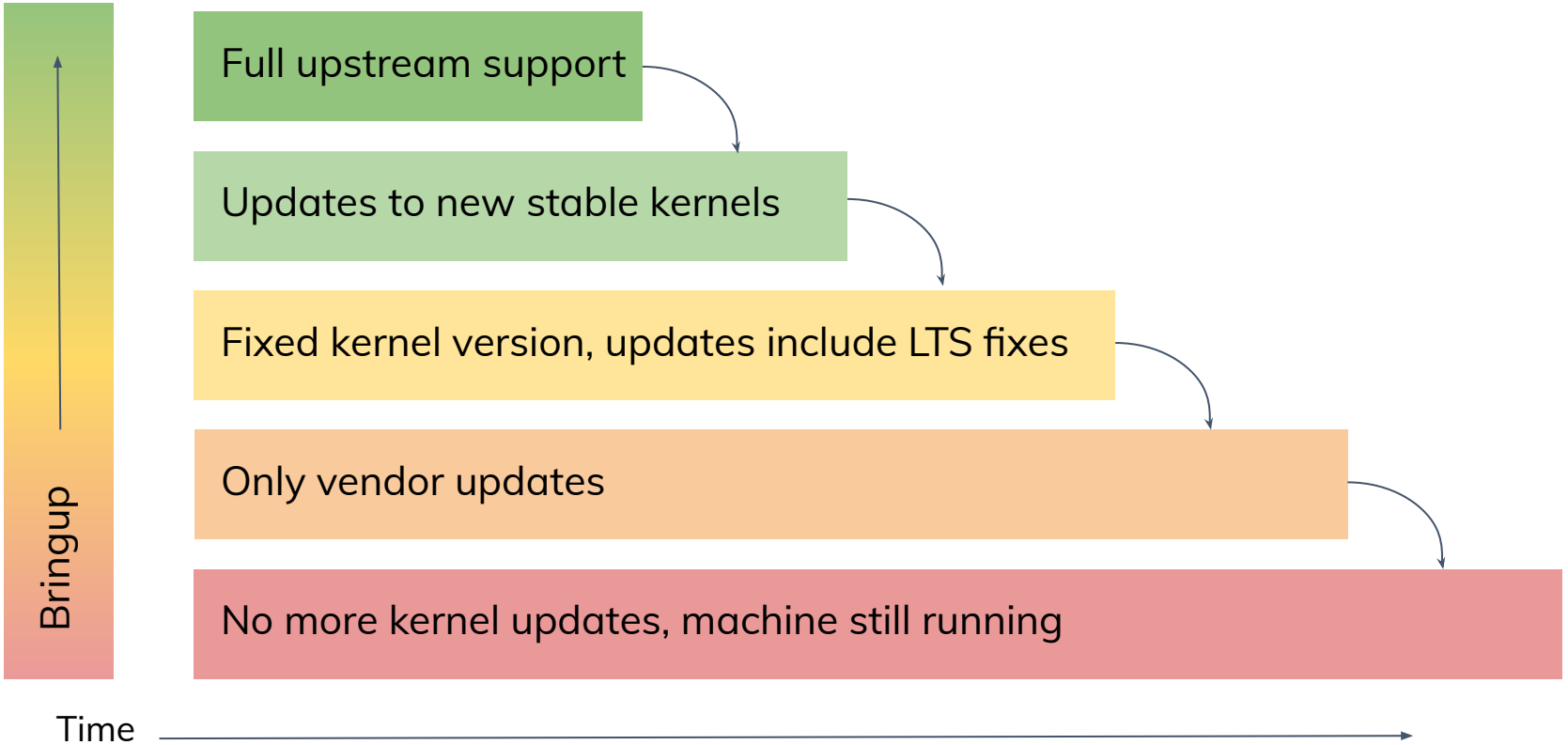
Arnd Bergmann <arnd@linaro.org>



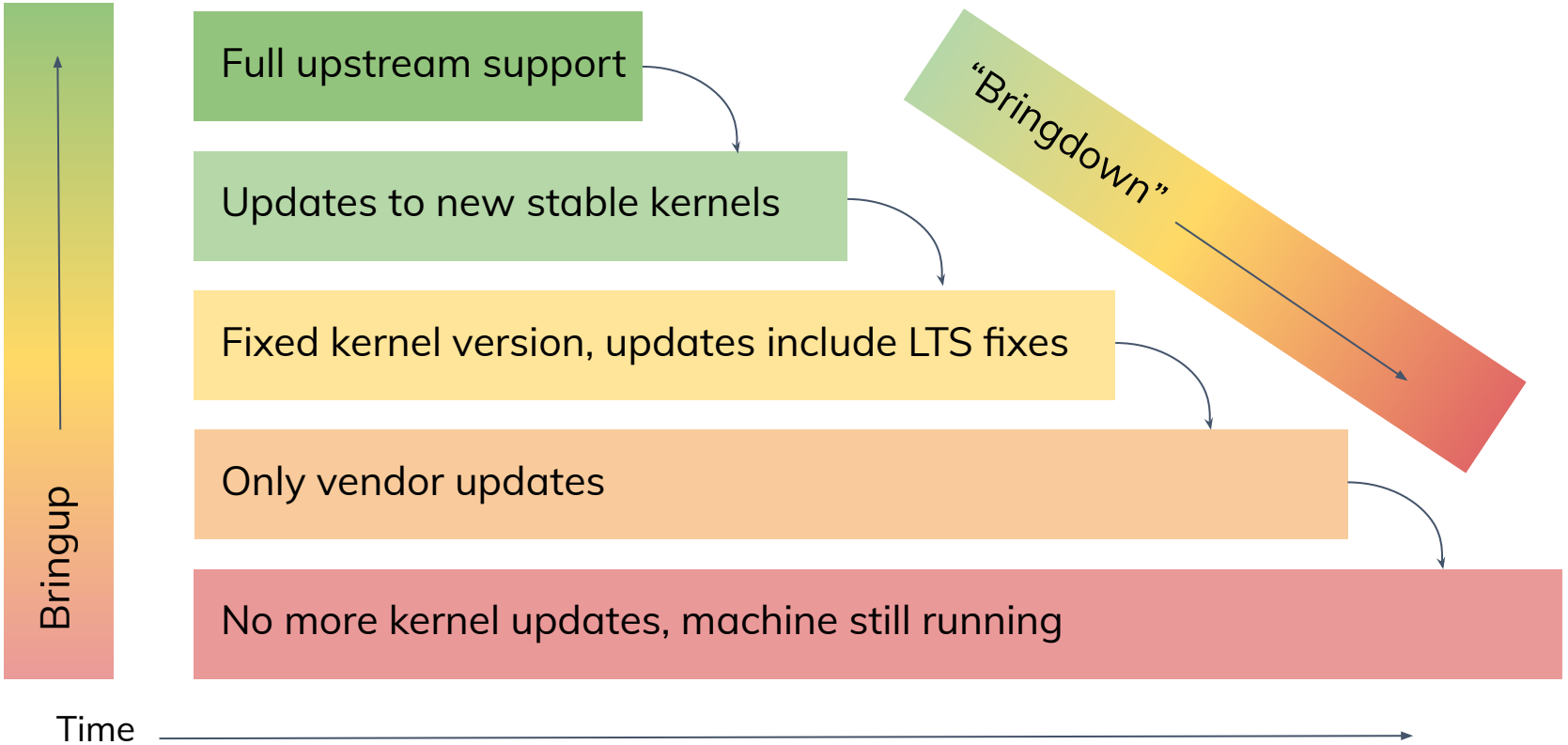
Platform/Kernel lifecycle



Platform/Kernel lifecycle



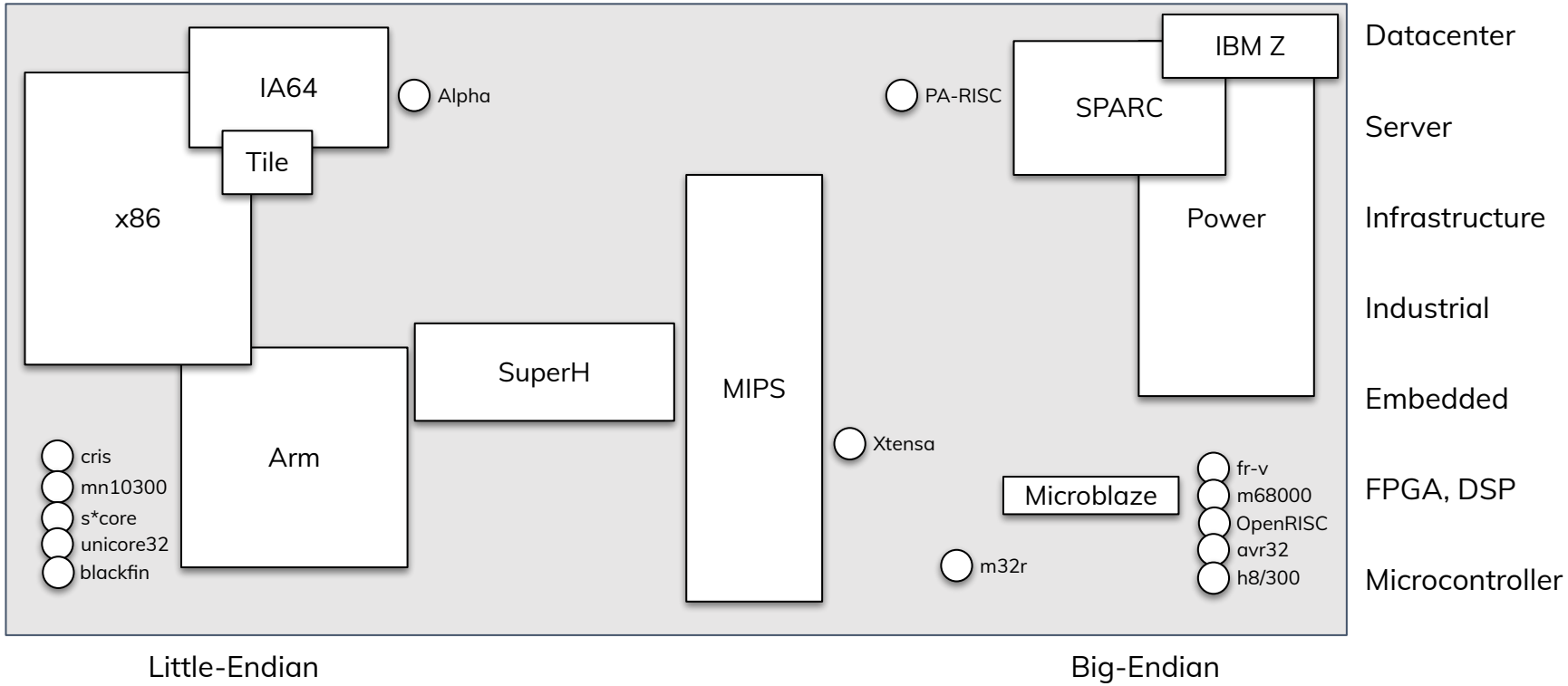
Platform/Kernel lifecycle



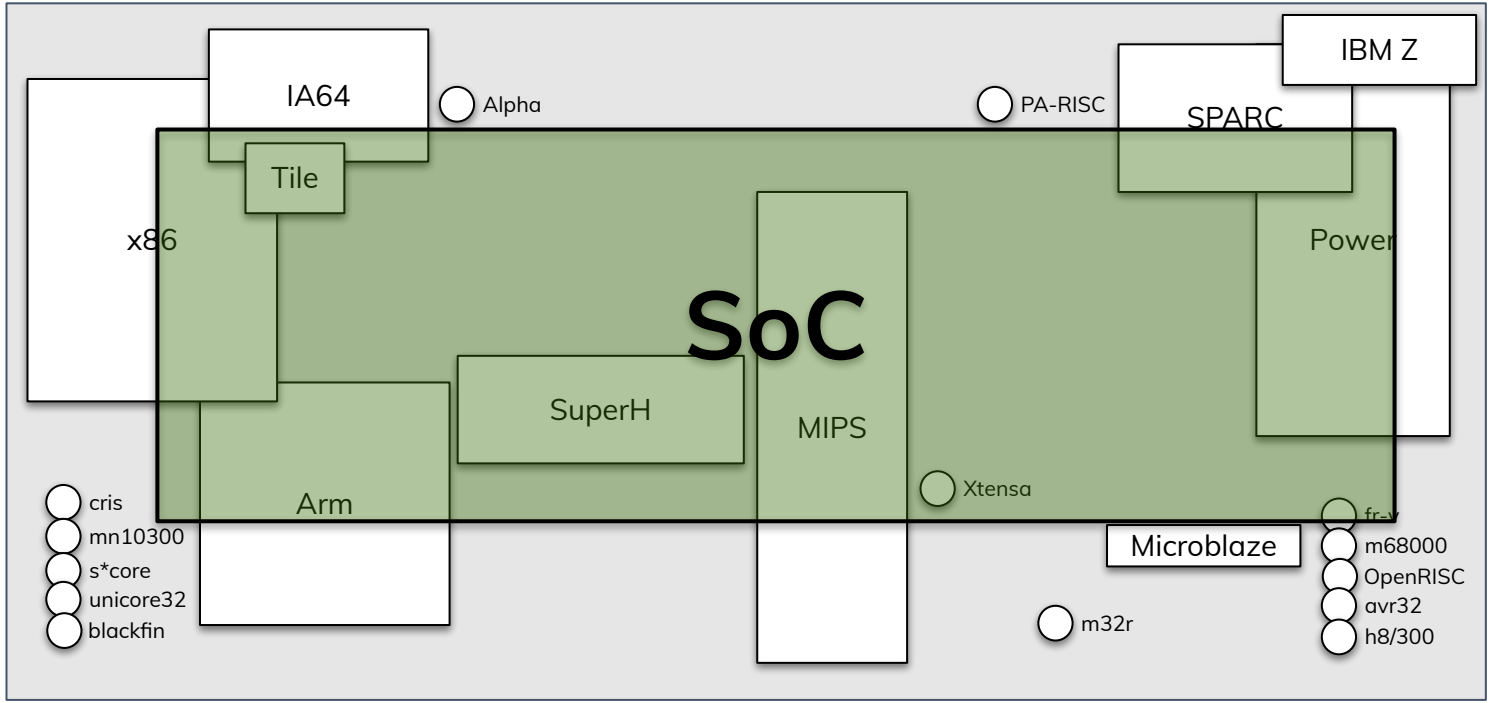
Obstacles to upstreaming

- GPU drivers
- Android patches
- Short time to market
- Short lifespan
- Unannounced products
- Missing subsystem abstractions
- Competing subsystem abstractions

CPU architectures world map, ca. 2010



CPU architectures world map, ca. 2010



Datacenter

Server

Infrastructure

Industrial

Embedded

FPGA, DSP

Microcontroller

Little-Endian

Big-Endian

SoC generations (approximation)

Armv5/v7-M/MIPS/PPC/...	**Armv7-A**	**Armv8-A**
2000-2020	2007-	2014-
180-65 nm	65/40/28nm	28/14/10/7nm
2MB-128MB	256MB-2GB	2GB+
SDRAM/DDR1/2	(LP-)DDR2/3	(LP-)DDR4
PCI/PCIe Gen1	PCIe Gen1/2	PCIe Gen2/3/4
USB-1.1/2.0	USB-2.0	USB-3.0
802.11n/WIFI-4	802.11ac/WIFI-5	WIFI-5/6
GSM/2G	UMTS/3G	LTE/4G/5G
100Mb/1Gb Ethernet	1Gb Ethernet	1/2.5/5/10Gb Ethernet
Uniprocessor	1-4 cores	4+ cores

SoC generations (approximation)

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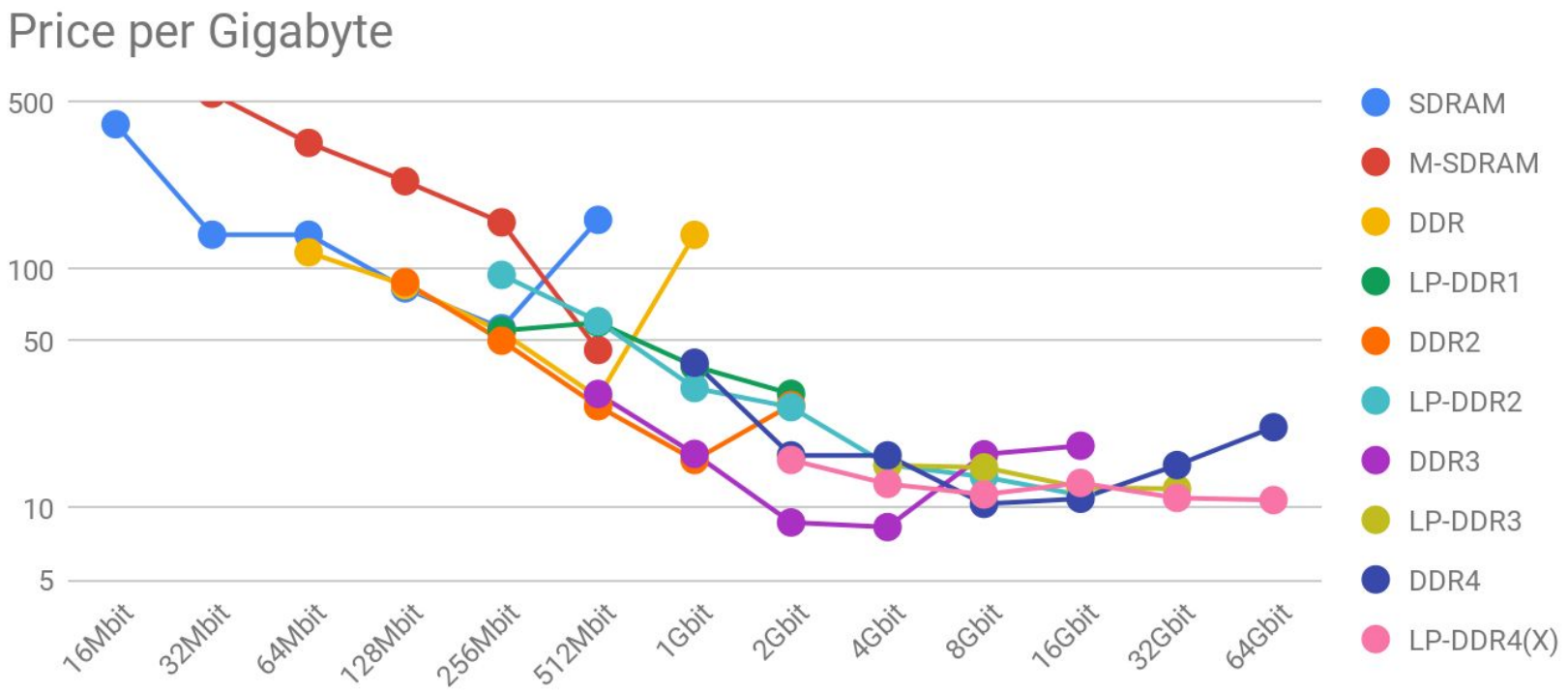
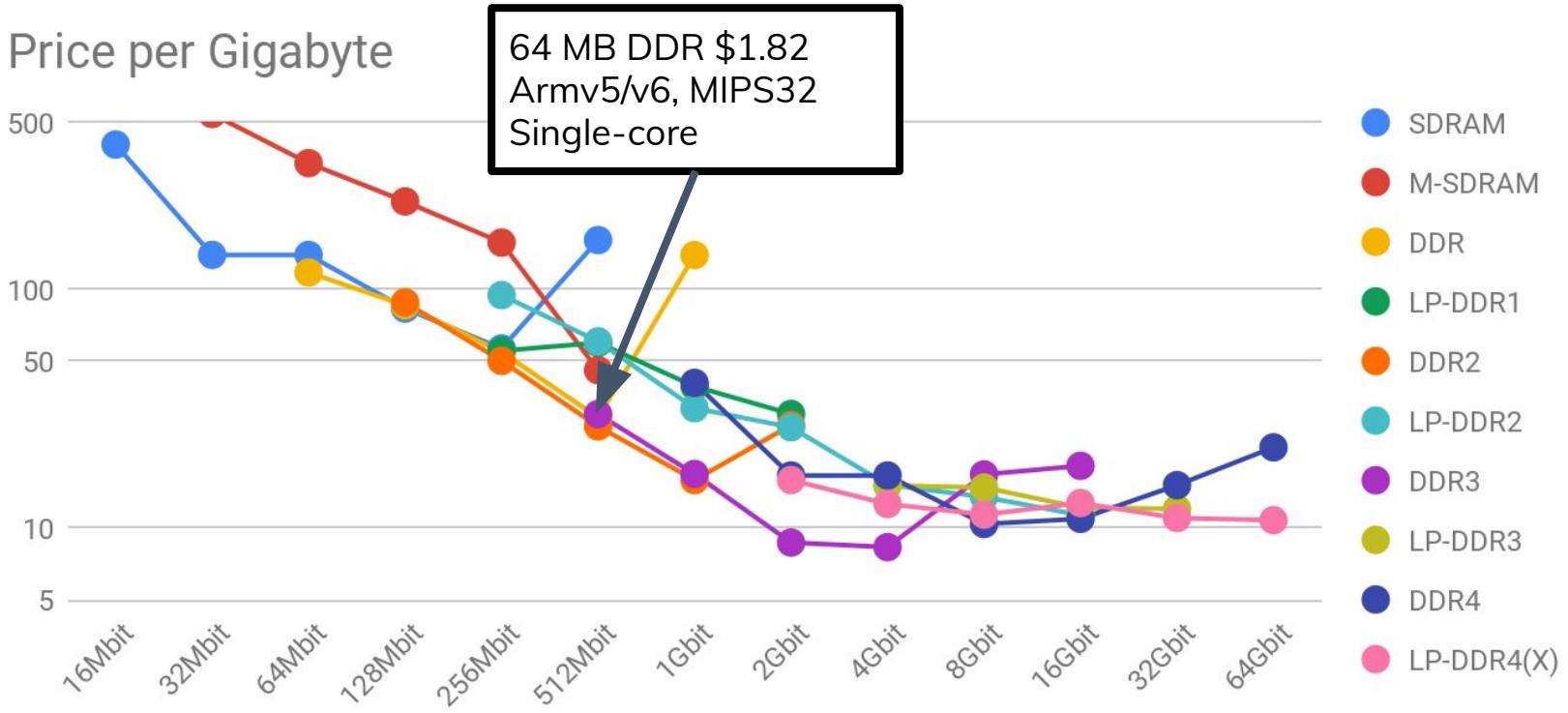
2MB-128MB	**256MB-2GB**	**2GB+**
SDRAM/DDR1/2	(LP-)DDR2/3	(LP-)DDR4
PCI/PCIe Gen1	PCIe Gen1/2	PCIe Gen2/3/4
USB-1.1/2.0	USB-2.0	USB-3.0
802.11n/WIFI-4	802.11ac/WIFI-5	WIFI-5/6
GSM/2G	UMTS/3G	LTE/4G/5G
100Mb/1Gb Ethernet	1Gb Ethernet	1/2.5/5/10Gb Ethernet
Uniprocessor	1-4 cores	4+ cores

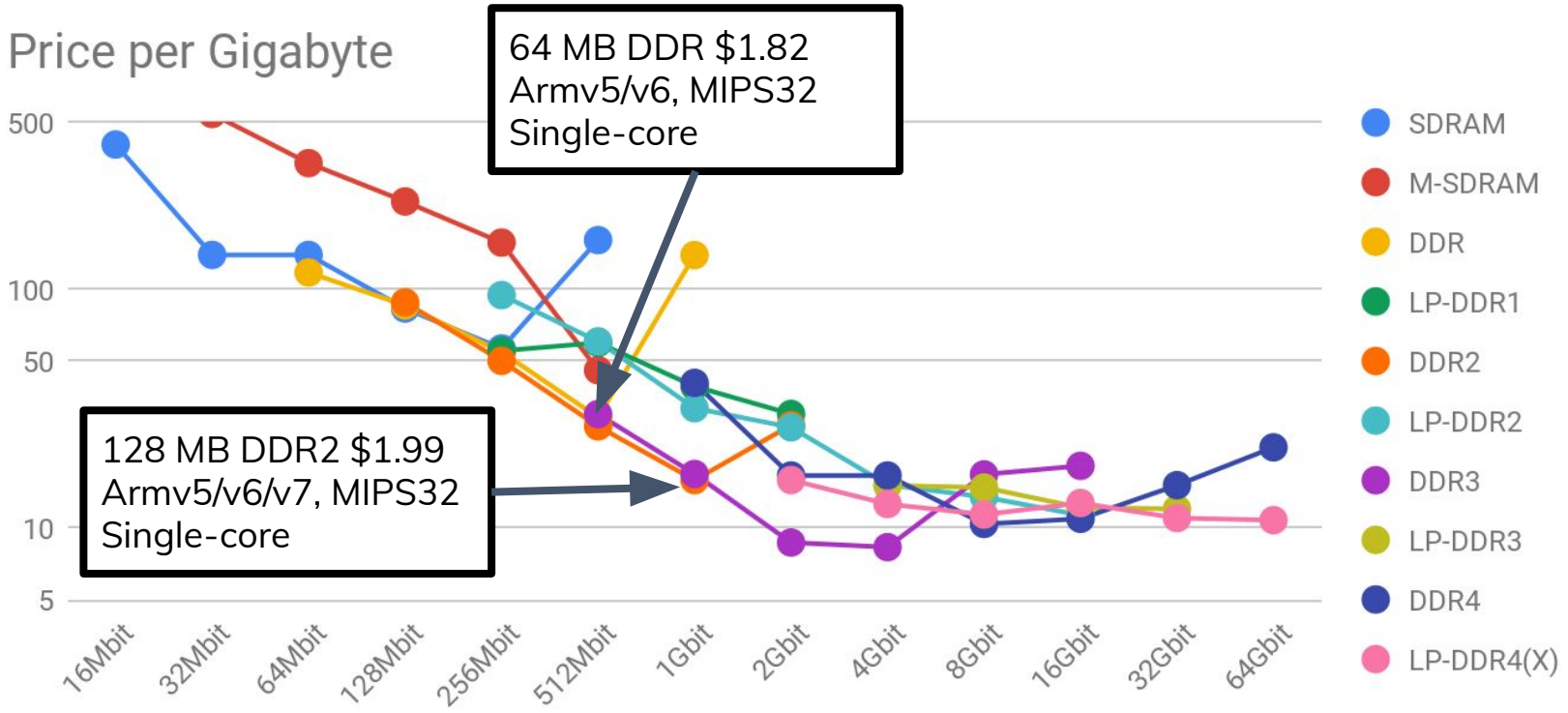
External SDRAM technologies



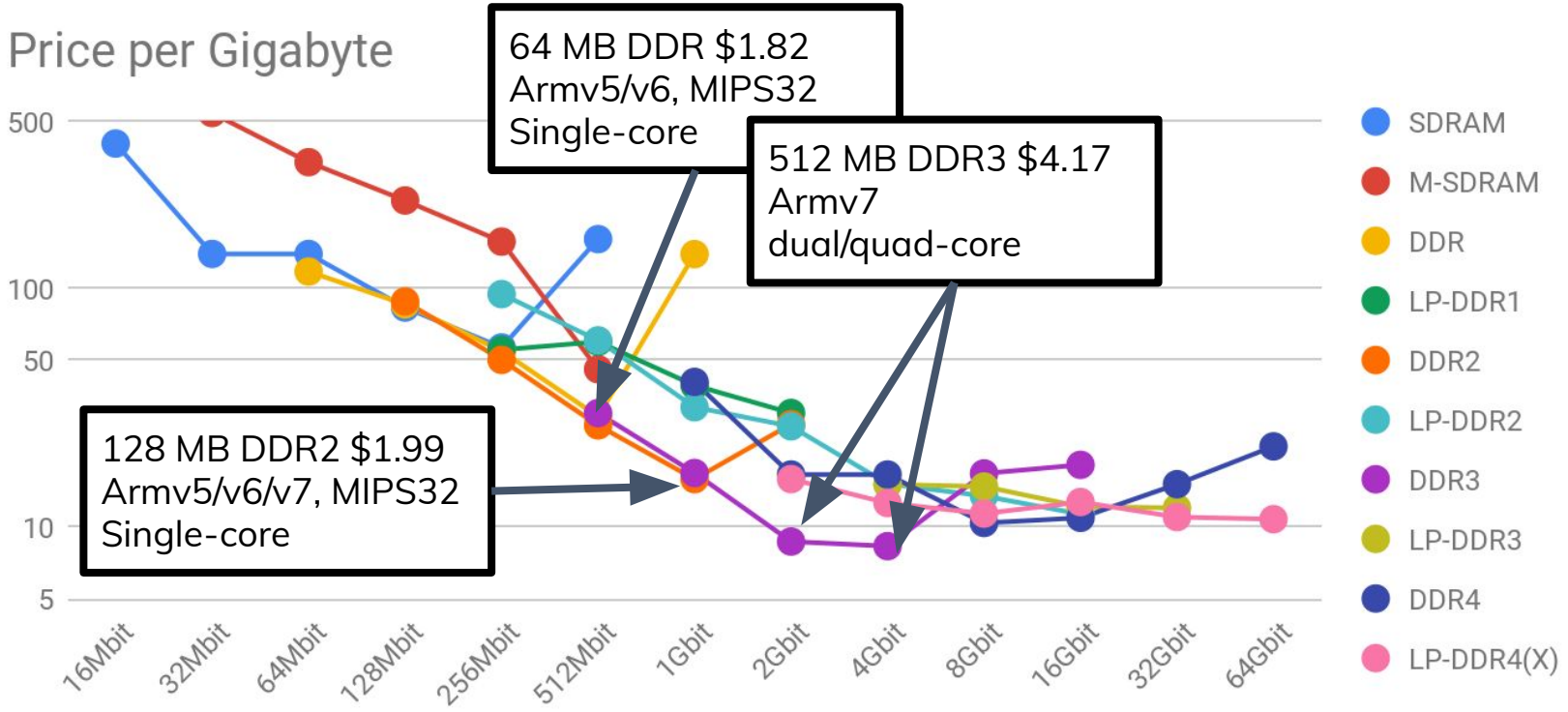
External SDRAM technologies



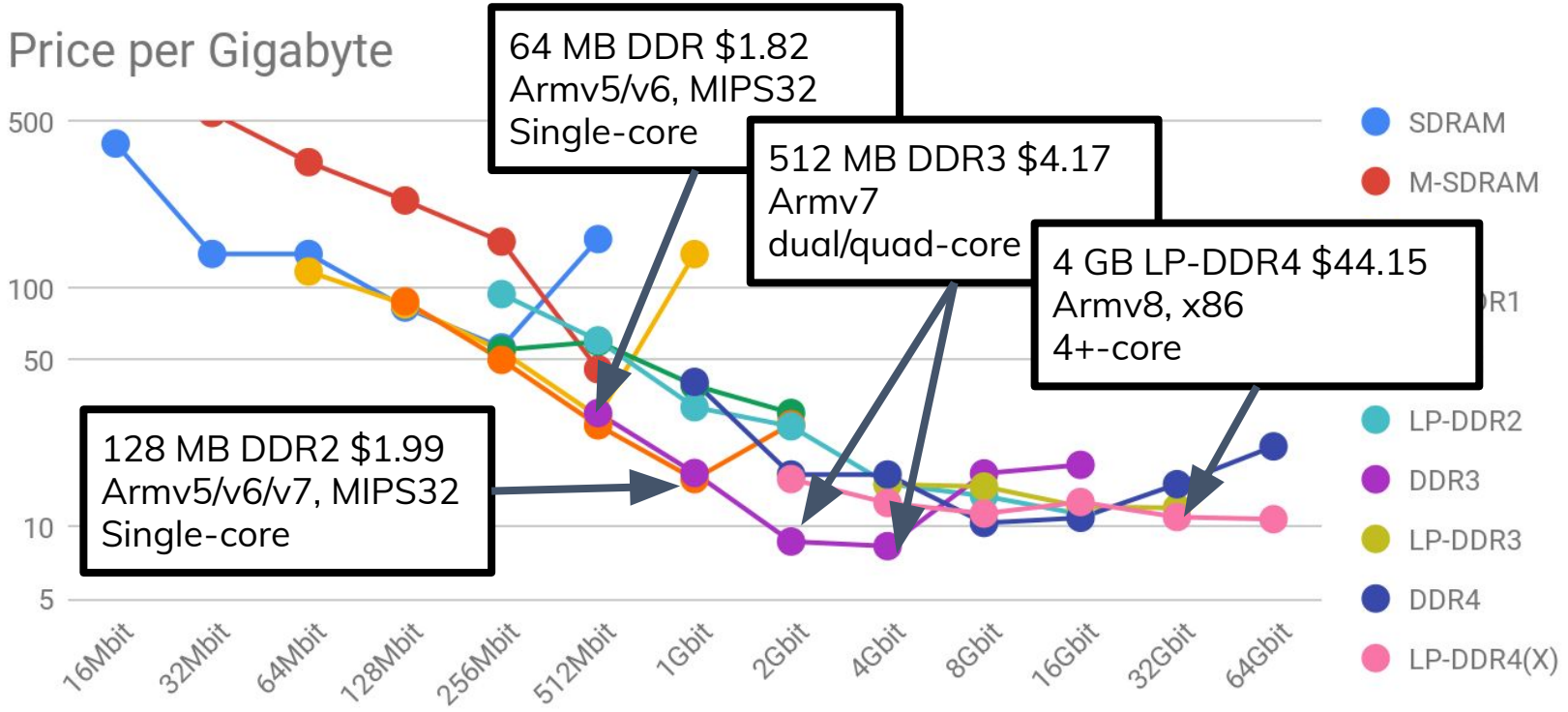
External SDRAM technologies



External SDRAM technologies



External SDRAM technologies



Minimum memory requirements

- Debian 10, 32-bit “armel” port: 256 MB

3.4 Meeting Minimum Hardware Requirements

Once you have gathered information about your computer's hardware, check that your hardware will let you do
type of installation that you want to do.

Depending on your needs, you might manage with less than some of the recommended hardware listed in the ta
below. However, most users risk being frustrated if they ignore these suggestions.

Table 3.2 Recommended Minimum System Requirements

Install Type	RAM (minimum)	RAM (recommended)	Hard Drive
No desktop	256 megabytes	512 megabytes	2 gigabytes
With Desktop	512 megabytes	2 gigabytes	10 gigabytes

Minimum memory requirements

- Debian 10, 32-bit “armel” port: 256 MB
- OpenWRT: 64 MB

Supportability issues

It is getting harder or even impossible over time to support devices with low Flash + RAM. **OpenWrt support for those devices will end with the 19.07 release**, ie. 19.07 will be the last release with support for 4/32 MB devices. There will be no future releases and no images ready for download after 19.07.

Advice

Users that are not expert users of OpenWrt (those that can build their own images) should consider

16/64 as an *absolute* minimum for any device, with at least 128 MB of RAM being preferred.

Users should expect that devices with less than 16 MB of flash and/or 64 MB of RAM may be unstable in basic operation under current versions of OpenWrt (17.X, 18.X). They should further expect that support for the device may be dropped at any time and that security patches/updates to the kernel, drivers, and/or application software will

Minimum memory requirements

- Debian 10, 32-bit “armel” port: 256 MB
- OpenWRT: 128 MB
- Alpine Linux: 100 MB

Requirements for Alpine

- A machine to install onto: Alpine supports phones, laptops, desktops, embedded, Ras
  - Most architecture, such as i386, amd64, arm, ppc, and x390.
  - At least 100 MB of RAM is necessary. A complete desktop system can require up t
  - For "sys" or "data" modes, a storage device is needed.

Minimum memory requirements

- Debian 10, 32-bit “armel” port: 256 MB
- OpenWRT: 128 MB
- Alpine Linux: 100 MB
- Sonos legacy products: 8MB (Linux-2.4/2.6, MIPS/PowerPC32/SuperH)

Beginning in May, software updates and new features from Sonos will only be delivered to systems with only modern products.

> After May, systems that include **legacy products will continue to work as before** - but they will no longer receive software updates or new features.

Sonos will work to maintain the existing experience and conduct bug fixes, but our efforts will ultimately be limited by the lack of memory and processing power of these legacy products.

Minimum memory requirements

- Debian 10, 32-bit “armel” port: 256 MB
- OpenWRT: 128 MB
- Alpine Linux: 100 MB
- Sonos legacy products: 8MB (Linux-2.4/2.6, MIPS/PowerPC32/SuperH)
- Microsoft Azure Sphere: 4MB (Linux-5.x, ARMv7-A)

Integrated RAM and flash

Azure Sphere MCUs include a minimum of 4MB of integrated RAM and 16MB of integrated flash memory.

Software architecture and OS

SoC generations (approximation)

Armv5/v7-M/MIPS/PPC/...	**Armv7-A**	**Armv8-A**
2000-2020	2007-	2014-
180-65 nm	65/40/28nm	28/14/10/7nm
2MB-128MB	256MB-2GB	2GB+
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GSM/2G	UMTS/3G	LTE/4G/5G
100Mb/1Gb Ethernet	1Gb Ethernet	1/2.5/5/10Gb Ethernet
Uniprocessor	1-4 cores	4+ cores

Low end Linux – race to the bottom

Common features

- Under $5/chip
- Under $10/board
- Diverse CPU architectures
- Small in package RAM
- Low-speed I/O
- Some without MMU
- RTOS competition

Examples

- Broadcom BCM2835 (Armv6K)
- Microchip SAM9X60 (Armv5)
- Mediatek MT7688 (MIPS32)
- ST STM32F4 (Armv7-M)
- Espressif ESP32 (Xtensa)
- Kendryte K210 (RV64)
- Nationalchip GX6605S (C-SKY)
- Ingenic X1000 (MIPS32)

Embedded 32-bit Linux – middle class squeeze

Common features

- Dual/Quad Cortex-A9/A7
- 512/1024MB DDR3
- Larger systems move to 64 bit
- Smaller systems obsolete

Phasing out

- Armv5/v6, MIPS, PowerPC, …
- Cortex-A15/A17
- USB-3.0/PCIe
- DDR2, LP-DDR2/3/4

Examples

- NXP i.MX6
- Allwinner H3
- Mediatek MT6580
- Xilinx Zynq 7000
- ST STM32MP1
- Qualcomm IPQ4029
- Aspeed AST2600
- Marvell Armada 38x
- TI AM3 (Cortex-A8)
- TI AM5 (Cortex-A15)
- Mediatek MT7621A (MIPS32)

64-bit embedded – taking over

Common features

- Cortex-A53, A72
- Large LP-DDR4
- High-speed I/O

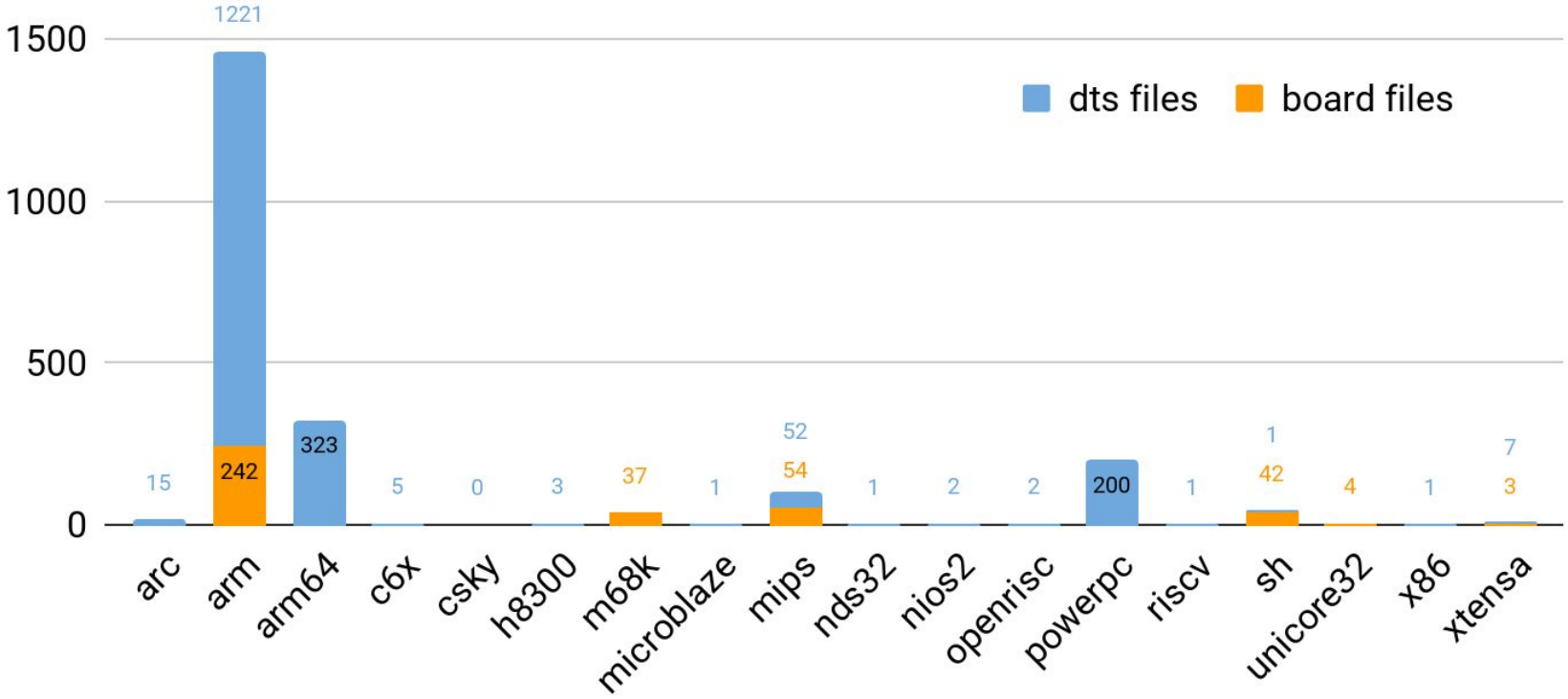
Alternatives

- Embedded x86_64-bit
- Future: RISC-V 64-bit

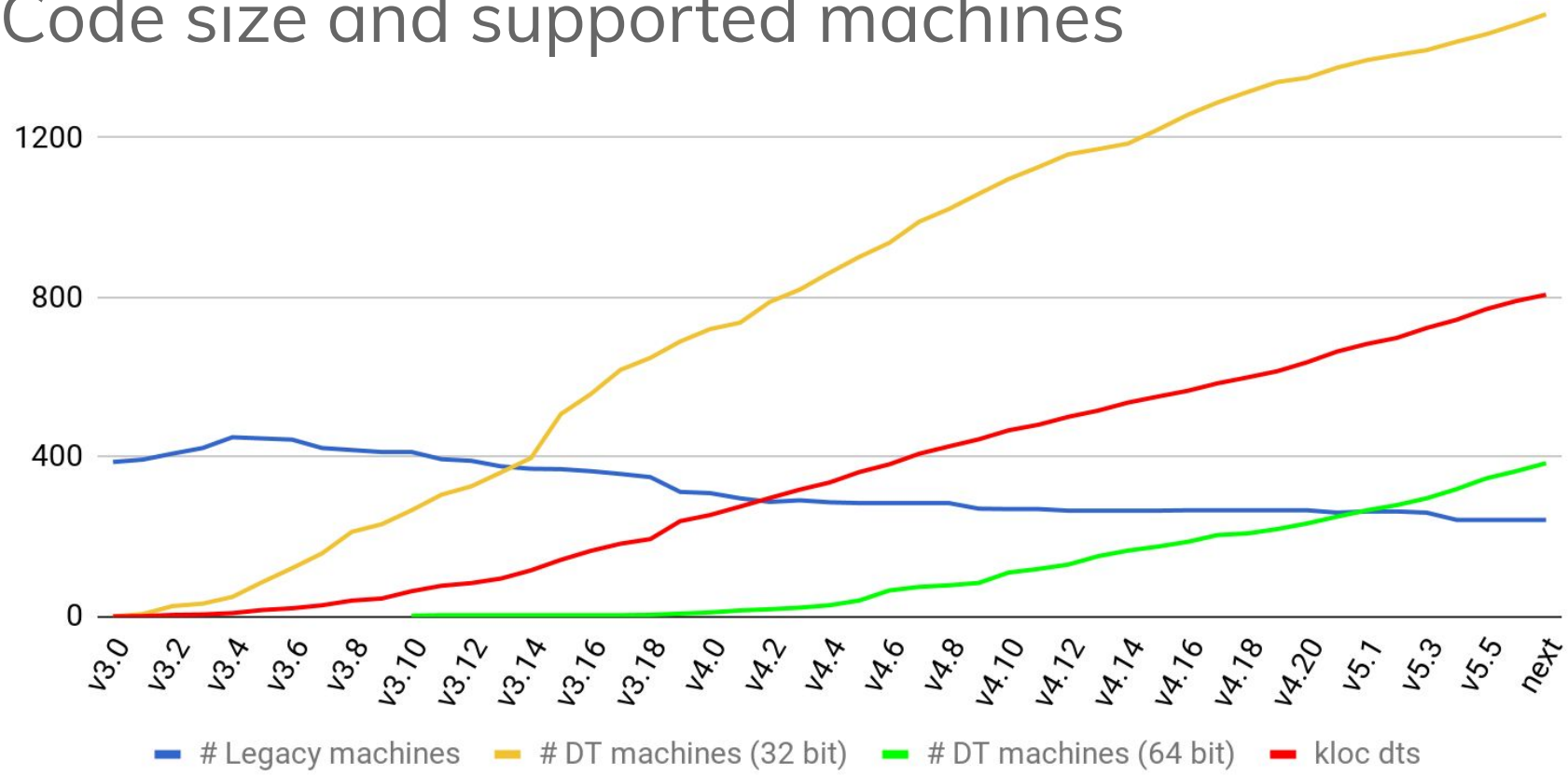
Examples

- NXP Layerscape, i.MX8
- Renesas R-Car
- Qualcomm Snapdragon
- Rockchip RK33xx
- Amlogic Meson
- Nvidia Tegra
- Mediatek Helio
- Hisilicon Kirin
- Allwinner H-series
- Marvell Armada
- Samsung Exynos
- Xilinx ZynqMP
- ...

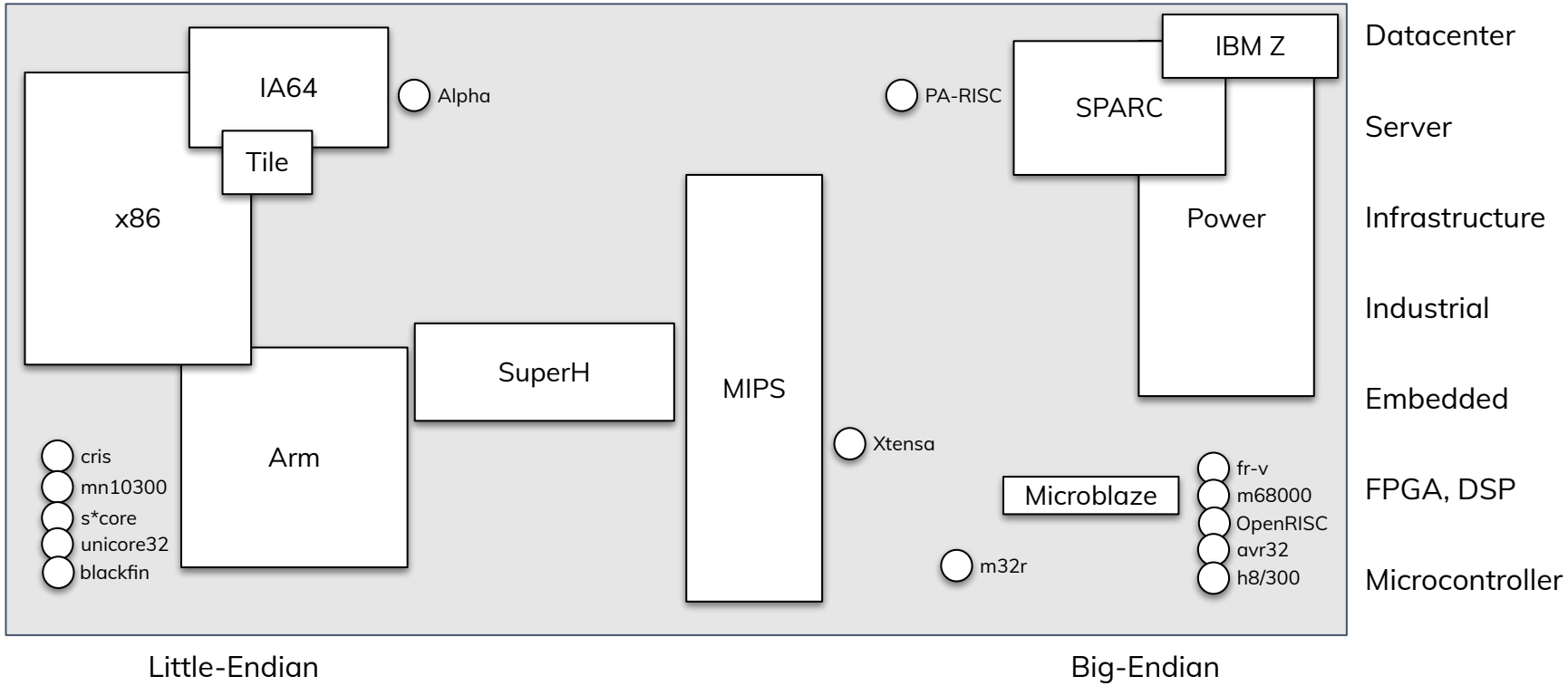
Upstream machines in Linux-5.6



Code size and supported machines



CPU architectures world map, ca. 2010



Obsolete architecture removal

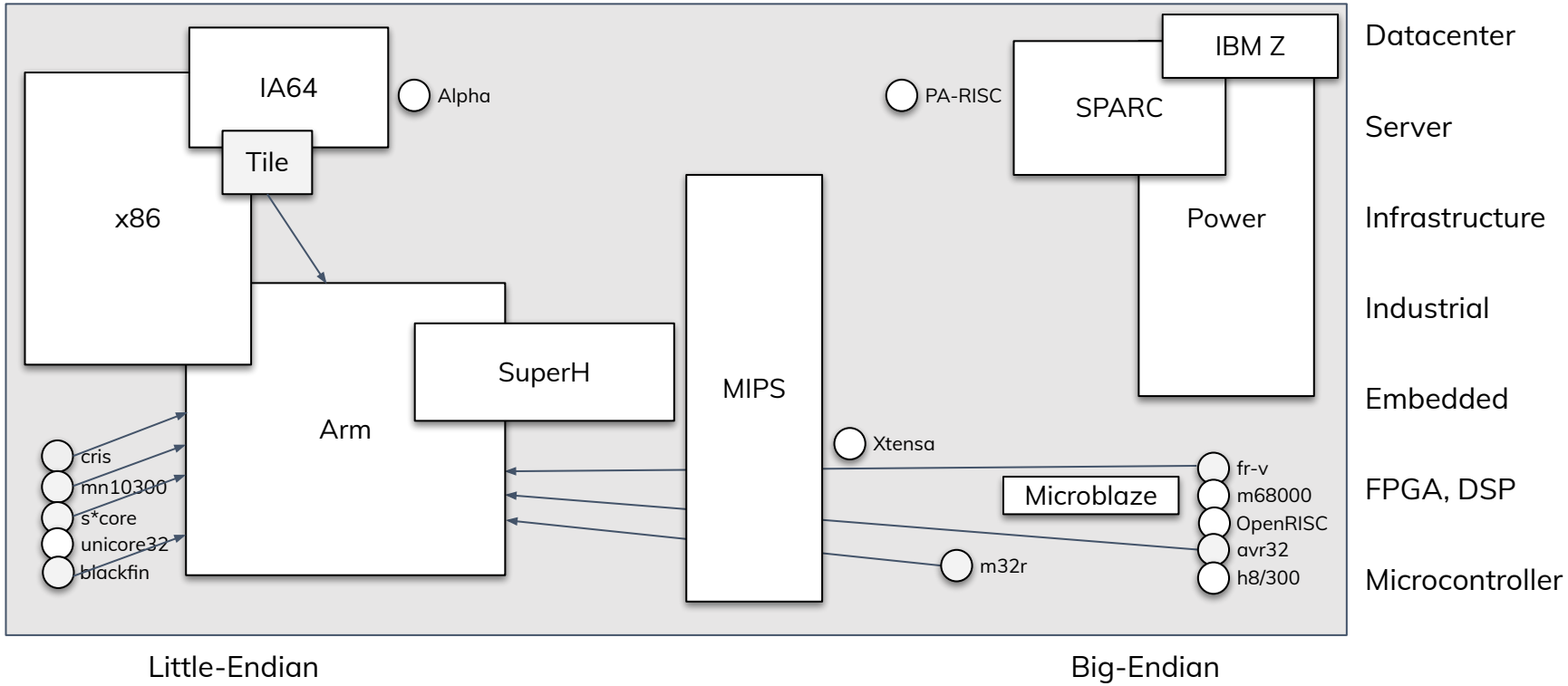
Reasons

- No upstream users
- Migrated to Armv7/v8 cores
- Afterlife as microcontroller/RTOS

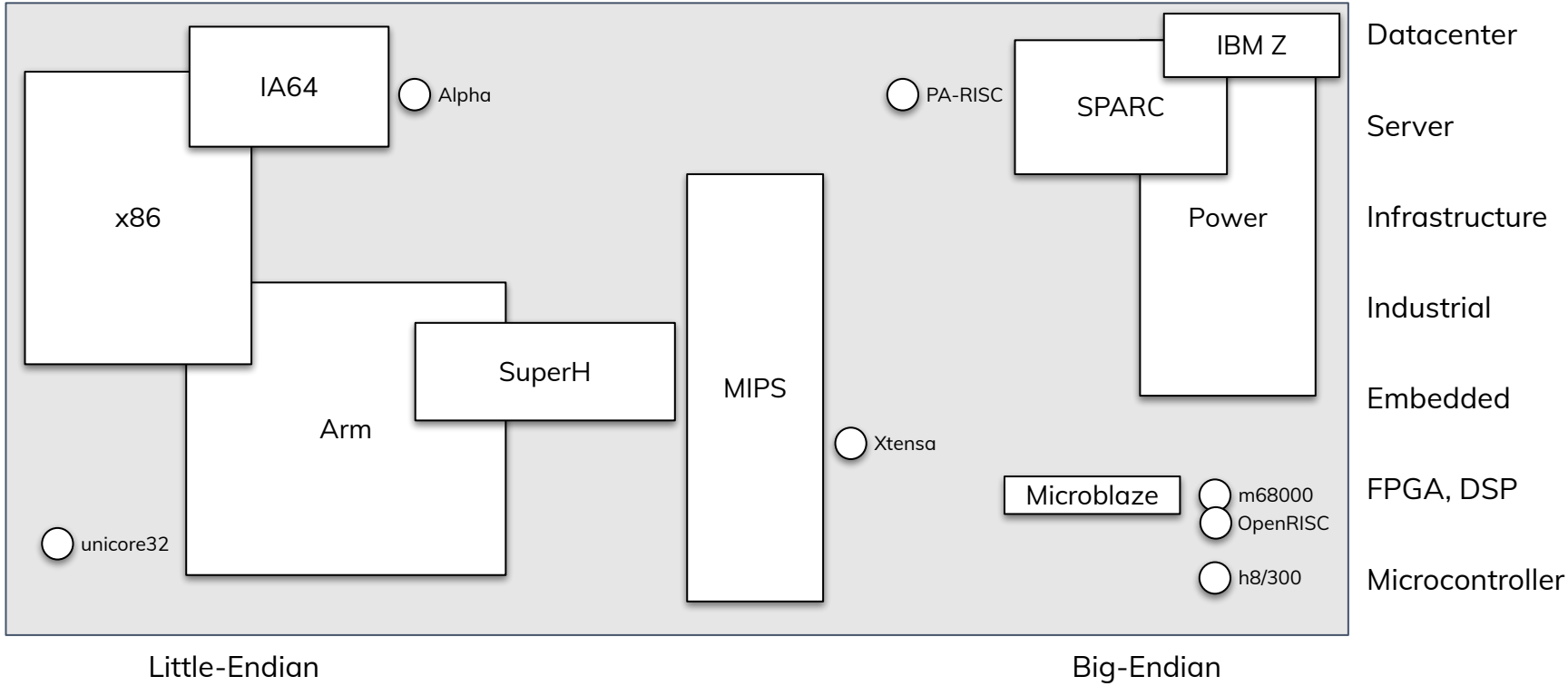
Removed in 2018

- Analog Blackfin
- Axis ETRAX CRIS
- Fujitsu FR-V
- Imagination Meta
- Matsushita mn10300
- Mitsubishi m32r
- Sunplus S+Core
- Tilera TileGX

Obsolete architecture removal



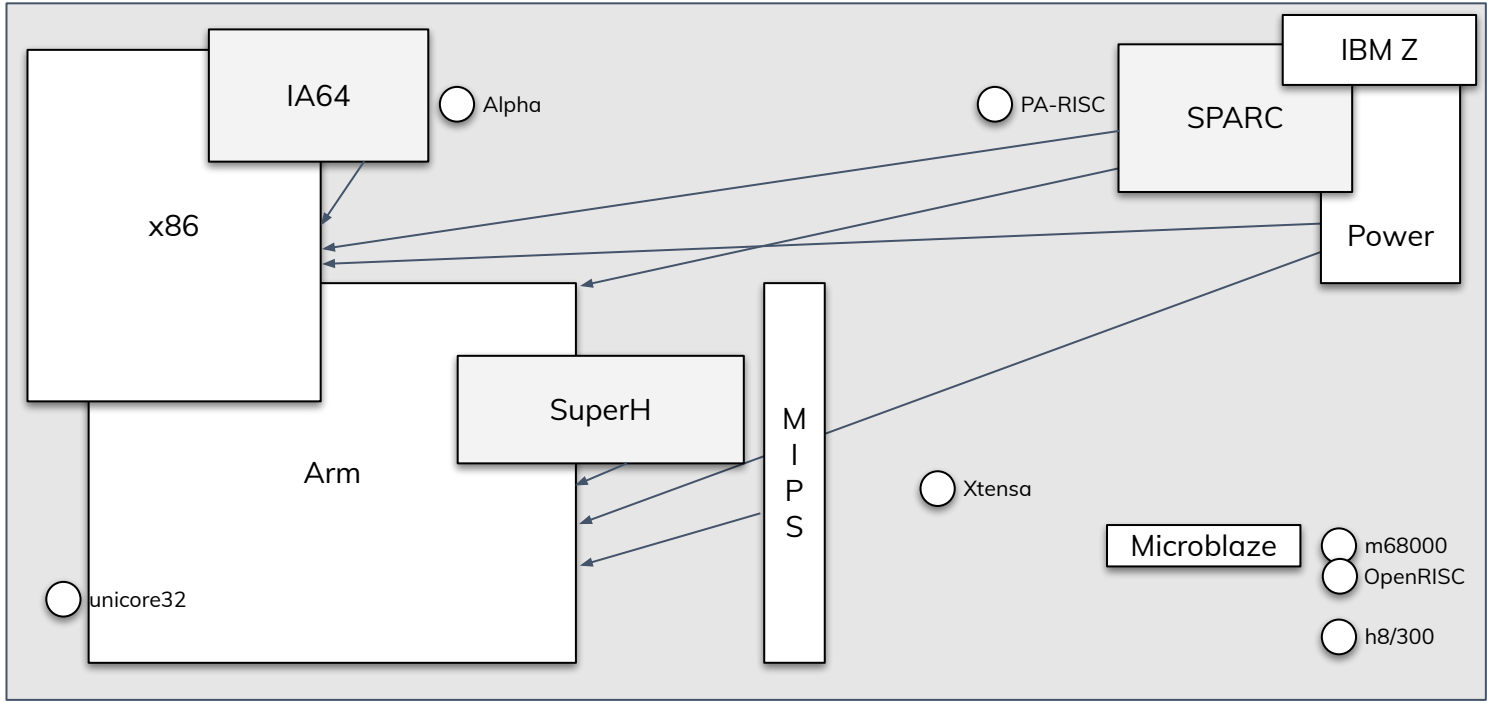
Obsolete architecture removal



2017: Endgame

- Intel Itanium “Kittson”
- Oracle Sparc M8
- Fujitsu SPARC64 XII
- MIPS I6400-F Core
- Andes N15/D15 (nds32)
- Xtensa LX7
- C*Core C9000 (PowerPC32)

User migration



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FPGA, DSP

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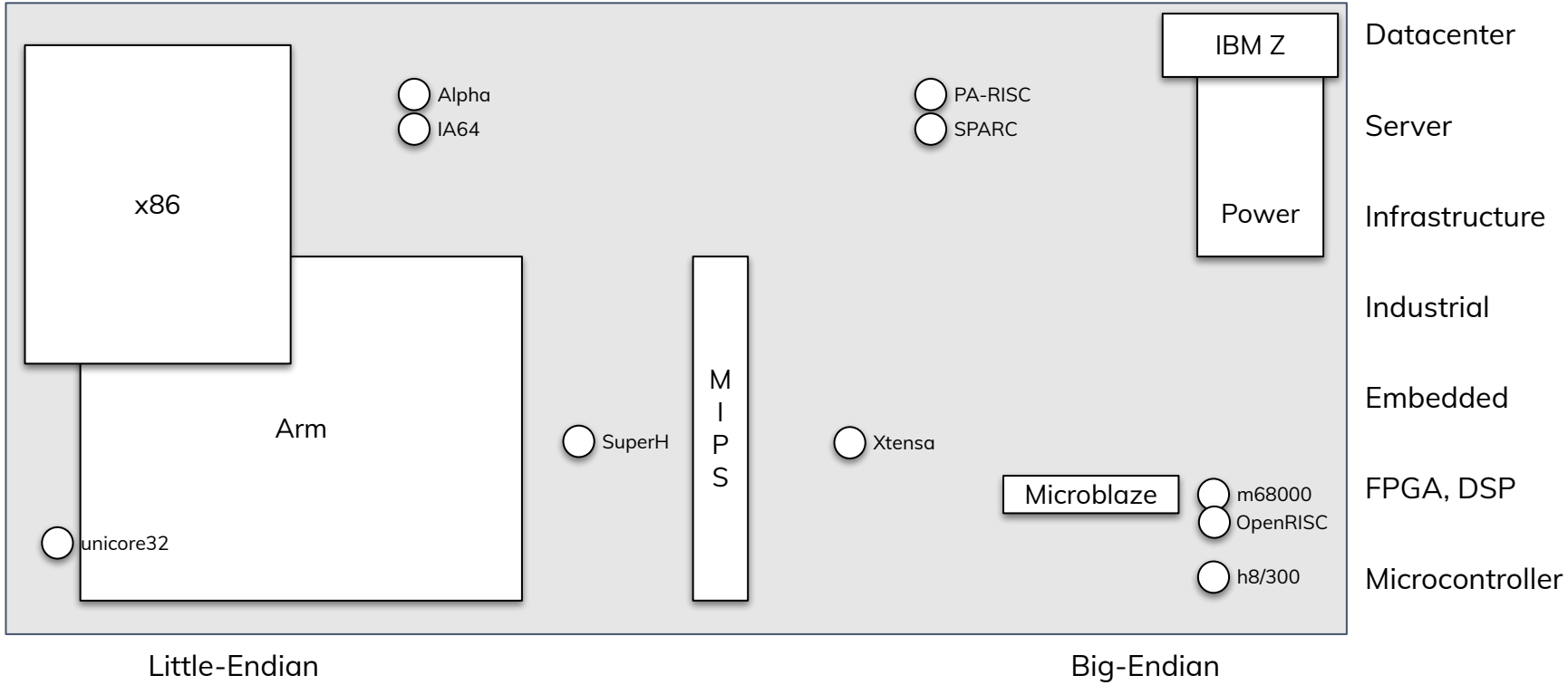
Little-Endian

Big-Endian

User migration



Architectures with new hardware in 2019+

Obviously

- x86-64
- Armv7-A
- Armv8-A

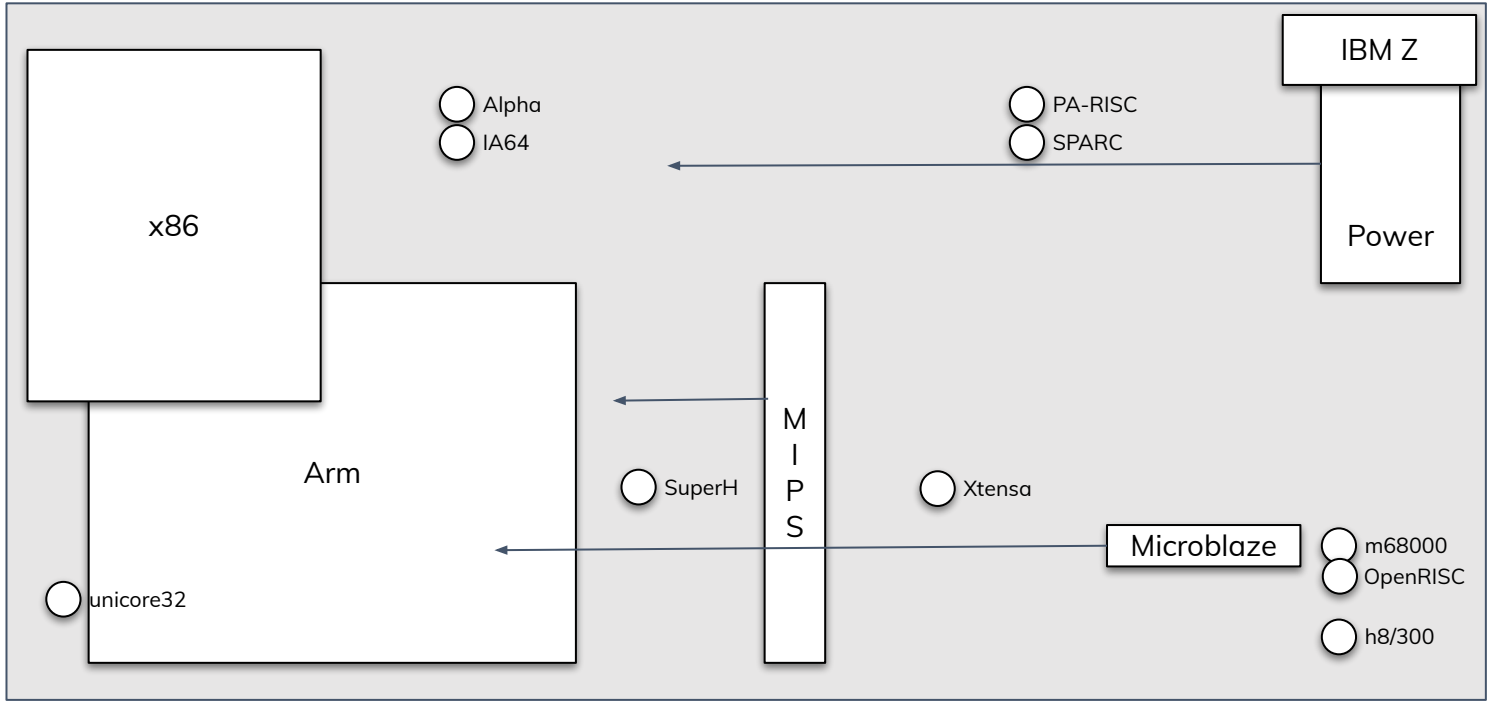
Others

- RISC-V (>50 microarchitectures)
- IBM Power 10
- IBM z15
- Synopsys ARC EV7x, VPX5
- Cobham Gaisler Leon5 (SPARC32)
- Xilinx Microblaze 11 (32/64 bit)
- Loongson 3A4000 (mips64)
- Ingenic X1830 (mips32)
- Microchip SAM9x60 (Armv5)

Big-Endian phasing out

- Changing to little-endian
  - PowerPC64
  - Microblaze
  - Realtek MIPS
- MIPS32 Changing to Arm/x86
  - Atheros
  - Broadcom
  - Lantiq
- No new chips after 2017
  - PowerPC32 (NXP, AMCC)
  - SPARC64
  - m68k
  - PA-RISC
  - h8/300
- Started migration to 64-bit RISC-V
  - SPARC32/Leon
  - OpenRISC
- Remaining
  - IBM Z

Endianess change



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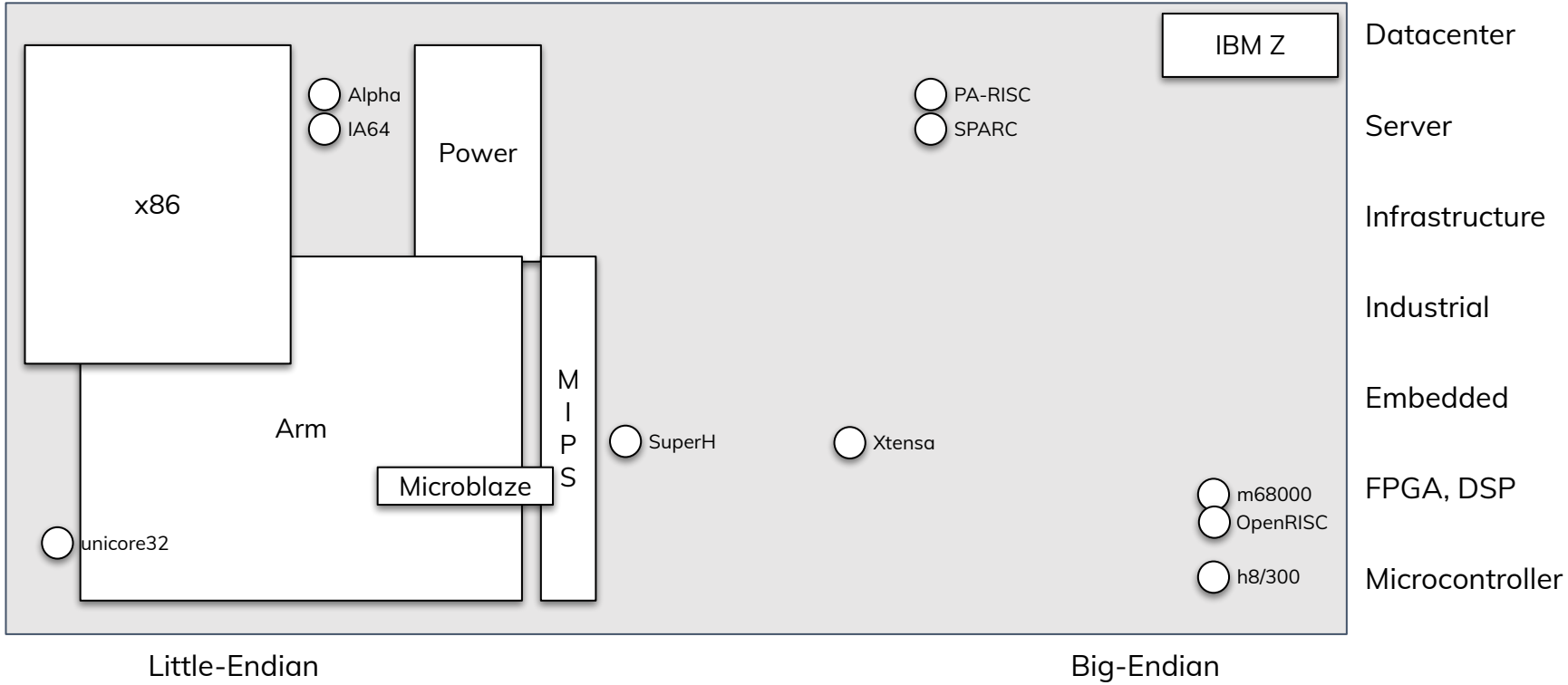
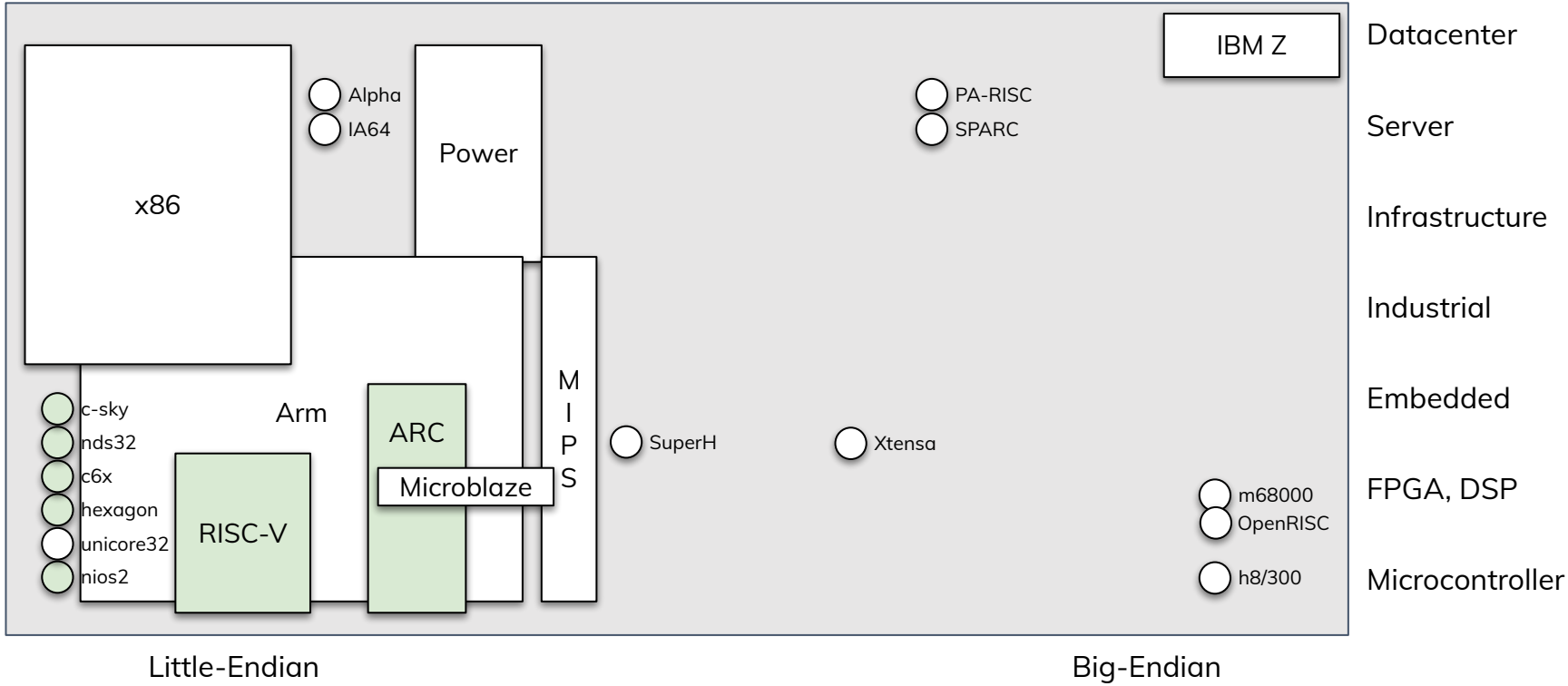
Endianess change



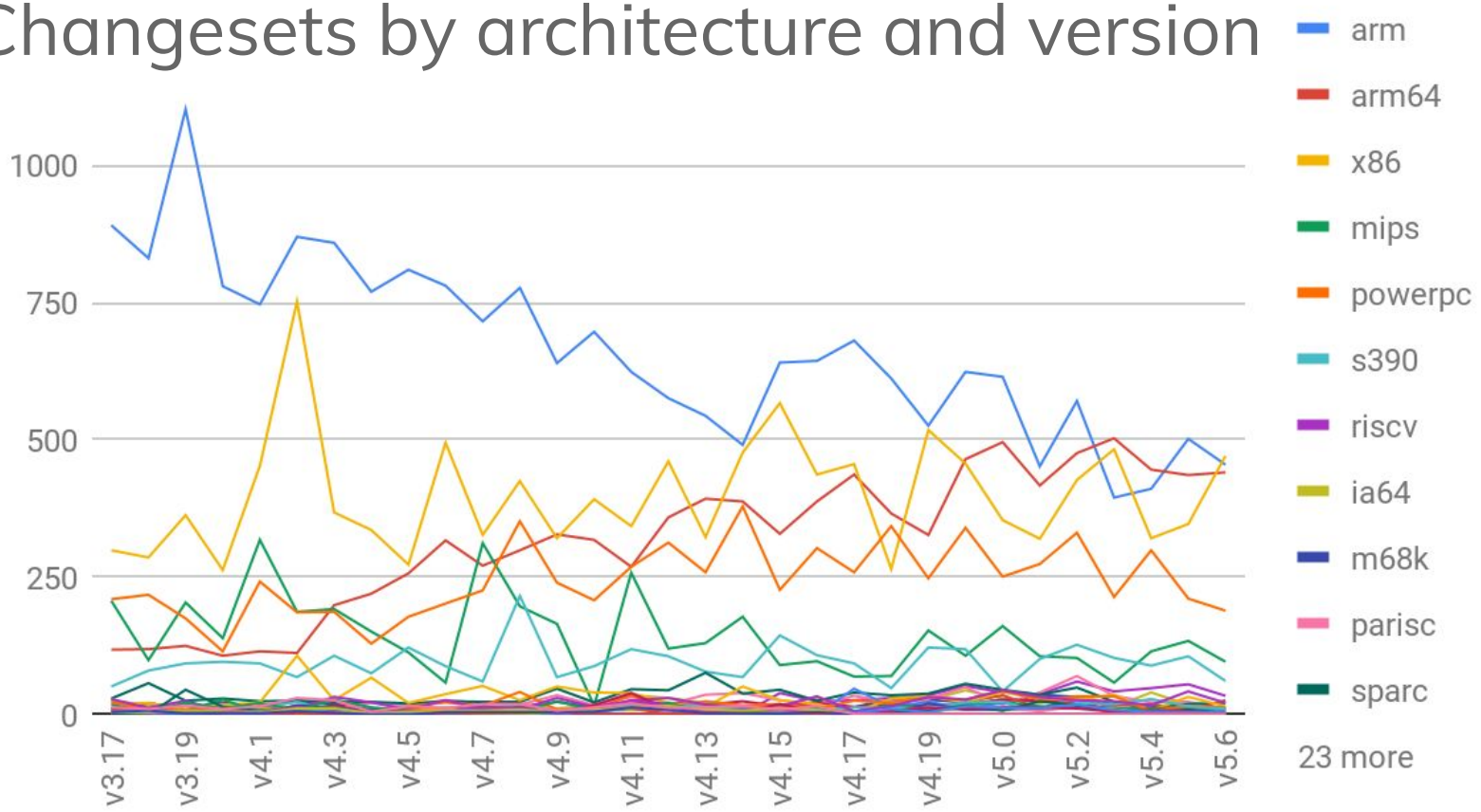
New architectures

- RISC-V (RV32, RV64)
  - Dozens of cores
  - High expectations
  - No products in 2019
- Synopsys ARC
  - 32-bit licensable RISC
  - Active ecosystem
  - Highly popular
  - Limited mainline Linux board support
- Alibaba C-Sky, Andes NDS32
  - 32-bit licensable RISC
  - obsoleted by RISC-V
- Altera/Intel NIOS-II
  - 32-bit licensable RISC
- Imagination Meta
  - Replaced by MIPS, then RISC-V
  - Already gone
- TI C6x, Qualcomm Hexagon
  - Proprietary DSPs
  - Linux uncommon

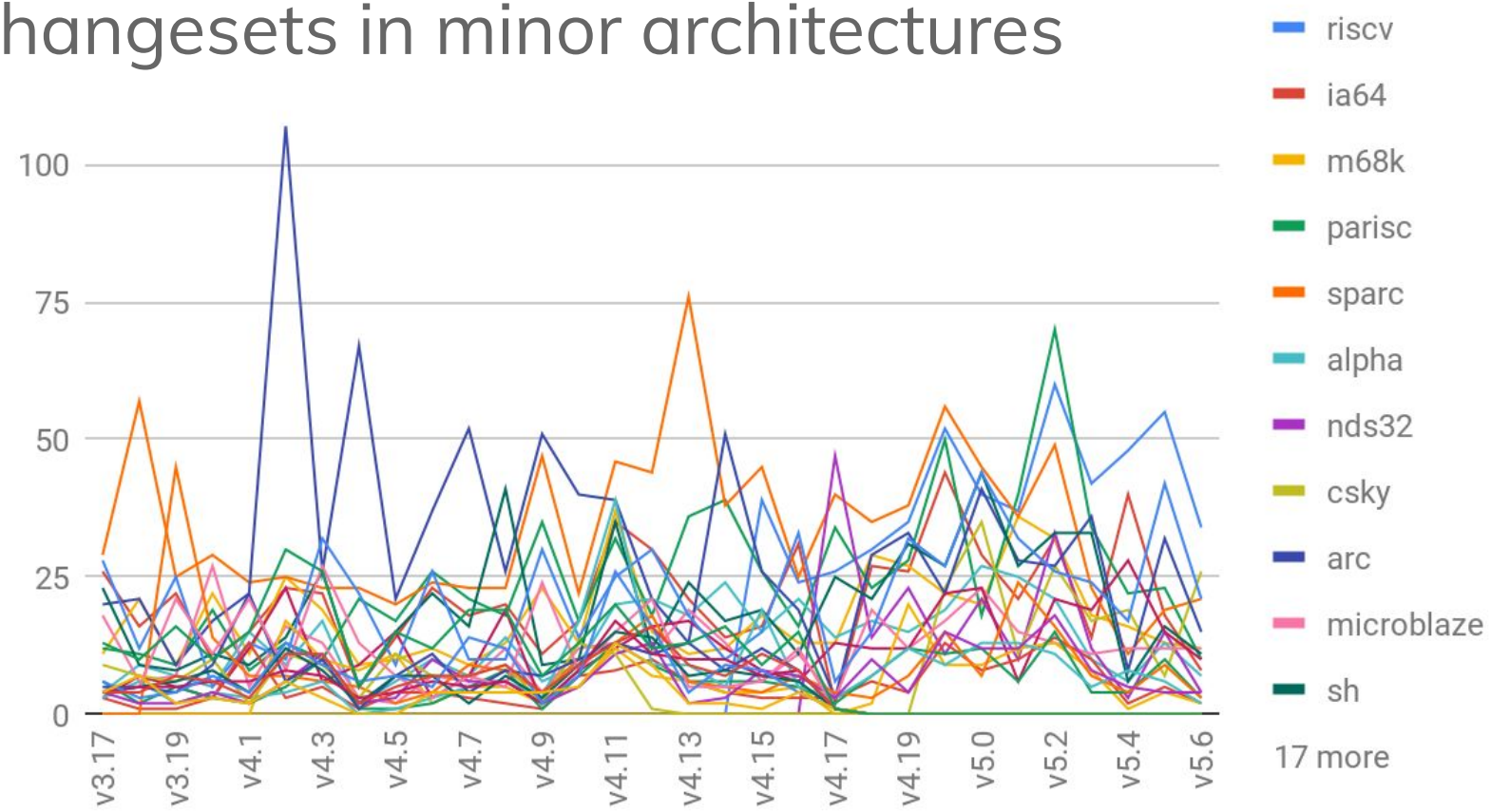
New architectures



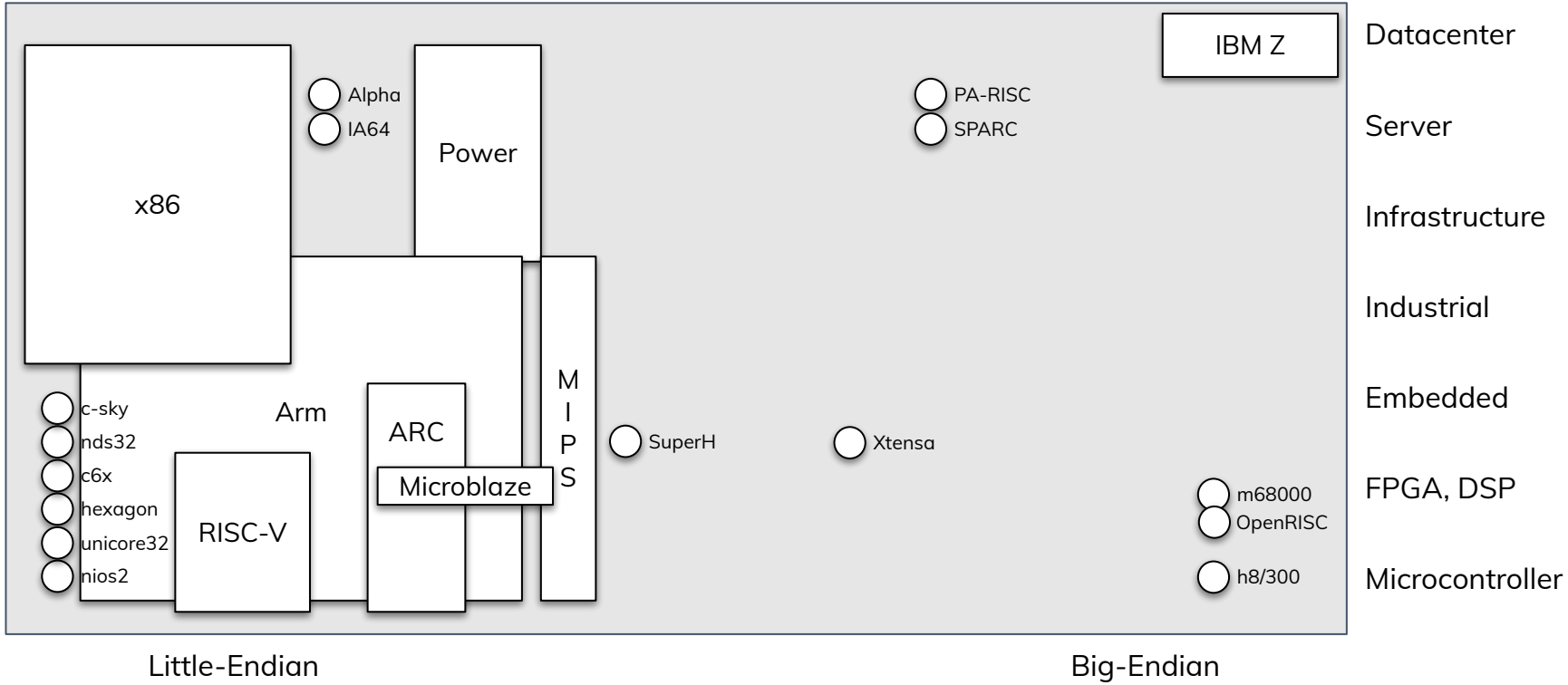
Changesets by architecture and version



Changesets in minor architectures



CPU architectures world map, ca 2020



Arnd's prediction for 2030

- x86-64, Armv8+, riscv64 split the market
- Upstreaming further improving
- Last Armv7/RV32 chips released, still shipping
- More creative multi-chip packages
  - Chiplets
  - System-in-package
- IBM Z mainframes still profitable
- No important new ISAs
- Start of 128 bit computing
  - see also CHERI/Morello talk LTD20-110
- Everything else obsolete

Thank you

Accelerating deployment in the Arm Ecosystem

SoC support in the kernel

Arnd Bergmann <arnd@arndb.de>