

Mobile Architectures

Mobile Systems

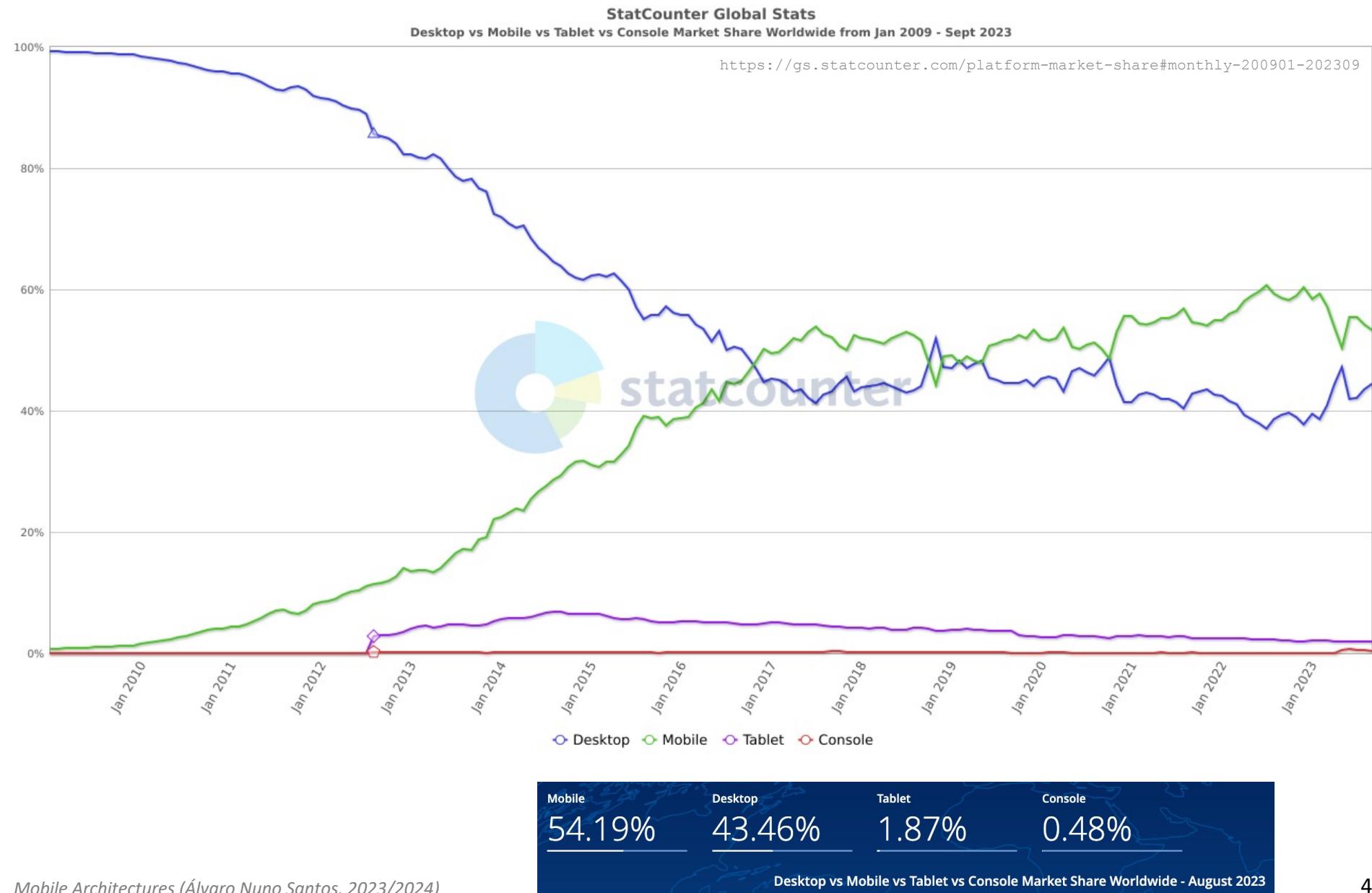
Mobile operating systems

- Operating system
 - Software layer that virtualizes the hardware, facilitating and maximizing its use
- Mobile operating system
 - It is an operating system suited to the specificities of mobile devices/platforms

Mobile operating systems



Market share

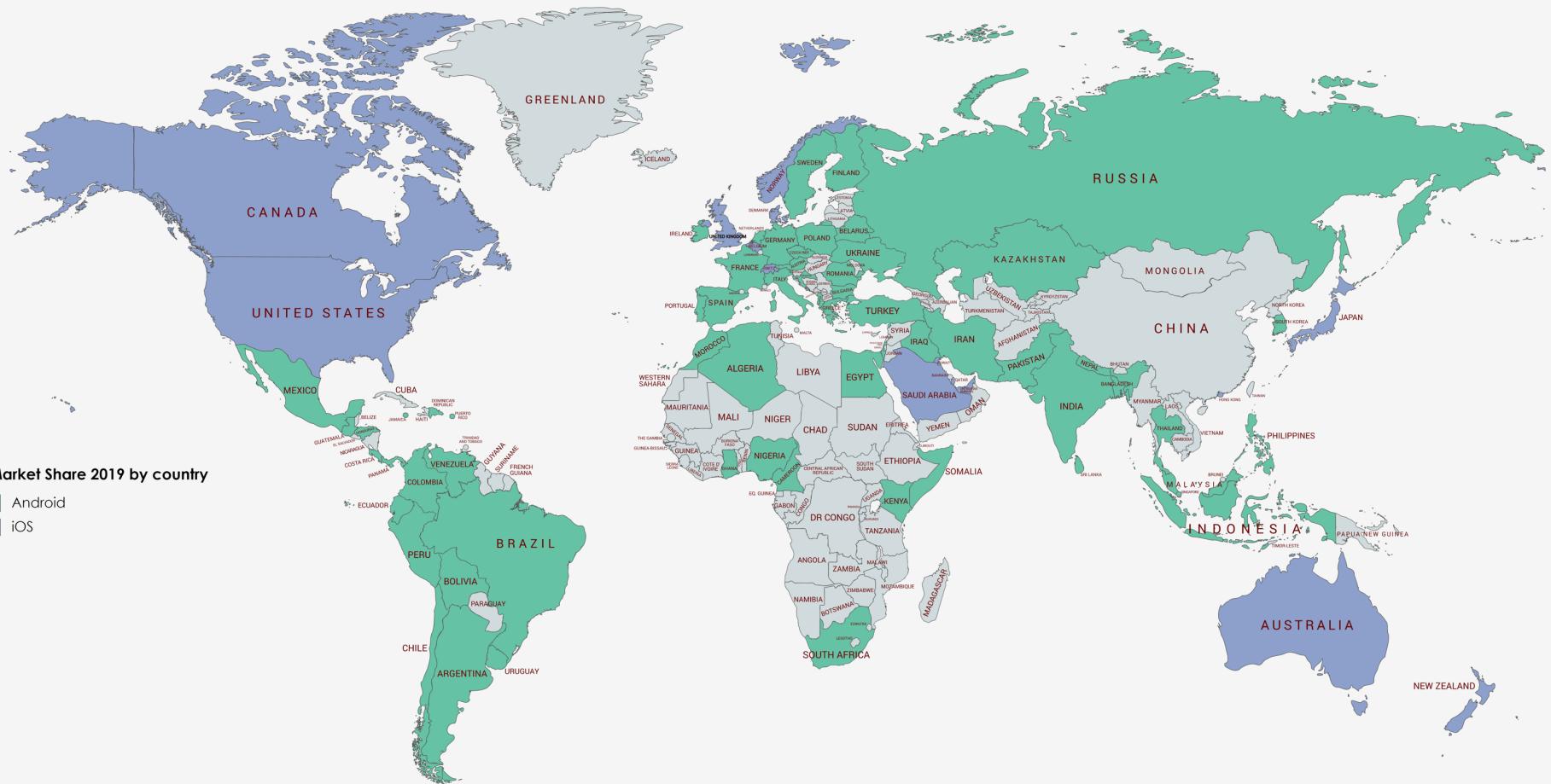


Mobile operating systems

- Symbian OS
- RIM BlackBerry OS
- iOS (Apple)
- Windows CE
- Windows Mobile
- Windows Phone
- Android
- Firefox OS
- KaiOS
- LiMo
- Maemo
- MeeGo
- Bada
- Mer
- Tizen
- Open Web OS/ webOS
- Jolla Sailfish OS/ Sailfish UI
- Ubuntu Touch
- ...
- HarmonyOS

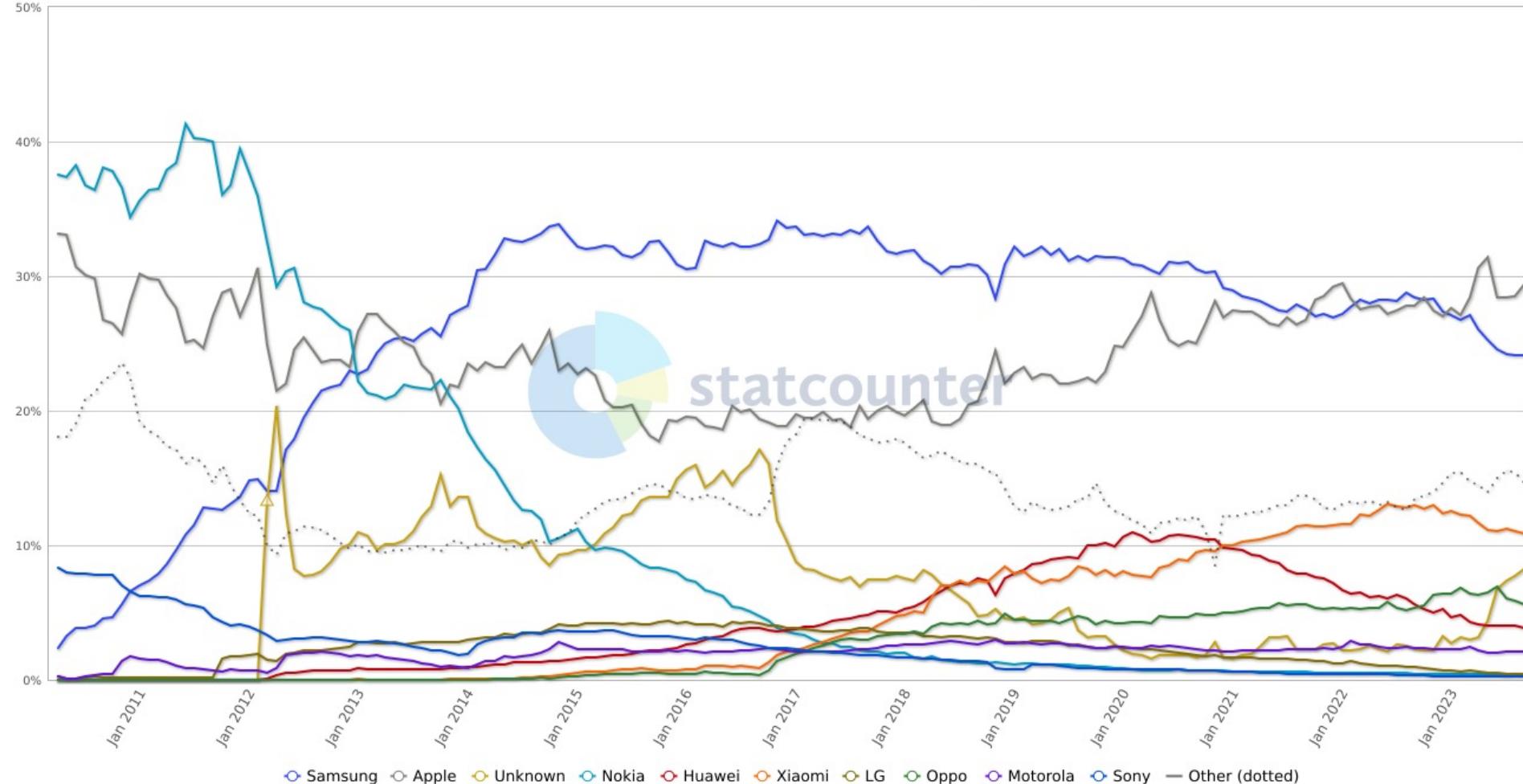


Dominant OS



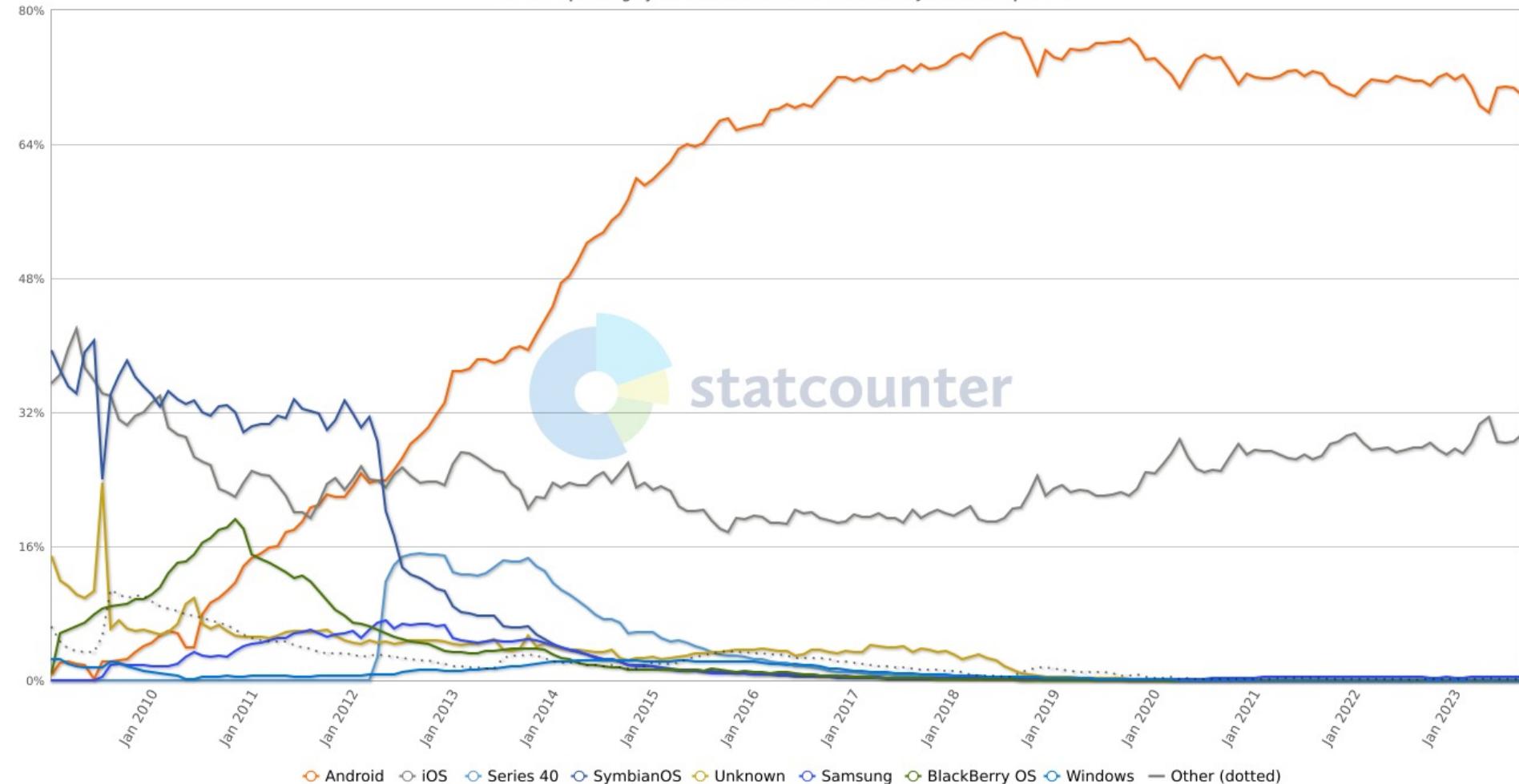
Manufacturers

StatCounter Global Stats
Mobile Vendor Market Share Worldwide from Mar 2010 - Sept 2023



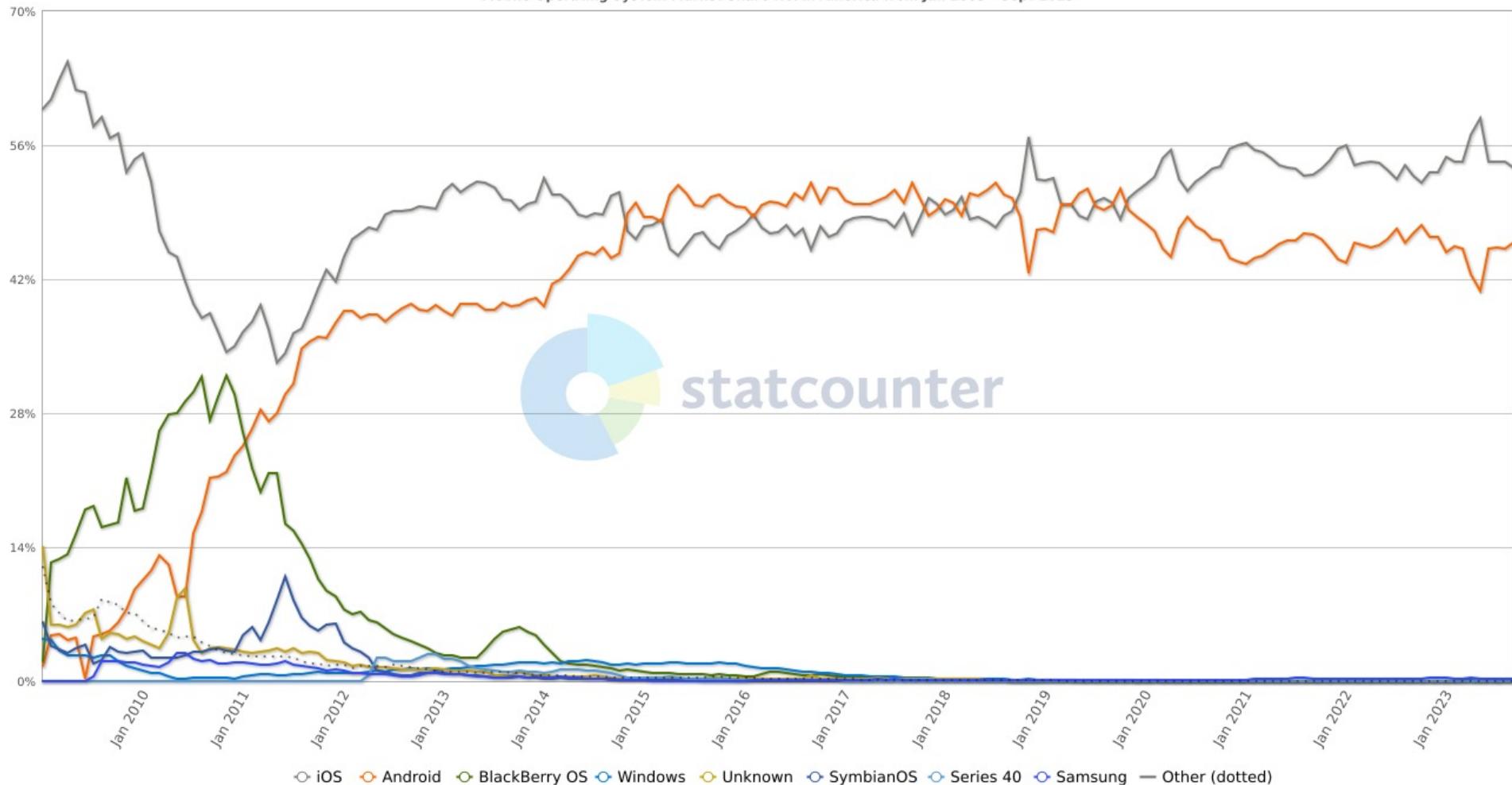
Worldwide

StatCounter Global Stats
Mobile Operating System Market Share Worldwide from Jan 2009 - Sept 2023



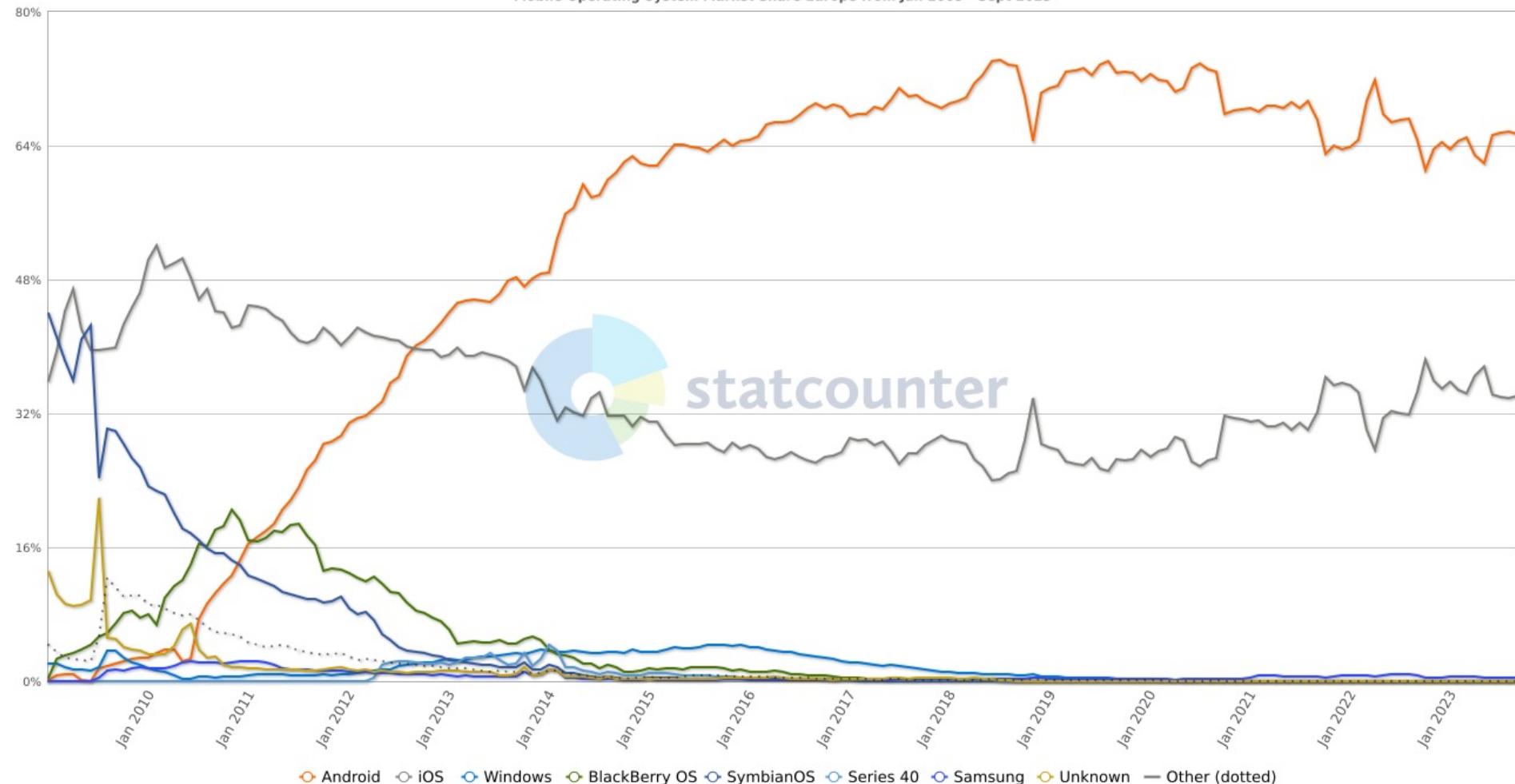
North America

StatCounter Global Stats
Mobile Operating System Market Share North America from Jan 2009 - Sept 2023



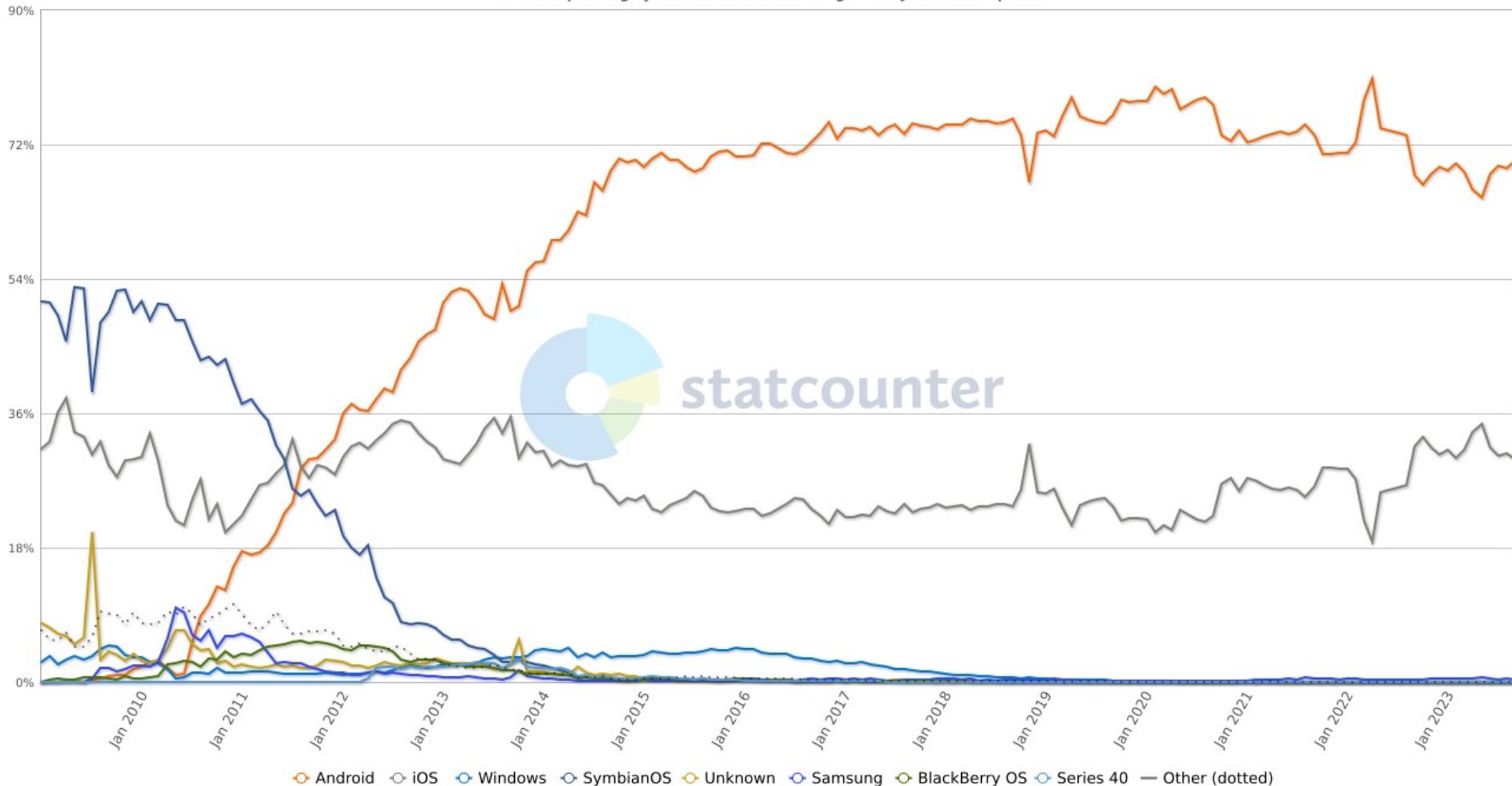
Europe

StatCounter Global Stats
Mobile Operating System Market Share Europe from Jan 2009 - Sept 2023



Portugal

StatCounter Global Stats
Mobile Operating System Market Share Portugal from Jan 2009 - Sept 2023



Mobile OS

Feature	Android	iOS	Tizen	Sailfish OS	Ubuntu Touch	Mobian ^[1]	Plasma Mobile	PureOS	PostmarketOS	KaiOS	HarmonyOS
Developed by	Google, Open Handset Alliance	Apple Inc.	Linux Foundation, Tizen Association, Samsung, Intel	Sailfish Alliance, Mer, Jolla and Sailfish community contributors	UBports and Ubuntu community contributors (previously Canonical Ltd.)	Debian on Mobile Team	KDE and Blue Systems	Purism	PostmarketOS community	KaiOS Technologies Inc.(TCL)	Huawei
Market share ^{[2][3]}	71.90%	27.33%	0.22%	N/A	N/A	N/A	N/A	N/A	N/A	0.14%	4%
License	Base system is free and open-source, but practically unforkable. Increasingly, closed-source drivers are often needed for hardware support, and basic functionality like calendar, maps, location, ^[4] and the alarm clock (only available in Google Play). Proprietary apps are often pre-installed. ^[5]	Proprietary, open source kernel and core	Partial; both proprietary and open-source components, assorted licenses	Free and open-source, but the UI and the SDK are proprietary and closed source	Free and open-source, mainly the GPL ^[6]	Free and open-source, mainly the GPL	Free and open-source, mainly the GPL	Free and open-source, mainly the GPL	Free and open-source, GPL	Proprietary except for open source kernel patches (formerly the MPL 2.0 B2G OS)	Proprietary except for open-source components
Current version	12L	16.0	4.0.0.7	4.3.0.15	16.04 OTA-22	20210516	5.24.3	10.0	21.12 Service Pack 3	2.6.0	3.0.0.76
Development version	13	16.1	6.0 M2	Unknown	Unknown	20220612	Unknown	Unknown	N/A	N/A	3.0.0
Current version release dates	March 7, 2022; 6 months ago	September 12, 2022; 8 days ago	May 30, 2020; 2 years ago ^[7]	February 16, 2022; 7 months ago ^[8]	February 18, 2022; 7 months ago	May 16, 2021	March 8, 2022; 6 months ago	October 2, 2021; 11 months ago	March 13, 2022; 6 months ago		July 27, 2022; 55 days ago
OS family	Modified Linux kernel based	Darwin	Linux (based on a combination of Linux MeeGo and Samsung Bada)	Linux	Linux (based on Ubuntu)	Linux (based on Debian)	Linux (mainly based on KDE neon)	Linux (based on Debian)	Linux (based on Alpine Linux)	Firefox OS / Open Web (based on Linux kernel)	Unix-like (based on Linux kernel multi-kernel layer)
Supported CPU architecture	ARM (32-bit ARMv7-A and 64-bit ARMv8-A only), x86, x86-64 ^[9]	64-bit ARMv8-A only	ARM, x86, x86-64	ARM, x86-64	ARM, x86-64	64-bit ARM, RISC-V, x86, x86-64 and LoongArch	ARM	ARM, ?	Convergence operating system	ARM	64-bit ARM, x86, x86-64
Programmed in	C, C++, Java, Kotlin	C, C++, Objective-C, Swift	C++, Xamarin.Forms (.NET C#, F#, VB ^[10])	C++, QML, Python	Apps: HTML5, QML, Go, JavaScript, C++ System: C, C++, QML	C, C++	C++, QML		Python install tool and shell script packages	HTML5, JavaScript	C, C++, Java (until HMSO 3.0), JavaScript, eTS and Cangjie ^[11]
Public issues list	Yes ^[12]	3rd party ^[13]	Yes ^[14]	Yes ^[15]	Yes ^[16]	No ^[citation needed]	Yes ^[17]	Yes ^[18]	Yes ^[19]	No ^[citation needed]	Yes ^[20]
DRM-free ^[21]	No ^[22] since Android 4.1 ^[23] and Android 4.3 ^[24] and more restrictions on Android 4.4 ^[25]	No – FairPlay	Yes	Yes	Yes	Yes	Yes ^[citation needed]	Yes ^[citation needed]	Yes	?	No – Huawei WisePlay ^[26]
Device independent system updates	Partial system updates since Oreo ^[27] 3rd party software like LineageOS ^[28]	Yes ^[29]	No	Yes	Yes ^[30]	?			Yes, ^[31] Intended for use on old mobile devices	For feature phones, not smart phones	Yes ^[32]
Wireless system updates	Yes	5+ ^[33]	No	Yes	Yes		?				Yes
GPU accelerated GUI	3+ ^[34]	Yes	Yes	Yes	Yes	?					Yes. Since 3.0 ^[35]
Feature	Android	iOS	Tizen	Sailfish OS	Ubuntu Touch	Mobian ^[1]	Plasma Mobile	PureOS	PostmarketOS	KaiOS	HarmonyOS

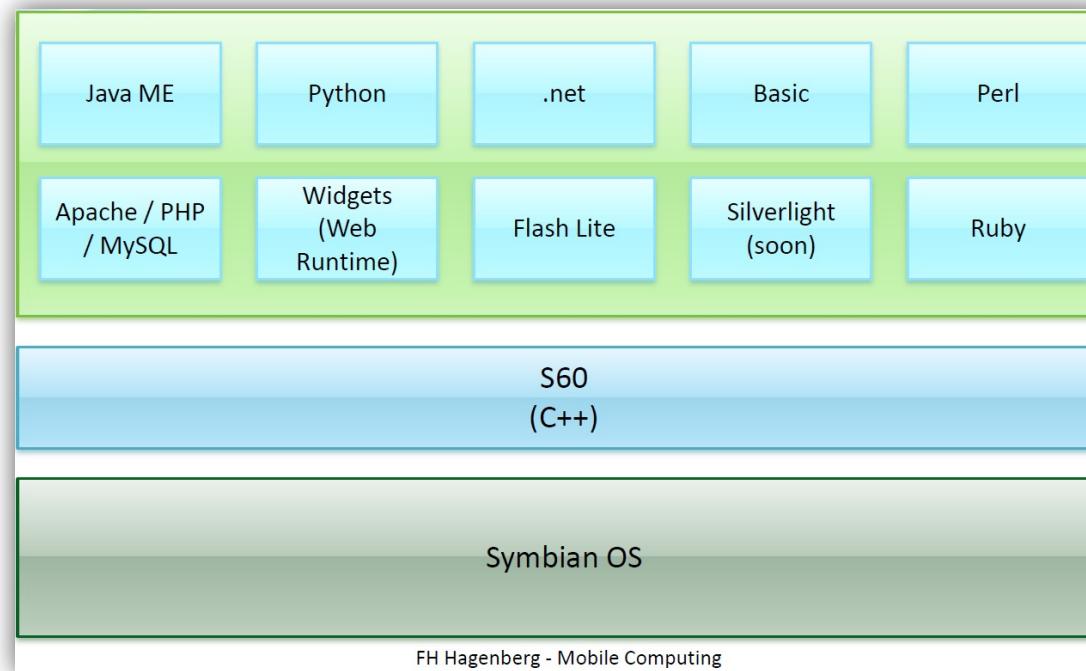
https://en.wikipedia.org/wiki/Comparison_of_mobile_operating_systems. [Set 2022]

Symbian OS

- Evolution of PSION's EPOC system (1989-2000) designed for PDA
- *Symbian* was created in 1998
 - Joint venture between *Psion* and some mobile phone manufacturers (*Ericsson, Motorola* and *Nokia*)
- The first version of Symbian OS came out in 2001
 - Nokia 9210
- In 2008 Nokia acquired *Symbian Software Limited*
 - *Symbian Foundation* was created – autonomous and non-profit entity to manage Symbian OS
 - In November 2010, the project was abandoned, leaving only support and development for specific markets
- Preemptive, single-user, multitasking operating system with memory protection
- <http://www.symbian.org>

Symbian OS

- Development...
 - Programming was essentially carried out in C++
 - Symbian C++
 - Subsystems were developed to support other languages/development platforms



RIM BlackBerry

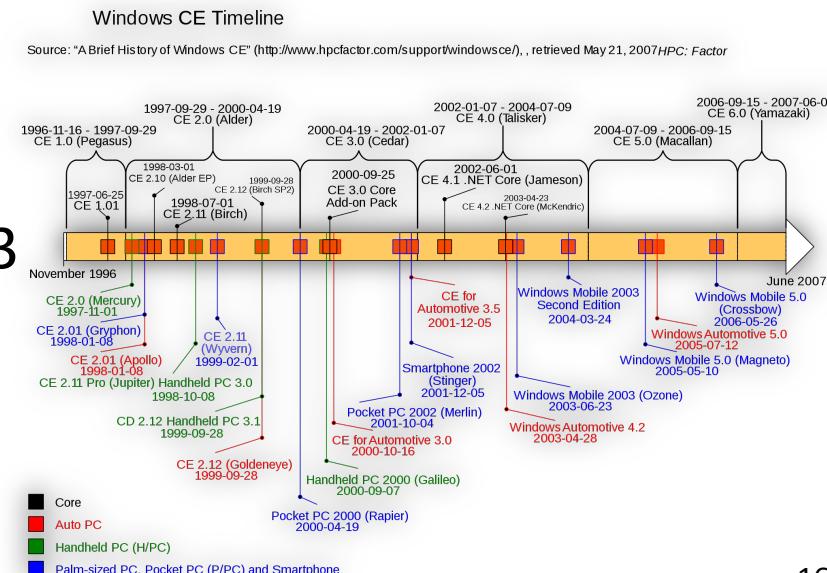
- RIM – *Research In motion*
 - Canada
 - 1996
- Main objective: “personal digital assistant”
 - Email
 - Calendar
 - Tasks
 - **Security**
- Development
 - Essentially JAVA
 - *Web Service extensions (Server + Client)*
- Evolution (more recent years)
 - Android system was adopted for their devices
 - Dedicated to business and security services





Windows CE

- Windows Embedded Compact
 - Some call it “Windows Compact Edition”
 - Microsoft says “Compact, Connectable, Compatible, Companion, and Efficient”
- Developed by Microsoft for embedded systems and/or limited resources
 - Goal: Provide “similar” features to those found on a Windows computer
- 1st version: 1996
- Last version: 8
 - Windows Embedded Compact 2013



Windows Mobile

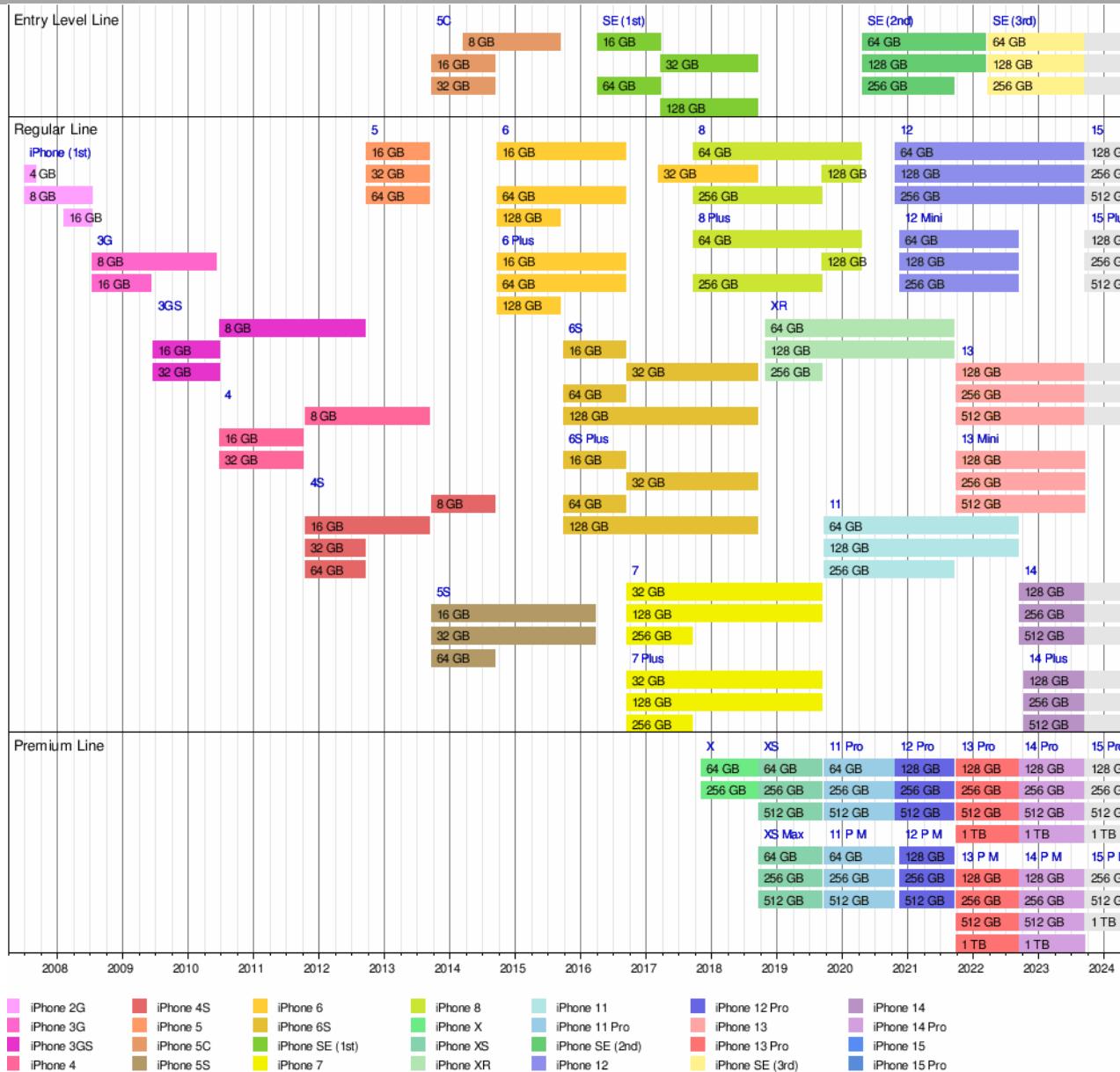
- Based on *Windows CE*
 - Windows *Mobile 6* is based on *Windows CE 5.2*
- Used on cell phones/*smartphones*
- *Standard* and *Pro* versions
 - The *Pro version* has touchscreen support
- Latest version: 6.5.5
- Development
 - Various languages
 - Initially, the most common was C/C++ (Win32-API, MFC)
 - After, development began to be supported through the .NET Compact Framework
 - Subset of the .NET Framework
 - Version of the .NET Framework adapted to devices with limited resources
 - Continues to offer services not normally associated with this type of equipment
 - For example, SQL – using the Microsoft SQL Server CE version
 - C#
 - VB.NET

Windows Phone

- *Windows Phone 7*
 - Based on *Windows CE 6.0*
- *Windows Phone 8 and 8.1*
 - Based on *Windows NT + Windows 8*
- *Windows 10 Mobile*
- Pleasant interface but failed to gain market share
- Main advantage: integration with business applications and Office
- Cortana assistant was introduced to respond to the competition (Siri, Google Now)
- Development
 - Based on two technologies
 - Silverlight
 - XNA
 - Development platform: Visual Studio
 - There was a version of Visual Studio Express prepared for developing applications for Windows Phone
 - Base language: C#
 - Applications were made available through the Windows Phone Marketplace/App hub
 - 30% to Microsoft
 - \$99/year

- Designed for *iPhone* and *iPod Touch* from Apple
 - Strong relationship with *hardware*
 - Simplicity of use
 - Stability
- iOS devices are considered the main reference in *smartphones* and *tablets*
- Initially based on OS X 10.5 (*Leopard*)
- Multitasking support began with the release of version 4
 - In previous versions it was already possible to multitask between some specific applications (e. g., music)
- Latest version released: iOS 16.6.1
 - *The iOS 17 and the new iPhones will be available on September 22, 2023*
 - <https://www.apple.com/apple-events/>
 - In recent versions, there has been an approximation in the provision of functionalities until now associated with other systems (mainly Android)
 - iPadOS appeared with the launch of iOS 13

iPhone



iOS (iPhone, iPad)

- Development
 - Applications distributed through the 'App Store'
 - Free applications
 - Paid applications
 - 30% to Apple
 - \$99/year to subscribe to iOS Developer Program
 - iOS Developer University Program
 - Necessary tools and requirements:
 - SDK
 - Xcode – development environment
 - Includes iPhone Simulator
 - Languages: C, C++, Objective-C, Swift
 - Computer with macOS
 - iPhone, iPad, Apple Watch, Apple TV



Android

Android is a trademark of Google LLC.

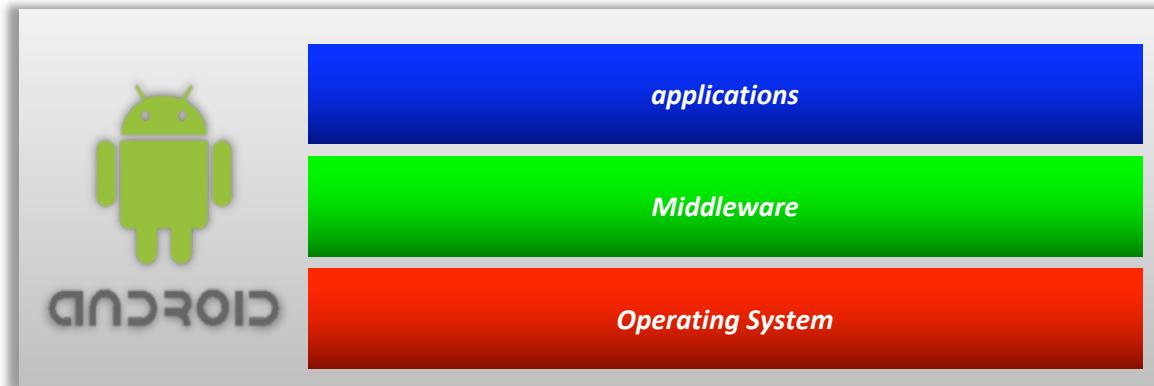
- Open-source initiative developed by a group of companies, headed by Google, which was named Open Handset Alliance

“Today, there are 1.5 billion television sets in use around the world. 1 billion people are on the Internet. But nearly 3 billion people have a mobile phone, making it one of the world's most successful consumer products” (**November 5, 2007**)

http://www.openhandsetalliance.com/oha_overview.html

Android

- Software suite that includes the operating system, *middleware* and applications
 - Linux-based (initially, version 2.6)
 - From version 4 of *Android*, version 3 of Linux started to be used
 - From version 7 of *Android*, version 4 of Linux started to be used
 - From version 11 of *Android*, version 5 of Linux started to be used
 - Support for the latest applications and technologies in the area of mobile devices (photography, video, GPS, compass, accelerometer, games, OpenGL, SQLite, ... and cell phone 😊)



Android

- Google has followed a policy of launching its “own” device to support the presentation of a new version of the Android system (with significant changes)
 - *Nexus One* (manufactured by HTC)
 - The way chosen for commercialization undermined the success of the project
 - Android 2.1
 - *Nexus S* (made by Samsung)
 - The commercialization model followed in the second model was more successful
 - In addition to the innovations in terms of the Android system, it served to present a set of new technologies (e. g., NFC, curved screen)
 - Android 2.3
 - (Samsung) Galaxy Nexus
 - Android 4.0
 - Nexus 7 (Tablet - ASUS)
 - Android 4.1
 - Nexus 4 (LG)
 - Android 4.2
 - Nexus 7 2013 (Tablet - ASUS)
 - Android 4.3
 - Nexus 5 (LG)
 - Android 4.4



Android

- Nexus 6 (Motorola)
 - Android 5.0
- Nexus 9 (Tablet - LG)
 - Android 5.0
- Nexus 5X (LG)
 - Android 6.0
- Nexus 6P (Huawei)
 - Android 6.0

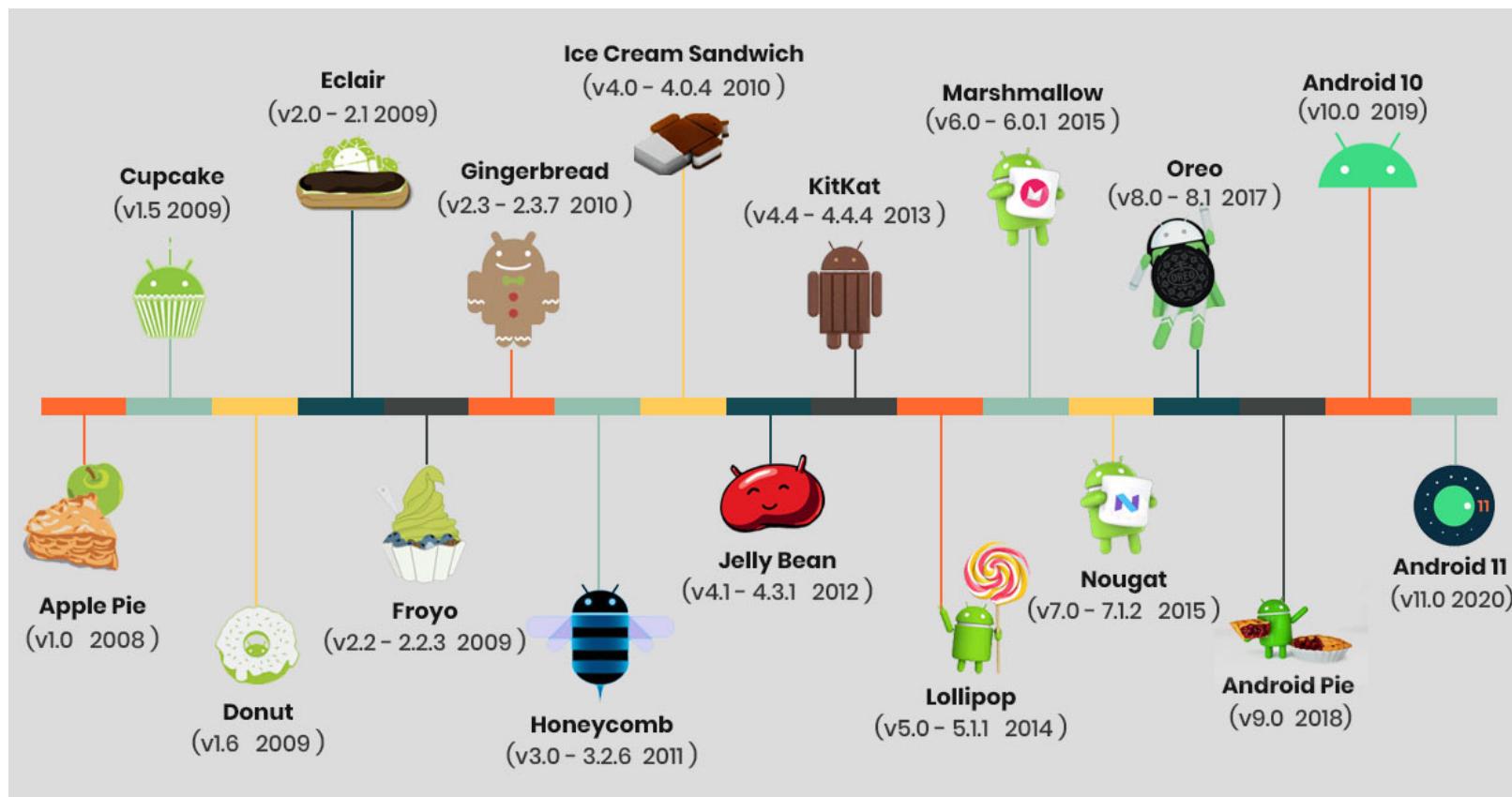


Android

- Pixel
 - Android 7.1
- Pixel 2 and Pixel 2 XL
 - Android 8
- Pixel 3, Pixel 3a, Pixel 3 XL
 - Android 9
- Pixel 4, Pixel 4XL, Pixel 4a and Pixel 4a(5G)
 - android 10
- Pixel 5 and 5a
 - Android 11
- Pixel 6, 6a and Pro
 - Android 12
- Pixel 7 and Pro
 - Android 13
 - More recently:
 - Pixel 7a, Pixel Fold and Pixel Tablet



Versions



12

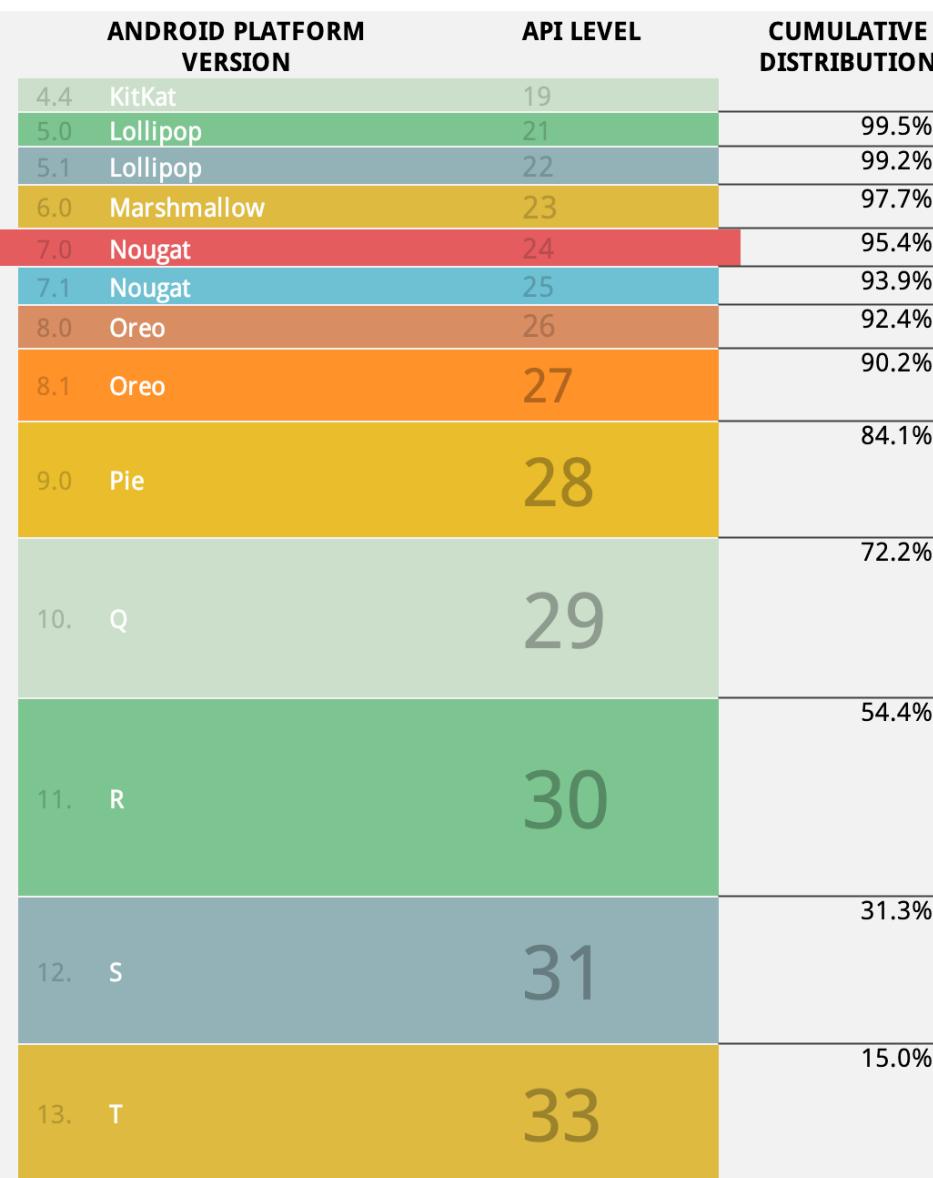
2021.10.04

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2022.08.15

source: Temok IT Services (@ Temok_IT) | Twitter

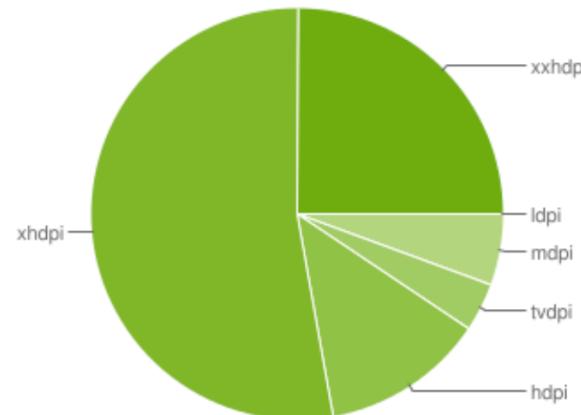
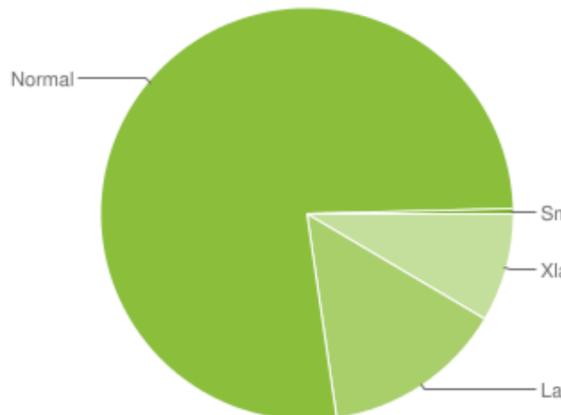
Versions



- Android versions for different devices:
 - Android OS
 - Smartphones, tablets and similar devices
 - WearOS
 - Smartwatches and similar
 - Android TV
 - TV and large screens
 - Android Automotive/Auto
 - AndroidCar
 - ~~Android Things~~
 - IoT

Screen resolution

	ldpi	mdpi	tvdpi	hdpi	xhdpi	xxhdpi	Total
Small					0.4%		0.4%
Normal		0.1%	0.3%	7.9%	45.4%	23.2%	76.9%
Large		1.2%	3.4%	1.1%	6.8%	1.7%	14.2%
Xlarge		4.3%	0.1%	3.8%	0.3%		8.5%
Total	0.0%	5.6%	3.8%	12.8%	52.9%	24.9%	



Data collected during a 7-day period ending on January 6, 2023.

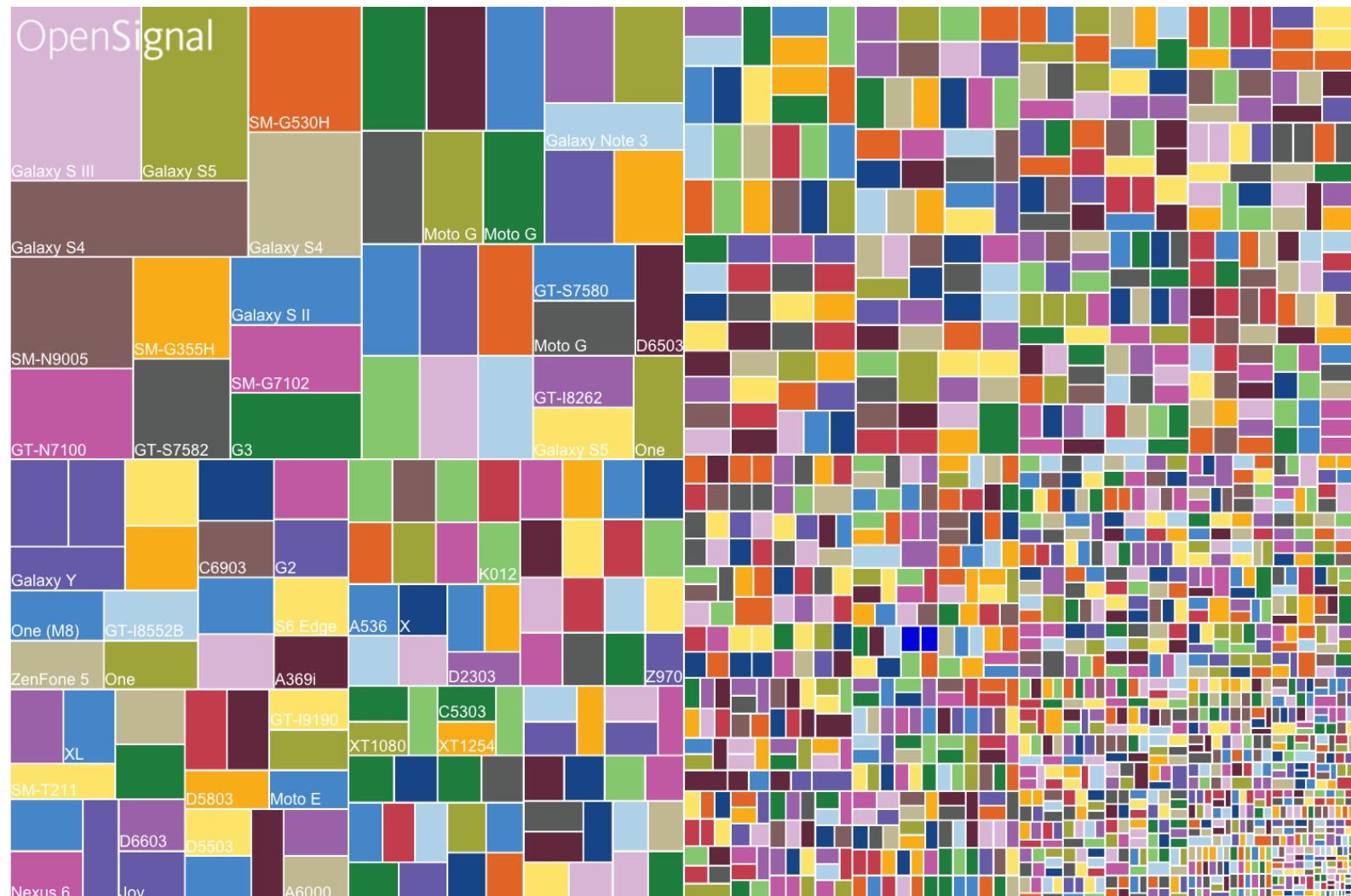
Any screen configurations with less than 0.1% distribution are not shown.

Android Fragmentation

- The problem of fragmentation, usually associated with the Android system, which makes it difficult to create new applications compatible with the various existing devices, arises due to several reasons:
 - Different versions of Android active at the same time
 - Different device manufacturers, with different operating system update policies
 - Economic context of the Android customer opting for cheaper devices
 - Different hardware
 - Screen sizes and resolutions
 - Processors
 - Memory capacity
 - Sensors
 - Communication technologies

Android Fragmentation

DEVICE FRAGMENTATION

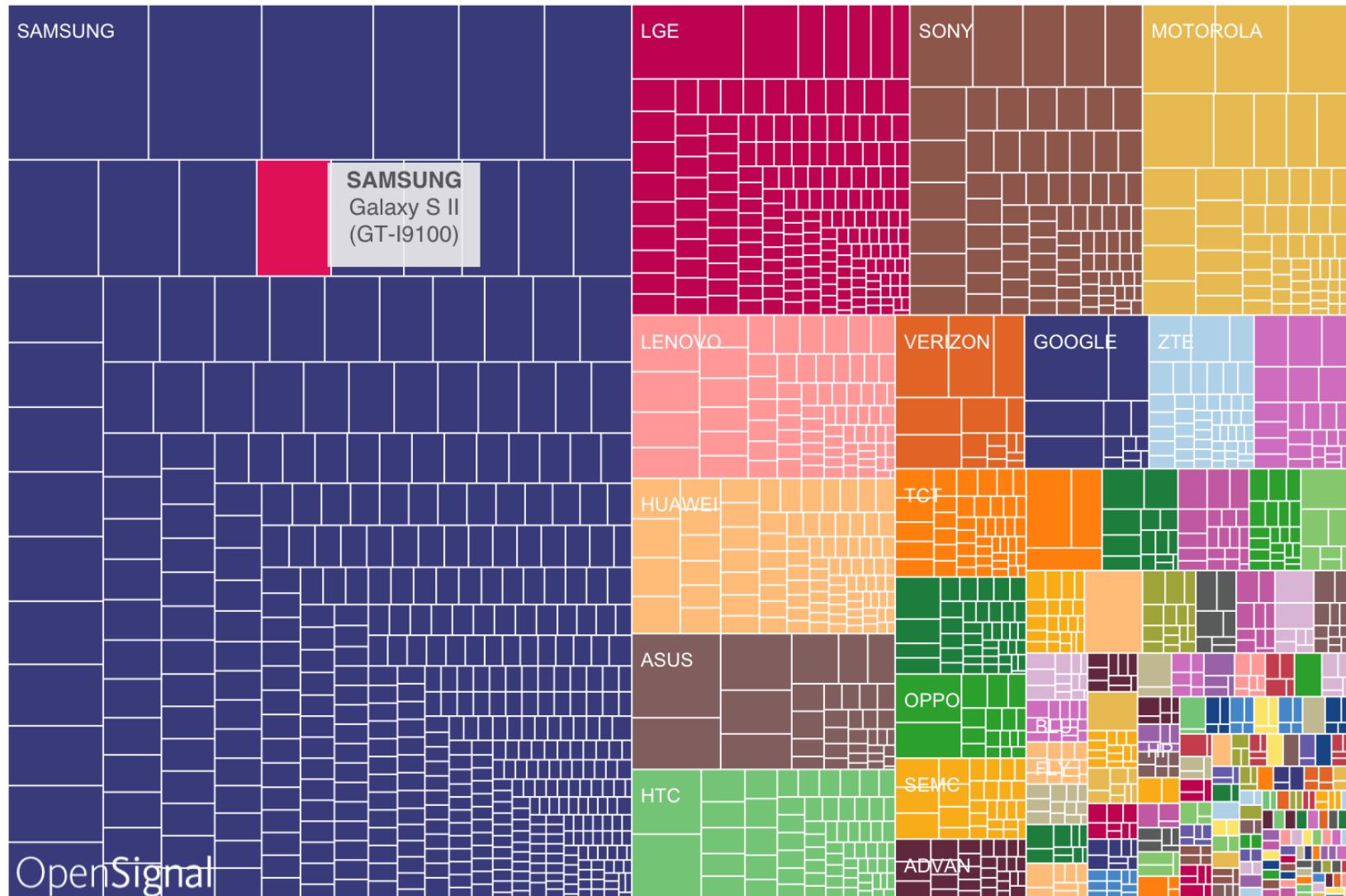


August 2014

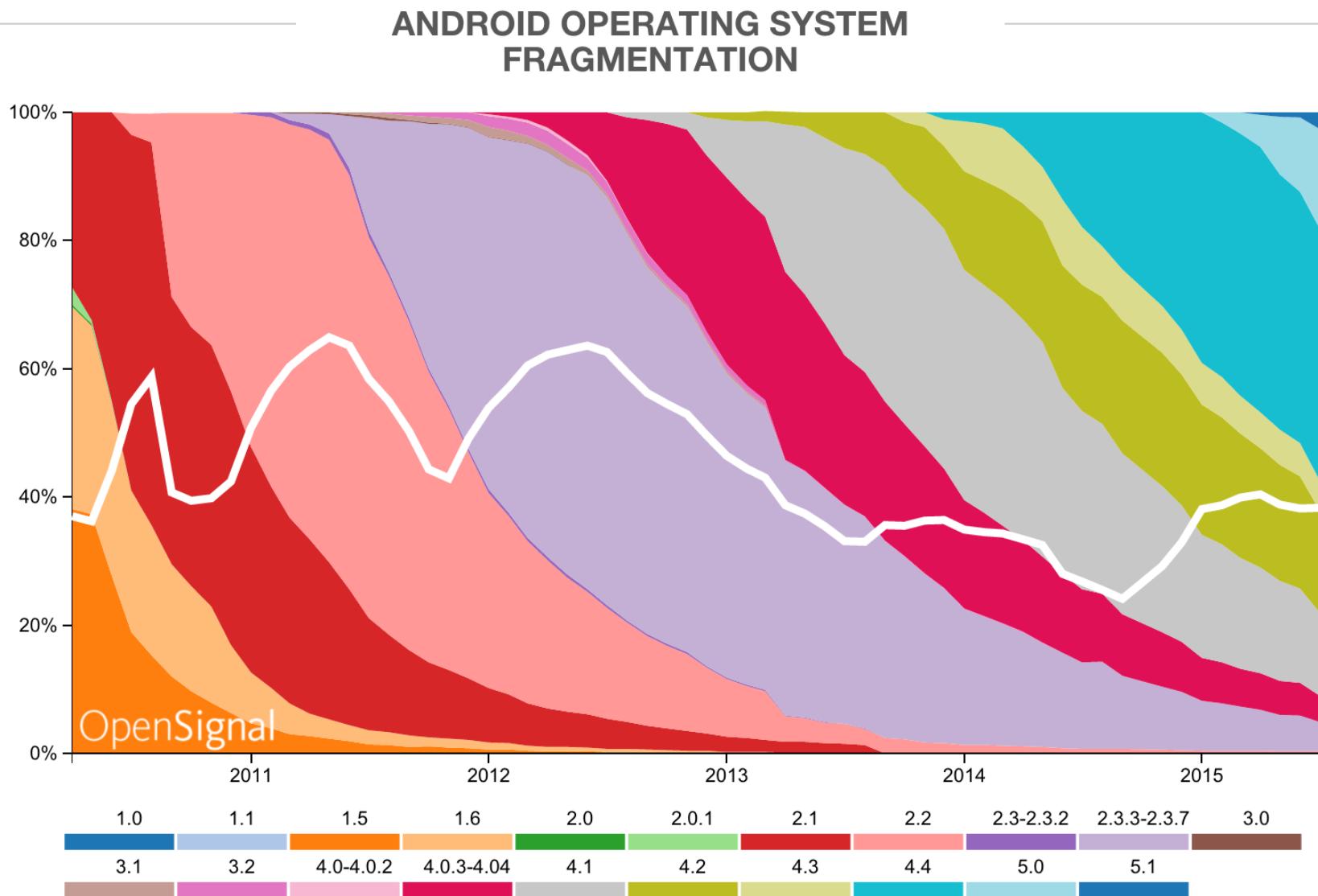
August 2015

Android Fragmentation

BRAND FRAGMENTATION

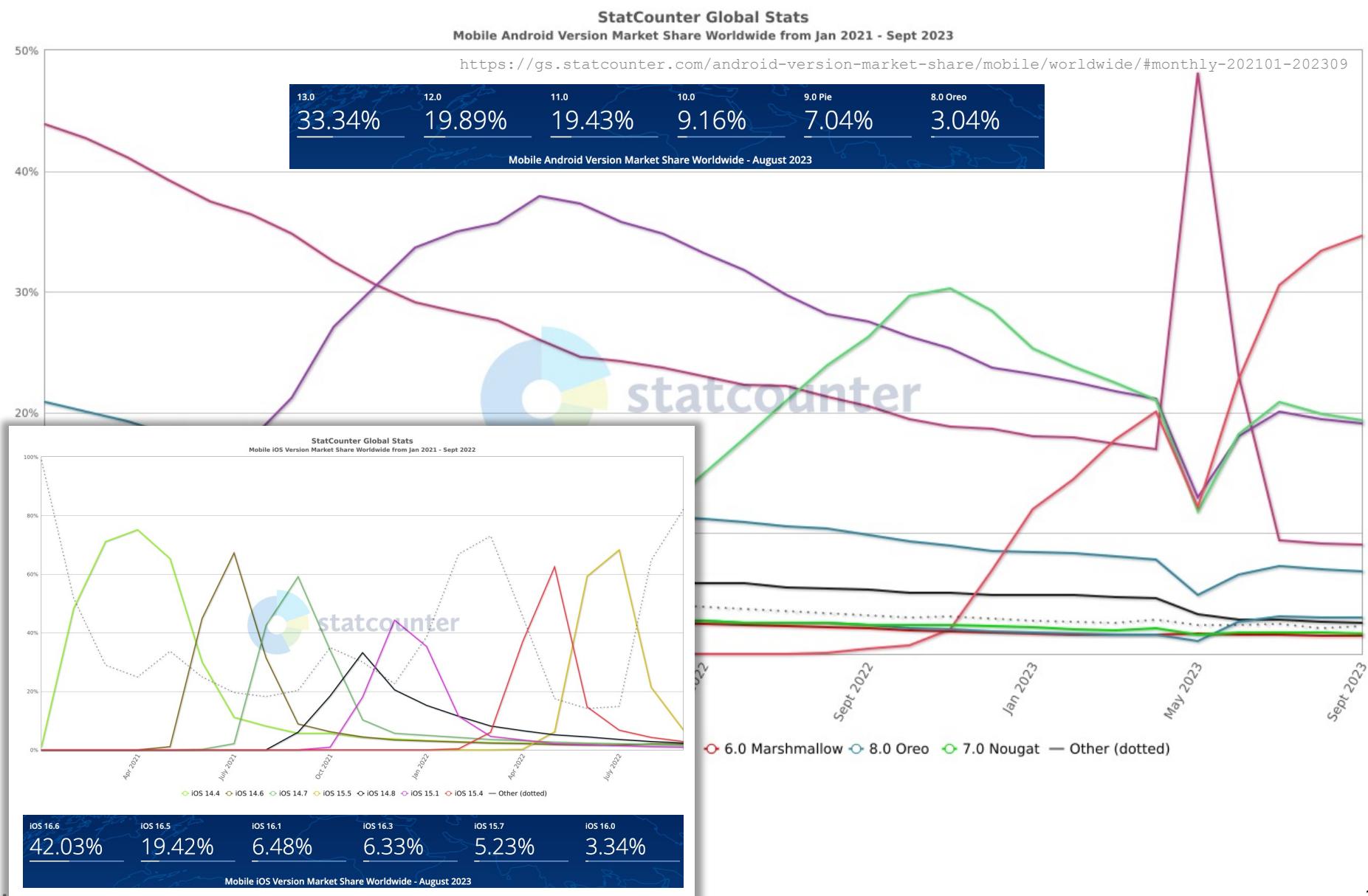


Android Fragmentation



The white line shows the market share of the leading API level at any time

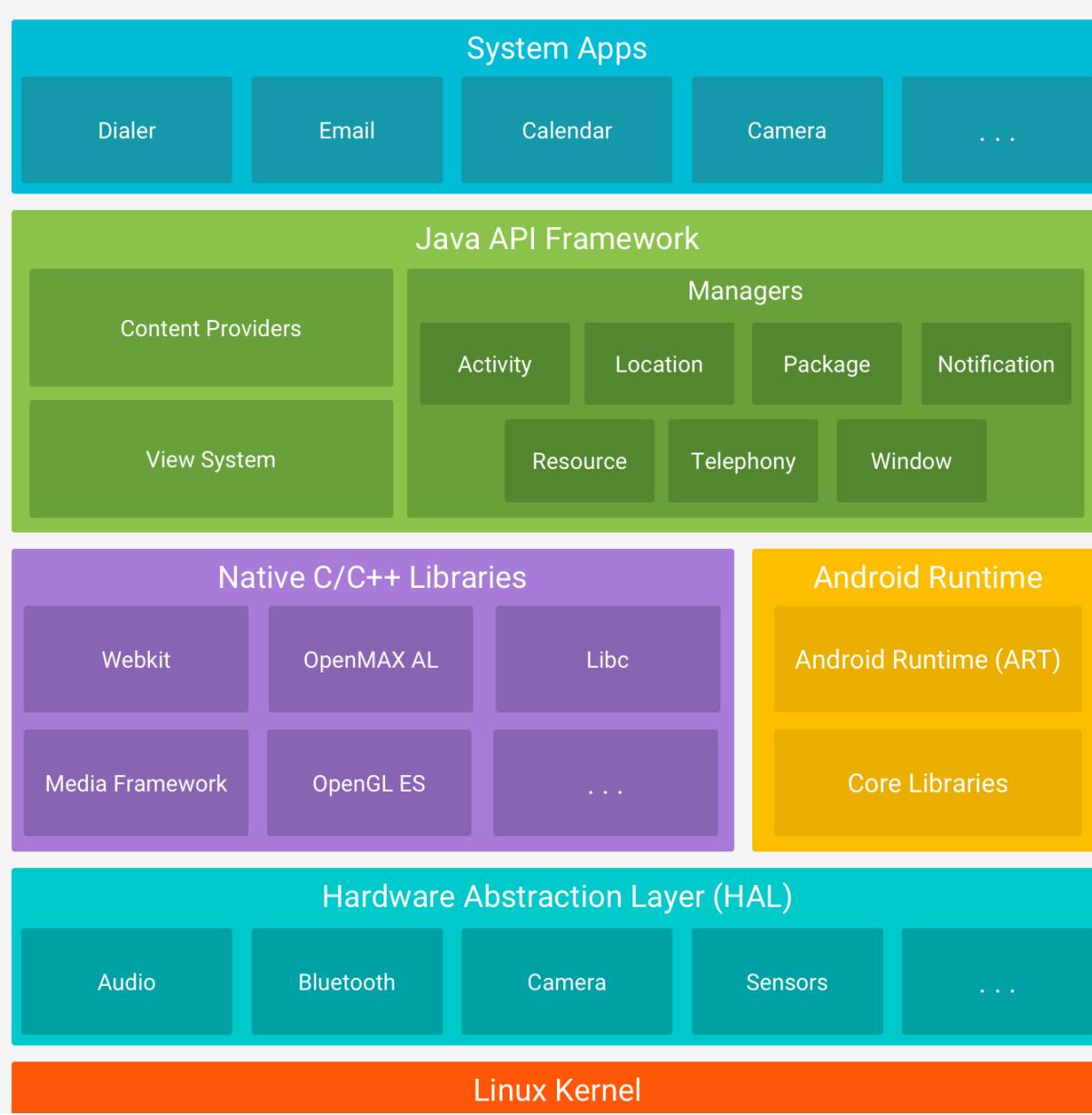
Android Fragmentation



Android architecture

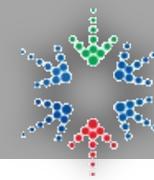


Android architecture



Android development

- Java, Kotlin and C/C++
 - A SDK is provided (Android SDK)
 - IDE: Android Studio, based on IntelliJ by JetBrains
 - Includes emulators for the various versions of Android
- Application distribution
 - packages ".apk"
 - For more recent versions it is mandatory to use bundles ".aab"
 - Google Play Store and other “parallel” markets
 - Packages copied directly to the cell phone can be installed
 - Google Play Store registration has a \$25 one-time fee
 - Fee of 30% of the price of each application sold
 - Free applications are not subject to any fees

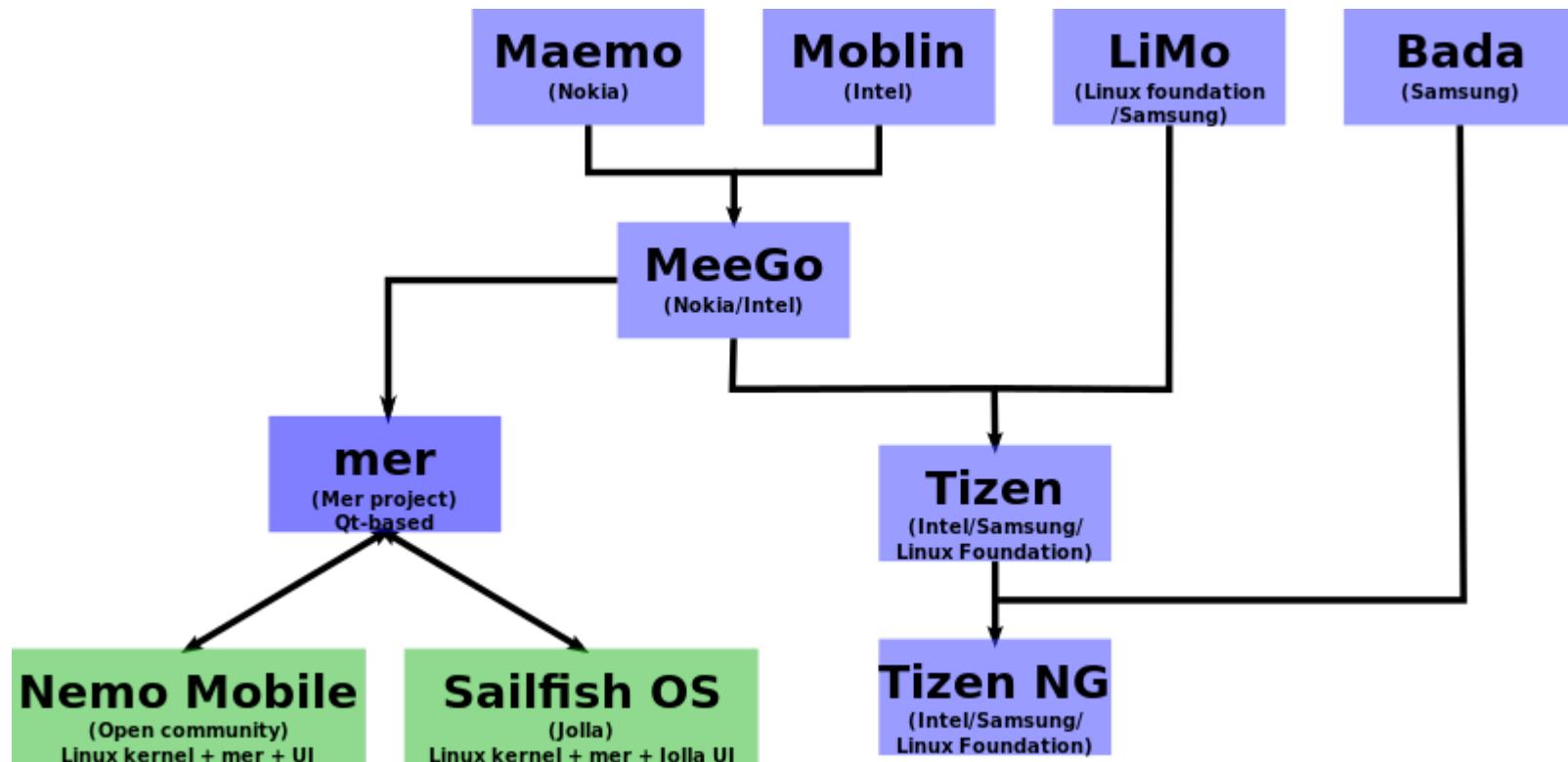


- LiMo – *Linux Mobile*
- Management and development by the *LiMo Foundation*
- Essentially focused on *middleware*
- The platform is not *open source* but it is all based on *open source modules*
- Programming/development technologies
 - Java
 - HTML + Javascript
 - C/C++
 - Flash



Tizen , Sailfish ,...

- LiMo + Meego + ... => Tizen



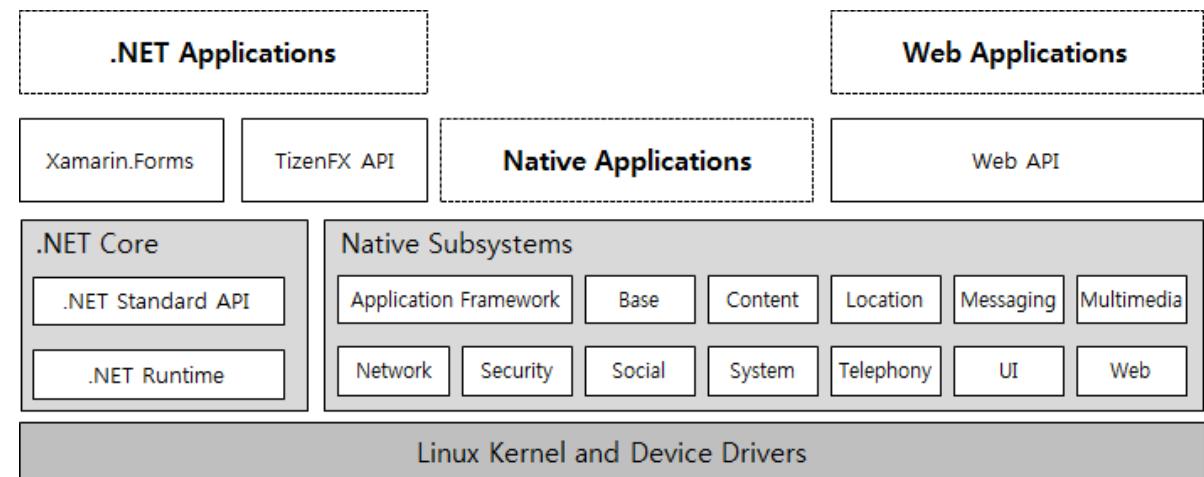
Sailfish OS



- Jolla devices
- Development carried out in:
 - QML (Qt Framework)
 - C++

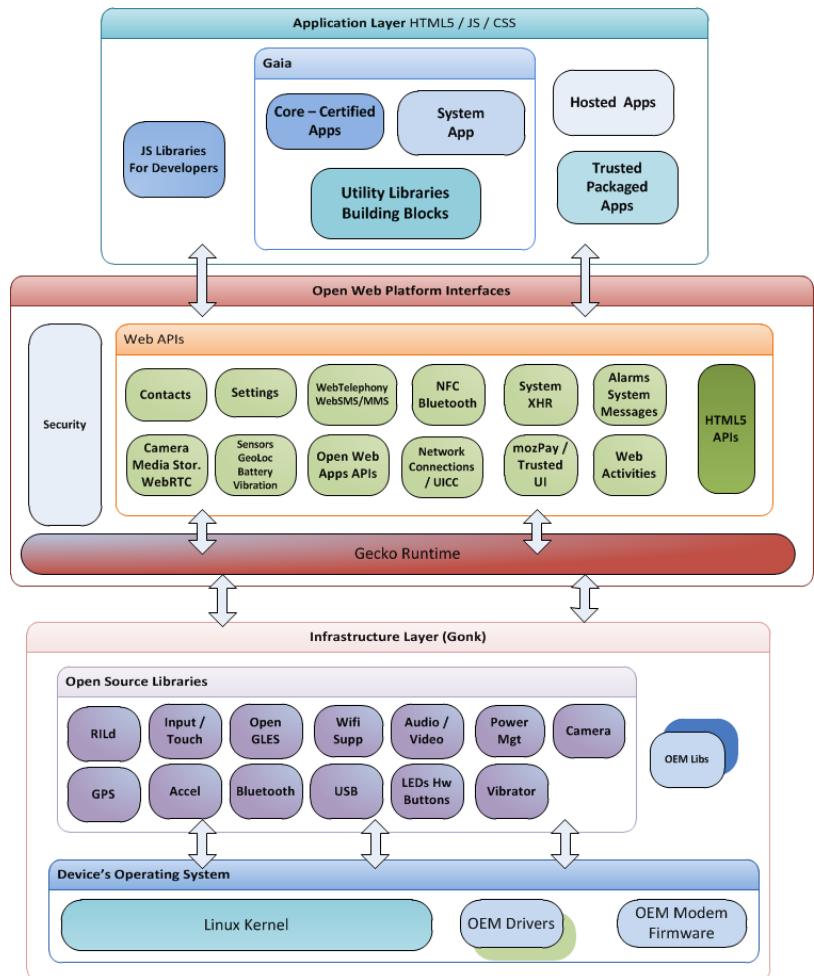


- Project supported by the Linux Foundation
- Development based on
 - Linux kernel
 - GNU C libraries
- Applications developed using
 - Web (HTML5, CSS, JavaScript)
 - Native
 - .NET Applications (C#)



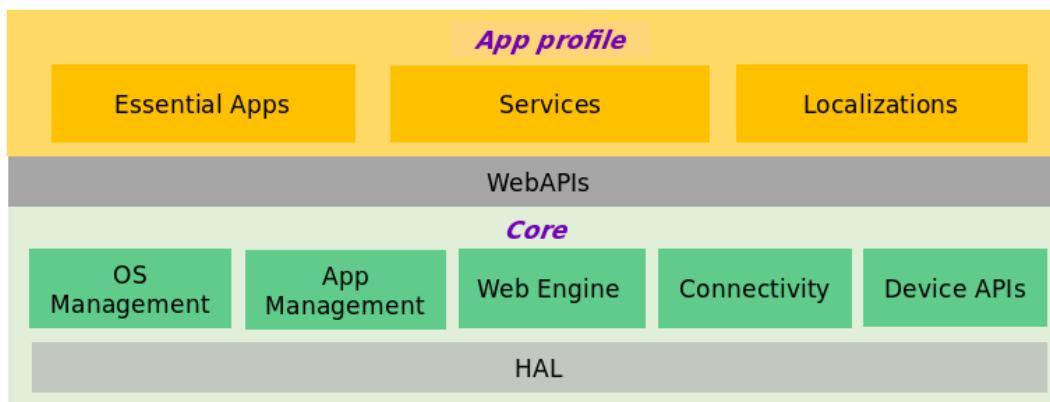
FirefoxOS

- Mainly web-oriented system
- Use of existing Web standards to provide applications
 - HTML5
 - JavaScript
- Use WebAPIs to access resources available on the hardware
- 1st version: August 2012
- Latest version: May 2016 (version 2.6)



KaiOS

- Linux-based
- Designed for lower-cost cell phones, normally with associated keyboards
- 1st version: March 2017
- Latest version: 3.1 (March 2022)



Cross-platform applications

- Main goal
 - Develop only one version of the application that will run on different operating systems
 - Faster development



Cross-platform

- Benefits
 - Same development language for all systems
 - It is not necessary to have specialized development teams for each system
 - Teams focused on providing new features rather than adapting to different systems
 - Application support made easy
 - Larger target audience
- Disadvantages
 - Possibly lower application performance
 - Limited access (possibly) to internal equipment resources and sensors
 - Difficulty adapting interfaces to a greater diversity of screen sizes and interaction systems
 - Related to the fragmentation problem mentioned earlier, although existing platforms try to minimize them

Cross-platform

- Until recently, the main solution was the Java language
- There are currently several cross-platform solutions on the market
 - Cross-platform development environments
 - With native code generation for different platforms, or...
 - With object code generation that runs in the context of a pre-installed framework on devices
 - Based on the capabilities of Javascript and HTML5
 - Web Applications
 - Hybrids (native + web)

