

## *Lecture 11*

### Market Overview of Mobile Operating Systems and Security Aspects

Mobile Business I (WS 2020/21)

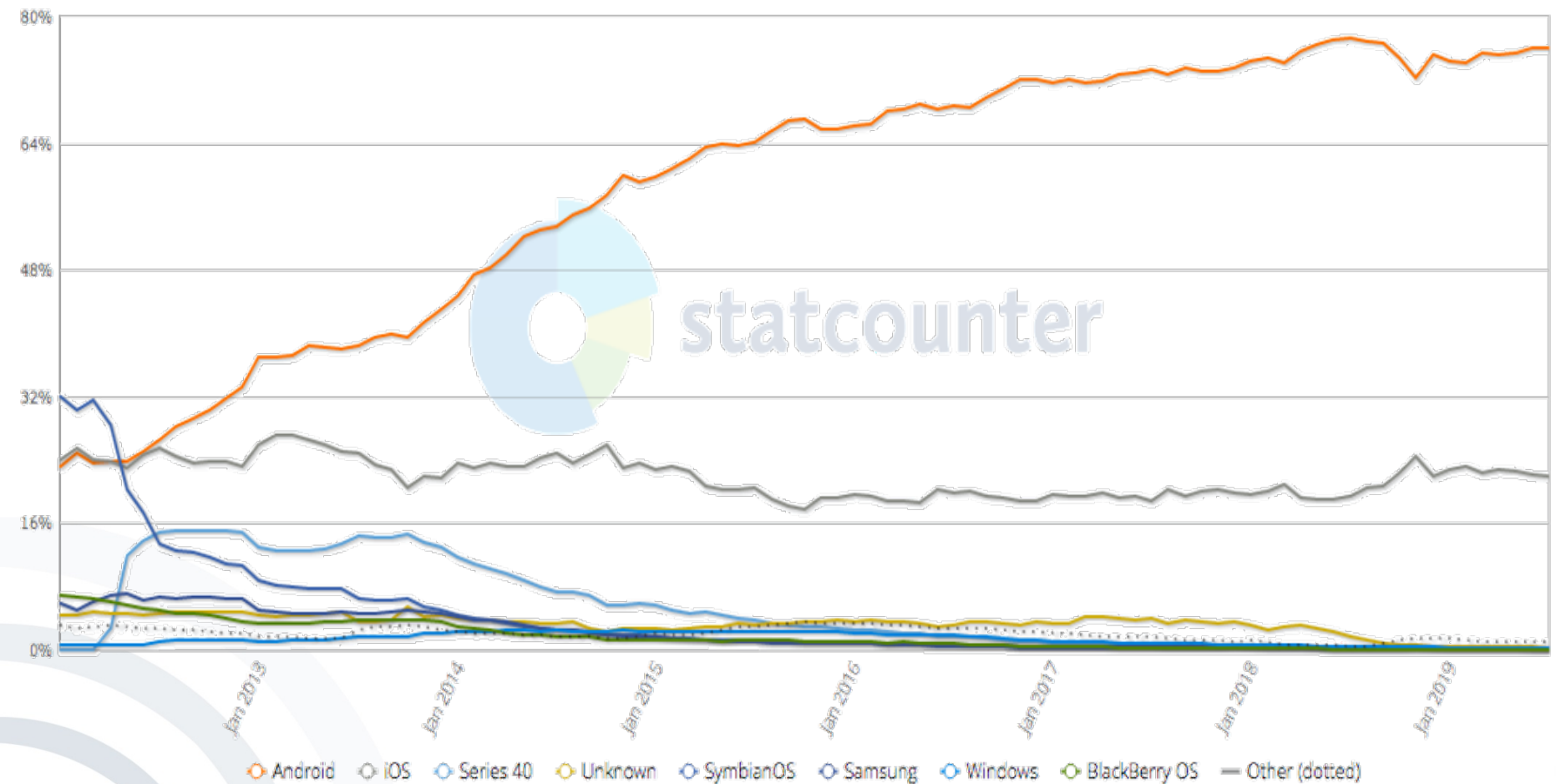
Prof. Dr. Kai Rannenberg

Chair of Mobile Business & Multilateral Security  
Goethe University Frankfurt a. M.



- The market for mobile devices and mobile OS
- Mobile OS unavailable to other device manufacturers
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  - KaiOS
  - HarmonyOS
- Threats, attacks and countermeasures
  - Threats and attacks
  - Countermeasures

# Worldwide smartphone sales to end users by operating system (2012-2019)

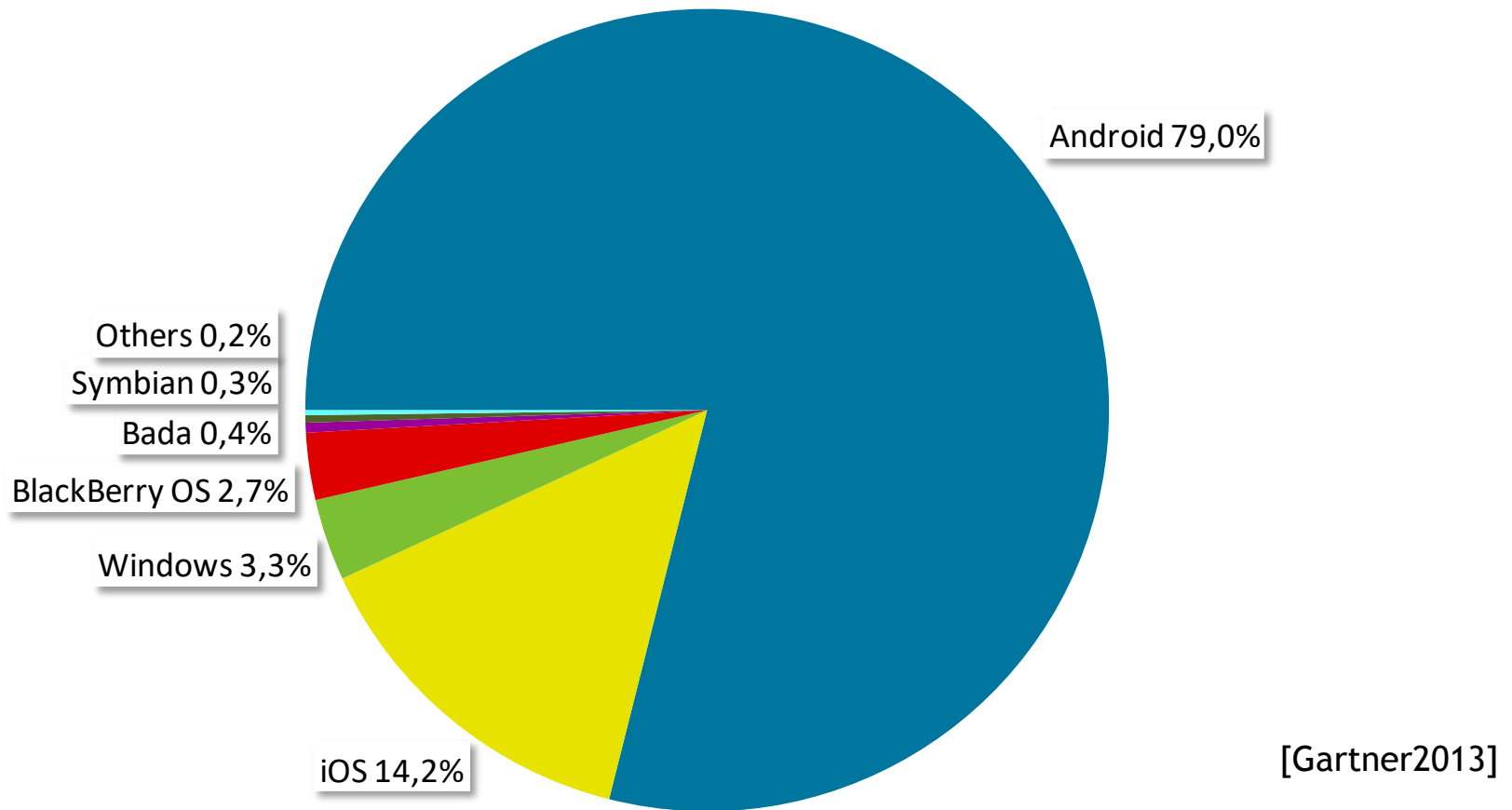


# Worldwide smartphone sales to end users by operating system (2017/18)

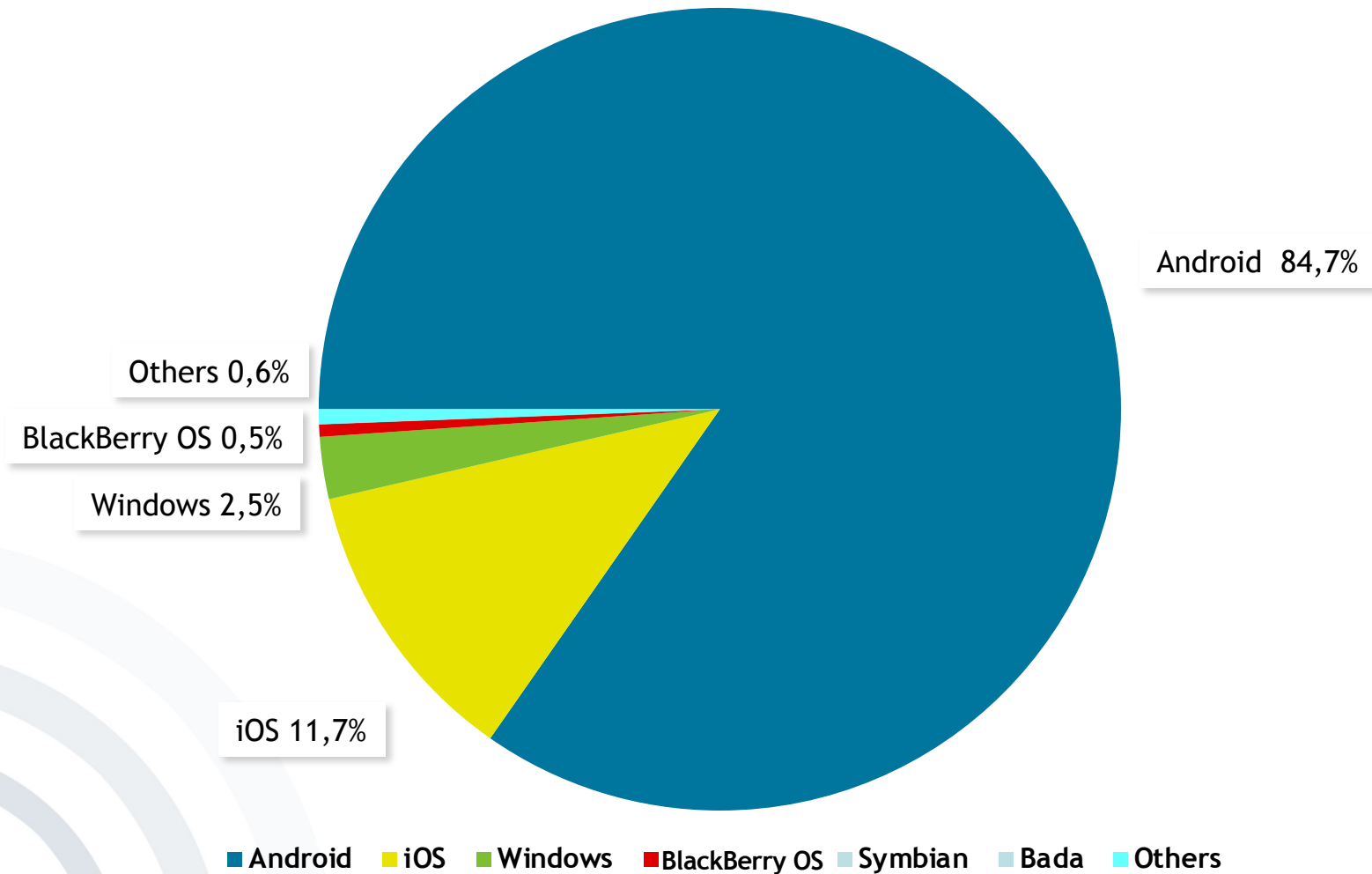
Operating System	1Q18 Units	1Q18 Market Share (%)	1Q17 Units	1Q17 Market Share (%)
Android	329,313.9	85.9	325,900.9	86.1
iOS	54,058.9	14.1	51,992.5	13.7
Other OS	131.1	0.0	607.3	0.2
<b>Total</b>	<b>383,503.9</b>	<b>100.0</b>	<b>378,500.6</b>	<b>100.0</b>

Operating System	2Q18 Units	2Q18 Market Share (%)	2Q17 Units	2Q17 Market Share (%)
Android	329,503.4	88.0	321,848.2	87.8
iOS	44,715.1	11.9	44,314.8	12.1
Other OS	112.1	0.0	433.1	0.1
<b>Total</b>	<b>374,330.6</b>	<b>100.0</b>	<b>366,596.1</b>	<b>100.0</b>

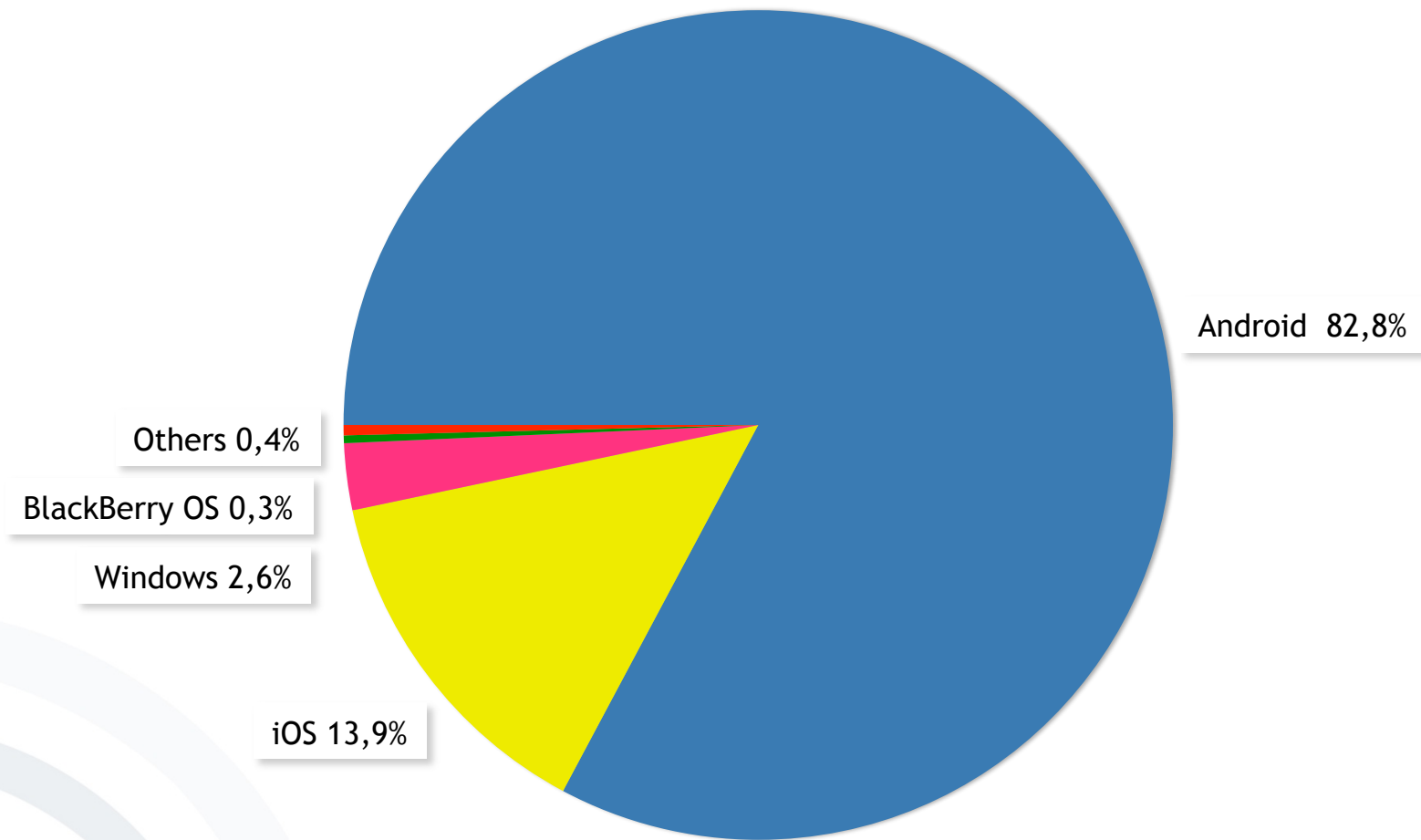
# Worldwide smartphone sales to end users by operating system (Q2 2013)



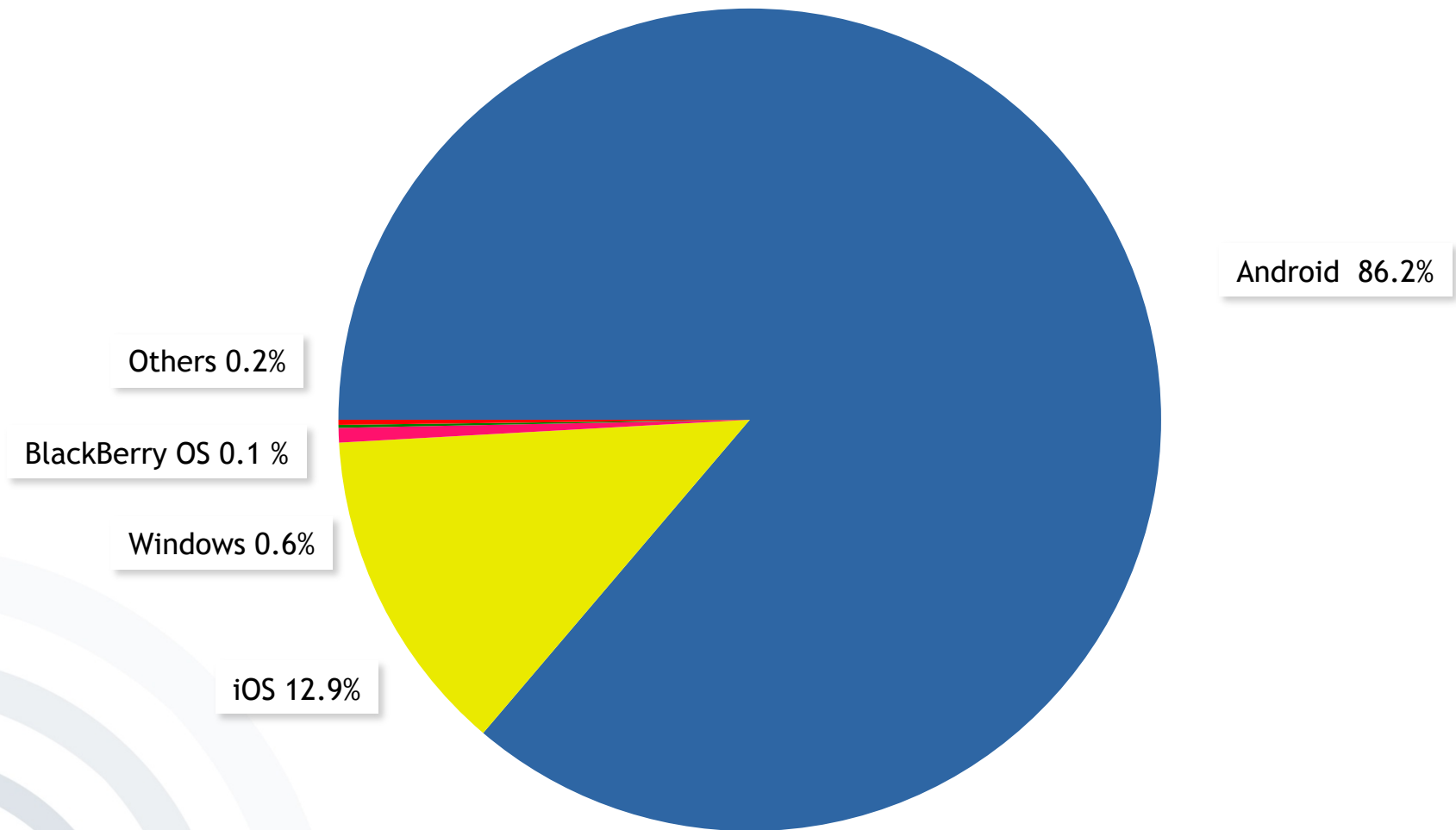
# Worldwide smartphone sales to end users by operating system (Q2 2014)



# Worldwide smartphone sales to end users by operating system (Q2 2015)

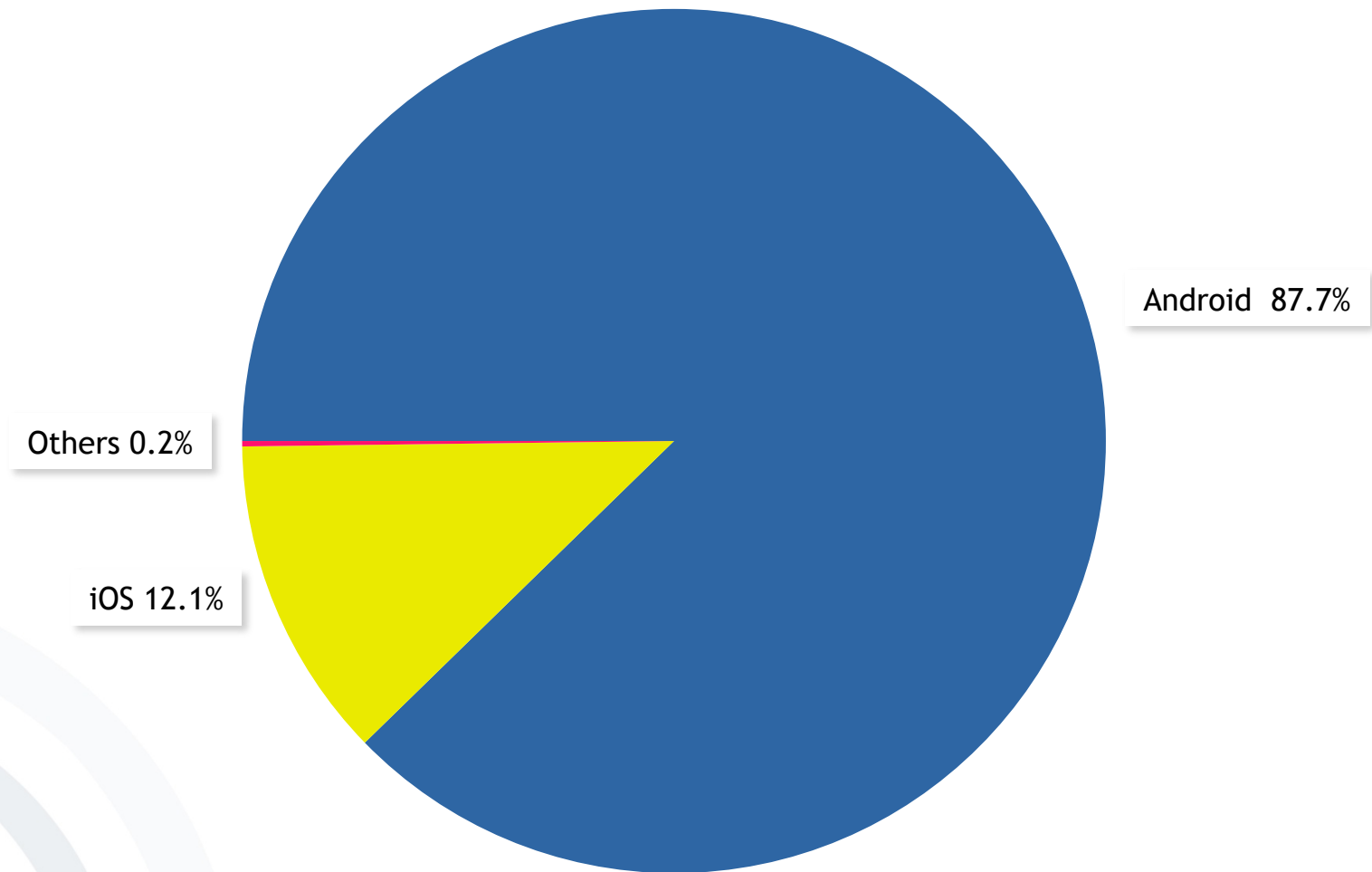


# Worldwide smartphone sales to end users by operating system (Q2 2016)

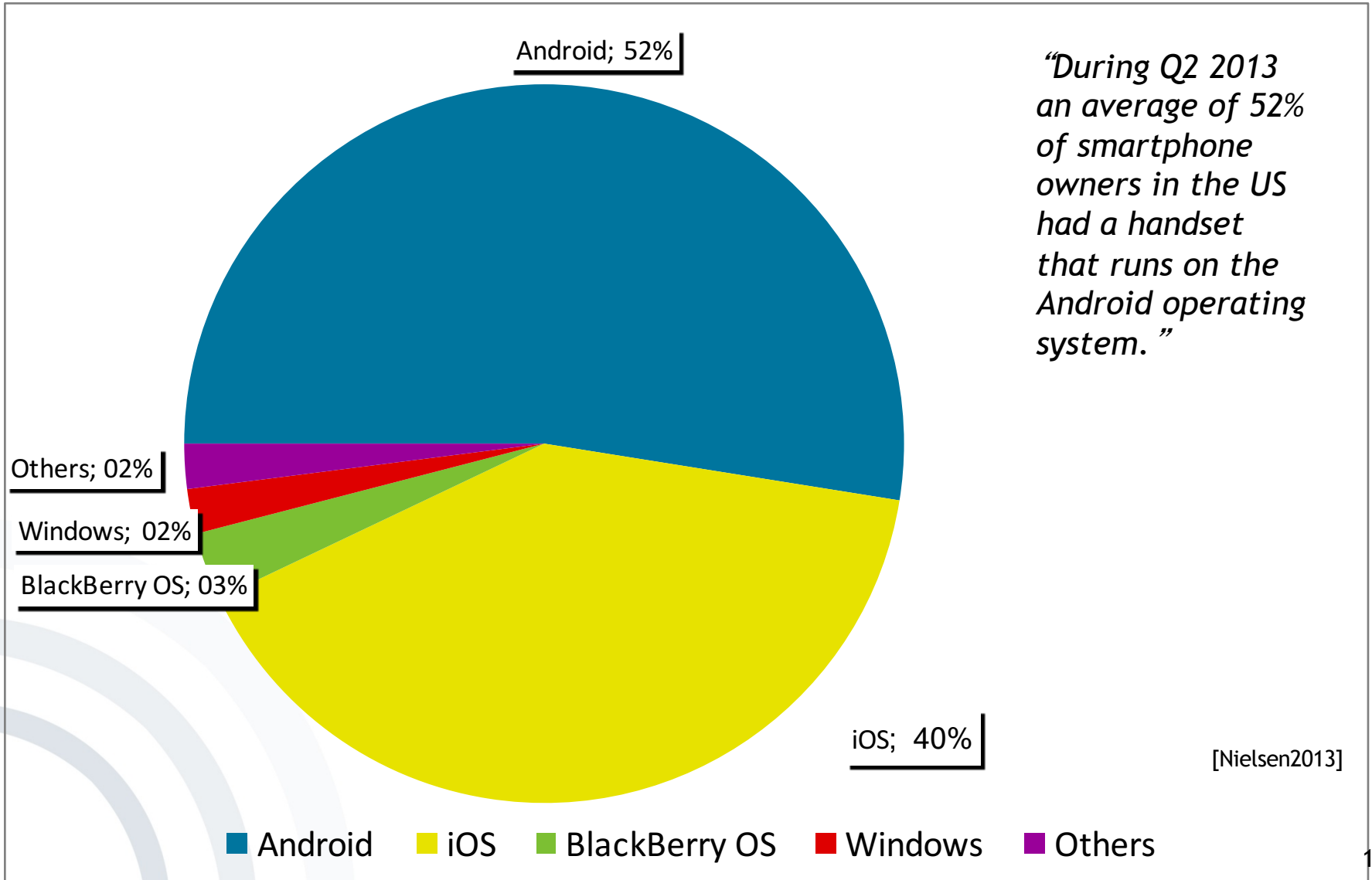




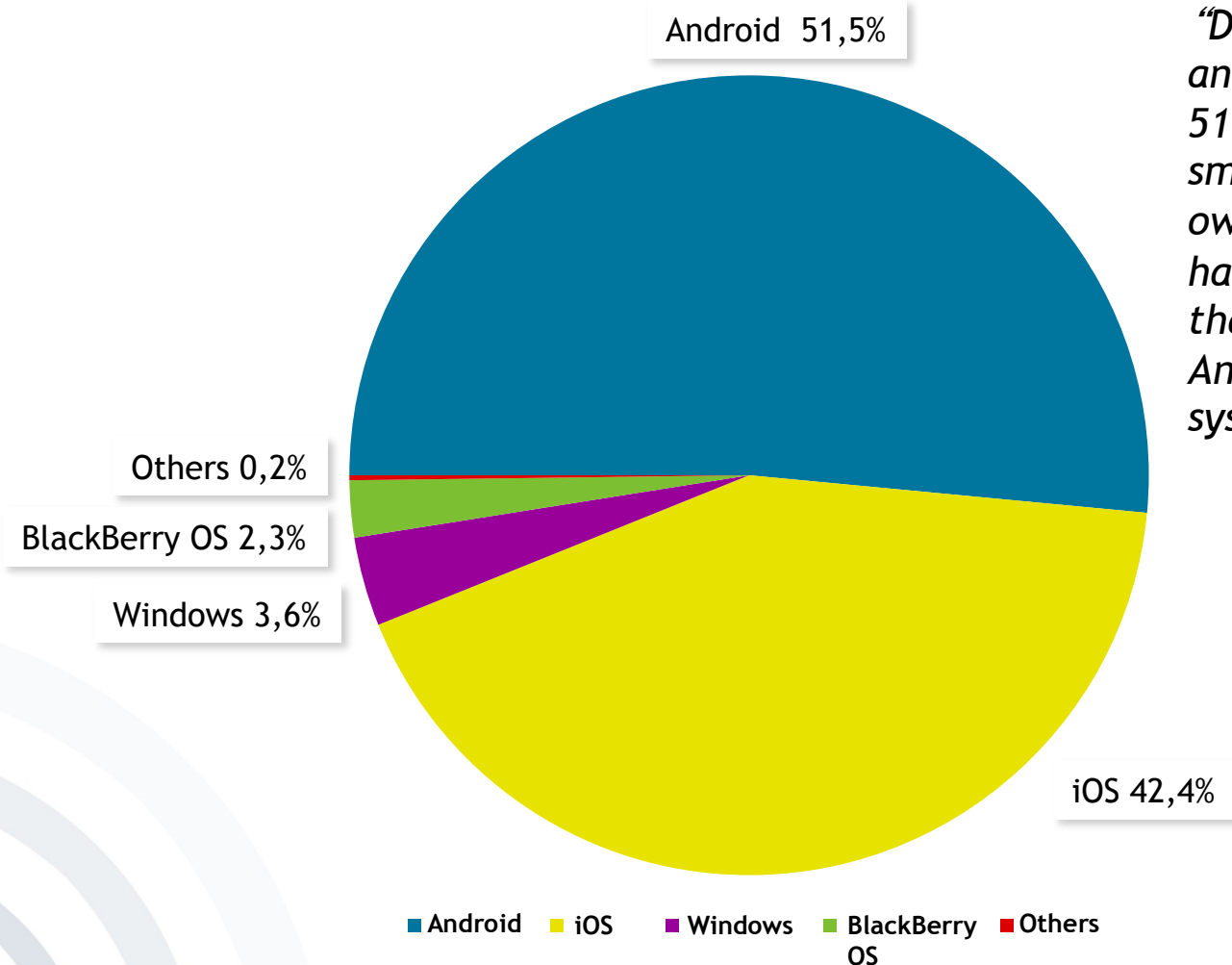
# Worldwide smartphone sales to end users by operating system (Q2 2017)



# US installed smart phone base by operating system(Q2 2013)

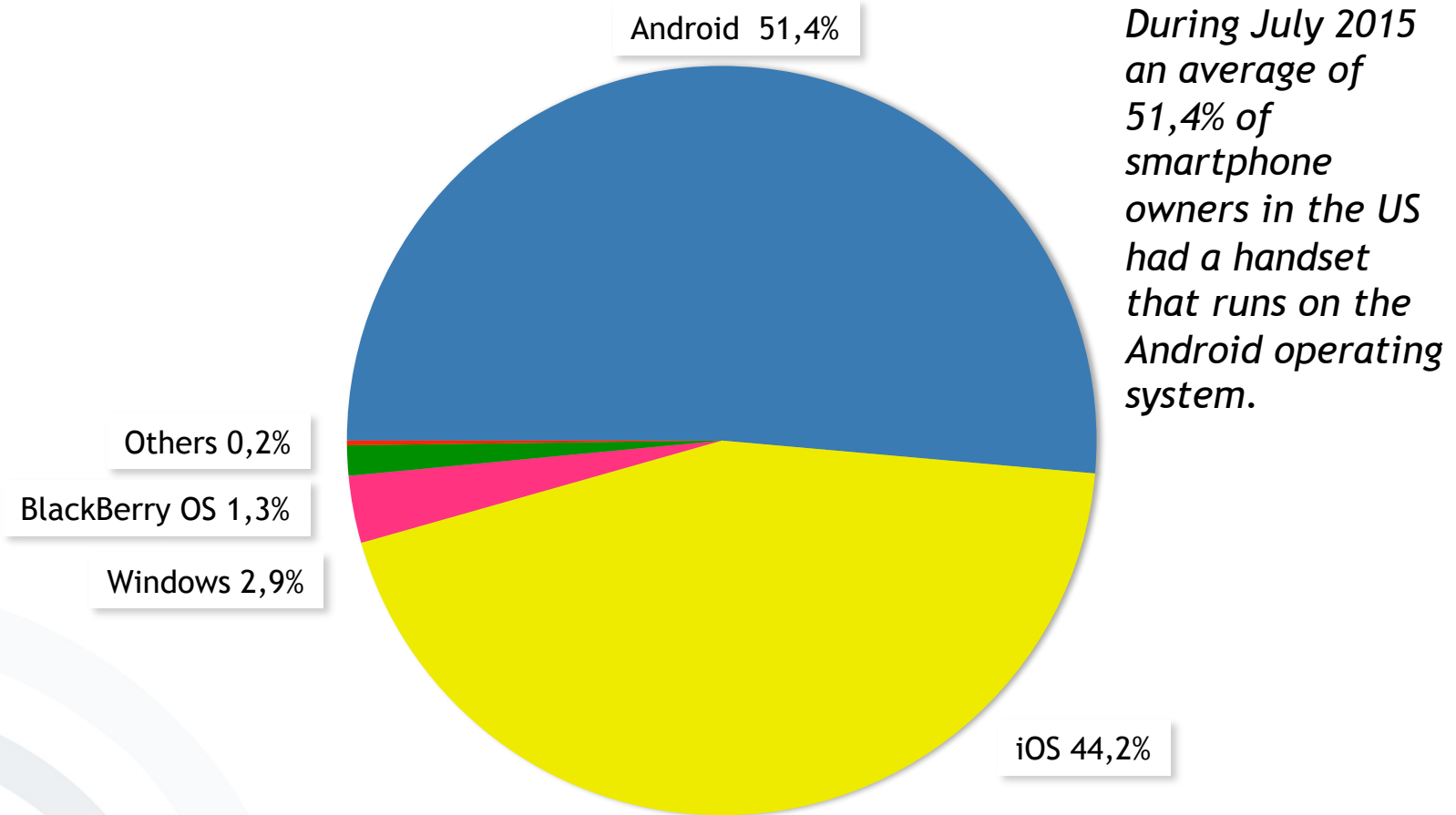


# US installed smart phone base by operating system (July 2014)



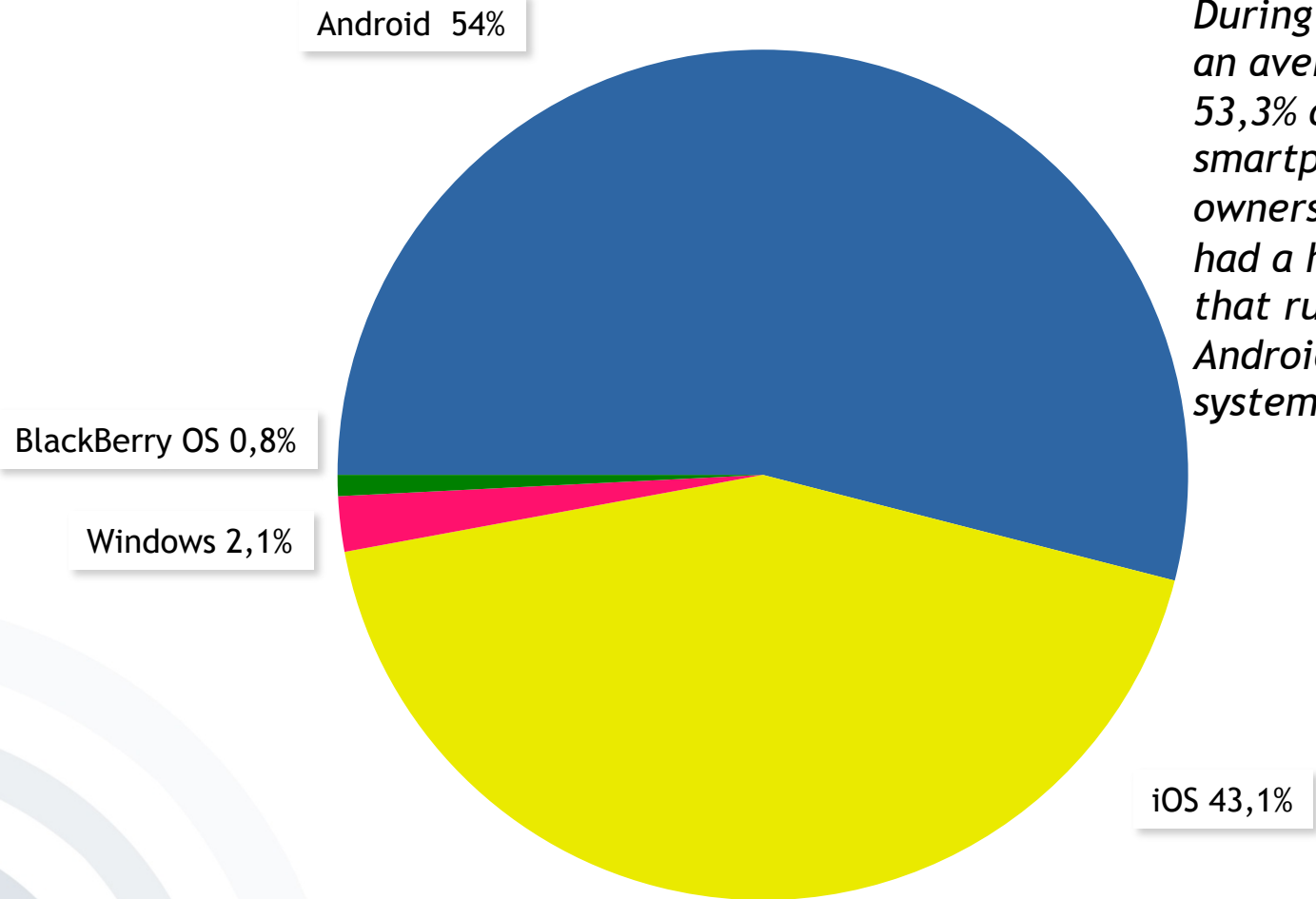
*“During July 2014 an average of 51,5% of smartphone owners in the US had a handset that runs on the Android operating system.”*

# US installed smart phone base by operating system (July 2015)



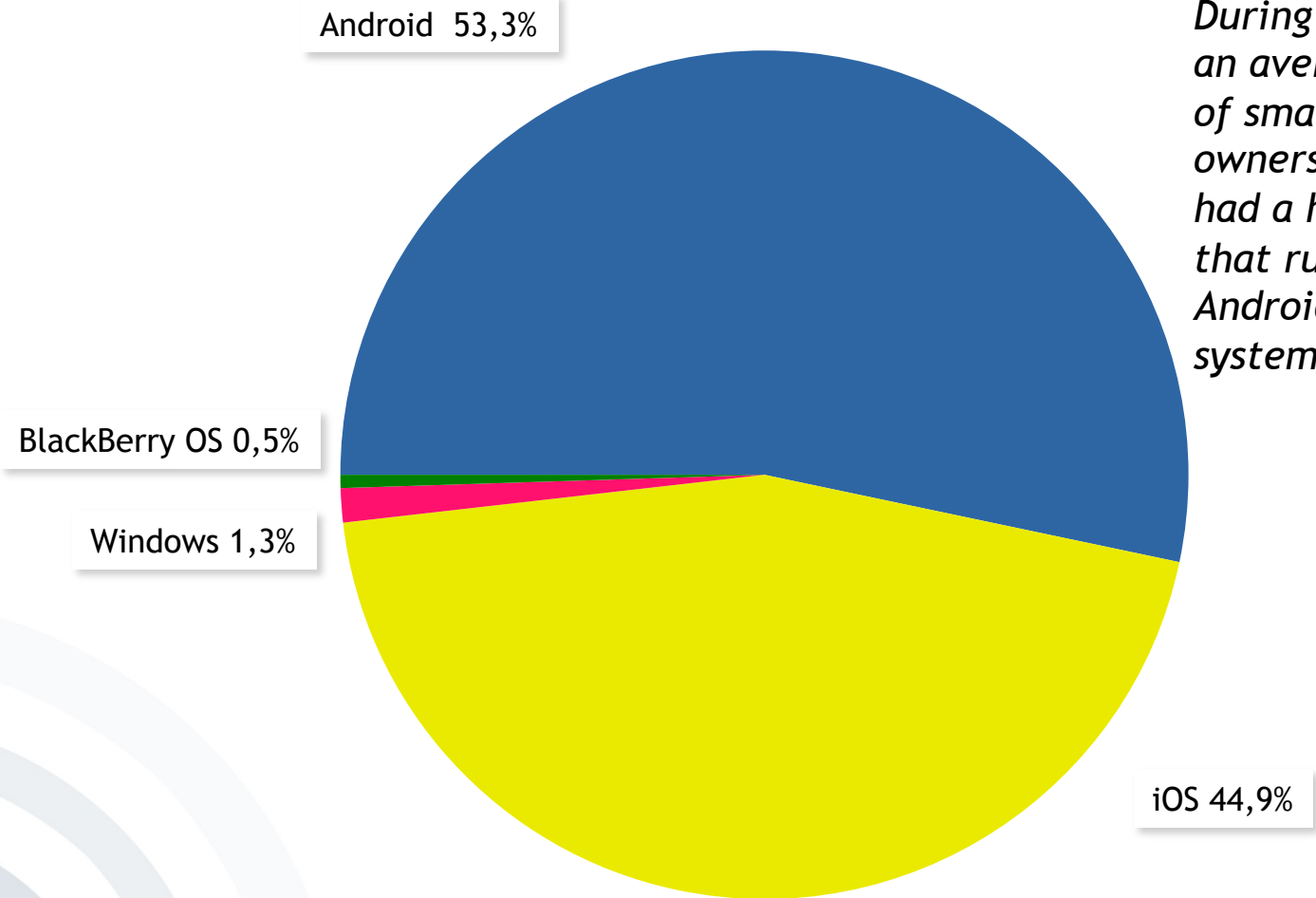
# US installed smart phone base by operating system (July 2016)

*During July 2016  
an average of  
53,3% of  
smartphone  
owners in the US  
had a handset  
that runs on the  
Android operating  
system.*



# US installed smart phone base by operating system (June 2017)

*During June 2017  
an average of 54%  
of smartphone  
owners in the US  
had a handset  
that runs on the  
Android operating  
system.*



# Worldwide smartphone sales to end users by operating system Q2-2016 vs. Q2-2015 vs. Q2-2014

In 1.000 Units

Operating System	2Q16 Units	2Q16 Market Share (%)	2Q15 Units	2Q15 Market Share (%)	2Q14 Units	2Q14 Market Share (%)
Android	296,912.8	<b>86.2</b>	271,010	<b>82.2</b>	243,484	<b>83.8</b>
iOS	44,395.0	<b>12.9</b>	48,086	<b>14.6</b>	35,345	<b>12.2</b>
Windows	1,971.0	<b>0.6</b>	8,198	<b>2.5</b>	8,095	<b>2.8</b>
BlackBerry OS	400.4	<b>0.1</b>	1,153	<b>0.3</b>	2,044	<b>0.7</b>
Others	680.6	<b>0.2</b>	1,229.0	<b>0.4</b>	1,416.8	<b>0.5</b>
<b>TOTAL</b>	<b>344,359.7</b>	<b>100.0</b>	<b>329,676.4</b>	<b>100.0</b>	<b>290,384.4</b>	<b>100.0</b>

# Worldwide smartphone sales to end users by vendor Q2-2017 vs. Q2-2016 vs. Q2-2015

In 1.000 Units

Company	2Q17 Units	2Q17 Market Share (%)	2Q16 Units	2Q16 Market Share (%)	2Q15 Units	2Q15 Market Share (%)
Samsung	82,535.1	22.5	76,743.5	22.3	72,072.5	21.9
Apple	44,314.8	12.1	44,395.0	12.9	48,085.5	14.6
Huawei	35,964.3	9.8	30,670.7	8.9	25,825.8	7.8
Lenovo*	Others		Others		16,405.9	5.0
OPPO	26,092.5	7.1	18,489.6	5.4	Others	
Others	177,327.7	48.4	174,061.0	50.5	167,286.6	50.8
<b>TOTAL</b>	<b>366,234.4</b>	<b>100.0</b>	<b>344,359.7</b>	<b>100.0</b>	<b>329,676.4</b>	<b>100.0</b>



- Big players (originally from neighbouring fields) often have some (sometimes relatively modest) market share due to high investment:
  - Microsoft: Architectures, operating systems
  - Nokia: Feature phones
- Killer Application Champions are very successful for some time until their killer application is also available from the big players:
  - Palm: 1st small and affordable PDA with address book, calendar, and PC connectivity
  - RIM Blackberry: 1st PDA phone with push email

- Due to the limitations of the mobile devices, mobile operating systems also have to cope with the following challenges:
  - Limited device capabilities and resources (storage, memory, processing time, etc.)
  - Usability issues
  - Security and system integrity issues

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- Originally, most mobile phone manufacturers used their own “closed” operating systems for their mobile devices.



- *Palm OS (Garnet OS)*
  - Latest release: Palm OS Cobalt 6.1 in February 2004



- Apple iOS (Unix-based)
  - Latest release: iOS 13.0



- BlackBerry OS
  - Latest release: BlackBerry OS 10.3.3
  - Newer Blackberry models (*PRIV*, *DTEK60*, and *DTEK50*) run on Android



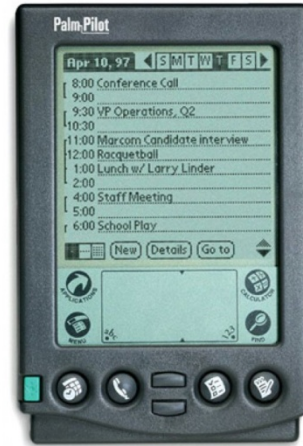
- LuneOS (formerly WebOS, initially developed by Palm, later HP)
  - Latest release: LuneOS Cortado
  - Not to be confused with Palm OS (now: Garnet OS) that was also initially developed by Palm



- Samsung bada
  - Latest release: v2.0, e.g. on Samsung Wave 3 S8600 (discontinued 2013)

- ***Advantage:*** Tend to be not as much affected by malware compared to operating systems available to many external manufacturers
- ***Disadvantage:*** Less flexible, as 3<sup>rd</sup>-party software cannot be easily installed and executed
- Later, more and more platforms switched to more open and interoperable operating systems (e.g. Windows CE, Symbian OS, Android).

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All screens are simulated.

- The operating system is made by *palmsource*
- Several device manufacturers:
  - Palm (e.g. Treo series)
  - Handspring
  - Garmin (navigation devices)
  - Fossil
  - Samsung
  - Sony
  - ...
- Last version 6.1 (Cobalt) - 2004
  - There are no devices using version 6.1 on the market. Most of the devices are equipped with Palm OS 5.4 (Garnet), such as the Tungsten series.





- Communication:
  - IrDA
  - Bluetooth
  - WiFi (IEEE 802.11)
  - GSM/GPRS
  - CDMA
- Support of the TCP/IP network protocol
- Integrated personal information management (PIM)
- Support for several encryption and security algorithms (e.g. RSA, SHA1, RC4)
- Large choice of 3rd party software available
- Long battery life



- 1996: Palm Pilot 1000, first device using Palm OS
- 1998: Palm III using Palm OS v3
- 2000: Palm IIIc, first device using Palm OS and a colour display
- 2003: Palm OS 5
- 2004: Palm OS 6.1 (Cobalt) and Palm OS 5.4 (Garnet)
- 2006: Palm's "*Treo Smartphones*" with Windows Mobile
- Name change to Garnet OS - future versions to be based on the Access Linux platform
- 2010: Hewlett-Packard acquired Palm for \$1,2 billion, name change to HPwebOS
- 2011: HP announced to stop the production of all HPwebOS devices, including smart phones and tablets

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## Apple iOS



- Developed by Apple for iPhone, iPod Touch, iPad, Apple Watch and Apple TV
- Latest release: iOS 14
- iOS derived from Mac OS X, a Unix-based operating system
- Apple does not permit the OS to run on third-party hardware



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- Linux: LiMo (Linux Mobile), Openmoko Linux, Qt Extended (Qttopia)



- Symbian platform

- Latest release: “Nokia Belle Feature Pack 2” for Symbian^3 devices



Android 7.0 Nougat

## Android (by Open Handset Alliance)



- Latest release: 10.0

## Windows Mobile

- Latest release: Windows 10 Mobile 1703 (10.0.15063.608)

## Windows Phone

- Latest release: Windows Phone 8.1

## Maemo (by Nokia) → MeeGo (by Nokia, Intel) → Sailfish OS (by Jolla)

- Latest release: Sailfish OS 2.1.0.1 (Iijoki) (April 2017)



## Tizen (by Samsung, Intel, Linux Foundation)



- Latest release: 3.0 (May 2017)

## Firefox OS (by non-profit organisation Mozilla)



- Latest release: 2.2.0 (April 2015) - Cancelled in September 2016

## KaiOS (by Boot to Gecko)



- Latest release: 2.6.0 (May 2019)

## HarmonyOS (by Huawei)

- Launched in August 2019



= Linux-based



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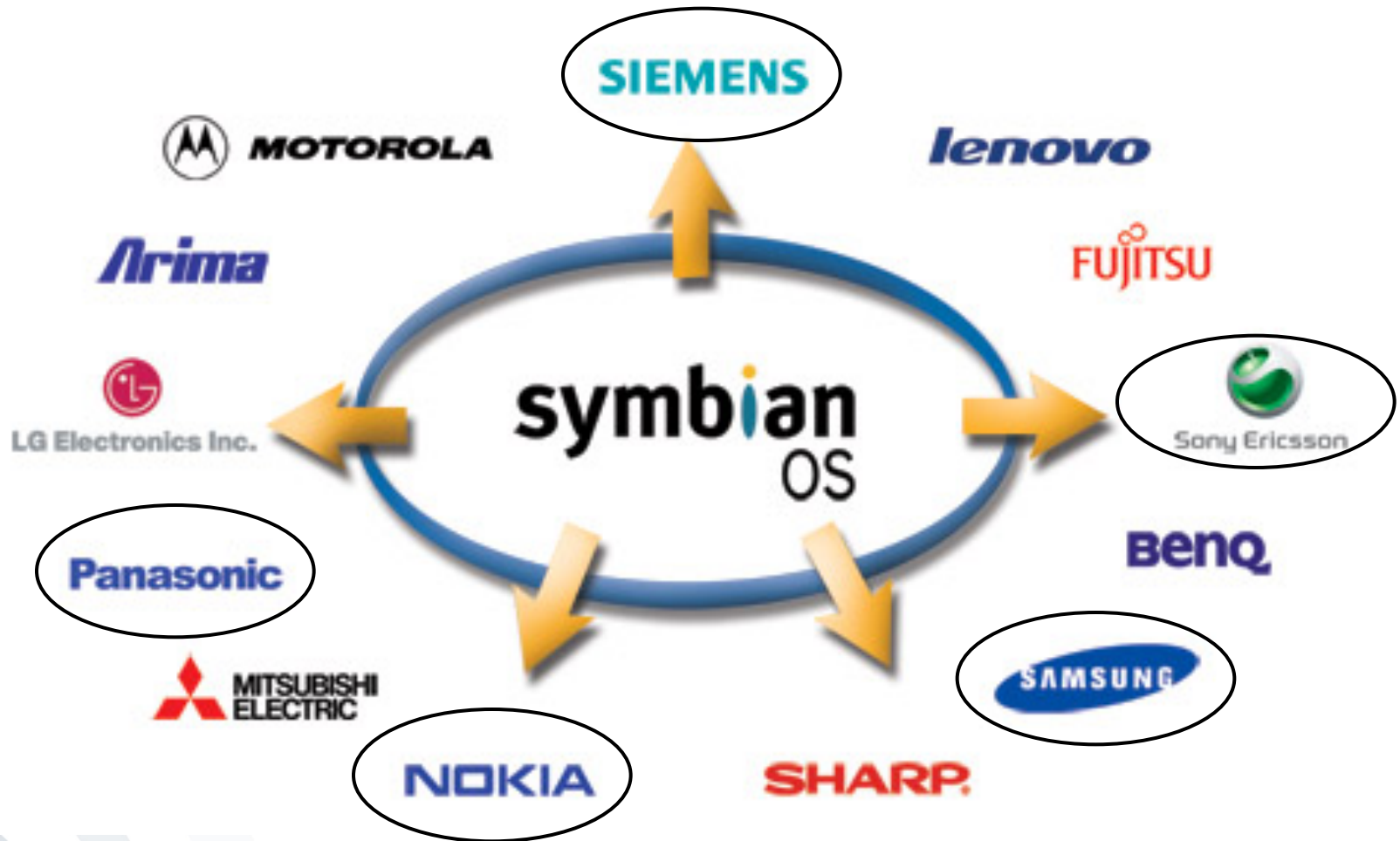


# symbian

Symbian OS - the mobile operating system







In 2006, Symbian was owned by 

[Symbian2006]

- Symbian was founded as a privately owned company in June 1998.
- Owner: Ericsson, Nokia, Panasonic, Psion, Samsung Electronics, Siemens and Sony Ericsson
- „Open“ Symbian OS telephones were available since 2001
  - „Open“: It is possible to install 3<sup>rd</sup>-party applications.
  - Beginning of 2001: Nokia 9210 Communicator
- 2004: Symbian OS 8.0
- 2005: Symbian OS 9.1 (S60 3rd edition)
- 2006: Symbian OS 9.3 released, extending the OS with WiFi and HSDPA
- 2007: Symbian OS 9.4 (S60 5th edition) = Symbian^1 („Symbian One“)
- 2008 June: **Symbian Foundation** announced
- 2008 December: **Nokia** buys Symbian Ltd. and becomes the **major contributor** to code of Symbian platform



- 2009: Symbian Foundation founded  
Symbian platform successor to Symbian OS and Nokia Series 60.
- 2010: Symbian OS 9.5 (Symbian^3). Nokia N8 first smartphone to run Symbian^3.
- 2010 November: Due to a lack of support from funding members, **Symbian Foundation transition into a licensing-only organisation**. Nokia takes over governance of the Symbian platform.
- 2011: Symbian Anna and Symbian Belle as an update to Symbian^3
- 2011 February: Nokia collaborates with Microsoft and adopts Windows Phone 7 for their smartphones. **Relevance of Symbian platform, especially in the mobile app market, drops significantly**. Market share in sharp decline, notably in the high priced smartphone segment
- 2011 September: Nokia **outsources** Symbian software development and 2,300 employees to Accenture
- 2012: Symbian Belle renamed to Nokia Belle
- 2013: Nokia Belle Feature Pack 2 (latest version)
- 2014 January: No new applications can be published in the Nokia Store (store.ovi.com) [Nokia2013]
- 2015 January: Nokia Store discontinued and partially transferred to Opera Mobile Store.



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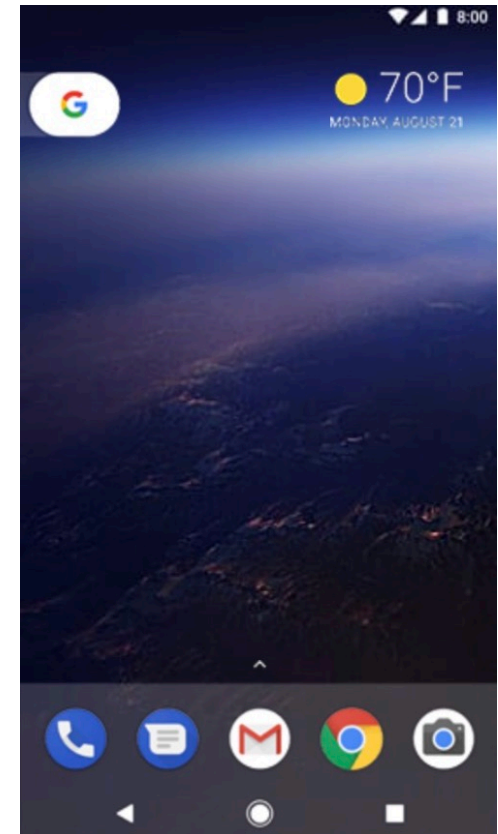


- Linux is an „*Open Source*“ operating system.
- Only a limited amount of device manufacturers were offering devices with a pre-installed Linux solution (e.g. Motorola, NEC, Panasonic).
- However, there are several Linux distributions, such as  $\mu$ CLinux, that can be installed on existing devices (e.g. iPAQ).
- Motorola, as one of the major mobile phone manufacturers, was using Linux as (one) of their OS platforms.



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- Google and other members of the **Open Handset Alliance** collaborated to develop and release Android.
- Open Handset Alliance (OHA) established in 2007
- Android based on modified version of Linux kernel
- October 2008: First commercially available phone running Android: T-Mobile G1
- September 2019: Version 10.0





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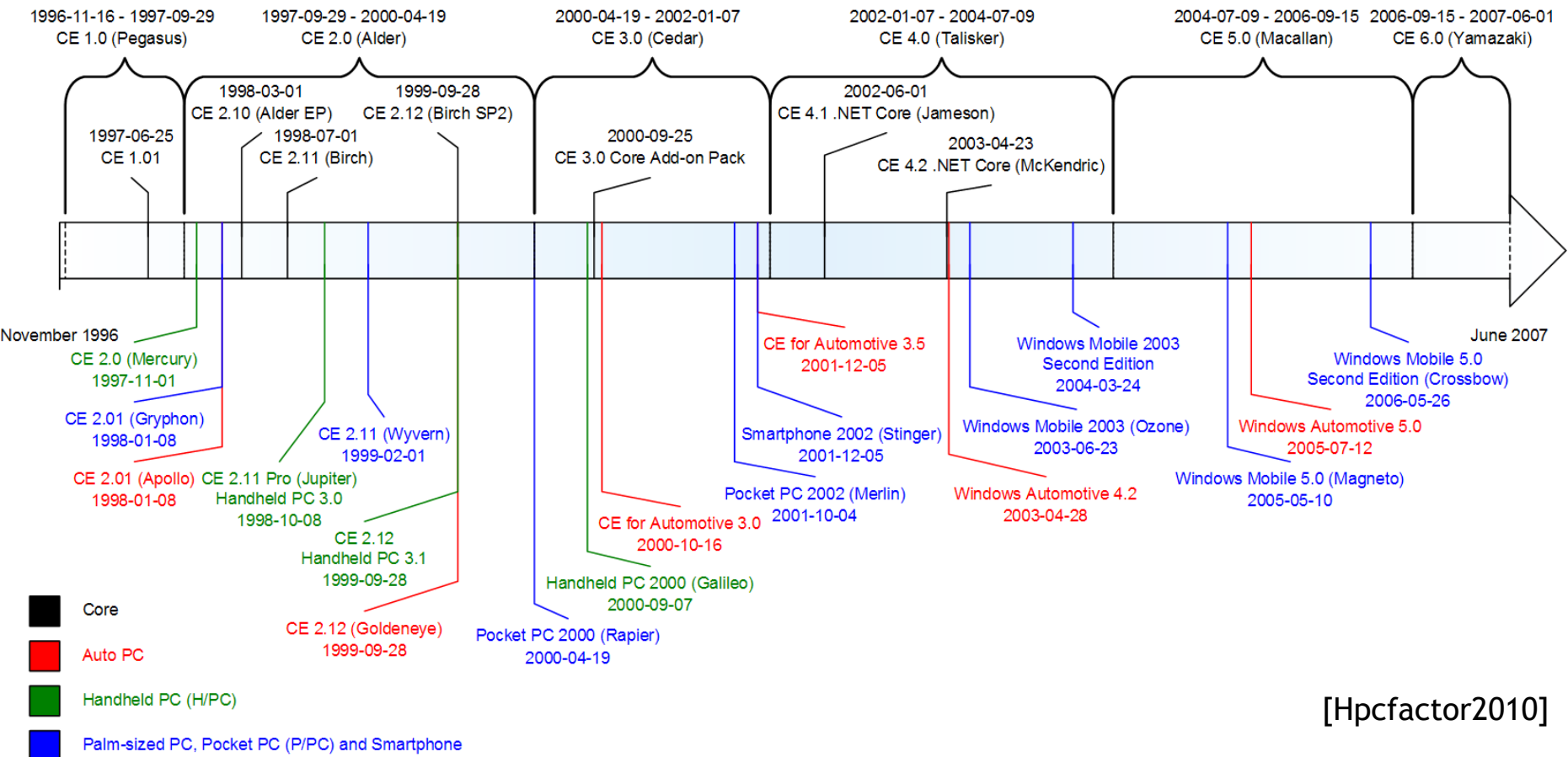


All screens are simulated.



## Windows CE Timeline

Source: "A Brief History of Windows CE" (<http://www.hpcfactor.com/support/windowsce/>), HPC:Factor, retrieved May 21, 2007



[Hpcfactor2010]

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# Microsoft Windows Phone 7

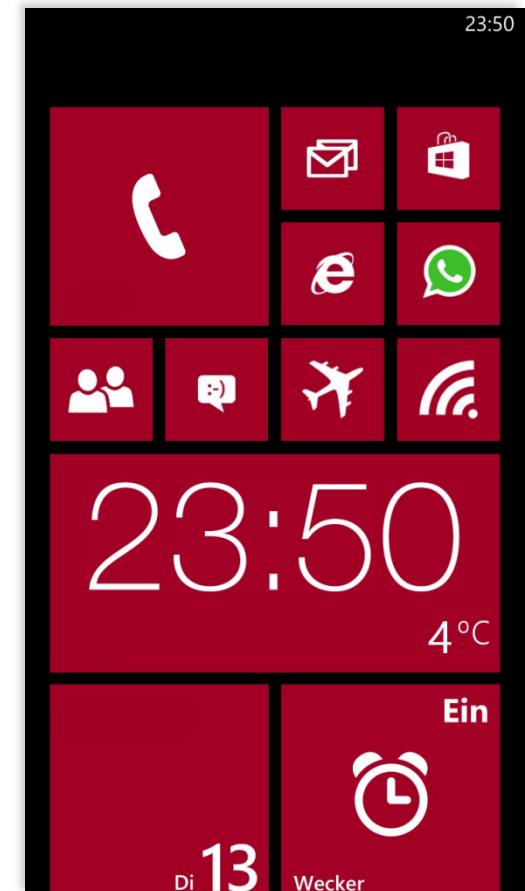


- Launched in October and November 2010
- Successor to Windows Mobile platform, but **technically a new and different platform without backward compatibility**
- Aimed at consumer market instead of enterprise market unlike Windows Mobile
- New user interface



## Windows Phone

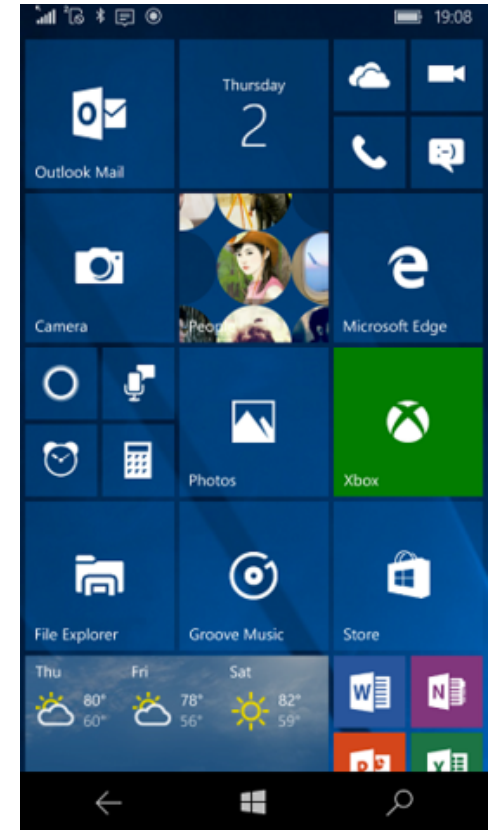
- Windows Phone 8 launched in October 2012 together with Windows 8 with similar optics
- Successor to Windows Phone 7
- Latest release: Windows Phone 8.1 in April 2014





# Microsoft Windows 10 Mobile

- Windows 10 Mobile Insider Preview available in July 2015.
- November 2015: Supported phones include HTC One (M8) and 36 Lumia models.
- Other eligible Windows Phone devices can receive updates since March 2016.
- Discontinued (last security update in January 2020)



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- Linux-based open-source mobile OS for smartphones and tablet computers
- Originally developed by **Mozilla**, a non-profit organization known for the Firefox web browser
- Focus on open standards, e.g. HTML5 applications
- 2012-02: Firefox OS first publicly demonstrated
- 2013-07: First commercial Firefox OS based phones launched:
  - *ZTE Open* in Spain by Telefónica
  - *Alcatel One Touch Fire* in Poland by Deutsche Telekom (also sold in Germany by subsidiary *Congstar*)
  - *LG Fireweb* in Brazil by Telefónica brand *Vivo*
- Mozilla expressed strong position on **user privacy**
  - Upon installation of applications, a reason is stated why certain rights are necessary and need to be granted by the user.
  - User data will be analysed locally on the device, not transferred to servers, exploited or traded.
- 2015-12: Mozilla announced to stop offering smartphones through mobile operator channels.
  - Possible pick-up: H5OS by Acadine Technologies
- 2016-09: Mozilla work on Firefox OS ceased
- Latest release: 2.2.0 (2015-08)
- Latest developer version: 2.6.0 (2015-10)
- Forked to form KaiOS



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- A mobile OS based on Linux
- Owned by KaiOS Technologies, a US-based company
- Forked from B2G (Boot to Gecko), an open source community-driven successor of Firefox OS
- 2017: Initial release
- 2018: Google invested US \$ 22 million in the OS. India-based telecom operator Reliance Jio also invested \$ 7 million in cash to pick up a 16% stake.
- KaiOS beat Apple's iOS for second place in India, while Android dominates with 71%:
  - Largely attributed to popularity of the competitively-priced Jio Phone.
  - In Q1 2018, 23 million KaiOS devices were shipped in Asia, Africa, Middle East, Latin America, and North America.
- KaiOS supports:
  - 4G LTE E, VoLTE, GPS and Wi-Fi with HTML5-based apps.
  - A dedicated app marketplace called KaiStore enables users to download applications.
  - Lightweight hardware resource usage, and is able to run on devices with just 256 MB of memory.
- Latest release: 2.6.0 (2019-05)



Source:  
<https://www.zdnet.com/product/nokia-8110-4g/>

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# HarmonyOS (Hongmeng OS)

- Launched August, 2019
- Self-developed operating system
- Initially developed for Huawei smart TVs
- Conflict with the U.S.: more platforms in planning for HarmonyOS 2.0
  - HarmonyOS 2.0 will support devices with up to 128MB RAM, such as smart wearables and other IoT devices
  - 2021: support devices up to 4GB RAM, such as tablets and entry-level smartphones
  - End of 2021: this RAM limit will increase over 4GB to support more powerful smartphones



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- Many mobile operating systems allow the execution of 3<sup>rd</sup>-party software:
  - Malware can be executed on mobile operating systems, either intentionally or by security leaks inside the mobile operating system (exploits).
- Possible threats for the user are:
  - Device malfunction
  - Loss of data (malware erasing data)
  - Loss of money (e.g. malware sending SMS to premium services )
  - Shorter battery runtime (more processing/resource usage)

### Beginnings of mobile malware

- *09/2000*: Liberty Horse Trojan
- *12/2000*: Telefonica SMS Mailer
- *08/2001*: Flooder sends unwanted SMS
- *09/2001*: Phage erases data on Palm devices
- *02/2003*: Nokia V-Card exploit
- *09/2004*: First Symbian OS malware
- ...

### Strong growth of mobile malware

- The number of malware programs masquerading as legitimate mobile apps grew by more than 600 percent in 2012
- Most popular target: Android



[ATD2013]



# Timeline mobile threats 2004-2016

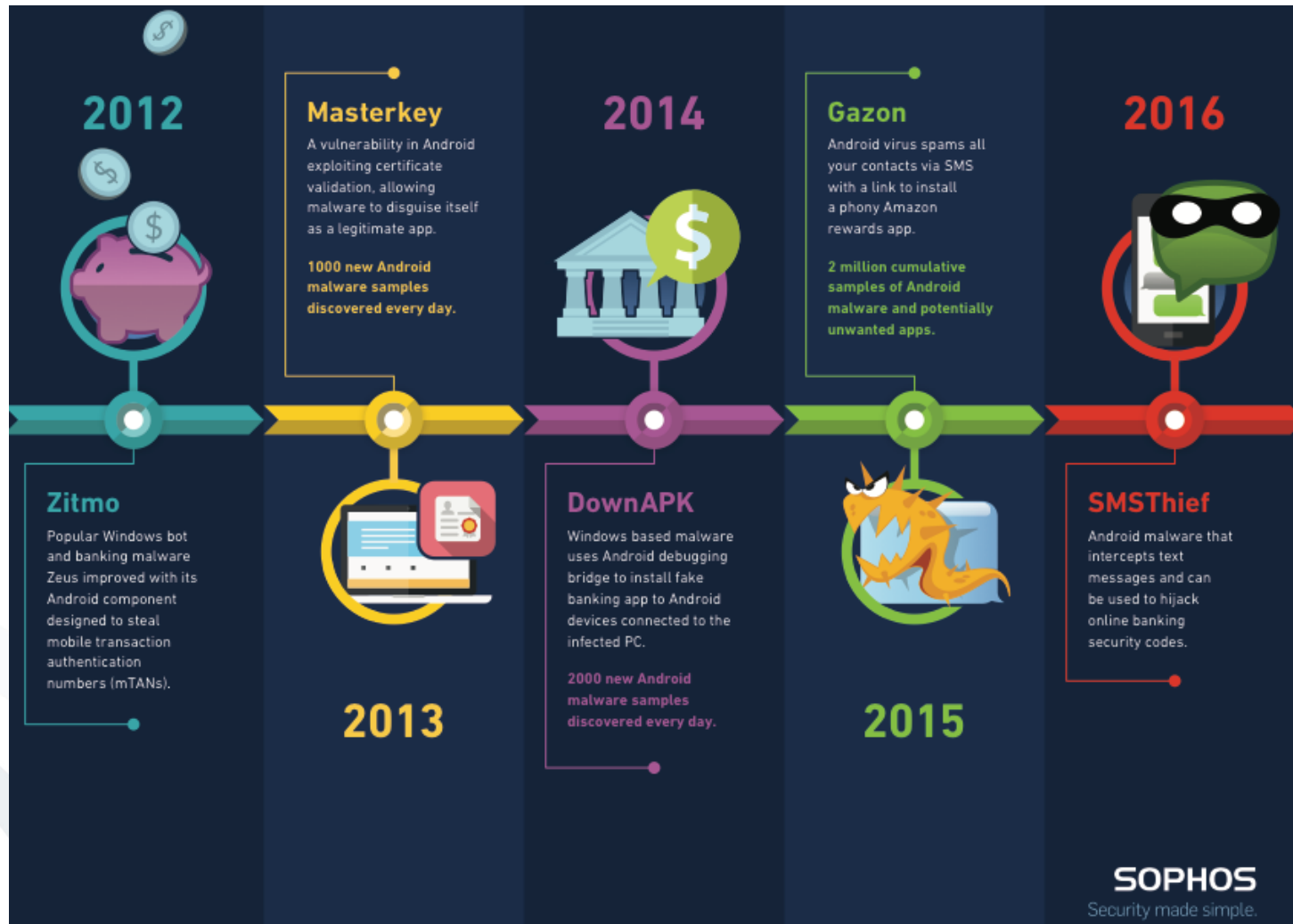


[Sophos2016]

# Timeline mobile threats 2004-2011



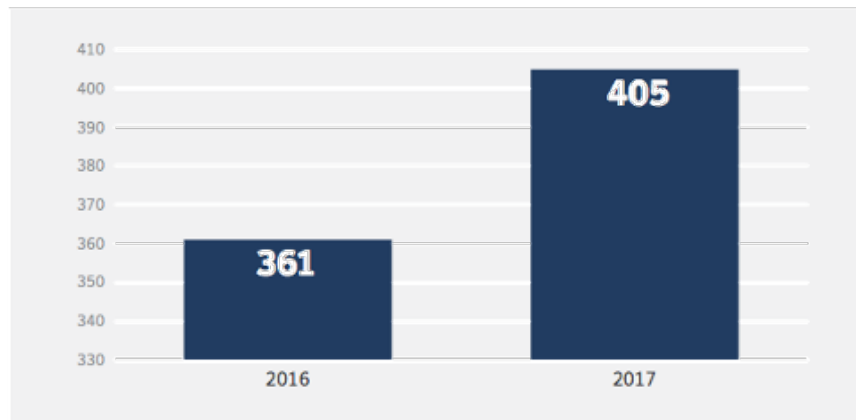
# Timeline mobile threats 2012-2016



# Mobile threats in numbers

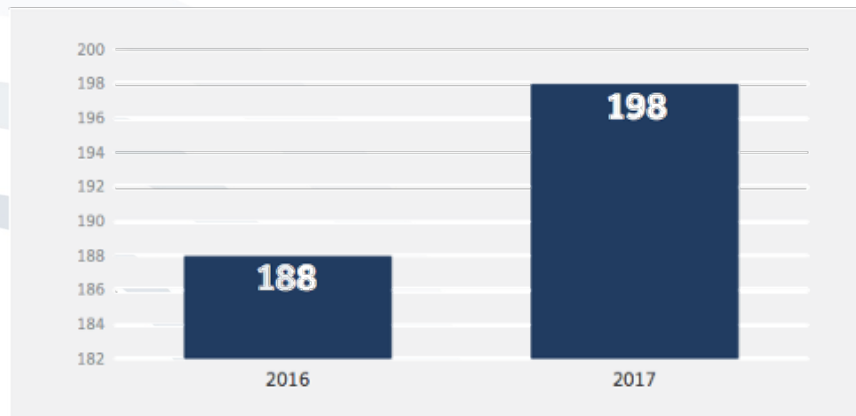
## New mobile malware families

The number of new mobile malware families increased by 12.2 percent between 2016 and 2017.



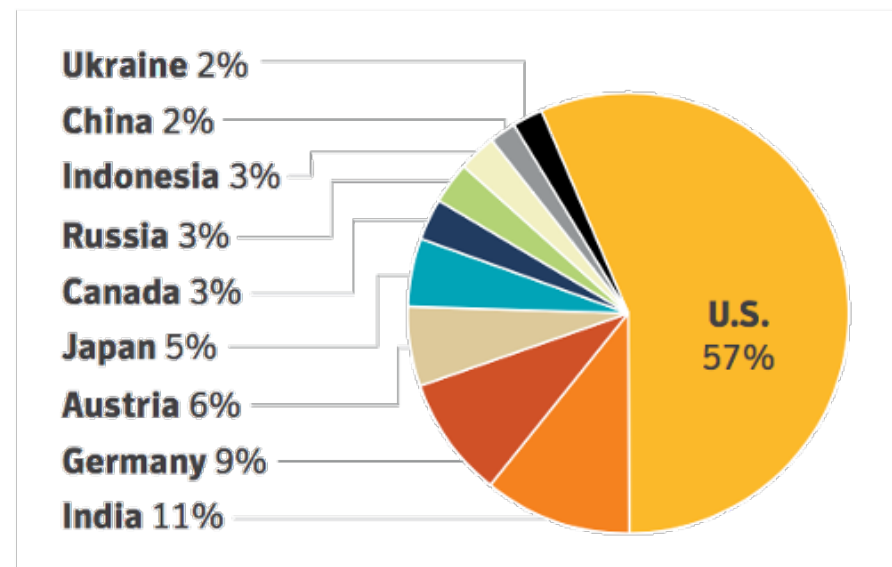
## New mobile grayware families

The number of new mobile grayware families grew by 5.3 percent in 2017.



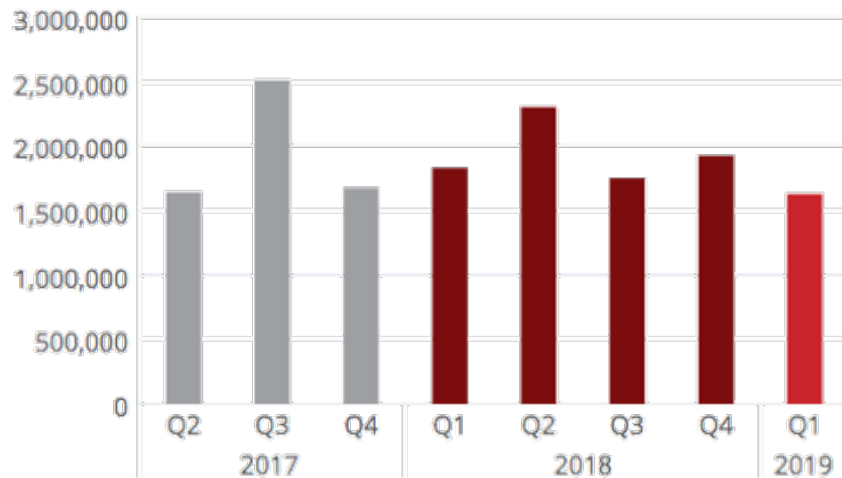
## Top countries for mobile malware

Top 10 list of countries where mobile malware was most frequently blocked in 2017.

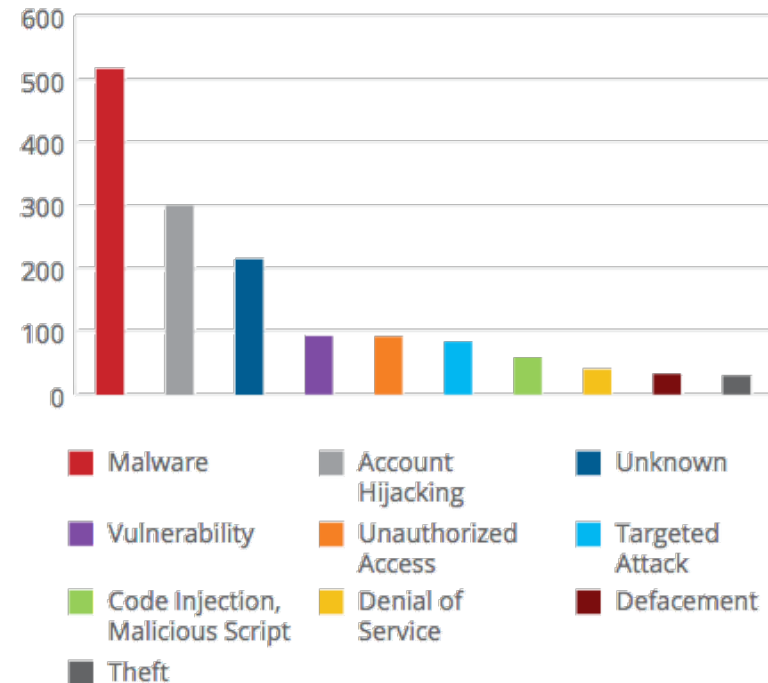


# Mobile threats in numbers

New Mobile Malware

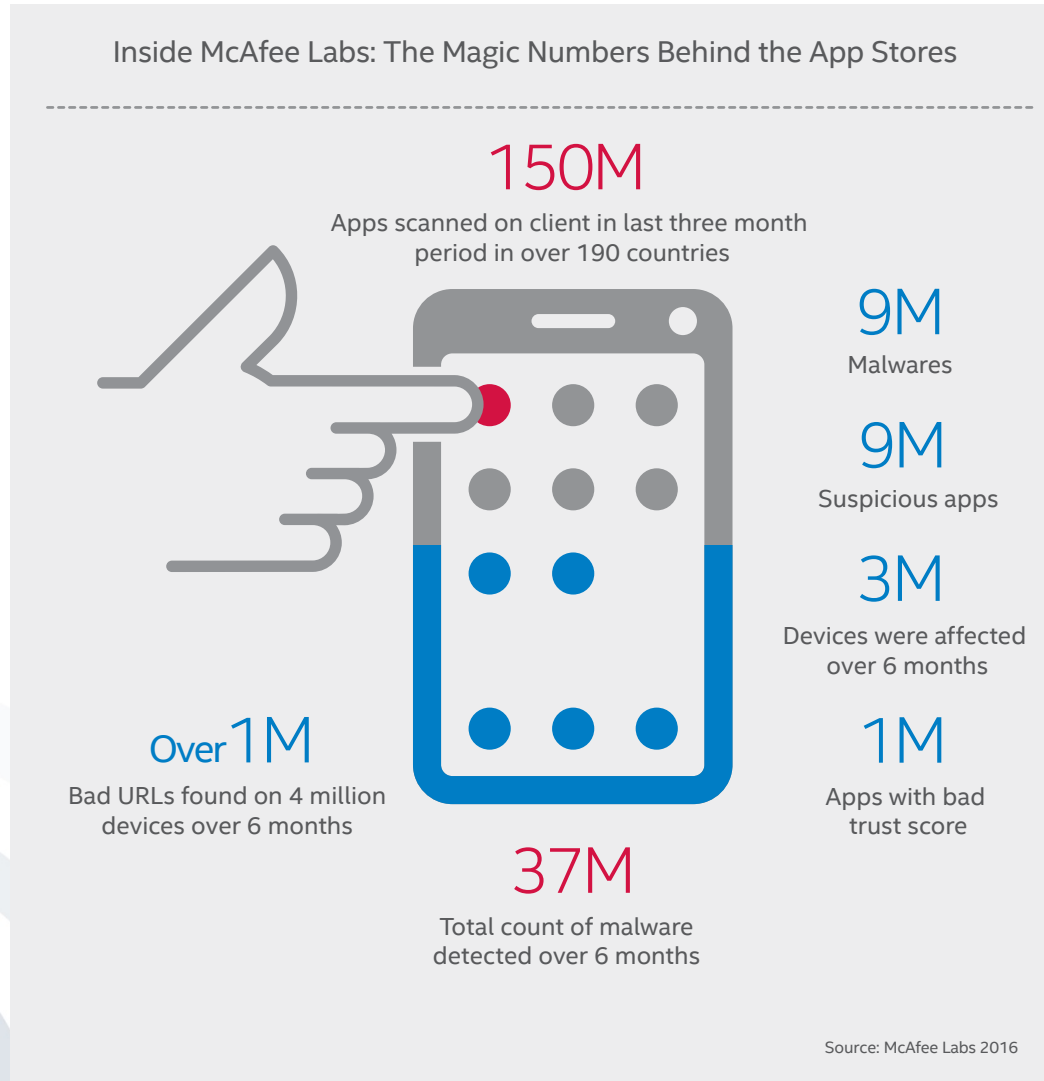


Top 10 Attack Vectors in 2018-2019  
(Number of reported breaches)



- Attacks are becoming commercial services for “customers” (e.g. distributed-denial-of-service).
- Mobile devices may get „recruited“ for executing attacks.
- States attack mobile devices upfront (e.g. FBI vs. Apple).
- Apps and security softwares are major attack vectors.

# Mobile threats within 6 months in 2015-2016



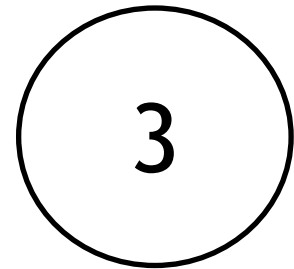
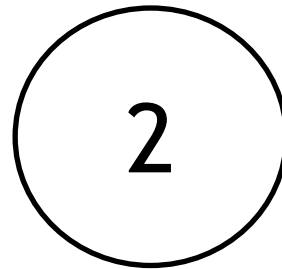
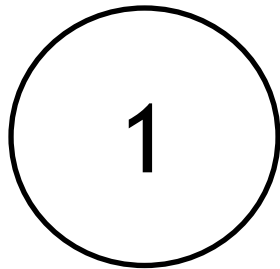
[McAfee2016]

- A one-week behaviour analysis of top 10 Android fitness apps revealed:
  - They accessed sensitive data while users were not interacting with devices.
  - They transmitted sensitive data to remove servers without user's knowledge.
  - Transferring data to outside EU (GDPR issue).
  - Promises did not match actions (privacy policies Vs. real behaviour).



- The market for mobile devices and mobile OS
- Mobile OS unavailable to other device manufacturers
  - Overview
  - Palm OS
  - Apple iOS (Unix-based)
- Manufacturer-independent mobile OS
  - Overview
  - Symbian platform (by Symbian Foundation)
  - Embedded Linux
  - Android (by Open Handset Alliance)
  - Microsoft Windows CE, Pocket PC, Pocket PC Phone Edition, Mobile
  - Microsoft Windows Phone / 10 Mobile
  - Firefox OS
  - KaiOS
- Threats, attacks and countermeasures
  - Threats and attacks
  - Countermeasures

- A3: Android App Behaviour Analyser



Responsible for  
monitoring apps'  
behaviour

Analysing  
potential  
privacy risks

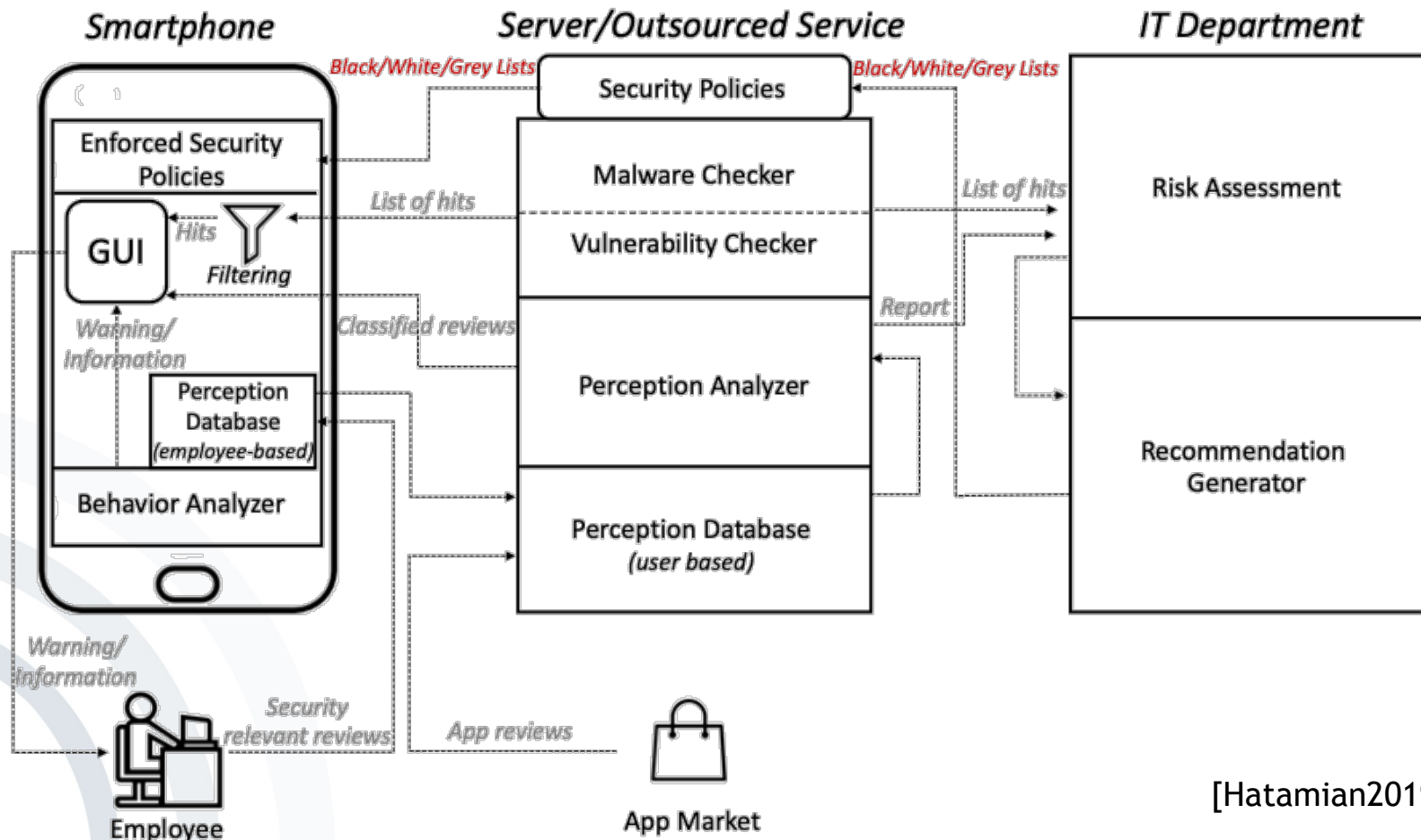
Risk  
communication  
to users

## ■ A3: Android App Behaviour Analyser

The app interface consists of four main screens:

- List of suspicious apps:** Displays a list of installed apps with their permission counts. Apps like AccuWeather (2 permissions), Always On Display (1 permission), and Android system (4 permissions) are highlighted. A search bar is at the top.
- List of suspicious apps (Detailed View):** Shows a detailed list of permissions for selected apps. For example, 'Access to coarse location information' is listed 9 times, and 'Access to fine location information' is listed 4 times. A 'REPORT' button is visible.
- Scan Options:** Allows users to configure scan settings. Options include Scan Duration (Default), Scan Interval (5 Seconds), Delete Older Scans (Default), and Wifi only (Networking, only when connected to a Wifi network).
- Report:** Displays a detailed report of access events. It lists specific times when certain permissions were accessed (e.g., 'Access to coarse location information' at 14:38:55, 14:39:18, etc.). It also includes a section for users to provide an explanation for why they want to report these resources, with 'CANCEL' and 'REPORT' buttons at the bottom.

- ESARA: A Framework for Enterprise Smartphone Apps Risk Assessment



- Memory protection
  - Processes are not able to access the memory of other processes.
- File protection
  - Encryption
  - Access control
- Access controls
  - Definition of access rights and monitoring of their enforcement.
- Support for security modules
- Secure I/O
- Code integrity management: Integrity of programs is checked before they are started by e.g.
  - Checking certificates
  - Proof Carrying Code
- Additional security software may be needed, e.g.
  - Virus scanners
  - Firewalls

- Every user has certain assigned access rights, e.g.
  - Reading a file
  - Writing a file
  - Accessing a peripheral device
  
- The OS controls that users or the processes started by a user, can only execute those actions, which they are allowed to.

<i>Object</i> <i>User</i>	<i>File 1</i>	<i>File 2</i>	<i>File 3</i>	<i>Device's periphery</i>
<b><i>U1</i></b>	Read		Read	
<b><i>U2</i></b>				Print
<b><i>U3</i></b>		Read	Execute	
<b><i>U4</i></b>	Read Write		Read Write	

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