



Sponsored by



In partnership with



# A New Direction for the Mobile Industry

Making the Case for More Open and Transparent Mobile Software

**September 2023**

Gordon Graham

Foreword by Raul Quino, Futurewei Technologies



# A New Direction for the Mobile Industry

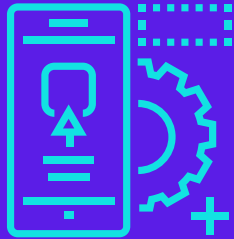
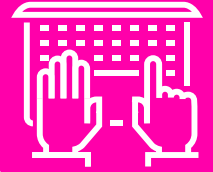
99% of smartphones run either Android or iOS.



Mobile app developers and original equipment manufacturers (OEMs) making Android devices face vendor lock-in, inflexible terms and conditions, and high costs.

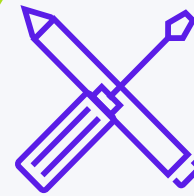


Open source opportunity: Mobile Native Foundation (MNF) supplies developers with the infrastructure for building large-scale mobile apps.



Outside China, Google Play or Apple's App Store serve 95% of all apps.

OEMs making Android devices also face tying of the free Android Open Source Project (AOSP) with the proprietary Google Mobile Services (GMS).



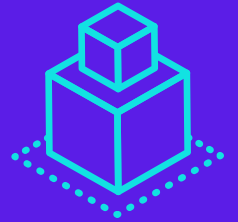
Open source opportunity: BharOS provides an alternative mobile operating system stack for device vendors in India.

Market dominance by only two platforms slows progress, drives up costs, blocks new entrants, and stunts the growth of the mobile sector.



Open source mobile software offers transparency, community, enhanced security, a faster time to market, and lower costs.

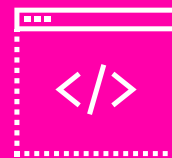
Open source opportunity: Open Mobile Hub (OMH) provides an open source alternative to GMS, including compatible API layers that allow existing Android apps to function without requiring new code.



Regulators recognize the mobile market is not competitive. Since 2018, the European Union (E.U.) has issued more than \$11 billion in fines against Google.



Open source opportunity: The OpenJS Foundation's NativeScript empowers developers with JavaScript for native APIs on iOS and Android.



Open source opportunity: Overture Maps Foundation (OMF) provides open map datasets that include national and regional boundaries, buildings, places of interest, and detailed road networks.



# Contents

Foreword .....	5
Executive summary .....	6
Overview of the mobile ecosystem .....	7
A first-ever slump in 2022.....	7
Participants in the mobile ecosystem .....	7
Two platforms dominate the market.....	8
Spotlight on new digital regulations in the E.U. ....	8
Challenges for mobile app developers and Android OEMs .....	9
Challenges for mobile app developers and Android OEMs .....	9
Vendor lock-in .....	9
Inflexible terms and conditions .....	11
High costs, high risk.....	12
Tight tying of GMS to Android AOSP .....	13
What happens if an OEM doesn't license GMS? .....	15
Summing up.....	15
On the other hand.....	16
App stores are getting better.....	16
Any innovation faces the chicken-and-egg problem.....	16
Addressing these challenges .....	17
Developers banding together .....	17
Open sourcing more of the Android stack.....	17
Launching lawsuits.....	18
Drafting new legislation .....	18
Some cracks in the walled gardens.....	18

## Contents, continued

<b>A vision for an open mobile sector .....</b>	<b>19</b>
Open standards and open source.....	19
The benefits of open standards.....	19
The benefits of open source .....	20
Design guidelines for open source mobile software.....	21
<b>Some exciting open source mobile projects .....</b>	<b>22</b>
BharOS, a new mobile OS for India .....	22
Mobile Native Foundation, infrastructure for large-scale mobile apps.....	22
NativeScript, empowering JavaScript with native platform APIs.....	23
Open Mobile Hub, a universal Android stack .....	24
Overture Maps Foundation, mapping the world .....	24
<b>Conclusion: Open source delivers at every level .....</b>	<b>26</b>
<b>Acknowledgments.....</b>	<b>27</b>
<b>About the author .....</b>	<b>27</b>
<b>References.....</b>	<b>28</b>



## Foreword

Open ecosystems have many advantages over closed ecosystems. They increase innovation, make collaboration more efficient, encourage industry standards and interoperability, and help everyone in the ecosystem adapt to evolving markets and changing environments.

In the software domain, open source is one of the most authentic forms of an open ecosystem. The benefits are so overwhelming that even the dominant platform providers find it in their interest to embrace the open source principle. Two great examples are Microsoft's support of the Linux operating system and Google's open sourcing of the Kubernetes cloud native platform.

In the end, the proper management of open ecosystems can benefit everyone. Consumers can get cheaper, richer products; developers can suffer less friction and ship new products quicker; and markets can expand to less affluent populations. And an open and competitive market gives regulators many fewer issues to deal with.

Unfortunately, a healthy, open ecosystem is glaringly absent for the most vital technologies in our lives: smartphones and mobile apps.

We all feel this dysfunction, individually and collectively. As consumers, app developers, device manufacturers, or market regulators, we suffer from the consequences every day.

But what are the core problems? How can we work together to solve these challenges? And why does the world need an open mobile software stack now?

This insightful white paper from Linux Foundation Research offers a keen analysis of what troubles this ecosystem and how open source could solve most of these troubles. This is timely research that we should all care deeply about.

**Raul Quino,**  
**Business Partner Director,**  
**Futurewei Technologies**



## Executive summary

In the smartphone space, innovations are slowing down, and sales are slumping. When sales stall, every ecosystem member—from carriers to content providers—loses.

Two firms, Apple and Google, dominate the mobile industry. Their platforms account for 99% of all smartphones sold, and their app stores are the primary source of downloaded apps.

Regulators are coming to see this as a market failure. Since 2018, the E.U. has fined Google more than \$11 billion for anticompetitive behavior related to Android, advertising, and search. Australia, India, Japan, Mexico, South Korea, the U.K., and the U.S. are all writing new regulations to foster a more competitive mobile market.

Yet mobile decision-makers still encounter many challenges, including vendor lock-in, inflexible terms and conditions, and the high cost and high risk of creating any new app or mobile device. OEMs also face tight coupling of the open source Android with the closed apps and services of GMS and Google Play Services.

These issues slow down progress, block new entrants, and stunt

the industry's growth. There have been various responses tried or proposed to solve these problems, such as developers banding together, more open sourcing of Android, launching lawsuits, and drafting new regulations.

The industry needs to push further to create a more open mobile ecosystem that supports innovation, welcomes new entrants, and encourages participation by all while providing security and room to differentiate.

One proven way to create a flourishing ecosystem is with open source software. This enables participants to work together to build effective, standards-based products that benefit the whole sector.

Today, at least five open source projects are underway in different areas of the mobile space. This report briefly describes each project.

We invite everyone in the mobile sector to get behind these efforts and work together to move the industry in a new direction that inspires collaboration, partnership, and shared success.

# Overview of the mobile ecosystem

All is not well in the mobile sector. After more than 15 years of rapid growth, innovation and sales have slowed down noticeably.

“Innovation in the smartphone industry seems to have reached its peak,” says a recent report on a major mobile trade show in E.U. rope. Phone makers now must work hard to get anyone excited about their new models.<sup>1</sup>

Mobile software faces the same challenge.

“In the past few years, the Android platform has received very few meaningful updates,” says the PhoneArena blog. “Google has neglected improving important sections of its platform.”<sup>2</sup>

iOS updates promise little except bug fixes. Apple now expects consumers to hold on to their phones for three years instead of two.<sup>3</sup> All this speaks to a slowing pace of innovation.

“If the products are all the same, then why should I buy a new product?” asks CEO Carl Pei of Nothing, a tech manufacturer based in India. “That’s why the entire smartphone market is contracting.”<sup>4</sup>

## A first-ever slump in 2022

Smartphone sales and app downloads always set new records every year. But in 2022, that stopped. Worldwide sales of smartphones dipped 12% to the lowest level since 2013. And the number of apps downloaded sank, for the first time in history, by a full billion.<sup>6</sup>

The downturn continued through 2023, with global sales of smartphones expected to fall another 4%.<sup>7</sup> By August 2023, Apple acknowledged that the U.S. smartphone market is in a slump.<sup>8</sup> There is an expectation that revenue will dip even lower again in

2024 and then flatline until at least 2028.<sup>9</sup>

Some analysts say we passed the high point in smartphone sales—or “peak smartphone”—in 2016.<sup>10</sup>

And when a market stalls, every member of the ecosystem loses. But it doesn’t have to be this way. This white paper analyzes the current mobile industry and then points to a way to kickstart innovation and get sales moving again.

## Participants in the mobile ecosystem

The mobile ecosystem includes various participants with many different business models:

- Carriers sell connectivity.
- OEMs sell mobile devices.
- Platforms license system software.
- API providers license software.
- App stores collect revenue splits.
- App developers license software and sell in-app purchases.
- Content providers sell subscriptions.

Regulators monitor the ecosystem in each country on behalf of consumers.

Despite playing different roles, decision-makers must work with many other members of the mobile ecosystem. Everyone is in it together.



## Two platforms dominate the market

Every mobile decision-maker must find a way to coexist with the two dominant platforms, Apple and Google.

Together, iOS and Android make up 99% of the installed base for smartphones.<sup>11</sup> Apple and Google serve as curators for the app stores where most consumers find their apps.<sup>12</sup>

Google serves 94% of all mobile searches outside of China.<sup>13,14</sup> This is partly due to a lucrative deal where Apple sells iOS mobile traffic to Google for at least \$12 billion a year.<sup>15</sup>

These facts have not escaped the attention of regulators. The E.U. is leading the way with groundbreaking legislation for digital platforms (see box). Other governments around the world are closely following the E.U.'s efforts. Regulators in Australia, India, Japan, Mexico, South Korea, the U.K., and the U.S. are also probing their mobile sectors and writing new regulations to foster a more open and competitive market.

But their work is nowhere near complete.

## Spotlight on new digital regulations in the E.U.

In recent years, the E.U. has broken new ground in data and technology policy with two far-reaching pieces of legislation:

- **The Digital Markets Act (DMA)** addresses competition and transparency for online platforms, hosting services, and network services such as Internet service providers.
- **The Digital Services Act (DSA)** aims to create a safer digital space and “establish a level playing field to foster innovation, growth, and competitiveness.”<sup>16</sup>

With a focus on creating “a E.U. rope fit for the digital age,”<sup>17</sup> the E.U. has prioritized clear standards in data, technology, and infrastructure. Rather than merely following the lead of other jurisdictions, it has seized the leadership.

By targeting the dominant tech platforms and imposing strict regulations on those with the most influence, the E.U. aims to ensure a more open and competitive digital landscape.

For example, all the major tech platforms operating in E.U. rope must now report their user numbers. Platforms with over 45 million monthly users, about 10% of the E.U. ropean population, face the most stringent rules.<sup>18</sup>

Through these regulations, the E.U. is shaping the future of data and technology policy and establishing a benchmark for global regulatory frameworks.

Other jurisdictions around the world are closely monitoring the E.U.'s actions as they seek to implement similar measures that foster fair competition, transparency, and responsible use of data in the digital age.





## Challenges for mobile app developers and Android OEMs

Mobile app developers and Android OEMs face numerous challenges, including vendor lock-in and inflexible terms and conditions. These add higher costs and more risk to everyone else in the ecosystem.

OEMs face a further challenge: the tight coupling of open and closed layers of the Android stack. Here are some examples of each challenge.

### Vendor lock-in

Vendor lock-in happens when developers or OEMs face tremendous business pressure to buy into one platform, follow its policies, and not challenge its restrictions.

Lock-in signs that partners put up with since they can't afford to switch away from that platform include:

- Missing features
- Gatekeeping
- Incompatible standards

## Challenges for mobile app developers and Android OEMs

### Vendor lock-in

- Missing features
- Gatekeeping
- Incompatible standards

### Inflexible terms and conditions

- Black box design
- Complex licensing
- Subjective reviews
- No room to innovate

### High costs, high risks

- Managing APIs and platform releases
- For developers, limited discoverability
- For OEMs, a major effort to build an ecosystem

### Tight tying of GMS to Android AOSP

## Missing features

Developers sometimes encounter missing features provided in full by the other platform.

In iOS, all browsers are just a “skin” on Safari, with no features beyond what Safari provides through the WebKit engine. Developers say this has delayed advances such as push notifications, app badging, and a full-screen API for more than 10 years.<sup>19</sup>

In addition, iOS developers can’t load any other browser as a workaround. Since every browser has the same limitations, developers must accept that some features are missing on iPhones.

They also suspect those features are missing because they could provide workarounds to the App Store and Apple Pay that would cut into Apple’s revenues.

Android browsers don’t have these same restrictions, but iOS developers can’t afford to drop that platform over this issue. Since Apple knows this, there is little market pressure on the platform to improve the browser.

## Gatekeeping

Before any app can be included in an app store, it must pass a review by the related platform. App stores, however, aren’t the only places where the platforms stand as gatekeepers.

“There’s a growing number of projects where data is the main competitive advantage, for instance, mapping,” says Marc Prioleau, executive director of the OMF.<sup>20</sup>

While he believes a serious developer can build local search, routing, or map rendering apps, those apps are useless without map data to draw on. But only the largest companies have the resources to develop that data.

“Map data is currently a proprietary asset. Since 2008, Google has spent hundreds of millions of dollars each year to build their own map dataset,” he notes.

Now that Google owns those digital maps, app developers need permission to use it. And any agreement enables Google to collect further data through those apps.

As Google powers applications in a specific vertical, they accumulate insights about that industry; then they offer vertical “solutions” that effectively displace many of the incumbents. The Google Maps Platform website already shows these solutions for financial services, real estate, retail, and transportation & logistics.<sup>21</sup> More will likely arrive in the future.

Developers and OEMs remain on the sidelines, collecting neither revenue nor data, but still locked into Google Maps.


The OMF seeks to end this dependency, with open source map datasets freely available to any developer.

## Incompatible standards

While both mobile platforms follow many industry standards, they also provide some incompatible systems that don’t interoperate.

For example, Apple Pay and Google Pay are closed payment systems that can’t talk to each other. Unlike any regular bank account or credit card, you can’t transfer money from one directly to another.<sup>22</sup> Both platforms are adding features to their digital wallets to build out these walled gardens.

The proliferation of incompatible digital wallets from different banks, companies, nations, and altcoin exchanges is the driving force behind the OpenWallet Foundation (OWF). The OWF aims to build the fundamental layers of an open source digital wallet to help any developer create a wallet that can share data with any other wallet built on the same foundation.<sup>23</sup>



In August 2023, Google announced it was joining the OWF as a platinum member, a positive development toward data and mobile wallet interoperability between disparate platforms.<sup>24</sup>

On the hardware side, devices can use proprietary hardware and drivers.

Apple and Android smartphones, for example, use different USB ports to prevent the swapping of their charging cords. This causes headaches for every household where people use both platforms, creating a subtle pressure to standardize on one platform or the other. That's why the E.U. has decreed that by the end of 2024, all smartphones and tablets must use the same USB-C connector.<sup>25</sup>

Any proprietary standard forces ecosystem members to spend extra resources to support it. Without open standards that everyone follows, members must incur additional costs and significant switching costs, which tend to lock them into one platform or the other.

### Inflexible terms and conditions

With only two mobile platforms to choose from, developers face many take-it-or-leave-it choices. Since Apple makes its own devices, OEMs can only design for Android, giving them even less choice.

Without choice, there is no competition. Without competition, there is no incentive for any provider to improve or innovate.

Here are some of the inflexible terms and conditions associated with mobile platform interactions:

- Black box design
- Complex licensing
- Subjective reviews
- No room to innovate

### Black box design

The iOS software stack is locked and proprietary.

While Android purports to be open source, that openness does not extend up and down the stack. All of GMS, Google's popular apps, and many Play Store services are closed source and proprietary, which can lead to problems.

"Google Maps caused Uber's largest mobile outage in history," says Ty Smith, principal engineer for mobile at Uber.

For several hours in late 2018, every app accessing Google Maps crashed. For the next three days, Uber and other Android apps suffered intermittent failures. Google resolved this by tracking down the problem and pushing out a new update to Play Services, and Uber did their own client-side fix.

"As a utility app, we have a big concern around reliability," notes Smith. "Play Services is a closed source black box that updates itself and does feature flagging internally. So, our normal practices for reviewing third-party code go out the window."


Black box software prevents developers from diagnosing problems, making fixes, or suggesting improvements. Again, it's a take-it-or-leave-it deal.

### Complex licensing

Any business involves some legal paperwork, but the mobile platforms impose especially complex licensing on their partners.

Beyond signing up for GMS, OEMs must navigate a thicket of agreements to set the default search engine, place apps on home screens, and send data and search traffic back to Google.

"GMS is just one piece of the agreement," confirms Karthik Ayyar, an Indian software architect who is building a non-GMS mobile OS. "It's not just one agreement; Google has a whole web of agreements."<sup>26</sup>



The apps any OEM can preload are based on complicated contracts between at least four parties: Google, the OEM, the carrier, and third parties that distribute apps.<sup>27</sup> OEMs must devote significant resources to handle all this licensing.

### Subjective reviews

Traditionally, you could only load iOS apps through Apple's App Store for a 30% cut of revenues and in-app purchases. Google Play took a similar approach with a similar cut.

"The two-horse race we have today is not adequate. That's not going to give you a fair development ecosystem where everyone can thrive," says Rimma Perelmuter, former CEO of the Mobile Ecosystem Forum.<sup>28</sup>

Developers dislike capricious app store reviews and lack of any appeal process. Many question the real purpose of the review.

"The problem with the App Store review is you've got 10 million app updates a week and maybe 500 non-software engineers vetting them, who just look at the user interface and the results of some automated tools," notes Alex Moore of the Open Web Advocacy group.

"What we've heard is App Store review is there mostly to enforce Apple's business rules. Like, are we getting our cut of all the purchases?"<sup>29</sup>

### No room to innovate

For their part, OEMs can't use any hardware that conflicts with the Android stack. Any OEM that wants to use a new type of sensor, for instance, must clear that with Google. Otherwise, their device may fail Google's Play Protect certification.

Getting a new Android device certified already takes months. Any further delay can dramatically disrupt a new device's time to market.<sup>30</sup>

"For handset makers, the problems are painful. They are stuck in a situation where they have little leeway to differentiate on top of a 'free' operating system," notes consultant Jonathan Goldberg.<sup>31</sup>

In short, both developers and OEMs have limited options to add new features that help their products stand out from the crowd.

### High costs, high risk

In an era when smartphone sales are slumping, developers and OEMs want to keep their costs low and avoid needless risk. Here are some issues that add cost and risk for mobile partners:

- Managing APIs and platform releases
- For developers, limited discoverability
- For OEMs, a major effort to build an ecosystem


### Managing API and platform releases

Each new platform release provides a new set of APIs, and developers often integrate APIs from third parties to add functions or access data. But working with a collection of APIs from different sources is never simple, and APIs from different sources can conflict.

"Developing an app while dealing with API issues is a significant and difficult step for developers," says web design firm Fullestop, listing APIs among the top 10 challenges for Android app makers.<sup>32</sup>

Another complication, certainly with Android, is the fragmentation of the installed base of devices across at least three system releases,<sup>33</sup> at least four screen resolutions,<sup>34</sup> and various OEM implementations.<sup>35</sup>

That means developers routinely make dozens of versions of an Android app to cover the market. Every version requires a permanent investment to cover its ongoing maintenance.



“Developing apps that work across the whole range of Android devices can be extremely challenging and time-consuming,” confirms the latest annual report on Android fragmentation from research firm OpenSignal.<sup>36</sup>

Complex and time-consuming challenges across multiple versions spell high development costs to maintain a functioning app.

### **For developers, limited discoverability**

On both platforms, preloaded apps fill home screens. Apple controls this for iOS. For Android, Google negotiates this with OEMs and wireless network operators.

The average smartphone owner uses 10 apps a day and 30 apps a month.<sup>37</sup> In iOS 17, Apple provides 38 built-in apps, from App Store to Weather, plus another 20 utilities.<sup>38</sup> The Android + GMS bundle varies by OEM and carrier, but it’s roughly equivalent to Apple’s.

Out of the box, many of the apps most users require are already on their smartphones. Most users only load a few other big-name apps such as Facebook, LinkedIn, or TikTok.

There are 3.5 million apps in Google Play and 1.6 million in Apple’s App Store.<sup>39</sup> With so many apps competing for attention, it’s tough to discover any new apps.

One way to promote a new app is to pay for search ads in the app stores. Since all app store advertising flows to Apple and Google,

this gives the platforms an incentive to keep organic discovery low. That way, app developers must spend more on advertising to gain traction—another high cost extracted by the platforms.

### **For OEMs, a major effort to build an ecosystem**

“Android is free, yes,” says an experienced technology architect in New Jersey. “But to actually get a device to market, you have to spend a whole lot of time, get a whole lot of certifications, agree to bundle Google’s apps for years, and then you still have to break into the carriers and get featured in their marketing.”<sup>40</sup>

All that adds up to a major effort, topped off by a further effort to build an effective ecosystem of carriers and developers.

An OEM can spend a bundle building a new Android phone that never gains much traction or delivers a good ROI for its development costs. That makes developing any new smartphone a high-cost / high-risk gamble.

### **Tight tying of GMS to Android AOSP**

Another issue for app developers and OEMs is how the closed GMS layer of Android is tightly tied to the open source core AOSP.

When people say Android is open source, that isn’t the whole story. As Table 1 shows, Android’s software stack includes three layers, only one of which is arguably open source.

**TABLE 1**  
**THREE LAYERS OF THE ANDROID SOFTWARE STACK**

LAYER	PROVIDES	AVAILABILITY
Proprietary mobile apps	From Google: popular apps such as Chrome, Google Drive, Gmail, Google Maps, Google Play, Google Search, and YouTube From other developers: any other games and apps	From Google: a per-device licensing fee, often preloaded and tied to GMS if regulations allow From other developers: downloaded from Google Play (or equivalent)
Google Mobile Services (GMS)	Hundreds of essential services, such as authentication, cloud storage, location, maps, purchases, push, QR scans, SMS, security, and more	Not open source: OEMs must sign complex licenses and pay a per-device licensing fee
Android Open Source Project (AOSP)	Basic OS-level functions	Free open source: Google may not allow OEMs to fork the code

**The bottom layer** provides the mobile OS and AOSP. This is available free to OEMs, although Google frowns on anyone touching the code.

**The top layer** provides mobile apps from Google or any other developer. As usual, these are closed proprietary codes.

**The middle layer** is the problem. GMS includes hundreds of services that apps depend on, from authentication to in-app purchases. Yet, OEMs must license GMS for a per-device fee. So, this layer is closed and proprietary, yet tightly coupled to the open AOSP layer.

Google tries to camouflage this classic product tying by calling Android “open source.” Meanwhile, Google owns the Android name, controls the road map, runs its repositories, and assigns employees to lead the teams.

Calling Android open source seems a clear example of open-washing: calling a product “open” for marketing purposes while still behaving as though it is proprietary.<sup>41</sup>



## What happens if an OEM doesn't license GMS?

Any OEM that doesn't license GMS faces three large hurdles:

- They must forego hundreds of vital services, such as authentication, geolocation, in-app payments, security, and updates that apps rely on.
- They can't preload any must-have apps such as Google Search, Chrome, Gmail, Google Drive, Google Maps, Google Play, and YouTube.
- They must create their own app store and populate it with their own selection of apps.

"AOSP can be a wild and woolly world; you don't necessarily know what you are getting into," warns device management platform maker Esper. "You can often deliver equivalent functionality

## Summing up

To sum up, app developers and OEMs making Android devices face serious business challenges from today's mobile platforms, including vendor lock-in, inflexible terms and conditions, and high costs and risks.

through AOSP without GMS. But this takes due diligence and careful design."<sup>42</sup>

Most OEMs outside China (where GMS is not available) can't afford all this effort and expense, so they're effectively locked into the AOSP + GMS stack.

For developers, the extra effort needed to port an app to a non-GMS device adds costs and may generate paltry returns. Few app developers can afford to support every Android device on the market, so many draw the line at non-GMS models.

The result is that many Android ecosystem members feel locked into using GMS. OEMs must license GMS from Google to manage the Android stack and support must-have apps. Third-party app developers need to integrate with GMS services, or their apps may break. The risk and cost of switching are just too high.

If they choose not to license GMS, they must take on extra development effort and risk a broken user experience. All these challenges drive up costs, increase time to market, and slow sales in regions where smartphones are not yet popular.

## On the other hand...

Apple, Google, and their supporters can counter with some reasonable-sounding points. For example, they say each platform provides a complete set of tools and standards that make app development easier. Android also offers hundreds of built-in services that make it faster to develop apps and design mobile devices.

Platform advocates say all this lowers costs, improves quality, and promotes security. While some irritants remain, the sector is steadily improving.

### App stores are getting better

Many believe, for example, that app stores provide lots of convenience for both developers and consumers. Apple App Store reviews have reportedly become less controversial in the past year or two. Alternatives to the App Store and Apple Pay will soon be available in the E.U., and there has been a reduction in the 30% revenue split for smaller developers.

Similarly, the Android stack and Play Store support a healthier ecosystem than 15 years ago when every OEM was free to go their own way. That fragmented the Android market and cost developers dearly to maintain a dozen or more versions of each app.

### Any innovation faces the chicken-and-egg problem

No mobile service is free. Supporting any alternative requires developers and OEMs to make an ongoing commitment to test and maintain a compatible product. How can they make a business case to justify that expense?

Every new alternative faces the same chicken-and-egg problem. How do you attract developers without a huge installed base of devices? And how do you attract OEMs without a strong catalog of apps?

Any alternatives for the mobile sector must make sense and deliver real benefits. "Mobile platforms can be pretty territorial by nature, which makes sense," says Nathan Walker of nStudio. "Their demand for quality is and should be very high."

"We've seen open source innovators attack platforms, but that really only hurts innovation around them," he notes. "If we're going to innovate in open source, we have to lift up the entire industry by celebrating how these innovations help advance the platforms they're targeting, not tear them down or belittle them."<sup>43</sup>

In any case, iOS and Android are so dominant today that they are not going to crumble tomorrow. So, how can the smartphone industry preserve what it has achieved, yet take bold new strides into the future? How can we find the right balance between black box design and transparency, between security and openness?



# Addressing these challenges

There have been several suggestions or attempts to foster a more inclusive and competitive mobile industry:

- Developers banding together to press for changes
- Open sourcing more of the Android stack
- Launching lawsuits to clarify the rules of engagement
- Drafting new regulations to stop anticompetitive behavior

This section looks at each possibility in a little more detail.

## Developers banding together

What if mobile developers band together to press for more features? That is what developer / consultant Alex Moore and some colleagues in Australia tried, starting in 2021.

“We’d been asking Apple for push notifications for years. And we basically got ignored. So, we tried to apply pressure by posting in the WWDC forums, saying, ‘Look, Safari is miles behind; it’s ludicrously buggy; we need things like push, badging, installing web apps,’” he recalls. Again, they received no response.

“So, we emailed the entire WebKit mailing list of about 800 people. No response. So, we jumped into their Slack channel to say the same thing. And all we got was a dismissive comment from a senior executive at Apple.”<sup>44</sup>

The Coalition for App Fairness is a 501(c)(4) NGO with more than 60 app developers as members, all pushing for a reduction of the 30% “app store tax” and alternatives to Apple’s App Store and Google’s Play Store.<sup>45</sup>

As both groups have found, platform companies can easily ignore any requests from developers that challenge their revenues.

## Open sourcing more of the Android stack

We’ve seen how closed parts of the Android stack, such as GMS and Play Services, can lead to problems that outside app developers can’t help fix.

“In all other parts of Android development, we ban closed source code,” says Ty Smith, the principal engineer leading the mobile team at Uber. “So, we’ve pushed back a lot on Google to open source key parts of Play Services so we can understand and investigate issues.”


Some say Google should go further and open source the whole Android stack. That would clarify today’s confusing system, where the AOSP layer of the stack is open but the GMS layer is essentially closed. It would also relieve some of the company’s legal headaches.

“Google bought Android because they were worried about getting shut out of mobile search. Beyond that, it’s been this weird mix of competing directions,” notes technology consultant Jonathan Goldberg.

“The whole G-Suite has gotten Google in so much legal trouble, you’d think the legal team would say, ‘Stop charging for this. Just give it away!’”

That would eliminate the complex GMS licenses and back-and-forth negotiations over default apps, and it could well create a renewed surge of interest in Android.

“There are big entities who’d really like to see Android become more viable,” says Goldberg. “And right now, they don’t have any way to contribute other than begging Google for this fix or that fix.”<sup>46</sup>



Among these potential participants are Huawei, Meta, Oppo, Qualcomm, Samsung, Vivo, Xiaomi, and the Linux Foundation.

Open sourcing more of the Android stack would mean Google would have to give up some control and even revenue in return for long-term peace with partners and regulators. That sounds sensible to us.

## Launching lawsuits

When markets fail, unhappy partners often turn to the courts for relief.

Game developer Epic, for example, sued Apple when the App Store banned Epic for trying to sell its games through the Web. In 2023, the final appeal court came down mostly in Apple's favor, although the App Store can no longer block third-party payment services in California.<sup>47</sup>

Small developers in the U.S. earlier won a \$100 million settlement from Apple over its App Store fees in 2021. Amazon and Apple are now in court for conspiring to block resellers to drive up prices for iPhones and iPads.<sup>49</sup>

Governments have also gotten in on the act.

In 2021, South Korea fined Google \$177 million for not letting Samsung use a fork of Android on its phones.<sup>50</sup> In 2022, India fined Google \$126 million for the same issue and others.<sup>51</sup> From 2017 through 2021, the E.U. fined Google more than \$11 billion for abusing its market dominance.<sup>52</sup> Further lawsuits are underway around the world.

Antitrust cases are often murky, with reasonable-sounding arguments on both sides. No company likes to pay fines or face bad publicity.

But even if a case goes against a platform, billions in fines may not be enough. After all, Google declared more than \$76 billion in

profit in 2021, meaning five years' worth of E.U. fines amounted to less than eight weeks of profits.<sup>53</sup>

## Drafting new legislation

"Regulation," says Harvard Business School professor and author Shoshana Zuboff. "This is what the tech companies fear most."<sup>54</sup>

This is where Moore's Open Web Advocacy group has the biggest impact. Their insightful reports<sup>55</sup> and presentations<sup>56</sup> help regulators around the world grasp the need to update the rules for the mobile sector.

The recent legislation from the E.U. contains a detailed new code of conduct for online platforms (see page 8).<sup>57</sup> Other countries, including Australia, India, Japan, South Korea, the U.K., and the U.S., are developing new rules for mobile markets.

Country by country, new legislation may help to open up the mobile market for more competition. Apple and Google, however, have large legal and lobbying teams they can deploy to appeal and delay any new regulations.

## Some cracks in the walled gardens

"Competition, not walled gardens, leads to the best outcomes," concludes the detailed report from the OWA.<sup>58</sup> At present, cracks are beginning to show in the walls around the lucrative gardens where iOS and Android bloom.

After years of pressure from their ecosystem partners, Apple and Google have reacted:

Both platforms reduced fees on app stores from 30 to 15% for smaller developers.

Apple hired dozens of developers to add long-awaited features to Safari / WebKit.<sup>59</sup>

Google relaxed certain licensing terms on its bundle of Search, Chrome, and other apps in certain jurisdictions.

Other companies continue to push against the walls. For example, now that the E.U. plans to allow third-party app stores, Meta has announced it will enable Facebook and Instagram users in E.U. to download apps by clicking on ads, eliminating the need

for traditional app stores.<sup>60</sup> Microsoft is also interested in setting up a competing app store in E.U.<sup>61</sup>

All these developments are helping to open up the mobile industry, but they are still not enough to create an open and competitive ecosystem where all can flourish.

## A vision for an open mobile sector

The industry needs to push further to create a more open mobile ecosystem that supports innovation, welcomes new entrants, and encourages participation by all while providing security and room to differentiate.

Two proven ways to create a flourishing ecosystem are with open standards and open source software. These enable participants to work together to build robust and standards-based products that benefit the whole sector.

### Open standards and open source

Two vital components of a more open and competitive mobile ecosystem will be open standards and open source.

Open standards are detailed, public specifications for a certain technology. Working groups governed by cross-industry organizations generally create these standards through a group effort among participants. Once completed, the standard is generally open and accessible to anyone.

Open source is software code created by an open community of developers who work together on a project, with changes controlled by several maintainers. Once completed, the code is usually available on a public repository such as GitHub for anyone

to make, use, modify, or redistribute.

### The benefits of open standards

A true industry standard is not controlled by any one company; an industry standard is defined by an industry-wide organization to which many companies belong. This shared approach brought the world the Internet, networking, and USB. At a deeper level, nearly all Internet communications rely on open standards from the Internet Engineering Task Force, such as the basic Internet Protocol, DNS, TCP, and UDP protocols.

Industry standards deliver many benefits that help create a flourishing ecosystem. Open standards can help reduce development costs, accelerate time to market, and promote interoperability. Standards also help to grow markets by reducing consumer confusion, flattening any learning curve, increasing usability, and giving a better customer experience.

Ecosystem members can follow industry standards but still compete in areas such as implementation quality, performance, and power and system requirements.



## The benefits of open source

There is plenty of evidence to support the benefits of open source.

“An enlightened open source approach can prioritize human-centered design and social impact while creating value for the customer and the business,” says Rimma Perelmuter, former CEO of the Mobile Ecosystem Forum.<sup>62</sup>

An open source software stack for the mobile ecosystem can provide more transparency, a larger community, enhanced security, faster time to market, and lower costs.

### More transparency

Open source code is freely available for anyone to download, examine, and test. This enables developers to verify the quality of the code, identify vulnerabilities, and resolve bugs.

Developers appreciate working with a robust code base that adheres to industry standards. Confident that the lower levels are solid and well-designed, they can build new features at the application layer to differentiate their offerings and address different use cases.

### Larger community

Open source opens the doors to welcome anyone into the community. Developers can work together to combine their expertise and resources to address challenges, exchange knowledge, and foster innovation in mobile app development.

More ideas can come from more diverse people and places. This community can capture the highest levels of passion and creativity from participants who feel empowered to make a meaningful contribution.

## Enhanced security

The Internet runs on robust open source code that withstands constant attacks from hackers. With so many people working on code that is visible to everyone, open source provides many eyes continuously scanning for vulnerabilities and looking for the best ways to fix them.

## Faster time to market

Using open source code is like getting a head start on every project. Working from a pre-built foundation is faster than starting from the ground up. In open source, people work together to exchange, test, and select the best approaches. This avoids dead ends, rework, and wasted effort. All this helps developers and OEMs get products to market faster.

## Lower costs

With open source, projects come together faster, as many of the foundational layers and standards are already in place. Participants gain from the many months or years of effort already completed.

Many organizations also share the costs of coding, testing, maintaining, and updating the code base, which reduces risk and helps development budgets go further.

While open standards and open source are not the same, they are complementary and can help to create a more open mobile ecosystem.

## Design guidelines for open source mobile software

The design of any open source mobile software must help to deliver tangible benefits to diverse developers or consumers in various regions of the world.

These benefits may include superior customer experience, innovative features, lower cost, or some combination of all three.

To be truly open and transparent, any open source mobile software should follow these design guidelines:

- Is available free of charge from GitHub
- Has no license fees or restrictions
- Originates from acknowledged industry standards
- Has no proprietary components
- Has no link to any default apps or required functions
- Enables consumers to port their data across devices
- Supports a wide choice of mobile devices

## Some exciting open source mobile projects

Here are some exciting open source mobile stack projects that are now underway in the mobile sector:

- BharOS, a new mobile OS from India
- Mobile Native Foundation, infrastructure for large-scale mobile apps
- NativeScript, empowering JavaScript with native platform APIs
- Open Mobile Hub, a universal Android stack
- Overture Maps Foundation, mapping the world with open source



These projects represent a new direction for the mobile sector that will help developers break new ground and get a new group of consumers excited about picking up their first smartphones.

## BharOS, a new mobile OS for India

With a huge population and rapid growth in mobile, India is a significant market for smartphones, perhaps one-third of the global total.

When a government agency discovered an Indian company in stealth mode building a mobile OS, they wanted to tell the world. After a Tweet forced the company to hold a press conference, the news went viral.

“People really did get excited, and they still do,” notes Karthik Ayyar, software architect for the project called BharOS. “Within a week, I started getting calls from all over the world.”

Many Indian citizens are happy to hear of a third option beyond iOS and Google, especially one that will safeguard their personal data. Digital ID that protects privacy is a big concern of the national government.

“We’re focusing on applications where privacy and security are critical, not an afterthought,” notes Ayyar. “Our pitch is, if you want to own your digital life, we are one of the options available today.”

Users can currently load BharOS on an Android smartphone that’s been stripped down to the bare metal. The first users of BharOS phones will likely be in finance, government, and perhaps the military—anyone who needs to keep their communications and locations private and can’t afford to leak an ongoing cloud of data the way other smartphones do.

Ayyar calls BharOS “a Linux distribution with Android app compatibility.” After his team made significant changes to the lower levels of the stack, he considers it a fork of Android. Over Google’s protests, the government even set down new regulations to allow these forks.<sup>63</sup>

The design features no GMS, no Google Play, and no default apps. Instead, BharOS has a curated service called the Private App Store

Services, where you can find apps that pass a detailed screening.

Ayyar says companies and government departments across India and in other countries are evaluating the OS. Consumer phones may come to market after his company finds a solution to the chicken-and-egg problem of starting any new ecosystem.

“It’s challenging,” notes Ayyar. “But nothing is impossible if you can manage to get your message out and convince enough people.”<sup>64</sup>

## Mobile Native Foundation, infrastructure for large-scale mobile apps

Founded in 2020, MNF provides a neutral place to discuss how to improve large-scale Android and iOS applications. Members are larger enterprises, from Airbnb to Spotify, that invest heavily in mobility.


The MNF co-chairs are Ty Smith, the principal engineer leading the mobile team at Uber, and Keith Smiley, a principal engineer at Lyft. While their companies compete, they work together to find shared projects that can benefit anyone trying to scale mobile apps.<sup>65</sup>

“We’re trying to facilitate open discussions about what people are doing in the mobile ecosystem because a lot of that knowledge is locked up in these big companies today,” says Smiley.

MNF members are not mom-and-pop shops. Smith’s group, for example, numbers 800 mobile developers, a far larger team than the mobile platforms usually deal with.

“Most of the frameworks, tools, and processes are designed for small- to medium-sized teams. So, our companies often hit scaling limitations and have to rebuild our mobile infrastructure,” says Smith.

“A big focus of MNF is to standardize the industry direction for larger-scale mobile development.”



One popular project from MNF is the set of storage libraries donated by Dropbox. A grant from the Kotlin Foundation supported this project, building on the trend of cross-platform development with the Kotlin language.

An upcoming project is Fastlane, a popular release automation tool for iOS, which Google acquired from Twitter in 2017 and is now transferring to the foundation.

Smiley says most MNF projects begin at one company, sometimes with only a single maintainer. But that creates doubts about the future. What if the maintainer moves on, or the company cuts the project?

When a project is open sourced to the MNF, those doubts largely go away. Other participants can join in to help sustain the project, and everyone feels more comfortable when a project has a community behind it, not just a single company.

In 2022, MNF ran a mobile ecosystem survey taken by more than 500 developers that revealed some interesting insights. The foundation plans to repeat the survey in 2023 and continue to help large teams share the burden of scaling their mobile infrastructures with open source.

### **NativeScript, empowering JavaScript with native platform APIs**

NativeScript is a project hosted by the OpenJS Foundation that provides open source tools that save mobile app developers time.

Using NativeScript, developers can access native APIs from iOS or Android with code written in JavaScript. Developers can even use a mix of Java, Kotlin, Objective-C, or Swift as they prefer.

The resulting apps run quickly, powered by the V8 JavaScript engine used by both iOS and Android. The code is inherently cross-platform, requiring only platform-specific tailoring.

Founded in 2015 as an open source project managed by Progress, NativeScript became community-controlled in 2019.

“NativeScript gives you the platform API directly in JavaScript. Among other diverse cases, if an indie shop wants to develop an app that deploys to both iOS and Android, NativeScript is really good at that,” says Nathan Walker, CTO of nStudio.<sup>66</sup>

Developers can use NativeScript to gain access to all the latest innovations from three ecosystems: the mobile platform, the Web platform, and third-party tools and plug-ins.

“We never want to sacrifice one of those three. So, with NativeScript, we can tie all those pieces together to use any innovation appropriate for any given project,” says Walker.

“For our mobile developers, we always want the platform to be the guiding light—not some intermediate layer that could delay our shop from taking advantage of new innovation right away.”

“Whatever the platform does, wherever it goes, NativeScript expands your delivery options by providing the platform in JavaScript alongside platform languages like Swift and Kotlin.”

NativeScript doesn’t seek to create a whole new platform on top or do anything else besides work naturally with the platforms, which makes it ideal for developers.

NativeScript includes a metadata generator that can scan a new platform release and quickly show all the new APIs included. This gives developers immediate access to newly released APIs.

“We work on mission-critical delivery timelines and cutting-edge projects from entrepreneurs with exciting visions. We want to work with something new the moment a vendor says, ‘Here it is.’ NativeScript lets you use platform innovations that day, that minute, that second.”

The NativeScript open source development tool can save time and money for any mobile developer, from indie to enterprise.

## Open Mobile Hub, a universal Android stack

The OMH is an open source project aiming to create a set of standards-based APIs that support all essential services for all Android devices, GMS or non-GMS.

On a smartphone with GMS, all calls will pass to the normal apps and services.

On a device without GMS, all calls will go to alternative services for functions such as authentication, cloud backup, location, or payments. If those alternate services are in place, all popular apps will run smoothly on non-GMS devices instead of returning errors.

That means developers can switch API providers without any need to rewrite their apps, and API service providers can offer their services widely.

“With OMH, Android app development becomes more flexible, catering to a wide range of devices,” says Raul Quino, business partner director with OMH maintainer Futurewei Technologies.

“Our libraries provide a simplified interface to integrate essential mobile services. The goal is to save developers time and effort while enabling a single set of APIs to support any Android device.”

The initial release of the OMH SDK in August 2023 introduces three client libraries and a Gradle plug-in:

- The OMH Auth is an Android client library that makes it easy to integrate authentication providers on both GMS and non-GMS devices. This eliminates the need for separate codebases for different Android builds.
- OMH Maps is an Android client library designed to integrate maps on GMS and non-GMS devices. Again, this eliminates the need for separate codebases and saves developer resources.

- The OMH Storage Client Library supports app backup services and file management seamlessly regardless of whether GMS services are available. This provides developers with essential cloud backup functions on any Android device.
- The OMH Core is a Gradle plug-in designed to streamline the configuration, enabling, and setup of OMH client libraries in a developer’s project. With this plug-in, a developer can incorporate dependencies and activate custom-build variants that leverage the defined providers. By automating these processes, the plug-in simplifies the integration of OMH into mobile projects.

In future releases, the OMH plans to add further libraries that expand the range of services available.

## Overture Maps Foundation, mapping the world

Amazon Web Services, Meta, Microsoft, and TomTom founded the OMF in 2022 to provide open source mapping data.

In July 2023, the OMF released its first dataset of open source maps covering most of the world. These maps provide four layers:

- National and regional boundaries
- A total of 780 million buildings
- A total of 59 million places of interest
- Detailed road networks

“This release is a significant step toward a comprehensive, market-grade open map dataset for our constantly changing world,” says Marc Prioleau, OMF executive director.

“The Places dataset, in particular, represents a major, previously unavailable open dataset with the potential to map everything





from new businesses large and small to pop-up street markets anywhere in the world.”

A 20-year veteran of the industry, Prioleau knows firsthand the value of an open approach.

“Collecting map data has always been hard,” he says. Twenty years ago, teams would drive around making notes on what they saw. Every new release took a huge investment and about 18 months to complete.

Today, developers build maps with feedback from people’s phones. People want maps updated in real time to indicate things such as construction and traffic jams.

“If a thousand cars go down the freeway and we collect anonymized GPS traces, we have a very good idea what’s happening on that freeway,” notes Prioleau. “And if there’s a new road, we start to see it the day it opens.”

Prioleau says that it’s a modest effort to build mapping apps but a huge ongoing effort to create the dataset those apps need.

“Overture contends that most companies can build the software. What they lack is the data. So, do you want to build that as one company or as a consortium of many companies?” he asks.

“Our premise is that through the combined effort of a lot of people, we can build an open map dataset better than anything else in the market.”<sup>67</sup>

## Conclusion: Open source delivers at every level

At every level of the mobile stack—tools, frameworks, APIs, infrastructure, and datasets—open source is delivering more openness.

Each of the open source projects profiled here has different aims and a different level of maturity. But together, these six projects prove that a shared approach can inspire contributors from all over the world to work together for the common good.

Unlike Android, which some argue is open source in name only, these projects are open through and through.

One key to this puzzle is to understand the ideal level in any stack where openness should end and proprietary code begin. The higher that level, the more effort developers save, the more standards the industry benefits from, and the more choices consumers enjoy.

But if that level reaches too high, especially in mobile, the downside can be market fragmentation, less room to differentiate, and security risks. It's up to all of us to help find and defend the ideal level of openness.

Many mobile industry decision-makers agree that today's level

of openness is too low. As regulators learn the drawbacks of the mobile space, the calls for more openness become stronger.

Those calls are worth heeding. We need shared datasets freely available to anyone. We need robust development tools and digital wallets that can talk to one another. We need transparent infrastructure to help scale mobile apps to billions of people, and we need more than two mobile platforms to choose from.

We invite everyone in the mobile sector to get behind these efforts and work together to move the mobile industry in a new direction.

To find out more about any of the projects covered in this report, visit the links below:

- [BharOS mobile stack for India](#)
- [MNF for mobile scaling infrastructure](#)
- [NativeScript for mobile app development tools](#)
- [OMH dual GMS / non-GMS stack](#)
- [OpenWallet Foundation for digital wallets](#)
- [OMF for open map datasets](#)



## Acknowledgments

This report is based on interviews with 15 experts in six countries on various aspects of the mobile industry as well as extensive research into academic and government reports, recent news, and opinion pieces.

Special thanks to Marshall Van Alstyne (Boston University / MIT), Karthik Ayyar (JandK Operations), Giacomo-Balli (Apache Cordova), Jonathan Goldberg (D2D Advisory), Jun Harada (Signal), Caroline Lewko (Developer Relations Agency), Alex Moore (Open Web Advocacy), Marc Prioleau (OMF), Keith Smiley (MNF), Ty Smith (MNF), and Nathan Walker (NativeScript) for agreeing to be part of the interviews for this project. Several others shared their views but asked to remain nameless.

A big thanks to Linux Foundation colleagues Hilary Carter for expert guidance, Jason Perlow for interviews and advice, Anna Hermansen for valuable coordination, John Walicki for a sensible sounding board, and Rimma Perelmuter, who joined FINOS and Linux Foundation E.U. rope after she had an interview for this report.

## About the author


Gordon Graham—also known as That White Paper Guy—is an award-winning writer who has worked on 300+ white papers for clients from Switzerland to Silicon Valley. Gordon has written on everything from choosing enterprise software to designing virtual worlds for kids and for everyone from tiny startups to major enterprises such as 3M, Google, and Verizon. Since 2018, he has helped to create more than 15 white papers and case studies for the Hyperledger Foundation.

## References

- [1] Ryan Browne, "Sea of sameness: Are smartphone makers out of ideas?" CNBC, March 13, 2023. Retrieved from <https://www.cnbc.com/video/2023/03/13/sea-of-sameness-are-smartphone-makers-out-of-ideas.html>
- [2] Victor Hristov, "Is Android innovation getting slower? iOS catches up and Android 14 needs to show Google cares," PhoneArena, December 7, 2022. Retrieved from [https://www.phonearena.com/news/google-android-innovation-slower-editorial\\_id144108](https://www.phonearena.com/news/google-android-innovation-slower-editorial_id144108)
- [3] "More answers to your questions about Apple and the environment," Apple, no date. Retrieved from <https://www.apple.com/environment/answers/>
- [4] Danish Khan, "Smartphone market contracting due to lack of innovation; cos playing safe: Nothing's Carl Pei," Economic Times, July 13, 2022. Retrieved from <https://telecom.economictimes.indiatimes.com/news/smartphone-market-contracting-due-to-lack-of-innovation-cos-playing-safe-nothings-carl-pei/92849379>
- [5] Harmeet Singh Walia, "2022 global smartphone shipments lowest since 2013; Apple regained no. 1 rank with highest-ever operating profit share of 85%," Counterpoint Research, February 3, 2023. Retrieved from <https://www.counterpointresearch.com/2022-global-smartphone-shipments-lowest-since-2013-apple-regained-no-1-rank-highest-ever-operating-profit-share-85/>
- [6] Mansoor Iqbal, "App download data," [Businessofapps.com](https://www.businessofapps.com), May 2, 2023. Retrieved from <https://www.businessofapps.com/data/app-statistics/>
- [7] Gartner, quoted in Andrew Wooden, "Continued slump in device shipments forecasted for 2023," [Telecoms.com](https://www.telecoms.com), January 31, 2023. Retrieved from <https://telecoms.com/519673/continued-slump-in-device-shipments-forecasted-for-2023/>
- [8] Mark Gurman, "Apple admits there is a smartphone slowdown ahead of iPhone 15 debut," [Bloomberg.com](https://www.bloomberg.com), August 6, 2023. Retrieved from [https://www.bloomberg.com/news/newsletters/2023-08-06/apple-iphone-15-comes-amid-us-sales-slowdown-tim-cook-q3-earnings-comments-lkzfs14u?in\\_source=embedded-checkout-banner#xj4y7vzkg](https://www.bloomberg.com/news/newsletters/2023-08-06/apple-iphone-15-comes-amid-us-sales-slowdown-tim-cook-q3-earnings-comments-lkzfs14u?in_source=embedded-checkout-banner#xj4y7vzkg)
- [9] Statista, "Smartphones worldwide revenue," [Statista.com](https://www.statista.com), no date. Retrieved from <https://www.statista.com/outlook/cmo/consumer-electronics/telephony/smartphones/worldwide#revenue>
- [10] Felix Richter, "Have we passed the peak of the smartphone era?" [Statista.com](https://www.statista.com), August 13, 2021. Retrieved from <https://www.statista.com/chart/12798/global-smartphone-shipments/>
- [11] Statista, "Mobile operating systems' market share worldwide from 1st quarter 2009 to 2nd quarter 2023," [Statista.com](https://www.statista.com), no date. Retrieved from [www.statista.com/statistics/272698/global-market-share-held-by-mobile-operating-systems-since-2009/](https://www.statista.com/statistics/272698/global-market-share-held-by-mobile-operating-systems-since-2009/)
- [12] U.S. Department of Commerce, "Competition in the Mobile Application Ecosystem," U.S. Department of Commerce, February 2023, page 1. Retrieved from [https://www.ntia.gov/sites/default/files/publications/mobileappecosystemreport.pdf?\\_ga=2.84811728.813216929.1677623123-2030698341.1675111518](https://www.ntia.gov/sites/default/files/publications/mobileappecosystemreport.pdf?_ga=2.84811728.813216929.1677623123-2030698341.1675111518)
- [13] StatCounter, "Search engine market share worldwide," [StatCounter.com](https://www.statcounter.com), June 2023. Retrieved from <https://gs.statcounter.com/search-engine-market-share>
- [14] Similarweb, "Mobile search engines by market share," [Similarweb.com](https://www.similarweb.com), June 2023. Retrieved from <https://www.similarweb.com/engines/worldwide/mobile-phone/>
- [15] Daisuke Wakabayashi and Jack Nicas, "Apple, Google, and a deal that controls the Internet," The New York Times, October 25, 2020. Retrieved from <https://www.nytimes.com/2020/10/25/technology/apple-google-search-antitrust.html>
- [16] E.U.uropean Commission, "The Digital Services Act package," E.U.uropean Commission, last update June 6, 2023. Retrieved from <https://digital-strategy.ec.europa.eu/en/policies/digital-services-act-package>

- [17] E.U.uropean Commission, "The Digital Markets Act: Ensuring fair and open digital markets," E.U.uropean Commission, October 12, 2022. Retrieved from [https://commission.E.U.ropa.E.U./strategy-and-policy/priorities-2019-2024/E.U.urope-fit-digital-age/digital-markets-act-ensuring-fair-and-open-digital-markets\\_en#new-rules-in-a-nutshell](https://commission.E.U.ropa.E.U./strategy-and-policy/priorities-2019-2024/E.U.urope-fit-digital-age/digital-markets-act-ensuring-fair-and-open-digital-markets_en#new-rules-in-a-nutshell)
- [18] Tate Ryan-Mosley, "The Internet is about to get a lot safer," MIT Technology Review, March 6, 2023. Retrieved from <https://www.technologyreview.com/2023/03/06/1069391/safer-internet-dsa-dma-E.U./>
- [19] "Bringing competition to walled gardens," Open Web Advocacy, version 1.2, pages 17–18
- [20] Zoom interview, July 24, 2023
- [21] Google Maps Platform, <https://mapsplatform.google.com/>
- [22] Damien, "Google Pay to Apple Pay: Can I do that?" Stupid Apple Rumours, no date. <https://stupidapplerumors.com/google-pay-to-apple-pay-can-i-do-that/>
- [23] The OpenWallet Foundation. Retrieved from <https://openwallet.foundation/>
- [24] Linux Foundation E.U. rope news release, August 23, 2023. Retrieved from <https://linuxfoundation.E.U./newsroom/openwallet-foundation-welcomes-google>
- [25] E.U.uropean Parliament, "Long-awaited common charger for mobile devices will be a reality in 2024," E.U.uropean Parliament news release, October 4, 2022. Retrieved from <https://www.E.U.roparl.E.U.ropa.E.U./news/en/press-room/20220930IPR41928/long-awaited-common-charger-for-mobile-devices-will-be-a-reality-in-2024>
- [26] Zoom interview, June 15, 2023
- [27] U.S. Department of Commerce, "Competition in the mobile application ecosystem," U.S. Department of Commerce, February 2023, page 6. Retrieved from [https://www.ntia.gov/sites/default/files/publications/mobileappcosystemreport.pdf?\\_ga=2.84811728.813216929.1677623123-2030698341.1675111518](https://www.ntia.gov/sites/default/files/publications/mobileappcosystemreport.pdf?_ga=2.84811728.813216929.1677623123-2030698341.1675111518)
- [28] Zoom interview, March 28, 2023
- [29] Zoom interview, March 28, 2023
- [30] Teresa Reidt, "GMS certification: A complete guide from requirements to submission," Emteria, May 22, 2023. Retrieved from <https://emteria.com/learn/google-mobile-services>
- [31] Zoom interview, June 9, 2023
- [32] Fullestop, "10 common challenges faced by Android developers," [Fullestop.com](https://www.fullestop.com), May 31, 2023. Retrieved from <https://www.fullestop.com/blog/what-are-10-common-challenges-most-android-developers-encounter>
- [33] "Mobile Android version market share worldwide," [Statcounter.com](https://gs.statcounter.com), June 2023. Retrieved from <https://gs.statcounter.com/android-version-market-share/mobile/worldwide/>
- [34] Developer.android, "Device compatibility overview," [Developer.android.com](https://developer.android.com), no date. Retrieved from <https://developer.android.com/guide/practices/compatibility>
- [35] BrowserStack, "Testing for fragmentation: Understanding browser, OS, and device fragmentation," [BrowserStack.com](https://www.browserstack.com), October 22, 2019. Retrieved from <https://www.browserstack.com/blog/understanding-browser-os-and-device-fragmentation/>

- [36] OpenSignal, "Android fragmentation 2015," [OpenSignal.com](https://cdn.opensignal.com/public/data/reports/global/data-2015-08/2015_08_fragmentation_report.pdf), August 2015. Retrieved from [https://cdn.opensignal.com/public/data/reports/global/data-2015-08/2015\\_08\\_fragmentation\\_report.pdf](https://cdn.opensignal.com/public/data/reports/global/data-2015-08/2015_08_fragmentation_report.pdf)
- [37] Lauren, "Mobile app download statistics & usage statistics (2023)," buildfire, no date. Retrieved from <https://buildfire.com/app-statistics/>
- [38] Apple, "Apps included on your Mac," Apple, no date. Retrieved from <https://support.apple.com/en-ca/guide/mac-help/mchl110b00b7/mac>
- [39] Ash Turner, "How Many Apps are There in the World (Aug 2023)," bankmycell. Retrieved from <https://www.bankmycell.com/blog/number-of-mobile-apps-worldwide>
- [40] Zoom interview, March 29, 2023, name withheld by request
- [41] Openwashing, "Openwashing," [Openwashing.org](https://openwashing.org/). Retrieved from <https://openwashing.org/>
- [42] Keith Szot, "GMS vs. Non-GMS for Android devices," [Esper.io](https://blog.esper.io/gms-vs-non-gms-for-android/), February 4, 2022. Retrieved from <https://blog.esper.io/gms-vs-non-gms-for-android/>
- [43] Zoom interview, July 25, 2023
- [44] Zoom interview, March 28, 2023
- [45] Coalition for App Fairness, "App Fairness," App Fairness, no date. Retrieved from <https://appfairness.org/>
- [46] Zoom interview, June 9, 2023
- [47] Sarah Perez, "Apple wins antitrust court battle with Epic Games, appeals court rules," [TechCrunch.com](https://techcrunch.com/2023/04/24/apple-wins-antitrust-court-battle-with-epic-games-appeals-court-rules/), April 24, 2023. Retrieved from <https://techcrunch.com/2023/04/24/apple-wins-antitrust-court-battle-with-epic-games-appeals-court-rules/>
- [48] Isabel Woodford and Sarah Morland, "Google, Apple facing anti-competitive complaint in Mexico," [RE.U.ters](https://www.reuters.com/technology/apple-will-change-app-store-practices-after-settlement-with-small-developers-2021-08-27/), September 10, 2022. Retrieved from <https://www.reuters.com/technology/apple-will-change-app-store-practices-after-settlement-with-small-developers-2021-08-27/>
- [49] Mike Scarcella, "Apple, Amazon must face consumer lawsuit over iPhone, iPad prices, U.S. judge rules," [RE.U.ters.com](https://www.reuters.com/legal/apple-amazon-must-face-consumer-lawsuit-over-iphone-ipad-prices-us-judge-2023-06-09/), June 9, 2023. Retrieved from [https://www.reuters.com/legal/apple-amazon-must-face-consumer-lawsuit-over-iphone-ipad-prices-us-judge-2023-06-09](https://www.reuters.com/legal/apple-amazon-must-face-consumer-lawsuit-over-iphone-ipad-prices-us-judge-2023-06-09/)
- [50] Kim Jaewon, "South Korea fines Google \$177m for blocking Samsung, others on OS," [Nikkei Asia](https://asia.nikkei.com/Business/Technology/South-Korea-fines-Google-177mn-for-blocking-Samsung-others-on-OS), September 14, 2021. Retrieved from <https://asia.nikkei.com/Business/Technology/South-Korea-fines-Google-177mn-for-blocking-Samsung-others-on-OS>
- [51] Praveen Paramasivam and Aditya Kalra, "India orders Google to allow third-party payments, slaps on another fine," [RE.U.ters.com](https://www.reuters.com/technology/india-fines-google-113-million-second-antitrust-penalty-this-month-2022-10-25/), October 26, 2022. Retrieved from, <https://www.reuters.com/technology/india-fines-google-113-million-second-antitrust-penalty-this-month-2022-10-25/>
- [52] \$2.73 B in 2017, \$5+ billion in 2018, \$1.7 B in 2019, another \$1.7 B in 2021
- [53] Alphabet Inc, "Alphabet announces fourth quarter and fiscal year 2021 results," Alphabet Inc. press release, February 1, 2022. Retrieved from <https://www.abc.xyz/assets/d0/29/30a290dc4db49f55544ffa184e75/2021q4-alphabet-earnings-release.pdf>
- [54] Shoshana Zuboff, "Surveillance capitalism is an assault on human autonomy," [The Guardian](https://www.theguardian.com/books/2019/oct/04/shoshana-zuboff-surveillance-capitalism-assault-human-autonomy-digital-privacy), Oct 4, 2019. Retrieved from <https://www.theguardian.com/books/2019/oct/04/shoshana-zuboff-surveillance-capitalism-assault-human-autonomy-digital-privacy>
- [55] Open Web Advocacy, "Bringing competition to walled gardens," Open Web Advocacy, page 133, no date. Retrieved from <https://open-web-advocacy.org/walled-gardens-report/>
- [56] YouTube, "Open Web advocacy speech at the Digital Markets Act workshop," [YouTube.com](https://www.youtube.com/watch?v=S6oETjUpriQ), March 14, 2023. Retrieved from <https://www.youtube.com/watch?v=S6oETjUpriQ>

- 
- [57] E.U.uropean Commission, “The Digital Markets Act: Ensuring fair and open digital markets,” E.U.uropean Commission, October 12, 2022. Retrieved from [https://commission.E.U.ropa.E.U./strategy-and-policy/priorities-2019-2024/E.U.ropa-fit-digital-age/digital-markets-act-ensuring-fair-and-open-digital-markets\\_en#new-rules-in-a-nutshell](https://commission.E.U.ropa.E.U./strategy-and-policy/priorities-2019-2024/E.U.ropa-fit-digital-age/digital-markets-act-ensuring-fair-and-open-digital-markets_en#new-rules-in-a-nutshell)
- [58] Open Web Advocacy, “Bringing competition to walled gardens,” Open Web Advocacy, page 133, no date. Retrieved from <https://open-web-advocacy.org/walled-gardens-report/>
- [59] “Support us” section, [Openwebadvocacy.org](https://open-web-advocacy.org/), no date. Retrieved from <https://open-web-advocacy.org/>
- [60] Alex Heath, “Meta is planning to let people in the E.U. download apps through Facebook,” [TheVerge.com](https://www.theverge.com), June 29, 2023. Retrieved from <https://www.theverge.com/2023/6/29/23778928/meta-E.U.-facebook-plans-app-install-android-ads>
- [61] Tim Bradshaw, “Microsoft plans mobile games app store to rival Apple and Google,” March 20, 2023. Retrieved from <https://arstechnica.com/gaming/2023/03/microsoft-plans-mobile-games-app-store-to-rival-apple-and-google/>
- [62] Zoom interview, March 28, 2023
- [63] Arpan Chaturvedi and Aditya Kalra, “Google accuses India antitrust body of protecting Amazon in Android probe,” [REUTERS.com](https://www.reuters.com), July 6, 2023. Retrieved from <https://www.reuters.com/technology/google-accuses-india-antitrust-body-protecting-amazon-android-probe-2023-07-06/>
- [64] All quotes from Zoom interview, June 15, 2023
- [65] All quotes from Zoom interview, July 27, 2023
- [66] All quotes from Zoom interview, July 25, 2023
- [67] All quotes from Zoom interview, July 24, 2023



Futurewei maintains ongoing, in-depth collaboration with forward-thinking companies worldwide. We pursue openness in research and development by embracing an open innovation model and striving to share ideas and knowledge with technology communities to create new business opportunities.

Our vision is *Shaping the Future Toward a Fully Connected, Intelligent World.*

Our mission is *Developing Innovations to Benefit an Intelligent and Digital Society via Open Source, Standardization, and Collaboration within Ecosystems.*

Our experts have actively engaged in standards programs for the past two decades. Through this work, we participate in developing next-generation wireless technologies and networks and building open ecosystems through open application platforms for ICT systems.

[www.futurewei.com](http://www.futurewei.com)



Founded in 2021, [LF Research](#) explores the growing scale of open source collaboration and provides insight into emerging technology trends, best practices, and the global impact of open source projects. Through leveraging project databases and networks and a commitment to best practices in quantitative and qualitative methodologies, LF Research is creating the go-to library for open source insights for the benefit of organizations the world over.



Copyright © 2023 [The Linux Foundation](#)

This report is licensed under the [Creative Commons Attribution-NoDerivatives 4.0 International Public License](#).

To reference this work, please cite as follows: Gordon Graham, "A New Direction for the Mobile Industry: Making the Case for an Open Mobile Software Stack," foreword by Raul Quino, The Linux Foundation, September 2023.

REVISED: This report has been updated since its original release on 26 September 2023. This second version, released on October 2, 2023 corrects errors found in the original text and graphics.

