



CATCHWORD

Mini-App Ecosystems

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1 Introduction

Since the launch of the first iPhone in 2007 and the Apple App Store for mobile apps for iPhones in 2008, almost 1.96 million apps have been made available on the App Store for iOS users (Statista 2021). This makes the Apple App Store the second-largest app store after Google Play, which hosts 2.97 million apps (Statista 2021; van der Aalst et al. 2019). These app stores, in conjunction with the underlying mobile operating systems, allow third-party developers to market their apps to users of smart devices (Basole and Karla 2011). Hence, the app stores supported by mobile operating systems act as multisided platforms and have fueled an ecosystem of third-party developers and users – which we refer to as a *mobile app ecosystem*. Mobile app ecosystems are based on network effects (Tiwana 2014; Stummer et al. 2018): the more third-party developers join the platforms, the more apps there are available for users, leading to more users joining the platforms; and vice versa, as the number of users increases, more third-party

developers will be attracted to the platforms. Ecosystem orchestrators such as Google and Apple govern the interactions of these groups to maximize value creation in the ecosystem.

However, an increasing reluctance of users to install mobile apps has become a concern (comscore 2017) for the orchestrators of mobile app ecosystems. While the high number of apps enriches app diversity to satisfy different users' needs, it also means users have to make an effort to search for a suitable app (Cheng et al. 2020). Further, initial costs of adoption that cover downloading, installing, and often registering for a mobile app have discouraged users. Consequently, developers of new apps struggle to achieve visibility among millions of apps while bearing high development costs which stem from complex development processes, developer-unfriendly revenue sharing schemes, and high maintenance costs (Cheng et al. 2020).

Orchestrators of mobile app ecosystems and other tech companies have noticed the discontent of users and begun to explore alternative approaches to providing apps for users of mobile devices. Most notably, the concept of mini-apps has emerged, which refers to lightweight apps that can be used without prior download and installation and which builds the foundation of *mini-app ecosystems* that comprise developers and users of mini-apps. One of the pioneers of mini-apps is Tencent, a Chinese technology conglomerate, whose social media apps like QQ and WeChat have attracted billions of users worldwide.¹ In 2017, Tencent embedded Mini Programs in WeChat, creating its own mini-app ecosystem. Since then, Apple and Google have reacted with their versions of mini-apps by releasing App

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¹ As of March 2021, QQ Monthly Active Users reached almost 638.8 million and WeChat Monthly Active Users reached more than 1 billion (QuestMobile 2021).

Clips in 2020 and Google Play Instant in 2017, respectively.

While the mini-app phenomenon has started to gain momentum, IS literature on digital platform ecosystems has not given it much attention. Digital platform ecosystems can be seen as a broader term spanning different subtypes such as mobile app ecosystems and digital industrial platform ecosystems (Hein et al. 2019). While there are numerous studies regarding platform governance (e.g., Tiwana 2014; Ghazawneh and Henfridsson 2013) and platform competition (e.g., Clemons 2019) for digital platform ecosystems, it is unclear to what extent these findings apply to mini-app ecosystems and to what extent mini-apps are different. We provide a starting point to address this gap by describing the phenomenon of mini-app ecosystems by means of the examples of WeChat Mini Programs and Apple App Clips, and we discuss implications for future research on platform governance and platform competition.

2 Mini-App Ecosystems: App-in-App Versus Native

Mini-apps have been created to address users' increasing reluctance to download entire apps from app stores and developers' struggles with engaging users. Mini-apps are lightweight apps that rely on a host app as a medium to reach users. They do not need to be downloaded or installed, making them immediately accessible to users who only wish to use single functions. Consequently, mini-app ecosystems emerge from within mobile app ecosystems as developers provide mini-apps to users of mobile devices.

Currently, there are two approaches to developing a mini-app ecosystem, as summarized with the illustrative examples of WeChat Mini Programs and Apple App Clips in Table 1. One approach, which we refer to as the *app-in-app approach*, is to enable mini-apps within another mobile app. This mobile app – the host app – hosts a marketplace that allows users to access a suite of mini-apps that offer additional functionality (Lu et al. 2020). The app-in-app approach transforms the host app into a semi-functional app store irrespective of the underlying operating system, and the host app governs how external developers publish their mini-apps on the marketplace of the host app (Cheng et al. 2020). In sum, the app-in-app approach essentially transforms a mobile app into a host app for a mini-app ecosystem.

The second approach – the *native mini-app approach* – extends an existing mobile app ecosystem by allowing native mobile apps (i.e., full apps) to offer parts of their functionality through mini-apps. Thus, each mobile app can become a host app for one or several mini-apps that

relate to the functionality of the host app. Users can access parts of a host app's inherent functionality through mini-apps on their mobile devices without needing to download the host app from an app store (Costello 2020). Unlike the app-in-app approach, the native mini-app approach relies on the presence of app stores and is subject to the underlying mobile device operating system. In other words, app stores, not host apps, govern the publication of mini-apps.

2.1 WeChat Mini Programs – Example of the App-in-App Approach

Let us take WeChat Mini Programs, the most successful example of the app-in-app approach to mini-app ecosystems, to illustrate this approach. WeChat Mini Programs were launched by Tencent in January 2017 and as of 2020, there were 3.2 million Mini Programs available in the WeChat ecosystem (Daxue Consulting 2020). WeChat, as the host app, becomes a platform mimicking an app store independent of the underlying mobile device operating system (Fig. 1). The resulting mini-app ecosystem includes WeChat, third-party developers, and users.

WeChat harnesses a range of different Mini Programs developed by third-party developers and, in turn, Mini Programs increase WeChat's app usability in terms of efficiency and effectiveness. A WeChat Mini Program has a maximum of 10 MB (Graziani 2019). It is small enough to run on WeChat's interface directly, and users do not need to install each Mini Program separately. Each Mini Program represents an easy-to-use tool or performs a particular service conveniently (Cheng et al. 2020). Thereby, the services can be unrelated to WeChat's built-in functionalities, such as food delivery or taxi booking, and are created to become "simple utilitarian tools addressing one specific problem" (Cheng et al. 2020). WeChat Mini Programs run on any smart device that has WeChat installed, irrespective of the device's operating system and version.

For instance, users can search for "MeiTuan Delivery" (美团), a popular food delivery service in China, on the Mini Program search page. After clicking through the MeiTuan Mini Program, users will be guided to the ordering page. Various selections are offered on the Mini Program page. After selecting the food to order from one of the merchants, the Mini Program would prompt users to pay with WeChat Pay. Users do not have to leave WeChat to complete the process.

Developers need less complicated development tools and a shorter time frame to develop a Mini Program compared to fully-fledged mobile apps. Developers have likened the Mini Program development process to implementing a website or a web app. They reported that knowledge of JavaScript, HTML, and CSS is already sufficient for the backend and frontend development (Graziani

Table 1 Comparison of app-in-app and native mini-app ecosystems with two illustrative examples

	App-in-app	Native
Illustrative example	WeChat Mini Programs	Apple App Clips
Operating system	Independent of the underlying operating system and version; runs on any smart device that has WeChat installed	Exclusive to Apple’s iOS 14 (and above)
Launch	January 9, 2017	September 16, 2020 (launch of iOS 14)
Number of apps	3.2 million	No official numbers reported; low numbers reported by users (10–20 App Clips), strong growth expected
Host app	WeChat App	Can be any app available on the App Store
Programming language	JavaScript, WXML (based on HTML), and WXSS (based on CSS)	Swift
Notification method	Users need to authorize to receive notifications that can be pushed with no time limit	Users need to authorize to receive notifications for a period that spans more than a day
Revenue sharing scheme with developers	Transaction-based commission and advertising commission from Mini Program developers	Subject to App Store’s 30% commission model
Entry points	Mini Program Redirection, Advertising, QR Code, Official Account, Searching, WeChat Official Account menu, embedded into WeChat article, Discover tab of WeChat, Sharing card on WeChat groups	NFC Tags, QR Codes, Safari App Banner, Links in Messages, Place Cards in Maps, Recently Used App Clips
Limitations	App size: 10 MB Limited discoverability (no real app store)	App size: 10 MB App Clips cannot access Apple Music and Media, data from apps like Calendar, Contacts, Files, Health, Messages, Reminders, Photos, and Motion Limited discoverability (no real app store)
Further examples	AliPay Mini Programs: AliPay as the host app, focuses on finance and e-commerce, compatible with all operating systems Baidu Mini Programs: Baidu as the host app, focuses on search and information flow, compatible with all operating systems TikTok Mini Programs: TikTok as the host app, focuses on e-commerce and short videos, compatible with all operating systems	Google Play Instant: lightweight with 15 MB size limit, act as samples of native full apps, multiple entry points including access from Google Play, only compatible with Android

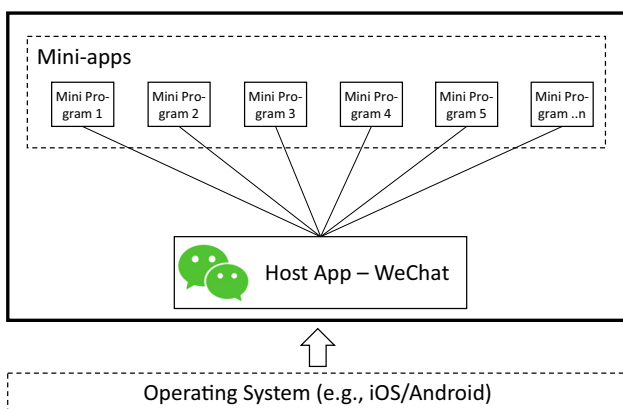


Fig. 1 App-in-app – WeChat Mini Program ecosystem

2019). Besides, WeChat provides pre-designed UI frameworks and easy-to-use drag and drop components for Mini Program development (Cheng et al. 2020). The

development time can also be substantially reduced from months to days. Overall, the WeChat Mini Program ecosystem imposes low entry costs for developers while offering them access to WeChat’s 1 billion active users. Furthermore, developers can rely on Tencent’s existing interconnected platform infrastructures to drive business growth. Already in 2013, Tencent launched WeChat Pay, an independent mobile payment system for users to conveniently pay for all services linked to WeChat. Also, Mini Programs and WeChat Official Account² organized by the same developers can be integrated and developers can

² WeChat Official Account allows brands, writers and free-lancers to open their self-media accounts to engage users. It has broken down traditional media’s communication barriers and decentralized the power to publish personalized media information. WeChat Official Account receives millions of active users daily.

divert user traffic from their Official Account into their Mini Programs and vice versa.

Another distinctive feature of WeChat Mini Programs is the notification method that conventional apps do not possess. In April 2020, WeChat introduced the subscription notification model.³ When a user clicks a specific button in a Mini Program, a popup window will appear to request a subscription. Only after the user takes the initiative to click on the authorization, the Mini Program can push service notifications to the user at any subsequent time. There are two types of subscription messages: one-time subscription messages and long-term subscription messages, both with no time limit (WeChat Open Class 2020). Overall, the subscription notification model gives developers more freedom to interact with users.

In terms of revenue sharing, Tencent takes transaction-based commission and advertising commission from Mini Program developers. For developers of games, after the business income reaches a certain scale, Tencent takes a percentage of income from in-app purchases as the platform commission. For e-commerce Mini Programs, the company takes a certain percentage of commission according to the size of “gross merchandise value” transacted within WeChat. In 2018, WeChat added an advertising component to the Mini Program configuration package. Developers can publish banner ads and video ads. Tencent charges advertising fees based on user activity and shares with developers by a certain ratio (CITIC Securities 2018).

Although WeChat Mini Programs offer convenience to users and reduced effort for developers, they face the challenge of discoverability. For native full apps, the app stores represent an “obligatory passage point” (Tilson et al. 2012) where users may discover new apps if the apps have collected enough ratings or reviews or have been included in one of the category ranking lists (Bresnahan et al. 2014). As there is no such centralized app store for WeChat Mini Programs, users may find it challenging to discover Mini Programs organically, especially when they do not have prior brand awareness (Cheng et al. 2020). Over time, WeChat made an increasing number of entry points for Mini Programs available. WeChat users can directly search for Mini Programs on WeChat by typing in the name of a Mini Program, a keyword, or by searching for Mini Programs associated with locations nearby. There are no reviews or ratings as in app stores to help users to choose Mini Programs. Users can also pin and store their frequently-used Mini Programs by pulling down the chat screen resembling a smart device home screen. Users can share Mini Programs with their friends and chat groups or

discover them offline through QR code scanning. Other methods include accessing the WeChat Official Account menu or WeChat Official Account articles that embed Mini Programs.

Other major host apps that have adopted the app-in-app approach, like AliPay, Baidu, and TikTok, have common technical features as WeChat. Each host app provides developers rich APIs and ready-to-use components that help to ease entry costs to launch a mini-app on the host app. Thereby, the host apps’ existing business focus is reflected in the types of mini-apps that emerge in the mini-app ecosystem. WeChat, with social media at its core, has become a fertile ground for numerous information, entertainment, and gaming mini-apps. AliPay’s mini-app ecosystem shows a focus on marketing, credit systems, risk control, lending, and other finance-related mini-apps. The theme of Baidu’s mini-app ecosystem is search and information flow. TikTok’s mini-app ecosystem focuses on e-commerce transactions through short video interactions. Notably, mini-apps of each host app are mutually exclusive from each other so that users can only stay within their predetermined ecosystem boundary.

2.2 Apple App Clips – Example of the Native Approach

The native approach to mini-app ecosystems is taken on by orchestrators of mobile platform ecosystems. They enable conventional, native apps (i.e., full apps) in their app stores to act as host apps, allowing developers to make parts of the host apps’ native functionalities available through one or several mini-apps. Users can use these mini-apps without downloading the entire host app (Costello 2020). Apple and Google have adopted this approach with App Clips and Google Play Instant, respectively. We take App Clips as an example to illustrate the native mini-app approach and briefly comment on Google Play Instant.

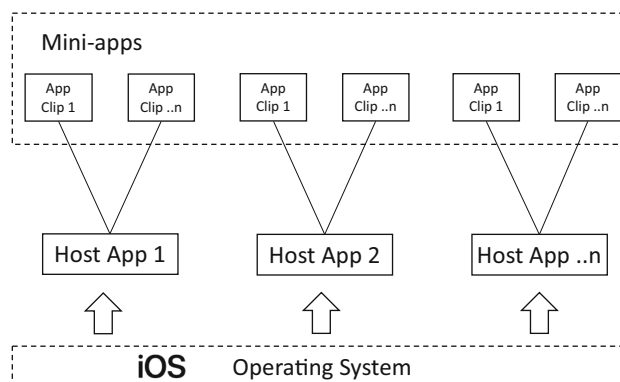


Fig. 2 Native – Apple App Clips ecosystem

³ In April 2020, WeChat changed its notification model from what is called “template notification” to “subscription notification”.

Apple introduced App Clips on September 16, 2020 to address the issue of users' increasing reluctance to download apps (Fig. 2). The current adoption rate of App Clips by developers remains low – Apple has not published official numbers but lists curated by Apple users include 10–20 App Clips as of December 2020 (e.g., Gangwar 2020). However, Apple expects the number of App Clips available for download to increase in the future (Lumb 2020). Similar to a WeChat Mini Program, an App Clip is lightweight with a maximum of 10 MB (Aver 2020). It delivers small pieces of functionality without needing to download the entire host app (Aver 2020). For each host app, developers can develop multiple mini-apps to perform specific functionalities. App Clips are designed to quickly demonstrate the host apps' value to users before they receive in-app offers to download the full host apps. App Clips are automatically deleted from users' devices 30 days after download (Aver 2020). Furthermore, users can log in with their Apple ID and authenticate in-app payments with Apple Pay (Costello 2020). Apple essentially helps users avoid entering any personal information or additional payment verification steps when using App Clips.

Examples of the use of App Clips are food delivery apps such as the one by Panera Bread (Polly 2020). By providing an App Clip that interacts with Apple Maps, customers of Panera Bread can order food directly from Maps, without having to open the Panera Bread app. Authentication and payment are handled through the Apple ID and Apple Pay, requiring no further user input.

App Clips and their host apps are interconnected. Users' information stored on App Clips can be seamlessly transitioned to the host app if it is installed later. Additionally, if users already have installed the host app, opening App Clips will prompt only the relevant functionalities of the app instead of re-downloading the App Clips (Bathe 2020). Since App Clips are complementary to apps downloadable on App Store, developers can develop App Clips while developing the full app by using the same iOS SDK and Swift as the programming language (Apple 2020a). Developers can also manage App Clips as part of their full app in App Store Connect (Apple 2020a). Access to App Clips is limited to Apple users who have an iPhone, iPad, or iPod Touch running on iOS 14 or iPadOS 14 and above (Costello 2020).

In terms of push notifications, App Clips embed default time restrictions which can only be overridden with the users' permission. Developers can schedule or receive notifications for up to 8 h after each launch without the users' prior authorization, but users can disable it in the App Clip. For a period that spans more than a day, an App Clip needs to explicitly request the user's permission to send notifications (Apple 2022).

The Apple App Store allows only developers of full apps to develop App Clips for their apps. App Clips cannot

be submitted for app review independently, therefore Apple's standard review process applies to Apps Clips as well. Concerning revenue sharing, developers are subject to the same 30% commission for App Clips that apply to conventional apps published in the Apple App Store.

App Clips are subject to limitations. Firstly, like WeChat Mini Programs, the discoverability of App Clips is limited. Users cannot search for them directly in the App Store like they usually do for conventional apps. Instead, Apple tries to use App Clips to connect offline and online scenarios and simplify user interaction with physical objects and places (Aver 2020). Offline methods include (1) App Clip Codes that were placed for users, for instance by store owners; (2) QR codes that work the same way as the App Clip Codes; (3) Near Field Communication (NFC) functionality that triggers an App Clip download at devices placed in direct vicinity; and (4) Apple Maps which can suggest App Clips tied to specific locations (Apple 2020a). Online methods include the Smart App Banner for App Clips from Safari (Apple's browser; Apple 2020a) and sharing App Clips via the Messages app between users (Costello 2020).

Secondly, to protect user privacy, App Clips restrict user tracking between host apps and their App Clips. For instance, App Clips cannot perform background activities, nor can they access Apple Music and Media, or data from apps like Calendar, Contacts, Files, Health, Messages, Reminders, Photos, and Motion (Apple 2020b). The intention to uphold users' privacy thus restricts certain app functionalities. It may reduce third-party developers' willingness to embrace App Clips.

It is worthwhile to provide brief remarks on Google Play Instant because of the importance of Android as the underlying mobile operating system. Similar to Apple's App Clips, Google Play Instant refers to lightweight versions of conventional apps. From that host app, developers can create multiple Google Play Instant mini-apps to offer different functionalities, reinforcing users' incentives to download the host app from app stores later. Thereby, Google Play also governs the publication and revenue sharing of mini-apps. Unlike App Clips, users can download Google Play Instant from the Google Play app store. Moreover, it is reported that Google Play Instant may pose privacy threats including mini-apps that are downloaded without permission or that create security vulnerabilities that compromise the Android operating system (Terry 2021).

3 Implications and Avenues for Future Research

Mini-app ecosystems address different needs and requirements from users and third-party developers, compared to

traditional mobile app ecosystems. They reinforce, rather than replace, mobile app ecosystems, requiring providers that engage in mini-app ecosystems to reevaluate platform governance and platform competition. We summarize the implications of the mini-app ecosystem phenomenon in Table 2 along with avenues and exemplary research questions for future research.

3.1 Platform Governance

Platform governance typically refers to the partitioning of decision rights, implementation of control mechanisms, and pricing structures in a digital platform ecosystem (Tiwana 2014). One exemplary tradeoff in platform governance is the balance of openness and control through boundary resources (Ghazawneh and Henfridsson 2013). We reconsider platform governance in the context of mini-app ecosystems as opposed to mobile app ecosystems.

3.1.1 *Balancing the Benefit of Lightweight Apps Against the Limitations of Mini-Apps*

When implementing mini-app ecosystems, ecosystem orchestrators need to balance the benefit of having lightweight apps against the limitations of mini-apps. Lightweight apps offer an alternative solution to accommodate the users' reluctance to use apps but lead to limitations for developers. The restrictive size limit and the limited storage space allocated to them constrains the functionality of mini-apps. It means that developers cannot implement complex functions within the mini-app technical framework, which may discourage developers from engaging in the mini-app ecosystems. Maintaining a balance between satisfying users' needs and developers' interests is a crucial issue that ecosystem orchestrators need to consider.

3.1.2 *Challenge of Managing and Optimizing Entry Points*

Both approaches to mini-app ecosystems face the challenge of managing and optimizing entry points, highlighting the issue of limited discoverability of mini-apps. As mini-app ecosystems are relatively new to the market, ecosystem orchestrators must attract users to find and use mini-apps and ensure the users' needs are met to generate positive momentum. We observe that WeChat Mini Programs and Apple App Clips have adopted similar approaches. To help users find mini-apps easily, ecosystem orchestrators no longer rely on user ratings and reviews displayed in their app stores. Instead, ecosystem orchestrators explore offline engagement to create new channels to find mini-apps and encourage online community sharing, such as via chat messages.

3.1.3 *Relationship Management with Third-Party Developers*

Orchestrators of mini-app ecosystems need to maintain relationship management with third-party developers. If third-party developers do not understand the value of mini-apps, they will continue developing only full apps for users. Ecosystem orchestrators should keep developers interested in their ecosystems by enabling them to develop a 'teaser' for users without bearing much up-front cost. Both WeChat and Apple have offered standardized and simplified development support and tools to keep developers' costs and technical investment down. Moreover, as mini-apps are a relatively new product, ecosystem orchestrators should help developers decide when a mini-app is more helpful than a full app (in the case of the app-in-app approach) or what features of the full app would be most promising as mini-apps (in the native approach). For instance, in January 2021, Apple invited developers to participate in an event called 'Building Great App Clip Experiences' to increase developers' awareness of the App Clips feature introduced in iOS 14 (Clover 2020). The benefit for ecosystem orchestrators is that they can use standardized rules and guidelines to regulate developers' behaviors over time (Ghazawneh and Henfridsson 2013).

Moreover, Apple and WeChat have adopted different approaches to govern their developers. Apple App Store allows only developers of full apps to develop App Clips for their apps, therefore Apple's standard review process applies to the same developers. For WeChat Mini Program, the mini-app review and governance take place independently from app stores' policies, although WeChat itself is subject to app stores' regulations. The divergence essentially means native apps with an app-in-app approach carve out their distinctive circle of influence within the broader framework governed by app stores. Such an 'ecosystem within ecosystem' phenomenon can lead to a conflict of interests as both models gain traction, yielding an interesting field for future research.

3.1.4 *Business Model for Developers of Mini-Apps*

An ecosystem orchestrator that has adopted the app-in-app approach challenges the revenue sharing model of the ecosystem orchestrator that owns the underlying mobile operating system and might have established its own exclusive mini-app ecosystem, using the native approach. The current revenue sharing models of WeChat and Apple indicate that there are two opposing strategies: Tencent takes transaction-based commission and advertising commission from Mini Program developers, while host app developers who develop App Clips are subject to the same non-negotiable 30% model conventionally implemented by

Table 2 Avenues and questions for future research

Topic	Research avenue	Exemplary research questions
Platform governance	Balancing the benefit of lightweight apps against the limitations of mini-apps	What limitations are acceptable for third-party developers? How can third-party developers capture value from their participation in both mobile app ecosystems and mini-app ecosystems?
	Challenge of managing and optimizing entry points	What entry points are most efficient in attracting users to the mini-app ecosystem? How do offline and online entry points impact cross-side network effects?
	Relationship management with third-party developers	How can ecosystem orchestrators support third-party developers in deciding when a mini-app is suitable? How can ecosystem orchestrators balance control and openness in a way that attracts third-party?
	Business model for developers of mini-apps	How can ecosystem orchestrators that adopt the native approach to mini-app ecosystems govern their relationship with ecosystem orchestrators that adopt an app-in-app approach? What features can ecosystem orchestrators include in their revenue sharing and incentive models that help to motivate app developers to join the mini-app ecosystem?
	Novel privacy and security issues	How can ecosystem orchestrators who adopt the native approach to mini-app ecosystems govern their revenue sharing scheme with ecosystem orchestrators that apply an app-in-app approach? What novel privacy and security issues arise from mini-apps and how can ecosystem orchestrators respond?
	Platform competition	App-in-app ecosystems as an approach for platform envelopment
Increased lock-in effects		How can mini-app ecosystems leverage data network effects to fuel growth? How does the growth of mini-app ecosystems fuel the underlying ecosystems and what regulatory concerns does this raise?

Apple App Store. Given WeChat's success in scaling up Mini Programs, Apple has required WeChat to comply with Apple App Store standard 30% commission for all in-app purchases, including purchases made in Mini Programs. However, there has not been an agreement reached between the two parties leaving it unclear how the two systems could sustain their co-existence.

3.1.5 Novel Privacy and Security Issues

Finally, scholars have identified new privacy and security risks inherent to mini-app ecosystems. For instance, API permission policies are unclear (Lu et al. 2020), and phishing attacks from improper user interface management (Lu et al. 2020; Aonzo et al. 2018) have been observed. When monitoring the quality of mini-apps, ecosystem orchestrators can actively review their privacy policy and service documentation or set up data access restrictions like App Clips where Apple blocks user tracking between App Clips and full apps. Ecosystem orchestrators should also advise users to reduce privacy risks, such as avoiding

scanning dubious QR codes to open doors for malware attacks. Addressing these issues is important, given that trust in platform ecosystems where users and developers participate independently and autonomously is crucial for its success (Nambisan and Sawhney 2011).

3.2 Platform Competition

Platform competition takes place between different ecosystem orchestrators when an ecosystem orchestrator in one market (the origin market) enters another market (the target market), leveraging overlapping user relationships or shared components or modules between the origin market and the target market (Eisenmann et al. 2011). This is also referred to as a platform envelopment strategy. Mini-app ecosystems provide new pathways for ecosystem orchestrators to engage in platform competition and envelop other platforms (Alt and Zimmermann 2019).

3.2.1 *App-in-App Ecosystems as a Platform Envelopment Strategy*

App-in-app ecosystems can be considered an approach to envelop currently dominant mobile operating systems. In the case of WeChat Mini Programs, its owner, Tencent, does not provide a mobile operating system but, with WeChat, Tencent runs a successful mobile app that is used by billions on devices with iOS or Android operating systems. Tencent has used this position to its advantage by creating a WeChat Mini Program ecosystem that builds on WeChat as the host app. This app-in-app approach eliminates the need for users to download multiple apps by centralizing frequently used functions of different apps within the mini-app ecosystem (Cheng et al. 2020). Thereby, the mini-app ecosystem becomes an alternative to the mobile app ecosystem, reducing the users' dependency on the underlying mobile operating system.

Essentially, the app-in-app approach challenges the dominant status quo of mobile app ecosystems that build on the mobile operating systems iOS and Android. Thus far, the app-in-app approach has a strong presence mostly in China (such as WeChat Mini Programs, AliPay Mini Programs, Baidu Mini Programs, and TikTok Mini Programs). However, it lays out a new avenue for other global ecosystem orchestrators to circumvent the dominance of Google and Apple.

From the perspectives of Google and Apple as the incumbent ecosystem orchestrator, the native mini-app approach might be more of a favorable option than a direct threat to their ecosystems. The native mini-app approach serves incumbents' self-interests by remediating the issue of users and developers leaving the mobile app ecosystem as users become less willing to download apps. Since a mini-app requires a host app as a medium to reach users, the mini-app can enrich user stickiness to the host app by securing user acquisition. Users who desire more functionalities will still rely on the mobile app ecosystems to use native full apps.

3.2.2 *Increased Lock-in Effects*

Common to the different approaches to mini-app ecosystems is the fact that ecosystem orchestrators compete to increase lock-in effects. First, they attract users and keep them in the mini-app ecosystems by addressing as many user needs as possible in the most convenient way possible. Mini-app ecosystems extend the reach to secure a complete value chain connecting the online and offline world. Second, by enabling the ecosystem orchestrator's user ID for app authentication and payment, ecosystem orchestrators can exercise more influence on users' behavior and monitor their digital footprint. Third, mini-app ecosystems lock in

numerous small-to-medium-sized third-party developers cost-effectively. They help explore user experience niches as mini-apps give ecosystem orchestrators a detailed view of users' preferences. By keeping third-party developers and users engaged with mini-app platform ecosystems, ecosystem orchestrators can offer more personalized services in the ecosystem. For instance, WeChat Mini Programs now offer a broad spectrum of online and offline services, including retail, e-commerce, lifestyle services, municipal services, and games. Additionally, the more users engage in the ecosystem, the more user data ecosystem orchestrators can collect, creating data network effects (Gregory et al. 2020). With their advanced technological infrastructure, they can strengthen data interoperability and discover new data usage scenarios (Alt et al. 2021). Once there are a large number of users in the ecosystems, ecosystem orchestrators can secure market bottlenecks and establish industry infrastructure (Choudary 2020).

The resulting growth of host apps such as WeChat and mobile app ecosystems such as iOS leads to interesting dynamics in platform competition but might also raise new regulatory concerns as the ecosystem orchestrators collect data across more and more domains of users' daily lives.

4 Conclusion

The rise of mini-app ecosystems is highly relevant for shaping the future of mobile app ecosystems. Mini-app ecosystems are an innovative solution to keep users engaged even when they do not want to download and install mobile apps. Two main approaches to mini-app ecosystems exist: (1) the app-in-app approach that allows companies with popular apps to create mini-app ecosystems around these host apps, and (2) the native approach that allows orchestrators of mobile app ecosystems to expand their mobile app ecosystem with a mini-app ecosystem. We provide initial insights on how both approaches impact platform governance and competition and how they can co-exist, and we suggest that these questions need further research to improve the understanding of mini-app ecosystems.

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