How Do Mobile Applications Enhance Security? An Exploratory Analysis of Use Cases and Provided Information

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Abstract

The ubiquity of mobile applications has increased dramatically in recent years, opening up new opportunities for cyber attackers and heightening security concerns in the mobile ecosystem. As a result, researchers and practitioners have intensified their research into improving the security and privacy of mobile applications. At the same time, more and more mobile applications have appeared on the market that address the aforementioned security issues. However, both academia and industry currently lack a comprehensive overview of these mobile security applications for Android and iOS platforms, including their respective use cases and the security information they provide.

To address this gap, we systematically collected a total of 410 mobile applications from both the App and Play Store. Then, we identified the 20 most widely utilized mobile security applications on both platforms that were analyzed and classified. Our results show six primary use cases and a wide range of security information provided by these applications, thus supporting the core functionalities for ensuring mobile security.

CCS Concepts

• Security and privacy → Software security engineering.

Keywords

Mobile Security Apps, Use Cases, Security Information, Systematic Analysis, Mobile App Analysis

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1 Introduction

In the course of the rapid digitalization of society and the economy, the spread of mobile applications has increased significantly in recent years [8]. The number of available mobile applications on the Play Store and the App Store has grown over two million¹. As a result, mobile devices and applications have become lucrative targets for cyber attacks. This is reflected in a staggering 50% increase in attacks on mobile devices between 2022 and 2023, culminating in an incredible 33.8 million attacks worldwide in 2023².

This digital revolution and the ubiquity of smartphones have created a vast attack surface for adversaries. Each device can potentially be used as a gateway to sensitive personal and corporate information. The potential attack vectors can range from phishing schemes that exploit the limited security features of mobile devices, to malware disguised as legitimate applications. Moreover, the implications of this surge in mobile-targeted attacks extend beyond individual users, potentially compromising entire organizational networks. As our reliance on mobile technology continues to grow and evolve, the urgency to develop robust, adaptive security measures that can keep pace with the evolving threat landscape is of utmost importance.

Both research and practice are looking into the security and privacy aspects of mobile applications and platforms. For example, some research focuses on the security and privacy of mobile applications through detailed analyses that consider static and dynamic technologies [13, 17], while other studies examine the security awareness of users in connection with the use of mobile applications [23, 27]. However, due to the large number and diversity of the applications, it is difficult to tell what the available apps are used for. For instance, it can be argued that these applications provide a solid foundation for sharing threat intelligence data due to the fact that they can provide timely information for the users (e.g. attack and vulnerable asset information).

However, academia and industry currently face the challenge of lacking a comprehensive overview of mobile security applications for Android and iOS platforms. This includes detailed insights into their respective use cases and the specific type of security information they provide, which was done in other domains such

 $^{^1} https://42 matters.com/google-play-statistics-and-trends, https://42 matters.com/ios-apple-app-store-statistics-and-trends$

 $^{{}^2}https://www.kaspersky.com/about/press-releases/2024_attacks-on-mobile-devices-significantly-increase-in-2023$

as automotive [19, 20], self-adaptive system [18, 24] and web [21] domains. Such comprehensive information can serve as a backbone for future developments and provide a foundation for more targeted research in the domain of mobile security applications. Thus, we empower users to make informed decisions about which security tools best suit their needs. Understanding the types of security information these applications provide allows users to better protect themselves against evolving threats. Moreover, this study lays the groundwork for developers and researchers to identify gaps in current mobile security offerings, potentially leading to the creation of more effective and user-centric security solutions.

To the best of our knowledge, no other work has compared mobile applications' actions across different platforms until now. To address this gap, we investigate the two aforementioned aspects by focusing on the following two research questions:

RQ1 What are the use cases of mobile security applications?RQ2 What type of security information is provided by mobile security applications?

To answer these research questions, we conducted an exploratory systematic analysis of popular mobile security applications in the App and Play Store. We systematically identified a total of 410 applications, of which we analyzed the 20 most utilized applications in both the App Store and the Play Store. These were retrieved using a custom tool we developed and then manually classified according to dimensions described in Sections 4.2 and 4.3.

According to the results of the study, we identified six different common use cases including *Security Education & Training, Antivirus Protection, Secure Browsing, Privacy Management, Network & Device Management,* and *Secure Communication*. In regards to the type of security information the applications provide, *countermeasure, asset, threat* and *risk information* were found to be the most prevailing type of information.

CONTRIBUTIONS. We want to emphasize the role of mobile security applications and the security information they provide. After shaping the problem space in Section 2:

- First, this is done through a custom-developed tool, we collect 410 security applications (Section 3.1);
- Next, we select the top 20 most used applications for each store and rigorously review these (see Sections 3.2 and 3.3);
- Finally, we analyze their use cases and type of provided security information³ (Section 4).

The rest of the paper also includes Section 5 that discusses key findings and limitations of the research at hand, while Section 6 concludes our work and provides an outlook on future work. For the purpose of open science, we release all our resources at: https://github.com/irdin-pekaric/MobileAppACMSE2025.

2 Related Work

The existing body of related work on mobile security applications and conventional security tools is highly limited. This limitation

underscores the necessity of exploring the related works that cover both domains in order to gain a comprehensive understanding of the state-of-the-art. However, we consider related works that focus on analyzing security aspects of a single application out of scope and we only consider the ones that target multiple applications. This is due to the fact that this work investigates multiple applications. Accordingly, we identified studies investigating conventional security tools, privacy of mobile applications, and security awareness of mobile applications' users.

Conventional security tools - Two notable studies exist in this particular realm. Kuehn et al. [12] conducted a categorization of security tools, focusing on seven general dimensions. Similarly, the paper by Curphey and Arawo [3] classified web application security tools based on high-level types, which provided insights into the broader landscape of security tools. However, compared to our study, the classifications presented in both of these papers were not applied to the domain of mobile applications, leaving a gap in understanding the ecosystem of mobile security tools.

Privacy of mobile applications - The most addressed security aspect of mobile applications in previous works is privacy. Li et al. [13] conducted a study on the detection and analysis of personal information security wherein they applied static analysis, dynamic analysis, and manual review to detect and analyze the 40 installed mobile applications. The results demonstrated that the applications had significant problems in regard to privacy policies, permission applications, information collection, and data storage. Likewise, Yu et al. [26] also analyzed the privacy policies of Android applications by performing a systematic study that automatically identified three kinds of problems in privacy policies. They proposed a tool that successfully discovered that one in four applications has at least one type of policy-related issue. Papageorgiou et al. [17] analyzed the security and privacy aspects of mobile health applications. The paper highlighted the concerning state of security practices in mobile health applications by manually investigating selected mobile health applications, which resulted in a finding that the majority of the analyzed applications did not follow the established practices, guidelines, and legal restrictions. Similarly, Ikram et al. [9] covered the domain of Android VPN (Virtual Private Network) permissionenabled applications. In their study, they analyzed the behavior of 283 applications regarding malware presence, third-party library embeddings, and traffic manipulation, including privacy aspects. The results showed that a significant number of applications use insecure VPN tunneling protocols.

Security awareness of mobile applications' users - Zeybek et al. [27] performed a user study wherein they investigated the security awareness of public institution personnel about the use of mobile devices. A similar study was conducted by Moletsane et al. [15] that assessed factors that impact the mobile security awareness of students. The study proposed a conceptual model of mobile information security awareness that demonstrated a significant relationship between students' knowledge and behavioral intentions in case of threats from various security threats. Tao et al. [23] proposed SRR-Miner, which is a review summarization approach that automatically retrieves security-related issues from user comments in mobile applications. This is achieved by applying methods such as a keyword-based search and deep analysis of sentence structures.

³The original motivation behind this study was to investigate what type of security information is shared by mobile cyber threat intelligence applications. However, we were not able to identify these particular types of applications so we focused on general mobile security applications in order to determine which type of security information is present since these can be utilized as a part of the broader cyber threat intelligence processes as demonstrated by Mavroeidis and Bromander [14]. Additionally, this approach can provide insights into the future development of mobile cyber threat intelligence applications.

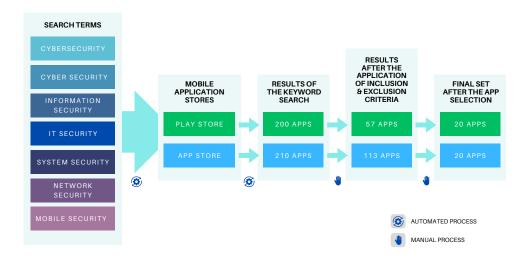


Figure 1: Overview of the Search and Selection Strategies

The study that can be considered as the closest to this work is by Yao et al. [25]. They conducted an empirical analysis of Android security applications by considering multiple aspects such as metadata, static analysis, and dynamic analysis. In addition, they also provided insights into the behaviors and operations of the analyzed applications. However, these aspects are completely different compared to what this study addresses⁴. Our motivation behind this study was to gain a comprehensive overview of security applications and to explore their potential for cyber threat intelligence sharing. Thus, we focus on the type of security information the applications provide as well as detailed information on specific use cases of each application based on the NIST Cyber Security Framework [1]. In addition, we also consider applications from the App Store as well as cover some other aspects that are discussed in detail in Section 3.3.

3 Proposed Method

In this section, we present the design of our systematic review of mobile security applications (see Figure 1). We outline our search strategy (see Section 3.1), selection of mobile security applications (see Section 3.2), and their analysis (see Section 3.3).

3.1 Search Strategy

To identify relevant mobile applications in the security domain, a keyword search on both ${\rm App}^5$ and Play Store was conducted. We considered only these two as they are the two most popular mobile application stores. The search process is somewhat different compared to conventional systematic literature reviews [11] wherein a single string is formed by combining keywords with logical operators. In this study, multiple standalone search strings had to

be formed because neither the App nor the Play Store supports advanced searches. Thus, the following seven search strings were formed: "Cybersecurity", "Cyber Security", "Information Security", "IT Security", "System Security", "Network Security", and "Mobile Security". We tested various keyword combinations and opted at the end for the aforementioned general strings because, in this case, the results of the searches included more relevant applications⁶.

Given that multiple searches had to be conducted (i.e. for each specific string on both application stores) and that both stores advertise specific applications (i.e. which we wanted to avoid), we opted for an automated search by crafting a Python 3 script. The script utilizes $google_play_scraper^7$ library for the Play Store search and direct $iTunes^8$ search using the $requests^9$ library for the App Store applications. We searched for the top 30 applications for each search string on each of the stores. This is because the Play Store search only provides 30 results and we wanted to keep the search strategy consistent. The results of the search were recorded in two separate spreadsheets wherein each sheet included seven tabs for each specific search term. Moreover, our scripts automatically provided meta information (e.g., cost, number of downloads, user rating, etc.), which were utilized for selection of relevant applications.

3.2 Application Selection

The search strategy resulted in a total of n=190 applications for the Play Store and n=210 applications for the App Store. In the next step, we manually checked all the identified applications. The goal was to obtain the final list of the top 20 most relevant security applications for each of the stores. Consequently, the following inclusion and exclusion criteria were applied. All the applications that were not

⁴We also wanted to investigate if there were any common applications that were analyzed both by Yao et al. [25] and this study. However, Yao et al. [25] did not openly publish their artifacts.

https://www.apple.com/at/app-store/

⁶If the search strings were too specific, many applications were not found, and in some cases, fewer than ten applications were identified.

⁷https://pypi.org/project/google-play-scraper/

https://itunes.apple.com/search

⁹https://pypi.org/project/requests/

Table 1: Overview of Identified Mobile Security Applications: Functions, Use Cases, Provided Security Information, and Popularity based on Downloads or Ratings. (Note: I = Identify, P = Protect, D = Detect, R = Respond, N = None, R' = Recover, UC = Use Case, A = Asset, A'=Attack, C = Countermeasure, R = Risk, T = Threat, V = Vulnerability, O = Other, DL = # of Downloads for GPL Applications, RT = # of Ratings for IOS Applications). The Table is Sorted According to the Use Cases

		Functions addressed						Security Information							1	Popularity	
ID A ₁	pp Name	I	P	D		R'	G	N	UC	A	A'	C	R	T		0	DL/RT
GPL01 Et	hical Hacking University App							x	UC1	x	x	x	x	x	X		680k
	earn Ethical Hacking: HackerX							x	UC1		x			X	x		6.5M
	Cybersecurity Pocket Prep							x	UC1	x	x	x	x	x	x		162k
	earn Ethical Hacking							x	UC1	X	x	X	X	X	x		5.2M
GPL18 Le	earn Cyber Security							x	UC1	x	x	x	x	x	x		739k
	ompTIA Security+ Exam Prep							x	UC1	X	x	X	X	X	x		5.8k
IOS03 CI	BT Nuggets							x	UC1	x	x	X	x	x	X		5.8k
IOS09 IT	Cybersecurity Pocket Prep							x	UC1	x	x	X	x	x	X		4.8k
GPL04 AV	VG AntiVirus Security	x	x	x	x				UC2	X	x	X	X	X	x		465M
GPL06 AV	VG Protection	x	x	x					UC2	x	x	X	x	x	X		46M
GPL07 ES	SET Mobile Security Antivirus	x	x	x	x				UC2			X	x	x			35M
GPL08 VI	PN Antivirus by Kaspersky	x	x	x	x				UC2	x	x	X	x	x	X		124M
GPL10 Av	vast Antivirus Security	X	x	x					UC2	x	x	x	x	x	x		392M
GPL11 No	orton Genie: AI Scam Detector	x	x	x	x				UC2	x		X	x	x			1.5M
GPL12 Bi	tdefender Antivirus	x	x	x	x				UC2	x	x	X	x	x	X		9.1M
GPL13 Av	vira Security Antivirus VPN	X	X	X	\mathbf{x}				UC2	X		X	X	X			38M
GPL14 M	obile Security Antivirus	X	X	X	\mathbf{x}	x			UC2	X	x	X	X	X	\mathbf{x}		6.2M
GPL15 Bi	tdefender Mobile Security	x	x	x					UC2	x		X	x	x			17M
GPL16 No	orton360 Antivirus Security	X	X	X	\mathbf{x}				UC2	X	x	X	X	X	\mathbf{x}		78M
GPL20 Bi	tdefender Central	X	\mathbf{x}	\mathbf{x}	\mathbf{x}	x			UC2	\mathbf{x}	\mathbf{x}	\mathbf{x}	\mathbf{x}	\mathbf{x}	\mathbf{x}		1.6M
IOS08 M	Secure	X	X	X					UC2			X	X			\mathbf{x}	47.7k
IOS16 Av	vast Security Privacy		x	x					UC2	x	x	X	x	x	X		24.6k
IOS20 No	orton360 Mobile Security, VPN	x	x	x	x				UC2	x	x	X	x	x	X		123.5k
GPL02 Ph	none Guardian VPN: Safe WiFi		\mathbf{x}	\mathbf{x}					UC3	\mathbf{x}							33M
GPL19 Tr	rustd Mobile Security	X	\mathbf{x}	\mathbf{x}					UC3	\mathbf{x}		\mathbf{x}	\mathbf{x}	\mathbf{x}			332k
IOS04 Du	uck Duck Go		x	x					UC3	x	x	X	x	x	X	x	4.1k
IOS05 Go	oogle Authenticator		\mathbf{x}			x			UC3	\mathbf{x}	12k						
IOS10 Su	ırfshark VPN: Fast Reliable		\mathbf{x}	\mathbf{x}	\mathbf{x}				UC3			\mathbf{x}	\mathbf{x}	\mathbf{x}			86.6k
IOS11 W	ireVPN - Fast VPN Proxy		X						UC3	X		X					85.7k
IOS12 Ph	none Guardian Safe Mobile VPN		x	x					UC3		x	x		\mathbf{x}			39.2k
IOS17 Br	rowsec VPN: Fast Ads Feed		\mathbf{x}						UC3	\mathbf{x}	\mathbf{x}	\mathbf{x}	\mathbf{x}	\mathbf{x}			16.4k
IOS18 M	cAfee Security: Privacy VPN		\mathbf{x}	\mathbf{x}					UC3	\mathbf{x}	\mathbf{x}	\mathbf{x}	\mathbf{x}	\mathbf{x}	\mathbf{x}		175.8k
IOS06 Sa	afe Lock - Private Photo Vault		\mathbf{x}	\mathbf{x}					UC4	\mathbf{x}		\mathbf{x}		\mathbf{x}			23.4k
IOS07 Pr	rivate Photo Vault - Pic Safe		\mathbf{x}	\mathbf{x}					UC4	\mathbf{x}	\mathbf{x}	\mathbf{x}	\mathbf{x}	\mathbf{x}			1M
IOS14 Ro	oboForm Password Manager		X						UC4	X		X	X				43.2k
	ide Photos Video - Hide it Pro		X			x			UC4	X		X	X	X			46.1k
GPL17 Fin	ng - Network Tools		X	X					UC5	X			X	X	\mathbf{x}		62M
IOS02 Du	uo Mobile	x	X	X	\mathbf{x}		x		UC5				X	x	X		4.8k
IOS15 W	ebSSH - SysAdmin Tools		X						UC5	X		X					0.6k
IOS13 Sig	gnal - Private Messenger		x				x		UC6	X		X					853k

freely available and did not provide or relate to any security topics were excluded from the final set. Additionally, we discarded all applications with fewer than 10,000 downloads and an application rating below 3 on the Play Store. For the App Store, we excluded applications with fewer than 1,000 user ratings and an application rating below 3. Moreover, we eliminated all duplicates, resulting in a total of 57 applications for the Play Store and 113 applications for

the App Store. Finally, we ordered the list of applications based on the ratings and selected the top 20 applications for each store as a part of the final set that will be utilized for further analysis.

The aforementioned search strategy and application selection process resulted in a diverse corpus of applications. This encompassed a wide range of applications, from educational tools for security certifications to actual security implementation applications such as antivirus software or VPNs. We acknowledge that

classifying all these applications under the umbrella term "mobile security applications" may not be ideal, as it groups together applications with vastly different purposes. For instance, applications designed to help users study for security certifications (e.g., CBT Nuggets or CompTIA Security+ Exam prep) serve a fundamentally different purpose compared to applications that actively secure devices or protect user privacy (e.g., antivirus applications, VPNs, or privacy-focused browsers such as DuckDuckGo). However, the reason for doing this is due to the fact that we wanted to provide an overview of mobile security applications including their use cases, functions, and the type of security information they provide. In order to achieve this, it is necessary to cover all the different security-related domains, which aligns with the goal of this study.

Furthermore, we also note that the provided functions vary significantly. Educational applications may not deal with the identification of security risks such as the case with antivirus applications. Thus, the security measures implemented in *Norton360 Antivirus Security* would be expected to be more extensive than those in an exam preparation application, given the difference in their nature.

3.3 Application Analysis

In order to analyze and classify all the identified applications, two authors were assigned to each specific application. During this process, the relevant metadata about the applications, as previously mentioned, was automatically retrieved. Any information that could not be automatically obtained had to be supplemented by manually analyzing the respective documentation in the respective stores. Below, we list all the steps and the type of information that was obtained as a part of the analysis.

In the first step, the following information was automatically collected for each application: a *unique identifier*, the application's *name*, its *current version*, the *cost*, the total *number of downloads*, the *average user rating*, the list of *permissions* requested upon installation¹⁰, the year of the application's *first release*, the year of its *last update*, the *types of notifications*, and whether a *desktop version* is available.

In the second step, to address RQ1, we extracted and investigated detailed information on the specific *use case* (UC) of each application and how it supports the *functions* of the NIST Cyber Security Framework [1]. In doing so, we differentiated among the following six functions:

- Identify (I) The application identifies current security risks and vulnerabilities in the system.
- *Protect* (P) The application offers protective measures and controls for protection against threats.
- Detect (D) The application provides information about threats detected on the system.
- Respond (R) The application provides suggestions on how to respond to a threat or improve the system's security.
- *Recover* (R') The application offers mechanisms to restore data and the system to a previous state.
- Govern (G) The application provides information on security regulations and certifications.
- Other (O) The application does not support any of the functions (i.e. I, P, D, R, R', or G) mentioned in the NIST CSF.

In a third step, to address RQ2, we extracted and examined the *type of information* the application provides on various security aspects. In doing so, we differentiated among the following six information types [10]:

- Asset (A) Information about sensitive information or services of the system.
- Attack (A') Information about a deliberate form of compromise, i.e. an unwanted or unauthorized act to cause damage to assets or systems.
- Countermeasure (C) Information about a measure or technique that reduces the impact of a threat or vulnerability by eliminating or preventing it.
- Risk (R) Information about a potential threat or vulnerability that may compromise the confidentiality, integrity, or availability of the assets or the system.
- Threat (T) Information about the potential cause of an attack that could damage the assets or the system.
- Vulnerability (V) Information about an asset's or system's weaknesses that can be exploited by a threat.
- Other (O) The application provides other types of information than those (i.e. A, A', C, R, T, V, and O) mentioned.

After completing all the classification tasks, we measured the inter-coder reliability score. This was done for all the 40 applications. We observed an agreeability score of 94%, denoting that the authors likely reached the same conclusion. Finally, any classification discrepancies were resolved through in-depth discussions. The aforementioned procedure resulted in a spreadsheet containing classified applications with all the relevant information, which we will discuss in detail in Sections 4 and 5.

4 Results

In this section, we present the results of our systematic study of mobile security applications (see Table 1). We provide a general overview (see Section 4.1), discuss their use cases (see Section 4.2) and the security information (see Section 4.3) they provide.

4.1 Overview of Mobile Security Applications

Overview. Table 2 provides the statistical overview of the 40 analyzed applications ¹¹. Our investigation revealed that 24 applications have a dedicated desktop version, and 7 applications offer a web version. Only about 20% of the applications are exclusively available on mobile devices. The average rating of all the analyzed applications is 4.72 out of 5. This indicates that we only focused on the best-rated applications. Furthermore, we reviewed which store tag each app was assigned to. The results indicated a tendency toward the *Tools, Education*, and *Utilities* categories. It is important to note that the Google Play Store and the App Store do not always use identical tags. Google Play uses the tag *Tools*, whereas the App Store refers to this category as *Utilities*.

Timeline. Another aspect that we investigated was the timeline of applications starting from their first release to the last update. According to Figure 2, the large majority of all applications are regularly updated and maintained (n=36), while 4 applications did not receive any updates in the last six months and these can be considered

 $^{^{10}\}mathrm{We}$ utilized the respective Application Store to identify permissions listed for each of the applications.

¹¹We could not directly compare the application usage numbers between the two stores because the download rates for App Store applications were unavailable. Therefore, we used the rating count as a proxy.

Table 2: Overview of Applications' Metrics and Statistics

Description	Value								
Number of apps per store	20 GPL, 20 IOS								
Average # of downloads GPL	63,574,897.45								
Total # of downloads GPL	1,271,497,949								
Average ratings count for IOS	290,303.05								
Total ratings count for IOS	5,806,061								
Average rating (both stores)	4.7232 stars								
Other app implementations	Desktop: 24, Web: 7, Mobile-only: 9								
Maintenance	Actively maintained: 37, Inactive: 3								
Apps have a paid option	Yes: 34, No: 6								
Provided information counts	Countermeasures: 36, Assets: 34, Threats:								
	34, Risks: 33, Attacks: 24, Vulnerabilities:								
	23, Others: 3								
CSF: Use-Case counts	Protect: 32, Detect: 25, Identify: 16,								
	Respond: 12, Recover: 4, Govern: 2, None: 8								

inactively managed, which can potentially create security-related issues for the users of these applications.

Popularity. In order to assess the popularity of the analyzed applications, we compared the number of users (downloads for GPL and rating counts for IOS) with their average ratings ¹². Figure 3 presents this comparison, with the GPL apps displayed on the left y-axis and the iOS applications on the right y-axis. In addition, the regression lines for both platforms, along with confidence intervals are demonstrated using red and blue shading. The plot shows a positive correlation between a higher number of users and better ratings, which is more evident for the IOS Applications compared to the GPL applications.

Permissions. Another general aspect that we considered was the applications' permissions. Figure 4 presents the distribution of permissions listed on the store page, required to utilize the full functionality of the examined applications. The number of required permissions averaged 3.575 per application. For simplicity, the analysis was limited to these basic listed permission categories, excluding specific and special permissions. This is due to the fact that specific and special permissions can indeed be too particular and differ for every application, making it very difficult to list all of these. For example, this can be permissions needed to schedule exact alarms or permissions to display and draw over other applications ¹³. Our results demonstrated that the most demanded permissions include Location (50%) and Storage (47.5%) permissions. This is followed by Photos/Media/Files (35%), Contacts (35%), Identity (27.5%), and Camera (27.5%) permissions. We only present the permissions that were identified four or more times. The detailed list of all permissions needed by each application we analyzed can be found in our publicly shared repository.

4.2 Use Cases of Mobile Security Applications (RQ1)

As depicted in Table 1, our investigations showed that the core use cases of mobile security applications are Security Education & Training (UC1), Antivirus Protection (UC2), Secure Browsing (UC3), Privacy Management (UC4), Network & Device Management (UC5)

and *Secure Communication* (UC6). In the following, we discuss these use cases by providing examples of selected applications ¹⁴:

Security Education & Training (UC1) applications are designed to teach users the basics and advanced concepts of security and ethical hacking and prepare them for professional certifications. For example, the Ethical Hacking University application, offers interactive courses that teach users how to protect digital assets by recognizing, preventing, and responding to cyber threats. Similarly, the Learn Ethical Hacking: HackerX application offers hands-on exercises and interactive modules to teach ethical hacking techniques and security skills. For those seeking industry-recognized certification, the IT & Cybersecurity Pocket Prep application provides comprehensive practice questions and learning materials. In addition, the CBT Nuggets application offers an extensive library of training courses accessible on mobile devices including various videos taught by experts, which can be downloaded for offline learning.

Antivirus Protection (UC2) applications focus on protecting mobile devices from a wide range of threats, including malware, phishing, and unauthorized access. For example, the AVG AntiVirus application is a comprehensive security solution that includes real-time virus and malware scanning, application blocking, encrypted photo storage, VPN protection, Wi-Fi threat detection, and hacker alerts. Another example is the ESET Mobile Security Antivirus application, which protects against malware, phishing attempts, and other digital threats to ensure a safe mobile experience. The Bitdefender Mobile Security application offers comprehensive protection against malware, phishing attacks, and privacy threats. Similarly, the Norton 360 Mobile Security & VPN application combines malware and phishing protection with secure VPN services to improve both security and privacy for mobile users.

Secure Browsing (UC3) applications are designed to enable secure internet connections and protect users' online privacy. For example, the Surfshark VPN application encrypts online traffic and masks IP addresses so that users can surf the Internet safely. The Phone Guardian Mobile Security application provides a secure VPN connection and alerts users to potential security threats to keep their data private. The Browsec application enables encrypted web browsing and access to multiple virtual locations, improving user privacy. The DuckDuckGo application focuses on secure and private online searches by blocking trackers and ensuring that users' search histories and personal data remain confidential.

Privacy Management (UC4) applications help users to securely store and manage their passwords and protect their private photos and videos. For example, the *mSecure* application enables users to manage and store their passwords and personal data with by utilizing efficient cryptographic algorithms such as AES-256 Encryption to protect their privacy. The RoboForm Password Manager application securely stores and manages all passwords and login credentials and enables quick and secure access to online accounts across multiple devices. To protect sensitive photos and videos, the Safe Lock - Private Photo Vault application offers a wide range of security features such as PIN codes, Touch ID, and intrusion alerts. With the Hide it Pro application, users can securely hide their

 $^{^{12}}$ For readability purposes, the number of downloads and the number of ratings is represented as $n \times 10^8$ and $n \times 10^6$ respectively.

 $^{^{13} \}bar{\text{https://developer.android.com/training/permissions/requesting-special?hl=en}$

 $^{^{14}\}mathrm{Due}$ to space constraints, we could not include all identified applications as examples in our explanations.

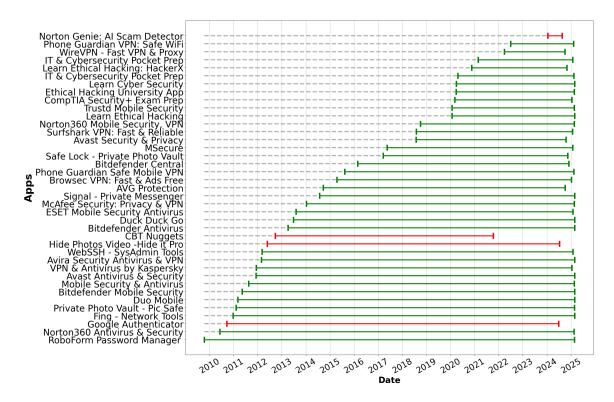


Figure 2: Timeline of Applications' Release Until Last Updates

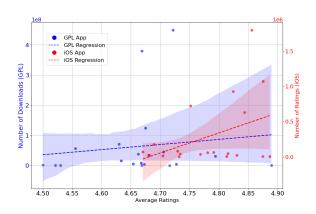


Figure 3: Number of Users vs. Average Ratings

photos and videos behind a screen lock, with additional privacy features such as customizable albums and escape unlock codes.

Network & Device Management (UC5) applications provide tools to efficiently manage, monitor, and secure networks and devices to ensure optimal performance and security. For example, the Fing - Network Tools application helps users manage and secure their home and business networks by providing detailed insights into connected devices, network performance, and security vulnerabilities. The WebSSH Essential application offers robust features for secure remote server management, including SSH, SFTP, TELNET, port forwarding, and secure access via Touch ID or Face ID. The Duo Mobile application enhances enterprise security through multi-factor

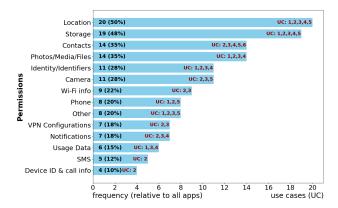


Figure 4: Distribution of Required Permissions and Use-cases

authentication, user identity verification, and protection against unauthorized access to applications and systems.

Secure Communication (UC6) applications prioritize user privacy by offering encrypted messages and calls. For example, the Signal application offers end-to-end encrypted texts, voice & video calls, and group chats while ensuring that any data is collected, maintaining user privacy and security. This application is particularly popular with users who are conscious of their digital privacy and want to ensure that communications remain confidential and protected from unauthorized access.

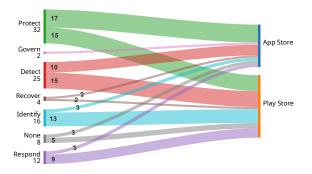


Figure 5: Overview of the Key Security Functions for Each of the Stores (for all the Selected Mobile Applications)

Figure 5 (left side) shows the analysis on how various mobile applications support key security functions. We found that 32 applications offer protective measures and controls to guard against threats encompassing both organizational and technical aspects(i.e. *Protect*). Another 25 applications include functions for monitoring system threats (i.e. *Detect*). 16 applications focus on identifying security risks and system vulnerabilities (i.e. *Identify*). Additionally, a small set provides functionalities for incident response (i.e. *Respond*; 12 applications) and recovery (i.e. *Recover*; 4 applications). Finally, only 2 applications support governance processes (i.e. *Govern*).

As shown in Figure 5 (right side), a comparison of the applications available in the App Store and Play Store reveals that functions for *Identify* are scarcely offered in App Store applications. In contrast, the Play Store exhibits a balanced distribution among the *Identify*, *Protect*, and *Detect* functions. The *Respond*, *Recover*, and *Govern* functions are similarly under-supported in applications from both stores.

Subsequently, we also investigated the relationship between specific use cases and requested permissions (see Figure 4). The results show the following associations: UC1 ≠ location, storage, photos/media/files, identity, phone, usage data permissions; UC2 ≠ location, storage, contacts, photos/media/files, identity, camera, WIFI information, phone, VPN configurations, notifications, SMS, device ID and call information permissions; UC3 ≠ location, storage, contacts, photos/media/files, identity, camera, WIFI information, VPN configurations, notifications permissions; UC4 ≠ location, storage, contacts, photos/media/files, identity, notifications, usage data permissions; UC5 ≠ location, storage, contacts, camera, phone permissions; UC6 ≠ contacts permissions.

4.3 Provided Security Information (RQ2)

A comprehensive analysis of various types of security information provided by mobile applications revealed several interesting findings (see Figure 6). Notably, *vulnerability* and *attack* information were found to be the least prevalent in these applications, primarily being provided by antivirus applications such as *AVG Protection* or *Avast Security Privacy*. Another observation indicated that applications from the Play Store exhibit a more security-oriented approach. However, when it comes to *countermeasures*, applications from the App Store (e.g. *Phone Guardian Safe Mobile VPN, Duck Duck Go*, etc.) are more represented compared to Play Store applications. This

discrepancy could be attributed to the higher identification of antivirus applications in the Play Store, thus affecting the distribution of security-oriented content. The most striking contrast between the Play Store and the App Store lies in the representation of *threat*-related information such as *Bitdefender Antivirus* or *Trustd Mobile Security*. Notably, *threat* information was found to be present in the Play Store 95% of the time, whereas it was identified in 75% of the applications in the App Store.

In general, the distribution of other types of security information appeared to be relatively uniform between the Play Store and the App Store, indicating a balanced approach to disseminating security-related content. Furthermore, the analysis indicated that 60% of Play Store applications and 35% of App Store applications provide all types of security information. In fact, these apps were predominantly categorized as educational applications (e.g. Ethical Hacking University application, CompTIA Security+ Exam Prep, etc.) and antivirus applications, wherein their role is to offer comprehensive security guidance and protection. Finally, the notable classification of three applications (Duck Duck Go, Google Authenticator, MSecure) in the App Store as others was due to their provision of general security advice, such as data backup and software update recommendations.

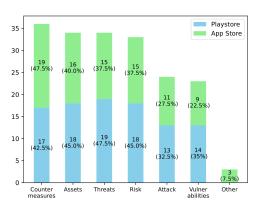


Figure 6: Type of Security Information for Each Store

5 Discussion

In this section, we discuss key findings (see Section 5.1) related to our research questions (RQ1 and RQ2), application development recommendations (see Section 5.2) and the limitations of our systematic analysis of mobile security applications (see Section 5.3).

5.1 Key Findings and Implications

Our research indicates that a significant number of mobile security applications are highly popular among users. Notably, applications with a large user base tend to have significantly better ratings, a trend that is particularly pronounced for iOS applications. Additionally, we discovered that many of these mobile security applications also offer desktop versions. This is often because they are extensions of established antivirus software (UC2). Furthermore, most of

these applications provide paid features, reflecting the substantial business opportunities they represent.

A more detailed analysis of application store tags and our identified use cases reveals that a significant proportion of popular mobile applications incorporate essential functions (cf. store tag "utilities") for threat detection and protection [4]. This trend is partly due to the prevalence of antivirus protection applications (UC2). Additionally, our research highlights the widespread availability of mobile educational tools (cf. store tag "education") aimed at enhancing security awareness and training (UC1)¹⁵. This underlines the importance of ongoing efforts to inform users about potential risks and provide practical guidance on mitigating various threats.

Furthermore, we have identified numerous tools (cf. store tag "tools") offering features such as secure browsing (UC3), privacy management (UC4), network & device management (UC5), and secure communication (UC6). Given that iOS and Android platforms also provide some of these security functions, it raises the question of why users opt for additional applications. This question is particularly relevant as our research indicates that these applications often require a significant number of permissions (as indicated by Gruschka et al. [7]), despite their focus on security and privacy, which necessitates a high level of user trust. Accordingly, a further question arises as to whether users place more trust in platform manufacturers or dedicated application providers in terms of security and privacy — especially because some studies showed that there is a misuse of private data that third-party applications are collecting [16]. While our study hints at the importance of user trust in this decision-making process, a more thorough investigation is needed to fully understand why users might choose third-party security applications over native security features. This could involve exploring various aspects and factors such as perceived effectiveness, additional features, brand reputation, or even misconceptions about built-in security measures.

On top of that, there is a significant relationship between permissions requested by mobile applications and user trust as well as popularity. Notably, applications that requested fewer permissions were often rated better by users. This suggests that privacy concerns play a critical role in application selection. This highlights an important need for developers in the community to minimize unnecessary permissions and communicate to users why specific permissions are required. This can be achieved by adopting a more rigorous permissions model, which should enhance user trust and encourage compliance with privacy best practices. Similarly, the features provided by popular applications can directly impact user engagement and perceived effectiveness. Our findings indicate that applications offering functionalities such as Privacy Management and Secure Communication tend to attract more users, which demonstrates the importance of integrating users' privacy needs into the design process. This correlation points out a crucial area for future development within the usable security field, where features should prioritize more user privacy.

Moreover, a closer analysis of the security information provided by these applications revealed that contrary to our initial assumptions, information about countermeasures, assets, threats, and risks is more common than details on specific attacks and vulnerabilities. This can be considered unusual because vulnerability information is crucial and utilized in a wide range of different cybersecurity approaches [6]. However, this finding highlights a significant opportunity for improvement in mobile security application development. Developers need to consider incorporating features that educate users about existing vulnerabilities in their devices and applications, as well as how to address them. Empowering users to take proactive measures to secure their devices is essential for enhancing overall mobile security.

Lastly, the majority of applications offer a variety of security information types. Surprisingly, we did not identify any cyber threat intelligence sharing mobile applications, which is a very unexpected finding given the current cybersecurity landscape — including the rise of cyber threat intelligence sharing platforms [22]. The absence of sharing capabilities is particularly concerning given the increasing complexity of cyber threats, which often require collaboration and community-driven approaches. This gap suggests the need to create such platforms that enable users to share insights and experiences related to mobile and any other types of security threats. This capability could become increasingly important in the future, as mobile security applications have the potential to act as security sensors, thereby enabling a form of threat intelligence sharing.

5.2 Development Recommendations

Our findings emphasize the need for mobile security application developers to define **clear use cases** that align with user needs across critical areas such as Security Education & Training, Antivirus Protection, and Secure Communication. Providing **comprehensive security information** is significant so users can recognize potential threats and make informed decisions regarding their security posture. A focus on **user-centric design** should enhance user experience, while **regular updates** help to adapt to emerging vulnerabilities. Furthermore, integrating mobile security applications with **native features of operating systems** can lead to a more unified and consistent user experience.

Additionally, promoting a culture of **cyber threat intelligence sharing** can improve general security awareness among users. Adopting a **privacy-first approach**, which involves transparent data collection practices and encryption, is critical for user trust. This means that engaging users actively and seeking their feedback will lead to **continuous improvement**, ensuring that applications evolve with respect to real-world challenges. Overall, these recommendations should improve user engagement and contribute to a more secure mobile ecosystem.

5.3 Limitations

The research at hand might be limited by a (i) selection bias of mobile security applications, (ii) incorrect application analysis, and (iii) missing out relevant applications. As described in Section 3.2, our selection strategy was systematic and based on certain criteria (e.g. number of downloads, license model, etc.) and the popularity of these applications as rated by users to ensure that (i) is minimized. Accordingly, the selection of applications was not based on individual decisions by the authors, but by the users of the respective applications. To prevent (ii), we opted for a type of cross-validation in which each author of this research paper had to analyze a subset of applications that overlapped with another author's set. In this

 $^{^{15}\}mathrm{This}$ corresponds to the findings by Drigas and Angelidakis [5] that mobile applications have a potential to take education out of classroom boundaries.

way, classification discrepancies were detected early and limited by reclassification. Finally, there is a chance that we missed some relevant applications (iii). To address the retrieval limitations of the Play Store, which restricted our sample to 30 applications, we implemented a strategic approach. This involved us originally testing and afterward applying multiple search strings to ensure that the applications from various cybersecurity domains were identified.

6 Conclusions

As a part of this study, we investigated the landscape of mobile security applications for Android and iOS platforms. This is achieved by systematically providing a comprehensive overview of the top 20 most used applications in each of the stores. As a part of the analysis, we employed both automated and manual techniques. The results underscore the critical need for ongoing research and development in this domain. By identifying common use cases and the prevalent types of security information, our findings offer valuable insights into security-related aspects of these applications. Presumably, the fact that no threat intelligence-sharing mobile applications were identified can be considered rather alarming.

Consequently, as the mobile security application ecosystem continues to evolve, our study resources have been made openly accessible, inviting further exploration and contribution to this vital area of study. As a part of future work, we plan to investigate the reasons for using and selecting these applications regardless if some mobile devices provide the same built-in security features. The question arises of whether users place more trust in platform manufacturers or dedicated application providers in terms of security and privacy. For example, this could be investigated by performing a user study on a targeted group of the population as shown by Braun et al. [2], which can include both questionnaires and interviews. In addition, we plan to extend this study by conducting the analysis on a larger number of applications and comparing their features to their dedicated desktop and web versions.

Furthermore, another aspect for future research is to evaluate whether these mobile security applications enhance measures provided by mobile operating systems and whether the security gains outweigh the possible risks of third-party apps. This investigation would provide insights into the effectiveness and necessity of these applications in the broader context of mobile device security.

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References

- Matthew P Barrett. 2018. Framework for Improving Critical Infrastructure Cybersecurity Version 1.1. (2018).
- [2] Tobias Braun, Irdin Pekaric, and Giovanni Apruzzese. 2024. Understanding the Process of Data Labeling in Cybersecurity. In Proceedings of the 39th ACM/SI-GAPP Symposium on Applied Computing (Avila, Spain) (SAC '24). Association for Computing Machinery, New York, NY, USA, 1596–1605.
- [3] Mark Curphey and Rudolph Arawo. 2006. Web Application Security Assessment Tools. IEEE Security & Privacy 4, 4 (2006), 32–41.
- [4] Akesh Damaraju. 2021. Mobile Cybersecurity Threats and Countermeasures: A Modern Approach. International Journal of Advanced Engineering Technologies and Innovations 1, 3 (2021), 17–34.
- [5] Athanasios S Drigas and Pantelis Angelidakis. 2017. Mobile Applications Within Education: An Overview of Application Paradigms in Specific Categories. International Journal of Interactive Mobile Technologies 11, 4 (2017).

- [6] Raffaela Groner, Thomas Witte, Alexander Raschke, Sophie Hirn, Irdin Pekaric, Markus Frick, Matthias Tichy, and Michael Felderer. 2023. Model-Based Generation of Attack-Fault Trees. In Computer Safety, Reliability, and Security - 42nd International Conference, SAFECOMP 2023. Springer, 107–120.
- [7] Nils Gruschka, Luigi Lo Iacono, and Jan Tolsdorf. 2018. Classification of Android App Permissions: Tell Me What App You Are and I Tell You What You Are Allowed to Do. In 17th European Conference on Cyber Warfare and Security (ECCWS 2018), Jøsang Ed. Oslo, Norway. 181–189.
- [8] Annika Hinze, Nicholas Vanderschantz, Claire Timpany, Sally Jo Cunningham, Sarah-Jane Saravani, and Clive Wilkinson. 2023. A Study of Mobile App Use for Teaching and Research in Higher Education. *Technology, Knowledge and Learning* 28, 3 (2023), 1271–1299.
- [9] Muhammad Ikram, Narseo Vallina-Rodriguez, Suranga Seneviratne, Mohamed Ali Kaafar, and Vern Paxson. 2016. An Analysis of the Privacy and Security Risks of Android VPN Permission-enabled Apps. In Proceedings of the 2016 internet measurement conference. 349–364.
- [10] ISO. 2009. ISO/IEC 15408-1: 2009 Information Technology—Security Techniques—Evaluation Criteria for IT Security—Part 1: Introduction and General Model. Int. Organ. Stand (2009).
- [11] Barbara Kitchenham. 2004. Procedures for Performing Systematic Reviews. Keele, UK, Keele University 33, 2004 (2004), 1–26.
- [12] Philipp Kuehn, Julian Bäumler, Marc-André Kaufhold, Marc Wendelborn, and Christian Reuter. 2022. The Notion of Relevance in Cybersecurity: A Categorization of Security Tools and Deduction of Relevance Notions. (2022).
- [13] Shuang Li, Meng Zhang, Che Li, Yue Zhou, Kanghui Wang, and Yaru Deng. 2021. Mobile App Personal Information Security Detection and Analysis. In 19th International Conference on Computer and Information Science. IEEE, 82–87.
- [14] Vasileios Mavroeidis and Siri Bromander. 2017. Cyber Threat Intelligence Model: An Evaluation of Taxonomies, Sharing Standards, and Ontologies within Cyber Threat Intelligence. In 2017 European Intelligence and Security Informatics Conference (EISIC). 91–98.
- [15] Tankiso Moletsane and Pitso Tsibolane. 2020. Mobile Information Security Awareness Among Students in Higher Education: An Exploratory Study. In 2020 conference on information communications technology and society. IEEE, 1–6.
- [16] Trung Tin Nguyen, Michael Backes, and Ben Stock. 2022. Freely Given Consent? Studying Consent Notice of Third-party Tracking and its Violations of GDPR in Android Apps. In Proceedings of the 2022 ACM SIGSAC Conference on Computer and Communications Security. 2369–2383.
- [17] Achilleas Papageorgiou, Michael Strigkos, Eugenia Politou, Efthimios Alepis, Agusti Solanas, and Constantinos Patsakis. 2018. Security and Privacy Analysis of Mobile Health Applications: The Alarming State of Practice. IEEE Access 6 (2018)
- [18] Irdin Pekaric, Raffaela Groner, Thomas Witte, Jubril Gbolahan Adigun, Alexander Raschke, Michael Felderer, and Matthias Tichy. 2023. A Systematic Review on Security and Safety of Self-adaptive Systems. J. Syst. Softw. (2023).
- [19] Irdin Pekaric, Clemens Sauerwein, and Michael Felderer. 2019. Applying Security Testing Techniques to Automotive Engineering. In Proceedings of the 14th International Conference on Availability, Reliability and Security. 1–10.
- [20] Irdin Pekaric, Clemens Sauerwein, Stefan Haselwanter, and Michael Felderer. 2021. A Taxonomy of Attack Mechanisms in the Automotive Domain. Comput. Stand. Interfaces (2021).
- [21] Clemens Sauerwein, Irdin Pekaric, Michael Felderer, and Ruth Breu. 2019. An Analysis and Classification of Public Information Security Data Sources Used in Research and Practice. Computers & security 82 (2019), 140–155.
- [22] Nan Sun, Ming Ding, Jiaojiao Jiang, Weikang Xu, Xiaoxing Mo, Yonghang Tai, and Jun Zhang. 2023. Cyber Threat Intelligence Mining for Proactive Cybersecurity Defense: A Survey and New Perspectives. *IEEE Communications Surveys & Tutorials* 25, 3 (2023), 1748–1774.
- [23] Chuanqi Tao, Hongjing Guo, and Zhiqiu Huang. 2020. Identifying Security Issues for Mobile Applications Based on User Review Summarization. *Information and Software Technology* 122 (2020), 106290.
- [24] Thomas Witte, Raffaela Groner, Alexander Raschke, Matthias Tichy, Irdin Pekaric, and Michael Felderer. 2022. Towards Model Co-evolution Across Self-Adaptation Steps for Combined Safety and Security Analysis. In International Symposium on Software Engineering for Adaptive and Self-Managing Systems, SEAMS. 106–112.
- [25] Weixian Yao, Yexuan Li, Weiye Lin, Tianhui Hu, Imran Chowdhury, Rahat Masood, and Suranga Seneviratne. 2020. Security Apps under the Looking Glass: An Empirical Analysis of Android Security Apps. In 2020 IEEE 45th Conference on Local Computer Networks (LCN). IEEE, 381–384.
- [26] Le Yu, Xiapu Luo, Xule Liu, and Tao Zhang. 2016. Can We Trust the Privacy Policies of Android Apps?. In 2016 46th Annual IEEE/IFIP International Conference on Dependable Systems and Networks (DSN). IEEE, 538–549.
- [27] Mine Zeybek, Ercan Nurcan Yılmaz, and İbrahim Alper Doğru. 2019. A Study on Security Awareness in Mobile Devices. In 2019 1st International Informatics and Software Engineering Conference (UBMYK). IEEE, 1–6.