

Assessment of Data Storage Strategies Using the Mobile Cross-Platform Tool Cordova

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Abstract—The mobile world is fragmented by a variety of mobile platforms, e.g., Android, iOS and Windows Phone. While native applications can fully exploit the features of a particular mobile platform, limited or no code can be shared between the different implementations. Cross-platform tools (CPTs) allow developers to target multiple platforms using a single codebase. These tools provide general interfaces on top of the native APIs. Apart from the performance impact, this additional layer may also result in the suboptimal use of native APIs. This paper analyses the impact of this abstraction layer using a data storage case study. Both the performance overhead and API coverage is discussed. Based on the analysis, an extension to the cross-platform storage API is proposed and implemented.

Keywords—Cross-platform tools; data storage; performance analysis; API coverage; Apache Cordova/Phonegap.

I. INTRODUCTION

An increasing number of service providers are making their services available via the smartphone. Mobile applications are used to attract new users and support existing users more efficiently. Service providers want to reach as many users as possible with their mobile services. However, making services available on all mobile platforms is very costly due to the fragmentation of the mobile market. Developing native applications for each platform drastically increases the development costs. While native applications can fully exploit the features of a particular mobile platform, limited or no code can be shared between the different implementations. Each platform requires dedicated tools and different programming languages (e.g., Objective-C, C# and Java). Also, maintenance (e.g., updates or bug fixes) can be very costly. Hence, application developers are confronted with huge challenges. A promising alternative are mobile cross-platform tools (CPTs). A significant part of the code base is shared between the implementations for the different platforms. Further, many cross-platform tools such as Cordova use client-side Web programming languages to implement the application logic, supporting programmers with a Web background.

Although several cross-platform tools became more mature during the last few years, some scepticism towards CPTs remains. For many developers, the limited access to native device features (i.e. sensors and other platform APIs) remains an obstacle. In many cases, the developer is forced to use a

limited set of the native APIs, or to use a work-around –which often involves native code– to achieve the desired functionality. This paper specifically tackles the use case of data storage APIs in Cordova. Cordova is one of the most used CPTs [22, 23]. It is a Web-to-native wrapper, allowing the developer to bundle Web apps into standalone applications.

Contribution. The contribution of this paper is threefold. First, four types of data storage strategies are distinguished in the setting of mobile applications. The support for each strategy using both native and Cordova development is analysed and compared. Second, based on this analysis a new Cordova plugin that extends the Cordova Storage API coverage is designed and developed. Finally, the security and performance of the different native and Cordova storage mechanisms is evaluated for both the Android and iOS platform.

The remainder of this paper is structured as follows. Section II points to related work. Section III discusses the inner workings of Cordova applications, followed by an overview of data storage strategies and their API coverage in Cordova and native applications. The design and implementation of NativeStorage, a new Cordova storage plugin, is presented in Section IV. Section V presents a security and performance evaluation of the Cordova and native storage mechanisms. The final section presents the conclusions and points to future work.

II. RELATED WORK

Many studies compare CPTs based on a quantitative assessment. For instance, Rösler et al. [26] and Dalmasso et al. [18] evaluate the behavioral performance of cross-platform applications using parameters such as start-up time and memory consumption. Willocx et al. [30] extend this research and include more CPTs and criteria (e.g., CPU usage and battery usage) in the comparison. Further, Ciman and Gaggi [17] focus specifically on the energy consumption related to accessing sensors in cross-platform mobile applications. These studies are conducted using an implementation of the same application in a set of cross-platform tools and with the native development tools. This methodology provides useful insights in the overall performance overhead of using CPTs. Other research focuses on evaluating the performance of specific functional components. For instance, Zhuang et al. [31] evaluate the performance of the Cordova SQLite plugin for data storage. The work presented in

this paper generalizes this work by providing an overview and performance analysis of the different data storage mechanisms available in Cordova, and comparing the performance with native components.

Several other studies focus on the evaluation of cross-platform tools based on qualitative criteria. For instance, Heitkötter et al. [19] use criteria such as development environment, maintainability, speed/cost of development and user-perceived application performance. The user-perceived performance is analyzed further in [20], based on user ratings and comments on cross-platform apps in the Google Play Store. The API coverage (e.g., geolocation and storage) of cross-platform tools is discussed in [24]. It is complementary with the work presented in this paper, which specifically focuses on the API coverage, performance and security related to data storage.

III. DATA STORAGE IN CORDOVA

A. Cordova Framework

A typical Cordova application consists of three important components: the application source, the WebView and plugins, as depicted in Figure 1.

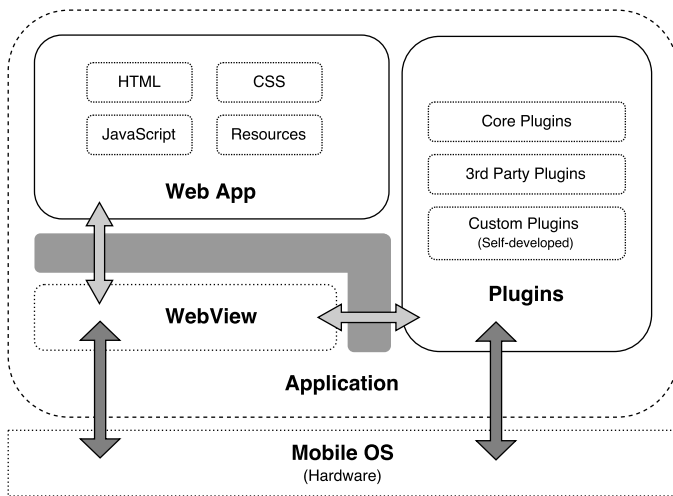


Figure 1. Structure of a Cordova application. Light grey arrows represent JavaScript calls, darker grey arrows represent native calls. The Cordova framework is illustrated by the grey area.

Cordova applications are, similar to Web apps, developed in client-side Web languages (i.e. HTML, CSS and JavaScript). Typically, developers use JavaScript frameworks such as Ionic and Sencha, which facilitate the development of mobile-friendly UIs.

The application code is loaded in a chromeless WebView. By default, Cordova applications use the WebView bundled with the operating system. An alternative is to include the Crosswalk WebView [13]. The Crosswalk WebView provides uniform behaviour and interfaces between different (versions of) operating systems.

Cordova developers have two options for accessing device resources: the HTML5 APIs provided by the WebView and plugins. Despite the continuously growing HTML5 functionality [11] and the introduction of Progressive Web Apps [8],

the JavaScript APIs provided by the WebView are not –yet– sufficient for the majority of applications. They do not provide full access to the diverse resources of the mobile device, such as sensors (e.g., accelerometer, gyroscope) and functionality provided by other applications installed on the device (e.g., contacts, maps, Facebook login). Plugins allow JavaScript code to access native APIs by using a JavaScript bridge between the Web code and the underlying operating system. Plugins consist of both JavaScript code and native code (i.e. Java for Android, Objective-C and recently Swift for iOS). The JavaScript code provides the interface to the developer. The native source code implements the functionality of the plugin and is compiled when building the application. The Cordova framework provides the JavaScript bridge that enables communication between JavaScript and native components. For each platform, Cordova supports several bridging mechanisms. At runtime, Cordova selects a bridging mechanism. When an error occurs, it switches to another mechanism. Independent of the selected bridging mechanism, the data requires several conversion steps before and after crossing the bridge. Commonly used functionality such as GPS are provided by Cordova as *core plugins*. Additional functionality is provided by over 1000 third-party plugins, which are freely available in the Cordova plugin store [12].

B. Storage API Coverage

This work focuses on data storage mechanisms in Cordova applications. Four types of data storage strategies are distinguished: files, databases, persistent variables and sensitive data. Databases are used to store multiple objects of the same structure. Besides data storage, databases also provide methods to conveniently search and manipulate records. File storage can be used to store a diverse set of information such as audio, video and binary data. Persistent variables are stored as key-value pairs. It is often used to store settings and preferences. Sensitive data (e.g., passwords, keys, certificates) are typically handled separately from other types of data. Mobile operating systems provide dedicated mechanisms that increase the security of sensitive data storage.

The remainder of this section discusses the storage APIs available in Cordova and native Android/iOS. A summary of the results is shown in Table I.

TABLE I. STORAGE API COVERAGE

	Cordova	Android	iOS
Databases	WebSQL IndexedDB SQLite Plugin	SQLite	SQLite
Files	Cordova File Plugin	java.io	NSData
Persistent Variables	LocalStorage	Shared Prefs	NSUserDefaults Property Lists
Sensitive Data	SecureStorage Plugin	KeyStore KeyChain	Keychain

1) *Databases*: Android and iOS provide a native interface for the **SQLite** library. Cordova supports several mechanisms to access database functionality from the application. First, the developer can use the database interface provided by the WebView. Both the native and CrossWalk WebViews provide two types of database APIs: **WebSQL** and **IndexedDB**.

Although WebSQL is still commonly used, it is officially deprecated and thus no longer actively supported [10]. Second, developers can access the native database APIs via the **SQLite Plugin** [6].

2) *Files*: In Android, the file storage API is provided by the **java.io** package, in iOS this is included in **NSData**. Cordova provides a core plugin for File operation, namely **Cordova File Plugin** (cordova-plugin-file) [4]. Files are referenced via URLs which support using platform-independent references such as *application_folder*.

3) *Persistent Variables*: In Android, storing and accessing persistent variables is supported via **SharedPreferences**. It allows developers to store primitive data types (e.g., booleans, integers, strings). iOS developers have two options to store persistent variables: **NSUserDefaults** and **Property Lists**. NSUserDefaults has a similar behaviour to SharedPreferences in Android. Property Lists offer more flexibility by allowing storage of more complex data structures and specification of the storage location. Cordova applications can use the **LocalStorage API** provided by the Android and iOS WebView. Although it provides a simple API, developers should be aware of several disadvantages. First, LocalStorage only supports storage of strings. More complex data structures need to be serialized and deserialized by the developer. Second, LocalStorage is known [1] to perform poorly on large data sets and has a maximum storage capacity of 5MB.

4) *Sensitive Data*: Android provides two mechanisms to store credentials: the **KeyChain** and the **KeyStore**. A KeyStore is bound to one specific application. Applications can not access credentials in KeyStores bound to other applications. If credentials need to be shared between applications, the KeyChain should be used. The user is asked for permission when an application attempts to access credentials in the KeyChain. Credential storage on iOS is provided by the **Keychain**. Credentials added to the Keychain are, by default, app private, but can be shared between applications from the same publisher. Cordova developers can use the credential storage mechanisms provided by Android and iOS via the **SecureStorage** (cordova-plugin-secure-storage) [7] plugin.

IV. NATIVESTORAGE PLUGIN

An important limitation of using HTML5 APIs (e.g., IndexedDB and LocalStorage) to store data in Cordova applications is that both on Android and iOS the cache of the WebView can be cleared when, for instance, the system is low on memory. This section presents NativeStorage, a Cordova plugin for persistent data object storage, mitigating the limitations of the HTML5 storage mechanisms.

A. Requirements

The requirements of the plugin are listed below:

- R_1 Persistent and sufficient storage
- R_2 Storage of both primitive data types and objects
- R_3 Support for Android and iOS
- R_4 App private storage
- R_5 Responsive APIs
- R_6 A user-friendly API

```

1 // coarse grained API
2 NativeStorage.setItem("reference_to_value", <value>,
  <success-callback>, <error-callback>);
3 NativeStorage.getItem("reference_to_value", <success-
  callback>, <error-callback>);
4 NativeStorage.remove("reference_to_value", <success-
  callback>, <error-callback>);
5 NativeStorage.clear(<success-callback>, <error-
  callback>);
    
```

Listing 1. NativeStorage – Coarse-grained API

```

1 // fine grained API
2 NativeStorage.put<type>("reference_to_value", <value>,
  <success-callback>, <error-callback>);
3 NativeStorage.get<type>("reference_to_value", <
  success-callback>, <error-callback>);
4 NativeStorage.remove("reference_to_value", <success-
  callback>, <error-callback>);
    
```

Listing 2. NativeStorage – Fine-grained API

B. Realisation

The plugin consist of JavaScript and native code. The JavaScript API provides the interface to application developers. The native side handles the storage of variables using native platform APIs.

NativeStorage provides two sets of JavaScript APIs, a fine-grained and a coarse-grained API, which are both asynchronous and non-blocking. The coarse grained API (Figure 2a) provides a type-independent interface, variables are automatically converted to JSON objects via the JSON interfaces provided by the WebView and passed as string variables to the native side. When a value is retrieved, the WebView is used to convert the string back to an object. The fine-grained API (Figure 2b) provides a separate implementation for the different JavaScript types. On the native side, the variables are stored via SharedPreferences in Android and NSUserDefaults in iOS.

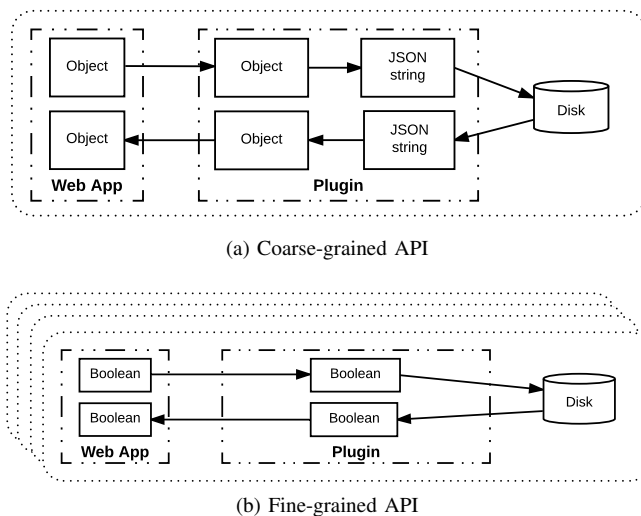


Figure 2. NativeStorage API

C. Evaluation

The plugin is evaluated based on the previously listed requirements.

Persistent storage is provided via the native storage mechanisms. The documentation of the used native mechanisms doesn't state a limitation on the storage capacity. Hence, as opposed to LocalStorage, the storage capacity is only limited by the available memory on the device, satisfying R_1 .

The native part of the plugin is developed for both Android and iOS. These mobile operating systems have a combined market share of 99% [15]. The used native storage mechanisms were introduced in iOS 2.0 and Android 1.0. The plugin, hence, provides support for virtually all version of these platforms used in practice, satisfying R_3 .

The plugin uses NSUserDefaults and SharedPreferences to store the data in app-private locations, ensuring that the variables can not be accessed from outside the application. This satisfies R_4 .

The APIs are implemented using an asynchronous non-blocking strategy, facilitating the development of responsive applications (conform R_5).

Web developers are familiar with duck typing used in languages such as JavaScript. These types of languages often have APIs that don't distinguish between data types. The coarse-grained API provides such a storage mechanism. This API is shown in Listing 6. Not all Cordova developers, however, have a Web background. Therefore, a fine-grained API (Listing 5) is provided for developers who are more comfortable with a statically typed language, satisfying R_6 and R_2 . Using both the coarse- and fine-grained API, the different JavaScript data types can be stored. Developers, however, need to be aware that the object storage relies on the JSON interface of the WebView to convert the object to a JSON string representation. The WebView, for instance, does not support the conversion of circular data structures. These types of objects, hence, need to be serialized by the developer before they can be stored.

Since its release to Github [16] and NPM [5] the plugin has been adopted by many Cordova application developers. We've registered over 4000 downloads per month. Furthermore, the plugin is part of the 4% most downloaded packages on NPM. The plugin has been adopted in Ionic Native (Ionic 2) [3] and the Telerik plugin marketplace [9]. Telerik verifies that plugins are maintained and documented, thereby ensuring a certain quality.

V. EVALUATION

The evaluation of the data storage mechanisms consists of two parts: a quantitative performance analysis and a security evaluation.

A. Performance

Developers want to be aware of the potential performance impact of using a CPT for mobile app development [21]. This section evaluates the performance of the different storage mechanisms for Cordova applications and compares the results with the native alternatives. Each storage strategy is tested by deploying a simple native and Cordova test application that

intensively uses the selected storage strategy on an Android and iOS device. For Android the Nexus 6 running Android 6 was used, for iOS the iPhone 6 running iOS 9 was used. The test application communicates the test results via timing logs that are captured via Xcode for iOS and Android Studio for Android. The experiments were run sufficient times to ensure the measurements adequately reflect the performance of the tested storage mechanisms.

1) Databases:

a) Test Application: The database test application executes 300 basic CRUD operations (i.e. 100 x create, 100 x read, 50 x delete and 50 x read) of objects containing two string variables. The performance is determined by means of measuring the total duration of all the transactions. This test has been executed using the SQLite (native and Cordova), WebSQL (Cordova) and IndexedDB (Cordova) mechanisms.

b) Results and Comparison: The results are presented in Table II. The mechanism for retrieving values by means of an index clearly results in a better performance compared to the SQL-based mechanisms. This analysis shows that IndexedDB provides an efficient way of storing and retrieving small objects. WebSQL –provided by the WebView– acts as a wrapper around SQLite. This is illustrated by the performance overhead associated with this mechanism. The deprecation of the specification/development stop could also have contributed to the performance penalty. The SQLite plugin suffers from a performance overhead caused by the interposition of the Cordova framework/bridge and has consequently a noticeable performance overhead. The performance overhead introduced by the Cordova bridge is discussed in more detail in the following section.

TABLE II. RATIO OF DATABASE EXECUTION TIME TO THE NATIVE (SQLITE) OPERATION DURATION (IN %). *IN IOS INDEXEDDB IS ONLY SUPPORTED AS OF IOS 10.

	Android Nexus 6	iOS iPhone 6
SQLite (Native)	100	100
IndexedDB	6.94	12.47*
WebSQL	153	128
SQLite Plugin	133	116

2) Files:

a) Test Application: The test application distinguishes between read and write operations. Each operation is tested using different file sizes, ranging from small files (~ 1 kB) to larger files (~ 10 MB). The performance of small files provides a baseline for file access. The performance of the read and write operations itself can be determined via the results of the large files. This test has been conducted ten times for each file size. The read and write operations consist of different steps on Android and iOS. Both the duration of the individual steps and the entire operation (i.e. read/write) is measured via timestamps. The application's memory footprint is measured via Instruments tool (Activity Monitor) in Xcode and via Memory Monitor in Android Studio.

b) *Results and Comparison:* The results of the timing analysis on Android and iOS is presented in Figure 3 and 4, respectively. In both Android and iOS a significant performance difference between the native and the Cordova mechanism can be observed. R/W operations via the file plugin take longer compared to the native mechanisms. On top of a performance overhead, Cordova also comes with a higher memory consumption, especially in iOS (Figure 5).

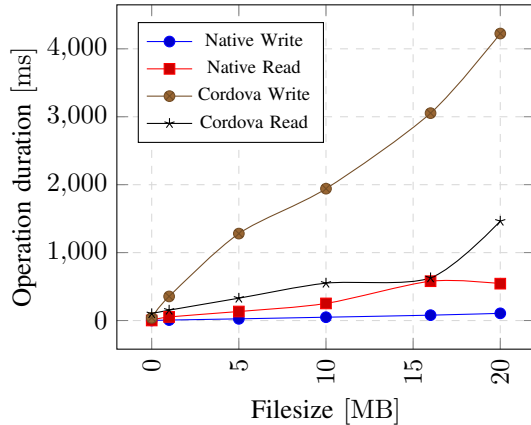


Figure 3. Duration of file operations in Android

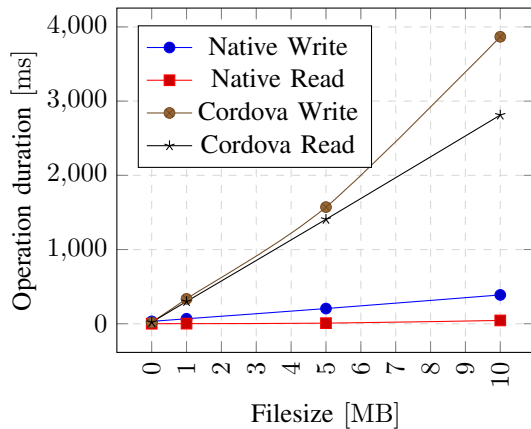


Figure 4. Duration of file operations in iOS

Speed. Tables III and IV give a fine-grained overview of the different operations executed during respectively a file read and write using the Cordova platform on Android. Tables V and VI provide the results for iOS. Before data can be sent over the Cordova bridge, it needs to be converted to a string. This can create significant overhead when large binary files such as images needs to be manipulated. Before they are sent over the bridge, the binary data is converted to a Base64 string. On Android, this is illustrated in the *Processing file* component of Table IV. Sending the data over the bridge also comprises a significant part of the overhead (i.e. *Sending over bridge*, from Table III). For small files, the overhead originates for the most part from resolving the platform-independent URL to a local path and retrieving meta-data. Similar observations can be made based on the iOS results.

TABLE III. EXECUTION TIME OF COMPONENTS ASSOCIATED WITH A READ OPERATION IN CORDOVA ANDROID (FILE PLUGIN). THE PROCEDURE "SENDING OVER BRIDGE" CONSISTS OF ENCODING, SENDING AND DECODING MESSAGES FROM THE JAVASCRIPT SIDE TO THE NATIVE SIDE.

Component	Duration [1 MB]		Duration [20 MB]	
	(ms)	(% total)	(ms)	(% total)
Resolve to local URL	58	46	59	7.56
Native reading	20	16	366	47
Sending over bridge	28	22	339	43
Total	126		780	

TABLE IV. EXECUTION TIME OF COMPONENTS ASSOCIATED WITH A WRITE OPERATION IN CORDOVA ANDROID (FILE PLUGIN). THE PROCEDURE "PROCESSING FILE" CONVERTS THE BYTES -AS AN ARRAYBUFFER- TO A STRING ARRAY. THE "EXECUTE CALL DELAY" REPRESENTS THE DELAY BETWEEN THE WRITE COMMAND EXECUTED IN JAVASCRIPT AND THE EXECUTION AT THE NATIVE SIDE.

Component	Duration [1 MB]		Duration [20 MB]	
	(ms)	(% total)	(ms)	(% total)
Processing file	108	65	1290	56
Execute call delay	38	23	632	28
Writing	20	12	369	16
Total	166		2291	

Memory. In iOS, applications manipulating large files will require large amounts of memory. This is illustrated in Figure 5. As shown, reading and writing a 10 MB file results in 400 MB of allocated memory. Reading and writing files larger than 10 MB can result in unstable behavior on iOS due to the large memory requirements. A solution for developers is to split large file operations in different steps.

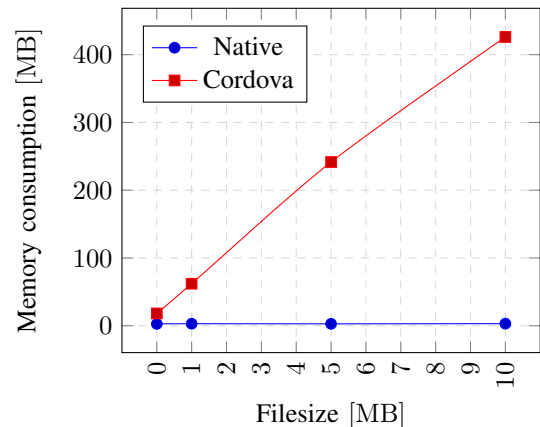


Figure 5. Memory consumption as a result of file operations in iOS

c) *Conclusion:* File storage on Apache Cordova comes with a number of limitation in terms of performance. This is a result of the Cordova framework/bridge technology. Allowing binary data to pass over the Cordova bridge could significantly improve the performance of plugins that perform operations on binary data. For instance, in [25] an bridging technology is

TABLE V. PERFORMANCE READ COMPONENTS IN CORDOVA IOS

Component	Duration [1 MB]		Duration [10 MB]	
	(ms)	(% total)	(ms)	(% total)
Resolve to local URL	11	3.56	16	0.6
Native reading	13.98	4.52	70	2.47
Arguments to JSONArray	202.77	65.62	2037.93	71.88
Sending over bridge	59.93	19.39	587.19	20.71
Total	309		2835	

TABLE VI. PERFORMANCE WRITE COMPONENTS IN CORDOVA IOS

Component	Duration [1 MB]		Duration [10 MB]	
	(ms)	(% total)	(ms)	(% total)
Processing file	266	97	2614	96
Native writing	7	3	96	4
Total	273		2710	

presented that allows access to native device APIs in HTML5 applications via WebSockets and HTTP servers, supporting the use of binary data.

3) Persistent variables:

a) *Test Application:* The performance is examined via storing and retrieving string values. The total duration of storing and retrieving a thousand variables is measured. The average storage and retrieval time is used to compare the different storage mechanisms. The Cordova mechanisms are LocalStorage and NativeStorage. These are compared to NSUserDefaults (iOS), Property Lists (iOS) and SharedPreferences (Android).

b) *Results and Comparison:* All mechanisms have an execution time under 1 ms, with the exception of NativeStorage and Property Lists. The set operation takes around 1.9ms, the get operation takes less than 1 ms. NativeStorage is the only mechanism which uses the Cordova bridge and framework, introducing a certain overhead. However, the NativeStorage API is asynchronous, hence, developers can continue processing while the value is being stored. The listed measurements include the time until the callback is fired. Property Lists load an entire file in an array, after which individual parameters can be read. As a consequence, the performance of the get operation, which takes 9.83 ms, is worse compared to the native alternatives. SharedPreferences and NSUserDefaults also load all parameters in memory, but this is done during the initialisation phase of the application, which is not incorporated in the measurements.

B. Security

On both Android and iOS the security of storage mechanisms strongly depends on the storage location and the platform's backup mechanisms. Data stored inside the sandbox of the application is only accessible by the application. However, the backup mechanisms used in iOS and Android can result in the exposure of sensitive data [27, 29, 28], or potentially exhausting the limited cloud storage capacity. On iOS, this can result in the rejection of the application (conform the Data Storage Guidelines [14]). On Android, data stored inside the

application sandbox (e.g., the WebView's storage) is included if a backup is taken. The Backup API of Android can be used to explicitly blacklist data that should not be backed up. On iOS, whether or not a file is included in the backup depends on the folder in which it is stored. For instance, by default, Cordova stores the WebView's data in a folder that allows backups. This behavior can, however, be changed by modifying a Cordova parameter.

1) *Databases:* All database mechanisms are by default private to the application and can be backed up on both mobile platforms, with the exception of the SQLite plugin in iOS. The plugin initially followed the default behaviour, but as a security measure the default storage location of the plugin in iOS was changed to a directory which is not backed up. This SQLite plugin also has an encrypted alternative, i.e. **cordova-sqlcipher-adapter**. This alternative provides a native interface to SQLCipher, encrypting SQLite databases via a user-supplied password.

2) *Files:* In iOS files are protected by a protection class. Each of these classes corresponds to different security properties. As of iOS 7, all files are by default encrypted individually until first user authentication. The file plugin doesn't allow changing this default behaviour. Native, each file can be secured using a protection class best suited for the security requirements of that file. The plugin allows the developer to choose between folders that are public/private and backup-enabled/disabled. However, on Android backup-disabled locations can be accessed by other applications.

3) *Persistent variables:* All persistent variable storage mechanisms are private to the application and included in backups on both mobile platforms, with the exception of Property List. Property lists can be stored in arbitrary locations, and can be backed up depending on the specified location.

4) *Sensitive Data:* The Secure Storage plugin provides storage of sensitive data on Android and iOS. On iOS, the plugin uses the SAMKeychain [2] plugin which provides an API for the native iOS Keychain. The plugin allows app-global static configuration of the KeyChain items' accessibility. This could entail a security risk, as it does not allow fine-grained protection of individual items. When a user backs up iPhone data, the Keychain data is backed up but the secrets in the Keychain remain encrypted with a phone-specific key in the backup. The Android KeyChain only allows storage of private keys. Hence, for storing other tokens such as passwords or JWT tokens, an additional encryption layer is used. The plugin generates a key that is stored in the KeyChain and used to encrypt/decrypt sensitive data. The KeyChain on Android is not included in backups.

VI. CONCLUSIONS

This paper presented an assessment of data storage strategies using the mobile cross-platform tool Cordova. An in-depth analysis was performed on the API coverage of the available data storage mechanisms in Cordova and Native applications. Based on the analysis, an additional Cordova storage plugin was developed that improves the storage of persistent variables.

Furthermore, the performance and security of the available storage mechanisms were evaluated. Our performance analysis

shows that using the Cordova bridge comes with a significant performance penalty. Hence, the WebView's JavaScript API should be used when possible. However, apart from performance, other parameters such as functionality and security can have an impact on the selection of the storage mechanism.

Databases. If access to a full fledged SQL database is required, the SQLite plugin should be used. However, in most mobile applications, the functionality provided by the significantly faster IndexedDB interface of the WebView is sufficient.

Variables. As described in Sections IV and V, it is recommended to use NativeStorage for storing persistent variables, since LocalStorage does not guarantee persistence over longer periods of time. This type of storage is often used to store preferences. Preferences are typically only accessed once or twice during the life cycle of the application. Hence, the performance overhead of NativeStorage does not have a significant impact on the performance of the application.

Files. The WebView does not provide a file storage API. Hence, developers have to use the core plugin, Cordova File Plugin (`cordova-plugin-file`).

Sensitive data. The security analysis presented in Section V-B shows that plugins such as SecureStorage offer increased security compared to the WebView's JavaScript API because they benefit from the platform's native secure storage APIs. It is therefore recommended to use a plugin such as SecureStorage to store sensitive data.

Future work on this topic can include an in-depth analysis of the CrossWalk WebView. Currently, Cordova applications suffer from a major performance penalty every time the JavaScript bridge is accessed. CrossWalk has its own plugin mechanism, which could show better performance than Cordova plugins.

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