

An Approach to Assess the Performance of Mobile Applications: A Case Study of Multiplatform Development Frameworks

Dany Mota² and Ricardo Martinho^{1,2} ^a

¹INESCC, Leiria Branch, ESTG, Polytechnic of Leiria, Leiria, Portugal

²School of Technology and Management, Polytechnic of Leiria, Leiria, Portugal

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Abstract: Comparative studies between software multiplatform development frameworks lack a proper approach that can be replicated in future performance assessments. Moreover, there is still a deficit in performance comparison tools. Also, performance comparisons realized between mobile applications developed under these multiplatform frameworks should be done with applications running in Release Mode, which ends up not happening in most studies. The objective of this paper is thus to create a whole comparative process as correct and stable as possible, so that we can use it to safely assess performance of mobile applications developed with these frameworks. As a case study, we compare the well-known Flutter and React Native frameworks, and present the obtained results under the proposed approach. With this work, developers can not only assess both these particular frameworks, but also use the approach for further comparisons.

1 INTRODUCTION

In December 2020, about 99.39% of the mobile operating system market share was dominated by the Android (72.48%) and iOS (26.91%) operating systems (Statista Inc. 2019). To reach this market share, software development companies can opt by: 1) develop separate mobile applications using native development. These applications only differ by the fact that they are intended for different operating systems; or 2) develop the mobile applications using only one code base and a multiplatform development framework, which can then deploy applications for both operating systems.

The first option (native development) implies a higher direct cost of software development and maintenance, since these activities will be done in at least two different programming languages (Java and/or Kotlin for Android and Swift and/or Objective-C for iOS), deriving most likely in two separate teams, with higher synchronization/agency costs between them.

For the second option (multiplatform development), it allows code reutilization and therefore less development time and cost, near-native services with access to device hardware and the use

of technologies that are well-known to developers (HTML5, Javascript and CSS) (Drifty Co. 2020).

Several studies already compare performance between different multiplatform development frameworks (see, e.g., (Bjørn-Hansen, Grønli, e Ghinea 2019; Gonsalves 2018)), using tools and metrics for different purposes. Other studies can also be found (as, for instance, in (Saarinen 2019)), which make a comparison of multiplatform development frameworks, focused on the execution time of certain software features. Nevertheless, there is a lack in literature about the process of realizing these performance benchmarks, conveying other important pre- and post-execution procedures and addressing other performance metrics.

Additionally, the existence of several multiplatform development frameworks ends up leaving the development community in doubt about which framework they should use in their projects. Another fact is that, until these multiplatform development frameworks arrive, there was no need for Android and iOS manufacturers to provide tools to test the performance of apps developed by non-native, third party frameworks. Therefore, the existing tools from these manufacturers still remain focused on assisting in the development of (native)

 <https://orcid.org/0000-0003-1157-7510>

applications and not for an evaluation of what is and/or has been developed.

The objective of this paper is, therefore, twofold: 1) to define and create a set of procedures and tests that can really be implemented to compare the performance of applications developed through any (native or non-native) development frameworks; 2) to help developers understand which multiplatform framework is better suited to the intended objectives in each application to be developed.

The remainder of this paper is organized as follows: in the next section we gather related work regarding performance assessment studies in mobile applications. In section 3 we propose an approach for preparing, designing, testing and concluding about performance assessment in mobile applications. Section 4 describes our case study and associated test cases, and in section 5 we present the obtained performance assessment results, using the proposed approach. Finally, section 6 concludes the paper and points out further research directions.

2 RELATED WORK

Using the following search string "cross platform frameworks" OR "hybrid mobile frameworks" OR "native mobile frameworks" performance metrics on the main scientific libraries (ACM, DBLP, IEEE and Google Scholar), and applying a date filter to show only the results after 2018, we could obtain 121 publications. From these, 100 were rejected because they did not fit the theme correctly. Of the remaining 21, we could collect valuable information that helped in the development of this work, namely:

- The testing tools used to assess performance (see, e.g., Asp Handledare et al. (2017));
- The performance metrics considered (see, e.g., Eskola (2018));
- The kind of features that were tested (see, e.g., Scharfstein and Gaurf (2013)).

In order to compose our approach, we considered the most referenced items within these three types of collected information. For the kind of mobile app features that were tested (3rd type) we made another search to find the most downloaded apps in 2019 and selected some of the most used features.

Our literature review also revealed that there are no "best" multiplatform development frameworks, but some can be best suited to a given situation, depending on the purpose and requirements of the intended mobile application. Additionally, the evaluation of the performance of a mobile application

is a complex process, which can easily be discussed. For instance, one of the evaluation steps that we found to be critical is to assure that applications are running in Release Mode when executing performance tests ; or, alternatively, in a mode dedicated to the evaluation of applications (if available) (Apple Inc. 2015; Lockwood 2013).

3 EVALUATION PROCESS PROPOSAL

Our evaluation process began by first identifying related works that already existed regarding mobile app performance assessment. Then, multiple mobile application development frameworks were evaluated to be used in the course of this performance assessment. With the frameworks selected, before proceeding, we analysed the possibilities for carrying out their evaluation. Therefore, the tools available for this purpose were studied. We then proceeded to a more practical part: the identification and implementation of mobile app software features that could be an asset in the comparison and evaluation of the development frameworks. Then, the design and development of the testing process was one of the most important points, taking into account that it was where most of the related works analysed showed failures. Finally, the process ended by executing all the designed specific tests, performing a statistical evaluation on the results obtained and providing some discussion on these.

3.1 Release Mode

The term "Release Mode" was mentioned in an official Apple lecture (Apple Inc. 2015) when describing their performance analyser tool known as Instruments. From here, and due to the lack of other works considering this issue, as well as the inconsistency of tools and metrics that were used, we incorporated the need of having this executable mode either in the proposed approach and in the tools used to assess mobile application performance.

3.2 Frameworks Selection

Bearing in mind that the defined objective involves the comparison of applications developed using distinct frameworks, we also tried to compare multiplatform frameworks that have a larger market share among the developers community today. In this way, the selection of the frameworks was based on

the most studied in the analysed publications in conjunction with the values of each official GitHub pages.

These criteria led to the selection of the 2 well-known multiplatform frameworks: one created by Facebook named React Native; and another that belongs to Google named Flutter.

3.3 Metrics and Feasibility of Measurement Tools

Due to the existence of a significant diversity of metrics and tools for benchmarking found in previous studies, we had to filter them according to some criteria. First, in relation to the metrics, the most found in the studies were selected, more precisely, those that occurred more than 5 times, namely:

- CPU usage;
- RAM usage;
- Execution Time;
- Frames per second.

Regarding testing/performance evaluation tools, it was defined that only official testing tools of the platforms / operating systems (Android OS and iOS) would be used. Then, we checked if they were compatible with the “Release Mode”. These criteria were sufficient to reduce the number of tools available.

For the iOS system the tool selected is Instruments, which is integrated with the official IDE, XCode. On the Android system, we selected the Systrace tool and the bash command `top`, originally integrated on Linux based systems, in this case the Android OS. However, it was still necessary to complement the tools in Android through scripts, due to limitations that these presented. We created three scripts for this matter: two bash-based and another using JavaScript (and NodeJS). These scripts were named like:

- Profile Extraction;
- Profile Top;
- Profile Transformation.

The Profile Extraction script is the largest, and controls all the process tests and the execution of the other two scripts with the rest of the necessary testing tools. It starts by checking which framework project is on the directory and automatically finding the Android device. After that, it makes sure that the application is not installed on the mobile device (by uninstalling it). Then, it restarts the device and executes the official approach of each framework to compile the release mode of the feature to be tested. Right after, the script runs the Profile Top script and

the Systrace tool. Ending the test all opened tools are closed and all collected data saved in an organised structure, to be consumed by the last script Profile Transformation.

After all this steps, one of the ten iterations of the test is completed, and the script Profile Extraction will automatically repeat the process ten times.

Profile Top is a script used to save the values resulting from the `top` command, since the execution of this command takes a few seconds. The script is then responsible to execute ten times this command in parallel with a small-time interval to make sure that during the test a larger number of samples is obtained.

Profile Transformation is the last script to be used, and it checks all structure of data registered, merges all iterations with all transformations and necessary calculations to save the data in tables to an easy human preview.

3.4 Features

In order to make a more comprehensive assessment, a search of the most used applications in 2019 was carried out to understand which features are most in need of evaluation. The keywords “most used apps 2019” were applied to this search, filtered by the results of the last month. As a result of this search, several sites were consulted, where a common referenced source was found: APP ANNIE (Venkatraman 2019).

According to this source, the most downloaded applications during 2019 were:

1. Facebook Messenger;
2. Facebook;
3. WhatsApp Messenger;
4. TikTok;
5. Instagram.

With the result of this search, we defined five (mini) sample mobile applications (one per feature), in order to understand which are the most common features that can be targeted for testing. After the sample applications were selected, an analysis process was initiated to meet the most frequent features they contained.

After analysing the various applications, nine features were selected to be reproduced and tested. These features are:

- Launch – feature that launches any mobile application;
- Lists – feature representing most of the content in any of the model applications. From lists, two distinct features originate: one directed to remote content lists and another to local content lists;

- Camera – taking into account that all model applications are applications of social variation and communication, all of them make it possible to capture images, both through photographs and videos. In this way, we have two related features: 1) image; and 2) video capture;
- Access to local multimedia content – for the same purpose of accessing the camera, users of model applications can choose to share media content that they have previously purchased. Thus, we are facing two more features: 1) images; and 2) videos access on the devices;
- Access to remote multimedia content – model application users are constantly consuming remote media content. Thus, another feature results as the reproduction of remote accessing media content;
- Animations – all model applications feature various animations, whether in navigation or in content interaction. Animations are present in order to make the use of the application a better experience. In this way, rendering animations was also selected as feature to be tested.

3.5 Testing Setup and Development

The development of the testing process required a significant effort and rigor, considering that all the values should subsequently analysed and translated into conclusions. In this process, one of the crucial points was the execution mode in which the applications must be to be properly tested, in this case the *release mode*. After ensuring this mode, the test environment was prepared.

In the testing environment, we chose specific devices for each operating system and ensured that they would not be obstructed by any other applications or communications during testing. In the case of features that need remote content, we created a mock server exclusively to reply to the requirements of this features and both parts, server and smartphones were connected to a 5G Local Area Network.

3.6 Tests and Evaluation

During the tests, in order for the entire assessment to be as reliable as possible, two important procedures were defined. The first procedure concerns the way the test is performed. Each test consists of a set of steps to obtain the results, namely: 1) removing a pre-installation of the application, if it exists on the device; 2) restarting the mobile device, so that any

information about the application in RAM memory is discarded; 3) installing the sample application by the framework itself in release mode; and finally 4) running the appropriate test.

The second procedure refers to the number of iterations for each test and for each sample application, in order to normalize the results. We defined that each test would run ten times, exactly the same number that Apple uses in the automated written tests.

After the tests were performed, coloured tables were used to provide a more intuitive and easier analysis. The evaluation is made for each application that is created within each selected functionality, through the consumptions that were registered in each operating system and each technology. In this process, points are also assigned to each technology, according to the metrics in which they have the best results.

3.7 Result Normalization and Presentation

To conclude a comparative performance assessment between mobile applications developed under different frameworks, the points that were used during the evaluation were assigned to each framework. Using these points and a leverage system resulting from the division between the registered values of each framework, a less detailed analysis was obtained to make a more evident and accessible comparison.

These final results are also presented in coloured tables, both from the perspective of the features of the sample applications developed, and of the metrics. These two perspectives have produced diverse results also with regard to the operating system and the development framework.

4 APPLICATIONS AND TEST CASES

In this chapter, the applications created (one for each framework to be compared) will be addressed, in response to the features previously identified, to be tested and evaluated. This chapter also discusses the procedure in which each application was tested.

In the case of applications that were created with the aim of simulating real functionalities, most of these would require user interaction to make use of their purpose. However, this interaction could jeopardize the impartiality of the results. In this way, a solution was found that was compatible with both Android OS and iOS operating systems, in order to

make the testing process free from human interactions. After the analysis of several automation tools, it was concluded that they had several limitations, such as, for example, not supporting the testing of applications in release mode, or the need to install additional applications on mobile devices, being unknown the interference they could have in the results.

In addition to this, there was another factor that prevented the use of these automation tools: their need to start the applications under testing, and this procedure goes against the process of executing the Instruments tool.

Without the possibility of implementing automated tests, it was decided to create automation procedures integrated directly into the applications, modelling some of the tests and reducing human interaction whenever possible.

The testing procedure was the same for both applications developed for Android OS and iOS. However, in certain cases, due to the limitations of the tools and / or some technologies as mentioned above, some tests were adapted to each platform, respecting the impartiality between the different platforms and frameworks so that, later on, the evaluations were also reliable.

In an attempt to perceive possible different consumption peaks on the platforms, certain applications were strategically created with waiting bars, so that the identification of these peaks was facilitated in a later analysis.

Bearing in mind that the frameworks being studied are dedicated to the creation of an application for two different operating systems, of each identified and studied feature, four distinct applications were developed, two for each framework.

However, there are some special cases regarding the features developed. For the “lists” feature, we tested lists with remote and local content and with different variations of the number of elements (10, 50 and 100 elements).

Since nine unique features are being studied and, in some of them, several variations of them are created, a total of 52 sample mobile applications are obtained, 26 of which are directed to the iOS operating system and the others to the Android operating system.

5 RESULTS

During the evaluation of the applications created for each feature, results were scored using points. A less

detailed view of the performance of the frameworks using these points is presented in Table 1.

Table 1: Points by operating system, framework and feature.

Features	iOS		Android	
	React Native	Flutter	React Native	Flutter
Launch	2	1	2	3
Local Lists	9	6	3	15
Remote Lists	3	12	8	10
Take Photos	0	4	0	5
Record of Videos	4	0	1	4
Access to Images	0	4	0	5
Access to Videos	0	4	1	4
Streaming	3	2	2	3
Animations	2	3	0	6
Total	23	36	17	55

As shown in Table 1, which uses the same colour scheme used previously to assist in the perception of results, Flutter is the framework that presents the best results in both operating systems, about 157% better in iOS and more than 3 times on Android OS. In the latter, all metrics are dominated by Flutter. However, on the iOS side, we have React Native which, although with fewer points, stands out with an advantage in 4 of the 9 features.

Performing an analysis but from the perspective of the metrics (Table 2), in terms of execution times, both frameworks present the same score, regardless of the operating system. Regarding iOS, it is visible that React Native is better when it comes to RAM consumption. However, if we compare values in Android OS, Flutter has better performance in all metrics, excluding the execution time which, as already discussed, has an equivalent performance.

Table 2: Points by operating system, framework and metric.

Metrics	iOS		Android	
	React Native	Flutter	React Native	Flutter
Execution Time	4	4	4	4
CPU	2	11	10	16
RAM	10	3	3	23
FPS	7	18	0	12
Total	23	36	17	55

Analysing global results, without distinguishing between operating systems, we obtain the perspective

of values presented in Table 3. Here we can observe the values of each framework and also conclude that Flutter is the one that presents the best global results in eight of the nine features considered. React Native only has a small advantage in capturing videos, having an equivalent level in launch and streaming. In total, Flutter achieves precisely twice as much as points obtained by React Native.

Table 3: Points by framework and feature.

Features	React Native	Flutter
Launch	4	4
Local Lists	12	21
Remote Lists	11	22
Take Photos	0	9
Record of Videos	5	4
Access to Images	0	9
Access to Videos	1	8
Streaming	5	5
Animations	2	9
Total	40	91

Through Table 4, also from the same point of view, but in relation to the metrics, React Native only obtains an equivalent performance regarding execution times, while all other metrics are largely dominated by Flutter.

Table 4: Points by framework and metric.

Metrics	React Native	Flutter
Execution Time	8	8
CPU	12	27
RAM	13	26
FPS	7	30
Total	40	91

In order to make an even more impartial comparison, the score obtained by the frameworks was normalised by dividing the highest value obtained in the metric by the lowest. In cases where the lowest value is zero, the difference between them was considered. In this way, the score obtained will more accurately reflect the real difference between frameworks and operating systems.

Table 5 shows leveraged scores obtained by operating system and framework. Through this representation it is noticeable that the difference between the technologies in the iOS operating system is less than that analysed above by points without leverage. React Native goes from about 64% of Flutter points to about 90% on the iOS system.

However, in the Android OS operating system, the difference between the frameworks intensified, thus changing React Native from about 31% of Flutter's points to approximately only 6%.

Table 5: Leveraged Points by operating system, framework and feature.

Features	iOS		Android	
	React Native	Flutter	React Native	Flutter
Launch	3,50	1,05	3,60	4,09
Local Lists	21,62	11,40	8,68	85,12
Remote Lists	15,36	20,52	10,08	116,80
Take Photos	0,00	9,70	0,00	7,49
Record of Videos	4,61	0,00	1,42	7,55
Access to Images	0,00	4,63	0,00	7,91
Access to Videos	0,00	4,51	1,61	10,49
Streaming	11,44	3,03	2,93	65,14
Animations	3,54	11,76	0,00	164,63
Total	60,07	66,60	28,32	469,22

Performing the analysis by metric, using Table 6, although React Native has worse performance in all metrics excluding one, this one shows to be significantly better in the management of RAM memory in the iOS operating system. Still, Flutter also has a great advantage not only in the management of RAM memory but also in the FPS of the Android OS operating system.

Table 6: Leveraged Points by operating system, framework and metric.

Metrics	iOS		Android	
	React Native	Flutter	React Native	Flutter
Execution Time	11,45	13,92	10,04	16,84
CPU	2,09	15,94	14,45	25,64
RAM	38,98	8,18	3,83	25,51
FPS	7,54	28,56	0,00	401,24
Total	60,07	66,60	28,32	469,22

By comparing the values in the developed applications excluding the division by operating systems (Table 7), the only feature in which React Native shows to dominate with better performance is the launch of applications. With an average performance of more than six times higher, Flutter once again reinforces its dominance in multiplatform development compared to React Native.

Table 7: Leveraged Points by framework and feature.

Features	React Native	Flutter
Launch	7,11	5,15
Local Lists	30,30	96,52
Remote Lists	25,44	137,31
Take Photos	0,00	17,19
Record of Videos	6,03	7,55
Access to Images	0,00	12,54
Access to Videos	1,61	15,00
Streaming	14,37	68,17
Animations	3,54	176,39
Total	88,39	535,82

Excluding operating systems, for a more direct comparison of frameworks at the level of metrics (Table 8), it is clear that React Native's strong point in relation to Flutter is RAM management for the iOS operating system. Apart from this metric, Flutter has a marked advantage over React Native.

Table 8: Leveraged Points by framework and feature.

Metrics	React Native	Flutter
Execution Time	21,50	30,76
CPU	16,55	41,57
RAM	42,80	33,69
FPS	7,54	429,79
Total	88,39	535,82

6 DISCUSSION

The assorted studies existing in relation to evaluations of technological alternatives available on the market for the development of mobile applications showed some inconsistencies in the procedures carried out, including studies that did not refer to the process that was used or the importance of several details such as, for example, the Release Mode or equivalent in the applications to be evaluated.

This situation reinforced the idea that there was a need to propose an approach, in order to assist all organizations that have to decide about the development framework to adopt for their mobile software applications.

In the course of this work, we did not expect that one of the biggest challenges would be related to the tools used to test the performance of mobile applications. To tackle this, we decided to use several tools of greater complexity and to create scripts

applicable to testing the various features in question. Thus, an approach for automating tests and recording evaluation metrics was proposed, combined with the official testing tools of the manufacturers of the Android OS and iOS operating systems.

7 CONCLUSION

The comparison between the React Native and Flutter frameworks was performed and analysed through the entire approach defined in the course of this work, as a case study.

From the comparison between these two frameworks, it can be concluded that, for the most part, Flutter is the best solution for the selected features, and regardless of the operating system targeted by the smartphone (iOS or Android OS). However, the comparison between the frameworks was carried out to cover a wider range of views and requirements. Thus, depending on the objective of those who are analysing these results, conclusions for a greater number of scenarios can be easily drawn.

Bearing in mind that the smartphone market is dominated by the Android OS operating system and assuming that the purpose of the application to be developed is to have the best performance in this operating system, there is no doubt that Flutter is really a good alternative for applications that bring together a set of features similar to those developed and analysed.

Still, if the goal is mostly Apple's operating system, iOS, there are already several features in which React Native stands out, turning out to be a good alternative. Examples include launching applications, applications involving local storage and lists, capturing video content and even consuming streaming content. From the metrics point of view, React Native also proves to be a good alternative for an economical application in terms of RAM, especially in the case of the iOS operating system.

After analysing all the values, a conclusion that can also be derived is that, if the goal is to develop an application without major visual effects for the iOS operating system, React Native is the best solution, especially if the application involves local SQLite storage. In the case of an application that involves better visual effects, this is one of Flutter's strengths, both in terms of performance and of ease of implementation, ending up with an application that obtains good consumption in general, in both operating systems.

8 FUTURE WORK

Future perspectives of this work will be focused on improving the testing approach proposed, as well as developing a solution that is as automated as possible. The aim is to develop a tool, based on the official ones and also those we developed, that will become a reference in the mobile application performance evaluation market.

Thus, we intend to take the scripting tool created to a more mature application, available for any computer, without the need of creating an entire complex test environment, as reported in this work.

The intended application will have several levels of use, aimed at both developers who want to evaluate the applications they produce, as well as other entities with less in-depth knowledge of programming. An entire automatic process of merging several features already implemented in multiple frameworks will also be incorporated. This aspect will allow any entity, even without having any knowledge of the technologies to be compared and even without any programming concepts, to be able to make a comparison in a much easier way.

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