Journal of Namibian Studies, 33 S2(2023): 2465–2486 ISSN: 2197-5523 (online)

Comparative Analysis of Cross-Platform Frameworks

OSCAR DANILO GAVILÁNEZ ALVAREZ[1], MARIANA ISABEL PUENTE RIOFRÍO[2], NORA TAHIRÍ MEJÍA CABEZAS[3], IRAIDA MARITZA GAVILÁNEZ ALVAREZ[4], VARGAS ÑAUÑAY ERICK JOEL[5], CHANGO VELA KEVIN ARIEL[6], CARDENAS CARDENAS LUIS ANGEL[7]

[1]ESCUELA SUPERIOR POLITÉCNICA DE CHIMBORAZO (ESPOCH), FACULTAD DE INFORMÁTICA Y ELECTRÓNICA, oscar.gavilanez@espoch.edu.ec

[2]UNIVERSIDAD NACIONAL DE CHIMBORAZO, FACULTAD DE CIENCIAS POLÍTICAS Y ADMINISTRATIVAS, mariana.puente@unach.edu.ec

[3]ESCUELA SUPERIOR POLITÉCNICA DE CHIMBORAZO (ESPOCH), FACULTAD DE CIENCIAS PECUARIAS, nora.mejia@espoch.edu.ec

[4]UNIVERSIDAD NACIONAL DE CHIMBORAZO, FACULTAD DE INGENIERÍA, iraida.gavilanez@unach.edu.ec

[5]INVESTIGADORES INDEPENDIENTES, erick1704vargas@gmail.com

[6]INVESTIGADORES INDEPENDIENTES, arielvela8910@gmail.com

[7]INVESTIGADORES INDEPENDIENTES, luixcard55@gmail.com

Abstract

The use of frameworks for cross-platform development, whether native or hybrid, is a fundamental part of the field of programming, facilitating in one way or another to software developers to save time, reduce compilation errors, and optimize resources, among other features that denote some advantage between one tool and another. For this reason, it was decided to perform a comparative analysis between the cross-platform application development frameworks Flutter, React Native, Ionic, and Xamarin, using relevant features of each tool as parameters. For this purpose, research was conducted through a literature review of research articles, theses, and books obtained using the Google Scholar search engine, and consequently, parameters were determined that allowed comparing the mentioned frameworks. As a case study, a simple web page was developed in the Flutter framework with the help of the Visual Studio Code environment, to experiment with the characteristics of the mentioned framework directly and briefly. It is concluded that the frameworks for multiplatform development are useful tools that optimize time and maintenance by not requiring writing code to

create a computer application on different platforms, benefiting developers and companies focused on software development.
Key Words: Cross-Platform Development, Framework, SDK, Software.

I. INTRODUCTION

Over time, the internet has evolved in terms of cross-platform development, as it has enabled institutions and individuals, whose knowledge revolves around application development, to work on the implementation of native applications using an integrated development environment (IDE) that provides the necessary tools for building and debugging applications, considering that the execution of this type of native application is on a specific platform, that is, it is necessary to take into consideration the type of device, the operating system (OS), and the version to use for its proper functioning. Unlike a hybrid application, which uses web technologies (HTML, JavaScript, and CSS) executed in a web container (web view) that offers an advantage in code reuse on different platforms, compared to native ones. Fortunately, there is currently a variety of frameworks that allow for the simplification of native or hybrid application development with adaptive design, accelerating work, reducing errors, and optimizing development time, among other features that denote the framework's usability level. For this reason, the interest arises to carry out a comparative analysis of the Flutter, React Native, Ionic, and Xamarin frameworks for cross-platform development, with the aim of determining parameters in which one or more frameworks stand out from the others.

II. LITERATURE REVIEW

A. Framework

Framework is an application that allows for the reuse of its components, which facilitates the creation of applications depending on the platform in which they are developed, allowing for time and maintenance savings. [1]

B. Cross-platform development

The development of cross-platform frameworks stands out for allowing the creation of an application for different platforms without the need to program it several times. [2] It allows companies to not have to program for different operating systems when developing an application, thus reducing the time for code construction while maintaining the functionality of the application regardless of the platform on which it is implemented. [3]

C. Native Development Framework

A native framework allows for the development of applications using integrated development environments (IDEs) necessary for building and debugging an application, being a way to implement software for a specific platform.

Characteristics

• The distributed applications are transferred to the App Stores.

• Possibility to interact with all the device's functions.

• No internet connection is required.

• Fast execution in the background mode.

• Notification of events in the application. [4]

D. Hybrid Development Framework

A hybrid development framework refers to the creation of multiple applications using the same code written only once (code reuse), allowing for multi-platform compilation. [5]

Characteristics

• Code reusability across different devices and operating systems.

• Cost-effective framework compared to native development.

• Shorter time required to develop an application.

• Agile and simple development process.

• Does not utilize hardware capabilities. [6]

E. React Native

React Native is a framework developed by Facebook and released in 2015. It is defined as a cross-platform tool for developing Android and iOS mobile applications using JavaScript ECMAScript, which is a programming language based on JavaScript. [7] The React Native development team based their work on React standards due to its simplicity and ease of use for the programming community. [8] Facebook introduced the concept of "learn once, write anywhere" to refer to the development of applications that are uniform across all operating systems, but with differences in their graphical interface. [9]

Characteristics

• Its multi-platform compatibility, meaning its APIs allow application development to run on different operating systems with the same code.

• Creating applications using native code will work just as well as a framework.

• It has instant updates using JavaScript, giving developers the flexibility to make any changes in a mobile update.

• It is easy to use, as it has JavaScript which can help understand its concepts.

• It offers a wide developer experience such as saving changes or also debugging or compiling code using the Google Chrome debugger.

F. Xamarin

Developed to build Android and iOS applications, Xamarin is a cross-platform tool developed by Microsoft that uses programming languages such as C#. [7] Xamarin is recommended for applications that don't require platform-specific configurations, allowing developers to create a general UI that adapts to both Android and iOS. [10]

Characteristics

• Applications built using this framework have access to available APIs.

• Capable of creating native code compilations, providing low runtime performance impact.

• Capable of being integrated into Microsoft Visual Studio, enabling the creation of applications for Windows.

• Has a focus on cross-platform development where complete coding is shared, having a business logic.

• Interfaces are programmed independently for each platform on which it will be available.

G. Ionic

Released in November 2013, Ionic is a framework with increasing popularity, standing out for allowing UI components to be available based on the development of web applications. It uses components combined with HTML, CSS, and JavaScript. [11]

As an open-source SDK, it provides tools and services that enable the development of hybrid mobile applications. [12]

It runs on Cordova which provides developers with various modules where they can make calls to the Operating System. [13]

When an application is developed based on Ionic, it will be able to perform various tasks such as geolocation services. [14]

Characteristics

• A typical Ionic application contains 4 files for each component created or up to 5 if a separate page is created from the main one.

• When creating a page, a module file is added that will contain declarations for all the packages that Ionic has.

• Optimized for AngularJs, it can process information, thereby improving its performance.

• Easy to understand operation and structuring, its structure is based on the Model View Controller.

H. Fluter

Google developed the Flutter framework to work based on Widgets, which are used depending on the mobile app. Its architecture is new, as it introduced the Business Logic Component with two layers where one is for UI and the other focuses on logic. [8]

As a hybrid technology, it can create native applications for Android and iOS with user-friendly interfaces where the code can be changed while the application is running. [15]

Within Flutter, there are Shells that are essential to the platform because they provide access to native APIs and give relevance to the platform. [12]

Characteristics

• Its second version, Flutter 2, can create apps for up to 6 platforms using the Dart language, the same language created by Google.

• It has fast development, which allows applications created to have a lifespan in just a few seconds through Stateful Hot Reload.

• It provides a toolkit for creating expressive user interfaces, where fast applications are created using widgets.

• It has a wide library of pre-created elements.

III. MATERIALS AND METHODS

To perform the comparative analysis that allowed the evaluation of the parameters of the four multimedia development frameworks: Flutter, React Native, Ionic, and Xamarin, the respective literature review was initially carried out.

The information about each of the frameworks was extracted from research articles, theses, and books obtained using the Google Scholar search engine. Additionally, information was extracted from the official websites of each of the tools.

Consequently, based on the characteristics of each of the aforementioned frameworks, parameters were determined to compare them. For this, a matrix was generated through benchmarking in which the comparison parameters were located with precise and documentary information about the features and functionalities that each framework possesses. The comparative analysis was carried out based on

benchmarking, determining findings that, depending on the parameter, position one or several tools compared to the others.

Finally, the Flutter framework was used to develop a simple website using Visual Studio Code.

IV. RESULTS

The frameworks have well-defined characteristics that differentiate them from other tools focused on cross-platform development. Based on these characteristics, parameters were established to allow comparison among the studied tools. Below are the individual results by parameter obtained from the literature review conducted:

A. Open Source

Open Source" is a parameter referring to the public availability of the tool's source code. Table 1 shows the results obtained based on the code availability.

Table 1: Open Source

Framework	Open source
Flutter	x
React Native	x
Ionic	x
Xamarin	x

B. Language used

In Table 2, the programming languages used by each framework for application development can be observed. It is important to highlight that there is a significant presence of high-level languages widely used in the market, such as C# and JavaScript.

Table 2: Language used

Framework	Language used
Flutter	Dart
React Native	JavaScript
Ionic	Web, HTML, CSS, JS
Xamarin	C#

C. Platforms

This parameter refers to the availability of development tools for different platforms, including operating systems and software. Table 3 shows the results obtained for each framework, where it can be observed that all tools are compatible with the Android and iOS operating systems.

Table 3: Platforms

Framework	Platforms
Flutter	Android
	iOS
	Web
React Native	Android
	iOS
	Web
	Windows
Ionic	Android
	iOS
	Web
Xamarin	Android
	iOS
	macOS
	tvOS
	watchOS
	Windows

D. License

Table 4 presents the results obtained for the license parameter, in which two types of licenses are distinguished: the BSD license, which allows the use and free distribution of the tool, and the MIT license, which is a permissive free software license that allows the distribution of the application as free or proprietary.

Table 4: License

Framework	License
Flutter	BSD.
React Native	MIT.
Ionic	MIT.
Xamarin	MIT.

E. Use

Table 5 shows the main uses of each framework.

Table 5: Use

Framework	Use
Flutter	-Development of Android and iOS applications without the need to write your own base code for each of these systems.
	-Development of desktop web

	applications
React Native	-Development of applications for Android, iOS, web and UWP. -Generation of native applications with performance similar to native
Ionic	-Creation of fast and highly interactive applications. -Development of hybrid applications based on web technologies
Xamarin	-Writing native mobile applications for Android, iOS and Windows. -Share code across multiple platforms. -Use of existing code programmed on another platform

F. Examples

Table 6 presents examples of applications developed by each framework, with the presence of well-known applications widely used today.

Table 6: Examples

Framework	**Examples**
Flutter	-Alibaba -Google Ads -App Tree -Tencent -Reflectly
React Native	-Facebook -Office -Outlook -Microsoft Teams -Discord
Ionic	-Aflac -Target -IBM -T Mobile -H&R Block
Xamarin	-UPS Mobile -BBC Good Food -Just Giving -Fresh Direct -Azure

G. Community

Table 7 shows the available channels of each framework used as community.

Table 7: Community

Framework	Community
Flutter	-FlutterES Facebook -FlutterES Telegram -@ESFlutter Twitter -Medium -Slack [16]
React Native	-Local Communities --Company-based communities -Content sharing [17]
Ionic	-Twitter -Discord -Facebook -YouTube -Forum -GitHub [17]
Xamarin	- Active Facebook community answering questions, producing samples, writing tutorials, creating books, and much more [19]

H. Company

Table 8 indicates the proprietary company in charge of the development and maintenance of the framework, which shows the renowned companies Google, Meta, and Microsoft.

Table 8: Company

Framework	Company
Flutter	Google
React Native	Meta
Ionic	Drifty
Xamarin	Xamarin (Microsoft)

I. Framework development platforms

Table 9 presents the operating systems in which the framework can be used for the development of computer applications

Table 9: Platforms

Framework	Platforms
Flutter	-MacOs -Linux -Windows -Web
React Native	-MacOs -Web -Windows
Ionic	-Windows -MacOs -Linux
Xamarin	-Windows -MacOs

J. Performance

The performance parameter refers to the number of frames resulting from rendering in each frame.

Table 10 shows the results using fps (frames per second) as the unit of measure.

Table 10: Performance

Framework	Performance (fps)
Flutter	60 a 120
React Native	60
Ionic	60

K. Hybrid or native development

Table 11 presents the type of development (hybrid or native) used by the framework

Table 11: Hybrid or native delopment

Framework	Hybrid or native development
Flutter	Hybrid
React Native	Hybrid
Ionic	Hybrid
Xamarin	Native

L. Accessibility

Table 12 presents results on the accessibility characteristics of each Framework

Table 12: Accessibility

Framework	Accessibility
Flutter	Support developers, who seek to make an app where a greater number of people use it, including people with disabilities such as blindness or motor impairment
React Native	Provides APIs that integrate applications with assistive technologies such as screen readers, these APIs allow your application to adapt to all users
Ionic	Displays information about the status of various accessibility features of Mobile OS. Allows an application to send a string to be spoken by the screen reader, or a command to prevent the screen reader from speaking.
Xamarin	Create accessible applications so that the app can be used by people who interact with the user interface with a variety of needs and experiences.

M. Price

In the price parameter, the commercial value of the framework was determined, these data are shown in Table 13

Table 13: Price

Framework	Price
Flutter	Free
React Native	Free
Ionic	-Indies and Startups: $49/month -Basic: $499/month -Standard: $2499/month -Enterprise: Price negotiable by contacting the company
Xamarin	Free

N. Language

The languages that are available in the tool and can be used are presented in Table 14.

Table 14: Language

Framework	Language
Flutter	16 languages, English is available by default
React Native	17 languages available, with 31 languages in progress or in need of contributions
Xamarin	Users choose their language within the tool depending on their region.

O. Requirements

Los requisitos de software y/o hardware para la instalación y uso de cada framework se presentan en la Tabla 15

Table 15: Requirements

Framework	Requirements
Flutter	Windows 7 onwards SP1 or 64 bits. -Storage space: 1.32 GB -.NET applications -Installation of Android Studio. -Visual Studio Code
React Native	-iOS 12.4. -Android 5.0 (API 21) or later -Windows -macOS -Linux .
Ionic	-Node and npm environment. -A code editor is required: Visual Studio Code.
Xamarin	-Dual-Core processor of 1.8 GHz or higher. -2 GB of RAM (4 GB or more recommended).

P. Creating a web page using the Flutter framework

A simple web page was made using the Flutter framework. It was necessary to install the Flutter SDK (Figure 2) and the Visual Studio Code programming environment (Figure 1).

Figure 1. Visual Studio Code

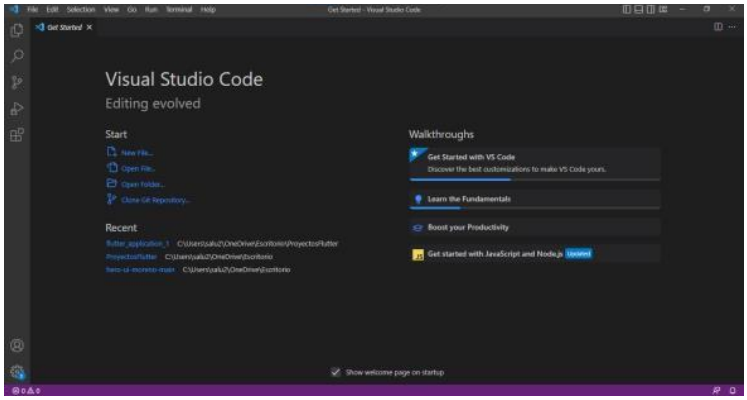
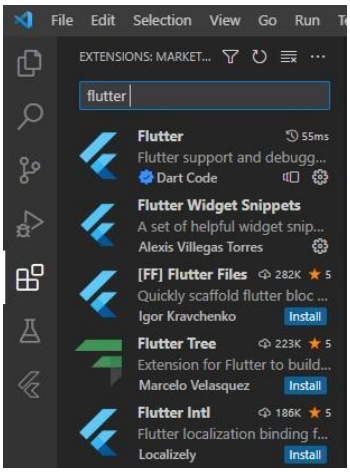


Figure 2: Framework Flutter

Within the Visual Studio Code programming environment, it was necessary to install extensions that allow us to use the framework as shown in Figure 3.

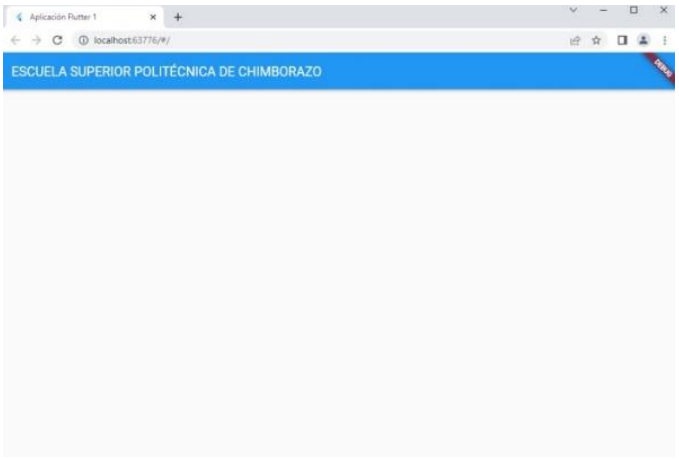
Figure 3: Flutter Extensions



To place the title of the web page (Figure 4,), the following code was applied:

home: Scaffold(appBar: AppBar(title: const Text('ESCUELA SUPERIOR POLITÉCNICA DE CHIMBORAZO'),),

Figure 4. Title



To change the name of the web page (Figure 5) the following code was applied:

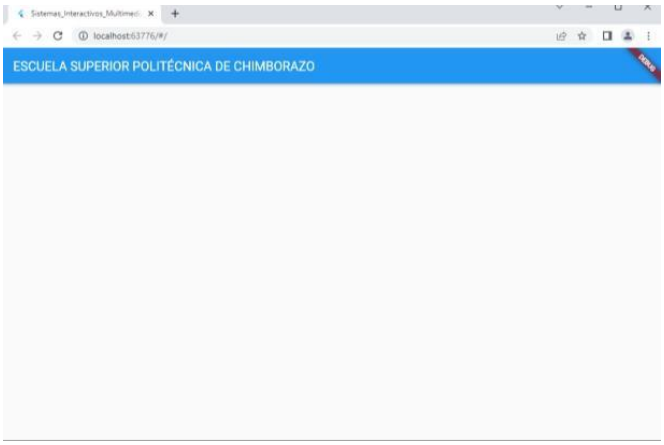
@override

Widget build(BuildContext context) {

return MaterialApp(

title:'Sistemas_Interactivos_Multimedia',

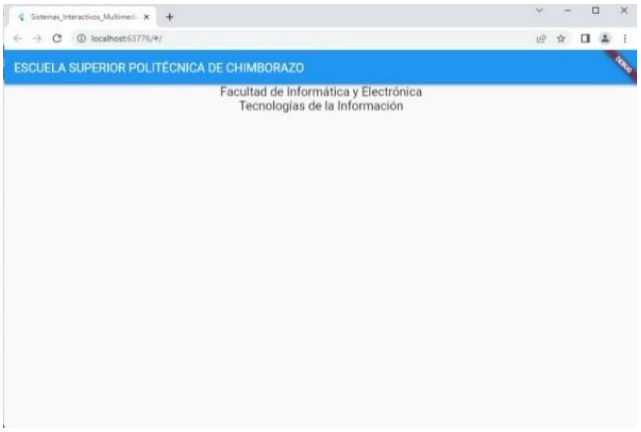
Figure 5: Website Name



To place text boxes (Figure 6), the following code was created:

```
body: Center(
child: Column(
children: [
Text(
'Facultad de Informática y Electrónica', textAlign: TextAlign.center, style:TextStyle(fontFamily:
'RobotoMono',fontSize: 20
), Text(
'Tecnologías de la Información', textAlign: TextAlign.center,
style: TextStyle(fontFamily:
'RobotoMono',fontSize: 20),
),
Text(
'Tecnologías de la Información', textAlign: TextAlign.center,
style:
'RobotoMono',fontSize: 20),
),
```

Figure 6: Text box.



To place images on the web page (Figure 7) the following code was applied:

```
SizedBox(
height: 250.0, width: 350.0,
child: Image.asset('assets/Logo.jpg'),
),
SizedBox( height: 250.0, width: 350.0,
child: Image.asset('assets/TI.jpg'),
),
```

Figure 7: Images

The final result of the web page created with the Flutter Framework through Visual Studio Code, can be seen in Figure 8

Figure 8: Web page

V. DISCUSSION

The frameworks under study (Flutter, React Native, Ionic and Xamarin) have common characteristics, Xamarin is a native development framework and the other Frameworks are hybrid development. All multiplatform frameworks have the purpose of facilitating the

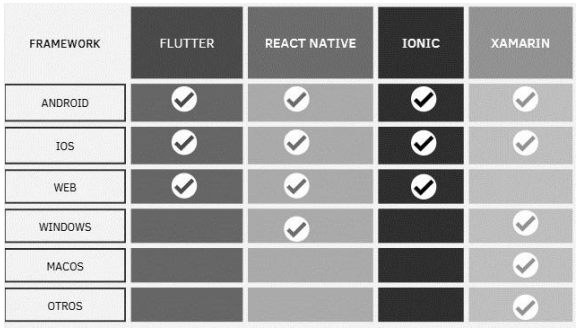
development of computer applications regardless of the platform on which it is implemented, therefore, despite the differences found in the results obtained, it can be affirmed that each multiplatform framework maintains a standard level. In other words, the software developer will oversee deciding which tool to use to generate the best possible solution, optimizing development and maintenance time.

A. Open Source

All frameworks are open source, exposing their source code in their official repositories. A fact that benefits developers for the contribution of improvements and location of vulnerabilities that allow the tool to reach the highest possible level of quality.

B. Platforms for which it can be developed

Figure 9: Platforms



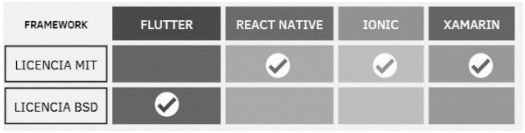
All frameworks support development for the most popular mobile operating systems today (Android and iOS). However, Xamarin extends by allowing development for the macOS, tvOS, watchOS, and Windows operating systems (Figure 9). In the case of the Flutter, Ionic and Reactive Native frameworks, they support web technology, gaining an advantage over Xamarin.

C. Language used

The Ionic and React Native frameworks use the JavaScript programming language, and Xamarin uses C#. This development represents an advantage over Flutter that Dart uses, because JavaScript and C# are languages with a longer time on the market compared to Dart, so developers will not need to acquire new knowledge in those programming languages to use Ionic, Xamarin and/or React Native.

D. License

Figure 10: Type of license



The Ionic and React Native frameworks offer an MIT license, that is, they distribute their product for free or proprietary. On the other hand, Flutter and Xamarin offer a completely free BSD-type license (Figure 10), marking a difference compared to MIT licenses. It will depend on the needs of the user to opt for a free or proprietary license.

E. Use

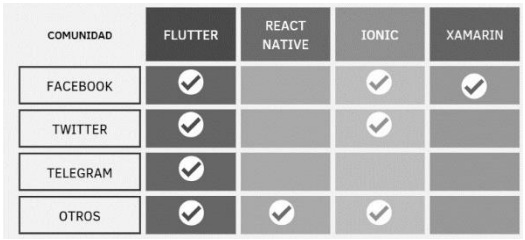
All the tools analyzed are dedicated to the development of applications for Android and iOS, allowing the creation of applications without the need to write their own base code for each of these systems. If you want to develop web applications, the end user must choose the Flutter, React Native and Ionic frameworks.

F. Examples of apps developed

Each of the frameworks presents different examples of applications that have been developed under their name. However, React Native stands out when used for the development of Facebook, Outlook, Teams and Discord, renowned applications that have evolved and facilitated communication over the Internet.

G. Community

Figure 11: Community



All the frameworks have a community where users can communicate with each other and/or with official technicians to solve problems, seek help or to provide their opinion on topics according to the tools.

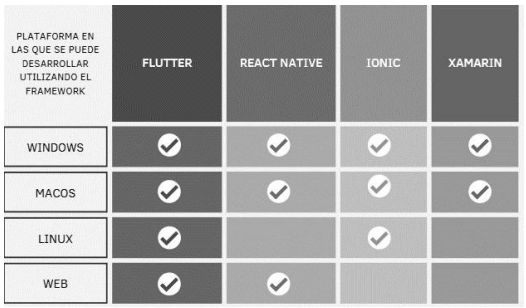
In this case, Flutter and Ionic stand out by having communities in the most demanded social networks today, such as: Facebook, Twitter, Telegram, among others (Figure 11).

H. Company to which it belongs

Each of the tools were created by a recognized company. In the case of Flutter, which was developed by Google, and React Native, which was developed by Facebook, they stand out as they are companies that constantly update their products.

I. Platforms on which the framework can be used

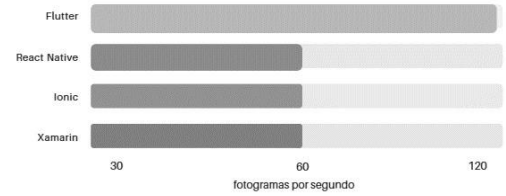
Figure 12: Platforms for the framework



All the frameworks allow the development of applications from the Windows and MacOS operating systems (Figure 12). However, Ionic and Flutter additionally allow app development using Linux. The programmer will have several platforms available to choose from for the development of computer applications.

J. Performance

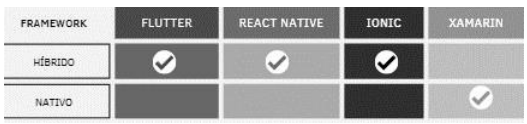
Figure 13: Framework performance



All the tools present a minimum performance quantification of 60 frames per second (fps), allowing the developed applications to have visual fluidity at the time of execution, adapting to the current device refresh rate standard. Flutter stands out in terms of performance by offering image rendering of up to 120 fps on devices that support it (Figure 13).

K. Hybrid or native development

Figure 14 Hybrid or native development



The Flutter, React Native and Ionic frameworks present a hybrid development, except Xamarin which presents a native development (Figure 14). In this regard, frameworks with hybrid development are considered to stand out by allowing them to work on different operating systems and using the same code base.

A. Accessibility

All frameworks allow developers to create applications with specific functions for users with some type of disability. Providing assistance such as through screen readers.

B. Price

The Flutter, React Native, and Xamarin frameworks offer free use. While Ionic, having an MIT license, establishes a usage price that varies between $49 to $2,499 per month, there is the possibility of contacting the company to reach a payment agreement.

C. Language

All the tools offer language packs for the use of these. Xamarin excels by allowing the developer to choose their language depending on the region they are in.

D. Requirements

For the installation of the tools, it is necessary to take into account the software and hardware requirements of the device from which it is going to be developed. In this case, Flutter is the framework that requires less hardware resources for its installation, requiring 1.32 GB of storage and a 64-bit Windows 7 operating system.

VI. CONCLUSIONS

The flutter framework is a free tool for cross-platform development that stands out from other tools in several aspects. It has a greater number of platforms from which it can be developed, increasing the number of developers who can opt for this framework without being limited by the operating system they use. In addition, being a multiplatform tool allows the creation of web, Android and iOS applications without the need to write separate code for each platform. Regarding its requirements, it should be emphasized that it does not require a large amount of hardware or software resources for its installation and operation, which makes it the ideal tool for developing multiplatform applications.

The use of Flutter is recommended for devices whose hardware is limited and for developers who want to expand their knowledge by learning the Dart language.

However, the other tools are excellent options to get to build the same solution. It will depend on the user to choose the framework according to the availability of their hardware and software resources that satisfy their developer needs.

Frameworks for cross-platform development are useful tools that optimize time and maintenance by not requiring writing code to create a computer application on different platforms, benefiting developers and therefore companies focused on software development.

VII. THANKS

To the engineer Oscar Gavilánez, for providing his knowledge, experience and guidance in the correct writing of scientific articles, directly contributing to our preparation as professionals.

To the Escuela Superior Politécnica de Chimborazo for being the headquarters of all the knowledge acquired up to now.

To all those people who, directly or indirectly, contributed to the development of this work

Bibliography

[1] J. R. M. Ríos, N. M. L. Mora, M. P. Z. Ordóñez, y E. L. L. Sojos, «Evaluación de los Frameworks en el Desarrollo de Aplicaciones Web con Python», Revista Latinoamericana de Ingenieria de Software, vol. 4, n.o 4, Art. n.o 4, sep. 2016, doi: 10.18294/relais.2016.201-207.

[2] M. A. López Corrales, «Implementación de framework para el desarrollo de aplicaciones móviles multiplataforma basada en componentes JSON aplicando SOA», Universidad Católica de Santa María, 2021. Accedido: 15 de diciembre de 2022. [En línea]. Disponible en: http://tesis.ucsm.edu.pe/repositorio/handle/20.500.12920/11505

[3] C. Zazo Millán, «Migración de aplicaciones Android hacia flutter, un framework para desarrollo de apps multiplataforma», vol. 18, n.o 1, p. ix, 2018, doi: 10.4995/ia.2014.3293.

[4] L. Delía, «Desarrollo de Aplicaciones Móviles Multiplataforma», Universidad Nacional de La Plata, 2017. [En línea]. Disponible en: https://host170.sedici.unlp.edu.ar/server/api/core/bitstreams/8f61d7e9-13f0-49fb-9857-a5b22b54ae8e/content

[5] P. A. Malla Duchitanga y C. G. Rivera Loja, «Diseño y desarrollo de una red social usando un framework de desarrollo híbrido para la conexión entre usuarios con intereses comunes por las mascotas», 2022, [En línea]. Disponible en: https://dspace.ups.edu.ec/bitstream/123456789/22073/1/UPS-CT009622.pdf

[6] D. B. Jimenez Anastacio, «ANALISIS COMPARATIVO DE LOS FRAMEWORKS HIBRIDOS Y NATIVOS EN EL DESARROLLO DE APPS PARA MOVILES ANDROID», 2022, [En línea]. Disponible en:

http://190.15.129.146/bitstream/handle/49000/12566/E-UTB-FAFI-SIST000363.pdf?sequence=1&isAllowed=y

[7] M. Bohara, «COMPARISON BETWEEN REACT NA- TIVE AND NATIVE APPLICATION DE- VELOPMENT PLATFORM», [En línea]. Disponible en: https://trepo.tuni.fi/bitstream/handle/10024/122735/BoharaMonika.pdf?sequence=2&isAllowed=y

[8] N. Simmonds Samper, «Análisis de frameworks para desarrollo de aplicaciones móviles y web», instname:Universidad de los Andes, 2019, Accedido: 14 de diciembre de 2022. [En línea]. Disponible en: https://repositorio.uniandes.edu.co/handle/1992/44885

[9] W. Danielsson, «React Native application development», 2016, [En línea]. Disponible en: https://www.diva-portal.org/smash/get/diva2:998793/FULLTEXT02.pdf

[10] M. Prajapati, D. Phadake, y A. Poddar, «STUDY ON XAMARIN CROSS-PLATFORM FRAMEWORK», vol. 4, n.o 4, 2016, [En línea]. Disponible en: https://www.ijtra.com/view/study-on-xamarin-cross- platform-framework-.pdf

[11] C. Griffith, Mobile App Development with Ionic, Revised Edition: Cross-Platform Apps with Ionic, Angular, and Cordova. O'Reilly Media, Inc., 2017. [En línea]. Disponible en: https://books.google.es/books?hl=es&lr=&id=x9MxDwAAQBAJ&oi=fnd&pg=PR2&dq=framework++IONIC+de+Max+Lynch&ots=9onKb0f y8r&sig=_cn8jQ6msTILGKsGADMFIh2_imw#v=onepage&q=framework%20%20IONIC%20de%20Max%20Lynch&f=false

[12] K. A. Lizárraga Osuna, «"Implementación de Flutter para el desarrollo de aplicaciones móviles nativas en iOS y Android"», dic. 2020, [En línea]. Disponible en: http://repositorio.upsin.edu.mx/formatos/A031LIZARRAGAOSUNAKEVINANTONIO6608.pdf

[13] C. Abades Ruiz, «Desarrollo de una aplicación iOS de comunicación de aplicaciones de salud con gIUCModel», Universidad Complutense de Madrid, 2018. Accedido: 14 de diciembre de 2022. [En línea]. Disponible en: https://eprints.ucm.es/id/eprint/50235/1/090.pdf

[14] C. Herrera, «Desarrollo de aplicaciones móviles con Ionic», may 2016, [En línea]. Disponible en: https://www.researchgate.net/publication/302999876_Desarrollo_de_aplicaciones_moviles_con_Ionic

[15] Mg. L. R. Quisaguano Collaguazo, Mg. M. S. Pallasco Venegas, A. A. Andaluz Guerrero, M. N. Martínez Freire, y Mg. S. H. Corrales Beltrán, «DESARROLLO HÍBRIDO CON FLUTTER», Ciencia Latina, vol. 6, n.o 4, pp. 4594-4609, sep. 2022, doi: 10.37811/cl_rcm.v6i4.2959.

[16] «Flutter». https://flutter-es.io/ (accedido 15 de diciembre de 2022).

[17] «React Native». https://reactnative.dev/ (accedido 15 de diciembre de 2022).

[18] «Ionic». https://ionic.io/ (accedido 15 de diciembre de 2022).

[19] «Xamarin», Microsoft. https://dotnet.microsoft.com/en-us/apps/xamarin (accedido 15 de diciembre de 2022).