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Towards PWA in Healthcare

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Abstract

Nowadays there is a very large number of mobile applications that use the network to offer some functionality to users and because of this, applications are limited by the network conditions, such as network latency. These mobile applications usually are developed in a traditional approach, designated as a native approach and its goal is to develop the application to a specific operating system (iOS, Android). Applications used in a working environment are known to improve its process, but the network has the potential to decrease application performance and traditional mobile development is inefficient. Healthcare is a field with huge opportunities for application development because applications have the potential to improve work efficiency and quality of patient care. This paper consists of introducing the Progressive Web Application mobile development approach in the healthcare industry as an m-Health solution. It highlights successful cases of such an approach and key features, that allow establishing a reliable and resilient mobile application, that deals with most challenges involving the network nowadays and is a valid opportunity in the healthcare business. This document also presents a mobile health application for dietary evaluation, compares the PWA approach and other traditional approaches with a SWOT Analysis, PWA success cases, the INTCare system (an intelligent decision support system available in the Centro Hospitalar do Porto) and the opportunity to use Progressive Web App in the INTCare's Electronic Nursing Record (ENR), which is a web interface that represents clinical patient information, integrated in a new proposed INTCare system architecture design.

Keywords: "Progressive Web App ; Intensive Care ; ENR ; INTCare ; m-Health"

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1. Introduction

Intensive care is aimed to treat critic patient conditions, such as organ failure, through continuous monitorization and treatment. These healthcare services are practiced in an intensive care unit (ICU). Since there is a lot of data available in the scope of an ICU [1], it emerges an opportunity to use the data to develop applications that can help ICU professionals to make important decisions, which can improve not only the quality of patient treatment but also the work efficiency [2]. Nowadays there is a vast number of diverse devices, which are used to access mobile sites and apps [3].Not only that, but most applications running on mobile devices often use the network to support some of the functionalities, so the performance of these applications are influenced by the network conditions in which the mobile devices are accessing the web, for instance, the transmission medium, such as bandwidth, reliability, and stability of the connection [4]. One of the issues that these network factors imply is that there are mobile applications that are developed to support business processes and are used by professionals, so these network conditions, being part of the user experience, becomes a business risk. To establish a reliable experience and service that performs independently from the network conditions to users, there is a multiplatform web application development approach that provides the developers the ability to build faster, more resilient, and more engaging web applications. This approach is defined as Progressive Web App [5]. This paper's main goal is to achieve the confidence of the readers to accept the Progressive Web App as a feasible and reliable solution in the healthcare industry, particularly, in the Intensive care scope. To achieve this goal, some objectives were defined, such as the exhibition of the PWA capabilities towards dealing with challenges that most applications based on other approaches are failing to handle nowadays and the definition of a healthcare system's architecture improvement featuring a PWA application. The accomplishment of these objectives led to the following contributions: Analysis of different mobile development approaches; INTCare's redesigned system architecture, featuring a PWA application.

This document is composed of: a Background section that includes the explanation of the technology behind Progressive Web Apps, mentions some successful cases of the PWA implementation, presents two Intensive care software solutions that have the opportunity to implement a PWA and presents a mobile health (m-Health) solution for dietary evaluation; a SWOT Analysis section that compares the PWA approach to other traditional development approaches; and a suggestion of a new INTCare System architecture that implements a PWA. Conclusion and future work are the last content of the document.

2. Background

2.1. Progressive Web Application

As mentioned before, Progressive Web App is multiplatform web application development approach, which means the application is intended to function on most mobile and desktop platforms available (Android, iOS, Windows, etc.) and this is possible because the application is accessible via browser and a browser is available on most operating systems [6]. The application can function independently of the network conditions because of three key components: the service worker, the cache API, and the BackgroundSync API [4]. **Service Worker** is a JavaScript file that is executed in a different thread than the browser and is able to intercept network requests [5],by listening to events such as the fetch event (which is triggered when resources are being consumed through the HTTP protocol) and handling them appropriately. **Cache API** is an application programming interface that enables the storage and retrieval of content. It functions in conjunction with Service Workers to enable these to cache network requests so that they can provide appropriate responses while offline. Web Applications often run in environments with unreliable networks, and sometimes, when a client is trying to post data to a server, it fails. **BackgroundSync API** enables the application to synchronize with the server when the network conditions allow it [4]. It also functions in conjunction with Service Workers. A service worker can listen to the sync event (which is triggered when the browser “believes” that the user has connectivity) and store the data that is meant to be posted to the server (usually it is used *indexedDB* as client-side storage). When the event is triggered, the service worker can handle the event by synchronizing with the server, i.e. it sends the data stored on the client to the server. Another key component of the progressive web app is the **manifest file**. This file provides information about the application (such as its name, author, icons, and description) and allows installing the application through a web install banner [5].

A Progressive Web App can implement an **Application shell** Architecture approach [5], which consists of the minimum amount of HTML, CSS and JavaScript code necessary to load the core user interface. The service worker can cache the files of the app shell when the user first visits the application. On later visits, the user interface will load instantly from the cache and the dynamic content will later be loaded on that user interface.

2.2. Existing PWA Solutions

OLA Cabs is an Indian company that provides transportation services through cabs. To support their business, OLA Cabs had developed two native applications, one for iOS and another for Android (a native application is intended to function only on a specific operating system, unlike a multiplatform one). This way, a customer can rent cab services with a mobile app [7]. OLA Cabs identified some challenges and opportunities to improve their business, such as to support consistent experience to users using the application in regions with intermittent cellular connectivity and to support users that have low-end smartphones with low memory and slow processors. To achieve business improvement, OLA Cabs developed a PWA capable of dealing with the challenges mentioned before [6]. After the release of the application, OLA Cabs found out that mobile traffic had increased by 68% on cities with weak network conditions and smartphones capabilities. They also measured the time needed to load the pages on the app and, with the cache feature, they concluded that the first visit on a page takes about 3.4 seconds and later visits are less than 1 second. **Twitter** is a social networking service accessible through its website interface where users can post and interact with messages known as tweets. Twitter has many users accessing it via mobile (about 80%) and to increase the mobile experience Twitter released, in April 2017, the Twitter Lite PWA [6]. The application was successful and the "Add to Home Screen" PWA feature improved the user engagement with Twitter because, since its release, 250.000 unique daily users were launching Twitter Lite from the home screen 4 times a day on average.

Before the release of the PWA Twitter app, other native applications available only to specific operating systems were available. Twitter compared the data consumption between the native apps and the PWA one and they concluded that data consumption on the PWA application is more efficient since it's only 600KB compared to the 23.5MB needed to install a native Android app. To guarantee consistent experience when network conditions are weak, Twitter Lite adopted the Application Shell Architecture [6] where the caching of the user interface resulted in a load of 3 seconds when a user returns to the PWA, even on slow mobile devices or networks.

2.3. Healthcare Software solutions

Intensive care is an important field in the healthcare scope and opportunities to improve the quality of care and workflow efficiency arise when reports highlights that at least 44000 patients die in hospitals, which could be avoided if medical errors (often calligraphy related errors) were reduced [8]. To deal with this problem currently, there are a good number of software solutions that present and allows the registration of clinical information. In this section, we introduce the INTCare System and the AdvancedMD EHR Software.

The **INTCare system** is an intelligent decision support system (IDSS) currently available in the Intensive Care Unit (ICU) of Centro Hospitalar do Porto (CHP) [9]. This system supports the decision making of ICU professionals [10] by detecting action demanding conditions that emerge through the continuous automatic scanning of relevant data, such as vital signs and laboratory results from exams [11]. The system's architecture uses intelligent agents integrated into a Multi-agent system (MAS) to automate the extraction, processing, and treatment of data available on sources, such as Bedside monitors, ventilators, ENR and Laboratory results. The system also automates data mining tasks, such as ETL (Extract, Load and Transform), storing the integrated data on a Data Warehouse and applying the relevant data mining model to predict the next day failure of six systems (liver, respiratory, cardiovascular, coagulation, central nervous and renal).

The INTCare system has a web-based interface, the Electronic Nursing Record (ENR). Doctors and other ICU professionals can use this interface to interact with the system, they can request prognostics and evaluate scenarios [12],visualize laboratory results and vital signs on appropriate charts [13] and tables and they can register, validate and consult clinical data.

AdvancedMD EHR Software is another healthcare solution, it is a Software Suite, composed by a multiplatform web application and an iOS native application. Its goal is to help healthcare providers manage patient medical records

and automate clinical workflows. The AdvancedMD EHR Software has a dashboard dedicated to the management of tasks in a workflow, this dashboard highlights critical tasks and urgent issues that help physicians avoid critical oversights. The Software also has a Health Care Analytics module which is composed of analytics tools used to evaluate clinical outcomes and evaluate the efficacy of healthcare processes. Another characteristic of this software is rooming functionality, which allows patient location tracking and admission status, which can reduce waiting time to fasten patient treatment. One of the key features of this software is, it allows the users to generate charts based on clinical information of the patients such as vital signs and laboratory results.

2.4. m-Health for dietary evaluation

Advances in mobile technology (mobile devices,3G and 4G networks) led to the appearance of Mobile health (m-Health) systems [14], such as healthcare monitoring and alerting systems, detection and prevention systems. These systems provide improvements in the pervasive interactions between doctors and patients, i.e. it allows the physician and patient to access clinical information anytime and anywhere, surpassing geographical and temporal barriers.

An unbalanced diet can cause obesity and cancer, these issues are very frequent in recent society. SapoFitness [15] is an m-health application for dietary evaluation. It presents features that alert and motivates the user to keep not only a balanced and healthy diet plan but also a systematic physical activity. SapoFitness requires several daily user inputs such as food, weight, and exercise. To establish the motivation for the user, the application uses social networks (Facebook, Twitter, mySpace, etc.) to share the user's successful milestones regarding health improvements in the user's diet plan progress.

3. SWOT Analysis

In this section, to clarify the disadvantages and advantages of a Progressive Web App, it is presented a comparison between the PWA and other traditional mobile development approaches, based on the research of some of the most applied mobile development approaches. Traditional development approaches are the native approach and cross-platform approaches, such as, PhoneGap and Xamarin. The native mobile application development approach consists of using a specific Software Development Kit (SDK) that is bound to an operating system. For instance, Android apps often require the java programming language and Android frameworks while iOS apps require Objective-C and Apple's frameworks [16]

Cross-platform mobile applications are based on web technologies such as HTML, JavaScript, and CSS and use the browser as their runtime environment and since the browser is available on most devices and operating systems, the cross-platform approach is therefore multiplatform. PhoneGap and Xamarim are examples of a cross-platform approach. Table 1 presents the support of important mobile features between the different development approaches.

Table 1. Comparison between mobile apps

Features	Native Approach	Cross-platform	PWA
Offline support	-	-	√
Background synchronization	-	-	√
Support for native features	√	-	√
Multi-platform	-	√	√
Discoverable	√	√	√

A SWOT Analysis is a technique to help an entity such as an organization or a product in the identification of its strengths, weaknesses, opportunities, and threats related to business competitors [17]. In this analysis, Strengths are characteristics of the PWA that establish an advantage over competitors and Weaknesses give it and disadvantage. Opportunities are elements in the environment of the PWA that can be used to gain advantage and Threats are elements in the environment that represent a risk to the PWA. In this analysis, the “competitors” of the Progressive Web App are the other development approaches, such as native web application and multiplatform.

Table 2. SWOT Analysis comparing the PWA and other development approaches.

Strengths	Weaknesses	Opportunities	Threats
Guarantees functionality of the application, without depending on the network conditions; Decreases the network traffic; Requires less space of installation;	Weak confidence level regarding the add to home screen feature. The user may not feel secure when asked of adding the app to the home screen, because of the existence of suspicious and malicious web sites, native features such as camera and GPS becomes a vulnerability;	Efficient development of the application, since it avoids the waste of time and resources spent on the development of a native app;	Restrictive functionality on the Safari iOS browser;

It can be concluded that the PWA approach while it's not completely compatible with the Safari iOS browser and can't guarantee the confidence for the user, still is a powerful approach that can guarantee benefits not only to the user experience and application performance but also to the development team efficiency.

4. New System design

In this section, it is proposed an architecture system improvement for the INTCare System mentioned in section 2. This architecture is organized into three different layers, the Data Sources layer, the Middleware layer, and the Application layer. The Data Sources layer is the same as the Data Acquisition illustrated, in the Healthcare Software solutions section. The middleware layer implements a programming abstraction and masks the heterogeneity of the underlying programming languages, hardware, and operating systems [18]. In Fig 1. a REST API (Representational State Transfer Application programming interface) lies between the Data Sources (Lab results, Bedside monitors, ENR, EHR and drug system, all of these in different hardware) and the applications (PWA and other applications that can be written in different programming languages).This API is based on CRUD operations, which are the basic operations applied on databases, these include Create, Read, Update and Delete database's observations. This API carries the task of receiving CRUD operations and translates the structured data available on the database into an external formatted data appropriate for transmission, in this case, the JavaScript Object Notation (JSON) format. By being based on CRUD and JSON, it allows different applications (application layer), written in different programming languages, to use the necessary services to establish their functionalities.

The application layer is composed of applications that use the REST API. Based on the SWOT Analysis, it is featured the PWA application in the design, alongside its key components, the Cache API and the Service Workers to add offline functionality not provided in the previous architecture design.

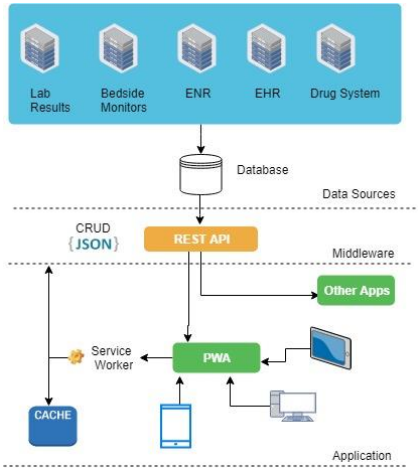

Fig. 1. New INTCare system design

5. Conclusion and Future Work

The SWOT Analysis revealed that despite the lack of functionality between the PWA and the Safari browser and the weak confidence level that may arise from the users, the PWA mobile development approach is more efficient and its features have the potential to establish an engageable and adaptable application in comparison with the other development approaches. The Twitter and OLA Cabs cases mentioned in this document are both successful examples of organizations that have implemented a Progressive Web App capable of enabling an engageable experience and dealing with network connection issues that other approaches couldn't. The improvements were impactful in a positive way both for users using the applications and the respective business.

The proposed architecture in section 4 seems like it can be a good improvement to the INTCare system, because the middleware layer implements a standard interface, the REST API, to the data sources, it enables the developers to efficiently expand the system with other applications without worrying with the heterogeneity from the hardware (devices and data sources). The INTCare's ENR has the necessary features to improve the quality of health care, by reducing medical errors and fastening clinical interventions, but while both INTCare's ENR and AdvancedMD EHR Software offer healthcare improvement opportunities, they cannot function in a consist way when network conditions are weak and they don't have the best tools to engage users. These key features can be unlocked by the PWA mobile development approach, and it doesn't exist yet a PWA Intensive care solution nor an EHR one. Solutions about healthcare are only m-Health based on traditional approaches like the one presented in this document (section 2.3).

Proceeding to future work, we are working on the implementation of the new architecture mentioned in this document, including the development of its Progressive Web App and REST API. In addition to the development of the PWA, we also will apply both visual and functional optimization of the current ENR.

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