



## Progressive Web App: An Adventure into Faster Web Experiences

*Simanshi<sup>1</sup>, Sankalp Pandey<sup>2</sup>, Shweta Sinha<sup>3</sup>*

<sup>\*1,2</sup>Student, Scholar, Department of Computer Science, National Post Graduate College Lucknow, India

<sup>\*3</sup>Assistant professor, Department of Computer Science, National Post Graduate College Lucknow, India [sinha.shweta020776@gmail.com](mailto:sinha.shweta020776@gmail.com)

### ABSTRACT :

Progressive Web Apps, enhance interaction of user by providing offline functionality, push notifications, and swift loading times. In contrast to traditional web applications, PWAs do not necessitate downloading from an app store. Users can access them directly via their web browsers and even pin them to their device home screens. This integration of web convenience with app-like features makes PWAs superior, offering speed, reliability, and accessibility to all internet users. This paper addresses the challenges faced by PWA developers, such as browser compatibility and security concerns, offering insights into creative solutions and the tools used to overcome these obstacles. Real-world case studies provide concrete examples of PWAs making a positive impact across various industries, showcasing improvements in user engagement, speed, and reliability. This paper glimpses into the promising future of PWAs, envisioning more intelligent and personalized experiences, integration with augmented reality, and seamless integration beyond traditional browsers.

Keywords : PWA , web development , native apps , responsive design , speed optimization , web apps

### INTRODUCTION :

PWAs use nifty technologies to let users use apps offline and load them faster. The goal is to unravel the secrets behind PWAs and show how they're not just keeping up but actually reshaping how we experience the web. As we dive into the details of PWAs, we'll discover how they tackle challenges and make web applications work seamlessly. From behind-the-scenes tech like service workers to smart strategies that make things load in a blink, PWAs are making waves.

We'll explore real-life stories of successful PWAs, learn from them, and gaze into the crystal ball to see where PWAs might take us in the future.

### *Background:*

Let's rewind a bit and get the backstory on why Progressive Web Apps (PWAs) became a thing. Traditional web applications had their struggles, especially when it came to giving users a smooth ride. Picture this: you're on your phone, trying to use a web app, and it's just not as snappy as you'd like – that frustration led to the birth of PWAs. As more people started using their phones for everything, from shopping to socializing, the shortcomings of regular web apps became apparent. They couldn't keep up with the expectations users had, especially when compared to the slick performance of native mobile apps. So, enter PWAs, the superheroes of web development.

The story gets interesting with the rise of technologies like service workers. These tech wonders act as middlemen, making it possible for web apps to do cool things like working offline. This was a game-changer because suddenly, your favourite web app didn't ghost you when you had a spotty internet connection. Responsive design, which makes websites look good on any device, also played a part in setting the stage for PWAs. The goal here is to give users the best experience possible, combining the accessibility of regular web apps with the snappiness of those fancy mobile apps.

In our journey through the background of PWAs, we'll uncover what makes them tick, how they've evolved, and what makes them stand out from the web apps we've known. It's a tale of tech evolution driven by the quest for better, faster, and more user-friendly web experiences.

### How PWAs Elevate User Happiness?

PWAs are like the superheroes of the web world, ensuring we can access our favourite content even without a constant internet connection.

1. No More Internet Woes with Service Workers - PWAs have a cool trick up their sleeves – service workers. These behind-the-scenes heroes make sure you can still check your stuff, like news or to-dos, even when your internet is playing hide-and-seek.
2. Say Goodbye to Loading Screens - Waiting for a website to load is so last season. PWAs are all about speed – they load in a snap, giving you a smooth and instant experience. They stash away important stuff using fancy tech called caching, making sure you don't waste time waiting. It's like turning the web into a page-turner book – quick and satisfying.
3. Fits Any Screen Like a Charm- PWAs are the chameleons of the web world. No matter if you're on a big computer screen or a tiny phone, the app looks and works great. No need for different versions for different gadgets. PWAs are the one-size-fits-all solution, letting you switch between devices without any hassle.

4. **Easy Navigation, More Fun-** Moving around in a PWA is a breeze. It feels just like using a regular app, making the whole experience super smooth. Push notifications keep you in the loop, even if the app isn't open. It's like a friendly nudge, bringing you back for more fun. In a nutshell, PWAs are changing the game by fixing common annoyances, giving you quick access, and making sure your experience is awesome, no matter what device you're using.

### **Foundational Concepts of PWAs: A Unique Framework [2]**

In establishing the groundwork for Progressive Web Apps (PWAs), a set of ten concepts officially guides their development. While some concepts align with conventional web development practices, others introduce innovative enhancements specifically designed for the mobile web.

- **Progressive Enhancement: Tailoring Experiences to Devices**  
The term "Progressive" within PWAs is intricately linked to the concept of Progressive Enhancement. This philosophy revolves around the idea that a product, such as a website, can progressively improve and advance based on the user's browser and device characteristics. This approach prioritizes content over browser capabilities, ensuring that users with devices featuring weaker hardware can still access and enjoy the website [3].
- **Responsive Design: Optimal Engagement Across Form Factors**  
At the core of mobile-compliant web design is the concept of responsive design. This approach ensures an optimal user experience across different form factors, encompassing elements such as font sizing, image placement, and grid stacking [4]. While not exclusive to PWAs, responsive design is fundamental for delivering a positive user experience on mobile devices.
- **Installable PWAs: Bridging Traditional Mobile Apps and Web Apps**  
PWAs possess the unique capability of being "Installable." Users can download and install them directly from their internet browser, marking a departure from the traditional app installation methods via constrained app stores. PWAs can be seamlessly installed through PWA-compliant browsers like Chrome or Samsung Internet, unifying the realms of traditional mobile apps and web apps.
- **Connectivity Independence: Paving the Way for Offline Functionality**  
The concept of "Connectivity Independence" sets PWAs apart from regular web apps. While conventional websites require an active internet connection, PWAs can adeptly manage offline contexts. Leveraging technologies such as Service Workers, local data, and asset caches, PWAs ensure a smooth user experience even when an internet connection is unavailable [5].
- **App-Like Experience: Blurring the Lines Between Web and Native Apps**  
PWAs are designed to offer an "App-Like" experience, closely resembling the look, feel, and functionality of regular native or cross-platform apps. Aligning with Google's vision for the mobile web, PWAs aim to be competitive with native apps, positioning the web as an integral part of the operating system.
- **Fresh Content Delivery: Ensuring Currency On and Offline**  
Through the use of Service Workers, PWAs can fetch new content from associated web services, ensuring that the app remains both available offline with potentially cached content and online with updated content for immediate consumption and caching.
- **Security: HTTPS for User Safety**  
To ensure optimal end-user security, PWAs must be served via HTTPS, as discussed in the underlying technologies section [5].
- **Discoverability: Indexing PWAs for Web Visibility**  
PWAs are inherently "Discoverable," allowing search engines to index their content. Despite their additional capabilities, PWAs retain their status as regular websites in this regard.  
**Re-Engagement with Push Notifications: Enhancing User Interaction**  
The introduction of the new Web Push API enables PWAs to be "Re-engageable." This allows them to deliver a re-engaging experience similar to regular apps by leveraging push notifications to draw users back into the app
- **Linkability: Standard Characteristics for Accessibility**  
Being "Linkable" is a fundamental characteristic for any accessible website, PWA, or otherwise. PWAs adhere to this standard, facilitating easy sharing of content through URLs. Additionally, PWAs can register intents on Android Chrome.

### **Comparison of PWA and Native Apps**

According to the research, there is a significant contrast in user reach between the mobile web and native apps. The mobile web records a substantial 11.4 million unique visitors monthly, surpassing the 4 million visitors accessing native apps. However, when it comes to user engagement, a distinct pattern emerges. Native mobile apps outshine standard web apps, with users spending an average of 188.6 minutes compared to a mere 9.3 minutes on the web.

This discovery led to a strategic decision—to address the gap between reach and engagement by delivering a native app-like experience on the mobile web. Hence, the development of Progressive Web Apps (PWAs) was initiated, aiming to provide users with an exceptional web-based experience.

To explore these nuances further and better understand the distinctions and advantages, let's undertake a thorough comparison of Native Apps, PWAs, and Standard Web Apps across various essential parameters.[1]

**Table1 : Comparison of PWA and Native apps[6]**

**PARAMETER**

**PWA**

**NATIVE APPS**

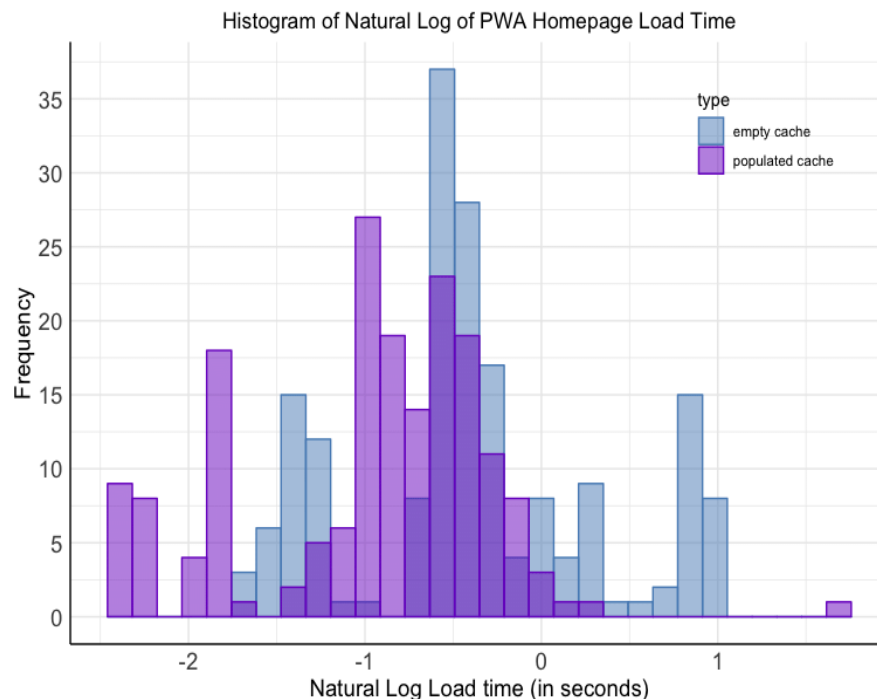
<b>ACCESSIBILITY</b>	Accessed via URL on browser	Accessed via an App Store
<b>CROSS PLATFORM FUNCTIONALITY</b>	Designed and developed for being compatible across multiple platforms	Not compatible with different platforms
<b>OFFLINE USABILITY</b>	Available to certain sections	Complete offline usability
<b>PERFORMANCE</b>	Instant page loading	Faster computational time
<b>BACKGROUND DATA SYNCHRONIZATION</b>	Yes, supported	Not supported
<b>DEVELOPMENT COST</b>	Less	More
<b>SECURITY</b>	Highly secure via https	Highly secure using multi factor authentication

**Turbocharging Speed: How PWAs Make Your Apps Lightning Fast:**

Prepare to have your mind blown – Progressive Web Apps (PWAs) aren't just user-friendly, they're also speed demons, transforming your web experience from sluggish to lightning-fast. Remember the frustration of waiting eons for apps to load? Forget about it! PWAs go toe-to-toe with native apps, delivering a level of responsiveness that rivals anything you'd find in the app store.

Their secret weapon? Caching. Think of it as having a personal assistant who preps everything you need beforehand, ensuring instant access to content. Whether you're catching up on news or checking social media, PWAs bring it to you in a blink, eliminating those agonizing wait times. But speed isn't their only superpower. PWAs are resource ninjas, employing clever techniques to avoid draining your device's memory. This translates to smooth, lag-free performance, even with multiple PWAs installed. Say goodbye to choppy transitions and hello to a consistently snappy experience. The real-world impact is undeniable. Companies are leveraging PWAs to supercharge their app performance and keep users smiling. From faster loading times to seamless interactions, PWAs are the unsung heroes, ensuring you get what you need, instantly and without a hitch. So, buckle up for a new era of web browsing – one powered by the speed-boosting magic of PWAs. They're not just changing how you use the web; they're changing how fast you can do it.

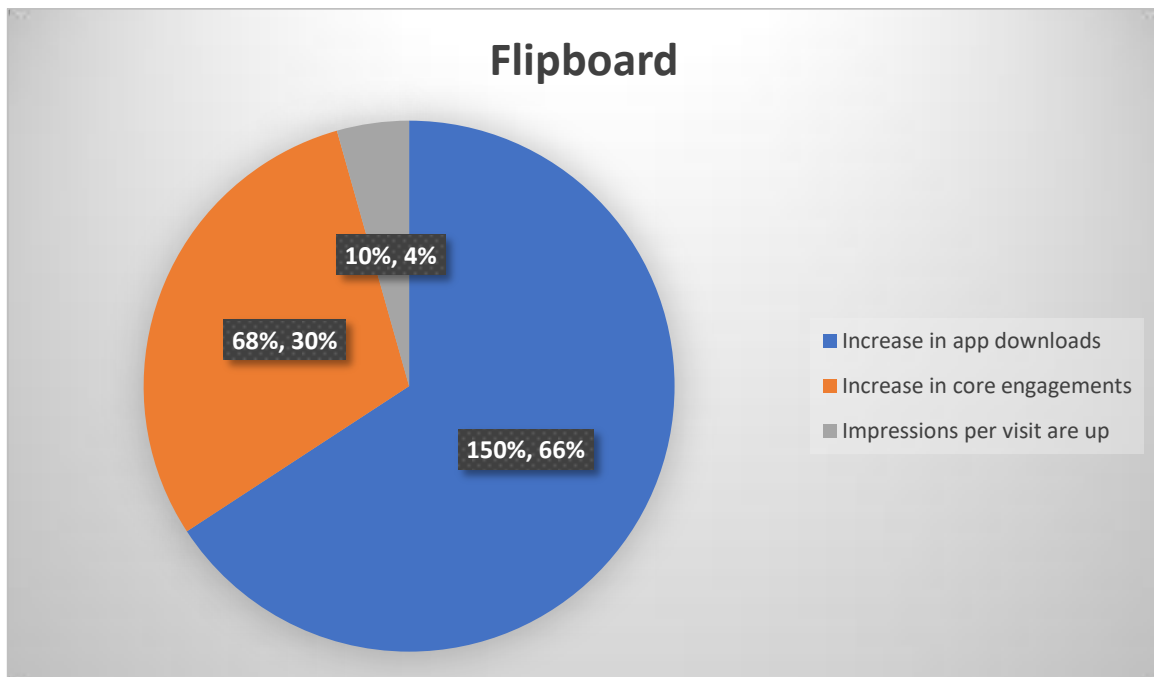
Below figure illustrates the log transformation of the PWA page load times. It can be observed that the skewness is much lower in the histogram of the log-transformed data. However, the Q-Q plot still tends to show not normally distributed data and after applying again the Shapiro-Wilk test, we obtain a p-value  $1.404e - 07 < \alpha$ , making us reasonably confident that the data collected for the page load times of our PWAs does not follow a normal distribution.[8]



**Fig. 1- Histogram of Natural Log of PWA Homepage Load Time [8]****Stories that Show PWAs in Action:**

Now, let's dive into real-life tales of how Progressive Web Apps (PWAs) are making waves, proving that they're not just tech jargon but real game-changers.

1. Starbucks - PWA allows customers to browse the menu, customize orders, and add items to their carts offline. Significant results include a 99.84% size reduction compared to the iOS app, doubling daily web orders, and improved user favoritism.
2. Debenhams - Transformed its website into a PWA, resulting in a 40% increase in mobile revenue and a 20% boost in conversions.
3. BMW - The new BMW PWA boasts high-resolution images, 4X faster loading times, a 4X increase in clicks to sales sites, and 50% growth in mobile users.
4. Flipboard - As a popular social magazine, Flipboard's PWA minimizes data usage, delivering a slick and fast browsing experience for news enthusiasts.

**Fig. 2- showing effect of PWA on flipboard[9]**

5. Soundslice - Revolutionizing music education, Soundslice's PWA facilitates efficient learning with an innovative music player, accessible on any device.
6. 2048 Game - The addictive puzzle game's PWA, playable in offline mode, mirrors the native app experience with smooth transitions and a full-screen view.
7. MakeMyTrip - MakeMyTrip's PWA triples conversion rates, reduces page-load times by 38%, and drives a 160% increase in user sessions.
8. Uber - Uber's PWA provides a native app-like experience on low-speed networks, loading within 3 seconds on 2G networks.
9. Pinterest - Pinterest's PWA, designed for international growth, results in a 40% increase in time spent, 44% growth in user-generated ad revenue, and a 60% rise in core engagements.
10. Spotify- Spotify's PWA, developed amid disagreements with Apple, offers a faster experience with a unique adaptive UI, prompting users to add it to their home screens.

These case studies paint a vivid picture of how PWAs are making a tangible difference in various industries. From social media giants to e-commerce leaders and beloved coffee shops, PWAs are proving to be the secret ingredient for delivering fast, reliable, and engaging user experiences. It's not just theory; these stories demonstrate the real impact of PWAs on the everyday digital lives of users.

**Balancing Act: Obstacles and Prospects for PWAs**

Progressive Web Apps (PWAs) have emerged as exciting contenders in the digital realm, offering a fusion of web app accessibility and the smooth, feature-rich experience native apps provide. Yet, this innovative technology must navigate a complex landscape, juggling both hurdles and opportunities.

One challenge lies in ensuring uniform compatibility across browsers and devices. Despite increasing support from major browsers, discrepancies between versions and devices can pose unexpected obstacles. This can disrupt the seamless user experience PWAs aim to deliver and potentially hinder wider adoption.

Additionally, PWAs face stiff competition from entrenched native apps found in app stores. Users accustomed to app store conveniences may not readily change their habits, necessitating PWAs to devise innovative strategies to differentiate themselves and offer comparable value.

Another obstacle is the limitation of offline functionality. While PWAs boast enhanced offline capabilities compared to traditional web apps, the extent of usable features relies on the app's design and pre-cached data. Complex interactions or features may remain inaccessible offline, impeding the complete user experience.

Monetization strategies also present a challenge. Striking the right balance between revenue generation and user experience is critical for PWAs' long-term success. Intrusive monetization tactics could alienate users, while overly restrictive models may hinder financial sustainability. Expertise in development and maintenance poses another hurdle. Creating and sustaining high-performance PWAs demands specific technical knowledge, which may not be readily available within all organizations. This could erect a barrier to entry for smaller entities or those lacking resources to invest in specialized talent. Finally, data privacy and security concerns require careful attention. With features like offline storage and potential access to device functionalities, safeguarding user data privacy and security is paramount. Developers must implement robust security measures, employ transparent data practices, and cultivate trust with users to address these concerns.

However, despite these challenges, PWAs offer a plethora of opportunities. Their accessibility via web browsers provides a broader reach compared to native apps, potentially enhancing user engagement and fostering larger communities. Moreover, development and distribution costs are often significantly lower compared to native apps, making them an appealing option for organizations and individuals with limited resources.

Performance and speed are significant strengths. PWAs leverage caching and service workers to deliver swift loading times and seamless performance, even on low-bandwidth connections. This results in a superior user experience, increasing the likelihood of user retention. The partial offline functionality also unlocks valuable opportunities. Users can access and interact with content even without internet connectivity, making PWAs particularly advantageous in regions with unreliable internet access or situations where online connection is intermittent.

Furthermore, the ongoing evolution of web technologies like Web Assembly and Service Workers heralds even more potent and versatile PWAs in the future. These advancements will further unleash the potential of PWAs and broaden their capabilities. Looking ahead, PWAs have the potential to seamlessly integrate with emerging technologies like AR/VR. This presents exciting possibilities for creating immersive and captivating user experiences across various industries, blurring the boundaries between the physical and digital realms. By acknowledging both the challenges and opportunities ahead, developers and organizations can strategically harness the power of PWAs. By ensuring compatibility, devising innovative monetization models, prioritizing user privacy, and staying abreast of technological advancements, PWAs can continue to evolve and establish themselves as transformative forces in the digital landscape.

### ***The Exciting Future of Web Magic:***

Progressive Web Apps (PWAs) have already established themselves as game-changers, effortlessly bridging the gap between web and native app experiences. But as we peer into the future, the potential of PWAs explodes, promising to rewrite the script and propel us into a truly interconnected and immersive digital realm.

- *PWAs as Portals to the Metaverse:* Imagine a world where physical and digital spaces seamlessly merge, creating the mind-bending Metaverse. Here, PWAs could act as our anchors, offering familiar and accessible web-based experiences that we interact with using AR/VR technology. Picture yourself attending virtual concerts, browsing 3D storefronts, or collaborating in dynamic workspaces – all through PWAs woven into the very fabric of the Metaverse.
- *AI-Powered PWAs: Your Personal Digital Genie:* Artificial intelligence (AI) is set to revolutionize our interactions with PWAs. Imagine PWAs that adapt to your individual preferences and usage patterns, anticipating your needs, curating content, and offering insightful suggestions – all in real-time. Think smart chatbots within PWAs providing personalized customer support and pushing user engagement to new heights.
- *PWAs and Web 3.0: Decentralization Reigns Supreme:* Web 3.0, driven by blockchain technology, envisions a decentralized and user-centric internet. PWAs can become champions of this paradigm shift, operating independently of centralized platforms and empowering users with control over their data and privacy. Imagine PWAs running on decentralized networks, fuelled by cryptocurrencies and enabling peer-to-peer interactions. This opens doors to entirely new possibilities for collaboration, financial transactions, and data ownership within the PWA ecosystem.
- *Beyond Browser Barriers: PWAs Take Centre Stage:* Currently, PWAs reside within the familiar confines of web browsers. But the future whispers of them breaking free, integrating directly into operating systems. Imagine your favourite PWAs readily available as desktop applications, launching seamlessly and functioning independently, offering a native-like experience without browser limitations. This would break down the walls between traditional apps and PWAs, solidifying their position as powerhouses in the digital landscape.
- *Bridging the Digital Divide: PWAs as Agents of Change:* As PWAs evolve and become more sophisticated, they have the potential to become bridges, connecting the unconnected. Their inherent accessibility and offline capabilities could prove invaluable in reaching underserved communities with limited internet access. Imagine educational PWAs offering offline learning resources, healthcare PWAs providing essential information in remote areas, or communication PWAs enabling basic connectivity where traditional infrastructure falters.

These are just a glimpse into the captivating future of PWAs. As technology leaps forward and PWAs adapt, we can expect even more groundbreaking applications to emerge. From collaborating with cutting-edge technologies like AR/VR and AI to thriving in decentralized networks and mending the digital divide, the possibilities are boundless. The future of PWAs isn't just about mimicking the app experience on the web; it's about redefining how we interact with the digital world altogether, unlocking a universe of potential for creativity, accessibility, and user empowerment.

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**Conclusion:**

PWAs are like the cool sidekicks of the internet – they make your online experience smoother, faster, and way more enjoyable. PWAs make sure we can still check our stuff, like articles or to-dos, whether we're online or not. PWAs are all about speed. They load in a snap, like turning the pages of a really good book. Whether you're on a computer or a tiny phone, the app looks great and works like a charm. No more struggling with different versions for different devices. Academic institutions should include teaching about progressive web apps, hybrid web apps, and native web apps. [10] Google Web Fundamentals is a major advocate for progressive web apps and is at the forefront of sharing knowledge about them. In a nutshell, PWAs are changing how we experience the web. They fix the annoying stuff, give us quick access, and make the whole online thing way more fun. So, cheers to the future of web development, where PWAs are the unsung heroes making digital lives awesome.

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