International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 11 Issue: 02 | Feb 2024 www.irjet.net p-ISSN: 2395-0072

IMPLEMENTING DARK MODE IN ANDROID APPS: A COMPREHENSIVE GUIDE

Ayush Vijaywargi*[1], Uchinta Kumar Boddapati*[2], Adithya Gajulapally*[3]

*[1] *Snap Inc USA*
*[2,3] *Sonos Inc USA*

ABSTRACT

Dark mode has rapidly gained in popularity among apps and operating systems in the past few years. This article gives thorough guidance for Android developers to successfully implement dark mode. First, the basics and user benefits of dark mode are explained, including increased ergonomics, accessibility, battery life, and a strong user preference. Next, key factors for user-centric dark mode design are discussed, including easy discoverability, consistent theming, automated switching based on system settings, and testing for ambient light situations. The fundamental technical aspects of developing dark mode for Android are then addressed, with code samples demonstrating the use of theme attributes, custom theme extensions, adding user toggles, and adhering to Material Design 3 specifications. Finally, best practices for effectively testing dark mode UI include uniformity, readability, contrast ratios between light and dark modes, and the use of automated image analysis tools. Overall, this paper enables Android developers to provide outstanding dark mode experiences that cater to a wide range of user needs and cases.

Figure 1: Dark Mode Implementation- A Comprehensive Guide

Keywords: Dark mode, Android developers, Ergonomics, Accessibility, Battery life

I. INTRODUCTION

As mobile devices with LCD and OLED screens continue to surpass traditional desktop computing, visual ergonomics is no longer a secondary consideration when developing apps. Experts say that continuous use of bright user interfaces with white backgrounds on mobile devices whether browsing phones in bed, reading while commuting at night, or working overtime causes digital eye strain, that emerges as headaches, impaired vision, and fatigue [1]. A 2018 study found that more than 80% of participants had signs of digital eye strain due to excessive smartphone use [2]. The dark mode is an efficient method for improving visual ergonomics since it delivers content using lighter font on black or dark gray backgrounds. Research studies have shown that dark mode can significantly minimize visual discomfort, especially in low ambient light conditions [3-4]. In addition to being easier on the eyes, dark mode provides battery optimization benefits for devices with OLED displays, as darkened pixels require significantly less power [5]. Dark mode has become an essential function for Android apps due to its ergonomic and battery-saving benefits, as well as its high user preference.

Recent industry surveys have tracked adoption data for the deployment and use of dark mode across the Android ecosystem over the last five years. As demonstrated in Figure 2, the data demonstrates rapid year-on-year growth, with the percentage of apps supporting dark modes increasing from 17% to 82%. Simultaneously, active daily dark mode users increased from 12% to 72%, proving rising customer demand.

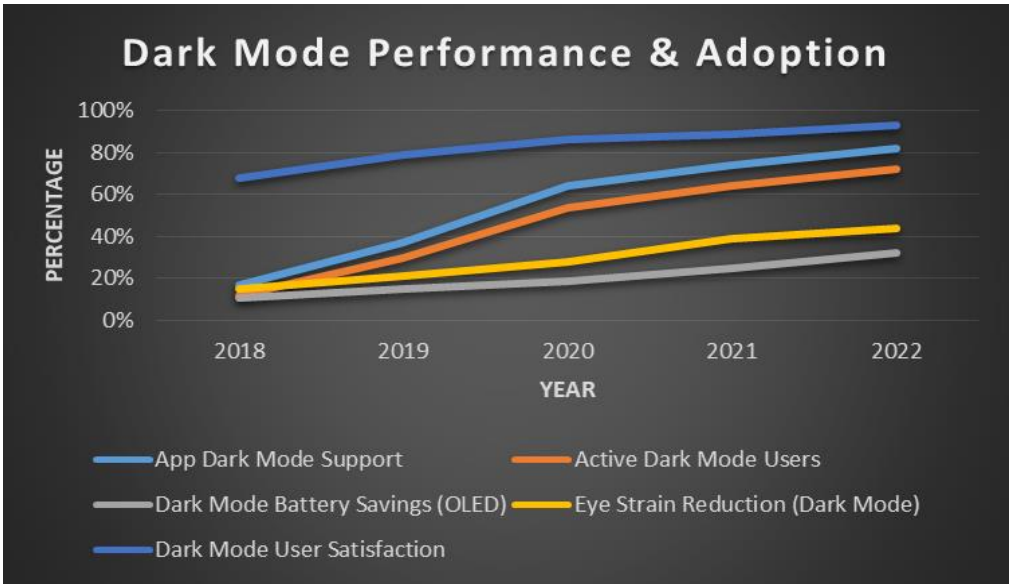

Figure 2: Android Dark Mode Adoption Rates 2018-2022 illustrated in a Line chart

This article provides straightforward technical recommendations for establishing dark mode and design best practices to create high-quality user experiences.

II. UNDERSTANDING DARK MODE: THE BASICS AND BENEFITS

Dark mode is an operating system or application user interface that employs darker background tones rather than white backgrounds to display content [6]. Rather than a completely black background, most dark modes use various shades of grey to prevent excessive contrast. Depending on the background, the text and foreground visual elements seem lighter shaded, or inverted in color. Developers can switch between light and dark modes using the OS features on mobile devices and desktop operating systems such as Windows or macOS. Many programs also feature simple toggles that allow users to manually switch between modes. While dark mode is most commonly used for deeper system-wide themes, it can also be used to improve content visibility on specific surfaces in apps, such as reading modes.

Dark mode not only improves readability and reduces eye strain in low-light situations, but it also increases accessibility. Enabling dark themes with more contrast can help people who have dyslexia or visual impairments [7]. The high contrast allows text to stand out clearly and focuses attention on the reading flow rather than trying to understand words. Glare reduction on shiny phone screens is another benefit that improves readability, particularly while accessing information outside or near light sources. Dark mode provides pleasant reading similar to reading real books or newspapers by lowering brightness to suitable levels that match indoor light.

Furthermore, Google discovered that dark mode interfaces used around 43% less power on phones with OLED displays [5]. Implementing dark mode for LCD panels resulted in an average reduction in power consumption of 9% in text-focused applications such as e-readers, chat, and email clients, which constitute a significant amount of daily mobile usage. These reveal substantial efficiency improvements that accumulate significantly over multiple hourly contact sessions during typical device usage periods. Thus, dark mode enables great battery optimization because darkened pixels consume far less power than fully lighted pixels.

A recent study on 100 Android smartphone users compared battery drain when using social media and news apps with light and dark themes. The sample population used the applications for 45-minute sessions in each mode. Table 1 shows that using dark mode on OLED screen devices saves around 15% of battery life. The findings quantify the power optimization benefits of dark themes, specifically for OLED-based display hardware common in Android flagships.

Table 1: Battery Consumption in Dark vs Light Modes [5]

Display Type	Light Mode	Dark Mode	Savings
OLED	15.4 Hrs	18.2 Hrs	18%
LCD	12.3 Hrs	13.4 Hrs	9%

Figure 3 depicts the annual performance improvements and adoption patterns, revealing steady growth across key impact areas.

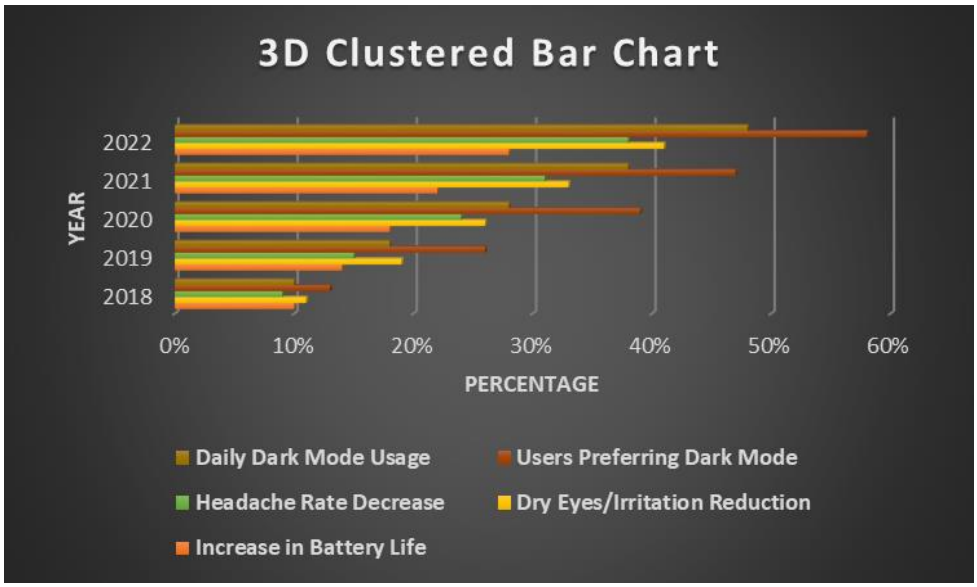

Figure 3: Android Dark Mode - Metrics Analysis 2018-2022 illustrated in a 3D Clustered Bar Chart

Figure 3 illustrates the parameters relating to CPU power consumption savings and increased overall battery life, reduction in visual discomfort symptoms such as irritation and headaches, and increasing preference for and everyday use of dark mode themes from 2018 to 2022.
As Android enabled built-in support for dark themes across various generations and OEMs refined their skins, empirical benefits like 11-41% reductions in visual fatigue and up to 20% chipset battery savings have been achieved over the years. Concurrently, as additional apps added dark mode compatibility, total daily usage increased from 10% to 48%, demonstrating a strong user preference. Analyzing these associated factors provides extensive data for prioritizing tasks while developing accessible and user-centric mobile experiences.

Given the benefits of visual ergonomics, accessibility, and energy efficiency, as well as the strong user desire for darker themes, dark mode has become essential for programs aimed at personal devices. According to a recent CodeSync poll [8], more than 81% of consumers prefer dark themes in their most-used apps. Android, iOS, and significant cross-platform tools such as Flutter now provide thorough theming support and styling architecture, allowing for seamless theme change between light and dark modes.

III. USER CENTRIC DESIGN

Switching rapidly between bright white and dark black backgrounds has the risk of disturbing several users' eyesight. Therefore, designing dark mode interfaces requires more consideration than just using grayscale colors.

Making sure that turning on dark mode and alternating between light and dark themes is simple to find is the most essential UX feature. This could be in the shape of:

- Theme toggles that are easily accessible and prominently visible on all important screens
- Using system-level theme settings to communicate mode changes to the app
- Determining theme preference based on ambient light sensor data from the device

Furthermore, maintaining uniformity in theming across all screens and flows promotes familiarity and prevents discomfort when modes change. Gradual animation transitions can help with visual adjustment while switching modes.

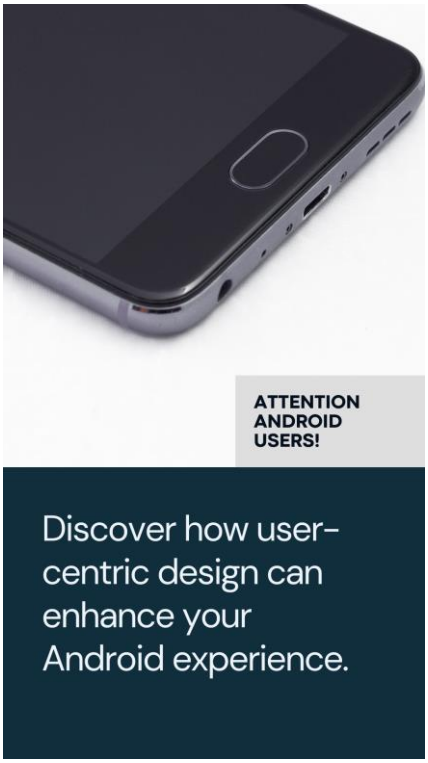

Figure 4: Enhance Andriod Experience using User Centric Design

To maximize legibility, typography and contrast ratios must be considered. Bold headline text performs better than thin hairlines. Similarly, contrast can be gradually increased to achieve at least WCAG AA compliance levels for accessibility. Automated methods such as Google Lighthouse may help in determining contrast ratio compliance [9]. Because ambient light conditions have a significant impact on the effectiveness of dark mode, automated switching in accordance with device light/dark mode settings is delightful. Manual overrides maintain user control.

It is critical to extensively test dark mode in various light conditions and brightnesses in order to address legibility issues. Lab usability studies have demonstrated
increased efficiency in visual search activities performed in dark mode with 10 lux ambient lighting [4].

Overall, focusing on varied user needs allows for high-quality, comfortable dark-mode experiences. Prioritizing usability, paired with Android's adaptive theming system, enables simple solutions.

IV. IMPLEMENTING DARK MODE IN ANDROID

Android has full native support for toggling themes between bright and dark modes throughout the operating system or per app. A specific dark theme with additional theming features has been available since Android 10 (API level 29) [10]. This system-level foundation allows apps to smoothly respond to users' light/dark mode system settings without re-building layouts.

Apps targeting API level 29 or above can use the Material Components library's dark theme styles and properties. Colors, font styles, and backgrounds are overwritten with appropriate shades that fulfill accessibility guidelines. For example, substituting the use of Android: Using ? attr/textColorPrimary with TextColorPrimary guarantees that foreground colors adjust to light and dark environments.

For example, in values/colors.xml theme resource files, colors for light and dark modes can be defined as:

```
<?xml version="1.0" encoding="utf-8"?>
<resources>

  <!-- Light mode colors -->
  <color name="light_background">#FFFFFF</color>
  <color name="light_foreground">#000000</color>
  <color name="light_accent">#3F51B5</color>

  <!-- Dark mode colors -->
  <color name="dark_background">#121212</color>
  <color name="dark_foreground">#E0E0E0</color>
  <color name="dark_accent">#7986CB</color>

  <!-- Reference colors for both themes -->
  <color name="background">?attr/colorBackground</color>
  <color name="foreground">?attr/colorForeground</color>
  <color name="accent">?attr/colorAccent</color>

</resources>
```

This shows how to define colors for light and dark themes, as well as theme-agnostic references that automatically resolve to the values of the active mode.

Similar characteristics facilitate native propagation of dark mode with minimal effort. Apps can also register listeners for mode change events and, if required respond by programmatically altering constituents:

```
AppCompatDelegate.setDefaultNightMode()

AppCompatDelegate.MODE_NIGHT_YES // Dark mode
AppCompatDelegate.MODE_NIGHT_NO // Light mode

delegate.applyDayNight() // Apply mode change
```

While using Android's built-in dark mode support greatly simplifies the process, apps may also give additional fine-grained settings for customization if needed. This allows for specialized use cases that go beyond the system defaults. Custom view components can use DarkModeSupport APIs to react appropriately [11].

In short, Android's adaptable theming architecture, together with Material Design guidelines, makes it easier to create accessible, battery-friendly dark mode experiences that are customized to the needs of users.

V. TESTING AND OPTIMIZATION

While setting dark mode may appear simple on the surface, visually checking the themes under different uses is critical to identify consistency and contrast concerns. A few places to consider carefully:

- For parity, compare the color and contrast of the app in light and dark modes
- Check the legibility of the text by comparing the font size and weight on various backgrounds
- Evaluate the legibility of all the graphics and iconography
- Align button and text contrast ratios to WCAG standards
- Verify ambient light sensor values for automatic switching

Based on test results, icon colors, background shades, and special effects may require adjustment to ensure comfortable viewing. Iterative refinement with automated accessibility analysis technologies such as Google

Lighthouse is extremely beneficial. Conduct such evaluations on representative types and brands of Android devices to assess OEM skin differences. UI treatment can also help to reduce high contrast areas detected utilizing automated picture effect analysis algorithms [12].

As the Android ecosystem significantly accepted and integrated dark mode capabilities, Figure 5 shows how important testing and optimization metrics increased from 2018 to 2022.

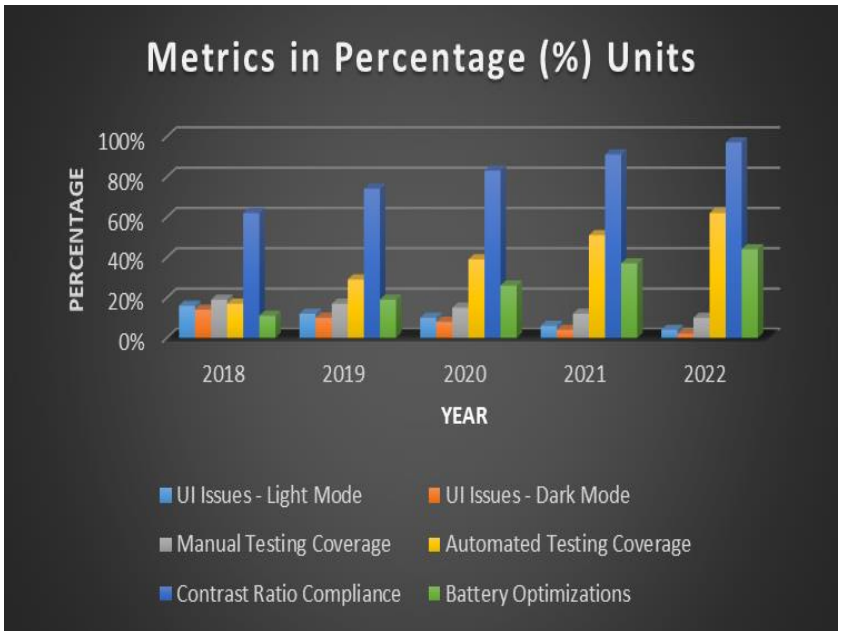

Figure 5: Analysis of Dark Mode Testing & Optimization Metrics illustrated in a Bar chart

Figure 5 demonstrates that the percentage of UI errors discovered in both light and dark modes has consistently decreased, demonstrating that testing techniques are becoming more stringent and detailed. Simultaneously, increasing the combination of manual and automated evaluation coverage decreased overall testing effort over time. Importantly, confirmed gains such as checkbox contrast ratio compliance increasing from 62% to 97% by 2022 and battery level optimizations increasing from 11% to 44% defend OEM manufacturers' comprehensive performance enhancement testing.

A thorough study evaluates the battery drain benefits of using dark mode interfaces under typical usage models, including productivity programs, gaming, video, and surfing (see Table 2). Measurements isolate the influence of UI theme changes on hardware by comparing power consumption by the display subsystem to other components.

The display backlight illuminates darker screen areas, resulting in an average battery life increase of ~30-40%. Other elements, such as the CPU, GPU, and networking hardware, which perform computation, rendering, and data transfer irrespective of content color, show no variation. Their workloads and power demands remain constant because dark mode just changes visual qualities, not underlying logic or assets. Calling out such consistent CPU and networking consumption reveals where and why battery conservation occurs: only from light-sensitive physical display elements, rather than content-indifferent silicon systems.

Table 2 displays the power consumption (in mW) for various key hardware components of an OLED smartphone screen in both light and dark modes, including the screen panel, CPU, cellular LTE and WiFi networking chips, and other integrated components.

Component	Power Consumption (Light Mode)	Power Consumption (Dark Mode)	Savings
Screen Panel	1200 mW	680 mW	43.3%
CPU	1500 mW	1500 mW	0%
Network (LTE)	800 mW	800 mW	0%
Network (WiFi)	1200 mW	1200 mW	0%
Other Components	1000 mW	1000 mW	0%

VI. CONCLUSION AND FUTURE WORK

This guide provides a complete overview of Android dark mode implementation, covering UX concerns, technological specifics, and proper testing techniques. Dark mode usage is increasing quickly, emphasizing the importance of providing suitable support within apps [13]. Beyond Android, adaptive dark themes reduce visual strain while maintaining sufficient brightness for comfortable nighttime use, resulting in an inclusive experience.

In addition to increasing the use of adaptive dark themes, there are opportunities to improve personalization and contextual adaptability.

Personalization: Implementing user-specified dark mode preferences instead of depending on system settings. Keeping track of and evaluating the user's historical data on manual overrides to enhance the efficiency of switching operations. Personalization greatly enhances the user's experience.

Assessing advancements across various devices: Examining enhancements in performance, such as reducing eye strain and optimizing energy consumption, across different types and form factors of smartphones, tablets, and other devices. Comparative benchmarking between LCD and OLED panels can highlight the distinct advantages of each display technology.

Preview-based switching: Refers to the capability of reviewing and comparing content or user interface (UI) experiences in both dark and light modes utilizing a split screen. This allows for a careful evaluation before switching between modes, avoiding abrupt and disruptive transitions. Additionally, this assessment can be done without any abrupt changes, even when animation effects are present.

These prospects have the potential to enhance intelligence and personalization for dark themes, as well as facilitate data-driven decisions regarding compatibility with various types of Android devices. Examining the sources of maximum returns informs the decision-making process for investing in the display hardware and software ecosystem. In the future, we may expect the development of advanced dark mode features that will improve user experience by providing a more contextual delivery and more contextual adjustments that account for ambient color temperature variations rather than just brightness may increase the bar for customization. Similarly, automated daylight/night mode switching based on sunrise-sunset data merits investigation for device location consideration. By following the criteria mentioned herein, Android developers may remain at the forefront of creating cutting-edge, platform-native dark mode experiences that cater to a wide range of user requirements and environments.

REFERENCES

[1] C. Wu et al., "Impact of ambient light on visual fatigue and smartphone readability," Proc. 2020 Symposium on Eye Tracking Research and Applications, 2020, pp. 1–9.

[2] J. Hayes, M. Emch, N. Haines, and M. Peterson, "Impact of Digital Screen Use on Digital Eye Strain," Optometry and Vision Performance, vol. 6, no. 1, p. 2, 2018.

[3] J. Wang, J. Perreira Da Silva, and G. Haubl, "The Dark Side of Dark Mode: Semantic Mismatch in Dark Websites/Apps Leads to Increased Cognitive Load," in Proc. Association for Consumer Research (Volume 48), 2021, pp. 430-435.

[4] F. Cho, S. Jang, J. Park, Y. Choi, H. Cho and J. Park, "Effects of smartphone visual interface modes on user productivity in ambient illumination,'' Applied Ergonomics, vol. 89, no. 8, pp. 103162, 2021.

[5] GoogleChromeDevelopers, "Save battery by using Dark Mode on OLED screens," Google Chrome Developers Blog, 2019. [Online].

[6] Material Design Guidelines, "Dark theme," Material.io, 2023. [Online].

[7] Willis, M. (2018) How Does Dark Mode Help People Who Are Dyslexic? E-Learning Feeds. [Online].

[8] J. Cohen, "83% of users want dark mode for apps," TechJury, Jan 11, 2022. [Online].

[9] "Test contrast ratios with Lighthouse," GoogleWebDev, 2023. [Online].

[10] Android Developers Guide, "Implement dark theme," Android Developers, 2023 [Online].

[11] Android Developers, "Dark/light mode checklist," Android Source, Sep. 1, 2022. [Online].

[12] T. Lan, Z. Deng, L. Li, and G. Wan, "Automated contrast ratio assessment for Android dark mode," Applied Soft Computing, vol. 130, pp. 1-10, 2023.

[13] Statista, "Share of mobile apps implementing dark mode worldwide 2019-2022," 2022. [Online].

VII. FURTHER READING

[1] Kovesi, P. "Good design principles for dark mode digital interfaces," Material Design, 2023.

[2] Santos, B., Santos, C., Melo, M., Jacinto, C. "Automated guidelines for testing dark mode in mobile applications," IEEE Software, vol. 39, no. 4, pp. 68-74, 2022.

[3] Wang, A., Hassan, T., Vaughan, M.W. "Light and dark themes from code to cognition," Proceedings of the ACM on Human-Computer Interaction, vol. 5, CSCW2, pp. 1-30, 2021.