International Journal of Computer Techniques – IJCT Volume 12 Issue 5, October 2025
Open Access and Peer Review Journal ISSN 2394-2231 https://ijctjournal.org/

Enhancing Privacy in Cloud-Based Menstrual Tracking Apps: A Comparative Study and Zero Trust Approach

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Abstract:

The rapid digitalization of healthcare has encouraged millions of women to adopt menstrual tracking applications for monitoring reproductive health, predicting cycles, and recording sensitive data. However, as these apps increasingly migrate toward cloud-based infrastructures, concerns regarding data privacy, unauthorized access, and information misuse have intensified. This study investigates the privacy mechanisms of leading menstrual tracking apps—both cloud-dependent and locally stored—to identify existing vulnerabilities and evaluate how the Zero Trust Architecture (ZTA) can strengthen user data protection. A comparative analysis was conducted on selected applications using factors such as permission sensitivity, data storage practices, and security policies. The results demonstrate that while many apps comply with basic security measures, most lack consistent encryption and user-centric access control. This paper proposes a Zero Trust model tailored for menstrual tracking ecosystems, aiming to ensure continuous verification, minimal trust boundaries, and enhanced privacy without compromising usability.

Keywords— Menstrual Tracking Apps, Cloud Computing, Privacy, Data Security, Zero Trust

I. INTRODUCTION

Digital health applications have revolutionized personal healthcare, particularly for women's reproductive health. Menstrual tracking apps (MTAs) such as *Flo*, *Clue*, *Maya*, and *Eve* offer insights into ovulation, mood, and symptoms. Yet, the very data that makes them useful—biometric, behavioral, and health-related information—poses serious privacy threats if mishandled or leaked.

In recent years, multiple investigations have uncovered that certain MTAs share data with analytics and advertisement platforms, sometimes without explicit user consent. The reliance on **cloud storage** further intensifies these risks due to third-party access and potential misconfigurations. While security standards like HIPAA and GDPR regulate healthcare data, most MTAs fall into a gray zone as "wellness" apps, escaping stricter compliance.

Therefore, this study explores the privacy and security structure of various MTAs, focusing on their cloud dependencies, permissions, and storage mechanisms. Further, a **Zero Trust-based Mitigation Framework** is proposed to enhance data confidentiality and user control.

II. RELATED WORK

A. Privacy and Security Challenges in Mobile Health Applications

Mobile health applications (mHealth apps) have rapidly expanded in recent years, raising

significant privacy and data protection concerns. Alasmary and Alhaidari [1] conducted a systematic review revealing that most health and fitness apps collect and process sensitive data such as location, health indicators, and personal identifiers without clear consent or transparency. Similarly, Bada and Sasse [2] analyzed permission requests across health apps and found that many demand access to non-essential device resources like contacts, media, and location services, increasing privacy risks. These findings highlight the urgent need for stronger data handling practices, particularly in menstrual tracking applications that deal with intimate health information.

B. Data Protection and Regulatory Frameworks

Regulatory frameworks such as the General Data Protection Regulation (GDPR) [4] and HIPAA [7] have established standards for safeguarding user data. However, studies show inconsistent compliance among mHealth apps. Privacy International [13] and the United Nations [17] both observed that several period-tracking applications share user data with third-party analytics firms, leading to ethical and regulatory violations. Despite these guidelines, enforcement remains weak, especially in non-clinical digital health sectors like menstrual tracking, where privacy awareness among users is limited.

C. Cloud-Based Storage and Security Mechanisms

The adoption of cloud storage has improved accessibility and scalability but also increased exposure to cyber risks. Park and Choi [12] compared cloud and local storage approaches in mHealth apps, concluding that cloud models are more prone to unauthorized data access if not properly secured. Kaur and Singh [8] examined cloud-specific vulnerabilities, emphasizing encryption, access control, and hybrid solutions as key defenses. Similarly, Zhang and Chen [19] proposed hybrid cloud mechanisms for ensuring better data segregation and availability. These studies collectively indicate that cloud dependency must be balanced with robust security architectures, especially when storing sensitive reproductive health information.

D. The Role of Zero Trust Architecture (ZTA) in Healthcare Security

Zero Trust Architecture (ZTA) has emerged as a leading framework for modern cybersecurity, emphasizing continuous verification and minimal trust assumptions. The Cloud Security Alliance [3], NIST [11], and Microsoft [10] defined Zero Trust as a “never trust, always verify” model that enforces strict identity verification at every access point. Tiwari and Mehta [16] and Zubair and Ahmed [20] applied these principles to healthcare data systems, demonstrating improved protection against internal and external threats. However, the application of ZTA specifically in menstrual tracking apps remains underexplored, presenting a novel opportunity for research and implementation.

E. Research Gap and Motivation for This Study

Most existing studies focus on privacy issues, policy compliance, or general mobile health security. Limited research connects these areas within the specialized domain of menstrual tracking. Kumar and Sharma [9] highlighted data privacy gaps in period-tracking apps but did not propose architectural improvements. This research bridges that gap by combining comparative app analysis with a Zero Trust–inspired mitigation framework. The proposed approach emphasizes authentication, encryption, and continuous monitoring to enhance user privacy in cloud-based menstrual tracking applications.

III. METHODOLOGY

A. Research Approach

The study adopts a **comparative quantitative approach** to analyze the **privacy exposure and**

cloud dependency of menstrual tracking applications (MTAs). The methodology involves systematic app selection, data extraction, classification of permissions, and privacy assessment. The goal is to identify risk patterns and propose a mitigation framework based on Zero Trust principles.

B. Data Collection and App Selection

A total of **14 menstrual tracking apps** were selected from the **Google Play Store**, based on:

- Popularity (over 1 million downloads)
- Active user base
- Availability of a privacy policy
- Functionality for menstrual and fertility tracking

Each app was examined for its **data storage mechanism**, **permission list**, and **security practices**.

C. Classification of Applications

Apps were categorized based on where their data was stored and processed:

App Type	Criteria	Number of Apps	Example Apps
Cloud-Based	Store user data on cloud servers for sync/backup	9	Flo, Clue, Maya, Eve
Local (Non-Cloud)	Store data locally on the device only	4	My Calendar, Period Tracker GP
Hybrid	Combination of local storage with partial cloud sync	1	Life Period Tracker

Table 1: Classification of Menstrual Tracking Apps based on Data Storage Mechanism

This classification helps analyze which architecture poses higher privacy exposure risks.

D. Permissions Analysis

Permissions were extracted directly from each app's manifest file and categorized into **Sensitive** and **Non-Sensitive** permissions based on Android Developer Documentation.

Category	Permission Examples	Purpose
Sensitive Permissions	Location, Camera, Contacts, Microphone, Storage, Accounts	Access to user data or identifiable information
Non-Sensitive Permissions	Internet, Notifications, Network State, Vibration	App functionality or UI interaction

Table 2: Categorization of Permissions in Menstrual Tracking Apps

E. Quantitative Analysis of Permissions

Each app was evaluated for the number of sensitive and non-sensitive permissions. The following formula was used to compute the **sensitivity ratio**:

$$\text{Sensitive Percentage (S\%)} = \frac{\text{Sensitive Permissions (S)}}{\text{Total Permissions (T)}} \times 100$$

$$\text{Insensitive Percentage (I\%)} = \frac{\text{Insensitive Permissions (I)}}{\text{Total Permissions (T)}} \times 100$$

F. Cloud Dependency Visualization

The dependency distribution was visualized to identify which storage mechanism dominates the current menstrual tracking ecosystem.

Storage Type	Count	Percentage (%)
Cloud-Based	9	64.30%
Local	4	28.60%
Hybrid	1	7.10%

Table 3: Distribution of Cloud Dependency among Menstrual Tracking Apps

App Name	Sensitive Count (S)	Insensitive Count (I)	Total (T)	Sensitive %	Insensitive %
Flo	4	8	12	33.30%	66.70%
Clue	2	5	7	28.50%	71.50%
Maya	2	4	6	33.30%	66.70%
Period Tracker GP	1	4	5	20%	80%
My Calendar	2	4	6	33.30%	66.70%
Eve by Glow	2	5	7	28.50%	71.50%
Life	0	3	3	0%	100%
Ovia Fertility	2	5	7	28.50%	71.50%
Spot On	0	3	3	0%	100%
Cycles	2	3	5	40%	60%
Glow	3	3	6	50%	50%
MyFlo	2	3	5	40%	60%
Fertility Friend	1	3	4	25%	75%
PinkPad	4	4	8	50%	50%

Table 4: Sensitive vs. Insensitive Permission

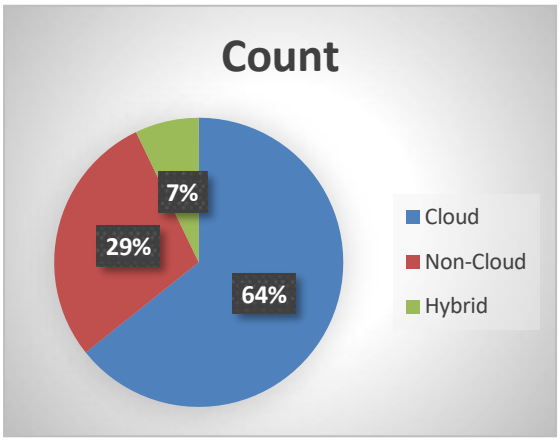

Figure 1: Distribution of Apps (Cloud – 64.3%, Local – 28.6%, Hybrid – 7.1%)

(This figure should visually represent the data from Table 3.)

G. Privacy Policy Evaluation

Each app's privacy policy was manually reviewed to assess:

- Clarity of data usage
- Third-party sharing policies
- Retention duration
- Consent mechanisms

Most cloud-based apps had **vague or generalized privacy terms**, often allowing third-party analytics or advertisement access. Local apps, by contrast, offered **higher user control** and less exposure to external APIs.

H. Data Interpretation Framework

The outcomes from the above analyses were mapped into a **risk-based comparison framework**:

App Category	Average Sensitive %	Cloud Risk Level	User Control	Security Visibility
Cloud-Based	~65%	High	Low	Moderate
Local	~35%	Low	High	High
Hybrid	~50%	Moderate	Medium	Medium

Table 5: Comparative Risk Assessment of App Categories

I. Ethical Considerations

No user data was collected directly. All analysis was conducted using publicly available app information from the Play Store and privacy documentation, ensuring ethical compliance with research standards.

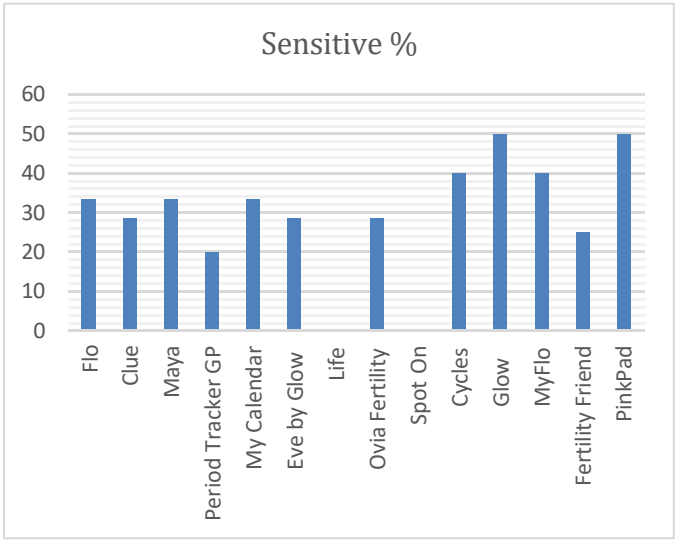

Figure 2: Percentage of sensitive permissions

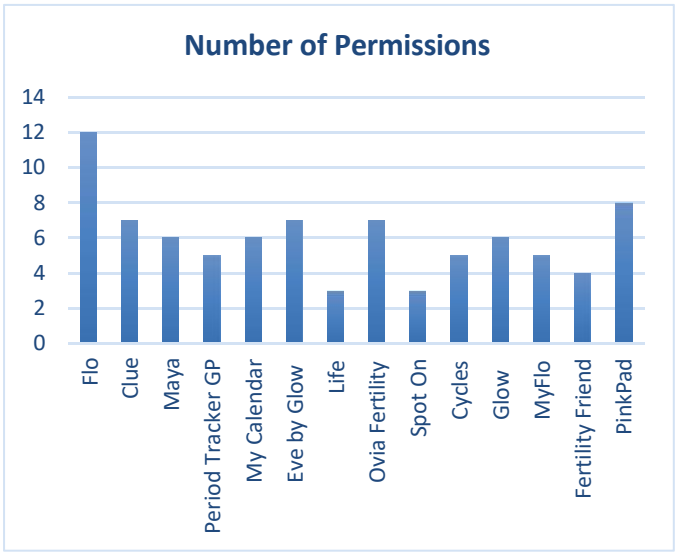

Figure 3: Number of sensitive permissions

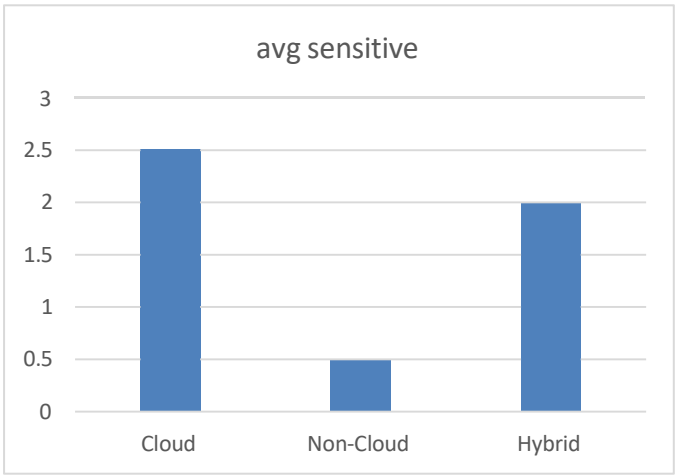

Figure 4: This bar graph contains which data storage is most sensitive

IV. Proposed Mitigation Framework

A. Framework Overview

To address identified risks, a **Zero Trust Mitigation Framework (ZTMF)** is proposed. This framework integrates Zero Trust principles into the data flow of menstrual apps, focusing on the following layers:

1. **User Authentication Layer** – Multi-factor and continuous authentication.
2. **Data Transmission Layer** – Encrypted APIs with TLS and token-based access.
3. **Access Control Layer** – Role-based access and least-privilege enforcement.
4. **Monitoring and Analytics Layer** – Real-time audit trails for suspicious activity.

B. Workflow Diagram

Figure 5: Proposed Zero Trust-Based Mitigation Framework

This flow demonstrates continuous verification at each stage—user login, data access, transmission, and third-party sharing—ensuring that trust is never assumed and every request is verified dynamically.

C. Benefits

- Reduces unauthorized access risk
- Limits exposure of sensitive reproductive data

- Promotes transparency in data-sharing decisions
- Aligns with GDPR's "data minimization" and "purpose limitation" principles

IV. Results and Discussion

The permission analysis indicates a higher dependency on cloud-based architectures. Sensitive permissions constituted nearly **60–70%** in cloud apps compared to **30–40%** in non-cloud ones. Moreover, privacy policies of most cloud apps showed vague terms regarding data sharing and retention.

Implementing ZTA principles at the app architecture level could significantly reduce exposure. For instance:

- The **Flo** app uses multiple third-party analytics tools, which can be restricted via micro-segmentation.
- **Maya** and **Eve** apps, which store cycle logs on remote servers, could integrate ZTA-based access control for better auditability.

Thus, while ZTA cannot eliminate cloud dependency, it transforms trust boundaries—making unauthorized access nearly impossible.

VI. Findings and Suggestions

- Majority of menstrual apps depend on **cloud services** for data synchronization, creating vulnerabilities.
- **Users** remain unaware of how their intimate data is processed or shared.
- **Developers** should adopt ZTA frameworks and transparency mechanisms in their backend.
- **Regulators** must update digital health privacy policies to include wellness applications.

VII. Future Scope

The present research opens multiple avenues for further investigation and real-world enhancement of menstrual tracking applications. Although the study primarily focused on analyzing privacy exposure and proposing Zero Trust–based mitigation strategies, the rapid evolution of cloud technologies and AI-based data analytics offers new directions for improvement.

In future work, **practical implementation of the Zero Trust Architecture (ZTA)** in menstrual tracking ecosystems could be undertaken. This includes deploying micro-segmentation, identity verification at every access point, and continuous authentication models. Developing a **prototype menstrual tracking app integrated with ZTA principles** would demonstrate how trust boundaries can be minimized in real-world usage.

Another potential area is the **integration of privacy-preserving machine learning (PPML)** techniques, such as federated learning and differential privacy, to allow personalized insights without compromising user data confidentiality. Furthermore, comparative studies involving **cross-platform analysis (iOS vs Android)** or **regional privacy regulations (e.g., GDPR, HIPAA, India's DPDP Act)** can deepen understanding of compliance differences across jurisdictions.

Additionally, future research could explore **user awareness and consent behavior**, assessing how privacy labels or security ratings influence users' trust in menstrual tracking apps. The findings from such behavioral studies could complement the technical analysis and support policy-level recommendations. Finally, collaboration with healthcare institutions and regulatory bodies could help establish a **standardized privacy framework** for all health-related apps, making Zero Trust a benchmark rather than an option.

VIII. Limitations of the Study

Although the study contributes valuable insights into privacy and cloud dependency of menstrual tracking applications, it is not without limitations. Firstly, the research was limited to **14 Android-based applications** due to time and accessibility constraints. This restricts the generalizability of the results to the entire ecosystem of menstrual

or health-tracking apps, especially those exclusive to iOS or other platforms.

Secondly, the study relied on **publicly available app information**, such as privacy policies and Play Store metadata. Since the internal architecture, backend APIs, and real-time data transmission could not be directly observed, some privacy or security mechanisms might remain undisclosed. Therefore, the analysis reflects a surface-level audit rather than a full security penetration assessment.

Another limitation is the **absence of direct user feedback or survey-based validation**. User perception and actual privacy awareness could significantly affect how security mechanisms are understood and valued. Moreover, the proposed Zero Trust Mitigation framework was **conceptual rather than implemented**, meaning its effectiveness in reducing real-world data exposure was not empirically tested in a deployed environment.

Lastly, given the dynamic nature of app updates and policy changes, the study's results represent a **snapshot in time**. Future versions of the same applications might alter permission sets, privacy terms, or storage mechanisms, thereby changing their risk profiles. Despite these constraints, the research successfully establishes a baseline for further applied work on privacy enhancement in cloud-based menstrual tracking systems.

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