Offline Payment System: A Secure Approach for Digital Transactions Without Internet

Syed Wajahat Abbas Rizvi
Department of Computer Science and Engineering
Amity University Uttar Pradesh
Lucknow Campus, India

Ankita Mishra
Department of Computer Science and Engineering
Amity University Uttar Pradesh
Lucknow Campus, India

ABSTRACT
Secure offline payment solutions need implementation within digital payment systems because of rising transaction requirements along with decreased dependence on internet connections. Poor connectivity exposes the limitations of the existing payment methods, which include credit cards, UPI, and mobile wallets in particular. The research evaluates existing offline payment systems through an analysis of their operational mechanics as well as their security measures together with their practical limitations. Research indicates that users choose payment systems that allow transactions between online and offline environments. The developed TOTP and SHA3-encrypted SMS-based payment method provides secure authentication for transactions. Through telecom networks, the system enables rural communities to access finance more easily and provides framework scalability along with fraud security and user-friendly features.

General Terms
Offline Systems,Digital Transactions,User Experience (UX),Time-Based OTP (TOTP),Security,Payment Systems.

Keywords
Offline Payment Solutions, Digital Transactions, Secure Authentication, SMS-Based Payment.

1. INTRODUCTION
Secure payment technologies have struggledto keep pace with the rapid growth of digital transactions, and the heavy reliance on internet connectivity in current systems poses significant access challenges in regions with intermittent service. Unstable internet conditions create barriers to using online payment platforms, and drastic service interruptions experienced by major providers underscore the need for internet- free operational solutions. Present payment systems that depend on online settlement suffer from limited functionality, prompting this study to investigate fully offline payment models that leverage time- based one- time passwords (TOTP) and SHA3- encrypted SMS OTPs for validation. By assessing solutions such as Stripe, UPI Lite, and Crunchfish Digital Cash, the research establishes an SMS- based transaction model—implemented via React-Native-get-SMS API and MySQL—that enables real-time, secure offline transactions.

In many regions, unreliable internet connections prevent users from accessing digital payment systems, since these platforms require constant connectivity. The electrical service outages experienced by payment companies like Visa and Square starkly reveal the weaknesses of internet- dependent transactions. Even so-called offline processing methods still necessitate some form of internet link, which greatly reduces their utility. To address this gap, the study develops a fully offline transaction solution based on TOTP and SHA3- encrypted SMS OTPs, ensuring both security and global financial accessibility through telecom channels. As Yash Kumar et al. (2021) [1] noted, online purchases surged during the COVID-19 pandemic, highlighting the vulnerability of wallet architectures that demand continuous connectivity; in response, three key scenarios were identified where fully offline transaction capabilities could benefit both customers and businesses [1]. General survey observations further reveal that existing “offline” solutions are either heavily reliant on infrastructure or unable to process truly offline payments [3][5][6][7].

Building on these insights, the main objective of this research is to evaluate different offline payment systems by examining their security weaknesses and recommending enhancements to strengthen transaction integrity and reduce fraud risk. Through the implementation of TOTP alongside SHA3- encrypted OTPs, the study demonstrates how robust cryptographic measures can support secure, efficient payment flows that operate independently of internet availability. Ultimately, the project aims to bridge technological barriers and financial progress, delivering smooth digital transactions even in connectivity-challenged environments.

To achieve this, the study analyzes offline payment security by implementing SMS-based TOTP transactions secured with SHA3 encryption. By removing internet requirements and leveraging telecom channels, the system promotes financial inclusion in rural and underbanked areas. It offers scalable features, high security standards, and an intuitive user experience, though it faces certain limitations: dependency on telecom services for SMS delivery may introduce delays, SIM card vulnerabilities pose potential risks, and the model still requires banking infrastructure for transaction processing—unlike UPI Lite and Stripe, which can operate without such dependencies.

2. EXISTING TECHNOLOGIES

2.1 Survey Analysis For The Need of Offline Payment System
The study demonstrates that users prefer online payments mainly because these transactions provide ease and secure convenience. The research shows that online transactions reduce the need to carry cash because multiple respondents pointed out that this strategy decreases their chances of losing money. The speed and convenience of online payments create an ideal environment when trading or shopping or when doing financial transactions. The capability to control money without accessing banks or using ATMs emerged as a significant factor based on the current state of slow financial services. People perceived that online payment methods offered better reliability and performance when processing large payments, including investments as well as business transactions.The growing adoption of digital payments has not

deterred some customers from conducting transactions offline for particular reasons. People tend to believe that having control over their spending happens through using actual money, thus improving their money management skills. Offline payment methods remain the transaction choice for everyday small expenses because they make budget planning simpler while reducing the common problem of careless spending through digital payment systems. The respondents selected offline payment because it helps them decrease their technological dependence and ensure transactions can proceed in case of system failures or internet outages. The participants indicated a preference for offline payment methods because these methods save paper or simply give them better comfort with traditional payment methods.The benefits of offline transactions over internet payments include better accessibility and financial discipline; therefore, such transactions retain significance regardless of internet.Such a combined strategy unites both approaches to support different payment methods and maintain user comfort.

TABLE I- Exploring factors affecting the adoption of mobile payment at physical stores[8]

Construct	Measurement Items	
Perceived Usefulness	Users find mobile payments time-saving, widely accepted, beneficial with bonus points, and offering additional value	Davis & Venkatesh, 1996; Devaraj et al., 2002
Perceived Ease of Use	Mobile payment apps are easy to download, learn, and use, with minimal steps required for transactions and appropriate screen sizes	Davis & Venkatesh, 1996; Leida, 2008
Attitude	Users find mobile payments attractive, valuable, and a wise choice	Davis & Venkatesh, 1996
Personal Innovativeness	Individuals are eager to experiment with and adopt new mobile payment technologies	Han, 2005
Social Influence	Users perceive social pressure to adopt mobile payments, believing it enhances their image	Shimp & Kanvas, 1984
Promotional Offer	Discounts and incentives such as red packets are appealing, useful, and reliable	Lichtenstein et al., 1990
Behavioral Intention	Users intend to utilize mobile payment services and m-coupons frequently in their daily transactions	Venkatesh et al., 2008

Table 1 lists seven constructs used to examine mobile payment adoption and outlines the measurement items used for each one. It reveals that using mobile payments matters to people for being easy and convenient, as well as app ease of use, while forming a good opinion about them. It also points out that people are willing to use new tech devices, the importance of other people's opinions, and the exciting discounts available. Lastly, it relates all these factors to the users' intentions to often use mobile payments and coupons.

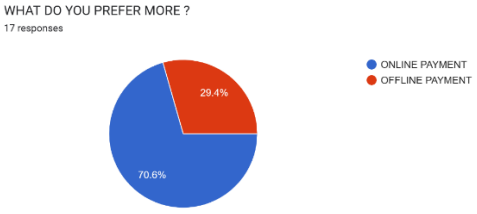


Fig. 1: Offline vs Online Payment Preference

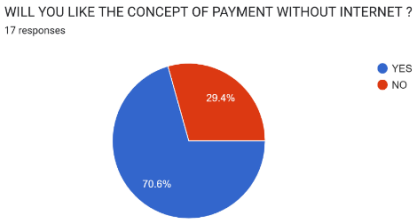


Fig. 2: Preference For Payment Without Internet

TABLE II: Analysis of Responses.

Question	Option 1	% (Count)	Option 2	% (Count)
What do you prefer more?	Online Payment	70.6% (12)	Offline Payment	29.4% (5)
Will you like the concept of payment without internet?	Yes	70.6% (12)	No	29.4% (5)

2.2 Current Technologies Used In This Field

Transactions can take place with little to no internet connectivity thanks to hybrid and offline digital payment systems. One of the most notable instances is Stripe, which allows transactions to be completed after internet connectivity is restored by offering offline payments using its Stripe Terminal. By temporarily holding payment information until the device reconnects to the internet, UPI Lite makes small-value transactions offline possible in India. Using touchless gestures and safe cryptography, respectively, Matera's Mobile Offline Payment system and Crunchfish's Digital Cash also offer offline payment options via mobile apps. Furthermore,

OPERA, an offline digital payment framework, uses an anonymous, self-verifiable method for atomic transfers to guarantee safe peer-to-peer transactions. Even in locations with erratic internet access, these solutions guarantee that digital payments are still available .[2] Google-pay linked with pine labs to conduct business in July 2019.The initiative permits store owners to start payment requests through mobile phone numbers on their Point of Sale services. Google-Pay involved with pine labs during July 2019 to allow merchants to enter customer mobile numbers into point-of-sale service for payment initiation.The Point of Sale service failed to succeed after initial implementation [1][10].

3. METHODOLOGY

3.1 Exploration Of Similar Project

My conceptual imagination found its realization through extensive research within a specific domain. The following development process explains how to create a project that matches my proposed targets. This project establishes a network system that eliminates the need for internet connections when performing secure payment transactions while presenting a streamlined financial transfer solution.

TABLE III- Other Technology vs SMS based Technology

Feature	Proposed Website	Existing Technologies	How our System Serves Better?
Internet Dependency	Works in **complete offline mode** using **SMS transactions**	Most solutions like **Stripe Terminal & UPI Lite require eventual internet connectivity** to sync transactions	**Fully independent from internet ,only banks need minimal connectivity**
Transaction Type	**Peer-to-peer (P2P) & Bank transactions via SMS**	Some models like OPERA support **P2P digital cash transactions** , but others rely on **stored balances** (UPI Lite)	**Works seamlessly with banks while supporting direct user transactions**
Scalability & Financial Inclusion	Works in **remote areas with feature phones**; ideal for **rural banking**	**Mostly smartphone-based** (UPI Lite, Crunchfish)	**More inclusive, accessible to users without advanced smartphones**
Double Spending Prevention	Bank verifies transaction before processing (SMS logs prevent reuse)	Some systems like **OPERA** use blockchain, others rely on internet sync	**Uses telecom infrastructure for real-time transaction verification**

3.2 Structure Of External System

- Users need to register their accounts on the website as their starting step.
- Users must use their registered login information to access the system.
- Users can execute transactions either through online connection or they can use SMS as a backup when internet is unavailable.
- Users will get SMS messages about the transaction process from the system.[1]

3.3 Structure Of Internal System

- The app activates the React-Native-get-SMS API to deliver an SMS notification to the registered device when the device has no internet connection. The request reaches the bank processing system for verification.
- MySQL functions as the database solution that protects user details through its secure performance of transaction management.
- The system processes and records transactions after receiving the SMS from both users.
- The offline transaction gets recorded within the transaction history upon reestablishing internet connectivity by the device. [1]

3.4 Comparison Between Various Technologies For OTP Generation

Table IV: Comparison Between Various Technologies For OTP Generation

Technology	How It Works	Pros	Cons	Security Level
GSM (SMS-Based OTP)	OTP sent via SMS using telecom infrastruc	Easy to implement, does not	Vulnerable to SIM swap, SS7	Low

Technology	How It Works	Pros	Cons	Security Level
	ture (GSM, LTE, etc.).	require internet.	attacks, and interception.	
SHA3/SHA2 OTP (HOTP/TOTP)	OTP generated using cryptographic hash functions (SHA3, SHA2) with a shared secret key.	Highly secure, resistant to replay attacks.	Requires **secure storage** of shared secret.	High
Time-Based OTP (TOTP)	OTP changes based on the current time using HMAC-SHA1/SHA2.	More secure than SMS, works without internet after setup.	Requires user to sync time properly.	**Very High**
Public Key Cryptography (RSA/ECDSA-Based OTPs)	OTP is generated using asymmetric encryption (private-public key pairs).	No shared secret, high security.	More complex to implement, needs device encryption.	**Very High**
Push Notification-Based OTP	OTP sent through push notification via a secure app.	No reliance on SMS, **end-to-end encrypted**.	Requires an internet connection, app dependency.	**Very High**
FIDO2/Web Authn (Hardware Token-Based	Uses physical security keys or biometric	**Phishing-resistant**, stronge	Requires specialized hardwar	**Extremely High**
OTPs)	s.	st security.	e.	

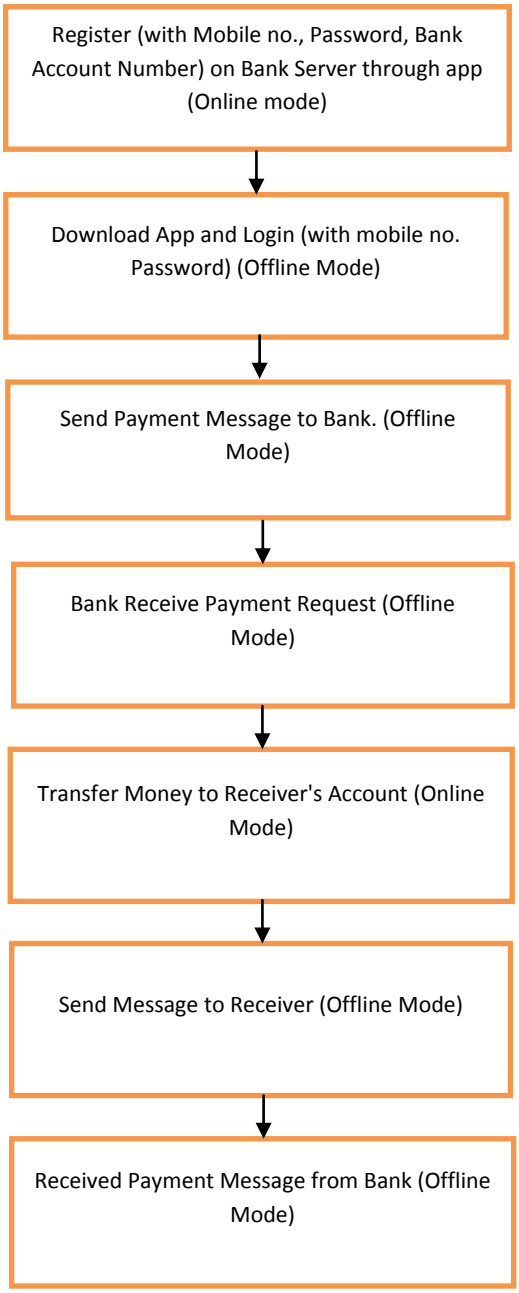
Table IV contains a comparison between authentication technologies from which the proposed system draws to improve security levels. This evaluation compares OTP protocols against each other through an assessment that reviews their deployment methods and examines pros and cons as well as security specifications.

Based on this analysis, the most suitable approaches for the system are :

1. **TOTP (Time-Based OTP with SHA3/SHA2)** – Since your system supports both online and SMS-based transactions, implementing **TOTP with SHA3/SHA2** provides high security while allowing offline authentication.
2. **Push Notification OTP (Backup for Online Users)** – Users with internet can receive push OTPs securely without relying on SMS.
3. **GSM-Based OTP (As a Last Resort)** – For users without an internet connection, **fallback to SMS-based OTP** but use **SHA3 hashing** before sending OTPs to minimize risks.

3.5 Inferences From The Comparison

- User registration along with login processes stay the same while the system implements TOTP-based OTP authentication to boost security levels.
- Users now have the option to authenticate transactions through SMS and online or TOTP for off-line authentication which reduces exposure to GSM-based OTPs.
- The enhanced system implements TOTP (SHA3/SHA2) for primary authentication together with Push OTP for online users and SHA3-encrypted SMS OTP as backup methods.
- The TOTP authentication system enables users to execute offline verifications without depending on SMS-based OTP authentication.
- The implementation of secure key storage enhances authentication security by being added to TOTP secrets which operate from the MySQL database.
- Transaction authenticity stays protected through secure OTP verification to avoid SMS fraud risks during reliable transaction processing.



Fig, 4. System Workflow of Payment Without Internet Application [1]

4. KEY FINDINGS

The available offline payment methods, UPI Lite and Stripe Terminal, together with Crunchfish Digital Cash, enable partial offline functions, although both settlements and authentication need periodic internet availability. Proficiency in encryption techniques is necessary because security hazards like SIM swap attacks along with SS7 vulnerabilities and replay attacks demand better authentication systems. The proposed system improves security through SHA3-encrypted OTPs and TOTP-based verification authentication methods that replace vulnerable GSM-based OTPs for interception. The research study both highlights the requirement for financial inclusion in remote areas and creates an improved transaction method for dependable transactions during periods of network unavailability. The research develops fundamental principles that support the development of a robust offline digital payment system that promotes efficiency and security alongside scalability.According to the study, while so-called offline systems UPI Lite, Stripe Terminal, and Crunchfish Digital Cash let people transact in case of internet disconnect, they enforce either checking or approving the transaction over the internet. Since these systems need to be connected to the internet to finish a transaction, they are less reliable where the internet is poor all the time.

The system involves using OTPs that are SHA3-encrypted by default and supports TOTP-based authentication for a stronger security. Thanks to these improvements, it is no longer necessary to use GSM OTPs, since they can fall victim to problems like SIM swap fraud and interception of SS7 messages. The findings show that secure offline payments are possible with the right kind of telecom infrastructure and strong encryption.

The study shows that financial inclusion could help the lives of people in underbanked and rural areas. Since the system runs offline and has only few technical needs, it can scale and respond well to new challenges. With this approach, transactions are kept secure and digital payments away from the internet are more confidently used by letting users verify their identity using a secure channel.

As a result, the system handles existing security risks and helps build an offline digital payment system that is more open to everyone.

5. DISCUSSION

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5.1 Comparison with Enhanced System Of System

Table V: Current vs Enhanced System

Aspect	**Current System**	**Enhanced System (TOTP, Push OTP, GSM with SHA3)**
User Registration	Users register on the website.	Same as current system.
User Login	Users log in with registered credentials.	Same as current system, but with **TOTP-based OTP authentication**.
Transaction Execution	Users transact online or via SMS when the internet is unavailable.	Users can **transact online, via SMS, or using TOTP** for offline security.
SMS Transaction	Users receive SMS	**Push OTP for online users, and SMS OTP**

Aspect	**Current System**	**Enhanced System (TOTP, Push OTP, GSM with SHA3)**
Alerts	notifications about transactions.	**(SHA3 hashed) for offline users.**
OTP Mechanism	Only GSM-based OTP (SMS).	**TOTP (SHA3/SHA2) for primary authentication, Push OTP for online users, and SHA3-encrypted SMS OTP as a last resort.**
Security Level	**Moderate** (Vulnerable to SIM swap & SS7 attacks).	**High** (Cryptographic hashing protects OTPs, Push OTP eliminates reliance on SMS).
Offline Authentication	Only SMS-based OTP .	**TOTP allows users to authenticate offline without SMS dependency.**
Data Storage	MySQL stores user details securely.	Same as current system, with **added secure key storage for TOTP secrets**.
Transaction Processing	Transactions are recorded after receiving SMS from both users.	Transactions are recorded using **secure OTP verification, reducing SMS fraud risks**.

5.1.1 Inferences Fromthe Comparison

- The proposed system functions independently from internet connections by using SMS thus addressing the dependency issue which exists in current transaction solutions.
- The system verifies transactions instantly through telecom infrastructure to prevent double-spending in a transaction process that does not necessitate blockchain or internet validation.
- The bank maintains secure and efficient data processing through this solution because transactions are handled and verified at their own location to enhance protection.
- The implementation of this solution demands no new equipment so banks easily integrate it better than other systems relying on NFC-enabled points of sale technology or special digital wallets.

6. CONCLUSION

The solution proposed is resistant to offline guessing attacks since strong hash functions are used to generate the passwords. Additionally, it demonstrates resistance to internet attacks including replay attacks, shoulder surfing attacks, key loggers, etc. Additionally, encrypting passwords to be used just once prevents replaying reused passwords.[4]

SMS-based authentication with TOTP and SHA3 encryption shows fundamental weaknesses as it can be compromised by new fraud techniques such as SIM swap incidents and late SMS arrival times. The cryptographic security measures reduce several risks but they lack the ability to observe transaction patternswhich exposes the system to complex fraud patterns.

The system needs a built-in on-device AI for anomaly detection to address this problem. The solution applies lightweight machine learning algorithms to individual devices which conduct perpetual detection of transaction patterns when disconnected. The AI system identifies abnormalities within standard parameters and automatically reacts to detected suspicious transactions in an environment without internet availability. The added AI security system improves both existing cryptography protection and offers dynamic security management which ensures dependable and trustworthy SMS-based transactions across evolving cyber threat environments. [9][11]

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