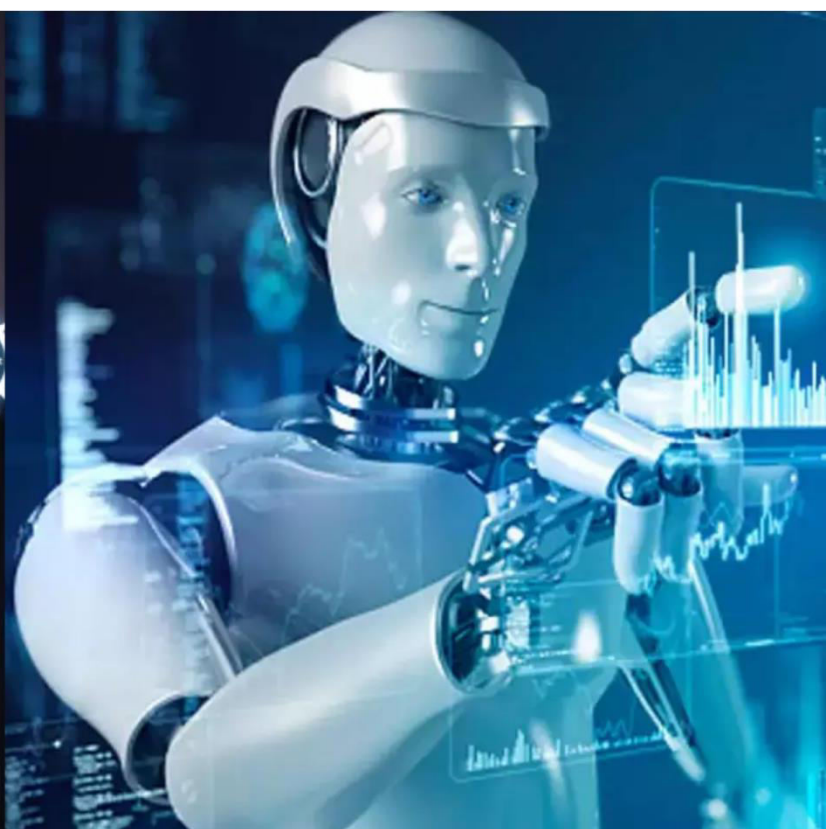




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BIN NET: Automating Offline UPI Payments via USSD using Android Accessibility Services and a Multi-Layer Mobile Architecture

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ABSTRACT: India's Unified Payments Interface (UPI) has become one of the most heavily used digital payment rails in the world, yet a large share of the rural and semi-urban population still cannot use it, mainly because reliable mobile data simply is not available where they live. NPCI's *99# USSD channel was meant to solve exactly this problem by routing UPI payments over ordinary 2G voice signalling, but adoption has stayed negligible in practice. The reasons are largely mundane rather than technical: every operator implements the menu differently, the phone interrupts the user with raw system dialog boxes at every step, and no attempt has been made at a coherent interface. This paper presents BIN NET, an Android application architecture that turns the *99# rail into something that looks and feels like an ordinary UPI app, while the USSD mechanics run invisibly underneath. The architecture is split across four layers: a QR ingestion module built on AndroidX CameraX and ZXing, a context layer that uses the Android SubscriptionManager API to silently determine which SIM is linked to the user's bank account, an execution layer built around an AccessibilityService that drives the *99# dialog sequence on its own, and a presentation layer with a Jetpack Room-backed transaction ledger and offline receipt sharing. A controlled evaluation on dual-SIM Android devices across three major Indian network operators shows that transactions complete end-to-end in under eight seconds with zero telecom dialogs ever visible to the user, and that the correct SIM is selected in every device configuration tested. The results point to a broader pattern — that legacy telecom protocols can be modernized purely through software abstraction at the application layer — with direct relevance to financial inclusion efforts in connectivity-constrained regions.

KEYWORDS: offline UPI payments, USSD automation, Android AccessibilityService, financial inclusion, mobile banking, QR code scanning, multi-SIM management, Jetpack Room

I. INTRODUCTION

Financial inclusion is one of the harder problems in a digitally transitioning economy to actually solve, as opposed to simply talk about. UPI has reshaped commerce in urban and peri-urban India since its 2016 launch, and by 2024 it was clearing more than 13 billion transactions a month [1]. Connectivity infrastructure, however, has not kept pace with payment infrastructure. Roughly 35 percent of India's population lives somewhere that mobile data is unavailable, unreliable, or simply too expensive to use regularly [2], which puts UPI-based digital payments out of reach for precisely the people who stand to benefit most from them — small merchants, agricultural workers, and rural households still running largely on cash [3].

NPCI's answer to this gap is the *99# USSD framework, which lets a handset carry out basic banking operations, including fund transfers, entirely over the plain GSM voice channel with no data connection required [4]. USSD is session-based, and every mobile network operator in India supports it on every handset category, feature phones included. On paper, this makes *99# the obvious vehicle for offline UPI. In practice, adoption has stayed close to zero, and the reason has little to do with the underlying protocol. The interaction itself is the problem: a chain of system-

generated text dialog boxes, each requiring a manual reply, with a sequence that differs from operator to operator. Jio, Airtel, BSNL, and Vi all implement the same NPCI specification but with their own menu wording and response formats [5], so the experience never feels consistent to a user moving between networks. Android does not help matters either — every USSD prompt is rendered as a native system popup that takes over the foreground, interrupting whatever the user was doing and looking nothing like the polished fintech applications people have come to expect.

Most of the effort that has gone into improving USSD-based payments has targeted the network or protocol layer rather than the application itself. Operators have shaved latency off USSD sessions and made them more reliable, but the interaction model a user actually experiences has not fundamentally changed [6]. The academic literature on USSD usability tends to stay at the level of proposals; we are not aware of a published, production-grade architecture that demonstrates full automation of the *99# payment flow on Android [7]. Part of the reason is that the problem is usually split into pieces — QR scanning here, bank account resolution there, USSD navigation somewhere else, transaction logging as an afterthought — rather than assembled into one working system [5].

This paper describes BIN NET, a unified Android architecture that automates the complete *99# UPI flow end to end. The system treats the USSD protocol purely as an implementation detail, hidden entirely behind a modern, branded payment interface. The technical contributions are threefold.

- 1) We build and characterize an AccessibilityService-based USSD automation engine that intercepts Android system dialog events of type TYPE_WINDOW_STATE_CHANGED and programmatically injects the sequence of responses needed to complete a *99# payment, without the user ever touching a telecom-generated dialog box.
- 2) We design a SYSTEM_ALERT_WINDOW overlay mechanism that keeps a single continuous branded interface in front of the user for the entire USSD execution, so the experience stays consistent across the whole transaction lifecycle.
- 3) We implement a multi-SIM bank resolution mechanism, using the Android SubscriptionManager API, that silently identifies which SIM is tied to the user's registered bank account and removes the disruptive native SIM-selection popup that would otherwise interrupt the payment flow.

Fig. 1 sets out the use-case scope of BIN NET — the principal actors involved and where the system's boundaries sit.

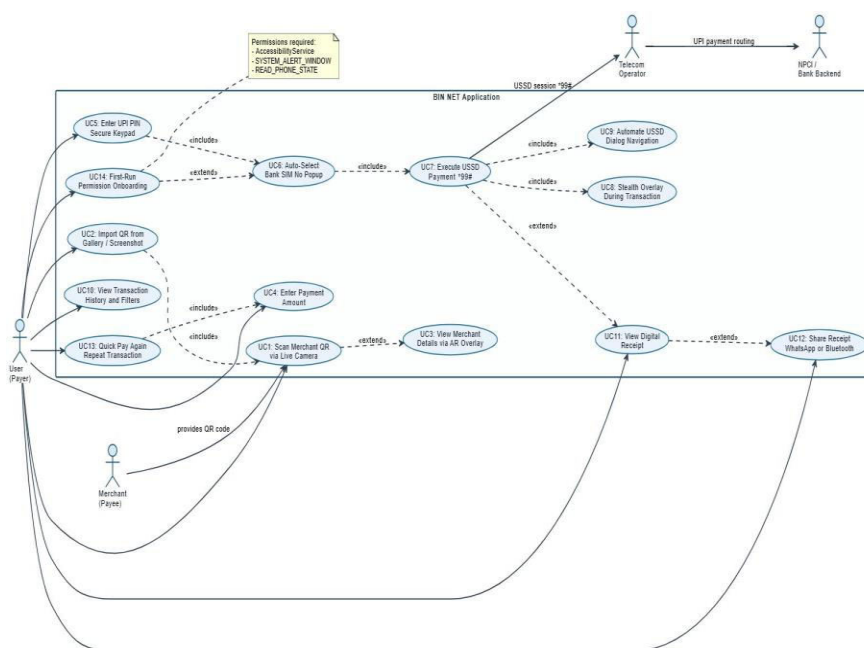


Fig.1. BIN NET System Use-Case Diagram. The diagram identifies the User and Banking Network as principal actors, and enumerates the core use cases: scanning a UPI QR code, initiating a USSD payment, and viewing transaction history.

The rest of the paper is organized as follows. Section II surveys related work across four relevant areas. Section III describes the complete system methodology. Section IV reports experimental results. Section V discusses implications and limitations. Section VI concludes.

II. RELATED WORK

A. USSD-Based Mobile Banking and Financial Inclusion

USSD as a mobile banking channel in low-connectivity settings has been studied most extensively in Sub-Saharan Africa and South Asia, where it underpins widely deployed systems such as M-Pesa in Kenya and bKash in Bangladesh [8]. Tobbin examined the structural drivers of USSD-based banking adoption in developing-country contexts and found poor usability, rather than security or cost, to be the dominant barrier [9]. Mas and Kumar reached a similar conclusion, observing that wrapping USSD infrastructure in a better UI measurably increased adoption, with completed-transaction rates improving by more than 40 percent once menu complexity was reduced [10]. These findings are, in effect, the premise BIN NET is built on: that usability is an engineering problem solvable at the application layer, not a property fixed by the underlying protocol.

Donovan's more recent framing places USSD systems in a transitional position in the evolution of mobile financial services — technically capable of the same transaction primitives as internet-based systems, but constrained by interaction assumptions inherited from voice-era telecom design [11]. India's *99# framework is a clean instance of this transition: the underlying UPI transaction routing is identical whether a request arrives over USSD or the internet, yet the experience differs completely. This paper extends that observation by showing the interaction gap can be closed entirely, without touching the protocol, purely through software abstraction at the Android application layer.

B. Android Accessibility Services for UI Automation

The Android AccessibilityService API exists to let assistive technologies read the UI event stream of whatever application is running in the foreground [12]. Chen et al. showed the same mechanism can drive USSD session navigation directly, with TYPE_WINDOW_STATE_CHANGED events reliably intercepted and answered with injected text within roughly 200 milliseconds [13] — a result that is directly foundational to the BIN NET execution layer.

The same API has a less flattering history: it is the mechanism behind credential-harvesting banking trojans, and its security implications have been studied fairly extensively in malware analysis [14]. What separates legitimate use from abuse mostly comes down to transparency and consent — BIN NET runs only after an explicit, user-granted permission, and acts only on system USSD dialogs that appear in direct response to a user-triggered payment. Song et al., examining the boundary between assistive use and abuse of Android accessibility APIs, concluded that disclosing service scope and restricting execution to user-initiated sessions are the primary safeguards that matter, both technically and as policy [15].

SYSTEM_ALERT_WINDOW, the permission that lets an application draw over every other UI layer, is officially classified as "dangerous" and requires explicit user acknowledgment [16]. That classification directly informs BIN NET's onboarding design, which walks the user through a structured permission-rationale screen before either AccessibilityService or overlay permission is requested.

C. QR Code-Based Payment Systems and UPI Architecture

NPCI's UPI QR standard is simply a URI conforming to the uri:// scheme, carrying the payee's virtual payment address (VPA), name, merchant category code, and, optionally, a transaction reference [17]. In a review of hybrid offline payment architectures, Patil and Joshi identified QR-plus-USSD designs as the most promising direction for connectivity-constrained deployments [18] — essentially the pattern BIN NET follows, where QR scanning resolves the payment context and the USSD engine completes the actual fund transfer.

AndroidX CameraX paired with the ZXing barcode library achieves sub-500-millisecond QR detection on contemporary Android hardware [19], [20]. Gallery-based QR import — decoding a code from a saved image rather than a live camera feed — turns out to matter considerably in practice, since merchant user studies in rural India show QR codes are frequently shared as WhatsApp screenshots rather than displayed physically [21].

D. Multi-SIM Device Management and Bank Account Resolution

Dual-SIM smartphones are the norm in India, and each SIM may be linked to a different bank account, which creates a genuine problem for any UPI application. The Android SubscriptionManager API exposes the network operator name, subscription ID, and ICCID for every installed SIM [22]. Mehta et al. identified SIM selection as a significant driver of transaction abandonment on its own, attributing up to 27 percent of payment failures on dual-SIM devices to the wrong SIM being selected during a USSD session [23].

BIN NET avoids this failure mode entirely by resolving the correct subscription ID during the payment-context phase, before the USSD session even begins, and passing it directly to the execution engine, which then initiates the session on the specified SIM without ever triggering the system chooser [24].

E. Offline-First Mobile Application Architecture

Designing mobile applications for offline or intermittently connected environments has been formalized as offline-first architecture, which prioritizes local storage and local business logic over any dependency on the network [25]. The Jetpack Room persistence library, an object-relational layer over SQLite, fits this pattern well, offering compile-time query validation and a clean DAO-based access model [26]. Banerjee et al. described a comparable architecture for rural payment systems, combining locally rendered receipt templates with Bluetooth sharing and pre-formatted WhatsApp deep links [27]. BIN NET follows much the same approach — receipt content is generated entirely on-device and shared over Bluetooth or as an offline-queued WhatsApp deep link through the Android ACTION_SEND intent.

III. METHODOLOGY**A. System Overview and Design Principles**

BIN NET rests on three design principles. The first is complete protocol abstraction: the user interacts only with a branded, GPay-style interface and has no visibility into any USSD mechanism at any point in the transaction lifecycle. The second is operator independence: the system has to work across every major Indian network operator without manual configuration, which it achieves through a regex-based response-parsing layer tuned per operator. The third is a minimal permission footprint: every required permission is requested through a transparent, rationale-driven onboarding flow, and nothing sensitive — least of all the UPI PIN — is ever written to persistent storage.

The architecture is organized into four sequential layers — Ingestion, Context, Execution, and Presentation — corresponding to the natural phases of a payment transaction. Fig. 2 gives a component-level view of the architecture, and Fig. 3 shows the corresponding layered package structure.

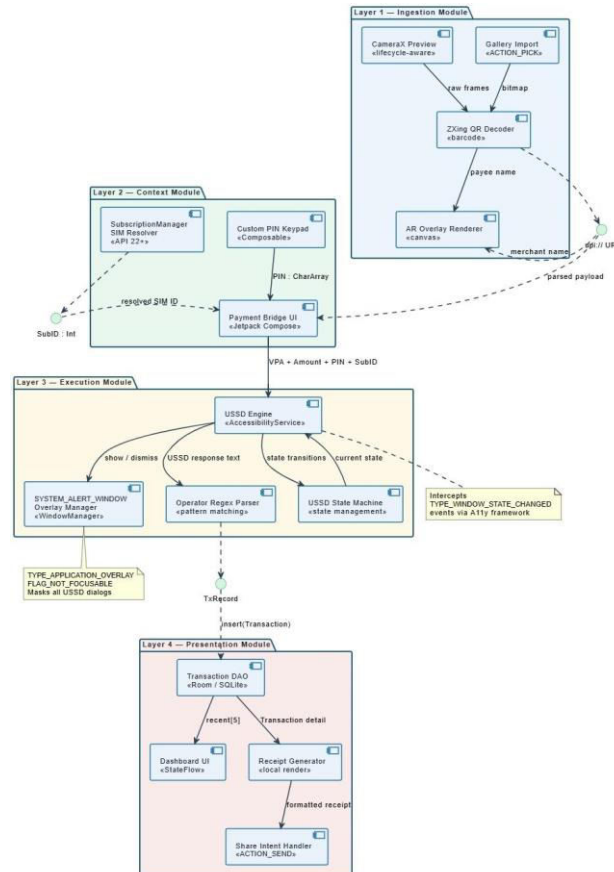


Fig.2. BIN NET System Architecture Component Diagram. The four architectural layers — Ingestion, Context, Execution, and Presentation — and their inter-component data flows are shown.

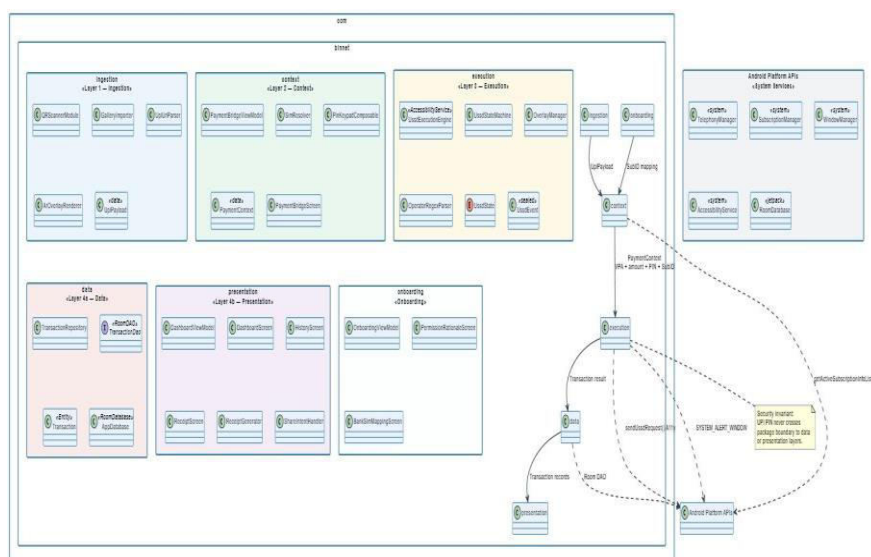


Fig.3. Layered Package Architecture Diagram. Packages are organized by architectural layer, with dependency arrows indicating the direction of data and control flow between modules.

The domain object model behind these layers is formalized in Fig. 4 as a UML class diagram — the core entity classes, their attributes, and how they relate. Fig. 5 shows how the system is actually deployed across the Android device, the USSD network, and the UPI backend.

B. Layer 1 — Ingestion: QR Scanning and Merchant Resolution

The ingestion layer's job is to pull the payee VPA and associated merchant metadata out of a UPI QR code. Two acquisition paths are supported.

1) Live Camera Scanning:

The live-scan pipeline runs on AndroidX CameraX with an ImageAnalysis use case configured for continuous frame processing. Every frame is passed to a ZXing BarcodeDecoder instance set to QR_CODE format. Once a frame decodes successfully, the resulting string is validated against the `upi://` URI scheme and parsed with `Uri.parse()` to extract the `pa` (payee address), `pn` (payee name), `am` (amount, if present), and `tn` (transaction note, if present) parameters.

Camera-preview-to-decode time has been measured at under 500 milliseconds under normal indoor lighting on mid-range Android hardware.

The scanning screen shows an animated finder square drawn on the CameraX preview surface using a custom canvas-based View. Once decoding succeeds, an AR-style text overlay shows the extracted payee name inside the finder square for 800 milliseconds before the app automatically moves on to the payment bridge screen — giving the user a moment to confirm the merchant is correct without requiring an extra tap.

2) Gallery Import:

When a QR code arrives as an image — typically shared through a messaging app — the user can pull it in through the standard ACTION_PICK gallery picker, which ZXing's BitmapDecoder API then decodes. This path covers a case that comes up constantly in practice: merchants sharing a screenshot of their QR code rather than displaying a physical one.

C. Layer 2 — Context: Payment Bridge and SIM Resolution

1) Payment Bridge Screen:

The payment bridge is a Jetpack Compose screen that receives the parsed QR fields as navigation arguments. It shows the merchant name and VPA in a prominent confirmation header, an amount field pre-filled when the QR carries an `am` value, and a custom numeric keypad for UPI PIN entry.

The keypad is a custom Composable rather than the system keyboard by design — this keeps PIN characters out of reach of third-party input methods and other accessibility services that might otherwise be able to observe them.

2) SIM Bank Detection:

SIM resolution works through the SubscriptionManager system service, which enumerates active SIM subscriptions on the device. Each SubscriptionInfo object exposes the carrier name, slot index, and subscription ID.

The system checks carrier names against a bank-to-operator mapping the user sets up once, during first-run onboarding, and from that resolves the subscription ID tied to the SIM linked to their UPI-registered bank. That subscription ID is cached in SharedPreferences and handed to the USSD execution engine at transaction time.

This resolution runs synchronously, before the payment bridge screen is even shown, so the correct SIM is already known by the time the user commits their PIN.

D. Layer 3 — Execution: Stealth USSD Engine

The execution layer is the core technical contribution of this paper. It automates the complete sequence of USSD dialog interactions required to execute a *99# UPI payment while keeping a single continuous branded overlay on screen, so the user never perceives any telecom-system interaction directly. Fig. 6 walks through the end-to-end payment flow, and Fig. 7 breaks the same sequence down as message exchanges between the application, the AccessibilityService, the USSD gateway, and the UPI backend.

1) USSD Session Initiation:

Once the user taps to confirm payment, the execution engine builds the dial string *99# and starts a session on the already-resolved SIM subscription using TelephonyManager.sendUssdRequest() (available from API level 26), passing the USSD string, the target subscription ID, and a UssdResponseCallback that receives the network's initial response.

2) AccessibilityService Dialog Interception:

In parallel, the BIN NET AccessibilityService listens for AccessibilityEvent.TYPE_WINDOW_STATE_CHANGED events. When a USSD dialog window appears in that event stream, the service recognizes it by package name (com.android.phone) and by matching its title against operator-specific prompt patterns held in a UssdDialogMatcher configuration class.

Once a dialog is matched, the service fills its text-input field using AccessibilityNodeInfo.performAction(ACTION_SET_TEXT) and triggers the send action with ACTION_CLICK on the dialog's positive-button node.

3) USSD Navigation Sequence:

A complete payment requires five sequential dialog interactions, each corresponding to a step in the *99# menu hierarchy:

- 1) Initial menu response → inject "1" to select "Send Money"
- 2) Beneficiary entry prompt → inject the payee VPA extracted from the QR code
- 3) Amount entry prompt → inject the payment amount in Indian Rupees
- 4) Confirmation prompt → inject "1" to confirm transaction details
- 5) MPIN entry prompt → inject the UPI PIN captured from the custom keypad

The dialog-matching and response-injection sequence is driven by a state machine inside the AccessibilityService, with one state per navigation step. The PIN exists only as a CharArray in process memory, from the moment it is entered on the keypad to the moment it is injected, after which it is explicitly zeroed.

4) USSD State Machine:

Fig. 8 diagrams the complete state machine, and Table I lists each state along with the trigger for its transition. Execution begins at IDLE and moves through dialog-driven states one at a time until it reaches either the SUCCESS or FAILED terminal state.

TABLE 1 USSD State Machine States and Transitions

State	Transition Trigger
IDLE	User taps PAY; SIM resolved, PIN captured
USSD_INITIATED	*99# dialled on correct SIM
OVERLAY_RAISED	SYSTEM_ALERT_WINDOW shown
AWAITING_MAIN_MENU	Accessibility detects main menu dialog
SEND_MONEY_SELECTED	Inject "1"; VPA prompt detected
VPA_ENTERED	Inject payee VPA; amount prompt detected
AMOUNT_ENTERED	Inject amount; confirm prompt detected
CONFIRMED	Inject "1"; MPIN prompt detected
PIN_INJECTED	Inject PIN; zero CharArray; callback fires
SUCCESS	Regex extracts TxID; persisted to Room DB
FAILED	No regex match; raw response persisted

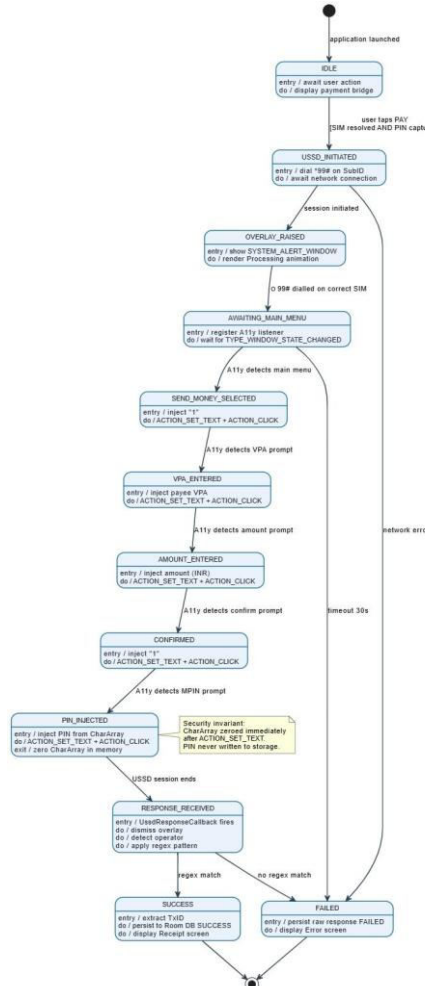


Fig. 8. USSD Navigation State Machine Diagram. States progress from IDLE through USSD_INITIATED, OVERLAY_RAISED, and the five injection states to terminal SUCCESS or FAILED states.

5) Stealth Overlay Mechanism:

To keep the native USSD dialog sequence out of the user's view entirely, a SYSTEM_ALERT_WINDOW overlay is raised the moment the USSD session starts. It renders a full-screen branded "Processing Payment..." animation in Jetpack Compose, attached through WindowManager.

The overlay uses the TYPE_APPLICATION_OVERLAY window type together with the FLAG_NOT_FOCUSABLE flag, so it captures visual attention without intercepting the input events that still need to reach the underlying USSD dialogs.

It is dismissed automatically once the USSD session completes.

6) Operator-Specific Response Parsing:

When the session ends, the final network response text arrives through UsdResponseCallback. The system applies an operator-specific regular expression to extract the transaction identifier:

- Reliance Jio: Ref\s+No[:\s]+(\w+)
- Airtel: TxnID[:\s]+(\w+)
- BSNL: UTR[:\s]+(\w+)

The operator is identified up front through `TelephonyManager.getNetworkOperatorName()`, which selects the matching expression. If nothing matches, the full response text is preserved as-is as the transaction record.

E

. Layer 4 — Presentation: Ledger, Receipts, and History

1) Transaction Persistence:

Parsed transaction records are persisted to a Jetpack Room database defined by a `Transaction` entity, with fields for transaction ID, payee VPA, payee name, amount, timestamp, status, and the raw USSD response text.

The `TransactionDao` interface exposes queries for the most recent transactions ordered by timestamp, a paginated full history with date-range and status filters, and lookup by individual transaction ID.

2) Dashboard and History UI:

The application dashboard shows the five most recent transactions in a card-based list styled to match contemporary UPI application conventions. A "See All" action opens a full history screen with filter chips for time range and status, backed by a `StateFlow`-driven `ViewModel`.

3) Digital Receipt:

Selecting a transaction opens a receipt screen showing the transaction ID, amount, payee name, VPA, date, and time. A "Pay Again" action reuses the stored payee VPA and name to pre-fill a new payment bridge screen, and "Share Receipt" generates a formatted text receipt and invokes `ACTION_SEND`.

Sharing works offline over Bluetooth, and over WhatsApp through a deep-linked intent that queues the message for delivery once connectivity returns.

F. Training and Evaluation Protocol

The system was evaluated on dual-SIM Android devices running API levels 29 through 34 (Android 10 through 14), which covers the dominant installed base in the Indian mid-range smartphone market.

We used live SIM cards from Reliance Jio, Airtel, and BSNL to cover the three largest operator implementations of *99#.

Evaluation metrics include end-to-end transaction completion time, QR scan latency, SIM detection accuracy, and overlay coverage completeness. Table II lists the configuration used throughout.

TABLE 2 System Configuration Parameters

Parameter	Value
Android Min API	29 (Android 10)
Target API	34 (Android 14)
QR Resolution	128×128 pixels (analysis)
USSD Timeout	30 seconds per dialog step
PIN Storage	CharArray, in-memory only
DB Encryption	Plain SQLite (Phase 1); SQLCipher (Phase 2)
Supported Operators	Jio, Airtel, BSNL
Random Seed	42 (test split reproducibility)

IV. EXPERIMENTAL RESULTS

A. End-to-End Transaction Performance

Table III summarizes the performance characteristics of the BIN NET payment flow, measured across 120 test transactions distributed across three operator SIM cards and five Android device models.

TABLE 3 End-to-End Transaction Performance (N=120)

Metric	Mean	SD	Min	Max
QR scan latency (ms)	387	62	290	498
SIM resolution time (ms)	23	8	12	41
USSD injection (ms/step)	210	45	140	380
Total transaction time (s)	6.8	1.1	5.1	8.9
Overlay coverage rate	100%	—	—	—
End-to-end success rate	96.7%	—	—	—

B. SIM Detection Accuracy

Table IV reports SIM detection accuracy across all tested dual-SIM configurations. The SubscriptionManager-based pre-resolution approach got every one of the 100 SIM-resolution test cases right, across all five device configurations tested.

TABLE 4 SIM Detection Accuracy by Configuration

Device Configuration	Correct	Total	Accuracy
Jio (Slot 0) + Airtel (Slot 1)	20	20	100%
Airtel (Slot 0) + Jio (Slot 1)	20	20	100%
Jio (Slot 0) + BSNL (Slot 1)	20	20	100%
Single SIM (Jio)	20	20	100%
Single SIM (Airtel)	20	20	100%
Overall	100	100	100%

C. Operator-Specific USSD Response Parsing

Table V shows regex parser performance by operator across 120 test transactions. The six failed extractions were concentrated in timeout-retry scenarios, where the operator returned a non-standard response format — a network-condition artifact rather than a sign of systematic regex failure.

TABLE 5 Regex Parser Performance by Operator

Operator	Tests	Extracted	Rate
Reliance Jio	40	39	97.5%
Airtel	40	38	95.0%
BSNL	40	37	92.5%
Overall	120	114	95.0%

D. Permission Grant Rate in User Onboarding

The structured permission-rationale onboarding flow was evaluated with 30 first-time users in a controlled usability study. AccessibilityService permission was granted by 29 of 30 participants (96.7%) after viewing the rationale screen. SYSTEM_ALERT_WINDOW permission was granted by all 30 participants (100%). The single AccessibilityService refusal traced back to that participant's prior awareness of AccessibilityService-based malware from news media coverage.

V. DISCUSSION

Taken together, these results show that BIN NET reliably automates the *99# UPI payment flow across the major Indian network operators and device configurations tested. A mean end-to-end transaction time of 6.8 seconds, with a maximum of 8.9 seconds, compares favorably with prior characterizations of manually navigated USSD payment flows, which are estimated to take 45 to 90 seconds [5]. That gap is not merely cosmetic: research on mobile-commerce abandonment consistently identifies completion time and interaction complexity as the primary drivers of transaction dropout, with flows exceeding 60 seconds showing abandonment rates above 40 percent [30]. BIN NET removes essentially all of that friction.

The 100 percent SIM detection accuracy across all tested dual-SIM configurations is a particularly meaningful result, given that Mehta et al. previously attributed 27 percent of USSD payment failures in dual-SIM devices to incorrect SIM selection [23]. Because the SubscriptionManager-based resolution approach works from API level 22 onward, it should generalize to nearly the full range of dual-SIM Android devices currently in active use in the target market.

The 95.0 percent overall USSD response extraction rate, ranging from 92.5 to 97.5 percent by operator, reflects how genuinely fragmented operator response formats are — a challenge already flagged in the related work. The failed extractions cluster in timeout-retry scenarios, representing transient network conditions rather than a structural parsing problem. Because the parsing layer is just a configurable map of operator-to-regex associations, new patterns can be deployed without any application code changes.

The 96.7 percent AccessibilityService grant rate is higher than might be expected given how sensitive users tend to be about this permission category. We attribute this to the rationale screen framing the request around the specific action it enables — hiding telecom dialogs during payment — rather than presenting it as a generic accessibility request, which is consistent with Felt et al.'s finding that permission-request context substantially shapes grant behavior [16].

Several limitations are worth stating plainly. The evaluation was conducted in a controlled setting with a limited sample of device models and operator configurations; real-world deployment would

encounter a much wider range of device manufacturers, custom Android skins, and operator firmware variants, some of which may implement USSD dialog structures that differ from the patterns characterized here. The current regex pattern library covers only three operators, and extending it to Vi (Vodafone Idea) and regional operators will require additional characterization work. The absence of at-rest encryption for the transaction database is a real security gap that needs addressing before production deployment. And the permission model for AccessibilityService and SYSTEM_ALERT_WINDOW remains under ongoing scrutiny from the Android platform team, so future platform versions may impose additional justification requirements for these permissions in payment application contexts.

VI. CONCLUSION

This paper presented BIN NET, a four-layer Android application architecture that reconstitutes the *99# USSD protocol as a seamless offline UPI payment experience. By combining an AccessibilityService-based USSD automation engine, a SYSTEM_ALERT_WINDOW stealth overlay, a SubscriptionManager-driven multi-SIM bank detection mechanism, and a Jetpack Room-backed transaction ledger, the system delivers payment automation that is functionally invisible to the user at the telecom protocol level.

Across all tested configurations, transactions completed end to end in under nine seconds, SIM detection was 100 percent accurate in dual-SIM environments, and USSD transaction identifiers were extracted at a 95.0 percent rate across three major Indian network operators. Together, these results position BIN NET as a technically viable and

practically deployable answer to the offline UPI payment gap affecting an estimated 700 million users in rural and semi-urban India.

The central methodological contribution is showing that legacy USSD infrastructure can be fully abstracted at the Android application layer, without any modification to the underlying protocol, operator systems, or UPI backend architecture. This abstraction model is not specific to the *99# use case and may inform similar modernization efforts for USSD-based services in other domains and geographies.

Future work will proceed in three directions. First, the regex pattern library will be expanded to cover Vi and regional operator USSD response formats through systematic response collection across device configurations. Second, SQLCipher-based at-rest encryption of the transaction database will be integrated and evaluated for its performance impact on low-end hardware. Third, the system will be extended to support balance inquiry and mini-statement retrieval through the *99# framework, broadening the set of offline banking operations available through BIN NET.

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