A Decentralized Screenless Mobile: Mesh-First Connectivity, DTN Resilience, and Self-Sovereign Identity

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Abstract—This paper presents the design of a decentralized, screenless mobile device that prioritizes proximity mesh links (Wi-Fi Aware/NAN), efficient voice transport (Bluetooth LE Audio/LC3), and long-range, low-power links (LoRa) with Delay/Disruption-Tolerant Networking (DTN) for store-and-forward, secured end-to-end with decentralized identifiers (DIDs) and Matrix-style cryptography. Inspired by mesh telephony deployments (Serval, Village Telco) and recent screenless assistants, the architecture addresses usability and resilience via local-first design, E2E encryption, and opportunistic federation. We detail hardware/software stack, interaction model, security, energy considerations, and an evaluation plan, and include implementable diagrams suitable for IEEE figures.

Index Terms—Decentralized mobile, mesh telephony, Wi-Fi Aware, LE Audio LC3, LoRa, DTN, DIDs, Matrix, wearable HCI.

1 Introduction

Screenless wearables illustrate the promise of voice-first mobility and the pitfalls of cloud dependence, motivating a local-first, decentralized rethink of the "phone" without a display. Community mesh telephony projects (Serval, Village Telco) demonstrated infrastructure-free calling and messaging in disasters and underserved regions using ad-hoc Wi-Fi and mesh relays. DTN and decentralized identity complete the resilience and trust story by enabling eventual delivery across disruptions and portable authentication without centralized accounts.

2 Background and Related Work

2.1 Mesh telephony and Serval / Village Telco

Serval integrated device-to-device calling over Wi-Fi with store-and-forward (Rhizome) and mesh extenders. Village Telco validated VoIP over community WLAN mesh with satisfactory QoS and adoption metrics.

2.2 Delay/Disruption-Tolerant Networking (DTN)

DTN's Bundle Protocol decouples endpoints in space and time and supports store-and-forward across intermittent links.

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2.3 Decentralized Identity and Matrix

W3C DIDs enable self-sovereign identifiers and verifiable credentials; Matrix provides decentralized, federated, end-to-end encrypted messaging suited for opportunistic federation when IP is available.

3 System Goals

The system goals are:

- Connectivity independent of infrastructure (mesh first).
- Graceful degradation under disruption (DTN store-and-forward).
- Privacy-preserving identity and messaging without centralized accounts (DIDs + Matrix).
- Audio/haptic-first interaction (LE Audio/LC3 for low bitrate voice).
- Modular radios and low energy footprint by omitting a display.

4 System Architecture

4.1 Hardware

An always-on low-power MCU handles wake-word and sensor gating; an application SoC runs networking and inference. Audio I/O includes far-field microphones and speaker or bone conduction; haptics provide private feedback. Radios: Wi-Fi Aware (NAN), BLE (LE Audio / LC3), and LoRa for sparse backhaul.

4.2 Software and Protocol Stack

Proximity discovery uses Wi-Fi Aware/NAN; when IP is present Matrix-style E2E messaging is used; DTN bundles provide store-and-forward spanning LoRa and other intermittent links. Identity and authentication rely on DIDs with signed DID Documents.

5 Interaction Model

The device is voice/haptics-first: wake-word, spoken confirmations, and tactile cues. LE Audio/LC3 improves intelligibility at low bitrates, lowering airtime and power. Nonvisual controls use tactile patterns for discreet notifications and mode switching. Context disambiguation leverages wearable HCI techniques for audio-only outputs.

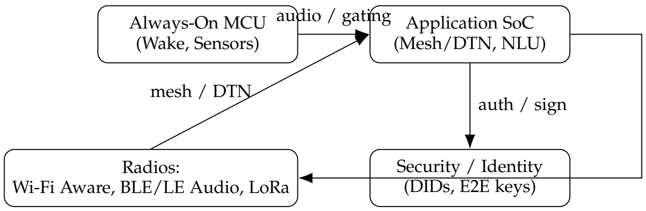

Fig. 1: System block diagram (compact, improved layout to prevent overlapping labels).

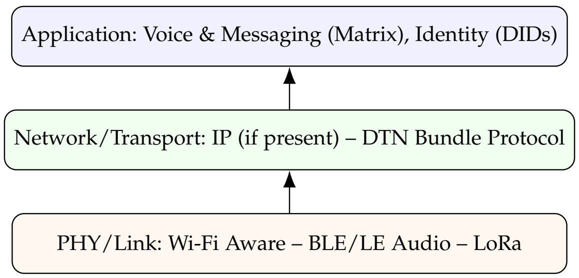

Fig. 2: Protocol stack diagram (improved spacing and readability).

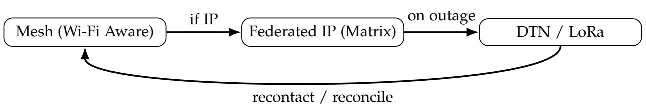

Fig. 3: Mode state transitions (compact).

6 Security and Privacy

Identity and trust are anchored in W3C DIDs with signed DID Documents and verifiable credentials; peers verify control and rotate keys without centralized registries. For messaging over IP, Matrix federation with E2E encryption prevents intermediaries from reading content while allowing self-hosted homeservers. Hardware privacy controls include physical mic mute and capture-LED transparency.

7 Mode State Machine

Prefer mesh (Wi-Fi Aware) for discovery and low-latency sessions; use federated IP via Matrix when reachable; fall back to DTN bundles over LoRa and queue for recontact. Reconciliation happens on recontact.

8 Energy Considerations

Displays dominate smartphone power in many modes; omitting the display improves endurance. LE Audio/LC3 reduces bitrate for comparable quality and improves packet loss resilience, lowering radio duty cycle. Opportunistic DTN transfers on LoRa shift background sync to ultra-low-throughput windows, with ADR balancing reliability and energy.

9 Proposed Solutions

9.1 Mesh-First Communication

Default to Wi-Fi Aware proximity sessions for discovery, signalling and data; form clusters that maintain calling/messaging functionality without APs.

9.2 DTN Store-and-Forward

Use Bundle Protocol overlay to queue and relay messages and voice snippets across partitions ensuring eventual delivery.

9.3 Sovereign Identity & E2E

Adopt DIDs for authentication and Matrix E2E for confidentiality in federated modes to avoid centralized account dependency.

10 Implementation Plan

Phase 1: Android-class prototype using Wi-Fi Aware APIs, BLE/LE Audio and external LoRa for DTN validation. **Phase 2:** Integrate DID libraries and Matrix clients for peer auth, E2E messaging and optional federation. **Phase 3:** Field trials mirroring Serval/Village Telco community meshes and disaster exercises.

11 Evaluation Methodology

Connectivity: delivery ratio, time-to-deliver, path diversity under induced disruptions comparing mesh-only, DTN-over-mesh, and federated modes. Energy: standby and active power with/without voice sessions; quantify savings from eliminating displays and adopting LC3. Usability: task completion, error rates, and subjective workload for voice/haptic tasks.

12 Limitations

LoRa's low rate constrains rich media and mandates prioritization of signaling, text and compressed summaries. Wi-Fi Aware support varies by chipset and OEM. Screenless interactions face discoverability challenges.

13 Future Work

On-device speech and compact edge LLMs for offline NLU/NLG; multi-radio policy learning to select among radios based on context; community deployment toolkits and governance models.

14 Conclusion

Combining mesh-first Wi-Fi Aware, DTN, and sovereign identity with Matrix E2E and a voice/haptics interaction model enables a decentralized, screenless mobile that preserves privacy, degrades gracefully, and improves energy endurance by omitting the display.

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