HACK4DELHI

Pitch Directly to the Government. Build for the Nation.

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The Shadow Brokers

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PROBLEM STATEMENT

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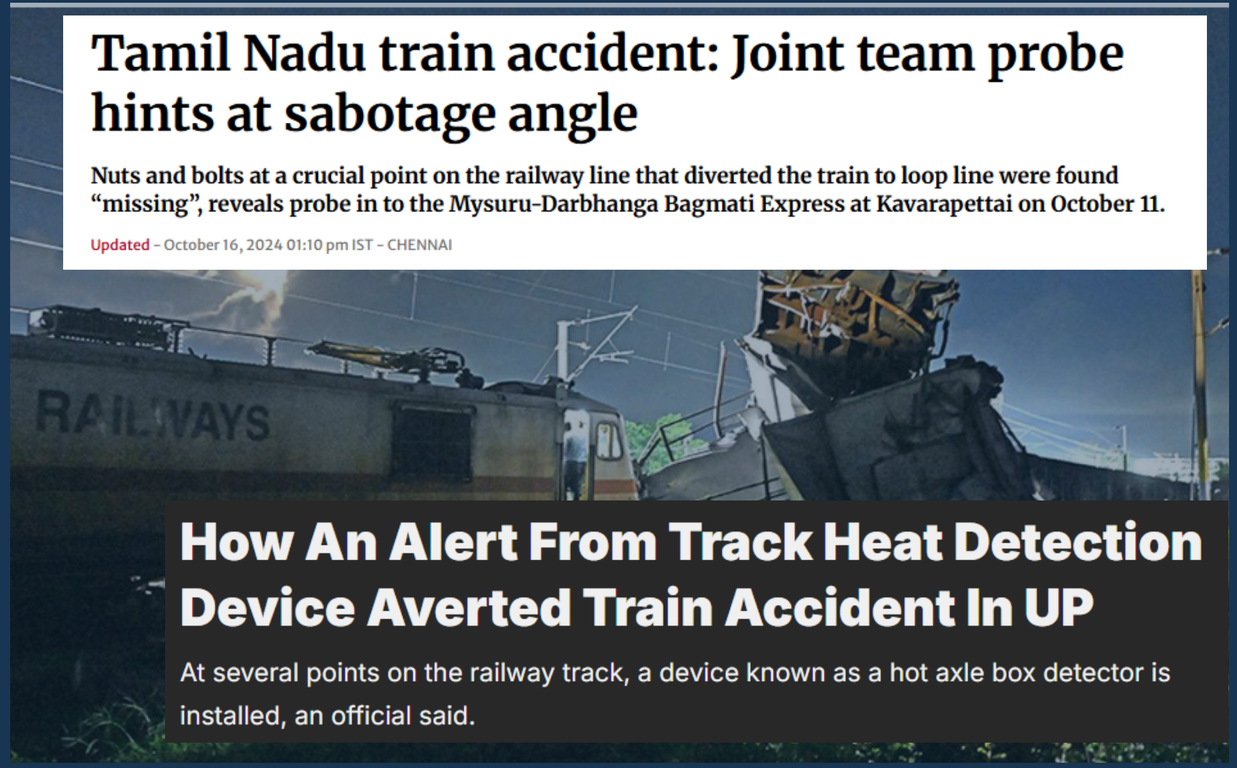
Railway tracks are critical national infrastructure, yet remain physically exposed to intentional tampering such as rail cutting, bolt/fishplate removal, and track obstruction. These incidents usually occur in remote or unmanned sections, at **night or low-visibility between manual patrol intervals**.

Why current systems fail:

- Manual patrols are infrequent and human-dependent
- CCTV systems are high-power, bandwidth-heavy, and weak at night
- Drones provide periodic, weather-dependent monitoring
- Track circuits detect faults, not tampering intent
- Single-sensor setups cause false alarms from rain, animals, or trains

As a result, tampering is often detected only after a derailment or near-miss, making today's response reactive instead of preventive.



This Problem Must Be Solved

- **Safety:** Prevent derailments and loss of life
- **Security:** Railway tracks are soft targets for sabotage
- **Economic Impact:** Avoid massive service disruption & repair costs
- **Scalability:** Thousands of kilometers cannot be manually monitored

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SOLUTION

- Decentralized, AI-powered IoT system for real-time detection of intentional track tampering
- Detects the act of tampering, not post-damage failure
- Designed for remote, low-power, large-scale railway deployment

Track Sensors
(Vibration + Audio + Magnetic + Tilt)
↓
Edge AI (TinyML on ESP32)
• Filters trains/weather
• Detects tool signatures
↓
3-Stage Lock Verification
(Vibration + Audio + Magnetic)
↓
Secure Transmission (MQTT over LoRa / LTE)
↓
Central AI Validation (FastAPI)
↓
Real-Time Alert + Evidence Dashboard

Problem	Our Solution
False alarms from rain/animals	Multi-sensor “3-Stage Lock”
Late detection (after derailment)	Detects sawing/hammering in real time
No visibility for officials	Evidence-backed alerts
Remote areas lack connectivity	LoRa + buffering + burst upload
High power CCTV systems	Wake-on-threat, 90% power saving
Drones provide only periodic & weather-dependent surveillance	Ground-mounted, weather-independent sensors
Manual patrols are infrequent & human-dependent	Continuous automated monitoring (24×7)
Track circuits detect faults, not intent of tampering	Intent-aware sensing using vibration + acoustic patterns

Layer	Innovation
Edge	TinyML + FFT on ESP32 (no raw streaming)
Logic	Multi-modal intent detection
Power	Sleep 99%, wake only on threat
Cost	~₹5,200 per node (scalable nationwide)

A practical, low-cost AI system that prevents railway sabotage instead of investigating accidents.

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ARCHITECTURE

1. Edge Layer (On-Track Node)
(ESP32 + Sensors)
Sensors collect:
• Vibration + Audio + Magnetic + Track Tilt

FFT + TinyML classify:
- Normal activity (train, weather)
- Abnormal activity (tampering)

Only suspicious events move forward

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2. Messaging & Communication Layer
MQTT Publish (QoS-1)
Topic: railway/track_id/data

Reliable delivery using:
- QoS Level 1
- Local FIFO buffering
- Burst transmission after reconnection

↓

Publish–Subscribe Model (MQTT)
- Sensor nodes publish data to topics
- Backend subscribes to all track events
- Decoupled, scalable, fault-tolerant

Time Accuracy
- NTP synchronization on ESP32
- Timestamps generated at event time, not upload time

Data Integrity
- FIFO buffering during network loss
- Burst transmission after reconnection
- QoS Level 1 ensures alert delivery
- Unique message IDs prevent duplicate alerts

- **Edge-first AI** → low latency, low bandwidth
- **MQTT + buffering** → works in remote rail sections
- **Time-series DB** → accurate forensic analysis
- **WebSocket alerts** → instant operational response

3. Cloud & Processing Layer
MQTT Broker receives events
(Mosquitto / HiveMQ)
↓
Backend API
(Python FastAPI)
- Performs multi-sensor AI fusion
- Validates tampering confidence
- Generates structured alerts

↓

Data storage:
• InfluxDB (sensor data)
• PostgreSQL (alerts)

↓

4. Control Room Layer
React.js dashboard
WebSocket-based live alerts
(React.js + WebSockets)
Displays:
- Alert location
- Severity
- Sensor evidence
- Timeline of events

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TECHNOLOGY USED

Edge & Sensing Technologies

Component	Technology	Contribution
Edge Controller	ESP32 / STM32	Low-power edge processing, deep sleep, supports on-device AI
Vibration Sensor	ADXL345	Detects cutting, hammering, abnormal rail vibrations
Audio Sensor	INMP441	Identifies grinder / hacksaw acoustic signatures
Magnetic Sensor	HMC5883L	Detects bolt or metal removal (silent tampering)
Edge Intelligence	TinyML + FFT	Local anomaly detection, reduces latency & bandwidth

Visualization & Alerts

Layer	Technology	Contribution
Frontend	React.js + Tailwind CSS	Fast, responsive control-room dashboard
Live Alerts	WebSockets (Socket.io)	Instant alert delivery without page refresh

Communication & Backend Technologies

Layer	Technology	Contribution
Communication	MQTT (LoRaWAN / Wi-Fi / LTE)	Lightweight, scalable, reliable in unstable networks
Message Broker	Mosquitto / HiveMQ	Decouples sensors and backend, supports large-scale deployment
Backend API	Python (FastAPI)	High-performance async processing & AI integration
Real-Time DB	InfluxDB	Efficient storage of high-frequency sensor data
Operational DB	PostgreSQL	Stores alerts, node metadata, system logs

The tech stack is optimized for low power, real-time detection, scalability, and deployment in remote railway environments.

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FEATURE/USP

The "False Alarm" Solution

- Doesn’t rely on single sensor
- Alert is generated if all sensors agree

Actionable Intelligence

- Existing dashboards show blinking red dot on map
- Our dashboard delivers proof, not just problems

The "Sleepy Sentinel" Power Architecture

- CCTV requires massive power and expensive cables.
- Our high-power sensors wake up for 10 seconds, when the low-power vibration sensors detect anomaly.

Tamper-Proof" Security

- Criminals cut the wires of security systems.
- Even if the device is destroyed, the circuit sends a final distress signal.
- Magnetic sensor detects if the track components(bolts / fishplates) are removed

Feature	Standard Competitor	Solution
Detection Method	Vibration Only (Single Modality)	**Quad-Fusion (Vibration + Audio + Mag + Vision)**
Verification	None (Guesswork)	**Visual & Audio Proof** included in alert
Power Source	Grid / Heavy Solar	**Micro-Solar / Battery** (Sleep Mode Focus)
Connectivity	High Bandwidth (Fiber/4G)	**Low Bandwidth (LoRa)** + 4G Burst
False Alarms	High (Weather/Animals)	**Near Zero** (Cross-validated)

Cost-to-Coverage Ratio

- Fiber optic sensing (DAS) costs millions per kilometer, while patrolmen are expensive and slow.
- Using mass-produced MEMS sensors, per-node cost of ~₹5,200 ($60) achieved.

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REFERENCES/LINKS

- **AI-powered TrackEi™ (L&T Technology Services):** High-speed, AI-enabled rail inspection using cameras and laser profiling for real-time defect detection and maintenance planning.
- **Track Geometry Cars:** Sensor-equipped inspection vehicles widely used for automated track measurement (alignment, twist, gauge) without disrupting operations.
- **Track IQ (Wabtec):** Multi-sensor systems (acoustic & condition monitors) deployed globally to detect wheel/track faults, showing industry adoption of sensing-based safety.
- **Academic sensor+ML works:** Machine learning applied for obstacle & crack detection on tracks using camera and IoT sensor data.
- **IoT-Enabled Railway Track Crack Detection System**: Presented at the International Conference on Innovative Computing & Communication, this research integrates IoT sensors along the track to detect cracks and anomalies in real time.

Github: https://github.com/thesurajarya/hack4delhi.git


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THANK YOU