Client Centric WiFi RRM

INTER IIT TECH MEET 14.0

System Design and Implementation

Team 33

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1 Project Overview: RRM-Plus

The core objective of this system is to address the limitations of historical Radio Resource Management (RRM), which relies on lagging and partial AP-side observations. We have implemented an **AI-assisted, client-aware RRM system** that utilizes Arista's dedicated additional radio for continuous environmental visibility without sacrificing serving capacity.

The system architecture is divided into five core modules, visualized and managed through a central dashboard powered by specific APIs defined in our mid-term design. Each module addresses a critical aspect of client-centric radio resource management, from environmental sensing to safe execution with production guardrails.

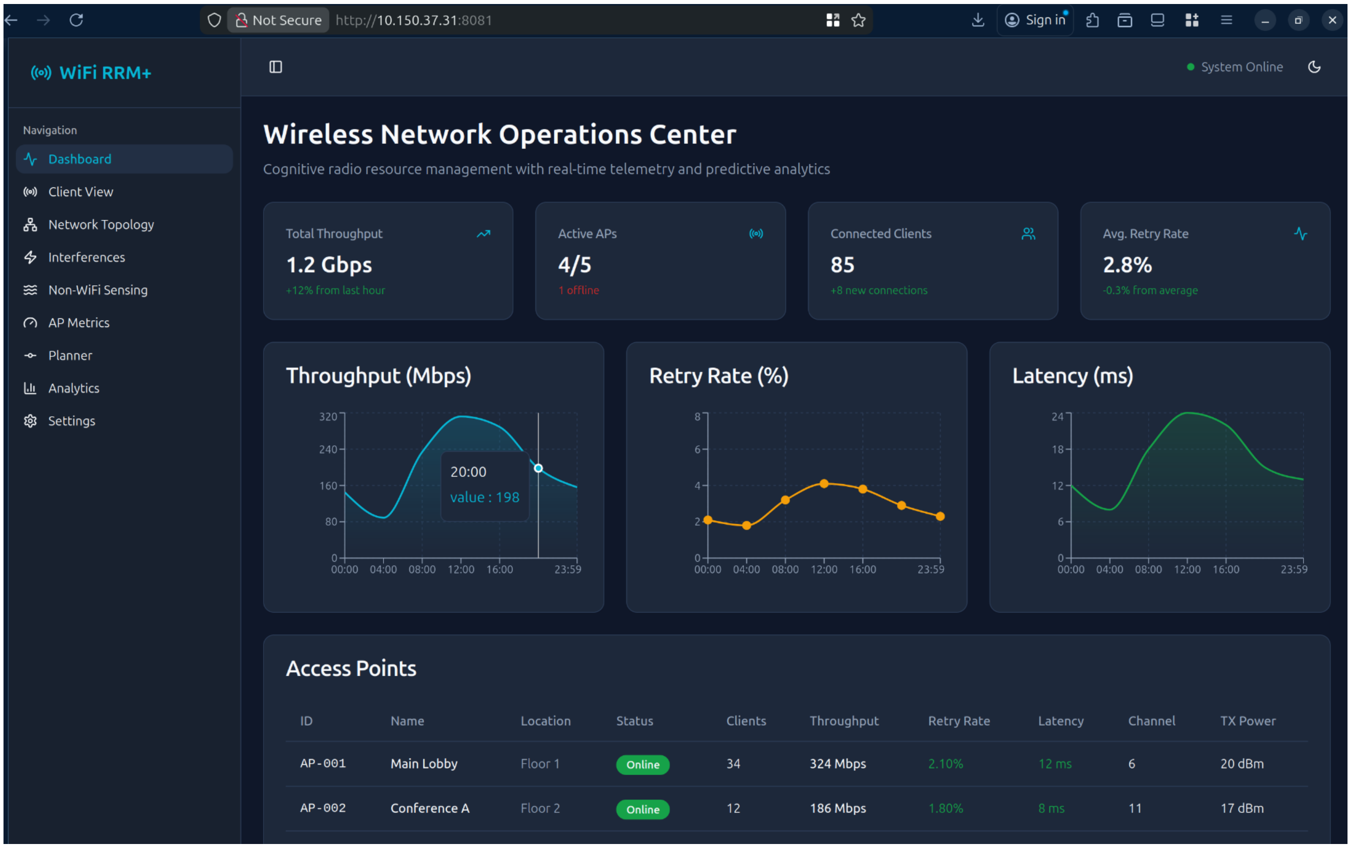

Figure 1: Enter Caption

2 Environmental Sensing and Classification

This module leverages the dedicated scanning radio to build a high-fidelity view of the RF environment. Unlike traditional periodic scanning, this allows for continuous monitoring without impacting client-serving capacity.

2.1 API Endpoint

Endpoint: `/sensing`

2.2 Core Capabilities

2.2.1 Spectrum Intelligence

The system ingests scan data from the additional radio to detect interference and perform adaptive dwelling. This continuous sensing capability ensures we catch short-burst interference that infrequent scans often miss, operating with zero impact on client serving capacity and adhering to strict airtime cost limits (e.g., $< 2\%$).

2.2.2 Non-Wi-Fi Classification

We utilize a lightweight classifier (CNN/feature-engine) to identify non-Wi-Fi sources such as:

- Bluetooth Low Energy (BLE)
- Zigbee devices
- Microwave ovens
- FHSS devices

2.2.3 Metric Visualization

The dashboard displays the following interferer characteristics:

- **Duty Cycle**: Percentage of time the channel is occupied
- **Center Frequency**: Primary frequency of interference
- **Bandwidth**: Spectral width of the interfering signal

Table 1: Sensing Module Key Metrics

Metric	Range	Purpose
Duty Cycle	0-100%	Quantify interference impact
Center Frequency	5170-5835 MHz	Identify affected channels
Bandwidth	20-160 MHz	Determine spectral extent
Airtime Cost	$< 2\%$	Ensure negligible overhead

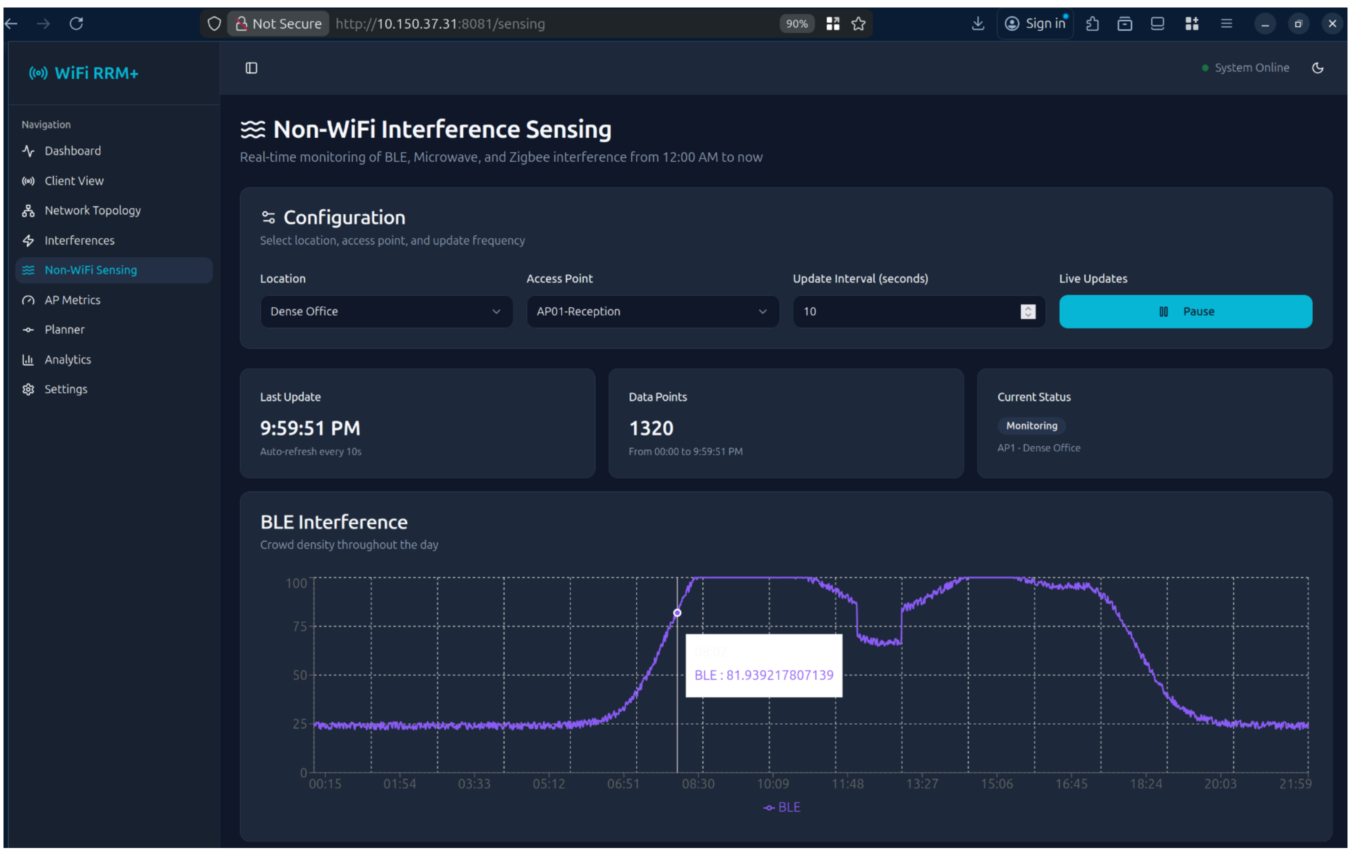

Figure 2: /sensing endpoint for BLE

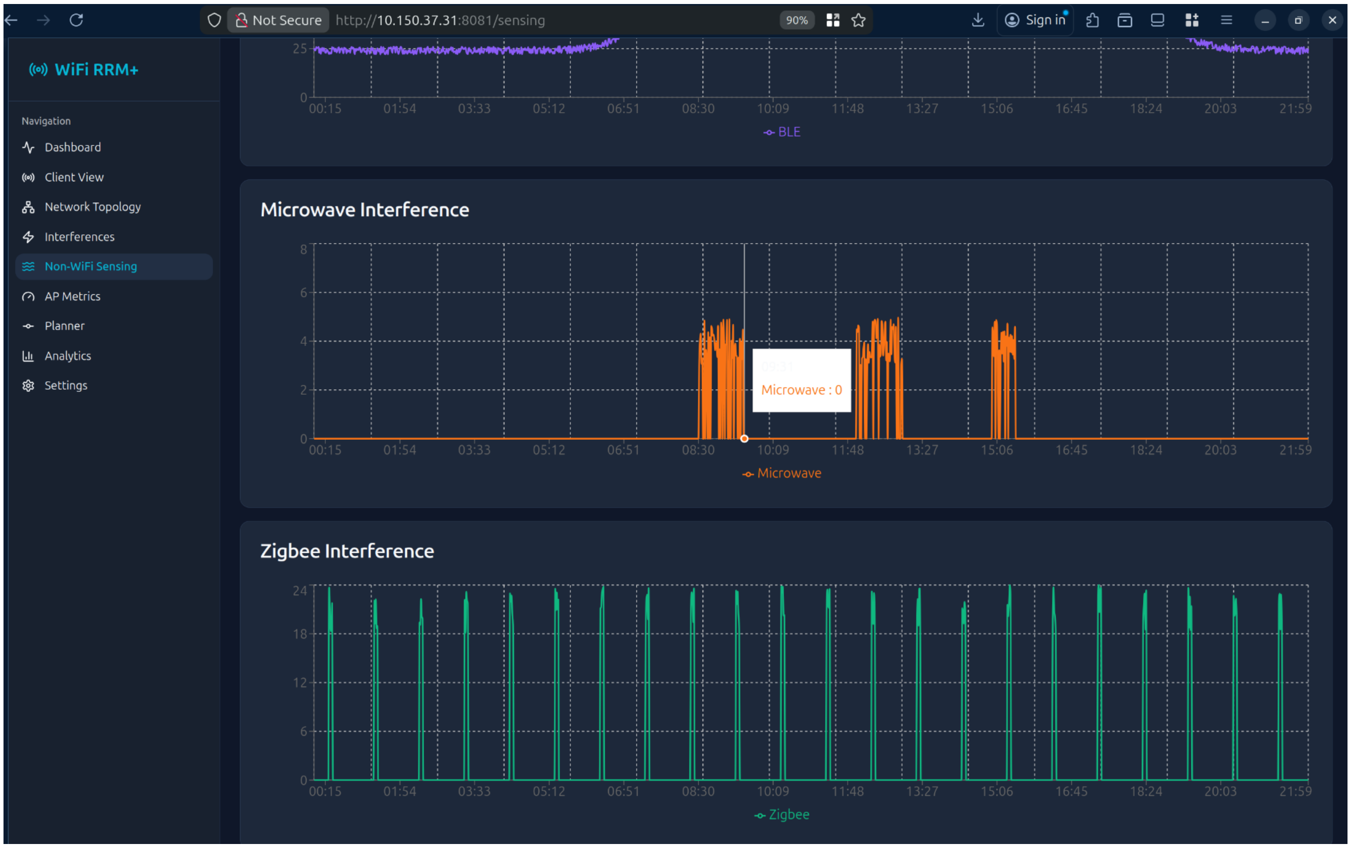

Figure 3: /sensing endpoint for microwave

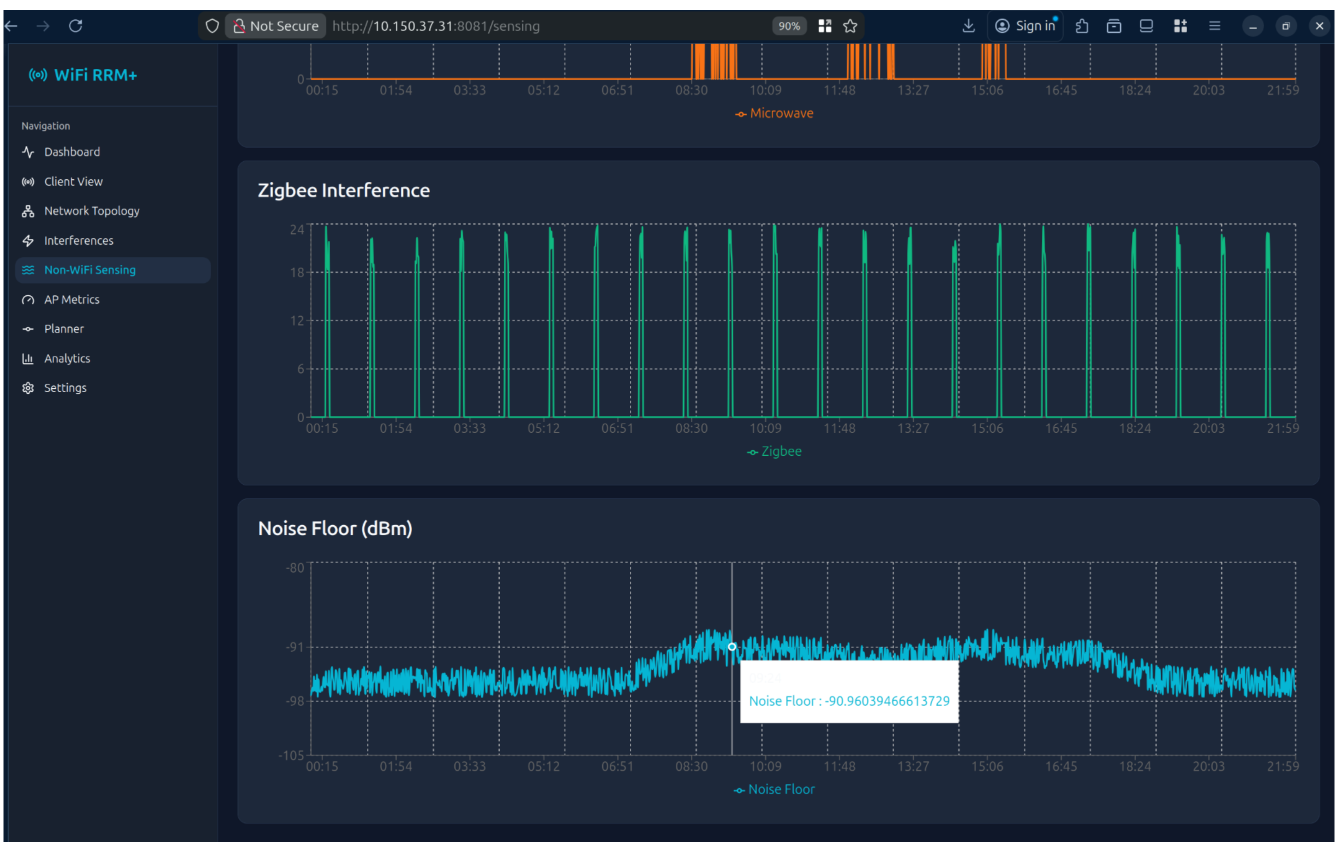

Figure 4: /sensing for Noise Floor

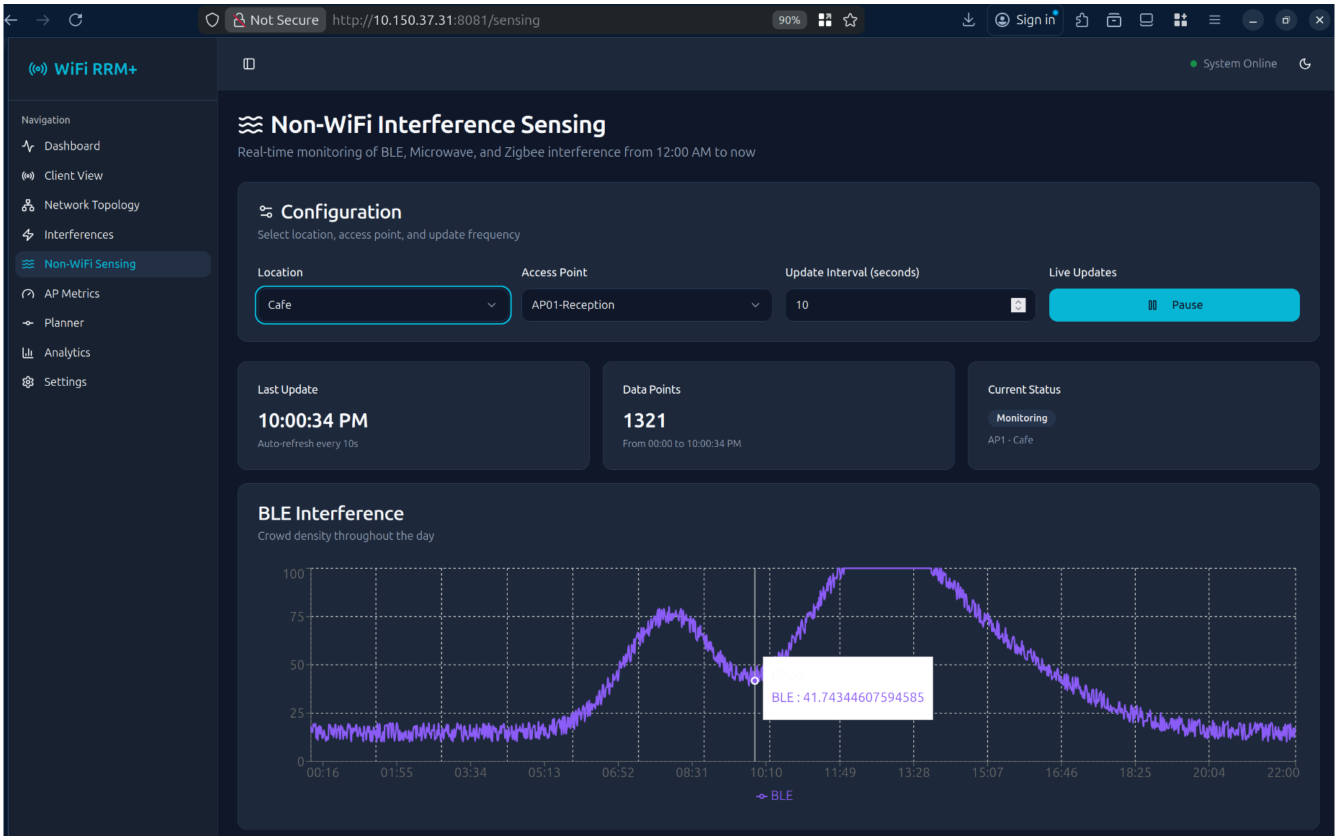

Figure 5: /sensing endpoint

3 Client-View Acquisition and Telemetry

To eliminate the blind spots of AP-centric views, this module aggregates telemetry directly representing the client's experience.

3.1 API Endpoint

Endpoint: `/client_view`

3.2 Core Capabilities

3.2.1 Telemetry Aggregation

The system collects key Quality of Experience (QoE) metrics including:

- **Throughput**: Per-client downlink and uplink data rates
- **Retry Rate**: Proportion of retransmitted frames
- **SNR**: Signal-to-noise ratio at client receiver

3.2.2 Node-Level Granularity

Data is aggregated and displayed per Access Point (AP) node, blending AP observations with client-side telemetry acquired via standards such as 802.11k (Neighbor Reports) and 802.11v (BSS Transition Management).

3.2.3 Blind Spot Elimination

By visualizing these metrics, the system identifies issues like hidden nodes or downlink/uplink asymmetries that the AP alone cannot see.

Table 2: Client-View Telemetry Schema

Metric	Source	Use Case
Throughput	Client reports	Identify edge-client issues
Retry Rate	AP + Client	Detect interference/contention
SNR	Client RSSI	PHY rate optimization
BSS Transition	802.11v	Steering decision validation
Neighbor Reports	802.11k	Build client RF map

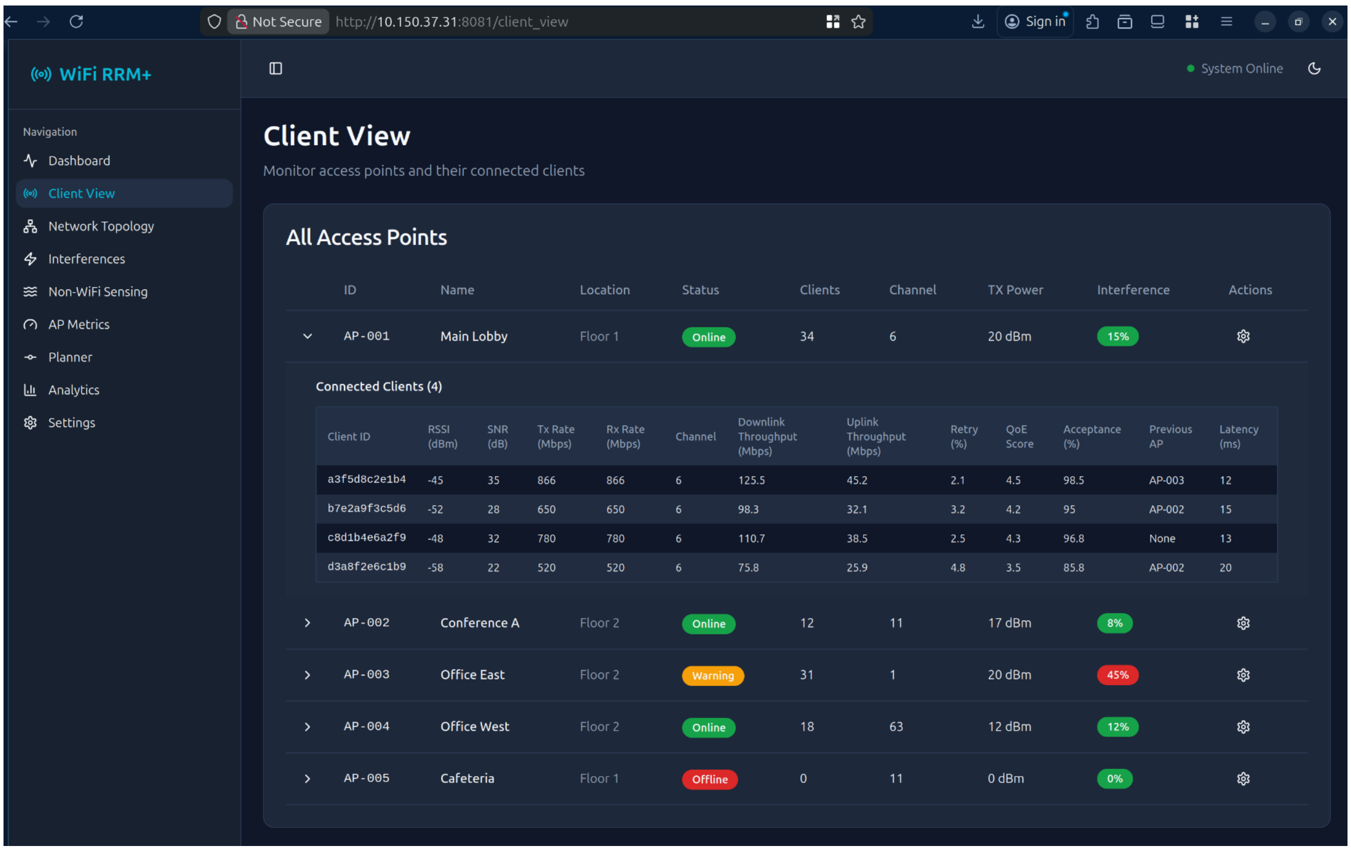

Figure 6: */client view* endpoint

3.2.4 Privacy-Preserving Client ID Hashing

To adhere to strict privacy standards and eliminate Personally Identifiable Information (PII), the system implements Client ID Hashing. Instead of storing raw MAC addresses, the system cryptographically transforms client identifiers into irreversible, unique alphanumeric strings (e.g., `a3f5d8c2e1b4`). This ensures compliance with "No PII" requirements while enabling persistent tracking of historical performance and roaming behavior

4 AI-Driven Planning and Proposal

This is the brain of the RRM-Plus system. It uses the gathered intelligence to propose network configuration changes aimed at optimizing performance.

4.1 API Endpoint

Endpoint: `/planner/propose`

4.2 Core Capabilities

4.2.1 Prediction Model

For every potential change (channel, power, bandwidth), the system logs a **Predicted QoE Delta**, utilizing AI/ML to estimate how much the user experience will improve.

4.2.2 Optimization Goals

The planner targets specific Service Level Objectives (SLOs), such as:

- Maximizing P50 throughput
- Keeping P95 retries $< 8\%$
- Maintaining steering success $> 85\%$

4.2.3 Bayesian Optimization

The underlying logic utilizes offline simulation and limited online Bayesian Optimization (BO) to tune channel width and OBSS-PD thresholds per AP cell.

Table 3: AI Planning Module Parameters

Parameter	**Range**	**Optimization Target**
Channel	36-165	Minimize co-channel interference
Power	1-30 dBm	Balance coverage and interference
Width	20/40/80 MHz	Maximize throughput under load
OBSS-PD	-92 to -52 dBm	Enable spatial reuse

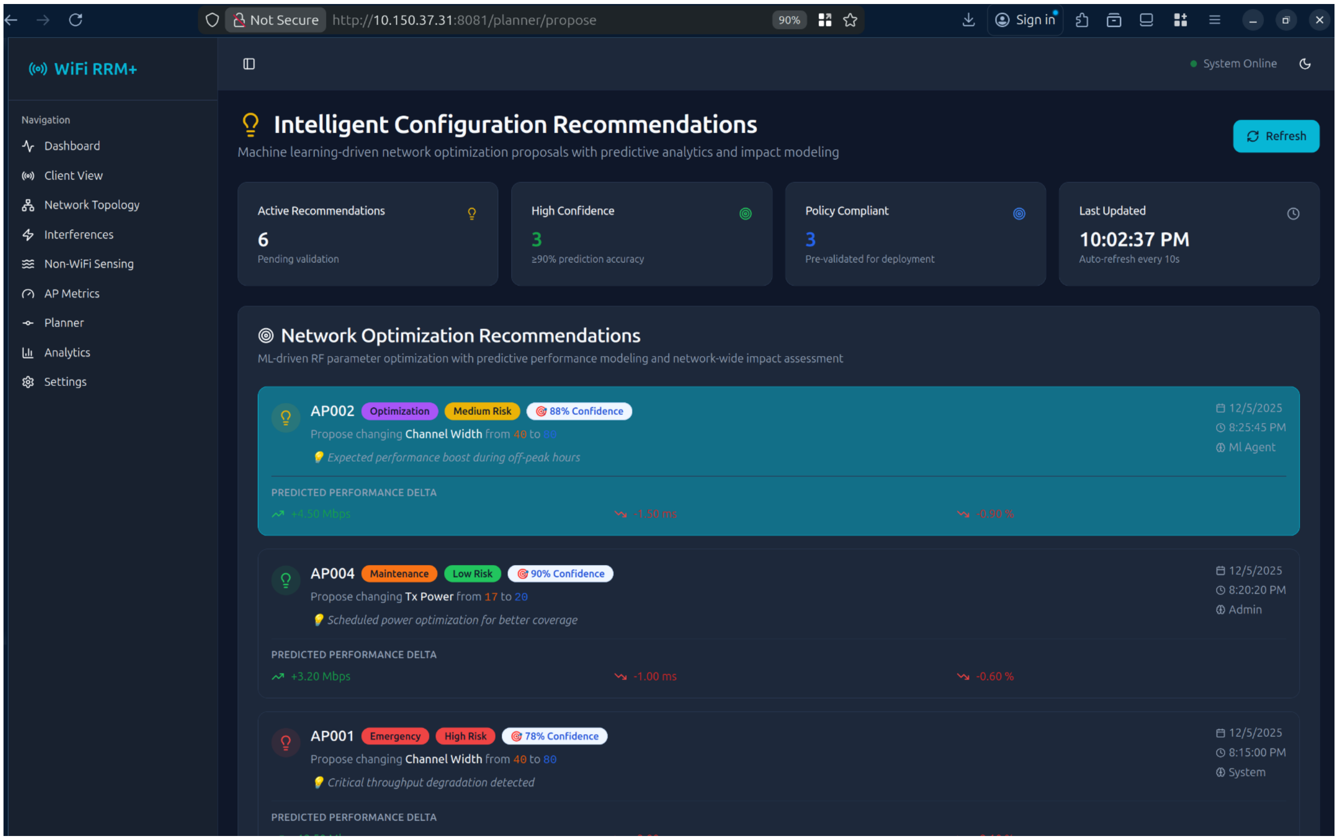

Figure 7: /planner/propose

5 Safe Execution and Governance

To ensure network stability, this module manages the actual deployment of changes, enforcing strict safety protocols.

5.1 API Endpoint

Endpoint: `/planner/commit`

5.2 Core Capabilities

5.2.1 Audit Trail

Every committed change is logged with a detailed audit trail, creating a historical record of system interventions.

5.2.2 Guardrails

The site broker enforces specific constraints before committing changes:

- **Blast-Radius**: Limits simultaneous changes to $\leq N$ APs per RF domain
- **Change Budgets**: E.g., ≤ 1 change per 4 hours unless an incident occurs
- **Hysteresis**: Requires minimum delta before accepting parameter changes

5.2.3 Rollback Mechanism

If post-change metrics degrade, the system utilizes stored rollback tokens to automatically revert configurations, ensuring do no harm operations.

Table 4: Production Guardrails

Guardrail	Constraint	Purpose
Blast Radius	$\leq N$ APs/domain	Limit failure scope
Change Budget	≤ 1 per 4h	Prevent configuration flapping
Hysteresis	Power $\geq$ 2dB	Avoid micro-adjustments
Rollback Window	60 seconds	Quick revert on degradation

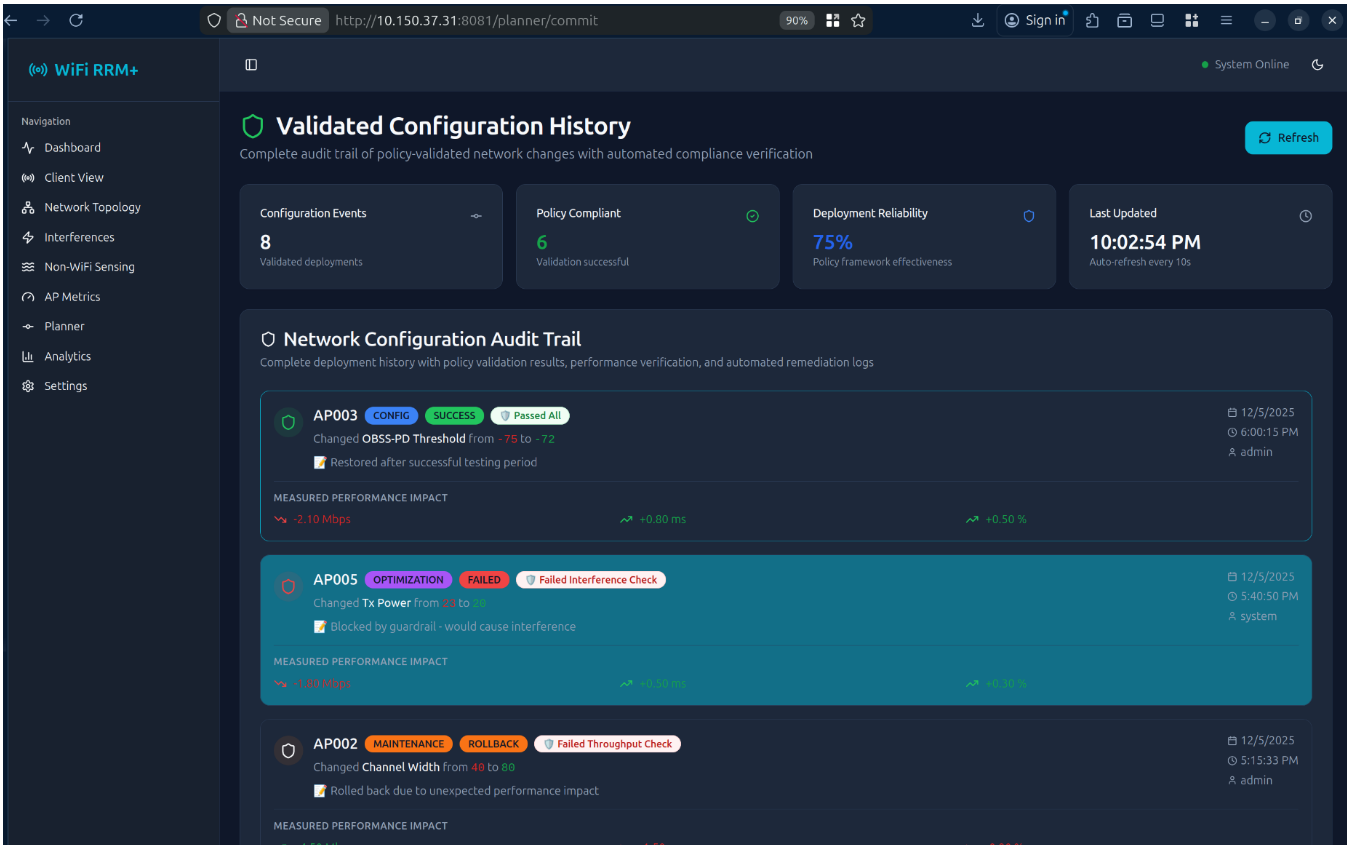

Figure 8: /planner/commit

6 Performance Monitoring and SLO Compliance

The final module closes the loop by monitoring the actual impact of changes against defined Service Level Objectives (SLOs).

6.1 API Endpoint

Endpoint: `/metrics`

6.2 Core Capabilities

6.2.1 Role-Based SLOs

The dashboard tracks compliance based on AP class and usage type (e.g., Guest, Voice WLAN, Exam Hall), applying distinct constraints for each (e.g., limiting voice WLANs to 20 MHz width).

6.2.2 KPI Tracking

We monitor critical KPIs to validate success:

- **Edge-Client Throughput**: Targeting a $+15-20\%$ lift in median downlink throughput
- **Reliability**: Tracking P95 retry rates ($\geq 20\%$ reduction) and Uplink PER
- **Steering**: Monitoring BSS-TM acceptance rates ($> 85\%$)

Table 5: Service Level Objectives by AP Class

AP Class	P50 Throughput	P95 Retry	Max Width
Guest	> 50 Mbps	$< 8\%$	80 MHz
Voice WLAN	> 10 Mbps	$< 5\%$	20 MHz
Exam Hall	> 30 Mbps	$< 10\%$	40 MHz
Enterprise	> 100 Mbps	$< 8\%$	160 MHz

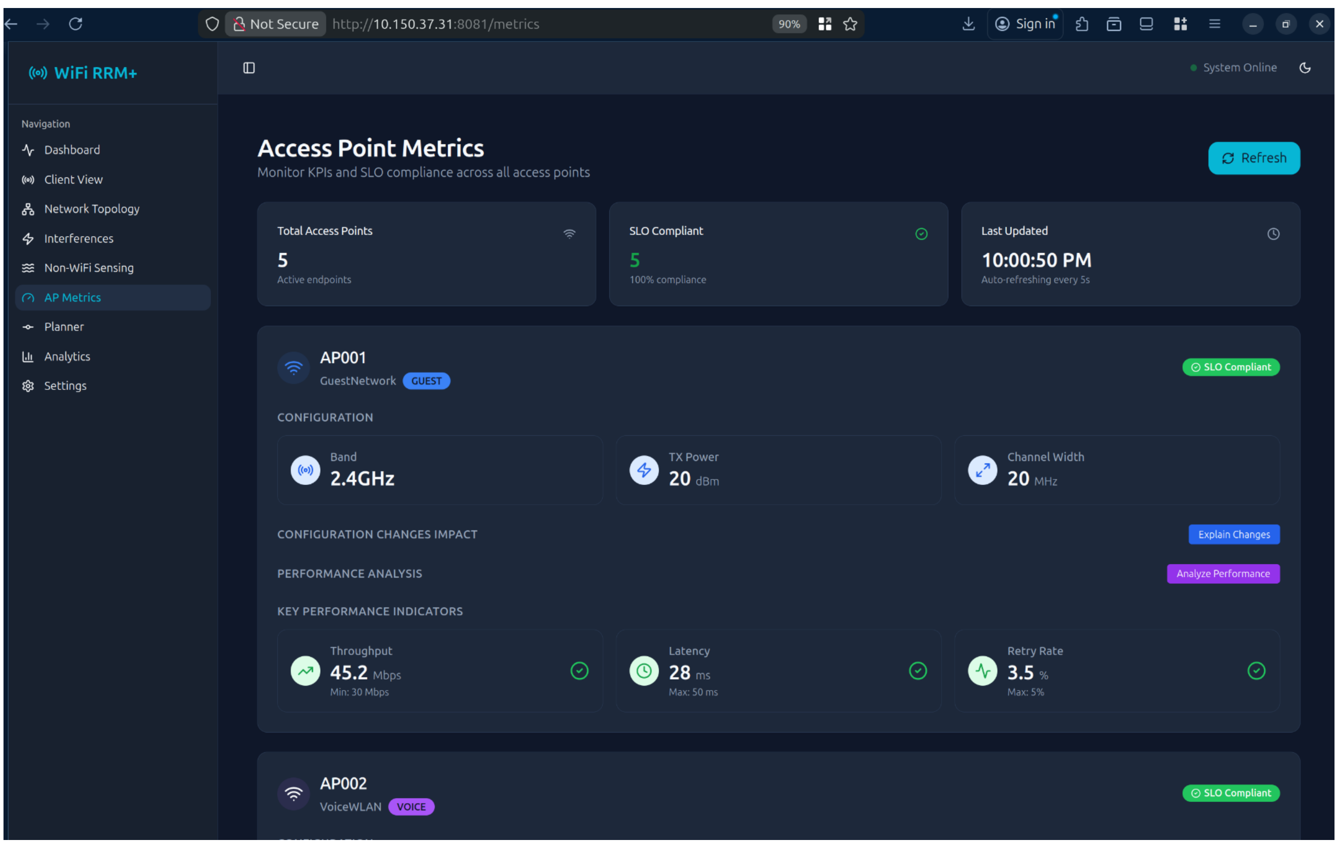

Figure 9: /metrics

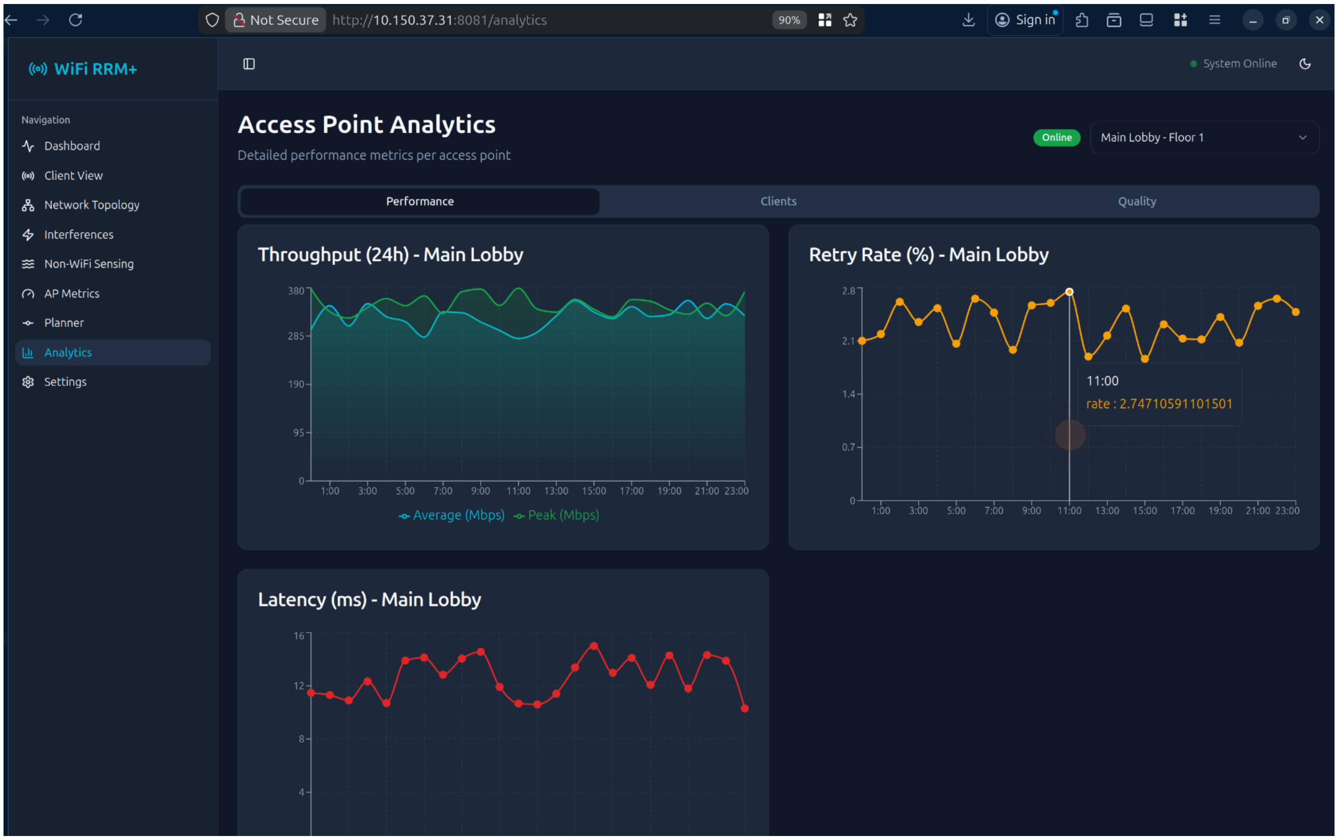

Figure 10: /analytics for Access Points

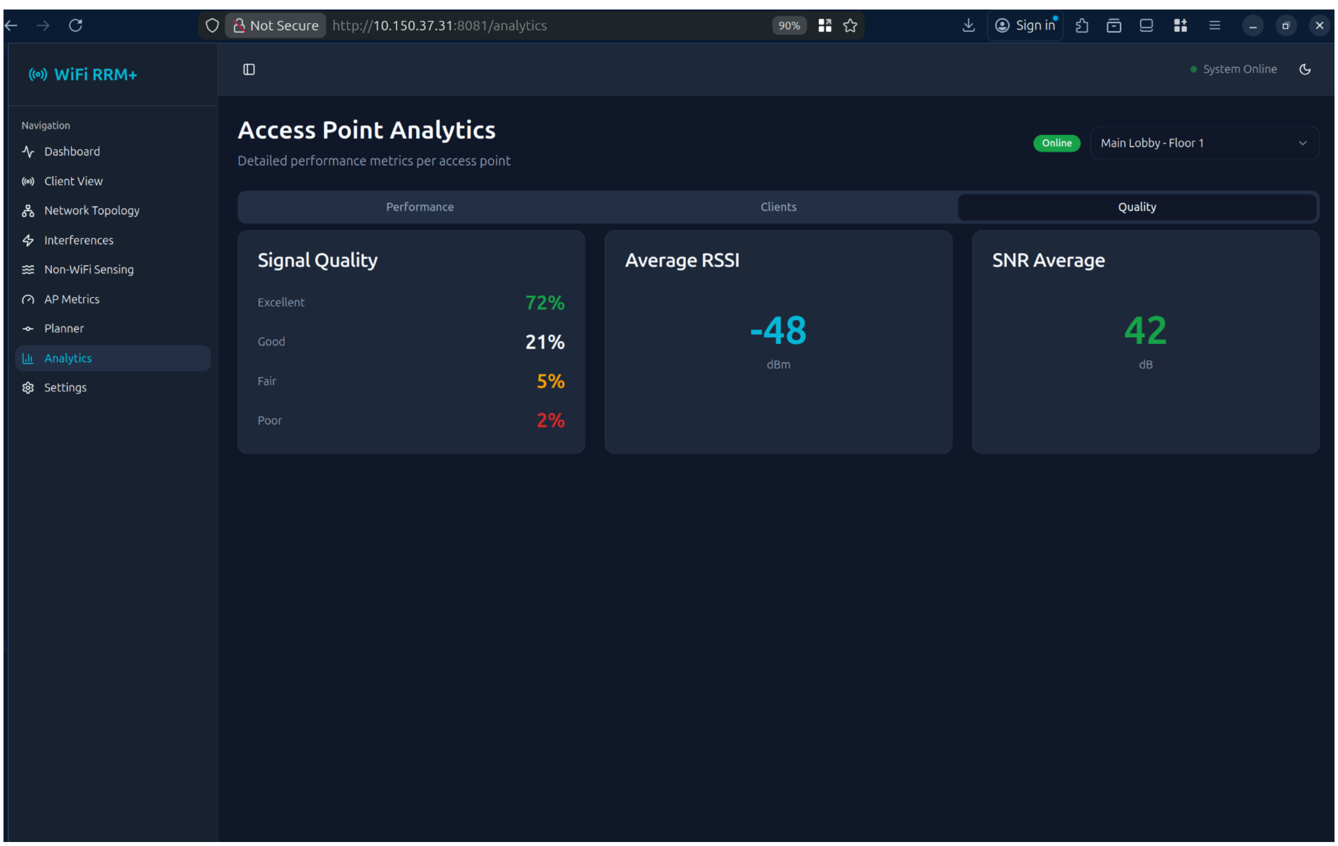

Figure 11: /analytics for Access Points

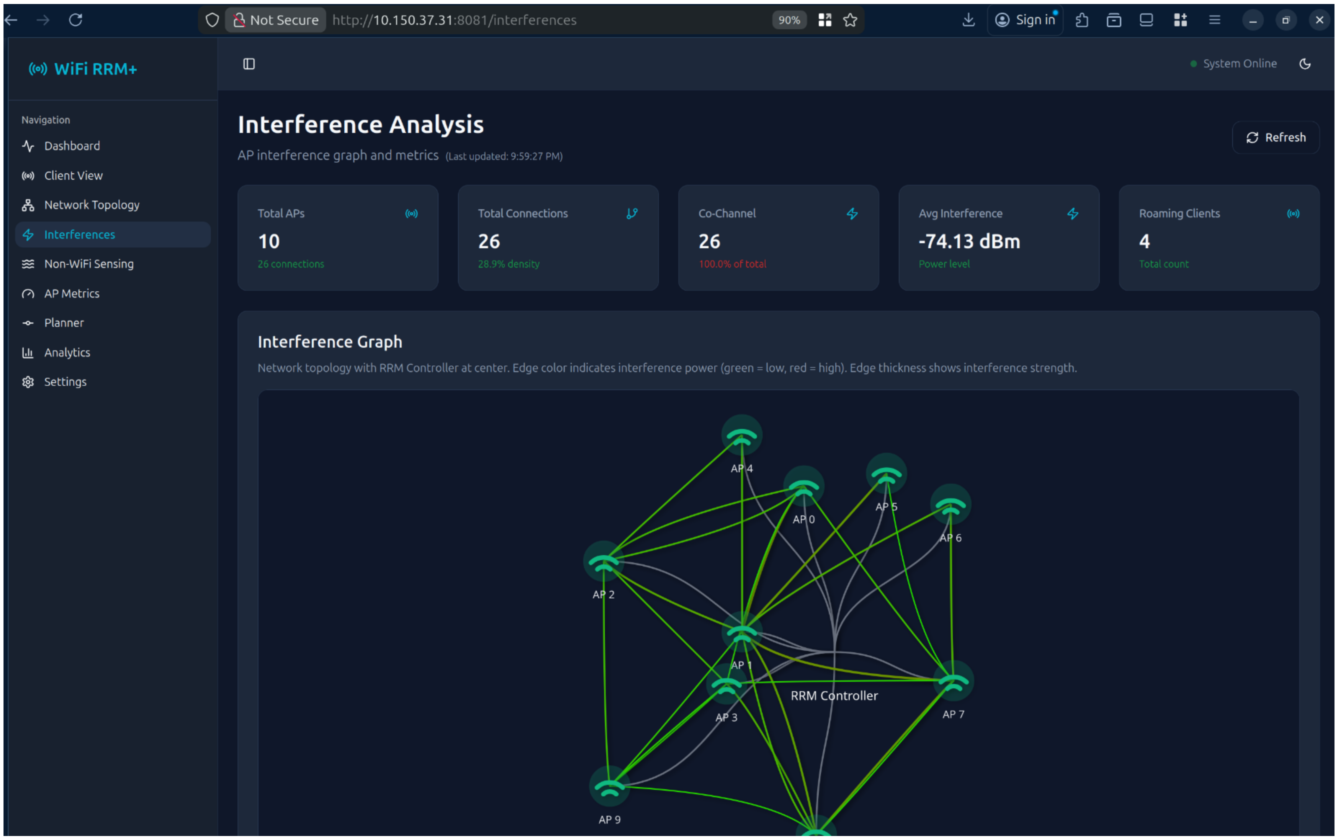

Figure 12: /interferences for Interference Graph

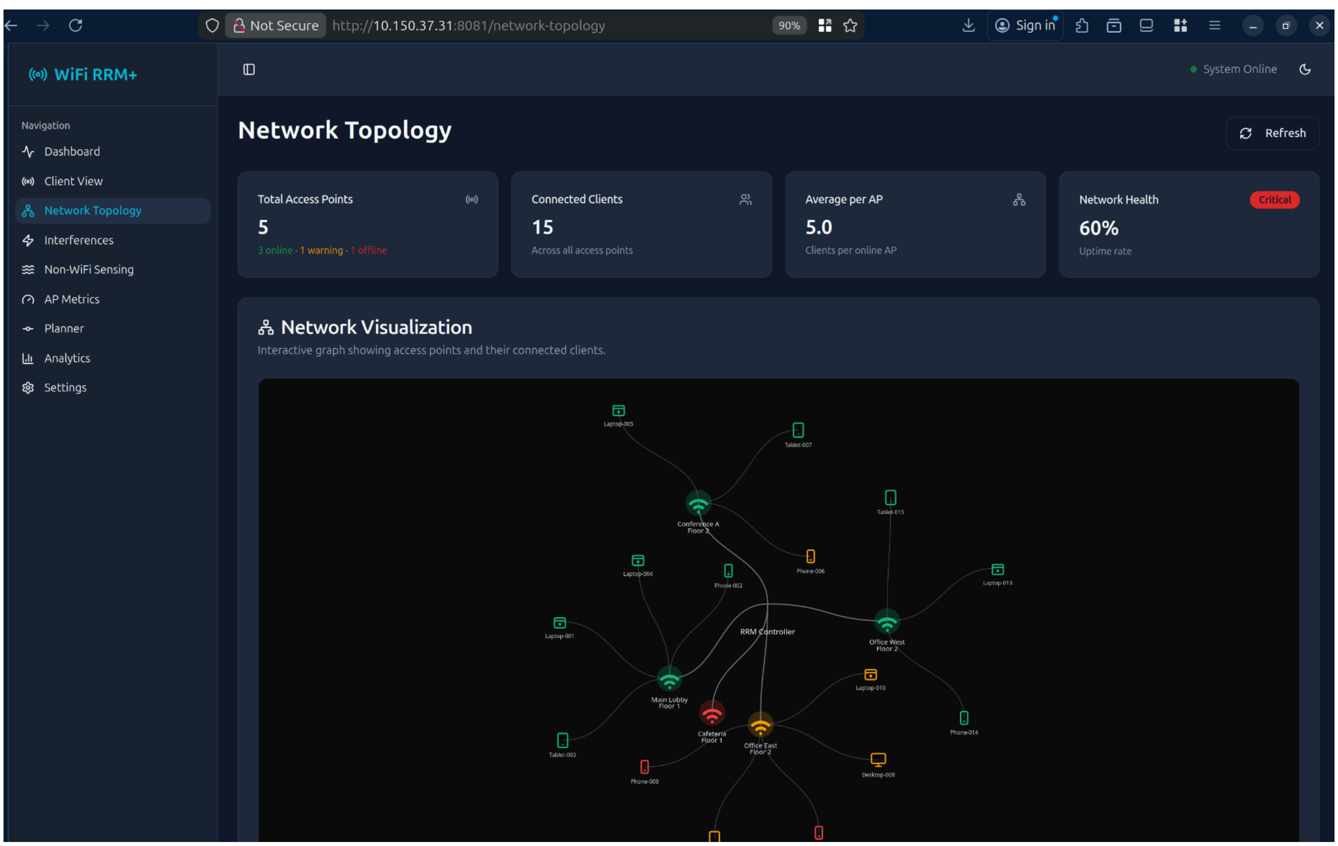

Figure 13: /network-topology for network topology

7 Conclusion

We have successfully designed the mid-term deliverables of the problem statement. By integrating the additional radio for sensing via `/sensing` and establishing a telemetry schema for client views via `/client_view`, we have created a foundation for safe, AI-driven automation that prioritizes real-world client Quality of Experience over static AP metrics.

The five-module architecture—spanning environmental sensing, client telemetry, AI planning, safe execution, and performance monitoring—provides a comprehensive framework for next-generation enterprise WiFi management. The system's emphasis on continuous sensing, client-centric metrics, and production guardrails ensures both optimal performance and operational safety.