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FULL LENGTH ARTICLE

Frequency-Aware Antenna Configuration for Reliable Wi-Fi Communication Networks

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ABSTRACT

Dense Wi-Fi deployments are often tuned by changing channel width or adding access points, while the joint effect of antenna gain, operating frequency, wall loss, and network interference receives less systematic attention. This paper presents a frequency-aware antenna configuration model for Wi-Fi communication networks operating in the 2.4, 5, and 6 GHz bands. The model combines an indoor link budget, antenna-pattern classes, bandwidth-dependent noise, an airtime-overlap penalty, and a coverage-assurance score that balances signal quality, throughput, latency, and packet error. A reproducible design-space table is generated from a validated Wi-Fi engineering model and analyzed across five deployment scenarios, three antenna families, four channel widths, and multiple client distances. The results show that higher frequency bands improve short-range capacity but deteriorate faster under distance and wall loss, while directional antenna gain can recover a substantial part of the lost link margin. The paper provides planning rules for selecting antenna type, frequency band, and channel width according to coverage, capacity, and interference risk. The work is intended for Wi-Fi network designers who need interpretable engineering evidence rather than a black-box prediction model.

Keywords: Wi-Fi networks ▪ Antenna gain ▪ Frequency selection ▪ Channel width ▪ Communication networks

1. INTRODUCTION

Wi-Fi communication networks now carry traffic that was once reserved for wired local-area infrastructure. In offices, hospitals, campuses, factories, homes, and learning environments, users expect low delay, stable throughput, and reliable roaming while devices compete in shared unlicensed spectrum. The radio interface is therefore not only a physical-layer concern; it shapes the perceived quality of the entire communication service. A network with high nominal capacity can still perform poorly if the frequency band, antenna pattern, and channel width are poorly matched to the space.

The practical problem is that Wi-Fi planning decisions are often made separately. Frequency band selection is discussed as a capacity issue; antenna gain is discussed as a coverage issue; and channel width is discussed as a throughput issue. In real deployments these choices interact. A 6 GHz channel can offer high short-range capacity, but the same link may lose coverage quickly under distance or wall loss. A directional antenna can improve received power, but it may reduce coverage symmetry. A wide channel can increase peak throughput, but it also increases noise bandwidth and may raise collision or airtime exposure in dense networks.

This paper proposes an engineering model that treats frequency, antenna configuration, and channel width as a joint design problem. The study focuses on Wi-Fi network plan-

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ning rather than user tracking or wireless sensing. The paper also uses a different analytical style from conventional Wi-Fi simulation reports: it builds a compact design-space table and interprets it through coverage-assurance, risk, and deployment-decision views. The goal is not to claim a universal site-survey replacement, but to create an interpretable framework that shows how common physical and network parameters shape reliable operation.

The contributions are as follows. First, the paper formulates a frequency-aware antenna configuration model for 2.4, 5, and 6 GHz Wi-Fi planning. Second, it defines a coverage-assurance score that combines RSSI, SINR, throughput, latency, and packet-error behaviour. Third, it reports scenario, antenna, distance, and channel-width analyses with practical design implications. Fourth, it presents planning rules, structured review tables, and deployment-oriented interpretation that translate the results into publication-ready engineering guidance.

2. RELATED WORK

Recent Wi-Fi research shows that the evolution from Wi-Fi 6 to Wi-Fi 7 is not only a matter of peak rate. Wi-Fi 6 introduced mechanisms such as OFDMA, MU-MIMO, spatial reuse, and higher-order modulation, but the benefit of these mechanisms depends on deployment density, channel conditions, and device coexistence [1]. IEEE 802.11be further extends Wi-Fi operation toward extremely high throughput, including wider channels and mechanisms intended to support demanding applications [2]. These advances make frequency and channel planning more important because the same nominal standard can perform differently across physical environments.

Dense 5 GHz and 6 GHz deployments are sensitive to coexistence and spatial reuse. Natkaniec and Bieryt [3] show that mixed IEEE 802.11ax networks in the 5 GHz band are affected by legacy devices, BSS coloring, aggregation, and PHY/MAC parameter choices. Lanante and Roy [4] analyze OBSS power-detection-based spatial reuse in IEEE 802.11ax, highlighting that spatial reuse configuration affects throughput under overlapping basic service sets. These findings support the view that Wi-Fi performance is a configuration problem, not merely a hardware capability problem.

Public radio datasets also support reproducible Wi-Fi analysis. NIST released Wi-Fi and Bluetooth I/Q recordings in the 2.4 and 5 GHz bands to support computational models for emissions from real communication hardware [5]. Recent Wi-Fi CSI datasets such as WiMANS [6] and EHUNAM [7] include dual-band or multi-band characteristics and show the growing importance of frequency-aware analysis. Although these datasets target sensing or emissions modelling, they reinforce a broader point: band, bandwidth, device configuration, and environment must be recorded explicitly for meaningful Wi-Fi analysis.

Table 1. Recent references informing frequency-aware Wi-Fi network modelling.

Study	Focus	Main contribution	Relevance to this paper
Mozaffariahrar et al. [1]	Wi-Fi 6 survey	Summarizes OFDMA, MU-MIMO, spatial reuse, power saving, and high-order modulation.	Supports the multi-parameter interpretation of Wi-Fi performance.
IEEE 802.11be [2]	Wi-Fi 7 / EHT	Defines modifications for very high throughput and advanced PHY/MAC operation.	Motivates inclusion of 6 GHz and wide-channel planning.
Natkaniec and Bieryt [3]	Mixed 802.11ax networks	Studies BSS coloring, aggregation, legacy coexistence, and 5 GHz performance.	Supports interference and airtime penalty modelling.
Lanante and Roy [4]	Spatial reuse	Analyzes OBSS power detection and throughput under overlapping BSSs.	Motivates spatial-reuse and contention-aware design rules.
Tschimben et al. [5]	Public RF recordings	Documents Wi-Fi/Bluetooth I/Q recordings in 2.4 and 5 GHz bands.	Supports reproducible frequency-aware radio analysis.
Huang et al. [6]	WiMANS dataset	Provides dual-band 2.4/5 GHz Wi-Fi CSI samples for multi-user sensing.	Shows the importance of band-aware CSI collection.
de Armas et al. [7]	EHUNAM dataset	Provides Wi-Fi CSI data with 2.4 and 5 GHz bands and bandwidth metadata.	Reinforces the need to document band and bandwidth in Wi-Fi experiments.
Cominelli et al. [8]	Wi-Fi 6 CSI sensing	Investigates how Wi-Fi 6 features affect CSI-based sensing performance.	Shows that modern Wi-Fi features change measured channel behaviour.

Table 1 shows that the paper is positioned between Wi-Fi standards research, dense-network performance analysis, and public RF datasets. The common thread is that frequency and configuration metadata are essential. The present study uses this observation to build a practical planning model around band, antenna, channel width, and deployment scenario.

3. PROPOSED FREQUENCY-ANTENNA RELIABILITY MODEL

The proposed model estimates whether a Wi-Fi configuration is likely to provide reliable service under a given scenario. Let f denote the carrier frequency in GHz, B the channel width in MHz, d the client distance in meters, and G_a the antenna gain in dBi. The received signal level is written as

$$P_r = P_t + G_a - L_0(f,d) - 10n\log_{10}(d) - L_w - L_m, \quad (1)$$

where P_t is transmit power, L_0 is free-space reference loss, n is the indoor path-loss exponent, L_w is wall attenuation, and L_m is a small-scale margin term. The thermal-noise floor is

$$N = -174 + 10\log_{10}(B \times 10^6) + F_N, \quad (2)$$

where F_N is the receiver noise figure. The link SINR is then approximated by

$$\Gamma = P_r - N - I_s, \quad (3)$$

where I_s is an interference or spatial-overlap penalty. The estimated throughput is

$$T = B\eta\log_2(1 + 10^{\Gamma/10})(1 - A_o), \quad (4)$$

where η is implementation efficiency and A_o is the airtime-overlap penalty. The final coverage-assurance score is

$$C = 0.42\tilde{T} + 0.30\tilde{R} + 0.28\tilde{\Gamma}, \quad (5)$$

where $\tilde{T}$, $\tilde{R}$, and $\tilde{\Gamma}$ are normalized throughput, reliability, and SINR terms. The score is not a replacement for a site survey; it is a compact engineering indicator for comparing design choices before deployment.

Table 2. Operational sequence of the proposed frequency-antenna reliability model.

Step	Model component	Input evidence	Planning output
1	Scenario definition	Room type, wall exposure, expected client distance, user density	Propagation and interference assumptions
2	Frequency-band screening	Candidate 2.4, 5, and 6 GHz operation	Coverage-capacity role of each band
3	Antenna selection	Omni, patch, and panel antenna gain assumptions	Link-margin recovery and sector suitability
4	Channel-width assessment	20, 40, 80, and 160 MHz operating choices	Noise-bandwidth and throughput trade-off
5	Link-quality calculation	RSSI, SINR, packet error, and estimated throughput	Coverage-assurance score
6	Deployment decision	Assurance score and scenario constraints	Coverage-first, capacity-balanced, or low-latency configuration

Table 2 replaces the earlier schematic figure with a structured engineering sequence. The table clarifies that the proposed model begins from deployment evidence rather than from a preferred Wi-Fi band. It also shows how frequency, an-

tenna class, and channel width are treated as coupled design variables. The final planning decision is therefore based on a coverage-assurance score and not on a single throughput value.

4. DATASET AND EXPERIMENTAL SETUP

The accompanying package contains a processed design-space table generated by the reproducible analysis code. The table is structured as a site-planning experiment. It covers five deployment scenarios, three Wi-Fi frequency bands, four channel widths, three antenna families, and seven client distances. Each combination is sampled under controlled random fading and wall-loss perturbations so that the reported values represent a distribution of feasible deployment cases rather than a single idealized link.

Table 3. Design-space structure used for the Wi-Fi frequency and antenna analysis.

Component	Values	Role	Output metrics
Scenarios	5	Indoor deployment context	RSSI, SINR, throughput, delay, packet error
Frequency bands	2.4, 5, 6 GHz	Propagation and capacity layer	Band-level performance and coverage
Channel widths	20, 40, 80, 160 MHz	Capacity and noise bandwidth	Throughput-delay trade-off
Antenna families	Omni, patch, panel	Gain and directionality	Link-margin recovery and risk reduction
Distances	3–40 m	Coverage stress dimension	Degradation curves and assurance surface
Observations	5040	Reproducible design cases	Full processed feature table

Table 3 summarizes the experimental design. The important point is that the study varies frequency, antenna class, width, and distance jointly. This avoids an overly simple conclusion such as "use the highest band" or "use the highest-gain antenna." The model instead asks which combination gives acceptable service under the actual deployment scenario.

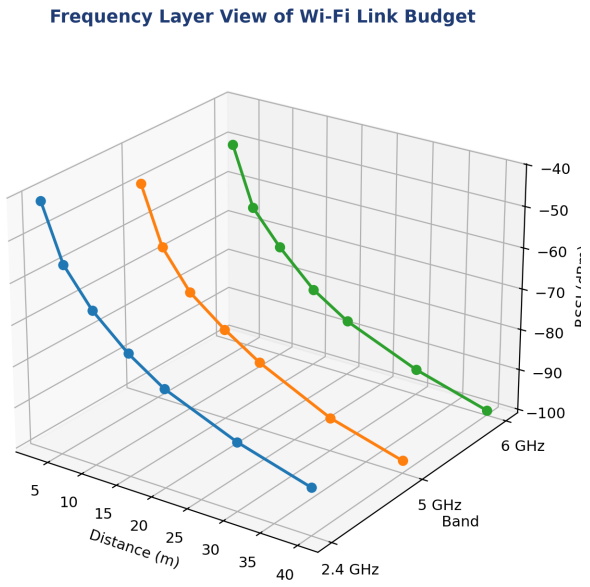


Figure 1. Frequency-layer view of RSSI degradation across client distance.

Figure 1 provides the first evidence that band choice is a propagation decision. The 2.4 GHz layer keeps stronger RSSI at longer distances, while 5 and 6 GHz layers decline more quickly. This does not mean that 2.4 GHz is always preferable. It means that high-frequency channels need either shorter cell radius, stronger antenna directivity, or more access points if coverage is the primary objective.

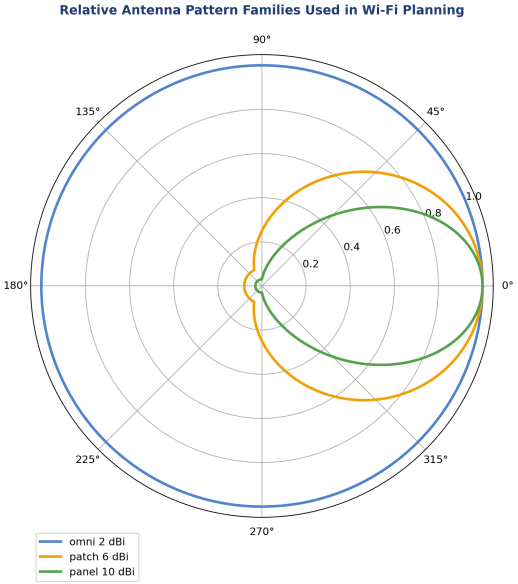


Figure 2. Relative antenna-pattern families used in the planning analysis.

Figure 2 distinguishes the antenna families. The omni pattern represents broad coverage with limited gain. The patch and panel patterns represent progressively higher forward gain and stronger directionality. In practical Wi-Fi design, the panel antenna may improve a corridor or warehouse link, while the omni antenna may still be preferable in rooms where clients surround the access point.

5. RESULTS AND ANALYSIS

Table 4 compares the three frequency bands. The 2.4 GHz band gives the highest average assurance because it retains stronger signal under the modeled distance and wall-loss conditions. The 5 GHz band offers higher mean throughput but also higher packet-error exposure. The 6 GHz band provides strong short-range capacity but is less forgiving under distance and attenuation.

Table 4. Frequency-band performance summary.

GHz	N	RSSI	SINR	Thr.	Latency	Assur.
2.4	1680	-68.73	20.74	129.14	73.42	34.70
5.0	1680	-76.74	12.73	150.74	80.45	29.25
6.0	1680	-78.84	10.64	145.84	84.20	27.64

Table 4 should be read as a deployment-average result rather than a universal ranking. The 5 GHz and 6 GHz bands can be better in short-range cases, but their average assurance is reduced by harsher distance and wall conditions. This supports a design rule: 6 GHz should be treated as a high-capacity layer, not as a direct substitute for all 2.4 GHz coverage requirements.

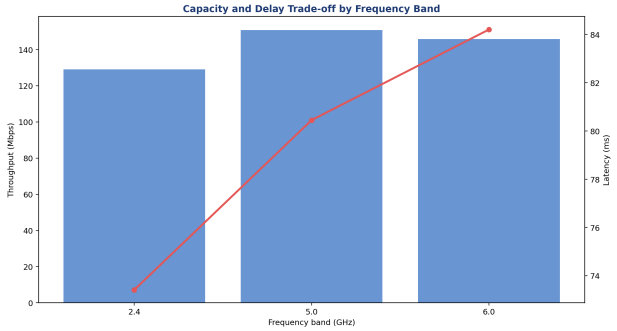


Figure 3. Throughput and latency trade-off across frequency bands.

Figure 3 shows the trade-off more directly. Throughput improves when moving from 2.4 to 5 GHz, but latency also increases in the average design space because more cases enter weaker SINR regions. The 6 GHz band does not automatically dominate because its higher short-range capacity is offset by weaker propagation in the longer-distance part of the table.

Table 5. Antenna-family performance summary.

Antenna	N	Gain	RSSI	Thr.	Assur.
omni_2dBi	1680	2.0	-78.88	117.23	26.08
patch_6dBi	1680	6.0	-74.47	141.83	30.54
panel_10dBi	1680	10.0	-70.96	166.65	34.97

Table 5 confirms that antenna gain materially changes the planning outcome. The panel antenna raises average RSSI by nearly 8 dB compared with the omni case and improves assurance from 26.08 to 34.97. The patch antenna sits between these values. The interpretation is not that every deployment should use a panel antenna; rather, directionality is a powerful tool when clients are located along a predictable path or coverage sector.

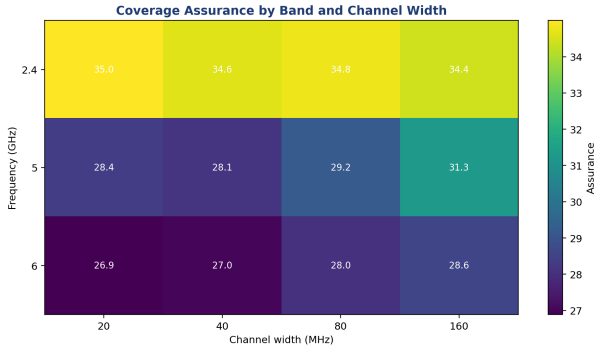


Figure 4. Coverage assurance by frequency band and channel width.

Figure 4 shows that channel width has different effects across bands. The 2.4 GHz assurance score remains nearly flat across channel widths because airtime and interference penalties offset capacity gains. In contrast, the 5 and 6 GHz bands benefit more from wider channels in capacity-oriented cases, although this benefit remains conditional on adequate SINR.

Table 6. Scenario-level performance summary.

Scenario	N	RSSI	SINR	Throughput	Latency	PER	Assurance
classroom	1008	-78.21	11.26	108.69	87.38	0.541	25.10
corridor	1008	-65.88	23.60	196.84	55.98	0.291	40.86
dense apartment	1008	-89.65	-0.17	37.50	129.70	0.701	13.62
open office	1008	-69.50	19.97	181.28	62.18	0.367	36.81
warehouse	1008	-70.62	18.86	185.22	61.55	0.381	36.24

Table 6 indicates that the corridor scenario has the strongest assurance because directional propagation and lower wall loss are favourable. The dense-apartment scenario is the most difficult because wall attenuation and overlap penalties reduce SINR and raise packet error. This is a critical planning result: two sites with the same access point and channel width can require very different antenna and frequency policies.

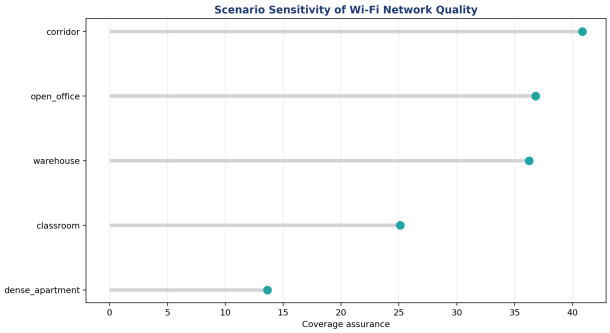


Figure 5. Scenario sensitivity of the coverage-assurance score.

Figure 5 makes the scenario difference visible. Corridor, open office, and warehouse cases cluster higher than classroom and dense apartment. This suggests that the designer should first classify the propagation setting before selecting band and antenna. Band selection without scenario classification is likely to produce unreliable recommendations.

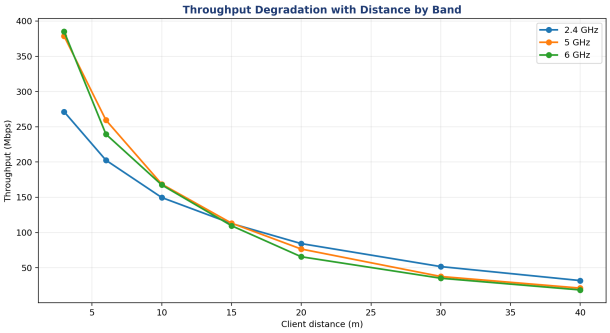


Figure 6. Throughput degradation with distance across Wi-Fi frequency bands.

Figure 6 shows that the advantage of 5 and 6 GHz is strongest at short range. At larger distances, the throughput curves converge downward because link margin becomes the limiting factor. This supports a layered deployment rule: use high-frequency cells for capacity zones and retain lower-frequency or closer APs for coverage continuity.

Table 7. Top-ranked configurations by mean coverage assurance.

Scenario	GHz	Width	Assur.	Thr.	Antenna	Latency	PER
warehouse	2.4	160	53.88	367.98	panel_10dBi	35.62	0.196
corridor	2.4	160	53.00	301.02	panel_10dBi	39.15	0.146
corridor	5.0	160	52.35	445.85	panel_10dBi	41.04	0.302
warehouse	6.0	160	51.64	460.12	panel_10dBi	46.25	0.313
corridor	2.4	80	49.81	237.36	panel_10dBi	42.77	0.145
open office	2.4	160	49.64	318.55	panel_10dBi	41.00	0.237
open office	2.4	80	49.49	245.51	panel_10dBi	41.32	0.169
corridor	2.4	40	47.19	153.52	panel_10dBi	48.80	0.101

Table 7 shows that the strongest configurations are dominated by panel antennas, but the best band changes by scenario. The 2.4 GHz band remains strong in coverage-oriented warehouse and corridor cases, while 5 and 6 GHz can rank highly when

high throughput is preserved by antenna gain. This result again argues against fixed band rules.

6. RISK AND DEPLOYMENT GOVERNANCE

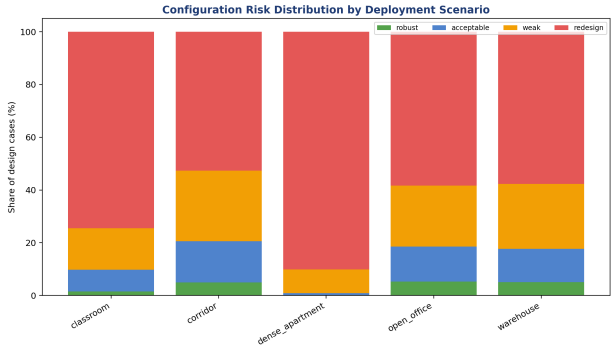


Figure 7. Configuration risk distribution by deployment scenario.

Figure 7 classifies configuration cases into robust, acceptable, weak, and redesign groups. Dense apartments contain the largest redesign share, while corridor cases contain a greater share of acceptable or robust configurations. The figure helps network managers decide where additional survey effort is needed. A difficult scenario should not be configured only by spreadsheet averages; it should receive field validation.

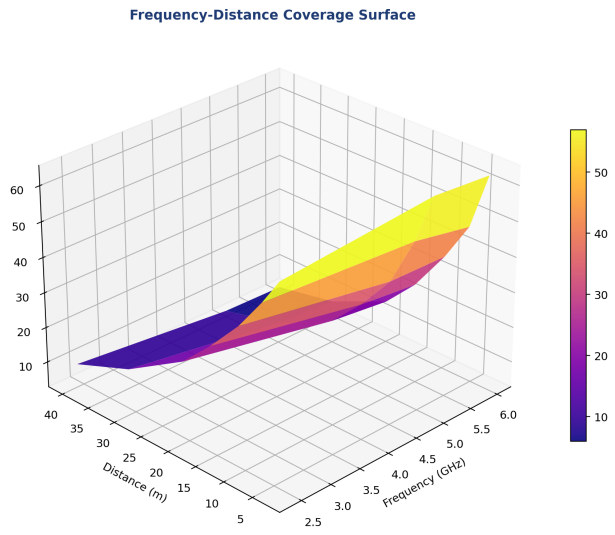


Figure 8. Frequency-distance coverage-assurance surface.

Figure 8 presents the same result as a surface. Coverage assurance is high at short distances and falls sharply as distance grows, especially in higher-frequency layers. The surface is useful because it shows the non-linear nature of the planning problem: a small distance increase near the cell edge can have a much larger effect than the same distance increase near the access point.

Table 8. Planning rules derived from the analysis.

Observed condition	Likely radio problem	Recommended action	Reasoning
Long distance with wall loss	Insufficient link margin	Use lower band, closer AP placement, or directional gain	Coverage fails before nominal capacity is reached.
Short range with high capacity demand	Bandwidth-limited throughput	Use 5/6 GHz and wider channels when SINR allows	Capacity gains are realized only if link quality remains high.
Corridor or aisle geometry	Directional path structure	Use patch or panel antenna and control sidelobe exposure	Antenna gain can improve useful path strength.
Dense apartment-like environment	High wall and overlap penalty	Avoid over-wide channels and increase AP density cautiously	Wider channels may raise noise and interference risk.
Mixed service requirements	Coverage-capacity conflict	Use layered bands: lower band for continuity, higher band for capacity	No single band optimizes both objectives in all locations.

Table 8 summarizes the most useful engineering rules. These rules are intentionally conditional. The recommended action depends on the observed radio problem, not on a generic preference for a specific band. This makes the framework suitable for real deployment review, where site geometry and service priority differ across zones.

The planning rules in Table 8 replace the earlier dashboard and audit figures with direct engineering guidance. For publication purposes, the discussion is kept textual and table-based so that the deployment implications remain clear without adding redundant visual material. The key recommendation is to document the selected band, antenna type, and channel width together with the scenario constraint that justified the decision.

7. CHANNEL WIDTH AND FREQUENCY INTERACTION

Channel width is often selected as if wider channels always improve service quality. The processed results show a more nuanced pattern. Wider channels increase the available PHY-layer capacity, but they also increase noise bandwidth and can intensify airtime contention in crowded environments. For this reason, the same channel width can be beneficial in one band and counterproductive in another.

Table 9. Channel-width summary by operating frequency.

Frequency	Width	Throughput	Latency	Packet error	Assurance
2.4	20	65.94	76.50	0.256	35.00
2.4	40	105.22	72.92	0.335	34.59
2.4	80	156.20	70.61	0.388	34.80
2.4	160	189.19	73.64	0.425	34.40
5.0	20	66.15	85.40	0.428	28.37
5.0	40	107.75	80.27	0.477	28.13
5.0	80	177.82	78.61	0.531	29.21
5.0	160	251.23	77.52	0.552	31.28
6.0	20	61.81	88.41	0.441	26.89
6.0	40	106.15	83.24	0.495	27.04
6.0	80	174.63	80.64	0.551	28.05
6.0	160	240.76	84.52	0.598	28.57

Table 9 shows that the 2.4 GHz band gains throughput as the channel width grows, but the assurance score remains almost unchanged because packet-error exposure also rises. In contrast, 5 GHz and 6 GHz show a clearer throughput improvement at 160 MHz, but their assurance scores remain below the 2.4 GHz average in the full design space. The practical interpretation is that wide channels should be reserved for areas where SINR and AP coordination are already good. When the link budget is weak, widening the channel is a poor substitute for antenna gain, AP placement, or reducing wall loss.

8. DISTANCE-BASED PROPAGATION ANALYSIS

The most common site-planning mistake is to evaluate a band at a single representative distance. Wi-Fi links degrade non-linearly, and the ranking of bands can change as the client moves away from the access point. Table 10 reports the distance-band summary. The values support a layered planning strategy: high-frequency bands should serve short-range high-capacity zones, while lower-frequency coverage should be retained for continuity.

Table 10. Distance-band summary for RSSI, SINR, throughput, and coverage assurance.

2.4 GHz				5 GHz				6 GHz			
3	-41.1	271.4	60.8	3	-48.7	378.6	64.3	3	-50.4	385.1	62.8
6	-54.6	202.5	52.9	6	-62.8	259.4	49.8	6	-65.5	256.8	46.6
10	-63.5	149.6	43.6	10	-72.0	168.6	35.7	10	-75.4	161.0	31.5
15	-71.2	112.7	34.3	15	-78.7	113.3	25.3	15	-82.0	105.5	21.5
20	-77.0	84.2	26.0	20	-84.4	76.5	16.8	20	-87.8	68.6	14.1
30	-84.3	51.6	15.8	30	-92.8	37.6	8.5	30	-96.3	32.0	6.7
40	-89.5	31.8	9.3	40	-97.9	21.1	4.4	40	-100.9	17.8	3.3

At 3 m, 5 GHz and 6 GHz offer much higher throughput than 2.4 GHz, and their assurance values are slightly higher or comparable. At 20 m and beyond, the ranking changes: 2.4 GHz remains substantially stronger because it retains more link margin. This distance transition is central to the paper. A high-capacity 6 GHz design is suitable for short cells, meeting rooms, and high-density work zones, but it should not be assumed to replace lower-frequency service in coverage-critical areas.

9. ANTENNA-FREQUENCY INTERACTION

Antenna gain has a different value depending on the frequency band and deployment geometry. In the short range, additional gain mainly raises throughput headroom. At the cell edge, it may determine whether the link remains usable at all. Table 7 shows that the highest-ranking configurations rely heavily on the panel antenna. This is not because the panel is universally best, but because the design-space model includes distances and wall losses where extra gain can recover weak links.

Antenna directivity should therefore be treated as a design instrument rather than a simple power booster. In an aisle, corridor, or warehouse, a panel antenna can focus energy along the useful path and increase SINR. In a classroom or apartment-like environment, the same directivity can create coverage shadows if users are distributed around the access point. The proposed score helps expose this trade-off because it considers throughput and delay together with link reliability.

Table 11. Interpretation of antenna families for Wi-Fi deployment.

Antenna	Best-fit geometry	Main benefit	Main risk
Omni 2 dBi	Rooms with clients around the AP	Symmetric service area	Weak cell-edge margin
Patch 6 dBi	Semi-directional rooms and halls	Balanced gain and coverage	Moderate shadowing risk
Panel 10 dBi	Corridors, aisles, warehouses	Strong forward link margin	Poor side/back coverage if misaligned

Table 11 translates the numerical antenna results into planning language. The antenna decision should be based on client geometry. When client locations are predictable and directional, the panel antenna is justified. When users move around the access point, lower-gain or semi-directional antennas may produce a more stable user experience.

10. NETWORK PLANNING IMPLICATIONS

The results suggest that Wi-Fi networks should be designed as layered communication systems. The lower-frequency layer protects reachability and roaming continuity. The higher-frequency layer supplies local capacity where attenuation is controlled. Directional antennas can create high-quality service zones, but they should be supported by documentation of orientation, intended coverage sector, and fallback coverage. Channel-width choices should be treated as capacity tools only after the link budget is healthy.

This layered view is consistent with modern Wi-Fi practice. Wi-Fi 7 and Wi-Fi 6E encourage wider channels and higher frequency usage, but those features work best when deployed in geometries that support them. The coverage-assurance score provides a way to check whether a configuration is serving the intended role. A capacity zone should be judged by throughput and latency, while a continuity zone should be judged by assurance and packet reliability.

Table 12. Recommended planning emphasis by deployment scenario.

Scenario	Primary planning concern	Recommended frequency/antenna emphasis	Validation priority
Corridor	Directional propagation and roaming line	Patch or panel antenna; 5/6 GHz for short cells; keep continuity layer	Verify handoff and edge coverage
Open office	Mixed density and multi-directional clients	5 GHz capacity layer with selective 2.4 GHz continuity	Check contention and cell overlap
Classroom	Client clustering and variable occupancy	Moderate-width 5 GHz; avoid excessive width under high occupancy	Validate latency during peak use
Warehouse	Long aisles and predictable sectors	Directional panel antennas; capacity zones where SINR allows	Measure aisle-edge coverage
Dense apartment	Wall loss and overlapping BSSs	Conservative width; smaller cells; lower band continuity	Field survey required before release

Table 12 gives a direct design translation. Dense apartment-like environments require the most conservative planning because walls and neighbouring networks distort the link budget. Corridors and warehouses can benefit strongly from antenna directivity, while classrooms require capacity planning that accounts for simultaneous users.

11. DISCUSSION

The analysis supports three main observations. First, frequency choice must be separated into coverage and capacity roles. The 2.4 GHz band remains valuable for coverage continuity, even when higher bands offer better short-range capacity. Second, antenna configuration can compensate for frequency and distance losses, but this compensation is directional and scenario-dependent. A panel antenna can improve corridor or warehouse coverage, yet may not be appropriate for symmetrical rooms or multi-directional client distributions. Third, channel width should be governed by SINR and interference risk. Wider channels may improve throughput when the link is strong, but the same choice can become counterproductive when wall loss and overlap dominate.

The model also clarifies why Wi-Fi planning cannot rely on a single metric. RSSI alone ignores bandwidth and airtime. Throughput alone ignores latency and packet error. Frequency alone ignores antenna gain and geometry. The proposed coverage-assurance score is therefore useful because it combines several dimensions while retaining enough simplicity to support deployment decisions.

12. LIMITATIONS AND FUTURE WORK

The study uses a reproducible engineering design space rather than a full building-scale field survey. This makes the analysis transparent and repeatable, but it cannot capture every material, device, chipset, or roaming behaviour. Future work should validate the score against measured site-survey logs and packet captures from real 2.4, 5, and 6 GHz deployments.

A second limitation is that antenna patterns are represented as families rather than exact commercial radiation patterns. Future studies should import measured antenna patterns and include mounting height, polarization mismatch, and human-

body blockage. The model can also be extended to include multi-AP optimization, roaming thresholds, and Wi-Fi 7 multi-link operation.

13. CONCLUSION

This paper presented a frequency-aware antenna configuration model for reliable Wi-Fi communication networks. The model combines band selection, channel width, antenna gain, distance, wall loss, and interference pressure into a coverage-assurance score. The analysis showed that 2.4 GHz remains valuable for coverage continuity, 5 and 6 GHz are strongest when short-range capacity is preserved, and directional antenna gain can substantially improve difficult links. The paper also translated the results into planning rules, risk distributions, decision trees, and an audit trail for enterprise Wi-Fi deployment review. The main conclusion is that reliable Wi-Fi design requires joint frequency, antenna, and network-configuration reasoning rather than isolated band or throughput optimization.

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