

PHA Wireless Communications: Technical Feasibility Study

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Date: January 2026

Document Type: Feasibility Study — Identifies hypotheses requiring field validation

Executive Summary

This document evaluates the technical and economic feasibility of deploying wireless internet and VoIP services to Public Housing Authority (PHA) properties using a **perimeter broadcast model** — outdoor access points broadcasting WiFi signals into building interiors without per-unit wiring.

This is not a business plan. This is a feasibility study that:

1. Reviews published literature on RF propagation through building materials
2. Identifies analogous deployments (humanitarian WiFi networks)
3. Proposes specific hypotheses that require field testing
4. Outlines validation methodology before capital commitment

Central Question: Can outdoor WiFi infrastructure penetrate residential building construction at sufficient signal strength to deliver usable internet service, achieving cost savings of 10-20x compared to traditional per-unit wiring?

Section 1: Literature Review — RF Propagation Through Building Materials

1.1 Primary Sources

NIST IR 6055 (1997) — "Electromagnetic Signal Attenuation in Construction Materials"

Stone, W.C., National Institute of Standards and Technology

DOI: 10.6028/NIST.IR.6055

The foundational government study on RF penetration through construction materials. Key findings at frequencies relevant to WiFi (2.4 GHz and 5 GHz):

Material	Attenuation (dB)	Notes
Drywall/Gypsum board	<1 dB	Near-transparent to RF
Plywood	<1 dB	Minimal attenuation
Glass (standard)	2-3 dB	Low attenuation
Brick (single)	4-8 dB	Moderate attenuation
Concrete (8" solid)	10-15 dB	High attenuation; varies with moisture content
Concrete block (hollow)	4-8 dB	Less than solid concrete
Reinforced concrete	15-25 dB	Steel rebar adds significant loss

Limitation noted: NIST tested samples cured for 28 days. Later German studies (Pauli & Moldan, 2015) found concrete loses 5 dB of attenuation between 1-month and 9-month curing, suggesting aged construction may be more RF-permeable than laboratory samples.

ITU-R P.2040-3 (2023) — "Effects of Building Materials and Structures on Radiowave Propagation Above About 100 MHz"

International Telecommunication Union - Radiocommunication Sector

The international standard for modeling RF propagation through building materials. Provides:

- Frequency-dependent permittivity and conductivity equations for common materials
- Multi-layer slab transmission models
- Building entry loss reference models

Key equation for real relative permittivity: $\epsilon' = af^b$

Where f = frequency in GHz, and a,b are material-specific constants from Table 3.

Relevance: Establishes that 2.4 GHz penetrates building materials better than 5 GHz due to longer wavelength. For wood-frame construction with drywall interior, cumulative wall losses of 3-8 dB are typical at 2.4 GHz.

Bytyqi & Jashari (2024) — "Experimental Assessment of the Effects of Building Materials on Wi-Fi Signal 2.4 GHz and 5 GHz"

Peer-reviewed experimental study measuring electric field strength through various materials:

Condition	E-field Reduction	Frequency
Concrete wall (30cm)	55-70%	2.4 GHz / 5 GHz
Glass window	10-15%	Both
Line-of-sight (2m → 6m)	46%	Both

Key finding: "Wi-Fi signal penetration is more pronounced at lower frequencies (2.4 GHz) as opposed to the Wi-Fi signal 5 GHz." Confirms frequency selection matters for outside-in deployment.

1.2 Building Construction Types — Alabama PHA Stock

Public housing construction in Alabama (and nationally) falls into several categories with different RF characteristics:

Construction Type	Typical Era	RF Penetration Expectation	% of Alabama PHA Stock (est.)
Wood-frame with vinyl/brick veneer	1970-present	Good (windows critical)	40-50%
Concrete block (CMU)	1960-1980	Moderate (8-12 dB loss)	25-35%
Brick masonry	1950-1970	Moderate (8-15 dB loss)	10-20%
Steel/concrete high-rise	1960-1980	Poor (15-25+ dB loss)	5-10%

Hypothesis 1: Garden-style apartments with wood-frame or brick-veneer construction (majority of Alabama PHA stock) will support outside-in WiFi deployment. High-rise concrete/steel structures may not be viable for this model.

Section 2: Analogous Deployments — Humanitarian WiFi Networks

2.1 NetHope Syrian Refugee Connectivity Alliance

Scale: 76 camps in Greece, Slovenia, Serbia (2015-2016)

Users served: ~500,000 refugees

Technology: Cisco Meraki outdoor access points, Ethernet Cat-6 cabling, centralized management

Backhaul: DSL, fiber, or cellular depending on location

Deployment model:

- Outdoor access points mounted on poles throughout camps
- No wiring to individual tents or structures
- Coverage designed for open areas and penetration into temporary shelters
- Remote monitoring via Cisco Meraki dashboard

Source: NetHope.org, "A Day in the Life: Installing Wi-Fi at a Greek Refugee Camp" (2016)

2.2 DadaabNet — Kenya Refugee Camp (500,000+ population)

Partners: NetHope, USAID, Cisco, Norwegian Refugee Council

Technology: WiMAX, WiFi, and mobile network with VSAT satellite backhaul

Scale: World's largest refugee camp complex

Key technical approach:

- "Demand aggregation model" — shared infrastructure across 20+ humanitarian organizations
- High concentration of facilities in close proximity enables coverage efficiency
- Enterprise-class connectivity, VoIP, and video conferencing

Source: NetHope.org, "DadaabNet: Providing Sustainable Internet to Refugees"

2.3 Jangala — Calais Refugee Camp

Scale: 5,000 users per week

Technology: Single 4G SIM card, custom-built WiFi distribution system

Cost: Minimal — homemade hardware, commodity components

Relevance: Demonstrates that outdoor-to-tent WiFi works at scale with minimal infrastructure investment. Temporary shelters (fabric, plastic sheeting) have far less RF attenuation than permanent construction — but the principle of outdoor broadcast extends.

2.4 Critical Gap in Literature

What exists:

- Extensive data on RF propagation through individual materials (laboratory conditions)
- Documented humanitarian deployments to temporary structures
- Hotel-style indoor WiFi (wired to access points inside buildings)

What does not exist:

- Peer-reviewed case studies of outdoor WiFi broadcasting *into* permanent multi-family residential buildings
- Published cost comparisons between outside-in and traditional wiring for MDU WiFi

Hypothesis 2: The perimeter broadcast model has not been commercially deployed in permanent housing because: (a) The incumbent model (per-unit wiring) is established and understood by contractors (b) Public housing has not been a priority market for WiFi providers (c) No entity has tested this approach systematically in permanent construction

This is a market gap, not necessarily a technical barrier.

Section 3: Economic Baseline — Traditional MDU WiFi Costs

3.1 EducationSuperHighway Data (2023)

EducationSuperHighway, the nonprofit that closed the K-12 classroom connectivity gap, has pivoted to affordable housing WiFi. Their published data:

Traditional MDU wiring cost: \$700-1,200 per unit

- Includes: switches, access points, CAT6 cabling to each unit, labor
- Source: Analysis of 50+ competitive bids (2021-2024)

Hotel-style WiFi network (hallway APs, not per-unit wiring): \$650 per unit average

- Includes: switches, hallway access points, fiber connection, 4-year maintenance
- Source: ESH pilot programs and state implementation data

Monthly service (bulk rate): \$10-25 per unit

- Delivered by Managed Service Providers (MSPs)
- Building owner procures single connection; residents connect to building-wide network

Source: EducationSuperHighway, "Free Apartment Wi-Fi: How States Can Close the Digital Divide in Affordable Multi-Dwelling Units" (July 2023)

3.2 BEAD Funding Context

The Broadband Equity, Access, and Deployment (BEAD) program — \$42.5 billion nationally — explicitly includes:

"Installing internet and Wi-Fi infrastructure or providing reduced-cost broadband within a multi-family residential building" as a priority eligible use.

Alabama's share: State BEAD allocation for MDU connectivity (specific amount TBD by Alabama Broadband Office)

Implication: Grant funding may offset 50-100% of capital costs for qualifying PHA properties. The economic model changes dramatically with zero CapEx.

Section 4: Proposed Perimeter Broadcast Model

4.1 Concept

Instead of wiring each unit, deploy directional outdoor access points around building perimeters. Signal broadcasts inward through walls and windows. Residents connect directly or use optional indoor extender.

Analogy: Refugee camp WiFi meets permanent housing. The building envelope replaces the tent wall.

4.2 Projected Cost Structure (Hypothesis — Requires Validation)

Component	Cost per Unit	Basis
WISP backbone (amortized)	\$10-20	Tower, fiber, base station shared across portfolio
Building receiver	\$5-10	Rooftop antenna + router per building
Perimeter APs	\$15-25	Directional outdoor units (1-4 per building)
Optional in-unit extender	\$15-25	Resident self-install if needed
Total CapEx	\$40-70/unit	vs. \$700-1,200 traditional

Cost ratio: 10-20x cheaper than traditional wiring if the technology works as hypothesized.

Critical assumption: Signal penetrates building envelope at usable strength for majority of units. This must be validated per building.

4.3 Three-Approach Comparison

Approach	CapEx/Unit	Pros	Cons
Traditional wiring	\$700-1,200	Proven, reliable, high performance	Expensive, disruptive, slow deployment
Perimeter broadcast	\$40-70	Cheap, fast, no unit access needed	Unproven in permanent housing; RF penetration uncertain
Hallway WiFi (ESH model)	\$650	Proven in hotels/apartments	Still requires interior wiring; moderate cost

Section 5: Validation Methodology

5.1 RF Site Survey Protocol

Before any capital commitment, each candidate building requires:

Step 1: Desktop Assessment

- Determine construction type from building records
- Identify wall materials, window placement, floor count
- Flag buildings likely unsuitable (concrete high-rise, metal siding)

Step 2: Field RF Survey

- Place temporary outdoor AP at proposed mounting location
- Measure received signal strength inside representative units (center, corner, ground floor, top floor)
- Document RSSI (Received Signal Strength Indicator) at multiple points within each test unit
- Record interference from competing WiFi networks

Step 3: Pass/Fail Criteria

Metric	Minimum for Viability	Target
RSSI at unit interior	-70 dBm	-60 dBm
Throughput at unit interior	10 Mbps	25 Mbps
Units meeting minimum	70%	90%

Step 4: Extender Assessment

- For units failing minimum RSSI, test with \$25 plug-in extender
- Determine if extender brings unit to acceptable performance

5.2 Responsibility Demarcation (Demarc)

Clear definition of what the operator delivers vs. resident responsibility:

Operator delivers:

- Usable WiFi signal at building perimeter / exterior walls
- Connection to VoIP phone service
- Network monitoring and maintenance

Resident responsibility:

- Optional purchase of in-unit extender if signal insufficient
- Troubleshooting their own devices

Why this matters: Avoids support burden of chasing signal complaints inside every apartment. Operator guarantees coverage to the building, not to every corner of every unit.

5.3 Pilot Deployment Recommendation

Phase 1 — Single Building Pilot (30-60 days)

- Select one garden-style apartment building (wood-frame, 20-50 units)
- Full RF survey, perimeter AP installation, performance measurement
- Document: cost, time, signal quality, resident feedback

Phase 2 — Multi-Building Expansion (90-180 days)

- Deploy to 3-5 buildings of varying construction types
- Validate cost model at small scale
- Identify building types that work vs. require different approach

Phase 3 — Portfolio Rollout (if validated)

- Proceed with proven model
 - Skip or modify approach for non-viable building types
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Section 6: Open Questions Requiring Investigation

6.1 Technical Unknowns

Question	How to Resolve	Risk if Wrong
Does signal penetrate brick veneer sufficiently?	Field testing	May need hallway relays for some buildings

Question	How to Resolve	Risk if Wrong
What is realistic throughput at center units?	Pilot measurement	May not meet FCC 25/3 Mbps for Lifeline qualification
How does competing WiFi affect performance in dense environments?	Spectrum analysis	May need channel coordination between buildings
Can 5 GHz be used, or 2.4 GHz only?	Test both	2.4 GHz has interference; 5 GHz may not penetrate

6.2 Regulatory Unknowns

Question	How to Resolve	Risk if Wrong
Does Lifeline certification require per-unit speed guarantees?	FCC/USAC consultation	May need to apply Lifeline to VoIP only
Do PHAs require specific broadband speeds in utility allowance?	HUD/PHA policy review	May affect funding eligibility
Are there local permitting requirements for outdoor AP mounting?	Municipal code review	May add cost/time

6.3 Economic Unknowns

Question	How to Resolve	Risk if Wrong
What is actual bulk internet cost for 4,000 units?	Carrier quotes	Model assumes \$3,500-7,500/month; may be higher
What is realistic Lifeline enrollment rate?	Survey of PHA residents	Model assumes 80-90% eligible; actual enrollment may be lower
Can grant funding cover CapEx?	Alabama BEAD application	If denied, payback timeline extends

Section 7: Sources and Citations

Academic and Government Publications

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6. National Telecommunications and Information Administration (2023). *BEAD Challenge Process Policy Notice*. U.S. Department of Commerce.
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Section 8: Conclusion

What We Know

1. **RF propagation through common building materials is well-documented** (NIST, ITU-R) — wood-

frame and brick-veneer construction allows significant signal penetration at 2.4 GHz.

2. **Outdoor WiFi deployment to temporary structures works at scale** — humanitarian organizations have connected hundreds of thousands of people without per-unit wiring.
3. **Traditional MDU WiFi costs \$700-1,200 per unit** — verified by EducationSuperHighway from 50+ competitive bids.
4. **Federal funding prioritizes affordable housing connectivity** — BEAD explicitly designates MDU WiFi as eligible use.

What We Don't Know

1. **Whether the perimeter broadcast model delivers usable signal** in specific Alabama PHA construction types — requires field validation.
2. **What percentage of units will need in-unit extenders** — directly affects true per-unit cost.
3. **Whether regulatory requirements (Lifeline, HUD) permit this approach** — requires consultation with FCC/USAC and PHA administration.

Recommendation

Proceed to **Pilot Phase** with a single suitable building to test the core hypothesis. If validated, the cost advantage (10-20x) justifies further investment. If not, the perimeter model should be abandoned or modified before committing portfolio-scale capital.

The question is not whether WiFi can penetrate walls. The question is whether it penetrates *these specific walls at sufficient strength for acceptable service*. Only field testing will answer that.

This feasibility study was prepared to support informed decision-making. All cost projections are estimates requiring validation. All technical claims cite published sources. Conclusions are hypotheses pending empirical verification.

Document Version: 1.0

Classification: Draft for Academic Review

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