Bharat6G Alliance

Bharat 6G Alliance Whitepaper

FIXED WIRELESS ACCESS: BHARAT'S BROADBAND BACKBONE FROM 5G TO 6G



October 2026 | Version 1.0

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Fixed Wireless Access:

Bharat's Broadband Backbone from 5G to 6G

Chair and Editor: Dr. Sonali Garg, HFCL Limited

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Executive Summary

Fixed Wireless Access has become India's fastest-growing route to home broadband without ever having been designed as one. India's 5G FWA base reached 13.21 million subscribers in July 2026, half of it rural, and FWA, counting 5G and unlicensed-band radio together, made up just over half of fixed broadband net additions that month. It has done this on the eMBB ecosystem: the same radio, core and chipset supply chain as the smartphone, with the customer premises equipment modelled, where it is modelled at all, as a handset that does not move. That shared ecosystem is FWA's greatest strength and this paper argues for keeping it. The gap is narrower and more specific: FWA has never had a deployment scenario, a channel model, an evaluation methodology or a device class of its own. Zero mobility and a stronger link budget are only part of the difference. The CPE is a rooftop terminal whose directional array changes the propagation geometry the channel model assumes; it carries a whole household's traffic, sustained through an evening busy hour, as one schedulable entity; and it is sold as a rate at a fixed address. The 6G study is the point at which these can be modelled.

The paper makes six points.

- India is not repeating the US or European FWA story. There, FWA competes with cable in cities. Here, it extends fibre that public investment has made service-ready at 2.18 lakh gram panchayats, about a third of which were working when CAG audited the programme, into settlements where the alternative is no wired service at all (Sections 1.2 and 6.3).
- Operators have built for FWA, not only sold it. Jio carries its FWA subscribers on a dedicated network slice of its standalone core; Airtel deployed FWA-specific core capacity. Both experiences show that FWA at Indian household density is a core-architecture and slicing problem as much as a coverage one (Section 2).
- The CPE is a distinct device class. A rooftop unit with a high-gain directional array, permanently mounted and mains-powered, is described by none of the assumptions in TR 38.901, TR 38.810 or the 5QI table. India's outdoor-first deployment, reinforced-concrete housing and 4.44-person households make the mismatch worse, and a purpose-built outdoor CPE specification for Indian conditions has already brought down monsoon replacement rates in a deployment of more than a million units (Sections 3 and 7.5).
- Radio capacity is not the only binding constraint in rural India; on sites still fed by microwave, the backhaul carries less traffic than the radio sector can deliver. Operators decide which addresses to offer FWA by estimating the busy-hour capacity the radio sector has left after mobile demand; on those sites that estimate admits more households than the site can serve, and such sites are concentrated in the rural areas FWA should serve first. The fibre already at the gram panchayat addresses the backhaul limit, after which radio capacity becomes the constraint again, and operator requirements — a sold speed tier held through the busy hour on sites shared with mobile users, sufficient uplink throughput for multi-user households, CPE cost and power, fixed-broadband-grade management, speed-tier guarantees at an address — are stated so that 6G can answer them (Section 5).
- 6G is being designed with FWA in view: upper 6 GHz and 7–8 GHz spectrum aggregated with existing bands gives area-capacity gains of about 500 per cent in vendor simulation, and the Release 20 studies in RAN, SA1 and SA2 already carry FWA threads. The decision points at which FWA is either recognised as a scenario or absorbed into eMBB again fall in 2026–2027 (Section 7).
- The 6G CPE is one of the few device classes where Indian manufacturers have a genuine opening, provided its requirements — power class, antenna configuration, environmental profile, security and management — are settled while the study is open (Section 7.6).

The recommendations in Section 8 follow: recognise FWA in broadband policy and subsidy design; secure upper 6 GHz and 7–8 GHz for IMT; fund 6G testbeds with FWA in scope; and, for industry, build FWA into core and RAN plans, adopt capacity- and backhaul-aware eligibility, build a product ladder rather than a single offer, and carry India's FWA requirements into 3GPP, ITU-R and TSDSI while the 6G framework is still being written.

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1 Introduction: FWA and the Bharat Broadband Vision

1.1 From voice networks to differentiated broadband

Mobile networks were built for people who move. Dimensioning, scheduling, mobility management and the evaluation methodology behind all of it assume a user walking or driving through a cell, generating traffic in bursts. Fixed Wireless Access does not fit that picture. The customer is a house or a shop. The terminal is fixed to a wall or a roof and never moves. Traffic is heavy and concentrated in the evening. What the operator has sold is broadband at an address, with the availability expectations that go with a fixed line.

FWA has not been completely absent from 3GPP. RAN4 has specified power classes and RF requirements for customer premises equipment, including FR2 power class 1 for FWA and higher-power classes for n77 and n78 [1] [2]; TS 23.316 has defined the 5G residential gateway since Release 16, integrated access and backhaul was standardised from Release 16 [3], and the SA2 6G architecture study now carries a key issue on FWA [4]. What has never existed is an FWA deployment scenario, a channel geometry for the fixed terminal, or an evaluation configuration built around it. FWA has been delivered on the eMBB ecosystem since Release 15 [5], with the CPE treated in those models as a UE that happens not to move. Commercially this has worked, and the shared ecosystem is a large part of why. A common radio, a common core and a common chipset supply chain let operators launch FWA within months of switching on 5G, on the network they had already built. Nothing in this paper argues for changing that.

The gap is in what gets modelled, and it is specific. The scenario set in TR 38.913 runs from indoor hotspot to rural macro without an FWA entry [6], so the deployment the operator is actually selling into is never the one being studied. TR 38.901 was reopened for 6G candidate bands in Release 19 and gained a suburban macrocell scenario, realistic terminal antenna models, near-field propagation and spatial non-stationarity [7] [8]. The new terminal antenna models include a CPE type [8], but an outdoor directional terminal at rooftop height, with its own line-of-sight probability and clutter model, was not among the additions. The evaluation methodology carries the same shape [9]: it measures spectral efficiency and mobility performance, not throughput held at one address through the household busy hour, sufficient uplink throughput, or availability sustained over months. Section 3 sets this out in detail.

1.2 Why FWA matters for Bharat

India's 5G FWA base reached 13.21 million subscribers in July 2026, growing by 272,820 in that month alone. Half of that base, 50.31%, is rural [10]. FWA is now among the fastest-growing segments of the broadband market, and in July 2026 accounted for just over half of fixed broadband net additions (477,140 of about 906,000), counting 5G and unlicensed-band FWA together; 5G FWA alone was about 30 per cent [11].

Fixed broadband penetration in India is low [10], and the obstacle is rarely capacity at the point of presence. It is the last few hundred metres: digging, right of way, getting into a multi-dwelling building, and the weeks between an order and a working connection. FWA takes that segment off the critical path. Where fibre has already been brought close to the customer, a wireless last hop turns an asset that is sitting unused into a paying connection [12]. The same audit found only about a third of service-ready gram panchayats working in November 2025 [12], so the panchayat node needs attention as well.

This is where the Indian case parts company with the markets that have shaped FWA thinking so far. In the US, FWA has grown mainly as a competitive broadband product in cities, taking share from cable in areas that already have wired options [13] [14]. In India it is doing something different: extending fibre that public investment has already brought close to the customer [15], into settlements where the alternative is not a worse wired service but no wired service. Sequencing frameworks built around the US case assume the backhaul asset has to be built. In much of rural India, as in other countries with fibre-to-the-village programmes, it is already there. Section 6.3 covers this architecture in full.

Operating FWA at this scale has also exposed conditions the standard does not represent. Outdoor CPE at rooftop height, spectrum shared between fixed and mobile traffic, and serving sites whose microwave backhaul carries less traffic than the radio sector can deliver are all ordinary in India and none of them are in the modelling framework. Section 5.3 states what operators need and are not getting. Section 7.6 takes up the 6G CPE, which is one of the few device classes where Indian manufacturers have a genuine opening, provided the requirements are settled while they are still open [16] [17].

2 Global FWA Market Landscape

2.1 Market momentum and speed-based monetization

Global FWA subscriptions across all generations are forecast to grow from 71 million in 2024 to 150 million by 2030, with 5G making up 88% of the 2030 total and growing at a 23% CAGR, taking total FWA service revenue to an estimated $46 billion by 2030 [18]. There are projections that India will overtake every other market to become the world's largest 5G FWA market by 2030, at 37 million subscriptions; Omdia puts India's share at 40 per cent [18].

More than half of global communications service providers (51%) offering FWA now include speed-based pricing options, up from 40% just twelve months earlier [19]. Operators build distinct price-speed tiers from two levers: the CPE variant, indoor or outdoor, which sets the link budget, and the network-side treatment of the subscription, namely carrier configuration, QoS profile and, on a standalone core, the network slice that carries it (Section 2.2). For entry level offerings based on 4G using indoor CPE, prices typically range from 1 to 2.3 times mobile broadband ARPU levels. For high-end offerings based on 5G using outdoor CPE, tariffs range from 3 to 5 times the mobile broadband ARPU levels [20]. Speed-based monetization is the mechanism through which the spectrum and channel capability discussed in Section 7 convert into operator revenue.

2.2 Leading operators and the India growth story

India's 5G FWA subscribers increased from 12.94 million at the end of June 2026 to 13.21 million subscribers in July 2026, with Reliance Jio accounting for 9.27 million and Bharti Airtel 3.94 million; just over half the national base 50.31% is rural [10] [11]. The two operators arrived at that scale through architecturally different paths, and the difference is instructive.

Jio built its FWA offering, JioAirFiber, as a purpose-designed slice of a 5G Standalone core from the outset. The slice carries its 5G FWA base (9.27 million in July 2026); the other 5.14 million JioAirFiber connections run on unlicensed-band radio and do not use it [10]. The performance targets the slice is engineered to, and the traffic model behind them, have not been published. An Opensignal study published in June 2024 reported that Jio's dedicated network slice for 5G FWA helps it manage network congestion, even though the average JioAirFiber user consumed around 400 GB a month [21]. Jio has also named standalone deployment with network slicing as the main factor behind its FWA growth [22]. By August 2025, Jio Platforms had activated ten live, production-grade network slices spanning enterprise, IoT, gaming, FWA and communication use cases on its standalone core [23].

Airtel launched AirFiber in August 2023 on its non-standalone 5G network and added FWA-dedicated core capacity in 2025, separate from its mobile broadband core. In April 2025, Airtel expanded its partnership with Nokia specifically to deploy Nokia's appliance-based Packet Core alongside its Fixed Wireless Access solutions. Later, Airtel adopted Ericsson's Local Packet Gateway, an infrastructure designed specifically to deliver FWA capacity and scale independently, in a smaller footprint and at lower total cost of ownership than routing that traffic through the existing mobile core [24].

Both operators, regardless of path, have converged on the same underlying point: FWA at Indian household density is a slicing and core-architecture problem as much as a radio-coverage one, which is the gap Section 3.2 argues the current standardization framework doesn't fully account for.

Traffic growth underlines the point. TRAI's performance indicators for the quarter ended September 2025 put total wireless data consumption at 69,090 PB, up 6.28 per cent on the previous quarter, with 5G carrying 24,064 PB, or 34.83 per cent, of it [25]. For network design the material quantity is not the subscriber count but the simultaneous busy-hour load of high-usage households on a site that also serves mobile users. From the operator side, the near-term opportunities that slicing opens are the separation and independent management of fixed and mobile traffic, premium home tiers with stronger assurance, enterprise FWA with differentiated service-level objectives, dynamic allocation of radio and transport resources through the busy hour, and dedicated connectivity profiles for SMEs, campuses and industrial users. Consumer slice monetisation is still at an early stage; the architecture that permits it is already in place.

2.3 Deployment strategy archetypes

Commercial FWA deployment worldwide clusters into three broad archetypes, differentiated by spectrum band and the coverage-versus-capacity trade-off each band carries.

Mid-band (C-band, n77/n78). Operating primarily in the 3.3 GHz to 3.8 GHz range, this TDD layer serves as the primary macro-cellular workhorse tier for mass-market FWA. It offers a workable balance between cell coverage radius and household throughput without requiring strict line-of-sight. By pairing this band with Massive MIMO digital beamforming, operators achieve high spatial multiplexing gains, making it the foundational layer for India's current FWA scaling.

mmWave (n257/n258/n260/n261). Reserved for high-throughput, short-range deployment in dense urban environments. Operating above 24 GHz, unlocking massive contiguous channel bandwidths (aggregating up to 800 MHz) for multi-gigabit spatial throughput. mmWave's propagation characteristics require near line-of-sight conditions and outdoor-mounted directional CPE, making it a premium-tier complement to mid-band coverage rather than a standalone access layer — this is the combination Section 7.2 discusses as a bridge technology into 6G-era gigabit FWA.

Sub-3 GHz (low-band). Operating below 3 GHz, this tier prioritizes extreme link budget extension and diffraction over peak spectral efficiency. While narrow channel bandwidths strictly limit aggregate sector capacity, the low attenuation characteristics allow macro-cells to project a massive coverage radius, serving geographically dispersed topologies where mid-band densification is commercially non-viable. This is the band profile most relevant to the gram-panchayat-anchored architecture in Section 6.3.

Operators often layer these three rather than choosing one: mid-band as the coverage foundation, mmWave added selectively for premium urban tiers, low-band extending reach into low-density geographies the mid-band grid doesn't economically reach.

2.4 Field Evidence: Indian FWA Pilot and Deployment Case Studies

The scale of India's FWA rollout provides a unique empirical lens into the limitations of traditional RF propagation modelling, particularly when executed across complex urban topologies. The most instructive methodological evidence at Indian scale comes from Jio’s deployment of its AirFiber network. Jio planned the rollout on building-level geospatial data. They constructed a national 3D geospatial database covering more than 100 million buildings across 900 cities and towns, achieving 98% positional accuracy within one to two metres. They used this to model line-of-sight feasibility down to individual floors before activating service [26]. This let the operator prioritize which of its more than 300,000 towers to bring online first, ranked by the number of viable customer premises each could actually serve. The planning covered AirFiber on both 5G and unlicensed-band radio, and the 92% prediction accuracy reported for urban centres refers to

the UBR coverage forecasts [26]. They put it as the system was built specifically to support "super-fast planning and faster deployment" at a rollout pace, conventional network planning tools were not designed to sustain [26].

The rural reach of this rollout is corroborated independently by regulatory data. TRAI's subscriber filings show India's FWA base carries a substantial rural component, and Punjab alone had 732,892 5G FWA subscribers in July 2026 (Jio 544,922, Airtel 187,970) plus 298,876 on unlicensed-band FWA [10]. CAG found Punjab and Gujarat to be the only states with more than 90 per cent of gram panchayats working on BharatNet [12]. The two figures sit side by side; the data does not show that one causes the other.

Airtel launched its FWA offering, Xstream AirFiber, in August 2023 to serve premises in areas without fibre access, at a time when fibre-to-home reached only 34 million Indian homes [27]. The technology has since demonstrated genuine capability in Indian conditions, with a February 2024 demonstration with Ericsson reaching 4.7 Gbps over mmWave on Airtel's network [28]. Airtel's later experience shows how sensitive FWA economics are to CPE cost and subscriber quality. Its FWA net additions fell to 83,377 in Q1 FY2027 from 665,842 the quarter before. Management linked this to rising global memory and chipset prices for CPE, higher churn in some customer groups and a choice to add fewer, higher-value subscribers, and described its approach as speeding up fibre while deploying FWA with sharper precision where the economics and customer quality justify it [29]. Fibre and FWA remain complementary in Airtel's portfolio, and its FWA base was growing again by July 2026, at 3.94 million [10]. The CPE cost point bears directly on Section 5.5.

Underlying both operators' experience is a structural condition specific to Indian housing stock. The country's residential and commercial construction is predominantly reinforced concrete and masonry. The low-loss and high-loss building models in TR 38.901 already include concrete (70 per cent of the façade in the low-loss model, 30 per cent in the high-loss model) [7]; what they do not capture is the thicker RCC slabs, denser reinforcement and smaller window area typical of Indian buildings, and measured loss data is needed to show the difference. Also, it sits alongside a national average household size of 4.44 persons per home [30], a density figure with direct bearing on concurrent in-home traffic load. Together, these two factors are what motivate the outdoor-CPE-first deployment pattern documented in Section 3.1, and they are precisely the operating conditions Section 7.5 argues the 6G evaluation framework should extend to capture explicitly, rather than infer indirectly from field experience after the fact.

3 FWA in 3GPP: What the Standard Delivers Today

3GPP's contribution to 5G has been a remarkable technical achievement: a New Radio air interface that is universally interoperable, rigorously tested, and deployed at global scale. FWA rides on the same radio interface as every other 5G device, but everything that makes a CPE behave, survive, and perform as fixed infrastructure sits outside 3GPP's remit entirely.

As 3GPP did not initially define a comprehensive FWA device class, the wider ecosystem had to bridge the gap. Industry bodies like the GSMA [31] define indoor and outdoor architectural baselines and minimum throughput floor. The Broadband Forum's TR-069 gives operators a device-management protocol. The link layer, which is the radio interface a CPE uses to reach the network, is standardized with precision. Everything above it: how the device is managed, how it behaves over a deployment lifecycle, how it is provisioned at scale, depends on operator-led integration of secondary, non-3GPP frameworks.

3.1 Customer premises equipment as a device class: form factors, siting, and the Indian outdoor profile

A 5G CPE unit is not merely a smartphone that remains stationary. In its outdoor form it is a permanently mounted, professionally installed radio endpoint designed for continuous AC power, characterized by a fundamentally different spectral efficiency, thermal profile and duty cycle. The outdoor unit uses high-gain directional antenna arrays deliberately engineered to secure an optimal, uninterrupted propagation path to a specific serving cell. This physical reality directly contradicts the "stationary UE" abstraction currently utilized in 3GPP eMBB evaluation methodologies. Recognizing FWA as a dedicated device class is a fundamental precondition for accurate channel modelling, scenario evaluation and capital efficient network planning.

Commercial CPE deployments worldwide fall into two primary architectural typologies:

- **Indoor Unit (IDU / Single-Enclosure Architecture):** An integrated desktop device combining the 5G modem, omnidirectional or moderate-gain antennas, Wi-Fi router, and Ethernet switch into a single housing, optimized for rapid user self-installation in high-coverage areas.
- **Outdoor Unit (ODU / Split-Architecture System):** A two-box configuration that mounts a high-gain, directional radio unit externally on an outer wall or roof while placing the Wi-Fi router indoors, interconnecting both through a single PoE cable to eliminate wall-attenuation losses.

Deploying these form factors effectively relies on siting dynamics, which transforms installation from a passive placement exercise into a precise network engineering optimization. Unlike smartphones, whose locations are continuous, random, and incidental as users move around, CPE siting is a fixed engineering decision that involves:

- Placement Selection (Indoor vs. Outdoor): Evaluating site-specific path loss to determine whether an indoor desktop unit suffices or if severe building attenuation mandates an externally mounted outdoor unit to bypass physical barriers.
- Directional Alignment and Gain Optimization: Precision-pointing high-gain directional antenna arrays toward the serving gNodeB, eliminating body-block loss and securing maximum line-of-sight signal quality for multi-carrier aggregation.

- Permanent Fixing and Channel Stability: Rigidly mounting the external hardware to ensure RF link characteristics remain invariant over time, providing network engineers with predictable link margins to accurately model sector capacity.

The global specifications lack the regional environmental context necessary for the Indian subcontinent specifically, extreme summer heat and severe monsoon moisture ingress. HFCL's case study of more than one million CPE units shipped and activated in a single financial year [32] reports monthly replacement rates above 5% during the monsoon for earlier outdoor units built to generic global specifications, mainly from moisture ingress and heat. HFCL's response was an outdoor CPE design for Indian conditions, referred to in this paper as the Indian outdoor profile, built around a sealed IP67 enclosure powered by a single PoE drop [32]. Across two full monsoon seasons, replacement rates for this design stayed below 2% [32]. The two figures are on different bases, so they show the direction of improvement rather than a like-for-like reduction. Because the single-cable design removed indoor electrical work and repeat site visits, average installation time fell from over 90 minutes to under 45 minutes per premise [32]. Figure 3.1 summarises the design and the reported outcomes.

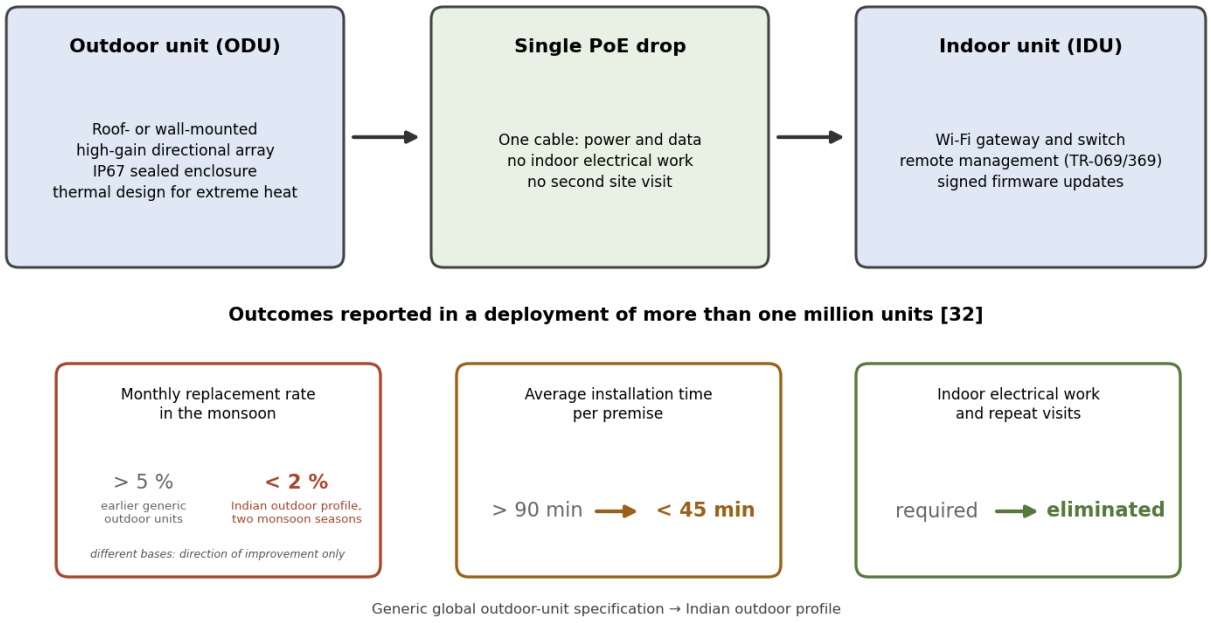


Figure 3.1. The Indian outdoor profile: split-architecture CPE with a single PoE drop, and outcomes reported across two monsoon seasons in a deployment of more than one million units [32].

3.2 Where FWA falls between the gaps: no dedicated scenario, no dedicated channel model, no dedicated evaluation

If Section 3.1 established that CPE is a genuinely distinct device class, evaluating it as a stationary handset is a category error, and it propagates through every layer of the standard built on top of it.

3GPP's evaluation methodology for 5G (TR 38.913, aligned to ITU-R's IMT-2020) was built around three primary usage scenarios: eMBB, URLLC, and mMTC. FWA was never assigned a dedicated scenario or evaluation framework. Instead, it is treated as a variant of an eMBB device held at zero velocity, ignoring

the unique physical, electrical, and topological realities of fixed infrastructure endpoints. This creates severe operational mismatches across the technical specifications like:

- **Channel modelling:** TR 38.901 leaves the terminal antenna to the evaluation assumptions, and Release 19 added a directional terminal reference pattern. Terminal height is not fixed at pedestrian level either: indoor terminals in UMa and UMi sit on floors 1 to 8, up to 22.5 m. What is missing is a line-of-sight probability and clutter model for an outdoor rooftop terminal, and the CPE does not appear in the evaluation assumptions of TR 38.802 or ITU-R M.2412. Without these, the framework cannot describe a directional CPE mounted 3 to 15 m above ground clutter, and it understates the link budget and sector capacity that a well-sited installation delivers.
- **Conformance and OTA testing:** TS 38.101-2 already defines FR2 power class 1 as the FWA UE (minimum peak EIRP 40 dBm, maximum TRP 35 dBm), with conformance in TS 38.521-2, and TS 38.101-1 has power classes 2 and 1.5 for n77 and n78 [1] [2]. The NR OTA test methodology in TR 38.810 evaluates devices by rotating them through 3D spherical coordinates to capture isotropic radiated power. There is no FR1 OTA method for a fixed-boresight outdoor unit aligned to a single gNB, and nothing yet for the 6G bands.
- **Traffic and QoS modelling.** TS 23.501 governs 5QI-based QoS classification, and FWA traffic is mapped to generic non-GBR eMBB profiles (such as 5QI 9) built for bursty, DRX-cycled handset sessions. But FWA is a multi-client gateway running near-continuous duty cycles at household scale. Operators already separate FWA traffic with operator-specific 5QIs (128 to 254), ARP and slice identifiers, as Jio does with its dedicated slice (Section 2.2). How far the gNB scheduler honours that separation depends on the vendor implementation, and scheduler design should remain so. Within the home, the CPE aggregates many applications onto one or a few PDU sessions, so differentiating those flows needs several QoS flows mapped by the CPE or queuing in the CPE itself. What is missing is a standardised FWA QoS profile, so that a household's primary connection is treated consistently across networks and vendors and can be assured.

Establishing FWA as a dedicated deployment scenario, complete with elevated directional channel models, dedicated RF/OTA conformance benchmarks, and tailored QoS frameworks, is an essential prerequisite for predictable, capital-efficient 6G network engineering.

4 Market Opportunities: Consumer and Enterprise

4.1 Consumer Opportunities

The consumer opportunity for FWA rests on three pillars: location; needs and buying behaviour; and the structural advantages of wireless delivery. Understanding all three together is what allows an operator to move from a single generic FWA product to a portfolio of tailored offerings that capture distinct customer segments.

4.1.1 Location

Beyond simply quantifying the size of the FWA opportunity across market segments, it is critical for operators to pinpoint precisely where that opportunity is addressable - down to the individual site and, increasingly, the individual address - and to understand the specific needs of the consumer groups within each location.

4.1.2 Needs and buying behaviour

Different consumer segments value different aspects of the FWA proposition. Some households place a high premium on the speed from decision to service: with FWA, the gap between ordering and an active connection can be a matter of days, compared with weeks for a fibre installation requiring civil works. Renters, in particular, often cannot or do not want to make potentially costly construction changes to a property they do not own, making FWA's ease of installation - frequently self-installable with no cabling - a decisive advantage. And many households, especially smaller ones of one or two people (a large and growing segment in many markets, including urban India), are simply seeking the most economical broadband option available, a need FWA is well positioned to serve given its lower deployment cost base relative to fibre.

4.1.3 No limits with wireless

Wide-area wireless coverage removes several structural limitations that constrain wired alternatives. Locations with only a single incumbent broadband provider - gated residential communities or apartment buildings, for instance - can use FWA to introduce competition and choice. Historic or heritage areas that face construction and permitting restrictions on new wired infrastructure gain a genuine alternative. And rural and remote geographies, where wireless coverage is frequently already available even when wired broadband infrastructure is not, find in FWA a direct answer to a longstanding broadband access pain point.

4.1.4 From tethering to premium experience: the FWA product ladder

To fully understand FWA's monetization potential, it helps to distinguish between several distinct home-broadband product tiers built on wireless technology, moving from the most basic to the most sophisticated:

- **Tethering / mobile broadband hotspot.** Not formally part of the FWA segment, but relevant because many of these connections represent a natural migration path to FWA. Here, a battery-powered pocket router provides Wi-Fi to home appliances using a data-only SIM, typically on a volume-based mobile plan with no service priority.

- **Best-effort FWA.** A household uses an indoor CPE with Wi-Fi or LAN connectivity, typically over 4G, with the CPE and subscription both nomadic - the family can relocate the router and it continues to work wherever coverage exists. Device handling and retail processes are inherited directly from mobile broadband. It resembles fixed broadband from the household's point of view but carries no committed speed or service level.
- **Typical-speeds FWA.** Priced on an advertised typical speed (for example 50-100 Mbps), checked for the specific subscribed address through coverage mapping. The rate is a planning target, not a per-session guarantee: the gNB time-shares the sector among all attached users, and the operator holds the typical rate by limiting how many households it sells to on each sector (Section 5.1). This is much closer in spirit to a genuine fixed broadband offering.
- **Tiered-speed FWA.** The mainstream large-scale monetization opportunity today, with price plans mirroring fixed broadband conventions (100, 200, or 500 Mbps tiers). Both indoor CPE (a fully integrated router, sometimes with an advanced antenna arrangement) and outdoor CPE (a separate outdoor receiver paired with an indoor Wi-Fi gateway, frequently self-installable) are used, managed to fixed-broadband service standards with remote configuration and fault management. Tiered offerings typically command materially higher ARPU than best-effort or typical-speed tiers.
- **Premium experience FWA.** An emerging tier delivered through 5G Standalone, 5G-Advanced, and network slicing, typically paired with outdoor CPE for maximum antenna gain and reception quality, and expected to evolve toward gigabit speeds with enhanced uplink and latency guarantees suited to gaming, hybrid work, and other latency-sensitive residential use cases.

4.2 Enterprise Opportunities

The enterprise FWA opportunity mirrors the consumer opportunity in structure - location, needs, and the advantages of wireless delivery - but with a materially different set of buying criteria and use cases, spanning small and medium enterprises through to large, mission-critical business customers.

4.2.1 Location and segment specifics

As with residential customers, it is critical for operators to identify precisely where the enterprise FWA opportunity is addressable and to understand the specific needs of each business segment - from a single-location retail outlet through to a multi-site logistics operation.

4.2.2 Needs and buying behaviour

Business customers bring distinct requirements to the FWA proposition. Many require high availability, frequently specifying redundancy across two independent access paths (for example, fibre plus FWA, or two independent FWA links) rather than relying on a single connection. Others are actively seeking to modernise legacy connectivity - ageing leased lines or point-to-point microwave links - with a more cost-effective and easily scalable 5G-based alternative.

4.2.3 No limits with wireless, for business

Wide, wireless coverage similarly benefits enterprises: shopping malls, airports, and exhibition halls with only a single broadband provider gain a genuine alternative; heritage commercial districts facing construction permitting constraints gain a viable wired-equivalent option; and rural and remote business

locations, where wired broadband is often simply unavailable, gain direct connectivity. FWA is equally well suited to genuinely temporary locations - construction sites, seasonal retail kiosks, and pop-up commercial spaces - where the multi-week civil-works timeline of a fibre installation makes no commercial sense.

4.2.4 Closing the digital divide for business

Beyond individual consumers, there is a substantial and often under-addressed opportunity to bring high-speed connectivity to small and medium enterprises (SMEs) that today rely on inadequate broadband or none at all. This is particularly consequential in India, where MSMEs are a foundational part of the economy and where reliable connectivity increasingly determines a small business's ability to participate in digital payments, e-commerce, and government digital services. FWA's fast time to market and low upfront cost make it a natural fit for reaching this segment at scale, in a way that fibre-only strategies, constrained by the economics of trenching to every commercial address, cannot realistically match within any near-term time horizon.

5 Deployment Models and Economics: The Operator View

FWA's commercial appeal ultimately rests on a straightforward economic asymmetry between fixed and mobile network investment. An analysis of eight countries (Canada, France, Italy, Norway, Sweden, Finland, Denmark and the UK) with a combined population of more than 250 million found that fixed and mobile services generate broadly similar annual revenues - around USD 81 billion each on average - yet fixed network capital expenditure runs at about 2.8 times the level of mobile capital expenditure for the same revenue base [13]. In other words, fixed broadband today is a materially more capital-intensive business than mobile broadband, for comparable revenue. FWA exists precisely to arbitrage this asymmetry: it lets operators deliver a fixed-broadband-grade experience while investing at mobile-broadband capital efficiency.

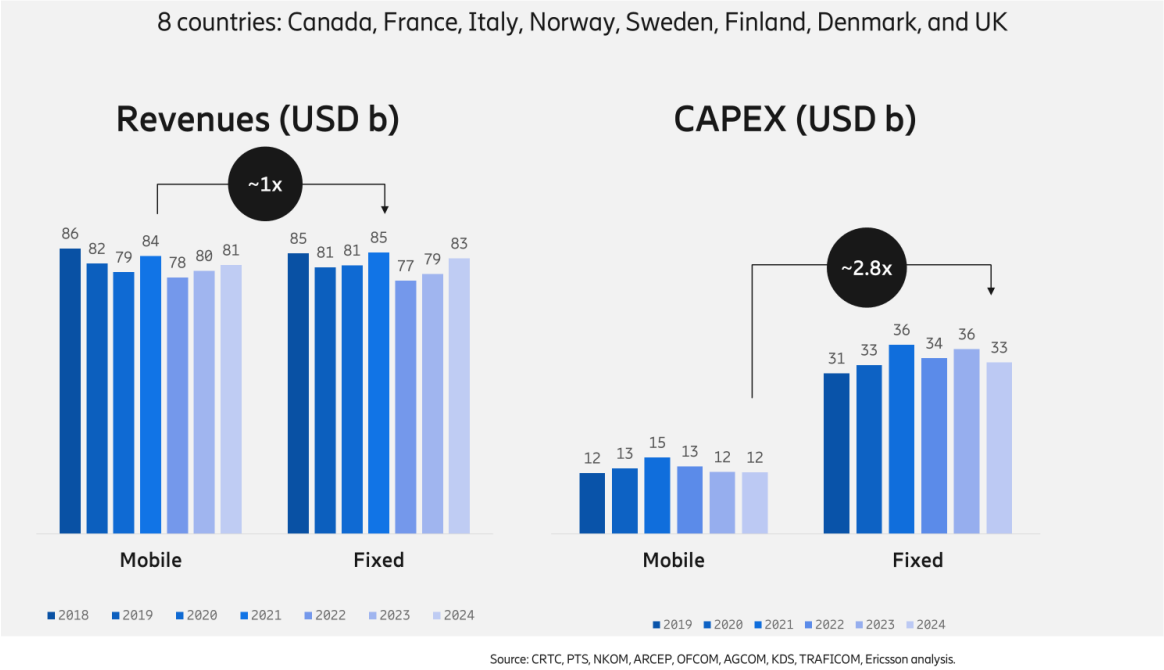


Figure 5.1. Fixed and mobile revenues are similar in size across eight studied countries, while fixed network capital expenditure runs at about 2.8 times the level of mobile capital expenditure.

FWA's speed of deployment is not simply a customer-experience benefit; it is a direct driver of capital efficiency and market-share capture. Because most FWA deployments require only an upgrade of existing mobile sites - adding new, higher-capacity radios rather than new physical infrastructure - the site survey, permitting, and civil-works burden that dominates fibre deployment timelines is largely avoided. Installation at the customer premises is correspondingly faster: in most cases no civil works, cabling, or even technician visit is required at all.

5.1 Eligibility and provisioning: capacity prediction in practice

A key operational discipline that separates successful FWA deployments from underperforming ones is rigorous, data-driven eligibility assessment - identifying, before marketing a service to a given address,

whether the serving sector can carry the new household's busy-hour demand at the promised speed tier without degrading service to existing customers. Leading operators typically follow a forward-looking capacity-prediction model: first establishing current mobile broadband utilisation for a given sector, then estimating how that utilisation will grow over a defined horizon (commonly five years), and then estimating how available capacity in that sector will itself grow through new spectrum, technology upgrades, or densification over the same period [45].

A note on terms. A sector has no single capacity: the throughputs it can deliver form a rate region set by the locations and channels of the users it serves, and the scheduler selects the operating point. In FWA planning, and in this paper, capacity is used in the operational sense that vendors and operators apply: the busy-hour cell load at which the lowest-performing 5 per cent of households fall to the minimum rate the operator commits to [46]. It is a property of the network path, radio and backhaul together, although the model above is usually computed for the radio sector alone (Section 5.2). Spare capacity and headroom mean the difference between that load and the projected busy-hour demand. They are planning estimates calibrated against measured sector load and per-household throughput, not outputs of a standardised analytical model.

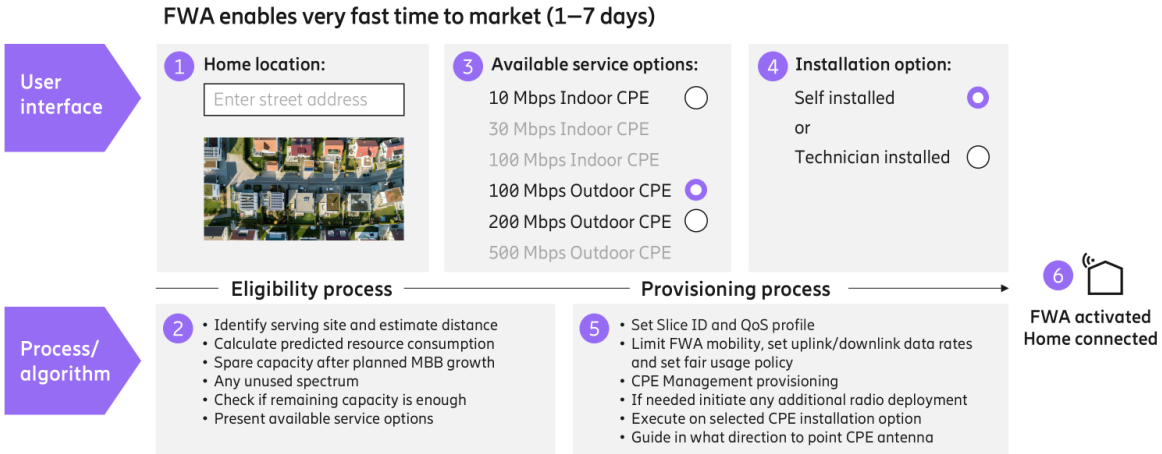


Figure 5.2. The FWA eligibility and provisioning journey: from address entry and automated eligibility check through to installation and activation, typically completed within one to seven days.

Operators approach FWA deployment through several complementary models, often used in combination across different parts of a national footprint: direct-to-consumer sales through existing retail and digital channels, reselling through partners, and, for markets with a genuinely rural or remote unserved population, targeted government-supported deployment models that blend commercial and public investment to reach the least dense, least commercially attractive geographies. The right blend depends heavily on local market structure, existing site-grid density, spectrum holdings, and - critically - the specific policy and subsidy environment that regulators put in place, a topic this paper returns to in its strategic recommendations.

5.2 Backhaul as a binding constraint in Indian rural deployment

The eligibility model in Section 5.1 computes headroom against radio capacity. In much of rural and semi-urban India it is not the only constraint, and often not the first to bind. The sites through which FWA would reach the most unserved households — those serving villages, small towns and the edges of Tier-2 cities — are disproportionately the sites still connected by microwave, and a microwave link typically carries a fraction of what a single mid-band massive-MIMO sector can now deliver. When a site's backhaul carries less traffic than its radio sector can deliver, an eligibility model that counts only the radio sector's capacity will accept households the site cannot serve through the busy hour, and it will do so in exactly the geographies this paper argues FWA should serve first.

The arithmetic is simple to state. Usable FWA capacity at a site in any future year is the smaller of two headrooms: radio capacity less projected mobile broadband demand, and backhaul capacity less the same demand, each measured at the FWA busy hour. Where the second is the smaller, no amount of spectrum or antenna gain changes the answer; only backhaul does (Figure 5.3). India's tower fibreisation stood at around 30 per cent when the National Broadband Mission set its 70 per cent target [33], and the remaining sites are, by construction, the rural and low-density ones. For much of that footprint BharatNet fibre is already at a nearby gram panchayat (Section 6.3), although not every service-ready node is working [12]; the work there is mostly to connect it rather than build it. Once a site is on fibre, radio headroom becomes the limit again. A formal model linking the sector's rate region, the backhaul and a household traffic model to the number of households that can be sold would put this calculation on a firmer footing; it is a natural task for the testbeds recommended in Section 8.1.

Three practical consequences follow. First, eligibility should be computed per site against both constraints, and the backhaul term should be refreshed as sites are fibreised. Second, backhaul upgrade and FWA launch should be planned together: an E-band or high-capacity microwave hop, a BharatNet spur, or an integrated access and backhaul relay [3] can each close the gap, and the choice depends on the distance to the nearest fibre-lit point of presence. Third, the standards and policy work in Sections 7 and 8 should treat backhaul availability as part of the FWA deployment scenario rather than as an operator implementation detail, because it determines how many households a rural site can be sold to.

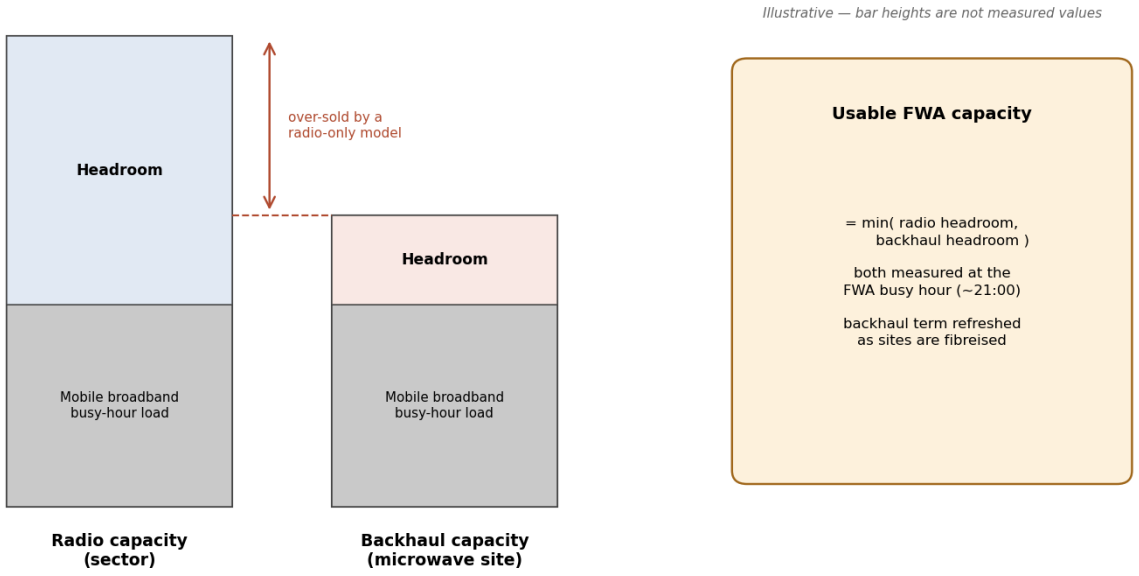


Figure 5.3. Usable FWA capacity at a site is the smaller of radio headroom and backhaul headroom (planning estimates, as defined in Section 5.1), both taken at the FWA busy hour; a radio-only eligibility model over-sells backhaul-limited sites (illustrative).

5.3 What operators need from the network that they do not have today

Sections 2 and 5.1 describe what operators have built. This section states what they still need from the network and the standard, as requirements, so that the 6G discussion in Section 7 has something concrete to answer. They are drawn from Indian deployment experience and from the lessons of the first three years of 5G FWA.

Five lessons come first. FWA fills the fibre-availability gap: it reaches homes and businesses without waiting for civil works, and it does so at scale. Demand extends beyond the metros: half of the national base is rural, so household broadband demand is not a city phenomenon. Capacity planning must be household-traffic aware: FWA load sits at fixed locations and peaks in the evening, so radio planning has to protect both the mobile user and the home-broadband throughput sold at an address. FWA is the most visible 5G monetisation path, packaged as a distinct broadband subscription with entertainment and home-service bundles. And installation quality decides the customer experience: CPE placement, signal quality, in-home Wi-Fi coverage and backhaul capacity matter more than headline peak rates, and installer and customer applications that guide placement have already reduced complaints.

From those lessons follow eight requirements.

- Speed-tier assurance on a shared site: A committed speed tier must survive the mobile busy hour on the same sector, which requires scheduler and slicing behavior that recognises the FWA session as a household's primary connection rather than one more non-GBR flow (Section 3.2).
- Uplink throughput: Multi-user households, video calling and home working make uplink the first resource to saturate; the 6G design should provide more uplink layers, uplink–downlink decoupling and CPE power classes in the 6G bands above those already defined for n77 and n78 (26 dBm and 29 dBm).
- Massive area-capacity scaling: Gigabit and multi-gigabit household service in dense neighbourhoods without degrading mobile traffic, through multi-user MIMO, more downlink and uplink layers and the new upper-6 GHz and 7–8 GHz bands aggregated with existing holdings (Section 7.2).
- Deterministic service assurance: Enforceable quality profiles for premium households, SMEs and enterprises through end-to-end policy and network slicing (one slice for the FWA subscriber base, or one per tier, each with its own resource and QoS policy), with billing and slice definitions flexible enough to support several sub-categories of FWA user.
- AI-native resource management: Demand forecasting, beam and spectrum optimisation, automated admission control and congestion mitigation in real time, and automated provisioning so that user addition scales without proportional operations effort (Section 7.3).
- Improved coverage economics: Higher cell-edge throughput and spectral efficiency so that underserved areas need fewer sites; reconfigurable intelligent surfaces are one candidate in both 5G and 6G bands and backhaul availability must be part of the calculation (Section 5.2).
- Affordable, energy-efficient CPE managed to fixed-broadband standards: Lower device cost, installation complexity and household power draw; minimal cabling to indoor Wi-Fi access points, set-top boxes and power; the ability to act as the home router for IoT and non-IoT devices; support

for higher power and up to 8T8R; and remote configuration, fault management and firmware control equivalent to a fibre ONT (Sections 5.4 and 5.5).

- Speed-tier guarantees at an address, with backhaul in the model: Eligibility and assurance computed per site against both radio and backhaul headroom, and integrated access and backhaul evolved so that one or more wireless hops can extend reach where fibre to every radio site is impractical (Section 5.2).

None of these is a request for a separate FWA technology. Each is a request that the shared 6G platform recognise the fixed endpoint explicitly, which is what the standardisation gap in Section 3.2 currently prevents.

5.4 Securing the network edge: remote management, trusted source and firmware integrity

A CPE fleet of millions of units is the largest attack surface in an FWA network and the one farthest from the operator's control. Three capabilities separate a managed fixed-broadband endpoint from an unmanaged consumer router, and all three belong in procurement specifications and, where the standard allows, in the device class definition.

Remote management at fixed-broadband standards. Fibre operators manage ONTs through auto-configuration servers; FWA CPE should be managed the same way. The Broadband Forum's TR-069 and its successor, the User Services Platform (TR-369), give operators zero-touch provisioning, configuration, diagnostics, Wi-Fi optimisation and fault management at scale [34]. Without them, every configuration change or fault becomes a site visit or a call, and the installation-time and repeat-visit gains reported for the Indian outdoor profile [32] are lost.

Trusted source and device identity. The network must be able to establish what a device is and where it came from. At the 3GPP level, the permanent equipment identifier and its type allocation code, checked against the equipment identity register, can identify FWA CPE hardware and bind it to a subscription profile whose mobility is restricted to the served address — mechanisms that Indian contributions to the SA2 6G architecture study have proposed under the FWA key issue [4]. At the supply-chain level, the National Security Directive on the Telecommunication Sector requires licensees to procure listed equipment from designated trusted sources [35]; operator-procured CPE at national scale brings the same logic to the customer edge, and procurement should require a hardware root of trust and secure boot on every unit.

Firmware integrity. Every CPE image should be cryptographically signed, verified at boot and on update, delivered over the air through the management platform, and protected against rollback to vulnerable versions. Because outdoor units are physically accessible and long-lived, the update path is the only practical way to remove a vulnerability from a deployed fleet; a device that cannot be updated remotely is a device that will eventually be operated by someone other than its owner. The Telecommunication Engineering Centre's mandatory testing and certification regime provides the domestic vehicle for turning these requirements into a certifiable profile [36].

5.5 Why CPE dominates the footprint and what follows for procurement

In a mobile network the base station is the expensive, scarce element and the handset is the customer's problem. FWA inverts that. For every site an operator upgrades it installs hundreds of CPE, the CPE is operator-procured and operator-supported, and it sits in the customer's home for five to seven years. In unit count, in the share of per-subscriber capital cost, in field failures, in installation labour and in electricity consumed, the CPE dominates the FWA footprint. CPE energy use also adds up: a few watts of idle draw across millions of always-on units is a national quantity.

Four things follow for procurement. First, specify for the environment: the Indian outdoor profile, with a sealed IP67 enclosure, single-cable PoE power and data, and thermal design for extreme heat, kept monsoon replacement rates below 2 per cent and halved installation time in HFCL's deployment of more than one million units [32]; the specification, not the brand, produced that result. Second, buy management and security capability, not only radio performance: the requirements in Section 5.4 cost little at the design stage and cannot be retrofitted. Third, treat idle power as a first-order parameter, with per-unit consumption targets and sleep behaviour in the specification, because lifecycle energy is an operator cost and a national one. Fourth, plan the lifecycle: firmware support periods, spares, return logistics and end-of-life recovery for outdoor units belong in the contract.

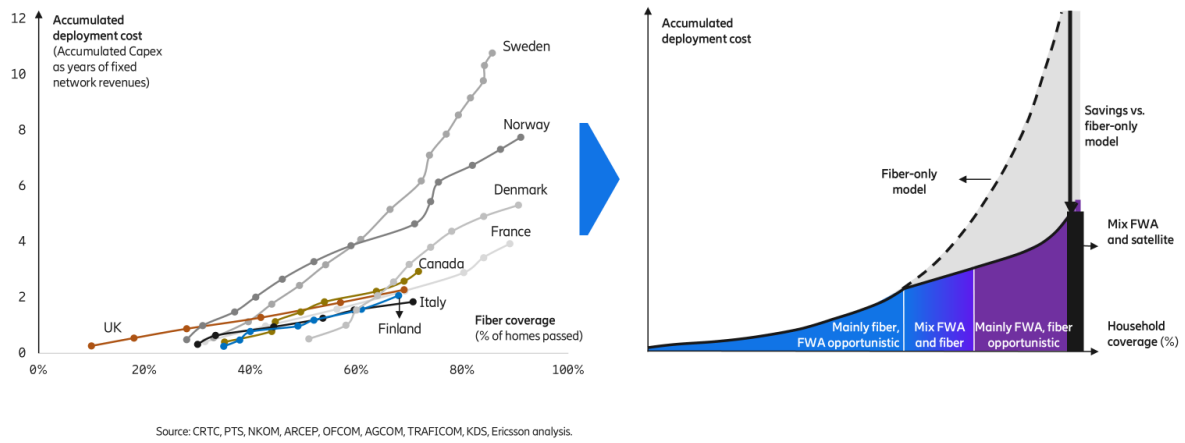
The scale is what makes this a national opportunity rather than a purchasing detail. A 6G CPE class whose requirements are settled while the study is open (Section 7.6) is a product Indian design houses and manufacturers can build to the world's specification with India's environmental profile already inside it; a CPE class inherited from handset assumptions is one they will import.

6 Fibre, FWA and Satellite Strategy

No single access technology can economically serve every home and enterprise in a country as large and geographically diverse as India. The most capital-efficient national broadband strategy - and the one increasingly adopted by leading operators and regulators worldwide - blends fibre, FWA, and satellite deliberately, matching each technology to the density and terrain profile where its economics are strongest.

6.1 How fibre costs evolve across the build-out cycle

Fibre deployment costs do not rise linearly with coverage; they rise sharply once a market moves past its most commercially attractive density tier. An analysis of fixed network spending against fibre coverage progress across eight studied countries shows a clear pattern: countries with moderate fixed capital-expenditure intensity are generally still early in their fibre build-out cycle, with deployment below 60 percent of homes passed, while countries with intense fixed network spending have typically pushed deployment beyond 60 percent of homes passed. In general, the level of required fixed network spending increases sharply once fibre coverage surpasses roughly 50-60 percent of homes - the point at which a market has exhausted its densest, most cost-effective deployment areas and must begin trenching into progressively lower-density, higher-cost terrain.



Source: CRTC, PTS, NKOM, ARCEP, OFCOM, AGCOM, TRAFICOM, KDS, Ericsson analysis.

Figure 6.1. Accumulated fibre deployment cost rises sharply once coverage surpasses roughly 50-60 percent of homes passed, as build-out moves from dense urban cores into progressively lower-density terrain. With FWA, the exponential cost rise is avoided.

6.2 A framework for optimal technology mix

This cost curve suggests a clear, replicable framework for sequencing investment across technologies as national coverage expands:

- **Primary fibre zone (roughly 0-60% of household coverage).** Densely populated urban and peri-urban areas where fibre build-out is genuinely cost- and time-efficient. This is where fibre should be the default technology of choice.
- **FWA pre-emption and competitive zone (roughly 50-70% of coverage).** Areas where service providers may deploy FWA ahead of fibre competitors to secure market share quickly, later evaluating case-by-case migration of individual FWA customers to fibre once the business case for extending fibre to that specific area matures.
- **Primary FWA zone (beyond roughly 70% of coverage).** The point at which fibre deployment costs become high and time-consuming relative to the addressable population. Here, operators with a strong existing mobile site grid and 5G mid-band spectrum holdings can deliver a fast, materially lower-cost broadband solution than a fibre-only strategy, at a fraction of the capital intensity.
- **FWA-and-satellite zone (the final few percent of homes).** The last remaining unconnected homes, where a combination of FWA and satellite is generally the right answer. Many countries already have 97–98 per cent mobile broadband population coverage, meaning the existing site grid can often be upgraded to deliver FWA with comparatively modest incremental investment; where low home density alone makes even that commercially unviable, or where mountainous terrain and topography genuinely limit mobile coverage, satellite becomes the more appropriate - and sometimes only - solution.

Two caveats to this framework matter in practice. First, it is a guide rather than a rigid formula: there are legitimate cases of FWA serving densely populated areas that could technically be served by fibre, just as satellite is sometimes deployed in suburban and even urban areas for reasons of speed to market or competitive positioning. Second, consumer demand for high-speed broadband is intense and immediate, and operators that move fastest and most boldly with any given technology frequently capture disproportionate market share in a given location, regardless of which technology theory would suggest is the 'optimal' long-run answer for that specific address.

Applied to India, this framework argues for a clear, deliberate segmentation: continued aggressive fibre investment in India's largest metros and Tier-1/Tier-2 urban cores, where density already justifies the capital intensity of trenching; 5G FWA as the default broadband technology for Tier-2 and Tier-3 towns and peri-urban geographies where fibre economics are marginal; and a combination of FWA (leveraging India's already extensive mobile site grid) and satellite for the most remote rural and difficult-terrain geographies, including the Himalayan belt, the Northeast, and island territories, where fibre and even standard FWA site-grid coverage remain genuinely challenging.

6.3 The gram-panchayat-anchored model: BharatNet fibre with an FWA last hop

BharatNet has built a middle-mile optical backbone at national scale, and its own design already makes room for wireless beyond fibre. When the Telecom Commission revised the programme’s implementation strategy in July 2017, it explicitly adopted an "optimal mix of media (OFC, Radio and satellite)" to connect Gram Panchayats [37]. For last-mile distribution from these administrative centres, the policy deliberately specified Wi-Fi "or any other suitable broadband technology" [37] as the intended mechanism. An open specification, not a Wi-Fi-only mandate, where FWA fits directly.

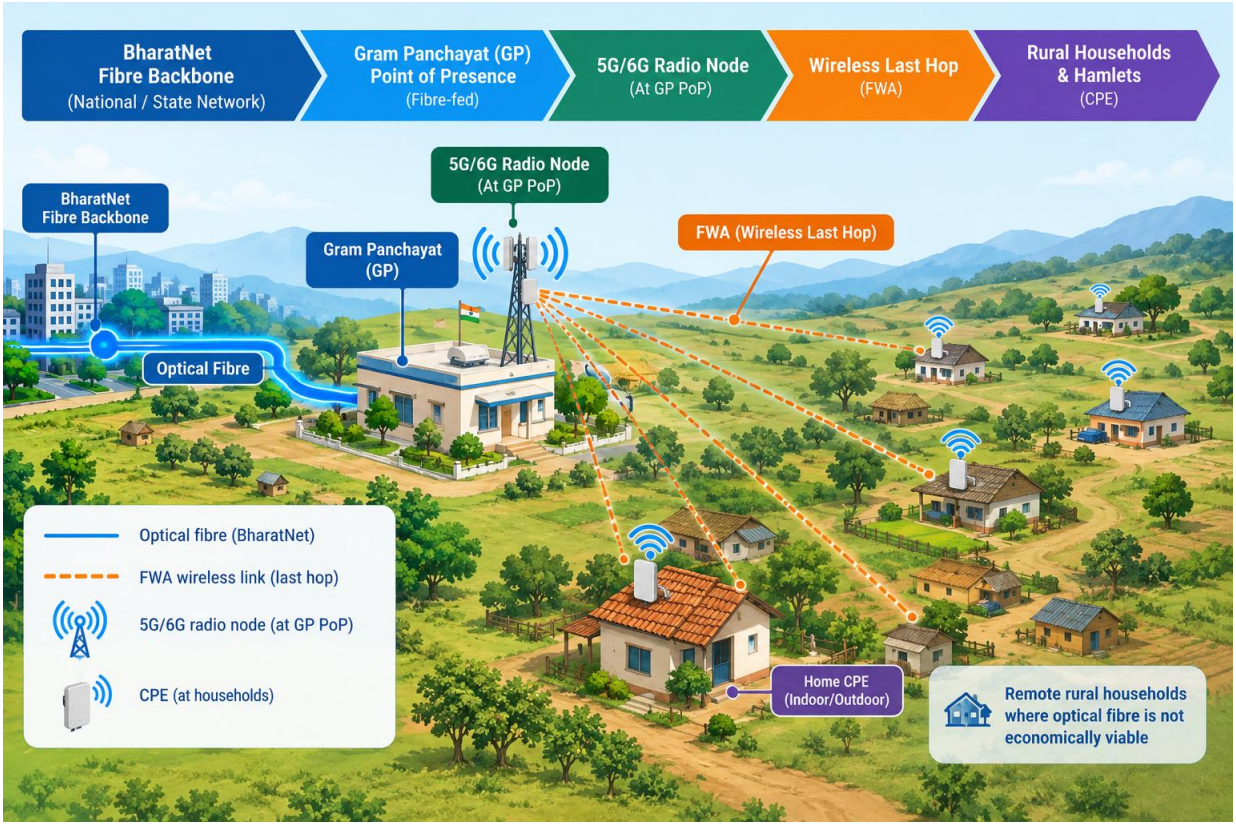


Figure 6.2. The gram-panchayat-anchored model: a BharatNet fibre point of presence at the gram panchayat with an FWA last hop to surrounding households and hamlets.

By January 2025 BharatNet had laid 6,92,676 km of optical fibre, and by March 2025 2,18,347 gram panchayats were service-ready [38]. The Amended BharatNet Programme has since widened the scope to 2,69,062 gram panchayats and traditional local bodies [41], and the service-ready count had reached 2.21 lakh by June 2026 [44]. This is the backbone the architecture in this section assumes, and most of it is already built.

What the same official figures show, set side by side, is the precise shape of the last-hop gap this section is arguing FWA should fill. Against the 2.18 lakh service-ready GPs, the last-mile network currently supports only 1,04,574 Wi-Fi access points and 12,21,014 commissioned Fibre-To-The-Home (FTTH) connections nationally [38]. Fibre has reached the administrative centre. Delivery from that centre to the household has not kept pace with it. It is also not always working there. CAG found 33.2 per cent of service-ready gram panchayats operational in November 2025, with fibre cuts behind about 48 per cent of the non-operational cases and an average restoration time of 17 days [12]. An FWA last hop from the panchayat is only as reliable as the node it depends on, so the GP node needs an uptime commitment of its own.

The Department of Telecommunications (DoT) has recognized this challenge. The Amended BharatNet Programme, approved in August 2023 and integrated into Phase III, specifically targets "future-proofing the network" through 5G integration and focuses heavily on "ensuring robust last-mile connectivity" [38]. That is the opening for FWA: a wireless layer radiating from the fibre-fed gram panchayat PoP that already exists, extending service to the surrounding households and hamlets; a further fibre spur was never going to reach economically or on the stated timeline.

The Gram-Panchayat-Anchored FWA model is a capital-efficient alternative. A 5G/6G radio node installed at the fibre-lit GP point of presence turns the gram panchayat into a wireless broadband anchor. This

eliminates the need for complex civil works inside the village, allowing households to be brought online via simple, roof-mounted CPE. Deploying FWA as the last hop on BharatNet puts the BharatNet investment to use: ₹42,068 crore approved for Phases I and II, of which ₹39,888 crore had been spent by November 2025 [12].

The operating model still has to be settled. BharatNet now sits with BSNL after the BBNL merger, so the open questions are practical ones: who owns and runs the radio node at the panchayat, whose spectrum it uses, on what terms a private operator gets access at the GP, how the node is powered and sited on a panchayat building, and who maintains it, given the restoration times CAG reported.

7 FWA in the 6G Evolution

6G is best understood as an integrated platform for AI and the digitalisation of society and enterprise, built on a small number of foundational cornerstones: cloud infrastructure, which has seen a decade of tremendous data-centre investment now accelerating further with AI training and inference capability; AI itself, increasingly embedded throughout the network stack rather than only layered on top of it; and connectivity, which is what allows AI and cloud applications to interact reliably with the physical world - whether that is a consumer's smartphone, watch, or future AI glasses, or an enterprise's IoT sensors, robotics, and physical-AI systems. Within that connectivity cornerstone, FWA represents the specific slice serving broadband to homes and enterprises where the device is fixed rather than mobile, and it is a deliberate, integral part of the overall 6G ecosystem picture rather than an afterthought.

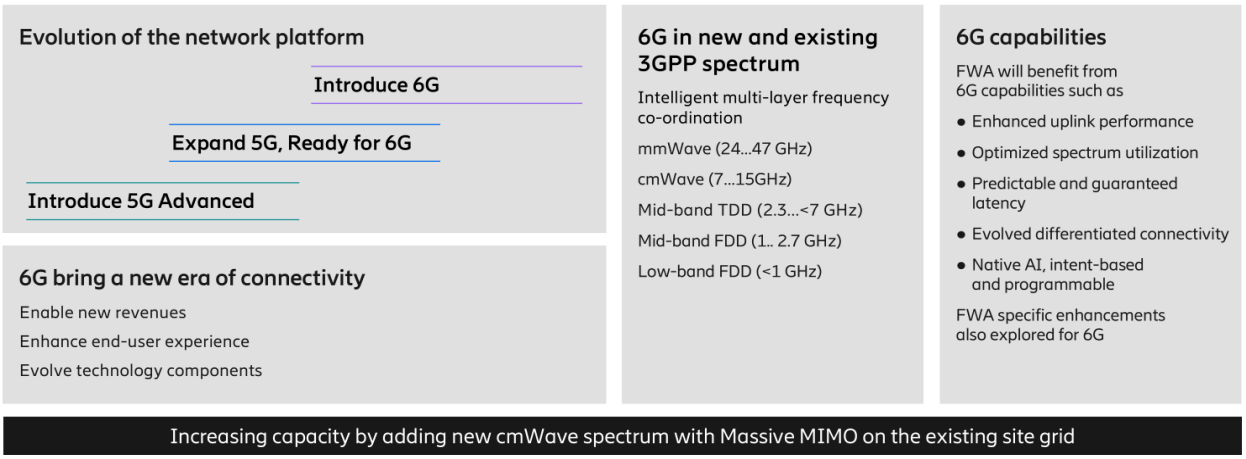


Figure 7.1. FWA is being designed as an integral part of 6G from the outset: new and expanded 3GPP spectrum, AI-native network capabilities, and evolved differentiated connectivity all carry explicit FWA benefits.

7.1 Learning from 5G, building for 6G

On spectrum specifically, 6G is being designed to operate across the same bands already used for 5G, while also introducing new spectrum. The upper 6 GHz band is gathering support: WRC-23 identified 6425-7125 MHz for IMT in Region 1, India and China are studying it, and some Region 2 countries have started to reserve it for IMT [43]. Whether upper-6 GHz becomes a common ecosystem band across most of the world's population will depend on how these and other decisions settle over the next few years. WRC-27 will also consider spectrum in the 7-8 GHz range under Agenda Item 1.7 (7125 to 8400 MHz in Region 3), with early signals of interest from a number of countries including India.

7.2 Spectrum: upper 6 GHz, the 7–8 GHz range, and the aggregation opportunity

One clear illustration of what 6G can deliver for FWA specifically comes from simulation studies of a suburban FWA deployment that aggregates new upper-6 GHz spectrum with existing low-band and mid-band holdings on the same site grid. Adding 200 MHz of new IMT spectrum in the 6 to 8 GHz range and aggregating it with the existing bands raises area capacity by about 500 per cent in a vendor simulation (Figure 7.2), measured as traffic per square metre at a 100 Mbit/s 5th-percentile floor, downlink only. This holds even though the new band propagates less well at the cell edge. The gain comes from aggregating the

new band with existing lower bands rather than using it alone, and 6G carrier aggregation is expected to remove some of the limits that constrained it in 5G. Uplink-downlink decoupling, which lets each device use its best downlink and uplink carrier independently, is a further gain not shown in the figure.

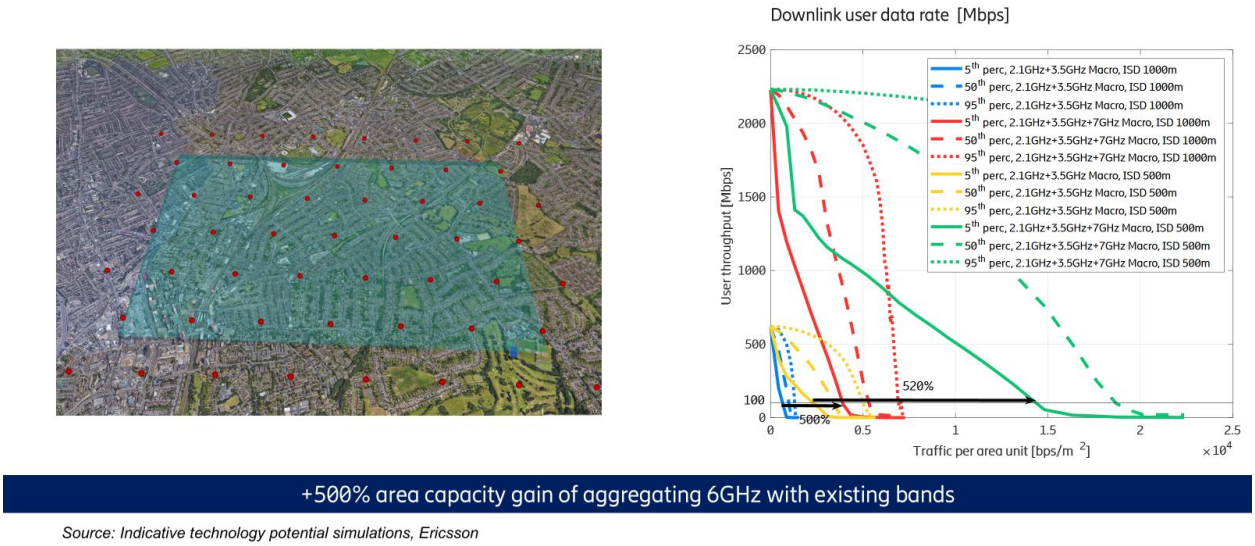


Figure 7.2. Area capacity when 200 MHz of 6-8 GHz TDD spectrum is aggregated with existing bands (vendor simulation, UK suburban layout, downlink only). Baseline deployment: 2.1 GHz and 3.5 GHz; inter-site distance 500 m and 1000 m.

Looking specifically at premium consumer experience, the combination of mid-band FWA with millimetre-wave spectrum discussed in Section 2.3 is expected to be a meaningful bridge technology into the 6G era, delivering genuinely gigabit-class fixed wireless service ahead of full 6G standardisation and giving operators an early, low-risk opportunity to build the commercial and operational muscle for premium differentiated connectivity that 6G will scale further.

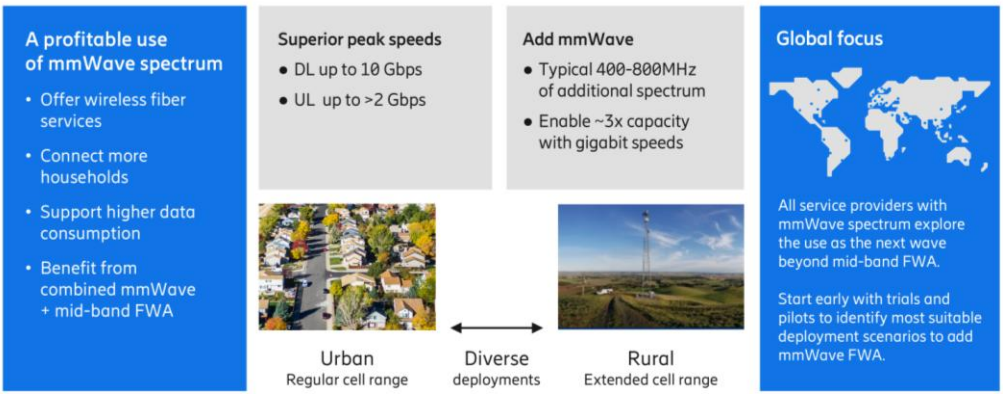


Figure 7.3. The next wave of premium FWA performance, combining mid-band coverage with millimetre-wave capacity to deliver peak downlink speeds up to 10 Gbit/s in dense urban and suburban deployments.

Coverage in the new bands will not come from spectrum and carrier aggregation alone. Reconfigurable intelligent surfaces (RIS), panels that steer a reflected signal into areas the serving site cannot reach directly, are one way to close the gap to a rooftop CPE that sits behind a building or below a ridge, at a fraction of the cost of a new site. India already has a published standard for this: TSDSI STD 5003, Methods and Interface Design for RIS-assisted Communication Systems, sets out the architecture, interfaces and control mechanisms of a RIS-assisted network, and TSDSI is now working on an update to it [42]. FWA is an easier case for RIS than mobile service, because a panel can be configured for a known set of premises rather than tracked as devices move. The coverage-economics requirement in Section 5.3 names RIS as a candidate for this reason, and the 6G evaluation of an FWA scenario should allow a RIS-assisted link to be modelled alongside the direct one.

7.3 AI-native networks and what they mean for FWA

In 6G, AI is expected to run inside the network functions themselves, in scheduling, beam management, energy saving and operations, rather than as an optimisation layer added on top. FWA is one of the easiest places for this to pay off, because the endpoint does not move: its location, antenna orientation and serving beams are known, its channel changes slowly, and its demand follows a daily household pattern tied to an address. That makes the network-side functions listed in Section 5.3 tractable: forecasting busy-hour demand per site, optimising beams and spectrum for a known set of rooftops, admitting new households against both radio and backhaul headroom (Section 5.2), acting on evening congestion before it reaches a committed speed tier, and provisioning new connections without manual intervention. For these functions to work across vendors, the fixed attributes of the CPE and its service tier need to be visible to network AI functions through standard interfaces, which belongs under the FWA key issue in the SA2 architecture study [4].

Where AI runs matters as much as whether it runs. Model training can remain centralised, but inference for interactive and machine-centric applications is moving towards the network edge: to the radio site or an edge data centre and, for FWA, to the customer premises itself. Four reasons make this important in India. Latency: interactive AI assistants, immersive applications and closed-loop industrial control need responses faster than a round trip to a distant cloud region allows. Backhaul: on the microwave-fed rural sites identified in Section 5.2, processing video, sensor and voice streams locally keeps that traffic off the link that binds first. Data locality: household and enterprise data processed on the premises or at a nearby edge site need not leave it, which simplifies privacy and data-protection obligations. Resilience: local inference keeps working when the backhaul is degraded. Two consequences follow for FWA. The CPE, being fixed, mains-powered and always on, is a natural host for local inference or an on-premises AI agent alongside its role as the home router (Section 7.6). And applications served by edge inference send more traffic upstream than today's download-heavy broadband, which reinforces the uplink requirement in Section 5.3 and makes the placement of user-plane functions relative to edge compute a planning question for FWA, as it already is for enterprise 5G.

On the application side, a number of AI-native application categories expected in the 6G era carry direct relevance to fixed customer premises equipment and household or enterprise connectivity, spanning both consumer-centric applications - immersive AI-assisted experiences, ambient intelligence in the connected home - and machine-centric, enterprise, or mission-critical applications - industrial automation, digital

twins, and autonomous systems. What is common across this diverse range of use cases is that many of them will need to communicate over 6G using a variety of device types, including, in many cases, fixed customer premises equipment rather than only mobile devices. This is, in effect, a natural marriage: the broader digitalisation of Indian society and enterprise will increasingly rely on fixed wireless connectivity, and fixed wireless connectivity in turn gains a durable, expanding application base by riding this broader 6G ecosystem momentum, exactly as it rode the 5G ecosystem before it.

7.4 The Release 20 study and where FWA enters it

The 6G study is no longer a proposal, on the radio side, 3GPP TR 38.914 sets the 6G scenarios and requirements that the RAN1 evaluation will follow [16], and the Release 19 extension of TR 38.901 supplies the channel model, including the upper-mid-band 7–24 GHz range and a suburban macrocell scenario [7], [8]. On the system side, SA1 has studied 6G use cases and service requirements [39] and SA2's architecture study, TR 23.801-01, carries FWA as key issue #10 [4]. The fixed endpoint itself is not new to SA2, since TS 23.316 has defined the 5G residential gateway since Release 16, but this is the first time the 6G architecture study has taken it up as a key issue. Release 20 closes these studies; Release 21 is expected to contain the first normative 6G specifications.

In parallel, ITU-R WP 5D has completed the IMT-2030 framework [17] and the evaluation guidelines, has adopted the draft technical performance requirements [40], and is developing the submission and evaluation process through which candidate radio interface technologies will be assessed. WP 5D has also set up a Drafting Group on IMT for fixed wireless access (DG IMT FWA), under the WG General Aspects and SWG National experiences WP5D [1394] Chapter 3 - Annex 3.8.

The decision points are therefore concrete. Whether the scenario list that RAN1 evaluates against carries a fixed-endpoint entry with an outdoor directional terminal at rooftop height, or treats the CPE as a stationary handset again. Whether the channel model gains a penetration-loss category and a spatial geometry that describe reinforced-concrete housing and dense unplanned settlements (Section 7.5). Whether the QoS framework distinguishes a household's primary connection from a handset session. Whether the CPE gains a device class with its own power class, antenna configuration and conformance method, so that RAN4 and RAN5 have something to specify and test.

7.5 Indian deployment conditions that the current framework does not capture

The evaluation assumptions behind 3GPP's channel models and the emerging ITU-R IMT-2030 framework were built around generalized global deployment conditions. They fail to capture the unique structural, spatial, and demographic realities of Indian network deployments. For 6G FWA to achieve the target KPIs in the Indian subcontinent, the standardization framework must account for the following critical deviations:

- **Severe Outdoor-to-Indoor (O2I) penetration loss in RCC construction:** The penetration-loss models in TR 38.901 already include concrete: the low-loss model is 30 per cent standard glass and 70 per cent concrete, and the high-loss model 70 per cent IRR glass and 30 per cent concrete [7]. Indian buildings add thicker RCC slabs, solid brick masonry, dense reinforcement and small

window areas, and the extra loss has not been measured into the model. India's LMLC rural configuration entered ITU-R M.2412 for IMT-2020 on measurement evidence, and the same route is open here. Extending the framework with a category reflecting Indian RCC structures would let operators plan indoor-outdoor CPE deployment more accurately.

- **Urban Density and "Urban Village" Geometries:** Current spatial models assume planned, grid-like street layouts and consistent building heights. India's hyper-dense "urban villages" (e.g., unplanned settlements within metropolitan zones) and Tier-2 cities feature chaotic vertical settlements, separated by exceptionally narrow alleys. This structural geometry drastically reduces ground-level LoS and nullifies standard street-canyon waveguide effects.
- **Household traffic concurrency:** The 3GPP and ITU-R evaluation frameworks have no household traffic model at all. India's average household size is 4.44 persons [30], often with several members on separate high-bandwidth applications at once. Behind one CPE, those users reach the gNB scheduler as a single UE with one aggregate, near-continuous flow. Under proportional-fair scheduling the household competes for a share comparable to a single handset's, while contention among its own applications moves into the CPE, most visibly in the uplink buffer. A concurrency adjusted traffic profile would give operators a more realistic basis for capacity planning.
- **Thermal operating conditions:** Outdoor CPE in India operates through sustained high ambient temperatures across summer, with direct solar loading adding to component thermal stress. Current evaluation frameworks that assume idealized thermal conditions don't fully capture the throughput and stability implications of sustained high-heat operation. Incorporating a thermal-derating profile into performance evaluation would give a more accurate baseline for what CPE can sustain in these conditions.

Each is a proposed extension to the framework, covering conditions that India's FWA rollout has made visible.

7.6 6G CPE as a device class: opportunity for the Indian device ecosystem

The handset market is closed to new entrants; the FWA CPE market is not. Volumes are large — India alone adds hundreds of thousands of units a month — the device is operator-specified rather than consumer-branded, the outdoor unit is an engineering product rather than a fashion one, and the requirements that will define the 6G generation of it are still being written. HFCL already designs and manufactures 5G CPE and has deployed it at million-premise scale [32], and the Indian outdoor profile in Section 3.1 is a specification it produced because the global one did not exist.

The 6G CPE will differ from today's in ways that are already visible. It will operate across upper 6 GHz and the 7–8 GHz range aggregated with mid-band and low-band holdings, with uplink–downlink decoupling (Section 7.2); it will need higher power classes in the new bands, as n77 and n78 already have, and larger arrays, up to 8T8R, to make use of the new bands from a rooftop; it will integrate the home network, with Wi-Fi 7 and its successors and enough routing capability to serve IoT and non-IoT devices without a second box; it will be managed and secured to the standard in Section 5.4; and it will be designed to an idle-power budget. Some of it will act as a relay, extending coverage through integrated access and backhaul to premises the serving site cannot reach directly. On-device intelligence for Wi-Fi optimisation and self-installation is a plausible later addition once the network-side AI functions in Section 7.3 are standardised.

None of this requires a separate technology and all of it requires a device class. The opportunity for the Indian ecosystem rests on three things being done in order: the device-class requirements — power class, antenna configuration, environmental profile, management and security baseline — contributed to RAN4 and to the Release 20 study while it is open; a conformance method for fixed-boresight outdoor units, which RAN5 does not yet have, developed alongside them; and an Indian CPE profile, through TSDSI and TEC, that turns the environmental and security requirements of this paper into a certifiable specification. The chipset will remain a global product. Everything around it — antenna, radio front end, enclosure, power, software, management, and the design know-how that comes from operating at Indian scale — is where domestic value can be built.

7.7 One integrated 3GPP stack for 6G

The consistent message from the FWA industry's engagement with 6G standardisation is that FWA must be fully considered as 6G is standardised and developed, so that it can leverage the same global scale, ecosystem innovation, and spectrum pooling that the broader 3GPP mobile ecosystem delivers - precisely the advantage that has always distinguished FWA from fixed-only wireless alternatives. A single, standardised, integrated 3GPP technology stack for 6G, with FWA treated as a first-class citizen within it rather than a secondary use case, is the explicit goal the industry - and the Bharat 6G Alliance specifically - is working toward, and it is a goal directly aligned with India's opportunity to lead in 6G by building on the strong 5G position the country has already established.

8 Conclusions and strategic recommendations

India's requirements for 6G are shaped by the country's scale and diversity, from crowded metros to remote villages and from flagship to entry-level devices. Delivering fixed broadband at this scale cannot be a matter of technology choice alone; it needs coordinated action from government and regulators, from operators, and from Indian participants in standardisation. The recommendations below are addressed to each in turn.

8.1 Recommendations for Government and the Department of Telecommunications

- **Recognise FWA in national broadband policy.** Count and incentivise FWA connections alongside fibre in broadband mission targets and Digital Bharat Nidhi, and direct subsidies to the geographies where FWA and satellite connect more households per rupee than fibre (Section 6).
- **Prioritise upper 6 GHz and 7–8 GHz spectrum for IMT.** Continue the focus on upper 6 GHz and support global harmonisation of the 7–8 GHz band ahead of WRC-27, so that Indian operators get the same equipment and device economies of scale as the rest of the world (Section 7.1).
- **Treat backhaul as part of FWA policy.** Assign E-band and V-band spectrum for backhaul, set tower fibreisation targets, give licensed operators access to BharatNet fibre at the gram panchayat, and attach an uptime commitment to GP nodes (Sections 5.2, 6.3).
- **Include FWA in 6G testbeds.** Ensure that DoT-funded 6G testbeds and research programmes treat FWA as an explicit use case, and report backhaul availability alongside radio results in testbeds and trials (Section 5.2).

8.2 Recommendations for telecom operators and vendors

- **Build FWA into core and RAN plans.** Carry FWA on a standalone core with a dedicated slice or equivalent policy separation, and dimension the RAN at the FWA busy hour, so that a committed speed tier and the mobile user on the same sector are both protected (Sections 2.2, 3.2 and 5.3).
- **Make eligibility backhaul-aware.** Compute FWA eligibility per site against both radio and backhaul headroom, so that FWA can scale without degrading service for existing mobile users (Sections 5.1, 5.2) [45], [46].

8.3 Recommendations for standardisation: B6GA, TSDSI and Indian delegations

- **Secure an FWA deployment scenario in RAN1 and ITU-R.** Contribute to the Release 20 evaluation an FWA scenario with an outdoor directional terminal at rooftop height, fixed geometry and a household traffic model, and seek the same configuration in the IMT-2030 evaluation, so that FWA is evaluated as it is deployed rather than as a stationary handset (Sections 3.2, 7.4 and 7.5).
- **Build the evidence for FWA in 3GPP evaluation work.** The conditions of Indian FWA deployment, including outdoor directional terminals at rooftop height, fixed geometry, household traffic, RCC penetration loss and dense unplanned urban geometry, are not yet reflected in the 3GPP evaluation assumptions or in TR 38.901. B6GA can support measurement campaigns in Indian deployments so that member companies have the data to bring these into the Release 20 evaluation work and any future channel-model study (Sections 3.2, 7.5).

- **Develop an Indian CPE profile through TSDSI and TEC.** Turn the environmental, management and security requirements of Sections 3.1, 5.4 and 7.6 into one certifiable specification that operator procurement and MTCTE certification can both reference [36].
- **Contribute Indian FWA experience to ITU-R.** The WP 5D Drafting Group on IMT for fixed wireless access is developing a report that draws on national deployment experience (Section 7.4). B6GA encourages its members to contribute India's deployment data and operating conditions through the national process, so that the report reflects conditions beyond the markets that have shaped FWA thinking so far.

The bottom line

FWA is simultaneously a broadband inclusion tool that can close India's remaining fixed-broadband access gap faster and more affordably than any alternative, an operator growth engine that converts existing mobile network investment into a new, high-margin revenue stream, and a foundational pillar of Bharat's 6G future that is being designed into the next generation of global standards from the outset. Capturing this opportunity requires coordinated, deliberate action from government, regulators, and industry alike - and the window to shape 6G standardisation with India's FWA requirements in view is open now.

9 Annexure: Glossary

3GPP — 3rd Generation Partnership Project, the body that specifies mobile radio, core and service standards from GSM to 6G.

5QI — 5G QoS Identifier, the scalar that maps a data flow to a QoS profile in TS 23.501.

ARPU — Average revenue per user.

B6GA — Bharat 6G Alliance.

BharatNet — India's public middle-mile optical fibre programme connecting gram panchayats.

CPE — Customer premises equipment: the terminal at the home or business that connects to the FWA network.

E-band — Millimetre-wave spectrum around 70–80 GHz used for high-capacity point-to-point backhaul.

eMBB — Enhanced mobile broadband, one of the three IMT-2020 usage scenarios.

EIR — Equipment identity register, the network function that checks device identifiers.

FR1 / FR2 — 3GPP frequency ranges below 7.125 GHz and in millimetre-wave bands respectively.

FTTH — Fibre to the home.

FWA — Fixed wireless access: broadband delivered to a fixed location over a mobile radio network.

GP — Gram panchayat, the village-level administrative unit at which BharatNet fibre terminates.

IAB — Integrated access and backhaul, the 3GPP Release 16 feature that lets a radio node use the NR air interface for its own backhaul.

IDU / ODU — Indoor unit / outdoor unit, the two CPE form factors.

IMT-2030 — The ITU-R designation for 6G; IMT-2020 is 5G.

ISD — Inter-site distance.

MTCTE — Mandatory Testing and Certification of Telecom Equipment, the TEC certification regime.

Network slice — A logical end-to-end network, with its own RAN, transport and core resources and policies, that an operator configures for a class of subscriptions; for FWA, typically one slice for the fixed-broadband subscriber base or one per service tier.

NSDTS — National Security Directive on the Telecommunication Sector, the trusted-source regime for telecom procurement.

O2I — Outdoor-to-indoor penetration loss.

OTA — Over the air, used both for radio conformance testing and for firmware updates.

PEI / TAC — Permanent equipment identifier and type allocation code, the 3GPP device identity and its manufacturer-model prefix.

PoE — Power over Ethernet.

RAN1 / RAN4 / RAN5 — 3GPP working groups for the physical layer, RF and performance requirements, and conformance testing.

RCC — Reinforced cement concrete.

RIS — Reconfigurable intelligent surface.

RIT / SRIT — Radio interface technology and set of RITs, the units of submission in the ITU-R IMT process.

SA (5G) — Standalone architecture.

TSG SA — 3GPP Technical Specification Group Service and System Aspects; SA1 and SA2 are its service-requirements and architecture working groups.

TEC — Telecommunication Engineering Centre, Department of Telecommunications.

TR-069 / TR-369 — Broadband Forum CPE management protocols; TR-369 is the User Services Platform.

TRAI — Telecom Regulatory Authority of India.

TSDSI — Telecommunications Standards Development Society, India.

UBR — Unlicensed band radio, TRAI's category for non-5G FWA.

WP 5D — ITU-R Working Party 5D, responsible for IMT.

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Contributors

Chair and Editor: Dr. Sonali Garg, VC-WG Technology, HFCL Limited

Table 1 lists the co-authors and their primary contributions.

Table 1. Co-authors and their contributions

Organization	Co-author names	Primary contribution
HFCL Limited	Swarna Jay Kumar	Sections 2, 3, 5.2–5.5, 6.3 and 7.4–7.6; overall editing
Ericsson	Rowan Hogman and Hakan Olofsson A	Sections 4, 5 (Introduction and 5.1), 6.1–6.2, 7.1–7.3, 7.7 and 8
Tejas Networks	Jishnu Aravindakshan	Inputs to Sections 2.2 and 5.3

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Bharat6G Alliance

Bharat 6G Alliance
2nd Floor, C DoT Campus,
Mandi Road, Mehrauli,
New Delhi- 110030 (INDIA)

info@bharat6galliance.com

www.bharat6galliance.com

