Bharat6G Alliance

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"Think Tank for Digital Transformation"

Bharat 6G Alliance Whitepaper

Cellular and WiFi Synergy: Global Pathways to Inclusive Connectivity

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Executive Summary

A 2030 connectivity agenda built on complementarity

The transition from 5G to 5G-Advanced and the IMT-2030/6G horizon is promising to be a unique and exciting journey and not simply a race for faster radio technology. The decisive issue is whether advanced network capabilities can be supported by the fibre, backhaul, computing, AI, energy, skills, investment and delivery models needed to create meaningful economic and social value. For India, this challenge is especially consequential because it must combine frontier technological ambition with affordable connectivity at continental scale.

The Bharat 6G Vision provides a useful and innovative frame for this task. It seeks to make India not merely a large adopter of next-generation communications, but a contributor to research, intellectual property, standards, equipment, manufacturing and deployment models. This paper identifies three practical tests of readiness embedded in that ambition: sequencing - preparing infrastructure before 6G deployment; scale - extending high-speed broadband and public access across a vast and diverse market; and ecosystem readiness - ensuring that Indian institutions and industry participate in designing, standardising, manufacturing and deploying the technology.

Cellular and Wi-Fi: distinct strengths, coordinated where useful

The central proposition of this paper is deliberately technology-neutral. Cellular and Wi-Fi will remain independently standardised and independently evolving access technologies. Cellular will continue to provide the principal platform for managed mobility, wide-area coverage, licensed-spectrum performance, service continuity and increasingly sophisticated consumer, enterprise and public-safety services. Wi-Fi will remain a flexible local-access technology across homes, offices, campuses, institutions, venues and selected public-access environments.

Their value lies not in forcing convergence, but in selective complementarity. Coordination can occur at several levels: simple coexistence; commercial bundling of mobile, fixed broadband and managed Wi-Fi; trusted discovery and authentication; standards-based traffic steering and switching; and, in compatible environments, simultaneous multi-access. Deeper integration is not automatically better. It should be adopted only where it produces measurable gains in performance, resilience, user experience or commercial outcomes.

The global evidence supports this measured approach. Mobile technologies and services generated an estimated USD 7.6 trillion in economic value in 2025, while global 5G subscriptions reached around 3.1 billion in the first quarter of 2026. Yet approximately 2.2 billion people remained offline in 2025. The coexistence of rapid network growth and persistent digital exclusion shows why coverage alone is insufficient. Meaningful connectivity also requires affordability, quality, suitable devices, skills, trust, relevant services and sustainable delivery models.

Infrastructure beneath the radio layer

The paper therefore places fibre depth and backhaul economics at the centre of 6G readiness. Fibre is not required at every location - microwave, fixed wireless and satellite will remain appropriate in many

circumstances - but high-capacity and resilient transport will be essential to connect radio sites, institutions, enterprises, data centres, cloud and edge resources. The economically important question is how to create sufficient recurring demand to justify deeper infrastructure.

To address this, the paper develops the idea of local connectivity clusters: geographically concentrated combinations of mobile sites, anchor institutions, enterprises, households and authorised public-access points whose combined demand can improve infrastructure utilisation and investment viability. Public Wi-Fi can contribute to such clusters where it is active, useful and commercially sustainable, but it should be measured by real usage, quality, uptime and viability rather than registrations or installations alone.

International experience and India's distinctive opportunity

Evidence from Comcast/Xfinity Mobile, Charter/Spectrum Mobile, Deutsche Telekom, WiFi4EU, OpenRoaming and enterprise Wi-Fi 7 trials demonstrates that cellular-Wi-Fi complementarity can take several forms. Some models are commercial, some technical, some identity-based and some publicly supported. They are not interchangeable, and no single architecture should be treated as a global template.

India's PM-WANI framework is relevant in this context because it addresses the granularity problem of serving very large numbers of individually modest public-access locations. By separating functions among authorised broadband providers, aggregators, application providers and local establishments, it creates an institutional model for distributed access. Its next phase should emphasise active sites, repeat usage, quality, transparent settlement, local support and commercial survival.

A practical delivery compact towards 2030

The paper recommends a collaborative framework based on technology neutrality, technical clarity, future-ready shared infrastructure, viable operator participation, voluntary interoperability, consumer choice, public-access innovation, balanced spectrum policy and evidence-based implementation. Security and trust must be integral: users should be able to identify legitimate networks, authenticate securely, understand who handles their data, see service terms clearly and know who is accountable for faults and redress.

For India, the 2030 pathway should focus on deeper fibre and common infrastructure; connectivity-ready buildings; commercially sustainable public access; regular measurement of active hotspots and fixed-line usage; operator-centred partnerships; and pilots that are evaluated before scaling. The objective is not to decide whether cellular or Wi-Fi will dominate. Cellular will remain foundational to mobility and IMT-2030. The strategic opportunity is to align advanced mobile innovation, shared infrastructure, trusted complementary access and commercially viable delivery so that India's technological leadership is matched by meaningful connectivity at scale.

1. The 6G Horizon: Global Ambition and India's Contribution

"Rather than arriving as one new technology, 6G would develop and evolve over a ten-year period through continuous improvements in standards, spectrum, radio systems, fiber, computing, devices, and commercial applications."

As the global telecommunications industry moves from 5G towards 5G-Advanced and the IMT-2030 horizon, the central question is no longer simply how much faster the next generation of mobile technology will be. The more consequential question is *whether countries can build the infrastructure, innovation capabilities and delivery models required to translate advanced network capabilities into meaningful economic and social value.*

This question is particularly significant for India, the world's most populous country and one of the largest and fastest-growing telecommunications markets. With more than 1.3 billion mobile connections, over 1.05 billion broadband subscriptions and hundreds of millions of citizens still dependent on mobile networks as their primary means of internet access, India's choices will influence not only its own digital future but also the scale, economics and inclusiveness of global connectivity. The country must prepare simultaneously for frontier technologies and connectivity at continental scale—across dense cities, dispersed rural communities, enterprises and public institutions, while keeping affordability central to meaningful digital participation. India's pathway must therefore combine technological ambition with infrastructure depth, commercial viability and inclusion.

1.1 The Bharat 6G Vision

It is within this global context that the **Bharat 6G Vision Document** , released by the Government of India in March 2023, assumes importance. The Vision is not merely an expression of intent to adopt the next generation of mobile technology. It seeks to position India as a contributor to the research, intellectual property, global standards, equipment, manufacturing and deployment models that will shape communications towards 2030. Its mission is to enable *"ubiquitous, intelligent and secure connectivity"* capable of contributing to a high-quality living experience in India and across the world.[3]

India's ambition is consequently twofold. It seeks to participate at the frontier of global technology development while also ensuring that advanced connectivity can address the scale, diversity and affordability requirements of a continental market. The Bharat 6G Vision recognises that achieving these objectives will require more than radio innovation.

The Bharat 6G Vision is unusual among policy documents in that it states its own preconditions. Three of them are directly relevant here:

- The first is sequencing. Among the attributes proposed for the 6G programme, the Vision records:
  "The infrastructure including the optical fiber network should be made ready before deployment of 6G keeping in mind the hyper capability of the technology."
  — Bharat 6G Vision, Section 5.1; Section 4.2

- The second is scale, and here the Vision puts numbers as objectives. Its indicative Digital India 2030 Cellular Mobile and Broadband Policy objectives set out a movement from fifty per cent of households with broadband to ninety per cent with high-speed broadband; from ten gigabits per second to every Gram Panchayat to five hundred, described as high-speed backhaul to complement fibre connectivity and, on the same table, from ten million public Wi-Fi hotspots to fifty million by 2030.

— Bharat 6G Vision, Table 5.3.1.

Fifty million public Wi-Fi hotspots is a quantified 2030 objective, placed in the Vision's own policy table alongside household broadband and Gram Panchayat backhaul. The Vision Document accordingly counts public Wi-Fi among the connectivity outcomes the 2030 network is to deliver on the same roadmap, to the same horizon and as part of the same programme.

The Bharat 6G Vision document seeks to position the country as a frontline contributor to the design, development and deployment of next-generation communications technologies. The Bharat 6G Alliance describes its objectives as strengthening Indian participation in global standards and enabling India to become a leading supplier of affordable 5G, 6G and future telecommunications solutions. These ambitions rest on collaboration among telecom operators, equipment vendors, academia, research institutions, start-ups and standards organisations

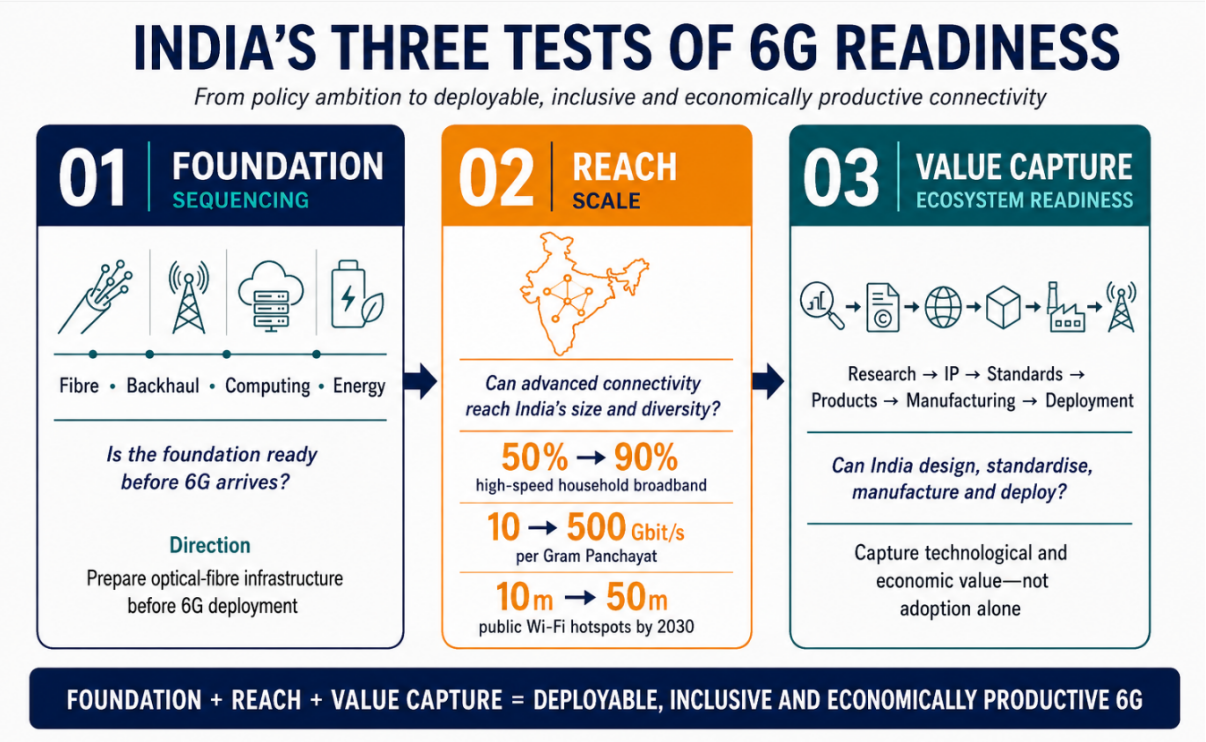
Three readiness tests are especially relevant to this paper: **sequencing, scale and ecosystem readiness**.

Table 1: Three tests of India's readiness for the 6G horizon

6G readiness test	What the Bharat 6G Vision establishes	Why it matters
1. SEQUENCING ***Is the foundation being prepared before the technology arrives?***	*"The infrastructure including the optical fiber network should be made ready before deployment of 6G keeping in mind the hyper capability of the technology."*[3]	Advanced radio capabilities require adequate fibre, backhaul, computing, energy and supporting infrastructure.
2. SCALE ***Can advanced connectivity reach the size and diversity of the Indian market?***	Indicative objectives include increasing households with broadband from approximately **50% to 90% with high-speed broadband**; increasing connectivity for every Gram Panchayat from **10 Gbit/s to 500 Gbit/s**; and expanding public Wi-Fi hotspots from an indicative **10 million to 50 million by 2030**.[3]	India's challenge is not technological capability alone. It is the affordable delivery of connectivity across households, rural institutions, enterprises and public-access environments.

6G readiness test	What the Bharat 6G Vision establishes	Why it matters
3. ECOSYSTEM READINESS ***Can India help design, standardise, manufacture and deploy the technology?***	The Vision and the Bharat 6G Alliance emphasise indigenous research, intellectual property, standards participation, manufacturing and collaboration among operators, industry, academia, research institutions and start-ups.[3] [4]	India's objective is to become a technology contributor and supplier—not only a large market for technologies developed elsewhere.

These tests form a connected delivery logic. Without sequencing, advanced network capabilities may be constrained by inadequate supporting infrastructure. Without scale, technological benefits may remain concentrated in selected urban or commercial environments. Without ecosystem readiness, India could become a substantial adopter of 6G without capturing a commensurate share of its intellectual property, manufacturing and economic value.



1.2 Scope and Proposition

India's 6G readiness extends beyond radio technology to spectrum, fibre and backhaul, cloud and edge computing, devices, energy, investment, skills, standards and institutional coordination. Within this wider delivery chain, the paper examines how cellular and Wi-Fi can synergise and contribute towards 2030.

Cellular and Wi-Fi will remain independently standardised and independently evolving access technologies. Their complementarity lies in coordinating infrastructure, access, identity and service delivery where this produces demonstrable technical, user or commercial value.

Cellular will remain the principal platform for managed mobility, wide-area coverage, licensed-spectrum performance and service continuity. Wi-Fi will provide complementary local access across homes, enterprises, institutions, venues and selected public-access environments. Public Wi-Fi is considered as one of the means of distributing authorised broadband locally. The paper assesses India's distinctive opportunity to connect two ambitions: contributing to the global development of 6G while building the infrastructure and delivery models through which advanced connectivity can become secure, affordable and meaningful across one of the world's largest and most diverse communications markets.

2. A Global Connectivity Landscape Defined by Complementarity

Cellular mobile communications have transformed the global economy and become the principal platform for personal connectivity at scale. GSMA estimates that mobile technologies and services generated approximately **USD 7.6 trillion in economic value in 2025**, equivalent to **6.4% of global GDP**, and projects that their contribution could reach approximately **USD 11.3 trillion by 2030**.[6]

The momentum behind advanced mobile connectivity is equally significant. Ericsson reported that approximately **162 million 5G subscriptions were added during the first quarter of 2026**, taking the global total to around **3.1 billion**. Approximately **390 service providers** had launched commercial 5G services, while worldwide 5G subscriptions were projected to reach **6.4 billion by 2031**.[7]

At the same time, universal and meaningful connectivity remains unfinished. The International Telecommunication Union estimated that approximately **6 billion people—or 74% of the world's population—were using the Internet in 2025**, leaving around **2.2 billion people offline**. Internet use stood at approximately **85% in urban areas**, compared with **58% in rural areas**.[8]

These figures reveal three simultaneous realities:

Table 2: Scale achieved, inclusion unfinished

Global connectivity reality	Evidence	Implication towards 2030
Mobile has become critical economic infrastructure	USD **7.6 trillion**, or **6.4% of global GDP**, generated by mobile technologies and services in 2025[6]	Continued cellular investment and innovation are indispensable to the 5G-Advanced and 6G pathway.
Advanced mobile adoption is accelerating	Approximately **3.1 billion 5G subscriptions** in Q1 2026[7]	The foundations for the next phase of mobile innovation are already being deployed at global scale.
Meaningful connectivity remains incomplete	Approximately **2.2 billion people remained offline** in 2025[8]	Coverage must be accompanied by affordability, quality, devices, skills, reliable quality, relevant services and sustainable delivery models.

The figures are not contradictory. Unprecedented growth in mobile networks can coexist with persistent digital divides. In fact, this paradox is a defining characteristic of the modern global telecommunications landscape. While network operators have expanded coverage and increased market value to historic highs, structural barriers continue to prevent billions of people from fully participating in the digital economy.

In many markets, mobile broadband coverage extends further than actual Internet use. The ' usage gap' may also reflect the cost of devices and services, inadequate backhaul, limited digital skills, insufficiently relevant content, unreliable electricity, lack of trust, or the absence of commercially viable mechanisms for serving small and dispersed pockets of demand.[8]

2.1 From Coverage to Meaningful Connectivity

A credible pathway to 2030 must distinguish between four related but different outcomes:

Table 3: From network presence to meaningful connectivity

Connectivity outcome	Test	Principal enabling conditions
Availability	Is a suitable network technically present?	Coverage, spectrum, infrastructure, energy and backhaul
Affordability	Can users reasonably obtain a device and sustain the service?	Efficient delivery, viable pricing, service choice and appropriate devices
Quality	Can the connection support its intended use consistently?	Capacity, network management, adequate backhaul and suitable access technology
Meaningful use	Can connectivity improve access to education, work, commerce, public services and social participation?	Skills, relevant applications, accessibility, trust and sustained usage

This distinction matters because one access technology cannot be expected to serve every location, user group and application in an identical manner. Mobile networks will remain the principal platform for wide-area connectivity, managed mobility, service continuity and advanced cellular services. Other access systems can address different combinations of indoor distribution, fixed connectivity, concentrated local capacity, enterprise requirements, remote reach and public access.

The objective is therefore not technological uniformity. It is to develop a connectivity environment in which each network performs the functions for which it is best suited, while appropriate technical and commercial coordination reduces friction for users and improves the utilisation of infrastructure.

2.2 One Objective, Multiple Access Pathways

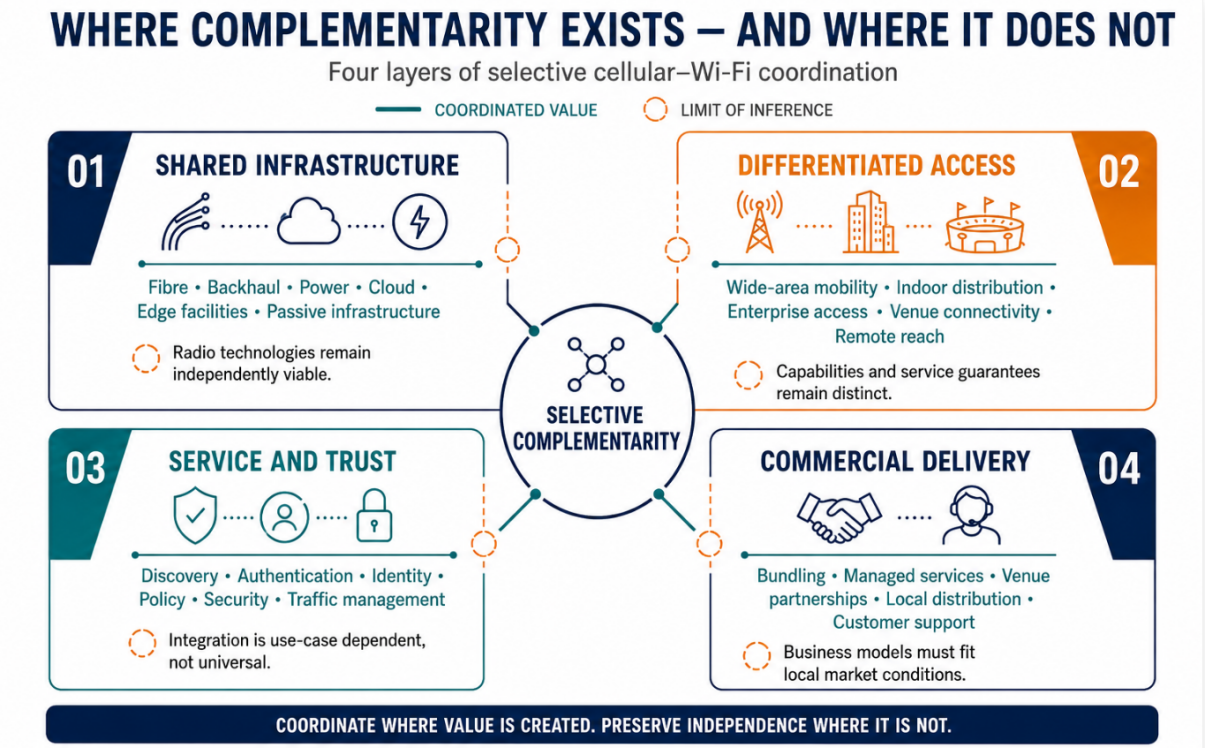
Most digital activity already traverses several network domains. A smartphone may use cellular connectivity while moving through a city, Wi-Fi in a home or workplace, and fibre-based transport to reach a cloud platform. An enterprise may combine fibre, managed Wi-Fi, public mobile connectivity,

private wireless systems and satellite-based resilience. A remote institution may depend upon fixed wireless or satellite backhaul while distributing connectivity locally through wired or wireless access.

From the user's perspective, these are not necessarily separate digital experiences. They are access pathways to the same applications, platforms and services. Their value lies not in being technologically identical, but in providing secure, convenient and commercially sustainable connectivity across different environments.

The Wireless Broadband Alliance's 2026 industry survey found that 60% of respondents expected Wi-Fi and 5G to coexist rather than compete, while the same proportion considered their combination beneficial to enterprise flexibility.[9] These results reflect the expectations of surveyed industry participants—not measured prevalence or performance across global networks—but indicate growing interest in multi-access connectivity portfolios..

This does not mean that coexistence automatically produces convergence. A household using cellular outdoors and Wi-Fi indoors represents coexistence. An operator offering mobile and fixed broadband in one commercial package represents commercial coordination. Secure onboarding, common identity, traffic steering or simultaneous use of multiple access networks represent progressively deeper forms of technical interworking or convergence. These arrangements are distinct and should be evaluated separately.



2.3 From the Digital Divide to a Portfolio of Solutions

The 2.2 billion people who remained offline in 2025 faced different combinations of coverage, affordability, device, energy, skills and service barriers.[8] No single access technology can resolve these constraints universally. Depending upon local conditions, the appropriate intervention may involve extending mobile coverage, strengthening backhaul, improving indoor or institutional connectivity,

reducing service and device costs, establishing viable public access, or using non-terrestrial systems where terrestrial deployment is impractical.

Technology neutrality should therefore mean selecting the network and delivery model according to geography, demand, performance requirements and commercial viability—not treating all technologies as interchangeable. Cellular will remain the foundation of wide-area personal connectivity, while complementary access can extend the locations and conditions under which meaningful connectivity is delivered.

The next section examines this relationship more precisely by distinguishing simple coexistence from infrastructure sharing, commercial coordination, service integration and standards-based interworking.

3. Understanding Cellular–Wi-Fi Synergy

Cellular and Wi-Fi are independently evolving technologies with different spectrum arrangements, network architectures, operating models and deployment characteristics. Their relationship is therefore best understood through **complementarity rather than hierarchy**.

Cellular networks provide managed mobility, wide-area coverage, licensed-spectrum operation, established subscriber relationships, operator-controlled authentication and a platform for increasingly sophisticated consumer, enterprise, industrial and public-safety services. Wi-Fi provides flexible local-area connectivity across homes, offices, campuses, institutions, transport hubs, hospitality venues, retail locations and selected public-access environments.

Their respective strengths frequently operate within the same user journey. A person may use cellular connectivity while travelling, connect through Wi-Fi at home or work, and use venue Wi-Fi at an airport, university or hospital. The two networks may serve the same device and application without being operated by the same entity or having any formal technical integration.

That distinction is important. It is complementary use of different technologies **.** The relationship may range from basic coexistence to progressively deeper forms of commercial, service and network coordination.

3.1 A Cellular–Wi-Fi Coordination Ladder

Table 4: The Cellular–Wi-Fi coordination ladder

Level	Nature of the arrangement	Illustrative application	Critical boundary
1. Coexistence	Cellular and Wi-Fi operate independently but serve the same user, premises or application.	A smartphone uses cellular outdoors and a separately operated Wi-Fi network at home or work.	No common operator, authentication, service policy or integration is required.
2. Commercial coordination	Cellular, fixed broadband and Wi-Fi are combined through common ownership, partnerships, bundling or venue arrangements.	An operator includes managed home Wi-Fi, enterprise Wi-Fi or access to selected partner hotspots within a customer proposition.	A commercial bundle does not necessarily involve technical integration.

Level	Nature of the arrangement	Illustrative application	Critical boundary
3. Service coordination	Discovery, identity, authentication, onboarding or customer experience is coordinated across eligible networks.	A subscribed user is recognised and securely connected to a participating Wi-Fi network without repeatedly entering credentials.	A common user experience does not necessarily mean that traffic is jointly managed.
4. Network interworking	Defined architecture and policies coordinate how compatible traffic uses cellular and non-cellular access.	Traffic is steered or switched between access paths according to network policy and service conditions.	Implementation requires compatible networks, devices, security policies and commercial arrangements.
5. Simultaneous multi-access	Eligible traffic may use multiple access paths within a compatible multi-access architecture.	supported 5G System multi-access PDU session uses defined non-3GPP access for selected traffic	Requires compatible devices, network functions, transport mechanisms, policies and security; it is not generic aggregation of arbitrary networks.

These levels are not mandatory stages through which every deployment should progress. Independent coexistence may be entirely sufficient in one environment; secure onboarding or network interworking may add value in another.. The appropriate level depends upon customer need, network architecture, security, service responsibility, operational complexity and return on investment.

The ladder also provides a discipline for assessing evidence. A combined mobile and home-broadband offer should not be described as technical convergence unless network-level coordination is demonstrated. A trial should not be treated as evidence of universal deployment. Conversely, the absence of deep interworking does not mean that coexistence, bundling or managed local access has no value.

It is worth making explicit that several of these coordination levels are already defined in 3GPP, so 'interworking' need not be reinvented. The 5G System specifies Access Traffic Steering, Switching and Splitting (ATSSS) for the coordinated use of 3GPP and non-3GPP access; trusted and untrusted non-3GPP access (via the N3IWF/TNGF) for bringing Wi-Fi into the 5G core under SIM-based identity; and 5G Wireline–Wireless Convergence (the 5G-RG/FN-RG architecture, 3GPP TS 23.316) for placing fixed and Wi-Fi access under a common core and policy framework. On the Wi-Fi side, Wi-Fi CERTIFIED Passpoint and the Wireless Broadband Alliance's OpenRoaming supply the trusted-discovery and

automated-onboarding layer. The existence of these standards matters in two ways: deeper interworking is available off-the-shelf where a use case justifies it; and, equally, adopting such a standard is a deliberate design choice with its own cost, security and accountability implications , not a default to be assumed.

3.2 Where Each Wireless Segment Fits

The Bharat 6G Vision refers to seamless integration of optical and wireless networks and the use of wireless fibre-like segments where appropriate. This formulation should be understood as a family of possible access instruments—not as a reference to one particular technology, but as an ecosystem or an umbrella of diverse, complementary access instruments.

Fixed wireless access, cellular small cells, distributed antenna systems, private networks, intelligent reflective surfaces and Wi-Fi access points can each extend connectivity beyond a fibre termination. The engineering choice depends upon the service requirement, spectrum environment, coverage area, mobility need, building characteristics, user density, security obligations and available economics.

Higher-frequency radio systems generally offer greater potential capacity but experience shorter propagation ranges and higher losses through building materials. These effects are reflected in the 3GPP channel model covering frequencies from 0.5 GHz to 100 GHz and in the ITU-R model for building-entry loss.[14] [15] As capacity demand rises and higher frequencies are introduced, networks may require denser radio infrastructure and deeper backhaul.

The technologies nevertheless perform different roles:

Table 5: Distinct roles within a complementary connectivity environment

Requirement	Cellular contribution	Wi-Fi contribution
Wide-area mobility	Designed for managed mobility and session continuity across an operator's service area	Primarily designed for local-area access; mobility depends upon the deployed environment
Spectrum environment	Predominantly licensed spectrum with operator-managed planning and quality controls	Predominantly licence-exempt spectrum shared under applicable technical rules
Indoor and local capacity	Indoor cells, distributed antenna systems and appropriately deployed macro coverage	Flexible local distribution of fixed broadband within premises and venues
Service assurance	Operator-controlled network, subscriber relationship and managed service framework	Depends upon the provider, deployment, interference environment and management model
Deployment ownership	Primarily telecom operators and authorised enterprise/private-network stakeholders	Households, enterprises, institutions, venues, operators and public-access providers

Requirement	Cellular contribution	Wi-Fi contribution
Principal 2030 role	Foundation for IMT-2030 mobility, coverage and advanced managed services	Complementary local access where it improves capacity, reach, usability or economics

Cellular remains the principal and most scalable platform for managed wide-area mobility, licensed-spectrum performance and service continuity. Wi-Fi serves a different role: adaptable local access using widely supported devices and comparatively accessible equipment, particularly where broadband already reaches or can economically be extended to the premises.

3.3 From Technical Interoperability to Viable Services

Technical interoperability does not by itself create a viable service. Any cellular–Wi-Fi arrangement must establish:

- the operational value it creates—such as improved coverage, capacity, resilience or customer experience;
- ownership of the local network and responsibility for authentication, data protection, service quality and customer support;
- how usage, performance and settlement will be measured; and
- whether the model reduces costs, generates revenue and allocates investment and operating responsibilities sustainably.

The opportunity should therefore not be limited to **traffic offload**. Offload may be useful in particular circumstances, but the wider commercial potential includes managed residential and enterprise connectivity, venue partnerships, fixed-mobile propositions, secure roaming, service resilience and local broadband distribution.

Artificial intelligence is likely to become an important enabler of multi-access connectivity, particularly as networks, devices and applications become more context-aware. AI-enabled functions at the device, access point, network edge and service platform may support radio optimisation, traffic steering, congestion management, anomaly detection, energy efficiency, quality-of-experience prediction and application-aware connectivity decisions. In a cellular–Wi-Fi environment, this does not imply automatic convergence of networks. Rather, it suggests that devices and networks may increasingly use policy, context, security status, application requirement, power consumption and measured performance to select or coordinate the most appropriate access path. India's 2030 connectivity framework should therefore encourage experimentation with intelligent multi-access management, while ensuring that such systems remain transparent, secure, standards-aligned and accountable.

The value proposition will differ across participants. Operators may seek stronger indoor performance, customer retention or broader fixed-mobile offerings; enterprises and venues may prioritise controlled capacity, resilience and managed access; fixed-broadband providers may extend the utility of their connections; and public institutions may provide secure local access to digital services. The appropriate model must therefore be determined by the use case and commercial setting

Cellular and Wi-Fi will continue to evolve through separate standards, spectrum arrangements and deployment models. Policy should neither compel integration nor treat deeper interworking as inherently superior. Coordination is justified where it improves performance, resilience, user experience

or commercial outcomes while preserving clear responsibility for security, service quality and investment.

3.4 Private networks and Wi-Fi: complementarity inside the enterprise

The complementarity examined so far concerns consumer and public access. A second and equally important expression of cellular–Wi-Fi synergy occurs inside the enterprise, where private 4G/5G networks — in India, Captive Non-Public Networks (CNPNs) — and enterprise Wi-Fi increasingly operate side by side rather than in competition.

The two are engineered for different jobs. Wi-Fi remains the most economical technology for high-density, best-effort indoor data — guest access, general IT, laptops and consumer devices — using unlicensed spectrum and an enormous device ecosystem. Private 5G is engineered, from the radio upward, for the conditions Wi-Fi was not designed for: deterministic latency and guaranteed delivery (URLLC) for control loops and safety systems; seamless make-before-break mobility for vehicles, cranes, AGVs and drones; licensed or locally-authorised spectrum that gives interference control and predictable performance; SIM/eSIM mutual authentication over a known, controlled device population; and long range with better penetration, so a mine, port, campus or corridor is covered with far fewer cells.

The practical enterprise pattern is therefore 'both/and', not 'either/or': Wi-Fi for the IT and best-effort layer, private 5G for the operational-technology and mission-critical layer, frequently over shared in-building infrastructure — structured cabling, small cells, distributed antenna systems and neutral-host arrangements. This is the same complementarity logic the paper applies to public access, expressed at the level of the factory, hospital, port or campus.

The policy implication reinforces the paper's technology-neutral stance. A robust 2030 framework should treat three instruments as complementary — licensed public 5G, unlicensed Wi-Fi, and locally-authorised private 5G (CNPN) — each with a defined role, rather than framing the question as cellular versus Wi-Fi. It also connects directly to the connectivity-cluster concept in Section 4: a CNPN can be the anchor tenant whose sustained, high-value industrial demand improves the economics of extending deeper fibre into a locality.

3.5 The spectrum dimension: licensed, unlicensed and locally-authorised

Any account of cellular–Wi-Fi complementarity is incomplete without the spectrum layer, because the two technologies draw on different spectrum regimes and the most consequential decisions of this decade sit precisely at their boundary. Cellular uses licensed spectrum (and, for CNPNs, potentially locally-authorised spectrum), which provides interference control and quality guarantees; Wi-Fi uses unlicensed spectrum, which provides low entry cost and ubiquity at the price of contention and best-effort performance.

The 6 GHz band is the current flashpoint. India in 2025 delicensed the lower 6 GHz range (5925–6425 MHz) for Wi-Fi (Wi-Fi 6E/7), while the upper 6 GHz range was identified for IMT at WRC-23 and is sought for 5G/6G capacity. A synergy-based framework should treat this not as a zero-sum contest but as a portfolio question — how much unlicensed, licensed and shared or locally-authorised spectrum best serves the national interest — and should explicitly recognise the third path alongside licensed public mobile and unlicensed Wi-Fi: local, administratively-priced spectrum for private networks, the natural spectrum home for the enterprise complementarity described above. Balanced spectrum policy, on this reading, is not only about protecting incumbents; it is about deliberately provisioning all three regimes so that each layer of the complementary ecosystem has the spectrum it needs.

The principle that follows is therefore one of disciplined complementarity. Cellular and Wi-Fi should remain independently evolving access technologies, coordinated only where doing so improves performance, resilience, user experience or commercial outcomes while preserving clear responsibility for security, service quality and investment. The next chapter applies this discipline to the cellular layer itself, clarifying why cellular remains the foundation for India's 5G-Advanced and IMT-2030 pathway even as complementary access models become more important.

4. Cellular as the Foundation of India's 2030 Connectivity Pathway

Cellular mobile networks will remain the foundational layer for India's transition from 5G to 5G-Advanced and IMT-2030. Wi-Fi and other local access systems can complement this foundation, but they do not replace the distinctive role of licensed cellular systems in wide-area mobility, service continuity, managed performance and national-scale connectivity.

The preceding section established that cellular–Wi-Fi synergy is a relationship of disciplined complementarity,. This chapter develops the foundation on which that complementarity must rest. Cellular remains the principal platform through which India will deliver managed wide-area mobility, licensed-spectrum performance, service continuity and the standards-based transition from 5G to 5G-Advanced and IMT-2030. A credible 2030 strategy should therefore avoid framing Wi-Fi, public access or other local-area models as substitutes for cellular investment. Their contribution is strongest when they operate around a robust cellular foundation supported by spectrum, sites, fibre, backhaul, devices, platforms, standards and sustainable operator economics.

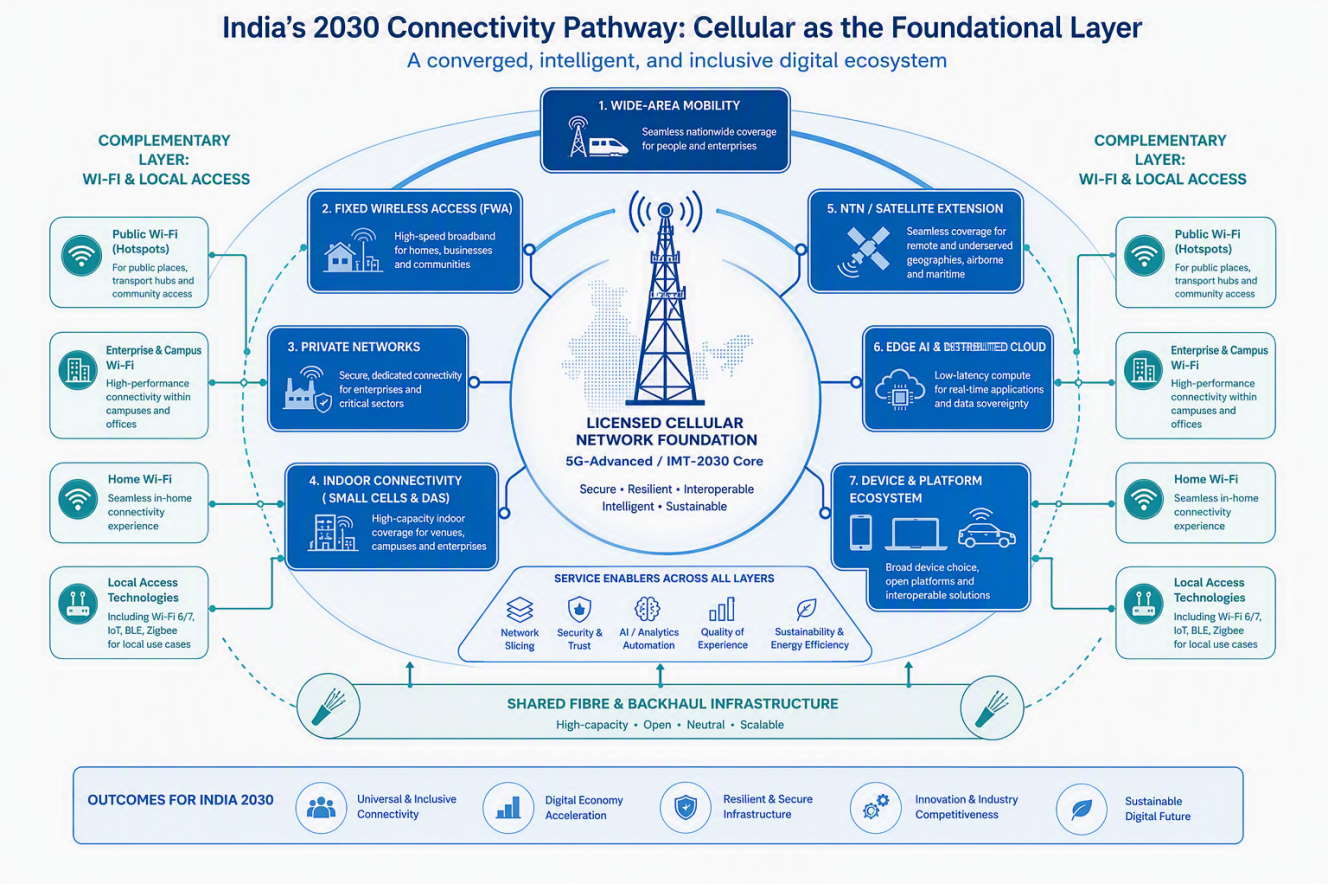


Figure 1: Cellular as the foundational layer for India's 2030 connectivity pathway, supported by shared fibre, devices, edge intelligence and complementary local access.

4.1 Why Cellular Remains Foundational

Cellular networks have several characteristics that make them structurally different from local wireless access. They are planned around licensed spectrum, wide-area radio engineering, managed mobility, subscriber authentication, lawful operation, service continuity and operator accountability. These attributes are essential for national-scale connectivity because users do not experience connectivity as a static indoor service. They move across homes, roads, schools, offices, factories, public spaces, transport corridors and rural areas. Cellular networks are designed to maintain continuity across this movement and to support a common service relationship across geographies.

Cellular capability	2030 relevance
Licensed-spectrum operation	Provides a managed environment for coverage, capacity, interference control and predictable investment.
Wide-area mobility	Supports movement across cities, villages, transport corridors and enterprise campuses.
Service continuity	Maintains user and application experience across cells, locations and network conditions.
Operator accountability	Enables responsibility for authentication, security, quality, billing, support and compliance.
Evolution to IMT-2030	Provides the standards-based pathway from 5G and 5G-Advanced towards future 6G capabilities.

4.2 The 5G-Advanced to IMT-2030 Evolution Pathway

The transition to IMT-2030 will not occur as a single replacement event. It will build on the capabilities, sites, spectrum, devices, software, core networks and operational practices established through 5G and 5G-Advanced. 3GPP Release 18 is widely recognised as the first 5G-Advanced release, extending the 5G system through work on RAN enhancements, AI/ML, reduced-capability devices, non-terrestrial networks, positioning, security, management, orchestration and operational support. This evolution matters because India's 6G readiness will depend on how effectively the country upgrades the cellular foundation during the second half of this decade.

5G-Advanced also shifts the cellular conversation from coverage alone to intelligent, differentiated and more efficient service delivery. Relevant capability areas include improved mobility, MIMO evolution, energy efficiency, RedCap and enhanced RedCap device support, positioning, XR and immersive media support, non-terrestrial network extension, network automation and early AI/ML use cases in the radio and system architecture. These capabilities are particularly relevant for India because they connect national priorities—coverage, affordability, sustainability, industrial competitiveness, emergency resilience and digital public infrastructure—to a standards-based cellular roadmap.

4.3 Cellular Capacity, Indoor Coverage and Fixed Wireless Access

India's mobile traffic growth and diversity of use cases require a cellular strategy that goes beyond macro coverage. Dense urban locations, transport hubs, hospitals, universities, industrial zones, high-rise buildings and public venues increasingly require a mix of macro cells, small cells, indoor systems, distributed antenna systems, private networks , WiFi and high-capacity backhaul. These deployments can improve performance where cellular mobility and service assurance are required, while Wi-Fi and local access can provide additional capacity where the service model and spectrum environment make them appropriate.

4.4 Device, Platform and Ecosystem Readiness

A cellular emphasis must also include the device and platform layer. Advanced cellular capabilities generate value only when they are supported by suitable smartphones, PCs, modules, routers, CPEs, industrial devices, vehicles, wearables, RF front-end systems, operating software and security frameworks. This is particularly important for 5G-Advanced and IMT-2030 because many future use cases will depend on the combined readiness of networks and devices: power efficiency, modem capability, spectrum support, antenna performance, secure credentials, software updateability and application integration.

For India, this has two implications. First, policy should avoid treating connectivity as a network-side issue alone. Device affordability, certification, spectrum-band support, security, domestic design capability and test ecosystems will influence the extent to which citizens, enterprises and institutions can use advanced services. Second, India's 6G contribution should include platform engineering, semiconductor design participation, device testing and standards validation, in addition to network deployment and use-case pilots.

4.5 Policy Implications for a Cellular-Led 2030 Pathway

A cellular-led 2030 pathway should therefore prioritise continued licensed-spectrum planning, predictable investment conditions, mobile-site fibreisation, infrastructure sharing where commercially and technically appropriate, energy-efficient network evolution, secure and interoperable devices, and standards-aligned deployment. Complementary access models should be encouraged where they improve reach, affordability, indoor experience, institutional connectivity or public access to provide enhanced consumer experience everywhere.

The practical policy position is therefore balanced: cellular should remain the primary national platform for mobility, licensed-spectrum innovation and IMT-2030 evolution, while Wi-Fi, satellite and other complementary access models should be integrated into the wider connectivity ecosystem where they improve user outcomes, infrastructure utilisation and commercial viability. This balance leads directly to the next question: what physical and commercial infrastructure must be in place for both cellular evolution and complementary access to scale sustainably towards 2030?

5. The Infrastructure Beneath 6G: Fibre Depth and the Economics of Reach

6G requires infrastructure beyond the radio network. Extending that infrastructure requires viable demand. Cellular sites, institutions, enterprises, households and useful public-access locations can collectively enhance that demand.

The capabilities envisaged for IMT-2030—including higher traffic capacity, low latency, reliability, ubiquitous connectivity, sensing and distributed intelligence—will depend upon the capacity and resilience connecting radio sites, computing resources, data centres and service platforms.

Fibre is important to this foundation because it offers high capacity, low latency and long-term scalability. It is not required at every location: microwave, fixed-wireless and satellite links may remain appropriate where fibre is technically or economically impractical. The objective is scalable infrastructure suited to the service requirement—not fibre deployment irrespective of demand or cost.

5.1 Infrastructure Readiness for 2030

The Bharat 6G Vision states that optical-fibre infrastructure should be prepared before 6G deployment.[3] National Broadband Mission 2.0 reinforces this direction through objectives that include extending operational fibre to 270,000 villages, connecting 90% of anchor institutions, increasing average fixed-broadband speeds and reducing right-of-way processing time.[16]

India's access structure illustrates the challenge. In May 2026, the country had approximately 1.080 billion broadband subscriptions, including around 47.4 million fixed-wired, 18 million fixed-wireless and more than 1.3 billion mobile-wireless subscriptions.[17] These figures describe access subscriptions—not fibre coverage, mobile-site fiberisation, available capacity or route resilience. They nevertheless demonstrate India's dependence on mobile access and the need for infrastructure capable of supporting continued mobile growth alongside deeper fixed, institutional and enterprise connectivity.

Infrastructure created for one service may support others where topology, capacity, ownership and commercial arrangements permit. Fibre serving mobile sites can potentially also support institutions, enterprises, buildings and local wireless access. Such sharing can improve utilisation, but fibre passing a location is not automatically accessible or economically usable by every service provider.

5.2 The Economics of Fibre Reach

The principal constraint on deeper fibre is often not technical feasibility but investment viability. Trenching, ducts, poles, permissions, fibre, electronics and installation create substantial upfront costs. Maintenance, power, repairs, customer acquisition and service assurance create continuing costs.

A route becomes commercially viable when expected recurring revenue from the services using it can support its capital cost, operating cost and investment risk over time. Its economics therefore depend upon more than distance. They are shaped by:

- the number and durability of paying connections;

- the mix of mobile, institutional, enterprise and household demand;
- opportunities to reuse ducts, poles and existing fibre;
- right-of-way and civil-work costs;
- take-up, pricing and service quality; and
- the ability to share capacity without weakening accountability or performance.

Demand aggregation and infrastructure sharing can improve this equation, but neither guarantees viability. Shared infrastructure with insufficient usage may remain uneconomic, while strong demand may still go unserved if deployment costs or regulatory barriers are excessive.

Recent research supports this qualified conclusion. Oughton and Jha found that infrastructure and fibre-backhaul decisions taken during the 5G period would materially affect the feasibility and cost of future higher-quality connectivity.[20] An India-focused study by Kumar and Oughton found that infrastructure-sharing scenarios could improve cost and net-present-value outcomes under the assumptions modelled, but results remained sensitive to adoption, revenue and existing infrastructure.[21] A subsequent systematic review similarly identified potential benefits from sharing alongside regulatory, technical and commercial barriers.[22]

5.3 From Anchor Demand to Connectivity Clusters

The use of concentrated demand to improve broadband economics is well established. ITU research identifies aggregated public demand from government offices, schools, health facilities and public-safety services as a means of creating a more predictable initial revenue base for network investment.[18] The ITU's *Last-Mile Internet Connectivity Solutions Guide* similarly recommends matching access solutions to local demand, density, existing infrastructure, affordability and financial viability.[19]

National Broadband Mission 2.0 applies comparable logic by prioritising schools, Primary Health Centres, Anganwadi Centres and Panchayat offices.[16] An anchor institution can establish initial demand around which additional mobile, enterprise, household and public-access services may develop.

This paper extends that principle through the concept of a **local connectivity cluster**:

A local connectivity cluster is a geographically concentrated group of mobile sites, institutions, enterprises, households and authorised access points whose combined demand may improve the utilisation and commercial viability of shared fibre or other high-capacity infrastructure.

The concept is an analytical framework, not evidence that every cluster will justify fibre. The appropriate solution may include fibre, microwave, fixed wireless, cellular or satellite connectivity. The principle is technology-neutral: aggregate credible demand and then select the infrastructure capable of serving it sustainably.

5.4 Where Public Wi-Fi Adds Value

Public Wi-Fi can contribute to a connectivity cluster where active access points provide useful local service and create recurring demand for authorised broadband. Such demand may improve the utilisation of infrastructure that also serves cellular sites, institutions, enterprises and households.

Its contribution is bounded. A hotspot does not necessarily require a new fibre connection; several access points may share one connection; alternative backhaul may be used; and registration or

installation does not establish active usage or revenue. Public Wi-Fi cannot substitute for cellular mobility but can help complement it.

Where public-access demand is active, aggregated and commercially sustainable, it can contribute to the utilisation of shared infrastructure and the case for extending broadband capacity deeper into a locality.

Infrastructure readiness for 2030 should therefore be assessed through usable capacity, active connections, utilisation, service quality and commercial sustainability—not fibre kilometres or registered hotspots in isolation.

6. International Evidence: Coexistence, Collaboration and Innovation

Cellular–Wi-Fi complementarity is already visible internationally, but its form varies across different regions and use cases. It may involve a fixed-network provider integrating mobile and Wi-Fi into one customer proposition; an operator testing multi-access resilience for an enterprise application; a federated identity framework enabling trusted onboarding; or a municipality supporting connectivity in public-service locations.

These examples should not be treated as components of one universal architecture. They operate under different ownership structures, funding mechanisms, security arrangements, network assets and commercial incentives. Their value lies in showing the range of models available—and the conditions under which each may be relevant.

6.1 Evidence Matrix: Different Models, Different Outcomes

Table 6: Selected international evidence of cellular–Wi-Fi complementarity

Model	Evidence	What it demonstrates
Comcast/Xfinity Mobile, United States—commercial fixed-mobile convergence	Comcast states that Xfinity Mobile combines nationwide 5G with access to approximately **23 million Wi-Fi hotspots** and reported in May 2026 that nearly **90% of Xfinity Mobile traffic** travelled over Wi-Fi.[23]	A fixed-network provider can use extensive managed Wi-Fi assets within an integrated mobile proposition while cellular provides wide-area mobility and continuity.
Charter/Spectrum Mobile, United States—Wi-Fi-centred mobile economics	Charter reports that more than **87% of Spectrum Mobile customers' traffic** is carried over Wi-Fi, including home and eligible out-of-home networks.[24]	Managed Wi-Fi can support traffic-cost optimisation, fixed-mobile bundling and service differentiation.
Deutsche Telekom, Germany—enterprise multi-access resilience	A proof of concept used 5G Standalone and Wi-Fi paths simultaneously for an autonomous guided vehicle; communication continued when one path was interrupted.[25]	Cellular and Wi-Fi can support resilience in selected enterprise and campus applications using multipath techniques associated with ATSSS.

Model	Evidence	What it demonstrates
AT&T, Intel and RUCKUS—enterprise Wi-Fi 7 trials	Under the reported trial conditions, Wi-Fi 7 Multi-Link Operation produced uplink-throughput improvements of up to **116% under interference** and latency reductions of up to **66%** for selected real-time traffic.[26]	Operators, equipment suppliers and chipset providers are collaborating on future enterprise local-area connectivity.
WiFi4EU—municipally supported public access	The programme supported more than **93,000 hotspots across over 7,200 municipalities** in community locations such as public squares, parks, libraries and health centres.[27]	Public support, municipal responsibility and common programme requirements can be combined to extend local access.
OpenRoaming—federated identity and onboarding	Participating identity and access providers can enable secure, automated Wi-Fi onboarding across eligible networks and venues.[13]	Trust and convenience can be improved without requiring one organisation to own every participating network.

The matrix demonstrates that "synergy" can describe very different outcomes:

- **commercial convergence**, in which mobile, fixed and managed Wi-Fi assets form part of one customer proposition;
- **traffic and cost optimisation**, where appropriate local access carries traffic that would otherwise use a wholesale or cellular path;
- **enterprise resilience**, where more than one access path is coordinated for a defined operational requirement;
- **trusted access**, where identity and onboarding reduce friction across participating networks;
- **technology innovation**, where operators participate in the development and testing of new local-access capabilities; and
- **public or community access**, where local connectivity is provided within defined public-service or venue environments.

These pathways are complementary but not interchangeable. The operator-led models of Comcast and Charter depend upon extensive fixed-network assets. Deutsche Telekom's trial and 3GPP ATSSS concern more technically integrated multi-access environments. OpenRoaming addresses identity federation. WiFi4EU is a publicly supported municipal programme. Their economics, accountability structures and intended outcomes differ materially.

The evidence therefore supports a bounded conclusion:

Cellular and Wi-Fi can preserve their distinct technological characteristics while creating additional value through selected commercial, service and network arrangements. The appropriate model must be determined by the use case—not by a presumption that every

network should converge. This underlies the core principle of modern telecommunications that **network coexistence is often superior to full network convergence.**

6.2 Operator Opportunities Across the shared Connectivity Value Chain

A constructive cellular–Wi-Fi synergistic framework must recognise telecom operators and authorised internet service providers as central commercial and technical participants. Operators possess infrastructure, spectrum rights, customer relationships, authentication capabilities, service-management systems, cybersecurity expertise, operational support and established billing channels.

Their participation can extend across the value chain:

Table 7: Operator opportunities across the shared connectivity value chain

Operator role	Potential proposition	Value created
Infrastructure provider	Supply fibre, fixed broadband, fixed wireless or other suitable backhaul to enterprises, institutions, venues and authorised access points	Additional utilisation and revenue from existing or extended infrastructure
Managed-connectivity provider	Design, operate and assure residential, enterprise, campus or venue Wi-Fi	Broader customer relationship and differentiated service quality
Fixed-mobile integrator	Combine mobile, fixed broadband and managed Wi-Fi within one proposition	Customer retention, service convenience and traffic optimisation
Identity and trust provider	Support secure discovery, authentication, onboarding and policy control	Reduced user friction and clearer service accountability
Ecosystem partner	Work with aggregators, institutions, venues and local businesses	Access to fragmented customer segments without replicating every local commercial function
	Measure usage, quality, uptime, security and customer experience	Evidence-based network management and commercially accountable service delivery

The Wireless Broadband Alliance's Operator Managed Wi-Fi work illustrates the development of architectures and operational requirements for provider-managed residential Wi-Fi.[28] Its significance is not that operators should replace independent Wi-Fi ecosystems. It is that customer experience increasingly extends beyond the cellular radio interface into the wider connectivity environment used by the subscriber.

Operator involvement can also improve accountability. Public and enterprise access arrangements require clear responsibility for backhaul, authentication, cybersecurity, service assurance, fault resolution, usage measurement and customer support. These functions are unlikely to be sustainable if every local venue must reproduce them independently.

The guiding principle should therefore be:

Any enterprise or public-access initiative should create a viable role for authorised connectivity providers and integrate them to ensure sustainability, security and scalability, thereby generating **measurable value for the infrastructure, service and customer relationships they support.**

6.3 Public Wi-Fi as a Practical Expression of Connectivity Synergy

Public Wi-Fi is one practical expression of the symbiotic relationship between local wireless access and wider connectivity infrastructure. In indoor environments viz. airports, railway stations, universities, hospitals, public-service centres, markets and commercial venues, it can provide an additional access option alongside cellular services.

Its value is context-specific. It may support visitor access, institutional connectivity, sponsored service, short-duration access, local digital services or connectivity for users who do not require—or cannot sustain—a full mobile-data proposition at that moment.

Public access should not be treated as a uniform product. A managed airport network, a municipal hotspot, an enterprise guest network and a neighbourhood access point have different users, security requirements, operating costs and revenue models. Their viability depends upon:

- the underlying broadband and equipment cost;
- expected user density and recurring demand;
- secure and convenient authentication;
- responsibility for operation and support;
- the availability of relevant local services;
- service quality and uptime; and
- the commercial interests of participating providers and venues.

The objective should be neither mandatory deployment nor substitution of cellular service. It should be the responsible creation of additional access opportunities where consumers, institutions, venue operators and authorised providers find them useful to help provide consumers connectivity in areas where cellular coverage maybe unstable and not sustainable.

The international evidence establishes the range of possible models. The next section examines a specifically Indian challenge: how fragmented local establishments and small pockets of demand can be organised into a scalable public-access ecosystem—and why PM-WANI based Public WiFi has the institutional shape it does.

7. The Granularity Problem, and Why PM-WANI Has the Shape It Does

The challenge is to acquire, connect, support, and sustain a large number of individually modest locations without reproducing the cost structure of a conventional direct-sales channel at every site.

India's indicative objective of 50 million public Wi-Fi hotspots by 2030 involves a level of commercial granularity unlike conventional network deployment. Small shops, cafés, institutions and neighbourhood establishments differ in ownership, demand, technical capability and revenue potential. Serving them individually can create high customer-acquisition, installation, support, authentication, payment and settlement costs relative to the value of each connection.

This is a distribution problem as much as a technology problem. A licensed telecom or internet service provider can supply the underlying broadband, but direct management of every small access location may not be economical. **PM-WANI based Public WiFi addresses this problem by separating the functions required to deliver public access in a democratised /liberalised manner .**

7.1 India's PM-WANI based Public WiFi Experience: A Globally Relevant Public-Access Model

As of 28 February 2026, official data reported **409,403 PDOs/public Wi-Fi hotspots**, supported by **207 PDOAs** and **113 App Providers**. Approximately **24.47 million cumulative users** and **58.64 petabytes of cumulative data consumption** had been reported since the framework's introduction.[30]

These figures demonstrate ecosystem formation, but they should be interpreted carefully. Cumulative registrations, users and traffic do not establish how many access points remain consistently active, their geographic distribution, service quality, revenue, user retention or commercial survival. The next stage of PM-WANI policy should therefore focus less on gross registration and more on sustained performance.

A candid assessment must also address demand, not only supply. India has among the world's lowest mobile-data prices,.. This is the structural reason the field must be judged by active use rather than registrations: a public-access site competes not against scarcity but against a cheap, ubiquitous cellular alternative. It follows that PM-WANI's durable value is unlikely to come from substituting for mobile data at large; it is more likely to come from situations where Wi-Fi is genuinely additive — dense indoor and venue environments where it offloads congested cells and improves experience; time-bound and situational access for travellers, students and migrant workers; enterprise, campus and institutional distribution; and locations where cellular coverage is unstable or capacity-constrained. Framing public Wi-Fi as a complement that captures incremental, context-specific demand — rather than as a parallel mass-market access network — is both more honest and more likely to yield sites that survive commercially.

A May 2026 Department of Telecommunications circular encouraged PDOs and PDOAs to consider short-duration plans of **15, 30 or 60 minutes**, particularly for travellers, students, commuters and other users with situational access requirements.[31] This illustrates one potential distinction between PMWANI based public Wi-Fi and a conventional mobile subscription: it can support locally tailored, time-bound access without presenting itself as a substitute for nationwide cellular service.

PM-WANI based Public WiFi can lower entry barriers, organise fragmented local participants and enable neighbourhood establishments to become points of broadband distribution. It may support access in markets, transport locations, educational areas, public-service environments and other places where concentrated local demand exists.

7.2 Relevance to the 2030 Connectivity Agenda

Within India's 2030 pathway, PM-WANI based Public WiFi should be positioned carefully:

It contributes to India's broader 2030 connectivity pathway. Though the 50 million hotspot number is mentioned as a 2030 objective, it will help in meeting Bharat 6G Vision objectives, in particular fiberization, by complementing the Cellular ecosystem through distributed public access. As an Indian distributed-access model, PM-WANI based Public WiFi can strengthen local connectivity where demand, authorised backhaul, trusted access and sustainable commercial participation come together.

PM-WANI based Public WiFi 's international relevance lies principally in its **institutional design**. It creates a structured interface among authorised broadband providers, platform aggregators, application providers and local establishments. This functional separation may offer lessons for other large and diverse markets seeking to organise distributed public access without requiring one operator or public authority to manage every location directly.

Its success should ultimately be judged not by whether India approaches a headline number of registered hotspots, but by whether active public-access locations deliver affordable, secure and useful connectivity while creating durable value for telecom operators, internet service providers, PDOs, PDOAs, app providers, venues and users.

8. Principles for a Collaborative Global Framework

The 2030 connectivity ecosystem should enable collaboration without imposing technological dependence, weakening investment incentives or obscuring responsibility for security and service quality.

International evidence does not support one universal architecture for cellular–Wi-Fi coordination. Markets differ in infrastructure, spectrum, affordability, institutional capacity and commercial structure. The appropriate global framework should therefore establish common principles while allowing countries and providers to select models suited to their circumstances.

8.1 Principles for Collaboration

1. **Technology neutrality:** Select access technologies according to use case, performance, economics and measurable public value.
2. **Technical clarity:** Preserve the distinction between IMT-2030 mobile systems and independently standardised complementary access technologies. Coordination does not make one technology a prerequisite for another.
3. **Future-ready shared infrastructure:** Treat fibre, backhaul, power, cloud and edge capacity as foundations capable of supporting mobile, fixed, enterprise, institutional and public-access services.
4. **Operator participation:** Create viable roles for authorised telecom and internet service providers across infrastructure, authentication, managed services, service assurance and customer support.
5. **Voluntary interoperability:** Enable discovery, authentication, roaming and multi-access coordination where recognised standards, security requirements and commercial arrangements support them.
6. **Global standards alignment:** Maintain alignment with global standards and certification ecosystems across cellular, Wi-Fi, fixed access, device platforms, security frameworks and roaming systems, including 3GPP, ITU, IEEE, Wi-Fi Alliance, WBA and relevant national bodies, while contributing Indian requirements into those processes.
7. **Consumer choice:** Allow users to select the access option appropriate to their location, device, application and willingness to pay.
8. **Public-access innovation:** Support PM-WANI and other local-access models where they address demonstrated demand and can operate securely and sustainably.
9. **Balanced spectrum policy:** Respect national allocation processes and the legitimate requirements of mobile services, incumbent users and wireless local-area applications without pre-judging outcomes.
10. **Advanced Wi-Fi spectrum and Wi-Fi 7/8 readiness:** Enable forward-looking ecosystem readiness for Wi-Fi 7 and future Wi-Fi 8 capabilities, including high-capacity indoor, enterprise,

campus and venue connectivity, while ensuring that licence-exempt spectrum policy remains balanced, globally informed where appropriate, and consistent with national spectrum priorities, incumbent protection and the requirements of licensed mobile services.

11. **Evidence-based implementation:** Measure active use, quality, affordability, provider value and commercial survival—not merely registrations, installations or announced capacity.

8.2 Security, Trust and Responsible Deployment

A network that is easy to access but difficult to trust will not deliver meaningful connectivity. The Wireless Broadband Alliance's 2026 survey identified network security as the leading concern for **76% of respondents**.[9]

For public, enterprise and federated access, the minimum trust framework should include:

Table 8: Minimum trust framework for coordinated access

Trust requirement	Required safeguard
Authenticity	Users and devices can identify legitimate participating networks
Authentication	Credentials and access exchanges use recognised and securely implemented methods
Privacy and consent	Personal information is limited to legitimate purposes and handled under applicable law
Equipment security	Access points, routers and platforms are securely configured, monitored and updated
Service transparency	Provider identity, price, duration, material conditions and support are visible to users
Operational accountability	Responsibility for uptime, faults, incidents, complaints and redress is clearly allocated
Quality assurance	Performance is measured against the service offered—not inferred from installation alone

Federated identity and automated onboarding may reduce access friction, but they must not dilute accountability. Users should be able to determine who provides the service, who authenticates them, who handles their information and where support is available.

Safeguards should remain proportionate to the service. A short-duration public-access service does not require the architecture of a mission-critical industrial network, but it still requires secure configuration, responsible data handling and an identifiable provider.

8.3 Priority Actions Towards 2030

Table 9: Priority actions towards 2030

Priority	Recommended action	Intended result
Common infrastructure	Accelerate mobile-site fiberization, institutional connectivity, common ducts, coordinated rights of way and dig-once deployment	Greater capacity and less duplication across multiple services
Connectivity-ready buildings	Provide fibre-entry points, structured cabling, power and suitable equipment space in building codes, model bye-laws and public facilities	Lower connection and retrofit costs
Connectivity clusters	Map mobile sites, institutions, enterprises, households and viable public-access demand along common routes	Stronger demand aggregation and backhaul economics
Operator-centred partnerships	Encourage operator-led and operator-partnered enterprise, venue and public-access models	Commercial accountability and service assurance
Trusted interoperability	Adopt recognised specifications for discovery, authentication and roaming where stakeholders elect to interoperate	Easier access without weakening security or responsibility
PM-WANI sustainability	Improve discoverability, settlement transparency, service standards, local support and viable propositions for PDOs	Higher activation, retention and commercial survival
Active measurement	Report active access points, repeat users, traffic, uptime, quality, geographic distribution, revenue and site retention	Evidence of actual performance against 2030 objectives
	Pilot institutional clusters, operator partnerships and interoperability models with published outcomes	Expansion based on demonstrated user and commercial value

These actions do not mandate one operator model or require Wi-Fi integration into mobile networks. They establish the conditions under which different access systems can contribute without fragmenting the connectivity ecosystem.

9. The Road to 2030: From Technological Ambition to Inclusive Connectivity

6G leadership will not be secured only through advances in laboratories or contributions to standards. While they would help establish the foundation, true leadership in 6G will be determined by real-world deployment, institutional readiness, and market adoption.

The transition from 5G to 5G-Advanced and ultimately IMT-2030 will place cellular mobile networks at the centre of a new phase of communications innovation. Managed mobility, wide-area coverage, licensed-spectrum performance, service continuity, sensing, intelligence and highly reliable connectivity will remain defining strengths of the mobile ecosystem.

This paper does not suggest that Wi-Fi is necessary for cellular networks or that Wi-Fi forms part of the IMT-2030 standard. Its technical conclusion is more precise:

Cellular and Wi-Fi will remain independently evolving access technologies. Their combined value arises where differentiated radio capabilities are supported by common infrastructure and coordinated selectively at the commercial, identity, service or traffic-management layers.

It is worth stating plainly the counter-proposition this paper rejects. One view holds that, given cheap devices and unlicensed spectrum, dense Wi-Fi could substitute for continued cellular investment in many settings. The evidence does not support it. Wi-Fi cannot provide wide-area managed mobility, licensed-spectrum interference control, guaranteed service continuity, or the deterministic and secure operation that mission critical applications require. The 6G era widens rather than narrows this gap, since integrated sensing (ISAC), AI-native operation and deterministic services all presuppose coordinated, licensed spectrum. Wi-Fi's own trajectory (Wi-Fi 7 and the emerging IEEE 802.11bn 'Ultra High Reliability' generation) will keep improving local and increasingly latency-sensitive performance, but in parallel with cellular rather than as a replacement for it. The right conclusion is therefore neither convergence nor substitution, but a deliberately provisioned division of labour that deepens as capabilities advance.

This distinction resolves the apparent choice between technological independence and ecosystem collaboration. Cellular does not require Wi-Fi in order to evolve. Wi-Fi does not need to reproduce cellular mobility or service assurance to remain valuable. Each should be used for the functions it performs best.

International evidence demonstrates several workable forms of complementarity: fixed-mobile propositions, enterprise multi-access trials, trusted onboarding, municipal access and distributed entrepreneurial models. It does not establish one universal architecture. The appropriate arrangement depends upon infrastructure, use case, security, provider responsibility and commercial viability.

For India, the opportunity is larger than choosing between access technologies. The country must simultaneously contribute to global 6G standards, deepen its infrastructure, extend meaningful connectivity and develop delivery models appropriate to its scale and affordability requirements. That calls for a focused delivery compact towards 2030.

Priorities for the 2030 Delivery Pathway

The principles set out above imply a small number of concrete measures. Each is non-fiscal, each is a matter of coordination or standard-setting rather than of public expenditure, and each serves the cellular layer and the fixed layer together.

- **Treat fibre depth as the common foundation.** Accelerated fiberisation of mobile sites, public and municipal fibre offered on open-access terms, and dig-once, use-many rules with common ducts.
- **Make buildings capable of hosting connectivity.** Structured cabling, a fibre entry point, mounting space and power, treated in national building codes and model building bye-laws as basic provision. This serves whoever serves the building, and costs a fraction at construction of what it costs as a retrofit.
- **Let the public-access ecosystem mature commercially.** Transparency of settlement terms between aggregators and hosting establishments, a discovery layer, and and recognised interoperability approaches for roaming could improve the survival rate of deployed sites without necessarily requiring large direct public subsidies.
- **Bring the layer into regular measurement.** Active hotspots, as distinct from registered ones, together with fixed-line usage and realisation, reported with the regularity that mobile parameters already are. Against a 2030 objective of fifty million, the absence of a reliable running count is a real handicap.
- **Treat authorised service providers as the principal beneficiaries.** Sustainable public-access expansion will require the participation of authorised telecom and internet service providers, alongside aggregators, venues and local entrepreneurs, so that connectivity, accountability and service assurance can scale together.

9.1 India's Contribution: From Standards to Scalable Delivery

India's role in the global 6G landscape need not be limited to scale of adoption. PM-WANI based public WiFi offers a different form of potential contribution: an institutional design for organising distributed local access through functional separation and entrepreneurial participation.

These contributions operate at different levels and should not be conflated. One concerns mobile standards; the other concerns broadband distribution. Together, however, they illustrate a broader Indian strength—the ability to translate the requirements of a large, diverse and cost-sensitive market into solutions that may also have relevance for other emerging economies.

The pathway to 2030 should therefore be guided by three disciplines:

- **technical clarity**, so complementarity is not mistaken for dependence;
- **commercial realism**, so deployment is sustained beyond targets and announcements; and
- **measurable inclusion**, so infrastructure produces useful and affordable connectivity.

The central question is not whether cellular or Wi-Fi will dominate the 2030 connectivity landscape. Cellular mobile will remain foundational to personal mobility and the IMT-2030 system. The more

useful question is whether India can align advanced mobile innovation, shared infrastructure, **trusted complementary access**, and commercially viable delivery into one coherent national pathway.

India's 6G ambition will achieve its fullest value when technological leadership is matched by the infrastructure depth, market participation and trusted access required to make advanced connectivity meaningful at scale

10. The Convergence Horizon: Policy and Architectural Frameworks for Cellular and Wi-Fi Synergy Toward the 6G Era (2030)

India's strategic delicensing of the lower 6 GHz spectrum (5925–6425 MHz) opens pristine, low-latency, and high-throughput unlicensed channels within a focused 500 MHz window. This operational framework caters strictly to Low Power Indoor (LPI) and Very Low Power (VLP) deployments, avoiding interference with licensed primary services while providing essential wireless capacity for next-generation IoT and consumer electronics ecosystems.

Historically, cellular networks (3GPP) and wireless local area networks (IEEE 802.11) operated as distinct architectural and regulatory silos. The modern digital economy requires a transition from competitive coexistence to deep architectural synergy. Moving into the 6G Release 21 specification window (targeted for a protocol freeze in December 2028), 3GPP and Wi-Fi networks are evolving into a single multi-access fabric. By natively incorporating the capabilities of Wi-Fi 6E and Wi-Fi 7 (802.11be) within strategically managed windows—such as the lower 6 GHz band (5925–6425 MHz)—next-generation mobile cores optimize unlicensed spectrum utilization, improve rural and urban broadband penetration, and deliver deterministic reliability. This white paper outlines how standard-driven interoperability, complemented by progressive frameworks like India's PM-WANI, Voice over Wi-Fi (VoWiFi), and targeted policy incentives (PLI/DLI), acts as a sovereign blueprint for digital inclusion, network resilience, and global hardware export leadership heading toward the 2030 commercialization horizon.

10.1:The Structural Shift to Core Convergence

For over a decade, 'Wi-Fi offloading' was treated as a basic, hard-switched mechanism designed simply to relieve cellular network congestion. If a terminal entered a Wi-Fi zone, cellular data transmission ceased, and Wi-Fi took over. This crude 'make-before-break' approach introduced noticeble session drops, packet loss, and severe security discontinuities. Today, with indoor data traffic consumption accounting for up to 80% of total national network loads, expanding licensed macro networks to meet this demand strains urban infrastructure and drives up capital expenditures.

The introduction of the 5G Core, 5G-Advanced, and the framework for 6G replaces legacy offloading with true Multi-RAT (Radio Access Technology) Convergence. When managed under a unified 3GPP core architecture, cellular macros and localized Wi-Fi networks function as co-equal, simultaneous data pipelines. This framework allows regulators to treat unlicensed spectrum as a cost-effective, hyper-localized extension of national digital infrastructure, boosting data delivery while conserving premium licensed spectrum chunks.

10.2: Exploiting Wi-Fi 6E, Wi-Fi 7, and the 6 GHz Band

The structural alignment realized in modern convergence standards is driven by the paradigm-shifting physical and link-layer capabilities of Wi-Fi 6E and Wi-Fi 7 (IEEE 802.11be):

- **Massive Unlicensed Spectrum Aggregation:** Strategic delicensing of the lower 6 GHz band (5925–6425 MHz) unlocks a focused 500 MHz window for Low Power Indoor (LPI) and Very Low Power (VLP) deployments. Providing continuous wide channels (160 MHz and 320 MHz) allows core networks to offload heavy, data-intense workloads—such as real-time Network Digital Twins or Immersive Extended Reality (XR)—without exhausting licensed cellular mid-band macros.
- **Multi-Link Operation (MLO):** Wi-Fi 7 introduces MLO, allowing a terminal to transmit and receive data across multiple frequency bands (2.4 GHz, 5 GHz, and lower 6 GHz) and channels concurrently, bypassing local congestion dynamically.
- **Geopolitical & Market Positioning:** While some administrations (e.g., China) restrict the entire 6 GHz band exclusively to licensed cellular networks, delicensing the lower 500 MHz creates a decisive first-mover advantage. Startups, OEMs, and MSMEs can design, validate, and scale native hardware locally, turning the nation into a premier development and export hub for over 90 countries utilizing lower 6 GHz unlicensed connectivity.

10.3: Democratic Spectrum Access via Progressive Public Frameworks

A key application of this regulatory synergy is illustrated by public unbundled frameworks, such as India's PM-WANI (Prime Minister's Wi-Fi Access Network Interface). PM-WANI decouples public internet delivery into three independent, interoperable layers:

- **Public Data Offices (PDOs):** Small local retail touchpoints establishing physical Wi-Fi access hotspots.
- **Public Data Office Aggregators (PDOAs):** Regional authorization, compliance, and traffic aggregation hubs interfacing directly with core backbones.
- **App Providers:** Independent client applications managing universal user discoverability, central authentication via QR codes or OTPs, and interoperable billing.

By establishing standardized SSID naming conventions and cross-provider authentication rules, this policy structure aligns with 3GPP goals to minimize onboarding friction. It decongests cellular macros by offloading localized data traffic onto public open Wi-Fi infrastructure, expanding democratic internet access to underserved communities.

10.4: Technical Framework: Traffic Steering (ATSSS) and Latency Optimization

To execute high-throughput, cross-RAT data orchestration without session degradation, the integration of 3GPP ATSSS protocols with Wi-Fi 7 Multi-Link Operation (MLO) establishes statistically uncorrelated parallel paths that eliminate tail-latency spikes. By formalizing this convergence within the 6G Core systems architecture framework (3GPP TR 23.801), next-generation networks can dynamically balance traffic at the packet level, dropping joint error and contention probabilities to as low as 0.25% over shared channels.

Standardization Evolution: The Foundation in 3GPP Release 16, Access Traffic Steering, Switching, and Splitting (ATSSS) moved traffic management from legacy, hard-switched connection drops to dynamic, multi-path steering inside the User Plane Function (UPF).

The 6G Architecture Framework - 3GPP TR 23.801 baseline developed by the SA2 Working Group has integrated ATSSS protocols directly into the next-generation core network blueprint. This ensures that

6G handles non-3GPP links natively at the control-plane level, bypassing the heavy protocol overhead and session discontinuities of traditional IPsec-tunnels.

Wi-Fi 7's Multi-Link Operation (MLO), which allows a single terminal to aggregate independent channels across the 2.4 GHz, 5 GHz, and lower 6 GHz bands (5925–6425 MHz) concurrently. 6G Licensed Layer operates concurrently on dedicated, scheduled licensed spectrum (such as upper mid-band or cmwave bands) overseen by centralized base stations (gNB architectures). Cross-RAT Orchestration: The 6G core uses ATSSS policies to interact directly with the client terminal's dual-radio baseband. Traffic is split or duplicated packet-by-packet, allowing real-time balancing across the cellular and Wi-Fi physical layers seamlessly.

To execute cross-RAT data orchestration without session degradation, 3GPP has codified Access Traffic Steering, Switching, and Splitting (ATSSS) from Release 16 directly into the 6G core systems architecture framework (3GPP TR 23.801). When ATSSS handles packet distributions across a 6G licensed carrier and a Wi-Fi 7 MLO configuration, it establishes uncorrelated parallel paths.

10.5: Voice over Wi-Fi (VoWiFi): A Model for Network Resilience

The mass adoption of Voice over Wi-Fi (VoWiFi) underscores the practical value of unified core networks. By routing voice call payloads through local broadband lines and back into the carrier's IP Multimedia Subsystem (IMS) framework via Trusted WLAN Interworking Functions (TWIF), VoWiFi eliminates indoor signal blind spots.

For policymakers, this provides two clear advantages: (1) Infrastructure Insulation, allowing operators to sustain coverage inside deep basements and high-rises without installing costly, power-heavy Distributed Antenna Systems (DAS), and (2) Emergency Communication Continuity, enabling citizens to maintain access to emergency dispatch lines and public safety alerts even during cellular tower outages caused by extreme weather or grid failures.

10.6: Security & Governance: SIM-Based Authentication Topology

A major hurdle for public networks is maintaining security compliance without introducing user friction. Legacy public Wi-Fi setups rely on unencrypted Pre-Shared Keys or unverified web portals. Convergence architectures solve this by routing Wi-Fi validation through the physical or embedded Universal SIM (USIM) card via Extensible Authentication Protocol-5G (EAP-5G) over the link layer, executing a structured key hierarchy:

1. Identity Concealment: The device masks user identities by transmitting a Subscription Concealed Identifier (SUCI) or a 5G Globally Unique Temporary Identifier (5G-GUTI) to the core's TWIF, blocking over-the-air tracking.
2. Mutual Authentication: The core validates credentials using 5G Authentication and Key Agreement (5G-AKA), checking the root key (K) and terminating rogue access point (Evil Twin) threats.
3. Cryptographic Derivation: From the central mobility key (K_AMF), a non-3GPP key (K_TWIF) is derived via HMAC-SHA-256. This is converted into an 802.11-compliant Pairwise Master Key (PMK) and pushed down to the local Wi-Fi 7 Access Point, which handles a 4-way handshake to secure the airlink via GCMP-256.

10.7: Enterprise and Industrial High-Margin Application Frontiers

By joining macro-mobility with the high-density local throughput of the lower 6 GHz band, advanced dual-market use cases become commercially viable:

- **Deterministic Factory Automation:** Wi-Fi 7 industrial IoT gateways and Automated Guided Vehicle (AGV) controllers combine with private cellular loops to sustain sub-5ms latencies for robotics and Automated Optical Inspection (AOI) vision hubs.
- **Smart Healthcare & Medical Telemetry:** Ultra-HD medical imaging routers stream uncompressed 8K video feeds for real-time surgical imaging and remote care without packet collisions.
- **Spatial Computing & Extended Reality (XR):** Wireless AR/VR/MR dongles offload complex spatial graphics to local computing hubs

10.8: Open Infrastructure & Multi-Access Edge Deployment types

To avoid vendor lock-in, multi-access industrial deployments rely on standardized, software-defined edge topologies:

- **Multi-Access Edge Routers:** Branch routers embedded with dual-SIM WAN links and native Wi-Fi 7 basebands. Cloud orchestration software dynamically directs traffic, pushing bulk analytics to unlicensed channels while pinning voice loops to premium cellular macro slices.
- **Turnkey Private Multi-RAT Gateways:** On-premises systems combining cellular small cells and enterprise Wi-Fi controllers under a single IT dashboard. Subscriber identities are linked directly to corporate Zero-Trust Network Access (ZTNA) policies.
- **Industrial Edge Computing Nodes:** Ruggedized edge computing servers running local core network microservices. These systems parse operational technology (OT) protocols (e.g., PROFINET) locally and balance them across the optimal real-time air interface.

Endnotes

1. International Telecommunication Union, *Recommendation ITU-R M.2160-0: Framework and Overall Objectives of the Future Development of IMT for 2030 and Beyond*, November 2023, https://www.itu.int/rec/R-REC-M.2160/en.
2. 3rd Generation Partnership Project, *Release 18*, https://www.3gpp.org/specifications-technologies/releases/release-18.
3. Department of Telecommunications, Ministry of Communications, Government of India, *Bharat 6G Vision*, March 2023, https://bharat6galliance.com/bharat6G/public/assets/OurOfferings/Bharat-6G-Vision-Statement-copy%202_1.pdf.
4. Bharat 6G Alliance, official institutional objectives and programme materials, https://bharat6galliance.com/.
5. Telecommunications Standards Development Society, India, "TSDSI's 5th Generation Radio Interface Technology Reaches Final Step to Be Notified as an IMT-2020 Standard by ITU," https://tsdsi.in/tsdsis-5th-generation-radio-interface-technology-reaches-final-step-to-be-notified-as-an-imt2020-standard-by-itu/.

   ☐ ITU-R Recommendation M.2410, *Minimum Requirements Related to Technical Performance for IMT-2020 Radio Interface(s)*: https://www.itu.int/rec/R-REC-M.2410/e
6. GSMA, *The Mobile Economy 2026*, https://www.gsma.com/solutions-and-impact/connectivity-for-good/mobile-economy/.
7. Ericsson, *Ericsson Mobility Report*, June 2026, global 5G subscription and commercial-deployment data, https://www.ericsson.com/en/reports-and-papers/mobility-report.
8. International Telecommunication Union, *Facts and Figures 2025*, https://www.itu.int/itu-d/reports/statistics/facts-figures-2025/.
9. Wireless Broadband Alliance, *Industry Report 2026*, https://wballiance.com/industry-report-2026/.
10. 3rd Generation Partnership Project, *System Architecture for the 5G System*, 3GPP TS 23.501, current release.
11. 3rd Generation Partnership Project, specifications and technical materials relating to Access Traffic Steering, Switching and Splitting within the 5G System.
12. Wi-Fi Alliance, *Wi-Fi CERTIFIED Passpoint*, https://www.wi-fi.org/discover-wi-fi/passpoint.
13. Wireless Broadband Alliance, *OpenRoaming*, https://wballiance.com/openroaming/.

14. 3rd Generation Partnership Project, *Study on Channel Model for Frequencies from 0.5 to 100 GHz*, 3GPP TR 38.901.

15. International Telecommunication Union, *Recommendation ITU-R P.2109-2: Prediction of Building Entry Loss*, https://www.itu.int/rec/R-REC-P.2109/.

16. Department of Telecommunications, Government of India, *National Broadband Mission 2.0*, https://www.dot.gov.in/static/uploads/2025/07/c7c060d6fec6ac6bb73230c65f134909.pdf.

17. Government of India, Press Information Bureau, Indian telecommunications and broadband subscription data for May 2026, PRID 2277922.

18. International Telecommunication Union, *The Impact of Broadband on the Economy: Research to Date and Policy Issues*, https://www.itu.int/ITU-D/treg/broadband/ITU-BB-Reports_Impact-of-Broadband-on-the-Economy.pdf.

19. International Telecommunication Union, *Last-Mile Internet Connectivity Solutions Guide*, https://www.itu.int/en/ITU-D/Technology/Pages/LMC/LMC-Home.aspx.

20. Edward J. Oughton and Ankit Jha, "Supportive 5G Infrastructure Policies Are Essential for Universal 6G," *IEEE Access* 9 (2021), https://doi.org/10.1109/ACCESS.2021.3097627.

21. Sunil Kumar and Edward J. Oughton, rural 5G infrastructure-sharing assessment for India, *Frontiers in Computer Science* 5 (2023), https://doi.org/10.3389/fcomp.2023.1191853.

22. G. Kibinda et al.,¯ systematic review of telecommunications infrastructure sharing and rural connectivity in emerging markets, *Telecommunications Policy* (2025), https://doi.org/10.1016/j.telpol.2025.103028.

23. Comcast, "How Xfinity Mobile's Converged Network Is Driving Faster Speeds," 12 May 2026, https://corporate.comcast.com/stories/how-xfinity-mobiles-converged-network-is-driving-faster-speeds.

24. Charter Communications, "Spectrum Is Transforming Everyday Life," https://policy.charter.com/spectrum-is-transforming-everyday-life.

25. Deutsche Telekom, "Deutsche Telekom Demonstrates Multipath for Fixed Mobile Convergence on Campus," 5 May 2021, https://www.telekom.com/en/company/details/deutsche-telekom-demonstrates-multipath-for-fixed-mobile-convergence-on-campus-625838.

26. Wireless Broadband Alliance, enterprise Wi-Fi 7 Multi-Link Operation trials involving AT&T, Intel and RUCKUS Networks, March 2026, https://wballiance.com/wba-validates-wifi-7-mlo-reliability-att-intel-ruckus/.

27. European Health and Digital Executive Agency, *WiFi4EU*, https://hadea.ec.europa.eu/programmes/connecting-europe-facility/wifi4eu/download-wifi4eu-app_en.

28. Wireless Broadband Alliance, *Operator Managed Wi-Fi*, https://wballiance.com/omwi-phase-2/.

29. Department of Telecommunications, Government of India, *PM-WANI Framework*, https://www.dot.gov.in/static/uploads/2026/05/a8ecc27af356369bcd592919ca6a747a.pdf.

30. Government of India, Press Information Bureau, "PM-WANI Scheme Accelerates Public Wi-Fi Expansion across India with Over 4 Lakh Hotspots," 2 April 2026, https://www.pib.gov.in/PressReleasePage.aspx?PRID=2248538.
31. Department of Telecommunications, Government of India, Circular 2/PM-WANI/2026, 22 May 2026, https://www.dot.gov.in/static/uploads/2026/05/04695d09cb0b666e72c6ff1ddf55c615.pdf.



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