GSMA Intelligence

Bharti Airtel taps into free-space optical communications to expand coverage and boost capacity

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Connecting the unconnected remains a challenge

Despite operators making considerable progress building out mobile networks around the world, a coverage gap of 4% of the global population persists. This equates to 350 million people. Thirty-one countries record a coverage gap of 10% or above. These countries tend to have sizeable communities who are predominantly rural, low-income and living in sparsely populated areas. Beyond coverage, the usage gap is often more significant in addressing the issue of the unconnected. A primary reason for the usage gap is the affordability of mobile and internet connectivity.

Fibre does not offer a universal solution, while wireless radio has capacity challenges

For most mobile operators, fibre is the preferred transport technology, as it provides the highest capacity reliably and at the lowest cost per bit. Fibre cannot always be laid point to point in a straight line, as there are obstacles and no-go zones that force a circuitous route or simply render deployment impossible. The business case is also frequently tough for fibre due to the high costs associated with obtaining permissions and rights of way (RoW) from authorities. In many cases, microwave has been used as an alternative technology for backhaul. Despite improvements, wireless radio still has limitations in terms of capacity or range.

Emerging technologies such as free-space optics can help plug the coverage gap

Operators and service providers are beginning to look at emerging technologies – such as free-space optical communications (FSOC) and non-terrestrial options (e.g. LEO satellites) – to provide connectivity to remote and underserved areas. FSOC is of interest to mobile operators as it uses light beams in the high terahertz spectrum range (unlicensed). As well as cost advantages in terms of spectrum use, there are additional benefits in terms of low energy use and ease of deployment. The economics of FSOC from a total cost of operations (TCO) point of view are also improving as a result of greater reliability introduced through new techniques. This places the technology somewhere between fibre and microwave, making it a potential alternative for operators and service providers.

Bharti Airtel has deployed FSOC in India

Bharti Airtel has deployed FSOC in four states in India. The primary use case is mobile backhaul. Fibre is prohibitively expensive to deploy in dense, urban areas such as Mumbai, and other parts of the country where fibre deployments are challenging for several reasons. Microwave is much easier to deploy than fibre. However, considering the growing demand for data in India, it is not a long-term solution for network congestion, due to relative capacity limitations in the radiofrequency spectrum. Taara's wireless optical communication (WOC), or next-generation FSOC, products have been deployed in these select areas to work around the constraints of fibre and deliver higher capacity backhaul links than microwave.

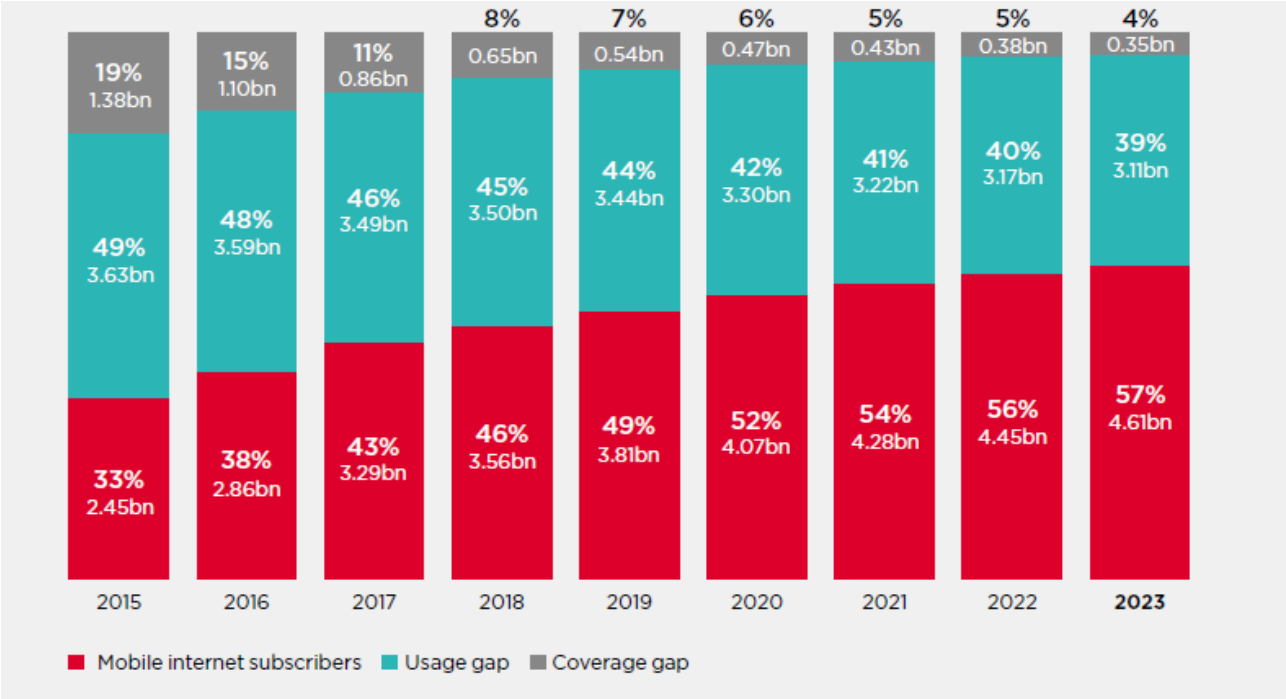
1. Connecting the unconnected

Despite significant growth, coverage and availability gaps persist

The mobile industry has seen spectacular growth in recent decades. Operators have deployed networks at significant scale around the world and built out the networks to deliver mobile broadband to 96% of the global population, which amounts to 7.7 billion people (see Figure 1).

The remaining 4% amounts to 350 million people around the world who remain unconnected. The 4% coverage gap is a global percentage, with several countries recording a larger gap of 10% or higher in their markets. These countries tend to have sizeable communities who are predominantly rural, low-income and living in sparsely populated areas. These are typically in least developed countries (LDCs), landlocked developing countries (LLDCs) and small island developing states (SIDS).

Figure 1: Global mobile internet connectivity, 2015–2023
Percentage of population



Source: GSMA Intelligence

There is the added challenge of the usage gap, which is significantly larger than the coverage gap in many countries. The usage gap refers to those who live within the footprint of a mobile broadband network but do not use mobile internet services. The usage gap exists for a number of reasons but most centre on affordability – or, in this specific case, the cost of broadband access.

Underserved communities remain across the world, in emerging, LMIC and advanced markets. Such groups lack broadband access for a variety of reasons. In many cases, the primary reasons are physical. Either the village or site is simply too far away to connect, or it is located in inhospitable terrain, such as in mountainous areas or on islands too far away for terrestrial links. Other remote sites face the challenges and limitations of adverse weather conditions, lack of reliable power/energy supply and other factors. In most of these cases, even if the physical challenges could be overcome, the economics are simply prohibitive and render the business case invalid.

Fibre deployments are ideal but viable up to the most economical point

The ideal solution for broadband access would be fibre to the home (FTTH) or fibre to the ‘x’ (FTTx). Not only is fibre used for retail broadband connections; it is also increasingly the preferred solution for backhaul transport networks for mobile. However, it is challenging to deploy fibre everywhere. Physical distance to the remote site, even on flat terrain, would mean a significant deployment cost, which would be prohibitive considering the civil works required to lay the fibre. Challenging terrain makes laying fibre even more difficult as the civil costs escalate sharply. Moreover, even in relatively urban and suburban areas, service providers need to acquire numerous permissions and rights of way to be able to dig and lay fibre. All these issues make fibre prohibitive in several deployment scenarios.

Emerging wireless technologies can help plug the coverage gap

Despite its benefits, fibre is not an option for universal transport across a communications network. As a result, operators and service providers have opted for wireless technologies such as microwave to plug the coverage gap. Microwave, rather than fibre, has become the backbone transport network in many emerging markets. However, microwave has significant disadvantages when it comes to capacity. Despite significant enhancements and the evolution of microwave to newer frequency bands, capacity is not keeping up with surging data consumption. As a result, operators and service providers have begun to look at alternative solutions such as free-space optical communications (FSOC).

2. What is free-space optical communications?

FSOC uses light waves to transmit data

Free-space optical communications is not a new technology; it has been decades in the making. The basic principle behind FSOC is to use light waves to transmit data, in much the same way data is transmitted over optical fibre cable (OFC). The key difference is the medium. While fibre-optic cables use thin strands of glass, FSOC uses light waves to aerially transmit data.

FSOC has been deployed for a number of use cases, but not at the same commercial scale as microwave and OFC. Use cases include backhaul transport for mobile networks, network redundancy for fibre and network outages, and as a more economical and practical alternative to fibre in select deployment scenarios.

FSOC faced challenges in its early iterations, and was unable to scale commercially due to the negative impact of weather patterns and external factors. The biggest challenge was maintaining clear line of sight (LoS) from one terminal to another to maintain connectivity through very thin laser beams. This is not always easy to maintain, as difficult terrain and natural obstacles can make LoS challenging. Moreover, inclement weather/conditions (e.g. fog and haze) can scatter the laser beams and disrupt the connection, particularly over long distances.

In recent years, FSOC has seen a resurgence of investment and innovation, as a number of companies have pioneered new techniques to mitigate some of the above challenges due to inclement weather and visibility patterns. This resurgence has seen a new wave of products examined more closely by operators and service providers as potential alternatives to established transport technologies such as OFC and microwave.

3. Case study: Bharti Airtel deploys FSOC

Bharti Airtel, part of the Bharti Group, is currently India's second largest mobile operator with more than 400 million subscribers. Airtel has licensed spectrum holdings across the country and currently operates 2G, 4G and 5G networks, as well as providing fixed broadband and DTV offerings.

Airtel's problem statement

Airtel's mobile network is expanding rapidly on the back of significant 5G rollout. As well as consumer 5G traffic, Airtel is seeing a surge in data consumption over its fixed wireless access (FWA) networks. As a result, backhaul has become a challenge that it needs to address, when viewed through its network guiding principles – cost leadership and experience leadership. While fibre is increasingly connecting sites and premises, most radio access network (RAN) sites in India are connected with microwave links. Fibre offers high capacity but cannot be deployed everywhere, while microwave has capacity challenges.

Airtel's FSOC deployment with Taara

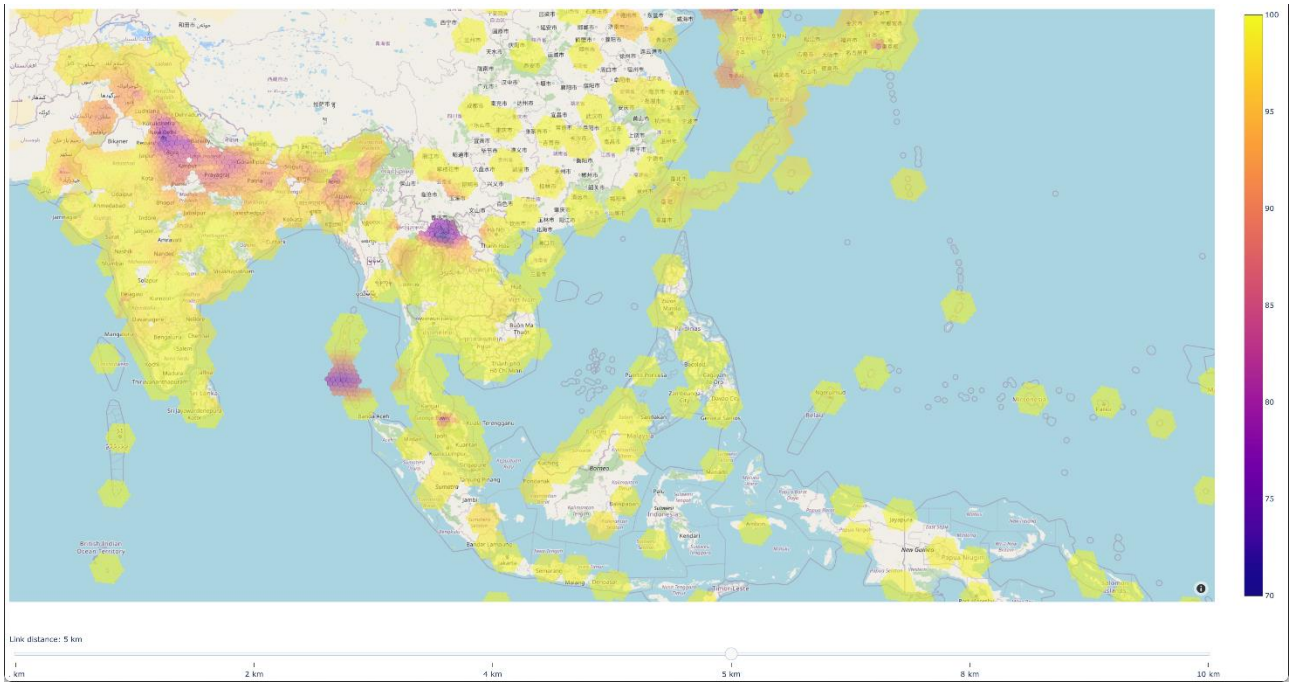
Despite significant network assets deployed across the country, coverage and usage gaps are still prevalent in India. In a number of cases, these reflect challenging terrain in remote areas. In others, there have been persistent challenges acquiring RoW and permissions from local authorities.

To complement the mix of fibre and microwave, Airtel has worked with Taara to deploy its WOC product in select areas for wireless backhaul. Taara – a team that sits within Alphabet's X moonshot division – has been among the pioneers of FSOC technology with advanced capabilities. Taara has deployed hundreds of its WOC links in several countries around the world. To overcome the challenges associated with FSOC, Taara has commercialised several new techniques that can enhance signal reliability that was previously compromised by bad weather conditions such as fog and haze, or interruptions to LoS with birds or commercial objects blocking or interrupting signals. These new techniques include improved atmospheric sensing, tracking controls and motion detection capabilities to enable the beams to stay locked in with each other.

In India, Airtel has deployed WOC in the states of Karnataka, Maharashtra, Kerala and Tamil Nadu. In each state, the ground conditions that necessitated the WOC links were different. For example, in Mumbai, the inordinate costs of RoW and rainy seasons meant short windows for laying fibre. In Kerala, permissions were delayed due to heavy construction in a densely populated area. In all these cases, WOC from Taara represented a workaround that allowed Airtel to rapidly deploy RAN sites and expand coverage.

Airtel has also taken advantage of Taara's new Link Availability Prediction Tool (see Figure 2). This is a network planning tool that considers multiple years of weather and visibility data from multiple sources to model the availability of WOC's links. Taara's tool is designed to provide operators with availability estimates for its links, and considers measured weather conditions such as visibility, temperature, rain rate, wind speed and scattering from pollution particles. It also calculates optical atmospheric propagation effects, including diffraction and scintillation.

Figure 2: Taara's Link Availability Prediction Tool



Note: X axis shows link distance; Y axis shows link availability (%). Taara's tool view shows India and parts of the Asia Pacific region. Blank areas on the map indicate regions where data is currently lacking.
Source: Taara, 2024

As well as addressing mobile backhaul requirements in certain areas, Airtel has identified FSOC as a potential solution in additional areas:

- **FWA** – India is currently seeing a surge of investment in and deployment of FWA, as operators Jio and Airtel push FWA and mobile broadband to address the large coverage and usage gaps associated with FTTx solutions. The number of sites that can be enabled for FWA today is limited by backhaul capacity at the site. If fibre is not possible, FSOC becomes an alternative, assuming weather and visibility patterns are favourable.

- **Hybrid transport solutions** – In areas where weather and visibility patterns are challenging, Airtel is using hybrid solutions, with FSOC deployed as the primary backhaul option to carry most of the backhaul capacity in favourable conditions, and microwave as a backup for redundancy when weather and visibility conditions turn unfavourable.

FSOC economics versus fibre and microwave

Operators such as Airtel will only deploy a network solution if the underlying total cost of ownership (TCO) is favourable compared to legacy solutions. In the domain of transport networks, if an operator or service provider is to consider FSOC as a transport solution, they would typically calculate the TCO in terms of the cost per bit delivered per kilometre.

At short distances, fibre could offer the lowest cost per bit, per kilometre in scenarios where the capacity requirements for backhaul are very high. At this level of data traffic, it would be economical for the operator to incur the additional costs of the civil works and the RoW/ permissions needed. However, if the backhaul requirements are lower, the operator could deploy technologies such as microwave. FSOC occupies a space between fibre and microwave, as it offers a lower cost and time to deploy than fibre, and greater capacity than microwave.

Airtel is currently deploying Taara's WOC technology in areas where fibre cannot be deployed, and microwave does not match capacity requirements. WOC therefore represents a 'third choice' for Airtel, and will be used in areas where the economics of fibre do not stack up and microwave cannot offer the required capacity. However, the TCO calculation could improve if greater reliability measures are implemented for FSOC, thereby increasing its availability for transport. If the TCO improves for the WOC option, Airtel could start to identify new use cases and deploy WOC at a larger scale across India.

4. Conclusions

Connecting the unconnected requires new solutions

Providing internet connectivity continues to be a challenge, despite significant progress by mobile operators in reducing the coverage gap around the world. The coverage gap stands at 4%, equating to 350 million worldwide currently not covered by mobile internet connectivity. Several countries have a coverage gap much greater than 4%. Reducing the coverage gap is necessary but not sufficient to address the problem of the unconnected. Many people do not use mobile internet services despite availability. This primarily reflects affordability challenges, with high prices of services and devices relative to income levels.

If universal connectivity is an imperative for mobile operators and service providers, there must be recognition that these goals cannot be achieved through traditional terrestrial network technologies alone. They must also consider and experiment with emerging technologies such as FSOC, as part of a broader mix that includes non-terrestrial options such as LEO satellite connectivity.

FSOC can be a viable alternative for transport solutions

FSOC is of interest to mobile operators as it uses light beams in the high terahertz spectrum range (unlicensed). As well as the cost advantages in terms of spectrum use, additional benefits include low energy use and ease of deployment. This is the reason why mobile operators such as Airtel have identified specific segments where FSOC could help them and have deployed the technology. Ultimately, mobile operators such as Airtel will consider technologies such as Taara's WOC from a TCO perspective and compare this against established alternatives (e.g. fibre and microwave). As the TCO improves with greater reliability measures implemented, operators could experiment with the technology for additional use cases. The market opportunity for technologies such as Taara's WOC would then increase.

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