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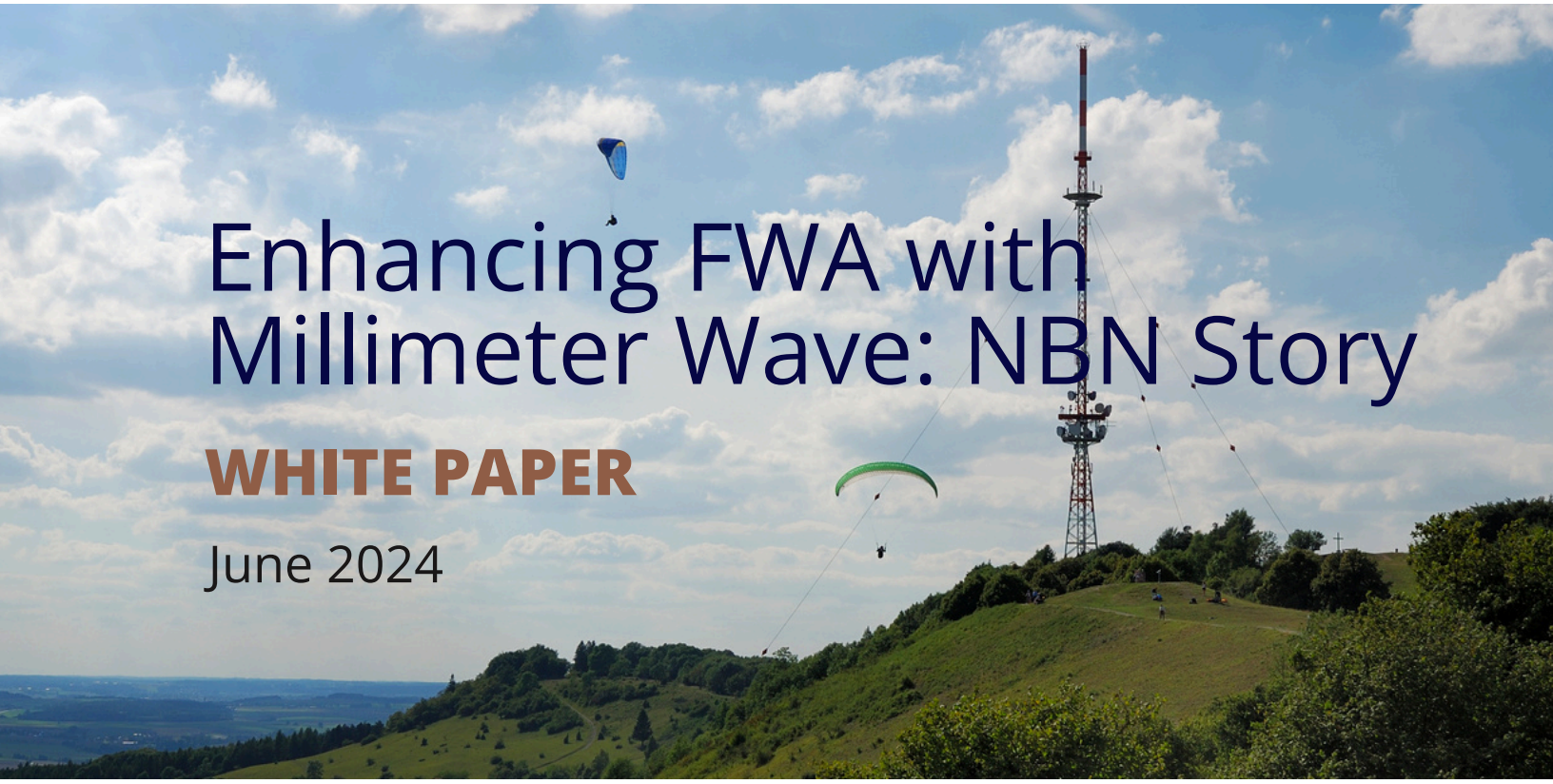

Enhancing FWA with Millimeter Wave: NBN Story

WHITE PAPER

June 2024

ABSTRACT

Fixed Wireless Access has proven an effective tool for operators to close the digital divide and expand the 5G business case beyond mobile broadband. Next-generation millimeter wave (mmWave) infrastructure and CPE solutions are mature enough to propel the FWA broadband connections higher.

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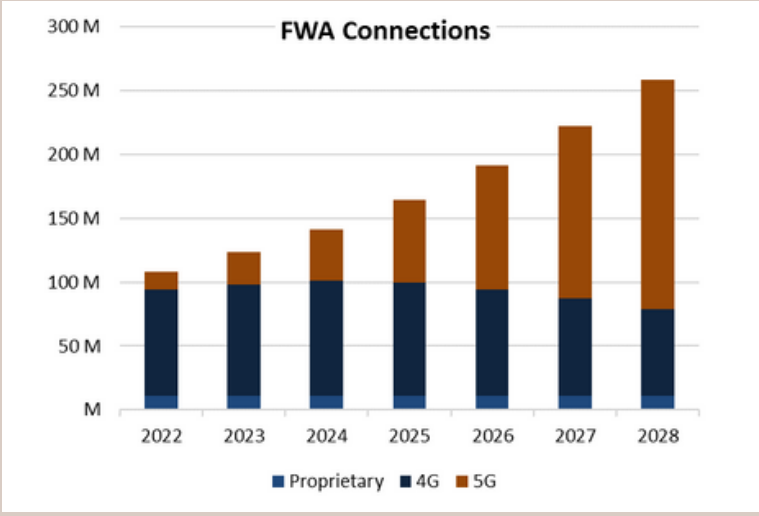
Closing the Digital Divide with 5G FWA

5G IS DRIVING FWA MOMENTUM WORLDWIDE

Fixed Wireless Access (FWA) continues to gain global scale as operators leverage their 5G network and "excess" capacity beyond the mobile broadband need to offer fixed broadband services to close the digital divide and offer compelling broadband alternatives in markets. Mobile Experts estimates the number of FWA connections worldwide had reached more than 120 million at the end of 2023 and is forecasted to reach 260 million by 2028.

5G FWA connections are expected to grow to around 180 million by 2028, representing almost 70% of FWA connections. Our forecast considers the proven 5G FWA business cases in developed markets, such as the United States, Western Europe, Japan, and Australia, and high ambitions in emerging markets, such as India, that have the potential to significantly drive economies of scale, resulting in lower-cost customer premise equipment (CPE) that can further enhance the 5G FWA business case in lower-ARPU markets.



Source: Mobile Experts' *2023 Fixed Wireless Access* report

FWA ADVANTAGES

The increasing momentum of FWA as a fixed broadband alternative to fiber and other high-capacity wireline technologies can be explained by three key advantages of FWA over wireline technologies. They are 1) faster time-to-market, 2) better economics in less dense areas, and 3) infrastructure reuse for mobile and fixed. Many large service providers view fiber and FWA as the future technologies for broadband to close the digital divide and replace older wireline technologies such as DSL.

Quick Time-to-Market

- Fiber buildout is long and labor intensive
- FWA service turn-up can be quick

Attractive Economics

- Fiber build is expensive especially outside of dense urban areas
- FWA has a lower cost profile, i.e., low initial CAPEX

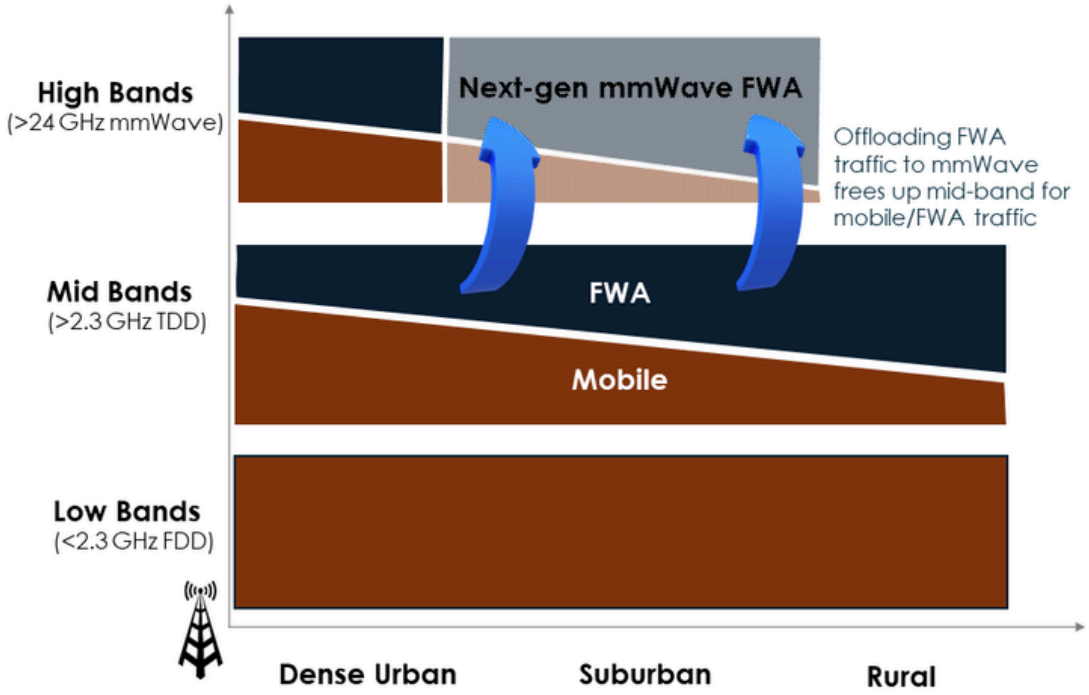
Network Reuse

- 5G network can be reused for FWA and mobile
- Shared infrastructure further enhances FWA economics

Sustainability of FWA

FWA IS MOSTLY BASED ON MID-BAND SPECTRUM TODAY

The success of FWA can be attributed to the introduction of a new spectrum with wide bandwidths in midband (e.g., n77, n78, n79) in the 5G network deployments worldwide and the immense network capacity the operators have been able to deploy. Advancements in massive MIMO antenna technology have also enabled operators to deliver more gigabytes at lower costs. With the "excess capacity" model, especially in less dense suburban and rural areas, operators have found success in offering competitive FWA services in underserved or unserved markets while allocating enough capacity for higher revenue per bit of mobile traffic.



MULTIPLE OPTIONS TO EXPAND 5G FWA COVERAGE

While many pundits believe the future growth of 5G FWA is limited due to capacity exhaustion, service providers have multiple options to add more FWA and mobile traffic capacity. They include the following with relative costs:

Add Spectrum	Advanced Radio	Densification	Outdoor CPE
• mmWave overlay on existing sites	• MU-MIMO • 256 TRx mMIMO	• build more RAN sites	• outdoor CPE install to extend reach and perf.
$	$$$	$$$$	$$

Long-Range mmWave FWA

MMWAVE OFFERS HIGH BANDWIDTH FOR FWA CAPACITY

As mentioned previously, operators have multiple paths to increase network capacity. They can add more spectrum and deploy high-capacity radios capable of MU-MIMO or higher-order MIMO to increase spectral efficiency per site further.They can add more cell sites to densify the network and migrate to outdoor CPEs to increase the RF link budget in cell edge conditions. Among these options, we believe adding a millimeter wave spectrum on existing sites and coupling with outdoor CPEs is most attractive given the large bandwidth (i.e., up to 1000 MHz per operator) available in major markets.

5G FWA can be a long-term broadband option; e.g., overlaying millimeter wave spectrum on existing sites is attractive given the large bandwidth available

MMWAVE CHALLENGES

The first-generation millimeter wave (mmWave) FWA system was based on low-power radios and CPEs that limited the range of millimeter wave site coverage. Typically, these mmWave FWA systems were deployed “below clutter” on small cell sites - limiting the coverage (a few hundred meters) and economics, i.e., fewer premises covered from a cell site. Because of these limitations, the mmWave FWA had been limited to dense urban areas and high-traffic venues like stadiums for offload scenarios.

NEXT-GEN MMWAVE INFRASTRUCTURE AND CPE SOLUTIONS

With the success of the 5G FWA service, many operators are exploring ways to tap the large bandwidth available in the millimeter wave spectrum bands as a dedicated spectrum for FWA. NBN in Australia is an excellent example of a service provider deploying the Extended Range mmWave FWA systems. The next-generation mmWave FWA system comprises high-power mmWave radios and high-power outdoor CPE receivers typically installed on a rooftop for maximal line-of-sight to a cell tower.

Next-generation mmWave radios and outdoor (roof top) CPEs can extend range up to ~10km in an ideal case, greatly expanding the passing areas

With next-generation mmWave radios that can extend the range of mmWave coverage greater than 10x that of first-generation mmWave radios, we believe the extended range mmWave FWA systems can increase network capacity 3-4 times more with 400-800 MHz of mmWave spectrum deployment and potentially offer 500 Mbps-1 Gbps service offerings.

NBN CASE STUDY

Dedicated FWA with mmWave

NBN Co, a wholesale provider in Australia with a footprint of over 700,000 premises, is demonstrating the sustainability of FWA with the deployment of long-range mmWave infrastructure, along with outdoor CPE with high-gain antenna systems, as well as upgrades to existing technology and software enhancements, to expand FWA coverage, meet higher minimum service requirements, and offer higher-speed wholesale FWA plans. nbn's 5G mmWave-enabled FWA provides a sustainable FWA roadmap by maximizing the broadband traffic (e.g., ~400-500 GB per month usage) offload to high bandwidth available in the mmWave spectrum where line-of-sight exists.

FWA at nbn and Business Challenges

nbn was established in 2009 to design, build, and operate a wholesale broadband access network for Australia. Of more than 12 million premises covered by the nbn footprint in Australia, just over 1 million premises are located within remote, regional, and rural areas of the country and serviced by FWA (over 700,000 premises) and satellite (400,000 premises).

With over 2,300 cell sites and between 75 MHz and 250 MHz of TDD mid-band spectrum, depending on the specific area, nbn uses a dedicated FWA network to offer broadband services. With the highly consumptive nature of fixed broadband service, where consumers are using over 400 GB per month on average and growing at a double-digit CAGR, nbn's FWA and satellite networks face ongoing capacity challenges, especially in areas with limited mid-band spectrum for FWA.

5G mmWave as "Limitless" Capacity to Enhance FWA

To overcome these challenges, the Australian Government and nbn are investing AU$750 million (approximately US$500 million) to modernize the FWA network with technology upgrades and an extended range 5G mmWave to help improve the customer experience (especially during busy periods), expand FWA coverage, offer faster speeds, and migrate satellite users to FWA, enhancing customer experience of the remaining satellite users as a result.

5G mmWave FWA is expected to decrease the cost-per-bit by a factor of 10 relative to 4G mid-band FWA in infrastructure cost

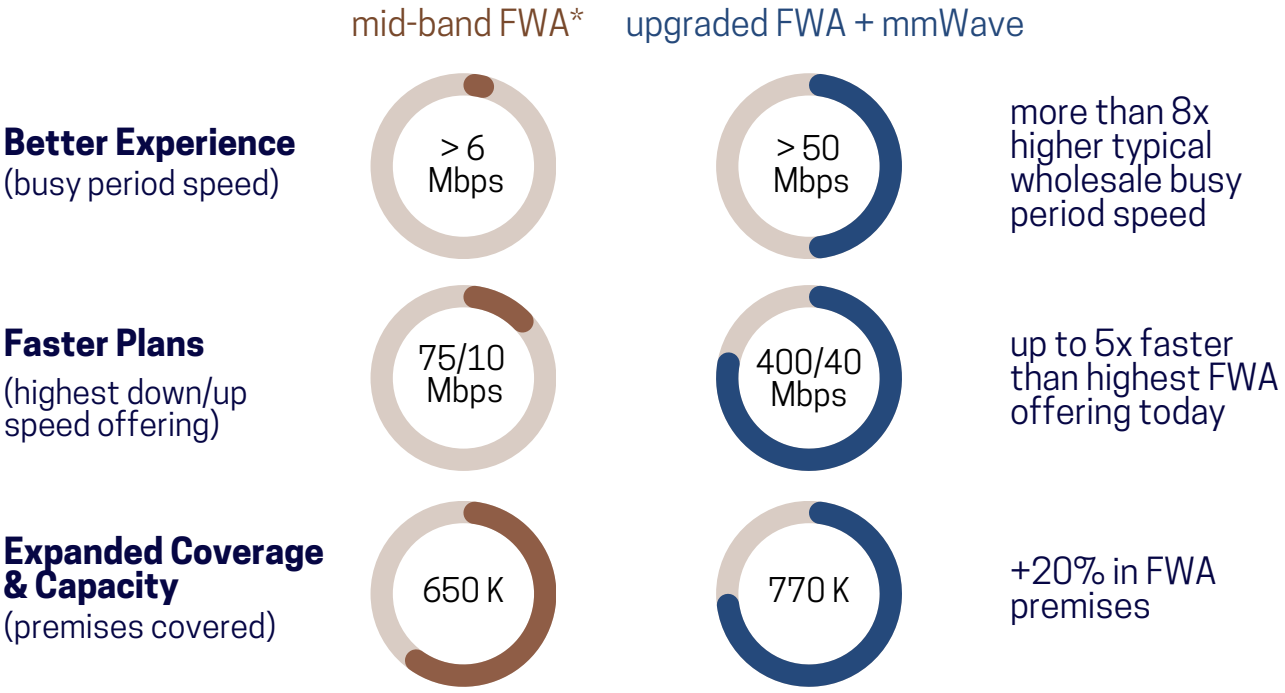
Working closely with its vendor partners, the nbn FWA network has the potential technical capability to deliver 1 Gbps peak speeds at up to ~10km range with 5G FWA on sub-6GHz or mmWave, deploying high-gain directional antenna on outdoor CPE. With 90% of its subscribers within 7km of a cell site, about 40% of FWA premises are expected to be eligible to connect to the 5G mmWave part of the network. With 1000 MHz of mmWave spectrum, nbn hopes 5G mmWave FWA has the potential to achieve an almost "limitless" capacity augmentation tool to offload FWA traffic, thereby extending the lifetime of the mid-band FWA layer to serve those "hard-to-reach" premises where direct line-of-sight connections aren't possible.

nbn 5G FWA

In addition to innovative antenna designs for maximal long-range mmWave FWA, nbn has developed predictive tools using high-resolution mapping data for professional installers so that they can quickly find an optimal placement location and direction of outdoor CPEs. The combined innovations in 5G mmWave infrastructure, CPEs, and installation processes will help optimize the time and cost of connecting each subscriber to the optimal network technology.

Business Outcome

With its fully upgraded 4G and 5G-enabled FWA network that employs Nokia's long reach mmWave CPEs, nbn's upgrades can expand the FWA coverage, offer higher typical busy period speed, and offer faster broadband plans. As a result, nbn expects to be able to migrate approximately 120,000 formerly-satellite premises to FWA, resulting in the ability to offer enhanced data allowances to remaining satellite broadband subscribers.



* As of the start of the upgrade program

Conclusions

5G FWA has enjoyed tremendous success, primarily built on the excess capacity model from 5G mobile network upgrades. Continued growth will depend upon solutions to tackle the capacity crunch operators face. 5G FWA with long-range mmWave is an excellent option for these operators. With its focus on regional and rural millimeter wave upgrades, nbn provides a shining example of how focused FWA planning, engineering, and innovation can yield superior results with a sustainable path for more growth.