Last Mile Connectivity

Addressing the Affordability Frontier

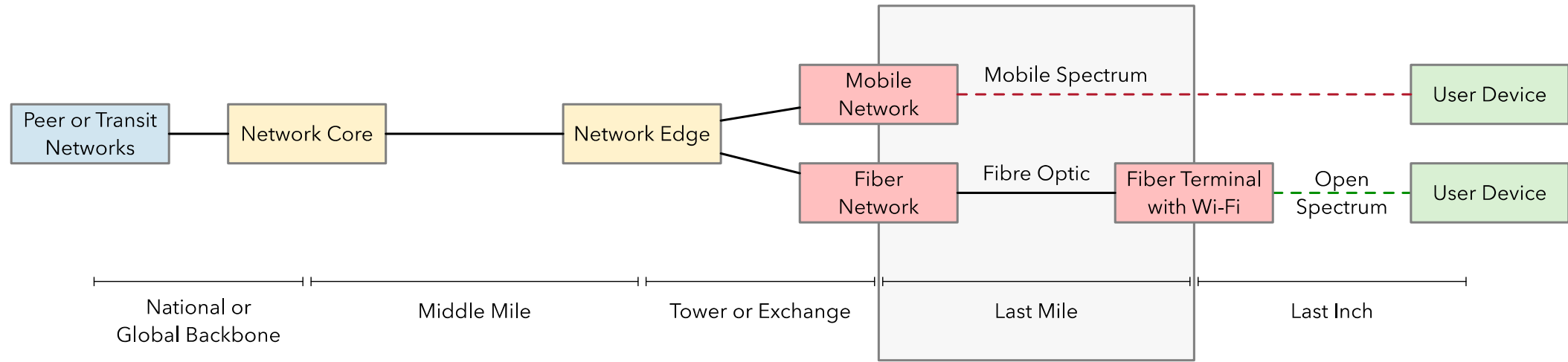Companion to ADB Sustainable Development Working Paper 83

Jonathan Brewer | APRICOT 2023, Manila, Philippines

The Last Mile

- Connects a user's device to telephony and the Internet, or
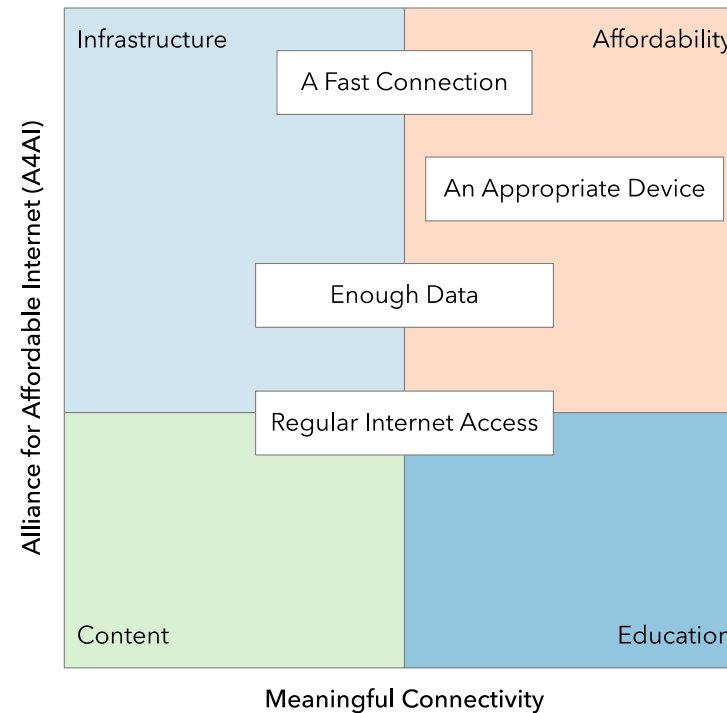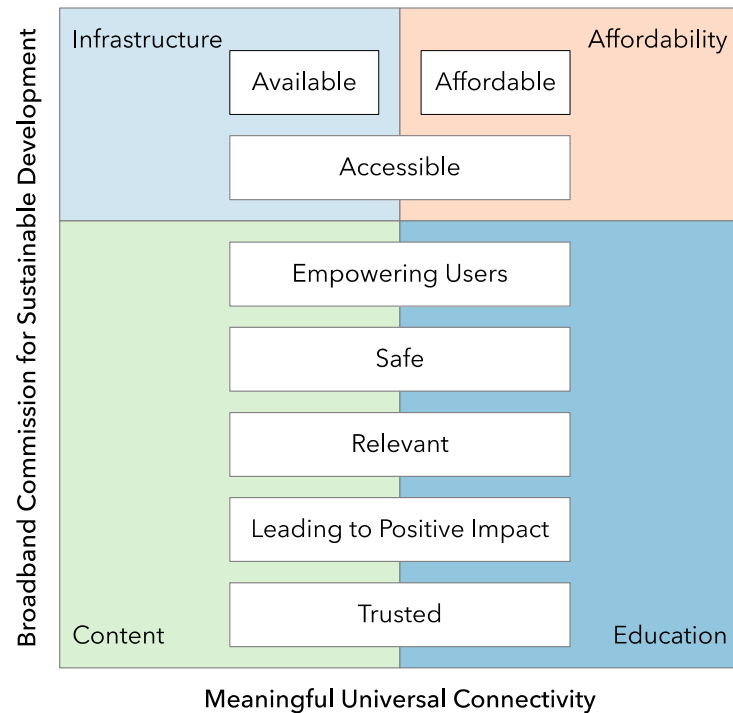- Connects a terminal that provides Wi-Fi for user devices

- In developing Asia, the Last Mile is usually mobile voice and data
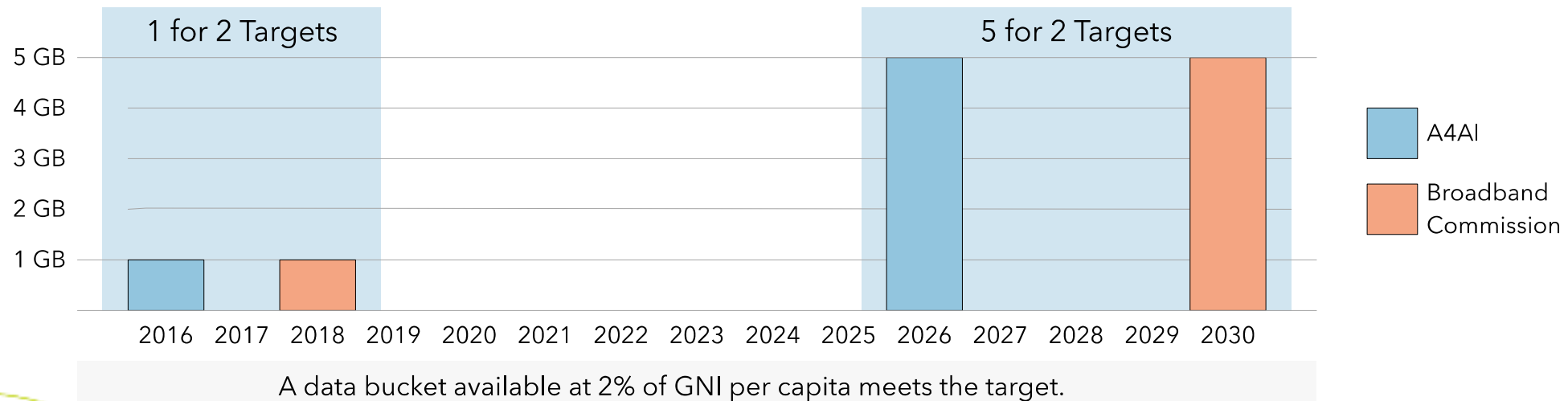
Meaningful Connectivity

- Framework to evaluate the quality of Internet access
- Promoted by A4AI and the Broadband Commission
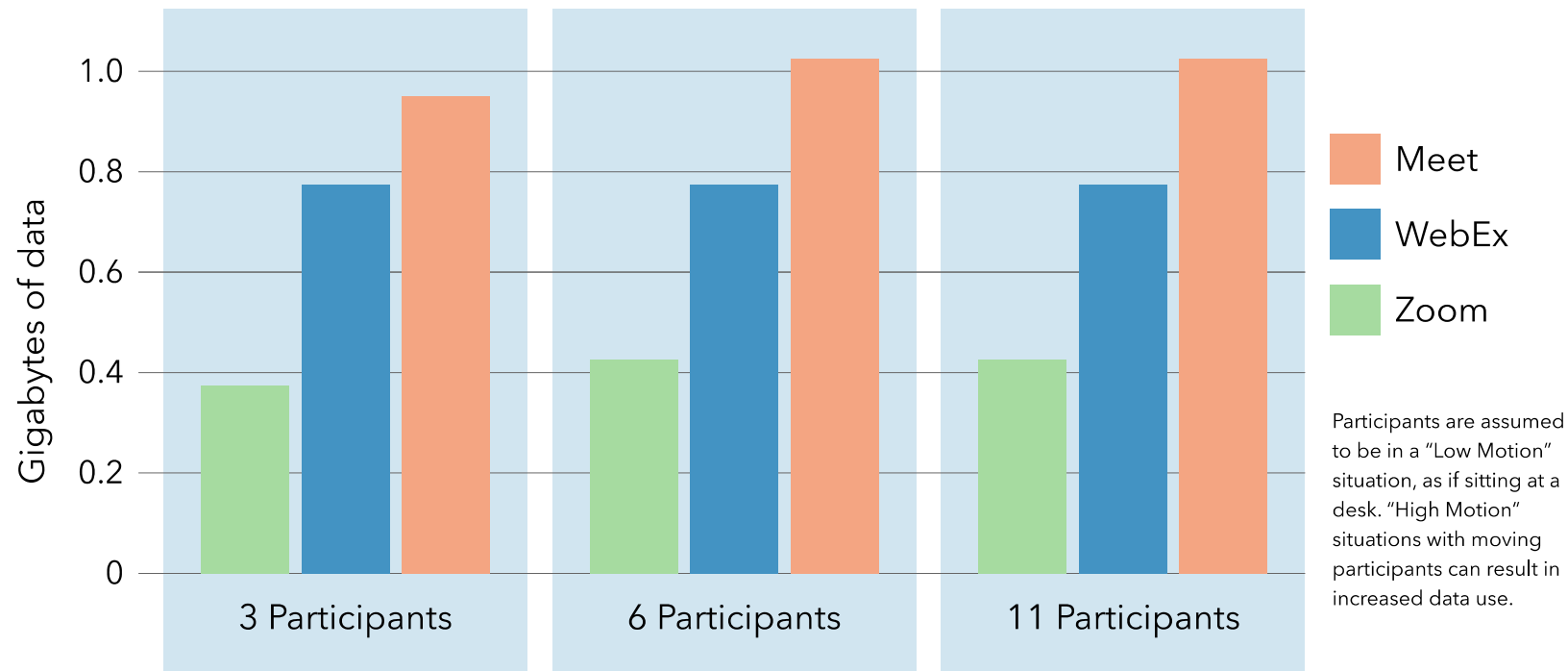- Goes beyond traditional Universal Service / Access definitions

Affordable Broadband

- Key tenet of Meaningful Connectivity
- Cost of data relative to 2% of GNI per capita is an accepted metric
- Both A4AI and the Broadband Commission set targets

A data bucket available at 2% of GNI per capita meets the target.

COVID-19 and Mobile Data Demand

- 1 or 5 Gigabytes per month is no longer enough for most users

Participants are assumed to be in a "Low Motion" situation, as if sitting at a desk. "High Motion" situations with moving participants can result in increased data use.

Source: Adapted from Chang, Hyunseok, Matteo Varvello, Fang Hao, and Sarit Mukherjee. 2021. *"Can You See Me Now? A Measurement Study of Zoom, Webex, and Meet."* In Proceedings of the 21st ACM Internet Measurement Conference, 216–28. New York, NY, USA: Association for Computing Machinery, 2021. https://doi.org/10.1145/3487552.3487847.
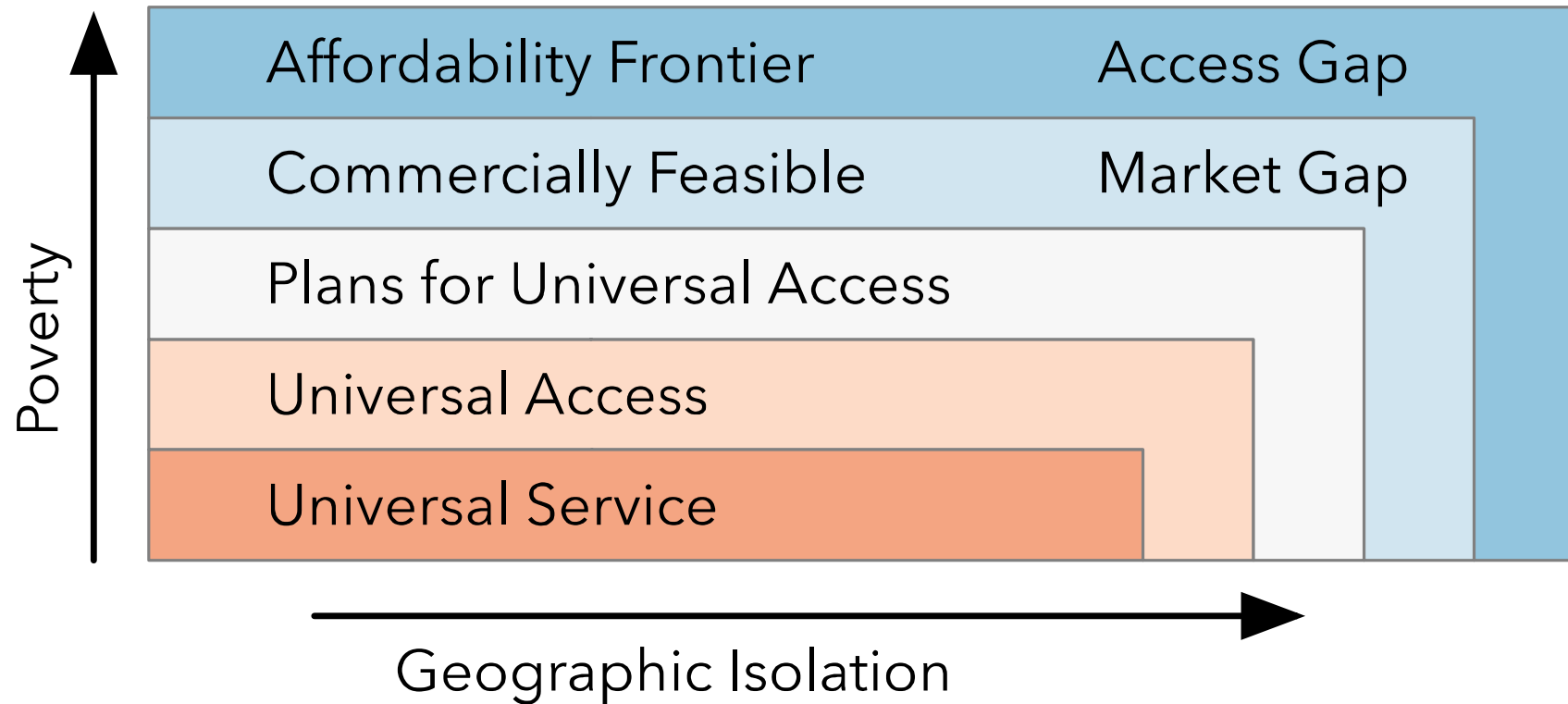
How Much Data is Enough Data?

- 2026 Asia mobile data use could average 40 GB / month
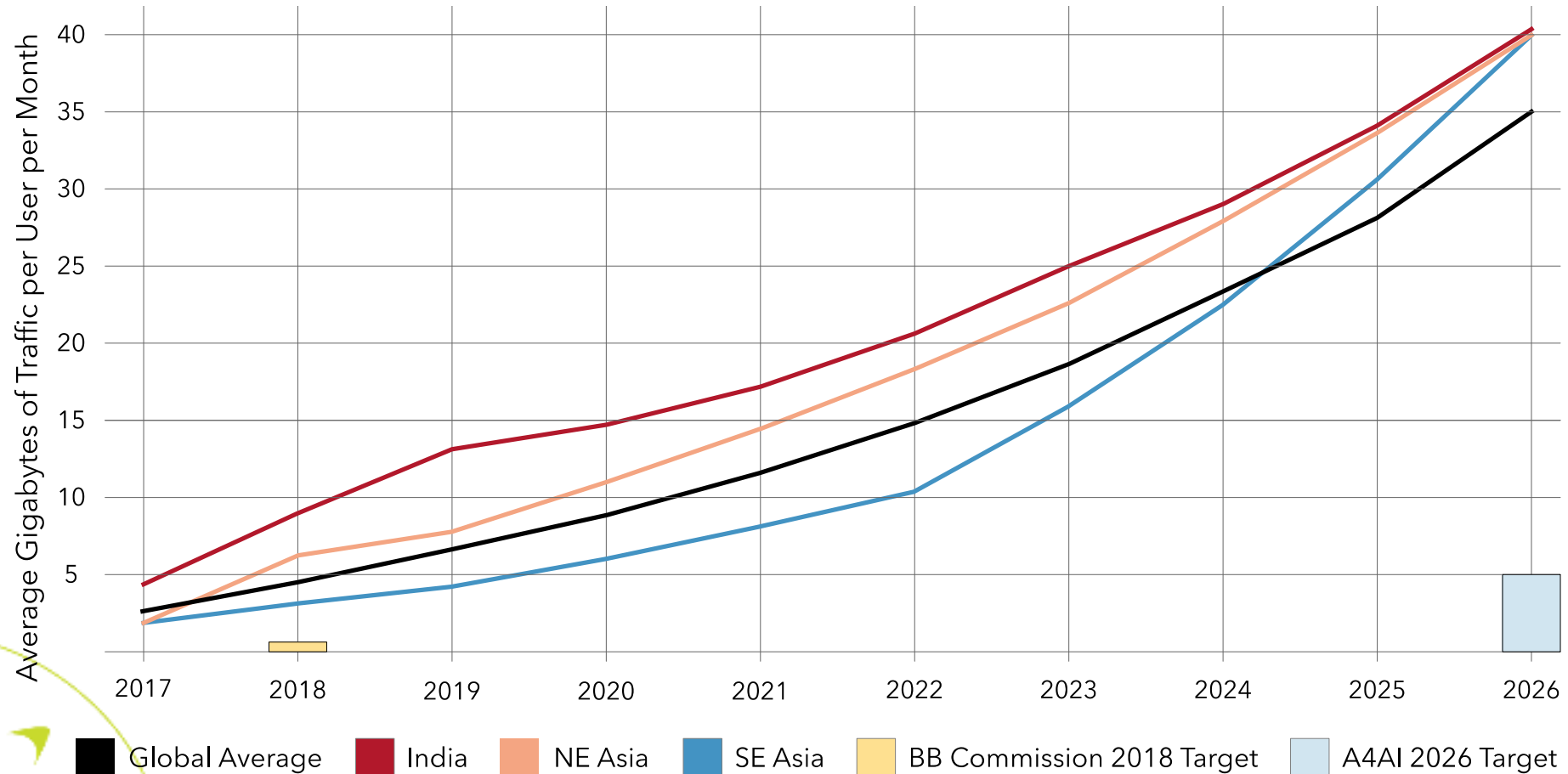
Targets of 5 gigabytes a month in 2026 or 2030 are not aligned with how people use the mobile Internet today.

The Affordability Frontier

Identifying Access Gaps

- Finding gaps is critical for delivering Meaningful Connectivity
- It relies on access to a wide range of people & infrastructure data

Population	Geography	Utilities	Mobile Coverage	OTT Data
Household Income	Digital Surface Map	Road Network	Tower Locations	Geolocation Reports
School-Aged Children	Land Cover	Electrical Connections	Technologies in use	OTT Quality Assessments
Address Points	Land Use	Fixed Telecoms Networks	Frequencies, power levels	Speed Reports

Source: Author

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Barriers to Last Mile Connectivity

- With gaps identified:
  - **Choose a technology**
  - **Find the right business model**
  - **Add finance**
  - **Problem solved?**

- Barriers stand in the way of Meaningful Connectivity

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Barrier: Geography & Population Density

Left chart — Inhabitants per km²:
- Tanzania: Urban 2465, Rural 37
- Indonesia: Urban 4159, Rural 72

Right chart — Monthly Spend per Revenue Generating Person:
- Tanzania: Urban $294, Rural $104
- Indonesia: Urban $568, Rural $194

Legend: Urban, Rural

Barrier: Access to Radio Spectrum

Peer or Transit Networks

Satellite

VSAT Terminal with Wi-Fi

User Device

Network Core

Mobile Network

User Device

Network Edge

Mobile / IMT Fixed Wireless

FWA Terminal with Wi-Fi

User Device

ISM Fixed Wireless

FWA Terminal with Wi-Fi

User Device

Peer or Transit Networks

Microwave Link

GPON

Fiber Terminal with Wi-Fi

User Device

Internet Backbone · Middle Mile · Tower or Exchange · Last Mile · Last Inch

Spectrum Types

ISM / Open

Microwave / Fixed

Mobile / IMT

Satellite

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Barrier: Access to Radio Spectrum

A survey of spectrum use shows that in ADB's developing member countries spectrum is under-allocated in many bands. 700, 2300, and 2500 MHz are examples where many regulators could increase 4G allocations.
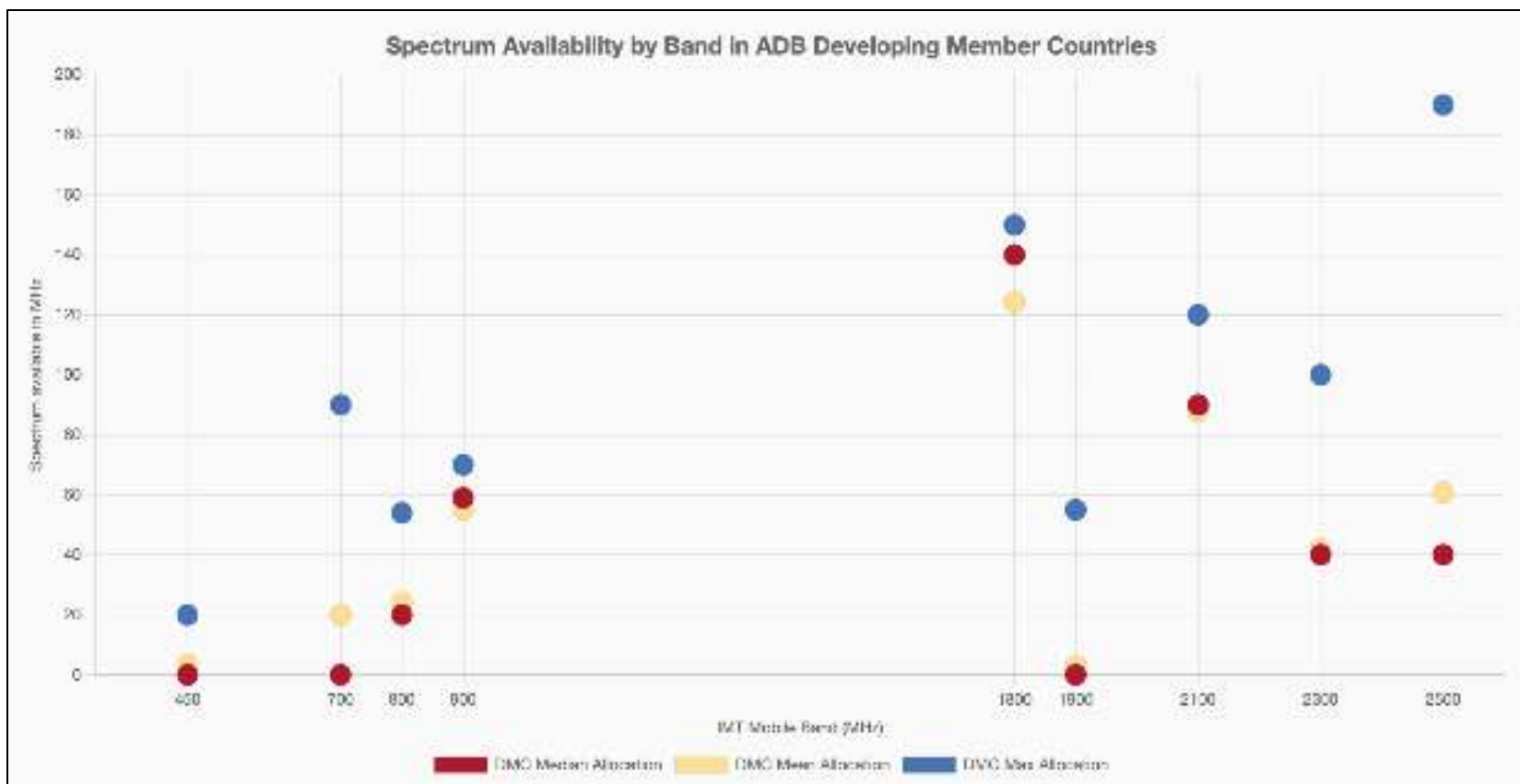
A full explanation of spectrum bands and roles is available in the paper.

Barrier: Access to Energy

- Cellular towers generally require reliable grid power

- Power is more difficult in rural & remote areas

- Alternative solutions can be large and costly

Photo: Chris Parker. RCG at TECT Park Cell Tower, 2021.
https://www.youtube.com/watch?v=9LlgH_mp2d4.

More Barriers at the Affordability Frontier

- Access to Land, Towers, and Buildings
  - More difficult for competitive providers

- Safety and Security of People and Property
  - More difficult in rural and remote areas

- Operator Licensing
  - Generally prohibits small operators from building infrastructure

- Access to Finance
  - More difficult for rural and remote operators

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# Technologies for Last Mile Connectivity

- Fiber and Wireless technologies are important for ADB DMCs

- Gigabit Passive Optical Network (GPON) is a great technology for
    - Fixed access
    - Mobile backhaul

- Several wireless technologies can address the affordability frontier
    - Some provide voice, SMS, and data
    - Some just provide data

Technology: Gigabit Passive Optical Network (GPON)

Passive optical networks don't need power between head ends (in a building or on a pole) and subscriber units. Networks can reach up to 40 kilometers and can use less than 1W of power per subscriber at the head end. Small, pole mounted network cabinets can provide service to 2,048 subscribers.
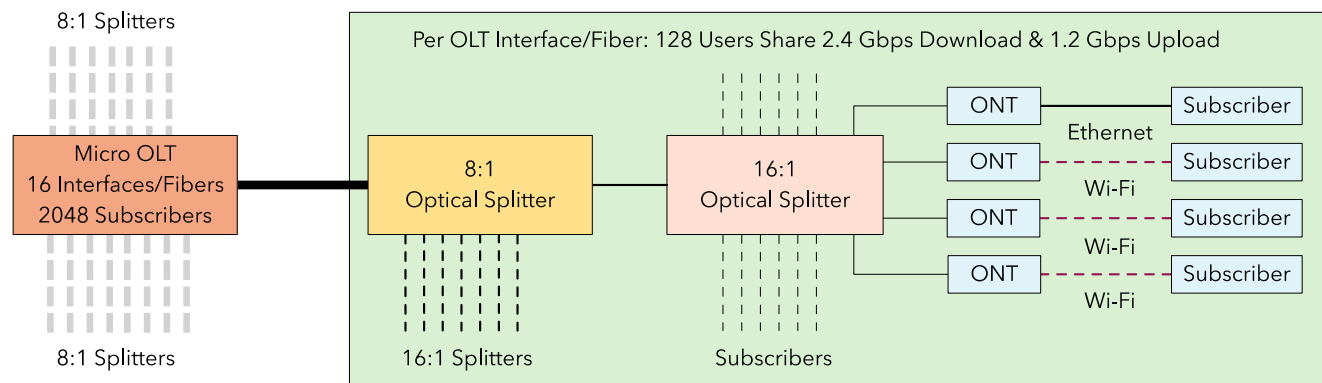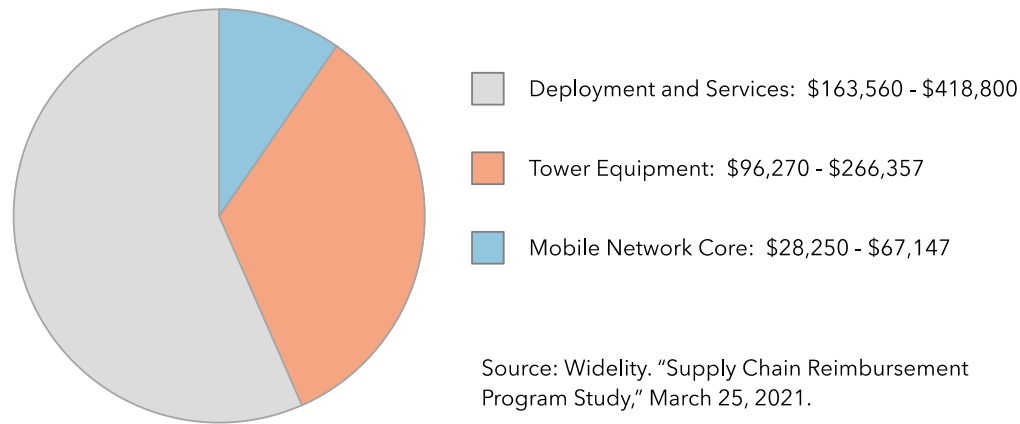

Photos of Huawei Airpon pole-mount GPON system.

Mobile Networks & RAN Sharing

- Mobile towers need 3000 daily users in 25km² to be profitable

- Tower sharing and wholesale roaming helps

- RAN sharing is most efficient for rural and remote infrastructure

Deployment and Services: $163,560 - $418,800

Tower Equipment: $96,270 - $266,357

Mobile Network Core: $28,250 - $67,147

Source: Widelity. "Supply Chain Reimbursement Program Study," March 25, 2021.

Average costs for a rural tower in the USA

Three-carrier RAN sharing tower in rural New Zealand

LTE Technology at the Affordability Frontier

- Small Cells: LTE at a very low cost
  - Up to 128 users per cell
  - 100-200 Watt power consumption
  - Small coverage area, or outdoor-only coverage
- LTE Fixed Wireless
  - LTE specifically designed for fixed wireless
  - 30 km typical reach, 200 km exceptional

LTE small cell in use for FWA service in Malaysia. Source: Tejas Networks

Technology: Community LTE

Community LTE (CoLTE) is based on the idea that any community should be able to operate its own LTE network. It starts with the concept of small cells and brings down cost and complexity further by eliminating the requirement for a mobile network core.

CoLTE operates like a Wi-Fi hotspot for phones and other devices that support LTE.

CoLTE networks lack mobility functions like handovers between cells and roaming. Most operators forego native voice and SMS services entirely. Users encouraged to communicate with over-the-top voice and messaging applications.

CoLTE is an ideal solution for remote communities and islands where there is no reasonable solution for continuous coverage or multiple cells but users can benefit from mobile broadband connectivity.

Community LTE Network in Bokondini, Indonesia
Photos: Matthew Johnson, University of Washington

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Open Spectrum: Wi-Fi and Fixed Wireless

- ## Many people use Open Spectrum daily
  - ### Wi-Fi & Bluetooth both use it
  - ### It's generally available world-wide

- ## Wi-Fi is a "Last Inch" technology
  - ### It works best when you're very close by
  - ### It's reliable to a few tens of meters

- ## Open Spectrum Fixed Wireless goes further
  - ### Often based on Wi-Fi chipsets, it's designed to go tens of kilometers
  - ### Fixed Wireless terminals are mounted in windows or on rooftops
  - ### Networks don't provide service directly to Wi-Fi phones or tablets
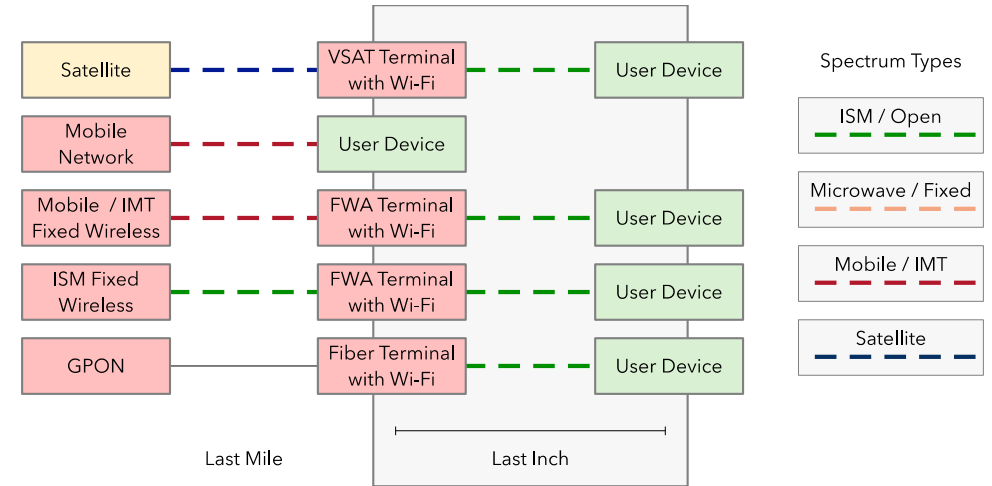
Open Spectrum: Wi-Fi and Fixed Wireless

Fixed Wireless Microsite. Photo: PromoWireless

Fixed Wireless. Photo: Gisborne.Net

Backhaul for Last Mile Connectivity

- All Last Mile solutions need backhaul

- Microwave is the most common mobile tower backhaul worldwide

- Open Spectrum FWA is a cost-effective substitute for Microwave

- GPON can be a good option where cables can be hung

- LEO Satellite networks are an emerging option for backhaul

Backhaul for Last Mile Connectivity

Starlink backhaul. Photo: Liam Farr

Microwave backhaul. Photo: Gisborne.Net

Last Mile Solutions at the Affordability Frontier

The table below considers options for addressing small, remote populations. Examples are based on market pricing and published specifications from Airspan, Baicells, Cambium, Huawei, Nokia, Softel, and Ubiquiti.

Technology	Mobile	Configuration	Barriers	Users	Typical Distance	Peak Mbps	Mbps /User	CapEx /User	Power /User
GPON FTTH	No	19" Rack OLT, 16 Ports	🏢 ⛰ 🏬	1024	1-40 km	1000	19	$193	0.8 W
GPON FTTH	No	Pole mount OLT – 1 port	🏢 ⛰	96	1-40 km	1000	104	$70	0.5 W
LTE Macro	Yes	3 sector, 160W, 4x4 MIMO	🏢 ⛰ 🗼 🏬 📡 💡	768	1-30 km	109	0.9	$243	2.5 W
LTE Small Cell	Yes	2 sector, 20W, 2x2 MIMO	🏢 ⛰ 📡 💡	128	1-10 km	109	2	$353	3.6 W
LTE FWA	No	2 sector, 20W, 2x2 MIMO	🏢 ⛰ 📡 💡	128	1-30 km	109	2	$353	3.6 W
LTE CoLTE	No	1 sector, 0.25W, 2x2 MIMO	🏢 ⛰ 📡	32	1 km	80	2.5	$135	0.6 W
ISM FWA	No	1 sector, 2W, 8x8 MIMO	⛰ 📡	128	1-30 km	91	2.9	$370	0.6 W
ISM FWA	No	1 sector, 1W, 2x2 MIMO	⛰ 📡	24	1-20 km	91	3.8	$85	0.3 W

⛰ Geography 📡 Radio Spectrum 🗼 Access to Towers 🏬 Access to Buildings 💡 Access to Electricity 🏢 Operator Licensing

Note the lowest cost, lowest power, and highest throughput solutions do not support mobility. Without access to a mobile network many banking and e-commerce applications that rely on text message authentication will not work.

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Finance Strategies

- Service Obligations
  - Can help regulators achieve access targets without cash commitment
  - Can be tied to operating licenses or radio spectrum licenses
  - Often include requirements for performance across geographic areas
  - France discounted 4G spectrum for rural service commitments
  - Brazil required 5G winners to build 4G/LTE in small towns

- Smart Subsidies
  - Minimum one-time subsidy required to help service become established
  - Direct funding of infrastructure providers to make projects viable
  - Vouchers help rural households pay one-time connection fees

Finance Strategies

- Subsidies for Open Access Infrastructure
  - Subsidies can unfairly advantage incumbents & discourage competition
  - Limiting subsidies to Open Access infrastructure lowers this risk

- Limited Subsidies for Managed Services
  - Anchor tenants (schools, health care providers) are funded for a fixed term
  - Service provider can be obligated to provide community access also
  - Networks can become unviable when anchor tenant funding stops

- Sending Party Pays (SPP)
  - Toll-free calls and free post are analog SPP examples
  - In the digital era, govts can pay carriers to provide education and government content on their networks at no cost to end users.

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Policies: Broadband Plans and People Focus

- Broadband Plans
  - National Broadband Plans and Digital Strategies are effective tools for planning and monitoring growth.
  - Many of this paper's policy recommendations could be incorporated into broadband plans for ADB's developing member countries.

- People Focus
  - Public Wi-Fi is important but limited for providing equitable access
  - Home Internet is needed for women and people with disabilities
  - Promoting personal devices is also key for closing the gender gap

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Policies: Streamlined Administrative Processes

- National regulations should establish norms for telco infrastructure
  - Consistent and well-defined rules for public space infrastructure are key
  - Regulate small masts, antennas, fiber pathways, and street furniture
  - Conforming infrastructure should never need local permits

- Consultation and permitting should require official cooperation
  - Permits should be deemed approved if not quickly rejected for cause

- Co-deployment should be enabled and promoted
  - Infrastructure projects should allow telecoms access on cost-sharing basis

- Right-of-way access should be non-discriminatory at cost recovery
  - Government and utility operators should not seek a commercial return from telecommunications operators for access to rights-of-way.

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Policies: Radio Spectrum Management

- Spectrum Roadmaps can help identify and allocate spectrum
  - They also provide regulatory certainty that can encourage investment
- Make spectrum available for services that benefit society
  - Additional mobile bands and increased ISM spectrum needed most
- Price spectrum to balance socioeconomic benefits and revenue
  - When carriers spend on spectrum, they pass that cost on to customers
- Open and harmonize ISM spectrum bands
  - Non-exclusive spectrum is key to innovation in rural and remote areas
- Provide a public register of radio spectrum
  - Transparency on spectrum use can lead to more efficient use
- Enable spectrum sharing and dynamic spectrum access

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Policies: Flexible Licensing Regimes

- Allow small and community providers to fill infrastructure gaps
  - Regulations and licensing conditions aimed at national Facilities Based Operators are often not fit for addressing the affordability frontier
  - Make limited facilities licenses available through a single window process.
  - Allow small providers to build fiber and ISM wireless on private property or through commercial rights-of-way arrangements

- Ease market restrictions for international operators
  - Passive, open-access infrastructure can benefit all market participants

- Allow global satellite companies to participate on a fair, open basis
  - Emerging Low Earth Orbit networks will provide global coverage
  - Allowing them to sell wholesale capacity without a local partner or franchise could benefit existing providers equally.

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https://www.adb.org/publications/last-mile-connectivity-affordability-frontier