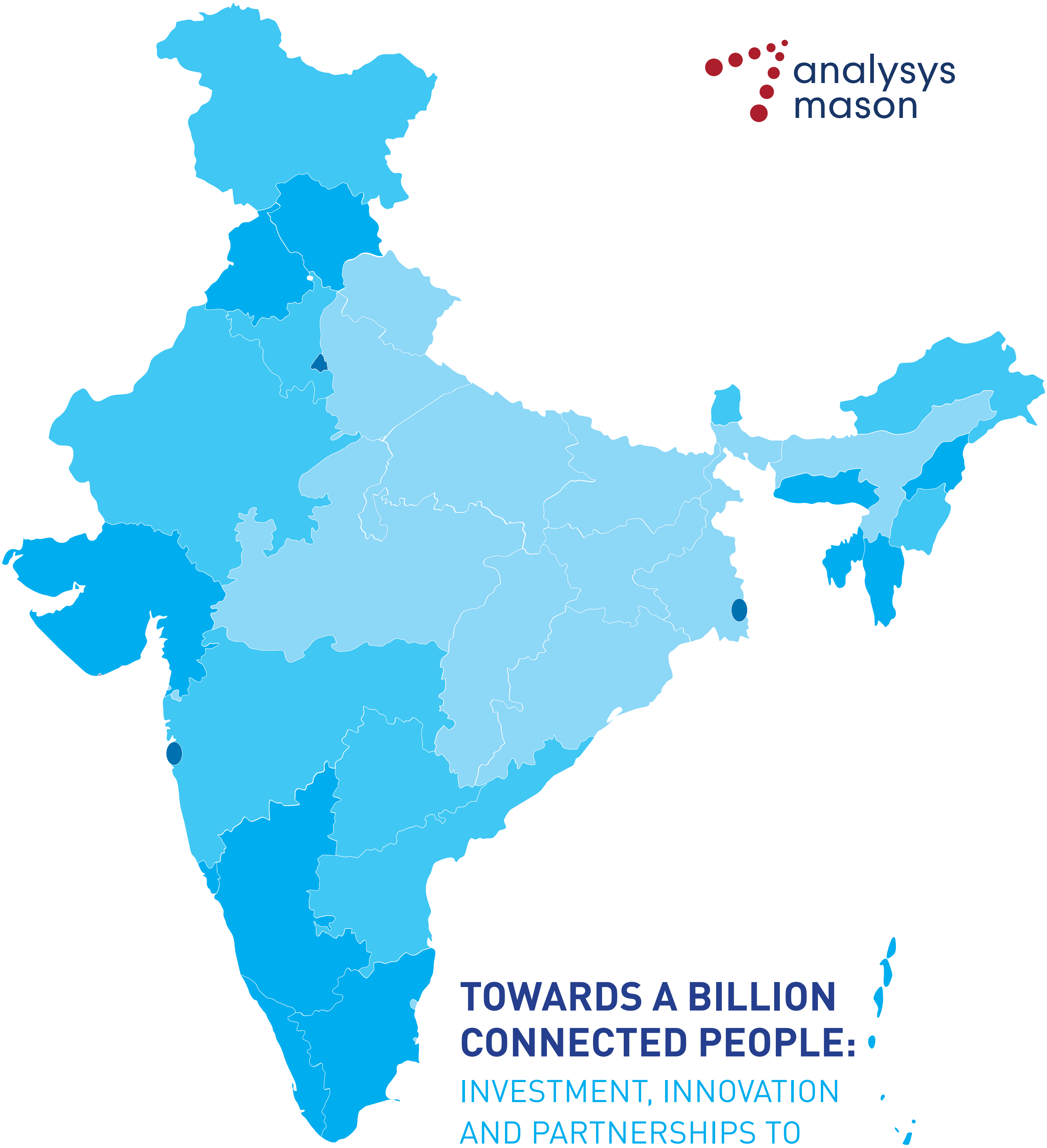

TOWARDS A BILLION CONNECTED PEOPLE:

INVESTMENT, INNOVATION AND PARTNERSHIPS TO ACCELERATE ‘DIGITAL INDIA’

A report on broadband connectivity in India

PENETRATION:

> 50% | 30-50%
20-30% | < 20%

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The analysis contained in this document is the sole responsibility of Analysys Mason and does not necessarily reflect the views of Google or other contributors to the research. Lead authors were David Abecassis (Partner), Kunal Walia (Principal) and Vishhal Chadha (Consultant), with additional input from Siddharth Thakkar and Ramprasad Putrevu (Associate Consultants). The report was edited by Frances Lubbe, with graphic design by Julie Bartram.

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Contents

1 Executive summary

Bringing one billion Indians online by 2020 could add USD200 billion (INR10 lakh crore) to India's GDP over the next five years, but achieving this challenging target will require more than just investment and innovation from many different stakeholders throughout the Internet value chain. For all stakeholders to work towards a common goal of expanding access across the country, public policies need to prioritise making broadband networks open and widely available, and maintaining an international outlook. Doing so will facilitate affordable data and devices, which are essential to broadband adoption and usage.

Public-policy approaches that support these goals include the following:

- **Implementing an appropriate spectrum policy and management framework** that focuses on increasing connectivity rather than raising revenue, and enables experimentation and innovation by making new spectrum bands available broadly. This is crucial as wireless technologies will remain the main technical solution to enable access networks to reach the more than 500 million Indians currently not covered by broadband at a sufficiently low cost.

- **Ensuring data and device prices are affordable to many more people** – this includes bringing down the cost of network deployment and having device policies that follow international standards, rather than new India-specific standards. The importance of affordability cannot be overstated – even accounting for expected economic growth, in 2020 over 62% of Indians will remain unable to afford a true broadband Internet experience.

- **Maximising the impact of public investment to support universal, affordable broadband** – very ambitious projects are underway, primarily through the BharatNet programme, and their success depends on ensuring they provide the inputs the industry needs, at the right price point, to truly expand broadband supply in India.

All these approaches imply taking a long-term policy view and emphasising the achievement of access and affordability outcomes rather than raising short-term revenues. A longer-term view is beneficial for government too, as increasing broadband take-up could bring in more revenue to the government in five years than the recent spectrum auctions.

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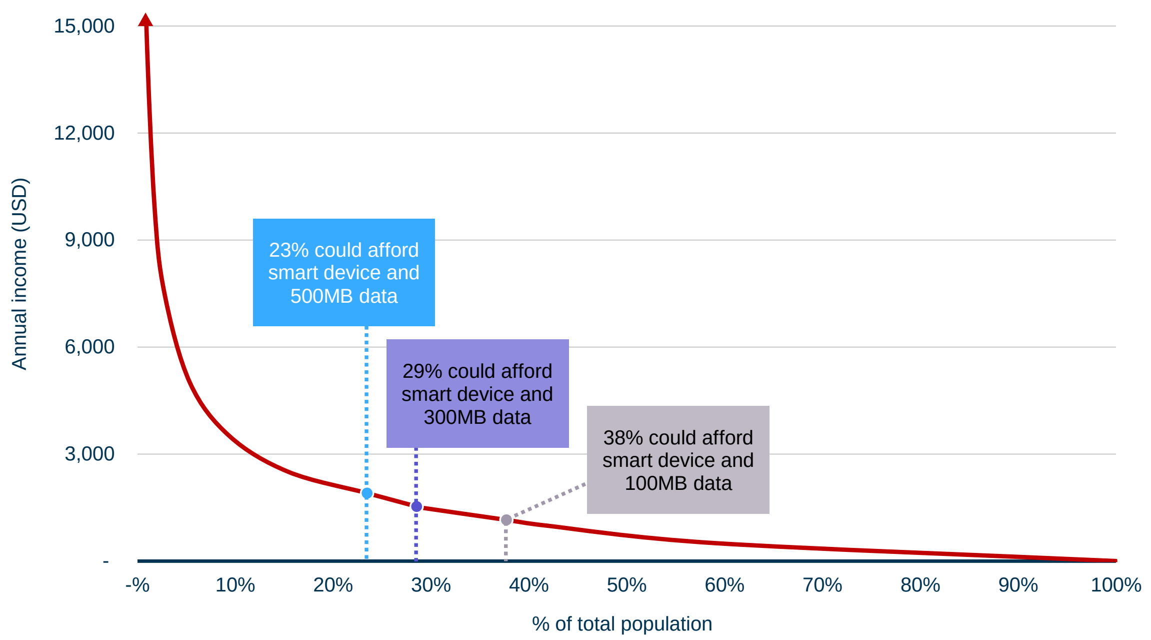
The potential of the Internet in India is tremendous: over 300 million Indians already use it and an estimated 750 million people will be online by 2020, yet this would still leave over 500 million without Internet access. If only half of those people – 250 million Indians – could be brought online by 2020, we estimate that economic benefits in the hundreds of billions of dollars could be realised (over 10 lakh crore rupees, or USD200 billion, over the next five years alone).

There are well-documented barriers to achieving this significant economic potential. At a very basic level, people must be within reach of suitable networks (availability) and must be able to afford the price of a device and of data services to connect to the Internet (affordability). In addition to these two types of barriers, which we explore in detail in this report, people are also hindered from connecting to the Internet by a lack of content immediately relevant to them, and their need to develop skills and an awareness of how and why to use the Internet.[1]

The situation in India today is that relatively few Indians have access to affordable, high-quality broadband connectivity: the majority have either low-quality or no access available where they live, and most people who can afford a smart device and a large enough data quota (500MB or more every month) are already using the Internet. Economic growth between now and 2020, will improve this picture, but even then we expect 62% of Indians to remain unable to afford a true broadband Internet experience, as shown in Figure 1.1 below.

Figure 1.1: Affordability of smart devices and data services in India (500MB, 300MB and 100MB per month) [Source: Analysys Mason, 2016, Euromonitor]



What can be done to change this state of affairs?

Clearly, the private sector is investing heavily: mobile operators have spent billions in 2016 obtaining licences for spectrum to expand the reach and quality of their networks; handset manufacturers and software developers are working to develop cheaper and more powerful devices, accessible to ever more Indians; and Internet companies are deploying servers and caches in data centres, investing in international connectivity and driving innovation. These efforts must be supported by a forward-looking policy environment that prioritises improvements in connectivity outcomes. This will require commitment by the government to translate such policies into action on the ground.

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1 See for example Google, *Measuring Connectivity: A Call to Measure Internet Development with Open, Timely, and Relevant Data*, 2015, and Facebook, *State of Connectivity Report 2015*, to which Analysys Mason contributed

First, expanding broadband access networks to reach the more than 500 million Indians currently not covered will need continued investment and innovation in infrastructure. Wireless technology will remain the main technical solution to achieve this at sufficiently low cost, through a combination of cellular, Wi-Fi and other technologies (e.g. TV white space spectrum and satellite). The government and regulatory agencies can enable this to happen by implementing a modern, agile spectrum policy, rather than focusing simply on optimising the current spectrum management regime. Such an approach has already been fruitful in cases where it has been applied – for example, using the 2.1GHz, 2.3GHz and 2.6GHz bands for cellular mobile whilst keeping the 2.4GHz band fully open and unlicensed for use by Wi-Fi. It balances the benefits of scale and standardisation (e.g. the licensing of standardised 3GPP bands to cellular operators) with a flexible regime that allows experimentation (e.g. shared access to TV white space spectrum that is not currently standardised, light licensing regimes for high-frequency or high-reuse bands such as the E-band).

Second, much remains to be done to make data services and devices affordable. This requires bringing down the cost of deploying broadband networks. The government is already reviewing right-of-way practices, which is a good start, and should also ensure that spectrum auctions are structured primarily to support desirable outcomes, such as rural coverage, rather than simply raising revenue. In fact, the GDP growth spurred by increased broadband take-up could yield more revenue to the government in five years than the recent spectrum auctions.[2] Affordability also requires low-cost devices to be widely available. Much progress has been made towards this goal, driven by both global and Indian manufacturers, but new mandatory standards should be carefully designed to avoid restricting this market and increasing the cost of handsets.

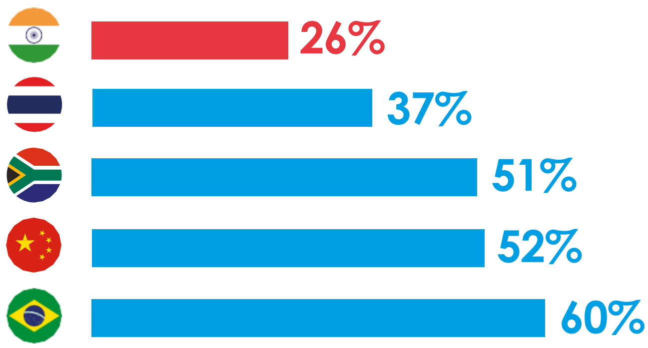
Third, the impact of public investment should be maximised by working closely with the private sector to ensure infrastructure bottlenecks are reduced in the right way, at the right price. Intervention in the supply of backhaul capacity, for example, should explicitly consider the applications for which the capacity is to be used. Perhaps most importantly, this would involve working closely with all parties involved in providing connectivity to ensure that the standards and the pricing for the upcoming BharatNet connectivity is compatible with the business case for Internet access providers, particularly in poorer and more rural areas.

Likewise, regulation should harness market forces rather than seek to constrain them. While the government has an important enabling role, it is the private sector that is often best placed to invest and innovate. This would, for example, allow pricing mechanisms to emerge as a result of competition, within broadly acceptable principles. Organisations with complementary skill sets, such as a telcos, network providers, regional ISPs and content companies could partner to improve the delivery of broadband to consumers.

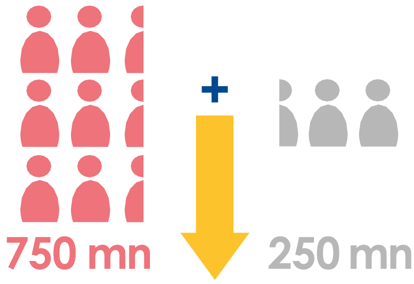
2 The Union Budget of India for 2015/16 estimated total tax revenue (minus the States' share) at INR81.5 lakh crore, about 6% of GDP. Applying this ratio to the USD200 billion incremental GDP for the five years to 2020 gives a potential tax increase of USD12 billion (INR820 billion). For comparison, the recent auction of 20-year spectrum licences raised around USD10 billion.

ACCELERATING DIGITAL INDIA THROUGH A BILLION CONNECTED INDIANS

Internet penetration 2015



Growth by 2020 and the impact on GDP



Additional GDP:
USD200 billion
from 2016-2020

AVAILABILITY

AFFORDABILITY

Connecting 1 Billion Indians requires a holistic approach to improving Availability and Affordability

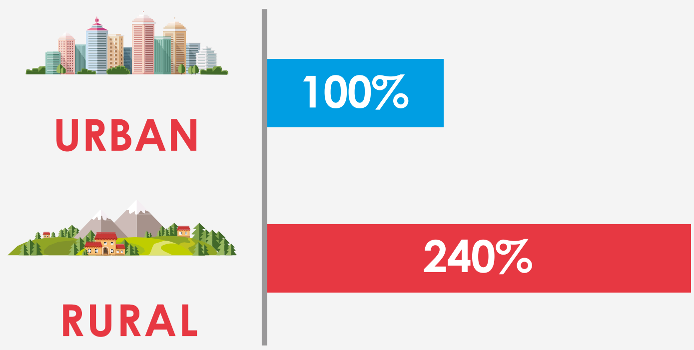
Mobile broadband coverage as a % of population

People who can afford true broadband Internet access (500MB data/month) | People who cannot afford true broadband Internet access

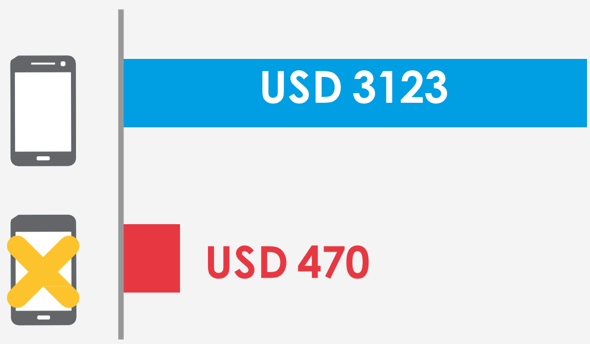
	URBAN	RURAL	People who can afford true broadband Internet access	People who cannot afford true broadband Internet access
In 2015	100% 350mn	50% 460mn	23% 290mn	77% 980mn
In 2020	100% 390mn	80% 820mn	57% 812mn	43% 606mn

Availability and Affordability challenges are closely related

Relative cost of deploying a mobile site



Median annual incomes of connected and unconnected Indians



WHAT CAN BE DONE TO SUPPORT A MAJOR EXPANSION OF CONNECTIVITY IN INDIA?:

- Ensure that network deployment costs are as low as possible, in particular by taking action on rights of way and spectrum pricing.
- Consider a radical review of the spectrum management framework, balancing efficient assignments for standardised bands with flexible licensing or de-licensing to support innovation.
- Design interventions (e.g. in fibre with BharatNet and in the satellite market) to ensure that standards and prices are consistent with desired outcomes.
- Harness market forces rather than constrain them, to foster innovation and leverage global standards.

2 About this report

Digital services delivered over the Internet can become an essential enabler for economic transformation, productivity gains and social benefits in India, as in other developing countries. However, for these benefits to be realised, people must be connected to the Internet, and the current level of connectivity in India remains insufficient to really unlock these benefits. Accordingly, connectivity is a central part of the Indian government's 'Digital India' initiative, which aims to provide universal high-speed connectivity across the whole of India.

The current connectivity landscape in India is very complex and needs to be better understood in order to identify pragmatic solutions that policy makers and private companies can put in place to improve connectivity. The factors that hinder connectivity are increasingly well documented: in some places, Internet access (and in particular broadband access) is simply not available; and in locations where connectivity is available, it may be unaffordable to many people, they may not understand what value it can bring to them, or they may lack the skills to access online services.

To address these challenges, forward-looking and result-oriented policy initiatives and industry mechanisms need to be developed. An investment-friendly policy environment is critical to improving the availability and affordability of broadband in India. Innovation, enabled by a flexible policy environment, is essential to overcoming the barriers to the broader availability and affordability of broadband in India. Finally, partnerships between the government and the private sector have a role to play in overcoming economic and social barriers to mass take-up of broadband.

This report offers a detailed quantitative analysis of the constraints on connectivity in India in terms of availability and affordability, and also proposes a number of recommendations to address these constraints. We hope that the report will help to broaden the 'common ground' of desirable policies and partnership approaches, and support the efforts being made to improve connectivity in the country.

The remainder of this document is laid out as follows:

- Section 3 first sets the context, comparing the status of connectivity in India with other major developing countries, examining historical growth, the current state of both fixed and mobile Internet connectivity, and the performance against government targets.
- Section 4 then describes the main constraints affecting connectivity, providing a detailed assessment of affordability and availability, and how they interrelated. In addition, there is a discussion of relevance and readiness as key constraints, although these are not analysed in detail.
- Section 5 provides an informed view on the key policy-level initiatives and mechanisms that could help address the previously discussed challenges. In particular, this section looks at investment policy, innovation and public–private partnerships (PPPs) from a policy point of view.

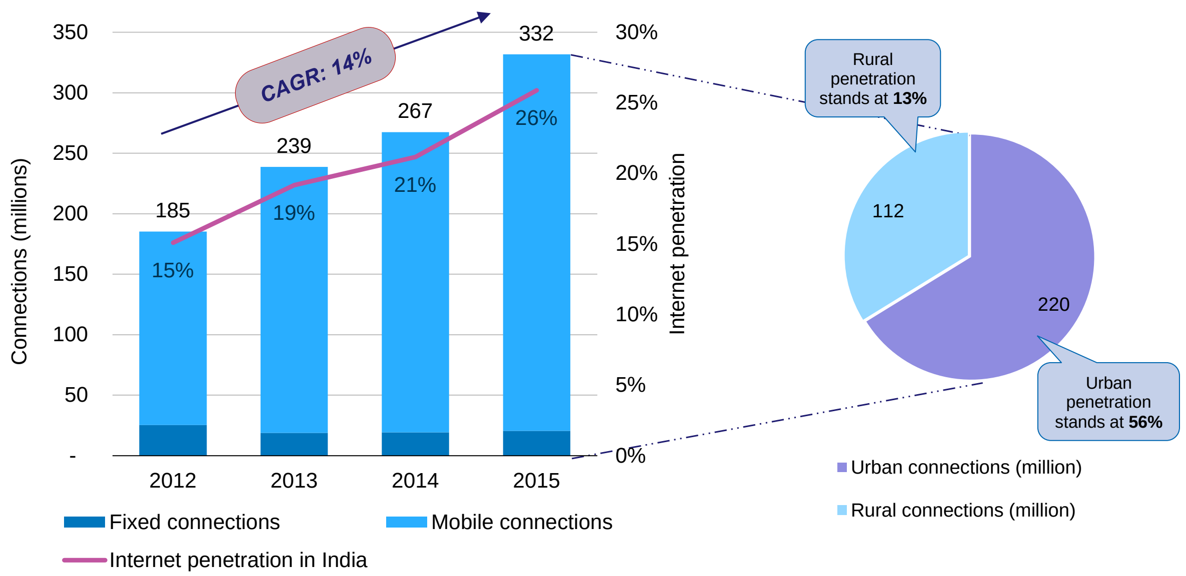
3 Accelerating broadband take-up is a major policy priority and could add USD200 billion to India's GDP by 2020

Internet penetration in India remains stubbornly low compared with many other developing markets, despite the huge potential for economic and social benefits arising from universal access to broadband. In this section, we describe what the Internet connectivity landscape in India looked like in early 2016, and provide estimates of the potential economic impact of broader and better Internet connectivity, based on published studies. The government of India is well aware of these potential benefits, and is proactively trying to improve broadband connectivity across the country.

3.1 India has significant headroom for growth of Internet penetration compared to other major developing markets

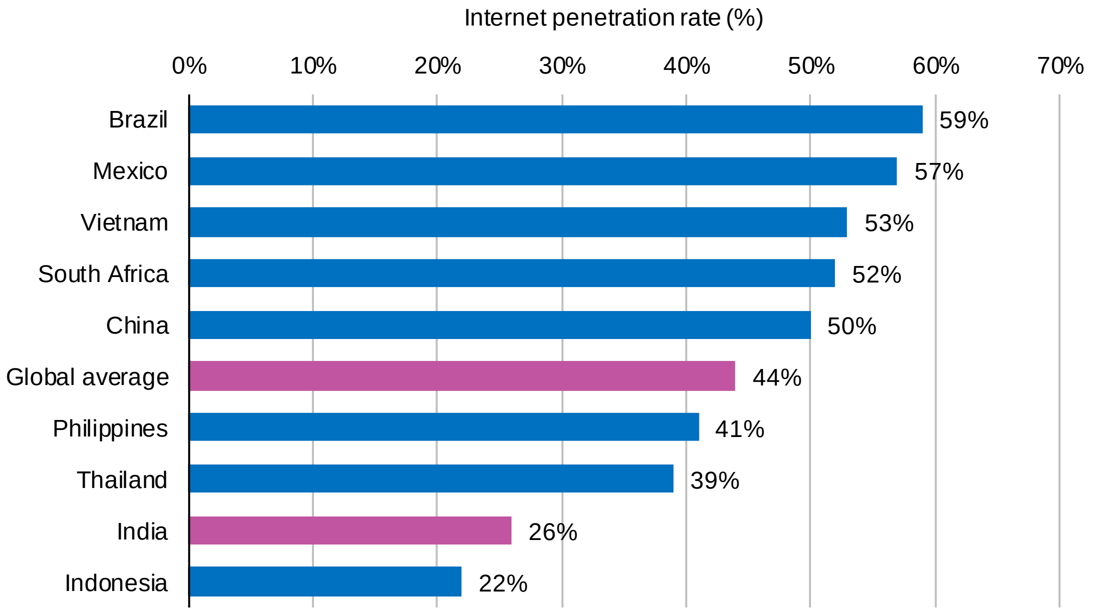
While the government aims to bring Internet connectivity to nearly everyone in India, at present connectivity is still essentially an urban phenomenon. Since around 70% of people live in rural areas, this means that only a small proportion of the population can connect to the Internet. Figure 3.1 illustrates the state of Internet connectivity in India as of December 2015. There were an estimated 332 million Internet connections, corresponding to 26% of the total population (32% of the population between 10 and 80 years of age). The telecoms regulator, TRAI, estimates that Internet penetration is 56% in urban areas, but only 13% in rural areas.

Figure 3.1: Internet connections in India, all technologies [Source: Analysys Mason, 2016, Euromonitor, TRAI Indian Telecom Services Performance Indicator Reports]



The growth in Internet penetration has been driven by an increase in *mobile* connections: the growth of fixed connections has slowed down significantly in the past few years, in large part because the geographical footprint in which it is available has not expanded beyond selected urban areas. Despite this continued growth, India's Internet penetration (26%) at the end of 2015 was lower than in many other large developing markets such as Brazil, Mexico, Indonesia, Philippines, Thailand, Vietnam, China and South Africa (see Figure 3.2). The global average Internet penetration (44%) also stood much higher than in India. India thus has significant headroom to grow its Internet penetration and unlock the wider economic benefits that are brought by universal broadband connectivity.

Figure 3.2: Benchmarking of Internet penetration in December 2015; this includes all connectivity, narrowband, broadband and shared connections [Source: Analysys Mason, 2016, ITU, Euromonitor]



3.2 Although most Internet users in India still connect via narrowband technology, investments across the value chain are improving the quality of connectivity

Most Indian users still rely on narrowband rather than broadband technology to access the Internet. Broadband technologies are defined very broadly by TRAI as those offering a theoretical throughput over 512kbit/s.[3] In contrast, narrowband connectivity offers lower speeds and is insufficient to access most forms of multimedia content (audio, video, high-quality pictures).

As shown in Figure 3.3 below, broadband was used by only 137 million users as of December 2015 (11% of the population and around 40% of Internet connections). Mobile is and will remain the main driver of broadband growth (see Figure 3.5 below): 3G coverage is fast expanding beyond the main urban areas, while the coverage of 4G[4] networks is also expected to increase rapidly over time (albeit mainly in urban areas). Hence this report focuses primarily on the growth potential for wireless and

3 There are many different definitions of broadband, as described in Section 4 (that section also discusses what broadband means from a supply and demand perspective).

4 4G refers to advanced, fourth-generation mobile technologies that can offer high-speed broadband. The most commonly deployed 4G technology is LTE.

mobile broadband, because it is best suited to delivering large-scale, high-speed connectivity across the country. The 'mobile first' aspect of broadband development in India has implications for the user experience, and is one reason why the actual speeds available in practice are lower than in other large developing countries (see Figure 3.3 and Figure 3.4).

Figure 3.3: Broadband vs. narrowband connections in India [Source: Analysys Mason, 2016, TRAI Indian Telecom Services Performance Indicator Report, Dec 2015]

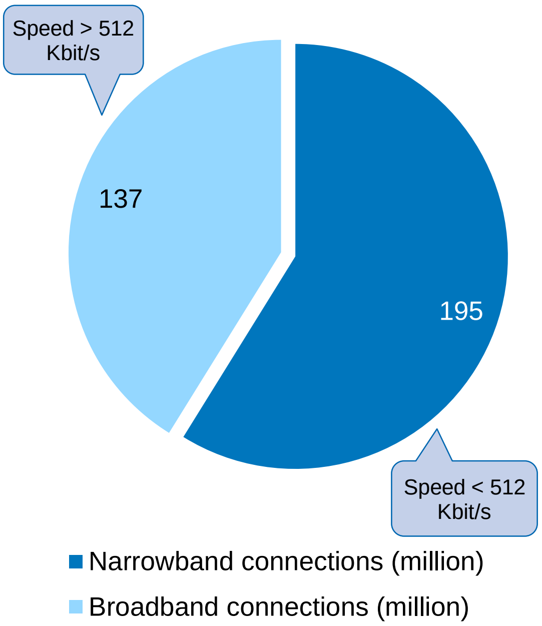


Figure 3.4: Benchmarking of Internet speeds [Source: Analysys Mason, 2016, Akamai's State of the Internet Report Q4 2015]

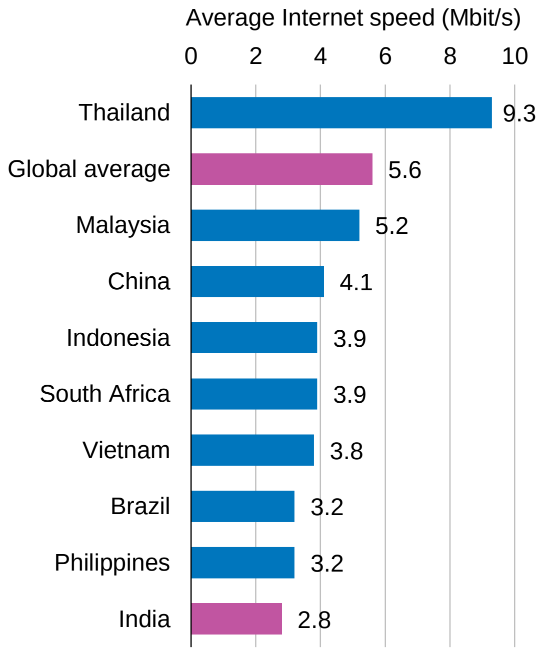
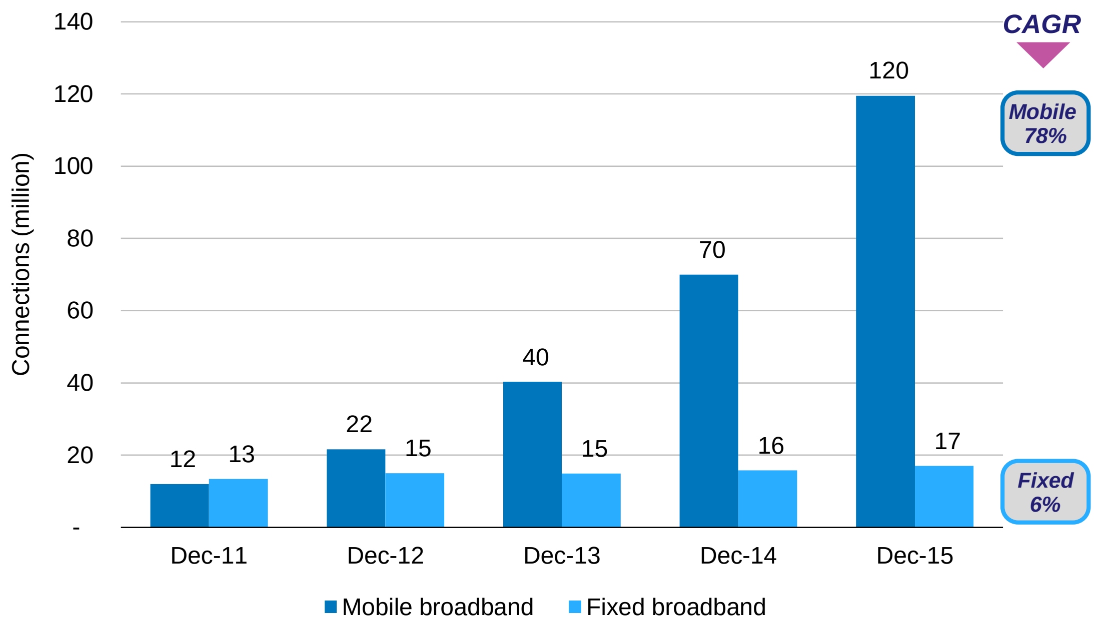


Figure 3.5: Mobile and fixed broadband connections in India since 2011 [Source: Analysys Mason, 2016, TRAI Indian Telecom Services Performance Indicator Reports]



The technology mix plays a major role in determining access speeds: where the share of fixed technologies is higher, end-user throughputs also tend to be higher. Conversely, mobile broadband speeds are on average lower. In India, mobile is the main way in which people connect to the Internet, many of them through 2G, which is much slower than 3G, 4G and fixed broadband. Even for mobile broadband (3G and 4G), actual throughputs in India are typically lower than in other markets because most telecoms operators are using a single 5MHz carrier for their 3G signal, which limits both overall capacity and end-user speeds.

A number of fixed access technologies are found in India, with fixed networks using a combination of DSL, FTTx, cable and other technologies (such as Ethernet, leased lines and fixed wireless). As shown in Figure 3.6, the majority of those connected using fixed broadband are still on older technologies such as DSL, which are slower than cable or fibre. The high proportion of legacy technologies used for both fixed and wireless broadband connections is a key reason for lower speeds.

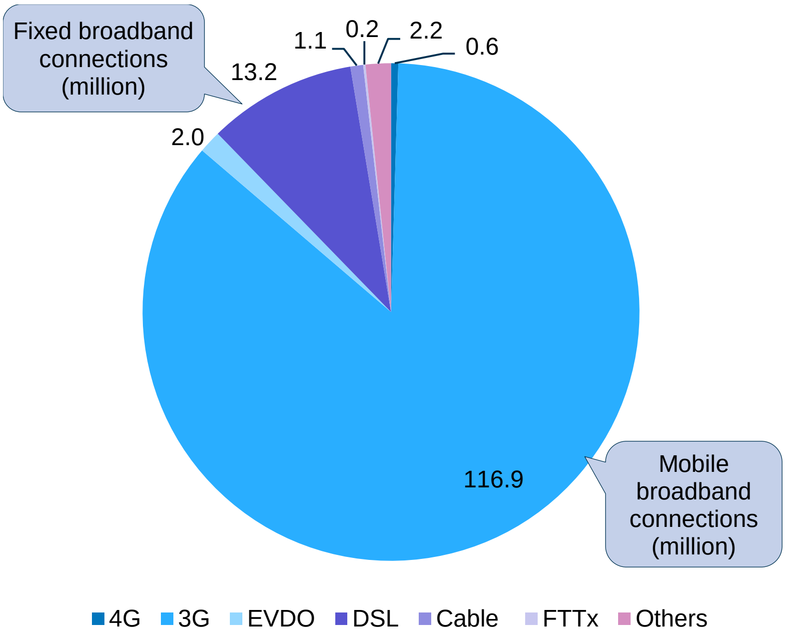


Figure 3.6: Split of mobile and fixed broadband in India, by technology [Source: Analysys Mason, 2016, TRAI Indian Telecom Services Performance Indicator Report, Dec 2015]

3.3 Broader and better broadband Internet connectivity in India promises productivity gains that could contribute an additional USD200 billion in GDP by 2020

The availability and take-up of high-quality broadband is correlated with the impact on economic growth and productivity that the Internet brings. The consensus from studies that have attempted to measure this quantitatively suggests that for every 10% of the population that is connected to the Internet, the growth potential of the economy increases by around 1%. In a country the size of India, the potential is enormous: if the number of people online in 2020 could be increased from the expected number of 750 million[5] (about 52% of the 2020 population) to 1 billion (69% of the 2020

5 Analysts’ forecasts – for a more detailed discussion see Annex A.

population), the annual GDP of India in 2020 could increase by over USD100 billion (in constant 2015 USD). Cumulatively, over the five years from 2016 to 2020, this extra growth could generate over USD200 billion in additional GDP.[6]

The government of India is keenly aware of these potential benefits, and has designed a range of policy initiatives aimed at increasing Internet availability and take-up. This will be driven, in part, by continued investment in broadband by public and private stakeholders. On the public-sector side, the main connectivity initiative, BharatNet, was originally planned to connect 250 000 Gram Panchayats (GPs)[7] with fibre and offer Internet speeds of up to 100Mbit/s. The project has since been extended to include 300 000 schools, 30 000 health centres and 200 000 government institutions, and will also facilitate the installation of 250 000 public Wi-Fi hotspots. The initiative is expected to cost USD11 billion,[8] although the exact cost will be dependent on implementation choices, which have not been finalised.

Private telecoms operators in India are currently investing heavily in 4G technology, which provides theoretical speeds in excess of 50Mbit/s, in many cases well in excess of 3G speeds.[9] The largest mobile operator, Bharti Airtel, has earmarked USD9 billion over the next three years for network modernisation. Likewise, Idea expects to invest USD1 billion in the financial year 2016 to accelerate its roll-out of 4G and associated fibre networks.[10] Finally, Reliance Industries has invested over USD23 billion since 2010 in its 4G Internet and telecoms venture, Jio, which aims to provide 70% population coverage when it launches (planned for the second half of 2016).[11]

Telcos, infrastructure companies, and Internet content and application providers (CAPs) are investing more broadly in India's digital infrastructure. Global CAPs such as Google, Facebook, Microsoft and Amazon, as well as Indian companies (including ecommerce firms such as Flipkart and Snapdeal, and BPO firms such as Infosys) are driving demand for hosting, transmission and content delivery infrastructure in order to improve the end-user experience. We estimate these investments to be over USD500 million[12] annually, with significant growth reported by many of the stakeholders interviewed.[13] More details can be found in Annex B.

Despite these tangible investments, the challenge to bring 1 billion people online by 2020 is significant, and this is the focus of the remainder of this report.

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6 Analysys Mason estimates assuming a 1.08% increase in GDP growth rate for a 10 percentage point increase in broadband penetration. For more details see Annex A.

7 A Gram Panchayat is a local self-government organisation in India within the Panchayati Raj system; it refers to the village or small town level.

8 Source: TeleGeography.

9 For comparison, theoretical throughout per user for 2G are below 0.4Mbit/s, at best a tenth of minimum 4G speeds.

10 Source: TeleGeography.

11 Source: Mobile World live.

12 Estimate based on interviews with industry experts, secondary research and proprietary analysis.

13 For example, one interviewee mentioned that CAPs are responsible for over 40% of the total demand for data centre capacity, and that this proportion is growing.

The government of India is aware of the huge potential for growth and is seeking to address this through major policy initiatives

Ambitious targets have been set for connectivity, although implementation has been slow.

- In 2012, the **National Telecom Policy** (NTP) set a target of 175 million broadband users by 2017 and 600 million by 2020, at a minimum speed of 2Mbit/s. Although liberalisation of spectrum and unified licensing have been implemented, the number of broadband users still stands at 121 million and the definition of broadband is yet to be upgraded from 512kbit/s.
- **Digital India** launched in 2015, conceived by the Department of Electronics and Information Technology (DeitY) with the aim of providing digital infrastructure to every citizen. Digital India's goals include connecting 2.5 lakh villages with broadband; setting up 4 lakh public Internet access points; enabling Wi-Fi in all universities; and providing 17 million people with job training in IT, telecoms and electronics by 2019. The slow growth in connectivity and the need to educate people on the use of online services have been key limitations.
- The **National Optic Fibre Network** (NOFN), launched in 2011, aimed to achieve universal connectivity by connecting 250 000 GPs with public Wi-Fi by 2015. Recently the government launched a newer and upgraded version of NOFN called **BharatNet**, a robust, future-oriented network with built-in possibilities of increasing its capacity. So far only ~40 000 GPs have been connected due to hurdles such as obtaining rights of way, and increases in costs. Policy changes and private-sector involvement are being considered as ways to put the project back on track.
- The government launched its **Smart City** initiative in 2014 with the aim of developing 100 smart cities by 2020. Each city will have smart solutions for energy, urban mobility, and waste and water management. Delays in funds disbursement have stalled progress. Timely clearance of land, along with financial support from states and the private sector, will be required for the Smart City project to become a reality.
- The **Education and Research Network**, a government agency, has provided last-mile connectivity solutions for remote areas like Andaman and Nicobar Islands and Lakshadweep. It is also testing new technologies, such as the use of TV white space spectrum (TVWS),[14] as potential solutions for affordable rural broadband provision.
- The public mobile operator **BSNL** is planning to set up **2500 Wi-Fi hotspots** across India in partnership with Quad Zen and Trimax. BSNL is also working with Facebook (the Express Wi-Fi project) and providing bandwidth to support affordable broadband at 100 Wi-Fi spots in rural areas.
- RailTel has partnered with Google for **Project Nilgiri**, which aims to provide free Wi-Fi at railway platforms. RailTel has over 45 000km of fibre network, which Google will utilise. The plan is to roll out Wi-Fi at 100 stations by the end of 2016, and to eventually connect 400 stations.

Apart from the initiatives mentioned above, the government has made a number of other policy changes to increase broadband penetration in India. In future, more proactive co-ordination between the Government of India, State Governments and the private sector is required to realise these goals.

14 White space is unused frequencies within bands of spectrum used for TV transmission. These frequencies can be used to provide wireless broadband connectivity.

KEY TAKEWAYS:

Accelerating broadband take-up is a major policy priority and could add USD200 billion to India’s GDP by 2020

- There is enormous headroom for growth of Internet penetration in India, which currently stands at 26%, lower than developing countries such as China, Brazil and Thailand.
- While broadband penetration in urban areas stands at 56%, rural areas lag behind with 13% penetration.
- Internet connectivity remains dominated by narrowband and primarily mobile technologies, but significant investments are being made in broadband infrastructure.
- The potential for broadband to drive economic growth and productivity in India is large, and a big push is being made by the government to realise this potential.
- Cumulatively over the next five years (2016−2020), over USD200 billion could be added to India’s GDP if 1 billion people used the Internet in 2020 instead of the expected 750 million.

4 Connecting 1 billion Indians by 2020 relies on connectivity being much more broadly available and affordable

The remainder of this report aims to provide a systematic approach to understand the challenges related to connectivity in India and the initiatives and mechanisms needed to address these challenges. We focus on the *availability* and *affordability* of broadband, although we also mention broader constraints such as the relevance of online services to new Internet users, and these users’ ability (or readiness) to adopt them.[15]

4.1 A structured and cohesive approach is required for addressing affordability and availability constraints for broadband connectivity

A number of research papers have addressed the constraints around connectivity, but have tended to discuss relevant initiatives to reduce these constraints in ‘silos’. In this report, we propose a perspective that links the availability of broadband and its affordability: at a very basic level, users must be within reach of suitable networks (availability) and able to afford the price of a suitable device and a service to connect to the Internet (affordability).

Network availability is often considered a supply-side factor, while affordability for end users is regarded as a demand-side factor; they are, however, closely related, as the economics of network availability determine a break-even level for demand and price. This break-even point can only be reached if the price is affordable to enough end users to achieve sufficient demand. Various factors drive the economics on both the supply and the demand side. On the supply side, the cost of network deployment (for each of the various technology options) is driven by the cost of last-mile access, backhaul, spectrum and equipment (including end-user equipment). On the demand side, the total cost of ownership (TCO) for end users includes the cost of a mobile broadband data package, the cost of an end-user device, and other related costs.

In certain low-density areas where deployments costs are high and income levels and expenditure thresholds are low, it may be difficult to find the right pricing equilibrium between the supply and demand. To resolve this, various policy-level mechanisms are needed. These include traditional mechanisms that directly address the high input costs of network availability and seek to reduce the TCO for end users. Non-traditional mechanisms are also important, including innovative network deployment options and measures to limit the TCO by reducing the cost of devices and services.

This report classifies these mechanisms into three broad categories: enabling private and public investments, promoting innovation, and developing partnerships between stakeholders(see Section 5). Figure 4.1 below provides a graphic representation of the framework linking availability and affordability, together with relevant mechanisms to improve broadband connectivity.

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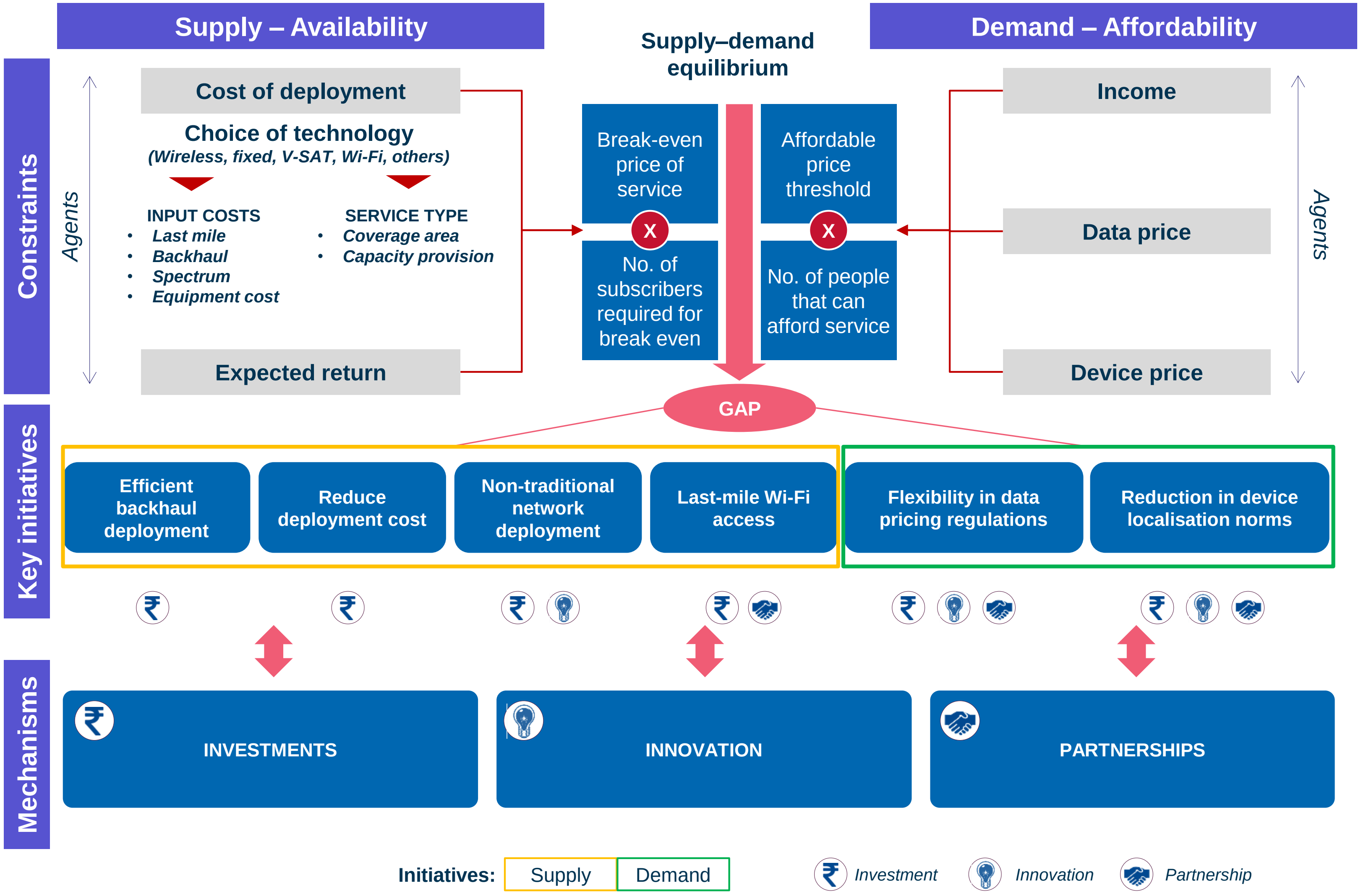
15 For a discussion of the global barriers to connectivity, see Google, *Measuring Connectivity: A Call to Measure Internet Development with Open, Timely, and Relevant Data*, 2015; and Facebook, *State of Connectivity Report 2015*, to which Analysys Mason contributed.

Figure 4.1: Framework: interdependency between broadband connectivity constraints and targeted mechanisms and initiatives [Source: Analysys Mason, 2016]



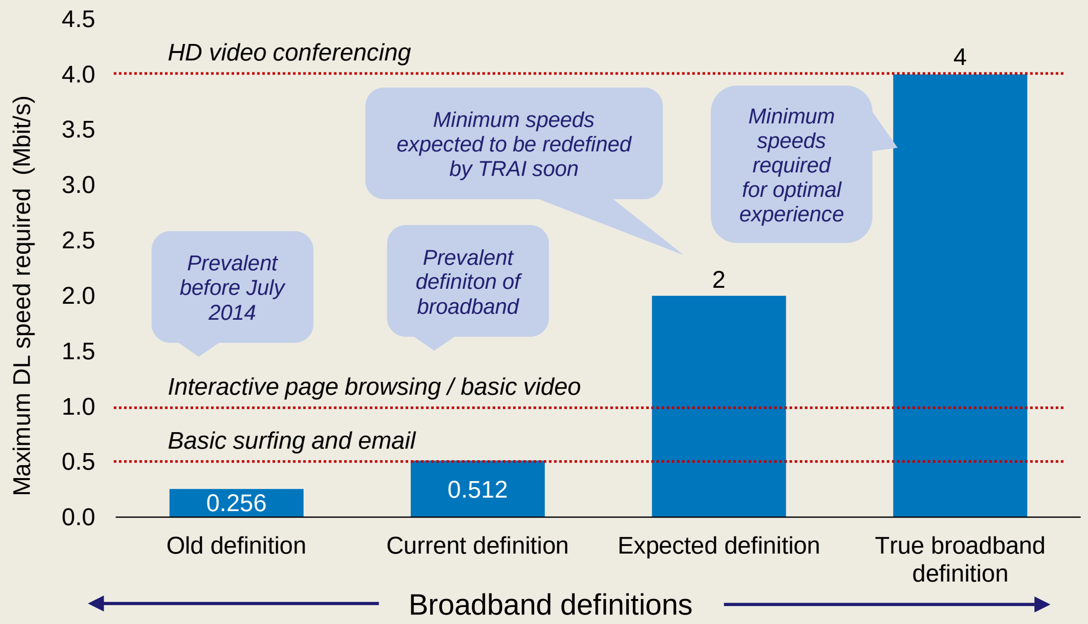
4.2 Universal availability of broadband networks cannot be fully realised in the short to medium term through traditional fixed and mobile commercial roll-outs

Connectivity in India has mainly been provided over mobile networks (2G, and increasingly 3G and 4G), while fixed broadband technologies have largely played a supplementary role, as they are more focussed on urban areas. Although various mobile operators have aggressively deployed mobile broadband networks, they have not yet been able to offer ubiquitous broadband coverage due to the size of the country, the high costs of rural roll-out, and the limited revenue opportunity in rural areas. The efficacy of the Universal Service Obligation (USO) fund in increasing broadband availability has also been limited: only 40% of the funds collected between 2002 and 2014 were spent on rural cellular roll-outs. The remainder of this section provides a perspective on the constraints that traditional fixed and mobile networks face, by focusing on the economics of network deployment.

What constitutes 'true broadband' connectivity from the supply-side perspective?

Availability of mobile broadband requires not only coverage by services, but also adequate quality of those services. But in India there is only limited coverage, especially in non-urban areas, and also limited quality, with broadband speeds typically being much lower than the 'true broadband' speeds required for an optimal broadband experience (see figure below).

Figure 4.2: Definitions of broadband in India [Source: Analysys Mason, TRAI, Federal Communications Commission]



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4.2.1 Although capable of covering large parts of the population, in rural areas traditional broadband access technologies are constrained by network economics

In urban areas, cellular mobile coverage – both narrowband and broadband – is ubiquitous

Almost all of the urban population in India (350 million people or 28% of the total population) has access to 3G mobile broadband provided by various private- and public-sector mobile operators. Subscriber traffic has also increased rapidly – 3G data usage per month per subscriber grew at a 20% CAGR between 2013 and 2015. This has led to capacity pressures on the mobile broadband networks, leading in turn to a poor quality of experience for end users, e.g. speeds that are significantly slower than the theoretical or headline speeds, frequent need to fall back onto slower 2G networks, and poor in-building coverage. There are several systemic bottlenecks that can generate such capacity pressures:

The amount of spectrum owned by mobile operators is limited

Most mobile operators in India[16] only have one carrier (5MHz) of 2100MHz spectrum available for 3G network deployment, which leads to capacity issues and consequently affects the quality of broadband experienced by users. Although more 3G spectrum will be available in the coming auctions, operators will face a dilemma on whether to invest more in 3G or to focus aggressively on 4G roll-outs.

The spectrum bands that can be used for 3G are limited

Certain frequencies on which mobile broadband is currently being deployed in India – such as 2100MHz (3G) and 1800MHz (4G) – have inferior indoor network propagation characteristics. Bands with superior indoor coverage (900MHz) are currently utilised by 2G networks, and re-farming this spectrum for broadband is not feasible as these networks are unlikely to be switched off in the near-to-medium term. 4G will provide much greater flexibility in the spectrum that can be used for broadband, but the vast majority of users will remain on 2G and 3G for the foreseeable future.

High-capacity backhaul is constrained by difficulties in obtaining rights of way

The majority of backhaul for mobile networks in India uses microwave technology, which is equally constrained by available spectrum. Optical fibre is a viable alternative for backhauling the higher levels of traffic generated by broadband services, especially in dense urban areas, but only around 15% of the mobile towers in India are connected using optical fibre. In order to offer greater quality of service to broadband users, operators are increasing the density of their sites, and many of these will need to be connected by fibre.

A key bottleneck is the delays experienced in getting permission to build fibre and sites – in particular, through rights-of-way (ROW) procedures. Even when ROW is granted, the charges tend to be high in many parts of the country, from a few thousand dollars per kilometre to more than USD200 000, depending on the municipal body. Rationalisation of ROW policies, as mentioned in the

16 The exception is Bharti Airtel in a few circles such as Tamil Nadu.

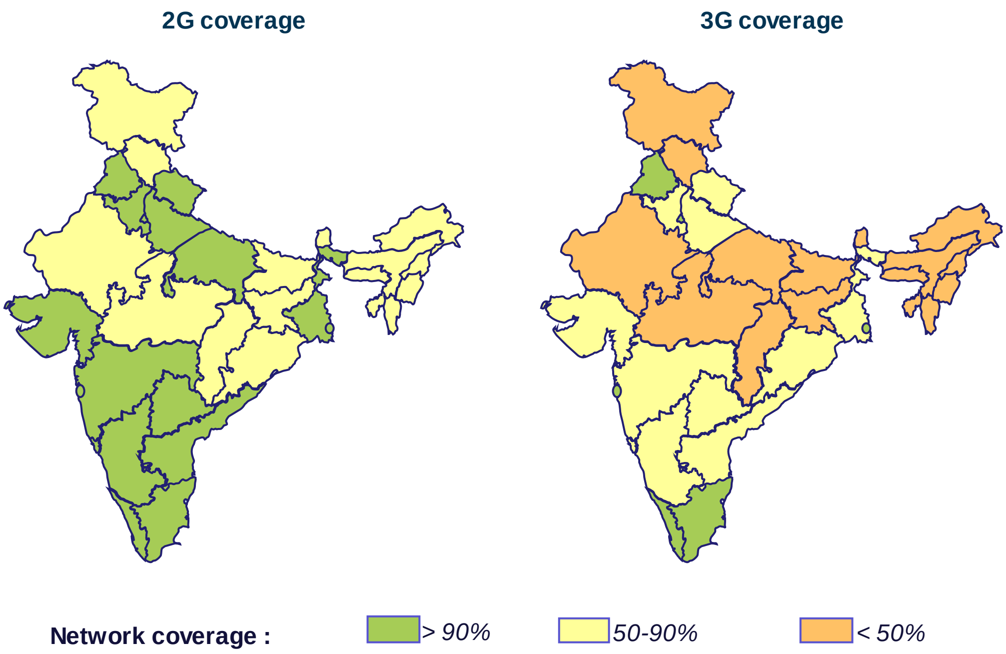
Department of Telecom's *Indian Telegraph Right of Way Rules 2016*, would be an important step in removing this bottleneck.[17]

Certain initiatives of the government such as spectrum sharing and trading norms have positive implications for the industry due to reducing spectrum-related constraints on capacity and coverage (see the breakout box 'Spectrum sharing and trading norms: a step in the right direction' on page 21 for more details).

Further 3G expansion outside cities is required to bring broadband to rural areas, but this faces even stronger constraints

Estimates suggest that the total population coverage of 2G and 3G networks in India stands at around 90% and 60% respectively, while 4G is still restricted to the large cities. An estimated 790–840 million rural Indians (85–90% of the total rural population) are covered by 2G networks, while 3G is available to 370−460 million (40–50% of the rural population). The estimated 2G and 3G population coverage is shown in Figure 4.3 below.

Figure 4.3: 2G and 3G population coverage in India, December 2015 (Andaman and Nicobar Islands not shown) [Source: Analysys Mason estimates, 2016][18]



17 http://www.dot.gov.in/whats-new/draft-indian-telegraph-right-way-rules-2016

18 The analysis of population coverage has been done based on publicly available data on the number of base stations deployed by mobile operators, as well as proprietary data available to Analysys Mason. Since this data is not consistently available across all 22 circles, this report provides the coverage numbers for a sample set of circles.

There are several constraints that make it challenging for conventional mobile broadband (3G) to provide ubiquitous availability to the rural areas of the country:

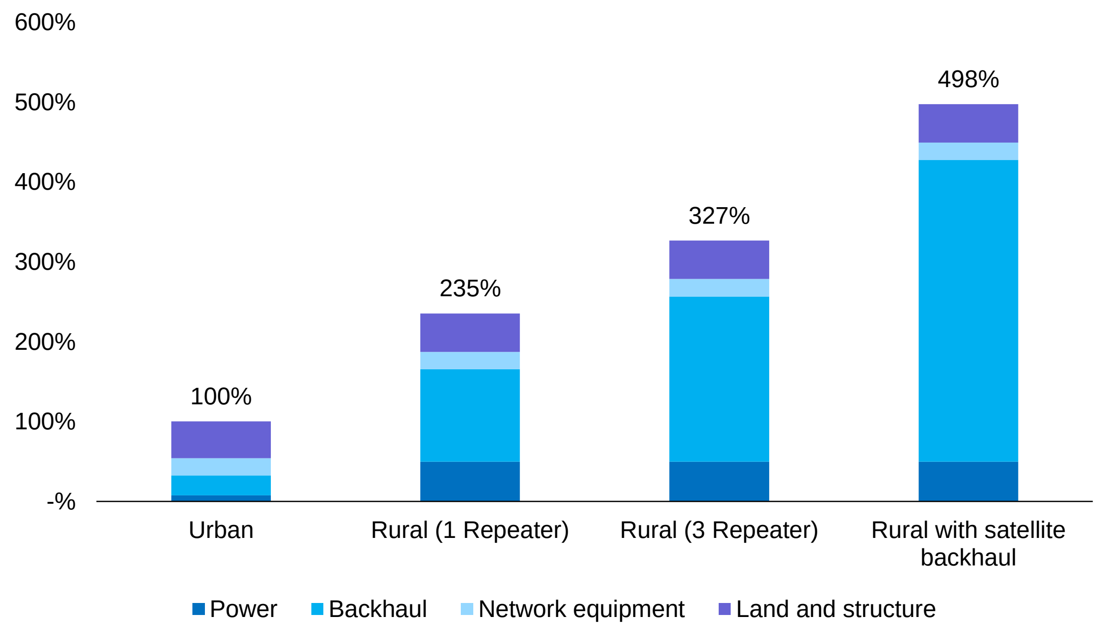
Roll-out challenges for 3G	The 2G mobile networks in India use predominantly the 900MHz band, which has much better propagation characteristics than the 2100MHz used for 3G. As a result, a 2G site covers a much larger area than a 3G site. Illustratively, covering a given area with 3G using 2100MHz spectrum requires around 140% more mobile sites compared to using 900MHz, and 50% more sites than 1800MHz. However, both these lower-frequency bands remain high utilised for 2G.[19]
Lack of backhaul infrastructure	Rural mobile sites face intrinsically higher costs that urban sites, due to many factors, including expensive non-grid electrical power and typically the need for more costly security and maintenance. In addition, the limited options for backhaul require substantial costs to be incurred, either by laying down multiple repeater sites[20] or using very expensive satellite bandwidth. Some operators, such as Bharti Airtel, have invested in their own fibre and microwave backhaul, but the scale of the country means that a universal backhaul network is beyond the scope of any single party. In light of this, the government's BharatNet initiative is highly significant, as it intends to roll out fibre to rural areas that could also be used as affordable backhaul by mobile operators.
Low revenue per user in rural areas	Lower incomes in rural areas result in affordability constraints, and therefore a reduced propensity to spend on broadband services. This limits the incentives for private operators to deploy expensive networks, as they run the risk of making the business case unfeasible.

Infrastructure sharing has been widely used to reduce both deployment and operational costs, but setting up additional 3G-only towers for rural coverage remains largely uneconomic for mobile operators due to the lower density of demand and lower revenue per user in rural areas (this issue of affordability is explored further in Section 4.3). Figure 4.4 below compares the costs of deploying urban and rural sites: the costs of rural sites are considerably higher, thus underlining the challenge of bringing broadband coverage to rural areas.

19 In addition, the 900MHz spectrum is too fragmented to be effectively used for 3G, as demonstrated by the lack of demand for small spectrum lots in that band at the 2016 auction.

20 Repeater sites are microwave sites that amplify radio signals over long distances.

Figure 4.4: Comparison of costs of deploying urban and rural cellular sites in India [Source: Analysys Mason, 2016]



Addressing this challenge will require a multi-pronged approach that enables each site to cover a greater area (e.g. by using lower frequency spectrum or aerial platforms); ensures wider availability of high-capacity backhaul at lower prices; and addresses the issues related to the cost of power and the affordability constraints that poorer rural users face.

A longer-term solution to improve rural connectivity through cellular networks involves the allocation of the 700MHz band for 4G, complementing the higher-frequency spectrum currently in use (1800MHz and 2300MHz). With the 700MHz band available for 4G, mobile operators could offer broadband coverage across India using only existing 2G infrastructure/towers as co-location points. This could significantly improve the economics of rural broadband coverage and help more people get online, provided 4G handsets become more widely available and significantly cheaper.

Norms for the sharing and trading of spectrum: a step in the right direction

In 2015, the Indian government approved norms for the sharing and trading of spectrum. Regarding spectrum sharing, these specify that:

- Sharing of spectrum is allowed in all bands as long as both operators hold at least some spectrum in the band.
- After the spectrum-sharing agreement, the spectrum holding of the each of the two operators should be less than 25% of the total spectrum held by all operators across all bands, and 50% within the shared spectrum band in a circle.
- Non-auctioned, or un-liberalised, spectrum cannot be shared with auctioned spectrum unless the market price has been paid for the former by its holder. If both licensees hold liberalised spectrum they are allowed to use any technology post sharing.
- Each of the two operators individually needs to fulfil its roll-out obligations and meet quality of service standards.

Spectrum sharing could lead to significant efficiencies in the broadband market in India, enabling large and small operators to share spectrum assets and thus alleviate coverage and capacity constraints on their operations. For instance, a small operator (in terms of both customers and footprint) could monetise its 2100MHz spectrum by sharing this with a larger operator which requires an additional carriers within that band to meet its capacity requirements in certain circles.

Spectrum trading is also allowed within all bands and circles, provided that the following criteria are met:

- Post trading, the spectrum holding of the buyer should be less than 25% of the total holdings across all bands by all operators, and 50% within the traded spectrum band in a circle.
- Trading is allowed only for spectrum in the 800MHz, 900MHz, 1800MHz, 2100MHz and 2300MHz bands that has been assigned through an auction in 2010 or later, or for which the seller has already paid the prescribed market price to the government.
- If the entire spectrum in a band is traded then any roll-out obligations for that spectrum will be transferred to the buyer. However, if only part of the spectrum in a circle is traded, then both buyer and seller individually will remain responsible for the roll-out obligations.
- The buyer of spectrum cannot further trade the acquired spectrum for two years from the date of transfer.

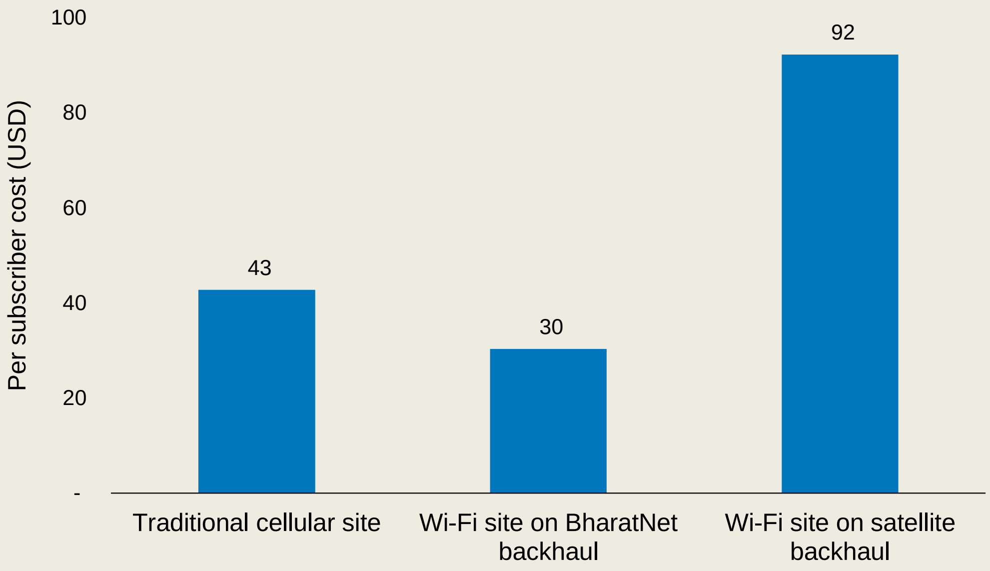
Spectrum trading could also generate efficiencies in the broadband market by allowing weaker operators to sell their under-utilised spectrum assets to larger operators. For instance, a smaller operator could trade its 2300MHz spectrum across circles to a larger operator which requires the spectrum either to launch LTE or meet its capacity requirements, depending on its current spectrum holding and future spectrum roadmap.

Non-cellular models for extending rural coverage

Cellular technology is an expensive means of providing rural broadband connectivity (see Figure 4.4 above comparing the deployment costs of urban and rural sites). The high deployment costs, coupled with lower average revenue per user, can lead to an unsustainable business case for mobile operators. As a result, alternative, non-cellular models for provision of rural broadband merit consideration.

Wi-Fi is a good alternative for rural networks, given the low upfront investments required and the relatively rapid pace of deployment compared to cellular infrastructure. However, a lack of middle-mile connectivity and backhaul can increase costs and make the current business case unviable in many places. In this context, different alternative technologies could be explored to provide backhaul connectivity to a rural Wi-Fi network.

Figure 4.5: Per-subscriber cost of various deployment models [Source: Analysys Mason, 2016]



In terms of achieving the lowest cost per subscriber, the ideal scenario seems to be the availability of fibre to the Gram Panchayat (GP) along with Wi-Fi access for last-mile connectivity. However, this requires the timely implementation of BharatNet, which is currently beset with implementation challenges and procedural delays. Alternate models include BSNL's partnership with Bluetown, a managed hotspot service provider. BSNL has mobile towers (mainly 2G) in 100 000 of the 250 000 GPs in India, while Bluetown has been given the long-term mandate of rolling out Wi-Fi hotspots in ca. 25 000 villages. Other models involving self-provided wireless backhaul (e.g. Air Jaldi) are developing, albeit on a relatively smaller scale.

Potentially, another model could be to provide backhaul to last-mile Wi-Fi sites through satellite (VSAT). However, currently the high cost of satellite-based backhaul and the limited capacity of transponders on the satellites mean that the cost per subscriber is almost double that of the above model. A key requirement for this approach to be viable is for satellite bandwidth costs to be lowered through various government interventions in the form of expanding satellite capacity, launching high-throughput satellites, etc.

Other innovative alternatives such as the use of TV white space, or high-altitude balloons and drones, could also be considered to improve the business case of Wi-Fi-based last-mile models.

4.2.2 Backhaul remains a constraint nationwide, particularly in rural areas where the public sector is taking an active role through BharatNet, despite slow progress

The availability of high-capacity fixed infrastructure in India, be it for access or for backhaul transmission, is primarily an urban phenomenon. It is enabled by the high density of the urban population (clustered housing) and a relatively high revenue potential for Internet service providers (ISPs), given that the urban population has higher incomes than the rural population. Rural areas face the combined challenges of low density and low incomes, making investment in rural fixed networks uneconomic.

As shown in Figure 4.6 below, fixed broadband coverage has mainly been driven by the private sector, including players such as fixed-and-mobile operators (e.g. Bharti Airtel), multi-system cable operators (e.g. Hathway and Den) and independent ISPs (e.g. ACT, You Broadband). Public-sector entities (e.g. BSNL) have so far had limited success in rolling out broadband beyond smaller urban settlements and into rural areas.

Figure 4.6: Fixed broadband coverage of leading players in India [Source: Company annual reports, News articles, Analysys Mason, 2016]

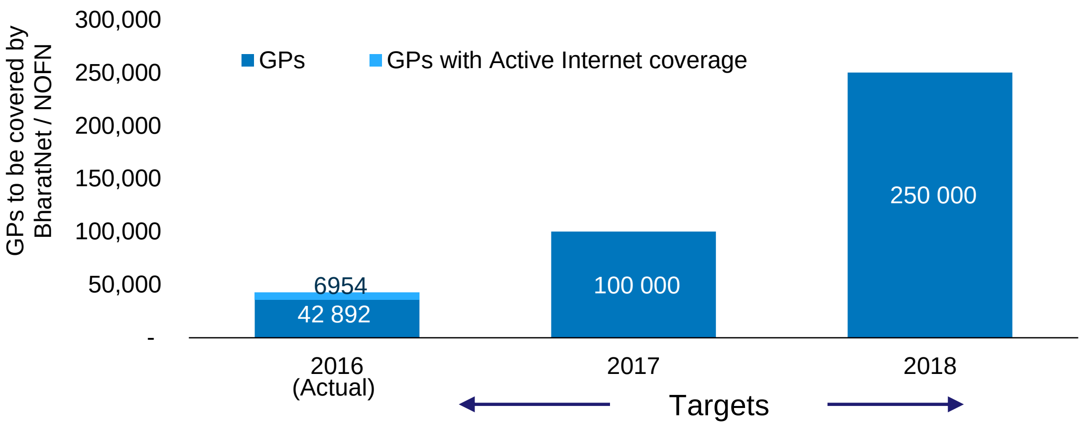
Player	Category	Technology	Coverage
Reliance Communications	Mobile operator	DSL, fixed wireless	• ADSL coverage in ~44 cities
Bharti Airtel	Mobile operator	DSL, FTTH	• ADSL coverage in ~87 cities across 16 circles
BSNL/MTNL	Mobile operator	DSL, FTTH	• ADSL coverage of over 700 towns / cities • Market leader, with a significant DSL network (especially outside the core urban areas) • Largest FTTH coverage (~161 cities)
TATA Communications	Mobile operator	DSL, fixed wireless, FTTH	• DSL and fixed wireless (WiMAX) networks • Some fibre deployment (primarily for corporates)
ACT Broadband	ISP	FTTx	• Coverage in Karnataka, Tamil Nadu, Andhra Pradesh, Telangana and Vishakapatnam • Largest wired broadband player with 0.9 million subscribers (Dec 2015)
You Broadband	ISP	Cable (DOCSIS), FTTx	• Presence in 12 cities, with 0.5 million subscribers (Dec 2015)
Hathway	Cable Television Network, ISP	Cable (DOCSIS)	• Presence in 21 cities • 2.3 million homes passed and 0.4 million subscribers (Dec 2015)
Tikona	ISP	Fixed wireless	• Broadband services in 25 cities with 0.3 million subscribers (Dec 2015)
DEN	Cable Television Network, ISP	Cable (DOCSIS)	• Launched broadband in Delhi and Kanpur; cable TV presence in 200 cities across 13 states

Fixed broadband network roll-outs cannot scale easily because of high deployment costs and the clustered nature of these networks. Costs such as ROW charges, trenching and the laying of fibre are all significant as they involve multiple stakeholders, long lead times and heavy civil works. In addition, the business case is highly dependent on the density of demand, which determines how much revenue can be earned from a given level of costs (i.e. the economies of scale are very significant).

In this context, the government's BharatNet initiative is highly significant. BharatNet aims to connect 250 000 GPs with fibre to enable high-quality connectivity[21] to reach rural areas. It will provide 'middle-mile' connectivity (between existing national backbone networks and future access networks) to all GPs over the next two or three years. Once implemented, BharatNet has the potential to significantly improve rural broadband connectivity by supplying areas where coverage would not be financially viable for the private sector, and reducing backhaul costs for fixed and mobile ISPs. Fibre connectivity could be complemented by access networks using wired connections (e.g. shared local area networks), Wi-Fi or cellular base stations.

Despite the importance of the project, BharatNet has been beset with implementation challenges which have resulted in the project falling far behind schedule. As of June 2016, just over 40 000 out of the planned 250 000 GPs have been connected, and of these, less than 7000 (under 3% of the planned coverage) have been activated.

Figure 4.7: Overview of connectivity targets for BharatNet [Source: Bharat Broadband Network (BBNL)]



Type of deployment	No. of GPs
Ring topology (fibre)	170 000
Linear topology (fibre)	57 000
Radio	20 000
Satellite	3 000

21 Plans call for 99.9% availability, guaranteed through service-level agreements (SLAs) for the majority of the GPs.

The agencies appointed to implement BharatNet, namely the central public-sector undertakings (BSNL, RailTel and PGCIL) and BBNL, have been slow in executing the scheme. They have faced multiple challenges related to:

- The technology and architecture used, e.g. ring topology in place of linear topology, and an unclear framework for integration with existing fibre infrastructure, such as State wide-area networks.
- The governance of the project, e.g. problems in achieving national network roll-out through limited agencies, limited project ownership by CPSUs, inability of BBNL to ensure timely project execution.
- Structural challenges related to the organisational set-up of BBNL such as prolonged delays due to multiple layers in decision making, involving the Union Cabinet, Department of Telecom, Telecom Commission, USO Fund, BBNL Board of Directors and BBNL project units). Another issue has been a lack of inter-agency collaboration in the absence of national and state-level mechanisms to ensure effective coordination between stakeholders – States and Central Ministries, National Information Infrastructure, National Knowledge Network, and state infrastructure bodies.
- Network maintenance issues, e.g. lack of skilled manpower at the GP level for repair and maintenance, difficulties in provisioning of space at GP level for housing equipment, and lack of reliable electricity supply and security.

The DoT plans to connect all GPs with Wi-Fi hotspots to enable last-mile connectivity. However, clear guidelines on the implementation are not currently available. Policy directions aimed at alleviating these challenges are needed to ensure adequate last-mile investments by ISPs, as discussed further in Section 5. In particular, it is clear that the pricing of connections and bandwidth at the GP level will be critical to the viability of access models, whether based on Wi-Fi or other technologies.

4.2.3 As additional spectrum comes onto the market and mobile operators invest in expanding their coverage, a larger proportion of the population will be covered by mobile networks

Additional mobile broadband spectrum is expected to be auctioned by the DoT over the next few years. This will play a key role in expanding availability, especially in rural areas.

- **700MHz (LTE)**: six pan-Indian slots of 2×5MHz each, auctioned in October 2016 but remaining unassigned (and available for future auctions).
- **2100MHz (3G)**: three 2×5MHz carriers are also expected to be released from the Defence forces. (Operators are now exploring 2100MHz for LTE deployment.)
- **850MHz (LTE)**: some spectrum in this band is available, but only in small amounts in most areas.
- **1800MHz (LTE)**: additional spectrum is expected to be available for LTE deployment following spectrum harmonisation.

- **Other bands**: spectrum in other bands such as 900MHz (2G/3G/4G) is available in some circles, and 2300MHz and 2500MHz (4G) is also expected to be available.

Industry estimates vary as to what this new spectrum may lead to in terms of rural coverage. There is consensus that rural coverage will improve, and indeed GSMA Intelligence and the Ericsson Mobility Report forecast that 3G coverage will catch up with 2G (reaching 90% population coverage by 2020). However, this view appears very optimistic because of intrinsic spectrum limitations. Coverage of mobile broadband through 4G should eventually reach these levels thanks largely to the 700MHz band, but the device ecosystem will take many years to mature sufficiently and device prices will remain out of the reach of many rural people for the foreseeable future.

Unconventional alternative technologies are expected to play a role in making broadband more widely available at more affordable prices (see Section 5). A short-term option involves creating many more Wi-Fi hotspots throughout the country. The challenges that such an approach might face include fragmentation (as many more hotspots than cellular base stations are required for the same coverage) and the availability of affordable backhaul, which will require significant decreases in the price of satellite services or a full roll-out of the BharatNet project at suitably low prices – see breakout box 'Non-cellular models for extending rural coverage' on page 22 for more details.

To bring broadband to the most remote areas, including mountain valleys and dense forests as well as areas presenting security risks, a number of possible technologies being explored, including satellite connectivity for backhaul (connectivity provided to North East and rural parts of Andhra Pradesh), TVWS (pilot projects are currently ongoing) and ground-breaking projects such as providing connectivity via high-altitude balloons ('Project Loon') and drones (see Section 3).

4.3 The price of handsets and broadband services remain high, but affordability is expected to keep improving as incomes rise and prices fall

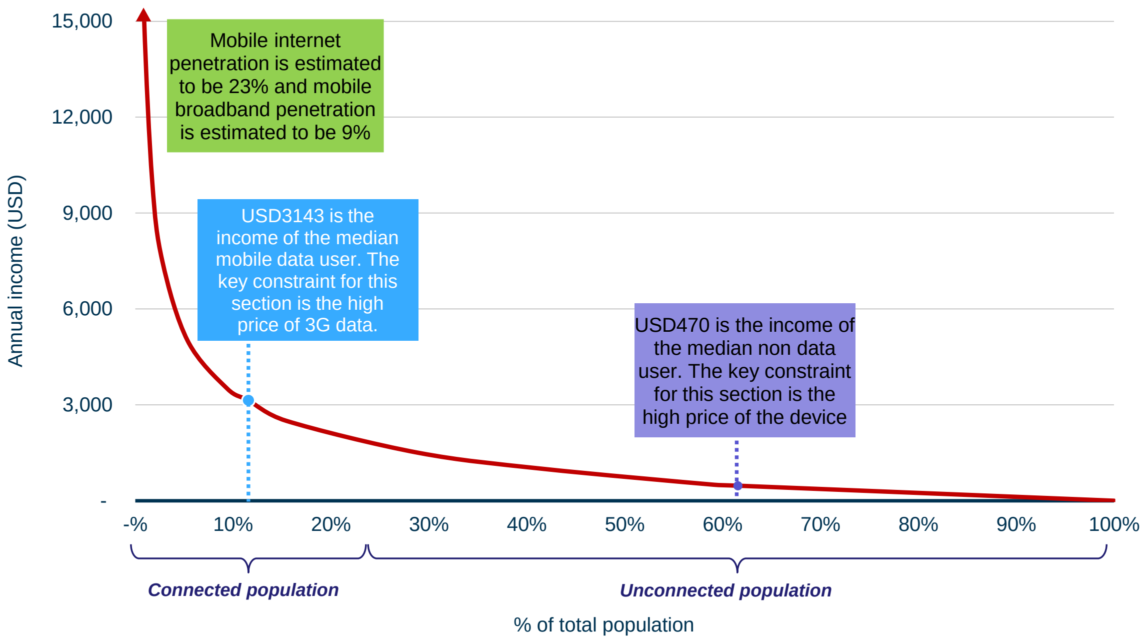
This section discusses and seeks to quantify the affordability of broadband services in India, considering different levels of usage, along with the main constraints on this affordability. There is a clear link between the cost of network deployment and the service price that can be offered to the end user, and therefore with whether or not operators can profitably offer broadband services in a given area. For end users, the key factors in the affordability of basic mobile broadband are the price of services and the cost of an Internet-connected device such as a smartphone, which both feed into the TCO.

There are an estimated 296 million users of mobile data services in India (23% of the population), but a significant portion of the population remains unconnected to Internet. It is important to understand the composition of these population segments before examining affordability. We can divide the population into an unconnected segment and a connected segment, as follows:

- **Unconnected population**: the majority of unconnected users own neither a smartphone nor even a basic/feature phone.[22] High device prices seems to be the key constraint for this segment.
- **Connected population**: the majority of connected users (62%) are on narrowband (2G) Internet, while the remainder are on new generation broadband technologies (3G/4G). The cost of a 3G or 4G data package is the main constraint for this segment.

We use an income distribution curve to understand the income level of the population and analyse its ability to afford broadband. This analysis is shown in Figure 4.8, which illustrates how many people earn more than a given amount each year; for example, the majority of the population (58%) earns less than USD1000. The income distribution curve is a very useful tool to understand the affordability constraints faced by different sections of the population, rather than considering aggregated statistics such as average income.

Figure 4.8: Population distribution across income levels in India in 2015 [Source: Analysys Mason, 2016, Euromonitor]



The affordability of mobile broadband services is a factor of people's income, the share of this income they can and choose to spend on data connectivity, and the TCO, which includes the cost of a mobile device, the price of a suitable data package and other ancillary costs such as power to charge the device.

The income distribution curve allows us to determine the median incomes of people who are connected (USD3143 in Figure 4.8) and people who are unconnected (USD470). These income levels are then compared to the components of the TCO for mobile broadband to identify the main

22 'Feature phone' refers to a phone which does not have the advanced functionality of a smart phone, such as support for third-party software.

barriers to affordability: the cost of a device is determined based on the cheapest available data-enabled device with specifications that allow for an acceptable level of user experience, and the cost of a mobile data package (3G or 4G) is set at the cheapest available price for a given amount of data in a month (e.g. 100, 300 or 500MB).

What constitutes ‘true broadband’ connectivity from the demand-side perspective?

In India, the average data consumption on 3G is estimated to be 750MB per month (source: Nokia’s *India Mobile Broadband Index 2016*). An analysis of the data usage patterns in other developing countries, recommendations by the Broadband Commission and the ITU suggest that 500MB is the amount of data required per month for an optimal broadband (‘true broadband’) experience.

Further, according to Cisco VNI, the bottom 80% (in terms of data usage) of Indian data users account for only 41% of data traffic, and shared data plans constitute 60% of all data plans. This indicates that data usage patterns for marginal data users are much lower than the average, given the constraint on spending.

In addition to carrying out analysis based on an assumption of 500MB of data usage per month, we have also conducted analyses assuming a monthly consumption of 300MB and 100MB of data, in order to examine a realistic range of affordability scenarios.

4.3.1 Three-quarters of Indians are unable to afford a smart device and a 500MB monthly data package

Smartphone penetration in India has grown exponentially over the last few years as device prices have fallen. As of December 2015, the installed base of smartphones in India was 310 million (only a third of 3G devices are actually connected to a 3G network), or a penetration of 24%. This is more than double the penetration a year previously (10%), and a significant jump from a few years ago.

Smartphone affordability remains the primary hurdle for people who are not connected to the Internet, and a large portion of mobile users still use feature phones. This cost is not only significant compared to the cost of services, it is also typically an upfront cost, which presents a further affordability barrier as many people are unable to obtain credit.

The affordability of mobile broadband is further constrained by the price difference between a GPRS phone[23] and a 3G smartphone (see Figure 4.9), due to different features and capabilities (see Figure 4.10). We have considered the average lifespan of a phone to be around two years, but in practice smartphones tend to be replaced faster than simpler handsets, which again reduces affordability.

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23 ‘GPRS phone’ refers to the most basic phone that supports mobile data connectivity.

Figure 4.9: Price of low-end feature phones and smartphones in India [Source: Analysys Mason, 2016, Flipkart]

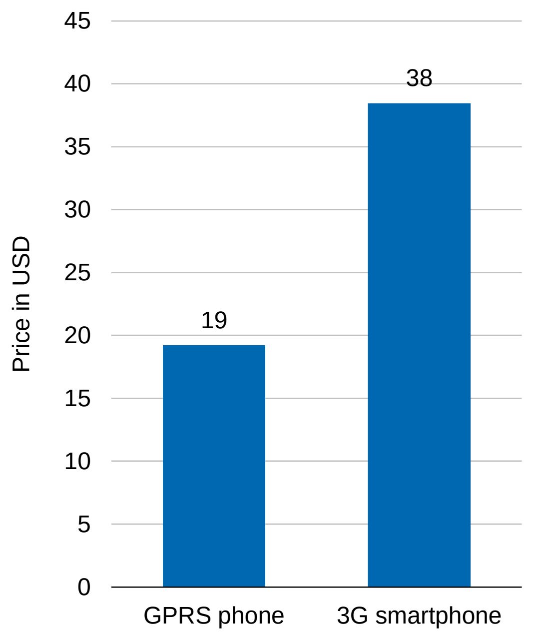


Figure 4.10: Minimum specifications assumed for devices [Source: Analysys Mason, 2016]

Specs	GPRS phone	Smartphone
Screen	2.4"	3.5"
Processor	-	1GHz
Memory	-	256MB
Wi-Fi	No	Yes
Camera	0.3MP	2MP

Among the phones offered by all major handset companies in India, the cheapest phones which meet these specifications were considered for our analysis:
GPRS phone – Karbonn Jumbo K9
Smartphone – Intex Cloud X15

We considered service costs of at least USD20 per annum, or less than USD2 a month. This is based on the lowest-priced 3G data package with 28 days validity offered by one of the larger operators.[24]

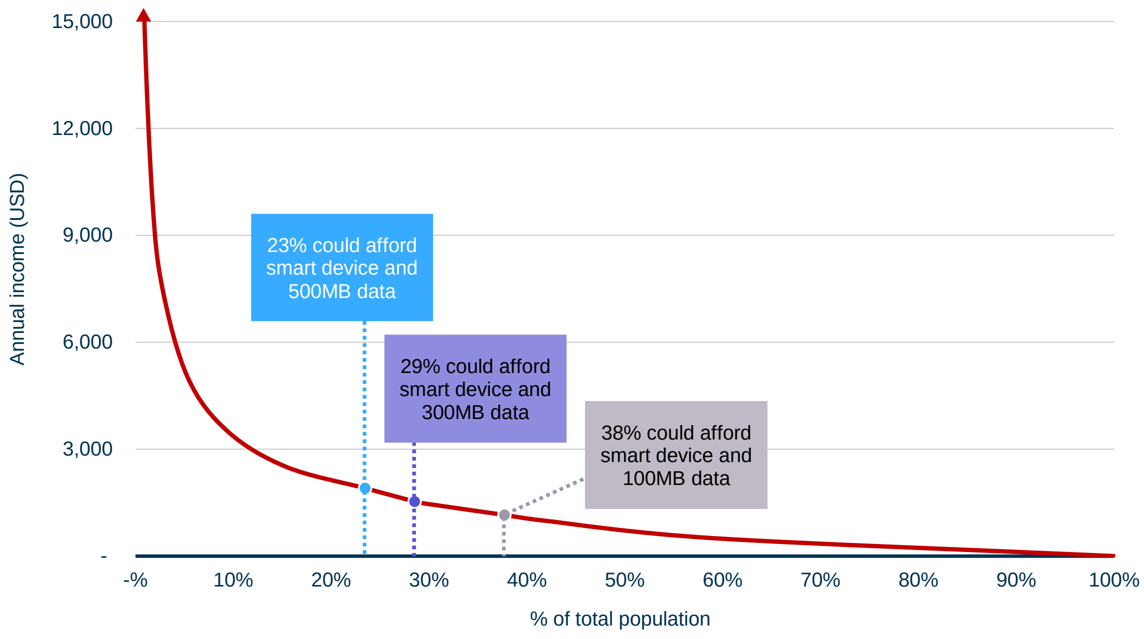
International benchmarks[25] consider broadband to be affordable if service prices do not exceed 5% of income. However, considering the average expenditure by Indians on devices and data as a portion of their income, our analysis suggests that a more realistic, India-specific threshold is closer to 2% of income. This reflects both willingness and ability to pay, and individual circumstances vary: many low-income Indians who rely on a phone for their jobs will be spending a much greater proportion of their income on mobile services.

Based on a data package of 500MB, we calculate that 23% of the population can afford a 'true broadband' connection in India (see Figure 4.11). If we consider smaller data packages of 300MB and 100MB, affordability increases to 29% and 38% of the population respectively. It is important to note, however, that the average 3G user currently consumes around 750MB per month.

24 More details can be found in the methodology section.

25 Source: the UN's Broadband Commission and the ITU.

Figure 4.11: Comparing affordability in India of a smart device and data package (500MB, 300MB and 100MB) [Source: Analysys Mason, 2016, Euromonitor]



4.3.2 Significant opportunities exist to connect new broadband users through mobile broadband or Wi-Fi packages

As much as 62% of mobile Internet users currently connect through narrowband (2G). For this segment of the population which already has access to an Internet-enabled device, 3G data prices are the main additional cost of broadband connectivity.[26] Leaving aside the cost of devices, the price of buying 500MB of mobile data every month currently costs less than 2% of income for 44% of the population (see Figure 4.11 above). However, using the same affordability threshold, a much larger portion of the population (85%) is able to afford a 100MB data package.

Further, an even larger portion of the population could be covered if Wi-Fi were provided as a means to connect to the Internet. Various private ISPs such as AirJaldi have been offering low-cost connectivity using Wi-Fi in public hotspots; these ISPs provide plans costing INR75 for access to 500MB data for a month, which would be affordable for 54% of the population. A comparison of the cheapest monthly data plans is provided in Figure 4.13 below.

26 Other factors such as availability and the quality of the network could play a role in the low percentage of mobile broadband users within the connected population.

Figure 4.12: Differential price per MB of key broadband technologies in India[27] [Source: Analysys Mason, 2016]

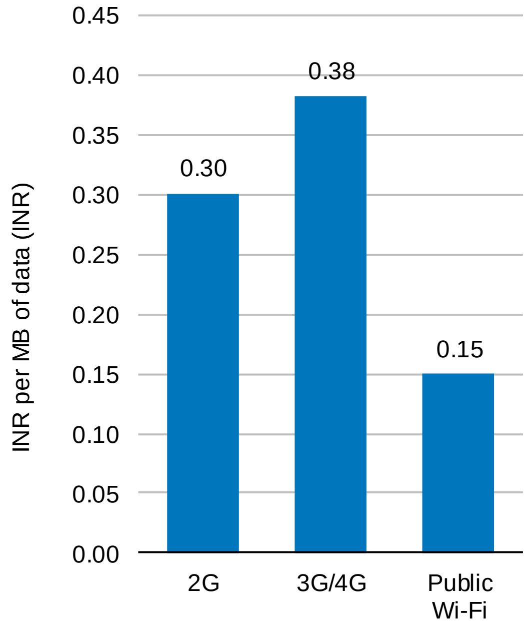
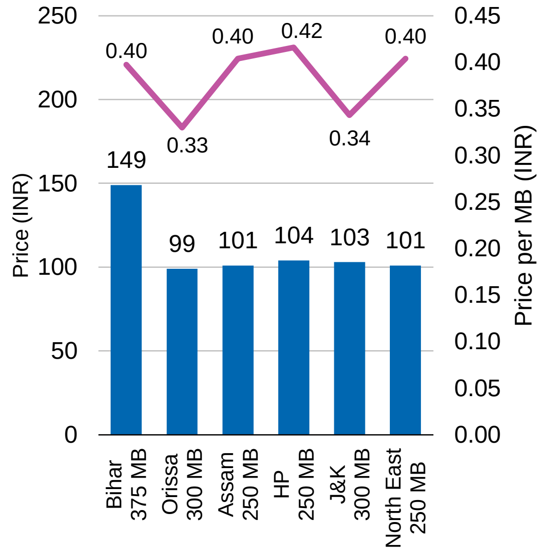


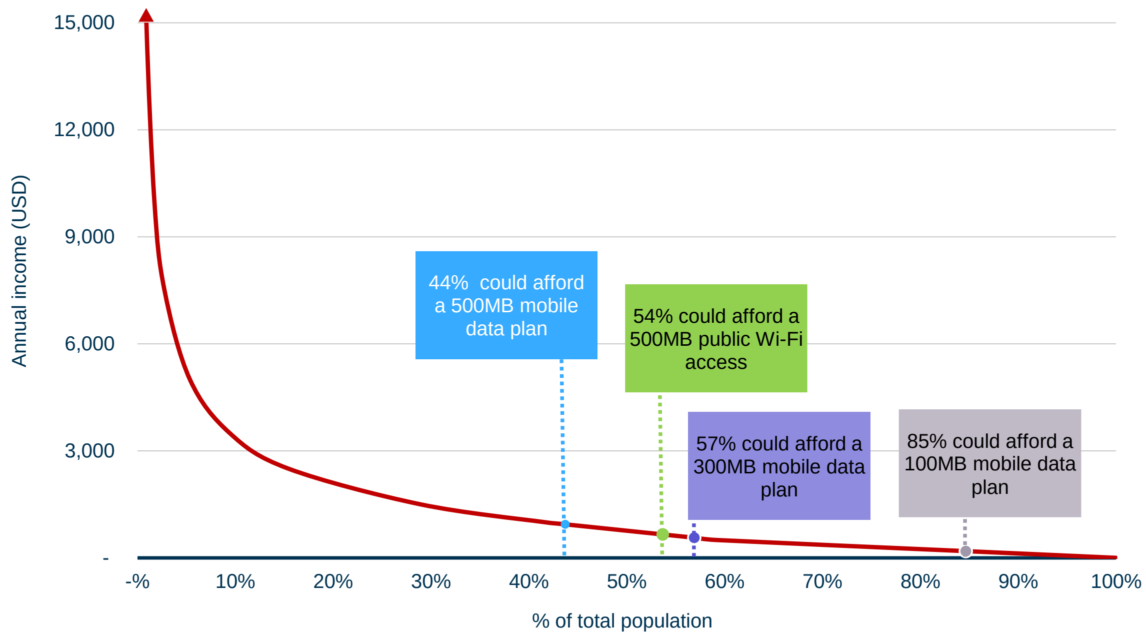
Figure 4.13: Cheapest prepaid broadband plans with monthly validity provided by major private operators Source: Analysys Mason, 2016, operators, Paytm]



This points to a significant opportunity to connect new broadband users by providing them with either basic broadband packages or public Wi-Fi wherever feasible. The income distribution curve in Figure 4.14 below shows the scale of this opportunity.

27 Price per MB is calculated by considering average price of data packs with the minimum amount required to have data access for 28 days, offered by major operators in six category C circles.

Figure 4.14: Comparison of affordability of mobile data offers for users who already have an Internet-enabled mobile device (100MB, 300MB and 500MB) [Source: Analysys Mason, Euromonitor, 2016]



Innovation in pricing can also play an important role in bringing down the cost of connectivity. 3G and 4G technologies offer much greater capacity for the same amount of spectrum, and therefore it is possible for operators to offer much larger bundles than with 2G for the same overall price. For people with very low and irregular incomes, smaller data packs with longer validity can also be helpful. Such 'sachet' packs could provide an affordable platform for first-time users to connect via broadband. Finally, greater availability of affordable Wi-Fi could help provide broadband speeds to people who have 2G-only Wi-Fi-enabled devices.

4.3.3 As incomes increase and device prices decrease, we expect 54% of the population to be able to afford a smart device plus a 500MB data plan by 2025

The future affordability of broadband connectivity in India is expected to be determined by growth in income levels and declines in the costs of various connectivity elements. Forecasts are always by nature uncertain, but it seems likely that incomes will continue to grow at 5% per annum,[28] data prices will decline further by a similar amount (-5% per annum),[29] and device prices will fall by around 7% per annum.[30]

Competition is a major driver of price decreases. The launch of Reliance Jio in September 2016 will exert some downward pressure on prices, but it is important not to overstate them: the focus on 4G

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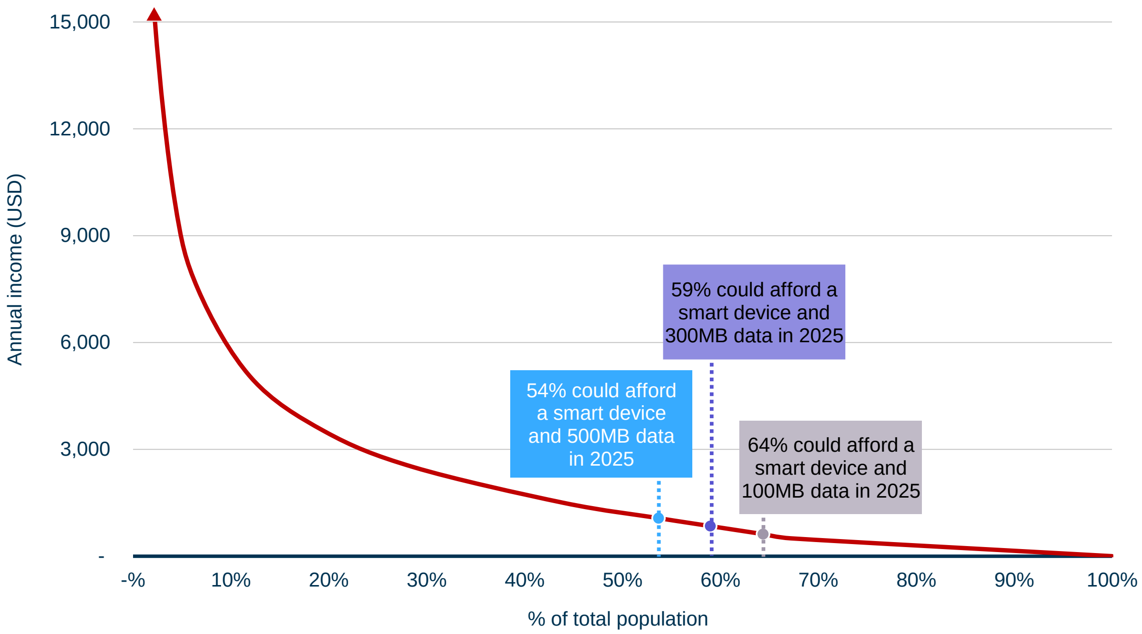
28 Based on forecasts by Euromonitor.

29 Further decrease will rely on increased competition from Reliance Jio and greater economies of scale with 4G. BoA and Merrill Lynch's Equity Research Report on Jio (December 2015) suggested a maximum theoretical reduction in prices of 9% per annum to 2025, but given the level of margins in the industry, operators are likely to try and limit price decreases, hence the slightly more conservative forecast put forward here.

30 IDC's *Worldwide Quarterly Mobile Phone Tracker* suggests a ~7% year on year decline in prices from 2014 to 2018.

means that the impact on the prices experienced by the vast majority of users (on both 2G and 3G) are unlikely to change materially. Furthermore, the pricing approach adopted by Jio at launch (offering large amounts of free data) is likely to change as subscriber numbers stabilise. That being said, the fall in prices described above will result in many more people being able to afford a smart device and a 500MB monthly data package: by 2020, this could rise to 38% of the population, and 54% by 2025.[31]

Figure 4.15: Forecasted affordability in India of a smart device and mobile data package in 2025 (100MB, 300MB and 500MB) [Source: Analysys Mason, 2016, Euromonitor]



Despite this improvement in affordability, nearly half of the population will still not be able to afford broadband in 10 years' time. Accelerating this process is essential in order to bring more Indians online faster, through appropriate mechanisms focusing on the prices of devices and data services.

31 More details regarding the methodology for forecasting income population distribution in India can be found in Annex A.

KEY TAKEAWAYS:

Connecting 1 billion Indians by 2020 requires a holistic approach to improving affordability and availability

- Broadband take-up is constrained in part by a lack of relevant content, appropriate skills and understanding of how and why to use the Internet. At a very basic level, however, people must be within reach of suitable networks (availability) and must be able to afford the price of a device and of data services to connect to the Internet (affordability).

- The availability and affordability of broadband are inter-related as the economics of network availability determine a ‘break-even’ level for demand and price, which can only be realised if the price is affordable to enough end users to achieve sufficient demand.

- The availability of mobile broadband is likely to improve rapidly through significant investments and the availability of 700MHz spectrum, but will remain constrained in rural areas by a lack of high-capacity backhaul and the high cost of deploying rural sites (~2.5 times the cost of urban deployment).

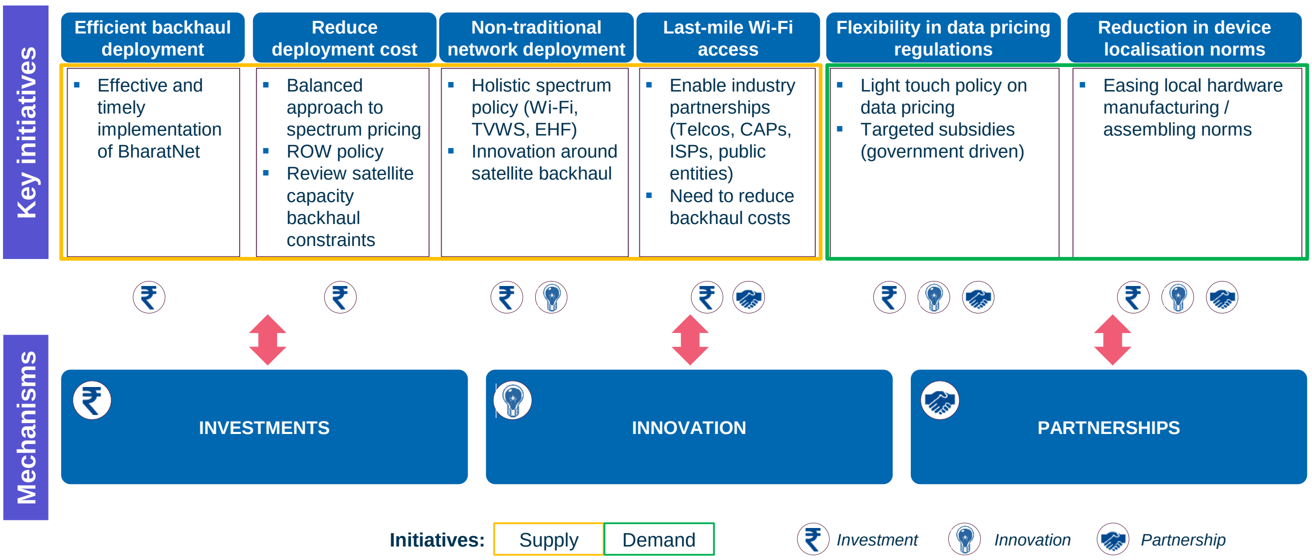
- Affordability constraints are mostly driven by the cost of Internet-enabled devices for over 75% of Indians, and by the price of data services for 56% of people; this will improve over time, but by 2020, 43% of Indians may still be unable to afford to use broadband.

5 Policy interventions that support and nurture innovation and risk-taking are essential to address these challenges

We now discuss the policy-level mechanisms needed to address broadband connectivity constraints examined in the previous section. Figure 5.1 below summarises a number of initiatives that could help remove supply- and demand-side obstacles to available and affordable broadband. These initiatives can be broadly classified into three themes:

- **Investments**: Policy measures which stimulate investments from both the public and private sector would incentivise the deployment of infrastructure, making broadband more widely available and increasing the affordability of services.
- **Innovation**: Flexibility and openness in policy making would enable innovation, which can help to address challenges that might otherwise be difficult to solve via traditional mechanisms.
- **Partnerships**: Partnerships between public and private stakeholders and among private players would enable synergies and economically feasible business models in otherwise unprofitable scenarios.

Figure 5.1: Framework: mechanisms and initiatives to address connectivity constraints [Source: Analysys Mason, 2016]



In this section, we consider a variety of initiatives that are already being implemented in India, a number of proposed initiatives, and some lessons from global initiatives that could be relevant in addressing availability and affordability constraints in India.

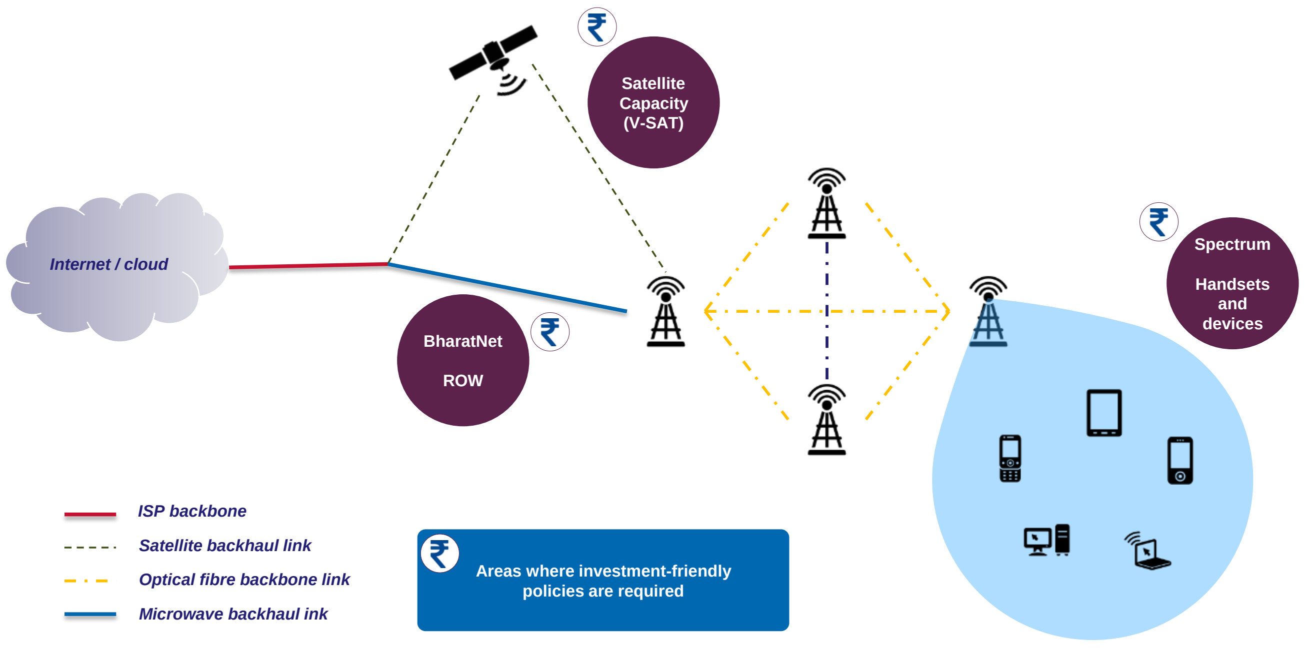
5.1 Providing high-quality ubiquitous broadband access will require investment-friendly policies that reduce input costs and widen the options for network deployment

The government and the private sector need to work together to achieve this objective – the former by creating an investment-friendly policy structure and the latter by making much-needed investments. Collaborative measures could also take the form of the public sector taking on some of the risk from the private sector, for example by sharing part of the deployment costs, committing to purchasing a minimum amount of bandwidth over a period of time, or by providing viability gap funding.

Key parts of the connectivity value chain that could benefit from investments are shown in Figure 5.2 below:

- backhaul or middle-mile connectivity, which could be benefited through public investment and co-ordination of BharatNet, but also by appropriate regulation of ROW and development of satellite capacity
- access or last-mile networks and suitable, plentiful spectrum
- end-user devices such as smartphones.

Figure 5.2: Key parts of the connectivity value chain that could benefit from investment-friendly policies [Source: Analysys Mason, 2016]



The BharatNet project is a unique opportunity to bring the Internet closer to most communities, but execution and pricing are key to its effectiveness

BharatNet is a watershed initiative which has the potential to enable universal broadband availability in the country, especially in rural areas. The initiative will ensure fibre deployment across the country to the majority of GPs (while connecting the remainder with microwave radio links and satellite), thereby providing access to broadband even in areas where the private sector would not normally invest. However, BharatNet has been faced with multiple implementation challenges and delays.

In order to ensure a healthy flow of investments from the private sector into broadband networks, the government must ensure rapid and effective implementation of BharatNet, including clearly defined downstream access models that BharatNet should support (e.g. Wi-Fi, 3G and 4G mobile sites), and affordable pricing of bandwidth.

Timely deployment of BharatNet is essential, and the government is moving in the right direction by taking measures to support a speedy and cost-effective implementation. Some of the initiatives being considered include:

- a shift from a centralised deployment model to a decentralised one with multiple stakeholders – an ecosystem of states, the private sector and Central Public Sector Undertakings (CPSUs)
- a model to effectively utilise existing public- and private-sector infrastructure
- innovative deployment models taking advantage of existing aerial infrastructure such as power transmission and distribution lines.

Rightly, the government is also considering offering financial support to State-led deployment models. This allows not only for faster deployment but also incentivises local governments to support BharatNet. However, for any large-scale decentralised system to work effectively, proper processes, mechanism and standards need to be in place to monitor the implementation timelines as well as the quality of the networks deployed.

What is missing from the BharatNet discussion is a holistic and systematic framework for rural connectivity *beyond* the GPs, i.e. clear policy directions regarding the last-mile access solutions, which are proposed to be driven by a Wi-Fi model. The rural Wi-Fi model has its challenges in the form of cost of backhaul, cost of deployment, awareness and uptake of end-users, etc. Certain areas where future policy could provide directions include:

- Guidance on possible business models for deployment such as advertising-based models, models part-funded by government, and models with anchor tenancy by government enterprises in order to provide guaranteed revenues.

- Clarity on the possible means to reduce deployment costs for local ISPs and entrepreneurs, such as access to government infrastructure such as masts, buildings, poles, rooftops and compounds.

- Light intervention on possible partnerships between various players including telcos, ISPs, CAPs and content providers.

- Measures to increase the awareness of the rural population regarding the availability of broadband and its potent role in enabling productivity, communication and digital empowerment.

- Affordable pricing of (primarily wholesale)[32] bandwidth to ensure sustainable last-mile network roll-outs. A Wi-Fi site using BharatNet-provided backhaul could potentially be deployed at a cost of USD30 per subscriber, compared to USD43 for a traditional rural cellular site (see breakout box 'Non-cellular models for extending rural coverage' on page 22 for more details).

Understandably, the government expects some of these initiatives to be driven by purely private partnerships (covered later in this section). However, given the large scale of last-mile roll-outs required, a policy framework along with guidance regarding business models is needed.

In summary, the key initiatives the government should consider to maximise the investment in and around the BharatNet project include:

- clear support towards rapid BharatNet implementation, leveraging government infrastructure
- clear directions on creating a last-mile access ecosystem (including business models, frameworks for content partnerships)
- affordable pricing of bandwidth.

On the following page we provide a case study illustrating how a decentralised model can be effective in this context.

[32] Google is involved in a wholesale metro fibre deployment initiative in Uganda and Ghana, called Project Link

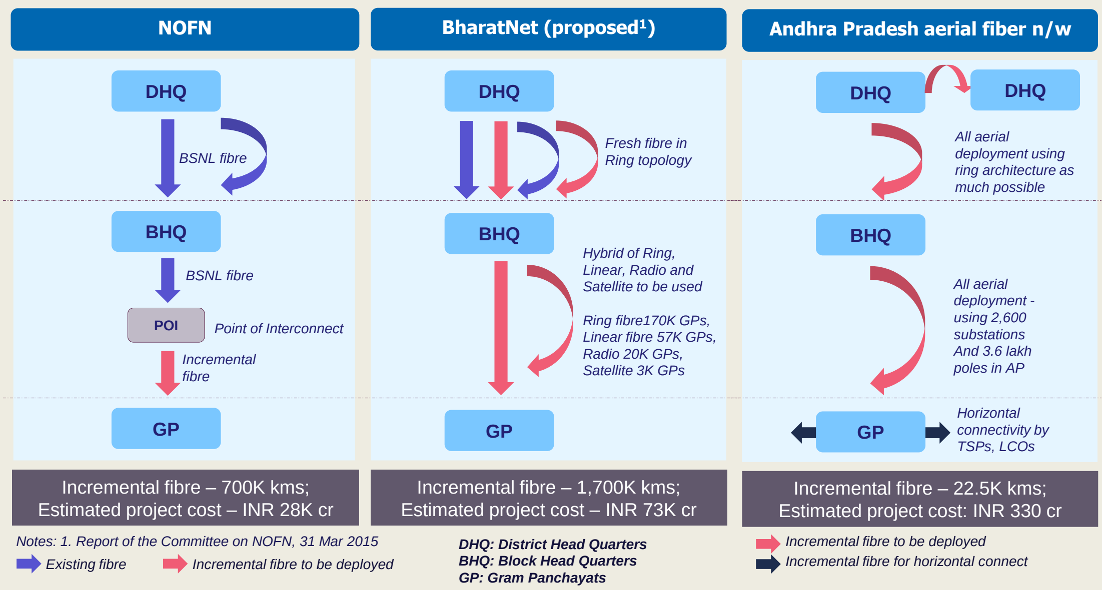
Case study 1: Decentralisation of BharatNet's implementation with clear standards can stimulate private-sector investments, speed up deployment and reduce costs

BharatNet, the key connectivity project of the government of India, is a significant step forward from its predecessor, NOFN. It was launched to address some of the technological and implementation challenges associated with the NOFN project, and to ensure that it is more aligned with the Digital India programme, and is accelerated. In comparison to NOFN, BharatNet introduces key improvements, such as:

- While NOFN only aimed to deploy new infrastructure, BharatNet will effectively integrate existing infrastructure such as state wide-area networks, other fibre infrastructure, etc.
- NOFN was a fibre-only model, whereas BharatNet will deploy a more realistic mix of fibre, radio and satellite technologies in order to connect hard-to-reach GPs effectively.
- NOFN involved a service-level agreement (SLA) with just 95% guaranteed availability, whereas for BharatNet the level is 99.9%.

To expedite implementation, some states have gone ahead with their own roll-out plans, some of which are different from the one proposed in NOFN. The Andhra Pradesh government has decided to leverage the existing infrastructure of state electricity boards wherever possible, making it possible to deploy an aerial fibre network and overcome some of the challenges associated with getting ROWs as well as reducing the deployment cost (see the figure below).

Figure 5.3: Comparison of network architecture for NOFN, BharatNet and Andhra Pradesh aerial fibre network [Source: Analysys Mason, 2016]



This model has reduced the cost for deployment significantly (from an estimated USD600 million to USD50 million)* thanks to the use of aerial fibre (rather than underground deployments) and the reuse of existing fibre and civil infrastructure.

* See http://telecom.economictimes.indiatimes.com/news/andhra-pradesh-to-install-23000-km-optic-fibre/50168331

According to industry experts, the main risk of this approach is that the quality of the Andhra Pradesh network could be inferior to the expected BharatNet standards, leading to potential future outages and related costs. These risks can be mitigated by providing clear guidelines and rules to enforce technical norms and quality standards in a decentralised model.

Clear guidelines and rules can also ensure that the expected decentralised deployments by other states are managed in a way that is sustainable in the long-term. Tamil Nadu and Kerala are currently evaluating such a decentralised approach:

- Tamil Nadu Arasu Cable TV Corporation Limited (TACTV), a public sector undertaking (PSU) of the state government, plans to utilise existing fibre infrastructure of other government agencies (primarily Tamil Nadu Transmission Corporation (TANTRANSCO) and Tamil Nadu Generation and Distribution Corporation (TANGEDCO)) to deploy a state-wide aerial fibre network along Extra High Tension lines, with the short last-mile distance either covered overhead using Low Tension lines or taken underground, to reach the designated points of presence (POPs).

- The Kerala State Information Technology Mission (KSITM), the autonomous nodal IT implementation agency for the state government's Department of Information Technology, is considering two implementation models: (a) a 'hybrid' model with fibre both laid underground and run overhead, which will comply with all the standards and guidelines issued by DoT for the BharatNet project; and (b) the 'Kerala State Electricity Board (KSEB) model, in which KSEB – through a special purpose vehicle company – will lay fibre using its own distribution poles and will maintain the network.

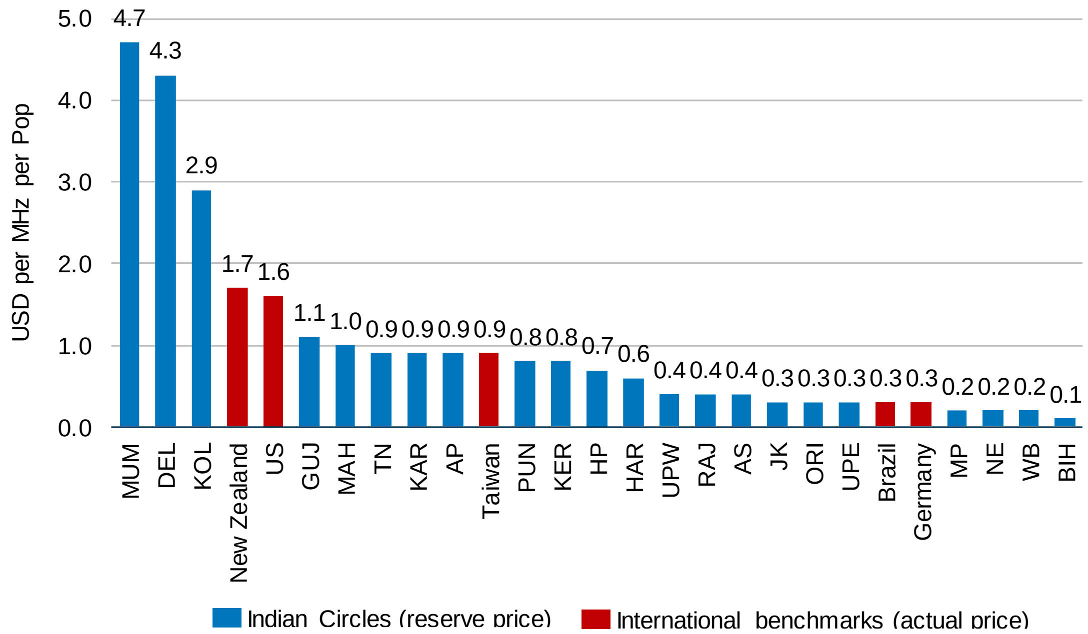
A balanced approach to spectrum pricing, based on outcome-oriented conditions on spectrum rights, would be more effective than a revenue-maximising approach

Spectrum is an essential resource to enable wireless connectivity to benefit the vast majority of the population, particularly in rural areas where wired access networks are highly unlikely to be deployed in the foreseeable future. A long-term solution to the problem of rural connectivity would be to deploy 4G technology using the 700MHz band. Currently, 4G is being deployed in India using 1800MHz and 2300MHz, but sub-1GHz bands like 700MHz and 850MHz (currently available only to a few operators, such as Reliance Jio) are ideal for offering blanket mobile broadband coverage to a large area such as the rural belt of India. This drastically reduces the upfront capex of mobile operators, as the number of sites and base stations required to cover a given area are reduced significantly. Low-frequency mobile spectrum is therefore essential to expanding broadband coverage across India using the existing 2G infrastructure and towers.

However, certain constraints would need to be addressed by the industry before the full potential of the 700MHz band can be unlocked. One constraint pertains to the need for a device and network ecosystem to develop, as explained later in this section. Another important concern of market participants relates to the very high reserve prices that were applied in the recent 700MHz auction:

these prices were at the very high end of benchmarks, and high compared to other bands (roughly four times those for 1800MHz as well as in Metros, Category A and some of the Category B circles). In fact, the reserve prices for the auction were higher than global benchmarks of the *actual* prices paid by operators (see Figure 5.4), and these unsustainably high prices for 700MHz spectrum resulted in no bid being placed, and valuable spectrum remaining unassigned and unused.

Figure 5.4: Comparison of 700MHz reserve pricing in Indian auction with international benchmarks (prices have been normalised to reflect relative populations) [Source: Analysys Mason, 2016]



In addition, the limited device ecosystem of the 700MHz band further reduces the attractiveness of this valuable spectrum, as at present only high-end devices are compatible with the band. This combination of high costs of supply (linked to spectrum) and high costs for end users could perpetuate the barriers to connectivity described in Section 4, resulting in affordability remaining low (currently just 23% for a smart device and 500MB of data monthly) and an unattractive business case for rolling out broadband further.

An ideal policy stance would be one that:

- Prioritises efficient use of spectrum for achieving connectivity goals, over and above raising revenue for the government. In fact, the GDP growth spurred by increased broadband take-up could yield more revenue to the government in five years than the recent spectrum auctions.[33]
- Strictly monitors and enforces predictable, agreed-upon rural coverage obligations to ensure they are met; this could be coupled with flexibility in the pricing of the 700MHz band, with a low reserve price that could be easily exceeded at auction.

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33 The Union Budget of India for 2015/16 estimated total tax revenue (minus the States' share) at INR81.5 lakh crore, about 6% of GDP. Applying this ratio to the USD200 billion incremental GDP for the five years to 2020 gives a potential tax increase of USD12 billion (INR820 billion). For comparison, the recent auction of 20-year spectrum licences raised around USD10 billion.

Further investment in backhaul capacity requires regulatory support through adequate ROW regulations and a review of constraints on satellite capacity deployments

ROW issues – such as high costs, unclear roles and responsibilities of government departments, multiple stakeholders such as municipal and state bodies, and delayed permissions – constitute a major bottleneck in network deployment, thereby impacting broadband availability. These issues have been around for a long time:

- In 2011, TRAI recommended that the DoT's policy on ROW for NOFN needed to be more detailed by laying down specific charges for ROW as well as time limits for the clearance of applications from infrastructure providers; it also recommended involving state governments and local bodies in the process. Despite this, fibre deployment ran into roadblocks due to lack of clarity on ROW, and by 2012 only 13 states and three UTs had agreed to not charge the centre or BBNL for ROW.
- In 2014, TRAI noted that lack of uniform guidelines from central government had led to different state governments adopting different rules, criteria, costs and time periods for clearances. To improve the situation, TRAI recommended lowering ROW rates.
- The proposed Indian *Telegraph Right of Way Rules 2016* could help overcome some delays in clearances and reduce high ROW charges.

Implementation of an appropriate ROW policy could lead to a revamp of the ROW situation in India – a fact that has been recognised by all stakeholders time and time again. A well-defined ROW policy which addresses the issues around the bureaucratic permissions process as well as the high cost of access through a single clearance window would not only help address the issue of the rural availability of broadband, but would also enable the deployment of fibre for mobile tower backhaul, which in turn would improve network capacity and quality. However, despite continuous attempts, the process has only reached a recommendation phase: quick policy making is needed to remove these hurdles and support network roll-out.

In addition to creating a systematic and investment-friendly policy environment for ROW, the government must also address bottlenecks in alternative backhaul solutions such as satellite (VSAT[34]). Currently, the cost of satellite bandwidth is very high in India due to supply-side constraints and limited capacity – issues that are discussed in Section 5.2 below.

The availability of affordable devices suitable for broadband access should be supported by policies that balance costs with features, and are mindful of the spectrum landscape

The government of India has recently issued several recommendations about incorporating features such as a certified battery, a panic button, a GPS locator, local language support and an iris scanner in mobile phones sold in India. These initiatives were conceived as a reaction to legitimate public

[34] VSAT (very small aperture terminal) is a two-way satellite-based technology using a dish antenna typically around 75 cm to 1.2 m in diameter.

concerns about security and the desire to push integration with Aadhaar.[35] However, we believe that these policies should be carefully modulated, or they may result in more harm than good for consumers, having an adverse impact on broadband take-up (especially for poorer Indians) and the profitability of the industry. New India-specific norms will put upward pressure on pricing, especially for entry-level smartphones, thereby leading to reduced affordability. Moreover, setting specific standards for the Indian market (such as a panic button and local language support) will result in non-standard devices having to be manufactured for India, which could delay phone launch schedules, while also fragmenting the local market with devices using a range of different languages. Finally, this type of policy could lead to a loss of confidence among foreign investors and manufacturers, given the uncertainty around norms and their timing.

Market forces can play a major role in ensuring that specific requirements are fulfilled, while retaining flexibility to have cheaper devices also available. Economies of scale in handset manufacturing tend to occur at the global rather than national level, so the cost of devices incorporating these features is unlikely to be affected by the mandates. Balancing regulation of device specifications and making them consistent with international norms will ensure that a key unintended hurdle to affordability is removed. It will boost private-sector investments in local assembly and manufacturing of both components and fully furbished devices, while also preventing undue escalation in prices of entry-level devices.

In addition to addressing concerns around norms and standards, it is worth noting that the ecosystem for 700MHz-compatible devices remains under-developed. According to the Global Mobile Suppliers Association, at present there are only 12 commercially launched APT 700MHz networks (Band 28) in the world, and only 139 compatible devices (of which 121 are smartphones) from suppliers including Acer, Apple, Asus, Samsung, HTC and Huawei. Entry-level phones are available for 900MHz and 1800MHz bands, while higher-end smartphones include bands such as 2100MHz and 2300Mhz. For 700MHz to be a true solution to the rural broadband connectivity constraint in India, development of affordable handsets is therefore an essential requirement.

In summary, the government's policy stance in the handset arena should aim to balance features and cost, and avoid mandates related to handset specifications which may seem popular in the short term but are likely to have unintended consequences for the entire sector in the medium term. Policy should also support key ecosystem requirements, such as low-cost 700MHz devices suitable for rural connectivity.

On the following page we provide a case study describing how mandating certain features of mobile devices can lead to higher prices.

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35 For example, several operators are already using Aadhaar to fulfil their obligations under 'know-your-customers' policies; further integration – e.g. with mobile payments systems – could be envisaged in the future.

Case study 2: Mandates on device specifications can lead to higher price

The government of India has introduced a series of mandates on specifications for mobile phones sold in India.

Figure 5.5: New mandates on mobile phone specifications in India [Source: Analysys Mason, 2016]

Norms	Scope	Timeline	Impact
Battery certification	Batteries for use in portable applications (usually imported as components by Indian handset makers) should comply with applicable Indian safety standards and mandatory registration before they are imported to, traded, distributed, or sold in India	1 June 2016	▪ Delays in product launches ▪ Smaller handset makers which operate on low volumes and thin margins will be hurt by the increased cost of compliance
Panic button	Every mobile phone sold in India should have an emergency call button	1 January 2017	▪ Delay in launch of international models in India ▪ Increase in handset prices
GPS	Every mobile phone sold in India should have the facility of identifying the location of the phone through a satellite-based GPS	1 January 2018	▪ Increase in handset prices ▪ Decrease affordability of lower end smartphone buyers
Local language support	Mobile phones should support readability in 14 scripts and 22 official languages, and support text input in English, Hindi and at least one other Indian language. The final standards have not yet been published	Yet to be published	▪ Delay in launch of international models in India ▪ Fragmentation of the Indian handset market on the basis of language chosen for user input
Mobile-based identity authentication	Mobile phones should have an iris scanner for biometric identification, to be linked to an Aadhaar number. The final standards have not yet been published	Yet to be published	▪ Increase in handset prices ▪ Delay in launch of international models in India ▪ Security concerns regarding biometric information

Although the intentions behind these mandates are well placed, they have unintended consequences due to uncertainty in the regulatory environment and the excessive customisation required. For example, if the regulations on a mandatory GPS locator and an iris scanner came into effect, it is estimated that the price prices of entry-level phones would increase by at least USD3, and as a result, we estimate that an additional 13 million people would not be able to afford mobile broadband (see Figure 5.6 and Figure 5.7 below).

Hence, it is important to take a more holistic viewpoint of the impact of introducing such requirements for mobile phone specifications. Even without policy interventions, market dynamics are likely to bring in such safety- and content-related measures by themselves: for example, there are already some phones in the market which have emergency call buttons, and manufacturers such as Micromax and Lava are selling phones which support a variety of local Indian languages.

Figure 5.6: Change in the price of entry level smartphones after the implementation of new mandates on mobile phone specifications [Source: Analysys Mason, 2016]

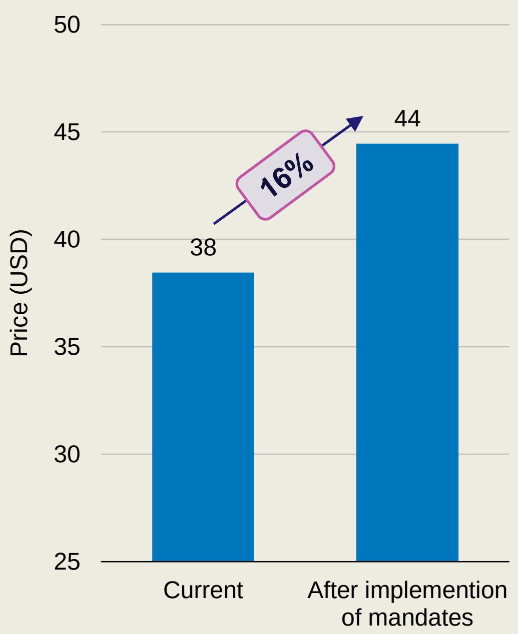
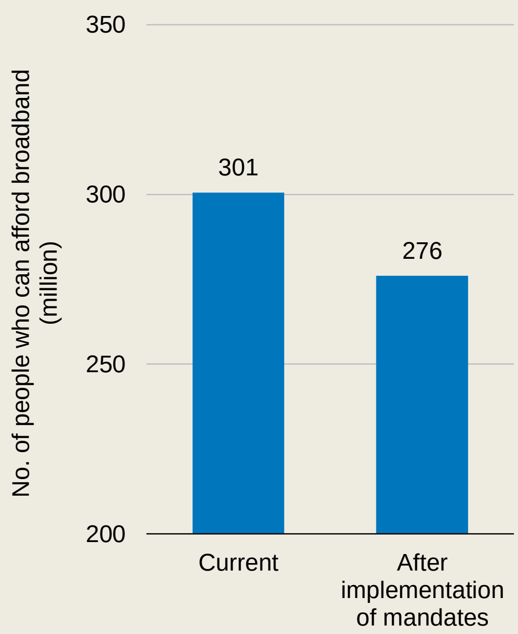


Figure 5.7: Change in the number of people who can afford broadband after the implementation of new mandates on mobile phone specifications [Source: Analysys Mason, 2016]



5.2 Bringing down the cost of broadband connectivity beyond cities and into hard-to-cover areas requires agile and flexible policies that reduce barriers to entry and the costs of experimenting with backhaul and access technologies

Conventional connectivity is unlikely to fully address the barriers to availability in rural India and connect the last 10–20% of the Indian population with 'true' broadband. Innovation, in the form of open and flexible policy-making is essential to providing sustainable solutions to address some of the connectivity challenges. Key areas that could benefit from innovation and flexibility in policy-making include:

- holistic spectrum policy, including Wi-Fi, TVWS, and extremely high frequency (EHF) bands
- satellite backhaul capacity
- device affordability.

Cost-effective deployments in rural areas can be achieved through access technologies such as Wi-Fi. However, backhaul is still a bottleneck for seamless connectivity, irrespective of the access technology used. BharatNet aims to fill this gap by bringing much higher bandwidth to rural areas throughout India, but given the large scale of the project and the implementation delays to date, it may take some time before universal fibre backhaul becomes a reality in India.

Innovative backhaul technologies can potentially act as a near-term solution for many rural areas, and bridge any gaps in connectivity left by BharatNet. Initiatives in this direction include the use of

TVWS spectrum and greater use of aerial platforms – initially satellites, but in the future potentially drones and balloons (which Facebook, Google and Thales are all reportedly developing).

Holistic and flexible approach to spectrum policy, keeping in mind the objective of rural connectivity

A holistic and flexible spectrum policy from the government can aid in expanding broadband coverage across the country. Currently the approach towards spectrum seems to be disjointed, linear and primarily driven by the goal of maximising revenue for the government. This approach has led to limitations in the mobile network coverage. Also, in certain instances there has been a lack of clarity on policy. For instance, after allotting TVWS spectrum for experimental pilots, including one by Microsoft to offer rural connectivity, the DoT recently decided against de-licensing the band and instead is looking to auction it in the future.

A more comprehensive spectrum policy is needed, which should not just be based on monetising the spectrum bands traditionally used for mobile networks, but should also allow innovative uses for currently unused or underused spectrum. As with Wi-Fi spectrum, this would involve trade-offs in de-monetising and de-licensing spectrum, keeping in mind the wider goal of rural connectivity.

Three types of spectrum bands are particularly interesting in this context:

Wi-Fi bands

Unlicensed Wi-Fi spectrum has significant economic and societal value in India, facilitating the provision of broadband connectivity and e-government services through Wi-Fi hotspots, especially in rural areas. At present, however, only a limited quantum of unlicensed Wi-Fi spectrum is available over 2.4GHz and 5.8GHz.

- Spectrum in the 5.1–5.3GHz band is currently licensed for outdoor applications, which severely limits its potential. De-licensing this band would ensure greater availability of Wi-Fi spectrum for traditional offloading[36] in urban areas and deployment of hotspots in rural areas.
- Further, only half of the 5.7–5.8GHz band is de-licensed and available for deployment. This must also be expeditiously de-licensed to facilitate take-up of Wi-Fi hotspots.

TVWS spectrum

TVWS has been the subject of recent debate, with some stakeholders (primarily established operators) arguing that is should be licensed through auctions like other cellular bands, whilst others (such as Microsoft) have argued for the spectrum to be made available on an unlicensed basis for innovative deployments in rural areas. Recently the DoT has decided against de-licensing the spectrum and indicated that in the future pricing may be

36 Offloading is a process through which data traffic from cellular-connected devices (e.g. smartphones) is carried over Wi-Fi rather than over the cellular mobile networks (3G or 4G).

determined through auctions.[37] Currently the spectrum has been assigned to various educational and research institutions such as ERNET for experimentation in TVWS technologies.

However, a hybrid approach to the licensing of TVWS is likely to be best-suited to India. A licensed model could be applied to that part of the band that is standardised by 3GPP for use with 4G and available nationwide (i.e. frequencies that are not in fact used for TV, at least at the telecom circle level or nationwide). This spectrum could complement the upcoming 700MHz band and be used to provide additional capacity or enable more competition.

A flexible model that recognises the benefits of both approaches could be most effective in India. Spectrum that can be easily integrated within operators' existing portfolios can help expand rural coverage and capacity in due time, while a light licensing model could encourage innovation by new or non-traditional market participants in the public and private sectors.

Currently, the only spectrum in the VHF and UHF bands below 700MHz that is standardised for 4G is Band 31 (452.5–457.5MHz uplink, paired with 462.5–467.5MHz downlink), and there are few commercial deployment to date (primarily in Northern Europe and Russia). Furthermore, the GSA reports that there are only three devices compatible with this band.[38]

On the other hand, spectrum that is not standardised for 4G, or is only available in some parts of the country, would not be easily useable by mobile operators for access. Whilst such spectrum could still be used for backhaul, it lends itself well to a different spectrum management model compared to cellular spectrum. Several countries, including the USA, the UK and Singapore, have adopted a lightly licensed (or even unlicensed) model where the spectrum is effectively shared between a large number of potential users, and coordination between these users to prevent interferences is managed through a database.[39]

EHF spectrum

The regulator and the DoT also need to consider de-licensing – or at the most lightly licensing – spectrum that is available in the millimetre-wave range, in order to provide a greater set of economical alternatives to the industry to promote roll-out, especially in the rural areas. The V-band (60GHz) is de-licensed in many countries such as the USA, Canada and Australia. The band offers a viable alternative to 2.4GHz and 5GHz for carrying Wi-Fi traffic, and

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37 See for example http://www.thehindubusinessline.com/info-tech/dot-says-no-to-releasing-tv-white-space-spectrum-clarifies-it-is-for-experiments/article8737575.ece

38 http://gsacom.com/wp-content/uploads/2016/02/160211-GSA_lte_ecosystem_report.pdf

39 See for example http://www.whitespaces.sg/ and https://www.ofcom.org.uk/spectrum/spectrum-management/TV-white-space-databases

given that the band enjoys good support from compatible devices in India, its use should be de-licensed.

The E-band (71–76GHz and 81–86GHz)[40] has favourable technological properties to provide high-capacity wireless links, and is especially suited for backhaul. A number of countries, including the US, the UK and Australia, have adopted a light licensing framework for allocating this band which operates on a self-coordinated, first-come-first-served basis with a register maintained by the spectrum authority. This licensing model typically results in lower fees for users, and encourages the emergence of innovative use-cases such as high-altitude balloons for connectivity. Therefore a light licensing framework could enable widespread adoption.

Case study 3: TVWS pilot in Harisal

TVWS refers to spectrum in the VHF and UHF bands which is available in many countries as a result of how TV signals are transmitted. In the Indian context, the term refers to spectrum bands currently allocated to Doordarshan for TV broadcasting but used only in some parts of the country, or in some cases totally unused. Pilots using TVWS technology are being conducted by both the government (through bodies such as ERNET, BHEL, IITs, IIIT and TAS) and the private sector (by Microsoft) to offer connectivity in rural areas.

A recent example is an initiative by the Maharashtra government and Microsoft, with the participation of DEITY, DOT and ERNET, to implement a TVWS-based broadband network in the village of Harisal. The pilot used TVWS as a means of providing backhaul connectivity to remote rural sites with Wi-Fi access points. The last-mile network was configured using an antenna, a white space receiver and a Wi-Fi router or CPE to propagate the signal to end-user devices (handsets and computers). The exercise was intended to demonstrate the viability of using TVWS as a non-cellular technology within a very infrastructure-constrained set-up. To simulate such an environment, the antennas were deployed on 20-foot high bamboo poles.

Based on our discussions with a number of experts and stakeholders in the industry (such as ERNET, DoT, mobile operators and CAPs) there are several advantages to such a TVWS model: the low upfront deployment costs, requiring only low-cost passive investments; and the low cost of backhaul (no fibre deployment, no expensive satellite backhaul). However there are key unresolved issues that the industry and government will have to settle before this technology can see mass-scale deployment in India. One is the lack of a broad-based device ecosystem: TVWS receivers will need to be compatible with commercial Wi-Fi routers, but two-in-one receivers and Wi-Fi CPEs are currently unavailable. In addition, there is a need for clear direction on the licensing model to be followed for TVWS spectrum (as discussed earlier, the issues around the different approaches – licensing, light licensing or no licensing – need to be resolved to provide a clear route forward for the industry).

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40 For more details, see http://www.analysysmason.com/Research/Content/Reports/Spectrum-management-approaches-for-E-BAND-7080GHz-in-selected-markets/

Satellite technology is being improved rapidly globally, and could play a greater role in India at the right price point

Connecting remote areas through satellite technology could drive connectivity further and, if the cost were reduced, could help expand backhaul options in areas already covered. Backhaul availability is a bigger concern in certain areas of the country which are hard to reach due to the nature of the terrain (e.g. mountainous, with dense vegetation, or in remote locations). Areas suitable for such an approach could include the rural belt of Indian states such as North East, Himachal Pradesh, Jammu and Kashmir, Chattisgarh, and the Andaman and Nicobar Islands. VSAT or other satellite technology could be an effective way of providing middle-mile or backhaul connectivity to cellular or Wi-Fi access deployments in these regions. However, there are currently several critical bottlenecks – primarily related to the quantity and cost of supply – which prevent large-scale take-up of VSAT as a backhaul solution in India: see the case study 'Why is satellite becoming a promising technology globally but not (yet) in India?' on the next page.

If these challenges were met, satellite could provide multiple benefits for rural roll-outs in the country, including:

- rapid deployment time – establishing a VSAT link with a satellite typically requires only a few hours (similar to tuning and establishing a DTH connection), so VSAT backhaul could significantly speed up rural roll-outs in the country compared to fibre-based solutions
- reduced upfront capex – installing a VSAT terminal costs much less than laying underground fibre for a connectivity link of similar length.

Considering the pros and cons of VSAT technology, it could be argued that at least in the near term (until BharatNet is fully realised) satellite could provide an effective way to connect far-flung areas of the country. But for this to be possible, intervention by the government would be required, such as enabling a reduction in the price of satellite backhaul through measures like relaxing regulatory restrictions on high-throughput satellites over India (either through a launch by the Indian Space Research Organisation (ISRO) or through collaboration with foreign players). The government could also purchase additional satellite capacity to help address the disequilibrium between demand and supply The USO fund could potentially be used to address investments required in this area. In addition, the regulatory process for approvals could be simplified to speed up deployment of VSAT, and position it as a viable option for commercial backhaul.

Case study 4: Why is satellite becoming a promising technology globally but not (yet) in India?

In recent years, technical improvements, coupled with increased spectrum availability, have led to significant advances in the throughput of telecom satellites. This in turn has led to more competitive broadband offerings both in terms of price and quality. The latest generation of high-throughput satellites have been proving the viability of these technologies. Satellite systems have increasingly moved from the Ku-band to the more abundant (higher-frequency) Ka-band, which offers 1GHz of spectrum per orbital slot. These higher frequencies have enabled the use of more concentrated beams, which allows greater re-use of frequencies across geographical regions, thereby increasing the total capacity of the satellite. The technique called polarisation diversity allows further capacity improvement, effectively doubling frequency re-use.

In aggregate, these developments have allowed capacities to increase from around 2–3Gbit/s in older Ku-band satellites up to 150Gbit/s in modern Ka-band systems (e.g. ViaSat1), leading to expectations of satellites with 1 Tbit/s throughputs in the not too distant future. ViaSat is intending to launch ViaSat2 in 2017 with a capacity of 300Gbit/s, and has announced plans for three Terabit/s satellites (ViaSat3) in 2019.

There are, however, drawbacks to ever-increasing frequency re-use in that the ground segment of the system (connecting the satellite to the Internet) has to become increasingly complex in order to accommodate the capacities required. For example, ViaSat1 with its capacity of 150Gbit/s requires 20 gateway stations on the ground, but if capacity is increased to close to 1Tbit/s a satellite is likely to require more than 40 gateway stations, doubling the cost of the ground segment.

Ultimately, these advances mean that the end user benefits from a higher-speed, lower-cost service compared to older satellite services, not only in the ongoing charges but also due to the smaller antenna required by the higher-frequency and more concentrated signal.

In the Indian context, there are three major constraints that limit the available supply of satellite capacity and result in very high prices (according to some estimates satellite backhaul in India is 85 times more expensive than comparable backhaul in the USA):

- *Limited indigenous supply of satellite capacity* – India has a domestic industrial policy which gives preference to domestic satellite capacity over capacity offered by foreign players. ISRO is the agency responsible for launching satellites into orbit, and it has to meet demand from multiple sectors: the fast-growing DTH industry with 40–50 million subscribers, the telecommunications industry, resource management services, the military, academia and cartography. The rapidly growing demand for satellite capacity has far outstripped ISRO's ability to keep pace: according to a CAG report in 2014, in the period from 2007 to 2012 ISRO provided only 22% of its planned capacity to DTH providers – the rest was provided by foreign satellite players.
- *Lengthy, bureaucratic procedures governing foreign supply* – India is unique in that the satellite regulator is also a direct supplier of bandwidth to VSAT and DTH players, and through its commercial arm (ANTRIX) is the sole arbiter of when and from which foreign players Indian players can lease satellite capacity (the sole exception is C-band broadcasting, where minimal interaction with ISRO is required; however the C band is not particularly attractive for DTH because it requires very large terminals).

According to research by Broadband India Forum, the typical waiting time for a VSAT operator to receive approval to lease foreign satellite capacity is around three years, and the approvals are also subject to data-rate limitations and antenna regulations. These factors disincentivise players from considering foreign supply. Further, India has been a long-time opponent of the 'Open Sky' policy which allows free market economic transactions between players (domestic and international): in India foreign supply is very tightly regulated, and although TRAI in 2008 recommended a reconsideration of the Open Sky policy, this was rejected by the DoT and the Department of Space, citing national security concerns.

- *Regulated market for high-throughput satellites operating in the Ka-band* – as spectrum availability in the C- and Ku-bands diminishes and demand for high-speed data services increases, the industry worldwide is shifting to the Ka-band, which offers additional spectrum and enables satellites to be built with smaller spot beams, leading to better frequency re-use and thus lower cost per bit. However, in India the Ka-band market is not yet regulated and therefore the band is not widely available to the VSAT and DTH industries. Although high-throughput satellites could lead to a drop in the price of capacity, ISRO will not launch such a satellite until 2018. Further, the government has been seen to have a very negative view of foreign operators wishing to operate Ka-band satellites over India, despite the expected cost savings for the local industry: for example, the Department of Space has expressed reservations regarding Hughes's application to build and operate a Ka-band satellite over India and may ultimately disallow it.

Policies regarding the standards for handsets sold in India could inhibit innovation

Device prices in India have been following a downward trend due to multiple factors including the surge in demand and competitive pressures. Given the competitive nature of the handset market, manufacturers have differentiated their offerings not just by adopting an aggressive pricing strategies, but also by innovating across other areas. These innovations include localised software and hardware features, content-side tie-ups, novel distribution strategies (e.g. partnerships with online marketplaces and mobile operators) and providing flexible financing options. These developments are examples of market-driven innovation which has benefitted the end user.

However, device prices need to decrease further, and certain policies aiming to provide specific standards for Indian handsets will act as a constraint to innovation and to investments, as discussed in Section 5.1 above.

5.3 Partnerships between public and private stakeholders and between mobile operators and CAPs are key to accelerating investment and innovation

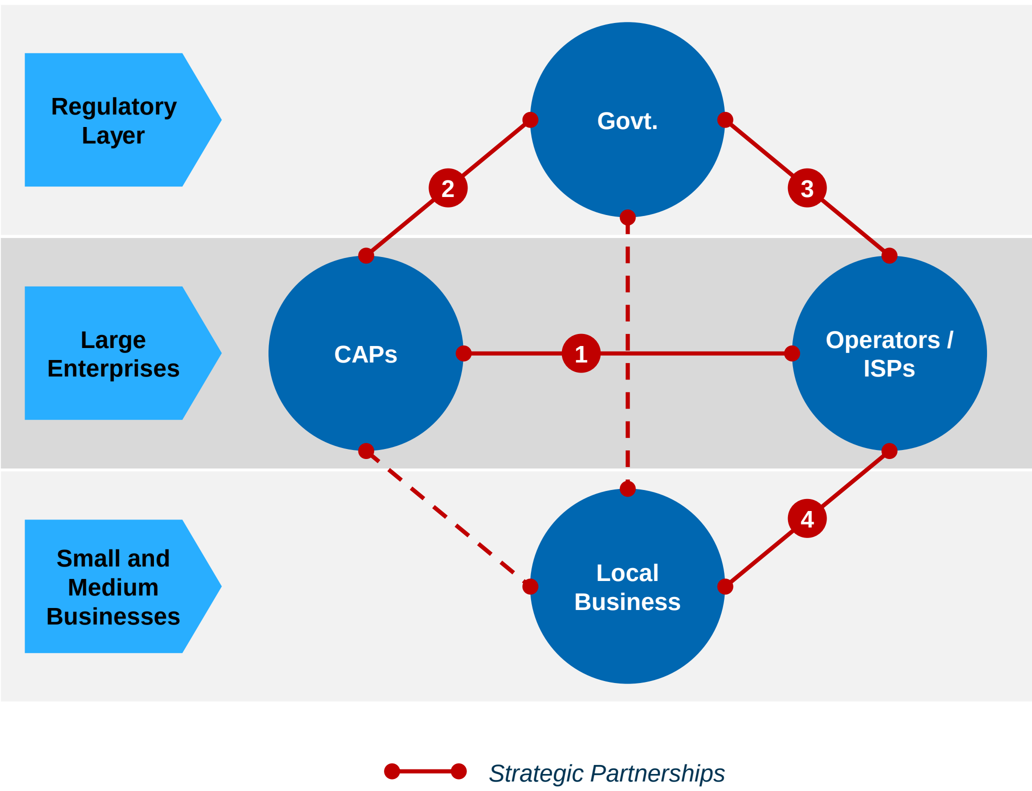
While the government has the important role of enabling the initiatives discussed so far, there is a parallel need for partnerships across the value chain in order to achieve effective implementation of these initiatives. The government's ideal role should be to provide positive intervention in areas where it is difficult for the private sector to build a sustainable business case. It could share the risk for projects that have a below-market return, establish balanced and business-friendly policies (including speedy procedural clearances) and provide a stable and investment-friendly overall regulatory climate. On the other side, the efficiency and expertise of the private sector is best suited to achieving speedy deployment of infrastructure and delivering high-quality services, supported by the government from an administrative, technical and financial perspective where required.

Furthermore, organisations with complementary skill sets – such as telcos, network providers, regional ISPs and content companies – can form partnerships to improve the delivery of broadband to consumers. Partnerships are particularly relevant to two types of initiatives that could improve the availability and affordability of broadband access, and which we explore further below, namely last-mile connectivity models driven by Wi-Fi, and affordable pricing and content provisioning.

Partnership-based Wi-Fi models will be essential to effectively address the rural connectivity challenge and to make the business model sustainable

Wi-Fi is a potent access solution for addressing connectivity needs of India, especially of the rural population and this is a major area where partnerships can be developed amongst mobile operators, CAPs, ISPs, government entities and local entrepreneurs. Figure 5.8 below provides a high-level view of the kinds of strategic partnerships that could be made in this area:

Figure 5.8: Strategic partnerships to address connectivity through Wi-Fi models [Source: Analysys Mason, 2016]



1. **Operators/ISPs and CAPs** can come together to jointly provide hotspot-based Wi-Fi services, with operators/ISPs offering expertise and service infrastructure such as backhaul, towers, poles, back-end billing systems and retail presence, and CAPs addressing project financing and roll-out of last-mile equipment, along with marketing and customer education initiatives. BSNL and Facebook have entered a partnership of this type to roll out 100 hotspots in rural India. Such partnerships can be based on a revenue-sharing model reflecting the value being added by each entity. Another possible partnership model is between operators and independent ISPs acting as downstream deployment arms for the operators. A key example is the tie-up between BSNL and Bluetown, a managed hotspot service provider, to roll out Wi-Fi using BSNL's existing infrastructure (towers, power units, backhaul) in the rural belt of India.

2. **CAPs and government entities** can also come together in a manner similar to the previous partnership model. Government entities with valuable and underutilised telecoms infrastructure such as fibre could partner with a CAP which can add value through project financing, last-mile deployment and marketing campaigns. An example is the partnership between RailTel and Google to roll out Wi-Fi at railway stations across the country; users currently have free access up to a given data usage. Such business models can work on a revenue-sharing basis, and can be replicated in other parts of the country.

3. **Government and local ISPs** – BharatNet, the universal middle-mile connectivity project of the government, should act as a potent partnership platform for innovative rural access solutions. With fibre available down to the GP level, local entrepreneurs could be incentivised to roll out last-mile networks through clearly thought-out policy interventions from the government, such as:
   - discounted bandwidth, to reduce the operational cost of the networks
   - availability of government-owned passive infrastructure such as Post Offices, poles and masts, which could significantly reduce the costs of roll-out
   - government departments with a physical presence in rural areas could act as anchor tenants on the networks, to provide guaranteed revenue
   - prioritised and subsidised business financing to speed up deployment.

4. **Public and private ISPs and local entrepreneurs** – rural ISPs could partner effectively with local entrepreneurs to create innovative distribution channels for broadband services. For instance, AirJaldi, a rural ISP in India, has created its own backhaul relay network that provides connectivity based on Wi-Fi hotspots to 10 states, connecting 100 000 rural users. AirJaldi is partnering with local entrepreneurs such as local grocery shopkeepers to act as distributors of their service by selling recharge cards for the Wi-Fi hotspots.

In addition to the above, various multi-layer partnerships can be developed to optimise the deployment costs and the service-layer offerings.

Wi-Fi models are seeing growing interest, as evidenced by various independent initiatives between different stakeholders providing both urban and rural connectivity.[41] So far, these initiatives have been small in scale and typically focussed on specific geographies: scaling up such initiatives will require large-scale planning and partnerships between stakeholders, supported by a robust policy framework.

Light-touch regulation of mobile data pricing, supported by industry-level partnerships, can go a long way to address the affordability challenges related to data pricing

As a consequence of the debate on differential content pricing in India, in February 2016 TRAI issued a regulation barring mobile operators from engaging in differential pricing of Internet content, in order to prevent them from acting as gatekeepers of content. After passing this regulation, TRAI has recently issued a consultation paper recommending three models in which content providers could incentivise data usage by consumers through a platform that is operator-agnostic:

- **rewards-based model** – reimburses a mobile Internet user for an intended action such as downloading an app or browsing content
- **toll-free model** – allows consumers free access to selected content such as a website or an application
- **direct-benefit model** – offers direct incentives for the end-user through a direct subsidy payment for data usage purposes.

There are risks to these approaches; for example, mechanisms such as volume-based payments based on how much traffic end-users consume on a given site can be operationally hard to police, and can lead to an imbalance of incentives or compensation.

Instead, other mechanisms could be explored such as sharing of advertisement revenues or a model where the government directly incentivises the end-user. Under the direct subsidy model, the government – taking the role of the subsidiser – can work together with CAPs and operators to offer affordable data services to the end-user: for example, operators could efficiently manage government subsidies to end-users for data usage, up to a certain threshold per month. Providers of specific relevant content such as payment wallets, online health and EdTech, as well as local news providers, etc. could be included in the partnership.

In addition, there are a variety of national and international examples where various stakeholders have partnered effectively to provide affordable data access to end users, whilst maintaining parity of content pricing. For instance, Mozilla, a CAP and handset manufacturer, has partnered with Grameenphone, a mobile operator, to provide free mobile data to users in Bangladesh in return for watching advertisements posted by partnering advertisers. Similar examples of strategic partnerships between players in the Internet ecosystem are provided in the table below:

41 More details on different Wi-Fi business models in India can be found in the IAMAI’s recent report *Public Wi-Fi for Broadband in India*.

Figure 5.9: International examples of models to incentivise data usage [Source: Analysys Mason, 2016]

Region	Company	Initiative	Description
Bangladesh	Mozilla, Grameenphone	Advertising-led	Users receive 20MB of free data each day in exchange for viewing an advertisement
Multiple African countries	Mozilla, Orange	Bundling free data with devices	Consumers can purchase USD40 Firefox OS smartphones that come packaged with six months of free voice and SMS, and up to 500MB of data per month
Malaysia	Maxis	Free 'experiential' Internet at throttled speeds	Free basic Internet at 64kbit/s for as long as the user's SIM remains active. Initially the data allowance was unlimited but recently it has been capped at 500MB per month
India	Paytunes	Advertising-led	The Paytunes app replaces the ringtone with advertisements and the user is given reward points for each call received, which can be used to buy data packs or voice talk-time, or to pay bills
India	Videocon	Free 'experiential' Internet to non-users	Videocon offers 750MB of free data valid for two months to all its non-data users

In summary, the government needs to adopt a light-touch regulatory stance regarding mobile data pricing so that market forces can play their part and come up with possible solutions. Making such innovative pricing models a success requires a flexible policy structure that allows strategic partnerships between various stakeholders including telecom operators, CAPs and the government itself. Such measures can be very effective in bringing the low-income population, which has never tried the Internet, online.

KEY TAKEAWAYS:

Policy interventions that support and nurture innovation and risk-taking are essential to address these challenges

- Investment-friendly policies are key to ensuring that the cost of deploying broadband networks is as low as possible. Such policies include reform of ROW prices and procedures, creating a ubiquitous well-priced backhaul network (e.g. via BharatNet or satellites), and making spectrum auctions focus on connectivity outcomes (not revenue-raising).
- A modern, agile and flexible spectrum policy will help to balance the benefits of scale and standardisation with a flexible regime that allows experimentation in areas such as TV white space, E-band, Wi-Fi, and modern satellite backhaul.
- Balanced regulation is essential to allow market forces to play out fully, be it in the handset market (where Indian manufacturers must be free to develop handsets in line with global norms to gain scale in international markets), or in data pricing (to allow innovation to bring affordable access to more people).

6 Conclusions and recommendations

India is currently bubbling with ideas, inventiveness and a shared purpose across public and private sectors to bring hundreds of millions more of the population online. In 2015, there were over 300 million people who regularly used the Internet, 100 million more than in 2013, yet this growth must accelerate further if the objective of having 1 billion connected Indians in 2020 is to be achieved.

Large benefits could stem from achieving this ambitious goal: if 1 billion people can be connected by 2020 instead of the 750 million that analysts currently forecast, the GDP of India in 2020 could be increased by over USD100 billion and the benefits would accumulate rapidly, amounting to an estimated USD200 billion between 2016 and 2020 alone.

In this report we have highlighted the two major areas of affordability and availability, demonstrating how they are closely intertwined and discussing what needs to be done to achieve improvements:

- **Continued investment throughout the value chain by the private sector** supported by timely and efficient delivery of the BharatNet programme, to provide broadband services at prices that truly expand the availability of affordable Internet connectivity, particularly in rural areas.
- **Regulation that fosters innovation and investment** by the private sector rather than hindering them, in areas such as spectrum management and pricing, rights of way, satellites, or even device standards.
- **Support for partnerships** across the value chain and with the public sector, to deliver the connectivity people need faster and more cost-effectively, whilst also recognising the need for relevant content and applications, as well as ensuring that people can acquire the skills and confidence to use the Internet.

Figure 6.1: Summary table of policy recommendations [Source: Analysys Mason, 2016]

Mechanisms	Recommendations	Description
Investment	*BharatNet project: execution and pricing*	▪ BharatNet is a unique opportunity to bring the Internet closer to most communities, but timely execution and affordable pricing are key to its effectiveness
	Spectrum: pricing and result-oriented conditions	▪ A balanced approach to spectrum pricing, combined with outcome-oriented conditions on spectrum rights, would be more effective than a revenue-maximising approach
	Clear ROW regulations and removal of satellite constraints	▪ Further investment in backhaul capacity requires regulatory support through adequate ROW regulations and a review of constraints on deployment of satellite capacity
	Availability of affordable devices	▪ The availability of affordable devices suitable for broadband access should be supported by policies that balance costs with features, and are mindful of the spectrum landscape

Mechanisms	Recommendations	Description
Innovation	*TVWS policy*	▪ A flexible approach to TVWS can help widen connectivity options in rural areas
	Lower prices for satellite capacity	▪ Satellite technology is being improved rapidly globally and could play a greater role in India at the right price point
	Handset standards and policies	▪ Policies requiring specific standards for handsets sold in India could inhibit innovation
Partnerships	*Wi-Fi access models*	▪ Partnership-based Wi-Fi models will be essential to effectively address the rural connectivity challenge and to make the business model sustainable
	Flexible pricing of mobile data	▪ Light-touch regulation of mobile data pricing, supported by industry-level partnerships, can go a long way in addressing the challenges related to data pricing related affordability

All these objectives are in line with, and support, the Digital India ambitions. Despite a common purpose shared between the government and the private sectors, there are inevitably tensions between different public-policy objectives, and with the constraints faced by private companies. The frameworks and recommendations presented in this report provide a perspective that cuts across these tensions and constraints, and can hopefully support further initiatives by all the actors to deliver truly universal connectivity to all Indians.

Annex A Notes on methodology

A.1 Context

A study by Ericsson, Arthur D. Little and Chalmers University of Technology has shown that doubling broadband speeds for an economy can add 0.3% to its GDP growth.[42] These benefits can manifest in the form of economic effects leading to increased innovation and productivity in business, social effects resulting in better access to services including improved health care, and environmental effects such as more efficient energy consumption.

A number of studies have highlighted the economic benefit of broadband and productivity in the forms of marginal broadband penetration and the incremental impact on GDP:

- A state-level study by ICRIER and IAMAI in 2011 estimates an increase of 1.08% in GDP growth rate for a 10 percentage point increase in broadband penetration.
- A World Bank study in 2009 estimates a GDP growth impact of 1.21% for developed countries and 1.38% for developing countries for a 10 percentage point increase in broadband penetration.

Market estimates suggest that the number of Internet users in India will reach 750 million by 2020, which amounts to 52% Internet penetration. This is supported by IAMAI and the Boston Consulting Group's forecast of ~580 million Internet users by 2018, and Google India's and Analysys Mason Research's estimate of ~750 million Internet users by 2020.

In an aggressive scenario, if existing constraints on infrastructure (backhaul and access), affordability (devices and services) and use cases (relevant or local services and apps) are addressed, Internet penetration in India could potentially reach 69% (1 billion people) by 2020, on a par with other developing countries such as Brazil, where Internet penetration has already crossed the 60% mark and is expected to reach ~70% by 2020.

Within this aggressive scenario, we have calculated the year-on-year increase in the growth rate of GDP using an estimate of 1.08% increase in GDP growth rate for a 10 percentage point increase in broadband penetration. This resulted in a USD100 billion (in constant 2015 USD) increase in the 2020 GDP of India. Cumulatively over the five years 2016–2020, the extra growth in GDP is estimated at over USD200 billion, compared to baseline forecasts provided by Euromonitor.

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42 See https://www.ericsson.com/res/thecompany/docs/corporate-responsibility/2013/socioeconomic-effect-of-broadband-speed.pdf

A.2 Availability

Analysis of mobile coverage

The availability, or population coverage, of mobile broadband technologies in India is defined as the number of people in the total population that are covered by the mobile radio signals of technologies such as 2G and 3G. Since 3G speeds are the minimum speeds required to offer a 'true broadband' experience, mobile broadband availability is measured as the population coverage of 3G networks. We have also split the coverage levels across geographical topologies ('geotypes'), namely urban and rural. Further, we have conducted a drill-down analysis to estimate coverage levels for the 22 telecom circles of India to provide a detailed picture of availability. Key drivers of our analysis are discussed in greater detail below.

- **Urban population coverage**: In our discussions with various mobile operators and network vendors, a key observation was made regarding the population coverage of the urban population. According to industry experts such as network vendors and mobile operators, 2G and 3G network coverage in urban areas of India is ubiquitous. Our model therefore considers 100% population coverage for the urban population for each circle.
- **Rural coverage of cellular sites for leading operators**: Mobile operators with the highest revenue market share in a telecom circle typically have the network with the highest coverage and best quality. We identified the leading mobile operator in each telecom circle using revenue data reported by TRAI. For each leading operator, we collected data on the number of rural coverage sites or base transceiver stations (BTSs) in that circle using a mix of industry discussions, TRAI data and modelling estimations.
- **Rural area coverage**: Using figures for the rural coverage BTSs of the leading operator in each circle, along with the cell radius for the relevant spectrum frequency band, and the total rural area of the circle, we estimated the percentage of rural area being covered with the current BTS deployment in that circle. This modelling is based on standard telecoms industry network-dimensioning methodologies regarding area coverage calculations.
- **Area coverage to population coverage**: Using census data on the rural population, number of inhabited villages and the areas involved, we have plotted a curve of area coverage vs. population coverage. This curve estimates the percentage of population covered at various levels of area coverage in rural areas. This analysis was done at the level of circle category, i.e. considering a sample circle from each of the three circle categories A, B and C.
- **Rural population coverage**: The resulting curves for area coverage and population coverage were then applied to the rural area coverage levels for each circle, to estimate the current rural population coverage.

As a last step, we aggregated the urban and rural population coverage for each telecom circle to calculate the total Indian population in urban and rural areas that are covered by mobile broadband.

Analysis of cellular per-subscriber costs compared to Wi-Fi

Cellular site costs: we have considered annualised capex and opex costs for a single 2100MHz site rolled out in a rural or remote area, including:

- Capex (passive or tower structure, power or back-up generator, RAN or antenna, feeder cables and radio equipment, backhaul or microwave links and repeater sites).
- Opex (power or diesel, maintenance opex including backhaul maintenance and site rental).

Wi-Fi costs: we have considered comparative annualised capex and opex cost for a typical Wi-Fi network serving a single village, deployed using Wi-Fi hotspots with VSAT (satellite-based) backhaul, including:

- Capex (Wi-Fi hotspots, VSAT terminal)
- Opex (satellite backhaul) – for satellite backhaul, we have considered VSAT bandwidth pricing in India (~USD670 per Mbit/s for 32GB) and an assumed contention ratio of 128 users (rural areas are expected to have limited concurrent traffic). Based on this we estimate backhaul costs at ~USD16 000 per annum.

Subscribers covered by cellular and Wi-Fi: using cell radii for each technology, average area per village (census data), Internet penetration, rural population density and the number of mobile operators in the area (typically only one operator in a remote village), we estimate the number of people covered by each technology.

Using the technology-related cost and subscribers covered, we then calculate the comparative annual per-subscriber cost for cellular and Wi-Fi.

A.3 Affordability

The percentage of the population able to afford broadband is defined as those who can purchase a smartphone and a prepaid mobile data package with a minimum monthly allowance of either 100MB, 300MB or 500MB for no more than 2.1% of their income. The 2.1% affordability threshold is estimated by calculating the average amount spent by existing mobile data users in India on device and data services combined. The methodology used is as follows:

1. **The income distribution curve**
   The data on the distribution of the population across various income levels has been obtained from Euromonitor. Since Euromonitor reports this data only for the population aged 15 years and above, the population aged under 15 years of age has been added to the lowest income strata, assuming that they have a negligible income, to arrive at the distribution of the entire population of India across different income levels.

2. **The affordability threshold**
   In order to arrive at the affordability threshold, the cost of a device and data service is divided by income. Only 23% of Indians use mobile data and it has been assumed that these people

are the top 23% on the income distribution curve. Keeping this in mind, the affordability threshold has been calculated for the marginal data user, which lies in the 23rd percentile of the population. The average annual spend on data in India is USD33. But since the annual cost of the cheapest data connection is half of this amount, it has been assumed that the marginal data user spends only USD16.5 on data annually. The average price of a smartphone sold in India is USD126. But since the cheapest smartphone is available at 30% of this price, and considering that the average life span of a smartphone is two years, it has been assumed that the marginal data user spends only USD19 on a device annually. The sum of the annual cost on device and data has been divided by the income of the marginal data user to arrive at a figure of 1.8%. Keeping in mind that the expenditure-to-income ratio of the low-income population is higher than that of the high-income population, this figure has been adjusted upwards to 2.1% using the following formula:

$$Affordability\ threshold\ of\ population\ earning < USD500$$
$$= Affordability\ threshold\ of\ population\ in\ the\ 23rd\ percentile \frac{\dfrac{Expenditure\ of\ population\ earning < USD\ 500}{Income\ of\ population\ earning < USD\ 500}}{\dfrac{Expenditure\ of\ population\ in\ the\ 23rd\ percentile}{Income\ of\ population\ earning\ in\ the\ 23rd\ percentile}}$$

3. **Total cost of ownership (TCO)**

   a. *Cost of data service* – the cost of using data has been calculated by considering 3G data prices across six category C circles, keeping in mind that these circles cover the highest proportion of the low-income population, which we consider to be the target population that needs to be connected to broadband. The minimum amount required to have consistent access to 3G data for 28 days provided by a widely available mobile network provider has been considered. This amount is used to arrive at a price per MB which is then normalised to arrive at an annual cost for 100MB, 300MB or 500MB of data per month.

   b. *Cost of owning a smartphone* – the cost of owning a smartphone has been arrived at by considering the price of the cheapest available smartphone (USD38) with specifications that allow for an acceptable broadband experience. Assuming an average life span of a smartphone to be two years, the annual cost of ownership of a smartphone is USD19.

   c. *Cost of a SIM card* – the annual cost of using a smartphone with a consistent 3G data connection are added to the cost of a SIM card with unlimited validity (~USD1) to arrive at the TCO of broadband access.

4. **The percentage of population able to afford broadband**

   The calculated TCO has been divided by the affordability threshold to arrive at the minimum annual income required for accessing broadband. In conclusion, the percentage population that earns more than this amount is represented as the population which can afford broadband access.

Annex B Estimating CAP investments in infrastructure

Investments by CAPs in the Internet value chain in India were estimated using a mix of interviews with industry experts, secondary research and Analysys Mason's proprietary analysis. These investments can be divided into *direct* and *indirect* investments within hosting, transport and delivery infrastructure.

Hosting infrastructure (data centres)

Direct investment by CAPs in hosting infrastructure implies expenditure on physical co-location centres in the country (e.g. Amazon Web Services, Microsoft Azure). We have estimated these investments using secondary research and discussions with industry experts. Investments were assumed to have been made over a two year period to estimate average annual investment.

Because of the high cost of investment and lack of flexibility associated with *captive* data centres (e.g. a data centre for an ecommerce firm's own operations), none of the Indian Internet firms have made any investments in the captive hosting space.

Indirect investments imply the investments in co-location data centre space made by third party providers on behalf of CAPs, i.e. due to the co-location demand generated by CAPs. This estimation was conducted using a mix of primary interviews, secondary research and proprietary modelling work. Broadly, the estimation exercise considered historical data on annual additions to co-location capacity (sq. ft.), average build cost (cost per sq. ft.) and average upgrade and maintenance cost (as % of overall capex). Further, we also considered the share of CAPs in the client portfolio of co-location providers (~40%, according to industry sources) to derive the share of CAP indirect investments.

Transport infrastructure (submarine and terrestrial cables)

No *direct* investments have been made by CAPs in submarine cables connecting India. *Indirect* investments were estimated using a mix of secondary research and proprietary modelling work. This exercise was conducted for each submarine cable connecting the country and included an analysis of average annual capex (primarily maintenance) per cable, the share of Internet bandwidth compared to the total traffic supported, and the share of CAPs in the Internet traffic.

Similarly no direct investments have been made by CAPs in *terrestrial* cable infrastructure. Indirect investments were estimated using the submarine investments estimated above, scale using an estimated ratio of submarine and terrestrial cable infrastructure in India.

Delivery infrastructure (content delivery networks)

Delivery infrastructure in India mainly involves content delivery networks (CDNs) for content caching. Direct investments in the CDN space were estimated using discussions with industry experts. According to our discussions with stakeholders, direct investments in CDN comprise ~10% of the direct investments in the hosting space.

Indirect investment in CDNs were estimated in a bottom-up fashion, by considering the average annual spend on CDN by firms in different size tiers (large, medium, small) and the estimated number of CAPs in India by tier. Key assumptions regarding average spend were validated from industry discussions, while estimates of the number of CAPs were collected through secondary research.

Annex C List of official consultation papers and reports reviewed for this report

Title	Issued by	Date of issue	Link	Scope
Gazette Notification Panic Button and GPS Rules 2016	Department of Telecommunications	22 April 2016	http://www.dot.gov.in/sites/default/files/u68/Gazette%20Notification%20Panic%20Button%20and%20GPS%20Rules%202016.pdf	• New mandatory hardware specifications for handsets
Draft Indian Telegraph Right of Way Rules, 2016	Department of Telecommunications	16 March 2016	http://117.240.214.4/images/pdf/draft_indan_telegraph_right_of_way_rules2016.pdf	• Principles for grant of Right of Way permissions for laying down telecom & internet infrastructure
Guidelines for grant of Unified License (Virtual Network Operators)	Department of Telecommunications	31 May 2016	http://www.dot.gov.in/sites/default/files/UL%20(VNO)%20Guidelines.pdf	• Broad guidelines for grant of Unified License (VNO)
National Telecom M2M Roadmap	Department of Telecommunications	12 May 2015	http://www.dot.gov.in/sites/default/files/Draft%20National%20Telecom%20M2M%20Roadmap.pdf	• Communications aspects of M2M with interoperable standards, policies and regulations
Report of the Committee on NOFN	The Committee on NOFN	31 March 2015	http://www.dot.gov.in/sites/default/files/rs/Report%20of%20the%20Committee%20on%20NOFN.pdf	• Recommendation on the migration path from NOFN to BharatNet (more robust, future-oriented, scalable network)
Draft Policy on Internet of Things	DeitY	8 April 2015	http://deity.gov.in/sites/upload_files/dit/files/Revised-Draft-IoT-Policy.pdf	• Policies for promotion of IoT and selection of essential domains
Consultation Paper on Free Data	TRAI	19 May 2016	http://trai.gov.in/WriteReadData/ConsultationPaper/Document/CP_07_free_data_consultation.pdf	• Possible options to facilitate free access to certain websites/content

Title	Issued by	Date of issue	Link	Scope
Recommendations on Valuation and Reserve Price of Spectrum in 700 MHz, 800 MHz, 900 MHz, 1800 MHz, 2100 MHz, 2300 MHz and 2500 MHz bands	TRAI	18 April 2016	http://www.trai.gov.in/WriteReadData/Recommendation/Documents/Response_18.04.2016_final.pdf	• Recommendations on valuation and reserve price of Spectrum in 700 MHz, 800 MHz, 900 MHz, 1800 MHz, 2100 MHz, 2300 MHz and 2500 MHz Bands as a response to reference received from DoT
Recommendations on Allocation and Pricing of Microwave Access (MWA) and Microwave Backbone (MWB) RF Carriers	TRAI	17 Nov 2015	http://www.trai.gov.in/WriteReadData/Recommendation/Documents/MW%20Reco%20Final29082014.pdf	• Recommendations on Allocation and Pricing of Microwave Access (MWA) and Microwave Backbone (MWB) RF Carriers based on comments received from DoT and comments received from stakeholders
Recommendations on Implementation Strategy for BharatNet	TRAI	1 Feb 2016	http://www.trai.gov.in/WriteReadData/WhatsNew/Documents/Recommendations_BharatNet.pdf	• Recommendation on a new implementation strategy for BharatNet, in light of developments since the release of Report of the Committee on NOFN
Consultation Paper on Regulatory Framework for Over-the-top (OTT) services	TRAI	27 March 2015	http://www.trai.gov.in/WriteReaddata/ConsultationPaper/Document/OTT-CP-27032015.pdf	• Implications of the growth of OTTs and consider whether or not changes are required in the current regulatory framework