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Subject: Consultation on *Review of Scope of Infrastructure Providers Category-I (IP-I) Registration*
Ref: Consultation paper dated 16 August 2019

Dear Sir,

This is with reference to the consultation paper on '*Review of Scope of Infrastructure Providers Category-I (IP-I) Registration*'.

Please find attached GSMA's comments on this consultation enclosed to this letter. We hope that our response will merit your kind consideration.

Yours sincerely,

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Copy: Shri R. K. Singh (rksingh@trai.gov.in)

Enclosed:
(i) GSMA response to TRAI paper (*number of pages – 04*)
(ii) GSMA Report '*Closing the Coverage Gap: How Innovation Can Drive Rural Connectivity', July 2019*

Review of Scope of Infrastructure Providers Category-I (IP-I) Registration

The GSMA welcomes the thoughts around infrastructure sharing and believes that Governments should have a regulatory framework that allows voluntary sharing of infrastructure among mobile operators / TSPs.

The regulatory framework of a country should facilitate all types of infrastructure sharing arrangements, which can involve the sharing of various components of mobile networks, including both so-called passive and active sharing.

Infrastructure sharing agreements should be governed under commercial law and, as such, subject to assessment under general competition law. Any sharing should therefore be the result of commercial negotiation, and not mandated.

As the concept of infrastructure-sharing is still evolving and has various techno-commercial dynamics involved, thus the GSMA is looking into this topic. A more detailed discussion around this topic can be accessed at the GSMA website[1].

In the following paragraphs, we provide our answers to the questions raised in the consultation paper.

Question-wise Response:

Q.1 Should the scope of Infrastructure Providers Category – I (IP-I) registration be enhanced to include provisioning of common sharable active infrastructure also?

GSMA Response:

We believe that government should have a regulatory framework that allows voluntary sharing of infrastructure among mobile operators and infrastructure providers. The regulatory framework should facilitate all types of infra sharing agreements, which can involve sharing of various components of mobile networks whether active or passive.

Considering the present circumstances of Indian Mobile industry, objectives of the NDCP and focus on 5G, the GSMA would support increasing the scope of 'Infrastructure Sharing'.

However, it will be important to understand the extent to which the TRAI would like to include the active network elements for purpose of common sharing with infrastructure providers, and how these elements are decided i.e. mechanism, assessment and impact on networks, services and competition with a comprehensive impact assessment and analysis.

Furthermore, extending these active elements beyond TSPs to IP-1 registration providers, we believe that a comprehensive assessment is required since sharing these assets can have a bearing on the license conditions, network (including performance), investments, service

[1] https://www.gsma.com/futurenetworks/wiki/infrastructure-sharing-an-overview/#38e38993fe53372e7c83a487ec3acaf7

provisioning, competition dynamics (infrastructure, network and services), regulations (including but not limited to QoS) and different types of players (e.g. UL (Access), VNOs).

Q.2 In case the answer to the preceding question is in the affirmative, then

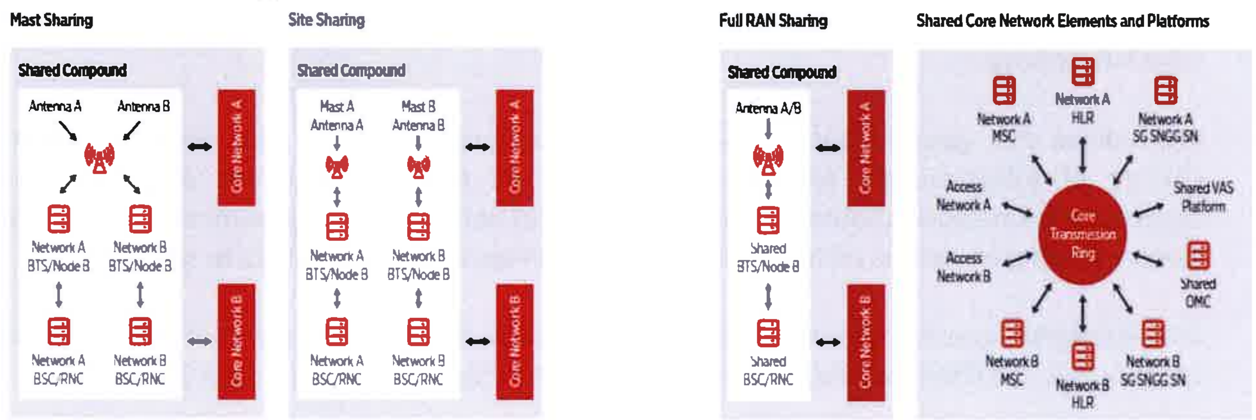
i) What should be common sharable active infrastructure elements which can be permitted to be owned, established, and maintained by IP-I for provisioning on rent/lease/sale basis to service providers licensed/permitted/ registered with DoT/ MIB? Please provide details of common sharable active infrastructure elements as well as the category of telecommunication service providers with whom such active infrastructure elements can be shared by IP-I, with justification.

AND

iii) Whether the existing registration conditions applicable for IP-I are appropriate for enhanced scope or some change is required? If change is suggested, then please provide details with reasoning and justification.

GSMA Response:

There are a range of active infrastructure elements in a Telecom Network from the RAN side (e.g. Tower, Antenna, eNodeB, BSC, RNC, Mast) to the CORE elements side (e.g. VAS platform, MSC, HLR), that may be looked at from the perspective of common sharing. The GSMA Public Policy Handbook shows the types[2] of possible sharing with some elements:



Source: GSMA

The GSMA welcomes the idea allowing sharing of active elements, and believe that a reformed policy should allow the Licensed TSPs to share their RAN and Core elements assets on a mutual / voluntary basis among themselves, subject to competition aspects.

[2] GSMA's Mobile Policy Handbook 2019, Deeper Dive - Types of Infrastructure Sharing, Pg- 86-87

As regards extending these active elements beyond TSPs to IP-1 registration providers, we believe that a comprehensive assessment is required since sharing these assets can have a bearing on the license conditions, network (including performance), investments, service provisioning, competition dynamics (infrastructure, network and services), regulations (including but not limited to QoS) and different types of players (e.g. UL (Access), VNOs).

ii) Should IP-I be allowed to provide end-to-end bandwidth through leased lines to service providers licensed/permitted/ registered with DoT/ MIB also? If yes, please provide details of category of service providers to it may be permitted with justification.

AND

iv) Should IP-I be made eligible to obtain Wireless Telegraphy Licenses from Wireless Planning and Coordination (WPC) wing of the DoT for possessing and importing wireless equipment? What methodology should be adopted for this purpose?

AND

v) Should Microwave Backbone (MWB) spectrum allocation be permitted to IP-I for establishing point to point backbone connectivity using wireless transmission systems?

GSMA Response:

No Comments

Q.3 In case the answer to the preceding question in part (1) is in the negative, then suggest alternative means to facilitate faster rollout of active infrastructure elements at competitive prices.

GSMA Response:

No Comments

Q.4 Any other issue relevant to this subject.

GSMA Response:

As mentioned earlier, we believe the policy should allow sharing of active elements among the TSPs, however it is important to understand the extent of active network elements that can be shared with IP-1, and the impact it can have on the licensing conditions, network, investments, competition dynamics (infrastructure, network and service) and various licenses.

An equally important aspect that we would like to bring to your notice here is the issue of pass-through for any such common active sharable element under a properly worked-out framework (i.e. an amount paid by TSPs to the sharable active infrastructure providers should be considered as pass-through to avoid the multiple regulatory levy).

Therefore, the review should consider these aspects and look at the scope expansion/change with a proper regulatory tool that ensures the level playing field among the stakeholders.

We are also pleased to attach a copy of our report[3] titled *"Closing the Coverage Gap How Innovation Can Drive Rural Connectivity"* that we hope will be useful for understanding how a greater rural coverage can be driven via innovative business models.

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[3] https://www.gsma.com/mobilefordevelopment/wp-content/uploads/2019/07/GSMA-Closing-The-Coverage-Gap-How-Innovation-Can-Drive-Rural-Connectivity-Report-2019.pdf

GSMA Connected Society

Closing the Coverage Gap

How Innovation Can Drive Rural Connectivity

The GSMA represents the interests of mobile operators worldwide, uniting more than 750 operators with over 350 companies in the broader mobile ecosystem, including handset and device makers, software companies, equipment providers and internet companies, as well as organisations in adjacent industry sectors. The GSMA also produces the industry-leading MWC events held annually in Barcelona, Los Angeles and Shanghai, as well as the Mobile 360 Series of regional conferences.

For more information, please visit the GSMA corporate website www.gsma.com

Follow the GSMA on Twitter: @GSMA

This material has been funded by UK aid from the UK government; however the views expressed do not necessarily reflect the UK government's official policies.

GSMA Connected Society

The Connected Society programme works with the mobile industry, tech companies, the development community and governments to increase access to and adoption of the mobile internet, focusing on underserved population groups in developing markets. Key activities include:

- **Generating and disseminating insights and learnings** on the mobile internet coverage and usage gap.
- **Supporting mobile operators** to extend coverage and drive usage.
- **Undertaking advocacy and policy work** to ensure that mobile operators' efforts to achieve greater digital inclusion are being effectively supported by governments, the international community and other stakeholders.

For more information, please visit www.gsma.com/connected-society

This report is based on foundational research by ABI Research which has been analysed, edited and added to by the GSMA.

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Acronyms

2G	Second Generation
2.5G	Second and a Half Generation
3G	Third Generation
4G	Fourth Generation
5G	Fifth Generation
API	Application Programming Interface
ARPU	Average Revenue Per User
CaaS	Coverage as a Service
dB	Decibels
ESCO	Energy Service Company
Gbps	Gigabits per second
GEO	Geosynchronous Equatorial Orbit
GHz	Gigahertz
GSM	Global System for Mobile Communications
LMIC	Low and Middle-Income Countries
HAP	High-Altitude Platform
IoT	Internet of Things
IP	Internet Protocol
ISP	Internet Service Provider
ITU	International Telecommunication Union
LED	Light Emitting Diode
LEO	Low Earth Orbit
LoS	Line of Sight
LTE	Long-Term Evolution
Mbps	Megabits per second
MEO	Medium Earth Orbit
MHz	Megahertz
NGO	Non-Governmental Organisation
NLoS	Non-Line of Sight
RMIO	Rural Mobile Infrastructure Operator
SDG	Sustainable Development Goal
UMTS	Universal Mobile Telecommunications Service
VoIP	Voice over Internet Protocol
WCDMA	Wideband Code Division Multiple Access

Introduction and key findings

The mobile industry has made incredible progress in delivering internet connectivity around the world. Over 3.5 billion people globally are now connected to mobile internet, and the percentage living outside a broadband network has more than halved since 2014.[1] In 2018 alone, the industry added an additional 300 million new mobile internet subscribers.[2]

Mobile broadband use not only facilitates communication, but also vastly improves access to life-enhancing information and services. It adds value to economies and society, as it has been proven to drive economic growth[3] and it supports the achievement of the United Nations Sustainable Development Goals (SDGs).[4] However, millions of people still do not live within reach of a mobile broadband network, and innovation is required to enable this change.

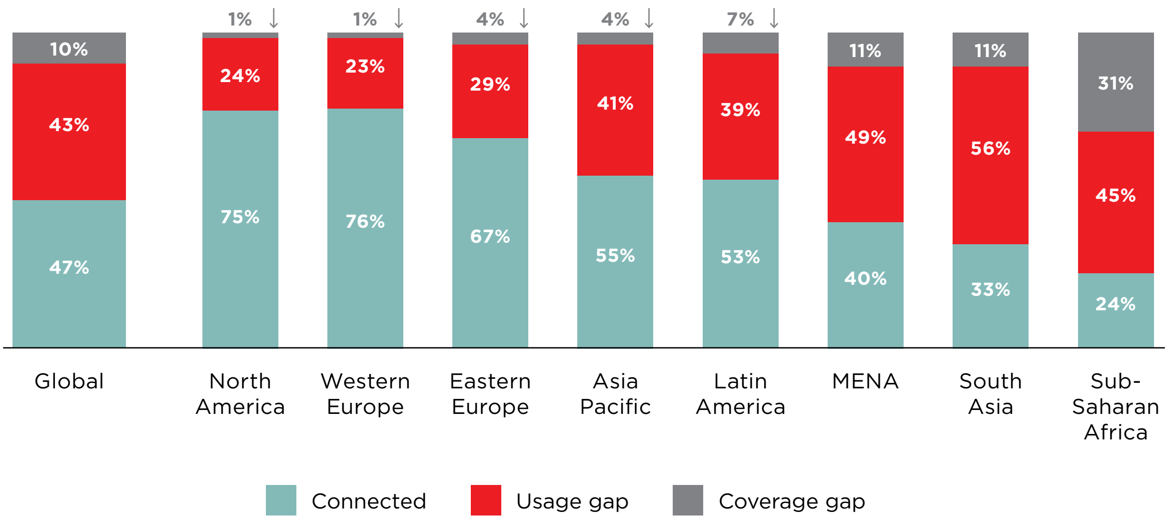
Sizing the mobile broadband coverage and usage gaps
For most of the world's population, mobile is the primary way to access the internet, and it is the best technology to reach the underserved, especially low-income populations, women and rural residents.[5] However, over 750 million people, around 10 per cent of the global population,[6] are still not covered by mobile broadband (a 3G connection or higher). This is known as the "coverage gap". This lack of coverage is particularly concentrated in rural and remote areas, especially in regions like Sub-Saharan Africa, which is home to 41 per cent of individuals globally without access to 3G or 4G connectivity (Figure 1).

Mobile broadband coverage is key to digital inclusion. However, it is only part of the solution as there are still 3.3 billion people who live within reach of a mobile broadband network but do not use mobile internet. This is known as the "usage gap". The reasons for not using the internet can be complex and varied, including being unable to afford internet-enabled handsets or data costs; being unaware of mobile broadband and its potential benefits; lacking the skills and confidence to use mobile internet; or being prevented from accessing the internet due to social norms.[7] Beyond closing the coverage gap, more needs to be done to stimulate adoption and use of mobile internet. This would not only help more people reap the benefits of the internet, but also improve return on investment for mobile operators, which in turn makes network expansion more financially viable.

1. GSMA, *The State of Mobile Internet Connectivity Report 2019*
2. GSMA, *The State of Mobile Internet Connectivity Report 2019*
3. Katz and Callord, 'The economic contribution of broadband digitization and ICT regulation' (2018)
4. The United Nations Sustainable Development Goals (SDGs) are seventeen global objectives agreed by the United Nations in 2015, with an aim to achieve each of them by 2030. Building on the success of the Millennium Development Goals (MDGs), the SDGs range from a commitment to end poverty (SDG 1) to strengthening international development partnerships (SDG 17). Mobile technology forms part of the 2030 Agenda for Sustainable Development and its targets and can play a key role in achieving many of the goals. In fact, countries with high levels of mobile connectivity have made the most progress in meeting their commitments to the SDGs (Mobile Industry Impact Report: SDGs, GSMA, 2018).
5. Across the 18 LMICs surveyed by the GSMA Intelligence Consumer Survey in 2018, an average of 57% of respondents who had used the internet in the previous three months accessed it exclusively on a mobile phone. This reliance on mobile for internet was even higher in certain countries and regions.
6. GSMA, *The State of Mobile Internet Connectivity Report 2019*

Figure 1

Sub-Saharan Africa has the widest coverage gap in the world



Source: GSMA Intelligence, 2018

*'**Connected**' refers to those who have used internet services on a mobile device. Mobile internet services are defined as any activity that consumes mobile data.*

*'**Usage gap**' refers to those who live within the footprint of a mobile broadband network but are not using mobile internet.*

*'**Coverage gap**' refers to those who do not live within the footprint of a mobile broadband network.*

Unique subscriber data is sourced from GSMA Intelligence, combining data reported by mobile operators with the annual GSMA Intelligence Consumer Survey. Coverage data is sourced from GSMA Intelligence, combining data reported by mobile operators and national regulatory authorities. Population data is sourced from the World Bank.

Reducing network deployment and operation costs are key to closing the coverage gap

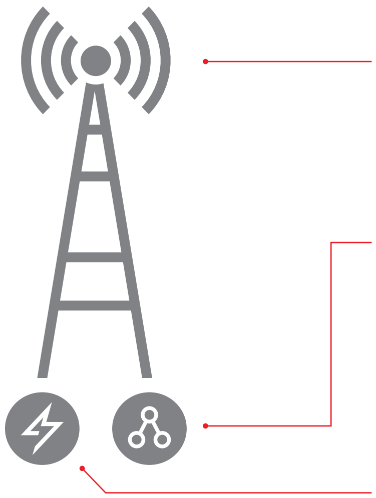
Operators often struggle to deploy mobile broadband in rural and remote areas, as costs can be prohibitive, revenue lower and logistics complex. The average revenue of a rural cell site can be 10 times lower than one in an urban setting, while the cost of building and maintaining network infrastructure in a rural area is often double. For rural mobile broadband coverage to be commercially viable and sustainable, the cost of rolling out and operating networks must be reduced, particularly in low- and middle-income countries (LMICs).

The GSMA has identified three main areas where infrastructure costs can be prohibitive: the mobile base station, the backhaul technology that connects users to the core mobile network and the energy (both supply and storage) that enables both these components to function (Figure 2). These elements account for a major share of the total cost of ownership for each network deployment, including operators' capital (CapEx) and operational expenditure (OpEx).[8] Based on extensive discussions with industry experts, comprehensive secondary research and analysis of over 30 technologies, this report identifies trends and discusses considerations for innovation in this area, and features some promising cost-saving examples.

7. Further discussion regarding the barriers faced by potential mobile broadband users can be found in *The State of Mobile Internet Connectivity Report 2019* and *The Mobile Gender Gap Report 2019*
8. Capital expenditure (CapEx) refers to initial investments in physical or other infrastructure, such as cell site towers or base station components. Operational expenditure (OpEx) describes the costs required to run a network or other solution. These costs could include the provision of power, staff costs and maintenance fees.

Figure 2

Priority areas for innovation in infrastructure



The base station provides mobile broadband coverage to an area. Deploying this technology can be very expensive – including transporting materials and undertaking extensive civil engineering in order to build the towers that host the base station.

Backhaul connects users to the core mobile network. This often uses fibre-optic cabling, or a wireless approach. However, cabling is costly and a significant financial and operational commitment. Similarly, transporting data over large distances using wireless technology demands many receivers and transmitters which also has large cost implications.

Energy represents a sizeable and ongoing cost for network operation. In many rural areas, due to the absence of a national grid, cell sites are powered using diesel generators which are expensive to install, operate, and maintain – an issue exacerbated by the diesel being a target for theft.

Key findings

- **Innovation has real potential to make rural broadband coverage commercially feasible.** Considerable innovation with the potential to drive down the cost of delivering mobile broadband coverage is occurring. However, it ranges from already tested solutions to many ideas that are still in the design phase.

- **Base station solutions for rural and remote locations are among the more commercially developed innovations**, particularly compared to those focused on backhaul or energy. Cell-site innovations focus on providing **lower cost, simplified or modular infrastructure**, including "light towers" that are cheaper and less complex to deploy.

- **More radical wide-area cell-site solutions, such as the Altaeros SuperTower and Loon, aim to reduce the costs of providing coverage to a larger or more dispersed population, but they have yet to be proven in a commercial setting**. Currently these solutions are designed to be 4G only, which in the shorter term could limit mobile internet adoption in lower income areas where 4G handsets are less available and affordable.

- **The potential for innovation in the backhaul sector is longer term**, or at least less immediate, than solutions tackling issues with cell-site deployments and energy provision. This is primarily because the innovation needed to provide rural backhaul must be fundamentally different to current solutions that have struggled to deliver rural connectivity in a commercially viable way. Investment is also longer term and considerable, particularly for the deployment of satellite constellations.

- **The next generation of satellite backhaul technologies could revolutionise rural communications**, making even the most remote deployments commercially feasible. However, uncertainty surrounds this technology, including whether business models are sustainable. Innovative uses of **microwave backhaul are therefore likely to continue to play a significant role in remote deployments** well into the future, particularly in Sub-Saharan Africa.

- **Solving the challenge of providing reliable and low-cost off-grid power is critical** to the roll out of mobile broadband as **diesel generators represent a considerable proportion of operators' capital and operational expenditure**, which prevents them from extending coverage to rural areas.

- **Renewable energy solutions, particularly solar-powered ones, are an increasingly common feature of many rural deployments**. They can play an especially important role in providing energy to cell sites designed to function off-grid or to serve particularly remote rural communities. While solar power is largely used as a secondary energy source — and shares some of the drawbacks of diesel generators, like the risk of theft or damage — renewable energy can still play a meaningful role in enabling connectivity.
- Cost-efficient and often environmentally friendly, **fuel cell generators could revolutionise the provision of power** for mobile broadband networks if suitable supply chains can be established. The ability of some of these innovations to generate power could make them suitable for even the most remote deployments.

Innovation should not be limited to technology; it should also extend to business models

Closing the coverage gap demands innovative approaches to technology, but also new ways of working. Current business models have been phenomenally successful in expanding mobile broadband coverage, but connecting the hardest to reach is increasingly an economic rather than technical challenge. With low population densities, low per capita income levels and less developed or non-existent infrastructure, developing a sustainable business model can be a challenge. This report explores a range of business models that address these challenges and could enable operators to deliver mobile broadband in a financially sustainable way.

Innovation is also likely to drive new and exciting partnership opportunities, such as with the energy and aviation industries. Continued engagement with government and the support of enabling policy environments will remain important, particularly as returns on investment may take some time to clarify and accrue. When delivering mobile broadband to the hardest to reach, context is key. Operators will likely need to explore different innovations, business models and collaborations across their networks.

Closing the coverage gap is essential

Those who could benefit most from the internet are at risk of being left behind — a particular concern in countries where mobile is often the only gateway to the internet. This disparity will increase as access to essential services, including e-government and mobile-enabled value-added services, increasingly require an internet connection.

The GSMA is committed to working with mobile operators to connect the unconnected. By identifying promising innovations and potentially sustainable models to roll them out, this report aims to provide operators, vendors and other partners with further guidance to close the coverage gap. This will enable progress towards a world where everyone can access the internet. This includes working to achieve SDG 9.c.,[9] which aims to increase the global population covered by a mobile network and provide universal and affordable access to the internet in least developed countries. Operators also have much to gain, including access to millions more customers.

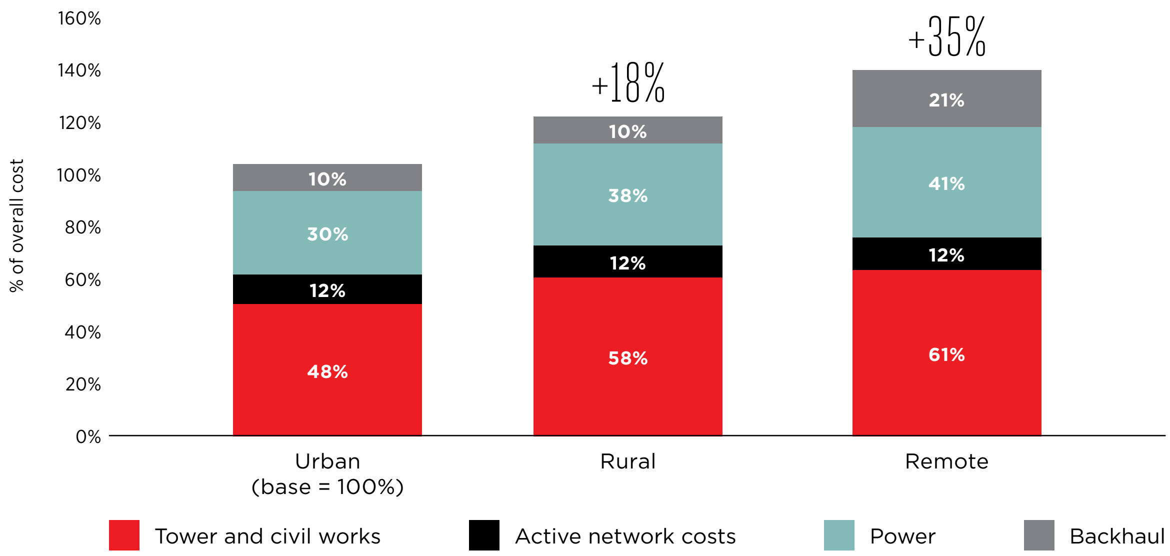
9. SDG 9 focuses on "build[ing] resilient infrastructure, promot[ing] inclusive and sustainable industrialisation and foster[ing] innovation". It has eight targets, with target 9.c focusing on "significantly increase[ing] access to information and communications technology and striv[ing] to provide universal and affordable access to the Internet in least developed countries by 2020". An indicator of success (9.c.1) is the proportion of the population covered by a mobile network, by technology. https://unstats.un.org/sdgs/metadata/?Text=&Goal=9&Target=

Promising innovations in rural network infrastructure

Mobile operators have made significant investments to make the deployment of their mobile broadband networks more efficient, but more needs to be done to close the coverage gap. The costs of key components of the network — base stations, backhaul and energy — must be reduced as these represent significant capital (CapEx) and operational (OpEx) expenditure (Figure 3) for operators.

Figure 3

Annualised cost of mobile coverage sites in rural and remote locations (relative to urban), by major component



All figures are GSMA generalised benchmarks, taken from GSMA Intelligence data.

There is considerable innovation in the mobile sector, from lab-based proofs of concept to fully commercial products. This is important because innovative solutions for base stations, backhaul and energy have the potential to drive comprehensive cost or efficiency savings. These reductions could make the provision of mobile broadband connectivity more feasible and, ideally, profitable in areas that are not currently commercially viable. Exploring these innovations, and the broader context in which they could be applied, is the focus of this section.

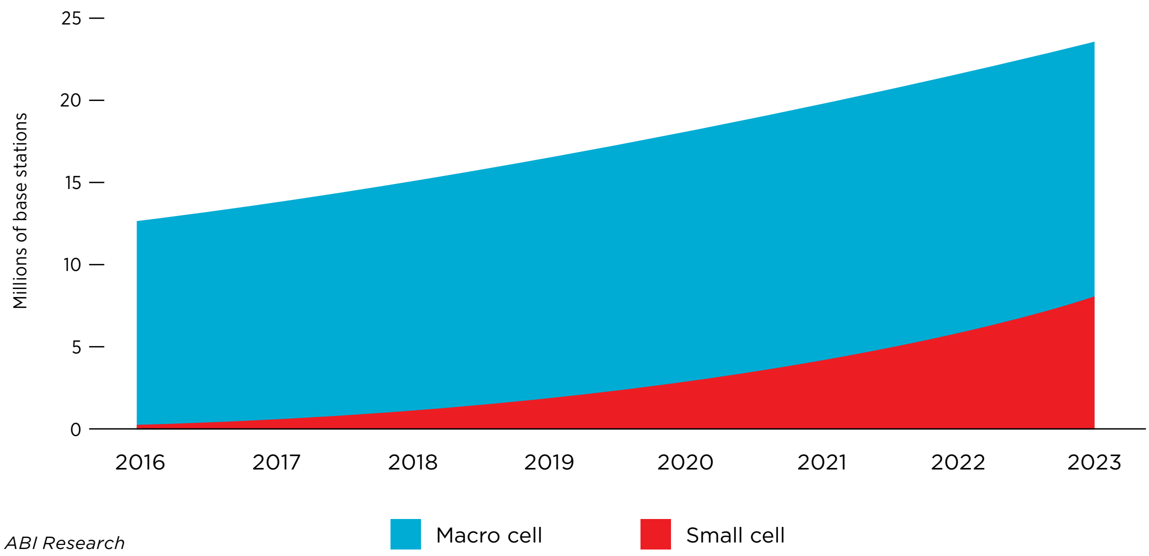
The pace and breadth of innovation in the mobile sector, and the fact that some of the solutions featured in this report are still in early stages, prevent us from providing a comprehensive summary of innovations in this area and assessing their potential real-world impact. Those we examine have been selected either because they represent a type of innovation gaining traction or they are particularly interesting or important due to their potential to accelerate mobile broadband coverage in uncovered or less covered areas.

Innovations in base stations

Context
By 2023, more than 20 million base stations will be installed around the world — 74 per cent of which will be macrocells[10] and 26 per cent likely smaller cells providing more targeted coverage (see Figure 4).

Figure 4

Installed base stations, by type



Source: ABI Research

Despite this progress, rolling out coverage in remote rural communities in emerging markets has been a challenge. The innovations in this report represent a shift away from the provision of macrocell solutions, which can be expensive and complex to deploy, can have variable signal strength (natural and artificial landscapes can block signals) and can require significant and reliable power supplies that are often lacking in rural areas.

To address the specific connectivity challenges of rural communities, operators will need a range of base station solutions (Table 1). For example, a combination of wide and continuous coverage solutions may be most suitable for village clusters, while more dispersed, isolated villages will likely require either a highly targeted coverage solution or a high altitude one with a large range. Innovation can also address several challenges encountered in the deployment of traditional macrocells, including reducing the total cost of ownership of a cell site, increasing energy efficiency, expanding the coverage area to increase the customer base, streamlining installations through lower or latticed central poles, refined components and smaller footprints.

10. A macrocell is the largest cell deployed in terrestrial mobile phone networks, typically on a large mast.

Table 1

Cell site and base station solutions, by type

	Wide coverage solution	Continuous coverage solution	Targeted coverage solution	Ultrawide area coverage solution
Coverage area	8–15 km; <7,000 residents	4–8 km; 3,000 to 7,000 residents	2–4 km; <3,000 residents	500–2,000 km^2; <7,000 residents
Height	Over 30 m	12–30 m	9–19 m	High altitude (240 m–20 km)
Power	Ideally diesel generator or grid hybrid power as a large power supply is needed	Ideally solar or wind powered, as the cell site is likely off-grid	Ideally solar and lithium powered as the cell site is likely off-grid	Ideally solar and lithium powered, as the cell site is likely off-grid
Composition	Tower cell site: typically lattice, standard network equipment and augmented coverage	No-frills cell site: two sectors, compact antenna and radio frequency equipment, solar powered	No-frills cell site: omni-antenna, solar power and non-line-of-sight or satellite backhaul transmission	Dirigible or other high-altitude solution providing wide area coverage. The signal may be attenuated and have capacity limitations.
Examples of existing innovations	Not applicable as this is standard deployment	Ericsson Psi; ZTE Rural Pole	Huawei RuralSatar; Nokia Kuha; Fairwaves; NuRAN Wireless, Cavium and Keysight OC-LTE	Altaeros; SuperTower

A number of base station innovations were explored in this research (see the Appendix for more examples). The three featured in this section are particularly promising, offering streamlined technology that may make it more feasible to deploy network infrastructure in rural areas. Of the three areas of innovation we studied – base stations, backhaul and energy – base stations are the most commercially developed.

Huawei Ruralstar

The Huawei Ruralstar is a comprehensive rural mobile broadband solution supporting 2G, 3G and 4G connectivity, and with non-line-of-sight (NLoS) wireless technology that allows multi-hop backhaul. Its lightweight design — using poles nine to 24 metres tall instead of complex 40 metre towers – also significantly reduces operator CapEx and OpEx. The Ruralstar can also be deployed without the need for concrete foundations, further reducing roll-out cost and complexity, and has been designed to function using solar power.

The Ruralstar has been successfully deployed in a number of rural and remote locations, some of which have been profiled in previous GSMA case studies. This includes a deployment in partnership with MTN in Ghana[11] and with Safaricom in Kenya[12]. The Huawei Ruralstar is not featured in this report solely because it was explored in greater detail in these case studies. It is a strong and increasingly proven solution for delivering mobile broadband to those hardest to reach.

11. See *www.gsma.com/mobilefordevelopment/resources/rural-connectivity-innovation-case-study-using-light-sites-to-drive-rural-coverage-huawei-ruralstar-and-mtn-ghana*.
12. See *www.gsma.com/futurenetworks/wiki/ruralstar-huawei-safaricom-case-study*.

Examples of innovations in base stations

Ericsson Psi

Summary

The Ericsson Psi relies on a single radio connecting three antennae together. It provides the same coverage as an ordinary three-sector base station equipped with three radio units, but with less hardware, making it more energy efficient than traditional macrocell sites. The Psi can also provide enhanced coverage in comparison to similar streamlined solutions. This is due to its three tower-mounted amplifiers with frequency shifting units and advanced radio software functionality.

Innovativeness

While providing the same coverage as a larger base station, Ericsson Psi can also deliver strong mobile internet connectivity. It is quick and cost-efficient to build in rural areas and supports three standards (LTE, UMTS and GSM, but not 5G). Compared to single carrier omni or splitter-omni sites, the uplink has three times the capacity, 5dB better coverage and Ericsson claims that the Psi provides a superior user experience and higher speeds with both downlink and uplink. More types of devices can be connected and a range of services are possible, including the Internet of Things (IoT). The Psi solution has reduced wind load, making it a good option in areas subject to extreme weather conditions. The power consumption of a Psi-based site is also 42 per cent lower than a corresponding site with traditional three-sector deployment.

Commercial readiness

Several operators have already deployed the solution for infrastructure sharing, including Vodafone Egypt, Robi Bangladesh and Vipnet Croatia. Ericsson has cited a 'first-in-world' deployment of a Psi solution that is cheaper to run using solar energy than a standard diesel generator.[11]

Because it uses less equipment and significantly less power than traditional solutions, Ericsson Psi lowers both CapEx and OpEx for operators. It also requires fewer site visits for refuelling, which is an important consideration in remote off-grid locations.

With less hardware (both fewer modules and the ability to adapt the capacity of modules to demand), time to market can be reduced. Lower power consumption further reduces the cost of operation and makes solar power a realistic alternative to diesel as a primary energy source. The analysis conducted as part of this study showed an overall reduction in total cost of ownership of 34 per cent,[12] with Ericsson data showing a 20 per cent faster return on investment.

Scope for innovation in rural coverage

Ericsson Psi is well suited to comparatively low-traffic sites, but is also flexible enough to scale to meet higher usage requirements. The system can combine products from current and previous equipment generations in the same deployment, making it easy to integrate in existing networks. It can be used in multi-band configurations and support both virtualised radio access network deployment (making future upgrades possible) and active network sharing, lowering costs per operator.

The Psi solution is also well suited to rural areas where coverage and high-quality connectivity is more important than serving high capacity. The ability for operators to replace diesel generators with solar power could also result in significant cost savings for rural and remote deployments.

11. For more information, see: www.ericsson.com/en/blog/2016/10/making-solar-power-economically-viable--for-our-children
12. Analysis conducted by ABI Research.

Altaeros SuperTower

Summary

The Altaeros SuperTower is a tethered aerostatic helium-filled blimp, providing wide area coverage from a height of 240 metres, allowing fully autonomous cell site deployment. The tether of each aerostat contains integrated fibre optics and a power conductor that also provides electricity for high-capacity radio. The solution is diverse and able to incorporate any number of radio systems to integrate in existing networks. It has high gain antennae and a 5G-ready, multi-sector LTE base station. It does not support 2G or 3G, which could be a drawback in poorer rural areas where the affordability and availability of 4G handsets is limited.

Innovativeness

The SuperTower provides the wide area coverage typically found in satellite deployments. One SuperTower can cover 10,000 km^2, equivalent to over 20 conventional towers, but at a lower cost and with a much simpler installation process. It can be installed rapidly and works with existing handsets. With multiple radio units, users are not sharing one signal, making internet speeds high enough for video streaming, not just basic connectivity. Fully autonomous, the SuperTower remains in place even in winds of up to 100 miles per hour and lower-category hurricanes. The solution monitors weather conditions and automatically returns to the ground if extreme weather events are detected. It then automatically resumes flying once the adverse weather is over.

Commercial readiness

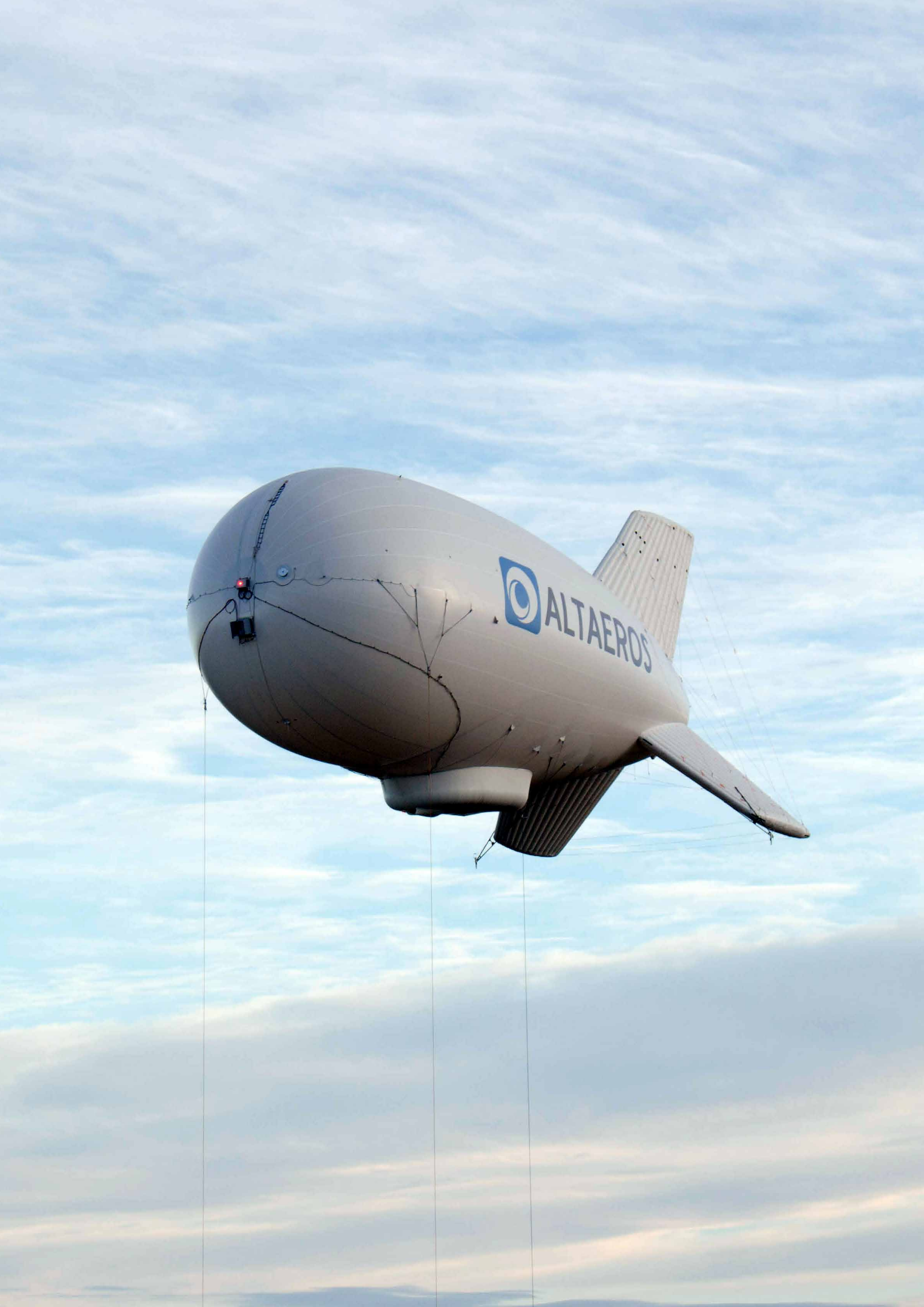
The SuperTower has been successfully trialled in Maine, USA, using an Ericsson radio system to deliver streaming video via high-speed LTE. Real-world deployments have not occurred at the time of writing, and the SuperTower has not yet demonstrated commercial sustainability. However, the SuperTower could gain traction in the sector, particularly with increased marketing efforts. Altaeros notes a potential reduction in CapEx of up to 70 per cent, compared to using existing technology to cover a similar area. The SuperTower can increase network coverage quicker and with less energy than conventional tower-based deployments. The small footprint and compact shipping further reduces costs, requiring less time and fewer resources to deploy the solution.

OpEx can also potentially be reduced. Network staff are only needed on-site for installation, with a target deployment time of one to two months, and for periodic maintenance. No full-time ground crew is required. During maintenance, the SuperTower is brought down and refilled with helium (about a one-hour process). Unlike other aerial solutions, particularly drones and aircraft, the SuperTower does not burn through fuel. Instead, 10 per cent of the helium volume is replenished per month at a cost of about USD 1,000–2,000.

Scope for innovation in rural coverage

The SuperTower can cover a large area compared to terrestrial sites: 10,000 km^2 versus the 50 km^2 that traditional macrocells can provide in very rural areas (depending on the terrain). It can be deployed quickly to provide network connectivity temporarily or long term. The aerial solution gives operators more flexibility with site placement and the potential to connect hard-to-reach areas. However, if the SuperTower is the sole connectivity solution for a major expanse, there is no network redundancy.

Altaeros has identified potentially significant reductions in CapEx and OpEx, although the OpEx savings may not be low enough for some rural deployments. The initial cost of a medium-grade system is around USD 200,000 and will require training a technical team to conduct ongoing maintenance. In addition, there are ongoing OpEx costs. The SuperTower is undoubtedly innovative and a radical shift from both the technology and deployment models used currently. It is an ideal solution for temporary coverage requirements and greenfield deployments, and promises reliability and resilience despite unfavourable weather conditions. It is 5G-ready and has significantly less impact on the surrounding environment than traditional solutions.


ALTAEROS

Nokia: Kuha Mobile Network

Summary

Nokia's Kuha Mobile Network is a community-hosted small-cell base station for rural deployments. A flexible solution based on OpenCellular principles, it supports multiple frequency bands and can connect with various backhaul solutions (backhaul transmissions are internet-based with a minimum bandwidth requirement of one Mbps). Kuha features simplified equipment and plug-and-play installation, reducing deployment times from months to days.

Innovativeness

The Kuha Mobile Network engages communities in the provision of connectivity, from set-up to deployment and ongoing maintenance. The installation experience is similar to setting up and operating a WiFi access point. Ongoing management is cloud-based, allowing the community and/or operator to enhance the quality of the experience. Cell site performance indicators can be viewed remotely and maintenance support can be accessed online. This enables immediate response to issues — a particular asset for rural deployments. The solution provides LTE coverage, with all traffic encrypted and sent over the internet via secure methods. Omni or directional antennas can be attached for optimum coverage. The base station can also connect to a local core network if needed, and public APIs enable integration with other operator services.

Commercial readiness

Trials and initial deployments have focused on rural communities in developed markets: Australia, Finland and Scotland. However, the solution will be made available to emerging market mobile operators, too. Site selection can be determined by the local community or local authority, enabling Kuha to meet the needs of less commercial areas.

Due to the simplicity of the design and installation, Nokia notes a potential reduction in capital expenditure of 80 to 90 per cent compared to macrocell solutions. One Kuha base station costs between USD 3,000 and 4,000, and can be installed and auto-connected to the operator's core network in under 30 minutes. Similarly, OpEx — primarily maintenance — can be reduced by over 75 per cent by training designated community members and leveraging remote management tools.

Scope for innovation in rural coverage

With a focus on building a simple, inexpensive and community-centric solution, Kuha is a strong candidate for rural deployments. Kuha can also interface with a range of backhaul solutions. Although it requires a continuous and reliable power supply, it can be integrated with Nokia's Fusion Grid energy solution. Using solar power and lithium batteries, this too can be managed by the local community and provides a holistic site solution (although some operators may prefer a more mainstream approach).

This community focus has drawbacks, however. Accessibility increases the risk of theft of the solution, although community ownership may mitigate this risk somewhat. Designed to be community managed, Kuha is less modular than other small-cell base stations currently being developed by other vendors. Overall, however, Kuha has much to offer operators seeking to reach remote or unconnected rural populations, or expand their network coverage.

Other considerations

3G and 4G mobile broadband have the potential to transform the lives of individuals and enhance the potential of societies and economies. However, nearly a quarter of the world's mobile phone subscribers have 2.5G handsets, and any cell site innovation must continue to meet the needs of 2.5G users with relevant products and services. This includes using VoIP over 2.5G architecture and supporting the 2.5G mobile internet experience.

This is an important consideration for solutions such as the Altaeros SuperTower and Loon, which currently only support 4G connectivity. Due to the lack of access and affordability of 4G handsets in many rural areas, closing the usage gap may be harder without 3G coverage. Similarly, focusing on 4G solutions may exacerbate the digital divide by excluding consumers who can only afford more basic internet-enabled handsets. If the coverage gap is to be closed, a broad approach is needed that considers both the supply side and the demand side.

High-altitude solutions, such as the aerostat and dirigible innovations being explored by Altaeros and Loon, as well as drones being used for emergency or short-term coverage, are undoubtedly innovative.[13] However, the impact of these solutions on connectivity still needs to be evaluated, and delivery will require engaging with stakeholders beyond the telecommunications and user communities, such as the local aviation industry, regulators and community leaders.

13. South Korean operator KT has also unveiled a 5G-based drone that scans for LTE and 5G mobile signals to identify missing individuals following disasters: www.zdnet.com/article/kt-unveils-airship-drone-for-use-in-5g-emergency-network

Innovations in backhaul

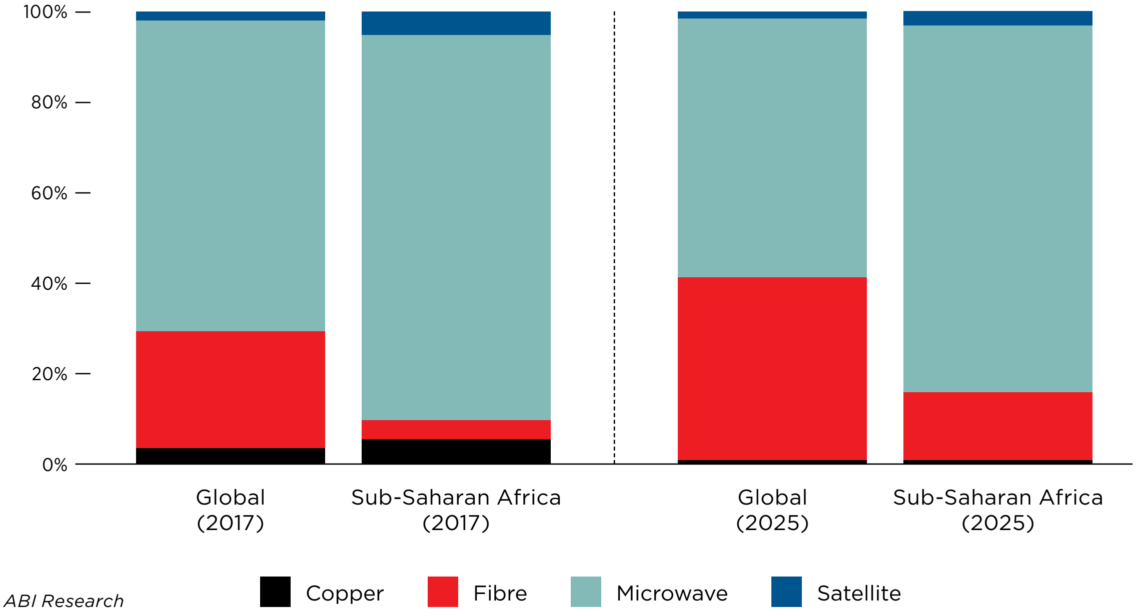
Context

Mobile data, voice calls and instant and text messages generated by end users within coverage of a cell site need to be routed to the core network in order to reach their destination. This process is called "backhaul" and comprises a range of wired and wireless technologies. Globally, backhaul primarily uses microwave frequencies or fibre optic cables. Satellite backhaul and copper cabling also represent a small number of connections, although use of copper cabling is expected to decline over the next few years.

In emerging markets, the composition of backhaul technology is different (Figure 5). In Sub-Saharan Africa and rural areas with isolated, dispersed or low-traffic populations, microwave or satellite solutions dominate, making it necessary to minimise backhaul costs. In these contexts, there is growing interest in balloon or aerial platforms, which although mainly still in the test phase, have the potential to reduce the costs and complexity of delivering rural backhaul solutions.

Figure 5

Total backhaul by method, globally and Sub-Saharan Africa (2017 and 2025)



Source: ABI Research

Innovation is required across all backhaul solutions to deliver rural coverage, particularly since the cost of backhaul in some remote areas can be double that of urban deployments. There is considerable innovation in the backhaul space, with refinements and advances being made to improve the functioning and versatility of microwave, satellite and aerial technologies. This innovation is broad, as highlighted by the range of technologies explored in this research (see the Appendix).

The innovative potential of backhaul technologies is perhaps longer term, particularly compared to base station and energy solutions, and the business models and innovations likely to have a major impact are also founded on longer term investment, particularly satellite deployments.

Examples of innovations in backhaul

DragonWave-X Harmony Radio Lite

Summary

Harmony Radio Lite uses licensed and unlicensed sub-6 GHz frequency bands to provide a point-to-point microwave solution. This reduces costs, enables NLoS connectivity, is easily deployed and provides pay-as-you-grow scalability. It provides flexible network architecture options, including self-healing mesh architecture to improve resilience — useful in rural deployments.

Innovativeness

Harmony Radio Lite makes microwave backhaul more versatile and useful. The NLoS system is less constrained by terrain and supports the bandwidth, synchronisation and latency requirements of 2G, 3G and 4G networks. It also offers improved throughput performance and reliability — important for rural network roll-out. As each Radio Lite unit has up to 230 Mbit/s aggregate capacity, it can be scaled to offer larger pay-as-you-grow network solutions. Easy to install, it is an integrated all-outdoor unit. Its network management system also allows for simple remote configuration and monitoring, which is useful in more challenging settings.

Commercial readiness

On the market since 2016, Harmony Radio Lite has the potential to significantly reduce CapEx and OpEx. A typical set-up can cost USD 1,400 compared to a traditional solution that can cost around USD 10,000. It can also use unlicensed spectrum, saving costs on spectrum licensing, and ongoing operational costs can also be reduced due to its self-healing mesh architecture.

Its plug-and-play modular system enables quick deployment and lower labour costs compared to line-of-sight solutions that require technicians to correctly align antennae. The incremental approach also allows operators to upgrade only when necessary, and the scalability of Harmony Radio Lite could drive longer term use. All these factors result in higher return on investment and can reduce total cost of ownership by over 40 per cent, especially OpEx.

Scope for innovation in rural coverage

Harmony Radio Lite is simple to install and its robust propagation properties make it suitable for a range of deployments. It works across multiple bands and can meet the needs of diverse use cases. The ability to use unlicensed spectrum could save operators significant expenditure on spectrum licences, although as some of these bands become increasingly prioritised for 5G and other services, this advantage could be lost. The design is also environmentally friendlier due to its smaller footprint and power consumption under 15 watts.

Harmony Radio Lite fully supports NLoS, making it a useful backhaul solution in environments where topography or other challenges prevent typical line-of-sight microwave deployments, simplifying network planning and roll out. Its line-of-sight capabilities also support longer distance transmissions than higher microwave backhaul solutions. Where the business case to connect rural communities is less clear, its pay-as-you-grow scalability has significant value (particularly since a single unit cannot support a large number of devices). It is also a lower risk deployment in areas where satellite or fibre networks are not feasible, and for smaller rural operators seeking to expand their overall customer base.

O3b Networks

Summary

The next generation of satellite backhaul technologies has the potential to transform rural connectivity. The Medium Earth Orbit (MEO) mPOWER solution being developed by O3b Networks appears to have a strong mix of commercial potential and the latency and capacity to deliver useful mobile internet connectivity to rural and remote areas.

Innovativeness

The O3b mPOWER constellation will leverage advanced satellite systems along with innovative ground infrastructure and network intelligence. The entire solution involves a range of new technologies and initiatives, including innovation in flat panel antennae, intelligent software (including edge computing capabilities) and managed virtual applications. This allows the constellation to seamlessly integrate with other network infrastructure, such as geostationary (GEO) satellites, fibre optic cabling and microwave technologies. The constellation will provide coverage of around 400 million km^2 with full global MEO coverage and the potential for multiple terabit throughput.

Commercial readiness

MEO is a proven solution, especially compared to (unproven) Low Earth Orbit (LEO) solutions that require more satellites to cover a similar area. Each satellite provides more than 10 times the capability of satellites currently used by O3b, and the constellation is expected to have lower CapEx compared to other LEO constellations, suggesting commercial viability. However, the GSMA is not aware of any commercial network deployment where MEO has been used to provide mobile backhaul.

The foundation of the mPOWER constellation is a collection of MEO high-throughput satellites — 16 of which were launched in 2018 and another four are planned for 2019. A partnership with Boeing will increase total satellite deployment. In June 2018, the United States Federal Communications Commission (FCC) authorised a total of 26 new O3b satellites, which could expand the constellation far beyond the satellites currently under construction.

Scope for innovation in rural coverage

The O3b mPOWER constellation has real potential and is starting from a foundation of experience. However, growing competition in the satellite space from new entrants, LEO satellites and solutions, such as high-altitude platforms (HAPs), could shift the competitive dynamics and affect the strategic plans of O3b. If successful though, the constellation could be transformational for rural coverage.

With multi-orbit resilience and intelligent beamforming, bandwidth can meet the needs of both customers and the network. Each satellite will be able to deliver up to 10 Gb of bandwidth per beam, boosting current offerings of up to 1.6 Gbps per transponder. The latency is better than GEO satellites and sufficient for day-to-day connectivity. However, with higher latency than LEO satellites, O3b may not be able to meet the needs of all applications. O3b will be providing connectivity as a service and not competing with mobile operators.

Loon

Summary

A solar-powered dirigible cell site and backhaul solution, Loon routes connectivity across a network of balloons and ground stations to provide high-quality LTE services. The balloon infrastructure is based on 4G LTE technology, with each balloon representing a "relay" in the overall network. This enables a high degree of reliability as the entire network can function autonomously and efficiently route traffic across balloons while adjusting for the motion of balloons, obstructions and weather events. Although featured here as a backhaul innovation, each balloon acts as both a backhaul component of the network and a base station.

Innovativeness

Each GPS-tracked weather-resistant balloon can cover 5,000 km^2, with hundreds of users able to connect to a single balloon. Direct connections reduce latency. Floating in the stratosphere, Loon relies on predictive wind modelling and algorithms for optimum balloon placement. Wireless signals are transmitted via the nearest balloon from a ground station and then relayed across the balloons until they reach the rural community. Loon has made extensive progress in backhaul between balloons. Recently, its team sent traffic nearly 1,000 km along a network of seven balloons and separately achieved a point-to-point link of 600 km between two balloons.[16]

Commercial readiness

Loon combines advancements in materials science, atmospheric modelling, machine learning, communications systems and more. It is currently in the trial phase, but has already made significant progress, reaching an initial commercial agreement with Telkom Kenya in 2018.[17] The CapEx and OpEx for a balloon is still being determined, with each balloon estimated at USD 40,000 (a smaller upfront investment than most cell site solutions) and around USD 73,000 per year to operate and maintain. However, the equipment for the balloon can be reused and recycled.

The ideal business model for this solution has not been determined, but balloons will likely be deployed by third parties rather than mobile operators, with the third party splitting any revenue with the operator providing the LTE spectrum. Securing regulatory approval may also be complex in some markets. Future deployments will likely improve reliability, with post-flight analysis of balloons helping to improve the design of the solution and network technology. Currently, deployments are focused on providing interim connectivity solutions as part of disaster relief efforts.[18]

Scope for innovation in rural coverage

The solution has been designed to address the challenges of providing rural coverage. The balloons have the potential to cover extensive unaddressed rural areas, providing mobile internet speeds of 10 Mbps. They can operate off-grid with renewable energy (and batteries) that can provide longer term coverage. However, given that LTE solution connectivity is limited to 4G, the solution may be less suitable in rural areas where 2G and 3G handsets still dominate.

Although Loon's long-term direction is not yet clear, both in terms of cost base and the business model, it could provide temporary or longer term coverage in extremely hard-to-reach areas. It is an exciting development and demonstrates the potential of combining multiple disciplines to address a global challenge.

16. Salvatore Candido (11 September 2018), *1 connection, 7 balloons, 1,000 kilometers: Creating a web of connectivity from the edge of space*.
17. See: www.bbc.co.uk/news/technology-44886803
18. See: https://9to5google.com/2019/05/29/loon-balloon-peru-earthquake

Other considerations

Although operators have a range of backhaul solutions to choose from, only a few are currently viable in rural areas of LMICs. These mainly include the low-frequency microwave, cellular relay and satellite technologies featured in this report.

Historically a contingency or interim measure, the new generation of satellite backhaul solutions could be a more sustainable and effective way to provide mobile broadband coverage to rural areas. However, this market is still developing and many players are in the mix, so the sustainability of satellite-backhaul business models has yet to be confirmed. Any profitable satellite solution would likely require a combination of rural, urban, institutional and wide-area mobility or tracking applications. As with other backhaul solutions, higher value applications may continue to underpin rural service provision. In this context, MEO may be the best option as GEO initiatives could focus on operating larger, high-capacity satellites while LEO firms may need to demonstrate demand for more mainstream, perhaps even urban, user adoption.

Although there has been a strong focus in the industry on satellite backhaul connecting rural areas, microwave technologies are likely to play a key role well into the future. This is likely to take several forms. In remote rural areas without terrestrial fibre optic connectivity, microwave backhaul may need to rely on point-to-multipoint solutions. In this case, links are made between senders and multiple receivers (rather than direct links between a sender and single receiver). This can make networks more flexible and robust, but may require regional or national licences in addition to point-to-point licences.

To further reduce the costs of multiple microwave links, new approaches are using 7 to 40 GHz frequency bands, which are lightly licensed, have very wide channels and can support the longer transmission distances (or “hops”) needed to serve especially remote populations. Solutions are also leveraging sub-6 GHz frequencies and unlicensed bands, deploying high- and low-frequency microwave links in tandem (to provide the best mix of capacity and reliability) or localising network traffic to reduce the costs and distances involved in data transfer.

Innovations in energy

Context

Cell site power is one of the most critical issues facing rural connectivity. Without a dependable power supply, cell sites cannot operate. Half of Sub-Saharan Africa and a third of Southeast Asia does not have access to power[19] and, in some cases, the lack of a cost-effective electricity supply (or energy storage option) is the main barrier to expanding rural network coverage. Of the three components examined here – base stations, backhaul and energy – energy can represent the largest cost increase for rural and remote deployments compared to urban roll-outs.

Rural sites are rarely connected to reliable on-grid power supplies, relying instead on expensive industrial-grade diesel generators — often one for day-to-day operation and another for backup. These are dirty and require frequent and ongoing maintenance, including monthly visits for refuelling. The diesel fuel can be contaminated by dirt or water and is often stolen, requiring some sites to provide security guards and infrastructure to protect supplies. Transporting diesel to more remote sites can also be challenging and expensive due to poor-quality roads. In many cases, these costs can make rural infrastructure roll-out prohibitively expensive.

In many deployments, power supply and storage is often the largest capital and operational outlay for operators. In Sub-Saharan Africa, diesel can represent up to 40 per cent of network OpEx. Here, a typical off-grid site may consume up to 13,000 litres of diesel a year and generate nearly 35 metric tonnes of CO_2 emissions. Reducing energy costs could play a major role in unlocking more rural coverage deployments.[20] With diesel generators accounting for much of the cost and complexity of rural sites, innovation has largely focused on reducing their role or replacing them completely with renewable energy sources and fuel cells.

Renewables are increasingly being used for cell site power, either as a single solution or in combination with a diesel generator. Combinations of renewable energy sources, such as solar and wind power, are also an option. More than 4,000 cell sites powered by renewable energy are currently deployed throughout Africa (representing around five per cent of all cell sites on the continent), coupled with a diesel generator as a main or backup power source.

Fuel cells are also beginning to gain traction (see the Appendix for examples). Hydrogen fuel cell generators using ammonia as a fuel – a commodity abundant in many emerging markets as a fertiliser product – can significantly reduce costs, maintenance and other challenges. Although the technology and supply chain are not yet established, fuel cell generators may be the least disruptive change to existing power supply chains, and perhaps the most disruptive solution to providing power to rural sites. In the next section we explore promising innovations in renewable energy and fuel cell technology.

19. Access to electricity (% of population), https://data.worldbank.org
20. GSMA (2019), *Rural Connectivity Innovation Case Study: Cellcard Cambodia and Solar Power*

Examples of innovations in energy

GenCell

Summary

GenCell is an innovative fuel cell generator solution that relies on an ammonia-based cracking approach to generate on-demand hydrogen fuel in situ, without power from an electrical grid. This telecommunications-specific product can power cell sites, but also provide power to wider village assets or services. It is more environmentally friendly than diesel generators as it emits water vapour and operates with less noise than other solutions.

Innovativeness

The GenCell uses ammonia to create energy. With a lifespan of 15 years and start-up time of under three hours, it has the potential to displace diesel generators. A particularly strong advantage is it provides a similar and familiar operational model, while tackling the many issues associated with existing generators. It could also significantly reduce OpEx, with one 12-tonne tank of ammonia providing a GenCell generator with enough fuel for a full year of continuous operation. However, the size of the tank could make it less suitable in some deployments.

The GenCell Remote Manager also allows the company to conduct remote diagnostics, including monitoring each fuel cell generator. This could reduce the need for the frequent site visits that diesel generators require, although the fuel cell component must be serviced every six months.

Commercial readiness

The latest GenCell product shipped at the end of 2018 and has attracted industry-wide attention, including a contract from an African systems integrator to include the generator in 800 base stations across Kenya. The company is still trialling the technology on test sites, but expects shipments to ramp up in 2019, and is currently showcasing the initiative to the telecommunications industry. GenCell states that using its solution instead of a diesel generator at 1,000 sites over a 10-year period could reduce OpEx on power by up to USD 250 million, and reduce an operator's carbon footprint by 310,000 tonnes.

GenCell is also in the process of assessing the ammonia supply chain in several countries. This is a particularly important process as the solution depends on a new supply chain being established. Solutions such as GenCell also highlight the potential to diversify existing business models. With lower CapEx and OpEx, a cell site generator could be used to provide power for other rural use cases, including education and health products and services. The scope of this is discussed in more detail in the Innovative business models section.

Scope for innovation in rural coverage

In settings where reliable power is often lacking, the GenCell generator could accelerate rural network deployments, especially if ammonia supply chains are established in emerging markets. Its weather independence makes it stand out from renewable products based on wind or solar, which are dependent on climatic conditions. It is a more environmentally friendly solution than diesel generators, although any ammonia run-off or discharge could have an environmental impact and affect human health.

Although the initial cost is higher than a standard diesel generator, there are likely to be significant long-term savings. The GenCell requires only semi-annual maintenance, has a low risk of theft, is modular in design and a single tank of ammonia can power a cell site for an entire year. Given that each of these areas represent major costs for operators, these savings could make rural network coverage more commercially viable.

Nokia Fusion Grid

Summary

Nokia's Fusion Grid initiative enables local power generation, addressing the lack of main-grid electricity that can limit deployments in more rural settings. The Fusion Grid can provide sufficient energy to power a small-cell base station and potentially deliver supplementary power for device charging. Assembled into a half-size shipping container, the Fusion Grid is a solar panel solution with lithium battery storage. It can provide continuous service and is intended to be low cost, plug and play, replicable and scalable.

Innovativeness

The Fusion Grid is a self-contained, holistic power solution based on the OpenCellular platform. It generates energy to power a Nokia Kuha base station and provide much-needed power to the local community. The initiative aligns power generation with mobile value-added services to support local entrepreneurship, for example, through digital marketplaces and mobile-delivered education and training. It is designed to be owned by the community, which therefore requires local stakeholders to be vested in its management and success.

The Fusion Grid has a modular design, allowing it to be rolled out incrementally to meet the needs of off-grid rural communities. The solution is also scalable, with a wider area power grid possible by connecting Fusion Grid power generator cells to support several micro-grids.

Commercial readiness

The first pilot deployment of the Fusion Grid was in Namibia in 2018, supported by a range of government, academic and private-sector partners. It is not yet a fully proven commercial solution, but was designed to minimise the CapEx and OpEx of operators as the price per kilowatt hour can be competitive with diesel generators. The total cost of the Fusion Grid power solution ranges from USD 4,000 to 7,000, although these costs can increase depending on the infrastructure and logistical requirements to deliver power to additional sites.

Given this ability to provide additional power — to charge handsets, tablets or laptops — a variety of deployment scenarios have been considered. This has included installing the Fusion Grid on school grounds or alongside rural business enterprises. As with other solutions, however, geography and customer demographics could significantly affect revenue opportunities.

Scope for innovation in rural coverage

Developed in conjunction with the Telecom Infra Project, the Fusion Grid tackles a key challenge for rural mobile deployments: the lack of a reliable power supply. As mentioned earlier, solar panels can also power Nokia's Kuha small-cell base station solution, providing a comprehensive connectivity solution for rural areas. Although a community can install the Nokia Kuha cell site solution itself, the Fusion Grid may require some specialist input.

In areas where rural communities are more self-contained, the micro-grid solution offered by the Fusion Grid could be an effective way to provide power. Where residents are more dispersed, it may not be the most effective solution since multiple units would be needed, presenting potential cost and technological limitations. Overall, however, the Fusion Grid has potential to deliver connectivity and power to rural communities, especially in combination with Nokia's Kuha base station.

PowiDian SAGES

Summary

The Smart Autonomous Green Energy System (SAGES) is a modular energy solution that allows network operators to select the most relevant components for their energy needs. Customers building a SAGES solution select from one or more energy-producing products (e.g. solar panels, wind turbines or diesel generators), one or more batteries and an energy storage solution (e.g. integrated hydrogen chain, fuel cell or similar). Remote management software can control all components of the SAGES solution, including optimising energy delivery.

Innovativeness

The SAGES solution is differentiated by its system integration and long-term hydrogen storage. While operating independently from diesel generators, it is similar in deployment as it can be integrated in existing installations. Each PowiDian solution can provide typical power of one to 500 kilowatts and can run solely from renewable sources, although this depends on the environmental conditions of the site. It has been designed to function in challenging and complex environments, and its remote software and management solution optimises the operation of the generator, forecasting power requirements, learning from historical data and fine-tuning energy production and delivery for each deployment. Environmental impacts are also reduced as excess energy is stored (and not wasted) and external noise is minimised.

Commercial readiness

The SAGES generator has the scope to reduce power-related CapEx and OpEx for operators, and PowiDian estimates it would deliver a two-year return on initial investment. Because energy is produced and stored on-site, there are no costs associated with purchasing fuel or refuelling. With fewer moving parts, the SAGES generator is more resilient and reliable than more complex power solutions. With a 15-year lifespan (estimated by PowiDian), the generator could last five times longer than a typical diesel generator and only requires an annual maintenance visit.

The solution can use both lithium ion and/or hydrogen batteries. Although hydrogen batteries are a more suitable solution for longer term energy storage, especially in the absence of renewable energy inputs like sun or wind, the solution is self-sufficient. PowiDian has formed several key partnerships, including with AEG, Saft Batteries, Siemens, EDF, Airbus and Thales. The concept was developed in the Airbus Renesta consortium, which includes Saft Batteries. It has been deployed in the Gulf Cooperation Council region in collaboration with Atlantic Telecom.

Scope for innovation in rural coverage

The SAGES solution generates power without any pollution, stores energy for long periods and can be managed and optimised remotely and autonomously. It can be adapted to the specific needs of different operators and settings, and can integrate new developments in technology. This is a powerful asset given that deployments for diverse and disparate populations are often unpredictable, however, it means that PowiDian must rely on hardware from third parties, which control the pace and pricing of its products.

Overall, the PowiDian SAGES generator could be very well suited to meeting the power supply and storage needs of a range of rural connectivity scenarios. Efforts to make the solution attractive to operators, including sharing similar deployment requirements as standard diesel generators, could help it gain significant traction.

Other considerations

The future of energy will likely see a diminished, or potentially non-existent, role for diesel generators. This could be transformational for rural deployments. As operators increasingly focus on alternative energy solutions to replace polluting, theft-prone diesel generators, the costs associated with rural deployments could go down. Lithium or lead acid storage batteries are also beginning to displace single generators on some cell sites. These are also needed for renewable energy sources, but battery theft is a growing problem.

Renewables also have a good track record in rural cellular deployments, but several challenges remain. First, solar cannot be used as the main power source in all areas due to varying sun exposure, and panels are at increasing risk of theft, which is even more damaging than diesel theft due to the significant cost of panels. However, in terms of technology performance, current solar cell technology is more than adequate to provide power to a cell site. Over the longer term, fuel cell generators are in a strong position to solve the rural power problem if suitable supply chains are established. Meanwhile, fuel cell technology has a significantly lower five-year total cost of ownership than other alternative energy solutions, even ones that rely solely on diesel generators for power. Overall, renewable energy solutions could make power supply a feasible proposition in rural areas and enable operators to reduce their environmental impact.

Beyond this, operators can continue to diversify their energy management and cost reduction strategies to minimise energy waste and power use. This includes reducing power consumption and upgrading inefficient equipment and network designs. There is also opportunity for tighter integration with off-grid power solutions. With energy supply increasingly decentralised or localised, this could accelerate rural connectivity. By co-locating energy production, energy storage, mobile services and energy provision (including USB charging points), rural coverage could become more financially viable.

Operators should also aim to coordinate their power supply efforts and investment plans with national and local energy companies. This would minimise the risk of duplicating energy provision or conflicting with their short- to medium-term energy provision plans.

Blue sky innovations

There are a number of promising future developments — or "blue sky" innovations — that promise to drive expansion of rural mobile broadband coverage or make it more effective. Although still in the proof-of-concept stage and relatively far from commercial deployment, they are worth watching.

Laser-based technologies for backhaul
Laser technology can be used to connect satellites and high-altitude platforms (HAPs), significantly reducing data costs. This is a key component of new LEO satellite systems and delivers higher throughput compared to radio links without interference. Equipment is also lighter and no spectrum licence is needed. However, it is complex to set up, requiring accurate beam-pointing algorithms and equipment, and can suffer from atmospheric attenuation.

Graphene as a future solution for energy provision
Advancements in the use of renewable energy, or new battery compositions, continue to drive progress in energy provision. One possibility is the use of graphene for rural cell site batteries. A single layer of carbon atoms in a honeycomb lattice, graphene is being explored in a variety of sectors, supported by significant research and development efforts. However, there is scope to use it to temporarily store energy (although much less than traditional batteries), allowing faster charge and discharge and potentially lower costs than traditional batteries if it can be fully commercialised. Although undoubtedly innovative, the commercial potential of graphene is not yet clear, particularly in the energy sector where advancements in battery technology could render it obsolete.

Base stations in space
UbiquitiLink aims to deploy cellular base stations in space, connecting fixed and mobile terminals using GSM and LTE directly from a large constellation of nanosatellites in a LEO. This would provide ubiquitous coverage and enable existing terrestrial systems to be extended into economically challenging areas. The solution would be compatible with existing devices and leverage partnerships with mobile operators to provide coverage in all rural and remote areas. Theoretically, the system could reduce the cost of mobile coverage per square kilometre by four times. The company plans to start with an initial periodic service with a few dozen inexpensive nanosatellites, as continuous service requires extensive investment in a larger number of them. In addition, the technology, business case and feasibility of operator partnerships are still being proven in a commercial setting, with space-to-ground testing with mobile operators planned for the second half of 2019.

Innovative business models

In addition to investing in innovative technology to reduce the cost of infrastructure, delivering mobile broadband connectivity to the 750 million individuals without coverage will require a shift in network deployment and management. This includes moving beyond the traditional business models that have enabled the roll out of networks around the globe to date.

As shown in Table 2, there are several business models that could make rural mobile broadband coverage a commercially viable enterprise.

Table 2

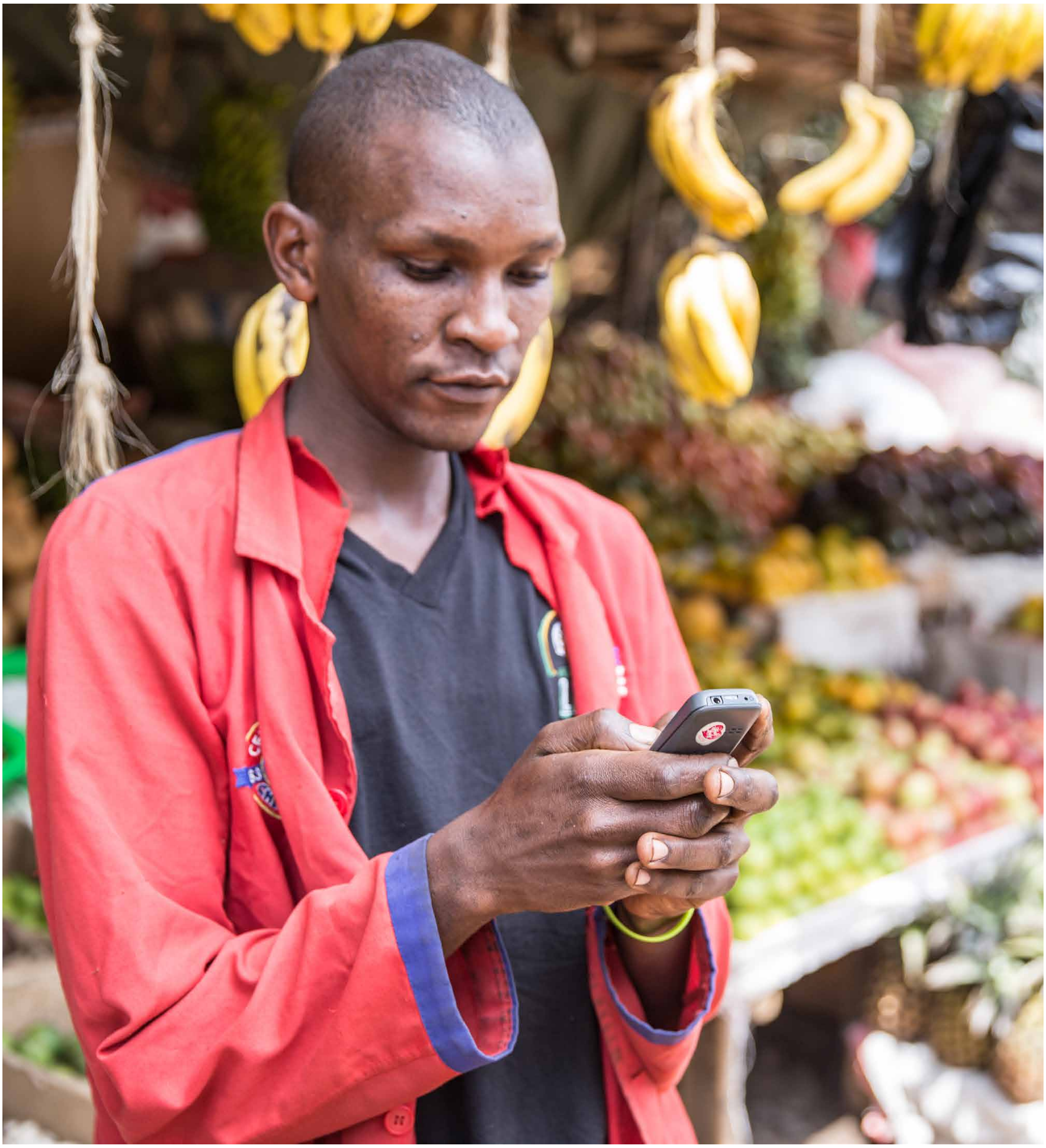
Summary of business models

	Commercial impact	Scalability	Replicability	Overall suitability for rural areas
Coverage as a service (CapEx model)	High	Medium	Medium	Medium
Coverage as a service (revenue-sharing model)	High	High	Medium	High
Community collaboration deployment model	Low	Low	Medium	Medium
Energy and connectivity business model	High	Medium	High	High

Given that every rural deployment is unique, it is unlikely that a single business model would address all the coverage issues an operator would encounter. Operators will therefore likely need to employ several of the business models in Table 2 across their network portfolios. For example, a community collaboration approach could make last-mile deployments feasible, while wider network deployments in slightly more populated rural areas could better leverage a revenue-sharing approach. In some locations, a combination of approaches may be needed in close proximity.

Previous GSMA research[21] has highlighted the value of combining network roll-out decisions with broader strategic priorities. For operators, this could include taking a more holistic view of the revenue opportunity and moving beyond voice, messaging and data to consider mobile financial services and enterprise solutions. This could reduce the initial investment risk and highlight the importance of connecting rural populations.

Aligning with non-connectivity projects and programmes could also make some deployments more feasible. This could include closer collaboration with government and other stakeholders as services are rolled out in remote and rural areas. The potential of this approach is discussed in more detail in *Model 4: Energy as business model for connectivity*.



21. See: www.gsma.com/mobilefordevelopment/wp-content/uploads/2018/07/mAgri-Toolkit-2018-Prerequsities-to-digitising-the-agricultural-last-mile.pdf

Model 1: Coverage as a service (CapEx model)

Overview

The coverage as a service capital expenditure model (CaaS-CapEx) has been the traditional deployment model for operators. It is a tried and tested approach in which the operator provides the capital expenditure, selects and secures the equipment and manages the operation and OpEx of the cell sites (often macrocell although small cells may be more relevant for rural locations), backhaul (microwave and satellite) and energy solutions (largely diesel generators). In this approach, the mobile operator is the key actor, securing finance, training personnel and coordinating logistics.

Ability to drive innovation

As the driving force of global mobile connectivity, this is an effective model, although often not in more rural or complex settings where return on investment can be lower or negative. However, an operator can still deploy lower cost, carrier-grade solutions that improve coverage and capacity at a competitive total cost of ownership. Technical features that reduce these costs include streamlined hardware, reducing the costs of electronics and minimising spend on backhaul and power. Remote and self-optimising analytics tools can also reduce OpEx.

Commercial impact

The commercial impact of the CaaS-CapEx model has been substantial. It has driven cost reductions by stimulating competition among infrastructure providers and vendors, with larger firms now competing with smaller vendors for rural and last-mile deployments. However, this model is extremely capital intensive, and in rural settings where ARPU is much lower than other areas, this issue is exacerbated. Limited revenue opportunities can disincentivise both capital and operational investment.

Scalability

This approach can be applied in any setting and scales very effectively in urban markets with dense addressable markets. It is the cornerstone of many mobile operator's operational strategies and allows the operator to differentiate its coverage, quality of service and range of services. There is also scope to combine the CaaS-CapEx model with other approaches and business models, particularly ones focusing on the needs of specific geographies or populations.

Replicability

The replicability of the CaaS-CapEx model has been proven. It has been implemented in all markets globally, although its more refined, rural-focused set-up has only gained traction in recent years. However, it has potential to provide mobile broadband coverage to some locations. This approach will likely require training operator and support staff living and working in rural communities. The model also requires increasing the amount of (and familiarity with) relevant vendor solutions, as well as additional funding from government, NGOs or other stakeholders that focus on rural communities.

Suitability for rural areas

This business model can be used to provide mobile broadband coverage in both developed and emerging market rural environments. However, to be commercially viable, operators must employ a range of cell site solutions. Existing rural macrocells, which typically have a radius of eight to 20 kilometres, would need to be complemented with other innovations, including small cells that target a village or cluster of villages.

For this model to be successful, operators must select cell site solutions that meet the requirements of the widest range of rural areas; optimise their entire approach to cell site infrastructure, backhaul architecture and energy; and engage meaningfully with local communities. This includes striving to make residents active stakeholders in coverage roll-out (to stimulate subscriptions and minimise theft and vandalism) and engaging with government and NGOs to attract financial support to connect the very last mile.

Real world example: Ericsson Psi in India

In late 2016, Idea Cellular in India opted to deploy the Ericsson Psi in its rural deployments to complement its existing GSM coverage with mobile broadband-capable, WCDMA and LTE access.

The Ericsson Psi would enable Idea to connect three antennae to a single base station radio rather than one radio unit per antenna. This design prioritises coverage over capacity, and Ericsson Psi's software capabilities also boost uplink capacity at the base station. Idea has also deployed Ericsson's microwave MINI-LINK solution. The microwave nodes are modular and capable of handling single hops as well as advanced hub sites.

For Idea, rolling out Ericsson's total site solution for mobile broadband decreased total cost of ownership. This was achieved by reducing the number of radios (from three to one), and delivering cost savings through lattice mast deployment and creating efficiencies in cell-site management.

Other markets where Ericsson Psi has been deployed include Cambodia, Indonesia and Myanmar.

Model 2: Coverage as a service (revenue-sharing model)

Overview

The coverage as a service revenue-sharing model (CaaS-revenue) moves beyond the mobile operator as a single actor in deploying mobile broadband infrastructure. Instead, a rural-focused third-party operator raises funds to deploy infrastructure in areas not covered by, and perhaps not strategically viable for, a traditional retail operator. The retail operator, which runs the core network over this infrastructure, then agrees to a revenue share with the rural operator.

Ability to drive innovation

This approach relies on strong shared incentives and extensive collaborative efforts to expand coverage. The complementary work of rural and retail operators can reduce costs and improve coverage for rural populations. Revenue sharing can also incentivise local NGOs and other actors to organise, deploy or sustain efforts to boost rural connectivity. This approach can also complement other models discussed in this section of the report.

Commercial impact

Although not fully quantified, the commercial impact of this model could be significant. Retail operators can support rural operators to deploy and operate network infrastructure for five or 10 years, while rural operators likely need between five and seven years to recoup their investment and deliver a reasonable profit. The partnership could be effective with clear and appropriate division of responsibilities and costs, and have a positive impact on the revenue of both organisations. However, the arrangement should be mutually beneficial: shorter contract periods or contract renewals could make rural operators nervous that a retail operator was going to deploy its own infrastructure.

Scalability

With the right frameworks and processes, including regulation, funding or subsidy, and effective dispute resolution mechanisms, this model can be highly scalable. Where strong shared incentives are in place, retail and rural operators can address the hardest-to-reach communities to mutual benefit. Where these incentives are weaker, rural operators can benefit from a fixed-fee agreement with a retail operator. This provides a market opportunity and revenue stream for a rural operator that may otherwise not have one, while allowing a core retail operator to increase their market share in a location that may not be strategically or commercially viable, and minimising often prohibitive CapEx and OpEx.

Replicability

This model could be replicated in other markets, although it may require alignment with broader policy efforts or initiatives to be commercially viable, such as Universal Service Funds or other subsidies. Individual operators could also take a revenue-share "lite" approach with locally managed service providers. However, as these are commercial entities, their interests and incentives may not fully align with the local community.

Suitability for rural areas

This model is aimed at emerging market rural communities, especially those without any broadband coverage. Strong shared incentives and collaborative partners can make connecting the unconnected more viable. Rural operators should be empowered to promote and sign up end users, while it is in the interests of retail operators to assist with training and guidance to ensure infrastructure is deployed and managed effectively.

The sustainability of this model is also an important consideration. The regulatory framework should clearly delineate the various stakeholders and areas of operation, and establish an arbitration process to resolve any disagreements. Furthermore, rural operators need to ensure they have a robust network plan that can withstand delays and unexpected cost increases, while retail operators must be committed to longer term partnerships with their rural counterparts. If all these elements are in place, this can be an effective route to expanding rural coverage.

Real world example: Rural Mobile Infrastructure Operators in Peru

Eighty per cent of localities in Peru lack internet coverage, most of which are rural. In response, the Peruvian Congress established the principle of the Rural Mobile Infrastructure Operator (RMIO) in 2013. The RMIOs can deploy network facilities and operate in rural areas where no mobile operator has previously deployed. The RMIOs do not have their own spectrum, numbering plans or end users, but the retail operator must use the assets of the RMIO's rural communities. The RMIOs are entitled to operate their own passive and active infrastructure and offer services on a wholesale basis to retail operators.

The overall aims of Peru's so-called "New Approach" are affordability through competitive service pricing, enabling cost-effective deployments and ensuring a community-oriented approach in which the RMIOs focus on the needs of rural populations. Telefónica has also introduced its Internet Para Todos ("Internet for Everyone") approach in Peru where it is striving to expand connectivity with an ecosystem-driven approach through the Telecom Infrastructure Project, including leveraging a revenue-share agreement with the RMIOs.

Model 3: Community collaboration deployment model

Overview

The community collaboration deployment model puts the village in the driving seat, with individuals from the local community trained to look after equipment. The equipment is a simplified small-cell solution, often designed to be easy to deploy and maintain. Site selection is also often led by the local community, so the operator must have confidence in the community's ability to install and maintain the site. More of a local model, this approach is not as comprehensive as the CaaS-revenue-sharing model.

Ability to drive innovation

This model is being deployed in developed and emerging rural markets, although many of the initial pilots were conducted in developed markets. One of these deployments is Nokia's Kuha Community Hosted Network, which is based on OpenCellular principles and local engagement and ownership. The success of this model depends on clearly defined and well understood roles and responsibilities, particularly in the local community where individuals should be actively involved in the project, and on ensuring that the equipment and set-up are tailored to the particular context.

Commercial impact

This model can be rolled out relatively easily in developed markets, but in emerging markets the lack of a reliable power supply is often a barrier. However, options are being proposed to resolve this (see Model 4: Energy as a business model for connectivity). In settings where power can be secured, costs will need to be minimised to maximise profit margin. Here, innovation is a priority: lower cost infrastructure, reliable and cost-effective backhaul, and community-driven or remote maintenance and management software, can all help to make this a more cost-effective and viable approach.

Scalability

The model is inherently scalable, as the technology is almost as simple as deploying a Wi-Fi access point. As a small-cell solution, it can be installed in a variety of locations, including public places. However, installation in more secure areas is recommended to minimise the risk of theft or vandalism. This model can also be combined with other business models and augmented with off-grid or renewable energy solutions. As noted earlier, the absence of reliable power limits the number of locations where the model can be deployed. In addition, as a focused solution, it would not be feasible for a national operator to install and manage a large number of small, non-standardised community networks.

Replicability

The model can be replicated in a number of markets since the entire solution, both the technology and approach, are designed to be as simple as possible to drive uptake. Effective marketing (such as that used in successful deployments) could encourage other communities to adopt this model. It could be particularly valuable in providing mobile broadband coverage to comparatively affluent rural communities in emerging markets, especially those currently limited to 2G voice coverage. However, again, wider replicability may be constrained by available power supply.

Suitability for rural areas

The success of this model in a rural setting depends heavily on community engagement, empowerment and partnership. The operator must work with the rural community to select an optimal site for deployment and provide suitable technology, including relevant backhaul solutions, to ensure long-term functionality. OpEx savings often come from having volunteers from the local community. The model can also have broad multiplier effects, such as helping to support businesses and building the technical skills of local populations.

Learning and shaping best practice is likely to be an important function of this model. This would include a comprehensive training programme, such as the one Nokia developed for its Kuha Mobile Network solution. If reliable power and backhaul sources are available, this model holds promise for extending coverage in rural areas, but likely at a smaller scale than other approaches, and targeted to specific communities.

Real world example: Zenzeleni Networks in South Africa

The South African initiative, Zenzeleni Networks ("Do it Yourself", in Xhosa) highlights the power of rural community efforts. Zenzeleni is a non-profit that provides affordable access to voice and data services — essential in a country where these services can absorb 22 per cent of average disposable income.[22] A Wi-Fi based internet service provider (ISP), Zenzeleni has its own internet and VoIP gateway and a billing system in Xhosa. Managed by local community managers, customers can use WiFi-enabled smartphones and tablets to access services.

Its first project was in Mankosi, a remote rural community in the Eastern Cape Province, in 2014. A cooperative of 10 local residents, the group designed 12 solar-powered mesh base stations, installing base stations on or inside their homes. This provided internet coverage to a 30 km area. It now aims to expand this coverage, providing connectivity to 300,000 people in 20 to 30 villages surrounding Mankosi. The state regulator has waived ISP licensing fees while Zenzeleni has secured backhaul internet connectivity from EastTel and OpenServe.

Although Zenzeleni has deployed a WiFi solution, there is considerable scope for operators to roll out community collaboration models, including by leveraging the innovations explored in this report. The Nokia Kuha community trials and deployments also highlight the potential for operators in this area.

22. See here: https://unctad.org/meetings/en/Presentation/enc162018p06_Esterhuysen_en.pdf

Model 4: Energy as a business model for connectivity

Overview
This model addresses not just connectivity, but also power supply, a common barrier to rural coverage and limiting factor for other business models discussed in this report. In this model, solar power, supported by lithium battery storage, provides energy to small-cell deployments. However, this is a particularly radical model as the mobile operator also functions as an energy service company (ESCO), providing end-to-end connectivity service and off-grid energy support to the wider community. Therefore, an operator would earn revenue not only from providing connectivity, but also providing energy to the local community.

Ability to drive innovation
This model requires an operator to take on a very different role. However, since power supply is a key catalyst for connectivity — and other essential products and services in rural settings — it is likely that the divisions between connectivity and power providers will blur in coming years. In this model, electrification is used as a platform for connectivity, with energy driving deployment for the local community, which subsidises connectivity costs. The operator therefore deploys both energy and connectivity technology.

Commercial impact
The commercial impact of this combined energy-connectivity approach could be dramatic, and could also stimulate more decentralised power production. Energy solutions are not inexpensive — ranging from USD 106,000 to 515,000 depending on the topography of the local area and expectations for excess energy supply — and operators may encounter difficulties securing funding for this radical shift in their business model (although funding sources could include governments, NGOs and energy companies). However, if successful, the market potential is significant and revenues are likely to increase. An operator would also need the assistance of an energy supply vendor.

Scalability
This model could be scaled up and implemented in a variety of rural village scenarios. Although the solution is still in the trial phase, initial results are promising. This approach is likely to require two to three additional years of testing and refinement, particularly to demonstrate the relevance and potential to governments and other stakeholders. The model currently has significant potential to be combined with a range of other approaches. It may be a particularly strong complement to the community collaboration model because of its role in providing community assets, and it may also strengthen the potential of both connectivity as a service models.

Replicability
This approach could be applied in a significant number of emerging market settings. Power supply and storage provides a foundation not only for connectivity, but also for the lives and livelihoods of these communities. It therefore has enormous relevance, providing an energy supply to drive mobile broadband connectivity and using connectivity to enable energy provision. With the latter, this includes using mobile technology to monitor the energy infrastructure and control access to the energy supply via mobile money payments.

Suitability for rural areas
This model is very well suited to providing mobile broadband connectivity to rural communities in emerging markets if a suitable revenue model can be reached between the operator and the local utility company. It must also be able to fully power the cell site(s) and have additional capacity to provide power to the community, including for phone charging and LED lighting solutions. The major consideration for this model is the long-term sustainability and economic viability of the solution, particularly in a real-world setting.

The cell site solution should be 2G, 3G and 4G-compliant for longevity. Renewable energy in combination with lithium batteries is likely to be the main deployment solution. More novel innovations, such as the GenCell ammonia generator, could be promising complements. Automation is also an important consideration to minimise OpEx. Although initial costs could be higher due to the extensive capital investment requirements, the scope to sell excess power alongside the core provision of connectivity offers significant revenue potential.

Real world example: Nokia Fusion Grid in Namibia

The Fusion Grid project aims to deliver connectivity and power to areas where full-scale infrastructure has not been commercially viable. An initial pilot has been undertaken in Namibia in collaboration with MTN that combined Nokia's Kuha — an easy-to-install small-cell 3G and 4G base station featured earlier in this report — with a Fusion Grid solution that powers the Kuha Mobile Network in areas with no electricity. It uses solar power as a primary energy source and lithium batteries to store energy. The pilot showed that the Fusion Grid and Kuha solution can deliver coverage up to an estimated three to five kilometres and has the scope to handle 600 consumers simultaneously.

The intention is that this off-grid power supply solution would also provide power to the wider community. The initial Fusion Grid cost approximately USD 16,000, and an additional USD 13,500 was required to develop the grid system in the village. This highlights the need to consider electrical loads and local topography when costing deployments. Total costs can vary between USD 106,000 and 515,000 depending on the electricity provided. Fusion Grid is part of a wider set of initiatives being promoted by the Namibian Government through its Off-Grid Energisation Master Plan for Namibia.

Looking forward

Innovation can play a key role in driving rural mobile broadband coverage. The cost of traditional base station, backhaul and energy solutions can prohibit the roll-out of mobile broadband connectivity to rural and remote areas. However, innovations in these areas have the potential to reduce CapEx and OpEx to the extent that rural deployment may become commercially viable.

Innovation is crucial in delivering this connectivity. In particular:

- Rural-optimised, **base station innovations** are a viable option for locations not addressed by traditional solutions. Terrestrial products, such as the Ericsson Psi (and, explored elsewhere, the Huawei Ruralstar), have much to offer here, while novel approaches like the Altaeros SuperTower have the potential to transform wide area coverage, but need to be tested at scale.

- New **backhaul** technologies, such as sub-6 GHz frequencies, Loon and the next generation of satellite deployments, could make rural mobile broadband deployments more feasible.

- Fuel-cell generators and renewable **energy** technology could considerably reduce OpEx and remove a major barrier to delivering rural mobile broadband coverage. This would, in turn, increase service adoption and strengthen the business case for operators.

Innovation can also offer solutions for the connectivity supply chain. For example, innovations like the MagiCube battery enclosure can help prevent and minimise theft and vandalism across deployments — a major performance and cost concern in many markets. More broadly, evaluating and assessing every solution operators use is important for highlighting the role of innovation in all areas of connectivity.

However, no single solution will solve all deployment challenges. Every setting has its own unique geography and population. There is no panacea to solve all rural community connectivity issues, but operators should continue to pursue innovative solutions and take a thoughtful and holistic approach, which would likely include deploying a combination of solutions across their networks.

Innovation should also not be limited to technology. To make it commercially viable to reach more remote or dispersed uncovered populations, new business models are required. This may include the coverage as a service (revenue-sharing) models that maximise rural community participation and incentivise rural stakeholder engagement. Or, ones that go beyond the provision of connectivity, such as the energy business model approach that combines connectivity with additional service delivery. With this approach, a solar-powered small-cell solution (with additional lithium storage) could provide connectivity and allow operators to sell excess power and enable device charging.

Applying innovation to mobile broadband coverage in rural areas

Operators and other stakeholders working to close the coverage gap should consider the following when exploring, deploying or managing innovation:

- **Avoid exacerbating the digital divide:** Innovations that provide 4G coverage are valuable, but the millions of individuals in rural areas who own 3G handsets must not be excluded. Also, innovation is not neutral — it is imbued with a range of social and economic characteristics both when it is created and deployed. These attributes can create, exacerbate or entrench inequalities.

- **Take a holistic approach:** There is no single solution to the coverage gap. Operators will need to combine innovations across their networks. Similarly, innovation needs to be incorporated at all levels and departments, including business planning, budgeting processes (to test and evaluate promising solutions) and business models.

- **Align with wider efforts:** Operators should engage with broader national priorities that could inform or catalyse their network roll-outs. This may reduce the risk and complexity of delivering mobile broadband to rural areas. One example may be the provision of energy in rural locations, reaffirming the relevance of the energy-as-a-business model approach.

- **Consider new ways of optimising investment in rural infrastructure:** Operators should use smart investment tools, such as the Mobile Coverage Maps developed by the GSMA,[23] to guide efficient investments, and explore the benefits of infrastructure sharing. The latter can significantly reduce operators' CapEx and OpEx and mitigate much of the associated risks of rural deployments.

- **Invest in learning from innovation:** The innovations featured in this report are promising, but not all are proven. Piloting is important, and as solutions are deployed, operators must commit to documenting and sharing what they have learned. This includes measuring not only the broad impact of innovation,[24] but also specific effects, such as environmental impact.

- **Work with policymakers to ensure that policy and regulatory efforts drive and support innovation:** An enabling policy and regulatory environment is essential to catalysing innovation and coverage. The innovations in this report also underscore the importance of broader engagement with affected industries. This may include sectors not typically involved in connectivity deployments, such as aerospace and other regulators.

The coverage gap must be closed to connect the unconnected

The mobile industry has made phenomenal progress in delivering connectivity to billions of people around the world. However, providing mobile broadband connectivity to another 750 million people demands a transformational shift in network design, deployment and customer engagement. As leaders in developing and implementing innovation, operators are well placed to drive progress in this area, connecting the unconnected and ensuring that the unprecedented potential of the internet is available to all. Policymakers, regulators, investors, the international community and other stakeholders also have a key role to play in supporting efforts to close the coverage gap.

23. GSMA Mobile Coverage Maps: www.mobilecoveragemaps.com
24. For example, see the International Development Innovation Alliance work on scaling innovation: https://static1.squarespace.com/static/5b156e3bf2e6b10bb0788609/t/5b1717eb8a922da5042cd0bc/1528240110897/Insights+on+Scaling+Innovation.pdf

Appendix: Other examples of innovations

The below table provides additional examples of innovations in infrastructure that could potentially impact the spread of rural mobile broadband coverage; it is not intended to be an exhaustive list.

	INNOVATION	DESCRIPTION	KEY FEATURES
Base station innovations	**FairWaves**	A single, self-contained cellular base station (UmSITE) powered from off-grid energy sources, such as solar power. It relies on a distributed (VoIP) core and has a flat IP architecture and software-centric design that enables flexibility. Available to purchase from FairWaves.	Streamlined base station provides low total cost of ownership; software-based communications and IP-based technology further simplify the solution.
	Gilat	The CellEdge Software-Defined Radio solution bundles a small cell for 3G/4G technology with a cellular backhaul over satellite solution. Available for purchase.	Small cell integrated in the solution and optimised via Gilat satellite backhaul.
	Huawei RuralStar	A comprehensive solution suitable for a wide range of scenarios. Non-line-of-sight wireless technology supports multi-hop backhaul. The RuralStar uses poles (9–24 metres in height) instead of a traditional tower (40 metres). Uses solar power rather than a traditional diesel generator.	Pole design enables a competitive low total cost of ownership, including concreteless foundations that allow the site to be moved at a lower cost. Renewable energy supply and low-cost backhaul further reduce costs.
	NuRAN Wireless, Cavium and Keysight OC-LTE	Open-sourced outdoor base station that serves as either a network-in-a-box or an access point. Runs entirely on solar power. Requires longer term testing.	Low total cost of ownership; open-source approach and modular design increase its flexibility.
	Parallel Wireless vRAN Solution	Offers an all-in-one approach for virtualising and abstracting Multiple Radio Technologies, and is self-configuring, self-optimising and self-healing. Commercially deployed; selected in 2016 by Telefonica for deployments in dense urban and remote areas.	All-in-one approach with network virtualisation can provide 3G and 4G connectivity to rural areas.

	INNOVATION	DESCRIPTION	KEY FEATURES
Base station innovations	**Vanu Community Connect**	Vanu's Community Connect is a low-power small-cell base station able to provide targeted coverage with lower OpEx. Numerous deployments in rural and emergency contexts.	Tailored to rural deployments with lower power requirements.
	Vivada	Commercially available from World Telecom Labs. Turnkey solution for the delivery of voice and data connectivity to remote and rural locations.	Low cost and low power with flexible backhaul options.
	ZTE Rural Pole	Highly integrated design with a smaller footprint. Includes a support relay and WiFi or microwave backhaul. Relies on a solar panel and battery for power supply. Commercially available, ZTE is continuing to refine technical and operational elements.	Pole design enables a competitive low total cost of ownership; renewable energy supply.
Backhaul innovations	**Astranis Satellite**	Micro-geostationary (GEO) satellites for GEO orbit using a software-defined radio system. Tested in Alaska in 2018 with high-definition video sent between base station and satellite.	GEO orbit reduces satellite count, but high latency could make it less suitable for some use cases.
	Ericsson MINI-LINK LH	Long-haul microwave backhaul increases the speed and range of data transfer possible. Particularly well suited for different terrains. Commercially available.	Single cabinet solution reduces footprint and offers high-speed transmission.
	ip.access	Optimised satellite backhaul delivering improvements in voice and data services. Tests in Indonesia found cost savings compared to non-optimised satellite backhaul.	Offers lower latency and better content availability for subscribers, and reduces costs.
	Intelsat	Packaged solution offering installation and management of satellite backhaul and power components, solar panel, RAN and supporting infrastructure. Selected by Ugandan Communications Commission in pilot to connect remote areas.	Turnkey solution delivered at a fixed monthly cost, eliminating upfront equipment and training costs.
	LeoSat	Satellite constellation in LEO (approximately 1,400 km above the Earth). Looking to launch two satellites in 2019 and expects full global coverage by 2022.	Lower latency, able to serve multiple equipment solutions used by satellite customers.

	INNOVATION	DESCRIPTION	KEY FEATURES
Backhaul innovations	**Mynaric Satellite**	Laser communication to transmit data for aerospace communications. Will not require licence or ITU frequency coordination, and has over 48 times additional bandwidth than existing radio frequencies. Yet to be deployed.	Laser communication and high-capacity bandwidth. Line-of-sight limitations, but functions over long distances.
	OneWeb Satellite	LEO Ku-band satellite constellation providing connections with lower latency and higher speeds. First group of satellites launched in 2019.	LEO and low latency increases usefulness of satellite backhaul for rural deployments, but large constellation needed.
	Phasor	Electronically steered flat panel antennae, allowing large data transfer and smaller-sized solutions. Can connect to satellites in all three orbits (LEO, MEO, GEO). Secured commercial contracts in 2018.	Smaller and easier to install antennae, which do not need to be moved to capture a new signal.
Power innovations	**ClearBlue Technologies**	ClearBlue provides the Smart Grid Power Pack for operators — a preconfigured, prewired power system that includes a cabinet, power source (solar, wind, diesel generator, batteries) and controller. ClearBlue also provides a cloud-based product to optimise power generation and use. The Power Pack is currently available on the market.	Pre-configured power packs and advanced controller to optimize energy generation and use.
	Energy Vision	Energy Vision's Clear Power as a Service product provides energy-as-a-service to operators with both off-grid and on-grid units. These consist of several energy sources: solar, diesel and wind turbines. It also provides a power interface unit. Currently available on the market.	Technology-agnostic power generation, rural application-specific solutions.
	Huawei PowerStar	Can power multiple radio access technologies with power-saving functionality. Supports intra-site and inter-site cell sleeping. AI-based software application allows for further power optimisation. Has been deployed in numerous rural settings.	Lower total cost of ownership, power efficiency optimisation.
	OMC Power	Smart mini-grids for consumer and industrial power, technology agnostic, and uses whatever energy source is widely available on the local market. OMC can also manage the power supply for operators. Several mini-grids are in operation.	Mini-grid operator for rural areas, but cellular use case depends on OMC footprint.

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