Connected Society

Rural connectivity innovation case study:

Using light sites to drive rural coverage - Huawei RuralStar and MTN Ghana

Authors:

Madeleine Karlsson, Insights Manager – Connected Society
Genaro Cruz, Senior Market Engagement and Advocacy Manager - Connected Society

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GSMA Connected Society

GSMA Rural innovation case study: Using light sites to drive rural coverage - Huawei RuralStar and MTN Ghana

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Executive summary

Mobile broadband (3G or 4G) coverage in the developed world is now almost ubiquitous. However, just over 1 billion people live in areas that are not covered by mobile broadband networks, with more than 95 per cent of them living in low or middle-income countries. This is primarily driven by economics: the uncovered live in areas that are typically both more expensive to supply and also have lower levels of demand.

Some of the most significant expenses that operators face in providing users with mobile coverage is the cost of deploying and maintaining cell sites in rural areas. Through analysing MTN Ghana's deployment of Huawei's RuralStar solution, this case study looks at the potential of a lightweight rural infrastructure option to extend rural coverage in a commercially sustainable manner.

Huawei's RuralStar is a lightweight rural network coverage solution supporting 2G, 3G and 4G connectivity. Our analysis identifies three clear potential use-cases for deploying RuralStar, depending on conditions of, for example, population distribution, the terrain, and the existing coverage footprint.

Key facts and findings

The mobile internet coverage and usage gap

4bn NOT CONNECTED to mobile internet worldwide

1bn lack mobile broadband coverage

In Ghana

4.44m people are NOT COVERED by 3G networks

Operators' largest costs

- Site deployment
- Backhaul
- Power

Light site-solutions

Can have a significant positive impact on **mobile coverage**[1]

Light sites + Accurate geographical mapping of uncovered populations = Potential for higher profits and incentives to increase mobile coverage

Light sites, like RuralStar, can positively affect network planning:

Alternative to macro-sites
Increase return on investment in low-density population areas

Extend network coverage
In areas where macro-sites are unprofitable

Densify the network
where coverage is patchy ('white spots')

RuralStar has

30% of the CapEx **14%** of the OpEx

on average, compared to a typical macro-site[2]

MTN Ghana has deployed

300 RuralStar sites to date[3]

to help them extend rural coverage cost-effectively

1. According to our coverage simulation results for Ghana.
2. Exact expenditure savings depending on conditions. Calculations based on cost figures from MTN Ghana's RuralStar deployment.
3. As of October 2018.

1. Background and context

1.1 Rural coverage: The need for innovation

1.1.1 The economic difficulty of providing rural and remote areas with mobile broadband coverage

At the end of 2017, the number of people subscribing to mobile services crossed five billion (or 66 per cent of the global population) for the first time. 3.3 billion of them were connected to mobile internet, a figure that has nearly doubled in the last five years.[4] This growth in access has brought a range of new jobs and services, information and opportunities to billions of people, spurring economic growth in the process.[5]

While this is hugely positive, more than four billion people remain offline, almost one billion of whom live in an area not covered by a mobile broadband network (3G or 4G).[6] Progress is being made: the significant investments from mobile operators and the wider industry mean that the percentage of people uncovered has halved since 2014 (from 25 per cent to 13 per cent) and 800 million more people are now covered by mobile broadband networks.[7] However, while coverage in developed markets is now largely ubiquitous, many developing regions have large gaps. Over 95 per cent of those lacking mobile broadband coverage live in low- or middle-income countries.[8]

For mobile operators, the market-led business model has proven effective in expanding coverage to current levels. However, the vast majority of the 13 per cent of people globally who are currently uncovered, live in rural locations with low population densities, low income levels and weak or non-existent enabling infrastructure (e.g. roads or electricity). All these characteristics negatively influence the business case for mobile network expansion, in terms of higher capital investment costs per site, higher operating costs and significantly lower demand (which translates to lower average revenue per user (ARPU)).[9] As a result, connecting this group is principally an economic - as opposed to a technological - challenge.

4. GSMA Intelligence (Q4 2017). At the end of 2012, there were 1.8 billion mobile internet subscribers around the world.
5. A wide range of literature deals with the topic of the economic impact of internet access. See for example: Changkyu Choi (2009); C.Z.W. Qiang, C.M. Rossotto (2009); Deloitte (2012); 'What is the impact of mobile telephony on economic growth? A report for the GSM Association'; ITU (2012), "The Impact of Broadband on the Economy: Research to Date and Policy Issues".
6. GSMA, State of Mobile Internet Connectivity 2018 (Aug 2018); GSMA Intelligence (Q4 2017).
7. Ibid.
8. GSMA Intelligence (Q4 2017).
9. GSMA, Unlocking Rural Coverage: Enablers for commercially sustainable mobile network expansion (June 2016).

1.1.2 The role of innovation in increasing coverage

Bringing mobile broadband coverage to underserved areas will require one (or both) of the following:

1. A reduction in the cost of supplying coverage; and
2. An increase in demand for mobile services from those living in currently uncovered areas.

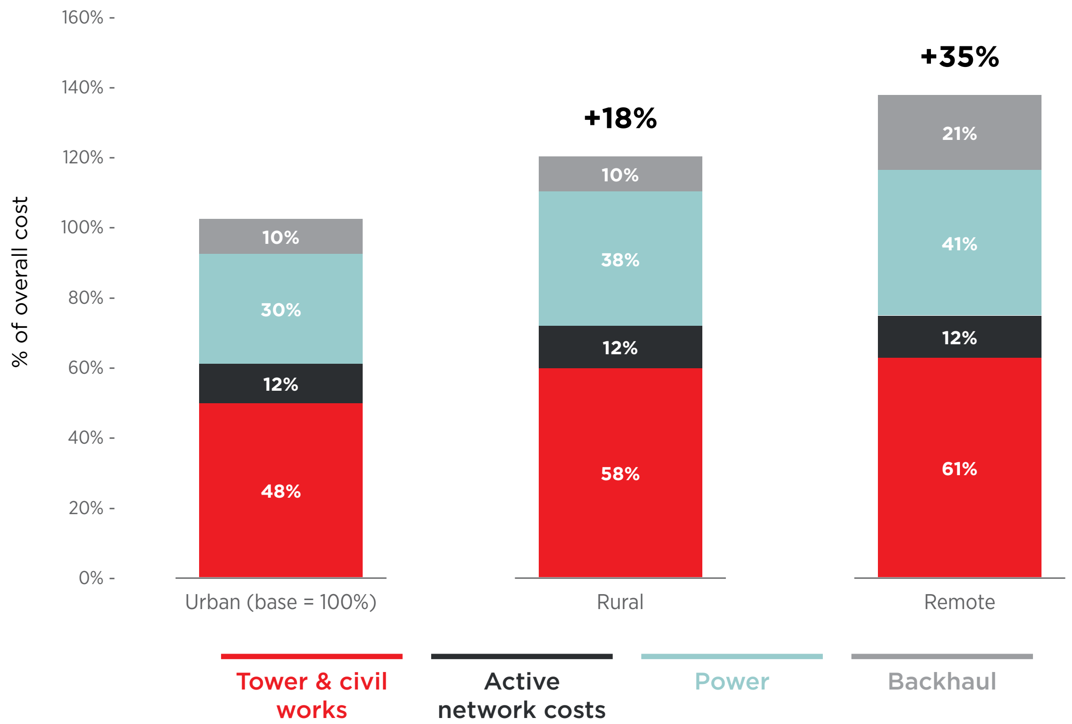
At present, the lower demand for mobile services that exists in rural and remote areas - driven by lower population density, lower incomes and lack of awareness or understanding about the benefits of mobile internet – is a critical barrier to building a commercially sustainable business case for expansion. Revenues per site are typically 80 per cent - 90 per cent lower in rural and remote areas compared to urban areas.[10] There are various complex reasons for this - covered in other GSMA publications - which if addressed could drive an increase in coverage.[11]

This case study series - 'Innovations in rural coverage' - focuses on the supply side of the equation, profiling innovations with the potential to bring down the cost of increasing coverage to currently underserved areas.

Figure 1

Source: GSMA Analysis

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



GSMA generalised benchmarks. Rural areas are defined as low-density areas where agriculture dominates and with basic infrastructure. Remote areas have even lower population density and extremely limited infrastructure.

Active network costs refer to the 'active' elements in the mobile network infrastructure such as the Radio Access Network (RAN) or network roaming. They can be usefully contrasted with 'passive' elements such as the cell towers. Active costs are largely consistent between urban, rural and remote areas.

10. GSMA analysis (global benchmarks).
11. GSMA, Tanzania rural coverage pilots: Performance report (Jan 2018), GSMA, Triggering mobile internet use in Cote d'Ivoire and Tanzania (July 2018); GSMA, Triggering mobile internet use among men and women in South Asia (Nov 2017).

As Figure 1 demonstrates, the higher cost of providing coverage in rural and remote areas is primarily due to:

1. **Tower and civil works:** Typically, the cost of installing and maintaining a cell site in rural areas is higher due to the lack of existing infrastructure and the more challenging terrain. For example, transportation costs are significantly higher. In addition, rural locations are often more prone to political or security issues.
2. **Backhaul:** The connection of a particular cell site with the core network is typically accomplished through fibre or microwave networks. However, this can be logistically impossible in some rural and remote locations, meaning it is necessary to use costly satellite backhaul.
3. **Power:** Base stations require significant amounts of energy to function. Power represents a substantial proportion of the on-going costs of running a site. In remote and rural areas, power costs are higher as connection to the electrical grid is unlikely to be available and alternatives are more costly.

1.1.3 The use of macro-sites and small-sites to cover rural areas

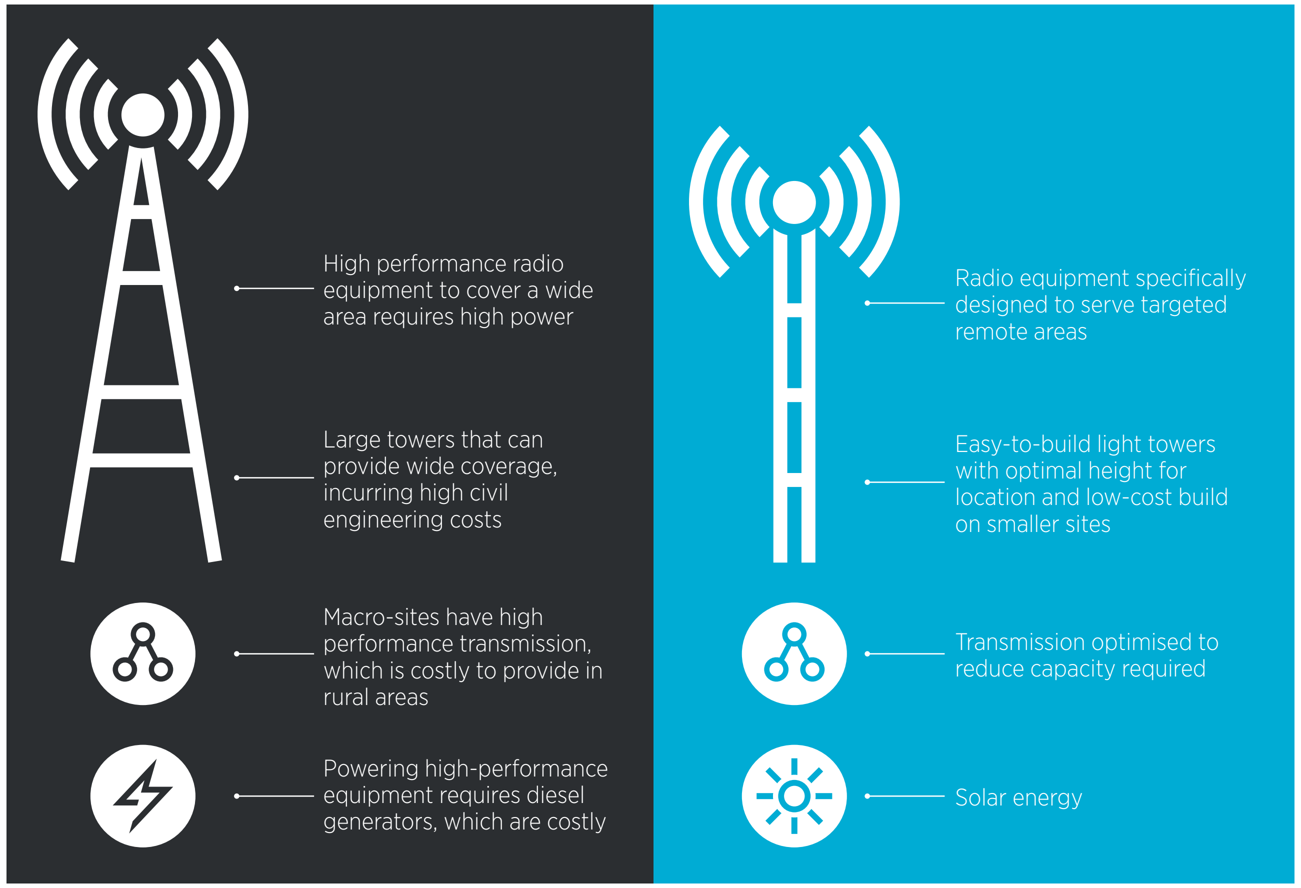
In order to extend network coverage in rural areas in a sustainable manner, the capital (CapEx) and operational costs (OpEx) need to be lowered to ensure there is adequate return on Investment (RoI). The traditional approach of deploying macro-sites that provide wide coverage and have large upfront- and operating costs is not always well suited to cover some rural areas, where villages are scarcely distributed and have low population density. In contrast, using a combination of lightweight infrastructure and accurate population mapping of rural settlements without mobile coverage allows operators to specifically target isolated settlements. This can increase the RoI of network expansion and unlock the business case for connecting remote communities. The choice between using macro-sites or lightweight infrastructure is however always best informed by the population distribution of the area in question – in some cases, it is more beneficial to cover a wide area, and in others deploying lightweight sites, with more focussed coverage, in specific spots is more effective.

As described in Figure 2 below, an alternative to macro-sites are small lightweight sites that utilise radio equipment tailored to cover specific smaller areas, and a lighter tower construction with optimal height to cover the targeted area. The backhaul to connect to the internet can also be optimised to reduce the required capacity and costs (especially in the case of satellite backhaul). As a result, these lower-capacity, lighter sites run on less power and can be designed to be compatible with alternative power solutions, such as solar energy, avoiding the reliance on costly diesel generators while also having environmental benefits.

Figure 2

Source: GSMA Connected Society analysis

Traditional rural site build compared to lightweight rural infrastructure site



In combination with accurate mapping to identify and target rural settlements without coverage, the above features make the lightweight site considerably more adept to serve rural areas in comparison to standard macro-site solutions. The trade-off of the smaller sites is their lesser coverage radius – whereas a macro-site is able to cover 10km on average, the small site can only be expected to cover 3-5km. However, both types of cell sites are effective in providing coverage in different scenarios. As such, the macro-site is most suitable in locations with high population density, where its wide coverage radius can connect people with continuous coverage. In contrast, in areas with lower population density and/or locations that have patchy coverage, the wide coverage radius of macro-sites is wasted and cost-ineffective. In these areas, targeted deployment of light cell sites make more sense. Considering the selection of the cell site location, and tailoring the type of network infrastructure accordingly, are thus key elements and crucial for minimising the cost per person covered.

The GSMA Mobile Coverage Maps

The GSMA Connected Society programme has developed a tool that will help mobile operators and partners to estimate the precise location and size of uncovered populations. The GSMA Mobile Coverage Maps allow users to:

- **Gain an accurate and complete picture of the mobile coverage** in a given country by each generation of mobile technology (2G, 3G and 4G);
- **Estimate the population living in uncovered or underserved settlements** with a very high level of granularity (e.g. small cities, villages or farms) ; and
- **Search for uncovered settlements** based on population size.

The GSMA Mobile Coverage Maps can aid operators (and others) to improve the efficiency of their investments. Using the maps, our analysis suggests in a given market millions of (uncovered) people could be reached in a commercially sustainable way. The tool can also help other stakeholders – including governments, NGOs, and private companies that rely on mobile connectivity – to strategically target their activities, by helping them identify the locations with existing coverage. Given the numerous ways in which organisations are using mobile technology to improve lives, this holds potential for significant social impact.

A number of maps are already available with further countries to be added in the near future.

To access the Mobile Coverage Maps, please visit: www.mobilecoveragemaps.com.

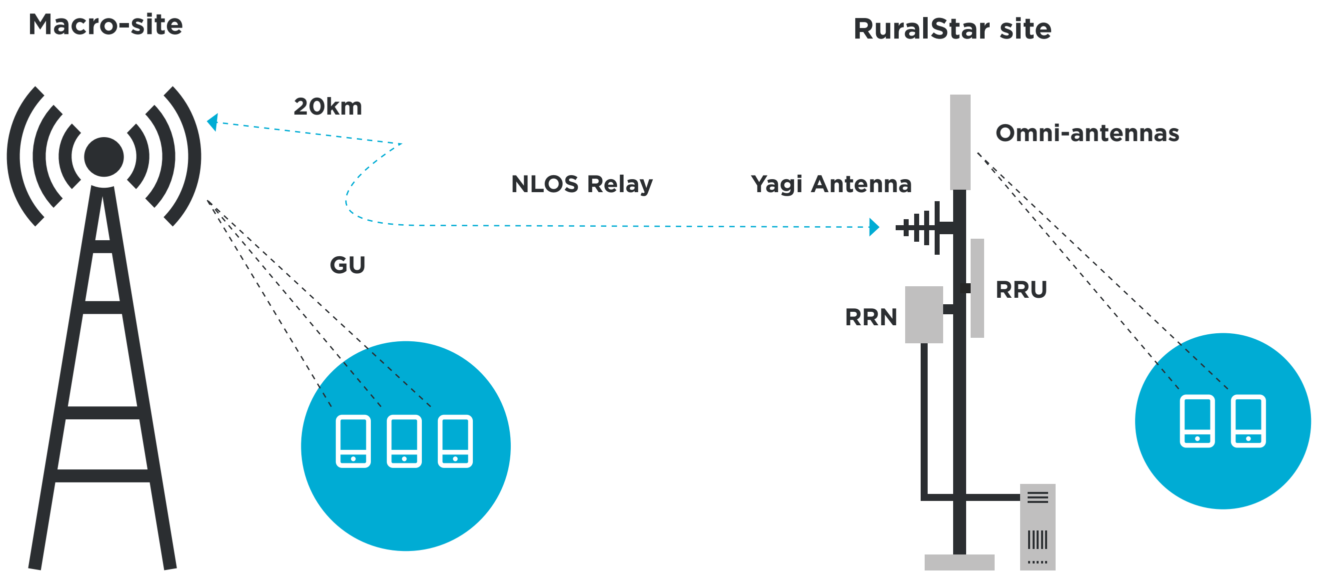
1.1.4 Huawei RuralStar for rural mobile internet coverage

Huawei is addressing the rural connectivity challenge with rurally adept infrastructure products, and have developed a range of innovative infrastructure solutions to facilitate mobile operators' deployment of cell sites in the emerging market context. One such solution is *RuralStar.*

RuralStar is a lightweight rural network coverage solution supporting 2G, 3G and 4G connectivity. Rather than using satellite or microwave backhaul, RuralStar introduces a more affordable non-line-of-sight (NLOS) wireless backhaul technology with 10-40km reach[12] via a cellular relay, linking connectivity from a 'donor' site (i.e. an existing macro-site). This is a useful function in emerging market geographies with e.g. mountainous, dessert, or island terrain. The NLOS backhaul also makes it possible to build the base station on guyed poles (9-24m height), rather than on high towers, which makes the site lightweight, reduces its physical footprint to 2m x 3m, and allows for concrete free foundations. Therefore for the site build there is no need for machinery and only a small truck is required for transporting the equipment, which reduces cost and time in the deployment process.

Figure 3 Source: Huawei

Overview of the Huawei RuralStar solution



GU *= GSM, UMTS*
NLOS *= Non-line-of-sight*
RRN *= Remote radio nodes*
RRU *= Remote radio unit*

12. The reach of the backhaul is dependent on the frequency and geography characteristics.

Image 1 Source: Huawei

Images of MTN's RuralStar sites in Ghana

The RuralStar technology consumes less power than standard cell site solutions, with lower power draw of the base band- and radio units compared to standard macro-sites found in the industry. This is made possible by a new type of power amplifier design and the breadth voltage only requires a power consumption of around 200-300W. It can thereby rely on solar panels instead of costly diesel generators in off-grid areas, which both eliminates fuel costs and reduces CO2 emissions.

To further improve performance, Huawei is currently refining the technology of RuralStar. Key improvements of the upgrade include:

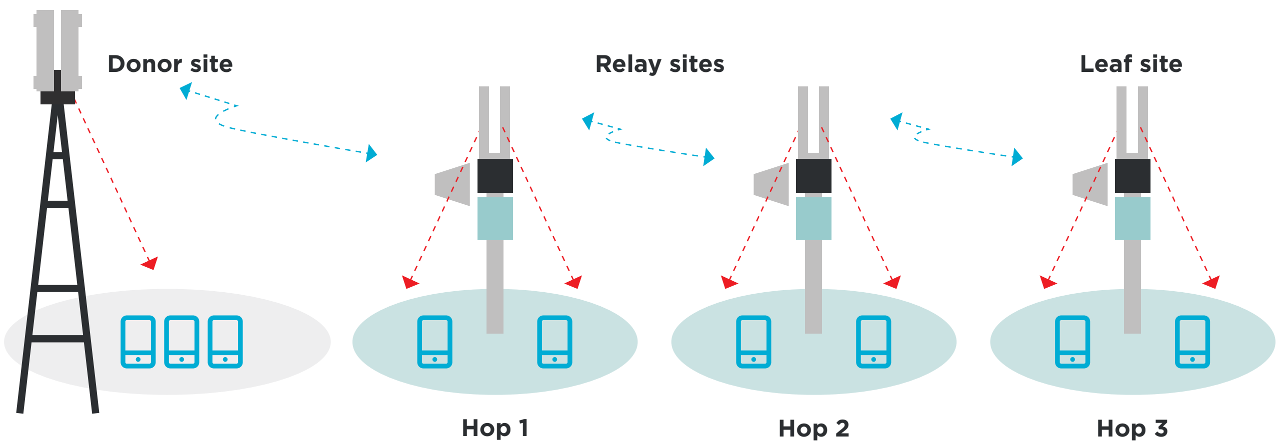
1. **The multi-hop relay technology:** RuralStar 2.0 is able to reach further distances, through added 'hops' between multiple RuralStar sites from the donor site. The donor site employs a high tower with high propagation ability. With the NLOS relay, the single-hop from the donor site to the first RuralStar site can be 10-40km. From there, multi-hops to two additional RuralStar sites is possible, reaching 5-10km each between the sites (the last site in this sequence is referred to as the 'leaf site'). As a result, the reach of the wireless backhaul link from the donor site can be extended to 60km.[13]
2. **Support of additional protocols:** In RuralStar 2.0, 3G connectivity is provided through GSM (G) and UMTS (U) protocols, and 4G connectivity is possible through LTE (L) in the single-hop from the donor site. In RuralStar 1.0, only GU protocols are supported.
3. **Standardised packaging:** RuralStar 2.0 comes as a packaged solution, allowing for easier and more affordable production and less risk of hardware deviations. Such standardised production ensures full compatibility of all components.

13. In Ghana, RuralStar 2.0 was deployed, but without the multi-hop feature.

Figure 4

Source: Huawei

RuralStar 2.0 typical application scenario, with the multi-hop relay function explained.



As indicated in Table 1 below, RuralStar can offer mobile operators a cost-efficient and streamlined solution for rural network coverage in emerging markets. On average, we estimate RuralStar to have c. 30 per cent of the CapEx and 14 per cent of the OpEx of a typical macro-site.[14]

Table 1

Source: Huawei

Cost and coverage comparisons of RuralStar relative to typical macro-site[15]

	CapEx	OpEx	5-year Total Cost of Ownership (TCO)	Signal reach (radius)
Typical macro-site	100%	100%	100%	8-10km
RuralStar	31%	14%	23%	3-5km

To date, RuralStar has been deployed by more than 50 operators in 24 countries across the world. In recognition for how the solution has solved common issues in transmission, infrastructure, base station design and energy consumption, Huawei won a GSMA 'Best mobile innovation for emerging markets-Global Mobile Award' at Mobile World Congress 2018 for RuralStar.[16]

14. Calculations based on typical macro-sites and RuralStar deployment and operation costs
15. Note: the indicative cost comparisons provided in this figure are general estimations – costs will vary between markets.
16. GSMA 2018, "Best Mobile Innovation for Emerging Markets - Huawei for RuralStar Connectivity Solution".

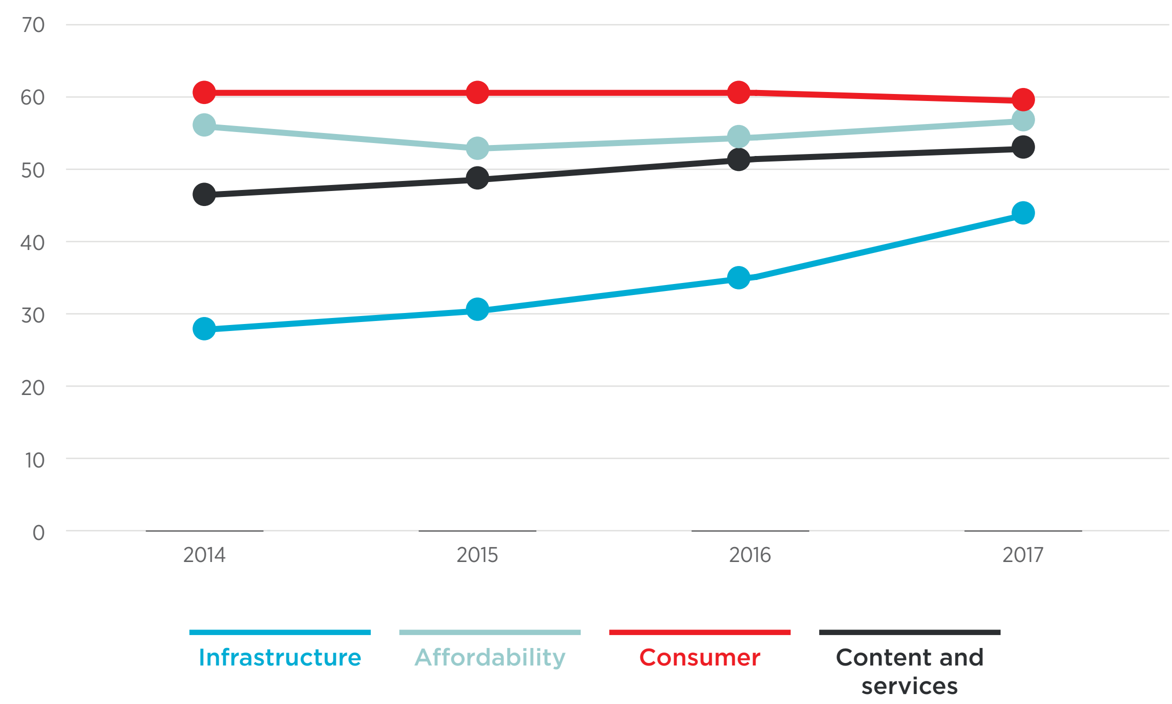
1.2 The rural connectivity landscape in Sub-Saharan Africa and Ghana

Rural connectivity expansion is a key issue in Sub-Saharan Africa, including in Ghana. In Sub-Saharan Africa, mobile broadband access is low: 36 per cent of the population are not covered by a 3G network and only 21 per cent are subscribing to mobile internet services.[17] A major reason for this is the fact that 60 per cent of the region live in rural areas.[18] The GSMA's Mobile Connectivity Index measures the performance of 163 countries against the four key enabling factors for mobile internet connectivity: infrastructure, affordability, consumer readiness, and content. It has data covering the years 2014-2017. Ghana's index score is 53 out of a possible 100. While the infrastructure score for Ghana has improved over the past four years it is still the weakest of the four enablers.[19] Universal mobile broadband connectivity is a challenge, partly due to the country's large rural population, (45 per cent live in rural areas),[20] and prevalence of poverty (particularly in Ghana's northern and rural areas).

Figure 5

Source: GSMA Connected Society and GSMA Intelligence 2018

Ghana's Mobile Connectivity Index scores, 2014-17



17. GSMA Intelligence (Q4 2017).
18. World Bank (2017).
19. GSMA Mobile Connectivity Index (2017)
20. World Bank (2017).

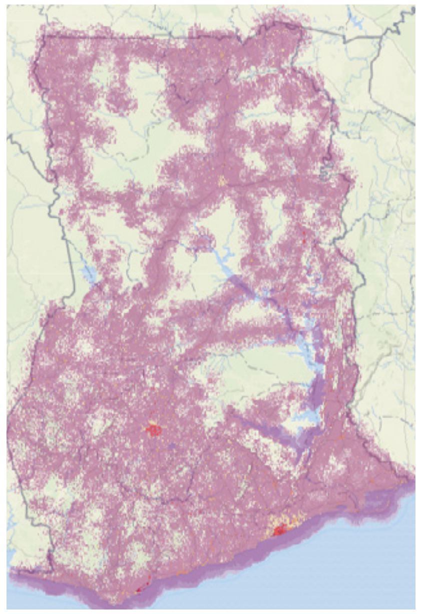
Despite having one of the highest GDP per capita in West Africa (at $1,641 in 2017) and having seen fast economic growth since the 1990's,[21] the success story in poverty reduction only holds true in the southern and urban areas of Ghana. There is a stark contrast between rural and urban households' living conditions - whereas the average poverty rate is 11 per cent in cities, the equivalent figure is 38 per cent in rural areas.[22] Extending Ghana's mobile broadband connectivity would thus require rurally tailored and cost-effective approaches that cater for lower-income end-users.

As illustrated by the maps in Image 2 below, coverage is denser in the southern regions while some of the more mountainous and heavily forested locations of rural Ghana remain uncovered by mobile networks, particularly for 3G and 4G. Where rural network coverage does exist, it often is not continuous, which means that mobile internet coverage can be patchy and many settlements in between the scattered coverage are left without mobile internet access. Ghana requires densification of mobile networks in order to have better quality coverage and performance in rural areas. In this regard, carefully targeted deployment of light cell sites that can provide cost-effective coverage could be a suitable solution.[23]

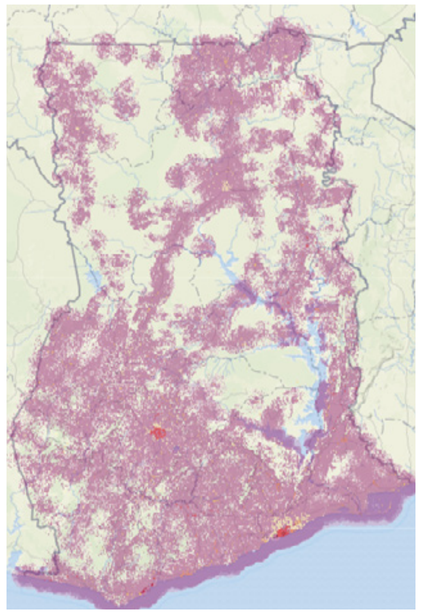
Image 2

Source: GSMA Mobile Coverage Maps

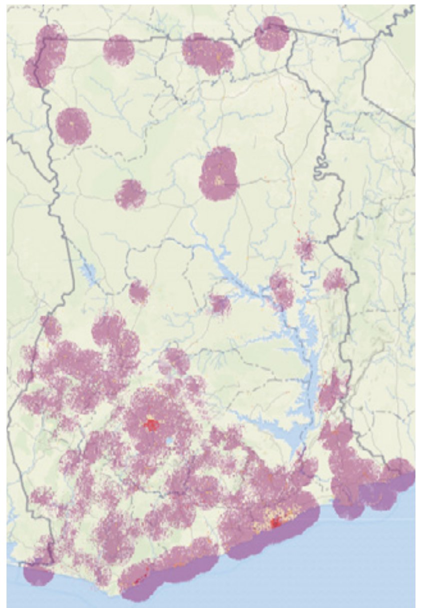
Maps of Ghana's 2G, 3G and 4G mobile network coverage



Map A: *2G coverage*



Map B: *3G coverage*



Map C: *4G coverage*

21. World Bank (2017).
22. Unicef, University of Sussex, Ashesi, The Ghana Poverty and Inequality Report 2016.
23. The coverage situation and suitable measures for extending rural coverage in Ghana is further elaborated upon in the analysis in section 3.

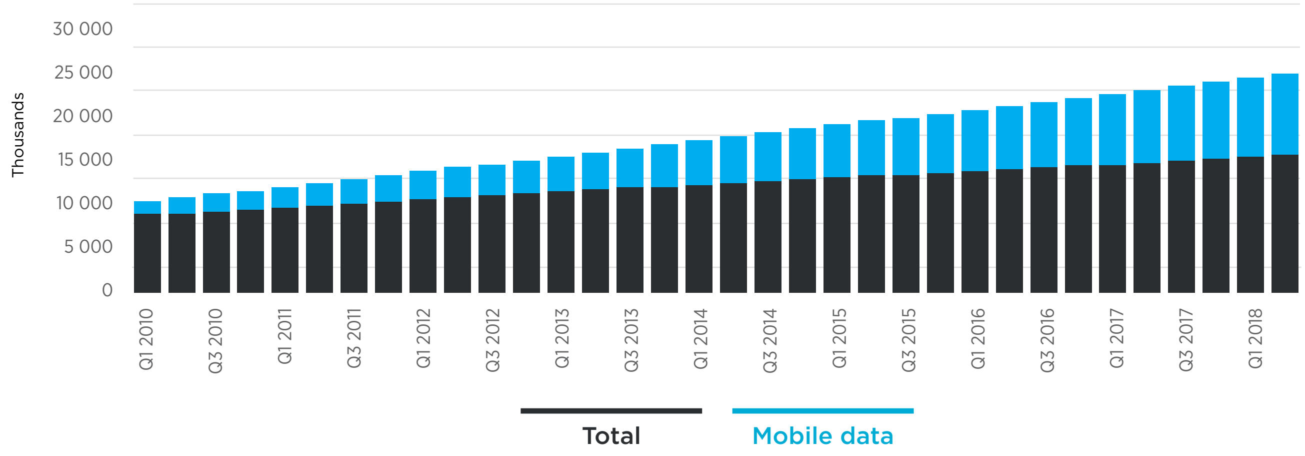
1.2.1 Ghana's mobile market

The largest mobile operator in Ghana is MTN (48 per cent share of voice connections), followed by AirtelTigo (27 per cent) and Vodafone (24 per cent).[24] Based on GSMA estimations, the number of mobile subscribers in the market have increased fivefold over the past ten years, and today Ghana has close to 16 million unique mobile subscribers – equivalent to 53 per cent of the population, which is above the average of 44 per cent for Sub-Saharan Africa.

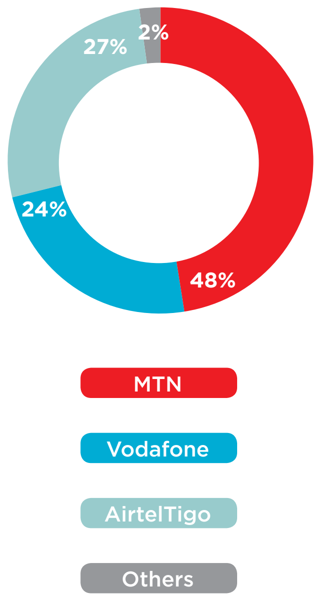
Figure 6

Ghana mobile market stats

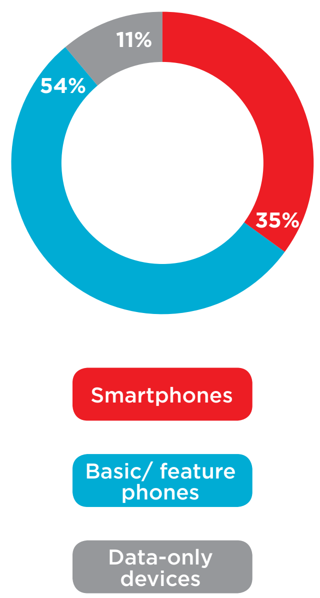
Mobile and mobile data unique subscribers in Ghana 2010-2018[25]



Ghana mobile connections market share, % of total voice connections[26]



Share of connections by type of device in Ghana[27]



24. Source: National Communications Authority of Ghana, July 2018
25. Source: GSMA Intelligence, 2018
26. Source: National Communications authority of Ghana, July 2018. Total percentage exceeds 100 per cent due to rounded figures
27. Source: GSMA Intelligence, 2018.

Compared to other West African markets, Ghana has low smartphone penetration, at 35 per cent of total connections, and is still a predominately basic- and feature phone market. Despite this, Ghana keeps up with the average annual growth rate of around 13 per cent in mobile internet subscribers across the region.[28] The growth of the telecoms industry in Ghana is having a measurable impact on the economic development of the country. In 2015, Information and Communications contributed GHS 3.1 billion to Ghana's total GDP.[29]

1.2.2 MTN Ghana

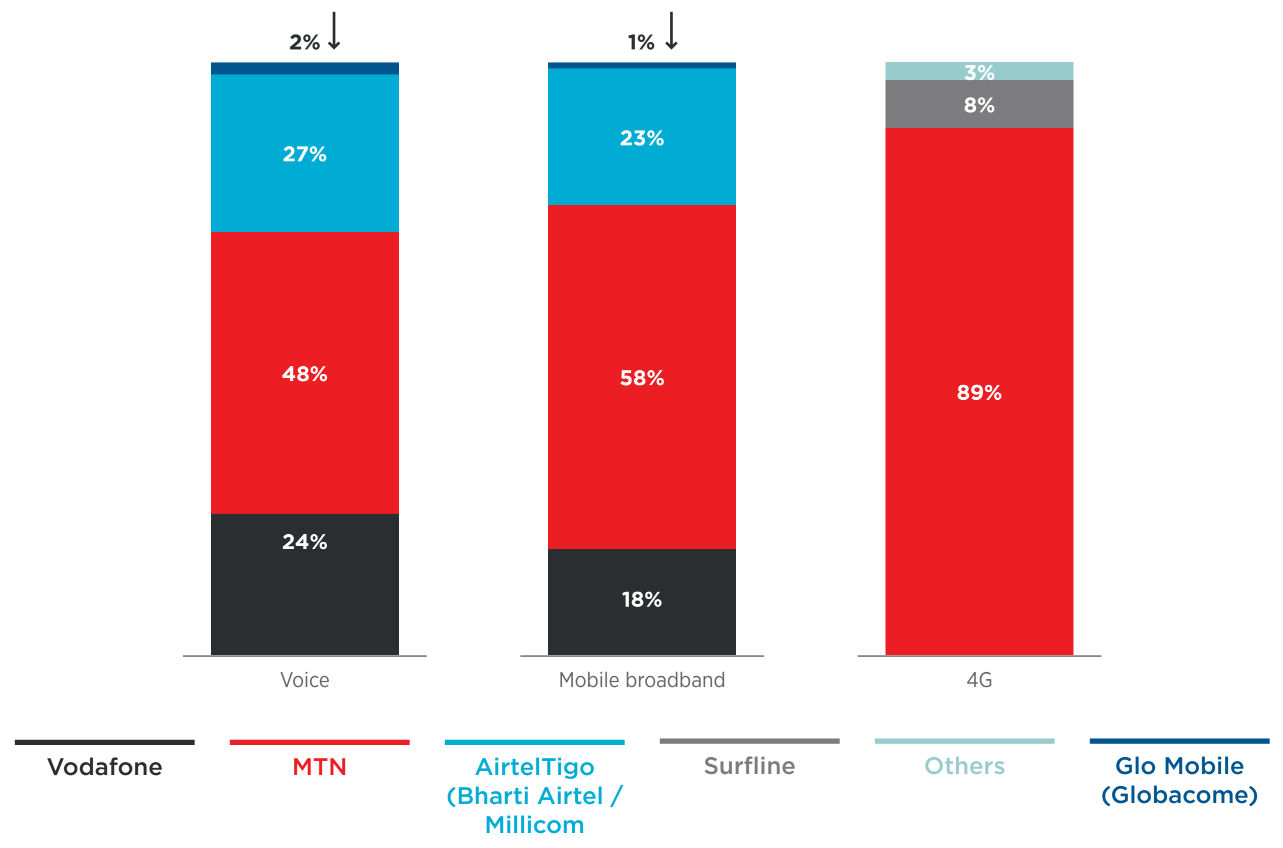
MTN Group operates in 22 emerging markets across Africa, Asia and the Middle East. Since MTN entered Ghana in 2006, they launched 3G services in 2010 and six years later introduced 4G. Today, MTN holds 58 per cent of all mobile broadband connections and 89 per cent of 4G connections in Ghana's increasingly competitive mobile market.

Figure 7

Source: Source: National Communications Authority of Ghana, July 2018

Mobile operators' market share by service in Ghana

% of connections (Q2 2018)



28. Source: GSMA Intelligence, Q3 2018.
29. Ghana Statistical Service.

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Being the market's largest mobile operator, MTN feels responsibility to be leading in extending rural mobile internet connectivity in Ghana.

As part of MTN's efforts in extending fast and reliable mobile telephony connectivity in rural areas, they are an integral partner of the Ghanaian government's Rural Telephony project, together with the National Communications Authority, Ghana Investment Fund for Electronic Communications (GIFEC), and Huawei Technologies Limited.[30] Under this partnership, MTN is rolling out new sites in rural areas utilising Huawei's RuralStar solution. To date, they have commissioned c. 300 new RuralStar sites and are committed to expanding the project further in Ghana.[31]

"MTN is committed to ensuring that every Ghanaian enjoys the full benefit of the internet and emergence of digital technology. We are also hopeful that the Rural Telephony project will ultimately open up our rural communities for social development and economic empowerment."

~ MTN Ghana

30. Government of Ghana, President inaugurates Abenaso Rural Telephony Project (Aug 2018).
31. As of October 2018.

2. GSMA analysis of the potential of Huawei RuralStar to extend rural coverage in Ghana

GSMA analysed MTN Ghana's RuralStar sites in order to explore their commercial sustainability and connectivity performance in the market. Using a modelling approach informed by MTN's reported costs, the analysis estimated the potential of lightweight sites, like the Huawei Rural Star solution, to extend rural coverage in Ghana and scenarios under which it could deliver rural connectivity in a commercially sustainable manner. The analysis was informed by the GSMA's coverage-mapping tool to determine the population size at each of the sites and results were contrasted against typical characteristics of a macro-site.

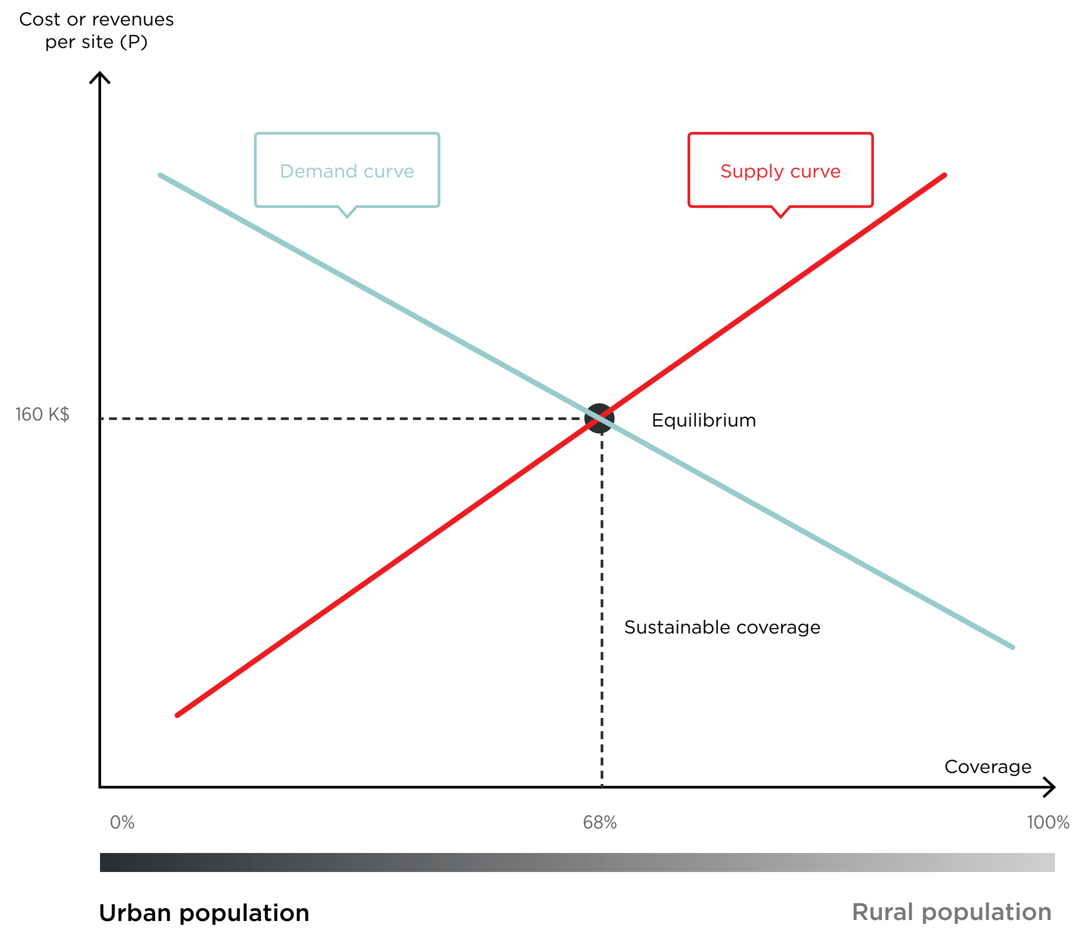
2.1 Methodology

The following method was used for the modelling analysis:

1. Analyse the cost and performance of the MTN Ghana RuralStar sites
2. Create a map with the population distribution grouped by settlements
3. Employ an algorithm that creates an ideal network - by selecting the type of site that yields the highest RoI for each specific location on the map (based on the exact population distribution of that location)
4. Use of the above algorithm to compare two scenarios:
   a. Scenario A: a world where the MNO can only deploy 'classic' macro-sites; and
   b. Scenario B: a world where the MNO has the choice to deploy a macro-site or a RuralStar site.
5. Estimate the sustainable coverage for each scenario, which corresponds to the level of coverage attained when deploying all the sites where the 5-year net present value (NPV) is greater or equal to zero[30] (see Figure 8).

Figure 8 Source: GSMA analysis

Mobile coverage supply and demand



32. The *sustainable coverage* can be seen as the equilibrium point where the supply and the demand for mobile services meet i.e. the level of coverage where adding a new site would be a loss-making deployment (see Figure 8).

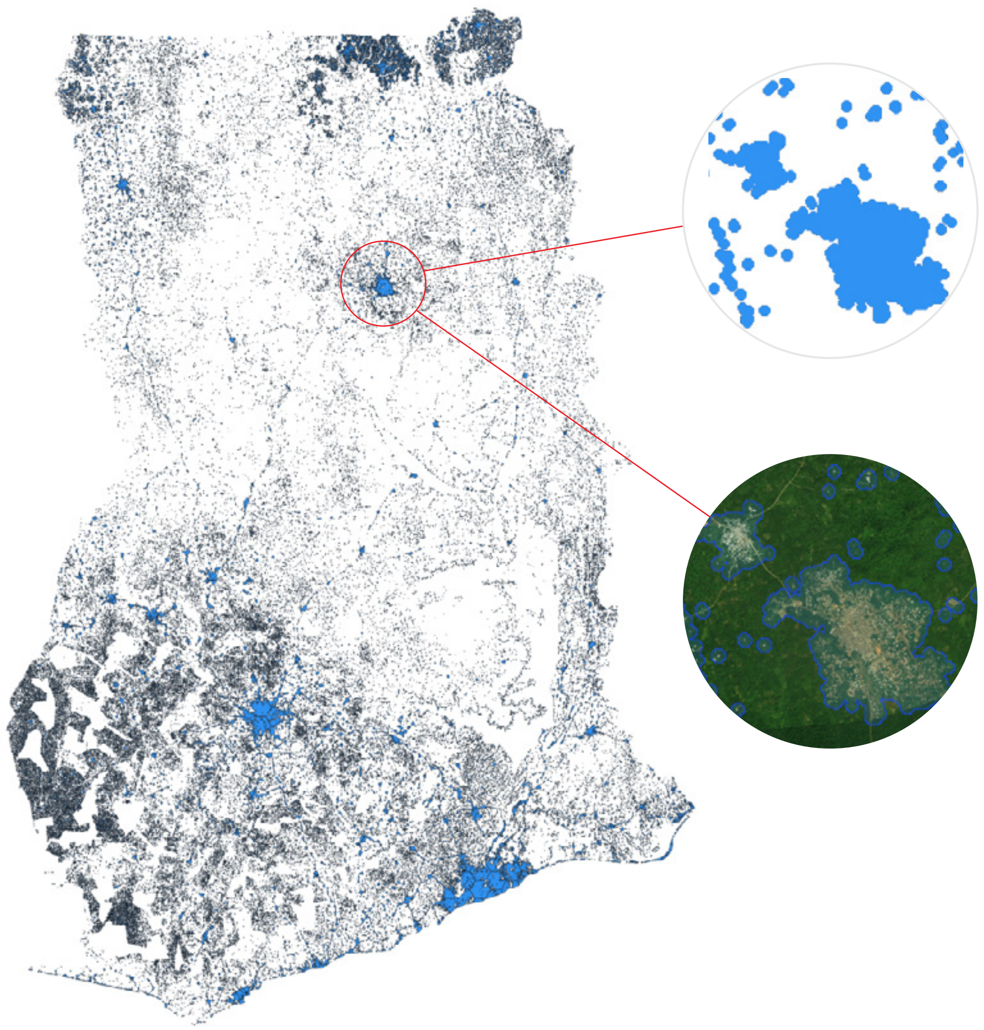
2.2 Results of the GSMA analysis

The figures below show the population distribution map for Ghana which was obtained by using a High Resolution Settlement Layer dataset,[31] which offers the most accurate population distribution publicly available.

Figure 9

Source: GSMA Mobile Coverage Maps

Population distribution map of Ghana (population settlements marked in blue)



Zoomed in from map:

Each blue spot represents a population settlement.

Satellite view of the above image, showing the settlements more clearly.

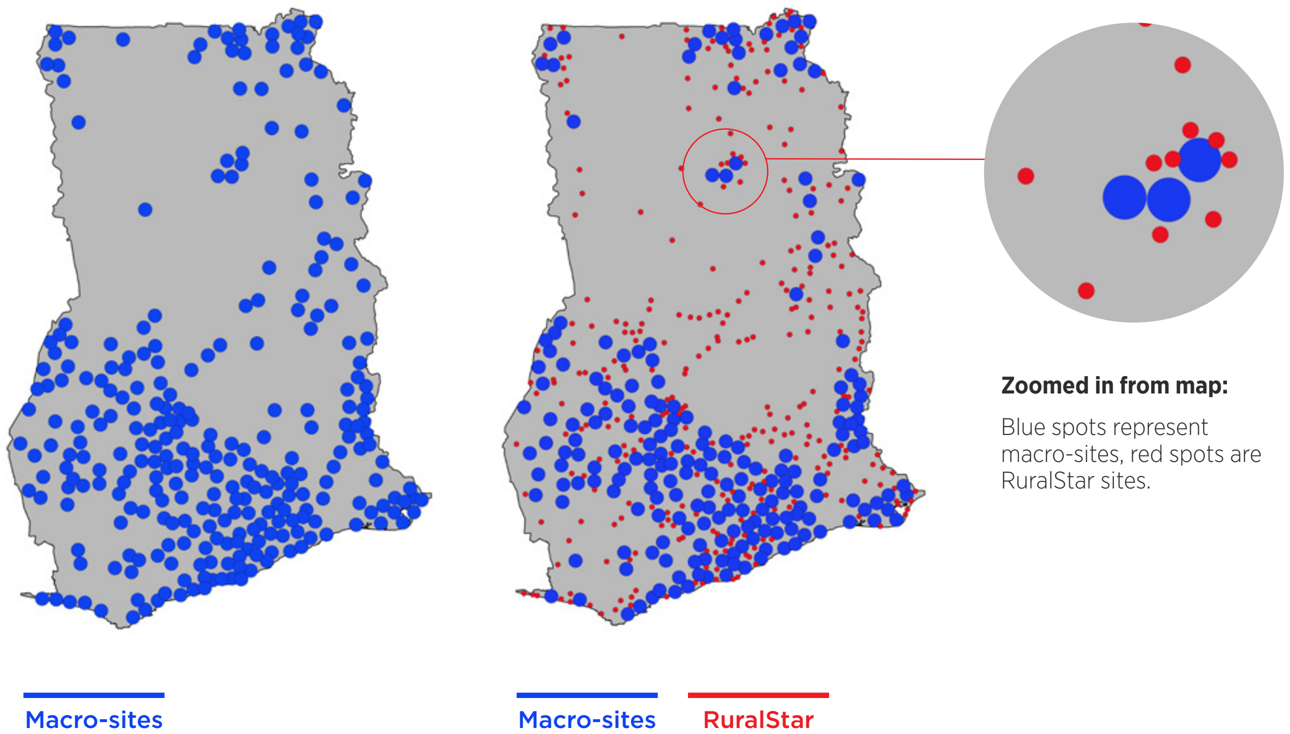
33. The dataset used is the High Resolution Settlement Layer, a dataset developed by Facebook Connectivity Lab and the Center for International Earth Science Information Network (CIESIN) at Columbia University, which estimates human population distribution at a hyperlocal level, based on census data and high-resolution satellite imagery.

The algorithm created an ideal network by testing different site configurations and locations, and selecting those with the highest return on investment. The advantage of this method is that it takes into account the population distribution and the site financial (CapEx and OpEx) and technical (site radius) characteristics to pick the best option for each possible location on the map. The figures below show the networks generated by the algorithm for each of the two scenarios (only the sites estimated to be profitable are shown).

Figure 10

Source: GSMA analysis

Coverage scenarios of Ghana with / without RuralStar deployments



Zoomed in from map:

Blue spots represent macro-sites, red spots are RuralStar sites.

Figure A: *Scenario utilising macro-sites only (no RuralStar)*

Figure B: *Scenario combining macro-sites and RuralStar*

The figures above only show the sites for which the 5-year NPV is estimated to be greater or equal to zero. As a rational investor, an MNO would be expected to deploy only the sites with a positive NPV i.e. the equilibrium where the revenues are greater or equal to the costs of deploying and operating the sites.[32] This can be referred to as the sustainable coverage.

34. In reality however, due to coverage obligations and the fact that people are not static, coverage is usually higher than this equilibrium.

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Table 2 below shows the sustainable coverage for the two scenarios

Table 2

Source: GSMA analysis[32]

Sustainable coverage rates of a scenario using macro-sites, and a scenario using macro-sites or RuralStar

Scenario	Sustainable population coverage
Scenario A: a world where the operator can only deploy macro-sites	67.9%
Scenario B: a world where the operator has the choice to deploy a macro-site or a RuralStar site	74.5%

The algorithm uses assumptions validated with MTN in terms of the expected ARPU and penetration, as well as the CapEx and OpEx of macro-sites and RuralStar sites. One limitation of the algorithm is that it uses a fixed radius for each site, instead of using the propagation pattern that would be expected in the specific terrain where each site is located.

The higher value for the scenario that includes RuralStar, means that operators would be able to cover more population in a sustainable manner. In other words, they would increase their revenues by increasing the RoI on infrastructure. This also means that operators would be encouraged to deploy sites in areas where revenues are lower, which has a positive impact for digital inclusion. RuralStar would allow operators in Ghana to profitably increase coverage by 6.6 percentage points, or 1.9 million people. Note that these results are theoretical and not directly applicable to Ghana today. The results are based on the assumption that RuralStar is introduced to a network that already exists, instead of being an available option from the inception of the network.

Figure 11 below illustrates the above scenarios, which shows the significance in terms of achieving a 6.6 percentage point increase in population coverage. It shows the relationship between the amount of population and the landmass where this population resides in Ghana. For example, the curve shows that 73 per cent of the population lives in only 20 per cent of the landmass. This curve is marginally decreasing, indicating that as the curve flattens, more sites will be required to cover the same amount of population. For example, increasing landmass coverage from 0 per cent to 20 per cent increases population coverage from 0 per cent to 73 per cent; however increasing landmass coverage from 40 per cent to 60 per cent only increases population coverage from 89 per cent to 96 per cent. This means that the required number of sites (and investment) drastically increases to cover rural areas with low population densities. Gaining few percentage points coverage in the flat sections of the curve requires very innovative and cost-efficient solutions, such as RuralStar.

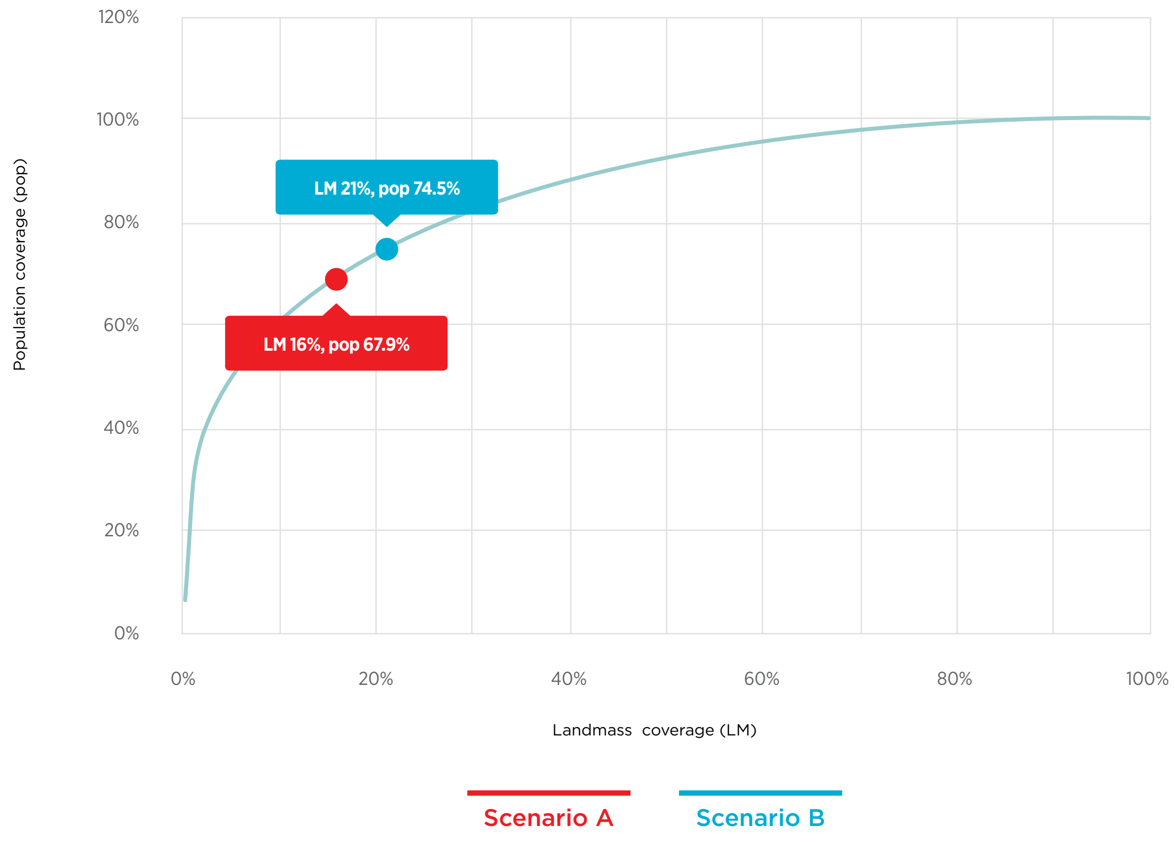
In the Figure, the red and blue points indicate sustainable coverage points for scenario A and B, in terms of landmass and population coverage.

Figure 11

Source: GSMA analysis

The relation between population density and ideal coverage scenario

Population distribution in Ghana



Based on the modelled analysis we can decipher three different use cases where RuralStar could be advantageous for a mobile operator to use:

1. Deploy RuralStar as an alternative for macro-sites to increase RoI in a given location
2. Deploy RuralStar in remote areas where macro-sites would not be profitable otherwise
3. Densify the network and cover white spots that lie in-between the coverage of macro-sites.

2.2.1 Use-case 1: Deploying RuralStar sites instead of macro-sites

Deploying RuralStar instead of deploying macro-sites is a possibility that only exists for green field sites, as it would make no economic sense to replace existing sites. There may be cases where it is more cost effective to deploy RuralStar over macro-sites based on the higher RoI of the former. Figure 12 below shows an example of this case, where the model identifies that deploying two RuralStar sites (radius in red) is more profitable than deploying one macro-site (radius in yellow). Despite the higher population covered by the macro-site, the lower TCO of two RuralStar sites have a higher 5-year NPV. Note that this result is entirely dependent on the spatial distribution and size of settlements (in blue in the figure).

Table 3 below shows financial predictions for the sites in Figure 12.

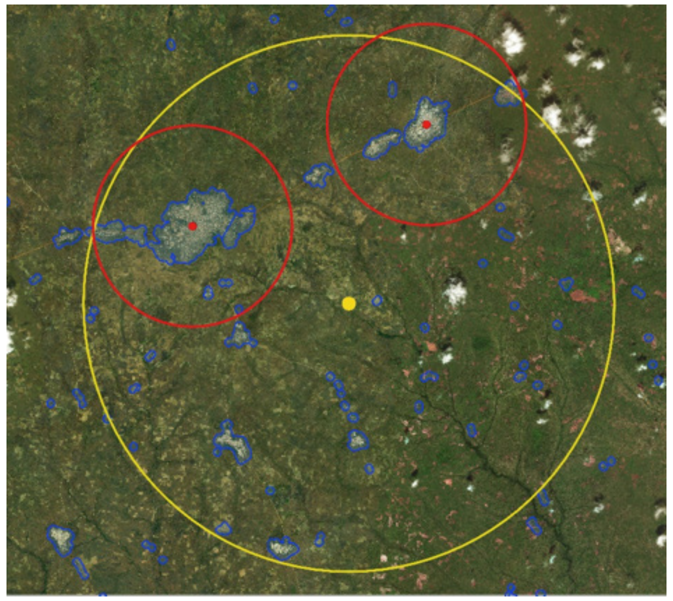
Table 3 Source: GSMA analysis

Financial predictions of RuralStar and macro-sites

Case	5-year TCO	Population covered	5-year NPV
Macro-site x 1	100%	27 911	100%
RuralStar x 2	31%	22 854	155%

Figure 12 Source: GSMA analysis

Map illustrating use-case 1 – deploying RuralStar sites instead of macro-sites



2.2.2 Use-case 2: Deploying RuralStar in remote areas where macro-sites would not be profitable

The second use case apparent from the modelling is the deployment of RuralStar in areas where a macro-site would not be profitable. In this case, RuralStar not only increases the revenues for operators (as in the first use case), but it also increases the total population covered by bringing the network to places where traditional infrastructure is not cost-effective.

This case is illustrated in Figure 13 below. Three sites can be identified, two of them are RuralStar (B and C) and one of them is a macro-site (A). Site A could act as a donor site in the RuralStar network topology. Sites B and C would be RuralStar leaf sites that use LTE backhaul as they are located less than 40km away from the donor site.

The location of site B in the map makes a good example for why it makes more sense to deploy a RuralStar site rather than a macro-site in that location. Table 3 below displays the corresponding financials and coverage results of deploying either a RuralStar or a macro-site at location B, (the coverage radius of the macro-site option is illustrated in the map by the yellow dotted circle). Note that despite covering a larger population, the 5-year NPV is negative for the macro-site deployment, which means that this is not deemed as a cost-effective option to the operator.

Table 4 Source: GSMA analysis

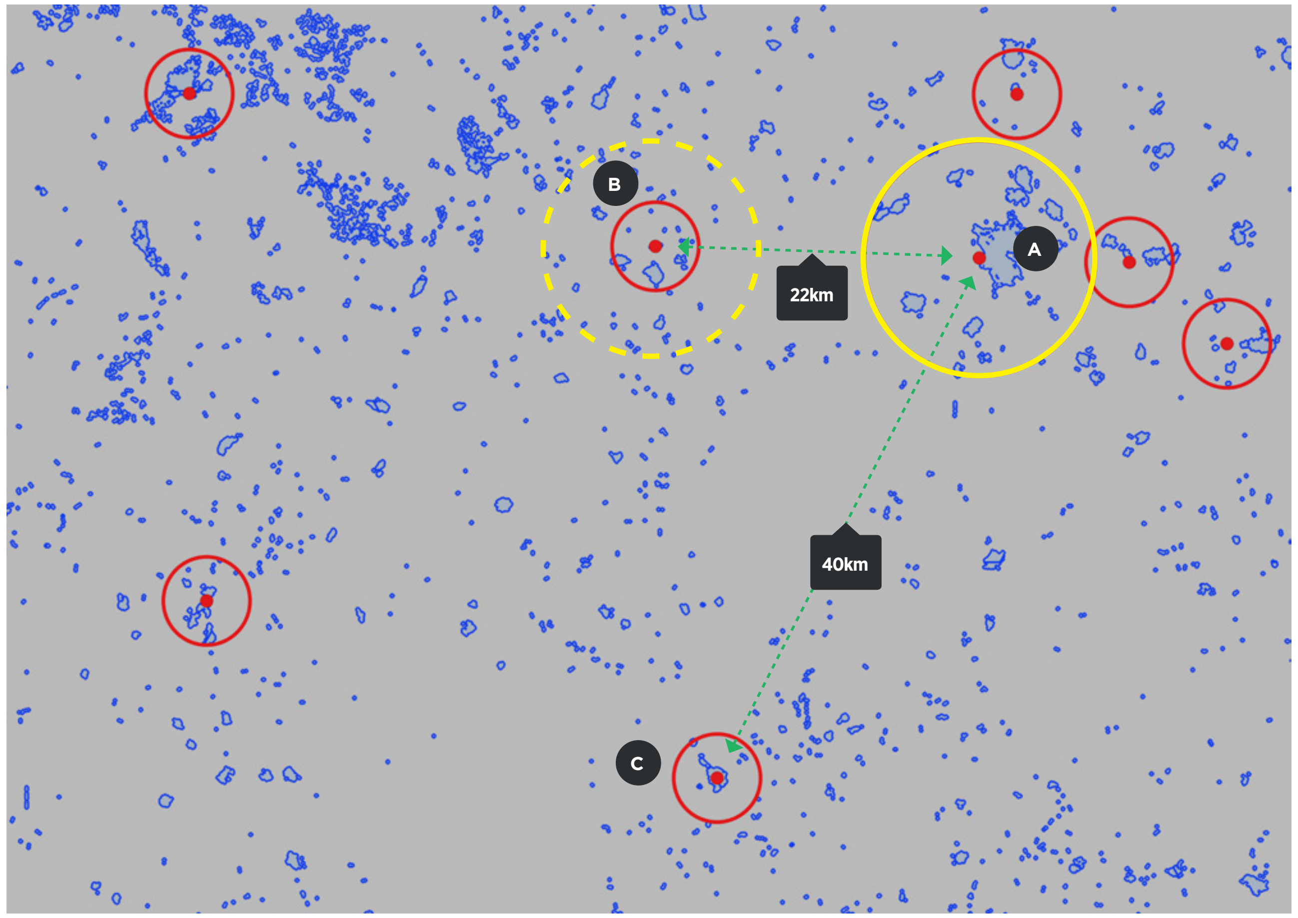
Financial predictions of deploying either RuralStar site or a macro-site in the same location (B)

Case	5-year TCO	Population covered	5-year NPV
Macro-site (B)	100%	10 870	Highly negative
RuralStar	31%	5 307	Positive

Figure 13

Source: GSMA analysis

Map illustrating use-case 2 - deployment of RuralStar in a remote area where macro-sites would not be profitable



The macro-site location is shown in yellow and RuralStar sites are in red.

2.2.3 Use-case 3: Densifying the network and cover white spots that lie in-between the coverage of macro-sites

The third use case for RuralStar is to densify the network and cover white-spots that appear within the coverage of macro-sites. This use case is illustrated in Figure 14 (A). In real life conditions, this use case would also apply for areas that are within range of a macro-site, but remain uncovered due to the terrain or other physical constraints affecting the signal propagation.

Such a case is identified in Figure 14 (B), where MTN decided to deploy a RuralStar site in an area with poor coverage. Note that all the macro-sites have high towers (more than 35m) to increase reach, and have several frequencies and/or sectors for capacity purposes. In contrast, the RuralStar site only has an 18m high tower, a single frequency and an omnidirectional antenna.

Figure 14

Source: GSMA analysis

Maps illustrating use-case 3 – deploy of RuralStar to densify the network and cover white spots.

Figure 14 (A)
Macro-sites are in yellow and RuralStar sites in red.

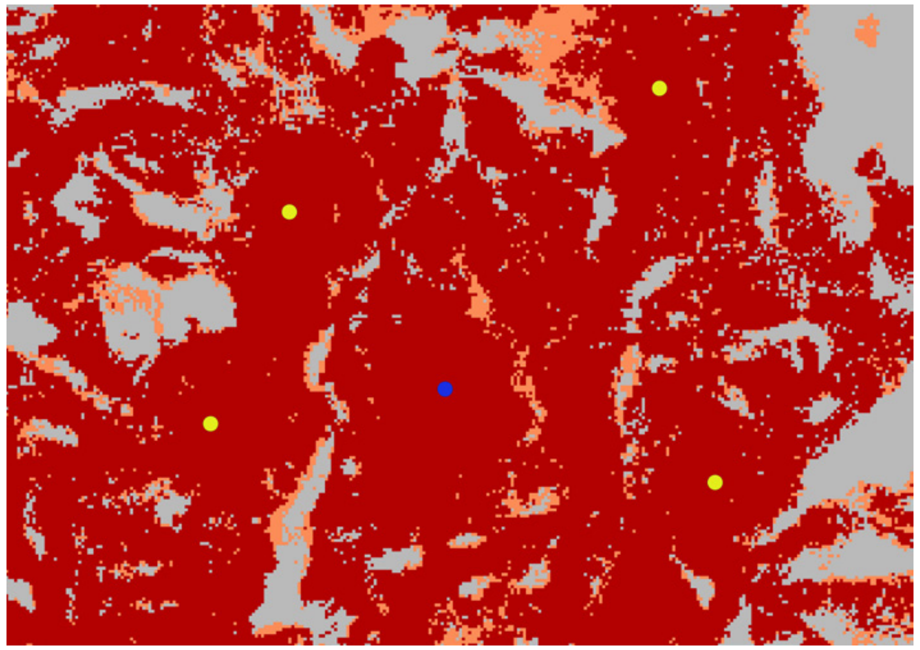


Figure 14 (B)
Macro-sites locations are in yellow and RuralStar site in blue. The coverage is illustrated in red and orange (simulated using propagation models).

3. Recommendations and implications

When working to extend mobile internet access to uncovered populations, deploying and maintaining cell sites in rural areas can be a significant challenge for operators. The analysis contained in this case study demonstrates the potential of lightweight sites, like Huawei's RuralStar solution, to address this issue and improve the business case. The main conclusions are summarised in the below SWOT analysis.

GSMA Rural innovation case study: Using light sites to drive rural coverage - Huawei RuralStar and MTN Ghana

Table 5

Source: GSMA analysis

SWOT analysis of using Huawei RuralStar for driving rural coverage

Strengths	Weaknesses
• Lower TCO compared to macro-sites: - Cheaper backhaul - Lower CapEx - Lower power costs - Ability to move sites to accommodate for unexpectedly high increases in demand • Quick deployment time • Less environmental impact (solar energy)	• Dependency on donor sites (i.e. existing macro-sites) for backhaul • If demand projections are not accurately assessed for the RuralStar site, possibilities of capacity and power upgrades are limited
Opportunities	**Threats**
Depending on the given population distribution and terrain characteristics, RuralStar can: • Give higher RoI than macro-sites for new deployments in greenfield rural areas • Extend coverage in areas where macro-sites would not be profitable • Densify coverage, to cover white spots in between macro-sites' coverage footprint	Due to the upgrading limitations of RuralStar, if demand is underestimated when planning deployment at the country level, large-scale replacement of RuralStar sites could be necessary, which in turn would require additional investment and weaken the business case

Overall, RuralStar can have a positive impact on the expansion of rural mobile internet coverage. The cost-effective wireless backhaul, lesser upfront investment and power expenditures mean that RuralStar has a lower TCO compared to macro-sites. In MTN Ghana's experience, the ability to easily move sites to accommodate for unexpectedly high increases in demand was also advantageous, as well as the speedy deployment (it took them less than 10 days for delivery and the set-up of a cell site).

As the backhaul connectivity for RuralStar sites is dependent on proximity to an existing macro-site, it is however important to consider how deployment in very remote greenfield areas might be problematic unless using alternative backhaul alternatives, which risks increasing the TCO. In addition, if demand projections are not accurately assessed in the network planning phase for the RuralStar sites, and demand outgrows capacity of the site over time, the possibilities of capacity and power upgrades are limited. As RuralStar is a light site, designed for light energy and capacity requirements, the dimensioning of power and spectrum in relation to expected demand of the sites is key.

In turn, due to the upgrading limitations, if demand is underestimated when planning deployment at the country level, large-scale replacement of RuralStar sites might be necessary. This in turn would require additional expenditures and could thus weaken the business case of RuralStar from an investment point of view.

GSMA Rural innovation case study: Using light sites to drive rural coverage - Huawei RuralStar and MTN Ghana

Depending on conditions of e.g. population distribution, the terrain, and the existing coverage footprint, deploying lightweight sites like RuralStar can make sense in the following three use cases:

1. When planning to deploy a new site in a low-density population area - deploying one or more light sites could make a suitable alternative to deploying one macro-site.
2. For extending existing network coverage, in areas where it otherwise would not be profitable to deploy and operate macro-sites.
3. When it is required to densify the network – in cases where coverage already exists nearby but is not providing sufficient network access for people living in white spots on the fringes of the connectivity footprint.

With lightweight sites like RuralStar, mobile operators are able to improve rural coverage quality and reach areas that traditional macro-sites would not be able to cover in a commercially sustainable manner. Hence, in combination with careful site location analysis, RuralStar can be an attractive solution for operators to increase coverage and revenues in rural areas and extend mobile internet access to underserved populations.

The GSMA Connected Society programme and rural coverage

We believe that the GSMA has a critical role in supporting our operator members and our industry to increase the availability of mobile internet coverage in rural areas. However, while mobile operators have a pivotal role to play in driving digital inclusion in developing markets, they face two key challenges:

1. Extending coverage remains economically challenging given the high costs of increasing coverage and issues connected to consumer demand
2. Inconsistent and distortive regulation from governments, which restricts public and private investment in connecting the unconnected.

Overcoming these barriers will require focus, innovation and collaboration between the public and private sectors. The GSMA is committed to supporting the industry in both these areas. Over the coming year, we will be continuing to support operators to pilot innovate solutions that help bring down the cost of providing coverage. At the same time, we will continue advocating to governments for an enabling policy environment that will create the right conditions for private sector investment.

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For more information, please visit the
GSMA Connected Society website at www.gsma.com/connectedsociety

GSMA HEAD OFFICE
Floor 2
The Walbrook Building
25 Walbrook
London EC4N 8AF
United Kingdom
Tel: +44 (0)20 7356 0600
Fax: +44 (0)20 7356 0601