

AFFORDABLE INTERNET WIFI FOR
RURAL COMMUNITIES IN AFRICA

TELECOM COMPANIES

can provide Internet access
for rural customers in **Africa**
with a very low investment



JOHN BARKER Ph.D. MIEEE

Affordable Internet WiFi for rural communities in Africa

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Second edition

Telecom companies have a rare opportunity to add millions of new customers who live in rural Africa and currently have no access to the Internet; all for a minimum investment

John D. Barker Ph.D., MIEEE

TELECOM COMPANIES: Internet for rural Africa

TELECOM COMPANIES can provide Internet access for rural customers in Africa with a very low investment

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FOREWORD

This book was written to share technical knowledge with Telecom companies; knowledge that has been gained over the past 15 years of providing Internet services to communities, groups and business customers. Telecom companies have a standard technical recipe to provide telephone and data services for customers. However budgets and technical constraints limit the percentage of the population that the Telecom Company can provide services for.

Mobile Telecom companies plan infrastructure investments, such as mobile phone towers, based in two primary parameters.

- Infrastructure budget allocation vs. expected income.
- Expected timescale for the return on investment and project profitability.

Millions of small rural communities around the world have no phone or data service. The majority of these small communities are located throughout Africa. It is not economically viable to provide a phone and data service for small rural communities. A community must have a minimum population size that will ensure the investment of the mobile phone infrastructure can be recovered within a reasonable time frame. The mobile infrastructure investment will include a 4G-LTE tower, plus the fiber landline or microwave link that will connect the tower to the Telco's network. A tower location will also need power plus backup energy storage. The cost of the tower infrastructure exceeds \$1M USD. Due to the economics of the mobile phone infrastructure, millions of small communities around the world have no phone or data service. Small community residents may have mobile phones that they can use when visiting larger communities that do have mobile phone infrastructure.

The telecommunications infrastructure that mobile phone companies are familiar with can now be augmented with new technologies that enable the provisioning of data services to millions of new customers for a very low investment cost. This translates to small investments that have a ROI of a few months and that generate new profits for the company.

This situation changed with the introduction of low cost satellite Internet services. The satellite service provided by one of the vendors, Starlink, is available almost worldwide. Individuals who have the financial means can install the Starlink service. However the Starlink service is too expensive for most members of a rural community.

Several Telecom companies are now providing a WiFi Internet service for small communities using a much lower cost infrastructure solution that combines the Guest Internet service management system with one or more Starlink antennas.

The cost of the satellite Internet service with a Guest Internet broadband network gateway controller and WiFi infrastructure for a community is a tiny fraction of a mobile phone service cost, approximately 0.01% of the cost of installing a 4G-LTE tower. The WiFi infrastructure cost includes providing fixed wireless access (FWA) to homes in addition to access for mobile devices.

It is now possible for Telecom companies to incorporate a budget that will support the deployment of a WiFi Internet service, using Guest Internet controllers, for thousands of rural communities. This will provide managed Internet access for millions of people who would otherwise not have access to the Internet.

The Telco has several methods to charge community residents for the Internet service. Three popular methods are listed below.

- Sale of access code vouchers for cash payments.
- Payment using Mobile Money via the Guest Internet mobile operators gateway.

- Subscription for FWA customers managed via the mobile operators billing system.

The WiFi community Internet service does not permit a mobile phone to make voice calls or send text messages through the mobile operators network, however there are many voice call and messaging applications, such as Whatsapp, that the community resident can use with the Internet data service. The community resident must purchase a phone from the mobile operator in order to have a valid phone number to register the Whatsapp application. This will stimulate the mobile operators sales of mobile phones, adding income from each community WiFi Internet project.

The technical information presented in this book will provide a roadmap for any Telecom business that is seeking to employ new technologies that will provide a data service for underserved rural communities. The cost of the investment is small and will provide strong income growth for the Telecommunications business.

INTRODUCTION

Guest Internet is the brand name of a range of products and software that are manufactured by Fire4 Systems Inc. in the USA. Guest Internet products were first launched in 2010 to provide a managed Internet service for hospitality businesses.

The Guest Internet system evolved to become the chosen user management and billing solution for thousands of smaller ISP's throughout the world. Guest Internet products are installed in over 65 countries that include all countries in Africa. The Guest Internet system has also been chosen by large telecom vendors that decided to provide a rural data service; obtaining a strong cash flow with a very low investment cost.

The Guest Internet system provides all the Broadband Network Gateway (BNG) features that telecom businesses are familiar with, for the management of subscriber data services. The Guest Internet BNG system includes the following important features.

- A range of hardware controllers for site installations, for less than 100Mb/s to 1Gb/s data throughput.
- A Guest Internet cloud management service where a cloud account can manage an unlimited number of controllers, enabling the deployment of multi-location networks, where each location can have any type of ISP connection, and users can roam between locations with the cloud providing a handoff service from one location to the next.
- Several methods to charge for the Internet service that include pay-on-demand alternatives, plus subscriber activation. All payment methods can be deployed concurrently to address the different needs of users.

- API integration with 3rd party systems that can include billing systems for payments with other processors, and integration with the Telco's back office subscriber management and billing systems. The Guest Internet cloud API supports concurrent external systems.
- Monitoring of the community infrastructure is implemented at three levels; remote site WiFi infrastructure failure monitoring, remote site Guest Internet controller failure monitoring, and failure monitoring of the ISP connection to the remote site. Failure warning messages can be incorporated into Telecom monitoring systems.
- Comprehensive firewall features that prevent abuse of the service at the remote location to permit hands-off administration.
- Status and traffic reporting for all controllers, groups and systems within the Guest Internet cloud account. Identify potential problems such as network congestion.

The advantage that the Guest Internet BNG solution provides for Telecom businesses is that it can be scaled down for the smallest community with a corresponding low investment. The Guest Internet system can be scaled up to provide an Internet service for millions of city or country inhabitants. Guest Internet technology is the only BNG deployment with this degree of scalability.

The Guest Internet cloud management system has a Mobile Money gateway service that is customized for each application and for the mobile network operator that will provide the API payment service. The Mobile Money gateway permits a community member to make a pay-on-demand purchase of Internet access online via the Internet service. A mobile phone connection is not necessary to make a purchase of Internet data. The Mobile Money gateway communicates with the mobile operators Mobile Money API payment interface.

The Guest Internet cloud service has an API that can be accessed by the mobile operator subscriber management system to activate and deactivate FWA subscribers who are connected to the community WiFi network and to set rate plans for those subscribers.

Guest Internet has made it possible for any Telco anywhere in the world to install a low cost Internet service in any rural community, no matter how big or how small. This book explains how Telecom companies can take advantage of new technologies to provide Internet access for millions of new rural subscribers, all for a very low investment cost that will fit any Telco's investment budget.

The author is a Member of the Institute of Electrical and Electronic Engineers (IEEE) has been involved with the Telecommunications industry for the past 35 years. The author has been responsible for the development and evolution of the Guest Internet technology since the first products were launched in 2010. Telecom companies can contact the author via the Guest Internet email address below for further information about providing a rural community Internet service.

info@guest-internet.com

1. The Rural Opportunity for Telecom Companies in Africa

TELECOM COMPANIES: Internet for rural Africa

1. The rural opportunity for telecom companies in Africa

1.1. Telecom companies can provide rural Internet with a very low investment

Telecom businesses around the world invest with the build-out of communications infrastructure in urban areas as a priority. Many customers can be acquired for an urban infrastructure investment. However rural areas present much higher investments costs for the acquisition of fewer dispersed customers.

Economically wealthy countries have large rural areas with limited communications infrastructure as rural infrastructure investments have a long return on investment (ROI) period, or else do not have a business case for the investment. Economically poorer countries do not have the capital to build a rural telecommunications network.

Many telecom companies are not aware that there has been a paradigm shift of infrastructure costs: recent technology developments permit rural telecom infrastructure to be deployed for a fraction of the cost of the traditional communications infrastructure. How is this possible? We explain the technical solution in this document.

1.2. How to benefit from the rural telecom opportunity

Telecom companies build telecommunications networks with fiber cables and microwave links. Such an infrastructure has a relatively short time to payback (ROI) for urban deployment. However rural deployments often have no business case. The distances and costs are higher and fewer customers are available to sign up for the service.

Guest Internet has developed an alternative low-cost telecommunications infrastructure design for rural areas. The Guest Internet low-cost rural telecom infrastructure technology has already been deployed by telecommunications businesses that are providing an economical rural Internet service, and making a profit doing so.

The Guest Internet technology has the following principal characteristics:

- Internet connection service via any ISP (e.g. fiber landline, Starlink satellite, etc).
- Can accommodate any ISP connection, including high latency services.
- Internet on-demand service for low customer cost, permitting more customers to share one infrastructure.
- Internet service charge via voucher cash sales via an on-line charge using Mobile Money payment (MoMo). A subscription service can also be implemented.
- Mobile access and fixed wireless access (FWA) for homes using low-cost WiFi technology.
- The economical Guest Internet controller (broadband network gateway – BNG) is installed at each rural location to manage authentication and access.
- The Guest Internet cloud management system that can provide distributed authentication services for an unlimited number of Guest Internet controllers.
- The Guest Internet cloud voucher printing service for applications that require cash sales of vouchers.
- The Mobile Money (MoMo) billing system that integrates with the Guest Internet cloud and the mobile operator API to charge for Internet use.

- Integration with the Telco's billing system for subscriber authentication.

The Guest Internet infrastructure can be deployed in many locations simultaneously with central co-ordination and billing via the cloud service. The most important aspects of the Guest Internet solution for telecom businesses are;

- Very low deployment cost.
- Very low operating cost.
- Very high reliability.
- Integration with the telecom management systems and other 3rd party systems.

The following sections of this document describe the Guest Internet technical solutions that telecom businesses can deploy to provide a low cost Internet service for rural customers.

1.3. Areas of the world with the biggest demand for low cost rural Internet

Most countries in the world have large rural areas where there is no telecommunications infrastructure, no fiber connection and no 5G towers. In countries that are economically developed there are individuals who reside in rural locations who can purchase a satellite antenna and pay for the Internet service.

There are parts of the world with large rural areas but where it is impossible for individuals to afford a satellite service for their own use. The areas in order of priority are listed below and shown on the world map figure following.

- #1 Africa; Majority of countries
- #2 Oceania; Thousands of small islands
- #3 Asia; Large rural areas

TELECOM COMPANIES: Internet for rural Africa

- #4 Central and South America; Rural areas
- #5 Caribbean; Haiti has the biggest demand

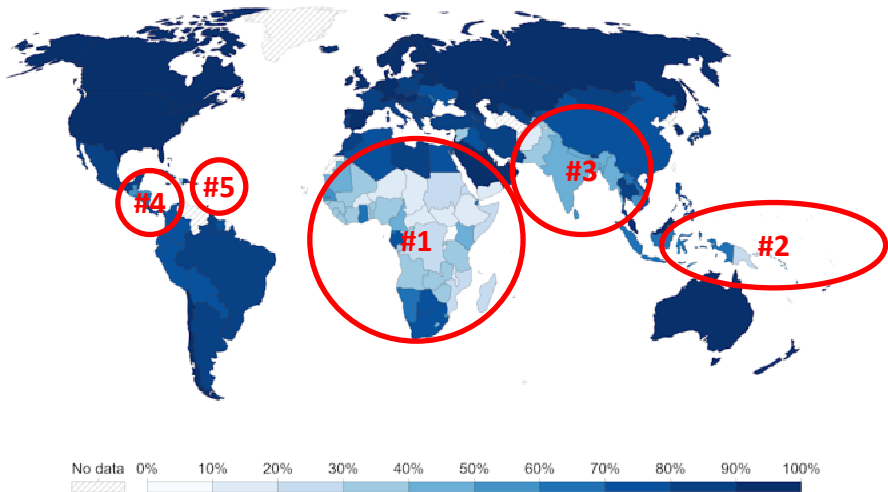
The continent of Africa has the highest proportion of the population with no Internet service. The demand for access to the Internet is very high, however the telecom companies cannot afford to build telecommunications infrastructure in the rural areas.

Using Guest Internet technology it is now possible for the telecom providers to build profitable infrastructure in rural areas.

Share of the population using the Internet, 2023

Share of the population who used the Internet* in the last three months.

Our World
in Data



Data source: International Telecommunication Union (via World Bank) (2025)

OurWorldinData.org/internet | CC BY

The map illustrates markets where the Guest Internet solution will address the biggest demands and have the greatest profitability.

1.4. Expectation of Internet growth in Africa

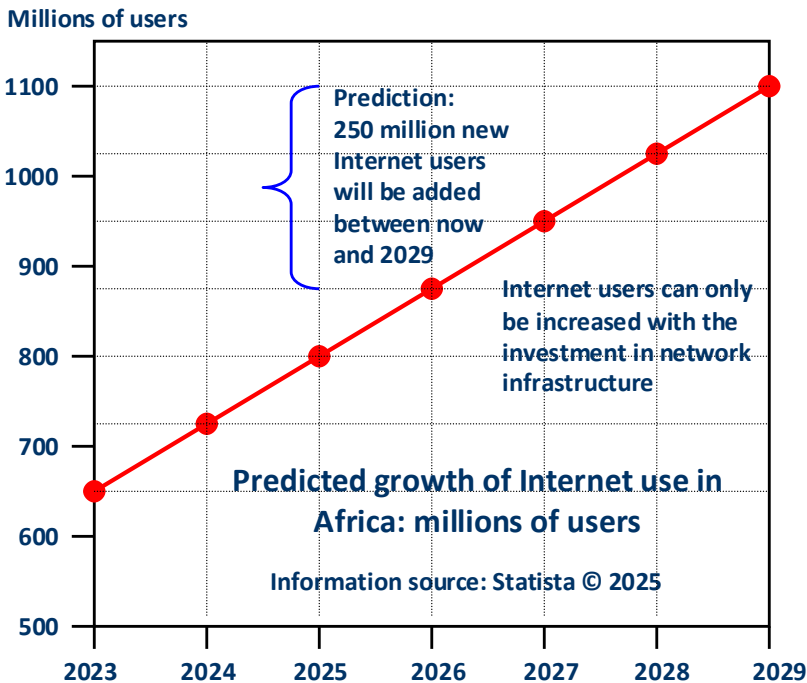
Internet access in many African countries has accelerated over past years due to the rollout of 4G-LTE infrastructures to provide Internet on mobile phones. 4G-LTE provides Internet access for urban areas, but due to the limited range of towers, it is impractical to provide good coverage over rural areas. The cost of installing a 4G-LTE tower for a small rural community cannot be justified as the small number of customers will not pay for the installation and operation cost of the tower. A 4G-LTE tower has to connect to the national network, which requires either a fiber cable or a microwave wireless bridge, both methods are not suitable for long distances which limits the location of 4G-LTE towers.

The market research company, Statista, published Internet growth information for Africa that indicates the number of Internet users will increase from 850M users at the present time, to 1100M users during 2029. It is unlikely that the 4G-LTE infrastructures can be expanded to add 250M users in a 3-year period. Therefore the prediction can only be realized when low cost methods are available to connect rural communities to the Internet.

The next graph illustrates Internet user growth in Africa, based on the predictions published by Statista. The data starts from 2023 with 645 million Internet users and extends to 2029 with 1.1 billion users.

While Internet use in Africa is growing, the continent's online population percentage remains below the global average. In 2025 less than 50% of mobile phones are smart-phones and 70% of Internet traffic originates from mobile smart-phones.

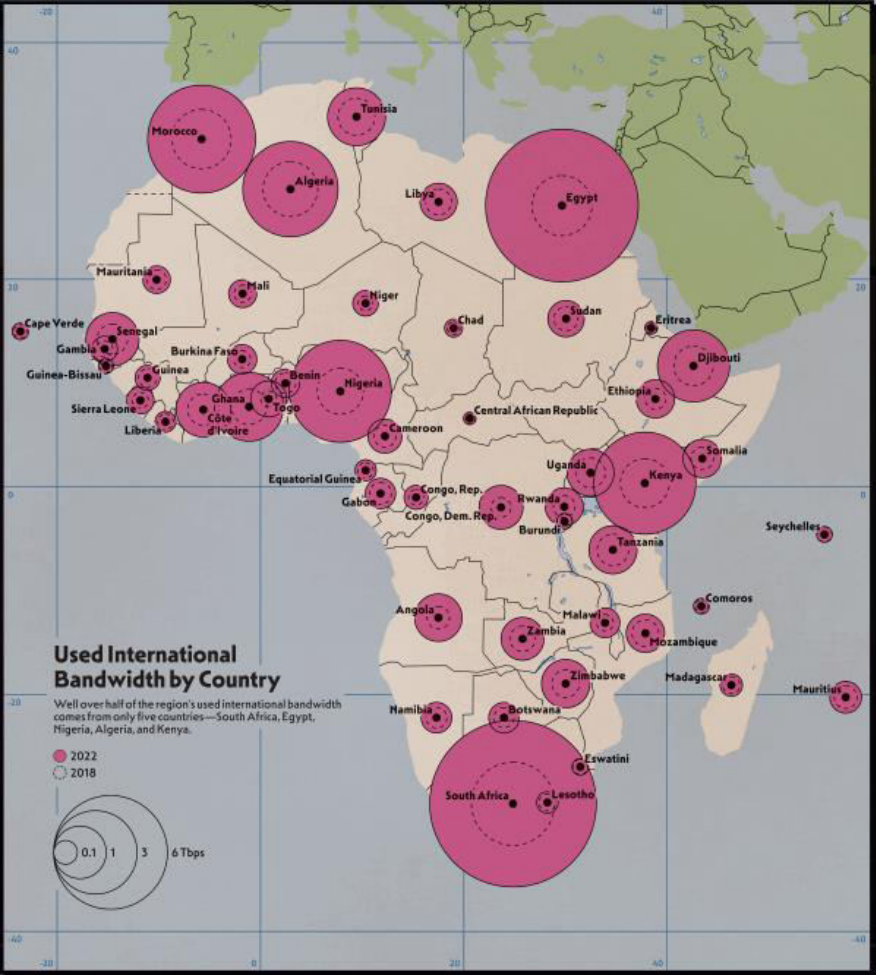
The only path to achieve the Statista growth projection for 2029 shown in the graph is for more than 1 million rural communities to install a shared satellite Internet service.



1.5. The bandwidth bottleneck sets a limit to the growth of Internet access

The availability of Internet access in the continent of Africa is limited by the bandwidth of the data communications infrastructure within each country and international data connections that integrate countries in Africa with the global Internet. The bandwidth limit represents a physical ‘bottleneck’ that establishes an upper limit on the number of people who can access the Internet in each country. The figure below shows Internet data capacity for countries in Africa, in Tb/s. In-country data capacities range from less than 100Mb/s to 6Tb/s.

TELECOM COMPANIES: Internet for rural Africa

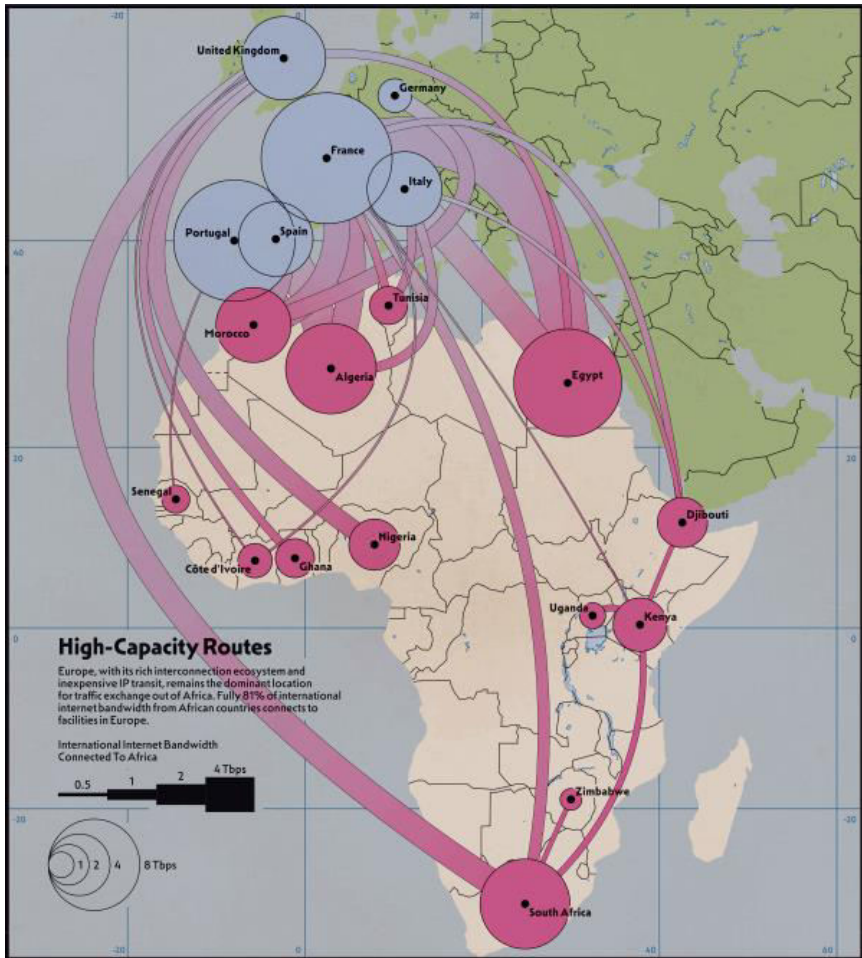


African in-country data capacity map. Copyright © TeleGeography, 2024:
<https://africa-map-2024.telegeography.com/>

The next figure shows international data capacity for countries with an international data connection to the global Internet. Countries with a high International data capacity, such as South Africa, have 8 Tb/s. Most countries in Africa do not have a direct International connection to the global Internet. Well over half of the region's

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countries connections to the global Internet comes via connections to only five countries that have direct international data connections; South Africa, Egypt, Nigeria, Algeria, and Kenya.



African international data capacity map. Copyright © TeleGeography, 2024:
<https://africa-map-2024.telegeography.com/>

Internet capacity in the majority of African countries is limited for two reasons

- Network infrastructure within the country is limited to urban areas.
- The data capacity across the borders of the country is restricted.

Within each country the majority of infrastructure investments have been directed towards urban areas, with limited investment for rural areas. Currently, most of the Internet users in Africa access the Internet through the mobile phone networks using smart-phones. 4G-LTE networks provide mobile data access, generally with low data speeds and low data caps.

In 2024 there was a total of 710M mobile phone users in Africa, and 416M of these users had Internet access. This indicates that in 2024 smart-phones represented 59% of mobile phones in use. In 2030 the total of African mobile phone users is expected to rise to 915M, of which 576M will have Internet access. The percentage of smart-phones is expected to rise to 62% of mobile phones in use.

The availability of a satellite Internet service, such as Starlink, can address the two types of data bottleneck.

- Direct connection to the global Internet service, eliminating the requirement to communicate via terrestrial international infrastructure.
- Localized network infrastructure that does not depend on the national data communications infrastructure, and has a correspondingly low deployment cost, suitable for the smallest village.

Low cost network infrastructure with satellite technology is the key to provide economical Internet for remote rural communities in Africa. Simple to use low cost Internet access for communities is made possible by combining several technologies into a managed Internet infrastructure. See the list below.

TELECOM COMPANIES: Internet for rural Africa

- Satellite Internet, the Starlink service currently provides the best performance.
- WiFi wireless distribution networks for outdoor and in-home Internet service.
- Network controllers (broadband network gateway) that manage access to the Internet and also interface with the system that charges people for use of the Internet service.
- Cloud management to administer and monitor the service, failure alarm features facilitates field maintenance of the service.
- Mobile Money charging to receive payments for the Internet service.
- Gateway software to inter-connect the community Internet service with 3rd party applications, such as telecom billing systems.

Telecom companies can deploy the network infrastructure and brand the service as part of the company's telecom services. Telecom businesses that have deployed satellite based network infrastructure for remote rural communities find that the service is profitable with a short ROI. The technology is simple permitting a rapid expansion of the telecom network in rural areas.

2. The Technology that Delivers Low Cost Internet to Rural Communities

TELECOM COMPANIES: Internet for rural Africa

2. The technology that delivers low cost Internet to rural communities

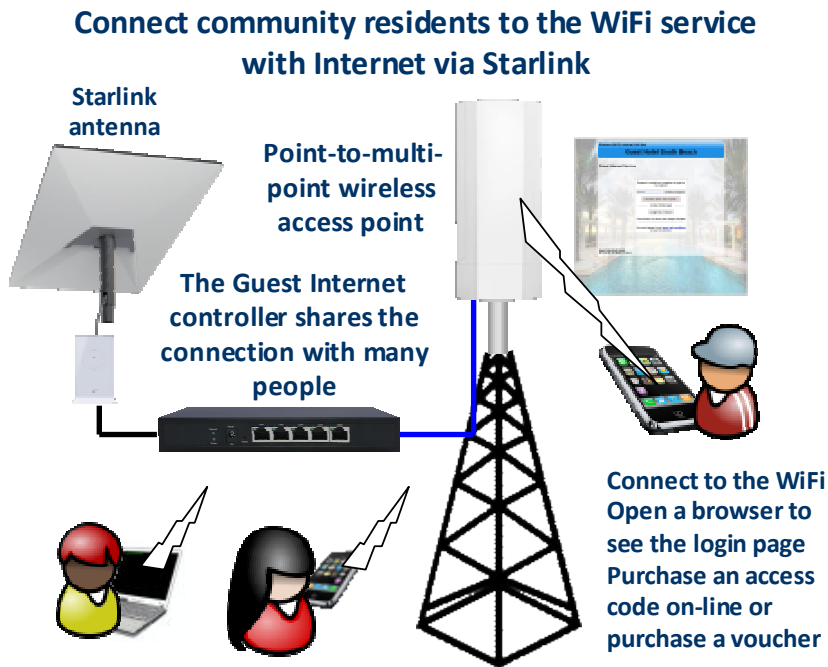
2.1. Adapting satellite Internet to provide a service for rural communities

Connecting remote rural communities with fiber cables or microwave bridges is often impractical for cost and logistical reasons. The distances are sometimes measured in hundreds or thousands of Km, and the income generated by offering the service will not permit the cost of the installation to be recovered, there is no return on the investment.

Satellite Internet, such as the service offered by Starlink, will provide community Internet access for a very low cost compared with any other terrestrial method of connecting the community to the global Internet backbone. Although Starlink is designed to provide the Internet service for a home, many tens of thousands of communities around the world are using the Starlink service to provide Internet for communities members, so that hundreds and thousands of people can have access to the Internet.

The Starlink service can be shared because the Guest Internet controller manages the Internet access for many people. Each user has a limited time to access the Internet, and has a limited data speed and limited data volume.

A frequently asked question is how many people can share a Starlink connection at one time? The answer depends on the duration of access and data speed that each community member is allowed. With limited duration and data speed for each user it is possible that 150 people can be connected to a Starlink antenna at one time. A service with one Starlink antenna may be adequate for a community of 500 people, as only a small percentage of the population will want to connect to the Internet at one time.



2.2. Satellite Internet provides the connection for remote rural communities

Currently, the dominant global Internet satellite network is Starlink, developed and operated by Space-X. The Starlink satellite constellation currently has over 10,000 satellites in orbit and will have more than double this when completed. The satellites orbit in several orbital shells, each shell at a different altitude and with a specific inclination to the orbit of the earth. Each customer has an antenna that can communicate with a satellite over approximately 180 degrees of the sky, and can swap the connection between satellites as each move across the sky. Each satellite relays the customer connection to one of the many ground stations around the globe. Each ground station has a high-speed connection to the

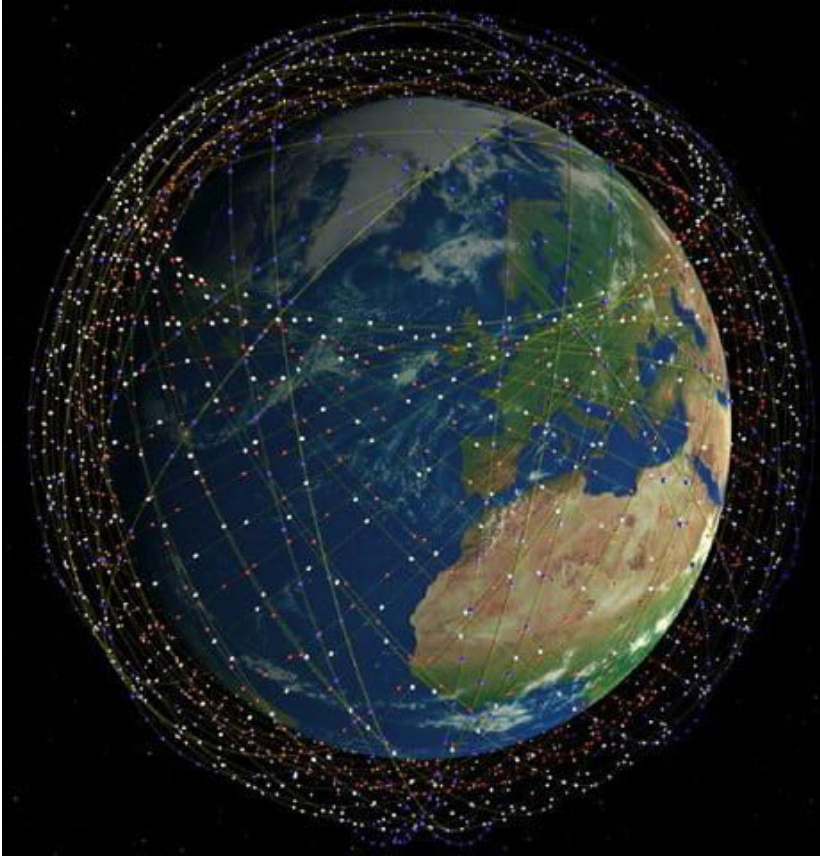
Internet. The next figure illustrates the orbits of satellites at different inclinations and in different shells.



Starlink satellite orbital inclinations; within shells at different altitudes.
(Image copyright © SpaceX 2021).

Each satellite has a fixed orbit in space however the earth is rotating and so each satellite will be over a different landmass with each orbit of the earth. It is possible that any point on the earth might have several satellites overhead at any time due to orbital shells with different inclinations. The customer ground antennas will have a 180-degree visibility of the sky and so several satellites might be visible to the antenna. The satellites will move across the sky from horizon to horizon in a few minutes as a low earth orbit

requires a much faster orbital velocity than the speed of the earth's rotation. The figure shown below illustrates the constellation of Starlink LEO satellites in orbit around the earth, within several shells, each shell at a different altitude.



An illustration of Starlink satellites in orbit around the earth, within several shells. (Image copyright © SpaceX 2021).

The Starlink antenna is a phase array beam forming design, which means that the antenna can be directed electronically over approximately 180 degrees of the sky. The antenna must have 180-

degree visibility of the sky to ensure that it can connect with at least one satellite. If the antenna is installed in a location that is surrounded by buildings or trees then the antenna must be mounted on a roof or antenna tower to provide 180-degree visibility of the sky.

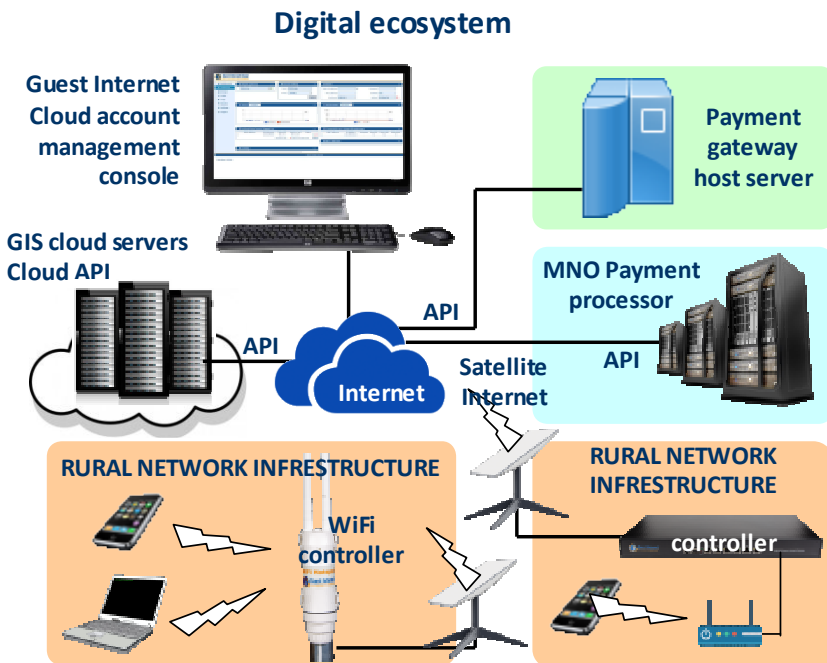
The operation of Starlink has to be approved in each country where it will provide service, as the frequencies used by Starlink require a license to authorize their use. At the time of writing Starlink is available in over 20 countries in Africa and has pending applications to operate in many more countries.



The map shows countries in Africa where the Starlink service is authorized (light color). (Image copyright © SpaceX 2026).

2.3. Functionality of the rural community Internet service

Implementing rural community Internet requires the integration of a group of technologies; a digital ecosystem that makes it possible to provide remote rural communities with low cost Internet access, and to charge community members for the service so that the costs of operating the service are paid. A small affordable charge paid by each resident for the shared Internet connection pays for the satellite Internet service. The rural Internet provisioning system has several components listed below and shown in the diagram.



- Rural site with three components, community members connect with smart phones.
 - Satellite antenna to access the Internet service; Starlink.

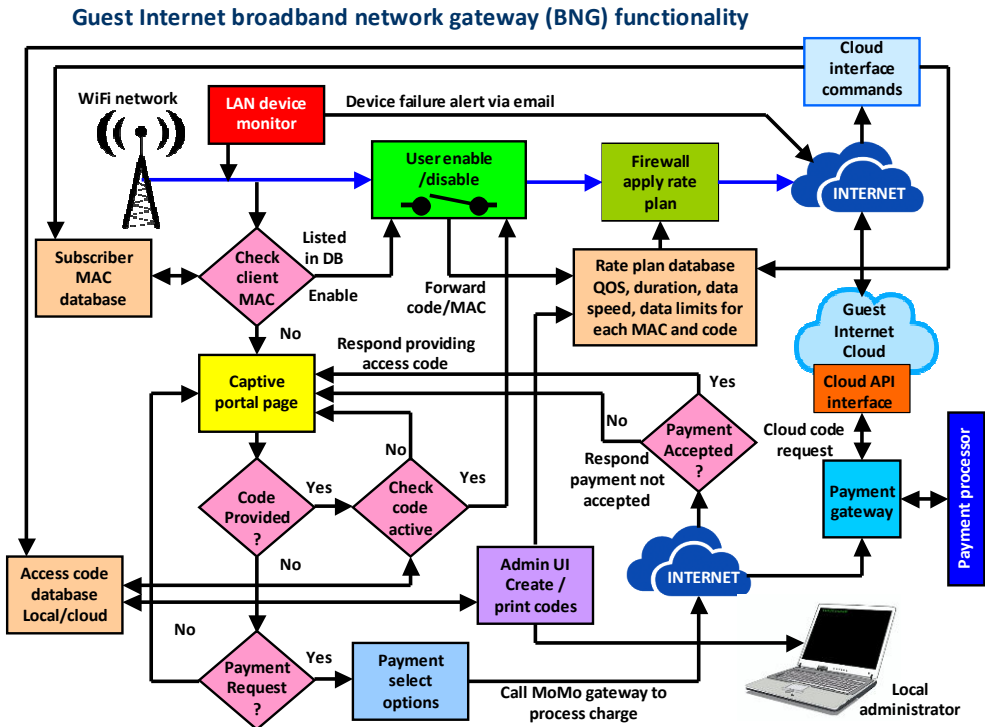
- Guest Internet controller; broadband network gateway (BNG), is managed by the Guest Internet cloud service.
- WiFi network infrastructure to provide Internet access for users.
- Guest Internet cloud management system; coordinates user authentication for all rural sites, with an API interface for a external applications software or Telecom billing systems.
- Payment gateway host server; manages the online access charge process.
- Mobile operator payment processor; an API service provided by the mobile operator.

2.4. Manage Internet access and billing for the rural community Internet service

Each rural WiFi Internet installation has a Guest Internet controller (called a broadband network gateway - BNG). The WiFi network infrastructure is connected to the Guest Internet controller, and the Guest Internet controller connects to the ISP service, such as a Starlink antenna. The Guest Internet controller shares access to the Internet for many concurrent users. The Guest Internet controller is also responsible for ensuring that users have paid for the service before being authenticated. There are two types of user authentication.

- Pay on demand; the user purchases an access code that can be used for a limited time, purchased either as a voucher, or purchased online.
- Pay by subscription; the user remains connected via fixed wireless access (FWA) while the monthly fee is paid. Payment is through one of several methods.

The next diagram illustrates the functionality of the Guest Internet BNG controller.



The Guest Internet controller (broadband network gateway: BNG) is a software and hardware product that is installed at the location where the WiFi Internet service will be provided. There is a range of Guest Internet controller products that are appropriate for all levels of cost and performance required for each installation. The Guest Internet controller has a stand-alone mode of operation for small installations. Larger installations and multi-site installations are supervised by the Guest Internet cloud service, which will manage the access of users to broadband networks at many locations.

The Guest Internet controller installs in a network between the Internet service provider (ISP) circuit and the end-user WiFi

network infrastructure, to control and manage access of many users to the Internet connection. Key functions of the Guest Internet BNG controller include:

- The Guest Internet controller manages the sharing of one Internet connection by many concurrent users, by supervising the data flow to avoid network congestion of the ISP connection.
- The Guest Internet controller customer authentication implements several different methods for authenticating customers to support several concurrent-billing methods.
- The Guest Internet controller internal database stores authentication information for each access, including the rate-plan (duration of access, data speed limits, etc) chosen by the customer.
- The Guest Internet cloud API (application program interface) is provided for integration with external customer billing software, that includes, subscription, Mobile Money and credit cards, plus interfaces with Telco billing and monitoring systems.
- The Guest Internet controller can monitor any device connected in the LAN network that has a UI IP address, this includes wireless access points and remote client premise wireless equipment (CPE's). When a failure is detected an alert is sent via email to the network supervisor and field service tech.
- The Guest Internet cloud service monitors the status of all Guest Internet controllers that are assigned to the account and the ISP connection to each controller. There is no limit to the number of Guest Internet controllers that can be assigned to one cloud account. When a failure occurs, an alert is sent via email to the network supervisor and field service tech when a failure is detected.

- The Guest Internet controller firewall implements a range of security measures that will prevent abuse of the service, including the prevention of users sharing one access credential with others. The firewall has other features, such as blocking access from a device that has an active DDoS virus.
- High reliability operation of Guest Internet controller products demonstrated by tens of thousands of robust controllers installed, and with some older controllers still in use after 15-years of operation.

Users that connect to the WiFi network have different methods of authentication, which depend on the billing mode assigned for the user.

- Pay by subscription; the customer is permanently connected to the Internet via a fixed wireless access (FWA) wireless connection. The customer is authenticated onto the network via recognition of the device connection. The billing system supervises the customer's connection and advises the Guest Internet controller to suspend the customer authentication if the monthly fee is not paid by the due date.
- Pay on demand; Access to the Internet is for a limited duration where an access code is purchased by one of several methods that include printer vouchers and online payment with methods such as Mobile Money.

The Guest Internet controllers and cloud management system have features to generate and print access code vouchers. In addition, the billing mode methods can be implemented by 3rd party software systems via the cloud API when required by the application. The steps for each user to obtain access to the Internet and maintain a connection to the Internet are as follows.

- The user connected to the network then the Guest Internet BNG controller receives this request and begins the authentication process.
- The Guest Internet BNG controller verifies user credentials against the internal database (populated by the Guest Internet cloud server). Successful authentication grants access, while failures are denied or redirected.
- Once authenticated, the Guest Internet BNG controller establishes a session, assigning IP addresses and applying policies such as bandwidth limits, rules, and security settings.
- The Guest Internet BNG controller consolidates user data streams, inspecting packets for security threats or policy violations. It then routes traffic to the Internet.
- Throughout the session, the Guest Internet BNG controller continuously monitors traffic, collecting data on usage, performance, and security events. This information supports network management and billing.
- When a user disconnects, the Guest Internet BNG controller terminates the session, freeing resources and updating usage records.

Each step ensures secure, efficient, and manageable broadband access, and manages the increasing complexity of large-scale multi-site distributed networks.

Some applications for Guest Internet controllers are listed below.

- Residential Community Broadband Providers (ISP's) use Guest Internet BNG controllers to authenticate multiple residential users, manage bandwidth, ensuring each household receives the appropriate bandwidth and security.

- Mobile and Wireless Networks use Guest Internet BNG controllers to implement pay-on-demand WiFi services for areas that do not have tower coverage.
- Public WiFi & Hotspot Management applications deploy Guest Internet BNG controllers to authenticate users, limit access durations, and protect against cyber threats, providing a safe browsing environment.

2.5. Network infrastructure for a community Internet service

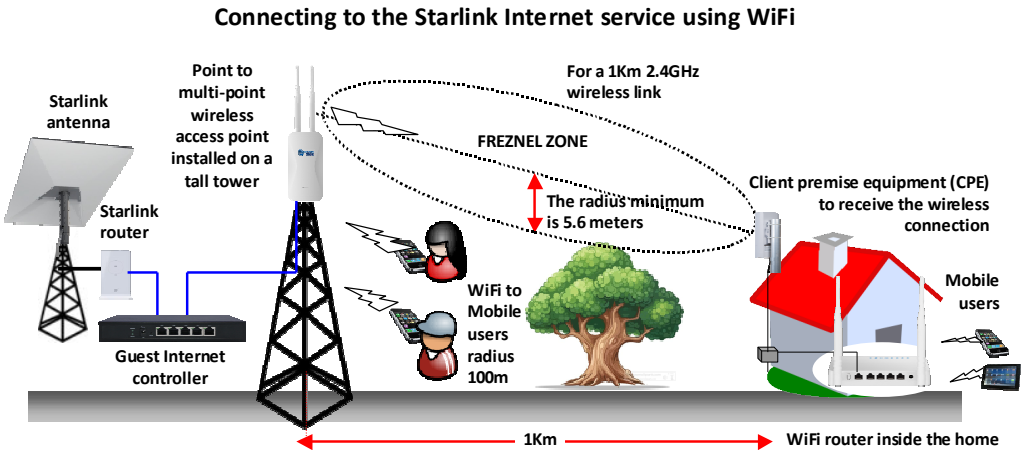
The network infrastructure for a community Internet service has three components.

- The Internet connection, usually a satellite service such as Starlink.
- The Guest Internet BNG controller that will share the Internet service with many people, has a mechanism to charge for the Internet access, and monitor the use of the service to prevent abuse.
- The WiFi network infrastructure, which can be an outdoor wireless access point for mobile devices, home installations for communication at greater distances, and wireless bridges to nearby communities that can share the Internet service.

By deploying Guest Internet controller and wireless WiFi Star-kits, the infrastructure investment is minimized while providing a secure, robust and high performance service for the community. Community members can access the WiFi service using mobile phones when in range of a wireless access point. Homes that have the CPE and wireless router kit installed (such as the Star-4 kit or Star-16 kit) can connect to the central antenna over a greater

distance, providing that there is a line of sight between the antennas.

The next diagram illustrates the community Internet installation.



A home that is connected to the central antenna via wireless, as a fixed wireless access (FWA) customer, can be charged for the service either as a pay-on-demand customer or as a subscriber. A subscriber will be connected to the Internet permanently while monthly payments are made for the service, and disconnected when a payment is missed. The subscriber chooses a rate plan, which determines the monthly charge and the maximum data speed corresponding to that charge. There may be other conditions such as a maximum monthly data cap.

Mobile users are always pay-on-demand customers, which means that the user purchases an access code, either as a printed voucher or purchased online using Mobile Money, or other payment system. The pay on demand access code has parameters associated with it, similar to the subscriber rate plan, the principal difference is that the access code has a limited duration; it is not a permanent connection. A summary of the access code characteristics follows.

- The access code can be generated by the Guest Internet controller or Guest Internet cloud; the code is a 6-digit alphanumeric code. A 3rd party application can generate and set access codes up to 9 alphanumeric digits.
- The access code has a limited time of validity after first use. The user may be offered a limited duration e.g. 1hr, 4hrs, 8hrs, 1day, 1week, etc. The person managing the system decides what duration will be offered for access codes.
- Maximum download and upload speed is set for each access code. The data speed of each user is limited in order to share the bandwidth available from the ISP between the numbers of concurrent users.
- Maximum download and upload data volume limits can optionally be set for each access code. This is the amount of data that each user can consume.
- Number of concurrent users for the access code. The default is one however any number can be set. A business might decide to generate an access code with unlimited users so that any person can get Internet access with the “code of the day”.
- Set the start date and time after which the code can be used. For a large community sharing one Internet access then access codes can be issued that can be used only after the specified date and time.

When the administrator is generating codes and printing vouchers, up to 10,000 codes or vouchers can be generated at one time with the same characteristics. Access codes generated on a Guest Internet controller can only be authenticated on that controller.

Any controller that is part of the cloud group can authenticate access codes that are generated using a cloud account group. There is no limit to the number of controllers that can be part of a cloud group.

2.6. Calculate how many people should connect to the Internet service

The calculation of the maximum downlink and uplink speeds to set for each code depends on three factors.

- The maximum upstream and downstream data speeds of the ISP's Internet service.
- The number of concurrent users expected.
- The contention ratio.

The first calculation is to divide the ISP's data speed by the number of expected concurrent users. For example, an ISP service with a maximum downstream speed of 150 Mb/s with an expectation that 200 people will concurrently access the service. Maximum downlink data speed per user $150/200 = 0.75$ Mb/s per person

The second factor is the contention ratio; this is the guessed amount that we can exceed the calculated speed per user because not all users will be using the maximum data speed. People streaming videos will use the maximum data speed, however people checking emails will use only a tiny fraction of the maximum data speed. A estimation for the contention ratio might be 3:1. Then multiply the maximum data speed by the contention ratio. The permitted maximum downlink data speed per user = $0.75 \times 3 = 2.25$ Mb/s per user. Repeat this calculation for the uplink data speed, which is usually lower than the downlink data speed.

In addition to setting the maximum data speed per user it is also possible to set a limit on the number of concurrent users who are connected to the system. Failure to set limits on the number of users and the data speed per user can result in network congestion, where all users will be disconnected from the internet service at the moment of congestion and will have to reconnect. The customer might be offered several rate plans to choose. Each plan has a cost and a maximum data speed. The customer can choose from options of cost and data speed. When a community has a

large number of members then cost can be a factor to persuade people to choose lower data speeds so that more people are able to connect the service.

2.7. Prevent potential abuse of the Internet service

It is extremely important to prevent people abusing the service. One type of abuse is the illegal sharing of copyright material, CD's or DVD's. The copyright owners monitor sharing services such as Torrent and aggressively pursue a remedy to stop the illegal sharing. When the ISP is located in a country outside the USA or Europe it is difficult or impossible for copyright owners to prevent illegal file sharing. However any user of an ISP located in the USA will have the Internet service terminated if using the service to share copyright material. Starlink is a USA corporation that provides the Internet service around the world. Any sharing of copyrighted material in any country will result in Starlink terminating the Internet service for that customer.

The Guest Internet BNG controller has a firewall feature to detect and block the use of Torrent protocols to prevent illegal file sharing. Users can connect via a VPN to encrypt the connection and hide illegal file sharing. In this case the IP address observed by the copyright holders will not be the IP of the location where the service is provided.

2.8. Comparing performance of WiFi vs. mobile phone technology

A frequently asked question from people who are considering installing a WiFi Internet service for a community is to ask about the range of the outdoor WiFi.

Most people who are not familiar with WiFi technology expect that the outdoor WiFi wireless products can communicate over many

Km of distance and are very disappointed when they discover that the range is a few tens of meters from an outdoor WiFi antenna to a mobile device. People expect that the range of WiFi must be the same as a mobile phone service, however there are many differences between the mobile phone technology and WiFi technology. Some characteristics of a mobile phone service compared with a WiFi service are listed below:

MOBILE PHONE TECHNOLOGY (LTE)	OUTDOOR WiFi TECHNOLOGY
Exclusive purchased licensed frequencies, no interference.	Many devices share public frequencies of 2.4GHz and 5,8GHz, a lot of interference.
Lower frequencies in the range of 800MHz to 1.5GHz that travel longer distances.	High frequencies of 2.4GHz and 5.8GHz travel shorter distances.
200x the wireless power output of a WiFi wireless access point.	WiFi has low wireless power limited by government regulations.
Antennas are installed on 30m to 50m tall towers for line of sight visibility.	Antennas are installed on building roofs limiting visibility.
Three wireless sector antennas are installed on the tower for maximum range.	One wireless access point with an omni-directional antenna limits the range
High performance and expensive wireless transmitters and receivers.	Mass-produced wireless equipment powered by a single chip, limited performance.
A mobile phone tower with equipment costs millions of USD.	A wireless access point with antenna costs hundreds of USD.
Communications distance to a mobile phone device, 2 Km to 5 Km	Communications distance to a mobile WiFi device, 50m to 100m
Longer distances of 5 Km to 15 Km using a 4G-LTE modem with rooftop YAGI antennas, with clear line of sight to the tower.	Longer distances over 1 Km when the home has a CPE antenna installed on the roof, with clear line of sight to the access point.

3. Community Network Infrastructure

TELECOM COMPANIES: Internet for rural Africa

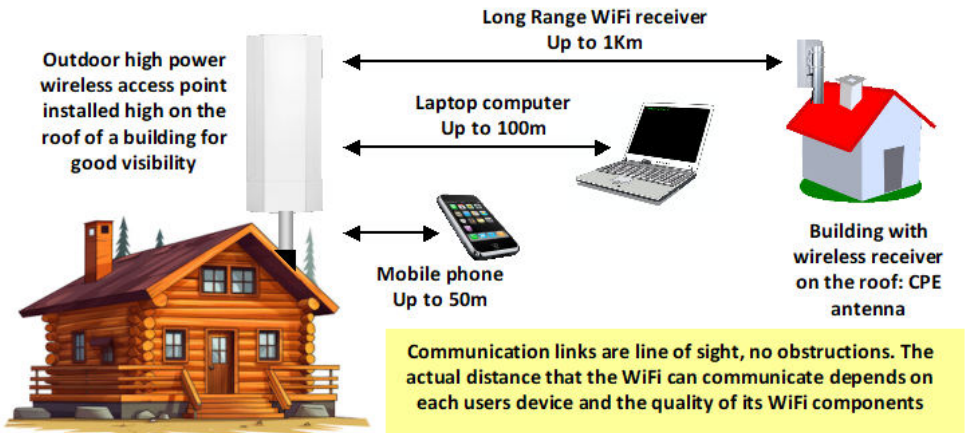
3. Community network infrastructure

3.1. Communication distances for outdoor WiFi devices in a community

WiFi communications for computer networks can be selected with every type of mobile device. Mobile devices use the WiFi service, when available, to connect to the Internet. WiFi was designed for short-range indoor use. The maximum wireless power of a WiFi device is low with the upper limit set by the government authority. In the USA the FCC sets the maximum wireless power limit for WiFi products. WiFi has been adapted for outdoor use with all-weather outdoor wireless access points and outdoor WiFi receivers, called client premise equipments (CPE's). The wireless power is low and so the range is limited. An outdoor WiFi installation has a central wireless access point antenna installed at a high point so that it is visible for the people who want to connect to it. A mobile device owner can connect to the WiFi antenna. The distance between the central antenna and the mobile device must be a clear line of sight. Any obstruction such as a tree or building will block the WiFi signal.

The central antenna can be configured for the maximum permitted power, however the distance of communication depends on the device that is connecting to the central antenna. Mobile phones can connect over a short distance only as most phones have a very low power WiFi chip and a basic antenna. Devices such as laptop computers can communicate further as they have a better WiFi chip and a better antenna in the laptop lid. Wireless devices such as the client premise equipment (CPE) can communicate much further due to better wireless circuits and a directional high gain antenna. WiFi communication distances are illustrated in the next figure.

Approximate point-to-multi-point WiFi communication distances to different devices with line of sight and no obstruction between antennas

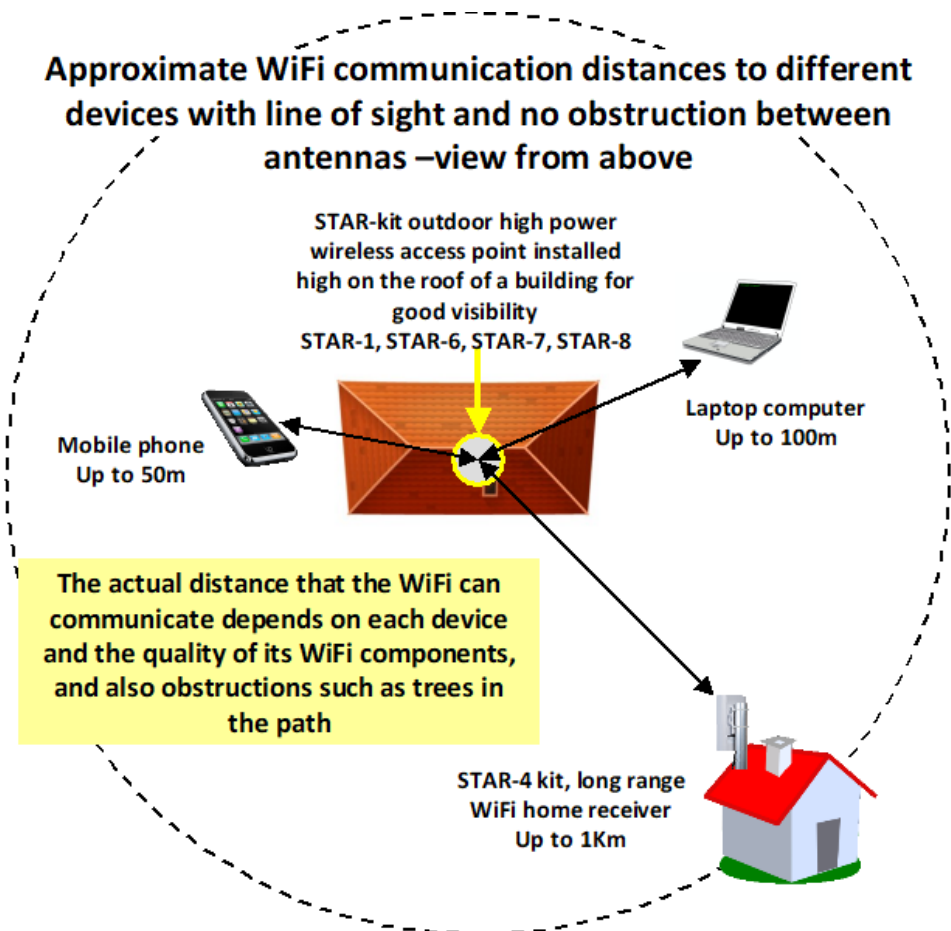


The central wireless access point antenna has an important characteristic that describes how the antenna operates.

- Point-to-multi-point: This characteristic means that several mobile or fixed devices can access the central wireless access point antenna simultaneously, each mobile or fixed device is sharing the bandwidth available from the central wireless access point antenna and so as more devices connect, the data speed becomes slower for each device.
- The number of devices that can connect to the central wireless access point antenna depends on its performance. Low cost central wireless access point antennas might be able to connect up to 20 or 25 devices simultaneously, limiting the number of devices that can be connected. Expensive high performance wireless access point antennas might be able to connect between 75 to 150 devices simultaneously.
- When considering the purchase of a wireless access point antenna the performance must be evaluated to ensure that

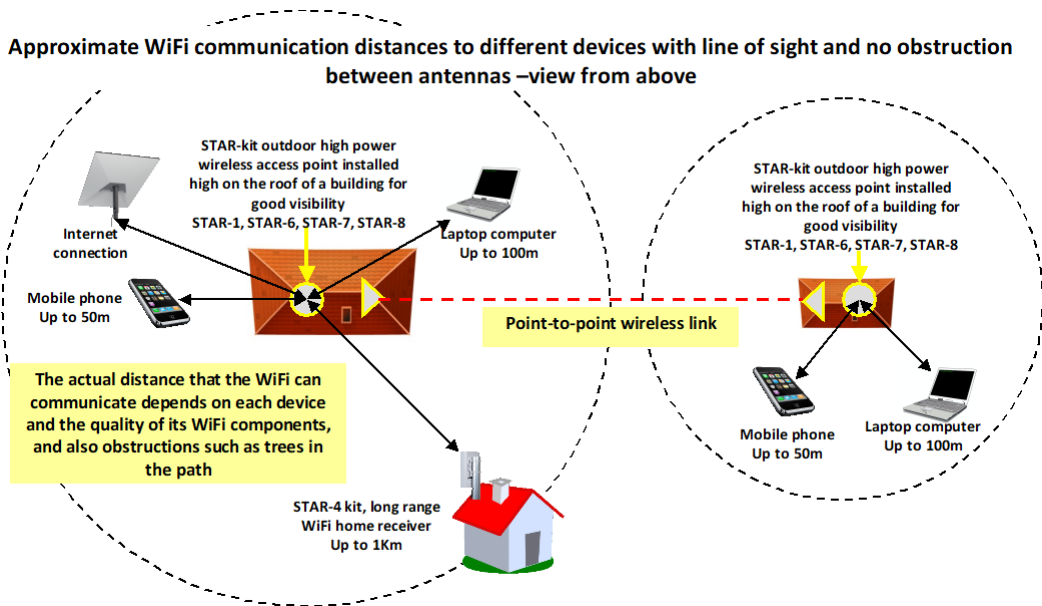
the product can meet the expectation of the number of users.

Most outdoor wireless access points that are installed for public Internet WiFi service have an omni-directional antenna. This means that the WiFi signal radiates 360 degrees around the central antenna location. This is illustrated in the next plan-view diagram.



Greater communication distances can be obtained for a higher cost by installing three wireless access points at the central tower location, each with a 120-degree sector antenna. This is the same antenna arrangement that is installed on mobile phone towers.

The area of WiFi coverage can be extended from the central location using a point-to-point WiFi bridge connection, then installing a second point-to-multipoint wireless access point antenna at the far end of the point-to-point link. This arrangement is illustrated in the next figure.



One central Guest Internet controller can only be used for the distant location when the point-to-point wireless bridge is configured for the Wireless Distribution System (WDS). This is essential in order to pass the user device MAC address to the central Guest Internet controller.

When configuring a community with multiple point-to-multipoint antennas a simple method of access control is to install a Guest Internet controller at each point-to-multipoint wireless access point location. This simplifies the configuration of the wireless distribution network.

3.2. The central WiFi Internet installation for a rural community

The central installation in a rural community requires a connection to the Internet. In most locations this will be a satellite service, either a geo-stationary satellite service or a low earth orbit (LEO) satellite service. The popular choice is the Starlink LEO Internet service due to availability, good performance and reliable operation.

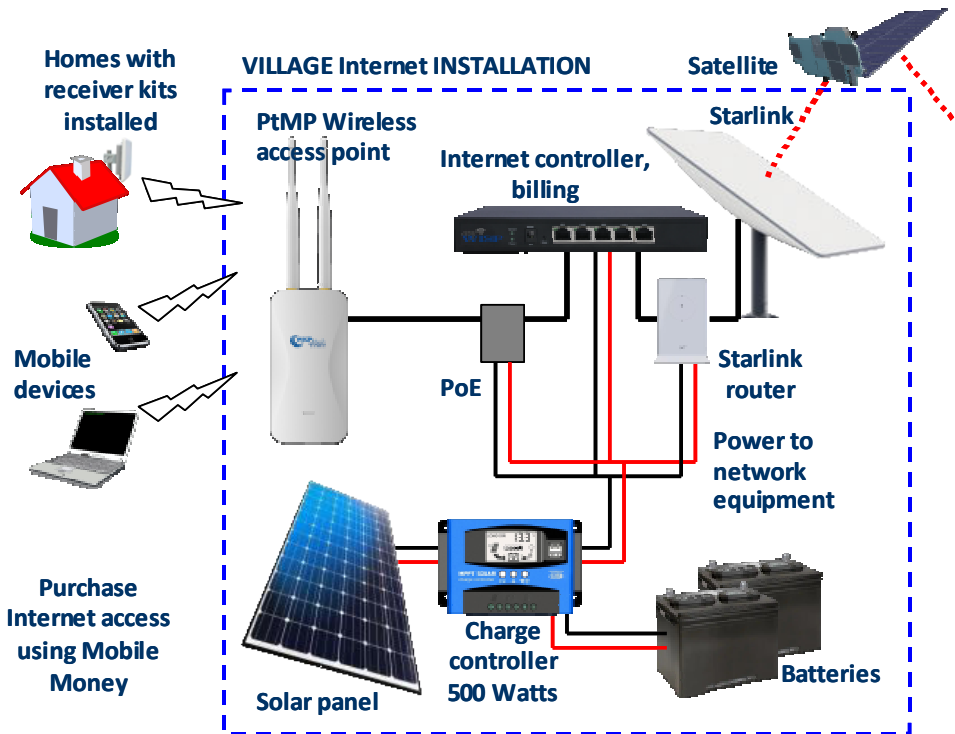
The Guest Internet BNG controller connects to the Starlink router; the Starlink router has to be configured in the bypass mode. One or more wireless access points of any make or brand are connected to the Guest Internet controller to provide the desired WiFi area of coverage. A single wireless access point with an omni-directional antenna is easy to install. For increased range and coverage three wireless access points can be installed, each with a 120-degree sector antenna. The wireless access point must be installed on a tall mast so that it is visible to the users. Construction and vegetation will block the WiFi signal.

The wireless access points offered with the Guest Internet controller are dual band, 2.4GHz and 5.8GHz with omni-directional antennas.

If power is available in the rural location where the equipment is installed then that is used to power the equipment. If the electrical power is intermittent, common in some rural locations, then an uninterruptible power supply (UPS) must be installed to power the equipment. In a location with no power then the installation can be

powered by solar energy, using a solar panel, batteries to store energy, a charger and voltage converter. The wireless access point and Guest Internet controller are low power and will consume less than 10 Watts each. The Starlink antenna consumes over 100 Watts. A 500-Watt solar power installation will be adequate to provide the base station power.

The next diagram shows the central installation satellite and WiFi equipment, together with the solar power equipment.

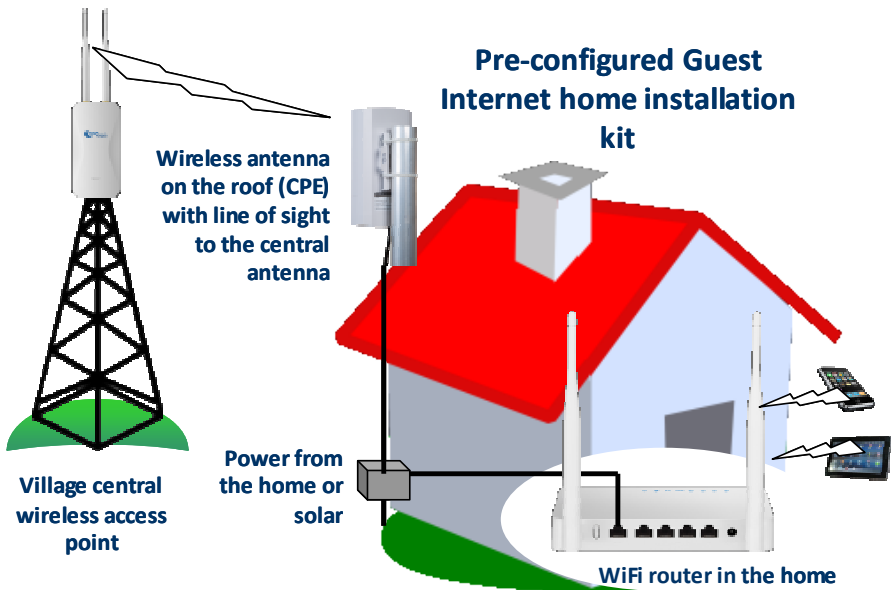


3.3. Connecting homes to the central antenna with fixed wireless access (FWA)

Homes can be connected to the central antenna via WiFi wireless; with a network configuration called fixed wireless access (FWA). A wireless product configured as a Client Premise Equipment (CPE) is installed on the roof of the home. The CPE antenna must have a clear line of sight to the central antenna. Buildings and vegetation will block the WiFi signal. A home can be connected to a central antenna over a much longer distance than a mobile device can, providing there is a clear line of sight. The CPE equipment has a directional antenna that permits a WiFi connection over a much longer distance than can be obtained with a mobile phone. The CPE connects to a wireless router inside the home so that the home residents can connect to the WiFi to get access to the Internet.

The home access can be configured as either subscription (permanently connected) or pay-on-demand, purchase an access code with a limited duration (connected only for the duration of the access code). Whichever configuration is used, the home access has a maximum download and upload data speed determined by the authentication method. All the home residents share the data speed configured for the home so when several home residents are using the Internet at the same time then the data speed for each person will be lower. The home CPE and wireless router equipment is low power, less than 10 Watts, and so can be powered from a 50-Watt solar panel with a battery and charger.

The next figure illustrates the home installation, with the CPE wireless and the wireless router. Guest Internet offers a pre-configured home kit to simplify the installation for people with limited technical knowledge. Guest Internet makes two Star-kits, one with a 2.4GHz CPE and one with a 5.8GHz CPE. The Guest Internet central wireless access points are dual band. The 5.8GHz backhaul is less prone to interference.



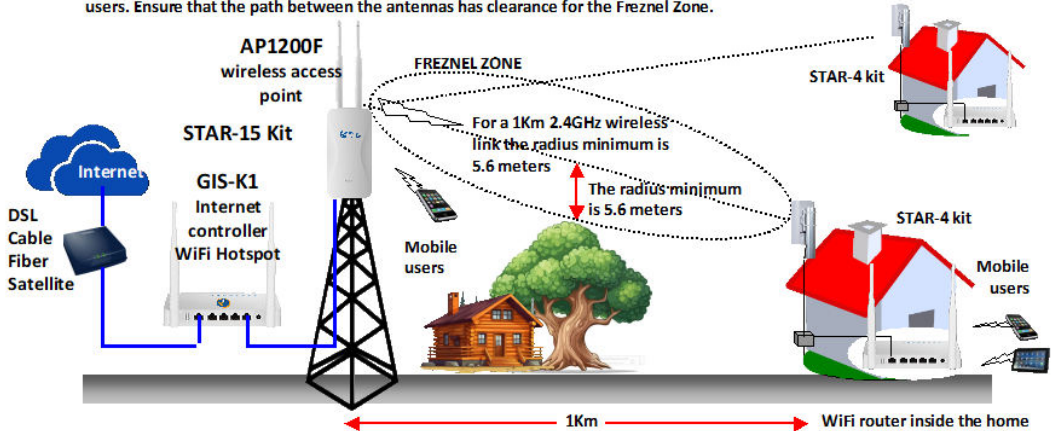
Lower cost CPE products have a directional panel antenna, which can communicate up to about 1 Km. The panel antenna has a wider beam-width than other types of directional antennas. The home can be located at a further distance if the CPE has a parabolic antenna, which has a narrow beam, and for that reason it is harder to adjust.

The distance between the home CPE antenna and the central antenna must have a clear line of sight without obstructions. A tree or building will block the WiFi signal. In addition, there must be a clearance around the wireless connection called the Fresnel Zone, which is illustrated in the next figure.

The Fresnel Zone clearance means that the antennas must be installed above any obstruction such as trees. Calculate the distance of the antennas above the obstruction, which depends on the frequency used for the connection and the distance between the antennas. Without the Fresnel zone clearance, the WiFi communication will not work.

Wireless distribution network for a community - Combine the STAR-15 kit with several STAR-4 kits

Install the AP1200F point to multi-point antenna on a tall tower so that it is visible to all the users. Ensure that the path between the antennas has clearance for the Frenzel Zone.



The Frenzel Zone clearances for the two frequencies used by WiFi are listed below.

- 2.4 GHz connection to the home: the line of sight between the home and central antennas must be at least 5.6m above the obstacle for every 1 Km of distance between the antennas. This means that a distance of 2 Km will require a clearance of 11.2m above obstacles.
- 5.8 GHz connection to the home: the line of sight between the home and central antennas must be at least 3.6m above the obstacle for every 1 Km of distance between the antennas. This means that a distance of 2 Km will require a clearance of 7.2m above obstacles.

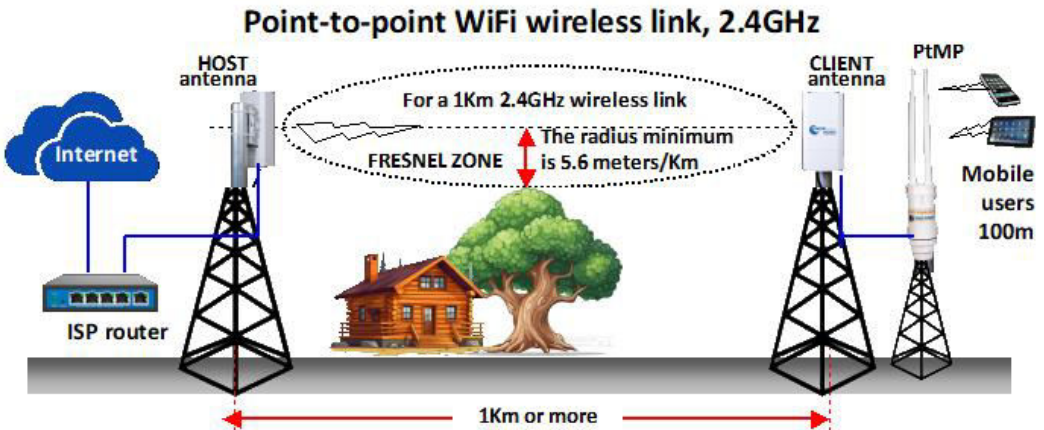
3.4. Adding adjacent communities to the central location

Adjacent communities can be connected together so that the residents of two or more communities can share one Internet service, such as a Starlink connection. Starlink has a throughput between 100Mb/s and 200Mb/s, which imposes a limit on the number of people who can have access to the Internet at the same time when connected to Starlink.

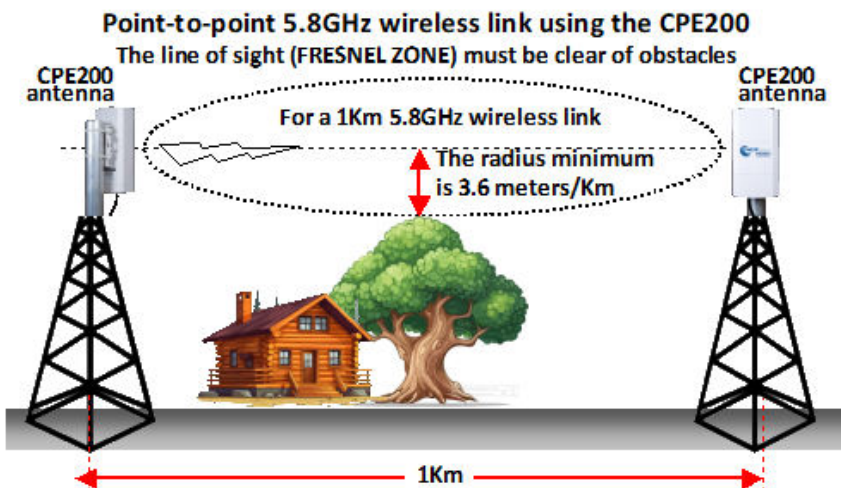
A distant community can connect to a central community using a wireless bridge, as shown in the next diagram. The wireless antennas of the bridge must be installed on towers so that there is a clear line of sight between the two antennas with the Fresnel Zone clearance; this is illustrated in the diagram. Guest Internet has two pre-configured wireless bridge kits, one for 2.4GHz and one for 5.8GHz. The 5.8GHz bridge will usually provide better performance due to less wireless interference. Wireless bridges are available from many manufacturers and products from Ubiquiti are popular. Products from other suppliers will require configuration. The wireless host and client units can have one of two types of directional antennas.

- Panel antenna, easy to install and align, distance up to 1 Km line of sight.
- Parabolic antenna, difficult to install and align, distances greater than 5 Km line of sight.

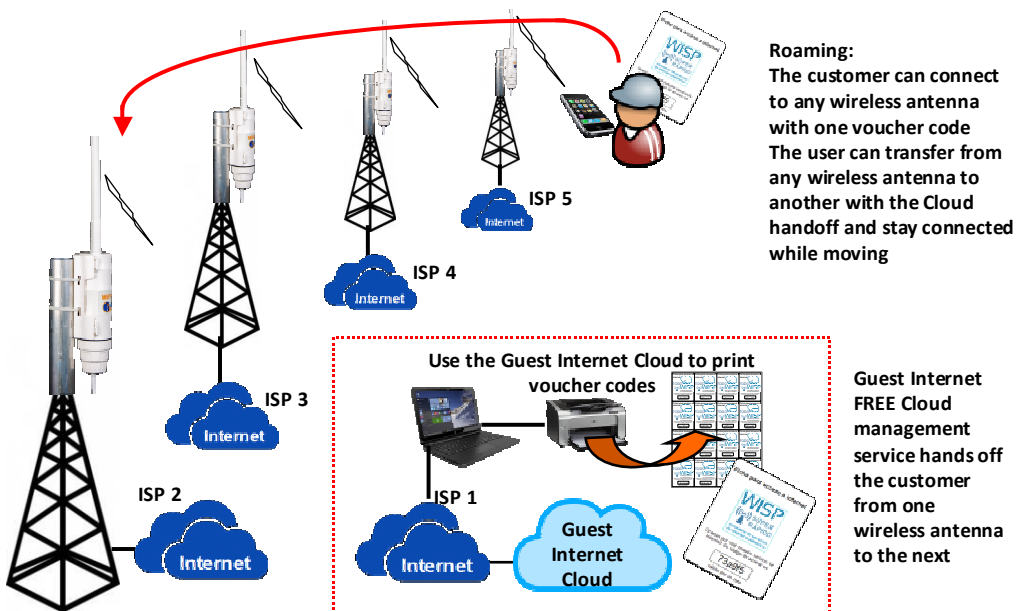
The point-to-point wireless bridge has to follow rules of installation, that include the Fresnel Zone clearance which means that the wireless access point antennas have to be installed on tall towers. The installation of a 2.4GHz point-to-point link is illustrated in the next figure. For 2.4GHz the Fresnel Zone requires the antennas to be installed 5.6m above obstacles multiplied by each 1 Km of distance between the antennas.



The 5.8GHz point-to-point wireless bridge is preferred as there is less interference in this band, and the bands are larger which means that the data rate between the two antennas can be higher. For 5.8GHz the Fresnel Zone requires the antennas to be installed 3.6m above obstacles multiplied by each 1 Km of distance between the antennas. See the next figure.

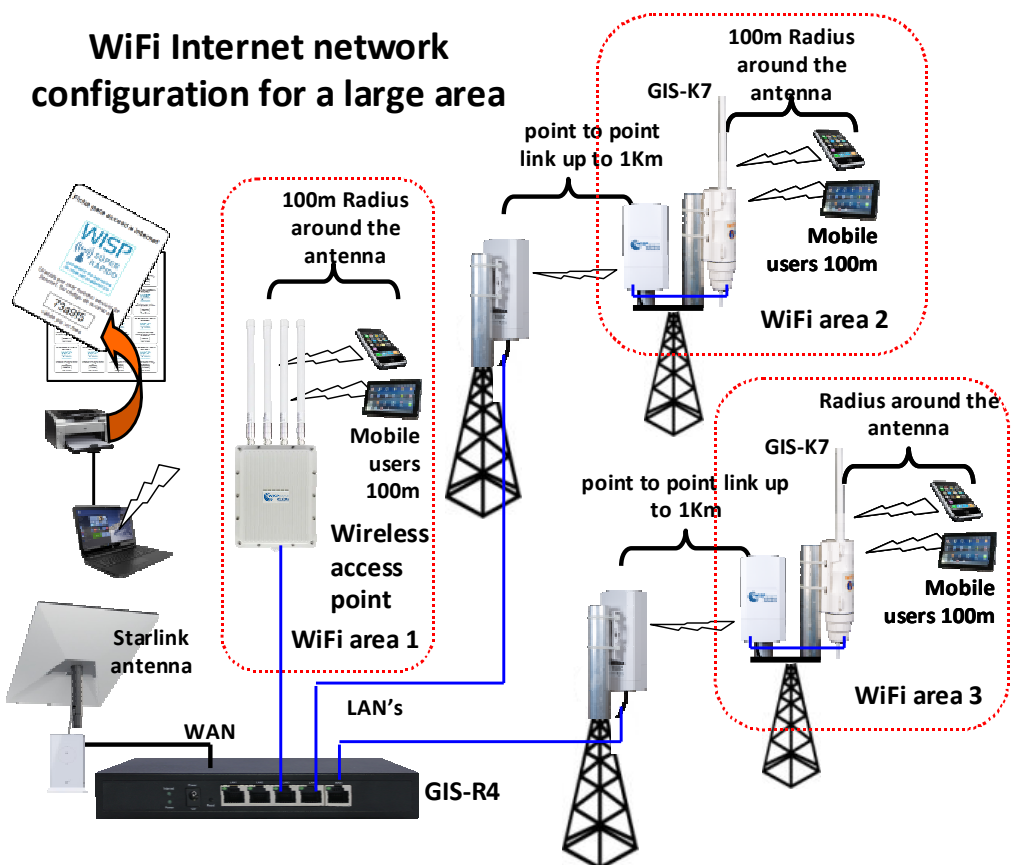


When a distant community is connected to the central community to provide the Internet service, the distant community must have a Guest Internet controller installed to manage access of the community residents. Guest Internet controllers in the central and distant communities are added to a cloud account group. Access codes are generated for the cloud group and roaming is configured for all controller locations. A resident in one community can connect to the Internet and then travel to the next community and remain connected to the Internet. This is illustrated in the next figure.



3.5. The network infrastructure for a larger community WiFi service

By combining the network technologies described in previous sections, a wireless distribution network can be designed and built to serve one or more communities. A remote rural community will not have access to any type of cable connection for the Internet service and so the only connection available will be via satellite. This can be a geo-stationary satellite service such as HughesNet or else a low earth orbit (LEO) service such as Starlink. A network schematic for a community WiFi Internet service is illustrated in the next figure.

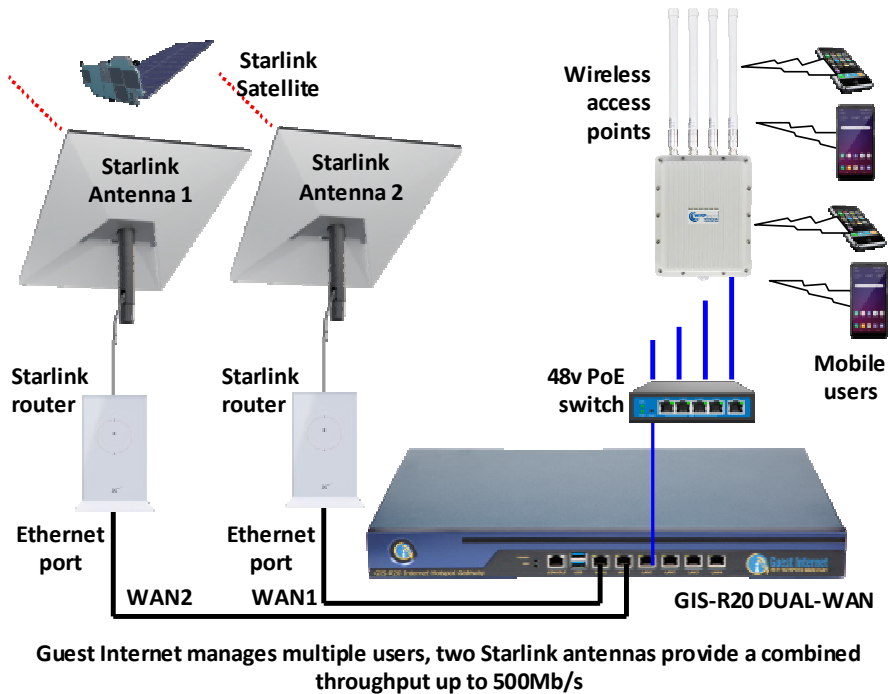


3.6. Expanding the Starlink satellite Internet service for larger communities

A Starlink antenna with Internet service can provide Internet access for a community of a few hundred people, when the Internet access is controlled and managed by a Guest Internet controller. Community sizes can range from less than a hundred people to several thousand people. Larger communities will find that one Starlink antenna does not provide the bandwidth required for the number of people who wish to use the Internet service at the same time. The community might be a town with a few thousands of inhabitants where several hundred people will be accessing the Internet at the same time. In this case the number of Starlink antennas can be increased to provide more bandwidth.

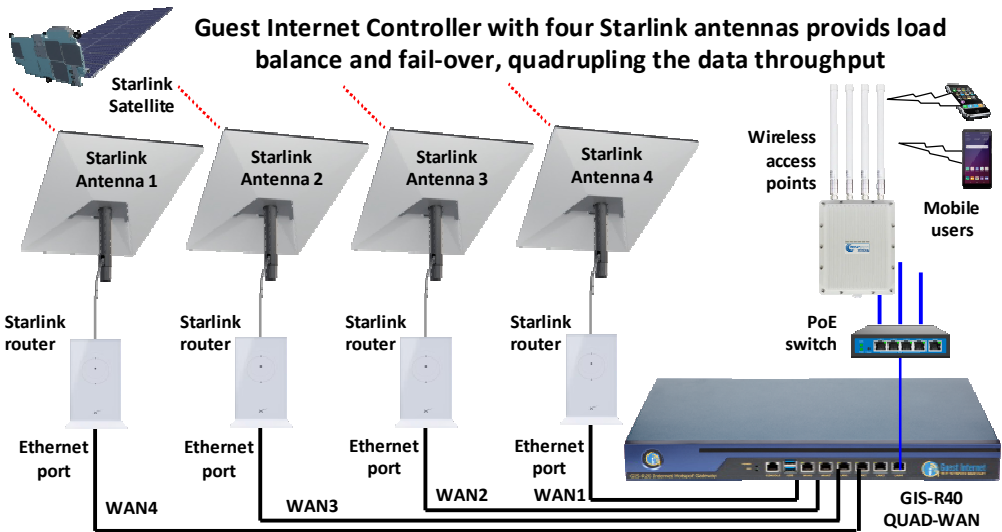
Guest Internet has two controllers that are designed to connect to two Starlink antennas, providing load balance and fail-over, the GIS-R10 and GIS-R20. Load balance means that the bandwidth of two Starlink antennas is available for the Internet users, effectively doubling the bandwidth available, and doubling the number of people who can connect to the Internet service. The GIS-R10 can comfortably manage 300 concurrent users and the GIS-R20 can manage 600 concurrent users. The actual number of users permitted depends on the bandwidth that each user is limited to use, set in the Guest Internet controller software, and also to the type of data traffic that is being consumed. Fail-over means that if one Starlink antenna loses connection with the Internet then the users connected through that antenna are switched to the working antenna. The next diagram shows the GIS-R20 product with two Starlink antennas connected. A wireless distribution network is connected to the LAN ports that will provide WiFi access for the community.

Guest Internet Controller with two Starlink antennas provides load balance and fail-over, doubling the data throughput



Larger communities can have up to four Starlink antennas connected to a GIS-R40 controller, all with load sharing and fail-over. The four-antenna satellite configuration can provide Internet access for 800 to 1000 concurrent users, depending on the data configuration provided for each user by the GIS-R40 controller.

The next diagram illustrates the connection of four Starlink antennas to the WAN ports of a GIS-R40 controller. The GIS-R40 LAN ports connect to the wireless distribution network that will provide WiFi access for the community users.



Guest Internet manages multiple users, four Starlink antennas provide a combined throughput up to 1Gb/s

The size of the network can be scaled up without limits, using multiple GIS-R40 controllers and Starlink antennas.

A later section of this report illustrates a large-scale application. This is a citywide Internet infrastructure with more than 50 Guest Internet controllers and using over 130 Starlink antennas distributed throughout the city. The wireless distribution network has thousands of wireless access points to provide WiFi connections for the city residents.

A countrywide Internet infrastructure can be built using Starlink antennas combined with Guest Internet controllers.

3.7. The customers procedure to connect a mobile device to the Internet service

The procedure for the user to connect to the Internet via the Guest Internet controller and WiFi network has a few simple steps.

TELECOM COMPANIES: Internet for rural Africa

- Connect to the WiFi service with the users device.
- Open the device browser.
- Open a browser tab.
- Type the name of the WiFi service; the default name is aplogin.com.
- The login page opens, type the purchased access code to get Internet access.

The user connection procedure is illustrated in the next diagram, for either the access code voucher or the online access code purchase using Mobile Money.



Two methods of purchasing access codes are available.

The first method is to print access code vouchers using the Guest Internet controller or Guest Internet cloud. Up to 10,000 vouchers can be printed at one time using either the controller or the cloud. The codes are used to access the Internet via a controller.

When a controller generates an access code, only that controller can authenticate the access code. When a network has multiple controllers the access code vouchers are generated and printed using the cloud service for a cloud group. Any controller in the cloud group can authenticate a cloud group code. There is no limit to the number of Guest Internet controllers that can be assigned to a cloud group. The vouchers that are printed can be sold for cash payments.

The second method to purchase an access code is on line using a payment system. The popular payment system for Africa is Mobile Money (MoMo). The Guest Internet cloud has a payment gateway for the online purchase of access codes. Access codes can be purchased either for a controller or for a group of controllers; this is determined when the Mobile Money gateway is configured for the customer. Mobile Money is country specific, each country's mobile operator provides the API for the Mobile Money payment. The Mobile Money payment system is customized for operation in each country and branded for the company that is selling the Internet service using Mobile Money.

Both the voucher and online payment methods can be used concurrently so that users have the option of paying online using Mobile Money or purchasing a voucher for cash.

When a purchase option for a pay-on-demand voucher or on-line payment is made, the customer sees a statement about the duration of the access code. In fact there are several parameters that the provider can be set for each access code generated. A Guest Internet controller and cloud group account can generate access codes with the following parameters.

- Four code types: - (a) random letter/number – (b) custom code (up to 9 characters) – (c) description with a custom code (up to 9 characters), - (d) a device MAC address (access code for a subscription account CPE device).
- Number of codes to create if code type is random.
- Expiration time, - time elapsed after first use.
- Date and time, after which the code can be used, used to delay use of the code.
- Number of concurrent users or concurrent devices, from 1 to 6, or unlimited (multi-user code).
- Maximum download and upload speeds permitted for the code (takes priority over the default speed setting).
- Maximum download and upload byte counts permitted for the code (takes priority over the default byte count setting).

4. Methods of Charging for the WiFi Service

4. Methods of charging for the WiFi service

4.1. Charging for the Internet service: comparing pay-on-demand to subscription

The most prevalent method that Telco's use to charge customers for the Internet service is by subscription; the customer is permanently connected to the Internet and pays a monthly fee for the service. If the monthly fee is not paid the service is disconnected. As customers are permanently connected to the Internet then there is a limit to the number of people that can connect to one Internet circuit. As the cost of the Internet circuit is shared between few people then the fee for each customer is high. There is also a billing cost to charge customers and receive payments. A customer in the USA might pay a monthly fee of \$75, which equates to 10c per hour over the month. Charges for subscribers around the world are similar.

An alternative to a subscription service is a pay-on-demand service. Pay-on-demand is a very popular billing method in many parts of the world, including Africa. With this method of charging for the Internet service the customer pays only for the time that the customer is connected to the Internet. As each customer has a limited time connecting to the Internet then more people can use one Internet connection, this means that the on-demand hourly Internet access cost per customer is lower and therefore the customer is charged less for the service. When an on-line payment method is used to charge for the Internet service, such as a Mobile Money payment, then the cost of billing is reduced, further reducing the cost per customer. With pay-on-demand the Telco does not need a subscription service billing system. The following table compares subscription with pay-on-demand.

USA: Pay for Internet via subscription	Africa: Pay on demand for Internet
The Internet service is always connected, the customer can connect to the Internet at any time and pays a monthly fee for this service.	The Internet service is connected for limited time duration, chosen by the customer when the purchase is made.
The customer has a bank account or a credit card and the monthly payment is made with either of these services, the Internet access is only suspended if the payment is not made.	A large sector of the population doesn't have a bank account or credit card, however many use a credit system for mobile phones called Mobile Money (MoMo) to pay small amounts.
Some USA travelers have experience with pay-on-demand; airports charge by the hour for Internet access with a credit card payment.	The Internet user connects to the WiFi service with a smart-phone and purchases a limited-time connection using the phone credit.
A traveler in an airport might have to pay \$5 per hour to get access to the pay-on-demand Internet service.	The user of the WiFi service who buys with Mobile Money might pay 1c to 2c per hour for Internet access.

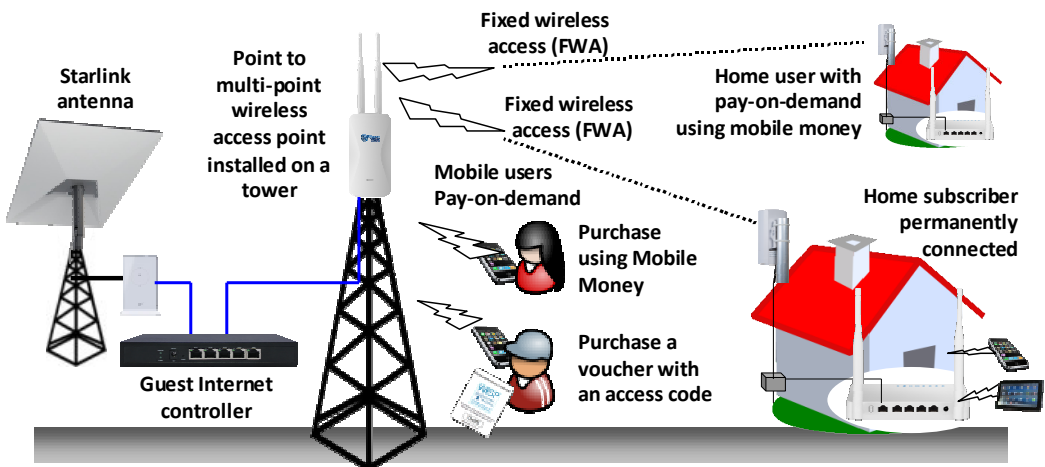
The economics of a small community pay-on-demand Internet service is illustrated by the following example. The small community might have 500 people who access the Internet using a pay-on-demand service that is paid with Mobile Money. The satellite Internet service provides 150Mb/s of bandwidth and is limited to a maximum to 150 people at peak times to prevent network congestion. Users connect using mobile devices and also homes have a connection using fixed wireless access (FWA). Assuming that the charge for the Internet access is 2c/hr, 50 hours of Internet access will cost \$1 USD. 500 people each using 50 hours per month generates \$500 USD in revenue. The Starlink Internet

service costs \$150/month, leaving \$350/month to amortize the equipment cost and provide a profit. Community members get a very low cost Internet service and the Telco can generate a profit by providing the service.

To provide a WiFi Internet service for mobile phones, the cost of a Starlink antenna, a Guest Internet controller to share the access with one wireless access point, and the Mobile Money custom installation is approximately \$1000. When home FWA connections are added then the cost of equipment per home is \$150 using a Guest Internet pre-configured Star-kit, plus installation labor. The investment can be amortized in 3 to 4 months of operation for the 500-member community.

Guest Internet controllers support both pay-on-demand and subscription methods of payment for the Internet service. Both payment methods can be used concurrently. In addition, several methods of pay-on-demand can be used simultaneously. The next diagram shows four payment methods that are frequently used concurrently.

Concurrent payment methods to purchase the Internet service



The four payment methods are listed below.

- Fixed wireless access: monthly subscription
- Fixed wireless access: pay-on-demand via Mobile Money
- Mobile device user: payment via voucher access code purchase
- Mobile device user: pay-on-demand via Mobile Money

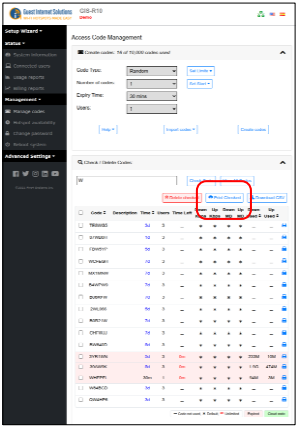
4.2. Pay-on-demand methods to charge for Internet with access code vouchers

Guest Internet controllers and the Guest Internet cloud have features to generate a quantity of access codes and to print the access codes as vouchers. In both cases the voucher design can be customized with text and a logo.

Up to 10,000 vouchers can be printed at one time using a letter size printer. Sixteen vouchers are printed on each page in a 4 x 4 format. After printing cut the page into individual vouchers, each with a unique access code.

Instructions for voucher printing are found in the product manual. Guest Internet also provides Star-kit installation guides with voucher printing instructions. Vouchers can be printed for a controller with a computer connected as the administrator. Vouchers can be printed for a group of controllers using a computer logged into the equipment owners cloud account. The diagram illustrates the process of creating access codes and printing vouchers.

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Create up to 10,000 access codes using the Guest Internet controller or cloud software and send to the printer



The voucher format is pre-configured



Cut up the sheets of fichas to have individual fichas for sale, each voucher has a unique access code



Print the sheets of vouchers using a letter size printer

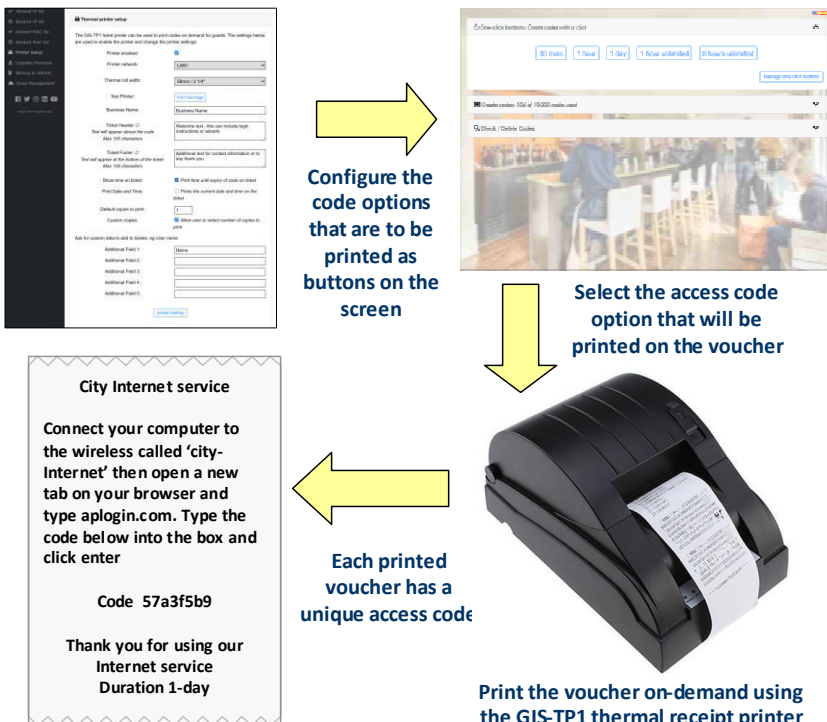
Access code vouchers can be printed on-demand using an Epson standard receipt printer connected to the Guest Internet controller via an Ethernet interface. Guest Internet has the GIS-TP1 thermal paper printer. The GIS-TP1 is pre-configured for use with any Guest Internet controller. The customer can also connect any Epson printer that has an Ethernet port. Contact Guest Internet support for Epson printer configuration information.

A display screen is configured for a phone or tablet with up to 10 buttons, each with a code duration and maximum data speed. When a button is tapped the printer prints a receipt with an access code. The administrator configures the information that is printed on the receipt.

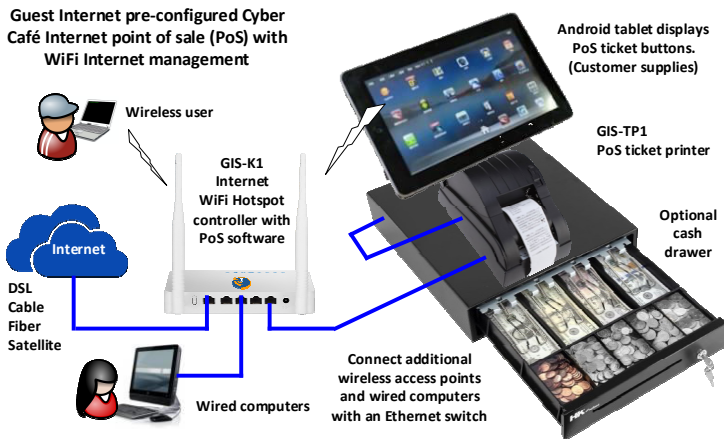
The GIS-TP1 is popular for several applications.

- Print one code at a time on demand.
- Hotel check-in desk, print an access code receipt for each guest who checks in.
- Cyber café point of sale (PoS) terminal, see the following page.

The next diagram illustrates the on-demand voucher printing process.



A point of sale (PoS) system is shown for an Internet café when the Internet connection is less than 100Mb/s. The software for the PoS is part of the Guest Internet software in the GIS-K1 wireless WiFi and controller product.



A point of sale (PoS) system is shown for an Internet café when the Internet connection is greater than 100Mb/s. The software for the PoS is part of the Guest Internet software in the GIS-R4 controller product. The GIS-R4 has wireless WiFi access points connected.

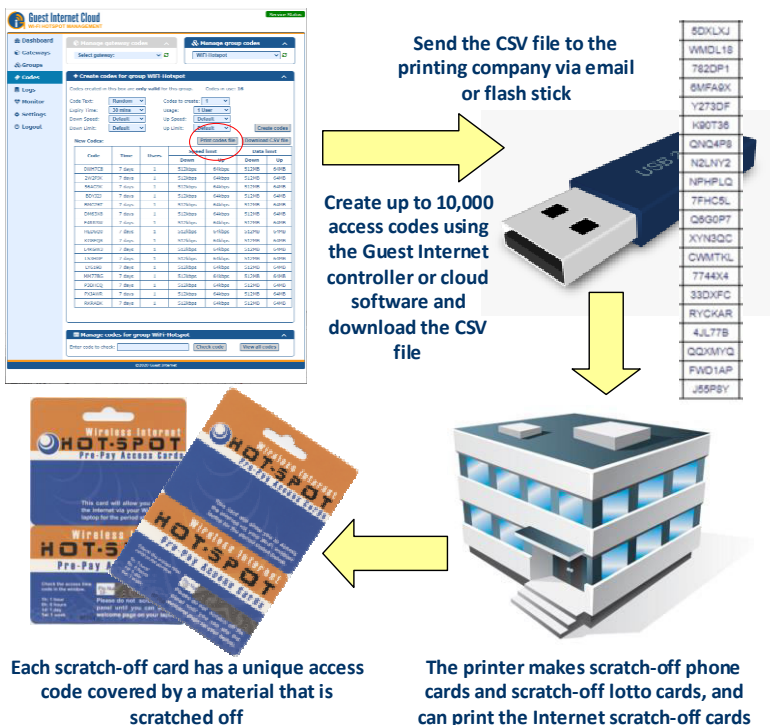


TELECOM COMPANIES: Internet for rural Africa

A popular option to sell access codes in a community retail outlet is the scratch-off card. These cards are very popular for pre-paid phone calls.

A list of access codes is generated either by the Guest Internet controller or the Guest Internet cloud. The list of codes is downloaded as a comma separated value (CSV) file. The file can be opened with any spreadsheet software.

The Guest Internet customer has to prepare a graphic design for the scratch-off card, or pay the printer to prepare the graphic design. The code file is sent to the printer together with the design artwork. The printer prints each code onto a card then covers the code area with an opaque plastic film. The plastic film can be removed by scraping it with the edge of a coin. The process to prepare and print scratch-off cards is illustrated in the next diagram.



4.3. Pay-on-demand method to charge for Internet with Mobile Money (MoMo)

Mobile Money (MoMo) is a popular credit payment method available throughout Africa to purchase products and services. Credit is added to the phone account via a cash deposit, and then the phone is used to make a payment that is subtracted from the credit. This eliminates the need to carry cash to pay for products and services. The Mobile Money billing for Guest Internet systems is a custom installation service that integrates the Guest Internet cloud with the mobile operator MoMo API, and brands the service. The custom installation service has an installation and hosting cost, and is available for any company that wishes to charge for the Internet service using Mobile Money.

A Telco advertising the Mobile Money credit service for mobile customers.





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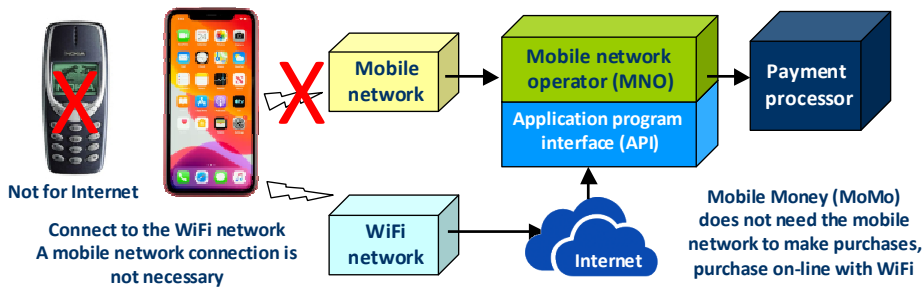
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Community Internet provider who installs the WiFi Internet service with payment using Mobile Money.

The purchase of WiFi Internet access is made through the WiFi network. It is not necessary to have a connection via the mobile network to make a purchase for the WiFi Internet service as illustrated in the next diagram. The user must have a smart-phone to make the Internet service purchase.

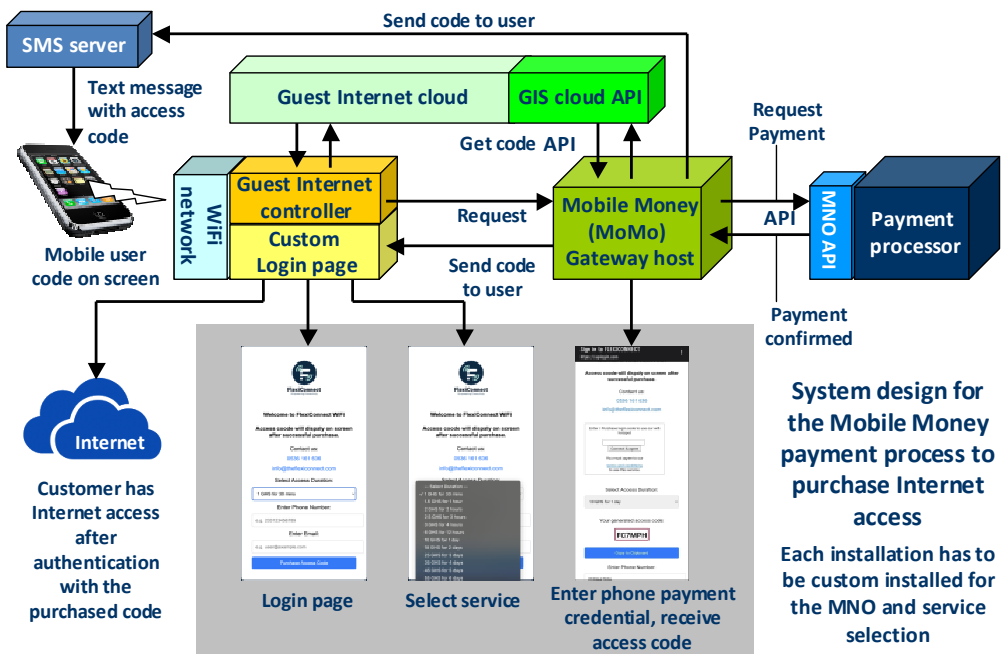


The sequence of events that occur when a user purchases Internet access is listed below. The sequence can be followed on the next diagram.

- Connect the user device to the WiFi.
- Open the browser and see the login page.
- Select a payment, duration and data speed option from the list.
- The user request is sent to the FlexiConnect Mobile Money gateway host.
- The user makes the payment via the FlexiConnect host using the mobile phone.
- The FlexiConnect host communicates with the payment processor via the API to receive the payment.
- When the payment is received the FlexiConnect host communicates with the Guest Internet cloud via the API to request an access code that corresponds with the purchase made by the user.
- The access code is sent to FlexiConnect by the GIS cloud.
- FlexiConnect sends the code to the users phone via SMS message.
- The code is displayed on the users browser page.
- The user can connect to the Guest Internet page any time using the code.
- When the code is entered into the Guest Internet controller login page it authenticates the code with the GIS cloud.
- After authentication the user is connected to the Internet.
- The user can use the code many times until the duration of the code expires.

The diagram illustrates the components of the Mobile Money payment system.

- The Guest Internet controller with custom login page; shows the MoMo options.
- The Guest Internet cloud service with API.
- The Mobile Money gateway.
- The Mobile Network Operator (MNO) with payment gateway API.



The custom login page installed on the Guest Internet controller displays the options; enter a code or purchase access. If the user has already purchased an access code it can be entered at this point to access the Internet.

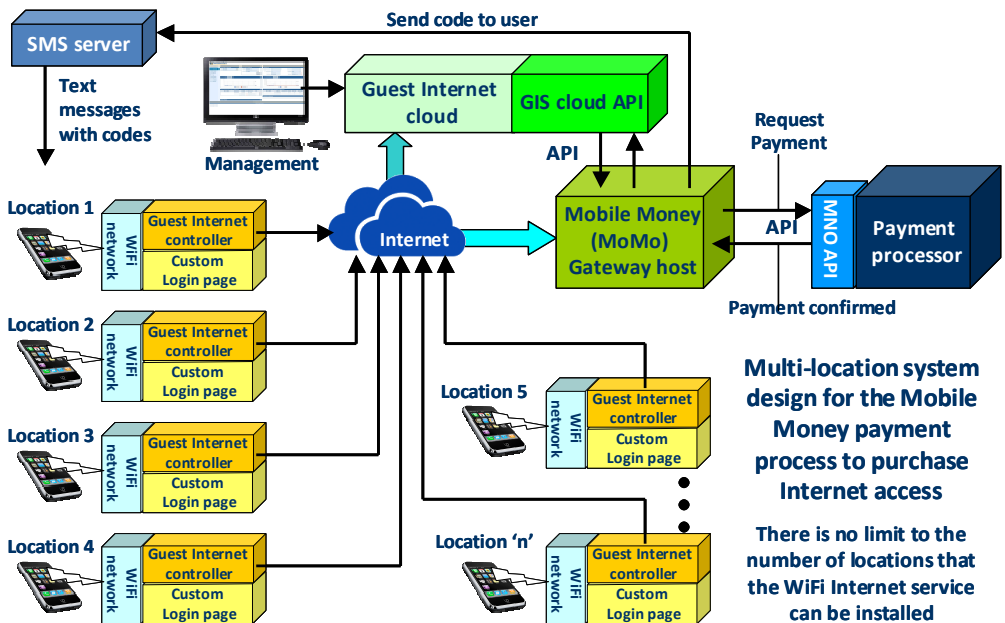
If selecting purchase access, the custom login page then displays the Internet offers; this is the duration of access to the Internet and

the cost to purchase the duration of access. The user can select the option required and is then connected to the Mobile Money gateway to make the payment.

When the payment is accepted the MoMo gateway requests an access code from the Guest Internet cloud and displays the code on the login page, the code is also sent to the users device via SMS. If the payment is not accepted then that message is displayed for the user.

The Mobile Money payment system is highly scalable. There is no limit to the number of Guest Internet controllers that can interface to the Mobile Money payment gateway. Guest Internet controllers can be distributed geographically and controllers can connect to any type of ISP, satellite or landline.

The next diagram illustrates the management and billing for geographically distributed Guest Internet controllers.



The Mobile Money login and gateway are customized for the implementation with the following features.

- Branding of the login page as required by the customer.
- Specify up to ten purchase options. Display option price and duration. The maximum down and up data speeds are also configured for each option.
- Choice of a mobile operator that supports the MoMo API.
- Mobile Money gateway integration with the mobile operators API.

4.4. A subscription service for Guest Internet community WiFi systems

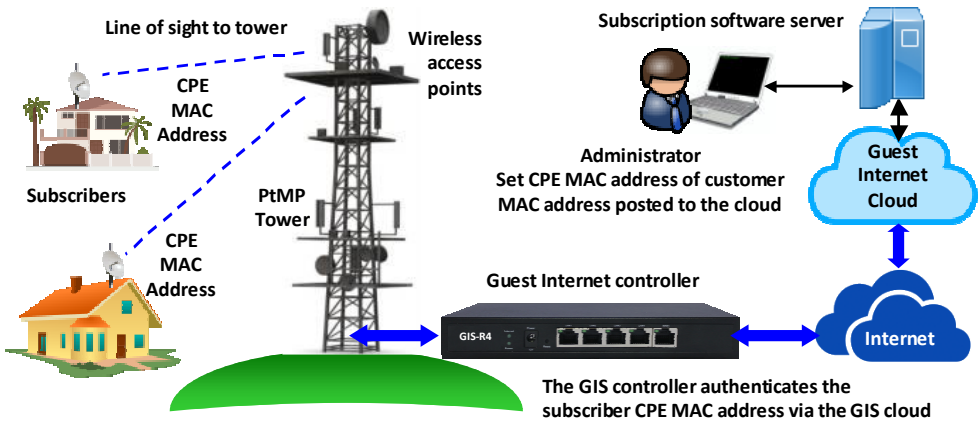
The Guest Internet Broadband Network Gateway (BNG) controller can support both on-demand access using codes, and subscription access where the subscriber has a permanent Internet connection. The subscriber connects to the network using fixed wireless access (FWA) and the MAC address of the subscribers CPE is used to authenticate the subscriber onto the network. To prevent any attempted access to the network the FWA link is encrypted and the Guest Internet controller can detect and block any MAC address-cloning attempt.

The Guest Internet controller can support both on-demand and subscription users concurrently to provide a flexible and low cost network with different access methods that the community may require.

A subscriber can be added to the cloud database by adding the subscribers CPE MAC address and the rate-plan characteristics for that subscriber. Once activated the subscriber has access to the Internet. If the subscription payment is not made then the subscriber can be deactivated using the Guest Internet cloud.

The Guest Internet controller can also be configured to check the health of the subscribers CPE device and issue a warning to the supervisor if the CPE loses the connection with the central wireless access point.

A Guest Internet BNG controller network configuration to manage subscribers is shown in the diagram. Subscribers can be managed directly via the Guest Internet cloud management interface, or managed with external software, such as a Telco billing system, that Integrates with the Guest Internet cloud.

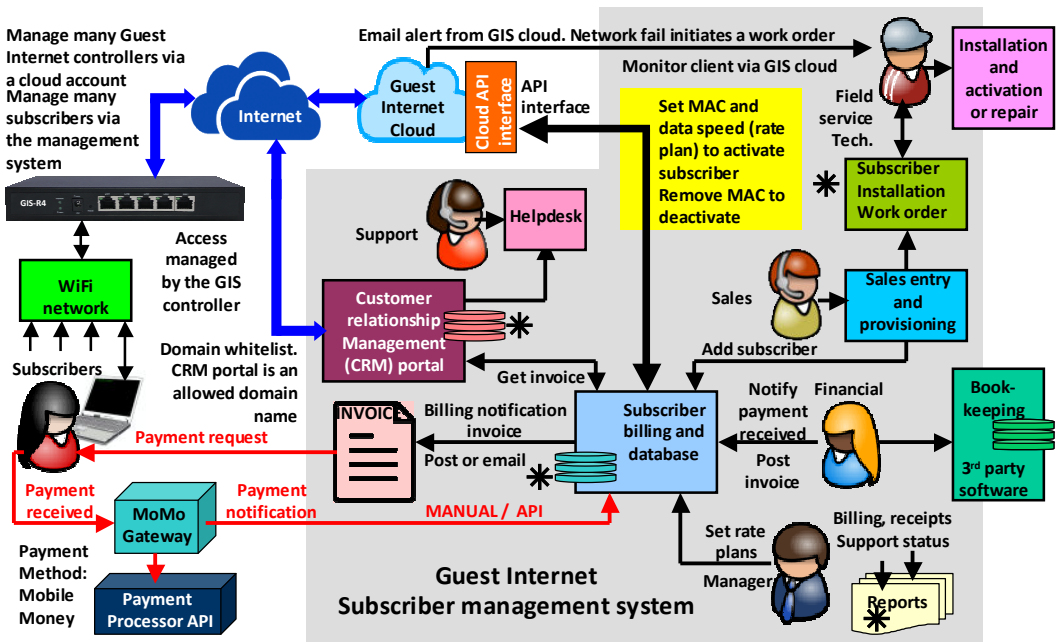


The Guest Internet cloud application program interface (API) permits subscriber management applications to be integrated with the Guest Internet cloud to automate the subscriber management process. The next diagram illustrates a subscriber management system that integrates with the Guest Internet cloud API.

Before adding a subscriber, the technical staff must confirm that the subscriber can be connected to the network via fixed wireless access (FWA). The sales person adds subscribers to the billing database. The subscriber's location and billing information is added to the subscriber record, and also the rate plan (data cost and speed) chosen by the subscriber is added to the subscriber record.

After adding the subscriber the sales person initiates a work order for the installation technician, and the technician replies with the MAC address of the CPE wireless unit that will be installed at the subscribers location. The sales person adds the CPE MAC address to the subscribers record. On completion of the data entry and confirmation of the billing cycle start date, the billing system sends a request to the Guest Internet cloud to activate the subscribers MAC address.

The manager sets and adjusts the rate plans that are offered to the subscribers. The system also provides a customer relationship management (CRM) portal where subscribers can initiate a ticket that is answered by the help desk. The financial staff issues monthly invoices. The financial staff also receives and posts subscriber payments. A separate document provides specifications for this system.



5. Large Scale Projects

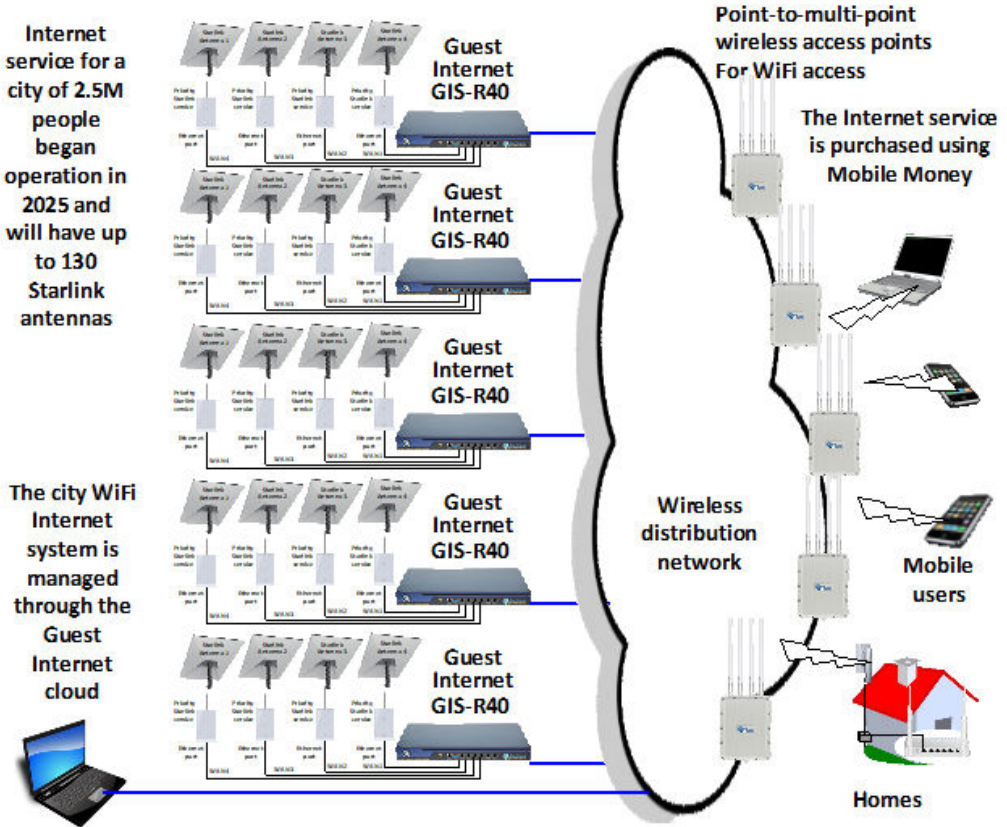
5. Large scale projects

5.1. A large-scale Guest Internet project example

The Guest Internet community Internet system can be scaled to any size of network. Guest Internet has a small system (e.g. the Star-15 kit) that is suitable for communities with less than 25 members. A large group of Guest Internet controllers can be configured in a citywide or countrywide system to manage the Internet service for millions of people. The only limitation is the availability of Internet connections via satellite or landline.

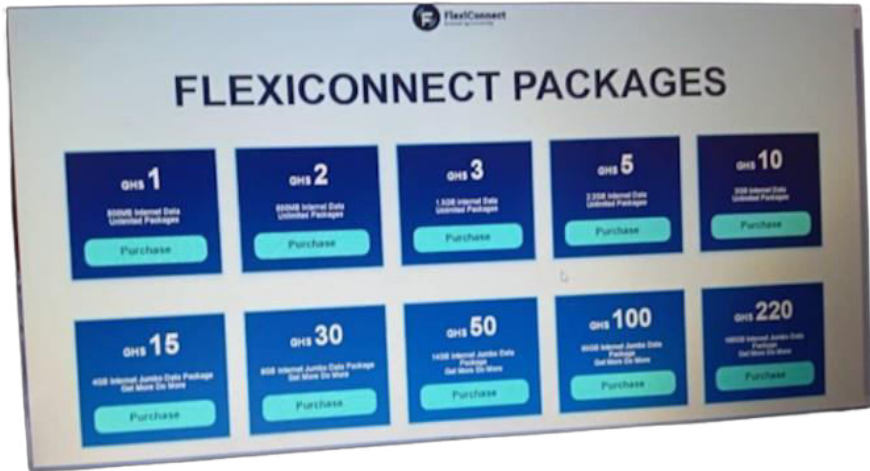
This section describes a citywide community Internet project for the city of Mogadishu in Somalia. The city has 2.5M residents who had no access to the Internet until the deployment of the Guest Internet system. The Somalia international Internet connection is via Kenya, which limits the data speed and therefore limits the number of people who can have access to the Internet. The deployment of Starlink satellite connections to the Internet overcomes the terrestrial communications bottleneck. The next diagram shows a simplified design of the Mogadishu infrastructure project.

The Mogadishu project deploys multiple Starlink antennas (approximately 130) to provide sufficient international Internet bandwidth for the city. Approximately 50 high performance Guest Internet controllers are connected to the Starlink antennas. The GIS-R40 controllers each have four Starlink antennas connected for a total throughput up to 800Mb/s. GIS-R10 controllers each have two Starlink antennas connected for a total throughput up to 400Mb/s. The antennas and controllers are located throughout the city. Each Guest Internet controller has multiple wireless access points connected to provide the WiFi Internet for the residents.



5.2. Residents view of the Internet service

Residents purchase Internet access using Mobile Money. The resident's mobile phone does not have to connect to the mobile network to make the purchase. When the resident's mobile phone is connected to the WiFi network the purchase is made via the Mobile Money gateway. When the resident connects a mobile device to the login page, the purchase options are presented, each option has a cost and a time duration that the resident will be connected to the Internet after first use. The login screen example is shown in the next figure.



The resident clicks on the purchase selection then provides the Mobile Money credential to complete the purchase. The resident receives an access code that can be used at any time. The code terminates when the duration expires after first use. The access code received by the resident can connect at any location in the network. As the resident moves from one location to the next the Guest Internet cloud roaming service hands off the resident from one Guest Internet controller to the next.

Other telecom businesses in Africa plan to deploy a similar community Internet system for communities that currently have no Internet service and there is no infrastructure to connect the community to the Internet.

6. Challenges and Hurdles

6. Challenges to deploy a rural community Internet service

6.1. Challenges facing mobile network operators in Africa

The demand for Internet services in Africa is very high, and the current investment in the build-out of mobile networks will not meet that demand. Mobile network acceptance faces three hurdles.

- The investment cost per subscriber is high; this cost is the construction of 4G-LTE towers and the connection of the towers to the network Telco, either via fiber or microwave link.
- The 4G-LTE operating costs per subscriber and therefore the subscriber charge, either as a monthly subscription or pay on demand is high.
- The mobile operator has a fixed infrastructure expansion budget, which is calculated as a percentage of revenues to expand the network; limit for the build-out of new 4G-LTE towers is financial.

The approach taken by the Guest Internet to develop the technology that is in use to provide Internet services for communities, overcomes the limited investment hurdles faced by mobile operators; hurdles that slow the growth of mobile networks for data use.

Guest Internet technology addresses the investment-limited hurdles and provides billing options.

- **The investment cost per subscriber:** Guest Internet technology can be implemented with satellite connections, and community residents can access the Internet service

using their mobile phone WiFi interface. The investment cost for a 300-person community basic mobile WiFi Internet service can be less than \$1000.

- **The operating costs per subscriber:** By providing a pay-on-demand service it becomes possible to share one low-cost satellite Internet connection with a community of several hundred people, each having a cost to access the Internet for a few cents per hour.
- **Fixed infrastructure expansion budget:** The telecom company can do much more for less. For the cost of one 4G-LTE tower the telecom operator can provide WiFi Internet service for 1000 communities. The Guest Internet installation in 1000 communities will provide a much greater cash flow than one rural 4G-LTE tower. The added benefit for the mobile operator is that the WiFi Internet service facilitates the identification of communities that can have a profitable service expansion with a 4G-LTE tower.
- **Charge community members for the Internet service:** The Guest Internet cloud can manage an unlimited number of controllers at different locations, and provides a gateway for any type of billing method, as well as the facility to print vouchers for sale. Guest Internet provides a method of charging for Internet use with Mobile Money (MoMo) payments. The mobile operator can also integrate the Guest Internet cloud API with any mobile billing system.

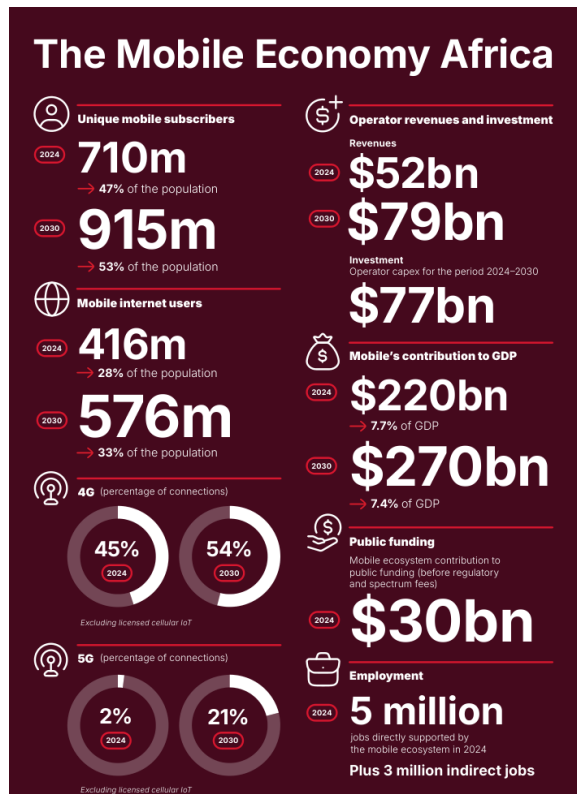
The mobile operator can further reduce the cost of providing the satellite internet service by becoming a reseller of a service such as Starlink, this will have the benefit of access to lower cost terminals and also a lower cost of the data service. Some telecom operators are using the Starlink service to provide a network connection for 4G-LTE towers in remote areas.

The following figure shows an infographic published by GSMA Intelligence, GSMA (Global System for Mobile Communications) is

the industry association for mobile network operators (MNO's). The GSMA Mobile Economy Africa 2025 report provides many useful insights into the African mobile telecom market, and includes predictions for the growth of services to 2030. The information provided by GSMA about mobile Internet users shows a large expected increase from 416M users in 2024 to 576M users in 2030. Although this increase is large, the demand is far larger. Based on demand information published by Statista of 1100M potential users in Africa by 2029, the conclusion is that there will be $1100 - 576 = 524\text{M}$ potential customers who would like to have Internet access but cannot get it because there is no infrastructure to provide it. Deployment of satellite Internet plus Guest Internet technology can provide Internet for a proportion of the 524M potential users by 2030.

Info-graphic
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6.2. Next steps to develop Internet services for rural communities

A large number of very successful deployments of Guest Internet products that use a Satellite Internet service demonstrate that the Guest Internet solution meets and exceeds the requirements that rural communities have for access to the Internet. Guest Internet cloud services provide the ability to scale the Internet service from the smallest community to the largest city, and beyond to provide a countrywide Internet service for rural and remote communities. The Guest Internet cloud service with the Mobile Money interface provides a simple and convenient method of charging for the service that is acceptable for most potential users. The extremely low cost of operation means that the cost of Internet access per user is low, while ensuring a good profit margin for the mobile operator.

6.3. Guest Internet can help with network infrastructure projects for rural communities

Consult with Guest Internet engineers to help identify and qualify the Internet service business opportunity in the territory where the MNO provides service. Guest Internet engineers can help the MNO plan the infrastructure deployment and prepare operational procedures.

Please contact Guest Internet at:

support@guest-internet.com

Glossary:

Of technical acronyms

Glossary of technical acronyms

0-9

3G, 4G, 4G-LTE, 5G, mobile phone data connection types.

A

AAA; Authentication, Authorization and Accounting.

ADSL; Asynchronous Digital Subscriber Line.

API; Application Programming Interface.

APN; Access Point Name.

ARPU; Average Revenue per User.

AS; Application Server.

B

BNG; Broadband Network Gateway.

BSS; Business Support Systems.

C

CAGR; Compound Annual Growth Rate.

CAPEX; Capital Expenses.

CAT-n; Category n.

CATV; Cable TV.

CDMA; Code Division Multiplexing Access.

CDR; Charging Data Records.

CPE; Customer Premises Equipment.

CRM; Customer Relationship Management.

D

DDoS; Distributed Denial of Service.

TELECOM COMPANIES: Internet for rural Africa

DHCP; Dynamic Host Configuration Protocol.

DSL; Digital Subscriber Line.

E

EIRP; Effective Isotropic Radiated Power.

F

FTTH; Fiber to the Home.

FTTP; Fiber to the Premises.

FWA; Fixed Wireless Access.

G

GB; Gigabyte.

GE; Gigabit Ethernet.

GHz; Giga Hertz.

GSM; Global System for Mobile Communications.

H

HDTV; High Definition TV.

HSPA; High Speed Packet Access.

HSS; Home Subscriber Server.

HTTP; Hypertext Transport Protocol.

HW; Hardware.

I

IAB; Integrated Access and Backhaul.

IEEE; Institute of Electrical and Electronics Engineers.

IGW; Internet Gateway.

IP; Internet Protocol.

IPTV; IP Television.

IPv_n; Internet Protocol version n.

ISDN; Integrated Services Digital Network.

ISP; Internet Service Provider.

ITU; International Telecommunication Network.

K

KPI; Key Performance Indicator.

L

LAN; Local Area Network.

LTE; Long Term Evolution.

M

MB; Mega-byte.

MBB; Mobile Broadband.

MHz; Mega Hertz.

MIMO; Multiple Input Multiple Output.

MNO; Mobile Network Operator.

N

NAT; Network Address Translation.

NPV; Net Present Value.

O

OPEX; Operational Expenses.

OSS; Operations Support System.

P

PDN; Packet Data Network.

PoP; Wholesale telecom provider Point of Presence

POTS; Plain Old Telephony Service.

PtMP; Point to Multi-Point wireless connection.

PtP; Point-to-Point wireless connection.

Q

QoS; Quality of Service.

R

RADIUS; Remote Authentication Dial-In User Service.

RAN; Radio Access Network.

RF; Radio Frequency.

RJ11; Registered Jack 11 on Ethernet cables.

RTP; Real Time Protocol.

RTT; Round Trip Time.

S

SDTV; Standard Definition TV.

SIP; Session Initiation Protocol.

SLA; Service-Level Agreement.

SME; Small and Medium-sized Enterprise.

SNR; Signal to Noise Ratio.

SPID; Service Profile Identifier.

STB; Set Top Box.

SW; Software.

T

TCP/IP; Transport Control Protocol /Internet Protocol.

TDD; Time Division Duplex.

TV; Television.

UL; Uplink.

USD; United States dollars.

W

WAN; Wide Area Network.

WISP; Wireless Internet Service Provider.

About the Author



John Barker is an Electronic Engineer with over 50 years of experience in the areas of networking, telecommunications and cybersecurity. John has consulted with many telecommunications companies regarding business strategy and technical design, and has assisted telecommunications companies to deploy new technologies and to develop new and profitable market opportunities.

John is an Electronics Engineering graduate and holds M.Sc. and Ph.D. degrees. He is a member of the Institute of Electrical and Electronic Engineers (MIEEE).

