A Basic Guide to Backhaul for Community Centred Connectivity Providers

Introduction

A number of guides to community-centred connectivity already exist. They cover community organisation, access technologies, legal and regulatory issues, as well as sustainability strategies[1]. However, one topic that perhaps does not receive the level of attention it deserves is the question of “backhaul” or where does the upstream bandwidth come from that feeds a community connectivity provider.

This document is intended to serve as a guide for community-centred connectivity providers to better understand technology and service choices for upstream connectivity for their networks. It also suggests policy and regulatory measures to improve affordable access to backhaul. This will include a taxonomy of types of wholesale operators e.g. infrastructure owners vs resellers, types of service typically available, considerations in developing a constructive relationship with service providers. It will also examine the constraints that keep backhaul costs high and how they might be addressed.

Backhaul may be defined as any network connection that serves to connect a local network to a larger network, typically the whole internet. This can exist in many different scenarios; operators both large and small have backhaul connections serving their networks. In the context of this paper, we are focusing on the backhaul network connection that connects a small ISP to the global Internet network. Without a backhaul connection, a small ISP remains a private network in which network elements can communicate with each other but not the global internet.

There are other terms that are sometimes used interchangeably for backhaul. Sometimes it is referred to as “upstream connectivity”. In any case, it is a network connection that allows your network to connect to the global Internet.

Why Has Backhaul Become So Important

The era of streaming media ushered in by YouTube but now with many streaming services from Netflix to TikTok to Instagram and a host of others has dramatically increased data consumption per user. Users expect streaming media to be readily available. Video conferencing tools like Zoom, Teams, Google Meet, and others have further increased data consumption and user expectations of network performance. To meet this demand, small ISPs must purchase backhaul connections with greater and greater capacity as well as reliability. Understanding backhaul options and design, negotiating effectively with backhaul providers, and managing network connectivity effectively are becoming more and more critical to the sustainability of small ISPs. Often the cost of backhaul is the single biggest recurring operating expense for a small ISP.

1 A brief appendix listing some of these guides can be found at the end of this paper.

Types of Backhaul

Context

At a very simple level, if you have a home connection to the Internet that you get from an internet company, that is a very simple kind of “backhaul". It connects the local network in your home to the internet. For the most rudimentary of small ISPs, there may be very little difference between their backhaul and a home internet connection. In fact, some of the earliest small ISPs such as Freifunk[2] in Berlin in the early 2000s began by sharing home ADSL connections via WiFi to their neighbours. Similar things happen now with small ISPs in some regions using Starlink subscriptions, which were designed for individual/household consumer use, with their wider communities.

Buying backhaul from a service provider falls into two categories: Direct Internet Access or IP Transit. With Direct Internet Access you rely on your upstream provider to manage much of your connection with the rest of the Internet. All of your data traffic travels directly via your upstream provider. You don’t have the freedom to directly interconnect with other network operators. Getting an IP Transit connection from an upstream provider offers the freedom to shape how your network connects with every operator on the Internet. However, IP Transit has some technical prerequisites that may take new operators some time to acquire and become comfortable with.

Public and Private IP Networks

To understand the difference between DIA and IP Transit, it is important to also understand public vs private IP networks. This guide assumes a basic understanding of IP addresses which are the numeric identities attached to computers and other networked devices on the Internet[3]. Any network device with a public IP address is visible to any other device on the Internet. A private IP network has IP addresses that are only visible within its own networks. Private networks can connect to the public internet through a public IP network using a mechanism called Network Address Translation or NAT[4]. When purchasing DIA, you will be connecting your private IP network to your backhaul provider via a NAT operated by your upstream provider. With IP Transit, you will have your own set of public IP addresses and will make your own decisions as to what parts of your network are public and private. The benefits of this are explored below.

2 Wikipedia entry for FreiFunk https://en.wikipedia.org/wiki/Freifunk
3 See https://www.fortinet.com/resources/cyberglossary/what-is-ip-address for a more detailed explanation of IP Addresses.
4 See the Wikipedia entry for Network Address Translation for more background https://en.wikipedia.org/wiki/Network_address_translation

Direct Internet Access

Direct Internet Access or DIA is similar in many respects to your home internet connection. You buy internet bandwidth from a service provider in Mbps or perhaps even Gbps. Beyond your connection to your backhaul provider, you have no control over the overall performance of your internet service and are dependent on how your backhaul provider is connected to the internet. In some cases, your backhaul provider may themselves purchase DIA from a larger provider. The advantage of DIA lies in its simplicity. The complexities of network routing, peering, transit, and caching are largely invisible to you and you are at liberty to focus on managing your local network. The downsides of DIA are that you have less control over some aspects of how your network performs and that DIA can be a more expensive option, especially as your demand for capacity increases. DIA is usually the best place for small ISPs to begin with purchasing backhaul.

Retail vs Wholesale DIA

The difference between your home internet connection and a wholesale DIA service for your small ISP lies in a few key factors.

- **Terms of Service**. Typically retail internet services come with an agreement regarding how you are allowed to use the internet connection. For retail / home internet subscribers, this agreement or terms of service usually preclude the resale of internet capacity. This means that even though you might be able to share this internet connection with others, you won't be able to charge for providing internet connectivity to others. This is unlikely to be a satisfactory situation for small ISPs who depend on subscribers to pay for the cost of backhaul. Communication regulators too often make a distinction between cost sharing of a network connection and reselling a network connection for profit, for which an ISP license of some form is often required.
- **Contention**. Another key difference between home internet and DIA is the issue of contention. Retail internet service providers offer an advertised bandwidth e.g. 50Mbps on the expectation that you, as an individual household consumer, will not require 50Mbps of capacity all the time. Thus, where they may have their own backhaul connection of 50Mbps of capacity, they may sell a 50Mbps service to 10 retail customers on the expectation that all 10 customers will not want 50Mbps at the same time. This is known as a contended service, in this example with a contention ratio of 10:1. Subscribers of a contended service will get the advertised bandwidth on their service some of the time but not all of the time. Contended services save Internet Service Providers money on their own backhaul connections and are often satisfactory for home or individual subscribers. However, a contended service is unlikely to be a satisfactory solution for any small ISP that is reselling its services to others.
- **Symmetric Upload and Download Speeds**. Retail internet services often offer asymmetric services to customers with much faster download speeds than upload speeds. This is often fine for retail use where customers typically download much more data than they upload. For a network operator, who may have many clients with different needs, it is important to be able to offer adequate capacity for both upload and download.

- **Quality of Service**. Related to the above, retail home internet services are usually provided on a best effort basis. Issues of contention but also latency, jitter, and more serious interruptions. Small ISPs wishing to provide their own quality of service guarantees to their constituencies will want Quality of Service commitments from their backhaul service providers. This kind of agreement, known as a Service Level Agreement (SLA) is typically only available in commercial wholesale DIA services.

For the purpose of this paper, it is assumed that DIA service refers to a wholesale commercial service provided for the purposes of resale.

IP Transit and Peering

The alternative to purchasing Direct Internet Access from an upstream provider is purchasing IP Transit. However, in order to explain what IP Transit is, it is necessary to provide some context as to how internet traffic is managed and paid for in general.

Background

Who pays for the Internet? It is relatively straight-forward to understand who pays for the physical infrastructure of the internet, the cables, routers, etc. But who pays for the effort in making sure Internet traffic is successfully delivered from origin to destination?

Imagine two independent post offices in neighbouring towns. Call them TownA / PostOfficeA and TownB / PostOfficeB. Every morning PostOfficeA collects all the mail that is destined for TownB and drops it off at PostOfficeB. PostOfficeB does the same for Town A. Each post office bears the responsibility of delivering mail locally for the other post office. PostOfficeA needs to pay its workers to deliver Town B's mail locally, thus they might charge PostOfficeB a fee for making all those local deliveries. However, the same is true for PostOfficeB. If the amount of mail being delivered to Town A is roughly the same as that going to Town B, PostOfficeA and PostOfficeB might decide that they are doing roughly the same amount of work for each other delivering local mail and that it doesn't really make sense to bill each other roughly the same amount. Analogously, two network operators that carry each other's traffic may decide to forgo billing each other for the service and acknowledge that value is being created roughly equally on both sides. This is known as peering. Peering comes in two different flavours: Settlement-free peering happens when both parties agree to deliver each other's locally destined traffic at no charge. The other scenario is Paid Peering, which happens when one peer is delivering disproportionately more traffic than the other peer and negotiates a fee for the additional traffic.

However, exchanging traffic with a peer network is not enough. In order to access the entire Internet, operators must connect with a network that is willing to ensure the "transit" of data to its intended destination by traversing multiple networks. IP transit enables Internet traffic to move from one network to another. The complex network of internet connectivity around the world carrying vast amounts of data to millions of users is largely managed on the basis of these two arrangements, IP Transit and Peering.

IP Transit for Small ISPs

In the previous section we talked about purchasing Direct Internet Access from an upstream or backhaul provider. With DIA, all of the complexity of how your network traffic gets to and from the rest of the internet is managed by your upstream backhaul provider.

Purchasing IP Transit backhaul is a significant shift in how your network sees and connects with the wider Internet but also in the level of technical sophistication needed to manage your connection to the rest of the Internet. In contrast to DIA, where you are effectively operating your own private network and all of your access to the wider Internet is mediated by your upstream provider, obtaining an IP Transit connection for your network means that you have become part of the global addressable network of the Internet, an entity recognisable by other operators around the world.

The implications of this are significant. It means that you have the capacity to choose how traffic flows in and out of your network and connects with other networks on the internet. IP Transit is a paid service where your network pays a backhaul provider for access to the entire Internet routing table.

Autonomous System Numbers (ASNs)

In order to purchase IP Transit for your network and, by consequence, participate in the global fabric of the Internet, your network needs to be identifiable to the rest of the Internet. That is where Autonomous System Numbers or ASNs come in. We have become familiar with IP addresses which are used to identify individual devices, computers, servers on the Internet but for an internet service provider or community network to be able to direct traffic to and from the devices on their network, another identifier is needed which identifies the organisation and the IP addresses associated with it. Typically, each AS is operated by a single large organisation, such as an Internet service provider (ISP), a large enterprise technology company, a university, or a government agency.

As with the previous example of post offices delivering each other’s mail, you can think of Autonomous Systems as being those post offices. In a world with many post offices, mail goes from post office to post office until it reaches the right town, and that town's post office will then deliver the mail within that town. Similarly, internet traffic finds its way from origin to destination by moving from AS to AS until it reaches the AS that contains the traffic destination whereupon it is locally delivered.

Every AS represents an organisation’s network or group of networks that has a common policy for how traffic is routed. Every computer or device that connects to the Internet is ultimately connected via an AS and each AS has a unique identifier known as an Autonomous System Number (ASN). In the case of Direct Internet Access, you don’t need your own AS because you rely on the AS of your upstream internet backhaul provider and their routing policy.

ASNs are obtained through Regional Internet Registries[5] that manage the allocation and registration of Internet number resources within a region of the world. Internet number resources include both ASNs and IP addresses. As of 2024, there are nearly 118,000 ASNs registered around the world.

Internet Exchange Points (IXPs)

Now that we have a basic understanding of **how** traffic is exchanged on the Internet i.e. through peering and IP transit agreements, it is important to understand **where** traffic is exchanged. Network operators can and do negotiate direct agreements with any other operator to connect their networks together. That is what happens with a small ISP purchasing IP Transit backhaul from a larger operator. However, direct arrangements like these can lead to inefficiencies at scale. Imagine that network operator A in Johannesburg, South Africa has purchased IP transit from a large network operator in London, England. Another network operator B in Johannesburg, South Africa has done the same. Now, if operator A wants to send traffic to operator B, the only way they know how to send traffic is via London. This means that the data from an email or video call between two people who may be less than a kilometre away from each other may have to travel all the way to London and back.

Enter the Internet Exchange Point or IXP. IXPs represent a collective decision by network operators in a given region, often a major city, to find a common physical location where they can choose to exchange internet traffic so that internet traffic that has a local destination is exchanged locally. A IXP consists of a location that has space to hold the routers of multiple network operators as well as having reliable power and security. IXPs are often managed through a consortium of operators but can also be managed by governments. Nearly every country in the world has at least one IXP and most have several.

Content Distribution Networks

Content Distribution Networks represent an advanced form of data caching that is having a significant impact on how we understand the Internet. Content caching has been around for a very long time. Your browser caches content so that when you go back to a website that you have already been to, it doesn't have to reload the page, saving you time and reducing your bandwidth consumption. Historically, ISPs have done the same thing at the network level storing popular content locally to be able to offer it faster and more cheaply than otherwise. This provided a valuable cost savings on the use of upstream bandwidth by ISPs. With the evolution of encryption as a default for web services user web requests became opaque to ISPs, dramatically reducing the utility of generic caching services operated by ISPs.

In the late 2000s, caching took on a new form. Google began offering a YouTube cache to ISPs in the late 2000s, which grew into the more generic Google Global Cache. Similarly, Facebook offered the Facebook Network Appliance to cache their content as did Netflix with Open Connect. More generic caching services also emerged including Akamai, Cloudflare, Fastly, CacheFly, Amazon Edge services and many others. Today tens of thousands of independent

5 https://en.wikipedia.org/wiki/Regional_Internet_registry

CDNs exist around the world. Because these caches were operated by the content providers themselves, encrypted web services were no longer a barrier. Operators of CDNs may choose to locate their equipment inside the networks of very large operators or they may choose to locate their CDN at an IXP, sometimes both.

When CDNs choose to locate their equipment at IXPs, all operators connected to the IXP benefit from improved performance by being able load locally rather than downloading from an international connection. Small operators benefit in particular as they are not large enough to justify a CDN being installed directly inside their network as some larger operators are able to do.

DIA vs IP Transit

Given the obvious additional complexity (and expertise) involved in purchasing IP Transit, you may wonder why a small operator would go to the trouble of taking this route. The process of applying for an ASN can seem daunting. Not to mention the challenge of developing the skills to understand network routing protocols like the Border Gateway Protocol (BGP) that shape traffic flows from ASN to ASN on the Internet.

DIA represents a very easy entry to understanding backhaul. It offers less flexibility in managing traffic and is almost always more expensive per Mbps than IP Transit but it is easy to set up and configure. Your backhaul provider is making all the decisions about routing, peering, caching. DIA is probably the most natural place to start for backhaul for small operators. However, its limitations should inspire small operators to begin developing the skills necessary to manage an AS and purchase IP transit and hopefully peer at the nearest IXP. Not only is it important from a growth, efficiency, and cost-savings perspective but it is also tremendously important for the voice of small operators to be heard in Internet fora on how the network architecture and traffic flows are managed as the Internet becomes increasingly dominated by large platform companies.

Considerations When Purchasing Backhaul

A small ISP purchasing DIA for the first time faces challenges in getting the right product for the right price. Prices and services can vary dramatically based on the maturity and competitiveness of the market. In mature markets with several competitors, prices and services are likely to be more normalised across service providers, making it easier to compare offers. However, in less well developed markets, backhaul service providers may charge higher prices simply because they can.

It can also be a challenge for a new operator to have a sufficient level of technical understanding to assess the sometimes complex offerings from backhaul internet service providers. In some cases, unscrupulous operators may promise speeds and quality of service that do not live up to their promise in real life. They may also attempt to sell value-added services of questionable value that increase the price of the service. small ISPs new to the

industry may struggle to assess the value of backhaul ISP offerings. While unscrupulous operators may represent a tiny minority of service providers, their existence highlights the importance of having the help of an experienced practitioner to assess connectivity offers.

Where possible new small ISPs should seek the advice and support of a more experienced operator in the market to provide guidance in negotiating offers from backhaul service providers

Understanding Your Backhaul Provider

Wholesale internet service providers come in all sizes from national operators who own their own national fibre optic backbones to the smallest of licensed operators who may not own any physical infrastructure of their own but resell access to larger networks.

For a new small ISP, you may end up requesting services from large and small operators alike, depending on what is available. For any backhaul provider, it is useful to know which parts of their network they own and operate themselves and which parts they use infrastructure from other providers.

Ask potential backhaul providers for details about the ownership and operation of their network infrastructure.

Large Backhaul Providers	Small Backhaul Providers
They own their own infrastructure	May struggle to provide true quality of service
More reliable for uptime	May provide cheaper more flexible options
Less responsive to smaller operators	More personal service
Often less flexible on price	Often shorter track record

Location of Service

There are many factors involved in selecting a backhaul provider. One of the most significant factors is how far away your network is from the provider's nearest Point of Presence and what, if any, obstacles lie in the way of connecting to the Point of Presence.

In some cases, a backhaul provider may offer to bring connectivity to your network with their own technologies. For example, they may offer to install a client WiFi AP to connect to their Point of Presence where they already have a tower installed with existing Point to Point or Point to MultiPoint wireless equipment. Alternatively, they may only offer service from their Point of Presence expect you to establish a connection to them.

There are pros and cons to both scenarios. If the backhaul provider provides a connection all the way to your network, it may result in more reliable service, removing the possibility of the backhaul provider blaming network interruptions on your connection to their PoP. It may also simplify negotiations with the provider in terms of access to their PoP premises to adjust, update, or replace your end of the connection. The downside is that it may be more expensive to have the backhaul provider establish the link to your network than building it yourself. Your team may also choose to prioritise the experience gained in building your own backhaul connections.

Another factor to consider is that some backhaul providers may offer services at multiple locations on their network, meaning that, with a single contract, you may negotiate backhaul from more than location. If you are serving more than one community or are serving a geographically spread out community, this may be an option to explore with your backhaul provider. For example, you may negotiate for 100Mbps of capacity from a backhaul provider but have 50Mpbs made available at one PoP and 50Mbps at another. This kind of flexibility will vary from provider to provider.

Redundancy

As reliance on the internet grows, our frustration with any interruption in service grows. Community expectations of internet service from small ISPs may begin as "best-effort" but as internet access weaves its way into their personal and work lives, the ability of small ISPs to rapidly recover from network interruptions will become essential. This is true for local network access managed by the small ISP and for backhaul connections. Part of the answer lies in having systems in place for timely response to network interruptions and having skilled personnel to set them to rights. When it comes to backhaul networks, some network interruptions may take a day or more to repair. In this context, it is essential for backhaul operators to have one or more alternate backhaul routes so that a network failures resulting in a re-routing of

True resiliency doesn't lie in having a failsafe network connection but in having connections that are safe when they fail.


Ask potential backhaul providers about their network redundancy and failover infrastructure.

Quality of Service

Reliability of service is a key factor to consider when choosing a backhaul service provider. An interruption of service from your backhaul service means your entire network is disrupted. As indicated above, it is important to understand what lengths your backhaul provider has gone to ensure their network stays up through redundant links on their network. Another indicator of confidence in your backhaul provider lies in what quality of service they will commit to on their network. This is often expressed in the form of a Service Level Agreement or SLA that describes what uptime they will commit to having on their network as well as a commitment to how quickly they will resolve interruptions to their network service. In some cases an SLA may contain penalties for a failure on the part of the backhaul provider to meet those commitments.

In practice SLAs may prove useful as a general commitment on the part of the backhaul provider but it can be a challenge to hold a provider to account on service interruptions. At a minimum, it is essential to have robust network monitoring tools, practices and logging to be able to effectively document service interruptions with your provider[6].

Contract Period

Contract periods offered by backhaul providers may vary from monthly billing to a contract for one or more years. There are trade offs to consider with longer and shorter terms. Backhaul providers will typically offer a lower price in exchange for a longer commitment. Predictable income has value to a backhaul provider, which creates an incentive for them to offer better pricing. However, backhaul bandwidth prices trend downwards over time. This means that the going price may drop below what you have contracted for at some point during the contract period. Longer term contracts preclude the ability to switch to another service provider who offers you a better deal. At the same time, backhaul providers may be leary of or less responsive to operators who only commit to month-to-month services. It's important to take the contract term period into account when comparing offers and weigh the benefits.

Understanding the Chain of Connectivity

An oversimplification of how the Internet works would be to say that smaller networks connect to larger networks who connect to the largest networks who interconnect with each other. However the reality is much more nuanced and complex. When speaking to potential upstream backhaul providers, it is important to try to understand the chain of connectivity for those providers i.e. who do they get their backhaul from. Understanding the broader ecosystem of backhaul

6 TBD - link to resources on network monitoring

providers and services can help you choose the right backhaul provider and identify options for more economical, more efficient, and or more redundant connectivity.

Type of Operators

Backhaul operators may have different names and different characteristics from country to country depending on the licensing framework established by the communication regulators, however there are some broad categories of providers.

Internet Service Providers (ISPs)

Internet providers who offer retail internet services may also offer backhaul service to other operators. ISPs may go by different names but their common characteristic is that they offer retail internet connection to home customers and to businesses.

Examples: Mawingu (Kenya) - https://mawingu.co/

Wholesale-only operators

Some countries offer a license to operators to operate a wholesale-only internet service. In this case the operator may only sell to other licensed operators and not direct to consumers or businesses. Wholesale operators position themselves as a partner rather than a competitor to ISPs. Wholesale operators may only offer local backhaul connectivity where they own and operate their own infrastructure or they may offer IP transit services as well. In the case of the former, purchasing backhaul would consist of buying local backhaul on the wholesale operator network and also purchasing international IP transit.

Example: CSquared (Uganda) - https://csquared.com/

Infrastructure Providers

Some service providers provide only the physical medium to carry the Internet. In some cases they may provide fibre optic infrastructure but require their customer to provide the equipment to light the fibre. A city may provide duct access but require operators to put fibre optic cable through themselves. A power company may provide access to their electricity poles but require the operator to string fibre along their poles.

Example: Dark Fibre Africa (South Africa) - https://dfafrica.co.za/

Global ISPs

In some cases, global ISPs may offer IP transit without owning any local infrastructure. By trading capacity on their global network, these ISPs can offer IP transit at IXPs. This represents a regulatory grey area and illustrates the complexity of network infrastructure and the “chain of

connectivity" mentioned above. IP transit from such global ISPs may be very affordable but their minimum purchase may be out of the reach of smaller network operators. In addition, their services are typically only available at an IXP, meaning that additional backhaul to connect to the IXP may be needed.

Example: Hurricane Electric (Kenya) - http://he.net/

National Research & Education Networks (NRENs)

NRENs are a special class of ISP that only serves higher education institutions. They typically have a network of high speed infrastructure connecting universities, research organisation, and other institutes of higher learning. Depending on the country, NRENs may have an ordinary ISP license or they may have special recognition / dispensation from the regulator or government. A key characteristic of NRENs is that they are non-profit entities that seek to bringest the fastest broadband for the lowest price to their community. In one sense they are a community network. As such, depending on their mission and existing regulations may be able to offer backhaul to community network operators.

GARNET (Ghana) - https://garnet.edu.gh/

Policy and regulatory considerations

Operator Licensing

Operator licensing is compulsory in most countries in the world. Regulator administrative requirements and fees can vary substantially from country to country. It is usually necessary to have an operator license in order to purchase wholesale services from other operators.

Open Access

Many backhaul service providers advertise themselves as being Open Access. Open Access networks typically offer the potential for multiple service providers to use the same network infrastructure to deliver their services to consumers. It allows operators to define the services they offer on the network as opposed to being limited to a set of options by the infrastructure owner/operator. Open Access networks are typically technology-neutral meaning they are not restricted to a specific type of technology or service, such as internet, voice, or television services. In practice there is no official definition of Open Access and the above principle is variously interpreted by operators.

There is a growing trend among large mobile network operators to separate their fibre assets into a separate infrastructure company[7]. These new fibre operators typically operate on Open Access principles.

Transparency

Pricing

Small operators typically suffer from information asymmetries when it comes to backhaul pricing. It can be a challenge to know when you are being offered a good price from a backhaul provider. In some countries, regulators require operators to publish a rate card[8]. However, this kind of transparency requirement is far from the norm.

Infrastructure

A simple challenge for new operators is finding out where backhaul infrastructure and operators exist. Some operators publish maps and details of their Points of Presence through which access can be had but many do not.

Encouraging the use of Open Data standards for describing telecommunications infrastructure can lead to more transparency in the sector and a more level playing field for small operators in terms of options for backhaul services. Standards such as the Open Fibre Data Standard (OFDS) developed with the support of the World Bank are with promoting with regulators and operators[9].

Backhaul technologies

An introduction to various backhaul technologies and their strengths and weaknesses. Many communication technologies can serve as both an access technology delivering services to an end user as well as a backhaul technology. This section will focus on technologies for backhaul.

7 In 2023, MTN separated its fibre network infrastructure into a separate company called Bayobab. https://www.mtn.com/mtn-globalconnect-rebrands-as-bayobab-to-strengthen-its-commitment-to-digitally-connecting-africa/ Airtel followed suit in 2024 creating a company for its fibre optic infrastructure assets called Telesonic https://itweb.africa/content/lwrKx73Ywl1qmg1o

8 The regulator in Benin, ARCEP, published a decree in 2018 requiring operators to publish an interconnection rate card. https://arcep.bj/wp-content/uploads/2018/12/BTI-SA-CATALOGUE.pdf

9 https://linktr.ee/opentelecomdata

Wireless Point to Point

License Exempt (WiFi)

WiFi technology has emerged as one of the most powerful backhaul tools for small ISPs. Companies such as Ubiquiti, Mikrotik, Cambium and others have produced a wide range of Point to Point (PtP) radio devices that are widely available and very affordable. As use of WiFi for PtP connectivity has grown, manufacturers have found ways to make more and more efficient use of available spectrum while making the technology easier to deploy. Mass manufacturing has also led to lower costs for WiFi technologies.

WiFi PtP technologies are limited by the amount of spectrum available in the ISM bands as well as the limits on power outputs built into the regulation of license exempt spectrum. The popularity of WiFi has reduced its utility as a technology in urban areas where spectrum interference has become an issue due to multiple WiFi PtP users being too close together.

WiFi is also limited by the need for clear line of sight between origin and end point in a WiFi PtP link. Hills, foliage, buildings can all present obstacles to the deployment of WiFi PtP links.

Licensed

An alternative to License Exempt spectrum is to acquire a spectrum license in radio frequencies designated for microwave PtP connectivity. Many WiFi manufacturers also produce relatively low-cost wireless PtP devices that operate in licensed frequencies. The exclusive nature of spectrum licences for microwave use ensures that PtP connections will not suffer from interference. Licensed spectrum also often allows for higher power output levels making it possible to establish longer and higher capacity PtP links.

Acquisition of spectrum licences for microwave PtP connectivity can be time-consuming and onerous for small network operators. Perhaps most significantly, these spectrum licences are often comparatively expensive, putting them out of the reach of small operators. This is particularly true for regulators that have not revised their regulations on licensed or license-exempt spectrum for PtP connectivity.[10]

Find out if your communication regulator has improved their regulations around spectrum for PtP connectivity in both licensed and license-exempt spectrum, recognising rapid growth of the market.

10 See Innovations in Spectrum Management for more information on reforms to spectrum licensing for PtP use. https://www.internetsociety.org/resources/doc/2019/innovations-in-spectrum-management/

Fibre Optics

There is very little that can compete with fibre optic cable as a backhaul technology in terms of both capacity and longevity. The speed of fibre networks is orders of magnitude greater than almost any other backhaul technology. When well deployed, fibre technologies can also have a dramatically longer lifespan to other access technologies. Terrestrial fibre can last up to twenty years, and is often upgradeable without disrupting the fibre cable itself. It can also be an easier technology to manage than wireless because it is not prone to interruptions from interference, new physical obstacles or device deplacement by users or natural events that can cause disruption to wireless connections.

A key limitation of fibre though is the upfront cost of the network build. The upfront cost of building backhaul with fibre optic technology is significantly higher than wireless backhaul. This can present a significant obstacle to fibre adoption. However, the much longer lifespan of fibre technology means that the total cost of ownership of the technology may not be so different from wireless when considered over a period of say 15 years. Network operators that can take this longer view from an investment point of view may find fibre a more attractive choice.

Another challenge with fibre optic technology is that permission often needs to be sought to deploy the fibre whether trenched underground or deployed aerially on poles. For fibre deployed underground the property owner must give their permission before an operator can dig a trench to deploy fibre. Known as Rights of Way or Wayleaves the permissions required by property owners can vary from quite expensive to free depending on the scenario. Understanding wayleave charges is key to calculating the sustainability of a fibre backhaul solution.

Similarly, owners of pole infrastructure such as power companies may charge a periodic fee per pole before allowing an operator to deploy fibre on their poles. They may also have minimum requirements in terms of how many poles must be leased which may be beyond the reach of small operators.

Satellite

In remote areas satellite may be the only option for backhaul. Satellite predates most other backhaul technologies and has gone through several evolutions in terms of types of satellite technology. Satellites technology broadly fall into two categories: geosynchronous satellites (GEO) that rotate in sync with the earth's rotation so that they stay in one spot relative to a user on the ground; and, satellite constellations that rely on a mesh of satellites to provide coverage to users. This latter group can be further divided based on their altitude of deployment: Middle Earth Orbit (MEO) and Low Earth Orbit (LEO).

	LEO	MEO	GEO
Altitude	35K kms	5-12K kms	< 2000 kms
Satellite Size	Small	Medium	Large
Satellite Cost	Low	Medium	High

Communication Latency	~500ms	~120ms	~30ms
Number for global coverage	> 100	6	3
Antenna Tracking	Fast	Slow	Fixed
Lifespan	5 years	12 years	15 years
Application	Consumer / corporate broadband	GPS, Navigation, MNO backhaul	Broadcast TV, Weather, limited data use

New generation (known as High Throughput Satellites or HTS) GEO satellites are capable of delivering affordable backhaul for network operators in remote areas. Their most significant downside is the latency of their connectivity due to the very high altitude of the satellites. It can take over a second for data to travel up to a GEO satellite and back. Latency is most notable in interactive applications such as gaming or video conferencing. For other streaming services that are largely download services, latency is less noticeable.

In recent years, LEO satellite constellations, such as Starlink, have dominated satellite broadband news. Starlink operates a constellation of over 6000 satellites in low earth orbit. The price and performance of Starlink equipment makes them a very attractive option for backhaul for small operators. Starlink's business model is oriented to retail end users. Its general terms of service don't permit resale by operators. However, in some cases Starlink has offered backhaul service for operators although at a higher price than their retail service. In some cases, network operators may use a retail Starlink service for backhaul, despite their terms of service. It is not known whether Starlink is actively pursuing users who do so.

The LEO satellite constellation environment is rapidly changing with several other constellations expected to come online in the next two to three years. The rapidly evolving nature of the satellite industry means it is one that small operators should pay particular attention to when evaluating options for backhaul.

Choosing backhaul

Key questions to ask when choosing a backhaul service provider

- Do benchmark wholesale prices exist
- Is there a min/max amount of mbps, price differences, possibilities of up or down scaling (in case the network loses or gains more subscribers)?
- Are there transit offerings available with less tech/responsibilities burden on the CN?
- What are the general responsibilities for CNs and small ISPs in terms of maintaining the link and users counting?
- How to know where/how is the backhaul provider nearest to the target location?

[this section is embryonic. To be expanded.]

Appendix A - Community Network Development Guides

Internet Society - Community Network Readiness Assessment https://www.internetsociety.org/resources/doc/2022/community-network-readiness-assessment-handbook/

Internet Society - Community Network DIY Toolkit https://www.internetsociety.org/resources/community-network-diy-toolkit/

NYC Mesh - How to start a community network https://www.nycmesh.net/blog/how/

The community network manual: how to build the internet yourself https://direitorio.fgv.br/en/publication/community-network-manual-how-build-internet-yourself

Start Your Own ISP https://startyourownisp.com/