Airwaive

DECENTRALIZING THE LAST MILE INTERNET

Airwaive Project White Paper

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Most of the world lacks affordable access to broadband Internet, creating a division in the Digital Age that benefits those with high-speed access and those that do not enjoy the same access. Although the backbone of the Internet is a decentralized, global network of interconnected servers, the connection between the user and the nearest Internet Service Provider (ISP), referred to as the last mile of Internet, is often centralized. This centralization results in limited options, if any, for many users and contributes to the lack of broadband access.

Utilizing a disruptive model for network creation and operation, the Airwaive Project aims to decentralize the last mile of the Internet using wireless technologies, thereby lowering the cost of providing broadband Internet and bringing more users into the Digital Age.

The community plays a significant role in this mission. There are new roles in this model, including network creators wireless access points that enable connectivity between users and the Internet and validators of such connectivity to generate the rewards that form the incentive to build networks. This model is possible now because of new advancements in wireless technology like 5G, and because of decentralized technologies like blockchain.

The Airwaive Project provides the tools and incentives for the components of a decentralized wireless network to thrive, offering service providers, network creators and validators the resources and motivation to build and scale the Internet using wireless to reach everyone on the planet. Our mission is not complete until 100% of the world has affordable access to broadband Internet.

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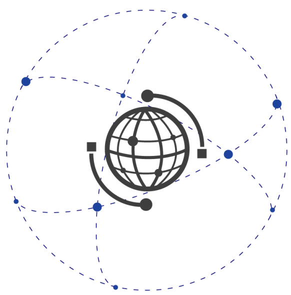
THE CENTRALIZED “LAST MILE”

What is the Last Mile and Why is it Centralized?

Thanks to the transmission protocols that govern the Internet (TCP/IP), the ***backbone*** of the Internet is a decentralized network. It is a connection of millions of servers/routers that are linked together, owned by many different individuals and organizations. The Internet was designed so that traffic can be routed from one router to the next, avoiding routers that are offline or congested. It can also be used to route traffic using the least expensive path, ensuring competitive prices for data transmission. The average user is not aware of the path that his or her data request takes across the backbone of the Internet, nor the companies that handle the transmission.


Internet

Yet nearly every user knows the Internet Service Provider (ISP) that handles the last mile connectivity between the user and the Internet backbone because there is often only one ISP, if any, to provide this service. In the figure below, this is represented by one choice for the data path from the user to the Internet. This **centralization** creates monopolistic behaviors that can affect prices and service levels.

Internet

Although most of the Internet is decentralized and traffic may be routed across the most network- and cost-efficient path, the connection between the user and the ISP is often a single wireline. No network optimization. No competition to optimize prices.

The reason for the last mile issue is the installation cost of a wireline between a home or business to the nearest ISP. In the early days of the Internet, users often connected over their telephone line for access. Since most users already had telephony service, an ISP did not have significant costs to install new lines to a home or business. Today, many users with broadband speeds utilize their cable line for access. Once again, cable companies could easily provide this service because of their existing lines into buildings.

Although there are wirelines that are more suitable for providing high-speed broadband access, such as fiber lines, the cost for a new ISP to install lines into buildings is significant and often prohibitive. Thus, most of the world can be summarized as follows:

"Last Mile"

- **0 Providers**

  The last mile is cost prohibitive for wireline broadband access (cable/fiber). This may be the case in rural areas of developed nations and in many areas of developing nations.

- **1 Providers**

  The last mile is costly for a new wireless broadband ISP and is normally dominated by the sole, existing cable provider.

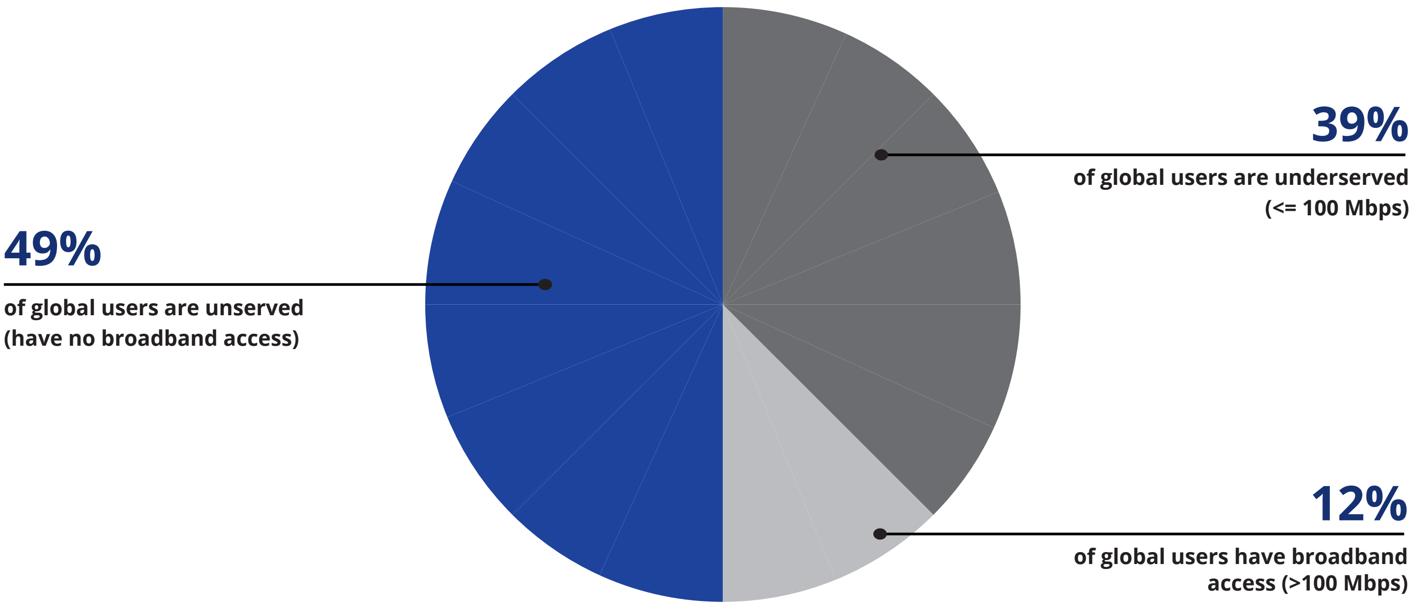
The Effects of Centralization and the Digital Divide

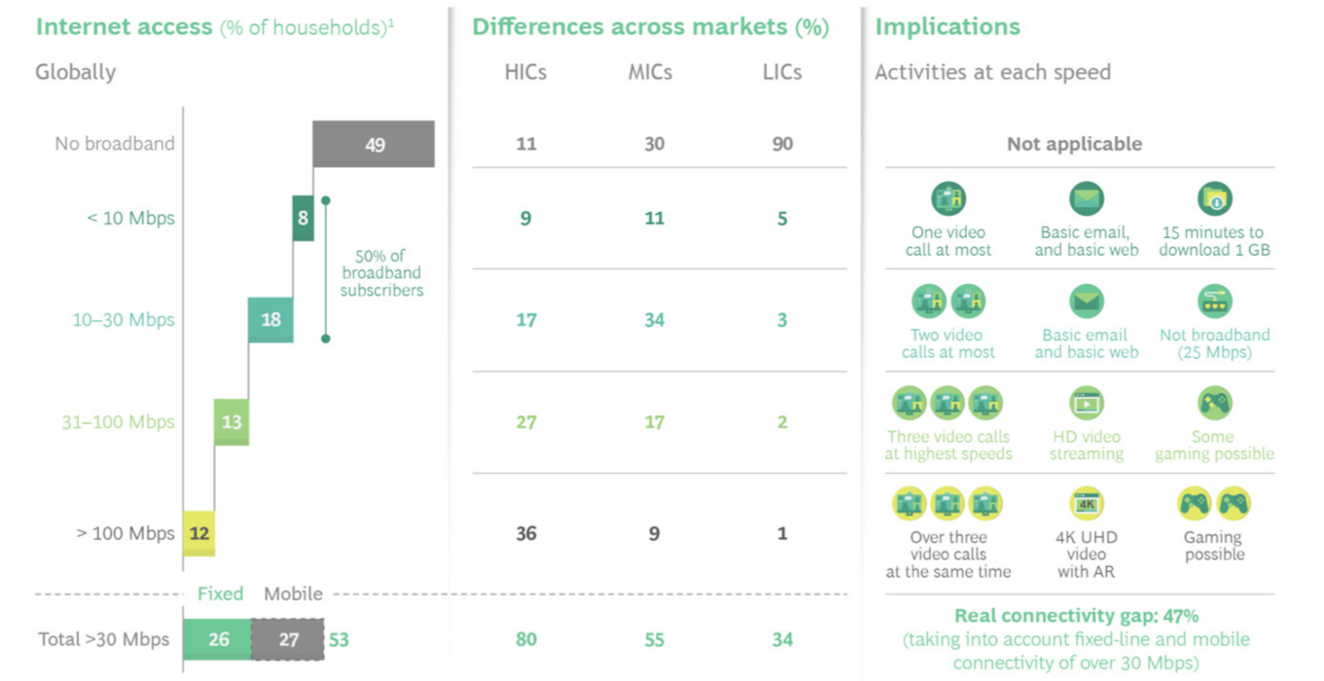
How does this centralization of the last mile affect user **broadband** adoption? First, we need to define broadband access. Fortunately, most of the world's population has experienced the Internet in some form, with roughly 67% of the population owning a smartphone [1]. But this still does not qualify as broadband because a basic smartphone is not adequate to experience the full Internet.

During COVID-19, people were forced to work or learn from home as the pandemic spread. Video services such as Zoom became household names during the pandemic. However, most of the world was unable to take advantage of such services because they lacked Internet access, or the required speeds for broadband. In school, kids without Internet may be months behind their peers who have broadband Internet. In the workplace, employees that are online have access to jobs that are not available to those without practical online speeds.

In August 2021, the US Senate passed an infrastructure bill raising the broadband threshold download speed to a minimum of **100 Mbps**, and the minimum upload speed to 20 Mbps. This speed allows a family of four, working and learning from home, to be on video calls simultaneously [2].

According to a report from late 2020, when this new broadband threshold is applied to the world's population, **only 12% of the world** meets or exceeds this threshold.





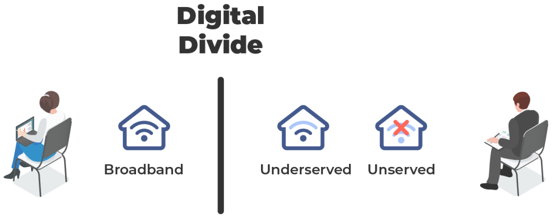
Sources: FCC; Frontier; WBIS; BCG analysis.

Note: Because of rounding, the percentages shown may not add up to 100. Calculations assume one subscription per household. AR = augmented reality; HIC = High-income country; LIC = low-income country; MIC = middle-income country; UHD = ultra-high definition.

The Digital Divide

In the past few decades since the rise of the Internet, products and services have migrated online quickly. News travels around the world in an instant. Products can be ordered from the comfort of the home and arrive within hours. Money can be transferred with the click of a button. But these services are not enjoyed by everyone on the planet, and this leads to inequality. This is the digital divide. Those without Internet are classified as **unserved**. Those with Internet, but at speeds considered too slow, are classified as **underserved**.

The users that lack the benefits of broadband access are referred to hereafter as underserved since they can be categorized as any user without access to 100 Mbps+ broadband service, inclusive of the unserved.



Why are we so divided?

This division of Internet access can be summarized into one of two categories: lack of access or affordability. When networks are built by private enterprise, both ultimately come down to economics.

Lack of Access

Creating networks has a cost and organizations that seek a return on their investment must always evaluate the cost of building a network compared to the fees they get from subscribers. This is an issue in rural areas where the cost to install a line (cable or fiber) may be incredibly expensive to reach a single home. This is also an issue in certain low-income urban or suburban areas, where the total subscriber fees may not justify installation costs. When these decisions are left to private companies, an ROI business case prevents the decision to install the necessary infrastructure to bring users online.

Lack of Affordable Options

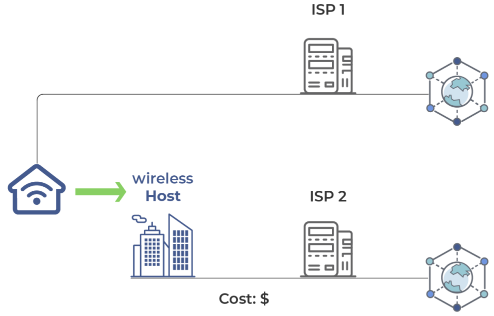
In other cases, access to broadband exists but the user chooses not to subscribe to it. This is often due to price, which can be traced back to a lack of competition. Wirelines, particularly cable, have offered the best economics for service providers to invest in the last mile infrastructure to homes to provide both Internet and television services. Yet when there is only one potential line into a home to use, a monopoly is created, causing prices to rise. As an example, cable operators have a two-thirds market share of all broadband Internet in the United States, with two companies accounting for the majority of all cable subscriptions: Comcast and Charter [3].

THE DECENTRALIZED LAST MILE

Using wireless to solve the last mile problem

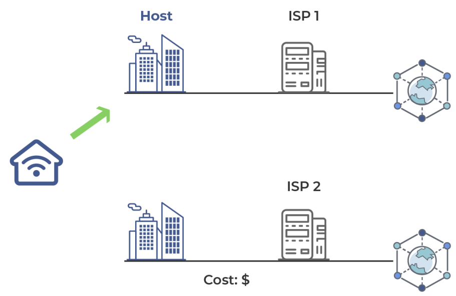
Wireless broadband has the possibility to simultaneously extend the reach of broadband coverage and lower broadband prices. Known as fixed wireless, a high-speed broadband signal reaches a home and connects into the home's router, which is then converted to the local area network connection (often Wi-Fi). It's the equivalent of a cable modem, using wireless instead of a wireline.

In a region where only one wireline ISP exists, one or more wireless ISPs create the decentralization of the last mile that is needed. The user now has a choice to route their traffic, based upon network availability, service levels or prices.



2+ Providers

In a region where there are no existing wireline ISPs, it takes two or more wireless ISPs to decentralize.



2+ Providers

In the first example where there is an existing wireline ISP, wireless solves the ***affordability*** issue by its competitive nature, assuming it competes with an incumbent wireline provider. Competition naturally brings down prices.

In the second example where there are no existing wireline ISPs, wireless solves the ***access*** issue. The cost to install a line into a home can often be thousands, if not tens of thousands of dollars, in rural areas. Wireless, on the other hand, does not have the same installation costs. If a home is within range of a wireless access point, the cost is the equipment at the access point and the cost of the equipment in the home to receive the signal, for a total cost in the low thousands of dollars. Furthermore, the cost of the access point can be reused across multiple homes within range of the signal.

Fixed wireless is not new, so why now?

First, is the recent introduction of 5G wireless technologies. 5G can reach gigabit speeds [4]. Although this depends on several factors, such as the frequency that is being used, it can certainly be configured to support a download threshold speed of 100 Mbps. Prior to 5G, cable always had an advantage over wireless because cable speeds were significantly faster.

Second, is the recent allocation of unlicensed frequencies that can be used by any service provider. The allocation of the 6 GHz frequency in many countries is just one example [5]. This allows new companies and organizations to be formed, building wireless networks, without requiring significant capital to license wireless frequencies. As an example of the capital required for licensed frequencies, the top US wireless carriers spent more than $80 billion for frequencies in the 3.7 GHz range in January 2021 [6].

Utilizing unlicensed frequencies has its downsides because it is not guaranteed that spectrum will be available due to conflicts with other users using the same frequency. But there are ways to mitigate these issues. Wi-Fi operates in unlicensed frequencies, typically 2.4 GHz or 5 GHz, yet most users don't recognize any conflict when using Wi-Fi devices. These Wi-Fi frequencies, along with other suitable mid-band frequencies such as 3.5 GHz and 6 GHz, are ideal for building low-cost wireless networks. Mid-band is a term for frequencies between 2 GHz and 6 GHz that are a good blend of range and speed. Typically, a lower frequency has a longer range, but a slower speed.

Unlicensed Frequencies and Decentralized Wireless Networks

Unlicensed frequencies also enable the decentralization of wireless networks because barriers to become a service provider have been greatly reduced. In each country, there are often only three or four companies that retain rights to licensed frequencies for nationwide use, thereby reducing a consumer's option. By comparison, unlicensed spectrum opens the possibility of an unlimited number of potential service providers, creating a decentralized network.

The Airwaive Project's mission is to enable a new generation of Internet service providers (ISPs) and private property access point hosts with a network deployment model and incentive program that allows them to prosper, fulfilling the goal of **reaching the world's population with broadband Internet.**

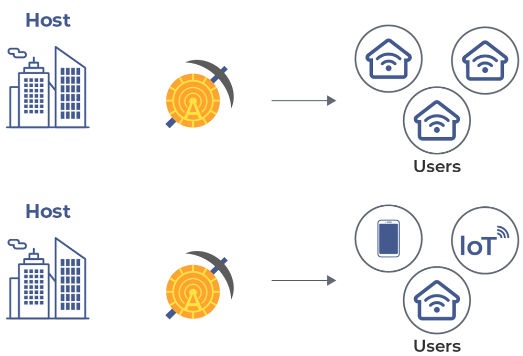
The token and reward system to decentralize

The *network creation token* is the reward and currency for network creators to build the decentralized last mile. Network creators may include property owners hosting wireless access points (hosts), Internet service providers (ISPs) including fiber backhaul providers, equipment manufacturers and contractors in the design, development, and deployment phases of access points. The token may be circulated amongst these creators, and to the subscriber utilizing the network, as the currency that encourages growth and usage of the network. The host is one of the most important parties within the group of network creators because a local network cannot form without a physical location to place an access point.

Token Mining

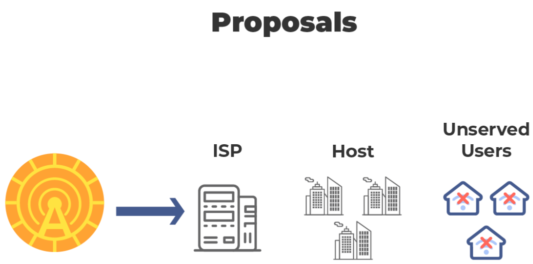
The primary allocation of tokens is the mining process, using *Proof of Connectivity* as the consensus mechanism to determine the rewards for a network creator. To align with the project's mission to close the digital divide and provide broadband access to everyone, the reward must provide the incentive to connect end users. This is referred to as proof of connectivity. When an end user connection is proven, a reward is generated. A greater number of connections results in a greater number of rewards.

Mining - Proof of Connectivity



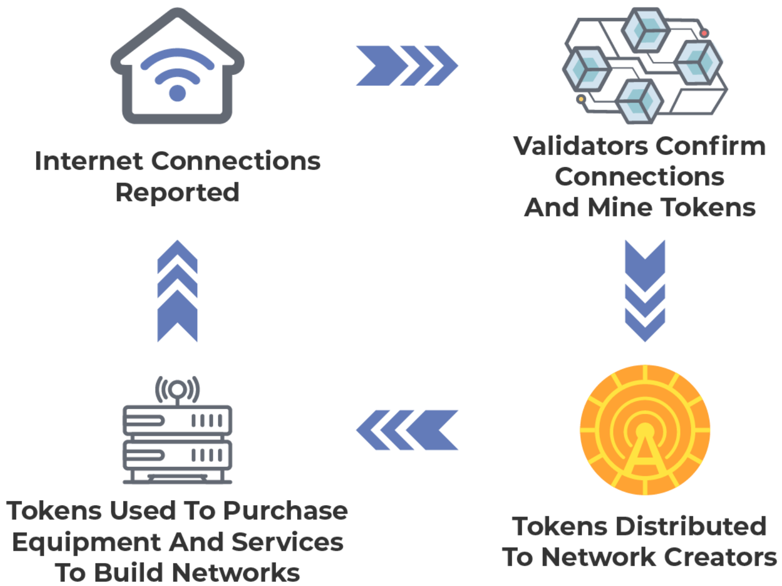
Special Proposals

A responsibility of the Airwaive Project will be to review proposals that enable a decentralized Internet, including special grants to ISPs or Hosts to build in targeted areas for underserved users. This will allow donations and stimulus funds to be applied to select areas that need the infrastructure to build a decentralized last mile.



Token Circulation

In the early stages of the decentralized wireless network model, the ISP and the host are the essential entities to encourage growth and alignment with the project's mission. Once ISPs and Hosts receive their tokens, they begin circulation, capable of being distributed to other network creators. For example, an ISP compensates a Host for providing wireless access. A Host pays the fiber provider for data backhaul. The fiber provider pays an equipment provider for new hardware for the next build.

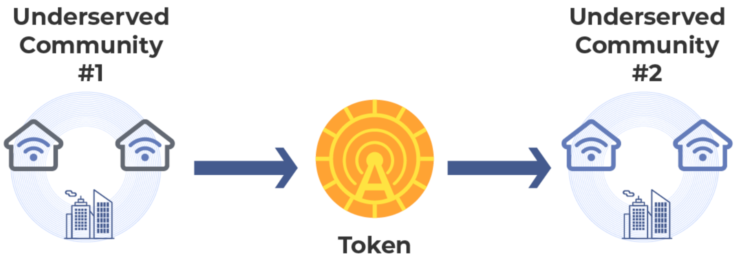


In the later stages of the decentralized network, the token may be in circulation to the end user, able to pay the ISP and keep the token in circulation without the need to purchase or buy back tokens.

The role of blockchain to validate networks

Broadband access programs are ideal for a blockchain technology and an independent source to validate access. The United States is one such example where subsidies and grants have been offered to ISPs to extend broadband access to more Americans, yet the data reported back to the US government on broadband penetration does not match reality [7]. Millions of users are being counted as covered for broadband when in fact they are not. One of the issues is the reliance on ISPs to self-report their data back to the Federal Communications Commission (FCC). Should an ISP be trusted to self-report data on its broadband subscribers? Can a single entity, even if it is independent from the ISP, be trusted to self-report this data?

Blockchain shifts the trust from people and organizations to a trust in technology. It's ideal to solve the problem of ISPs self-reporting broadband data. Instead of relying on a single organization to report this data, the community or a set of rules programmed into the network, reports on this data that validates broadband usage. This data is public and validated by multiple nodes within the network, gaining trust within the ecosystem. Furthermore, a token on this blockchain can be tied to the mission of increasing connectivity and utilized by members within the ecosystem as a currency to purchase equipment and services for future network builds, thus perpetuating the mission.



These are the questions that need to be answered in a trust mechanism to validate that broadband is truly available and affordable and that the last mile has been decentralized:

- Is the wireless access point located in an area that has two or more options for Internet access?
- How many individuals or households are connected to the Internet in this coverage area?
- Are these connections at broadband speeds?

Blockchain is an appropriate solution to establish the trust that is necessary to build an ecosystem of service providers, access point hosts and partners for the next generation of wireless broadband.

THE ISP, HOST AND VALIDATOR

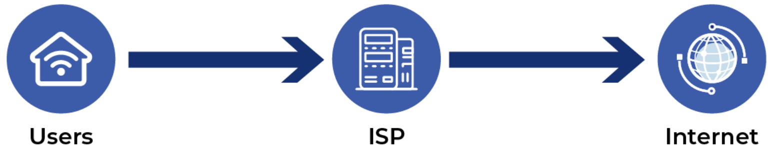
The role of the Internet service provider (ISP)

The ISP is the entity that has the responsibility of providing a user access to the Internet. The Internet itself is a global network of computers, interconnected by a network using standardized communication protocols. The Internet's backbone consists of networks owned by many companies, routing traffic. Thus, an end user that connects to the Internet is typically connecting through an ISP that pays wholesale rates to connect to the Internet's backbone, which then routes the user's traffic anywhere in the world.

Of course, the ISP plays a critical role connecting the end user to Internet, but contrary to conventional thinking, the ISP does not need to be a large, for-profit organization. An ISP could be as simple as a single individual providing access to others. *For the definition of an ISP in this paper, the ISP is the customer-facing entity responsible for end users and does not distinguish between ISP tiers.*

The role of the ISP in this context:

- Provides the connection between the user and the Internet
- Pays for data transmission to the Internet backbone
- Charges the user for Internet access, *if applicable*

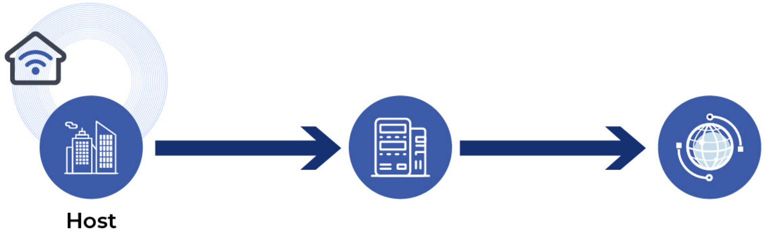


The role of the property owner (Host)

In the proposed wireless network deployment model, the network is not reliant upon the ISP to own and control every wireless access point (the location where the wireless signal from the user's device is converted to a wired connection to the Internet). A network scales much faster, and requires less capital, when property owners share the responsibility to create a wireless network and become hosts of the equipment required to form a wireless access point.

The role of the Host:

• Provides the property hosting the wireless access point, forming the connection between the user and the ISP for access to the Internet

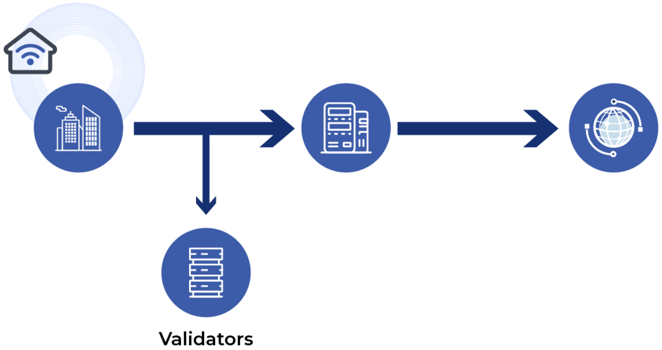


The role of the community (Validators)

When an ISP receives external funding to build a network, it should be held accountable for proper use of such funds. External sources may include government subsidies, donations, or the proposed token in this paper. In these examples, the community has an important role. If funds are intended to close the digital divide and bring a greater number of individuals and households onto the Internet at broadband speeds, the community should be able to confirm these connections. This process can be trusted to validators –two or more nodes that confirm user connectivity and traffic and write it to a public ledger.

The role of the Validator:

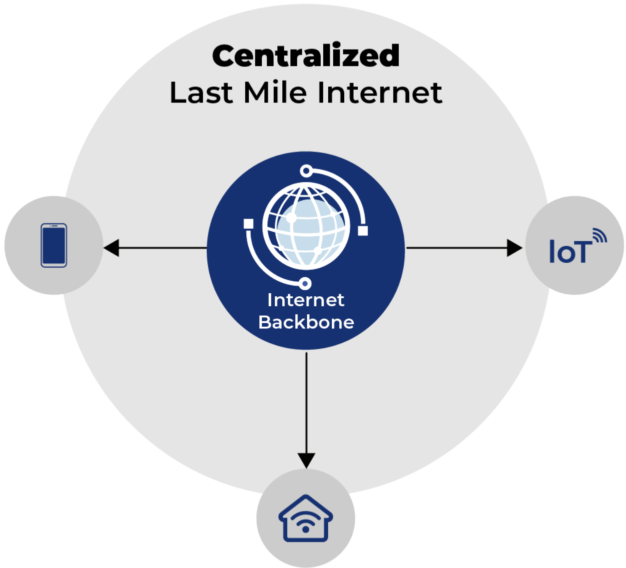
• Validates connectivity between the user and the host and/or the ISP



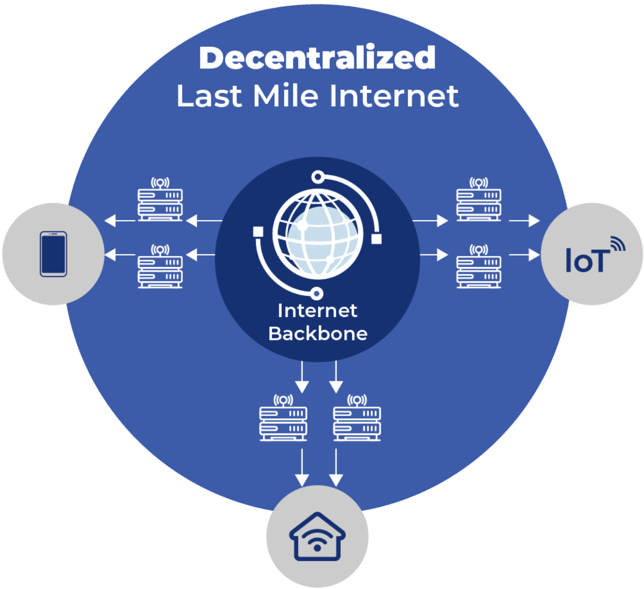
TOKEN ARCHITECTURE

Last Mile Internet – Decentralized Wireless Network

Summarizing the network topology of the Internet, the core of the Internet is a decentralized network of interconnected servers and routers, yet most of the devices that connect to the server are centralized through a single line of communication to the nearest Internet service provider, known as the last mile of the Internet. This leads to a single point of failure and monopolistic behavior in the last mile.



Utilizing new wireless technologies, the last mile of the Internet may share the same characteristics of the backbone, able to route traffic through the most optimal and cost-effective path. This decentralization requires at least two connections (routes) for any type of device that is connected to the Internet, including fixed broadband, mobile and IoT devices.



The proposed network includes new wireless access point hosts, across geographic locations to be within wireless range of devices needing access to the Internet. A decentralized last mile network of ISPs and hosts increases competition, lowering prices and driving network expansion. This should benefit billions of users that are currently categorized as underserved.

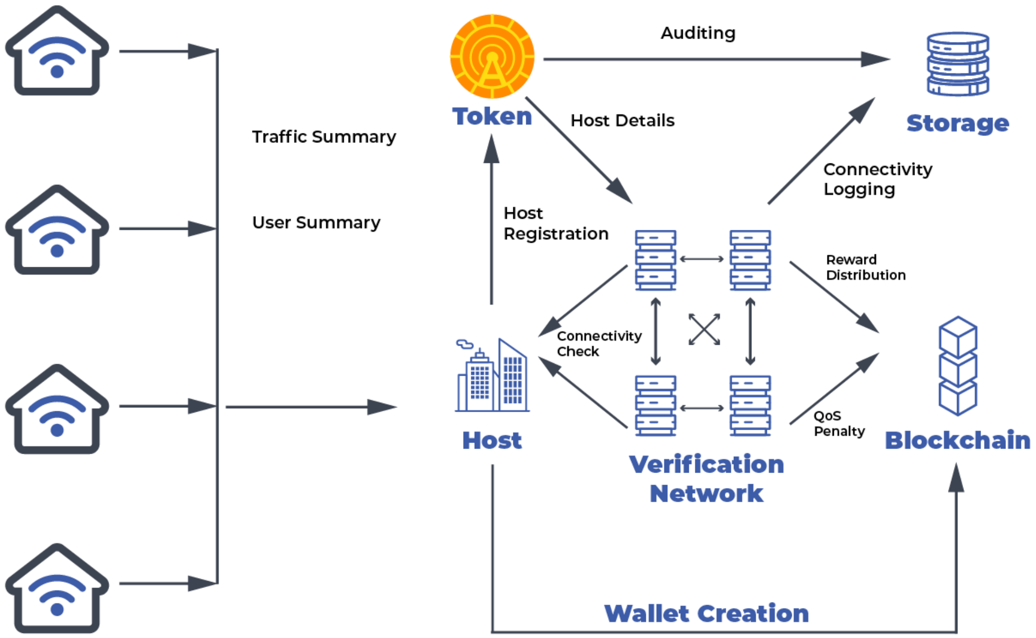
The key attributes of a decentralized wireless network in an ISP – Host – User model are:

- A device should have two or more routes to connect to the Internet
- A user should be able to easily switch ISPs for optimal pricing
- A host should be able to work with multiple ISPs

Token Architecture

Hosts are an important component of the decentralized wireless network model, and the reward system is designed to encourage hosts to participate in the network creation and provide connectivity to end user devices. The latter is important because the ultimate mission is to enable users with connectivity. Hosts are a necessary component to achieve this goal.

The following illustrates the token architecture and the use of a blockchain and verification network for the reward mechanism. This assumes that an active host provides connectivity for one or more end user devices. When connectivity is established, the user, or user's device, is authenticated for a valid connection. This is important in a reward mechanism to validate a true connection and deter fraud. A summary of the traffic is also reported from the host. This is important to understand the type of device (fixed, mobile, IoT, etc) or the speed of the connection to validate true broadband access.



According to this diagram and model:

- Users and hosts work in a decentralized manner. All users that have broadband service may also be hosts. A host provides service to other users by providing a wireless access point.

- The verification network uses a Proof of Connectivity consensus algorithm to ensure that a host provides Internet connectivity according to the service level agreement.

- The verification network logs all service and QoS information in storage and distributes the reward to hosts through the blockchain. It also decides the penalty that will be applied to the host in case of service interruption.

• To ensure the host gets the right reward and provides service in the correct coverage area, the owner needs to have a wallet in the blockchain and must also register itself to a host registration platform (such as the Airwaive marketplace).

The wireless access point equipment used by hosts, or the gateways that they connect into, will vary by ISP and hardware manufacturer. The Airwaive Project will maintain modules for each type of equipment or gateway to standardize the collection of user and traffic information. These modules will not only be open sourced to allow the community to contribute to the development for each type of hardware, but it is also important to keep these modules open to the public to ensure that no user or traffic information is abused. These modules should only collect summary information to validate connections for the purpose of the reward mechanism, and never read or store the contents of the data being transmitted.

Proof of Connectivity Consensus Algorithm

In a decentralized network, a mechanism is needed to prove that a node provides services as expected. In this case, it is the Proof of Connectivity consensus algorithm.

The consensus process is as follows:

1. The verification network gathers all node information from hosts.

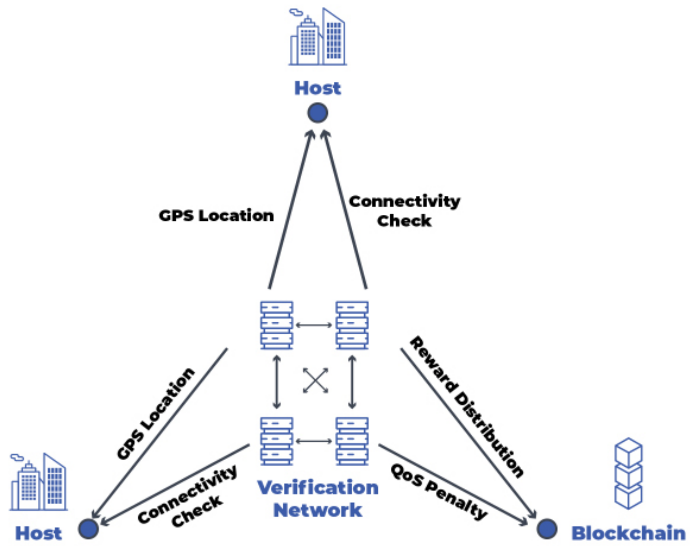
2. Based on node information, verification randomly picks a node to call the API on the node to check its connection status as well as GPS location information. This occurs at constant time intervals.

3. The verification network logs the connectivity check result.

4. An internal process generates the connectivity check report in a certain time period and stores the report in logs/storage.

5. The verification network then triggers the reward distribution transaction to the blockchain to issue the reward to participating nodes. If the quality of service (QoS) of a certain host is below the threshold, a penalty transaction is triggered to the blockchain.

This process ensures that all hosts are working as expected and all network creators in this local network are eligible to receive rewards.



This consensus mechanism aligns with the project's mission – to enable connectivity of devices onto the Internet. No single entity should be trusted to report true, accurate numbers of connections and speeds, especially when that same entity is incentivized for larger numbers. Instead, the community verifies connections and traffic through a host access point to determine the tokens that are granted as the reward mechanism. This is referred to as Proof of Connectivity consensus when validators agree upon the tokens to distribute to a host and it is committed to the blockchain.

Proof of Connectivity requires the following to be validated:

- Host location matches the registered location for the Host's access point. This is determined by matching the GPS location of the access point equipment when traffic is served.

- Connectivity check confirms a unique device connection and its traffic. This is determined by matching the device's identifier (e.g. SIM card) and traffic to validate it is a true connection.

USE CASES

Wireless Broadband Networks

The primary use case discussed in this paper is wireless broadband Internet to homes and businesses, known as fixed wireless. The *ISP – Host – User* wireless model is a cost-effective way to build broadband networks, especially when combined with incentive programs for hosts to participate in the development and operation of the network.

As an example, a country with a low rate of broadband penetration can seed the development of initial wireless networks in underserved communities by funding tokens that are used by ISPs to purchase equipment, fiber backhaul and installation services and compensate hosts. After validation of connectivity in the first communities, and the mining of new tokens from this connectivity, ISPs continue the cycle of building networks to bring more users online with wireless broadband.

Although the *ISP – Host – User* model is the backbone of this architecture, ISPs can be generalized as Operators that build and manage a network, and Hosts can be thought of as one of many parties within the group of Network Creators that are essential to building a local network of wireless access points. In general form, it is an *Operator -> Network Creator -> User model.*

Mobile Networks

Using the general form, a mobile carrier is an *Operator*, defined as an entity that provides users access to a network for mobile devices such as phones, thus needing a host property to deploy wireless equipment. The primary difference between mobile networks and fixed wireless networks is that a mobile device may roam between host access points. The operator also needs equipment, fiber backhaul and installation services, in addition to the host, all of whom are defined as network creators. *Operator -> Network Creator -> User.*

As an example, an existing wireless carrier (mobile network operator) is allocated rights to new frequencies to increase coverage or capacity in a city. Using this model, the operator identifies and compensates hosts and fiber companies to install and manage access points for mobile devices, increasing time to market and reducing capital costs to build their own sites.

IoT Networks

The same *Operator – Network Creator – User* model can be applied to the Internet of Things (IoT), where the Operator is now the service provider of IoT applications. There are many cases of IoT devices that need to be deployed in a network configuration, sometimes requiring permission from property owners (hosts) to install these devices.

As an example, a car company with autonomous driving features may require roadside information that is transmitted to and from their cars on the road. These roadside devices are known as vehicle-to-everything, or V2X, and are like the wireless access points used by fixed and mobile devices but for cars. Using this model, the operator identifies and compensates network creators in a similar way.

Edge Computing Applications

The *Operator – Network Creator – User* model is not limited to connectivity. It can also be used for applications and services that require compute or storage capacity at a host site. There are many applications that benefit from being closer to the user, to reduce latency or to reduce the volume of data that must be moved across the Internet.

As an example, a company with a photo and video sharing service may store these files closest to the user, by utilizing a server at a host site for storage. The most common viewers of these files tend to be the user, or friends and family within the same city. This decreases latency to load files and reduces traffic across the Internet. Using this model, the photo sharing company identifies host locations with access points and storage capacity and compensates the host accordingly. In this use case, network creators include products and services that reside at the Internet's edge, physically residing at a host property.

THE FUTURE OF THE PROJECT

The Airwaive Project is managed by a distributed, autonomous organization that governs the blockchain and token in support of a mission to build and operate decentralized networks. This includes supporting platforms, such as Airwaive's own marketplace platform for Operators and Hosts (www.airwaive.com), as one of the platforms that integrates the token. However, the Airwaive Project is independent of Airwaive's marketplace platform, which allows the token to be used by any platform that shares the project's mission and allows any developer to build upon the project's open-source code.

Creating Reliable, Affordable Internet Access

When the last mile of the Internet is truly decentralized, and when competition is created to offer consumers more options, reliability tends to go up and prices tend to go down. The future of the Airwaive Project will align with its mission to drive reliable, affordable Internet.

Ultimately, the community plays a significant role to bring affordable broadband to the world and increase the penetration of broadband closer to 100% of the world's population. Networks need funding. A new generation of ISPs are needed that build cost-effective, wireless networks. Property owners are needed as access point hosts to reach end users and complete the network. Validators are needed to ensure that networks are living up to their promise and people are truly connected.

As they say, a rising tide lifts all boats. Bringing affordable, broadband Internet to the world and connecting every individual at broadband speeds should have an economic and social impact for everyone on the planet, not just those that were previously *underserved.*

Creating Useful Applications and Services

A broadband connection without a useful application or service to connect to is meaningless. Fortunately, the Internet is a collection of millions and millions of web sites and applications that provide value to users. However, it can take the Internet time to adjust and scale to significant changes and events. One such example is the sudden shift to work- and learn-from-home during COVID. Most schools were ill-prepared to bring educational services online, such as video streaming between kids and teachers. Although this example may now be solved in many communities, there will always be a new challenge that tests the Internet's ability to deliver applications and services across the network.

The next phase of the Airwaive Project's mission is to connect the right applications and services to the right people, in a distributed manner that allows for the greatest scale and flexibility. Decentralized applications not only allow for quick scalability, but when placed at the edge and closest to the user have cost efficiencies that can be passed to the end user in the form of lower prices. With the help of the development community, the Airwaive Project may be extended to include decentralized connectivity, compute and storage for applications processed at Host access points.

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