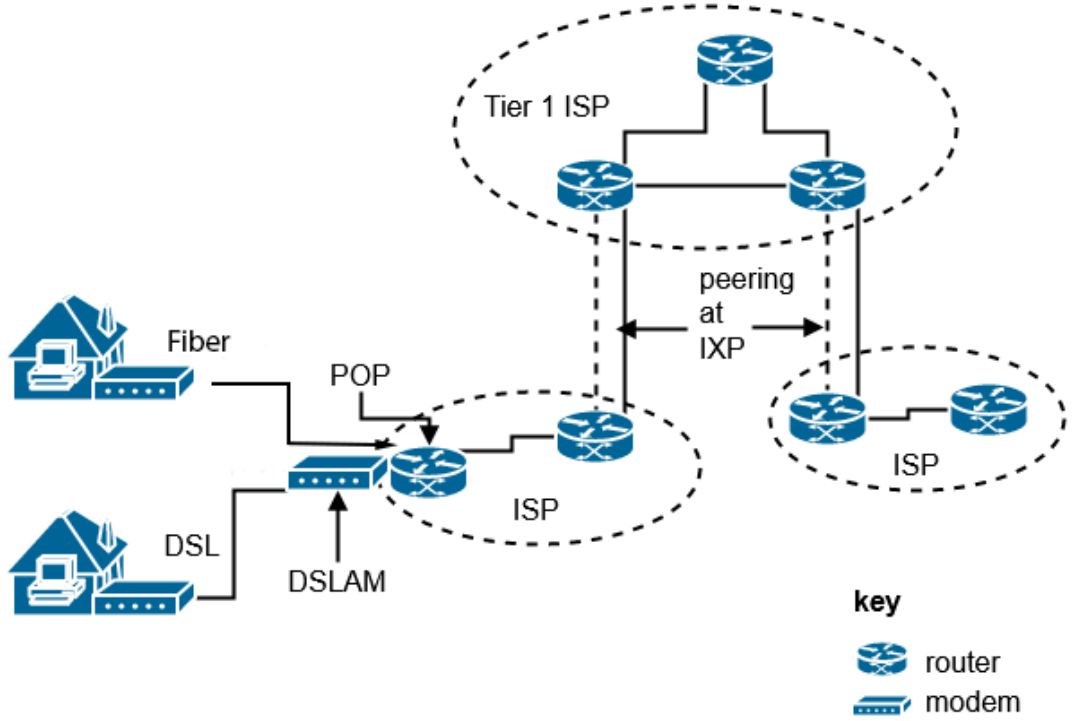
ISP Architecture

After examining what a WAN is and the role played by ISPs, we can take a closer look at what happens when a user connects to the Internet.

The connection is not made directly to “the entire Internet”. Instead, it first passes through the network of the user’s own provider, which is in turn connected to other networks.

The image below shows what actually happens when a user connects to the Internet.



To connect to the Internet, a computer connects to an **ISP**, which allows it to exchange packets with all the other hosts that can be reached through the Internet.

Common methods of connecting to an ISP include copper telephone lines, optical fibre, mobile networks and, in some cases, radio or satellite links.

Below, we examine telephone lines and optical fibre.

Telephone Line

DSL, or **Digital Subscriber Line**, uses the telephone line to transmit digital data.

With DSL, the computer is connected to a device called a **DSL modem**, which converts digital data into signals suitable for travelling over twisted-pair telephone cables.

At the other end, a device called a **DSLAM**, or **Digital Subscriber Line Access Multiplexer**, receives these signals and transfers them into the operator's network.

This method is limited by the **last mile** of the connection.

In telecommunications, the term **last mile** refers to the section of cable connecting telephone exchanges to end users. In other words, it is the part of the telephone network known as the **access network**.

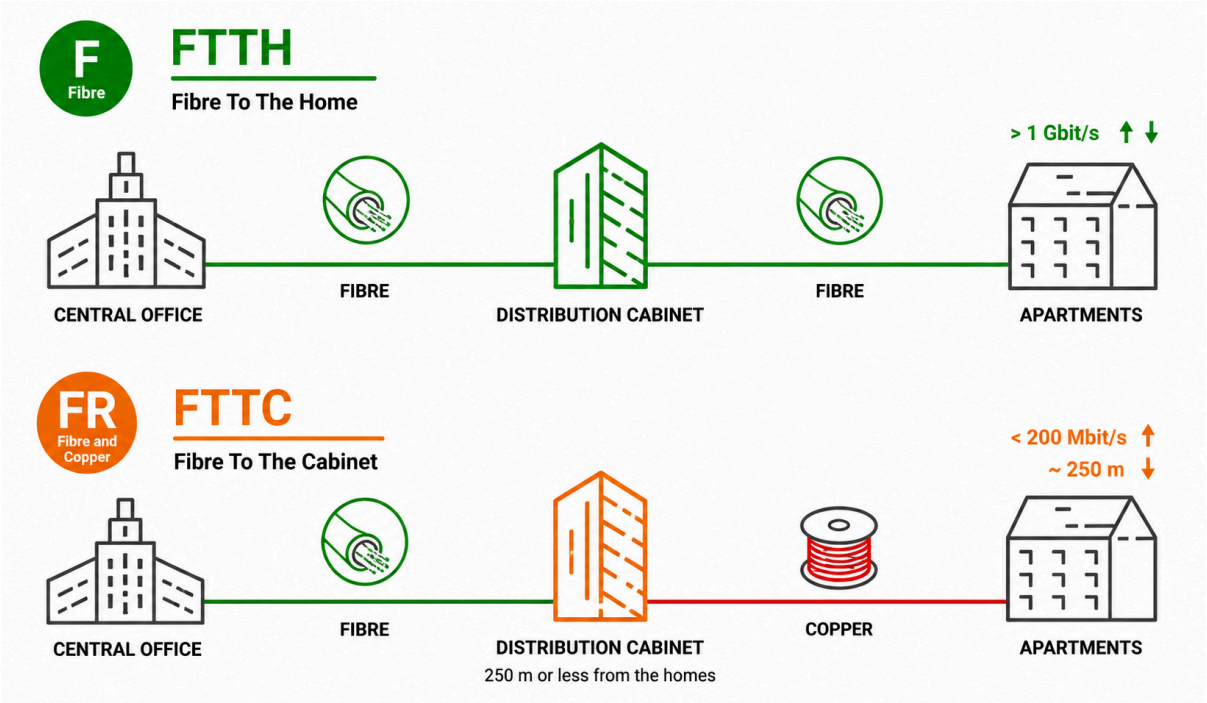
Connection performance may decrease in this section because the last mile uses a slower system—the telephone line—than the system generally used within the ISP's network, namely optical fibre.

Optical Fibre

To provide faster Internet access, optical fibre can be installed all the way to users' homes. Optical fibre is much faster than a traditional telephone line.

This can be achieved through configurations such as **FTTH**, or **Fibre to the Home**, and **FTTC**, or **Fibre to the Cabinet**.

- With **FTTC**, optical fibre reaches a cabinet located near residential or commercial buildings. From the cabinet, the signal reaches the customer through a different technology that uses the existing copper cables for the final section of the connection. The last-mile limitation is therefore still present, although its impact is reduced.
- **FTTH** provides better performance and more stable connections than FTTC because the optical fibre reaches the user's home directly. The final section is no longer made of copper but of optical fibre, greatly reducing the bottleneck typical of connections based on telephone cables.



At this point, data packets can enter the ISP's network.

The point at which packets enter an ISP network is called a **Point of Presence**, or **PoP**.

ISP networks may operate on a regional, national or international scale.

An ISP's **backbone** consists of long-distance transmission lines that connect PoPs located in the different cities served by the ISP.

Example
Imagine that you live in Palermo. Your ISP has a PoP in Palermo that is connected by optical fibre to its national backbone.

When you browse the Internet, your traffic enters the local PoP, where it is processed and routed through the national or international network.

When a packet needs to reach a destination on the Internet, it may follow different paths:

- If the destination is located within the same ISP's network, the packet can be routed directly through the operator's network.
- If the destination is located on a different network, the packet must pass through an interconnection between networks. ISPs can exchange traffic through **peering agreements**, which allow two networks to connect directly and exchange data.

Many of these exchanges take place at **Internet Exchange Points**, or **IXPs**. These are physical locations where ISPs, corporate networks and major content providers interconnect to exchange traffic more efficiently.

Example
IXPs are not located everywhere. They are mainly found at major strategic connection points: cities with extensive network infrastructure through which national and international operators pass.

An IXP can be compared to a “marketplace” where ISPs, corporate networks and content providers such as Google, Meta and Netflix exchange traffic to reduce costs and latency—the delay before data reaches its destination.

Several Internet Exchange Points operate in Italy, including MIX in Milan, NaMeX in Rome and TOP-IX in Turin.

When an ISP cannot reach a destination through its own connections or peering agreements, it can purchase **IP transit** from another operator known as a **transit provider**.

A transit provider is an ISP that sells connectivity to other ISPs or customers. It allows their data traffic to travel through its own network to reach destinations that would not otherwise be directly accessible from the customer’s network.

This gives the customer access to the Internet without requiring it to negotiate peering agreements with many different networks.

The connectivity supplied by a transit provider is called **IP transit**.

ISP Hierarchy

Now that we understand how an individual ISP works, we can examine the broader structure.

Not all ISPs are the same. They have different levels of coverage, independence and decision-making power, creating a logical and commercial hierarchy.

This structure forms an ISP hierarchy divided into levels known as **tiers**.

Understanding this hierarchy is important for explaining how the Internet operates globally, who manages its infrastructure and how data travels from one side of the world to the other.

The ISP hierarchy is commonly divided into three main levels:

- Tier 1
- Tier 2
- Tier 3

Tier 3 – Local or Retail ISPs

Tier 3 ISPs are the providers closest to end users.

- They do not operate an extensive network of their own.
- They purchase connectivity from Tier 2 ISPs—or, in some cases, directly from Tier 1 ISPs—which act as transit providers.

- They provide Internet access to households, schools, offices and small businesses.
- They operate on a local or regional scale.
- They do not participate directly in global peering.

Example
Tier 3 ISPs may include small local operators, wireless providers operating in mountain areas or regional providers serving areas with limited coverage.

Tier 2 – Regional Providers

Tier 2 ISPs act as intermediaries. They operate their own networks but cannot reach the entire Internet independently.

- They have local peering agreements with other ISPs operating at the same level.
- They pay one or more Tier 1 providers for IP transit—that is, to send data towards networks they cannot reach directly. In this situation, Tier 1 ISPs act as transit providers for Tier 2 ISPs.
- They often operate on a national or continental scale.
- They provide connectivity to Tier 3 ISPs or large organisations.

Example
An ordinary user will often obtain Internet access from a Tier 2 ISP.

Suppose that you live in Milan or Palermo and have a home Internet connection supplied by Fastweb, Vodafone or WINDTRE.

These operators have their own national networks, regional backbones, peering agreements with other providers and data centres.

However, they do not necessarily operate a fully independent global network. They must therefore purchase transit to reach other countries or continents and can consequently be classified as Tier 2 providers.

As an end user, you connect to a Tier 2 ISP, which may then rely on Tier 1 ISPs to reach the rest of the world.

A Tier 2 ISP may also act as a transit provider for another Tier 2 ISP for several reasons:

- **Economic reasons:** in certain regions, a Tier 2 provider may offer more competitive prices than a Tier 1 provider.
- **Technical reasons:** it may provide better-quality connections along specific routes.
- **Redundancy:** using multiple transit providers, including both Tier 1 and Tier 2 operators, improves resilience and service continuity.

Example

A Tier 2 ISP with a strong European network may provide transit to another Tier 2 ISP that requires efficient access to that region, even when the second provider is already connected to a Tier 1 network.

A more specific example would be:

- ISP A is a Tier 2 provider in Italy with a strong national network and connections to two Tier 1 providers.
- ISP B is another Tier 2 provider operating in Spain.
- ISP B may purchase IP transit from ISP A to improve routing towards Italy or to use it as a backup path.

Tier 1 – Global Backbone Operators

At the top of the hierarchy are large international backbones consisting of thousands of routers connected through optical fibre.

These ISPs, known as **Tier 1 providers**, do not pay for transit and operate international backbones that carry global traffic from one continent to another through transoceanic submarine cables.

A Tier 1 operator can reach every network on the Internet without purchasing IP transit, thanks to its own connections and peering agreements with other Tier 1 operators.

Tier 1 providers therefore play a fundamental role in connecting major networks and continents.

A Tier 1 ISP has peering agreements with all the other Tier 1 providers. This means that they exchange traffic without purchasing transit from one another, based on a settlement-free and mutually beneficial exchange of data.