August 2020

Internet Infrastructure and Standards

pkSIG 2020

Naveed Haq
Regional Director, Infrastructure and Connectivity
haq@isoc.org

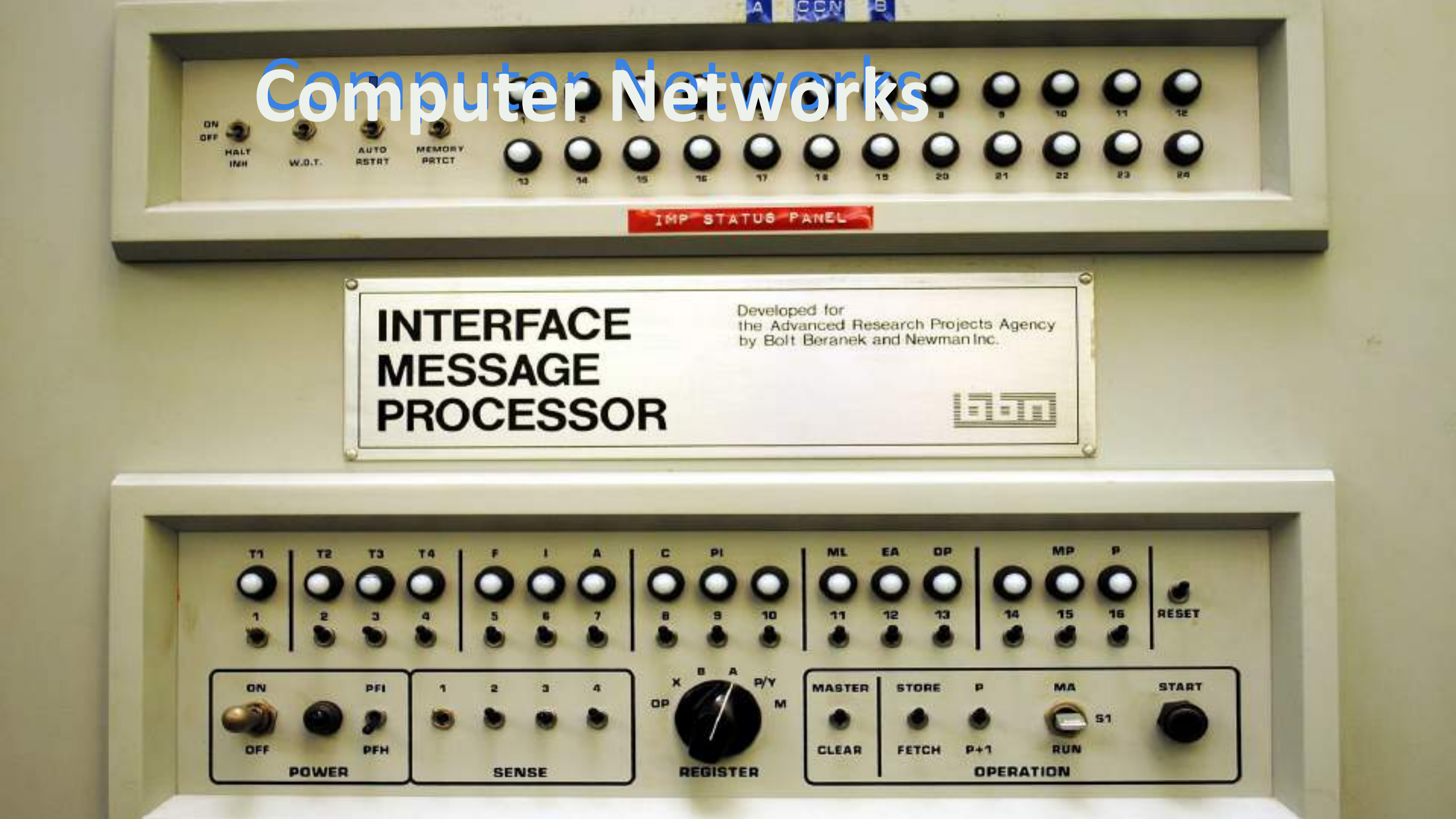
Internet Infrastructure

The Telephone Network


LONDON
PARIS

Our Heritage

- The major technology achievement of the twentieth century
- Connected handsets to handsets
- The network was intentionally transparent
- Real time virtual circuit support between connected edge devices
- Network-centric architecture with minimal functionality in the edge devices


Computer Networks
IMP STATUS PANEL
INTERFACE
MESSAGE
PROCESSOR
Developed for
the Advanced Research Projects Agency
by Bolt Beranek and Newman Inc.
POWER
SENSE
REGISTER
OPERATION
RESET

Computer Networks

The original concept for computer networks was the telephone network

The network was there to enable connected computers to exchange data

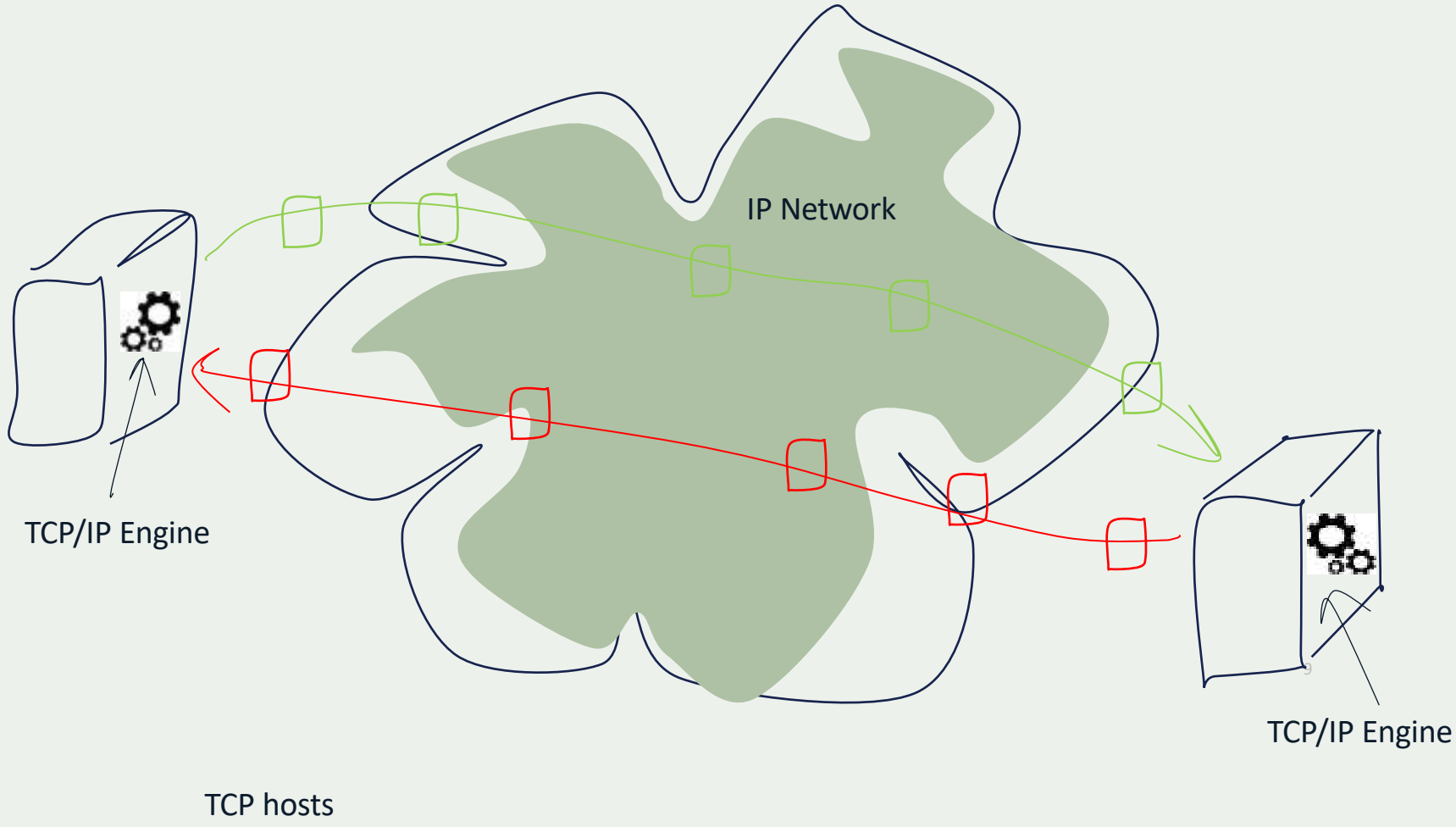
- All connected computers were able to initiate or receive “calls”
- A connected computer could not call ”the network” – the network was an invisible common substrate
- It made no difference if the network had active or passive internal elements

Internet Architecture (c1980's)

"End-to-End" design:

- Connected computer to computer
- The network switching function was stateless
- No virtual circuits, no dynamic state for packets to follow
- Single network-wide addressing model
- Single network-wide routing model

Internet Architecture (c1980's)



The Result was Revolutionary!

By stripping out network-centric virtual circuit states and removing time synchronicity the resultant packet carriage network was minimal in design and cost and maximized flexibility

More complex functions, such as flow control, jitter stability, loss mitigation and reliability, were pushed out to the attached devices on the edge

History of the Internet

1968 - DARPA (Defense Advanced Research Projects Agency) contracts with BBN (Bolt, Beranek & Newman) to create ARPAnet

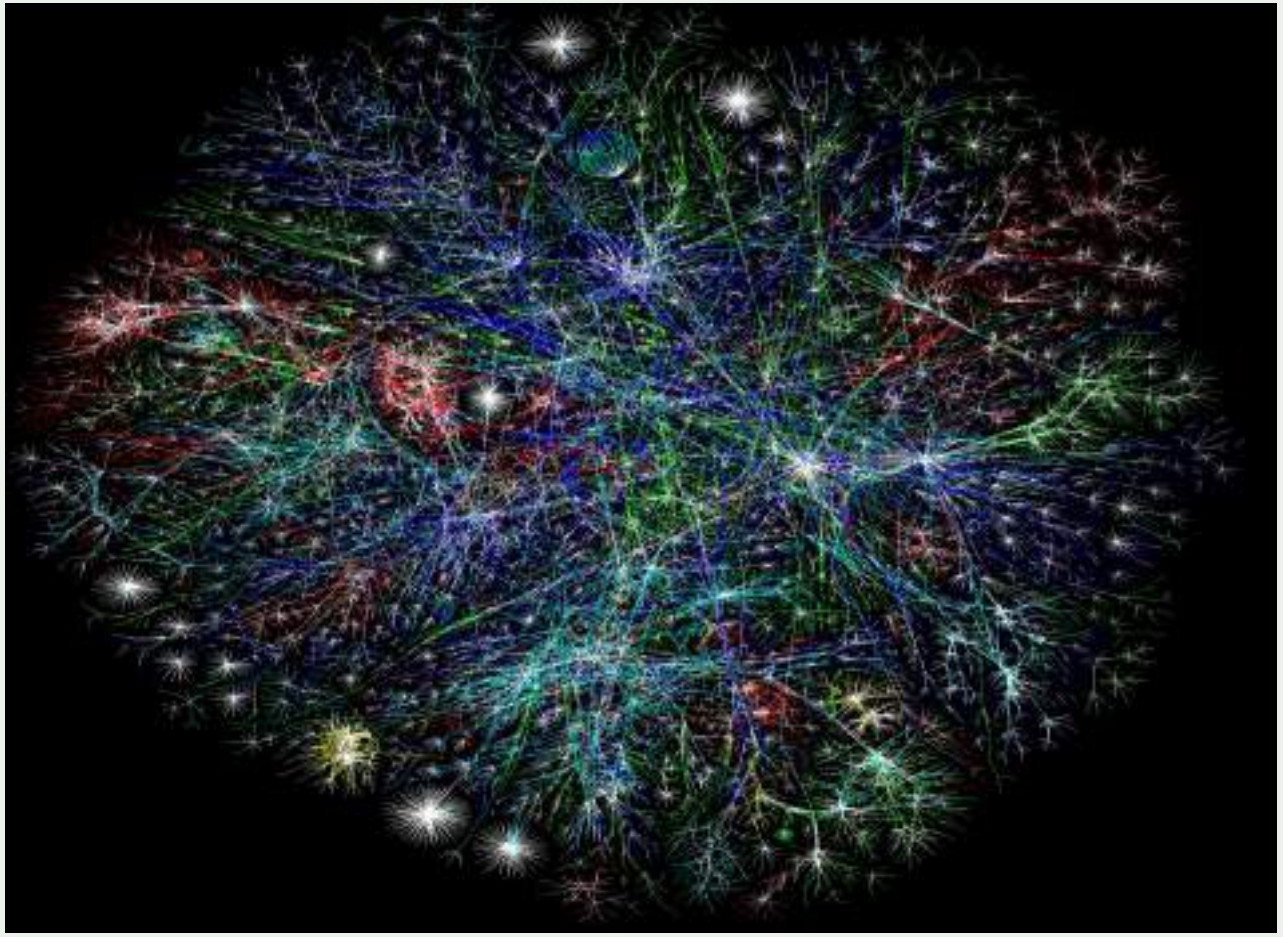
1970 - First five nodes:

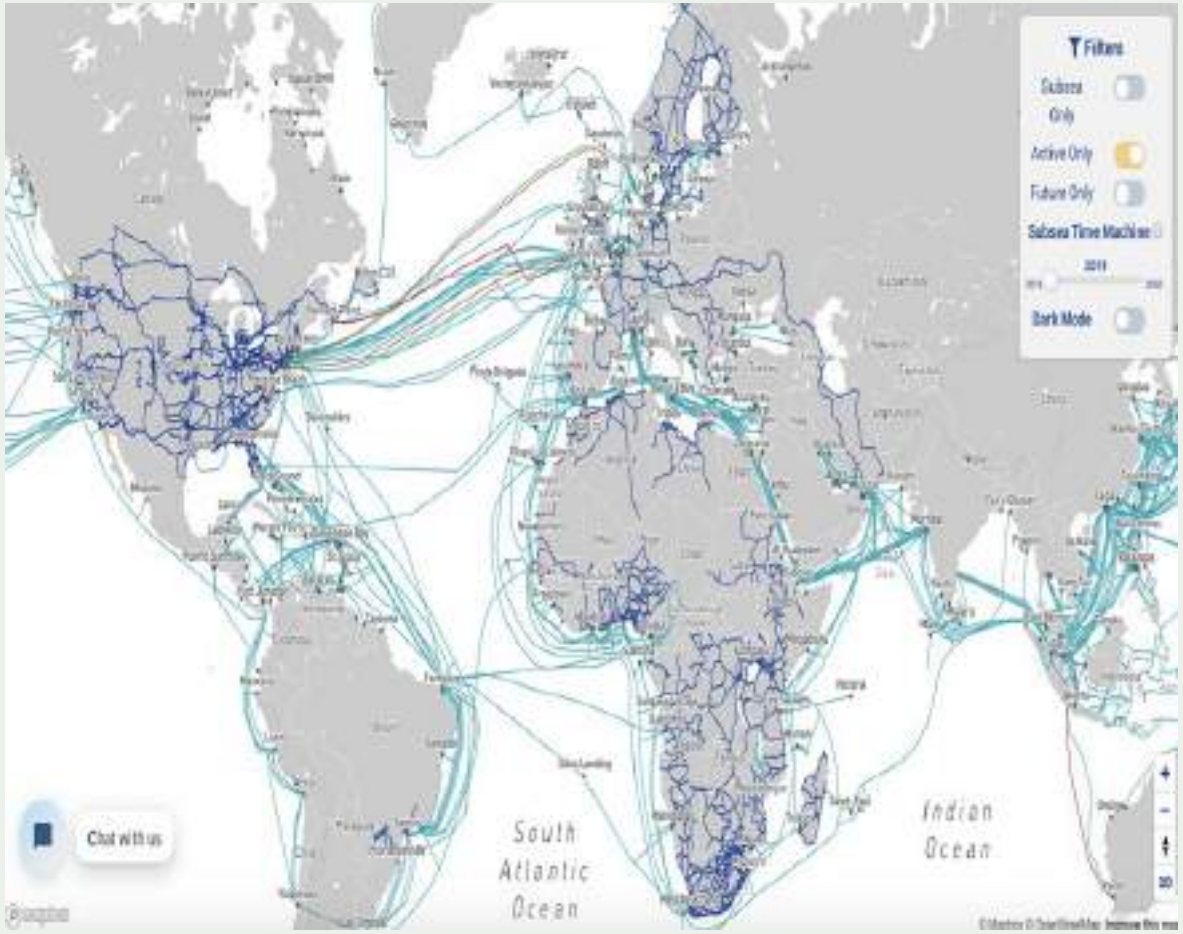
UCLA
Stanford
UC Santa Barbara
U of Utah, and
BBN

1974 - TCP specification by Vint Cerf

1984 – On January 1, the Internet with its 1000 hosts converts using TCP/IP for its messaging

Internet Today





Internet Infrastructure

The Internet is made up of thousands – if not millions – of independent networks, from the smallest network here in this venue to the largest international carrier facility.

Each of these networks can communicate with and send and receive packets to the others (though for routing and management efficiency, many of the smaller networks are aggregated into single management or addressing domains).

The Internet's infrastructure is made up of several different components:

Internet Service Providers (ISPs), including 'last mile' ISPs, regional ISPs and 'backbone' ISPs, and Internet Exchange Points (IXPs).

Internet Infrastructure

The Internet is often described as an ‘overlay network’. Unlike telephone networks, there is no close coupling between the physical infrastructure and the Internet itself.

This allows the Internet to be carried over virtually any type of physical infrastructure, from optical fiber, to copper, to wireless links.

The ability to deliver the Internet over any type of physical infrastructure is enabled by the unique arrangement of the forwarding, management, and control of Internet packets.

Internet Infrastructure

Last Mile

The '**last mile**' is a phrase used within the telecommunications industry that refers to the final leg of the telecommunications network that delivers connectivity to residential customers – the connection between the customer's house and the broader network.

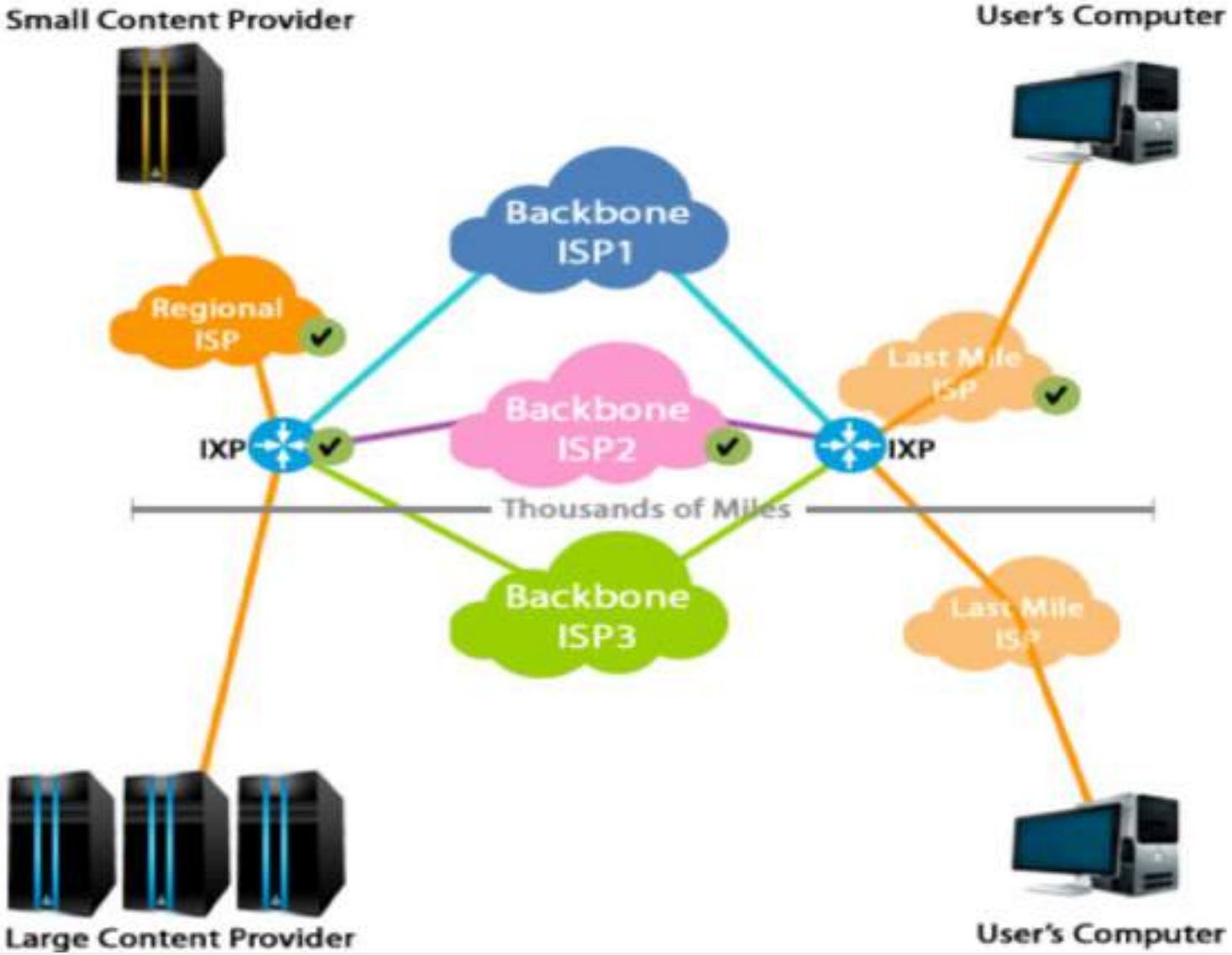
Regional ISP

In some countries, **the last mile provider is the same business as the regional ISP**; in other countries, a different ISP may provide and manage last mile connectivity.

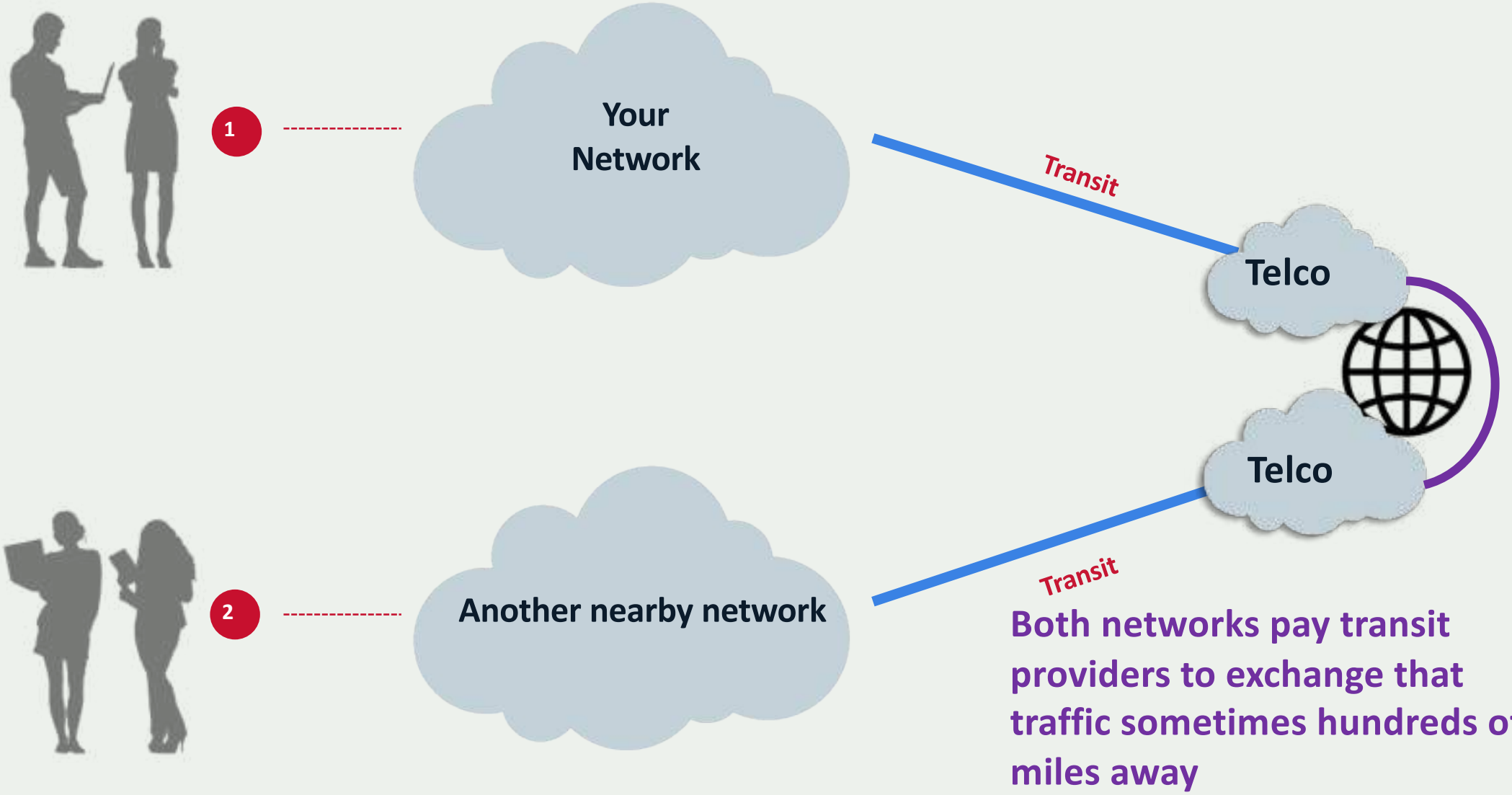
From the regional ISP's hub or aggregation point, the Internet traffic is carried by the regional ISP to a local or regional Internet Exchange Point (IXP).

Back bone

The backbone ISPs carry the traffic to another IXP elsewhere in the country, or the world, where another regional ISP then carries the traffic across the destination last mile to the designated recipient.



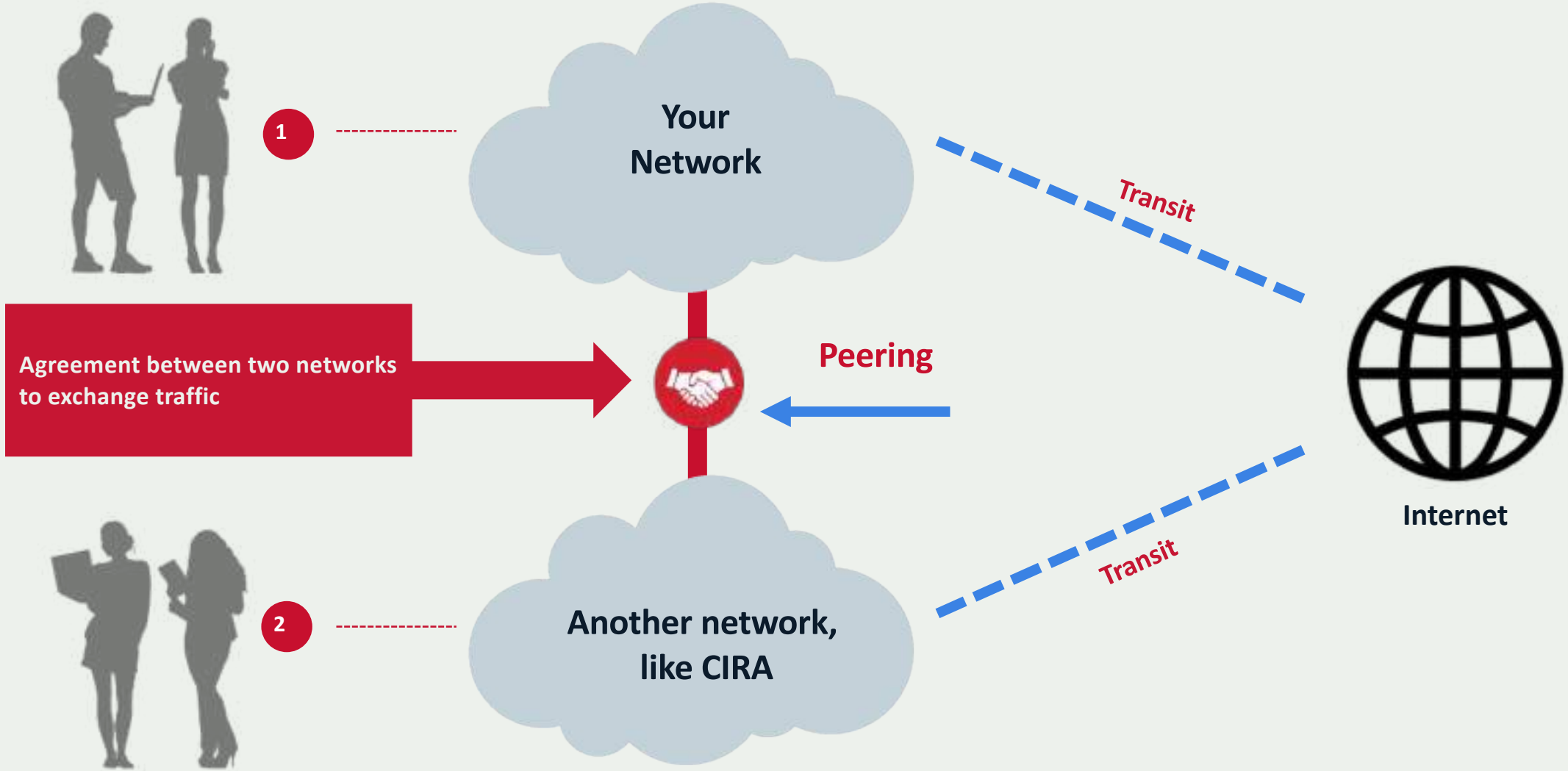
What happens when you exchange traffic with a nearby network?



Both networks pay transit providers to exchange that traffic sometimes hundreds of miles away

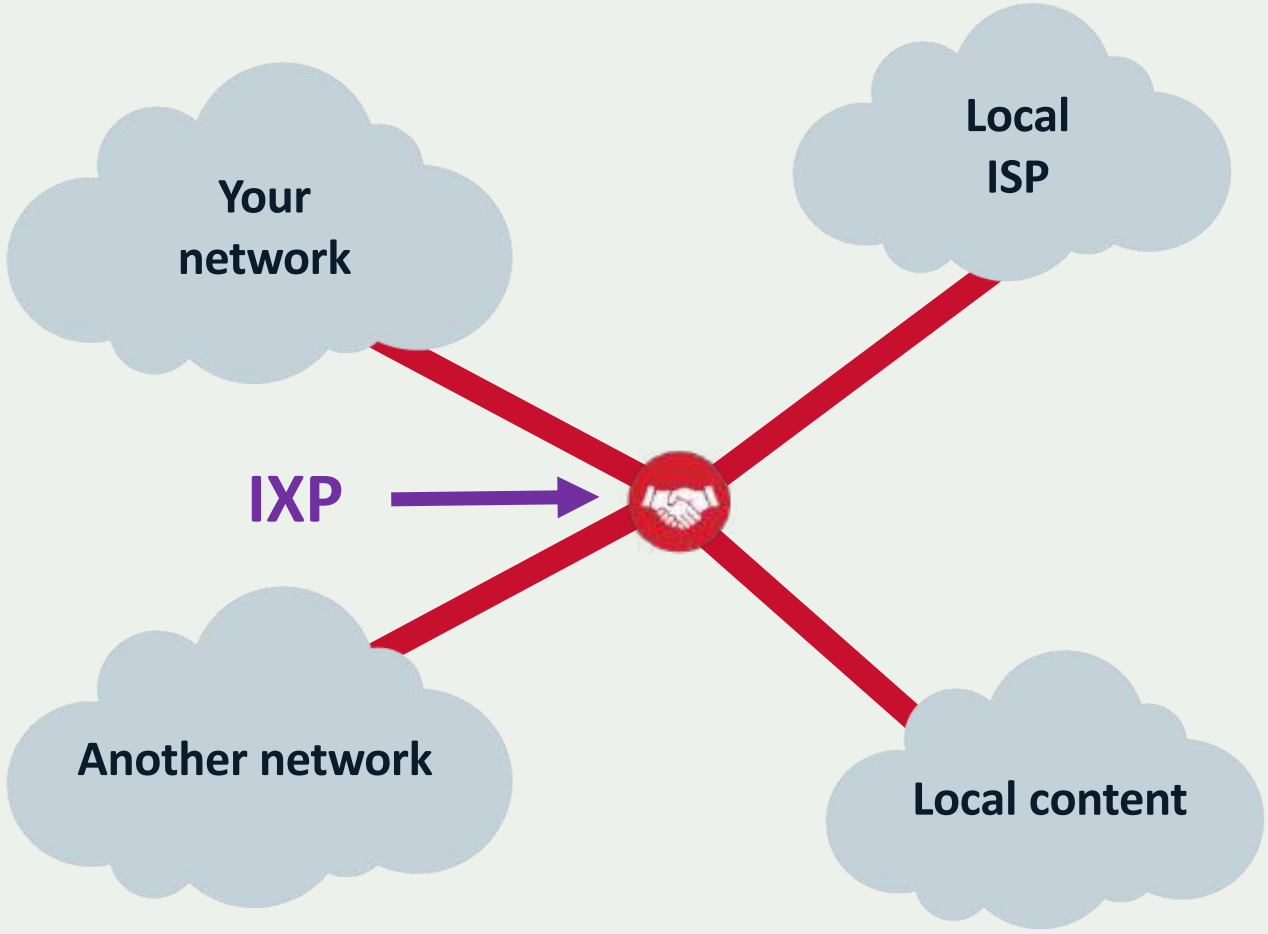
Mission of an IXP

By interconnecting two networks in the same location, peering reduces latency, cost, and increases resiliency



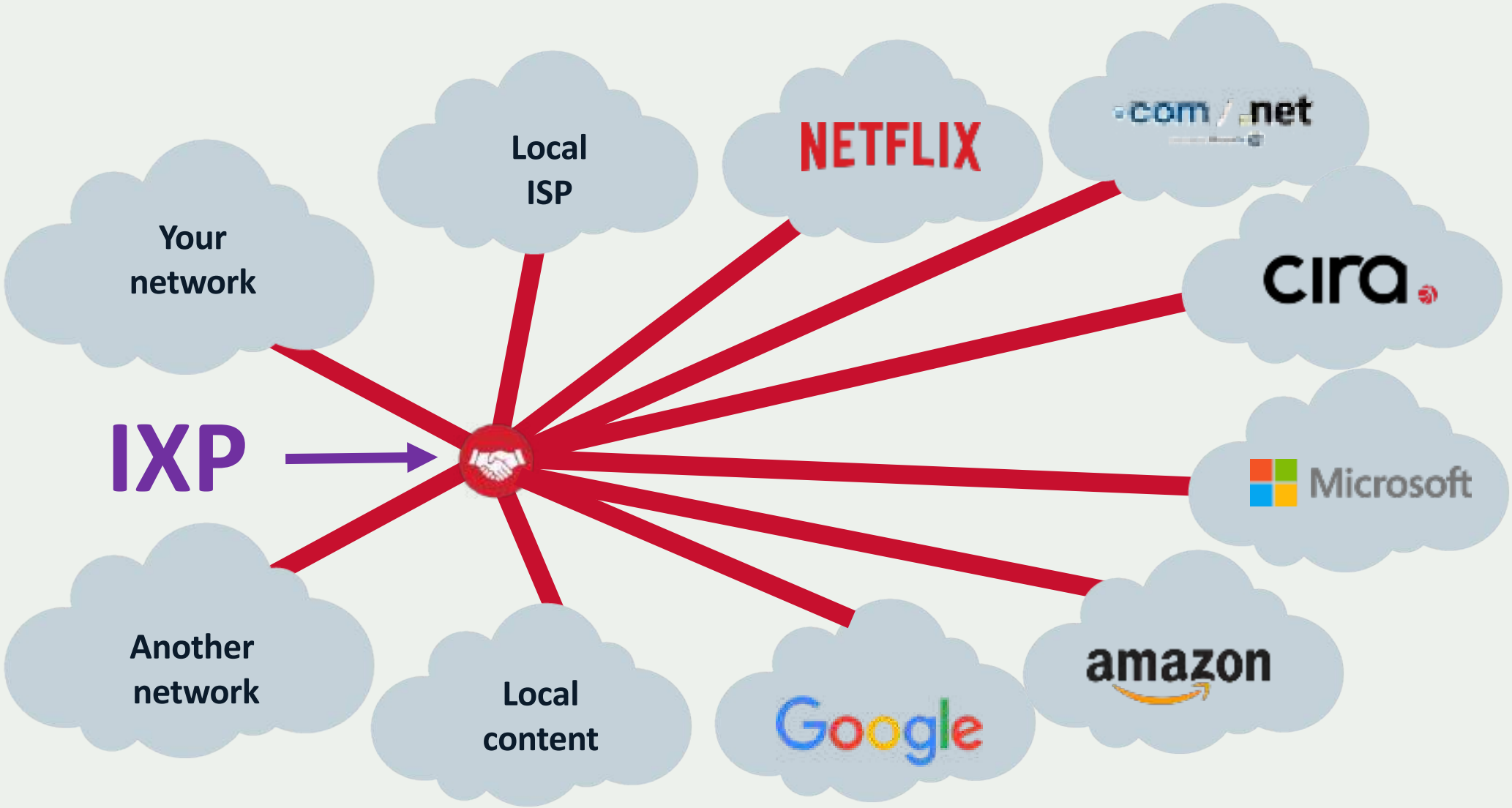
Peers exchange their own routes only! You still need transit for all the other networks

And if you have more than two peers in the same location, you need an **Internet Exchange Point** (IXP)



Remember: All these networks are connected to the internet as well

…Which will attract key infrastructure and content providers…



Remember: All these networks are connected to the internet as well

What is an IXP?

- A shared (layer 2) Service platform (aka, a switch).
- In a neutral and convenient location.
- Where network operators can freely exchange traffic.
- Most often than not, not-for-profit managed by its members.

The role and benefits of IXPs.

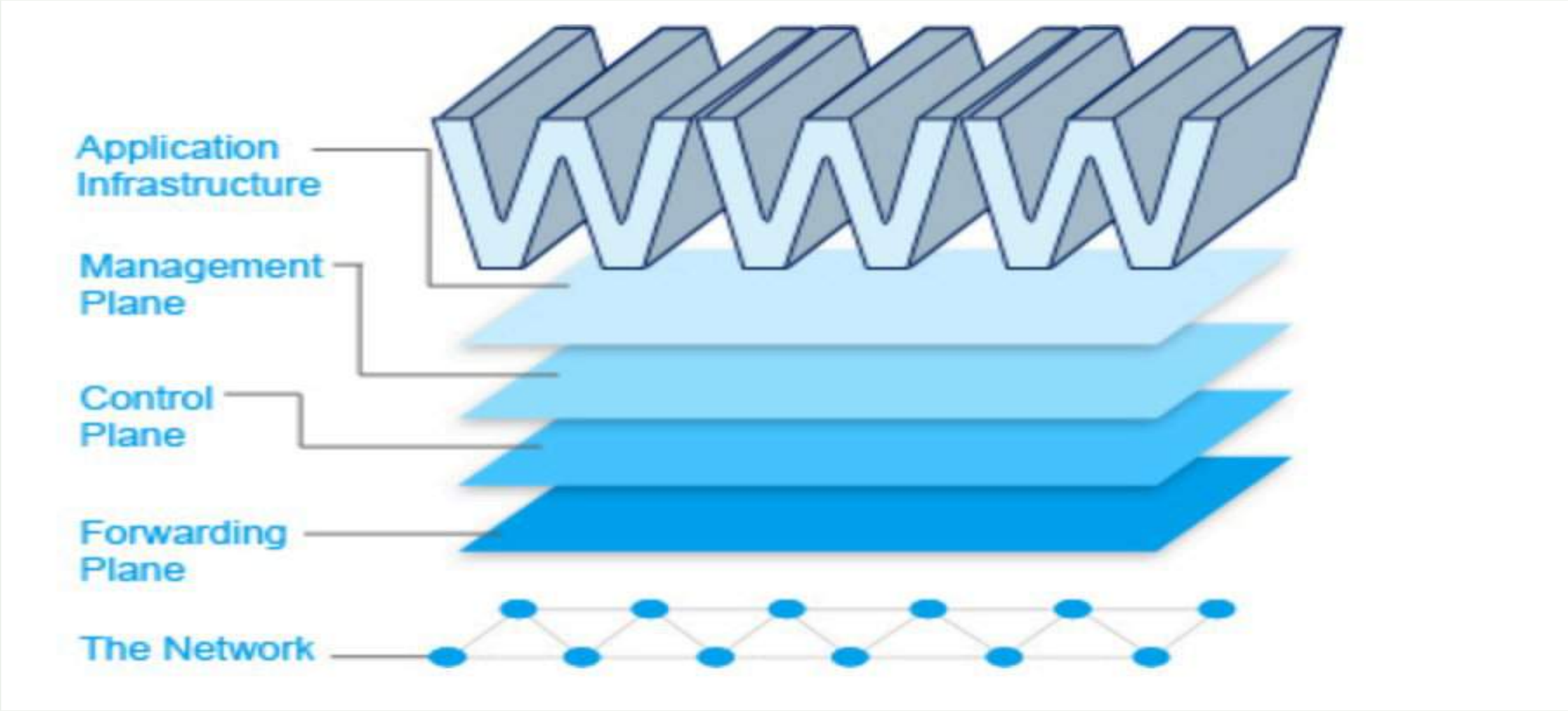
- **Keep traffic local.** IXPs keep traffic within local infrastructure and reduce costs associated with traffic exchange between networks.
- **Improve performance.** Improve the quality of Internet services and drive demand by reducing delay and improving end-user experience.
- **Attract investment.** Create a convenient hub for attracting key Internet infrastructures within countries.
- **Spark development.** Act as a catalyst for overall Internet development including commercial, governmental and academic stakeholders.
- **Improve resiliency.**

IXP Mapping Project – APAC [www.ixpmap.org]

- Mapping all active IXPs in South Asia, Southeast Asia, North/East Asia, Pacific
- Identifies cities that would benefit from an IXP based on population
- On-going project, *initiated specifically to support AP-IS**; contributions welcome
- www.ixpmap.org

*Asia-Pacific Information Superhighway
http://www.unescap.org/our-work/ict-disaster-risk-reduction/asia-pacific-information-superhighway

Communications or Protocol Stack



Forwarding Plane

This primarily includes the TCP/IP technology.

TCP is the workhorse of most Internet networks, supporting the operation of the World Wide Web, electronic email, file transfer.

TCP is part of the TCP/IP suite and is a connection-oriented protocol.

For example, if an Internet user requests a webpage in his or her browser, the browser uses HTTP to send a request to the web server, via TCP. The server responds by using HTTP to send the requested web page back, also via TCP.

TCP supports the reliable end-to-end transfer of data.

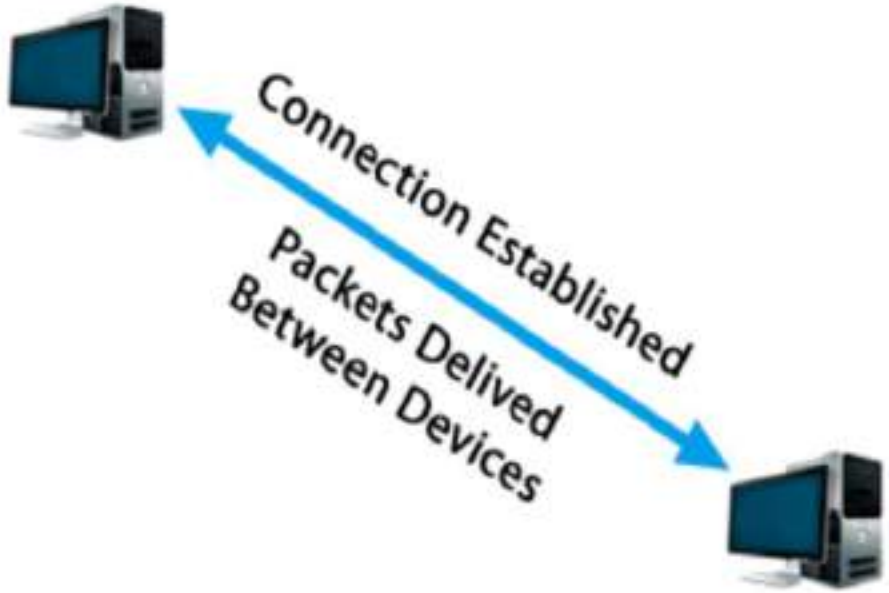
Forwarding Plane

The purpose of TCP is to ensure that packets are delivered between devices.

TCP establishes a connection with the receiving device.

If some packets are lost along the way, TCP seeks to retrieve them and deliver them.

The connection is terminated when all the packets are delivered, or when packets are irretrievably lost.



The role of IP is to deliver the packets to the designated IP address.

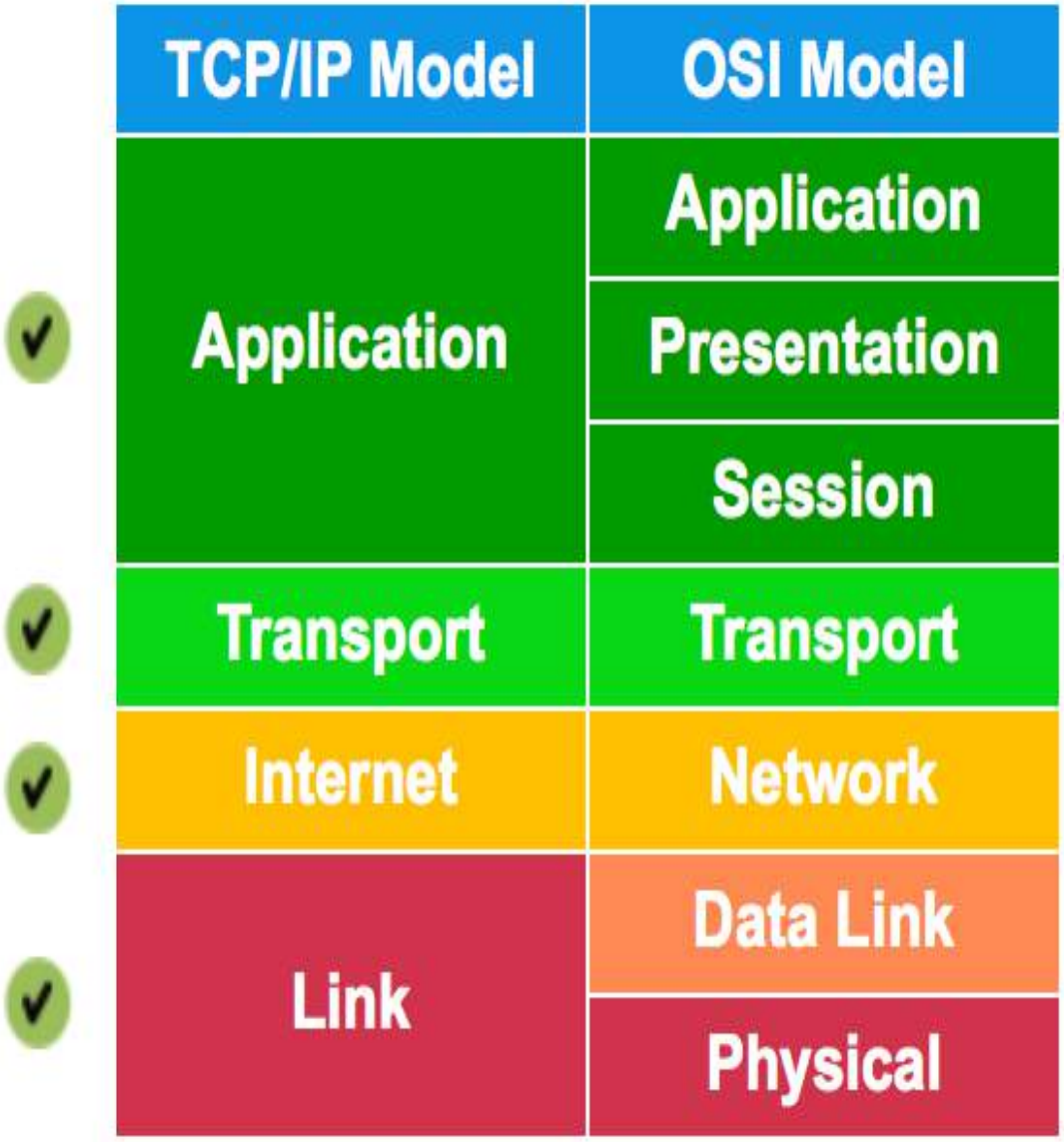
Packets consist of a header followed by a body.

The header describes the packet's destination and, optionally, the routers to use for forwarding until it arrives at its final destination.[4]

The body contains the data being transmitted. It is helpful to analogize a data packet to an envelope.

The header is like the mailing address, whilst the body is like the contents of the envelope.

Forwarding Plane



In the Application layer, applications create user data and communicate this data to other applications.

Communications partners are often called “peers.” This is where "higher level" protocols are used: such as SMTP for email, FTP for file transfer, and HTTP for web browser applications.

The Transport Layer provides a uniform networking interface that hides the actual topology (layout) of the underlying network connections. This is where flow-control, error-correction, and connection protocols exist, such as TCP. This layer deals with opening and maintaining connections between Internet hosts.

The Internet Layer has the task of exchanging datagrams across network boundaries. It is therefore also referred to as the layer that establishes internetworking. Indeed, it establishes the Internet.

This layer defines the networking methods by which hosts communicate without intervening routers.

Control Plane

Once the message is chopped up into individual packets, they are forwarded across the Internet to their ultimate destination through devices called routers.

The routers inspect each packet header, read the destination address, and then forward the packet to an appropriate egress port. Routers act like busy airports, where the airline passenger is analogous to the Internet packet.

Internet routers communicate with each other to determine the shortest route a packet needs to travel in order to reach its destination. This internet-router communication is referred to as the Internet routing protocol or control panel.

Control Plane

In fact, there are several variants of Internet routing protocols in use.

Which is most appropriate will depend on the size of the network and whether it is within a single management domain.

However, there is only one routing protocol for the forwarding of packets between different management domains, which is referred to as BGP - **Border Gateway Protocol**. BGP is the protocol used between different, independent networks.

It is one of the two protocols, the other being the Domain Name System, explained later in this module, and the one that raises the most issues with respect to Internet Governance.

Network operators try to route traffic in the best way possible, in terms of limiting costs and latency.

Often, independent networks find themselves in conflict with each other as they try to pursue the same objective.

The temptation might be to try to offload as much traffic as possible onto a competitor's network, while simultaneously limiting the amount of traffic that is delivered from that competitor's network.

Control Plane

The IETF has established many rules within BGP to try to manage this behavior to properly provide the **shortest path between two points** on the Internet.

BGP identifies an Internet user's routes to the world, and determines that user's reachability, as seen by other users on the network.

Deployment of BGP entails programming in many rules and filters to prevent attacks and improper routing.

Deliberately or accidently changing these rules can cause havoc throughout the global Internet.

Although the BGP filter and rules tables are managed by network engineers, they can have huge geo-political implications in terms of security and cyber-attacks.

That is why the IETF is working on standards to secure BGP to prevent unauthorized IP address announcements.

Management Plane

The Internet **management plane** includes a varied set of protocols and tools used to:

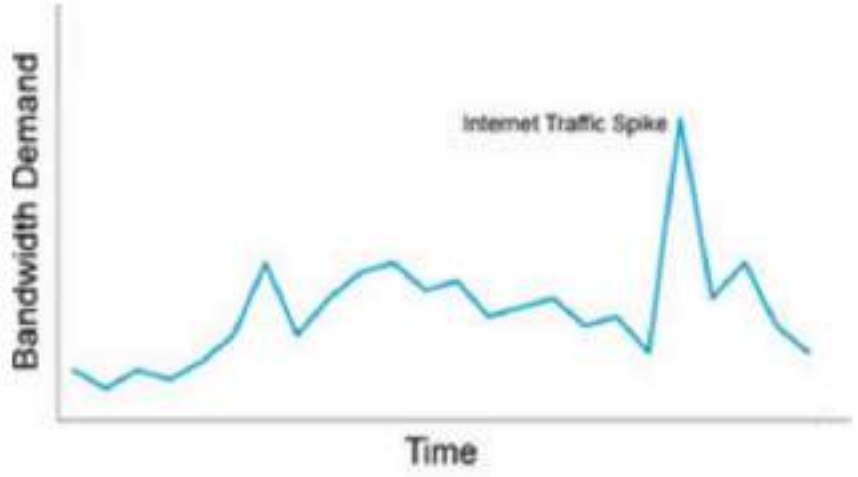
- access;
- manage; and
- monitor all of the network elements.

This plane supports all required provisioning, maintenance, and monitoring functions for the network. Like the other IP traffic planes, management plane traffic is handled in-band with all other IP traffic.

Most service providers and many large enterprises also build separate, out-of-band (OOB) management networks to provide alternate reachability when the primary in-band IP path is not reachable.

Telecommunications carriers and Internet Service Providers use network management techniques to:

- optimize traffic flows;
- block against cyber-attacks; and
- re-route traffic in the event of 'flash events' such as spikes in demand (from, for example, a number of users seeking to download the same YouTube video at the same time), amongst other reasons.



Application Plane

This is the plane where usually most of the users interact with the Internet. It includes the most popular HTTP protocol for transmitting information as part of the World Wide Web, but it also includes important services like Domain Name System (DNS) and email. Many people do get surprised to think of the DNS as an application.

The Internet could operate without the DNS service, but it would make our lives miserable.

With many applications there are separate governance and standard bodies involved, for example World Wide Web Consortium (W3C) and Moving Picture Expert Group (MPEG)

Internet Standards

Internet Standards

The Internet is built on technical standards, which allow devices, services, and applications to be interoperable across a wide and dispersed network of networks. The use of openly developed, openly accessible standards and protocols is fundamental to the successful growth of the Internet

Without open standards there is no open Internet. Internet standards and protocols provide the means by which the Internet's vast network of networks is woven together, enabling end-to-end connectivity.

Additionally, open standards, such as those developed by the Internet Engineering Taskforce (IETF), are freely available encouraging innovation and promoting interoperability.

Internet Standards Development

Important as TCP/IP is, there is much more to the technical development of the Internet. Underpinning the Internet's continuity and stability are decades of open standards and protocol development.

There are a number of organizations involved in developing standards for the Internet, the foremost of which is the IETF. The IETF operates as a large, open, international community of network designers, operators, vendor experts, researchers, and other interested technologists, under the organizational umbrella of the Internet Society. It is the principal body engaged in developing new Internet standard specifications.

The Internet Architecture Board (IAB), chartered both as a committee of the IETF and as an advisory body to ISOC, is responsible for architectural oversight of IETF activities, Internet Standards Process oversight and appeal, and the appointment of the RFC Editor. The IAB is also responsible for managing the IETF protocol parameter registries.

The IETF's mission is to

> *make the Internet work better by producing high quality, relevant technical documents that influence the way people design, use, and manage the Internet.*[6]

The IETF's 100 or so (volunteer-run) working groups operate largely online, coming together in person at the IETF meetings (occurring three times a year at different locations around the globe).

The Internet Research Task Force (IRTF) is affiliated with the IETF via the IAB. It is chartered to conduct long-term research being done on the Internet protocols, applications, and architecture. The IRTF's mission is to promote research of importance to the evolution of the future Internet by creating focused, long-term, and small Research Groups working on topics related to Internet protocols, applications, architecture, and technology.

Internet Standards Development

The Internet also relies on several other types of technical standards, developed by a range of other organizations.

For example, the Internet makes extensive use of the:

- telecommunications infrastructure standards developed by the International Telecommunications Union (ITU);
- hardware standards developed by bodies such as the Institute of Electrical and Electronics Engineers Standards Association (IEEE-SA); and
- software standards, such as those developed by the World Wide Web Consortium (W3C), discussed later in this module.

A Building Block Approach to Standardization

The value of this building block approach is seen in the range and depth of innovation and development in Internet technologies and services.

New components – whether networks, services, or software – work seamlessly with existing deployments, as long as all pieces correctly implement applicable standards on the network. This 'future proofing' approach makes the field of possible innovations virtually limitless.

Apart from the focus on protocols for interoperability, **successful Internet standards share certain characteristics:**[7]

Freely Accessible Specifications	All relevant written specifications required to implement the standard are available without fee or requirement of other contractual agreement (such as a non-disclosure agreement).
Unencumbered	It is possible to implement and deploy technology based on the standard without undue licensing fees or restrictions.
Open Development	In order to maximize the likelihood of standards being relevant, it is critical that all parties working with impacted technologies are able to participate in and learn from the history of the development of an Internet standard.
Always Evolving	As the Internet itself continues to evolve, new needs for interoperability are identified, so the standards that support it must evolve to address identified technical requirements.

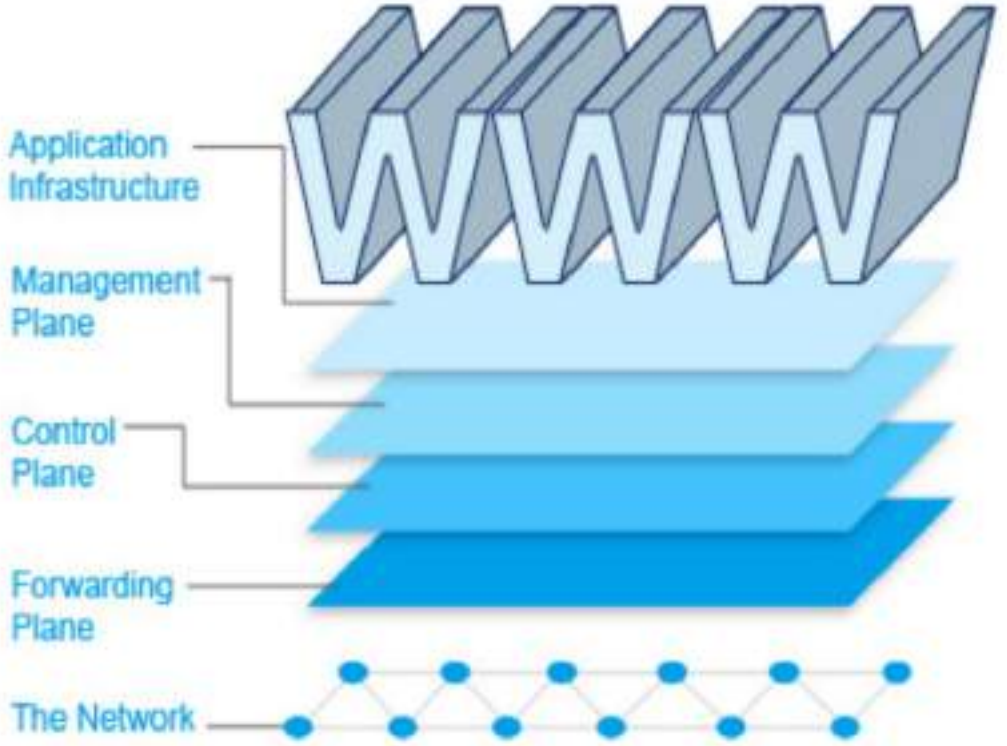
Web Standards

Before looking at Web standards it is important to understand the difference between the Internet and the World Wide Web.

The World Wide Web is a way of accessing information over the medium of the Internet. It is an information-sharing model that is built on top of the Internet.

The Web uses the HTTP protocol, only one of the languages spoken over the Internet, to transmit data. Web services, which use HTTP requests and responses to allow applications to communicate, use the Web to share information.

The Web also utilizes browsers, such as Chrome or Firefox, to access Web documents called Web pages that are linked to each other via hyperlinks. Web documents also contain graphics, sounds, text, and video.



The Web is just one of the ways that information can be disseminated over the Internet. The Internet, not the Web, is also used for e-mail (which relies on SMTP), Usenet news groups, instant messaging, and FTP. The Web is just a portion of the Internet, albeit a large one, but the two terms are not synonymous and should not be confused.[8]

Web Standards

HyperText Markup Language (HTML) was developed by **Tim Berners-Lee** and his colleagues at CERN in Geneva as a means for structuring information so it could be shared more easily over the Internet.

Through providing the means to directly link to documents, images, and other media types, HTML created a user-friendly way of managing and accessing information over the Internet.

Since its first version, the HTML standard has been constantly upgraded with new features, to allow for managing databases, video, and animation.

HTML (and XHTML and XML) standardization work is carried out within the framework of the **World Wide Web Consortium (W3C)**, which could be considered the 'IETF' for the Web.

Internet Society

Founded in 1992 by pioneers of the early Internet, the Internet Society drives technologies that keep it open and safe. We promote policies that empower people to enable universal access for all.

We stand for a better Internet.

Our Story

We are a global movement that champions an open Internet for all. This is an Internet that offers hope, brings opportunity and celebrates humanity.

With a growing community of chapters and members, we continue to support Internet-led innovation, promote the use of best practice technologies, and encourage the adoption of policies that enable an open Internet for all.

IETF

The Internet Engineering Task Force (IETF) is the premiere Internet standards organization.

The mission of the IETF is to make the Internet work better by producing high quality, relevant technical documents that influence the way people design, use, and manage the Internet.

The Internet Society is the organizational home of the IETF.

Global Presence

Our global community of members and Chapters span over 230 countries, territories, and areas of geographic interest world-wide.

Chapters Play a Key Role

Chapters address unique local and regional perspectives on emerging Internet issues.

Internet Society Chapters form a community that advances our mission to:

- Engage members through a common global vision
- Offer technical workshops and training
- Provide educational and networking events
- Inform policy and decision makers

Our Partners

The Internet Society cannot achieve its goals alone.

Because the Internet impacts all of us, we work with partners of all shapes and sizes to address the wide range of social, economic, and policy issues. Our partners include:

- International bodies and assemblies
- Local non-governmental organizations
- Technical experts and engineers
- University and academic institutions
- Local and global businesses
- Rural or urban students and teachers

Get involved.

There are many ways to support the Internet. Find out today how you can make an impact.

Quai de l'île 13
CH-1204 Geneva
Switzerland

11710 Plaza America Drive
Suite 400
Reston, VA 20190, USA

Rambla Republica de Mexico 6125
11000 Montevideo,
Uruguay

66 Centrepoint Drive
Nepean, Ontario, K2G 6J5
Canada

Sin El Fil, Dekwaneh Highway
Aramex Building, 2nd Floor
Beirut, Lebanon

Science Park 400
1098 XH Amsterdam
Netherlands

internetsociety.org
@internetsociety

9 Temasek Boulevard
#09-01 Suntec Tower Two
Singapore 038989