Internet Structure: Networks of Networks

Computer Networks Notes

Overview

Key Idea

The Internet is a massive **network of networks**. Hosts connect via **Access ISPs**, which in turn must interconnect so that **any two hosts anywhere can communicate**.

- The resulting network is extremely complex.
- Evolution is driven by **economic incentives**, **competition**, and **national policies**.

Scaling Challenge

Problem: Connecting Millions of ISPs

- Given millions of access ISPs, how can they all be connected efficiently?
- Direct connections between each pair of ISPs requires $O(N^2)$ links — not scalable.
- Option: connect all access ISPs to a single global transit ISP.
- Economic reality: if one global ISP is profitable, competitors will emerge.

Economic Relationships Between ISPs

Customer–Provider and Peering

- **Customer–Provider:** Small ISPs pay larger ISPs for Internet access.
- **Peering:** ISPs exchange traffic without monetary transactions.
- **Internet Exchange Points (IXPs):** Physical locations where multiple ISPs interconnect.
- **Regional Networks:** Bridge between smaller access ISPs and large providers.

Content Provider Networks

Bringing Content Close to Users

- Large content providers (Google, Microsoft, Facebook, Akamai) often operate **private global networks**.
- Connect their **data centers** directly to the Internet.
- Bypass Tier-1 and regional ISPs to improve performance and reduce costs.
- Enable **CDNs (Content Delivery Networks)** to bring services closer to users.

Internet Core: Tier-1 and Content Networks

Well-Connected Large Networks

- **Tier-1 ISPs:** Level 3, Sprint, AT&T, NTT — provide global connectivity.
- **Content Provider Networks:** Google, Facebook operate private networks connecting data centers directly.
- Small number of large networks form the **highly connected core** of the Internet.

Detailed Internet Structure Diagram

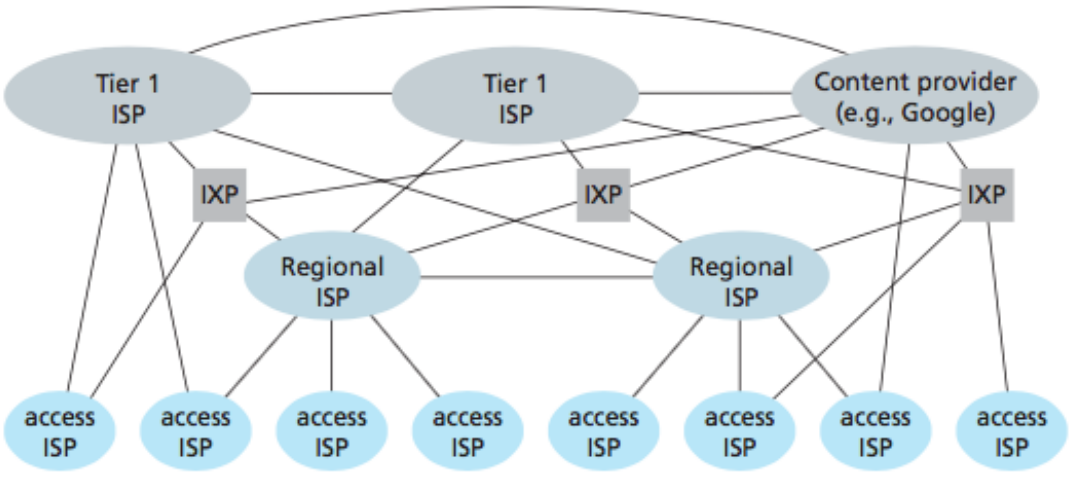

Figure 1.15 ♦ Interconnection of ISPs

Figure Explanation

This diagram illustrates the hierarchical structure of the Internet:

- **Tier-1 ISPs:** Provide global connectivity (e.g., Level 3, AT&T).
- **Content Provider Networks:** Google, Facebook, Akamai — run private networks for improved performance.
- **Regional ISPs:** Connect smaller access ISPs to the global Internet.
- **Access ISPs:** Local ISPs connecting end hosts.
- **IXPs / Peering Points:** Facilitate direct traffic exchange between ISPs, reducing transit costs.
- **End Hosts:** Users, servers, and devices connected to the Internet.

Summary

Essence of Internet Structure

- The Internet is a hierarchical, economically-driven **network of networks**.
- Access ISPs connect end-users, and multiple layers of ISPs interconnect globally.
- IXPs and regional networks facilitate efficient routing and traffic exchange.
- Content provider networks optimize delivery by connecting directly to key parts of the Internet.
- The highly connected **core** ensures global reachability.