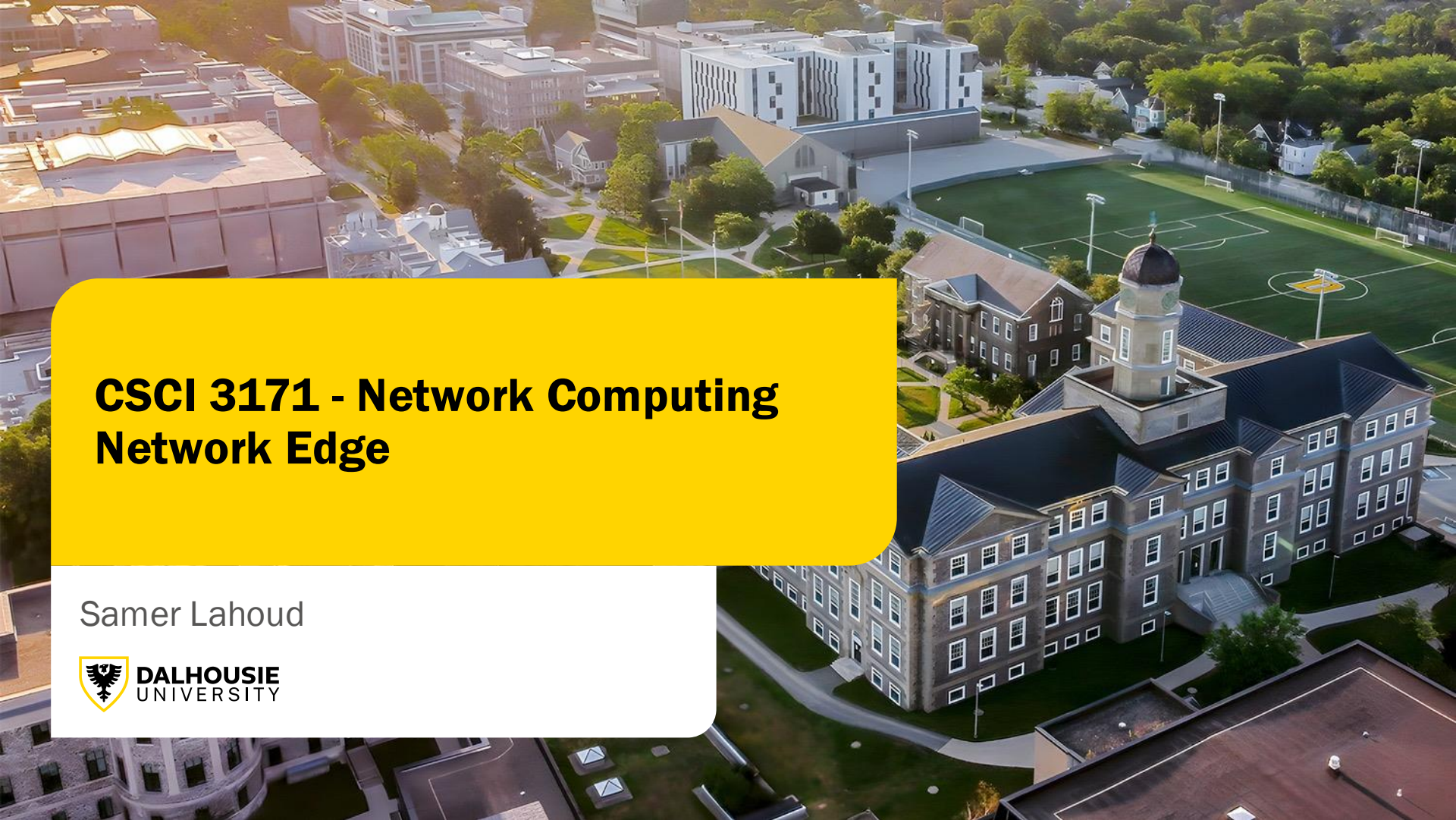
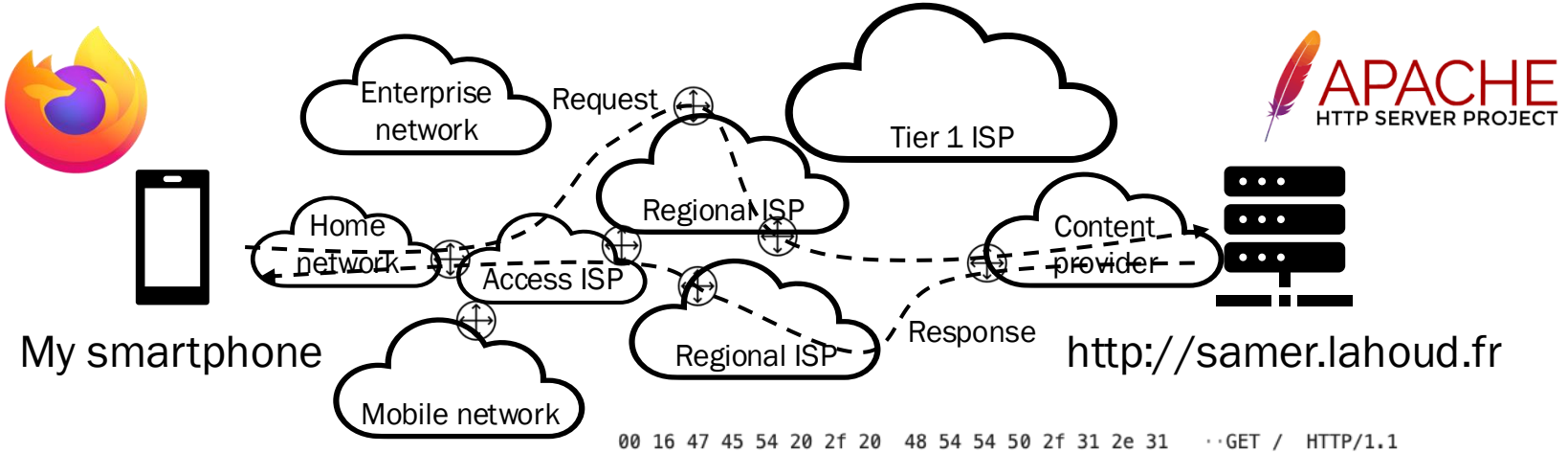


CSCI 3171 - Network Computing
Network Edge

Samer Lahoud

DALHOUSIE UNIVERSITY

Recap: Structure of the Internet



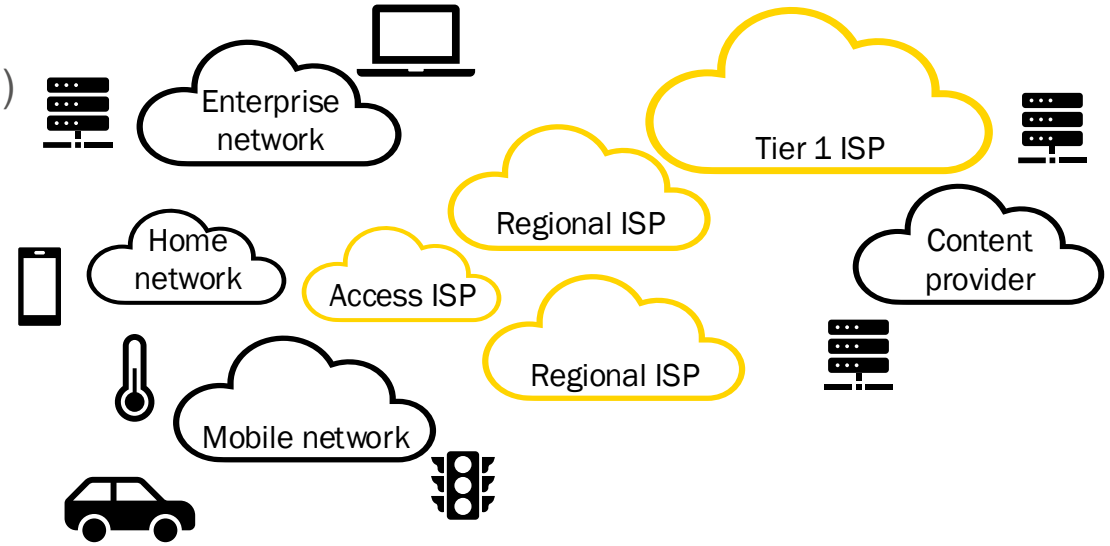
- Devices, services, applications, protocols, packet switches, networks, links

Goal and Roadmap

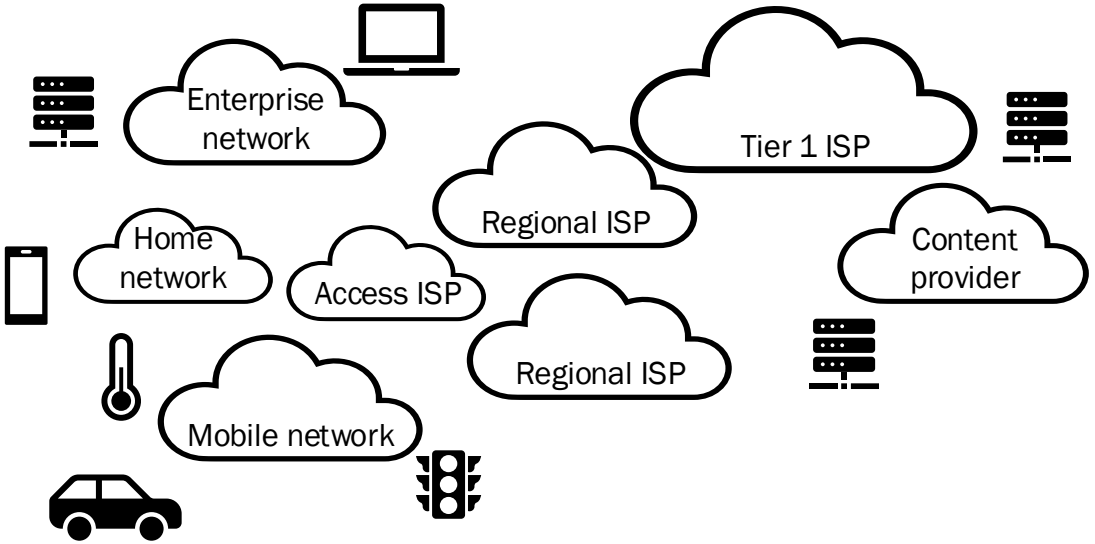
- Goal:
  - *Big picture* of the Internet
  - Introduction to terminology
- Overview and roadmap
  - What is the Internet? What is a protocol?
  - Network edge: hosts, access network, physical media
  - Network core: packet switching
  - Performance: loss, delay, throughput
  - Packet and circuit switching
  - Protocol layers, service models
  - Internet structure and challenges

A Closer Look at the Internet Structure

- Network edge
  - Devices (hosts and servers)
- Network core
  - Interconnected routers
  - Network of networks

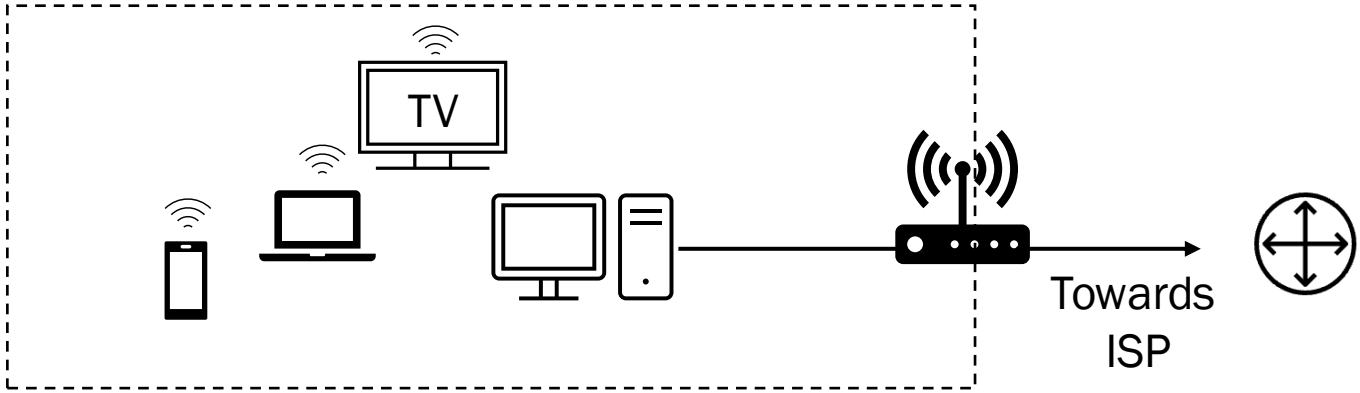


Network Edge



1. How to connect devices inside local networks?
   - Residential, institutional, and public (mobile) networks
2. How to connect local networks to ISPs?

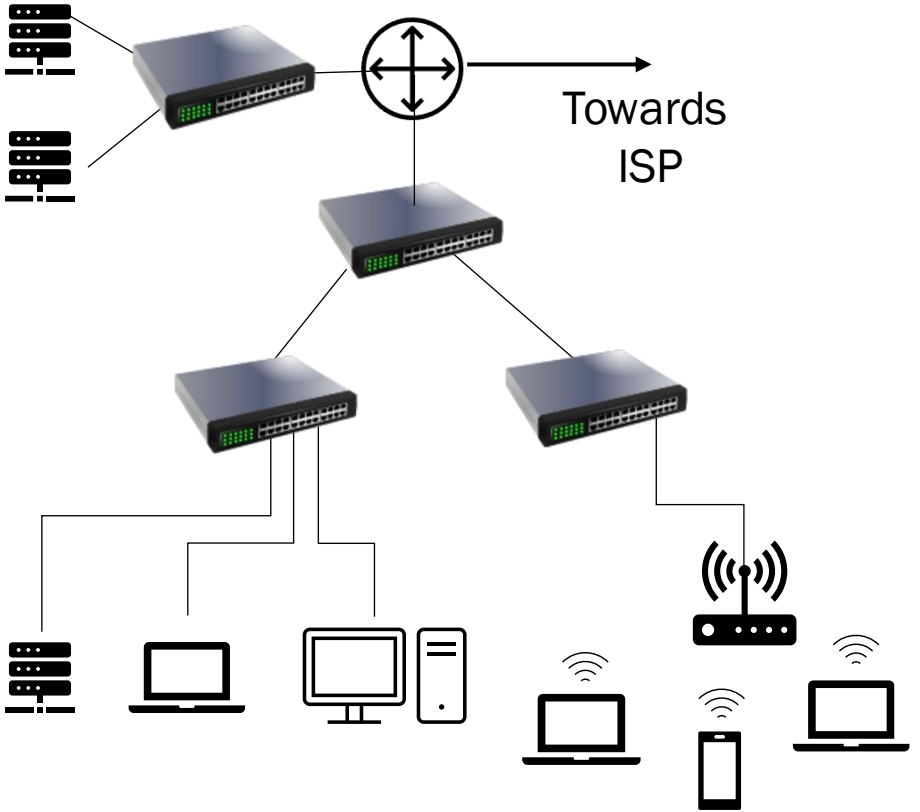
Illustration of a Home Network



- Two dominant technologies
  - WiFi: Shared wireless medium, sensitive to interference and distance
  - Ethernet: Dedicated wired link, full-duplex point-to-point communication

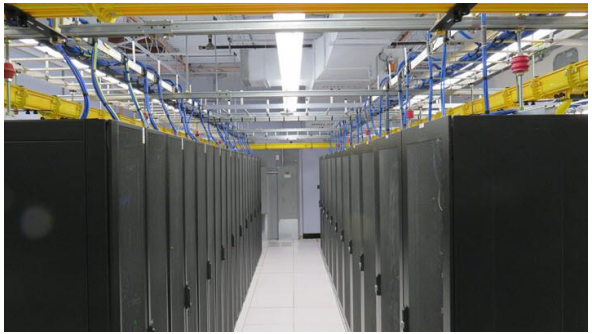
Illustration of an Enterprise Network

- Companies, universities, etc.
- Mix of wired and wireless technologies
  - WiFi and Ethernet
  - Connecting a mix of switches and routers



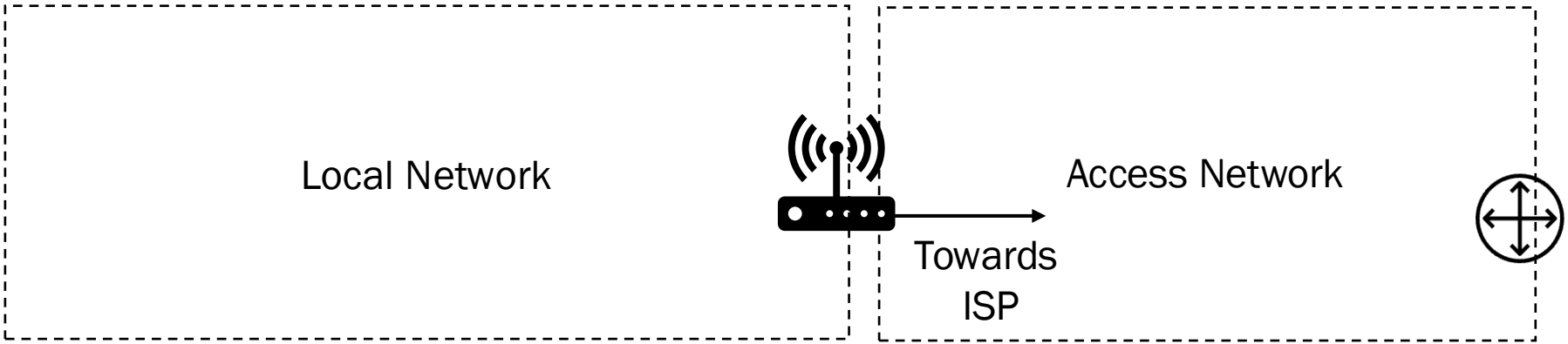
Data Center Networks

- High-bandwidth links (100 Gbps) connect hundreds to thousands of servers together, and to Internet



Eastlink datacenter in Halifax

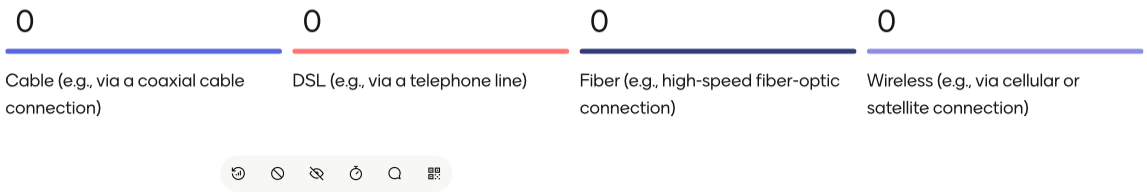
From Local Networks to Access Networks



- Why local network technologies cannot be used in access networks?

Join at menti.com | use code 5991 6227

Mentimeter



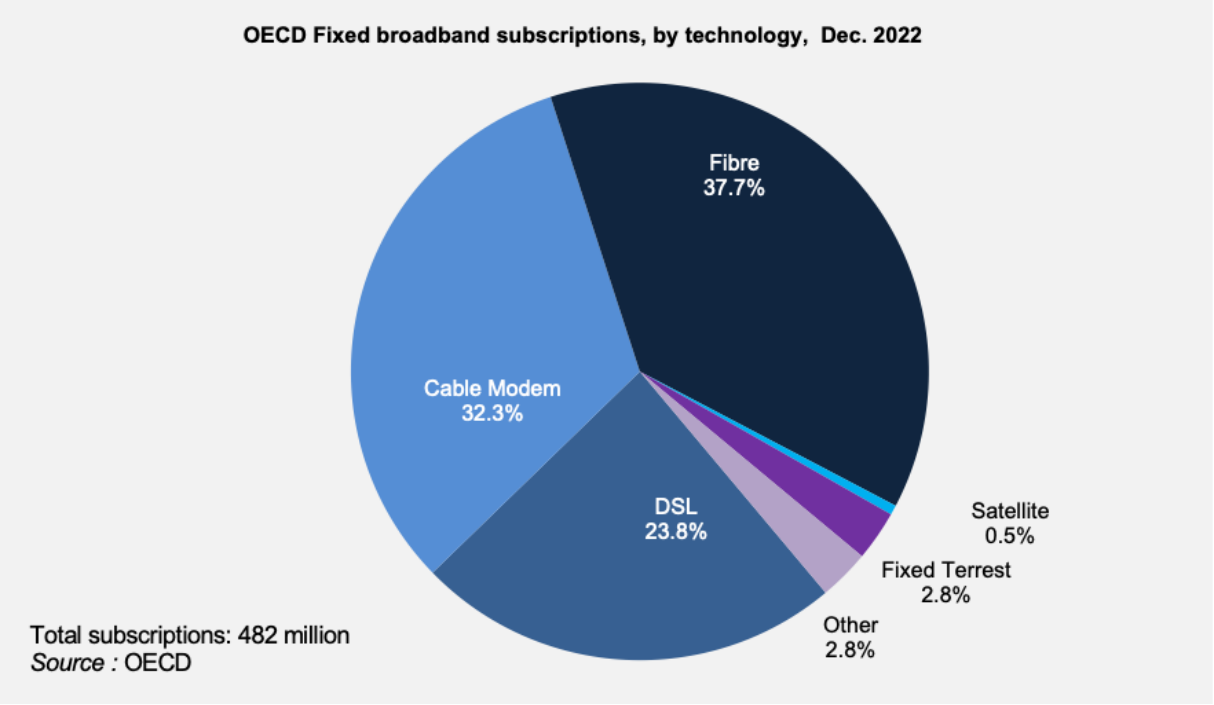
Overview of Access Network Technologies

Technology	Physical Medium	Peak Rates (DL / UL)	Coverage & Distance	Key Advantages	Main Limitations	Typical Scenarios
Cable (DOCSIS 3.1)	Hybrid fibre-coaxial	up to 10 Gbps / 1–2 Gbps	Shared coax segment in neighbourhood (few km)	Reuses legacy TV plant; high downstream capacity	Bandwidth contended among neighbours; modest upstream	Urban and suburban residential broadband
DSL (ADSL / VDSL2)	Twisted-pair copper	up to 24 Mbps / 1 Mbps (ADSL) ; up to 300 Mbps / 100 Mbps (VDSL2, ≤1 km)	Strong distance dependence along copper loop	Ubiquitous copper; low installation cost	Rapid performance decay with loop length; asymmetric	Legacy consumer service; small offices reusing copper
FTTx (FTTH/FTTB /FTTC)	Optical fibre	1–2 Gbps symmetric today; scalable to multi-10 Gbps	Tens of kilometres between OLT and premises	Symmetric high throughput; future-proof capacity; immune to EMI	Highest civil-works cost; deployment complexity in dense or historic areas	Greenfield builds; business districts; premium tiers
Fixed Wireless Access	Licensed or lightly-licensed radio (e.g., 3.5 GHz)	~50 Mbps–1 Gbps (link-budget dependent)	Up to several km line-of-sight; foliage and weather sensitive	Rapid roll-out; cost-effective for low density	Variable throughput; spectrum licensing required	Rural and peri-urban last-mile broadband
Satellite (GEO/MEO/ LEO)	Radio link to spacecraft	GEO ≤ 50 Mbps; LEO ≤ 500 Mbps	Global; no terrestrial last-mile	Universal reach; quick activation	GEO latency > 550 ms; expensive terminals; weather fade in Ku/Ka	Remote communities, maritime, disaster recovery

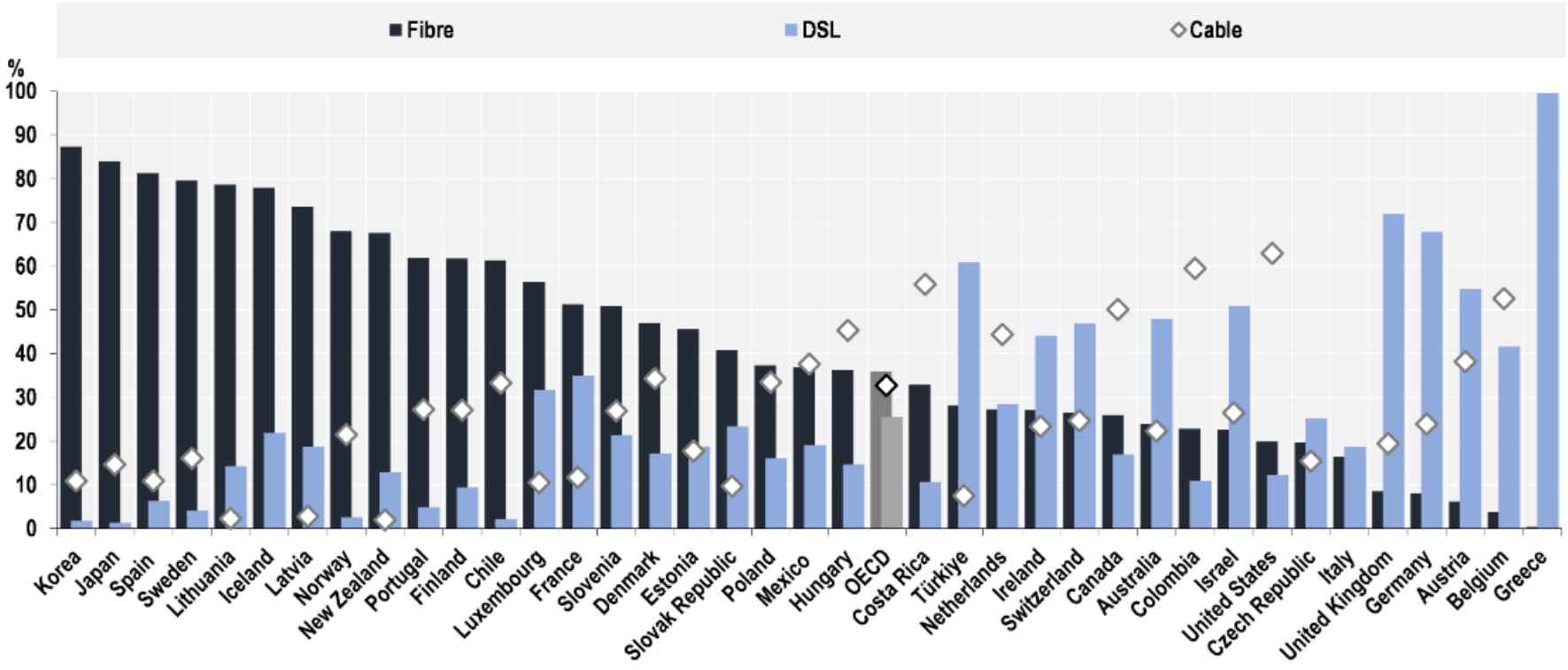
Key takeaways

- Spectrum versus Medium Trade-offs
  - Copper pairs (DSL) and coax (Cable) exploit legacy plant but inherit bandwidth or distance constraints.
  - Fibre provides high capacity but demands the highest capital expenditure.
  - Wireless solutions (FWA, Satellite) minimise civil works and reach otherwise inaccessible (e.g., Canada's rural and northern regions) areas, at the cost of variable link quality and spectrum fees.
- Asymmetry and Contention
  - Cable and ADSL allocate far more downstream than upstream capacity to match typical consumer traffic patterns, whereas fibre and many FWA deployments offer symmetric service tiers.
  - Cable's shared coax segment induces neighbourhood-level contention, which can be the primary bottleneck at peak hours.
- Latency and Quality of Experience
  - GEO satellite links incur round-trip delays > 550 ms, limiting real-time applications.
  - LEO constellations and terrestrial fibre achieve sub-40 ms round trips, approaching those of wired access networks.

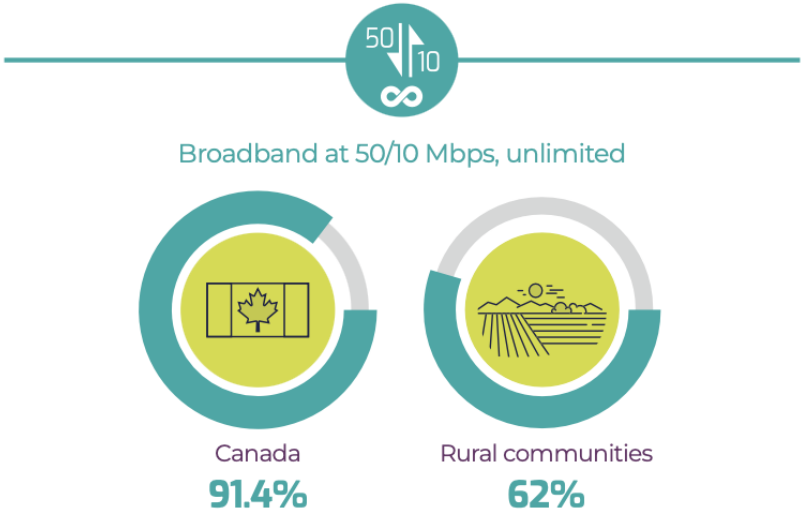
Access Networks in OECD Countries



Access Networks in OECD Countries

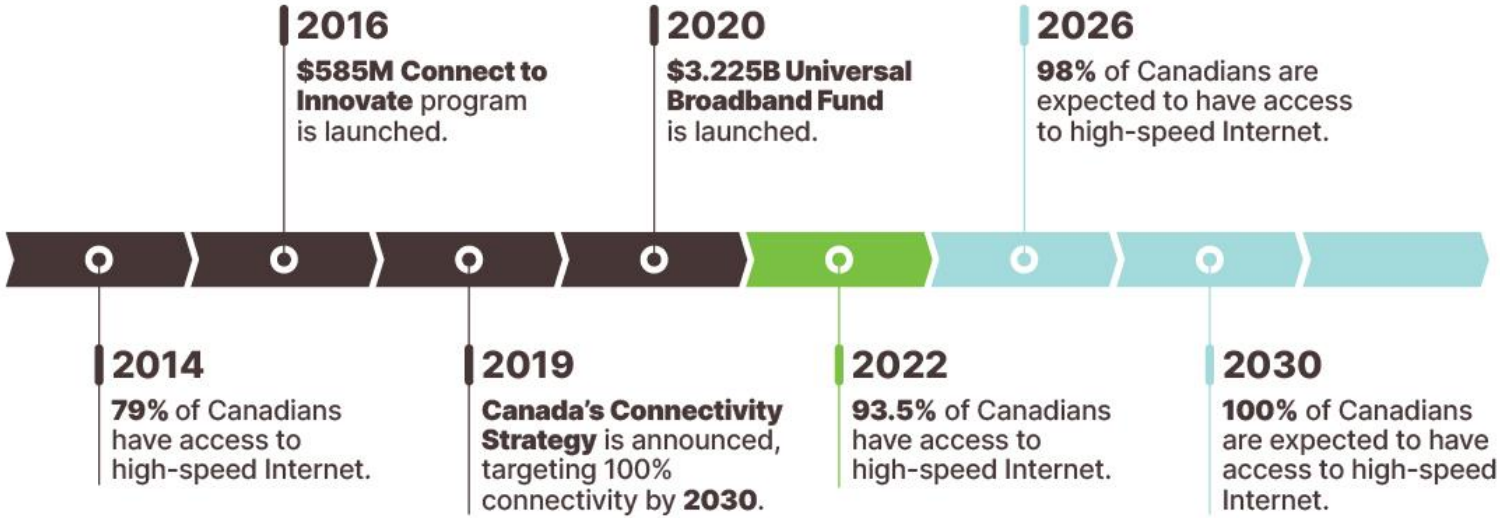


Broadband Access in Canada



- Broadband = high speed
- Map available at https://crtc.gc.ca/cartovista/internetcanada-en/

Deployment Timeline



Regulation in the Access Network

- Canadian Radio-television and Telecommunications Commission (CRTC)
  - Regulates wholesale rates
  - Ensures that all Internet data is treated fairly (*Net neutrality*)
  - Promotes competition in the Internet market (regulates how smaller ISPs are billed)
  - Works to close the digital divide
- CRTC sets targets for internet services
  - Speeds of 50 Mbps download/10 Mbps upload for fixed broadband services
  - An unlimited data option for fixed broadband services
  - The latest mobile wireless technology available (homes, businesses, and roads)
- Example of CRTC decision in November 23:
  - Large telephone companies are required to provide competitors with access to their fibre-to-the-home networks within six months

What is Net Neutrality?

- Network neutrality is the principle that ISPs must treat all Internet communications equally, offering users and online content providers consistent transfer rates regardless of content, website, platform, application, type of equipment, source address, destination address, or method of communication, without price discrimination
- Net neutrality rules prevent ISPs from controlling how users access the internet, prohibiting tactics such as throttling internet speeds, blocking legal websites, or charging more for access to certain ones

Are these Practices Allowed under Net Neutrality?

- Blocking access to a lawful application or website
  - Example: An ISP blocks access to a competing video platform.
- Application-specific throttling
  - Example: Video streaming traffic is slowed down only for YouTube but not for other services.
- Paid prioritization for specific content providers
  - Example: A content provider pays an ISP to be placed in a fast lane over the same access link.

Are these Practices Allowed under Net Neutrality?

- Reasonable congestion management applied equally to all traffic
  - Example: All flows are rate-limited during peak hours, regardless of application.
- Security-based blocking
  - Example: Blocking malware, botnets, or denial-of-service traffic at the access router.
- User-controlled traffic shaping
  - Example: A user configures their home router to prioritize gaming traffic.

Are these Practices Allowed under Net Neutrality?

- Zero-rating of specific applications
  - Example: Mobile data for a messaging app does not count toward the data cap.
- Prioritization of emergency or public safety traffic
  - Example: Emergency calls receive higher priority during network congestion.
- Network slicing in 5G access networks
  - Example: A slice with guaranteed latency is offered to industrial customers.
- Edge caching and CDN preference
  - Example: Traffic served from an ISP-owned CDN performs better than external content.

Wrap Up

- Scarcity exists at the access network, not the core.
- Many mechanisms operate below the application layer.
- Intent matters: congestion management versus market distortion.
- Technology evolves faster than regulation.
- Is net neutrality fundamentally
  - (A) a policy problem
  - (B) a technical design problem
  - (C) both?”

Net Neutrality Debate

- Arguments in Favor
  - Protects open innovation and fair access
  - Prevents ISPs from acting as gatekeepers or favoring their own content
  - Preserves user choice and democratic access to information
- Arguments Against
  - Limits ISP flexibility in managing congestion
  - May discourage investment in network infrastructure
  - Opens debate about whether all traffic (e.g., emergency services vs. streaming) should be treated equally

Recent Developments Related to Net Neutrality

- Europe, 2020: European Commission asked Netflix and Disney+ to lower video quality to reduce Internet congestion, not enforced by regulation but a negotiated compromise
- USA 2015: FCC imposed net neutrality by classifying ISPs as common carriers – repealed in 2017 allowing paid prioritization and zero-rating – reinstated in 2024 – overturned in 2025
- Canada: CRTC enforces net neutrality and has intervened against ISPs offering preferential data pricing to their own services