



Last Mile Technologies and Policy Issues

CYBR 4400 / 5400: Principles of Internet Policy, Lecture 2-3

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Today's Lecture

- ❖ Current events
 - ❖ Crypto-Gram Newsletter
 - ❖ SpaceX Starlink
- ❖ New paper assignment
- ❖ Last Mile Technologies Lecture

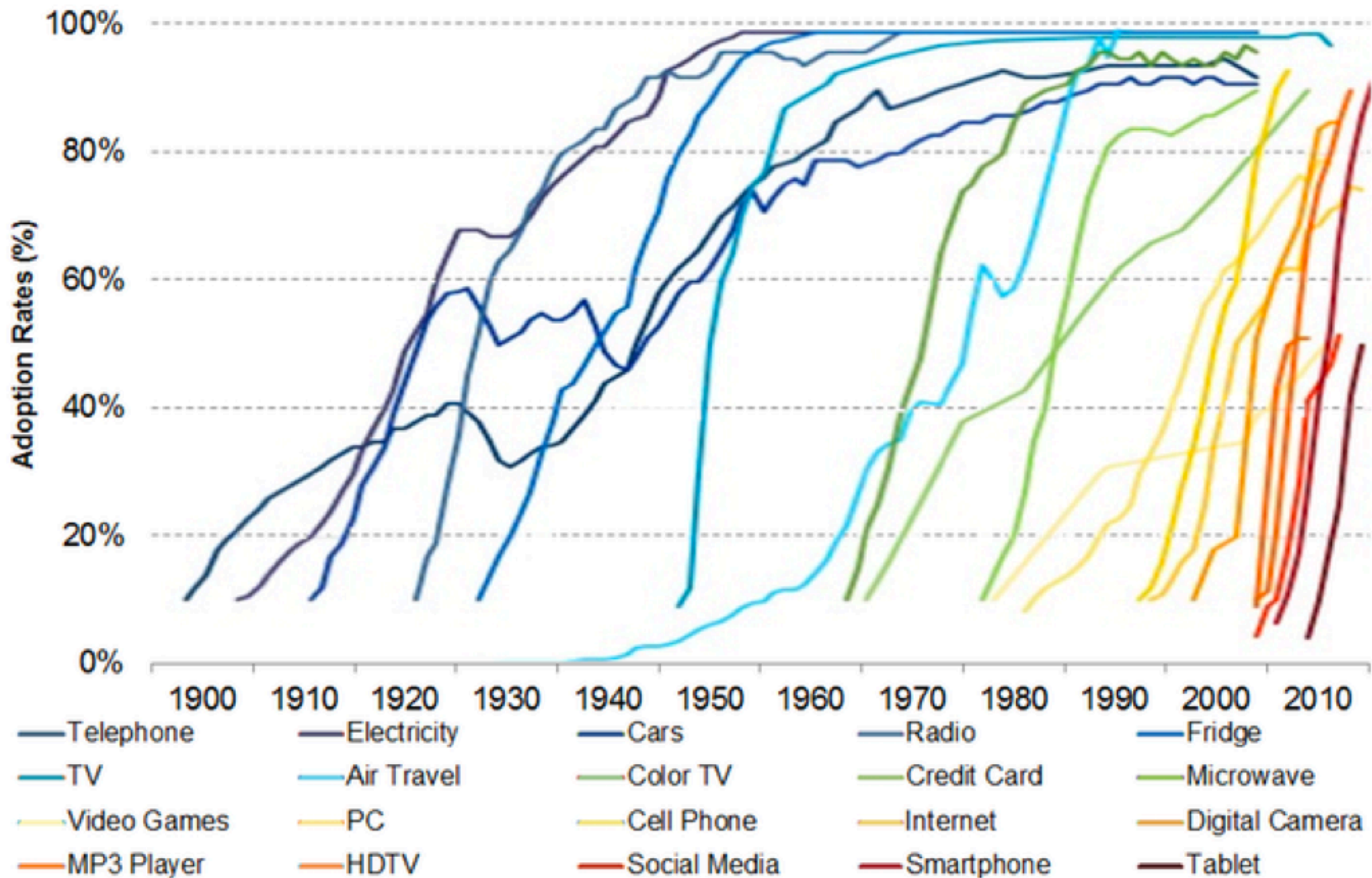
New Project Assignment

- ❖ Write short description of your project
- ❖ Project topic paragraph or abstract (in your own words)
 - ❖ Important objective is to consider scope of your paper proposal
 - ❖ What is your research question?
- ❖ Project plan (schedule) and methodology
- ❖ Due Friday, February 7 at 11:59 pm

Primer on Broadband Network Technologies

- ❖ Wireline Options: FTTH, DSL, and HFC
- ❖ Wireless Options: Fixed, Wi-Fi, and LTE
- ❖ Comparative Advantages and Weaknesses

Adoption of Technology in the US (1900 to the Present)



Market Realist[®]

Source: BlackRock

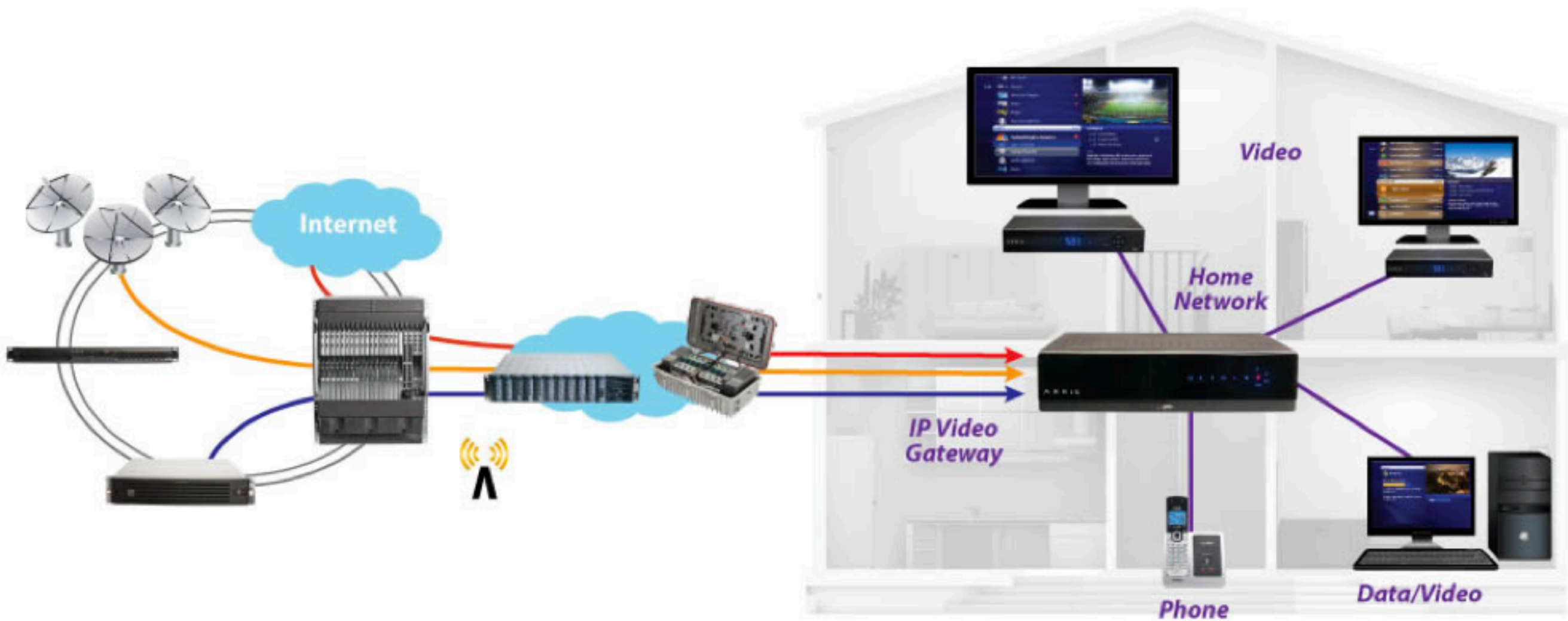
Source: FCC, 2018 Broadband Deployment Report

Broadband System

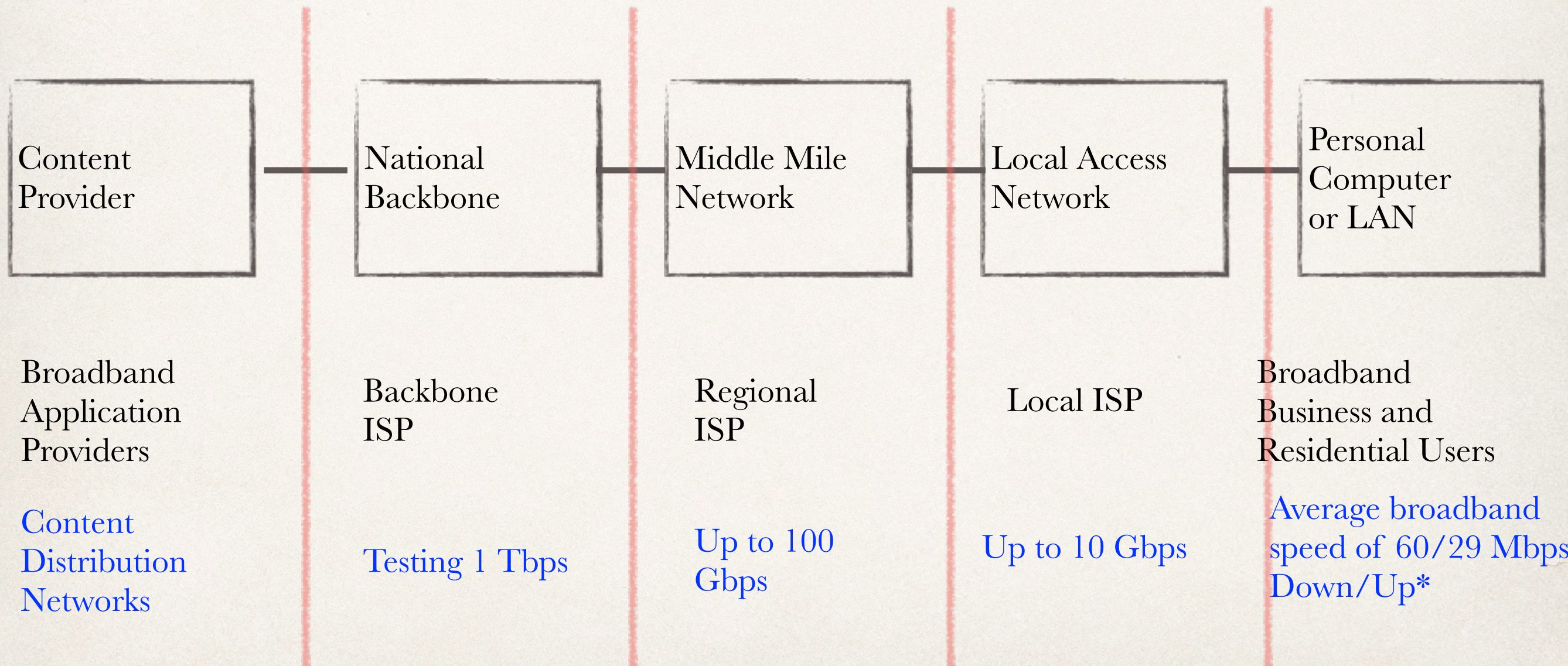
Service Creation

Service Delivery

User Experience



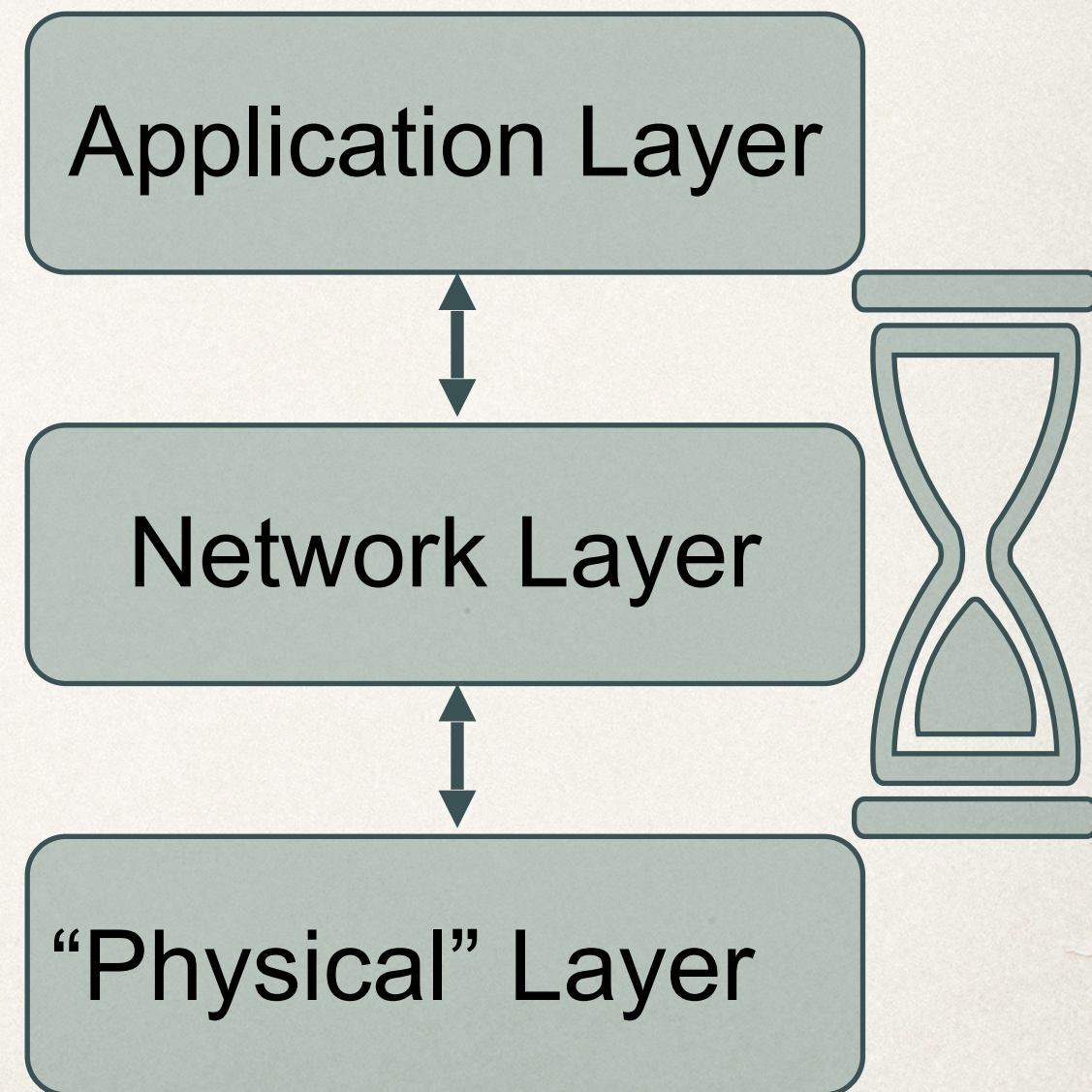
Engineer's View of Broadband Service Delivery



*Global average speed from [ookla speed tester](https://www.speedtest.net/), June 2019

Simplified View of Internet Layers

- ❖ Modularity – mutually independent functional layers
- ❖ Firms compete independently at each layer without having to enter market for services at other layers
- ❖ Openness – nobody owns core protocols
- ❖ Reality: “Hourglass” innovation



Local Access Network Options

- ❖ Telephone Network: Digital Subscriber Line (xDSL) or Fiber-to-the-Home
- ❖ Cable Network: Hybrid Fiber-Coax (HFC)
- ❖ Wireless Network: Wireless Internet Service Provider (WISP) or Long Term Evolution (LTE)

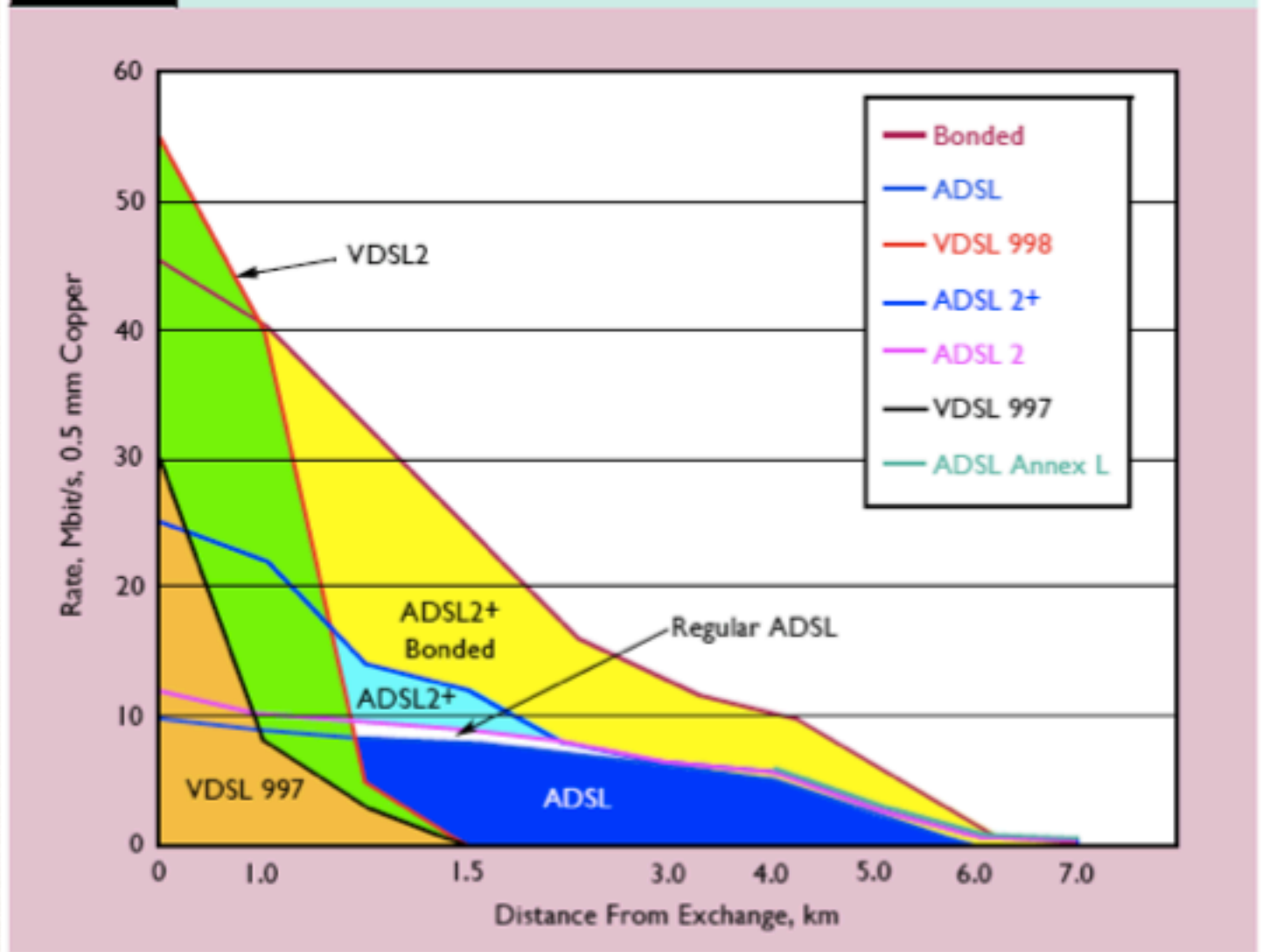
Varieties of xDSL over Telco

- ❖ An alphabet soup of alternatives can be used over the telephone network
 - ❖ ADSL / ADSL2 / ADSL2+ / HDSL / VDSL / VDSL2...
- ❖ Bottom line that you need to know:
 - ❖ Options differ in speed, transmission length, upstream capacity, generation / capability of technology

xDSL Speed vs. Distance

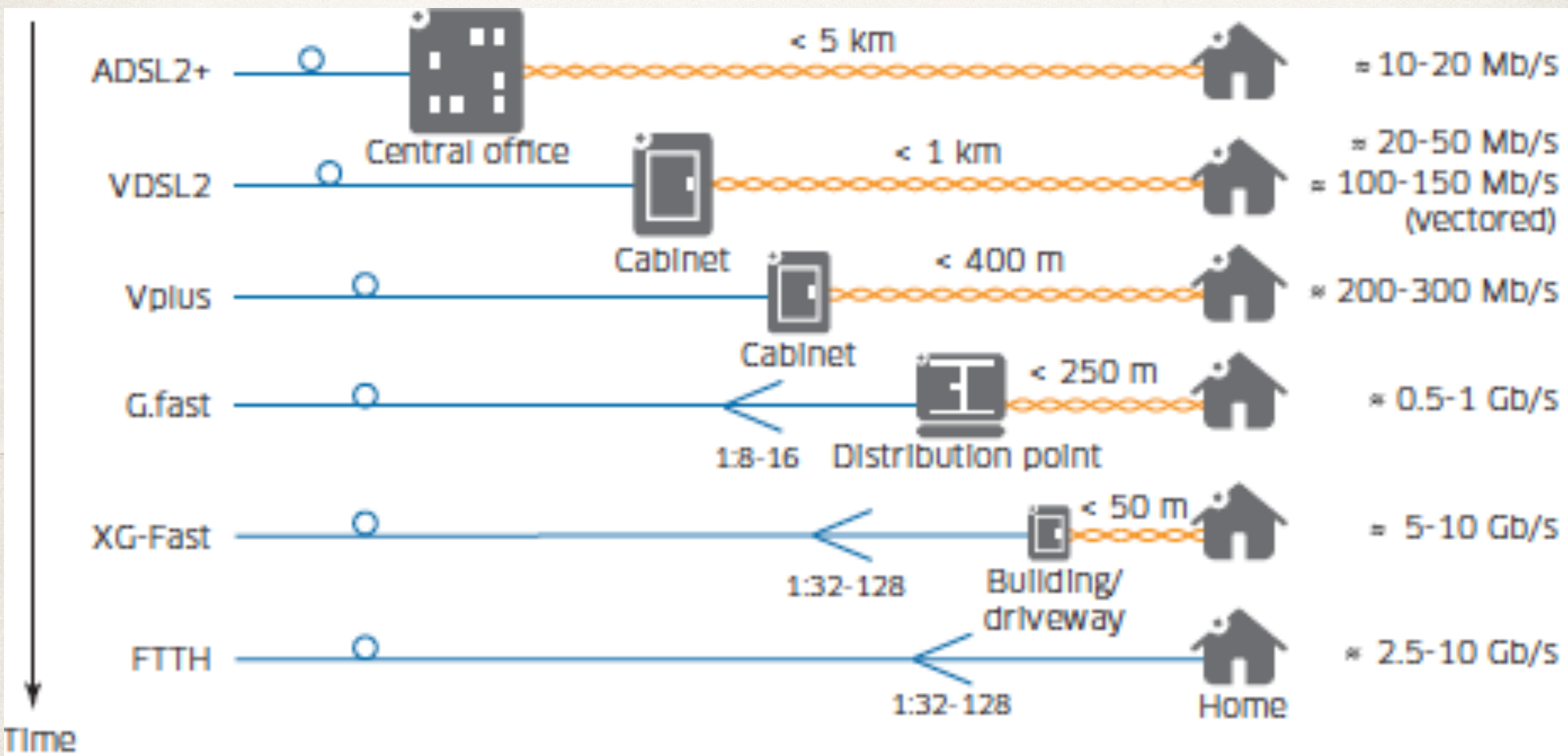
- ❖ Faster integrated chips increasing speed
- ❖ Fiber moving closer to customer
- ❖ Bonding uses more copper pairs per home if available

Figure 3 Relationship between reach and speed



Source: Marshall, "IPTV Thrives on a Fiber Rich Diet," *The Journal of The Comm. Network*, 6,1, January–March, 2007

DSL Network Evolution



DSL Tradeoffs

- ❖ Advantages

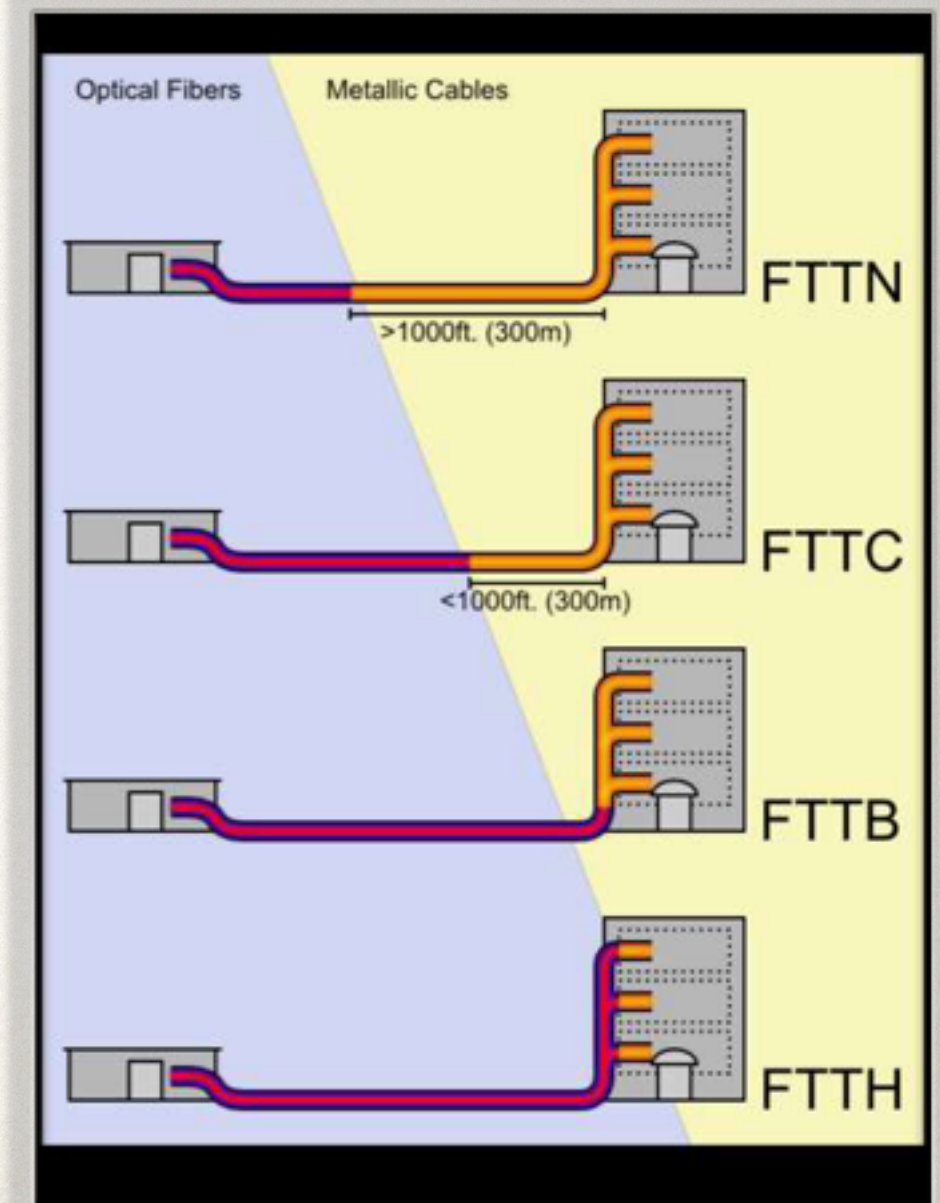
- ❖ Low cost when telephone network is present

- ❖ Disadvantages

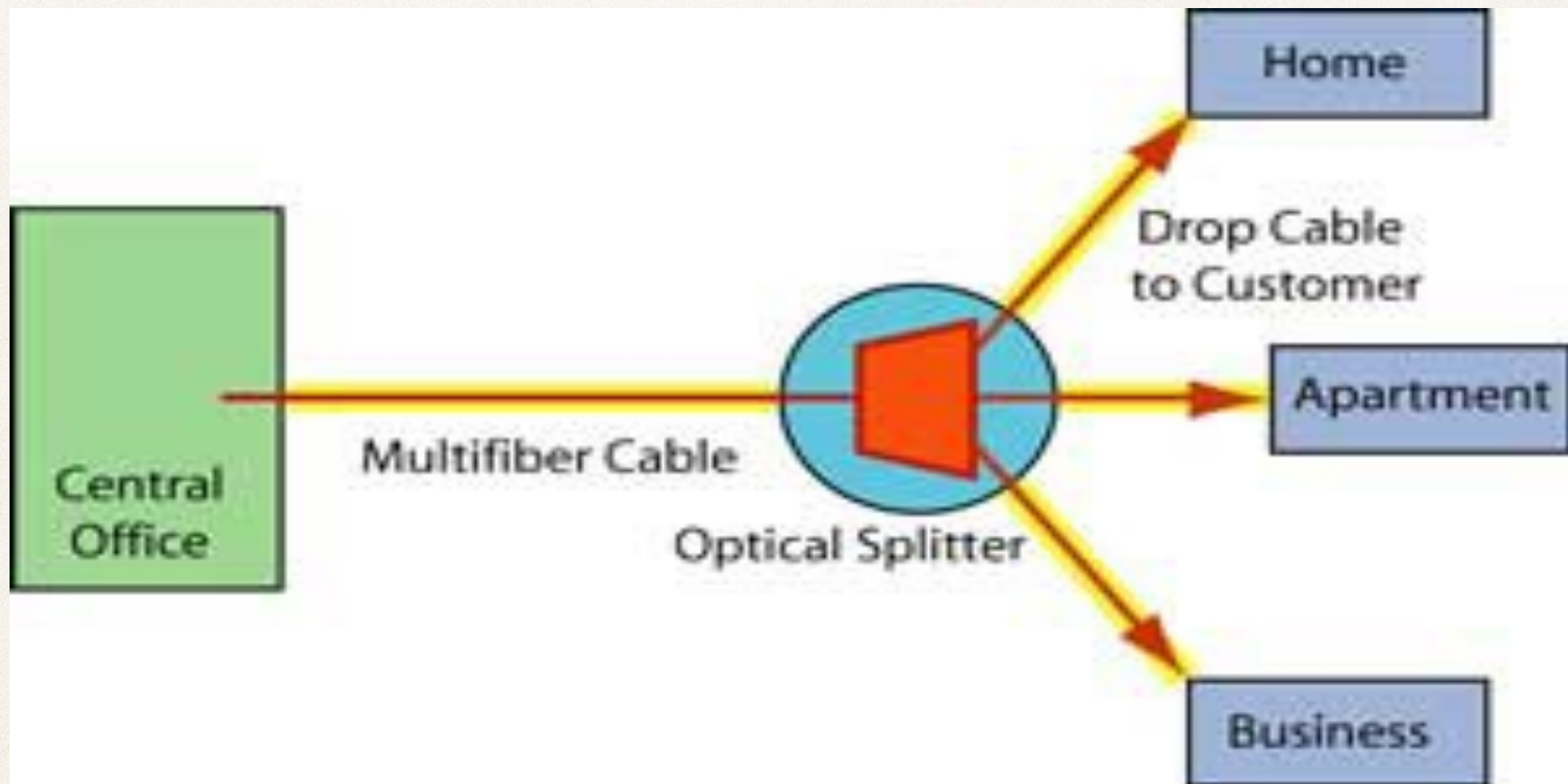
- ❖ Delivers relatively low broadband speeds unless fiber is extended very close (200 m.) to customer
 - ❖ Speeds delivered are not consistent for every customer

FTTX — Fiber to the...

- ❖ Fiber-to-the Neighborhood (FTTN)
- ❖ Fiber-to-the Curb (FTTC)
- ❖ Fiber-to-the Building (FTTB)
- ❖ Fiber-to-the Home (FTTH)



Typical PON deployment



One fiber “split” to serve typically 32 homes. PON splitters are bidirectional so signals can be sent both ways (to the home and back to central office)

Fiber-Optic Networking Technology

- Gigabit Passive Optic Network (G-PON) is the lowest cost and most broadly deployed FTTP access technology
- Four standardized options

PON Technology	Downstream	Upstream
G-PON (Gigabit)	2.4 Gbps	1.2 Gbps
XG-PON (10 Gigabit)	10 Gbps	2.4 Gbps
XGS-PON (10 Gigabit Symmetric)	10 Gbps	10 Gbps
TWDM-PON (Time Wavelength Division Multiplexing)	4x10 Gbps	4x10 Gbps

G-PON Wavelengths

- ❖ G-PON uses single, fixed wavelength in each direction – 3rd wavelength available for analog / digital cable transmission
- ❖ XG-PON uses single, fixed wavelength in each direction
- ❖ XGS-PON ONUs connect to the same port via TDMA (Time Division Multiple Access) upload and TDM download schemes
- ❖ TWDM-PON uses 4 upload and download wavelengths:
Tunable lasers dynamically assign customer wavelength

FTTH Tradeoffs

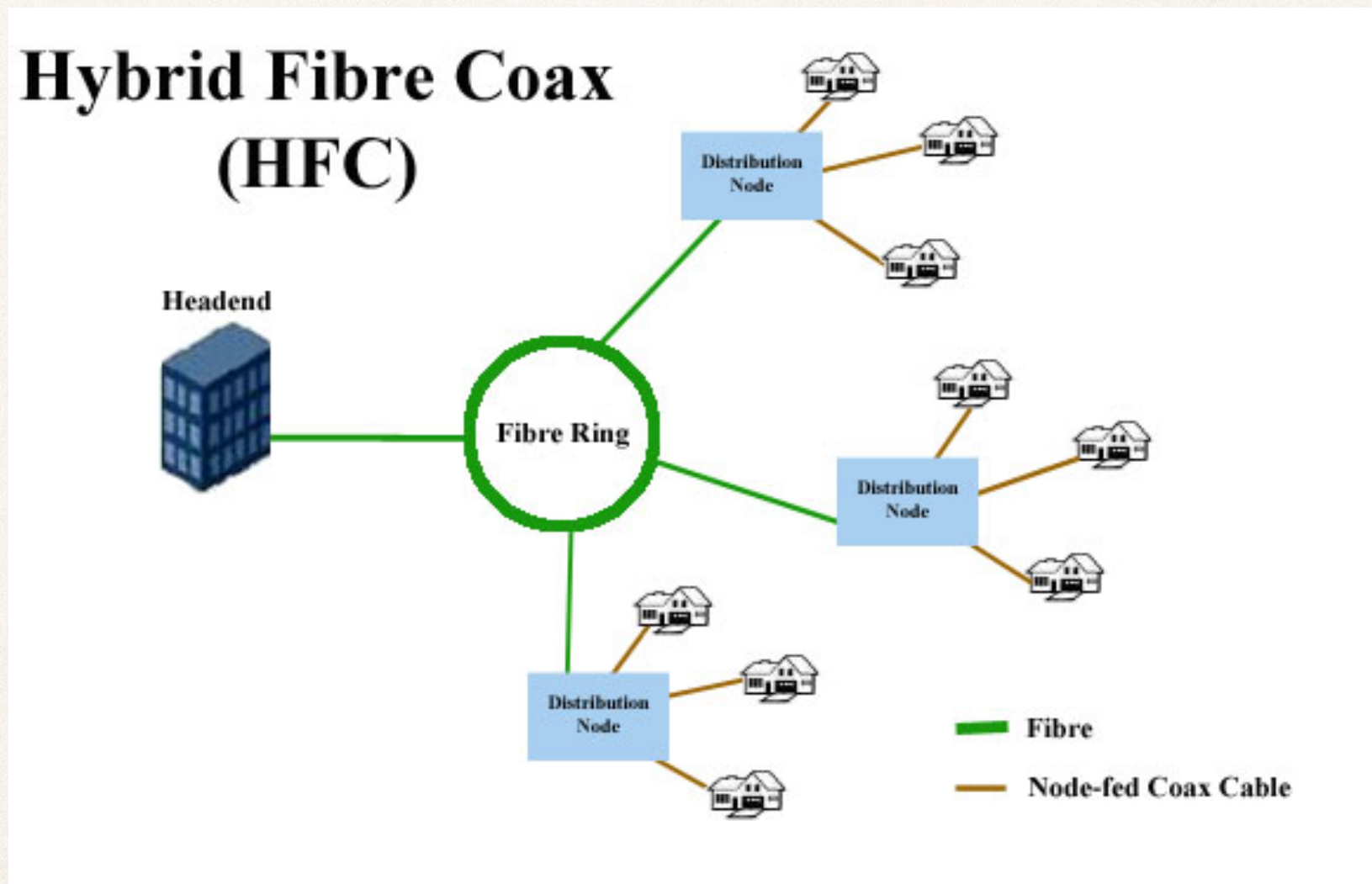
- ❖ Advantages

- ❖ Very high capacity (virtually unlimited bandwidth)
- ❖ Low operations costs (immunity to electrical noise and interference)

- ❖ Disadvantages

- ❖ Very high fixed cost

Cable Network



- ❖ Usually 750 MHz cable system (860 MHz or 1 GHz becoming more common)
- ❖ Old view: 6 MHz of cable spectrum = one “channel” of DOCSIS
- ❖ New view: 192 MHz channels of cable spectrum = max Internet “channel”

Cable Tradeoffs

- ❖ Advantages

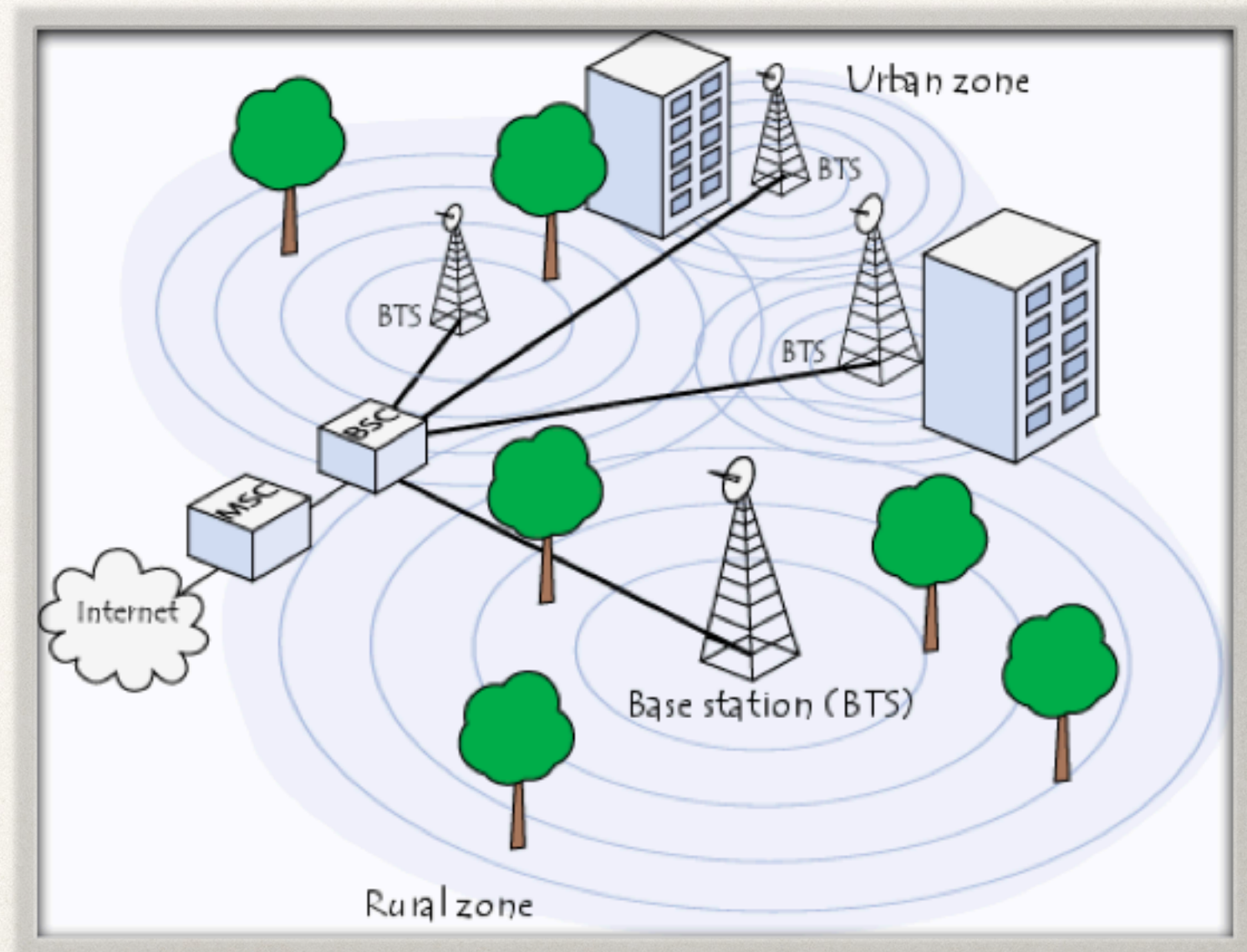
- ❖ Reasonable incremental costs to increase speed
- ❖ Delivers high capacity broadband
- ❖ Consistent service speeds to customers

- ❖ Disadvantages

- Upstream capacity limits

Wireless Network

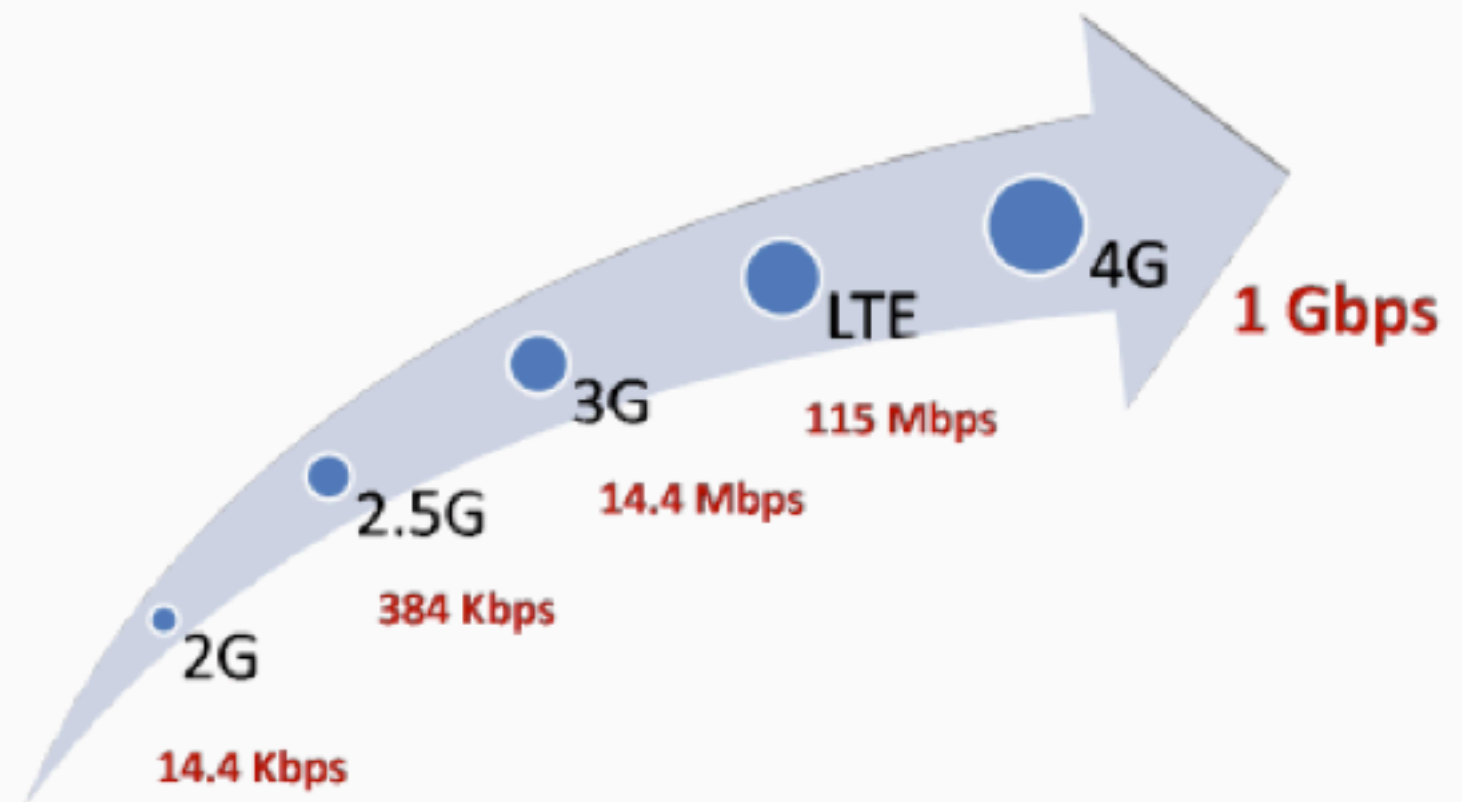
- ❖ Cells cover unique geographical area
- ❖ Designed for capacity vs. coverage limitations
- ❖ Cell splitting to increase capacity
- ❖ 5G upgrades may require dedicated fiber to the tower (FTTT)



Mobile Broadband: Long Term Evolution (LTE)

- ❖ LTE
Advanced =
4G
- ❖ Faster
broadband
speeds
- ❖ “All-IP”
network

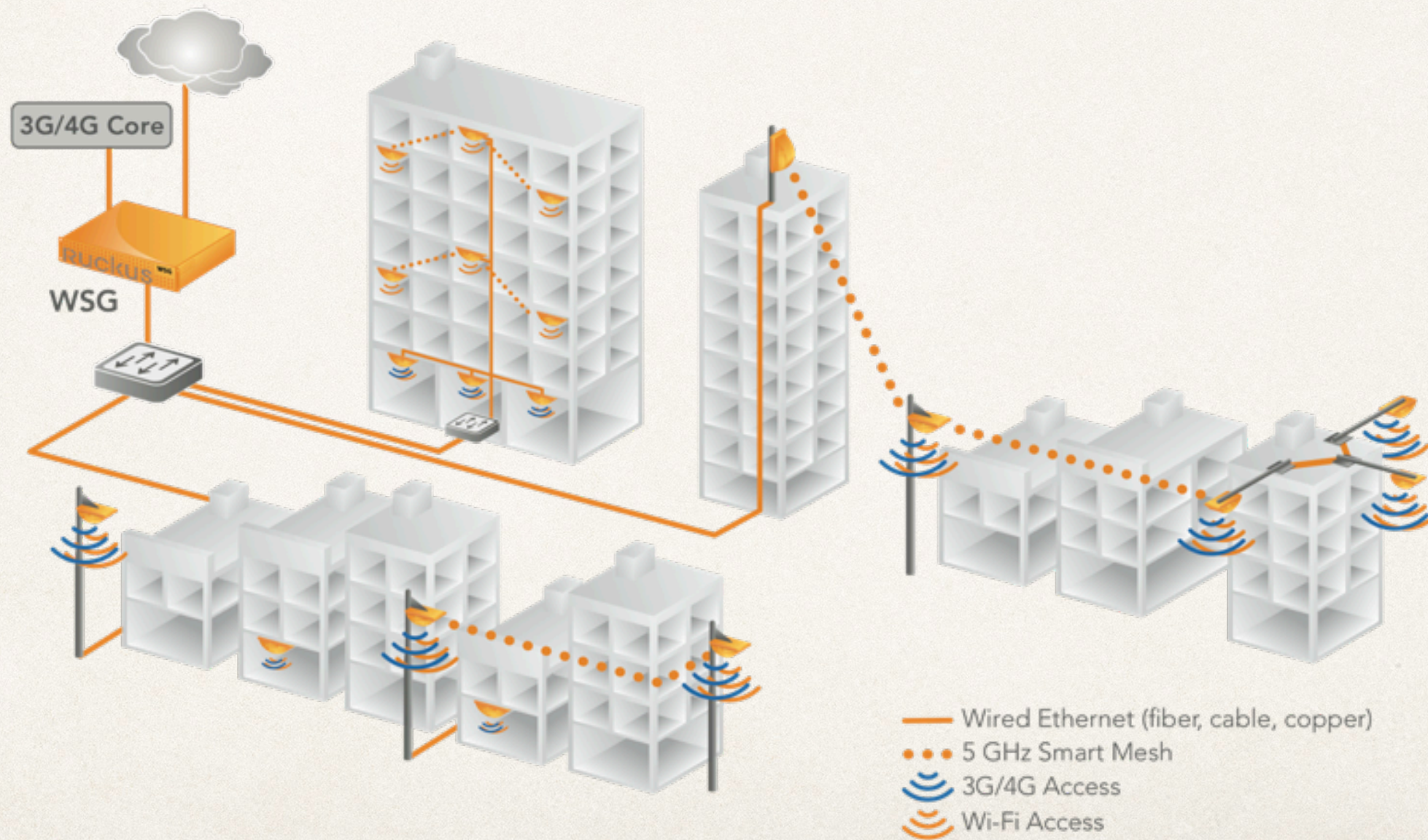
2G – 4G Data download rates



- 2.5G speed is based on the maximum offered by EDGE
- 3G speed is based on the maximum offered by HSDPA

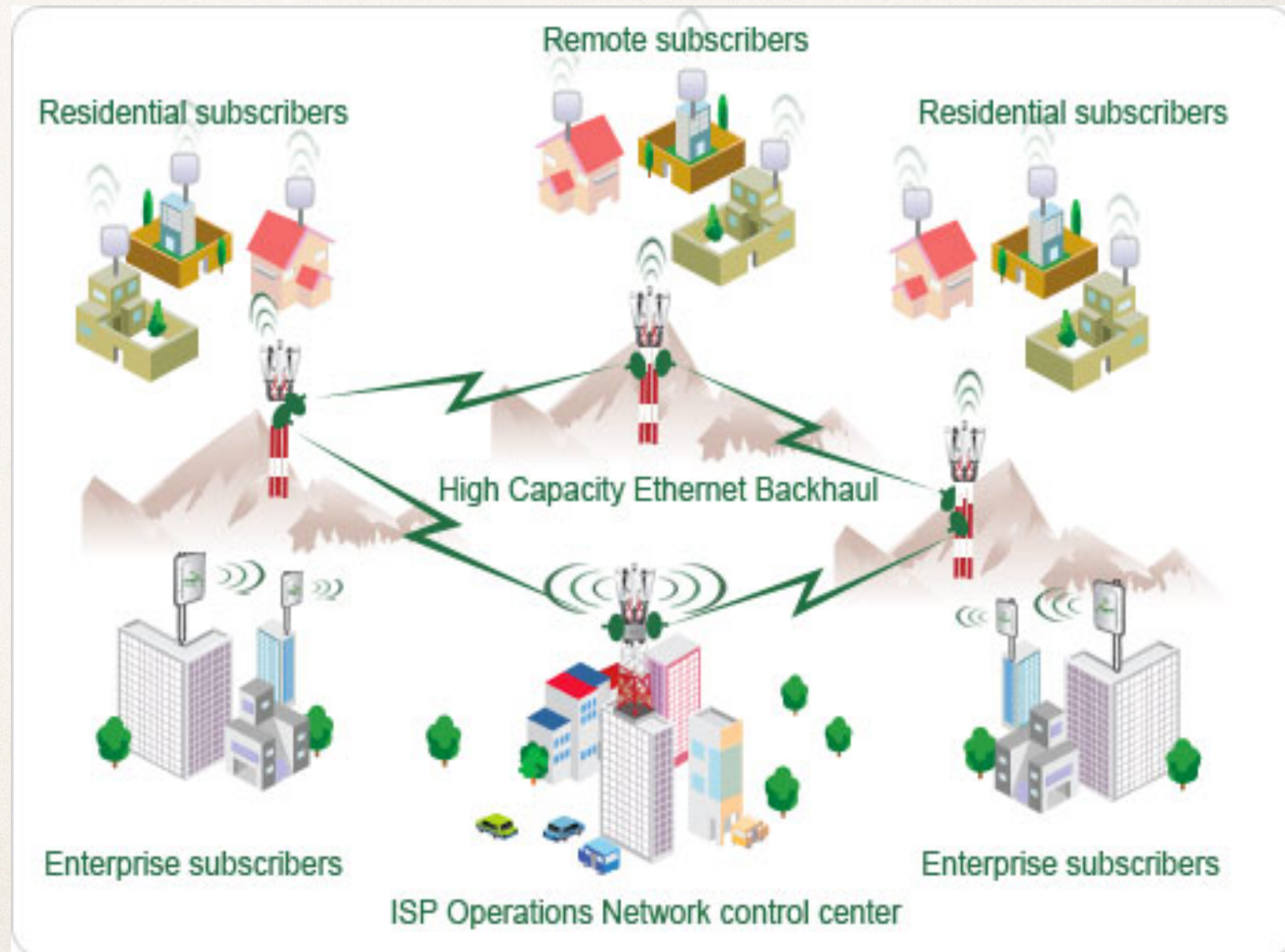
Increasing Wireless Capacity Using Small Cells

FIGURE 7: The Ruckus solution for a Wi-Fi and LTE small cell integrated network supported by Smart Mesh backhaul



WISP Approach

- ❖ Using wireless options with more bandwidth and longer range
- ❖ Usually requires line of sight connectivity for high speed
- ❖ TV White Spaces, WiMax, Microwave...



Wireless Tradeoffs

- ❖ Advantages

- ❖ Low cost in last mile
- ❖ Standards lowering equipment costs

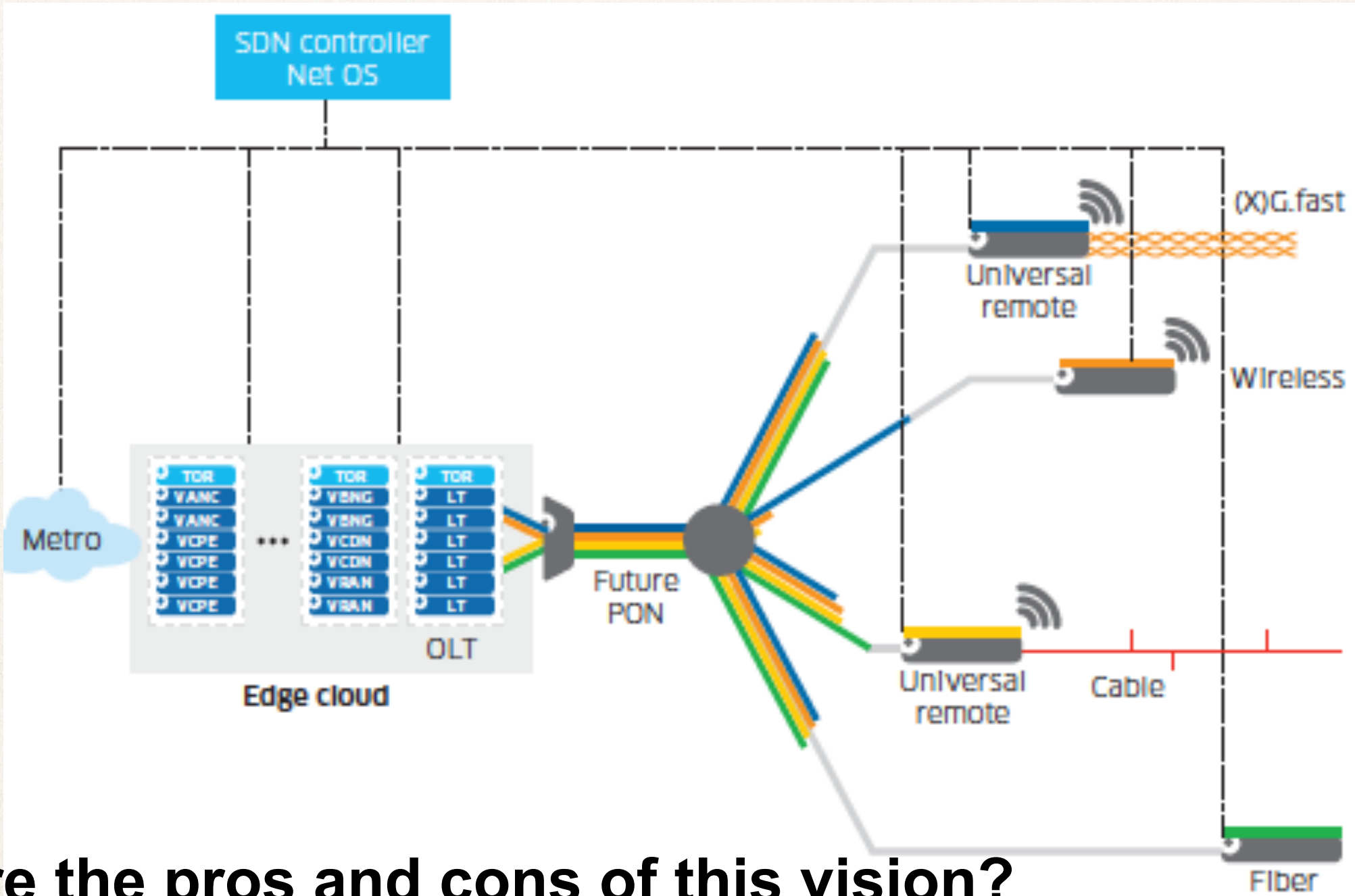
- ❖ Disadvantages

- ❖ Cost and characteristics of spectrum license
- ❖ Speed limitations

General Trends Summary

- ❖ Wireless newer, innovating more rapidly than wireline
- ❖ Wireless increases speed by smaller cells; wireline by building fiber closer to customer
- ❖ Wireline (fiber) intrinsically higher speed than wireless

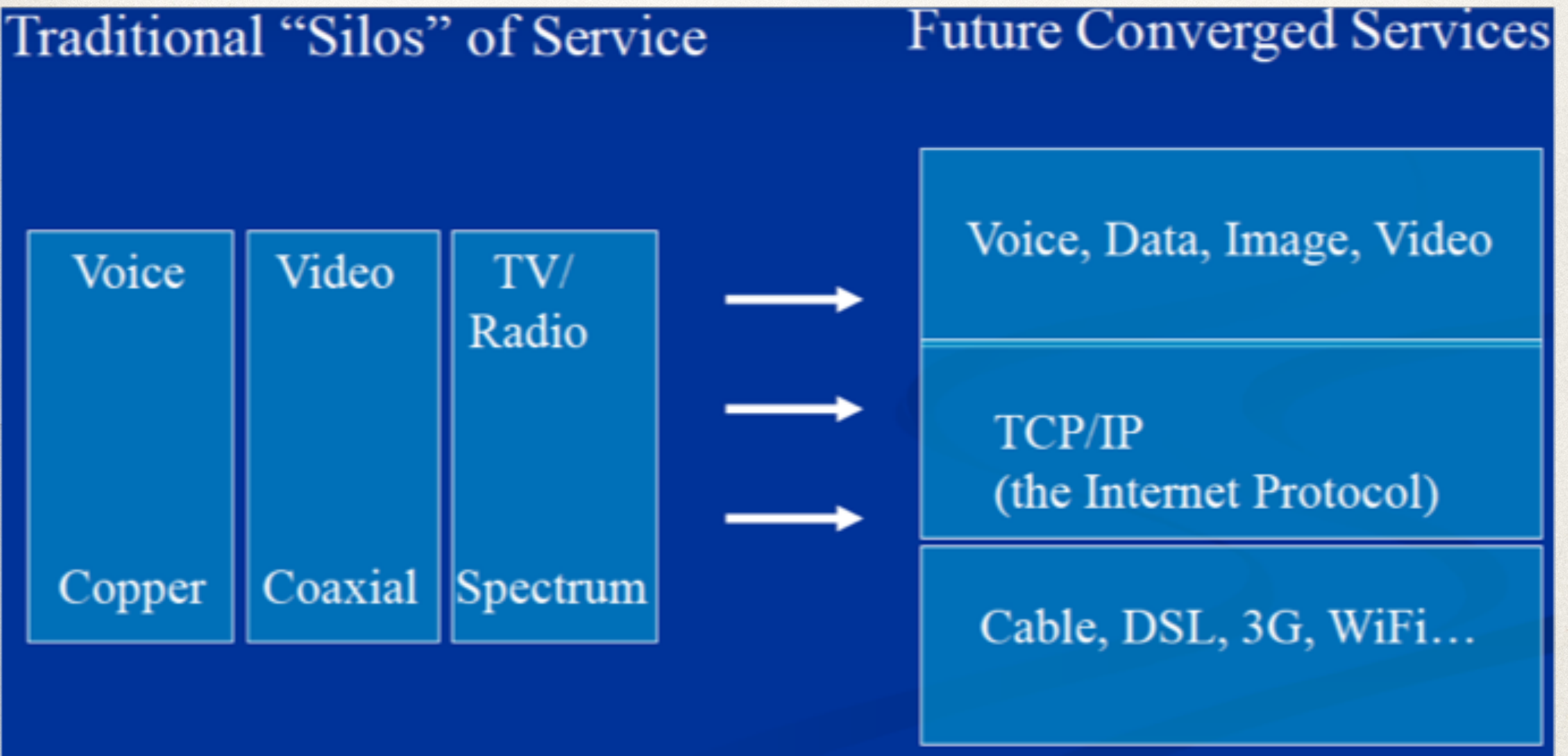
Converged Future?



What are the pros and cons of this vision?

Source: The Future X Network, A Bell Labs Perspective, Chapter 7, 2016

Most Important Technical Trend — IP Wins!



Access Network Policy Issues

- ❖ National Broadband Plans
- ❖ Universal Service
- ❖ Net Neutrality
- ❖ Privacy
- ❖ Cybersecurity