6.978/ESD.68 Competition in Access Networks

Sharon E. Gillett, MIT

The past: Silos

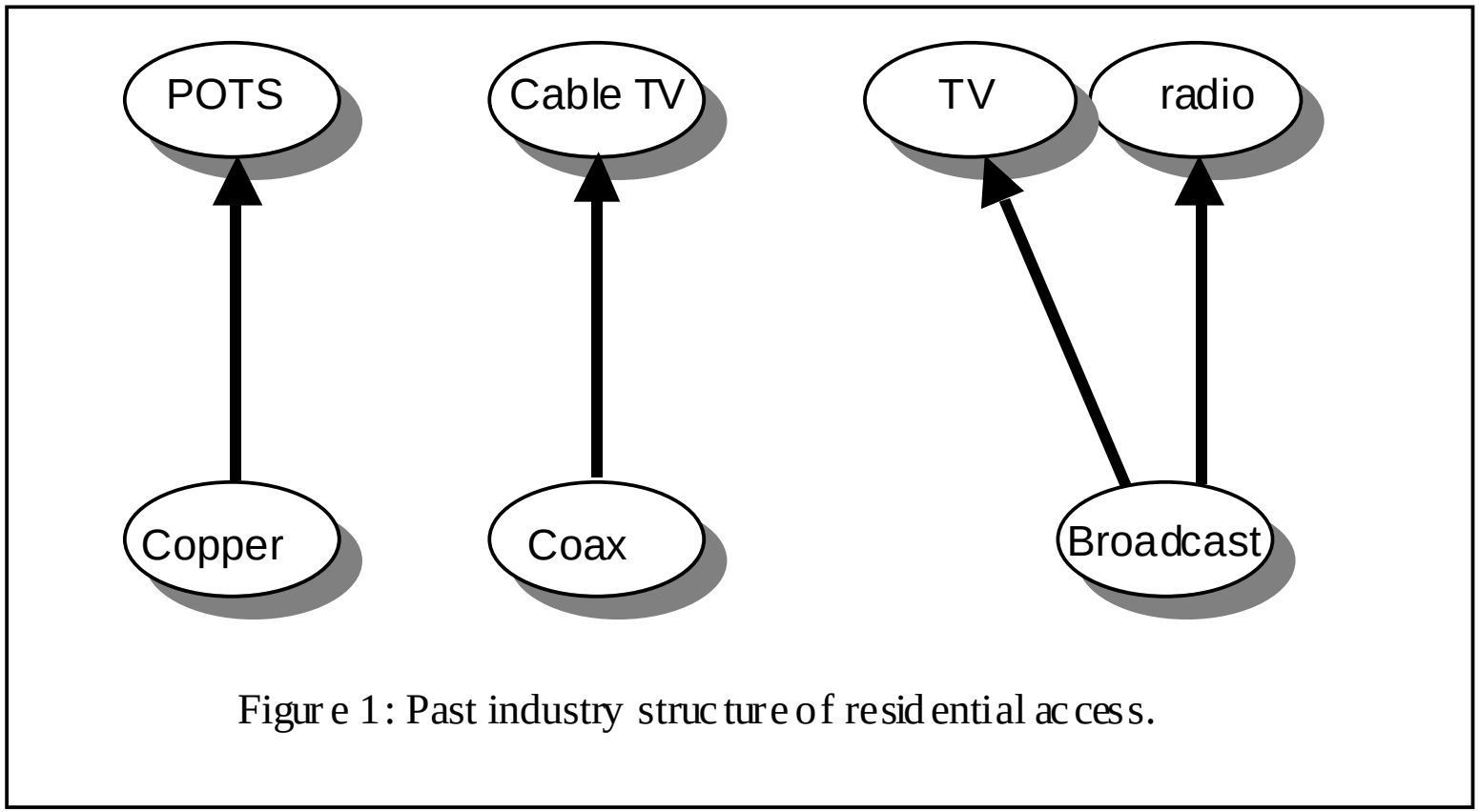


Figure 1: Past industry structure of residential access.

From (Clark, 1999)

The present: "Convergence"

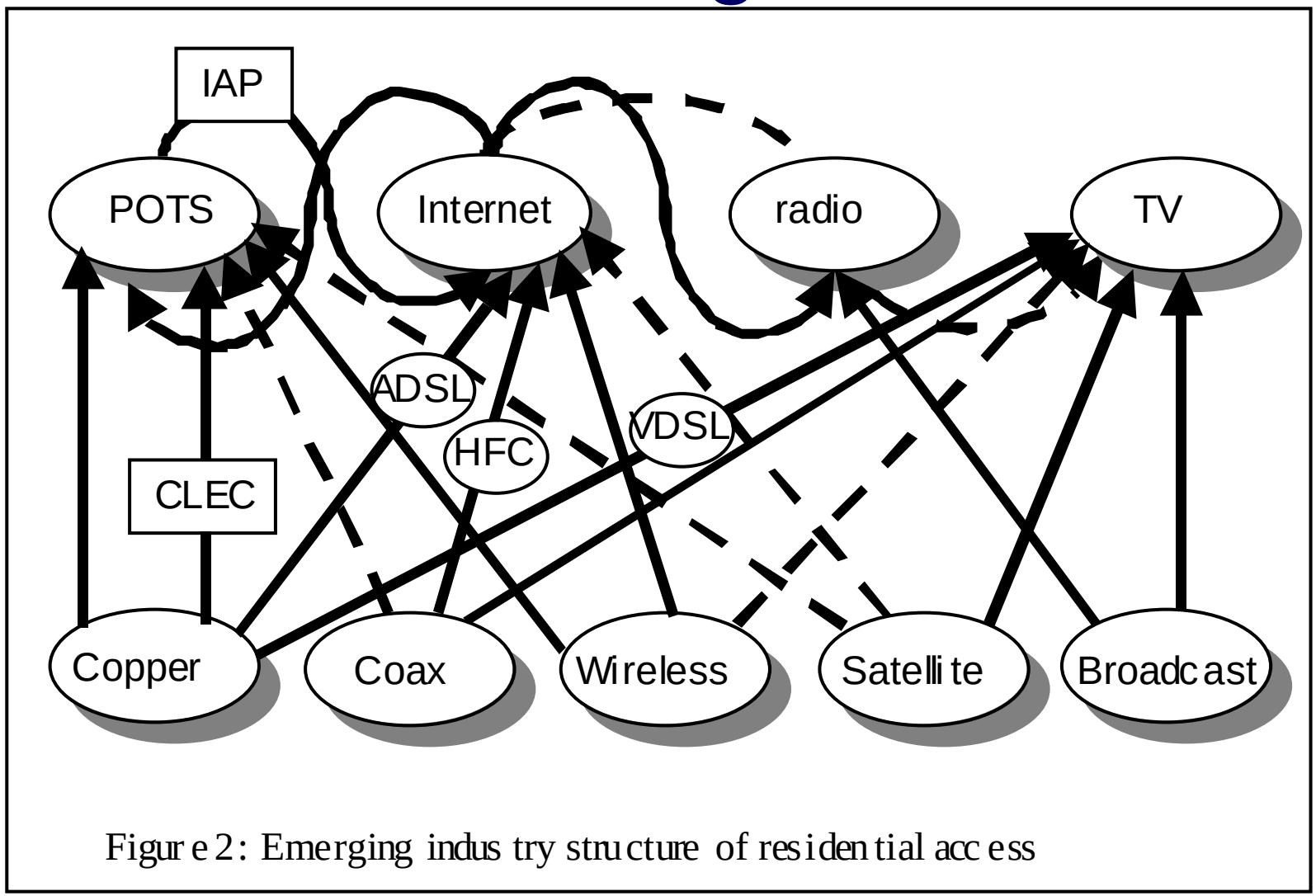


Figure 2: Emerging industry structure of residential access

From (Clark, 1999)

The Future(?): Internet as Platform

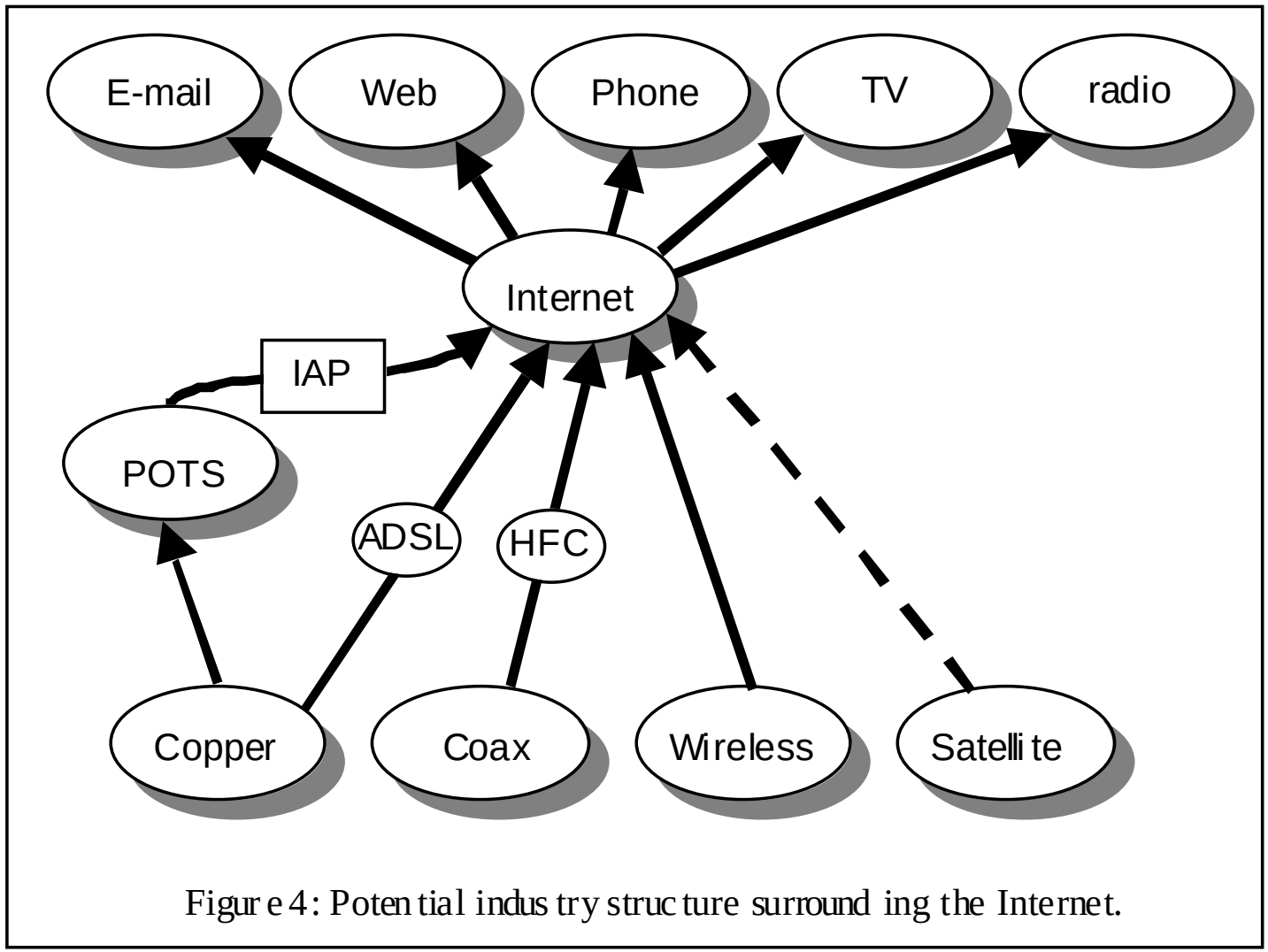
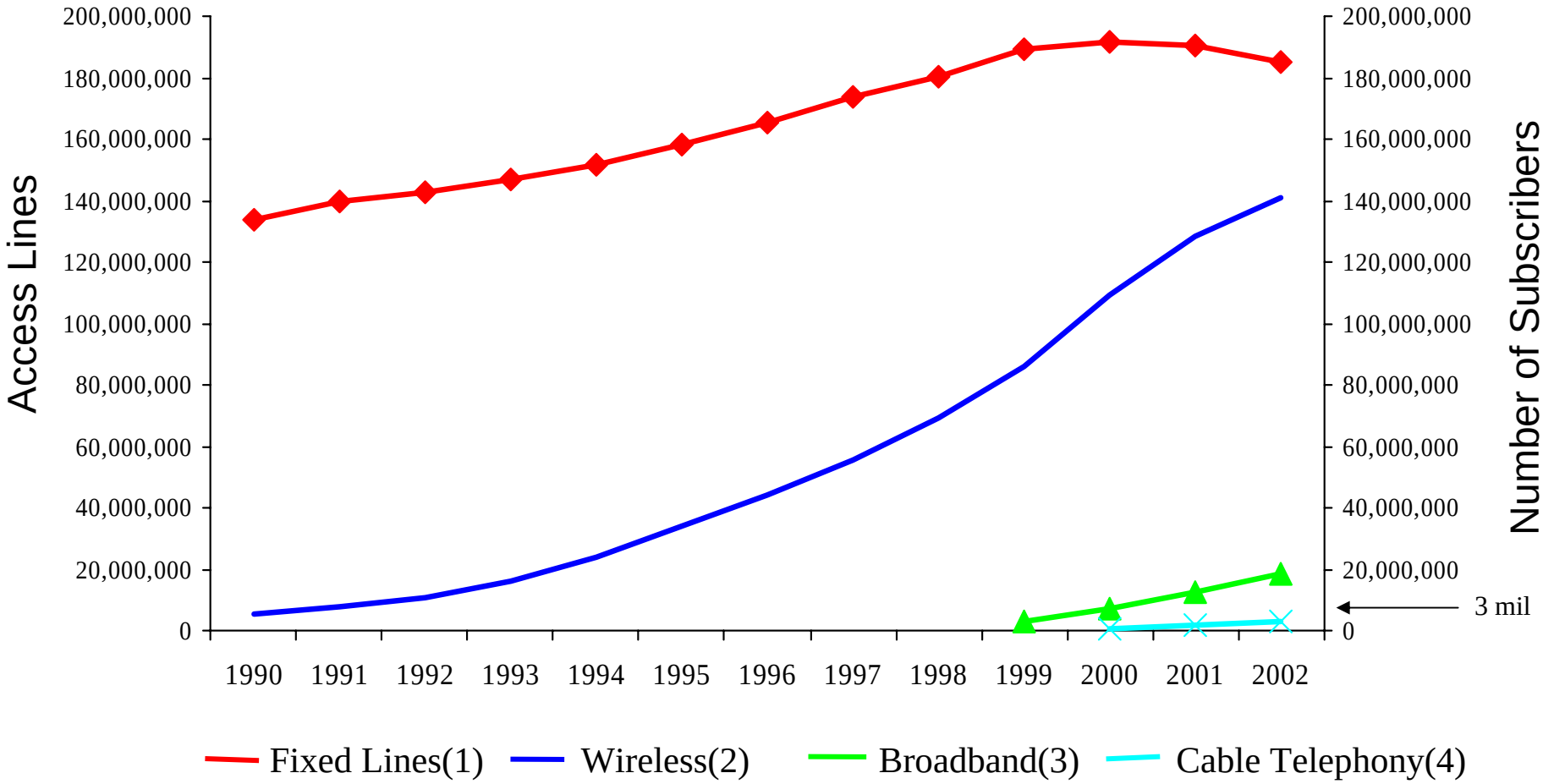


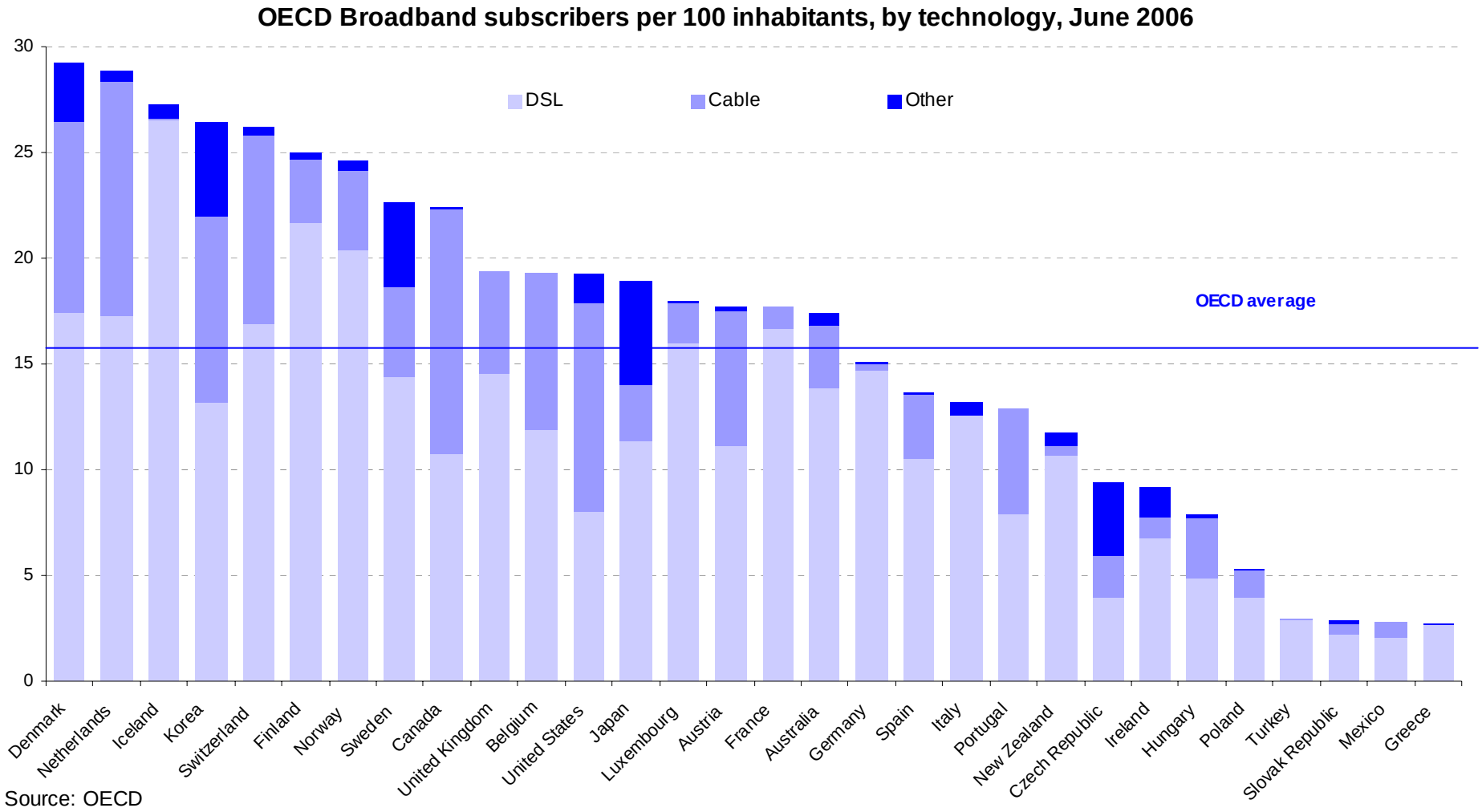
Figure 4: Potential industry structure surrounding the Internet.

From (Clark, 1999)

Wireless Telephony Competing With Fixed Lines, 2002



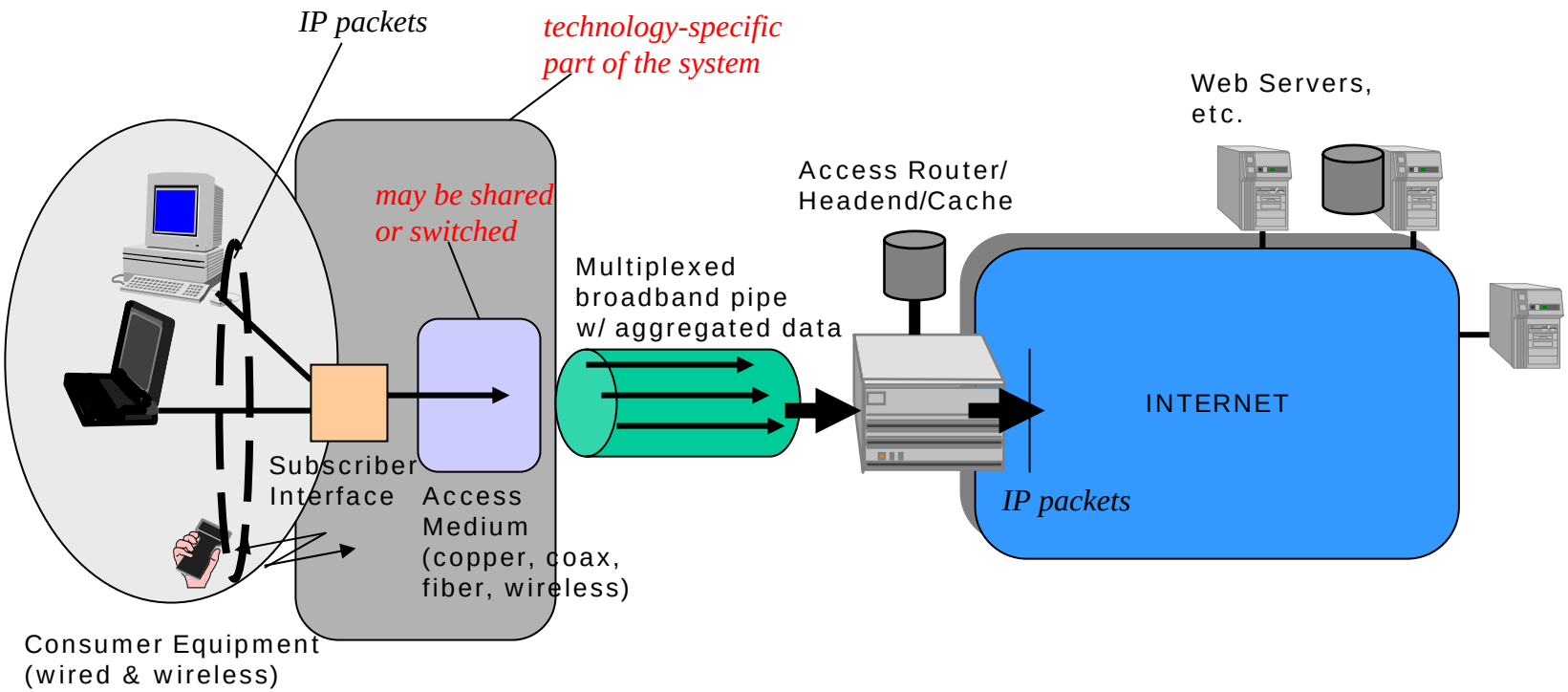
(1) 1990-1998 data from "FCC Trends in Telephone Service May 2002"; 1999-2002 data from "FCC, Local Telephone Competition: Status as of Dec 31 2002"; (2) CTIA Semi-Annual Wireless Industry Survey, published 2003; (3) 99-2001:FCC.COM: Trends in Telephone Service May 2002 (High Speed Lines with 200Kbps in at least one direction; Legg Mason Wood Walker, Inc. "Coming Down the Pipe - Interim Report 4Q 2002/1Q 2003 Industry Update - March 13, 2003"; (4) NCTA, "Residential Cable Telephony Subscribers"



3. Broadband Technologies

Network Architecture

- Generic model of a broadband access network
  - *system architecture common across technology alternatives*
  - *important differences in cost-performance and business models*



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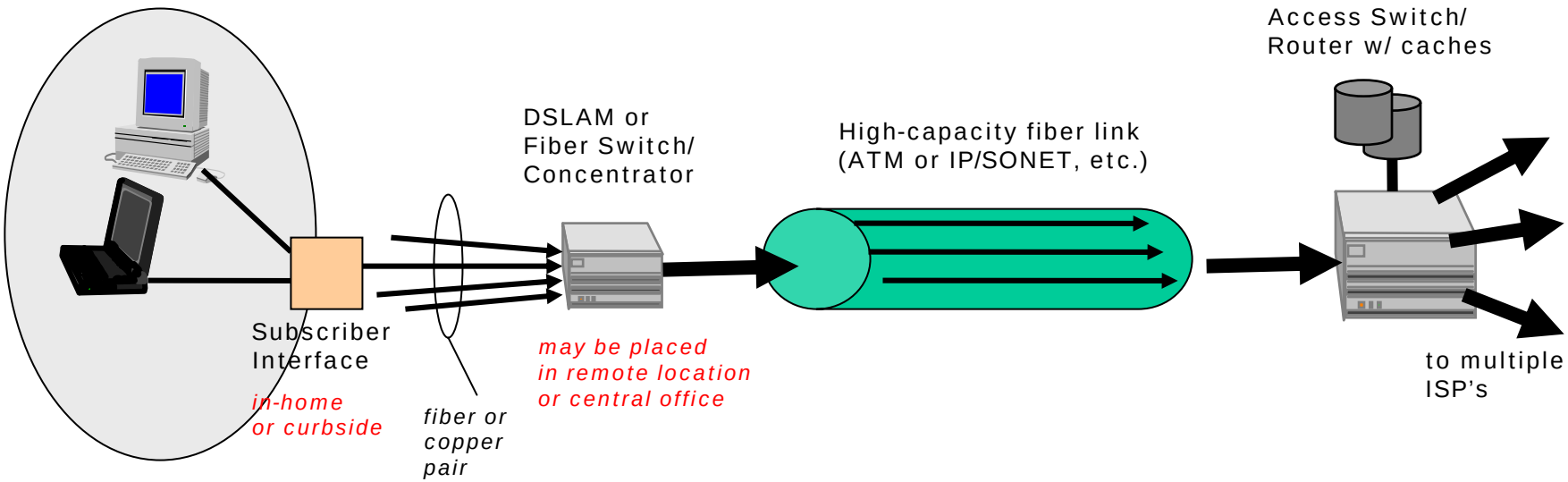
Wireline Options

- Hybrid fiber-coax
  - DOCSIS
  - Role of fiber (toward FTTC)
- Digital subscriber line (DSL)
  - Distance, crosstalk
  - Role of fiber (toward FTTC)
- Optical fiber
  - Flavors of fiber to the home (FTTH)
  - Service based on equipment at both ends
    - Depends on what “kind of “ FTTH: not all the same
  - High-performance endpoint—highest cost
- Powerline

DSL/Fiber Architecture

- **Same architecture evolves naturally from ADSL to VDSL to FTTC/FTTH**
  - *switching equipment tends to migrate closer to subscribers (..remote DSLAM, gigabit Ethernet switches, etc.)*
  - *system deployment cost dominated by physical wiring, due to rapid improvements in switching & transport cost/performance*



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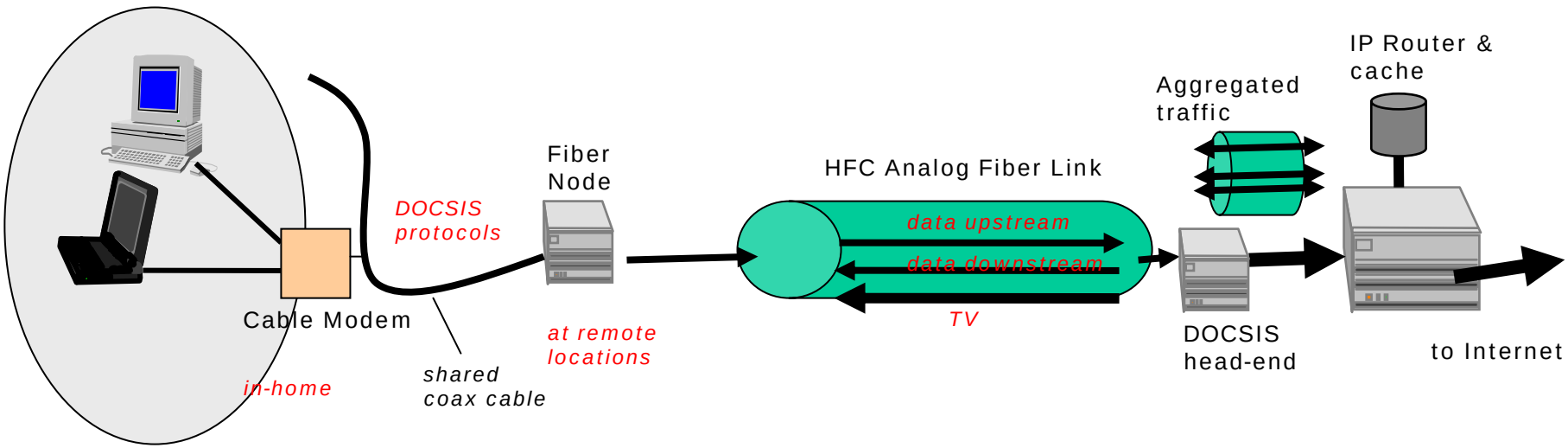
HFC Architecture

- **Broadband access over cable based on shared access (DOCSIS standard) to existing TV coax**
  - *Medium access control (MAC) protocol for coax sharing*
  - *Signal converted to analog fiber at remote node*
  - *System cost dominated by fiber upgrade investments, due to rapidly falling cost of DOCSIS modems & switching gear*
  - *Also evolves naturally towards FTTC/FTTH*



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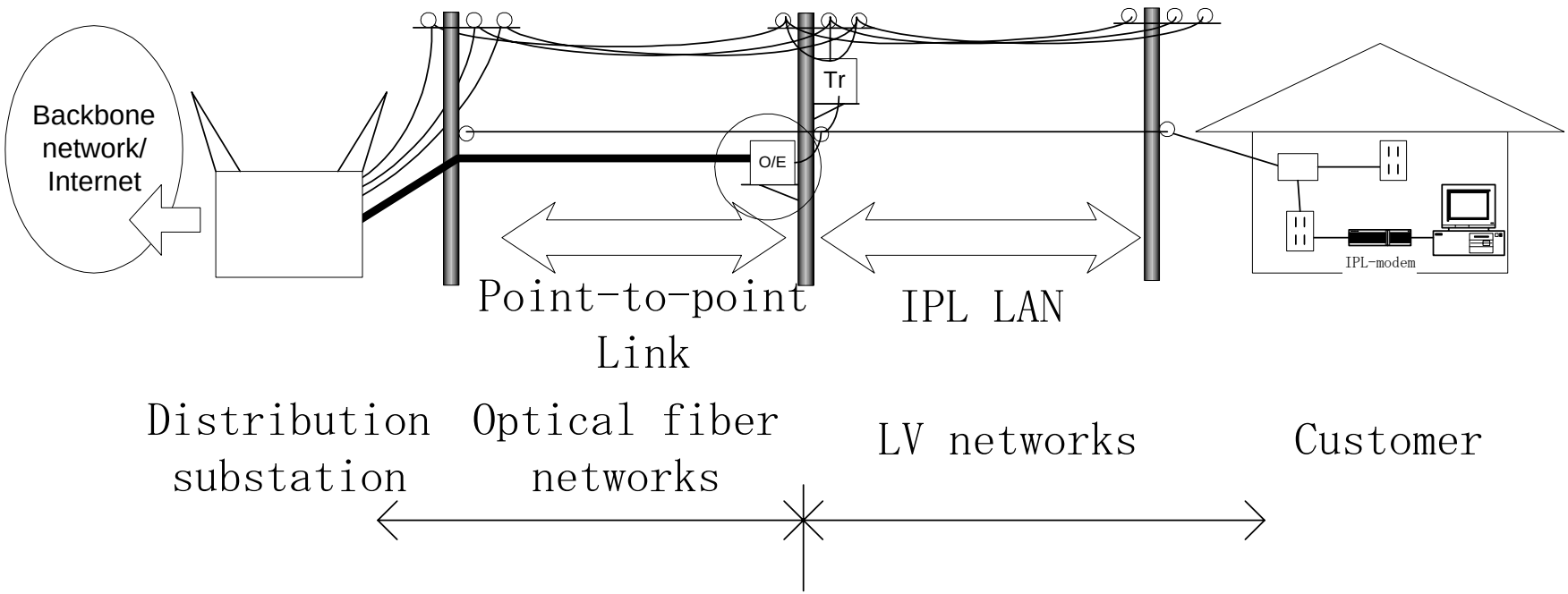
One Architecture for BPL

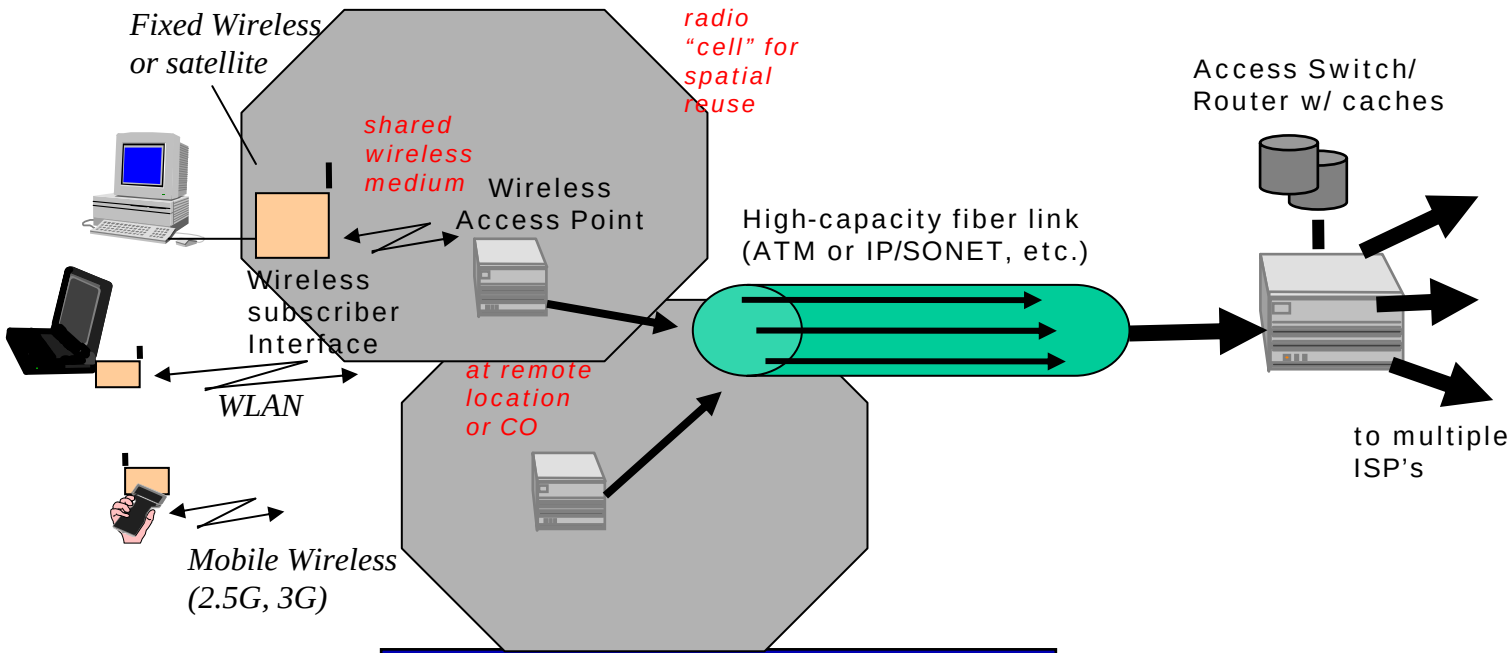


Wireless Options

- **Mobile/3G**
  - Future: seamless mobile & portable broadband
  - Reality: emerging 3G falling short of hype (capacity, speed..)
- **WLAN**
  - 802.11, unlicensed 2.4 and 5 Ghz bands
  - Bottom-up deployment is accelerating... (airports, offices, homes..)
- **FWA** (Fixed Wireless Access)
  - MMDS, LMDS,...
  - much potential, but uncertain business conditions ...
- **Satellite**
  - Geo-synchronous (GEOS) & Low-earth orbit (LEOS)
  - Viable for certain markets, but with capacity limitations...

Wireless Architecture

- **Broadband wireless based on shared access of radio medium (MMDS, LMDS, 3G, WLAN,..)**
  - *MAC protocol for shared use of radio (..similar to cable modems)*
  - *Switching or routing beyond access point (...similar to DSL)*
  - *FWA, satellite, WLAN & 3G/mobile as potential options, each with different entry cost and system cost/performance trade-offs*



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Local Access Techs in Context

- Total cost and performance depends on more than just local access
- Local access aggregates traffic from multiple premises at POPs, funnels to higher-capacity links
- “Second mile” connects to upstream aggregation
- Broadband providers pay for Internet transit service or establish peering arrangements
- Caches, service-supporting servers at POPs

Unbundling DSL

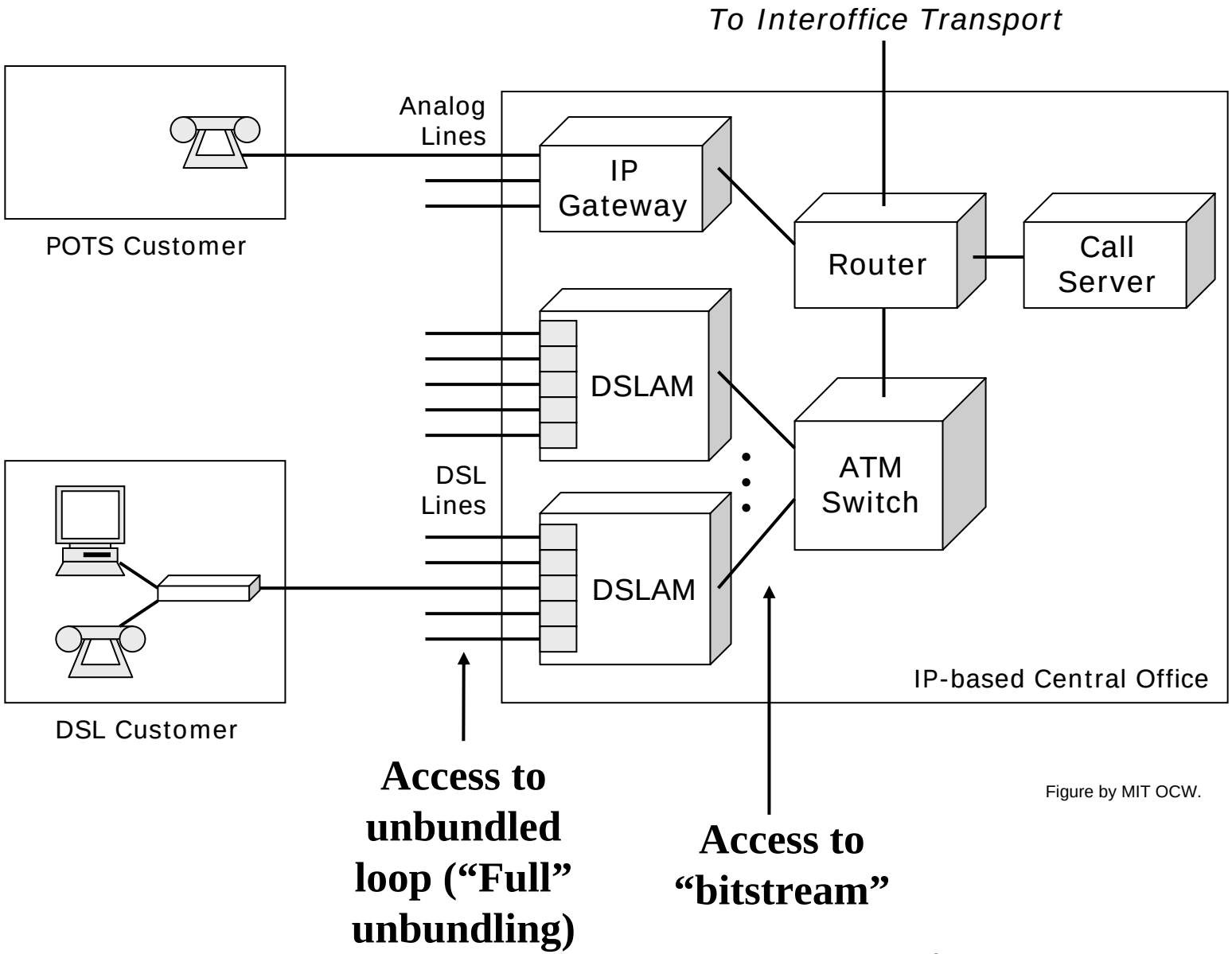
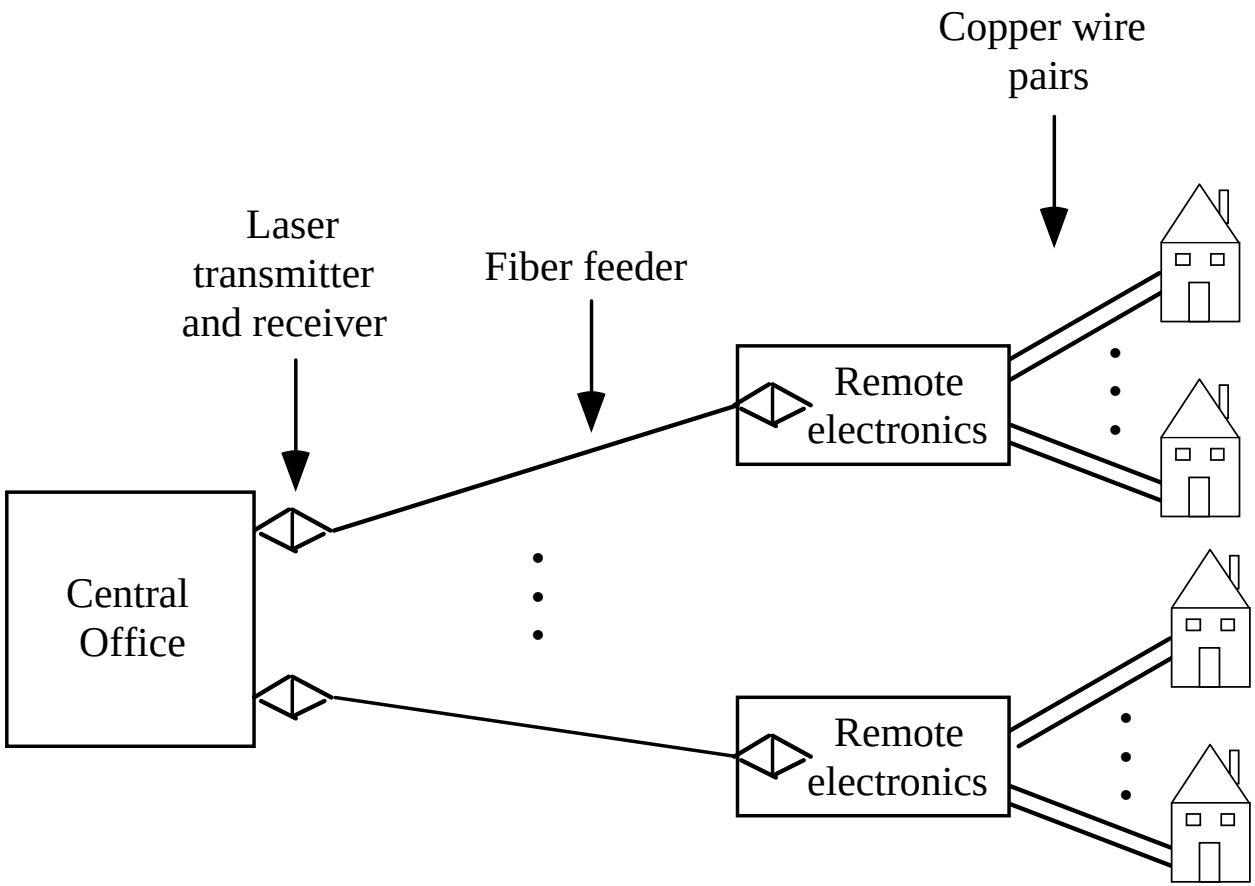


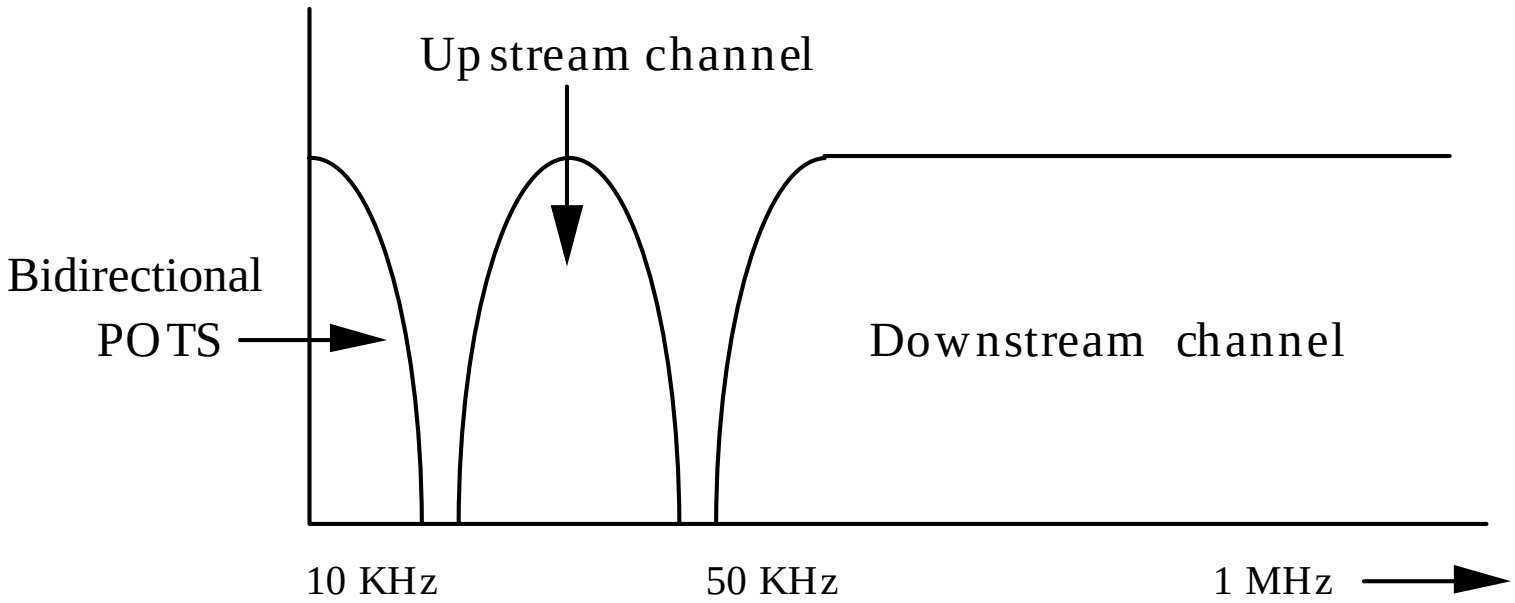
Figure by MIT OCW.

After Fryxell, Sirbu, and Wanichkorn, 1999.

Sub-loop Unbundling



ADSL Spectrum Allocation (Line Sharing)



Open Access and Layering

Layer:	**Municipality provides…**
0	Conduit and collocation facilities.
1 (Physical Layer Unbundling)	Dark fiber leasing, or perhaps, Optical Layer unbundling (CWDM or DWDM in PONs)
2 (Data Link Layer Unbundling)	Dark fiber and link-layer electronics at each end. For example, Ethernet-based VLAN, or ATM-based PVCs.
3 (Network Layer Unbundling)	Basic network service provided. For example, IP Layer 3 service over cable using policy-based routing to multiple ISPs

Regulatory Dilemma

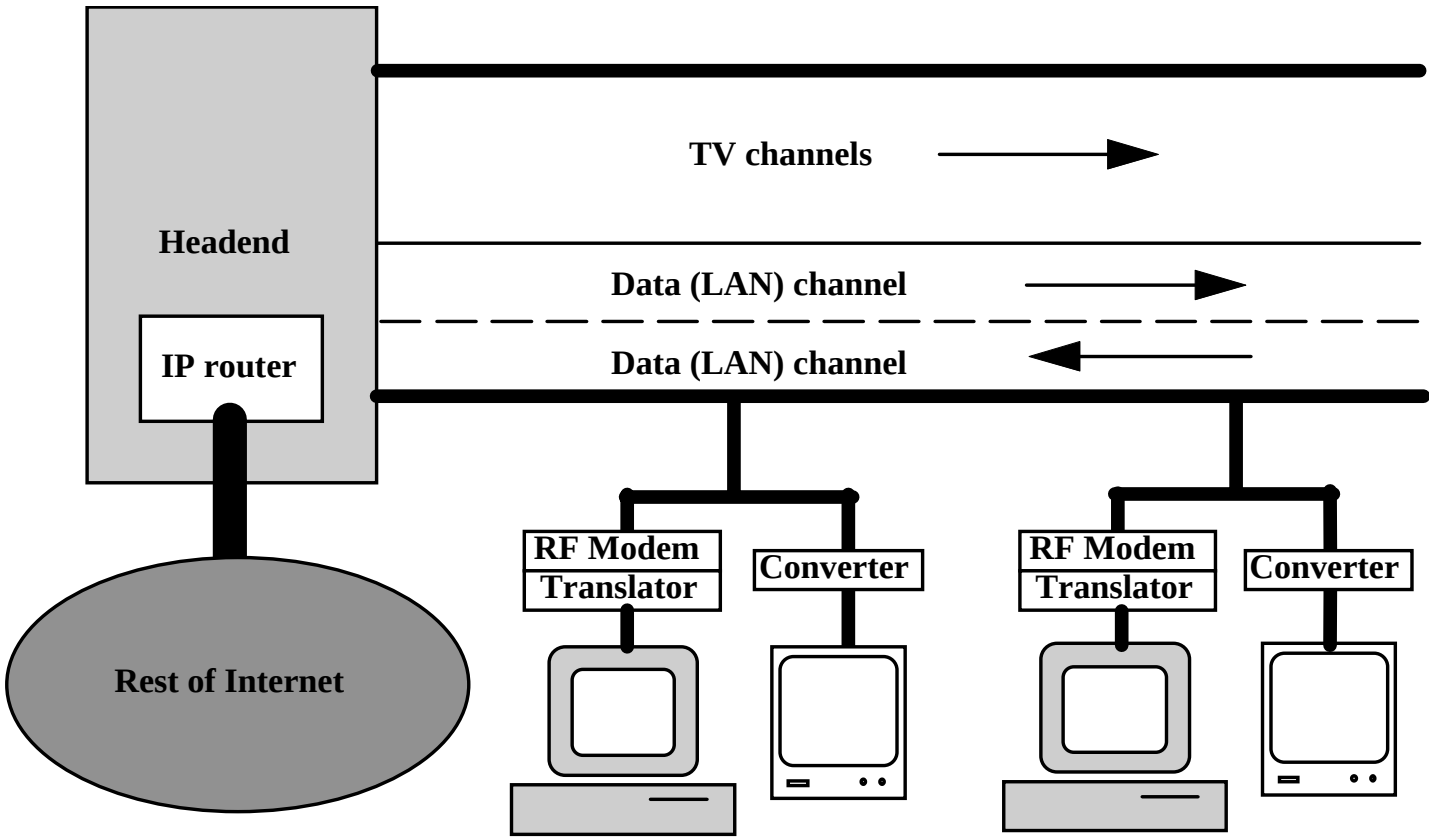
Heisenberg's Uncertainty Principle:

Can't observe situation without perturbing it

Fundamental Economics	**Regulatory Assumption About Competition**	**Outcome**
Competition is sustainable (competitive equilibrium exists)	Sustainable	Free market
	Not sustainable	Regulation stifles innovation, competition
Competition is not sustainable (no competitive equilibrium)	Sustainable	Government-sanctioned, unregulated monopoly
	Not sustainable	Necessarily regulated monopoly

Additional Tech Slides

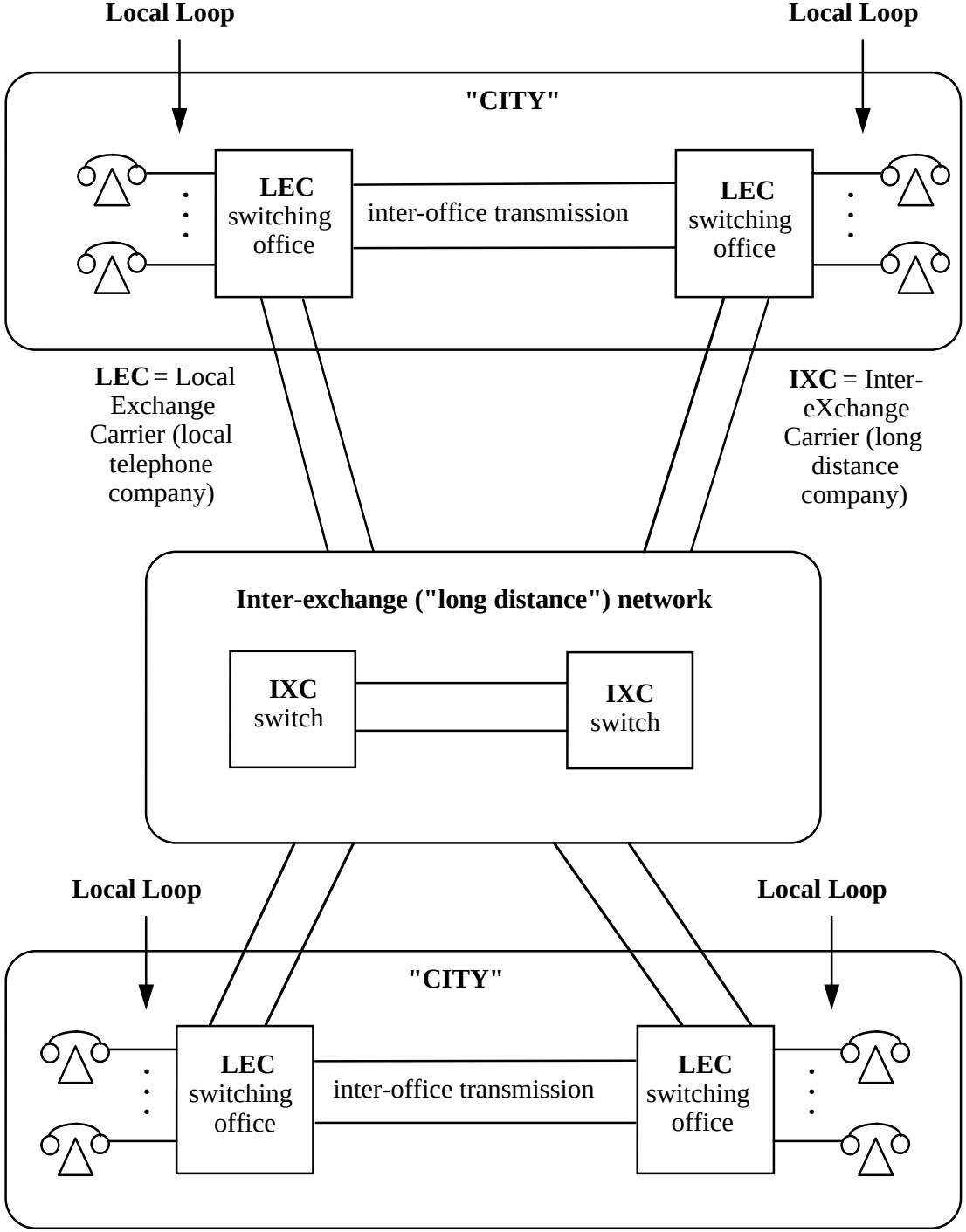
Internet Access via Cable



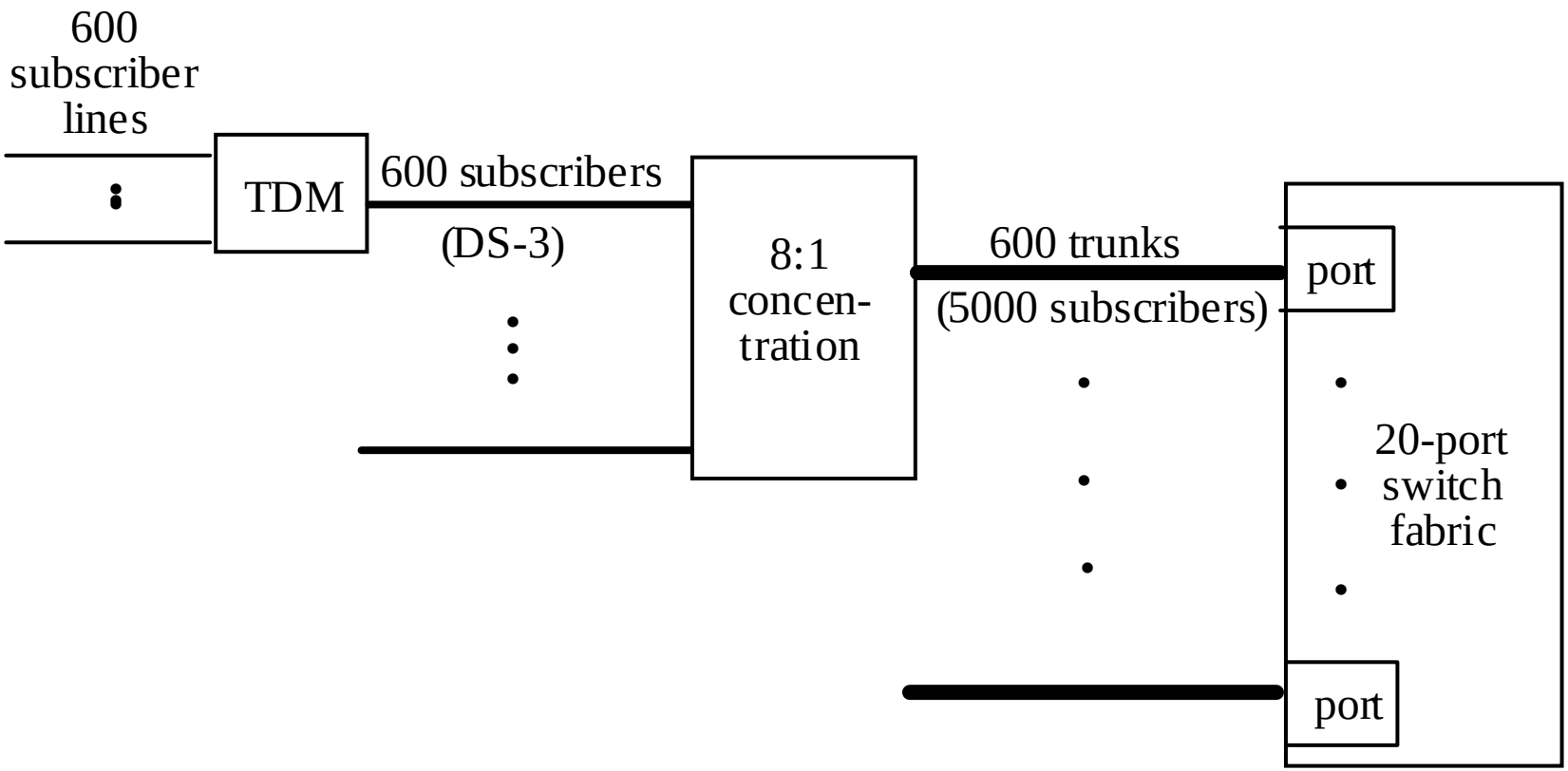
Telephone Network Hierarchy

Twisted-pair copper loops dedicated to individual subscribers

- Physical aggregation at “Central Office” (CO) via Main Distribution Frame
- CO Switching: Access
- IXC Switching: Tandem
- Increasing aggregation at each level

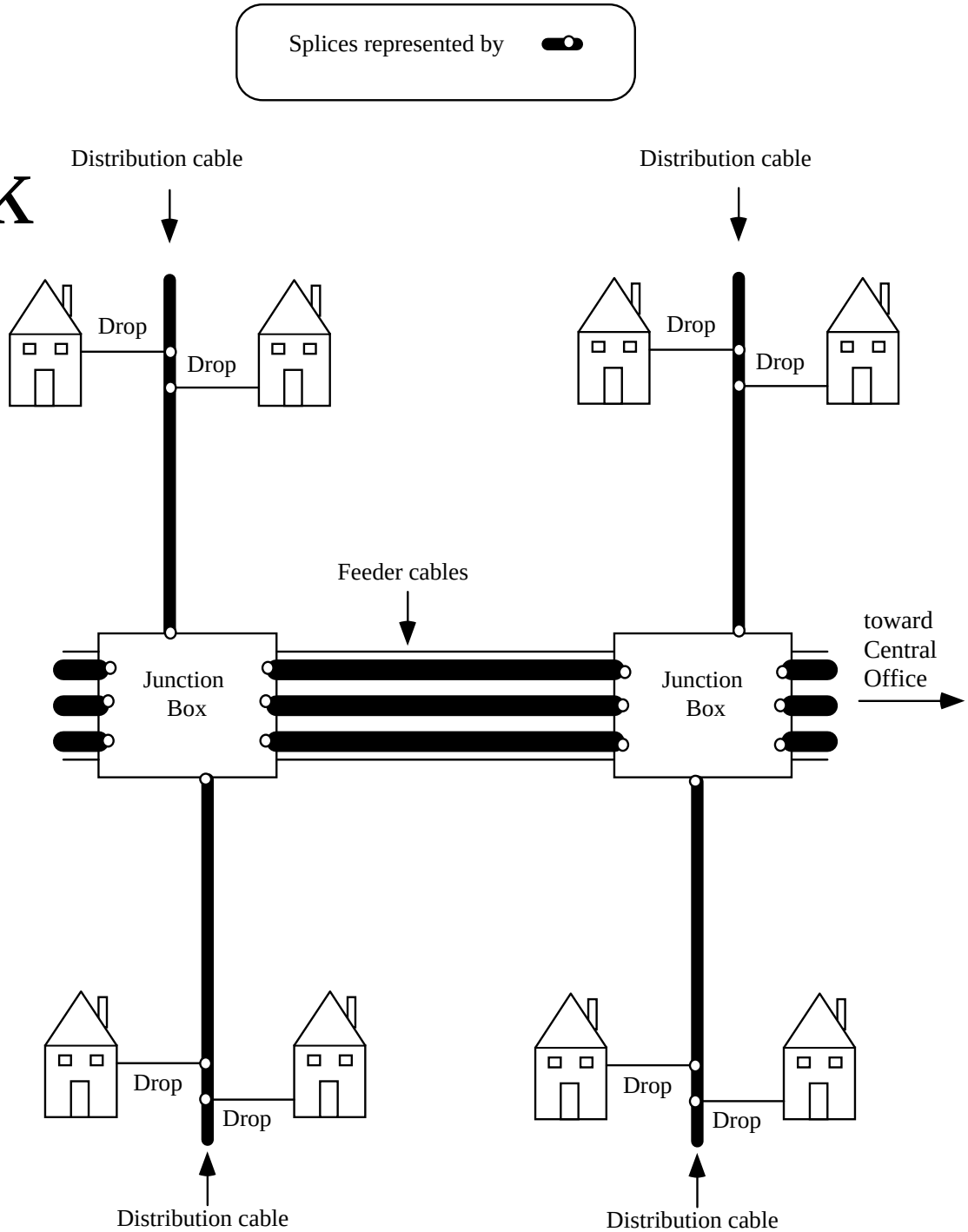


Multiplexing and Concentration in CO Switch



Telephone Access Network

- Feeder
- Distribution
- Drop
- Aggregation is *physical:* bundles of wire-pairs



Internet over ADSL (with VoIP)

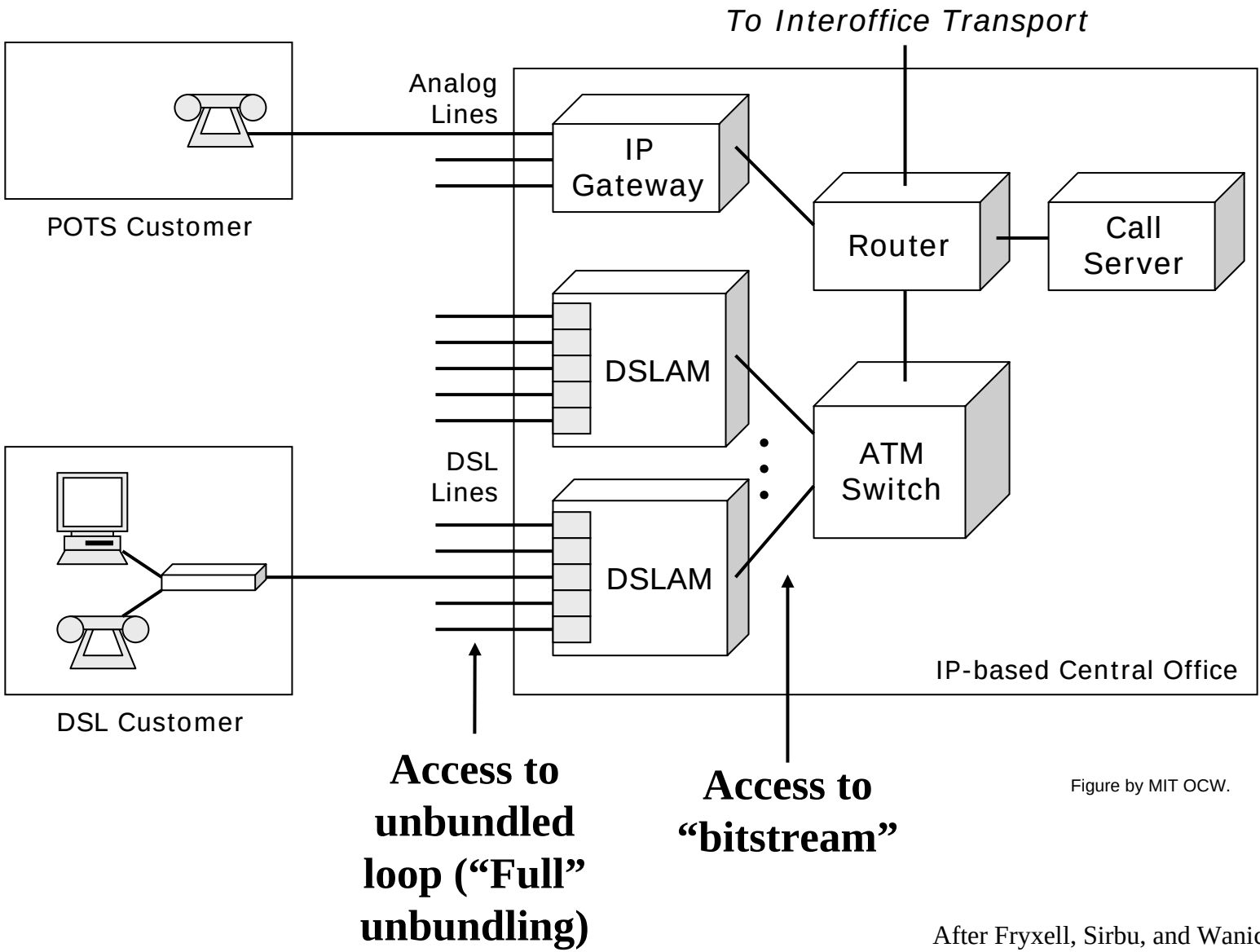


Figure by MIT OCW.

After Fryxell, Sirbu, and Wanichkorn, 1999.

Telco migration to Fiber-to-the-Neighborhood