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

OECD Broadband subscribers per 100 inhabitants, by technology, June 2006

Source: OECD

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
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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Access Switch/Router w/ caches

High-capacity fiber link (ATM or IP/SONET, etc.)

DSLAM or Fiber Switch/Concentrator

Subscriber Interface

- in-home or curbside

fiber or copper pair

may be placed in remote location or central office

Courtesy of CSTB. Used with permission.
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

![Diagram of HFC Architecture]

Courtesy of CSTB. Used with permission.
One Architecture for BPL

Backbone network/Internet

Distribution substation

Optical fiber networks

LV networks

Customer

Point-to-point Link

IPL LAN

Tr

O/E

Optical fiber networks

IPL-modem
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
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


Access to unbundled loop (“Full” unbundling)

Access to “bitstream”

Figure by MIT OCW.

Sub-loop Unbundling

- Laser transmitter and receiver
- Fiber feeder
- Copper wire pairs
- Remote electronics
- Central Office
ADSL Spectrum Allocation (Line Sharing)

- **Upstream channel**
- **Downstream channel**
- **Bidirectional POTS**
- Frequency bands:
  - 10 KHz
  - 50 KHz
  - 1 MHz
### Open Access and Layering

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

**Heisenberg’s Uncertainty Principle:**
Can’t observe situation without perturbing it

<table>
<thead>
<tr>
<th>Fundamental Economics</th>
<th>Regulatory Assumption About Competition</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Competition is sustainable (competitive equilibrium exists)</td>
<td>Sustainable</td>
<td>Free market</td>
</tr>
<tr>
<td>Competition is not sustainable (no competitive equilibrium)</td>
<td>Sustainable</td>
<td>Government-sanctioned, unregulated monopoly</td>
</tr>
<tr>
<td></td>
<td>Not sustainable</td>
<td>Necessarily regulated monopoly</td>
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</tbody>
</table>
Additional Tech Slides
Internet Access via Cable

- Headend
- IP router
- Rest of Internet
- TV channels
- Data (LAN) channel
- RF Modem Translator
- Converter
- RF Modem Translator
- Converter
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

- 600 subscriber lines
- TDM
- 600 subscribers (DS-3)
- 8:1 concentration
- 600 trunks (5000 subscribers)
- 20-port switch fabric
- Port
- Port
Telephone Access Network

- Feeder
- Distribution
- Drop
- Aggregation is *physical*: bundles of wire-pairs
Internet over ADSL (with VoIP)


Access to unbundled loop ("Full" unbundling)
Telco migration to Fiber-to-the-Neighborhood

- Central Office
- Laser transmitter and receiver
- Fiber feeder
- Remote electronics
- Copper wire pairs
- Remote electronics

Diagram showing the connection between the Central Office and homes, with laser transmitter and receiver, fiber feeder, and remote electronics.