Outline

- Economic characteristics of communication networks
  - Economies of scale and scope
  - Network effects
- Interconnection and industry structure
  - Horizontal mergers
  - Vertical integration
Econ 1

Demand ← Market Structure → Supply

Price

Welfare (surplus) \( \{ \)

Producer Surplus
Consumer Surplus
Total Surplus
Supply & Demand in the Network Context

- **Supply**: cost of providing network service
  - fixed cost (FC)
  - marginal cost (MC)
  - average cost (AC)

- **Demand**: how much users value (and are willing to pay for) the service
  - more difficult to quantify
  - need empirical measurement
Economic Characteristics of Communication Networks

- Economies of scale
- Economies of scope
- Network effects
Economies of scale

- Average cost declines as output level increases
- Communication networks exhibit strong economies of scale
- High fixed cost
  - e.g., trenching cost, up-front capital investment
- Low/zero marginal cost
  - of sending traffic
Traditional Goods & Services

- $Q^*$ is optimal firm output
- Can support $N$ firms if market size $(Q_{TOT}) \geq NQ^*$
Infrastructure Goods & Services

- High FC, low MC $\Rightarrow$ declining AC curve (economies of scale)
- Therefore it is socially optimal to have the entire market served by a single firm (“natural monopoly”)
A monopolist maximizes profit, at expense of consumer welfare

A monopolist may become inefficient (lazy) in the absence of competition

What are alternatives?
- Public utility
- Regulated monopoly (e.g., AT&T and baby Bells)

Competition leads to marginal cost pricing; inefficient firms (higher MC) exit market

However, firms cannot recover fixed cost

Witness the recent collapse of the telecom industry: bankruptcy, mergers

ISP strategy: service differentiation, advanced services, vertical expansion, ...
Technological Change

- Natural monopoly may not last forever
- Technological change may result in new cost curve: same market may now be optimally served by multiple firms
Example: Telephony in U.S.

- AT&T as Regulated Monopoly
Monolithic Network
Long Distance Competition

Local Exchange Carrier (LEC) — Central Office (CO) — Inter Exchange Carrier (IXC) — Local Exchange Carrier (LEC)

Local Loop — Customer Premise Equipment (CPE) — Central Office (CO) — Class 5 Switch — MCI

MCI
**Divestiture (1984)**

- AT&T split up into Long Distance and seven regional bell operating companies (RBOCs, aka baby bells)
  - Pacific Bell, US West, Southwestern Bell, Bell South, Ameritech, Nynex, Bell Atlantic,
Local Access Competition
Economies of Scope

- Significant joint costs of production for multiple goods/services
- Examples:
  - GM plants produce sedans, SUVs, and minivans, etc.
  - Amazon.com sells books, music, and lawn-mowers, etc.
  - Internet (via its layering principle) supports multiple traffic types previously carried over different networks (telephony, radio, CATV, ...)

<table>
<thead>
<tr>
<th>Layer</th>
<th>Protocols</th>
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</thead>
<tbody>
<tr>
<td>Application Layer</td>
<td>HTTP, FTP, NNTP, SMTP, ssh, voice, video...</td>
</tr>
<tr>
<td>Transport Layer</td>
<td>TCP, UDP</td>
</tr>
<tr>
<td>Network Layer</td>
<td>IP</td>
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<tr>
<td>Data Link Layer</td>
<td>Ethernet, FDDI, SONET</td>
</tr>
<tr>
<td>Physical Layer</td>
<td>coax, twisted pair, fiber, wireless, ...</td>
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</tbody>
</table>
Service Differentiation

- Best Effort
- SLA
- email
- voice/video
Service Differentiation

- Best Effort
- SLA
- QoS Aware
- Internet
- email
- voice/video
Network Effects

- Also known as “Network externalities”
- Externality: value (including costs and benefits) of a good/service not fully reflected in its price
  - e.g., the price of an automobile does not include the economic impact of its potential to pollute
- Network externality: value of the network is a function of the network size
Positive Network Effects

- Value of network increases with network size
  - e.g., telephones, fax machines, email clients
  - Sarnoff’s Law: \( v \propto N \)
  - Odlyzko and Tilly: \( v \propto N \log(N) \)
  - Metcalfe’s Law: \( v \propto N^2 \)
  - Reed’s Law: \( v \propto 2^N \)
Negative Network Effects

- Value of network decreases with network size
  - e.g., due to increased likelihood of network congestion
  - During network congestion, each data packet incurs a social cost to other packets (e.g., delay, packet-drop)
Summary

- Communication networks exhibit
  - High fixed cost, low marginal cost (strong economies of scale)
  - Significant joint costs (strong economies of scope)
  - Positive/negative network effects (demand-side economies/diseconomies of scale)
Network Interconnection

- Network effects motivate network operators to interconnect
- Network operators compete and cooperate with each other ("co-opetition")
- Different types of interconnection:
  - Transit
  - Peering (bilateral or multilateral)
- Settlement
  - Transit: customer pays provider
  - Peering: settlement-free ("sender-keep-all" or "bill-and-keep")
Network Interconnection

Backbone A

transit

Backbone B

Backbone C

multilateral peering

Backbone A

Backbone B

Backbone C

NAP

Network access point

Source: Kende 2000
Transit or Peer?

Source: Kende 2000

John Chuang
Transit or Peer?

Backbone B wants Backbone A to be a transit (paying) customer, not a peer

Source: Kende 2000
UUNET Peering Policy

http://www.uu.net/peering/

- Need to meet following requirements to peer with UUNET (2003):
  - Interconnection Requirements
    - Geographic scope (> 50% of UUNET scope)
    - Traffic exchange ratio (not exceed 1.5:1)
    - Backbone capacity (> 2.5Gbps)
    - Traffic volume (> 600Mbps per direction)
  - Operational Requirements
    - 24x7 NOC, fully redundant network, implement “shortest-exit routing”, ...
Discussion

- Size matters
  - Larger network can dictate terms of interconnection or even refuse interconnection with smaller network

- Market concentration raises anti-trust concerns
  - Horizontal mergers must be scrutinized
Industry Structure

- Horizontal merger
- Vertical expansion, vertical integration, vertical disintegration
- Determinants:
  - Technological efficiencies
  - Transactional efficiencies
  - Market imperfections
- Economics sub-field: Industrial Organization
Horizontal Merger

- Proposition: Economies of scale
- Objection: concentration leads to market power and reduction in competition
  - No network externality benefits (all networks are interconnected anyway)
  - Larger network has less incentive to interconnect, or to maintain a high quality interconnection
  - Larger network has negotiation power over smaller networks
Horizontal Merger

- Example #1: Internet Backbone
  - MCI-WorldCom (1998)
  - WorldCom-Sprint (2000; abandoned)

Source: Kende 2000
Horizontal Merger

- **Example #2: Local loop**
- **Seven Baby Bells Merging**
  - SBC + PacBell + Ameritech
  - Nynex + BellAtlantic (+ GTE)
  - Bell South
  - US West (+ Qwest)
- **1996 Telecom Act: unbundling and open access**
  - competition in local exchange (e.g., Covad, Northpoint and other CLEC’s)
- **Facilities-based competition**
  - e.g., wireless, cable, satellite, fiber, ...
Vertically Related Markets

- Upstream/downstream relationship
- Examples:
  - Detroit: steel v. automobile
  - Software: OS v. applications
  - Telephony: local v. long distance
  - Internet: physical transport v. internet access v. content/services
Vertical Integration

- **Good:**
  - economies of scope savings
  - internalize transaction costs
  - reduce prices & increase total welfare

- **Bad:**
  - if one component is monopolistic
  - foreclose competition in other component
Vertical Integration: Telephony

- Telephony was vertically-integrated industry
- AT&T (Ma Bell) offered end-to-end solution
- Divestiture in 1984
  - Local service (the seven baby bells)
  - Long distance service (AT&T)
  - Customer premise equipment (CPE)
- Removes hidden subsidies between local service (monopoly) and long distance (competitive)
Vertical Integration: Internet

- **Access networks (physical infrastructure):**
  - SBC, Verizon, Bell-South, Qwest (dial-up and DSL)
  - Comcast, Warner (cable)

- **ISPs (network service):**
  - AOL, Earthlink, SBC, Comcast, Roadrunner, MSN

- **Content:**
  - Time Warner, Yahoo!

- **Open access**
  - Competitive local exchange carriers (CLECs v. ILECs)
  - Cable open access (AOL v. ATTBI/Comcast)