Pricing and architecture of the Internet:

Historical perspectives from telecommunications and transportation

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A depressing litany of duds among major recent networking research initiatives:

- ◆ **ATM**
- ◆ **RSVP**
- ◆ **Smart Markets**
- ◆ **Active Networks**
- ◆ **Multicasting**
- ◆ **Streaming Real Time Multimedia**
- ◆ **3G**

And (largely encompassing all of these): QoS

All technical successes, but failures in the marketplace

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Internet: Success or disaster?

The most prominent networking technology of last few decades, also widely blamed for the dot-com and telecom bubbles and crashes.

Telecom executives are vowing to design the next generation Internet, and to "get it right this time," in particular by building in QoS and having fine-grained charging.

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Thesis: Price discrimination is the unifying thread

Basic architecture of the Internet: end-to-end principle, "stupid network," functionality at edges

Marginalizes carriers, pushes costs to edges, and inhibits price discrimination

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Underlying trends:

- ◆ **Incentives to price discriminate are increasing**

- ◆ **Technology to price discriminate is improving**

- ◆ **Privacy will be victim, since it inhibits price discrimination**

Price discrimination likely to be the most notable feature of *The New Economy*

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"Frictionless capitalism" vs. reality:

Dell Latitude L400 ultra light laptop listed at $2,072.04, $2,228, and $2,307 on Dell Web pages (designed for state and local governments, small businesses, and health-care companies, respectively).

Wall Street Journal
June 8, 2001

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Standard economic argument for price discrimination

Charlie: willing to prepare a report on digital cash for $1,500

Alice: willing to pay $700

Bob: willing to pay $1,000

Uniform pricing makes transaction impossible

Charging Alice $650 and Bob $950 makes everybody better off (in conventional economic model)

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Price discrimination is ubiquitous, often concealed and often disputed:

- ◆ **Student and senior citizen discounts**
- ◆ **Medical fees**
- ◆ **Gasoline wholesalers' "zone pricing"**
- ◆ **Undergraduate financial aid**
- ◆ **Sales, coupons, price-matching**
- ◆ **Roaming charges for cell phones**

Less certain:

- ◆ **Movie ticket and popcorn pricing**

Questions of whether price discrimination is being practiced is often muddled by issue of "joint costs"

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Clear example of dominant influence of price discrimination: Fares offered at www.continental.com on February 27,2002:

Minneapolis to Newark, NJ on Wednesday, March 20, returning Friday, March 22: $772.50

Minneapolis to Newark, NJ on March 20, returning March 27: $226.50

Newark, NJ to Minneapolis on March 22, returning March 27: $246.50

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Regulatory price discrimination usually rooted in corporate practices from an early era:

The terms for leasing two telephones for social purposes, connecting a dwelling house with any other building, will be $20 a year; for business purposes $40 a year, payable semi-annually in advance.

Bell Telephone Association, 1877

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Open architecture vs. drive to price according to value:

[Alexander Graham] Bell should have anticipated Bill [Gates] and let someone else put in the phone infrastructure while he collected by the minute and distance (and even importance of the call if he could have figured a wait to monitor it) in perpetuity.

email from Warren Buffett to Jeff Raikes of Microsoft, Aug. 21, 1997

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Absurdities of government regulation often rooted in corporate practices:

Cats is 'dogs' and rabbits is 'dogs' and so's Parrats, but this 'ere 'Tortis' is a insect, and there ain't no charge for it.

Punch, 1869

Versioning is motivated by incentives to price discriminate:

It is not because of the few thousand francs which have to be spent to put a roof over the third-class carriages or to upholster the third-class seats that some company or other has open carriages with wooden benches. What the company is trying to do is to prevent the passengers who pay the second class fare from traveling third class; it hits the poor, not because it wants to hurt them, but to frighten the rich.

And it is again for the same reason that the companies, having proven almost cruel to the third-class passengers and mean to the second-class ones, become lavish in dealing with first-class passengers. Having refused the poor what is necessary, they give the rich what is superfluous.

Jules Dupuit, 1849

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Versioning is increasingly leading to "damaged goods": higher costs for lower functionality

IBM, 1990:

        Laser Printer: 10 pages/min.

        Laser Printer E: 5 pages/min.

FedEx: afternoon delivery only in the afternoon.

Open Internet ➡ Innovation

"killer apps" of the Internet:

- ♦ **Email**
- ♦ **Web**
- ♦ **Browsers**
- ♦ **Search engines**
- ♦ **IM**
- ♦ **Napster**

Not one invented by service providers or their suppliers

Extreme example of industry design: Minitel, a closed system that barely succeeded, and only by accident (chat rooms were possible and turned out to be key)

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Key question:

How much control over content should carriers exercise?

- ♦ **Block video?**
- ♦ **Prevent WiFi hot spots?**

Voice telephone content is private now, but:

> In Britain in 1889, postal officials reprimanded a Leicester subscriber for using his phone to notify the fire brigade of a nearby conflagration. The fire was not on his premises, and his contract directed him to confine his telephone ``to his own business and private affairs.'' The Leicester Town Council, Chamber of Commerce, and Trade Protection Society all appealed to the postmaster-general, who ruled that the use of the telephone to convey intelligence of fires and riots would be permitted thenceforth.

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General historical trend in telecommunications:

Pricing becoming simpler, and involving less price discrimination

But this is a new era, and price discrimination is becoming easier

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International telegraph rates from New York City (per word)

Year	London	Tokyo
1866	$10.00	-
1868	1.58	-
1880	0.50	$7.50
1890	0.25	1.82
1901	0.25	1.00
1924	0.20	0.50
1950	0.19	0.27
1970	0.23	0.31

Wide range of valuations strongly suggests price discrimination:

Service	Typical Monthly Bill	Revenue Per MB
Cable	$40	$0.00012
Broadband Internet	$50	$0.025
Wireline Phone	$70	$0.08
Dial Internet	$20	$0.33
Cell Phone	$50	$3.50
SMS		$3000.00

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18th Century: Beverley Beck Navigation

Cargo	Toll per Ton
Sand	2p
Timber, stone, salt	6p
Iron and lead	12p

Other examples:

- ♦ **canals**

- ♦ **turnpikes**

- ♦ **railroads**

Frequently see growth in sophistication of charging scheme (with notable exception, such as abolition of turnpike tolls in 1st half of 19th century)

English lighthouse fees:

13th century: 2p per ship

16th century: 6p for 2-masted ship

4p for 1-masted ship

2p for other vessels

17th century: based on cargo carrying capacity

1900: 2 – part tariff

English 18th century turnpikes: controversial but beneficial

- controversial:
  - open King's Highway transformed into toll road
  - widely praised and criticized, sometimes physically attacked and destroyed

- beneficial:
  - land carriage rates fell 10 to 15% after turnpike trusts were adopted (with tolls amounting to 10 to 15% of those rates)

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Long-haul is not where the action is:

▶ **360networks Transatlantic Cable**

Construction cost	**$850 M**
Sale price	**$18 M**
Annual operating cost	**$10 M**
Lit capacity	**192 Gb/s**
Ave. transatlantic Internet traffic	**70 Gb/s**

Internet bandwidth vs. potential fiber capacity

100,000 TB/month ≈ 300 Gbps

80–wavelength OC192 DWDM system → 800 Gbps/fiber

Telegeography 2002: in mid-2002, highest capacity
Internet route (NYC – Washington): ≈ 140 Gbps

9/11 disaster reports: Verizon central office at 140 West Street
in NYC had capacity of 3.6 million VGE ≈ 200 Gbps

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Distribution of Internet costs:
almost all at edges

U.S. Internet connectivity market (excluding residential, web hosting, . . .) $\approx$ $15 billion/year

U.S. backbone traffic: $\approx$ 150,000 TB/month

Current transit costs (at OC3 bandwidth): $\approx$ $100/Mbps

Hence, if utilize purchased transit at 30% of capacity, cost for total U.S. backbone traffic: $\approx$ $2 billion/year

Backbones are comparatively inexpensive and will stay that way!

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Residential broadband costs:

DSL and cable modem users: average data flow around 10Kb/s per user

If provide 20 Kb/s per user, at current costs for backbone transit of $100 per Mb/s per month, each user will cost around $2/month for Internet connectivity.

⟶ Most of the cost at edges, backbone transport almost negligible

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Other constraints on new architectures and price discriminations:

◆ **public policy**

    ♦ **innovation**

◆ **behavioral economics**

    ♦ **incentive to increase usage**

    ♦ **willingness to pay extra for simple pricing**

    ♦ **bundling**

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Migration of costs to edges
⟶ New business models

◆ **Customer-owned networks**

◆ **Outsourcing**

Conclusions:

◆ **Strong historical precedents and economic arguments for price discrimination and against end-to-end principle**

◆ **Even stronger arguments for keeping the open architecture of the Internet**

More evidence, arguments, and speculations in papers at:
http://www.dtc.umn.edu/~odlyzko

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