Brookings Workshop on Communications Output and Productivity

U.S. Bandwidth Price Trends in the 1990s

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February 23, 2000

Note: This presentation reflects only the views of the author. This presentation does not necessarily reflect the views of the Federal Communications Commission, its Commissioners, or staff members other than the author.

What's bandwidth?

1) Bandwidth is a widely and loosely used term. Bandwidth is used in discussions of radio spectrum ("bandwidth auctions"), signal processing ("filter bandwidth"), industry development ("the growth of broadband"), and in describing communications capabilities ("How much bandwidth do you have?").

2) For the purposes of this presentation, bandwidth is a measure of information transmission capacity available to the user: "the size of the communications pipe."

3) Bandwidth in this sense depends on the established communications protocols and management of the medium. "Raw bandwidth" or information-theoretic concepts of bandwidth typically have little current economic relevance.

4) Bandwidth can be organized in many different ways. One conceptually simple example is bandwidth defined between two points. Such bandwidth is known as private lines, leased lines, or dedicated transport. Bandwidth associated with voice service is usually called public switched services. Measuring bandwidth as information transmission capacity available requires translating specific communications services into this common measure.

5) In the 1990s, networks of point-to-point dedicated bandwidth has dominated bandwidth in use. Focusing on underlying network facilities and relevant end-points is important for a coherent, interpretable definition of bandwidth.

Why is bandwidth important?

1) Technological progress in optical transmission and processing technologies has been dramatic and appears to have eclipsed the rate of change in silicon (microprocessor fabrication) technologies. Changes in bandwidth in use indicate the application and spread of this technology in the economy.

2) Communications capability is often considered to be a key input for "new economy" enterprises and organizations. Bandwidth is a measure of communications capability.

3) Policy makers have sought to improve the performance of the communications industries, and, in particular, to promote the growth of "broadband." Bandwidth is an indicator of the performance of the communications industry. Promoting "broadband" is specifically about bandwidth.

Terminology

Table P1 Definitions	
Term	Definition
bit	binary digit (0 or 1)
byte	8 bits
Kbps	kilo (thousand) bits per second
Mbps	mega (million) bits per second
Gbps	giga (billion) bits per second

Note 1: Storage capacity and file sizes are usually measured in bytes while communications bandwidth is measured in bits per second

Note 2: When dealing with measures of digital information and communications, a thousand usually means 2^10=1024. In practice the difference between 1024 and 1000 is usually insignificant.

Table P2 Link Sizes	
Link	Bandwidth
OC-192	10 Gbps
OC-48, STS-48	2.48 Gbps
OC-12, STS-12	622 Mbps
OC-3, STS-3	155 Mbps
T-3, DS-3	44.74 Mbps
E-3	34.37 Mbps
E-1	2.048 Mbps
T-1, DS-1	1.544 Mbps
VG, DS-0	64 Kbps

Note 1: E-1, E-3 are terms most often used in Europe, while DS-1, T-1, DS-3, T-3 are terms most often used in North America. STS is a term originally associated with undersea fibre optic cables.

Note 2: Most of these terms were established when bandwidth was organized and managed for voice communications. They have been carried over into data communications, but it should be recognized that how to organize and manage bandwidth is currently a key focus of innovation and entrepreneurship.

Building a Price Index for Bandwidth: Some Problems

1) Assessing representative prices requires a lot of information.

a) Economies of scale in production promotes price dispersion.

b) Complex structure of bandwidth transactions – term, zone, volume, distance, geography.

c) Regulatory process is only broad source of systematic data.

2) New products (term, zone, volume offerings) have rapidly developed.

Base period weights and linking?

3) Changes in quantities of products demanded appears to have been driven by changes in production function rather than by changes in relative prices.

Is a cost-of-living approach informative?

Data

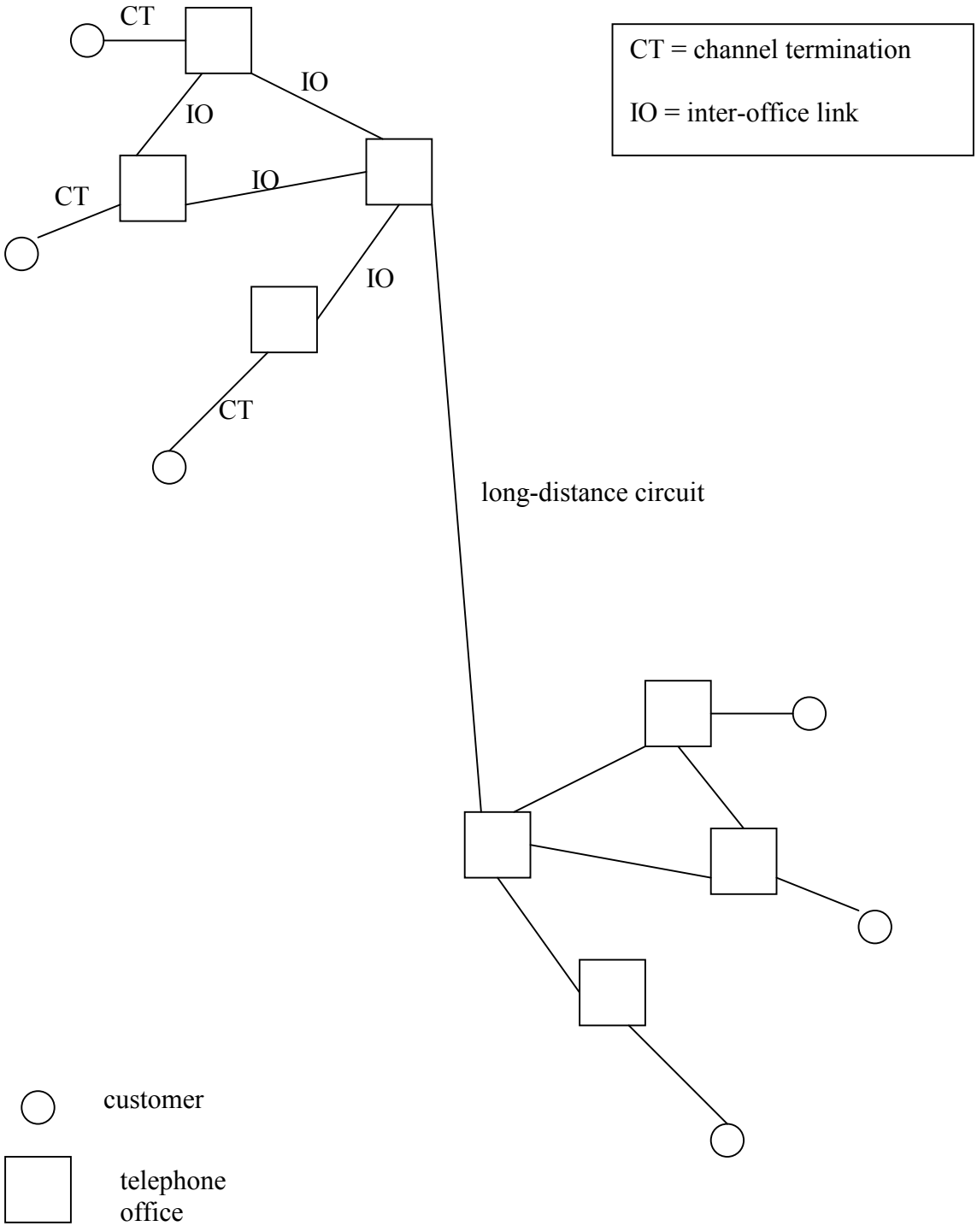
1) Detailed, yearly regulatory (FCC price cap) filings for local exchange carriers. Difficult to work with. Not standardized.

2) Sample was constructed from original Bell-Atlantic (now part of Verizon) and US West (now part of KPNQwest). The sample accounts for about 30% of incumbent local exchange carrier bandwidth.

3) Mid-year prices for VG, DDS (56Kbps), DS1, and DS3 local dedicated point-to-point links are aggregated into sub-indices based on previous calendar year demand. These circuits have accounted for over 80% of ILEC leased line revenue throughout the 1990s.

4) Links include channel terminations (prices not distance sensitive) and inter-office links (prices are distance sensitive). Inter-office link lengths have been standardized based on representative values.

Network Picture



Local Bandwidth Price Indices

Table P3
Local Bandwidth Price Index
(Chained Fisher Ideal from average prices for components)

Year	CT	IO	Over-all
1990	100.0	100.0	100.0
1991	100.9	94.6	98.6
1992	99.2	92.0	96.6
1993	95.9	71.1	85.6
1994	90.8	64.8	79.9
1995	93.4	63.4	80.7
1996	93.3	60.6	79.3
1997	96.8	60.4	81.0
1998	94.1	60.2	79.5
1999	96.9	60.4	81.0
2000	97.6	59.3	80.7

Notes: CT= channel termination bandwidth; IO = inter-office bandwidth. Chain 1999-2000 is Laspeyres index.

Table P4
Price Indices for
Over-all Local Bandwidth
(from component average prices)

	Laspeyres	Paasche	Fisher
1990-1995	86.3	79.4	82.8
1995-1999	101.4	101.3	101.4
1995-2000	100.8		

Indices representative of nominal local bandwidth prices have not fallen in the second half of the 1990s. Such indices declined about 20% in the first half of the 1990s.

Technical Points

1) Intrastate vs. interstate jurisdictional issue (Table 5 in paper). Price trends are not likely to differ by jurisdiction.

2) Volume, zone, and term developments are not controlled in components of indices. Components represent average prices. Bias not clear; better price index might show rise in the second half of the 1990s.

3) Long-haul bandwidth is not captured in Tables P3 and P4, except that local bandwidth is a component of long-haul bandwidth. Anecdotal evidence consistent with stable or rising prices (entry, but also big shift in demand).

4) Transaction prices for bandwidth; doesn't indicate imputed bandwidth prices for new integrated service providers. But integrated service provision is currently relatively unimportant.

Additional Price Data (1)

Table P5
Development of Product Offerings

	Bell Atlantic (South)			U S West		
	1990	1994	1999	1990	1994	1999
price range for 56Kbps DDS offerings	$114 monthly only offering	$60 (rate stability plan) to $110 (monthly)	$60 (rate stability plan) to $120 (monthly)	$30 (5 yr) to $37 (monthly)	$63 (5 yr) to $70 (monthly)	$70 (5 yr) to $88 (monthly)
price range for DS1 offerings	$227 monthly only offering	$165 (5 yr) to $216 (monthly)	$155 (7 yr, all zones) to $260 (monthly, zone 3)	$106 (5 yr) to $132 (monthly)	$101 (5 yr) to $119 (monthly)	$92 (5 yr, zone 1) to $135 (monthly, zone 3)
price range for DS3e offerings	$2,043 (5 yr group of 3) to $4,537 (monthly)	$250[1] (5 yr, cap. 12, grp price $4,500) to $3,670 (monthly)	$252[1] (5 yr, zone 1, cap. 12, grp. price $2520) to $3,222 (monthly, zone 3)	$72[1] (5 yr, cap. 12, grp price $5,554) to $1,255 (monthly)	$65[1] (5 yr, cap. 12, grp price $5,270) to $1,300 (monthly)	$67[1] (5 yr, cap. 12, grp price $5,265) to $1,500 (monthly)

Note: [1]Price for an incremental DS3, given purchase of DS3 group.

Additional Price Data (2)

Table P6
Channel Termination Bandwidth

	Ave. Price Per Mbps				Quantity (Mbps) Sold			
Year	VG	DDS	DS1	DS3	VG	DDS	DS1	DS3
1989					51,467	426	52,723	26,053
1990	300	1,622	123	17.9	39,158	577	66,710	52,611
1991	295	1,592	118	27.5	32,501	820	74,248	98,437
1992	305	1,707	112	24.8	27,040	1,195	78,218	137,417
1993	294	1,637	112	22.3	23,449	1,746	86,320	173,788
1994	299	1,366	102	22.7	21,000	2,502	102,061	214,916
1995	319	1,601	96	24.2	19,226	3,557	129,892	240,320
1996	319	1,444	98	25.3	16,344	4,626	149,762	256,791
1997	320	1,471	102	27.4	14,263	5,517	223,004	321,739
1998	311	1,453	96	28.3	12,579	6,417	294,242	392,783
1999	323	1,488	97	30.5	10,533	6,891	391,389	495,228
2000	320	1,383	99	31.7				

Notes: VG is 64Kbps and 128 Kbps; DDS is 56 Kbps type; DS1 is 1.54 Mbps; DS3 is 44.74 Mbps.

Table P7
Local Inter-Office Bandwidth

	Ave. Price Per Mbps				Quantity (Mbps) Sold			
Year	VG	DDS	DS1	DS3	VG	DDS	DS1	DS3
1989					14,372	332	29,724	11,235
1990	159	2,514	191	16.17	11,555	461	38,788	36,810
1991	156	2,421	174	19.03	10,392	693	47,260	57,309
1992	140	2,092	177	18.07	9,488	1,071	56,305	81,574
1993	121	1,399	136	16.21	8,551	1,583	65,092	114,879
1994	134	971	123	17.95	7,646	2,162	75,856	145,115
1995	140	1,171	114	17.15	6,846	2,843	91,269	176,971
1996	144	900	116	16.53	6,130	4,215	106,542	203,001
1997	138	846	118	16.46	5,493	4,846	156,675	285,119
1998	149	925	114	16.73	4,722	5,384	209,505	391,598
1999	147	942	113	17.49	4,225	5,763	265,800	525,694
2000	143	878	112	17.17				

Notes: VG is 64Kbps and 128 Kbps; DDS is 56 Kbps type; DS1 is 1.54 Mbps; DS3 is 44.74 Mbps.

Comparative International Evidence

1) UK: 64 Kbps national leased line prices constant in nominal terms since 1991; 2 Mbps circuit prices have fallen only slightly since 1995. UK has had significant local facilities based competition since the mid-1980's. UK has been a pioneer in telecom industry restructuring and has an experienced regulator. The UK is looking at ways to address the the poor industry performance it perceives with respect to leased line prices.

2) EU: Leased line pricing studies have not shown dramatic reductions in leased line prices. The Commission of the European Communities has recently issued recommended price ceilings for monthly leased line charges.

3) Bandwidth exchange data for major international routes. These show significant reductions (although prices appear to be stabilizing over the past 6 months). Such data is not representative of prices for bandwidth (very small share of transactions).

Conclusions

1) Bandwidth prices in the first half of the 1990s fell at a rate (3.7% per year) similar to over-all price reductions for broad categories of industrial and electrical equipment (SIC 35 and 36). Bandwidth prices fell much more slowly than "new economy" sectors such as electronic computers, semi-conductors, and related equipment (15-20% per year).

2) Bandwidth prices have fallen more slowly in the second half of the 1990s than in the first half of the 1990s. Changes in bandwidth pricing don't fit into a "new economy" story explaining productivity growth in the second half of the 1990s.

3) Bandwidth prices are not likely to decline rapidly without significant changes in communications industry structure and the nature of bandwidth transactions. More competition of the current sort is not likely to matter. For more detailed analysis, see papers on transforming network interconnection and transport available at http://www.galbithink.org

4) Structural change in the communications industry would change the opportunities and challenges associated with measuring bandwidth prices. Emergence of a geographically comprehensive lattice of carrier-neutral interconnection points would provide a natural platform for trading in differentiated wide-area network services. Such exchanges would produce importance price data for products more narrowly defined geographically but more differentiated in quality and type of service. Local bandwidth connecting to the wide-area network lattice would take many different forms and be provided by many different entities (wireless, cable companies, ISPs, utilities, cooperatives, local governments, etc.). Price of local bandwidth connecting to wide-area network lattice would be difficult to measure. Note reversal of type of data presented here!

Trends in bandwidth prices, and the challenges associated with measuring them, depend heavily on the extent of changes in industry structure.