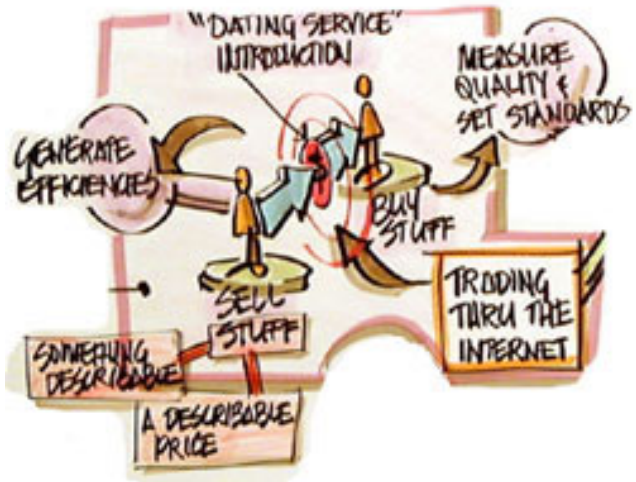

Carnegie Mellon

46-875 Corporate Telecommunications Networks

A Study of the History and Development of Bandwidth Commodity Trading Final

ABSTRACT

There is a market developing for the commodity exchange of bandwidth that has grown out of the private and public interconnection of networks, improvements in infrastructure hardware and software technology, and a growing demand for guaranteed service levels combined with the flexibility of short-term commitments. This is being driven by an increase in the variety, quantity and quality requirements of information being delivered across the Internet and the desire for bandwidth suppliers to generate revenues from idle capacity by connecting with new buyers. However, the incipient bandwidth market has been stymied by the telecommunications economic malaise, an overabundance of capacity, and significant business failures and consolidations.

This paper explores the history and development of the commodity trading of bandwidth. It begins with a look at the precursors to a bandwidth market and examines the environment—technical and economic—necessary for bandwidth trading to occur. This is followed by a detailed description of the actual trading process. The paper concludes with a look at the current state of bandwidth trading and its future in the face of an industry slump and the collapse of some of the pioneers of bandwidth trading.

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Related Web Sites

Company	Web Site
Amerex Energy	http://www.amerexenergy.com/
TFS Telecom	http://www.tfsbrokers.com/bandwidth/
Chapel Hill Broadband	http://www.chbroadband.com/
Arbinet-theexchange	http://www.arbinet.com/
Bandwidth Market	http://www.bandwidthmarket.com/
Band-X	http://www.band-x.com
Competitive Communications Association	http://www.comptel.org
RateXchange	http://www.ratexchange.com

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1 Introduction

There is a market developing for the commodity exchange of bandwidth that has grown out of the private and public interconnection of networks, improvements in infrastructure hardware and software technology, and a growing demand for guaranteed service levels combined with the flexibility of short-term commitments. This is being driven by an increase in the variety, quantity and quality requirements of information being delivered across the Internet and the desire for bandwidth suppliers to generate revenues from idle capacity by connecting with new buyers.

However, the incipient bandwidth market has been stymied by the telecommunications economic malaise, an overabundance of capacity, and significant business failures and consolidations which have altered the industry, its suppliers and its consumers. Despite this, there are sound economic reasons to treat bandwidth as a commodity much like is currently done with electricity and natural gas. A bandwidth market eliminates inefficiencies, lowers transaction costs, provides open and transparent access to all buyers and sellers, allows suppliers to be compensated for their contribution to delivering bandwidth, and reduces buyer and seller risks through the development of standardized contracts, financial derivatives and a market for resale.

This paper explores the history and development of the commodity trading of bandwidth. It begins with a look at the precursors and contributors to a bandwidth market such as the rapid growth of the Internet and changes in the structure of telecommunications providers. It examines the environment—both technical and economic—for bandwidth trading to occur and how bandwidth behaves in comparison to other commodities. This is followed by a detailed description of the actual trading process from both an internal perspective (trading infrastructure and technology) and external perspective (buyers, sellers, contracts and options). The paper concludes with a look at the current industry slump and the collapse of some of the pioneers of bandwidth trading, and prognosticates on the future of the bandwidth market in the face of these setbacks.

2 The Precursors

The roots of bandwidth trading as a commodity can be traced through several telecommunications industry developments that have taken place over the past 10 years. This chapter briefly goes through some of the significant developments to establish an industry perspective.

2.1 Growth of the Internet

There are currently about 200 million hosts and 800 million users on the Internet [33]. The United States alone boasts of as many as 100 million online users. The explosive growth of the Internet has created a huge market for the bandwidth required to sustain this growth.

In the US, this growth curve has plateaued over the recent past, the popular conception being that Internet penetration is reaching saturation in North America. However, it is still growing rapidly in other parts of the world, such as South America and Asia. Overall, the growth has slowed to "only" a doubling of demand every 11 months.

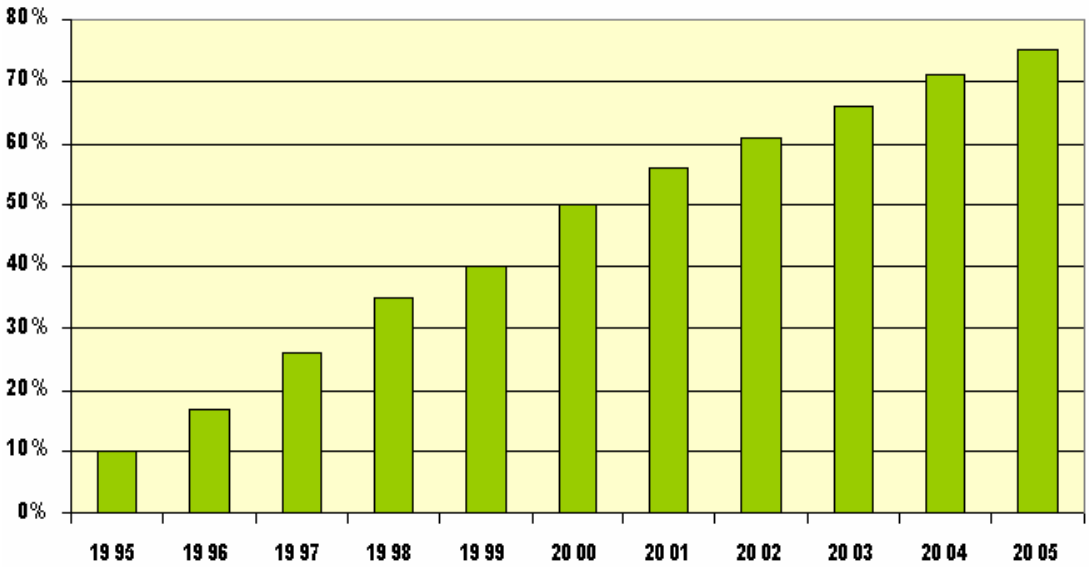


Figure 2-1: US Internet Usage as a Percentage of Population [8]

2.2 The Telecom Industry Structure

After the divestiture of AT&T in 1984, the structure of the telecommunications industry became compartmentalized. The parent company was broken up and it spun off parts of Western Electric (its equipment manufacturing arm) and several of the 22 regional Bell telephone companies. At the same time AT&T's regulated monopoly was discontinued, and new entrants were allowed to enter the telecommunications industry. A tiered structure was introduced to allow the entrants and the incumbents to compete in a fair and open market.

2.2.1 Local Exchange Carriers (LEC)

These companies provide the phone lines to the end-user. An LEC was defined as "any entity that is engaged in the provision of telephone exchange service or exchange access." It handles calls that originate and terminate within the local area and connects other calls to the Inter-Exchange Carriers via Toll-Offices. Examples are GTE, SNET, Frontier (competitive LECs), NYNEX, BellAtlantic, BellSouth (incumbent LECs). The LECs control one of the

significant "last mile" pipes to consumers—the phone line—and therefore affect the bandwidth available and, indirectly, the bandwidth demanded by consumers through the types of bandwidth-appropriate applications.

2.2.2 Inter-Exchange Carriers (IEC)

Inter-exchange carriers are the long distance providers that take calls originating from one LEC and transport it for connection to a caller outside the local area. The interface between the IEC and the LEC is the Inter-Exchange Carrier Toll Office. Companies such as AT&T, MCI, Sprint and Worldcom fall into this category.

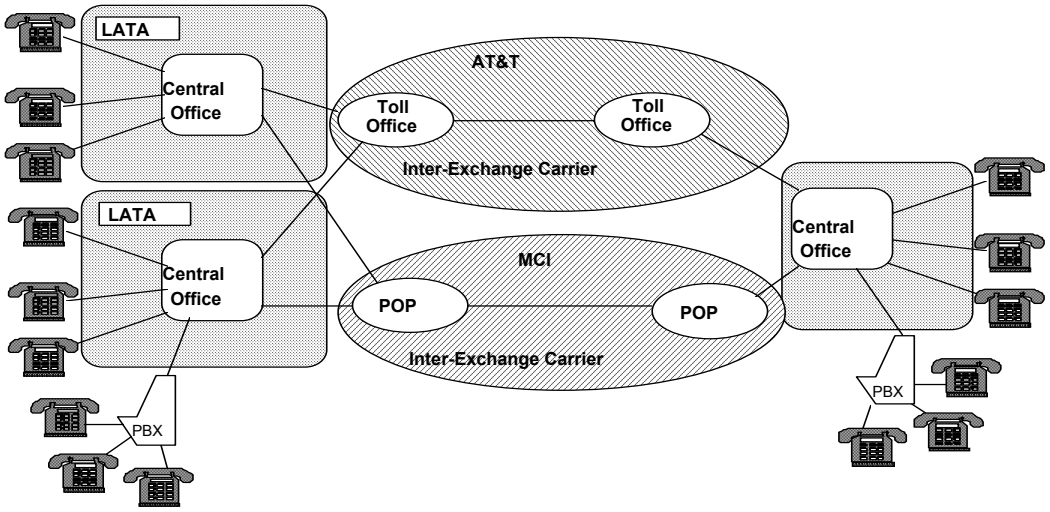


Figure 2-2: Telephone Network After Divestiture [30]

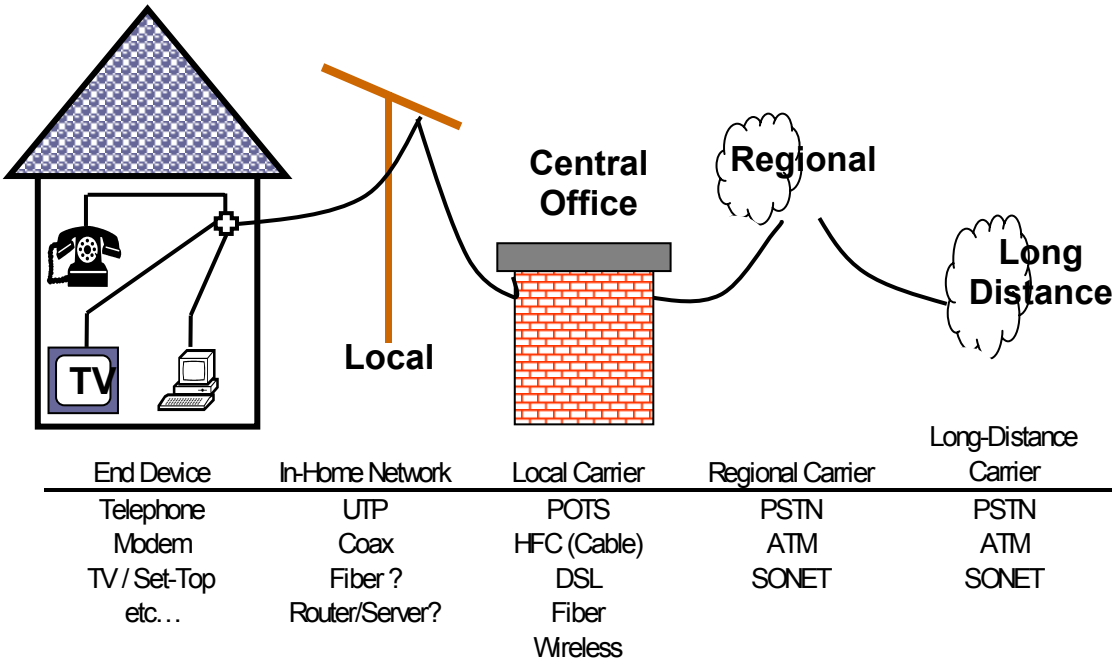
The inter-exchange carriers are the largest suppliers of bandwidth with large investments in equipment and networks. Current underutilization of these resources makes bandwidth trading an attractive means of generating revenue from these idle assets.

2.2.3 Equipment Manufacturers

These companies produce and sell hardware and software that is used by the other telecommunication industries. The term "telecommunications equipment" means equipment, other than customer premises equipment, used by a carrier to provide telecommunications services, and includes software integral to such equipment (including upgrades). Cisco, Lucent and Hewlett-Packard are such companies. These equipment manufacturers provide the hardware such as digital cross connects and switches that are necessary to create the pooling points used in bandwidth trading.

2.2.4 Enhanced Service Providers

The term "telecommunications service" means the offering of telecommunications for a fee directly to the public, or to such classes of users as to be effectively available directly to the public. Thus enhanced service providers would encompass all service providers that offer some service besides basic telephone service (for example Internet Service). AOL, and MSN are some companies that are in this section of the market.



End Device	In-Home Network	Local Carrier	Regional Carrier	Long-Distance Carrier
Telephone	UTP	POTS	PSTN	PSTN
Modem	Coax	HFC (Cable)	ATM	ATM
TV / Set-Top	Fiber ?	DSL	SONET	SONET
etc…	Router/Server?	Fiber		
		Wireless		

Figure 2-3: Supply-Chain Architecture of the Telecommunication Network [4]

Enhanced service providers represent some of the largest consumers of bandwidth. A bandwidth market increases the flexibility these providers have in obtaining bandwidth and responding to changes in demand.

2.2.5 Information Providers

The term "information service" means the offering of a capability for generating, acquiring, storing, transforming, processing, retrieving, utilizing, or making available information via telecommunications, including electronic publishing, but does not include any use of any such capability for the management, control, or operation of a telecommunications system or the management of a telecommunications service. These providers also represent potential buyers in a bandwidth market.

2.3 The Build-Out

Starting in the late 1980s and accelerating with the deregulation of the telecommunications industry under the federal Telecommunications Act of 1996, non-traditional companies entered the telecom business seeking to maximize their assets and opportunities. These included railroads (Southern Pacific-Qwest), pipelines and other energy companies (Williams and Enron) and construction companies (Level 3 and 360networks). These companies rushed to lay fiber optic cable along railroad and pipeline rights of way. All were chasing after the opportunity to offer bandwidth to the rapidly growing user base of the Internet and the potential to grab a piece of the lucrative voice traffic from the inter-exchange carriers established carriers. [37]

Simultaneously, the telecommunications industry was undergoing its own changes. The industry was previously compartmentalized after government intervention but there were advantages to companies that were highly integrated and could offer a portfolio of many services, as well as benefit from economies of scale. This led to mergers and consolidation between many of the smaller companies that emerged following the breakup of AT&T—at least to the extent allowed by the FCC. These companies also continued to develop their networks.

One measure of the phenomenal growth of both non-traditional entrants and incumbent companies is the massive increase in the purchase of hardware to support the growing networks. For instance, the DWDM (dense wavelength division multiplexing) systems market (equipment provider) increased from $4.2 billion in 1999 to $8.9 billion in 2000. The use of such technology also dramatically increased the capacity of existing fiber.

The telecom industry was growing more than twice as fast as the rest of the US economy, generating nearly $518 billion in 1999 spending, nearly $100 billion more than in 1997. See, for example, the growth in US spending on telecommunications equipment in Figure 2-4.

By the fourth quarter of 1999, competitive local exchange carriers (CLECs) accounted for 5 percent of local lines, up from 2.8 percent a year earlier. There were 158 CLECs with numbering codes necessary to operate their own switches in mid-1999 compared with only 20 in 1996.

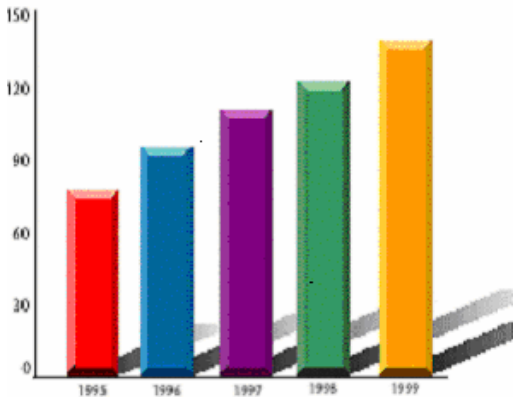


Figure 2-4: US Spending on Telecom Equipment (US$B) [32]

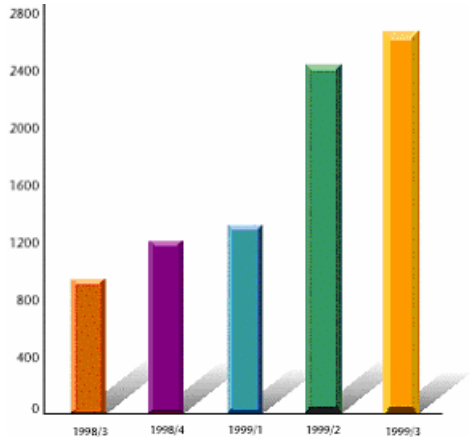


Figure 2-5: Venture Capital Investment in Communications (US$M) [32]

2.4 Excess Capacity

Technological advances and over-provisioning of bandwidth by carriers led to excess telecommunication capacity. It is estimated that much less than 10 percent of all fiber-optic capacity is currently being used. Consequently telecom companies have been cutting prices to maintain market share in a desperate struggle to drive their rivals to the wall.

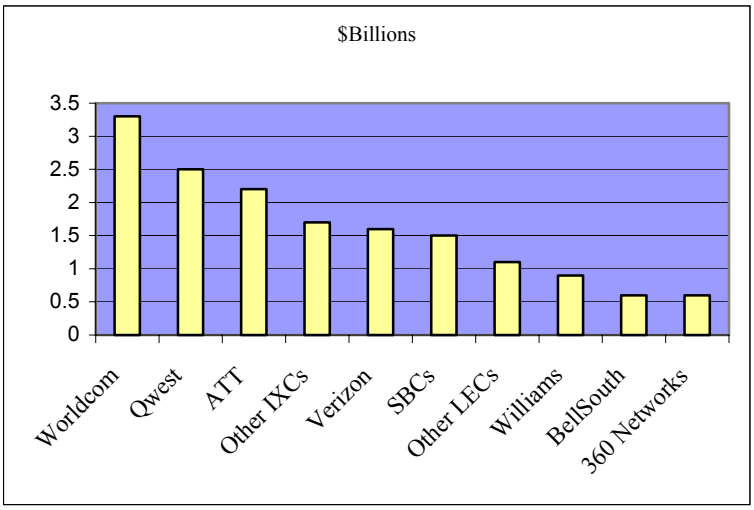


Figure 2-6: US Investment in the DWDM Optical Fiber Market [38]

It takes a relatively long time to build a new fiber network and many months to put a new long distance conduit in place. However once the conduit is in place new fibers can be pulled through (added) quite quickly, say, in a few weeks. Also conduits can house dark fiber (cable without the equipment necessary for transmission). In addition with multimode fiber and DWDM more wavelengths can be added to those already present in a lit fiber. This led to a tendency for telecommunication carrier companies to over-provision capacity. This fiber can easily be 'lit' to meet the future consumer demand for bandwidth.

2.5 Inter-Carrier Connectivity

The monopolistic nature of the industry made peering agreements hard to come by for most carriers. There was inherent reluctance on the part of LECs to carry calls originating from the networks of competitors.

2.6 Legislation

The government has been actively involved in telecommunication right from the 1970s through divestiture of AT&T in the 1980s to the present.

After the Telecommunications Act of 1996, the FCC introduced several reforms to ensure interconnectivity between telecommunication carriers. As per these legislations, the CLECs were allowed to purchase "unbundled network elements" from the ILECs and provision was made for collocation of their equipment at the premises of the ILECs. The rates for these settlements were also regulated using a "cost-based pricing methodology based on forward-looking economic costs" so to ensure "dynamic competitive markets."

In 2000, under pressure from several smaller (Tier 2 and Tier 3) companies, the FCC and the ITU intervened, and eventually, larger Tier 1 ISPs were compelled to publish their peering requirements.

In 2001, the FCC issued the Notice of Proposed Rulemaking (NPRM) regarding the concept of a unified inter-carrier compensation regime. Inter-carrier compensation includes both reciprocal compensation and access charges. This is considered a precursor to the trading of bandwidth in an open and deregulated market.

3 Bandwidth as a Commodity

Though bandwidth contracts are common between all telecommunication companies, the nature of these contracts has traditionally been negotiated bilaterally behind closed-door between lawyers of both companies, rather than in an open market. This is beginning to change slowly, although the transformation of bandwidth into commodity is not yet been fully accomplished.

3.1 Peering, Carrying and Transaction Agreements

Peering is usually a bilateral business and technical arrangement, where two providers agree to accept traffic from one another, and from one another's customers (and thus from their customers' customers). Peering does not include the obligation to carry traffic to third parties. Peering thus offers a provider access only to a single provider's customers. Peering is done on a bill-and-keep basis, without cash payments, where both parties perceive roughly equal exchange of value; and there is often an element of barter. Peering agreements tend to be restricted to large Tier 1 ISPs such as AT&T, MCI/Worldcom (UUNet), Sprint, PSI, C&W, Microsoft, as well as, NASA, DoD, DoE, NAS, and other government agencies. Due to their large size and dominant position in the market, these companies enjoyed low cost of inter-connection with other networks.

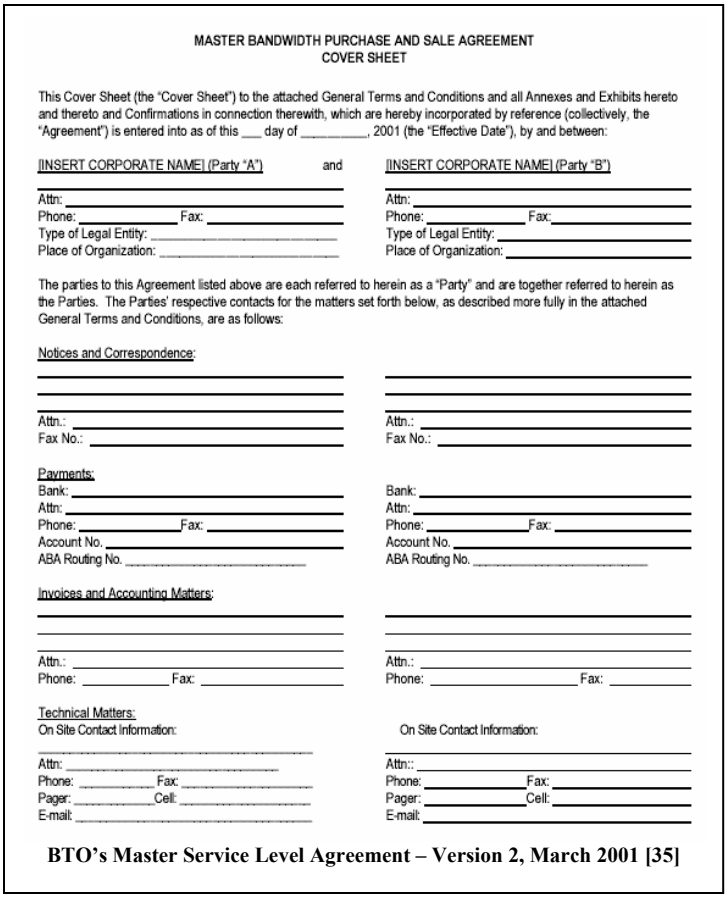
By February 2001, the traditional market had started to use OTC brokers or online line exchanges as third-party intermediaries, whereas few wholesale carriers would have considered the use of a commodity broker to help them purchase and sell bandwidth even a year ago. Prior to this, it was a market in which deals were struck between companies directly, usually with the one or two preferred providers. The deals were done on a best-effort basis without any guarantee of firm delivery or assured quality of service.

3.2 Development of Standardized Contracts

The capacity trading market is gaining momentum, particularly in the US, where it is being led by some familiar names from the energy markets. Efforts have been made to develop a platform for such trading characterized by transactions using a "standardized master agreement" that guarantees firm delivery and a standard quality of service with liquidated damages for failing to deliver. A standard contract stimulates the bandwidth market by allowing for price transparency, clearing and settlement, accountability for non-performance and quality consistency. It was seen as the replacement for the rigid, long-term, price-fixed contracts of the past.

A committee–consisting of members of the Competitive Telecommunications Association (www.comptel.org) and members of the Bandwidth Trade Organization (BTO)–worked to create a standardized contractual agreement between industry representatives. The Master Bandwidth Purchase and Sales Agreement is fruit of this work and is the most widely used standard contract today, however, many trades are still conducted under bilateral customized agreements.

The volume of these transactions was increasing; there were over 580 transactions completed by Enron Broadband Services (the industry leader and



MASTER BANDWIDTH PURCHASE AND SALE AGREEMENT
COVER SHEET

This Cover Sheet (the "Cover Sheet") to the attached General Terms and Conditions and all Annexes and Exhibits hereto and thereto and Confirmations in connection therewith, which are hereby incorporated by reference (collectively, the "Agreement") is entered into as of this ___ day of _____, 2001 (the "Effective Date"), by and between:

[INSERT CORPORATE NAME] (Party "A") and [INSERT CORPORATE NAME] (Party "B")

Attn: Attn:
Phone: Fax: Phone: Fax:
Type of Legal Entity: Type of Legal Entity:
Place of Organization: Place of Organization:

The parties to this Agreement listed above are each referred to herein as a "Party" and are together referred to herein as the Parties. The Parties' respective contacts for the matters set forth below, as described more fully in the attached General Terms and Conditions, are as follows:

Notices and Correspondence:

Attn.: Attn.:
Fax No.: Fax No.:

Payments:
Bank: Bank:
Attn: Attn:
Phone: Fax: Phone: Fax:
Account No. Account No.
ABA Routing No. ABA Routing No.

Invoices and Accounting Matters:

Attn.: Attn.:
Phone: Fax: Phone: Fax:

Technical Matters:
On Site Contact Information: On Site Contact Information:

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Pager: Cell: Pager: Cell:
E-mail: E-mail:

BTO's Master Service Level Agreement – Version 2, March 2001 [35]

proponent of the BTO) in the first quarter of 2001, which was more than the entire volume traded in 2000 [29]. Some option markets based on the underlying physical marketplace were also developed (An option is a contract that allows the holder the right but not the obligation to exercise that contract–a contract that allows the holder to buy or sell a commodity at a pre-determined time in the future for an agreed price.) Transactions were being executed quickly and efficiently over the course of a few phone calls, some were even concluded in one call.

3.3 Trading Issues

In spite of these developments in the bandwidth trading industry, transforming it from a pricey necessity into a competitive, readily accessible commodity is still very much in the nascent stages. There are several issues of concern that are still not adequately addressed by current market conditions.

3.3.1 Contracts and Pricing

The current nature of agreements between telecommunication companies usually involves a single contract price without individual components. This does not reflect the price of the individual components that are being traded. There are deal-specific terms and conditions restrict the applicability of portions of one contract in another situation. The long-term deals reduce the flexibility of buyers to adapt to changing market conditions. Over-provisioning has been a major outcome of this. The bilateral nature of the contracts means that they cannot be traded openly. Another issue is the high costs in SG&A that are associated with such contracts.

3.3.2 Fairness

Fairness is compromised because of the lack of anonymity. On the whole, the larger carriers are favored, because of the importance of reputation and negotiating power. Large carriers are unwilling to negotiate with smaller buyers, as they do not perceive any direct benefits from the deal. Though the regulatory bodies have attempted to mitigate this effect by trying to enforce openly published peering agreements, smaller buyers are still fear that they may not receive adequate quality of service.

3.3.3 Uncertainty

The issue of high interdependence is also a cause for concern. If one of the parties in the agreement reneges on its contractual obligations, the other party may be severely affected. There is no scope for re-provisioning the bandwidth required within a short period of time.

For example, in June 2001, internetnews.com [20] reported that Cable and Wireless (C&W) had cancelled its peering agreement with PSINet. According to the spokesperson for C&W, PSINet was “failing to meet the requirements of the contract between the two companies.” He said that each of C&W's peering partners must meet three requirements: they must have an OC-48 backbone, be able to maintain an exchange ratio of 2 to 1, and have nodes in nine regions. The exchange ratio with PSINet had apparently dropped to 3 to 1, which made C&W discontinue the peering. It was widely rumored that PSINet’s filing for bankruptcy protection at the time was the real cause, though the agreement was re-established within a couple of days.

3.3.4 Setup Time

Currently, trade agreements require months to implement. Bandwidth cannot be provided on a real-time basis as may be needed by some buyers. Complex contracts where every detail, either technical or of legal nature may be negotiated until an agreement is reached lead to a long setup time.

3.3.5 Market

The market is scattered and this hinders efficient price discovery. There are significant inefficiencies introduced by large search costs for discovering buyers, sellers and the market price for a certain service. The buyer risks paying too much and the seller risks charging too little for bandwidth. The absence of a centralized spot for trading means that market factors are often not accounted for when the trade is being made.

3.4 Taxonomy of Bandwidth Trading

This paper adopts the taxonomy proposed by Mindel and Sirbu, in the "Taxonomy of Traded Bandwidth." This classification divides the possible forms of bandwidth exchanges into 5 distinct components based on the infrastructure required for physical delivery of each bandwidth type. In this discussion, the term "pooling point" refers to the physical interconnection point used in the trading market.

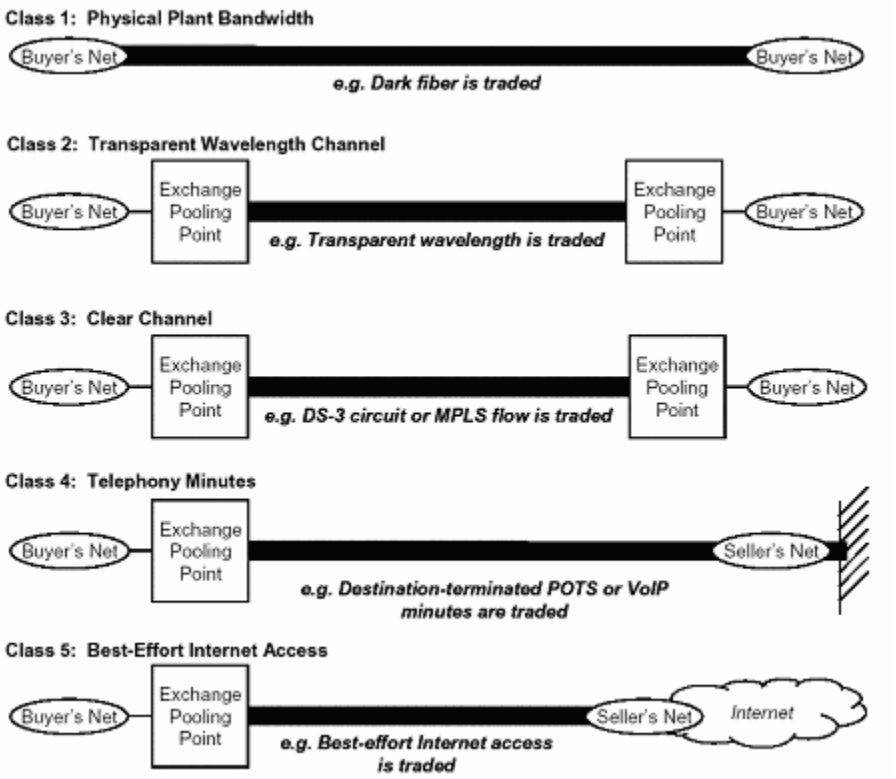

Figure 3-1: Taxonomy of Traded Bandwidth [18]

Enabling Bandwidth Class 0	In this trade, bandwidth is not actually traded. However commodities and services that are requisite for bandwidth are traded. These would include conduits, and locations for positioning transmission equipment.
Dark Fiber Class 1	This refers to the trade of the raw medium, such as dark fiber, or electromagnetic spectrum.
Wavelength Class 2	This refers to the trade of lit fiber, which is communication channel between a pair of pooling points (minus the specific transmission parameters involved), for example LightPaths, or a transponder for satellite links.

Clear Channel Class 3	This is also a trade of a digital communication channel between pooling points. The difference is that transmission parameters (throughput rate and frame format) are also bundled in the traded bandwidth. The service guarantees may be hard, statistical or best effort.
Switched Circuit Class 4	This is a trade of circuit-switched telephony that the seller agrees to route through its network. Typically there is a single pooling point at which the two networks interconnect.
Internet Access Class 5	This is a best-effort IP access to the Internet that is routed through the seller's network (again typically through a single pooling point).

The discussion of bandwidth trading as a commodity concentrates primarily on markets that are in Class 3 and 4 of the taxonomy. These are markets where the free-market trade of bandwidth has significant potential to grow and mature. In Class 5 markets, the impending entry of Quality of Service (QoS) into IP networks may introduce a market for bandwidth trading as a commodity.

3.5 Requirements for Bandwidth Trading

3.5.1 Transparent Centralized Market

The current market in which bandwidth is traded is neither transparent, nor centralized. (Centralization does not necessarily mean a single exchange exists, but that there are centralized exchanges which host the capacity from a number of suppliers much as there are different stock exchanges for the stock of many companies.) Both these attributes are necessary for all participants in the market to see a list of offers from different providers. In this scenario, the providers themselves may not be visible at all (an anonymous market). This is a public market open to anyone who has registered and is legally entitled to trade goods, providers, consumers of bandwidth, and speculators alike. It provides increased liquidity, the ability to develop risk-management instruments, transparent and competitive pricing and simplified charging, which is markedly different when compared to financial settlements in public and private network connectivity.

Arbitrage is defined as "the making of profit with no risk at a rate higher than the risk-free interest rate (e.g. of government bonds)" [7]. A transparent and centralized market prevents "arbitrage pricing."

3.5.2 Real-time Provisioning

Real-time provisioning implies the ability for buyers and sellers to negotiate and arrive at a settlement relatively quickly. In the current market situation, contracts usually take in the order of several months to chalk out due to legal and technical complications. However, for bandwidth to be effectively traded in the market as a commodity the supply time of bandwidth should be reduced to the order of hours or at most a few days–if this is not the case, the impact of market forces is difficult to assess.

3.5.3 Interconnection Standardization

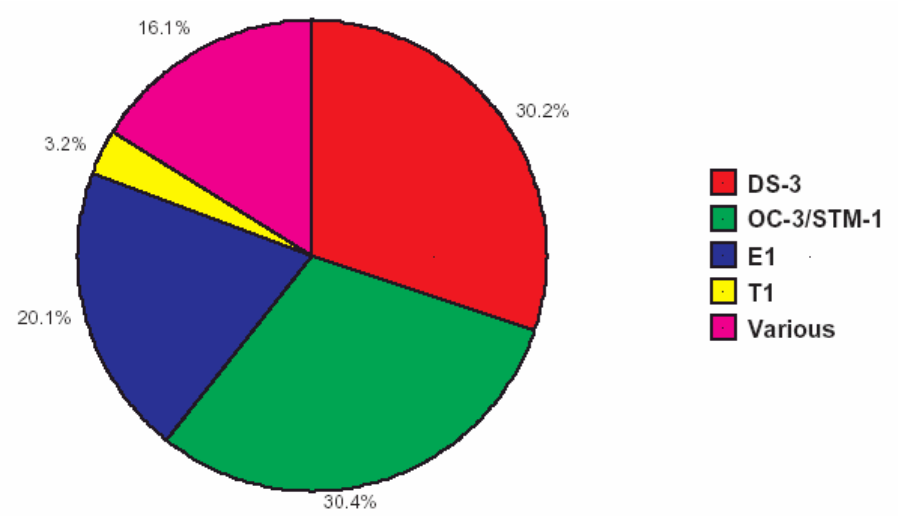

Figure 3-2: Over-the-counter Offers for Bandwidth Sale on RateXchange and Band-X on Dec 18, 1999 [7]

Figure 3-2 shows the relative volume of DS-3, OC-3/STM-1, E1 and T1 offers collected from the web sites of two well-known bandwidth trading sites. As can be seen the majority of the offers are DS-3 and OC-3/STM-1. This convergence is an encouraging sign for bandwidth 'commoditization'. Convergence to a particular standard makes comparison of offers easy in the market and brings about easy and seamless interconnection of networks.

3.5.4 Derivatives and Risk Management

Risk arises from the fact that market prices and liquidity vary, so a path contract's price and availability is also subject to change. Three risk factors from [7] are directly relevant to our discussion:

Price (Market) Risk is the risk associated with the change in value of a trader's positions caused by changes in market supply and demand.

Liquidity Risk stems from the lack of marketability of a contract at the current market price and is usually reflected in large price movements in response to any attempt to buy or sell.

Quality Risk is a side-effect of the lack of fully standardized contracts. In a market where quality is important yet not always well-defined, measurable or comparable, sellers may ask for widely varied prices, on the grounds of brand reputation or simply taking advantage of incomplete information on the buyers' side.

All three of the risk factors are interrelated and therefore not always distinct. For example, liquidity risk affects the price at which the liquidation of a large position could take place, while contract standardization would eliminate quality risk and reduce liquidity risk. The firm price quotes which first appeared in 2001 on the Enron Online website held the promise to mitigate both liquidity and quality risk, since Enron had offered to act not only as a broker, but also as a market-maker, buying form any supplier at exactly the publicly quoted prices. However, even after the appearance of some firm quotes, many trades were still conducted over the counter.

3.6 Comparison with Other Commodities

Much can be discovered about bandwidth trading—market dynamics, required infrastructure, problems and limitations—by comparing it to trading in two other commodities: electricity and natural gas. In addition to providing a useful contrast, these two markets offer lessons in management and regulation that can shape the development bandwidth market and offer a glimpse into its future.

3.6.1 Storability and Transportability

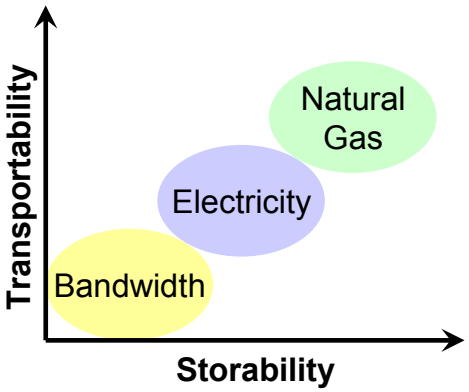

Figure 3-3: Commodity Transportability and Storability

Bandwidth, electricity and natural gas differ primarily along two dimensions: storability and transportability. A commodity is considered storable if it persists over time yet still remains tradable. Storable commodities allow the creation of inventories to smooth supply and demand fluctuations. A commodity is transportable to the extent that it can be moved from one location to another and remains tradable. Gold is, for example, both highly transportable and highly storable. A right of way along a segment of railway is neither transportable nor storable: it cannot be moved and the "right" at any moment in time vanishes if it is not used.

Natural gas has the highest level of storability and transportability among the three commodities considered, but it is still below that of a commodity such as gold. Natural gas can be moved from one part of the country to another, but is largely constrained by the topology and carrying capacity of the pipeline network. The ability to store natural gas and to transport it through alternative (albeit less efficient) means mitigates some of the network constraints.

On the other hand, electricity is not storable (at least not on the scale being considered here), but, the raw materials used in generation are. Generation capabilities can also be brought online as necessary beginning with the most cost-efficient, which provides a degree of flexibility in managing supply. When considered together, this provides a level of storability below natural gas. Transportability is also more restricted than natural gas. Electricity can be moved from one location to another, but it is bound to the topology and capacity limits of the transmission network.

Bandwidth is defined entirely by the topology and capacity of its network. The network is not the medium for distribution of a commodity as it is with electricity and natural gas, but is the commodity itself. As such, it is not transportable: bandwidth cannot be moved outside the confines of its physical media. Nor is it storable: a unit of bandwidth that is not used in the time it exists is lost forever.

Natural gas, electricity and bandwidth share another common characteristic: local monopolies of consumer distribution networks. All three are undergoing similar separation of the competitive components that are the subject of trade and the monopoly access components.

3.6.2 Market Dynamics

Differences in storability and transportability contribute to different market dynamics. Commodities with low degrees of storability and transportability typically develop into markets with the following characteristics [22]:

- High price volatility
- Brokered instead of exchange-style transactions
- Expensive and illiquid risk management instruments.

These characteristics are not, however, necessary or inevitable. It is certainly possible to alter market dynamics through the introduction of infrastructure that relaxes transportability and storability constraints. But there are other factors that contribute to the style of market that develops. A commodity with many supplier and buyers works to counter the above characteristics. The evolution of electricity pricing and an electricity trading market offers an example of altering market dynamics with its origin in industry deregulation and government rulings requiring open access to transmission systems in 1996 [15].

Prior to restructuring, electricity pricing was based on a contract path between small local zones. The rate reflected a "fictional transmission path agreed upon by transaction participants. However, contract path pricing does not reflect actual power flows through the transmission grid, including loop and parallel path flows." [36] This pricing strategy was required in part because the transmission system was not equipped with devices that could provide exact power flow control between facilities. This pricing did not consider (or compensate) the actual transmission facilities used and ignored congestion and capacity limits that might make delivery of the contracted electricity

impossible. In terms of the bandwidth market, this pricing strategy was equivalent the flat rate most consumers pay for the best-effort routed delivery of data between a source and destination across the Internet. The fact that much of the Internet infrastructure lacks the ability for dynamic re-provisioning and QoS guarantees is analogous to the flow control problems of the electric transmission grid.

Contract path pricing has since evolved into flow-based pricing due to improvements in both the infrastructure and the creation of trading platforms that can manage complex transactions. Flow-based pricing incorporates many factors in determining the cost of a transaction including the megawatts of electricity, the distance traveled, the parallel paths used to deliver the electricity, the actual transmission facilities used on a hop-by-hop basis, and loops. Such pricing allows all suppliers to the production and delivery of electricity to be compensated. The commodity is no longer electricity, but the pattern that describes its source, destination, timing and delivery. The agreement is the fundamental unit of trade and upon this is built derivatives for managing risk.

By analogy, flow-based pricing is similar to a virtual circuit (such as that created with MPLS) along a specific path with a contracted quality of service. The mapping between the price of a contract and the components that provide the service are evolving just as it did in the electric industry due to improvements in the infrastructure and the creation of efficient platforms for handling complex transactions.

4 Bandwidth Trading

There are a number of companies with a vested interest in bandwidth exchange that could create an environment for trading. The largest service providers and consumers of bandwidth could, for example, band together and improve the efficiency and consistency of bandwidth exchanges. This has not happened.

Instead, the industry has seen the development of third-party brokers such as Enron and Dynegy, RateXchange and Band-X. These companies have developed the platforms, infrastructure and financial instruments necessary to support bandwidth commodity trading.

Enron claims it conducted the first commodity bandwidth trade in December 1999 (see the actual press release at right). However, this is disputed by other companies including Telephone.com and Global TeleExchange (both of which are now defunct), Band-X and RateXchange which all claim to have conducted the "official" milestone trade sometime between 1997 and 2000. All claims aside, the timing establishes the beginnings of the bandwidth trading market.

Press Release

Enron Communications Announces First Commodity Bandwidth Trade
For Immediate Release: Thursday, Dec. 2, 1999

HOUSTON – Enron Communications, Inc., a wholly-owned subsidiary of Enron Corp. and a leader in the delivery of high-bandwidth application services, announced today the first forward trade of bandwidth.

"This is 'Day One' of a potentially enormous market," said Jeff Skilling, Enron president and chief operating officer. "Most companies that need bandwidth today are only able to secure inflexible multi-year deals for pre-set amounts of capacity – just like oil contracts in the 1970s, natural gas contracts prior to 1990 and electric power contracts prior to 1994. As was the case in those industries, the market structure for bandwidth is currently inefficient and expensive. We are demonstrating that bandwidth can be traded under flexible market-based contract structures with the assurance that quality standards are in place and monitored real-time by the buyer and seller."

The trade will result in a monthly incremental contract for DS-3 bandwidth between New York and Los Angeles that can move data at about 45 megabits per second—a speed that allows the transmission of streaming video and other bandwidth-intensive applications.

The seller in the transaction will be Global Crossing, a worldwide leader in the construction and operation of high capacity telecommunications networks.

"We are excited to be a part of this new concept. As a large-scale builder of network infrastructure, we are always interested in developing new, creative ways to bring bandwidth to market. We congratulate Enron on their leadership, and look forward to working with them," said Jon Tingley, president of Global Crossing Services.

4.1 Types of Trades

Brokers facilitate transactions in wavelengths, dark fiber and ducts that can be traded as point-to-point or multipoint connection under lease or indefeasible right of use contract terms [1]. These types of trades represent the standardization and automation of the exchanges that were previously conducted privately between two parties. The trading platforms provided by bandwidth brokers provide anonymity, price transparency and efficient matching of buyers and sellers. They do not, however, change the fundamental nature of these trades. The contracts are still long-term commitments with limited risk management options. The brokers are not involved in the bandwidth exchange once it has been completed. The true value of bandwidth brokers lies in managing trades of clear channel capacity, switch minutes, and Internet access. These trades represent bandwidth as a true commodity. In terms of the taxonomy presented in [18], commodity bandwidth trading occurs in classes 3-5 and facilitated traditional bandwidth exchange occurs in classes 0-2. The remainder of this section focuses on the commodity classes.

4.2 Anatomy of a Bandwidth Broker

There are three components necessary to effectively conduct commodity trades in bandwidth: pooling points, a trading infrastructure and mechanisms for managing risk. Bandwidth brokers such as RateXchange and Enron provide all three. Some provide only one or two components. For example, LightTrade, only provides pooling points and rely on other over-the-counter brokers such as Amerex to conduct trading. Companies earn revenue through connection fees to pooling points and through commissions on trades.

There is obviously much information to be gleaned from the buy and sell orders and contracts executed, and from the circuits setup and the quality of service provided. This mandates real (or designed) neutrality in providing bandwidth brokerage. Some companies, like LightTrade and Band-X, are truly neutral third parties with no networks of their own. Others like Enron have their own broadband network that directly competes with service providers using its trading platform. These companies therefore must design neutrality into their organizations. In the case of Enron, this was done through two wholly owned subsidiaries: Enron Communications and Enron Broadband Services. The need for neutrality may be one of the reasons most major bandwidth suppliers

4.2.1 Interconnections and Pooling Points

Pooling points are hubs where buyers and sellers connect their networks so that they can participate in bandwidth exchanges. They are frequently located in metropolitan areas (such as New York and London) where trading participants are already likely to have high-speed, high-capacity loops. Consider, for example, Figure 4-1 which shows the pooling points established by LightTrade at the end of 2001. With a single fiber connection to a pooling point, a bandwidth consumer has access to circuits from many different providers. Likewise, a service provider has access to many different consumers. Companies charge a connection fee for anyone connecting to a pooling point.

Figure 4-1: LighTrade Pooling Points in 2001

Each pooling point contains secure, managed space with digital cross connects and monitoring systems. Pooling points are interconnected either with a private network or an overlay network through other service providers and also include connections with the trading infrastructure described in the next section. How a buyer or seller connects to a pooling point depends on the class of bandwidth involved. For example, Band-X requires a Gigabit Ethernet connection to one of its pooling points to participate in Internet access exchanges.

The cross connects in the pooling point can be dynamically programmed to connect bandwidth providers and consumers by creating virtual private networks that isolates the traffic of the interested parties and provides security. They also provide the means to monitor the quality of service on established connections and to enforce service level agreements as part of a traded contract. When true QoS guarantees are not available such as the case of Internet access, the pooling point must still provide hardware to monitor the overall quality of the service being supplied. For example, Band-X dedicates one server to each Internet service provider to monitor traffic across the service provider's network. The servers collect information on throughput, latency, hop count and packet loss to a wide range of Internet hosts to ensure the service provider delivers an agreed upon service.

Redundancy and backup systems are necessary components to deliver the reliability needed by trading participants. However, it should also be recognized that, despite any local reliability, connecting to and depending on a single pooling point represents a single point of failure for both a consumer and provider of bandwidth. For this reason, it is not uncommon for participants to connect to multiple pooling points. The connection fees are typically low enough (for example, Enron's were capped at $1000 for capacities from DS-3 to OC-48) to make this cost-effective.

4.2.2 Trading Infrastructure

While a broker handling over-the-counter transactions in bandwidth does represent a form of trading infrastructure, it is not the type of infrastructure necessary to support commodity trades in bandwidth. Rather, a trading infrastructure consists of an electronic exchange with a trading interface for buyers and sellers, integration with

financial systems for settling trades, and integration with the pooling points to reprovision circuits and monitor the compliance with the terms of a trade.

The electronic exchange must provide price transparency and accurate market information. In addition, it is desirable to provide data and price aggregation information such that point-to-point bandwidth can be viewed irrespective of the multiple contributing service providers and pooling points. The platform interface should provide historical and trending information as well as appropriate indexes for categories bandwidth and common routes. The exchange must be capable of matching buy and sell orders that include many more criteria than a typical commodity trade. An order for bandwidth includes the following:

- Source and Destination Locations and Pooling Points
- Capacity (DS-0, DS-1, OC-1, OC-3, etc.)
- Availability Date and Term of Contract
- Contract or Standard Agreement Type
- Price or Monthly Recurring Cost (MRC)

An example of a trading platform is shown in Figure 4-2. Both buyers and sellers have access to the same market information, not unlike the environments provided by online brokerages like E*Trade and Datek.

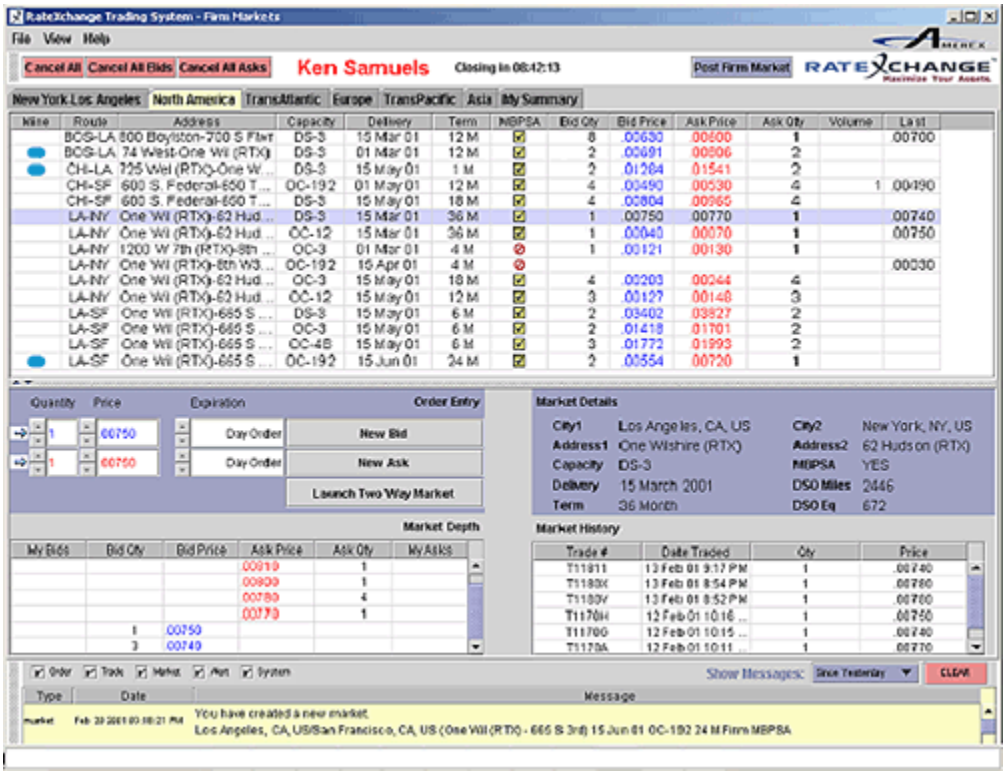

Figure 4-2: Bandwidth Trading Interface for RateXchange

The need for an electronic exchange and trading platform partly explains the emergence of energy trading companies such as Duke Energy, Dynegy, El Paso and Enron as major players in bandwidth market: they have the experience and basic software systems and integration with financial systems upon which to build bandwidth trading platforms.

Integration with financial systems is necessary to ensure the creditworthiness of participants and to quickly settle trades while maintaining anonymity of interested parties. Anonymity is a key feature of the trading infrastructure and a major advantage of using a bandwidth broker to carry out the transaction. A bandwidth supplier is more willing to supply capacity at prices below their retail price list because doing so does not cannibalize or compromise their retail pricing structure. Suppliers are also more likely to allow quality and performance data to be published as part of an offer when it cannot be traced back to the supplier.

Integration with the pooling point monitoring and management systems is necessary to connect buyers and suppliers circuits at the necessary pooling points and to set the quality of service parameters according to the terms of the contract. This level of integration is also necessary to monitor the exchange complies with the terms of the trade.

4.2.3 Contract Guarantees and Risk Management Instruments

The last component of a bandwidth brokering is mechanisms for guaranteeing contracts and managing risk. Buyers and sellers need to be reassured that not only will the contract terms be met, but that the broker carrying out the terms of the contract has the credibility to enact and enforce the terms. This is partly based on intangibles such as reputation and experience, but given the dismal state of many bandwidth brokers, assurance also requires that the broker be financially viable and have an infrastructure in place to monitor and maintain contracted service levels.

Companies can also offer means of reducing the risk in a bandwidth transaction. Enron pioneered the model of backing every trade with a money-back guarantee, a useful reassurance to buyers and sellers alike. Brokers like Band-X provide repurchase guarantees—at a premium—and in effect provide a means for buyers to hedge their commitment.

However, for bandwidth to be traded as a commodity there must be a number of derivative financial instruments (such as forward contracts and options) to help market participants manage risk and guard against price fluctuations. In addition to sellers and buyers of capacity, financial institutions also have a stake, according to [11], in creating and trading financial instruments related to bandwidth:

- Capacity providers and tier 1 carriers want to protect themselves against changes in the market price of capacity, which ultimately affects their bottom line.
- Carriers and telecommunication products resellers in possession of long-term contracts on specific destinations want to hedge some of the inherent risk of their contracts by purchasing derivatives on those routes before the contract expires. These derivatives may either lock-in lower prices or provide insurance protection against adverse price changes. Operators without such long-term contracts want to provision enough bandwidth for their clients as well as limiting their price exposures by locking-in future capacity prices and availability.
- Portfolio managers want to protect their telecommunication funds against major changes in the pricing structures in the industry. Professional speculators with industrial expertise want to profit from market inconsistencies using better knowledge of market trends.

Financial risk management instruments enabled carriers and market participants to control their costs and to protect themselves against the risks of a long-term contract as conditions change.

4.3 The Trading Process

The trading process begins with the posting of available bandwidth capacity by suppliers to the trading platform along with terms and asking price. Buyers make bids for capacity meeting specific terms and criteria through an interface similar tot that shown in Figure 4-3. A standard measure for comparing bandwidth capacity prices is the DS-0 equivalent per mile charge. This represents the cost for a single mile of 64Kbps of capacity for one month. The total number of miles is computed between the source and destination connection points so that total DS-0 equivalent connection cost can be compared regardless of the actual capacity. Then this measure is scaled to match the actual capacity (a factor 672 for a DS-3 channel, for example), the result is the total monthly recurring cost (MRC). The total cost of the contract is the MRC times the term of the contract in months.

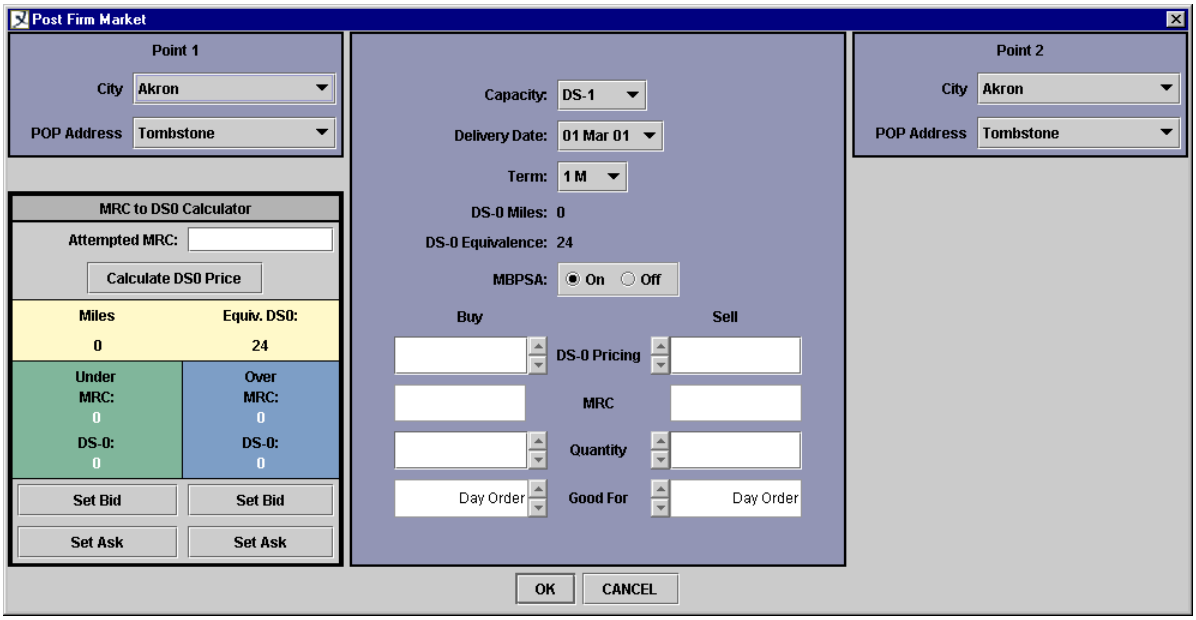

Figure 4-3: Placing a Market Order with RateXchange

Most trades are based on the standardized contract agreed to by a consortium of bandwidth suppliers, consumers and brokers, the Master Bandwidth Purchase and Sales Agreement. The platform matches buy orders with sell orders (or combinations of sell orders), performs financial checks on both participants and then commences the settlement and provisioning of the trade.

The trading and pooling infrastructures can support the execution of trades in a matter of seconds. Despite this, most trades in bandwidth are settled within 24 to 48 hours to allow financial transactions to complete. This is still a dramatic improvement over the months it used to take in discovery and in negotiating similar contracts between parties. It is the ability to optimize market inefficiencies such as contract negotiation and information discovery that has helped fuel the development of a bandwidth market.

5 The Bandwidth Market

This section describes the bandwidth market over the past few years. It discusses some of the problems and issues that have limited the deployment and acceptance of bandwidth trading and explores some of the reasons the commoditization and trading of bandwidth may yet succeed.

5.1 Industry Slump

In the past two years, the growth of Internet has slowed with the usage levels slowing into a plateau as they approach 80% of the population in the US. This can be attributed to a number of reasons: the dot-com industry meltdown, the death and dearth of killer applications, the last mile problem, and the relatively slow growth of broadband. The telecommunications industry had over-invested in bandwidth and this resulted in rapid cutbacks and many bankruptcies. Telecommunications has been the worst hit amongst the economic sectors.

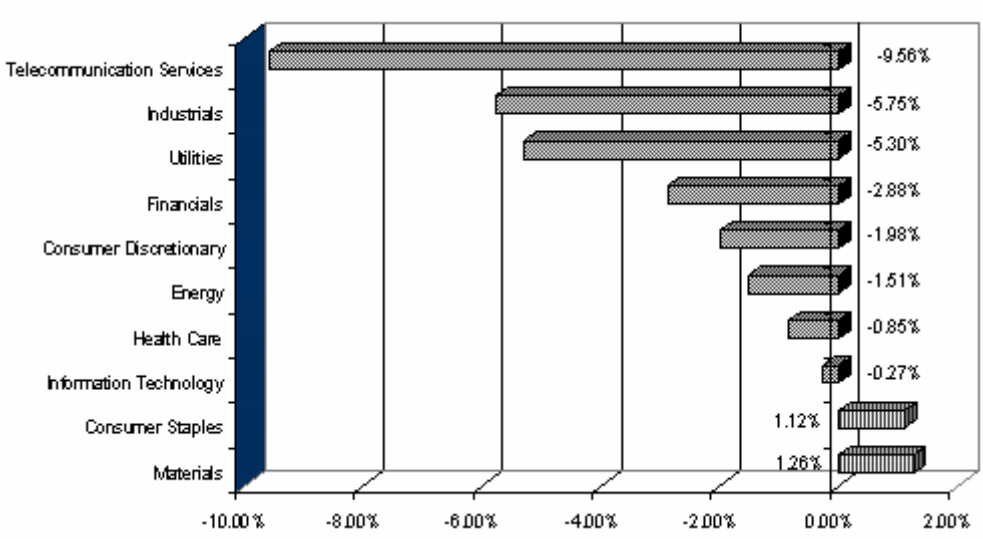

Figure 5-1: US Economic Sector Performance, January 2002 [19]

One of the biggest consumers of bandwidth is streaming media. "The biggest single factor controlling demand for your bandwidth is video" [7]. The interdependency of the two is often cited as a reason for neither industry being able to make an impact. For high-quality media, bandwidth is a necessity and for the consumer to purchase bandwidth. The need for bandwidth arises when applications require it, and multimedia itself is a primary "bandwidth hungry application."

Another category of bandwidth consuming applications is Peer-to-Peer applications, which have been plagued with legal complications right from the start. Napster and Kazaa are prime examples. While the music industry and their counterparts had marginal success in curbing the proliferation of these applications, they have been unable to come up with viable business models and the potential for bandwidth consumption remains untapped.

Outgoing Traffic	%
TCP other	45
TCP FTP	20
TCP Gnutella	11
TCP HTTP	10
TCP Kazaa	6
TCP NNTP	3
Other	5

Incoming Traffic	%
TCP HTTP	35
TCP other	20
UDP other	13
TCP NNTP	10
TCP Gnutella	8
TCP Kazaa	7
TCP FTP	4
Other	3

Table 5-1: A Day of traffic on the Wireless Network at the University of Tennessee [23]

The last-mile problem has also been a major bottleneck to bandwidth demand. However, with new high-speed technologies being deployed on a large scale (cable modems, DSL, Wireless in Local Loop), telecommunication companies are optimistic about the future.

On the commercial side, Internet companies have been unsuccessful in developing a successful business model to charge users based on their bandwidth consumption. The absence of end-to-end Quality of Service means that companies can't enforce and can't charge for categories of bandwidth consumption: "and as for a North American bandwidth glut, if there is one, it's a transitory phenomenon. The real problem facing carriers is not an oversupply of capacity but their inability to figure out a way to charge customers for anything other than voice traffic" [27].

5.2 Building Demand

When bandwidth trading first made its appearance in the late 1990s, most large carriers did not and would not participate and actually took steps to distance themselves from bandwidth as a commodity:

> "[Large carriers that sell wholesale capacity are] working to fight off commoditized bandwidth and focusing on 'Intel Inside'-type branding," says Carl Garland, principal telecommunications analyst for Current Analysis Inc. (www.currentanalysis.com). "If you resell AT&T [Corp., www.att.com] service, for instance, it's their brand on the line, and they are unwilling to concede that it's a commodity. Needless to say, they're very much into negotiating discrete contracts." [16]

This resistance stems from the anonymity conferred by bandwidth trading. Anonymity allows small suppliers to compete with large suppliers, but at the cost of eliminating many of the advantages large suppliers appear to offer a buyer: security, stability, credibility and, of course, brand differentiation. Large carriers also control large POPs which can be used to directly partner with customers and provide leverage in negotiating individual contracts.

Without sufficient suppliers connected to the pooling points, there are fewer reasons for consumers to connect. This is the chicken and egg problem of the bandwidth market. There must be a critical mass of buyers and sellers to generate enough trading activity to justify a market. There were three ways bandwidth providers dealt with this situation: partnering with smaller suppliers, becoming a supplier and consumer, and pursuing a "if we build it, they will come" approach.

Most bandwidth brokers worked to establish partnerships with smaller suppliers. Consider the list of current suppliers of capacity from the Band-X website in Table 5-2. Notably absent from this list are the largest carriers such as AT&T and Worldcom. By building a critical mass of available bandwidth, companies pursuing this approach hoped to use low prices maintained by competition between connected suppliers to attract the necessary volume of buyers. In a declining market, however, there was not enough different in price to persuade buyers to connect.

Connected and Live	Awaiting Connection
BIS	**Energis**
Cable & Wireless	**MFN / Abovenet**
Colt	**Nextra**
France Telecom	**Flag**
Globix	**Viatel**
Infonet	**Telefonica**
Lambdanet	**Tiscali**
Level 3	
Nildram	
Primus	
Reach	
Sprint	
Stealth	
Telia	

Table 5-2: Sellers on Band-X as of June 2002

The second strategy of serving as both supplier and consumer is also fraught with risks, foremost of which is the loss of apparent neutrality. A company that used this strategy was Enron: Enron Broadband Services offered bandwidth through Enron Communications.

The last approach, "build it and they will come," is a sure path to failure. Companies such as "Global TeleExchange spent so much money on infrastructure and connecting smaller customers to the exchange points that the funding ran out before the company reached critical mass, says Johnson" [31] This makes clear one of the other problems of developing a bandwidth market: significant capital outlays. The space, connectivity, hardware and software systems necessary to provision bandwidth trading require significant capital expenditures and substantial investments in maintenance and support organizations. As many companies discovered, it is difficult to generate sufficient revenues from connection fees and commissions to survive while a market develops. Global TeleExchange suspended operations a year after it opened. Even companies that appeared to have sufficient financial backing to field complete bandwidth trading infrastructures have turned out to have greatly overextended themselves in pursuing an infant market: "In fact, [Enron Communications], which never

became profitable, cost Enron more than $2 billion to build and operate, and critics wonder how much business was ever really conducted" [26].

5.3 A Declining Market for Bandwidth

There was, however, an even bigger reason in the year 2000 for resisting the commoditization of bandwidth: steadily declining prices: "In addition, some carriers ask privately why they should set up a commodity market for a product whose price has been headed down for years and is expected to keep going down" [16]. TeleGeography, a company that specializes in analysis of the worldwide carrier and telecommunications markets, reports that "the staggering increase in telecom capacity has sent bandwidth prices and, by extension, carrier revenues into a downward spiral" [34]. The prices for capacity between major cities has fallen by more than 70% annually for each of the past three years as can be seen in the price of an yearly OC-3 lease between major U.S cities in Table 5-3. This is the direct result of a significant oversupply of lit fiber, the proverbial "bandwidth glut."

Route	1Q 2000	1Q 2001	1Q 2002	Change 00 - 01	Change 01 – 02
L.A. - N.Y.	**$1,800,000**	**$600,000**	**$200,000**	**-70%**	**-70%**
Miami - N.Y.	**$900,000**	**$200,000**	**$100,000**	**-80%**	**-50%**
Atlanta - N.Y.	**$400,000**	**$200,000**	**$70,000**	**-50%**	**-70%**
Chicago - N.Y.	**$400,000**	**$200,000**	**$70,000**	**-50%**	**-70%**
Atlanta - Dallas	**$300,000**	**$200,000**	**$60,000**	**-30%**	**-70%**
L.A. - San Fran	**$200,000**	**$90,000**	**$30,000**	**-60%**	**-70%**
N.Y. - Wash, DC	**$200,000**	**$50,000**	**$20,000**	**-80%**	**-60%**
Boston - N.Y.	**$100,000**	**500,000**	**$20,000**	**-50%**	**-60%**

Table 5-3: Cost of an OC-3 Yearly Lease on Major US Routes for 2000-2002

In the same report, TeleGeography also observes a lack of market transparency: the highest price for a given circuit can be four times greater than the lowest price as shown in Figure 5-2. "This disparity suggests that neither bandwidth sellers—nor buyers—have systematic knowledge of their comparative position in the marketplace." This is precisely a problem that bandwidth trading is meant to address.

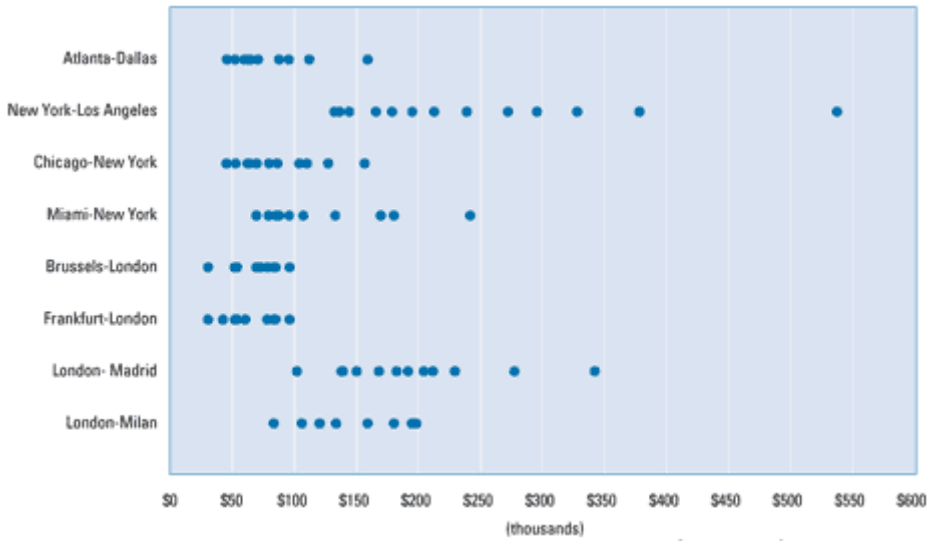

Figure 5-2: STM-1/OC-3 Annual Lease Prices on Major U.S. and European Routes for Q1 2002

Bandwidth capacity price declines are certainly due to an oversupply, but by some measures a bandwidth shortage actually exists: "Although there is a surplus in bandwidth capacity due to new wholesale build outs where carriers are using trading to offload their excess bandwidth, the available bandwidth connection points, in many instances, does not match the buyers' needs. In other words, sellers want to trade their excess bandwidth capacity, but all potential buyers are not interconnected" [29]. This suggests that the development of pooling points is still a vital part of delivering bandwidth trading and that doing so may help reduce the oversupply by increasing demand.

The industry may, however, already be nearing an end to the oversupply of bandwidth and precipitous price declines as market forces finally take hold: “With prices already at or even below costs, however, it seems unlikely that the capacity oversupply will depress prices any further. Any future price collapse would come as a result of other market forces, rather than the continuing capacity glut” [34]. Fear of insolvency establishes a lower bound for the price of bandwidth. As companies do fail, previously lit fiber will go dark, removing capacity from the market. The pricing of a commodity such as bandwidth (and derivative instruments) requires some level of understanding of supply and demand. If bandwidth prices finally do stabilize, then that will help accelerate the development of a liquid trading market.

But there are still other factors to be addressed before a true market develops. A Reuters article in January 2002 reports that “the trading that was happening prior to Enron's collapse was primarily between the major energy companies, including El Paso Energy, Reliant Energy, Dynegy and Aquila” [26]. In recent months these companies have dramatically scaled back or eliminated their telecommunications units. The general consensus among these former market participants surveyed in this article is the market for bandwidth commodity trading is at least 18 months out. Some small trades are occurring and companies such as RateXchange continue to operate their trading system. But “trading is essentially not happening.”

5.4 Questionable Practices and Loss of Credibility

The fledgling bandwidth has recently experienced additional setbacks due to the collapse of many of the most significant players and the loss of credibility due to questionably practices which artificially inflated trade volume and revenues. The list of bandwidth trading failures—which includes both business failures as well as companies which exited from the industry—is long and includes such companies as Global TeleExchange, LightTrade, Telephone.com, El Paso Global Networks, AIG Telecom and Enron.

In May 2002 following the demise of Enron, the SEC broadened its investigation into many companies that were suppliers, consumer or brokers of bandwidth. These companies, it was revealed, had engaged in practices such as round-tripping or wash sales where the same service was swapped between two vendors, each of which booked the sale as revenue and often capitalized the expense:

> Securities and Exchange Commission officials, concerned about an explosion of transactions that falsely created the impression of booming business across a range of industries, are conducting a sweeping investigation into a host of practices that pump up revenue.
>
> The inquiry is extending far beyond the disclosures by Dynegy Inc., Reliant Resources Inc. and CMS Energy Corp. that they engaged in illusory "swap" trades that boosted their apparent business. Questions about whether companies' revenues are legitimate are spreading from industry to industry, raising further questions about whether misleading practices contributed to the hyper-growth of the stock market during the late 1990s.
>
> In addition to the SEC's inquiry into the telecom companies Global Crossing Ltd. and Qwest Communications International Inc. swapping fiber-optic capacity to increase revenue, people familiar with the matter say the agency's investigation into Lucent Technologies Inc. is now also probing the role vendor financing played in its sales. The agency has won restatements in a look at three Internet firms that booked revenue from wire transfers among themselves that were purportedly payments for services; a lawyer familiar with the transactions says that at least in some instances there were no such services. [24]

Companies also used round-trip transactions to inflate the amount of volume traded on a bandwidth exchange. Such tactics allowed the operators to claim much higher transaction levels and use these to solicit additional business. The result of these improper and deceitful practices has been the loss of credibility among surviving brokers, suppliers and consumers.

6 Conclusion

There are three basic requirements for the development of a commodity bandwidth market: standards, transparency, and supply and demand [10]. Each of these is already present to some degree and continuing to develop in today's telecommunications industry. By most accounts, these factors have yet to reach the criticality necessary to result in a liquid market, but there are signs that such a point could be reached within the next 12-18 months.

The companies that developed bandwidth trading infrastructures—pooling points, trading platforms and financial instruments—established the necessary standards for a bandwidth trading market. These companies established an expectation of transparent and consistent pricing using standardized contracts and terms.

The forces that propelled the oversupply of capacity appear to be leveling off. The rush to create networks to capture growing Internet demand has ceased. Many suppliers themselves have ceased. Demand has also been increasing. driven by improvements in the "last mile" technology, the convergence of voice, video and data, and new classes of applications such as peer-to-peer sharing and grid initiatives. Measures and controls for delivering quality of service are appearing in the infrastructure which is a necessary first step in adapting business models to price demand based on its supply. The bandwidth trading companies have also helped reduce the mismatch between sources of supply and sources of demand through the creation of pooling points. This has increased the degree of connection (and decreased the degree of separation) throughout the Internet.

The commoditization and trading of bandwidth appears inevitable despite recent setbacks. With it will develop a market with liquidity and dynamicity: bandwidth traded in real-time, delivered in real-time to support real-time.