THE FLETCHER SCHOOL OF LAW AND DIPLOMACY

BANDWIDTH TRADING: MARKET ANALYSIS AND PRICE VOLATILITY MODELING

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Boston, April, 2001

INTRODUCTION

People have traded bandwidth since the emergence of telecommunications. The International Telecommunications Union's (ITU) international revenue-sharing arrangements date back to the nineteenth century[i]. However, during the last three years an embryonic market for trading bandwidth has developed thanks to the emergence of on-line exchanges that have attracted a significant number of new entrants including Williams Communications, El Paso Energy, and Koch Industry.

Both equity analysts and scholars (Lehr and McKnight:1998) have forecasted that bandwidth trading will become one of the largest commodity markets. Since then, modern bandwidth trading platforms have developed using Web-based exchanges with real-time switching possibilities. The current trading platforms (Enron, Band-X and RateXchange) have adopted similar business models. These models are based on the deployment of various hubs (pooling points) in major cities internationally aimed at achieving real-time switching all over the globe. However, they have not succeeded in attracting the necessary market players.

Liquidity is necessary to attract all the market participants. The positive economic externalities of an exchange could only arise if a critical amount of industry players, traders and speculators participate in the market. These externalities include lower transaction costs, the availability of hedging instruments, and the possibility of selling extra-capacity. Although, the interest on bandwidth trading has increased in the past years, no exchange has yet been able to attract a sufficient number of players. This situation has raised questions among industry players and scholars on the likelihood of the emergence of a truly liquid bandwidth trading market in the near future.

There are several arguments that try to explain this market failure. One of the arguments is that due to infrastructure constraints, the emergence of a bandwidth trading market has not been possible. Another discussed reason is that due to an over-capacity of bandwidth on the long haul, prices follow a downward sloping trend. Finally it is claimed that this market failure is the result of the supply and demand imbalances and the lack of accepted standards for bandwidth trading.

Plunging prices characterize the current market. In addition, different contracts and trading architectures are competing to become the market standards. A derivative market for bandwidth trading has not yet emerged. On the other hand, it seems that the carriers are stepping forward. This is reflected in the exponential growth of bandwidth trades closed in teh past year.

The purpose of this thesis is to assess the current state of the bandwidth market and the major obstacles that keep it from developing. This analysis will enable us to predict the future developments of this market through the construct ion of a system dynamics model. In particular, we will focus on the emergence of price volatility for bandwidth and the emergence of a derivative market.

In the first chapter, we will summarize past research outcomes and study the features of supply and demand. Specifically, we will focus on the economics of bandwidth trading and develop the exchange model discussed in “MATING, DATING AND PROLIFERATING”. In the second chapter, we will present the current state of the market and discuss the main changes that occurred in the past months. In the third chapter, we will focus on the implication of the imbalance of supply and demand of bandwidth. In particular, we will construct a system dynamics model to illustrate the emergence of price volatility. This will lead us to the last chapter, where we will describe the implications of price volatility for the emergence of a derivatives market. The final section of the thesis will include specific recommendation for future market research on bandwidth trading.

Chapter 1: Overview of bandwidth trading

Bandwidth is defined as “the width of the frequencies that comprises a signal that is allowed to pass through a communciation channel”[ii]. Bandwidth trading therefore is the purchase/sell of that specific telecommunications’ capacity (circuits, minutes or dark fibaer) by a buyer/seller for a specific route during a time period. This definition is not limited to the trading occurring on an exchange, since still today most of the trading of bandwidth occurs in bilateral transactions between carriers[iii].

The importance of exchanges is increasing, especially for certain routes on the long haul portion of the network and for some products such as minutes or circuits. Although, exchanges are currently not solely involved in the trading of bandwidth but they provide facilities to buy/sell many different telecommunications products such as dark fiber, switched minutes, collocation or VoIP.

Trading represents the activity of buying and selling a good for a profit. This profit margin or spread between the buy (ask) and the sell (bid) price should equal the transactions costs in a perfectly efficient market. The efficiency theory holds only if the traded product is fungible. This means trading a good that has the characteristics of a commodity. By commodity, we mean a good that cannot be differentiated from similar goods. This implies that both buyers and sellers make their choices based solely on price. In addition, a perfectly efficient market requires the commodity to be traded among a multitude of buyers and sellers. None of which is large enough to influence the price and where no asymmetrie information exists. Finally, an efficient marketplace requires very clear standards, including a well-accepted and enforceable regulatory framework. The exchange regulations and master agreement would clearly define and regulate contentious issues ranging from quality of service to liquidating damages. An example of a highly efficient market could be either grain trading or the Treasury bill market.

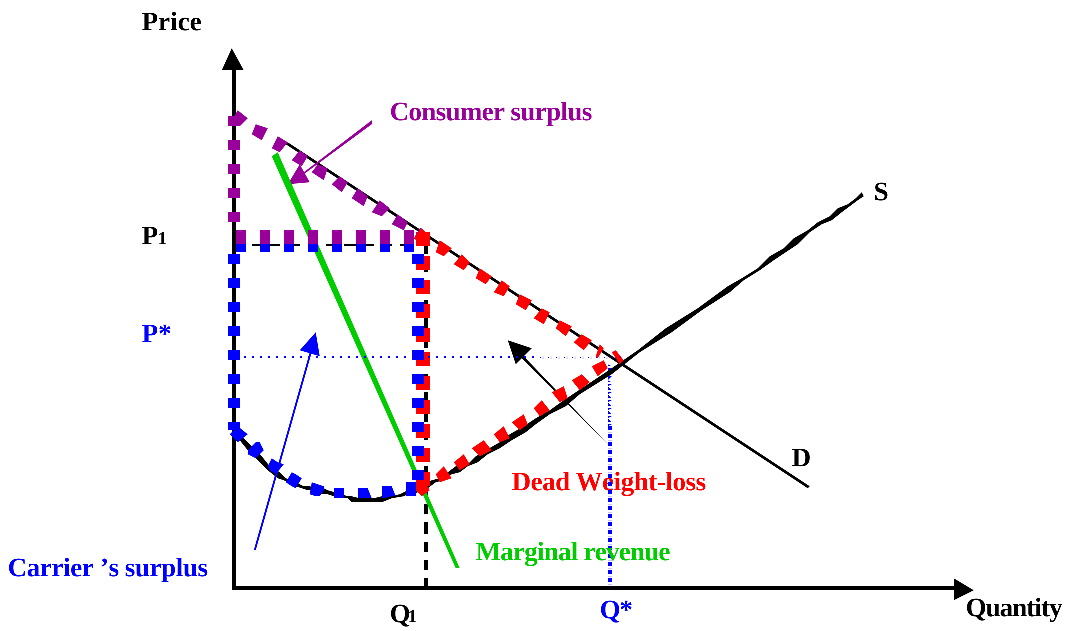
1. 1. Why bandwidth trading?

Starting with the ITU's international revenue-sharing arrangements, the trading of bandwidth among carriers consisted in a long negotiation process, often via the intermediation of a broker. This process required long negotiations about the pricing and the features of the contract. Often, it could take more than six months to reach an agreement. Then the capacity contracted was not even required anymore. In addition, most of the deals were on a one-time basis, and every new contract required the same long negotiations. Telecom companies (telcos) spent therefore large amount of time and money to contract these bilateral agreements. Their current high average sales and administration (SGA) expenses reflect this situation. Indeed, telcos' average SGA equals 25% of sales versus 16% for the average corporation in the United States[iv]. In addition, the terms of these agreements were drafted in favour of the carriers. The contracts required for example the buyer to commit to purchase the agreed capacity for very long periods (up to 5 years). On the contrary, the carriers were to make only relatively minor commitments. Their commitment to deliver bandwidth was on a best effort basis only. In case of non-performance liquidating damages would never exceed the value of the contract.

This situation had historical grounds. For over a century, bandwidth was traded only among large national telcos only. The market was limited to the few players that were all enjoying monopoly situations in their respective countries and benefiting of large producer surpluses. Indeed, the lack of suppliers and price transparency allowed the incumbent carriers to price their bandwidth (and minutes, …) where their marginal cost or supply line would intersect their marginal revenue (at a price P1 far above the optimal price P*. This situation allowed them to maximize their profits but created a situation where the non-optimal pricing was resulting in a dead weight–loss (DWL).

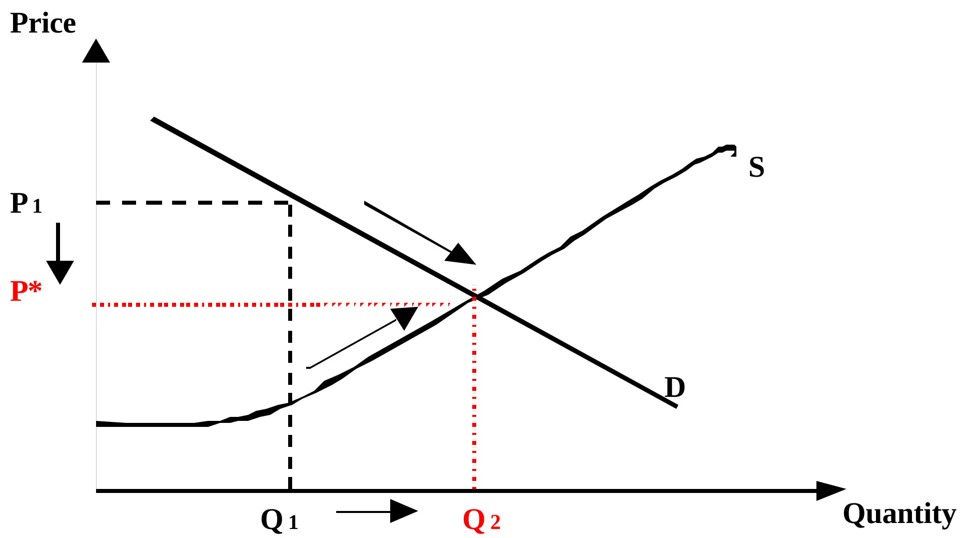
This situation had historical grounds. For over a century, bandwidth was traded only among large national telecommunication companies (telcos). The market was limited to those very few players that were all enjoying monopoly situations in their respective countries. Their monopoly situation allowed them to price their bandwidth at the point where the marginal cost or supply line intersects with the marginal revenue line. At the price P_1, carriers are able to maximize their profits. Indeed, the lack of competition and price transparency allowed the incumbent carriers to price their bandwidth (and minutes, …) far above the equilibrium price P*. This situation generated however an important loss for the consumers and for the society (charaterized by the red triangle dead weight-loss (DWL)).

Exhibit 1: Dead weight-loss and carrier's surplus



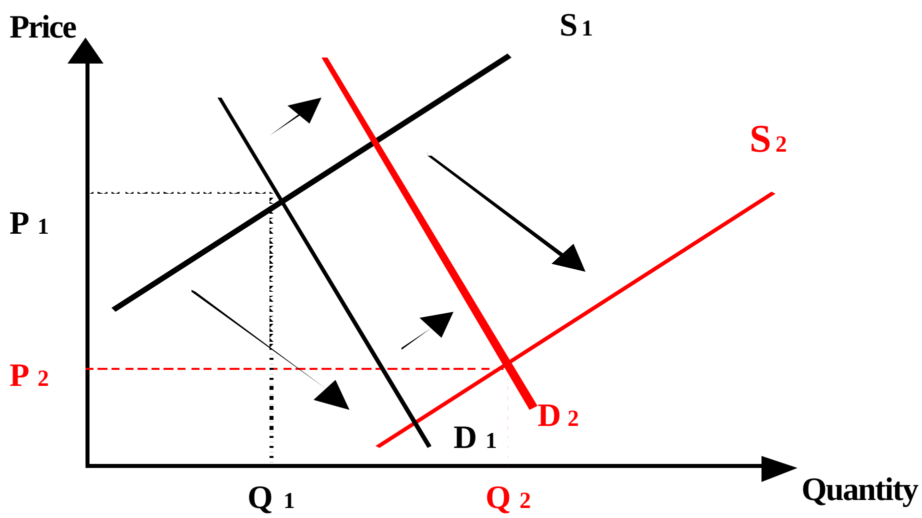
This situation started to change thanks to the upheavals that occurred in the telecommunications industry in the last two last decades. In the United States, several changes made bandwidth trading feasible. On the regulatory side, the Bell break-up of 1984 and the Telecommunications act of 1996, opened the doors to competition. Soon, a multitude of new carriers started to build there own networks and radically modified the supply side of bandwidth. The break-up of AT&T fostered that competition spiral. Competition among incumbent carriers (ILECs) and new entrants (CLECs) brought telecommunication prices down (please refer to exhibit 2). ILECs could no longer price the bandwidth at the P_1 level, but had to compete with other carriers.

Exhibit 2: Pressure on prices due to the increase capacity supplied



In addition, new technologies were deployed to offer more capacity at better and cheaper terms to customers (those technologies were often invented early on by the Bell labs, but never implemented in the network). The development of optical fibers and new digital technologies (i.e. DWDM) allowed carriers to increase exponentially their capacity supplied. Large increases in supply of bandwidth and a multitude of new entrants started to push prices down even faster. In exhibit 3, this is represented by the shift in the supply line from S_1 to S_2. However, the demand has not followed similar shifts. Mostly because the increased in supply S_1 to S_2 did occur only on the long haul portion of the network and not in the local loop. Therefore, demand was still constrained by a small supply in the metropolitan area network. These large infrastructure investments created on some specific routes enormous quantity of unused bandwidth. Part of the rationale beyond those infrastructure investments was the expectations that demand for bandwidth would match any capacity supplied thanks to the growing data traffic of the Internet.

Exhibit 3 : Shifts in supply and demand of bandwidth



Some brokers understood that there was an opportunity to improve the conjunction of supply and demand in the telecommunication market. This required to set-up more sophisticated trading structures. In this way Band-X, RateXchange, … decided to set-up the first online exchanges for the trading of minutes only. These first exchanges where simple bulletin boards where sellers could auction off their excess capacity anonymously.

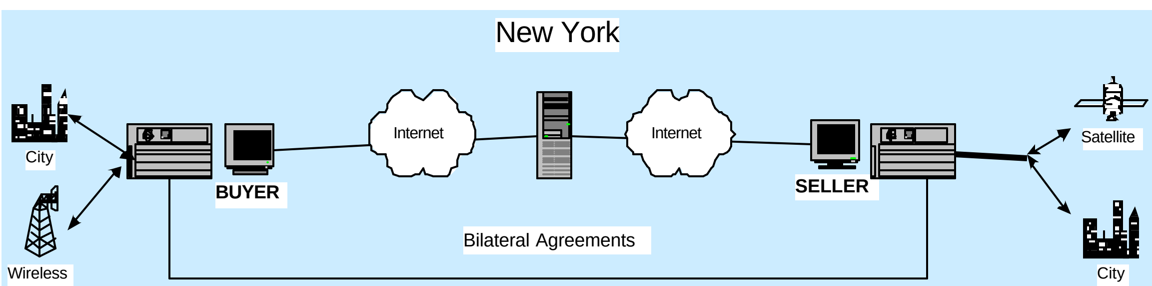
Afterwards, large energy companies, such as Enron, decided to start their own bandwidth trading operations. They perceived that the deregulation process that the telecommunication market was undergoing as a remake of the liberalization of the electricity and natural gas markets. Indeed, the similarities with electricity were striking and the possible profits to be captured even larger. Both industries had been regulated for a very long period. Electricity is a non-storable good and in both cases the incumbents attempted to refrain the commoditization of their product.

Thanks to the continuous emergence of new technologies and large investments, the primitive exchanges started migrating to more sophisticated trading platforms enabling real-time trading of bandwidth. This was possible through the creation of hubs (pooling points) in different locations where buyers and sellers could interconnect their networks, allowing real-time provisioning through switches. In December 1999, Enron announced the first ever automatically provisioned trade with Global Crossing over a New York – Los Angeles route opening the door to possibly the largest commodity market on earth.

1.2. Trading infrastructure?

As stated above, the first trading system was simply a bulletin board over the Internet where parties could place bids anonymously. In "DATING, MATING and PROLIFERATING", we defined this first business model as Direct Access Through Interconnected Network Gatherings (DATING) as described per the figure 1 here below.

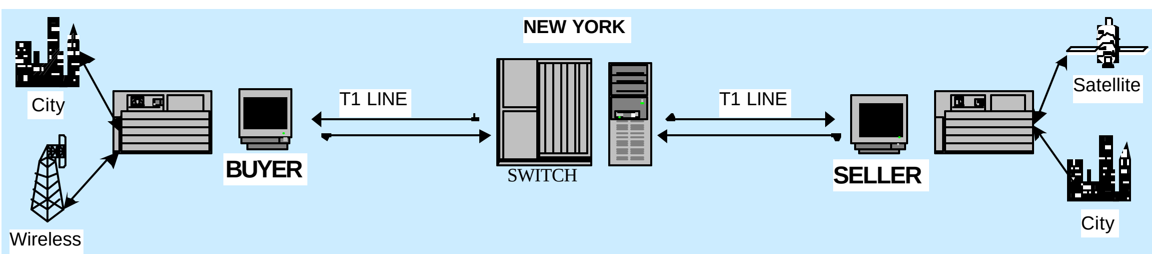
Figure 1: **DATING (Direct Access Through Interconnected Network Gatherings)**



DATING describes the generic business strategy used by many Telco subsidiaries (for example British Telecom) and web-originating, non-facilities based brokers (for example, Bandwidth Market Ltd). This business strategy is an on-line 'DATING' service in which buyers and sellers interact through virtual, web-based exchanges or bulletin boards. It is a natural extension of the traditional brokerage service offered by global carriers. Indeed, the exchange does not take responsibility in case of non-performance of one of the parties to the contract. In this sense, the parties trade among themselves and the exchange is only a facilitator since it never takes title over the traded bandwidth. The exchange acts only as a forum: hosting bids and offers for bandwidth between destinations. The exchange providers also provides model contracts to simplify the trading process and reduce legal costs.

This first business model is still widely used for the trading of switched minutes. However, the larger exchanges have migrated already since 1998 to more sophisticated business models starting with the Multiple Access Through Interconnected Network Gatherings (MATING)

Figure 2: **MATING (Multiple Access Through Interconnected Network Gatherings)**

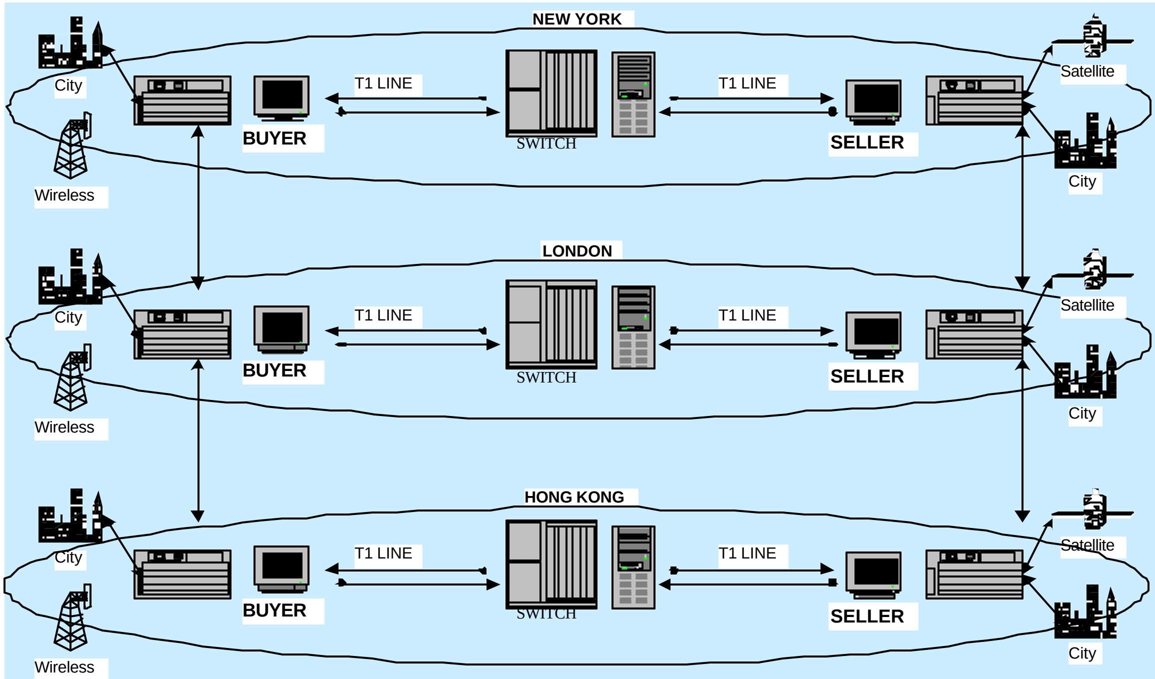


The MATING exchange model involves maintaining a switching hub in a telecommunications facility in a major city. Thus a MATING exchange adds a physical component to the virtual exchange system used in the DATING model. Bids and offers are posted online whilst carriers connect to a physical Hub containing IP exchange equipment to facilitate real-time bandwidth trading. This connection is either a leased line, Ethernet (or fast Ethernet) or a fiber link running ATM or POSIP. Several high-profile start-ups used to deploy the MATING model until last year, for example London-based Band-X and New York-based Arbinet.

This type of exchange represents a transition point before upgrading to the PROLIFERATING business model. Again, in this system the exchange does not take title over the bandwidth traded and is only a facilitator that in addition offers its services to provision the contract as agreed. In “DATING, MATING and PROLIFERATING” we forecasted that this type of exchange was not viable and would be therefore soon abandoned

The PROLIFERATING (Privately Run, Operated and Leased Internationally Focused Exchanges Resulting in Access To Inter-linked Network Gatherings) business strategy was the last exchange type to be analyzed in “DATING, MATING and PROLIFERATING”. As forecasted, the largest players have adopted this business model. Exchanges such as Band-X have been expanding significantly their facilities in the US and internationally in order to offer the largest possible network. Other exchanges have followed a similar path such as RateXchange. This business strategy represents an expanded version of the MATING strategy.

Figure 3: **PROLIFERATING (Privately Run, Operated and Leased Internationally Focused Exchanges Resulting in Access To Inter-linked Network Gatherings)**



This model confers some competitive advantages to electronic exchanges. Firstly, the market reach of an exchange is geometrically expanded in proportion to the reach of the big carriers connected to an exchange. The exchange need not establish direct lines between their hubs as the already carriers act as convenient links. Second, quality of service can be monitored at more points along the service route.

Currently, in addition to the exchanges many players have adopted the PROLIFERATING architecture. Enron was the first to propose to have the different networks to interconnect at various pooling points located in strategic locations. Other players such as Lightrade have developed a similar architecture with the intent of becoming a pure pooling point player. Finally, companies such as Fibernet took the pooling point philosophy to the next level to respond to the critics of the telcos. Many carriers explained their reluctance in connecting to other pooling points based on the costs related to such an operation and the location issues of these pooling points. They invested important amounts of capital in their current infrastructure. Therefore they are reluctant to migrate all their switching and monitoring operations to a pooling point, which is often located miles away from their current location. Therefore, Fibernet is promoting the concept of “meet me rooms” within large carriers hotel where every carrier can interconnect with other carriers’ networks.

The new players are directly competing with the various exchanges and traders’ pooling point models, because some carriers might prefer to go through a pooling point “administrator” rather than through an exchange or a competitor pooling point. This would allow carriers to maintain a better control over the evolution of the bandwidth market and to possibly slow down the fall of bandwidth prices.

This recent development demonstrate the growing interest in bandwidth trading. It also confirms the hypothesis formulated in “DATING, MATING and PROLIFERATING” where we forecasted that the PROLIFERATING architecture will be dominating the market.

1.3. Exchanges’ role

1.3.1. Exchanges lead the changes

The development of a liquid marketplace for the trading of a commodity does take time for a multitude of reasons. In particular, if the buyers and sellers are still missing the necessary infrastructure (carriers are not yet well interconnected). First, you need to have the various players to get accustomed to trading. Then, you need to see trading practices develop. When clear customs emerged, the traders, if in their best interest, would to create a neutral entity - an exchange – that will regulate the well functioning of the marketplace.

In the case of bandwidth trading, this process of building a marketplace has been reversed. Yet, an over-the-counter market did already exist, but it developed in an environment where the different players benefited of quasi-monopoly situations. The terms were therefore strongly biased in favour of the carriers. In addition, telcos are only marginally interconnected to each other. In the case of electricity instead, it seems that the players were already interconnected before the deregulation. This was critical for the fast development of a liquid market for electricity. Finally, no regulatory or quality of service standards were in place. The market for bandwidth is instead developing in the opposite way (as did the electricity market too). It is the exchanges (that belong to third parties) or new entrants that are attempting to set up the trading rules and infrastructure and not the various industry players..

1.3.2. Exchanges pros and cons

In “DATING, MATING and PROLIFERATING”, we concluded that the pooling point architecture was the most profitable and that most of the exchanges will adopt it. However, this does not mean that carriers are going to use them. The current market offers to the various players a range of alternatives for trading their capacity. A carrier can decide to auction its capacity through a broker. It can instead decide to connect its network at an exchange or trader’s pooling point. Finally, it can decide to interconnect its network in a meet me room and use a broker to sell its excess capacity. This broad range of choices might even be one of the causes of the relatively slow emergence of this market. Indeed, many players seem to be waiting to see which exchange model will emerge before deciding where to auction its supply.

In exhibit 4, we breakdown the different criteria that a telco will look at when deciding which exchange to join.

***Exhibit 4 :* Features of different types of exchanges**

		Real-time trading	credit risk	settlement risk	QoS monitoring	Market maker	Neutrality	Anonymous
DATING	Broker	No	HIGH	HIGH	No	No	Yes	Yes
PROLIFE-RATING	Neutral Exchange	Yes	HIGH	HIGH	Yes	No	Yes	Yes
	Trader's Exchange	Yes	LOW	LOW	Yes	Yes	No	No
	Pooling point administrator	Yes	HIGH	HIGH	Yes	No	Yes	Yes
	Meet me room	Yes	HIGH	HIGH	Yes	No	Yes	Yes

In particular, any market participant will give a close look at three aspects:

- **Real-time trading**: This category helps to distinguish the simple broker which offers its dating services, to exchanges which have the capability to provision real-time a trade.
- **Neutrality:** We believe this is an important aspect because when one trade through the pooling points of one of its competitors, it provides him with strategic information on market trends.
- **Risk:** Traders will want to ensure that the other party will fulfill its obligations. Therefore, when choosing an exchange, the different traders, speculators and arbitrageurs will prefer an exchange which protects them against any default that could occur.

We believe the last point to be the most critical and will determine the success of the market maker/trader exchange over the neutral exchanges. Especially today, when most of the potential market participants have very negative credit ratings. Indeed, when a carrier or a trader is considering to enter in a contract to buy or sell capacity, or take a derivative position, it will need guarantees that the counterparty will not back out of the transaction. Exchanges' role is to provide this certainty to the various players. By doing so they avoid to the parties to go through large credit analysis of the other parties and though facilitate trades.

"Whoever owns and operates pooling points needs a deep level of experience in telecommunications, aligned interest with other carriers and a deep balance sheet. If something goes wrong, you want somebody to go after. We are constantly upgrading our network – will these pooling points upgrade in the same time frame? If their equipment becomes archaic or unscalable to our needs, will they address the problem as quickly as we would ourselves?"[v]

1.4. Where will bandwidth be traded?

What distinguish bandwidth from most commodities such as corn is that bandwidth cannot be stored and that it has important geographical constraints. This implies that every single route represents anotehr specification of the same commodity. This is similar to the distinction between yellowcorn and another type of corn. As a matter of fact, these two specifications will trade at different prices because of dissimilitude in their supply and demand. This differences of price exist between on specification and another one simply because the two goods are not perfect substitutes. This explains why some routes are traded at multiples of thirty of other routes. Hence, a liquid market of bandwidth might emerge on the London-New York route in the next year, but the New York-Los Angeles market for bandwidth might instead never emerge. Similarly, trading of bandwidth might be very large on the long haul portion of the network and be nil on the metro area network. (MAN). Therefore we need to determine on which portion of the networks will bandwidth be traded.

1.4.1. The Long Haul

Currently, this is where all the trading is taking place. The reason being that there is a multitude of buyers and sellers competing on this portion of the network. By the same token, the capacity available on the long haul has been increasing exponentially on the last years. Thus, the prices are falling much rapidly than in any other portion of the network because of this increase in supply (we will be discussing more in deep the features of supply and demand in the third chapter). Here bandwidth is getting commoditized much faster. Trading is therefore emerging, but there is yet no liquidity due to the imbalances of the supply and demand. Thereby, liquidity will increase only when the bottleneck in the local loop will be reduced. However, trading on this portion of the network will precede trading on the Metropolitan Area Network (MAN) because it is a more competitive environment.

1.4.2. The Metropolitan Area Network

In the MAN, we encounter an opposite imbalance of supply and demand than in the long haul. In this part of the network, the quantity supplied is insufficient to satisfy increasing customers' demand. The expensive scalability of the existing SONET network and the high cost of installing a new network (i.e. Ethernet) are the main causes for this shortage of bandwidth. Nonetheless, many carriers are investing in new networks. However, local administrations are very reluctant in allowing disruptive infrastructure works necessary to lay down the new fiber. In addition, the carriers are interconnected only marginally making trading of bandwidth almost yet unfeasible.

Currently, on this portion of the network, no trading (real-time) is occurring. This is largely due to the lack of interconnectivity among the different players. Actors such as el Paso Global

Networks believe that this is to become (within tree years) the most traded portion of the network..

1.5. Barriers to the emergence of bandwidth trading

In the different sections above we have discussed the various features of bandwidth trading. However, as mentioned above, many still doubt that a liquid market for bandwidth trading will emerge. Others think that it is going to be a much longer process that forecasted since many important barriers are in place.

Supply and demand imbalances: This point will be developed extensively in the third chapter. However, it is important to remember that one of the main barriers to the emergence of bandwidth trading is this structural imbalance between supply and demand of bandwidth due in large part to the local loop bottleneck.

Infrastructure: Infrastructure represents one of the major hurdles to the emergence of bandwidth trading. The various networks must be all interconnected to allow real-time trading. Still, the necessary switching infrastructure in order to provision bandwidth on a real-time basis must be developed and installed. Finally, the various trading desks must be set-up (this requires among other things hiring traders from other sectors and having them accustomed to the specificity of bandwidth trading). Thus, the emergence of a liquid bandwidth trading market requires an important effort in terms of time and capital invested. Currently, part of the necessary infrastructure is yet missing. To interconnect the different networks, pooling points or meet me rooms might be the solution. However, this requires still an important effort and currently the necessary capital to undergo such changes is lacking.

Capital issues: Six months ago this was a non-issue. Currently, this might be one of the biggest hurdles that bandwidth trading has to face. Indeed, the plunging equity markets have reduced the market capitalization of all the various telcos publicly traded. Therefore, raising funds through initial public offerings is almost impossible. Equity markets have no appetite on investing in the telecommunications industry. Similarly, the capital markets have tighten the availability of credit significantly. Even large corporations like Lucent Technologies have faced major credit issues. They have been shut off from the commercial paper market, which was one of their major sources of short-term cash and bank are nervous to renegotiate their actual credit lines. This lack of necessary capitals to build the new networks is definitely going to slow down the emergence of bandwidth trading. Furthermore, it is yet not very clear if this shortage of capital is going to alleviate the imbalance of supply and demand. Indeed, the lack of capital is hurting the demand side too. Many Internet service providers (ISP) and Applications service providers (ASP) are going out of business because of their inability of raising new funds. Many software companies that were developing bandwidth hungry applications are slowing down their product development. Finally, new carriers that were attempting to breakdown the local loop bottleneck have to postpone their projects because of a lack of capital.

Credit issues: This critical aspect has been already discussed to some extent in the exchanges' role part. Indeed, exchanges play a fundamental role of reducing the credit risk of the different parties involved in a transaction in the exchange. The worsening credit quality of the different telcos represents an important barrier to the development of a liquid bandwidth trading market. An important fraction of the new players in the industry have very fragile balance sheet. Such a weak credit quality does not provide the necessary confidence that they will be able to fulfill their obligations.

"One of the main barriers to the emergence of bandwidth trading is the credit quality of the industry participants which do not have the ability to fulfill their contracts."[vi]

Therefore, this credit quality issue is significantly restricting the number of players that could participate in the bandwidth trading arena and represent another barrier to the emergence of a liquid market.

Lack of standards and accepted regulatory framework: This is another fundamental barrier to the development of a bandwidth trading market. Important progresses are taking place these days on this aspect as discussed in the next chapter. This is a critical dimension, since no sizeable trading can occur without industry-accepted standards. In particular, it is critical that the various parties develop a single contract accepted by all parties. This contract will be instrumental to create specific quality of service benchmarks necessary for the commoditization of bandwidth. Indeed, bandwidth can be traded only if it is a fungible good, which requires setting very clear specifications.

Carriers reluctance to participate in this new marketplace

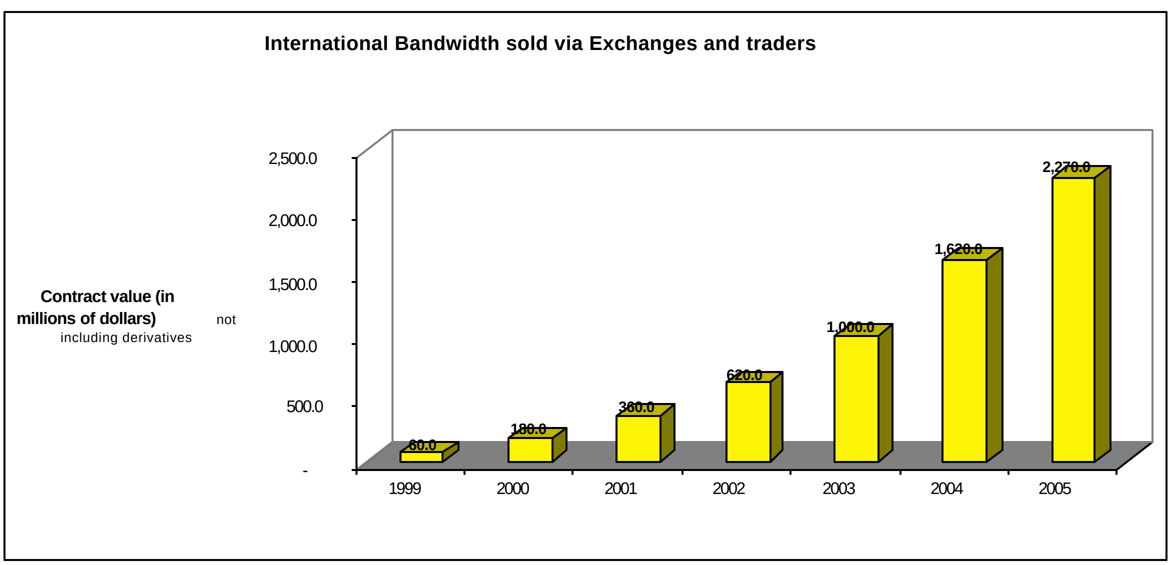
Finally, the last barrier to the emergence of a liquid bandwidth trading market is the reluctance of carriers to participate in this emerging marketplace, mostly because they refuse to recognize that bandwidth is a commodity. They claim that their bandwidth is different from the one sold by one of their competitor on the same route. That each carrier offers different quality of service and that customers are not ready to trade one for the other one. In addition, they often do not look at their network as a "long" bandwidth position with significant price risk associated .

"They (the carriers) do not really believe they have a risk. They think that their product is not fungible"[vii]

Chapter 2: Current market

Even though, bandwidth trading is facing a lot of hurdles, it has fostered in the last three years a lot of interest because the size of this emerging marketplace is enormous (please refer to Exhibit 4). In particular, many companies hope to capture a portion of the incredible revenue potential that this new marketplace could generate.

Exhibit 4 : **Forecast of bandwidth sold via exchanges and traders**



source: The Yankee Group, 2000

2.1. Carriers are stepping forward

This recent interest has materialized in an large number of conferences and articles in the press dedicated to bandwidth trading where the various exchanges, investment banks and energy companies attempted to educate the carriers to the benefits derived from bandwidth trading. As a result, we have seen in the last months the entrance of a number of new players in the bandwidth trading scene. This new players range from new exchanges, energy companies and, most importantly, the first carriers such as Global Crossing that has opened its bandwidth trading operations at the end of 2000.

However, some carriers are still reluctant to accept the commoditization of bandwidth and to take advantage from the benefits generated by trading. They correctly understand the cannibalization dangers as explained in the first chapter, but do not yet fully capture the benefits of trading. Indeed, trading can be an important source of revenues as well as a risk management tool.

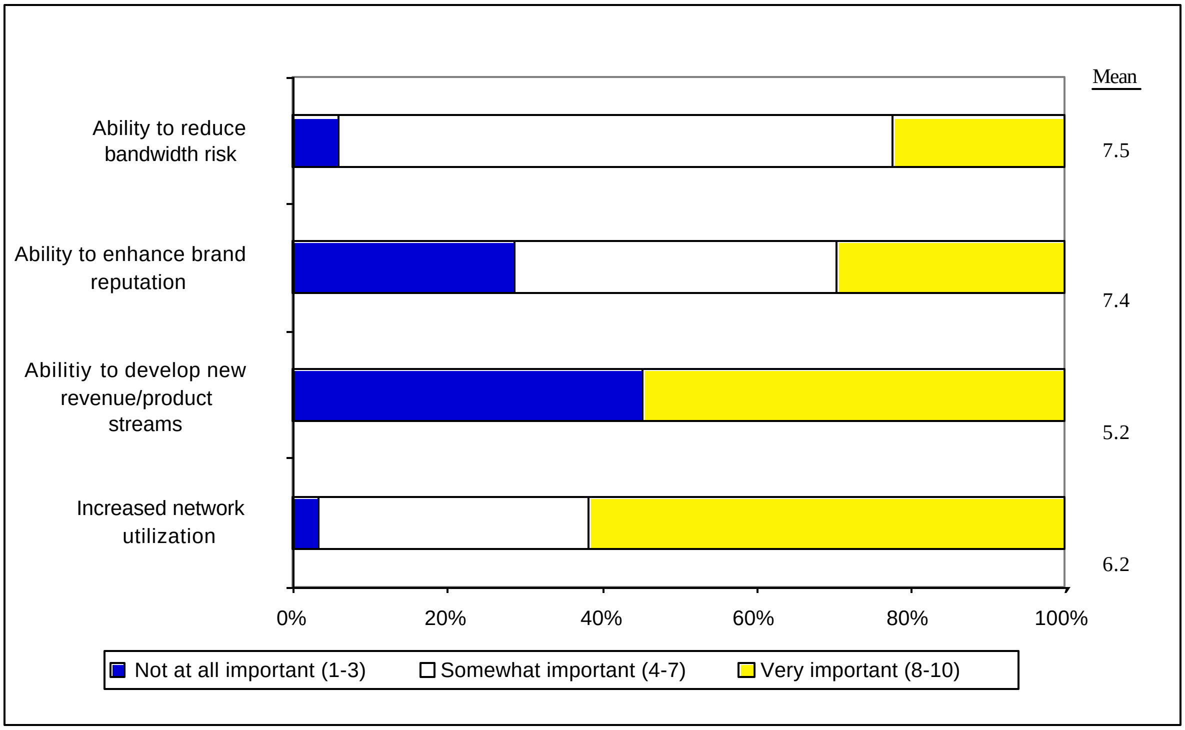
The recent drop of the telcos' stock prices and the tightening of the credit market are obliging them to look at new sources of capital. Bandwidth trading could represent this opportunity. Indeed, it seems that the stock market rewards involvement in new growth areas such as bandwidth trading. In Enron's case, some investment banks value the bandwidth trading opportunity up to 40% of their target stock price[viii]. This means that they value roughly the bandwidth opportunity in Enron's case around 29 billion dollars..

A survey done by Arthur Andersen unit this year confirms the changing perception of carriers about bandwidth trading [ix] This perception has been confirmed in different interviews:

"The most important change which occurred (at the Capacity 2001 conference in Atlanta at the end of March 2001) is the sentiment that carriers are stepping forward."[x]

Indeed, carriers start to recognize that bandwidth trading might not only result in the cannibalization of their actual revenues. They begin to perceive some other benefits associated to it. As per exhibit 5, we can notice that they perceive both the ability to reduce bandwidth risk and the ability to enhance brand reputation as the largest benefit of bandwidth trading. Indeed, when a liquid bandwidth trading will emerge, it will be possible to price different derivative products. Indeed, you need reliable spot prices in order to build a forward curve (similar to the yield curve for bonds). This forward curve will then allow the different players to price derivatives and offer risk management products to other companies. May be the most important advantage of bandwidth trading will be its risk management applications.

Exhibit 5: Survey of carriers concerning the benefits of bandwidth trading



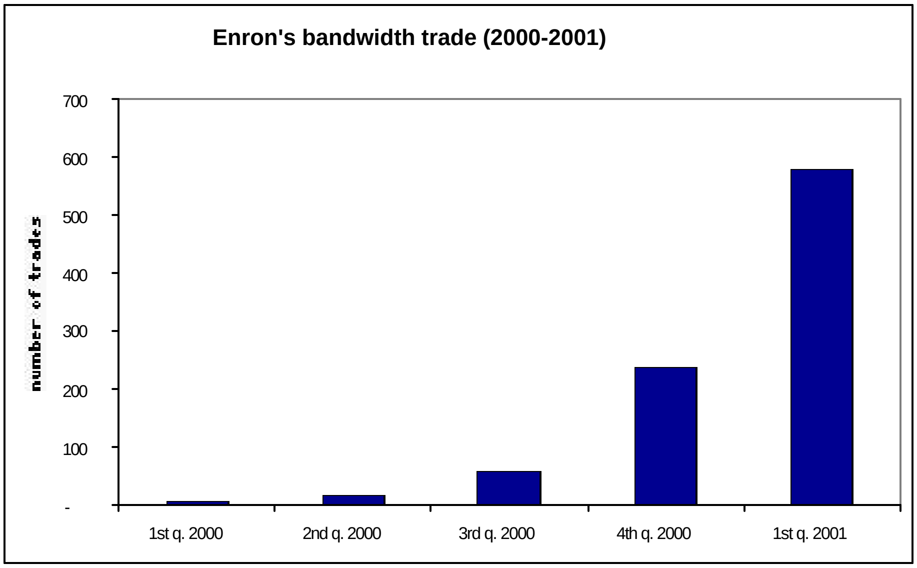
source: Arthur Andersen

2.2. Trading is beginning, but liquidity is still far away

This interest for bandwidth trading has materialized in large investments in infrastructure. Energy companies such as Enron or El Paso Energy for example have started to invest heavily in setting up the adequate infrastructure and trading force to get the market starting. Over 600 million dollars have been invested in 2000 and 2001 each year by Enron Broadband Services (EBS) in order to create the necessary infrastructure to trade bandwidth . Currently, EBS has fiber to 25 operating pooling points and EBS's 2001 goal include having 35 pooling points in place by year end and 570,000 terabytes of network services delivered.[xi]. Similarly, other new telcos have increased the capacity of their network in the past years. Level 3 Communications Inc has been building more than 20,000 miles of second generation fiber-optic networks in the US and in Europe, which includes undersea capacity across the Atlantic and Pacific.

The large investments in infrastructure that took place in the past two years have made trading of bandwidth possible, even though many hurdles are still in place. Pooling points are up and running and trading has, since December 1999, begun. For example, bandwidth trades closed on Enron's exchange have grown at an average rate of 270% per quarter, reaching at the end of the first quarter of 2001, 590 trades.

Exhibit 6: Growth in bandwidth trades (Enron)



Most of the trading however occurs between market makers which are looking at offsetting their position in order to remain hedged. Aquila bandwidth trading Vice President Keith Shoemaker mentioned that almost two third of its transaction are with market makers[xii]. Many would remark that this is the proof that bandwidth trading is a non-event, since all the trading is limited to the energy companies and that carriers will not participate. These detractors advocate that bandwidth is simply not a commodity. That it is not fungible and therefore cannot be traded as electricity or natural gas. Nonetheless, fewer people advance this standpoint lately. On the contrary, many advocate that to reach the critical mass that will attract all players, a market needs to have market makers that create the sufficient liquidity, even if artificially by trading back and fourth among themselves. In addition, trading often requires having for every position an offsetting trade. Therefore, it is normal to see more intra-traders trades than with the carriers, since position are continuously sold to other traders and that every trades requires an opposite transaction for the trader to be able to close its positions. This is called the transaction multiplier. For one physical transaction you often have a multitude of transactions following it (in the case of electricity trading for every trade you have on average seven subsequent transactions).

2.3. Changes in the regulatory environment

The regulatory environment is one of the aspects of bandwidth trading which has been knowing lately the most important changes. A first attempt to create a regulatory framework is underway. Exchanges on the one hand (Band-X, RateXchange, ACE, …) and market players (US operators, EBS, Williams) on the other hand have set up their own trading organization, respectively the e.bandwidthtraders.org (eBTO) for the first and the Bandwidth Trading Organization (BTO) for the latter. These organizations are working separately to set the standards that will regulate the trading of bandwidth. Each side is, as one could expect, very critic of the other. RateXchange's President Ross Mayfield and founding member of the eBTO says:

"Enron has too much vested interest in the set-up of a trading market and that it may unfairly leverage its influence to gain information arbitrage as a market-maker."[xiii] .

Instead, backers of the BTO say it's market buyers and sellers, not exchanges, who should set the rules for trading. Williams' Sharon Crow declares that :

"We want to help make the rules because we don't want to play someone else's game."[xiv] .

CompTel[xv] , sponsor of the BTO, has posted in February 2001the first master agreement drafted by only a portion of its members. Indeed, this first agreement has generated a lot of discussions. Carriers, which were participating in the negotiations for this first contract until December 2000, decided to stop participating in the drafting of that particular contract. Instead, they drafted their own master agreement, which has been released at the end of March 2001. In addition to the two currently competing contracts, soon the eBTO should release a third contract on behalf of the exchanges. At this point, market participants will have the choice among three different documents when transacting. Certainly, this is not going to help the emergence of a liquid market.

The main arguments of dissent among traders and carriers in regard to the master agreement centered on issues of force majeur and liquidated damages. Carriers are very reluctant to accept the concept of liquidated damages, which would oblige them to cover any damage caused by the non-fulfillment of their contractual obligations. Traders consider it as an essential disposition. It provides the parties to the contract with the certainty that they are going to be compensated in case of default. In particular, this clause is critical in the case of risk management. Indeed, in order to hedge a position, the party needs to be able to determine with certainty the exact risks it is exposed to.

This multitude of exchanges, bandwidth organizations, master agreements and other contradictory initiatives demonstrate the importance of bandwidth trading. They show that a fierce battle for the control of this marketplace is currently taking place. All the players are trying to shape the future evolution of this embryonic market in order to be positioned to capture the enormous revenues at stake. Nonetheless, all this competing standards and architectures are slowing down the emergence of a liquid market. Therefore, all the market players have an interest in finding some consensus document in order to accelerate the development of bandwidth trading.

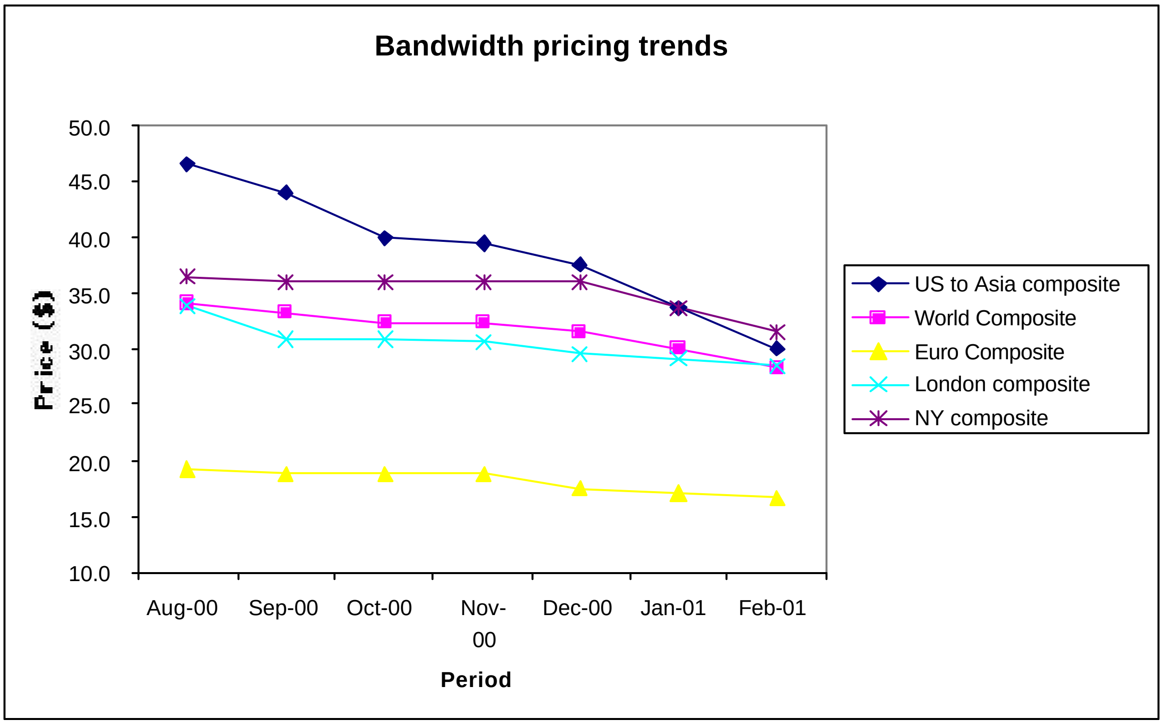
Indeed, this market needs to see the emergence of a standard that regulates quality of service issues and other legal issues. As soon as well-accepted norms are going to be in place, this should increase the number of bandwidth transactions. This standard will emerge either from consensus of the parties (doubtful) or from the industry practice. In the last scenario, we believe that market makers such as Enron, Williams or El Paso Global Networks are better positioned than exchanges and carriers to impose the trading standards. Their position as market makers provides them with an important leverage to influence the industry practices through their daily operations.

2.4. Prices are falling

Finally, collapsing bandwidth prices trends have not helped the emergence of trading. A DS-3 New York and Los Angeles which is today the most traded route, has lost 30% of its value this year. During the same period of time the prices of a DS-3 line between London and Frankfurt plunged 80%. And market participants are convinced that prices are far from their bottom. Indeed, in the past years, telcos had an almost unlimited access to capital through the continuous appreciation of their stock prices and thanks to highly receptive credit markets. This has allowed them to invest in the build-up of new capacity. New networks have been created on the basis that demand will explode. Unfortunately, this scenario was not to occur. Capacity on the long haul portion of the network was largely overbuild.

This phenomenon has critical implications for the development of a liquid bandwidth market. On the physical side, the continuously falling prices for bandwidth represent a disincentive for the carriers to sell their extra capacity on the market. They fear that by trading bandwidth, this will cannibalize their already shrinking revenues. On the derivative side, when prices follow a downward sloping slope without any major fluctuations, few speculators are going to be interested in selling puts or short future positions, even at very low exercise prices. This makes the emergence of a derivative almost impossible.

Exhibit 7 : Bandwidth pricing trends from August 2000 to February 2001



source: Band-X, March 2001

2.5. Derivatives and Risk management are the next step

Derivatives and risk management, as briefly discussed above, are currently capturing a lot of attention. They are seen by most market participants as the most important benefit from bandwidth trading (please refer to exhibit 5).

"The real value of bandwidth trading is in risk management" says Blakeslee from Global Crossing. *"It allows to optimize and monetize the network, removing short-term imbalances."* [xvi].

Different parties can use derivatives in various ways:

Risk management: They can be used to lock-in the future price of bandwidth and therefore stabilize the future revenue streams. They can be used to simply cap the possible losses in case of price fluctuations. In addition, derivatives are widely use to deconstruct risks in order to keep only the one desired and sell the rest in the market. This is extremely important, because it will considerably help the carriers that are considering laying new capacity to secure financing. Indeed, investors will be more willing to back a project where the revenues are protected against any major shift in prices.

Speculation: Derivatives are widely used to speculate. They allow to take positions without having to disburse the full amount of the contract. Speculators can take positions by depositing a margin in an account which will be marked-to-market every day.

Arbitrage: In this case, arbitrageurs are going to ensure that the price of a similar product (i.e. a New York – London route) is priced similarly in two different locations. In addition, the re might be more arbitrages opportunities not yet discovered. For example, if there is an increase in demand for the New York – Los Angeles route and prices are spiking, an arbitrageur could (if technically feasible) buy a New York – Houston route and a Houston – Los Angeles route. Then, he would combine them and sell them as a New York – Los Angeles route if the sum of the two routes is lower than the direct route. The difference would be its profit.

Currently, we are still far away from this scenario, but the implications are critical. Indeed, both buyers and sellers of bandwidth are unable to hedge their actual exposure to the volatility of bandwidth prices, exposing them to possible large losses. However, we believe the emergence of derivatives such as options or futures on bandwidth will be refrained until a physical market does not evolve. Indeed, derivatives are almost impossible to be priced without having an underlying physical traded(except for weather derivatives).

Chapter 3 – Supply and Demand imbalances and their impact on prices

As mentioned in the section 1.5 when discussing the main barriers to the emergence of bandwidth trading, the trend of falling prices of bandwidth is a major hurdle to the emergence of a liquid bandwidth market. In this chapter, we will analyze more in depth the causes of this trend. Furthermore, we will develop a simple system dynamics model to test the circumstances where bandwidth prices could oscillate..

3.1. Price transparency and trading.

Trading and price transparency might partly be responsible for the plunging of bandwidth prices. Certainly, bandwidth prices on certain routes are starting to be easily available (Bloomberg, the financial markets news group, started to quote prices on the main routes this year). However, trading cannot be the underlying cause for this fall in bandwidth prices. It merely can amplify or speed up this phenomenon. In no circumstances, can it be the cause of such a price fall. First of all, we know, that trading is extremely limited. Secondly, if trading were to be the cause of this price fall, we would see some volatility in this trend. This is not the case and prices are plunging almost linearly. This trend can be explained only by structural problems present in this industry.

3.2. Supply and demand imbalances

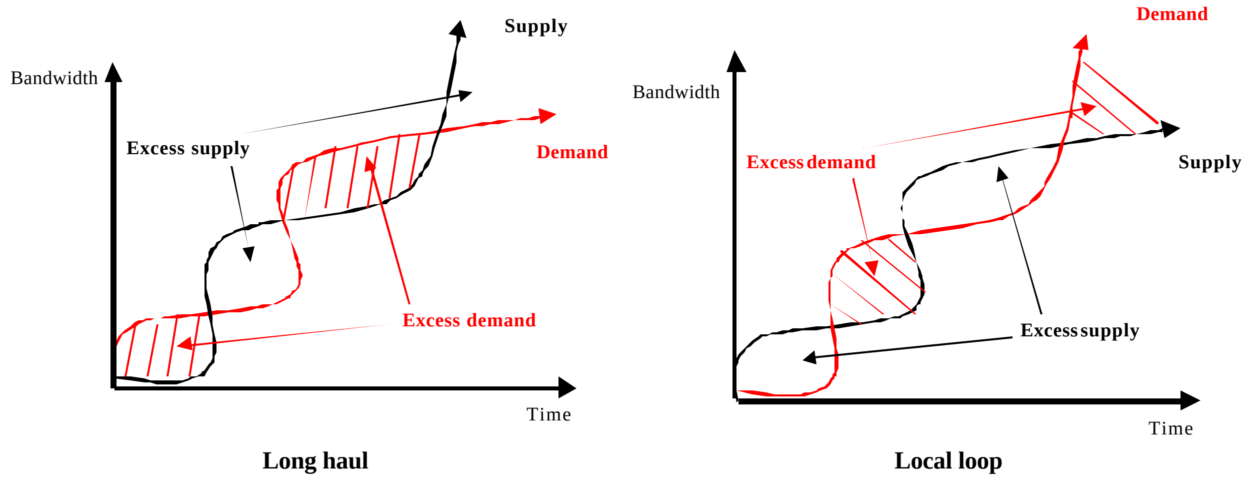
Prices are plunging because of the over-capacity on the long-haul portion. The technological and regulatory changes on the supply side discussed in the prior sections have led to the build up of new networks with immense new capacity. It is considered that supply of bandwidth has increased four hundred times since 1998 versus only twenty times for demand. However, these differences in growth rates are due mainly to the local loop bottleneck. This brings an important distinction when analyzing the supply and demand for bandwidth. The long haul and the local loop need to be analyzed separately because they have very different economics.

3.2.1. The local loop

The local loop is still facing important infrastructure problems that limit a fast increase in the capacity supplied. Indeed, the bandwidth available to households and offices currently is yet very limited and very expensive. This refrains the development of many bandwidth hungry applications such as streaming video or Napster, which are dependent on the capacity available to households.

Currently the incapacity to meet the capacity demand is due to two reasons. First, the excess of demand is capped by the incapacity to upgrade the old SONET network in the local loop. Indeed, the SONET network was ideal to transmit voice, but is not adapted to transmit data. And data transmission is growing exponentially generating therefore a bottleneck in the metropolitan area as depicted in the right figure in exhibit 8.

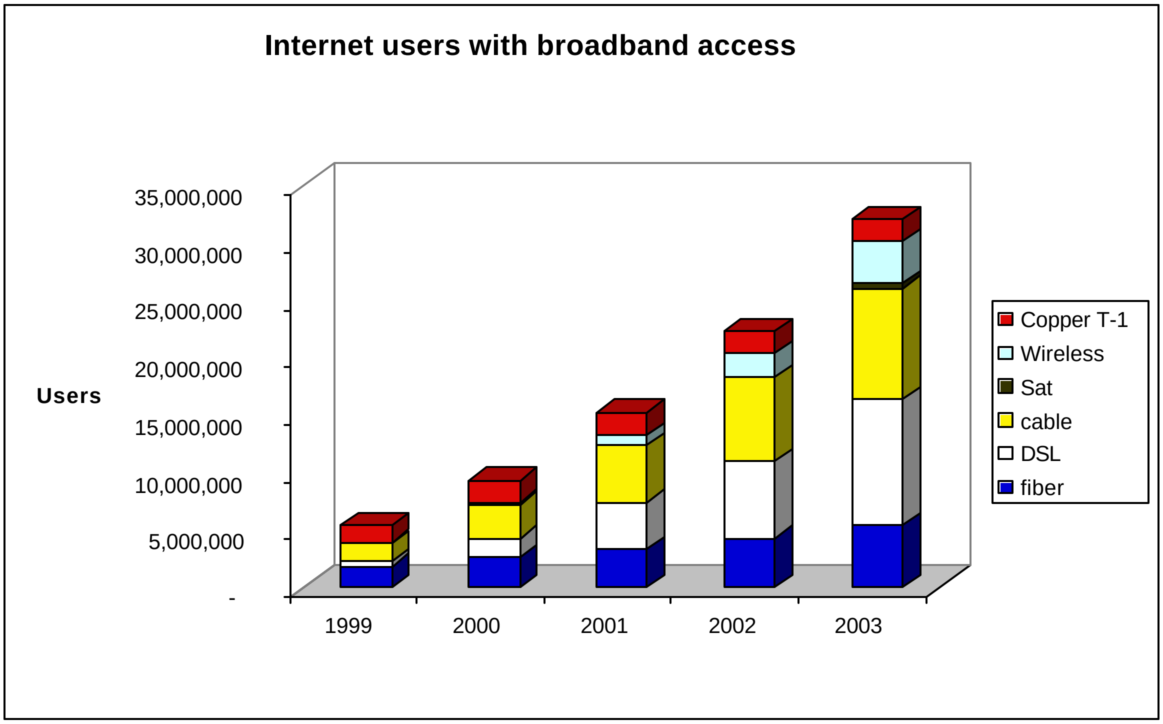
Exhibit 8: Supply and demand imbalances in the long haul and in the local loop



Secondly, the large costs related to cabling the last mile have limited the quantity of end-users access to broadband connections. Because the current network is unable to provision the sufficient capacity, new networks architectures are currently being deployed to replace the old SONET network. This opinion is relayed by many industry specialists, which foresee in the next two years the end of the local loop bottleneck. Already, companies with new network architectures are entering the local area network (LAN) in the hope of breaking the metro area bottleneck. For instance, Cogent Communications offers to business customers 100 megabit Ethernet lines at a flat price of USD 1,000 per month. This represents an increase of fifty times over the capacity of a1.5 megabit T-1 that was leased line from a RBOC at a similar price [xvii]. In addition, the reliability and the quality of service should improve too. By the same token, households in some cities are starting to receive broadband access via cable, xDSL or Ethernet. By 2002, there is a consensus among the industry analysts to see over twenty million users having a broadband access at home.

"When the US does hit a critical mass of residential broadband users (at about 15%-20% penetration), we expect a thermonuclear explosion in new demand for network capacity and equipment – particularly in the metro area"[xviii]

Exhibit 9: Internet users with broadband access



source: Broadband Solutions

The growth of supply of bandwidth is very progressive. The important costs and time delays associated with upgrading the existing network cause this pattern. In addition, the current infrastructure projects designed at developing the MAN are being delayed by local administrations which are very concerned by having large infrastructure project that will disrupt the traffic in the city. Therefore the system is in continuous imbalance. Either there is an oversupply or the contrary occurs. In addition, the differences between the local loop and the long haul in terms of costs and delays are such that today those two markets are completely segmented. In order to achieve sustainable prices in the long haul portion, it is critical that the local loop network gets upgraded. Unfortunately, the current drop in the stock market will slow down the upgrade of the existing network. Indeed, many carriers are facing important shortages in capital and have to put on hold their expansion projects.

3.2.2. The Long haul

Laying new capacity on the long haul portion is cheaper and easier. This explains the oversupply of bandwidth on this portion of the network. New companies like Level 3, 360 Networks and Williams have started to light their second generation networks and promised to cut actual bandwidth prices by 40% to 60%[xix] This new networks are incredibly more cost-efficient than the incumbent one's and will make prices fall even more in the near future. In addition, this new competition is going to increase the pressure on the carriers with first generation network, which might not be competitive anymore. Continuously plunging prices are putting a lot of pressure on the carriers to use more efficiently their networks. Bandwidth trading is going to be instrumental in helping the different carriers to optimize the use of their current operations.

This increase in demand in the local loop is going to affect bandwidth prices in the long haul network portion of the system. The expectation that demand is going to surge should affect in the near future the prices of bandwidth. Indeed, when traders and speculators will start expecting an increase in demand, then trading of physical bandwidth and of derivatives is going to emerge. Trading combined with the price pressure generated by the increasing demand and the delays to light new capacity are going to make prices oscillate. Nonetheless, in the long run we expect to see the prices of bandwidth continuing to follow a negative slope.

3.3 System dynamics model simulating the supply and demand of bandwidth

One of the fundamental characteristics necessary to see the development of a liquid market for bandwidth trading is price volatility. Hence, in a system where new capacity is continuously added and the demand remains constraint by technological barriers, you are going to have prices dropping without any oscillation for a long period. However, such an imbalance cannot continue forever. Indeed, a large drop in prices is going to affect negatively the supply of bandwidth. It will oblige many players to reduce the quantity of bandwidth supplied. These adjustments should in the long run make prices reach equilibrium and oscillate. The only obstacle to see price volatility would be if regularly large shifts in the supply curve due to new technologies improvements would to occur. These technology upgrades would allow for a minimal cost to upgrade the current lit capacity and supply would exceed demand greatly not allowing for any price fluctuations.

3.3.1. Hypothesis

The hypothesis underlying our system dynamics model represented in appendix I is that bandwidth prices, in the long haul, are going to be extremely volatile. This is due to the structure of supply of bandwidth. Indeed, the long delays necessary to upgrade the existing capacity or to lay new capacity are such that supply cannot respond instantaneously to a change in demand. This assumption is based on interviews where many industry actors confirmed the important delays that are imbedded in the system. An average of twenty-four months seems necessary in order to light fiber. Similarly, a period of almost three years is necessary from the moment the fiber is laid to the moment when the new capacity is available.

In the long term, bandwidth prices are to oscillate even if the local loop bottleneck was never to be removed. Indeed, most companies can not sustain for a long period of time a market where prices continuously plunge. Equity and credit market will start to refuse financing new infrastructure projects. Thus, supply will not increase forever. At a certain point (as it is starting to occur today), the most expensive networks are going to reduce the capacity supplied. Many carriers will have to switch off their network because bandwidth prices are below their marginal cost. Hence, either because the capacity supplied has been reduced significantly, or because the pool of competing carriers is much smaller, prices will reach an equilibrium level and oscillate.

3.3.2. Goal

This model has two main goals. First, it is to understand the dynamics of bandwidth prices and to see how the system responds to an increase in supply or demand. Secondly, the goal of this model is to demonstrate that prices of bandwidth are going to experience volatility.

The model in appendix I is based on some important assumptions spelled out in the next section. It is a crude simplification of the decision making process to lay or light fiber and its influence in prices. Therefore, the model has not to be read as a forecast tool of bandwidth prices, but as a simple method to understand the movements of prices for this particular industry. In addition, we believe that our model needs still to undergo some modifications to better represent the industry behaviours.

3.3.3. Basic assumptions

Based on our hypothesis, we had to make a number of assumptions in order to construct our model. (please refer to appendix III for an explanation of every single variable). Indeed, many data necessary to build the model were missing and no industry players was ready to give out confidential information. We therefore decided to base our model on rough estimates of the capacity demanded and supplied, the variable costs of operations and the laying and lighting rates.

Units: We used for our model as the unit to measure the capacity demanded or supplied terabits per second (tbpssec).

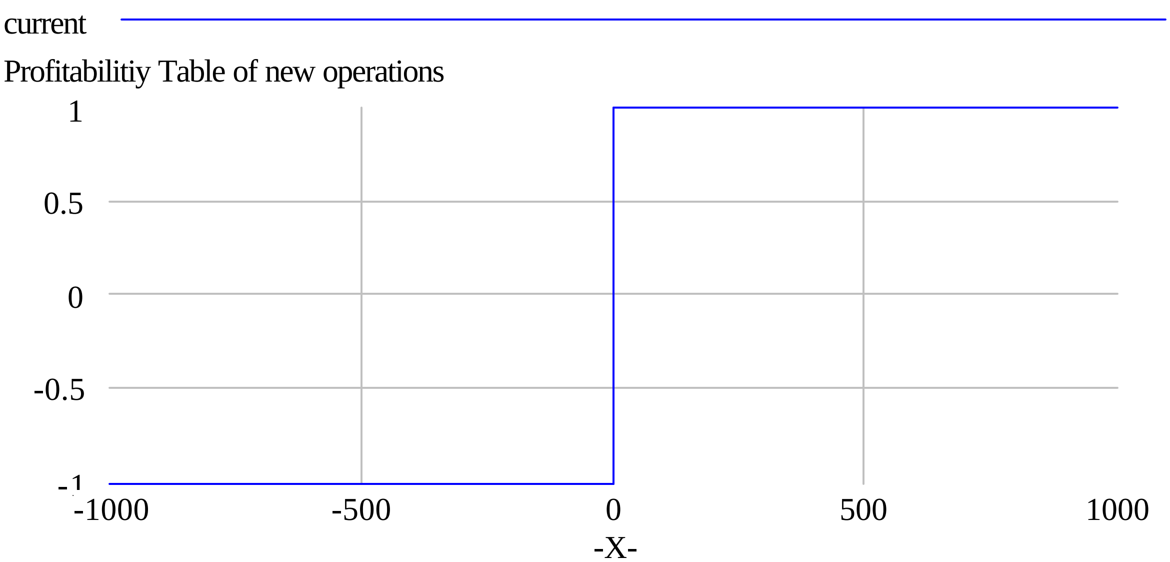
Quantity supplied and Quantity demanded: Since, it has not been possible to collect real data on points like marginal costs and total bandwidth available or demanded, we proceeded with ratios. We decided that currently the bandwidth available (600 terabits per second (tbpssec))was three time the bandwidth demanded (200 tbpssec). In addition we assumed that another 400 tbpssec were laid but were currently unused. During the different interviews, it has been recognized that these proportions are correct. Finally, we modeled the demand as an exogenous variable. This assumption is based on the idea that quantity demanded in the long haul is constrained by the quantity supplied in the local loop. This system was too complex for the purpose of testing our hypothesis.

Price: In our model (please refer to appendix I), we assumed that bandwidth prices had reached an equilibrium level in order to understand if the system would oscillate around this equilibrium price. This is an important assumption, since some might advocate that prices will never reach an equilibrium level. However, this assumption allowed us to simplify considerably the model building. It has to be noted that even with this simplification, we believe our model needs still some adjustments. For example, we are unable to explain the price movements in the first months (the period where price reach their maximum and oscillate slightly before plunging). We believe that the supply demand table provokes these initial movements, but we have not yet been able to resolve this problem. In addition, we noticed that the price volatility imbedded in the system is not provoked by the delays, but by the profitability of new operations switch (please refer to table 1). Therefore, that volatility is created by the continuous shifts in supply and delays are instrumental in smoothing these spikes. To correct these problems, we would need to develop some extra balancing loops.

Finally, we limited, for the purpose of this exercise, the fluctuation's band of price from a minimum of USD 1 to a maximum of USD 50.

Profitability of operations: This is an important variable because it represents the switch that decides if increasing the capacity in the network or decreasing the capacity in the network. We broke down this variable into two sub-variables: profitability of current operations and profitability of new operations. This distinction was necessary in order to take into account the lower marginal and variable costs of new technologies. Therefore, we had to establish two different switches. Indeed, when the price of bandwidth is at a level that make current operations no longer profitable, the new technologies operations might yet still be profitable and continue to increase building capacity..

Table 1: Profitability table of new operations



We understand that in reality, the decision to lay new capacity is not based only on a profitability ratio. However, often projects are approved on the basis of internal rate of return (IRR) or net present value (NPV) calculations. Both method are very similar to a switch: i.e., you approve the project when the NPV is positive. In the reality the switch would be less progressive and therefore we believe that the movements of quantity supplied and price are going to be less spiky in the reality than the ones our model generates.

Marginal costs: I assumed that the marginal costs of new technologies were equal to 50% the marginal costs of current technologies.[xx]

Lighting rate: Lighting rate is the rate at which carriers decide to lit the fiber that has been already laid but is still unused. We assumed a two years delay from the moment the profitability index from current operations indicates that it is profitable to light the unused capacity to the moment this capacity is available.

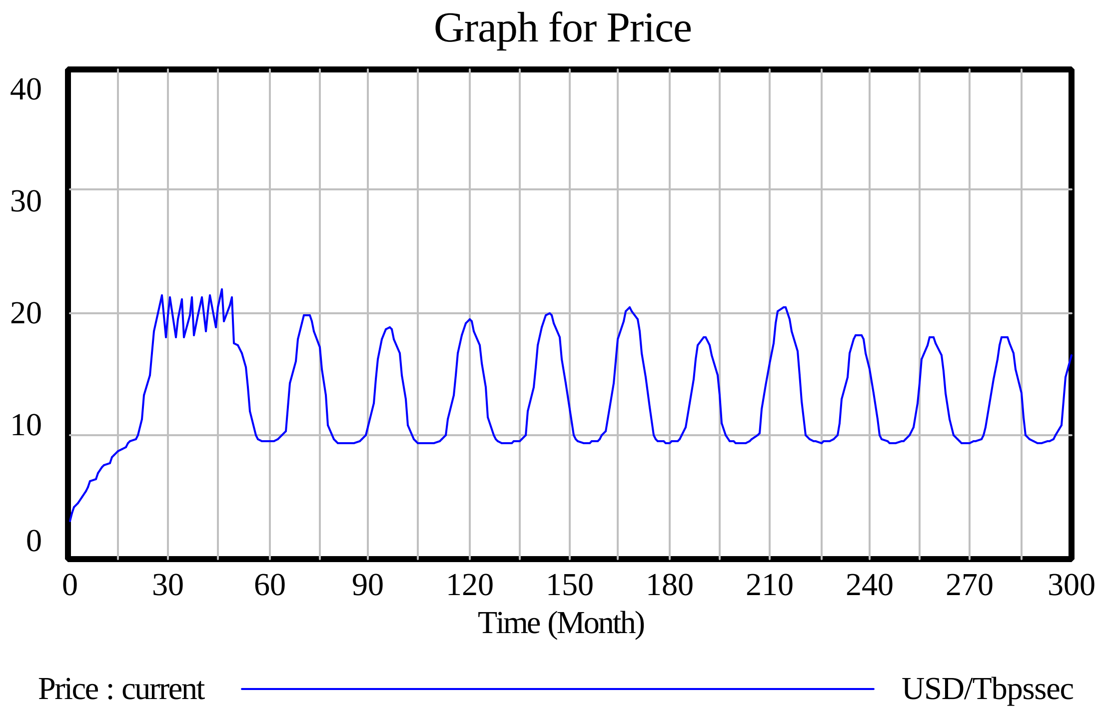
Laying rate: As the lighting rate variable, the laying rate represents the quantity of new capacity added. However, the laying rate does not draw from a stock of unused capacity as in the case of the lighting rate. We assumed that it takes on average a three years delay to lay new capacity.

Obsolescence rate: This is the rate at which capacity is removed from the system. We assumed that in this case the delay will be shorter and equal only two months.

3.3.4. Results

The model demonstrates that when prices are going to reach an equilibrium level, then they will be an important price volatility (as per table 2). This is true even when supply is much larger than demand. However, we believe that our model accentuates this volatility because the changes in prices are translated directly into new capacity via the profitability switches (please refer to table 1).

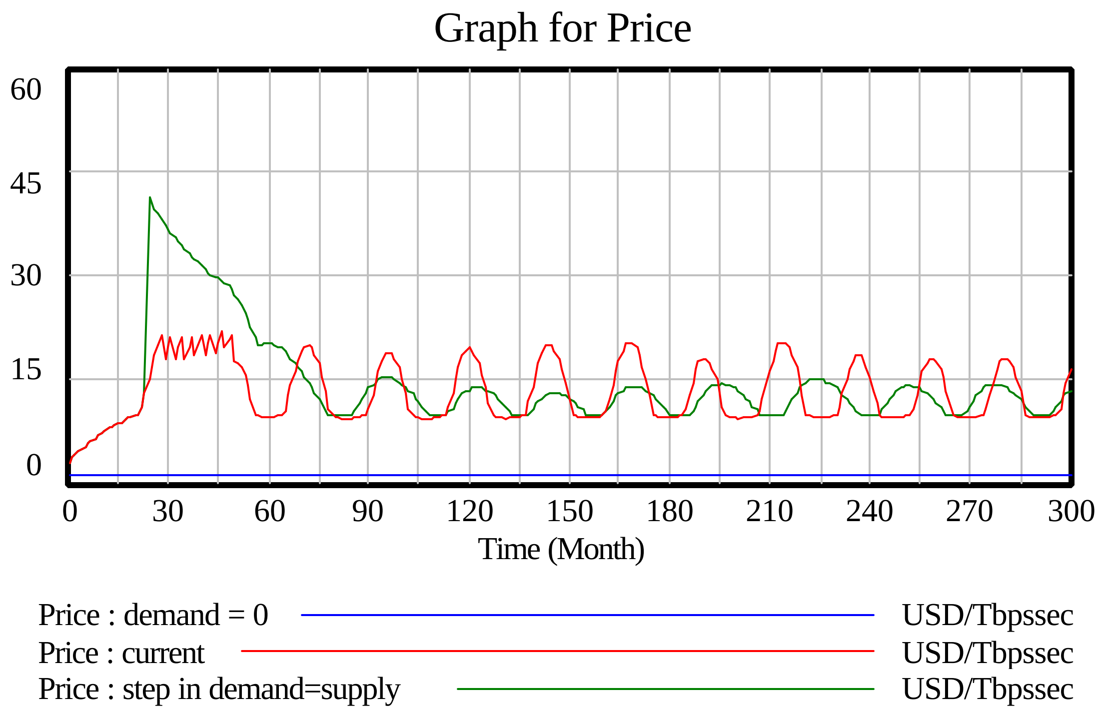
Table 2: Price behaviour at equilibrium



The current scenario is our initial scenario where supply is assumed to be three times greater than demand and where demand remains constant.

Prices continue to fluctuate even though we increased the demand for bandwidth at a level equal the capacity supplied. This is the scenario sketched in red in the table 3. We notice however two main differences with the original scenario. On the one hand, when demand increases at time 24 such to equal supply, then prices increase and reach a level four time above their equilibrium.

Table 3: Price patterns due to changes in demand

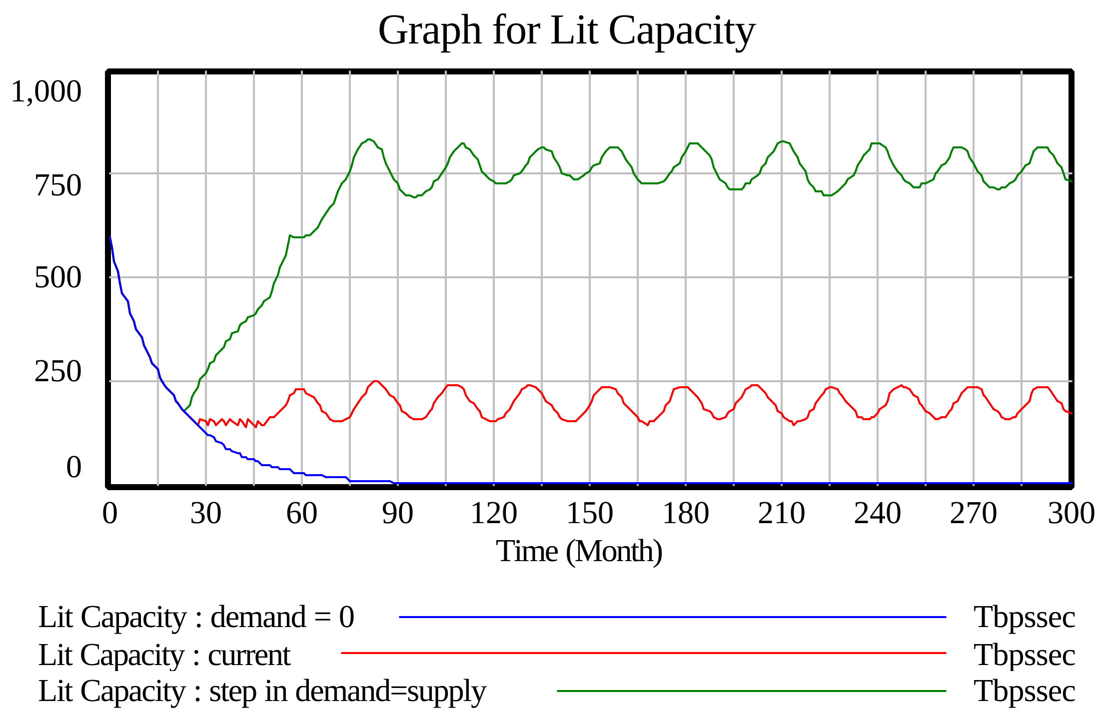


The current scenario is our initial scenario where supply is assumed to be three times greater than demand and where demand remains constant.
The step in demand = supply scenario sketches a sudden increase (as a step at time 24) of demand at a level equal to the quantity supplied.
The Demand = 0 scenario is the scenario where we decided that suddenly they would almost no more demand for bandwidth.

Then prices start to fall, since the industry is laying new capacity and lighting old capacity (in red, we can see that the stock of dark fiber is falling until reaching a new equilibrium). Then when the stock of lit capacity is sufficient to meet the current demand then prices start to fluctuate again due to adjustments in supply.

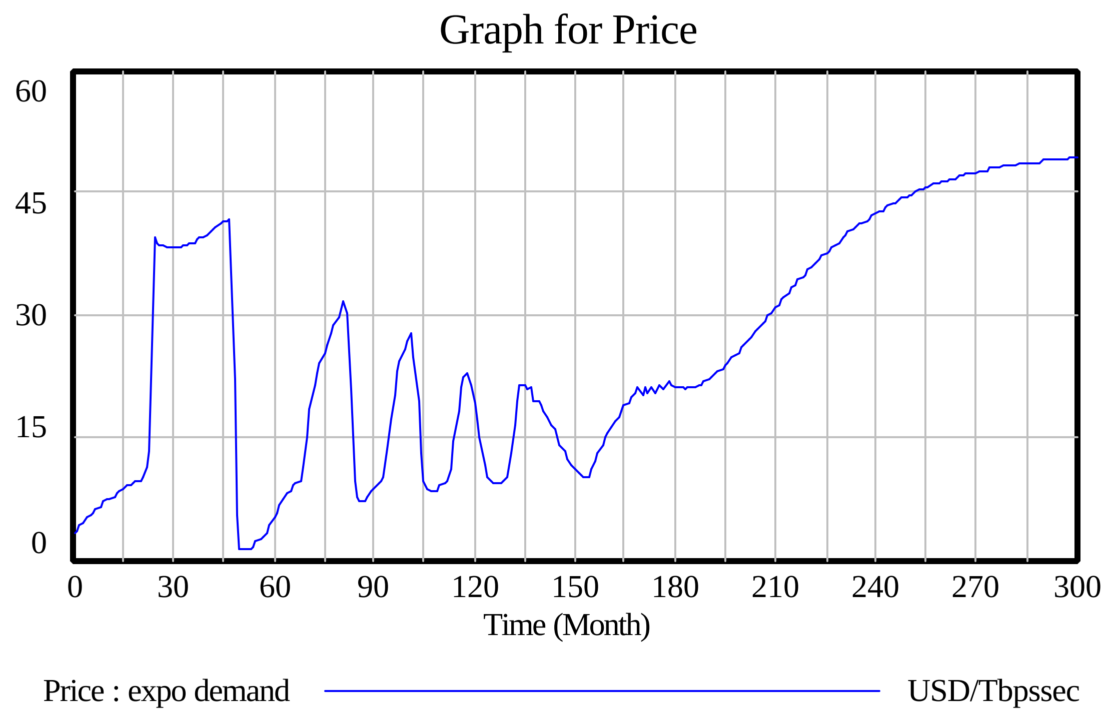
In table 3, we showed a third line (in blue) that sketches a scenario where demand would be equal to zero. Prices of bandwidth then would equal to zero and capacity available would start to drop until it reaches zero.

Table 4: Movement in capacity due to the increase in demand



Finally, I applied a scenario where demand increased, at time 24, exponentially by a factor of 1.05 (please refer per table 5). In order to see any reaction in my model, I had to increase the new technologies laying rate by one thousand times in order to match the increasing demand. The results shows that bandwidth prices would know enormous fluctuations in such a scenario would be fluctuating tremendously before settling at their maximum (50) due to the excess demand in comparison to the capacity supplied.

Table 5: Price behavior in case of an exponential increase in demand



Similarly, in a case where supply is considerably larger than demand (i.e. by a ratio of 1,000 to 1), then we notice that prices have no volatility (in our model they remain constant at the minimum level since my model is limited at a price level of 1). This would mean that in case supply is grossly above the quantity demanded, then prices would remain at their minimum without any volatility, until the system has not eliminated the excess capacity. This seems to be the situation that we are knowing today in the bandwidth trading market, where prices are plunging without any volatility.

3.3.5. Comments

The interest of this model was to show that price volatility is imbedded in the bandwidth system, especially in the long haul industry. Even though, we are not yet seeing any volatility today in the bandwidth prices, we expect volatility to pick up as soon as the quantity demanded increases at a faster rate. Indeed, the cause of a no volatility situation is that the capacity supplied exceeds greatly the demand for bandwidth.

Currently, we notice that bandwidth prices are volatile as it is occurring in the local loop. When one of the suppliers of capacity (cable, xDSL, …) goes out of business, the competitors immediately take advantage of this situation to increase their prices.

Chapter 4 –Possible market developments and new research

4.1. Derivatives and risk management

Volatility is going to characterize bandwidth prices in the near future. As electricity, both are non-storable commodities that require long and expensive infrastructure projects to respond to a surge in demand. This is what explains the extreme volatility of prices in electricity. This same volatility, we believe, will be experimented in the bandwidth market too.

This will lead to the emergence of market for bandwidth derivatives. Indeed, all the market participants will require hedging their bandwidth positions against price fluctuations. This process will take time. Carriers, yet, often do not recognize that their actual network represents a long position that needs to be hedged. A long educational process still needs to occur before the traditional telcos get accustomed to use financial derivatives in their day-to-day operations. Similarly than for the physical market for bandwidth, the derivative market will start in over the counter (OTC). Indeed, OTC markets offer often more flexibility than an established exchange. This is what happened with electricity, where the market for derivatives is predominantly an OTC one and only a small percentage of derivatives traded takes place on an established exchange. The emergence of a futures, options and forward market for bandwidth will play an essential role in fostering the development of the underlying physical market. The advantage of this market would be that it will allow traders to take more deals on their books, since hedging will become possible. This will increase the liquidity of the physical market enormously. Companies which are specialized in offering integrated risk management solutions, such as Enron, will tremendously benefit from the emergence of bandwidth derivatives.

4.2. Further research

Important research has still to be done in order to develop a model that integrates all the problems faced by bandwidth trading. In appendix II, we can see a model that sketches the price setting mechanism for traders. An interesting development would be to model a more robust system dynamics model for the supply and demand of bandwidth and integrate the trader's pricing model in order to understand if trading is going to accentuate or smoothen the volatility in bandwidth prices.

CONCLUSION

Bandwidth trading is still in its infancy. Indeed, many problems need to be resolved before we will see the emergence of a liquid market. The most critical of these obstacles are first, the supply and demand imbalances in the local loop and in the long haul. The different economics and regulations create a barrier between these two portions of the network. This provokes a situation where the long haul portion is over-supplied and local loop is under-supplied. Secondly, the lack of interconnection among the different carriers represents a barrier to the development of any real-time trading. Thirdly, bandwidth trading will not become a mature market until clear standards of quality and contractual obligations will not be set. Finally, the emergence of a bandwidth trading market might be slow-down by the tightening of the capital market and the plunging of the equity market.

The development of the bandwidth trading market depends on the removal of these various obstacles. In particular, it is critical that the different parties interconnect their networks at an agreed location and embrace a single master agreement. Indeed, even if the local loop bottleneck was to be removed, trading would not pick up until these two main problems are resolved.

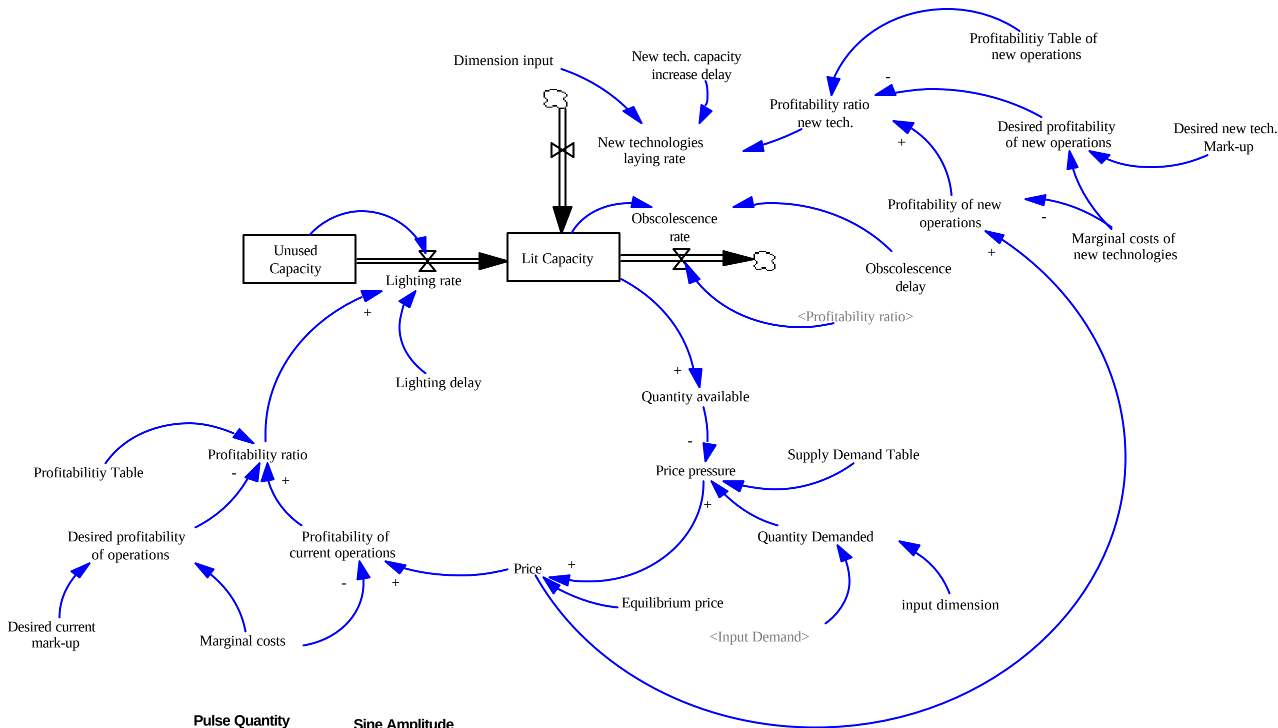
Falling prices should not represent a major hurdle to the development of bandwidth trading. Indeed, prices cannot fall forever without any volatility. Bandwidth prices will continue to follow a downward slopping trend in the long term as new technologies are implemented. However, as soon as the local loop bottleneck will be removed, then prices will start fluctuating because we forecast an enormous increase in capacity demanded. Through the system dynamics model we were able to illustrate this outcome.

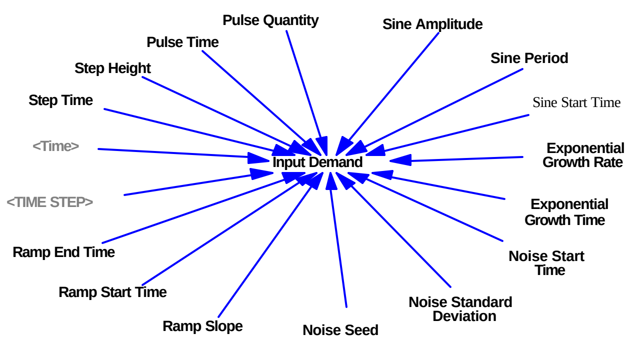
The main consequence of price volatility will be that it will induce the creation of a derivative market. This is a critical aspect because no physical commodity market can develop without a derivative market. It will allow the different players to take more positions and reduce their risks. On the same token, it will allow market participants to better manage their networks.

Due to the important hurdles that we have mentioned in this thesis, we forecast that we are going to see the emergence of a liquid market, but not before the end of 2003. Indeed, we think that it will take at least one year to see capacity demanded increase significantly and another year to have the various carriers to interconnect. Then only the market participants will agree on quality of service and contractual standards. Finally, the market makers through their daily transactions will shape the trading customs and have their master agreement emerge as the standard for the industry. Exchanges, instead, due their neutral position, will be unable to influence any industry practice.

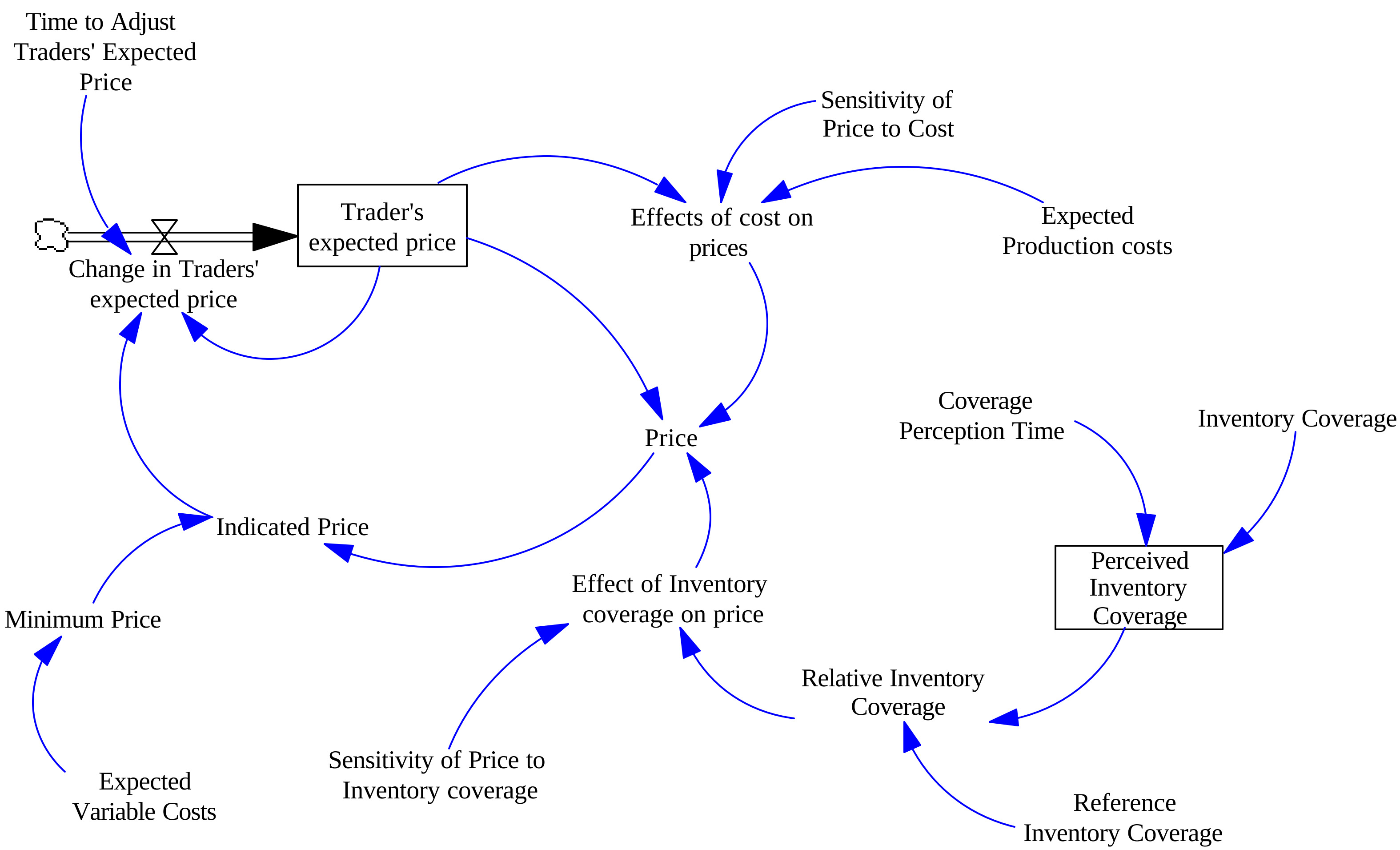
Regardless of the many obstacles yet to be removed, a liquid market for bandwidth trading is to develop. This might though take another three years..

Appendix I: Supply and Demand imbalances – Price volatility in bandwidth trading





Appendix II: Price setting process among traders



Source: John D. Sterman, Business Dynamics, Systems Thinking and Modeling for a complex world, Boston, IRWIN McGRAW-HILL, 2000, p.814.

Appendix III: Comments and description of the price volatility model (please refer to appendix I)

(01) "Desired current mark-up"=0.1
Units: Dimensionless
This is the percentage variable costs (10% of current variable costs) that we assume is required in order to imagine lighting the unused capacity.

(02) "Desired new tech. Mark-up"=0.1
Units: Dimensionless
This is the desired profitability margin (10% of new tech variable costs) that the carriers want to earn in order to decide to continue to lay new capacity.

(03) Desired profitability of new operations=(Variable costs of new technologies)*(1+"Desired new tech. Mark-up")
Units: USD/Tbpssec
This is the minimum profitability level for the carriers that has to be met in order to lay/lit new capacity.

(04) Desired profitability of operations=(Variable costs)*(1+"Desired current mark-up")
Units: USD/Tbpssec
This is the desired minimum profitability of operations. When this point is reached, the system starts lighting new capacity.

(05) Dimension input=100
Units: Tbpssec/Month

(06) Equilibrium price=10
Units: USD/Tbpssec
This is the price where the system is in equilibrium.

(07) Exponential Growth Rate=0
Units: 1/Month
The exponential growth rate in the input.

(08) Exponential Growth Time=24
Units: Month
The time at which the exponential growth in the input begins.

(09) FINAL TIME = 1000
Units: Month
The final time for the simulation.

(10) INITIAL TIME = 0
Units: Month
The initial time for the simulation.

(11) Input Demand=1+STEP(Step Height,Step Time)+(Pulse Quantity/TIME STEP)*PULSE(Pulse Time,TIME STEP)+RAMP(Ramp Slope,Ramp Start Time,Ramp End Time)+STEP(1,Exponential Growth Time)*(EXP(Exponential Growth Rate*Time)-1)+STEP(1,Sine Start Time)*Sine Amplitude*SIN(2*3.14159*Time/Sine Period)+STEP(1,Noise Start Time)*RANDOM NORMAL(-4 , 4 , 0 , Noise Standard Deviation , Noise Seed)

Units: Dimensionless

The input demand can be configured to generate a step, pulse, linear ramp, exponential growth, sine wave, and random variation. The initial value of the input is 1 and each test input begins at a particular start time. The magnitudes are expressed as fractions of the initial value.

(12) input dimension=1

Units: Tbpssec

It multiplies the inupt demand variable which is dimensionless in order to have a dimensionly correct system.

(13) Lighting delay=24

Units: Month

We assumed that there is a 24 months delay in the network from the moment the decision to light new capacity is taken to the moment this new capacity is fully operational. This very long delay is the underlying factor explaining the important oscillation of the model at equilibrium.

(14) Lighting rate=MAX(0,((Unused Capacity*(Profitability ratio)/Lighting delay)))

Units: Tbpssec/Month

The lighting rate is the rate at which the unused capacity is lighten. It is a function of the Unused capacity and the profitability ratio. There is a 24 months delay imbedded in the system. In addition, the lighten rate as a minimum value of 0, since it cannot be negative.

(15) Lit Capacity= INTEG (Lighting rate+New technologies laying rate-Obscolescence rate,600)

Units: Tbpssec

This is the stock of fiber lit. At time 0, it represents 60% of the total fiber layed in the ground. Both the lighting rate and the New technology laying rate increase the stock of available capacity. On the other hand, the obsolence rate decreases the size of the stock when the price of bandwidth is such that the profitability ratio is negative.

(16) "New tech. capacity increase delay"=24

Units: Month

We assumed, according to the interview data, that there is a 24 month delay from the moment a company decides to lay new fiber to the moment it can be lit and is available. We assumed that the full capacity was lit which is in reality not the case.

(17) New technologies laying rate = MAX(0, DELAY1("Profitability ratio new tech."*Dimension input,"New tech. capacity increase delay"))

Units: Tbpssec/Month

The new technologies laying rate is a function of the profitability index of rew technologies in the network. As per the lighting rate, the profitability ratio does immediately translate the required extra capacity in lit capacity. There is a 24 months delay that is assumed in this case. Finally, the new technologies laying rate can be equal as a minumum to zero.

(18) Noise Seed=1000
Units: Dimensionless
Varying the random number seed changes the sequence of realizations for the random variable.

(19) Noise Standard Deviation=0
Units: Dimensionless
The standard deviation in the random noise. The random fluctuation is drawn from a normal distribution with min and max values of +/- 4. The user can also specify the random number seed to replicate simulations. To generate a different random number sequence, change the random number seed.

(20) Noise Start Time=0
Units: Month
The time at which the random noise in the input begins.

(21) Obscolescence delay=2
Units: Month
This is a two months delay necessary to reduce the lit capacity.

(22) Obscolescence rate= MAX(0, (0.1*(-Profitability ratio)*Lit Capacity)/Obscolescence delay)
Units: Tbpssec/Month
The obsolescence rate represents the outflow of capacity from the Lit Capacity stock. It represents a fixed percentage of the total capacity stock and is negatively influenced by the profitability ratio from current technologies, since in the time frame analyzed by this model, this would be the first capacity to be removed in case prices are lower than marginal costs. The obsolence rate is capped at zero, since it cannot be negative. I have inserted a two months delay from the moment the profitability ratio is negative to the moment to the moment part of the lit capacity is reduced.

(23) Price=MAX(1, Equilibrium price+Price pressure)
Units: USD/Tbpssec
The price is the difference between the equilibrium price and the price pressure. We assumed that the imbalances of supply and demand in the network are automatically passed to the price. The reason being that we have already incorporated delays in the network at the level of lighting and laying rates, which are derived from interview data.

(24) Price pressure=Supply Demand Table(Quantity available/Quantity Demanded)
Units: Dimensionless
Using the lookup function "supply Demand Table" and the ratio of quantity available divided by the quantity demanded we derive the price pressure variable. This variable represents the changes (positive or negative) in price due to the excess supply or demand of bandwidth in the system.

(25) Profitabilitiy Table ([(-1000,-1)-(1000,1)],(-1000,-1),(0,-1),(0.99,-1),(1,1),(1000,1))
Units: Dimensionless
This is a lookup function.

(26) Profitabilitiy Table of new operations ([(-1000,-1)-(1000,1)],(-1000,-1),(0,-1),(0.99,-1),(1,1),(1000,1))
Units: Dimensionless
This is the lookup function that commands the profitability ratio of new technologies.

(27) Profitability of current operations=Price-Variable costs
Units: USD/Tbpssec
The profitability of current operations represents the difference between price and variable costs of current operations.

(28) Profitability of new operations=Price-Variable costs of new technologies
Units: USD/Tbpssec
The profitability of new technologies is the difference between the price paid by customers for the required bandwidth and the variable costs.

(29) Profitability ratio=Profitabilitiy Table(Profitability of current operations/Desired profitability of operations)
Units: Dimensionless
the profitability ratio is either 0 or 1 depending on the profitability of operations. When Operations are as or more profitable than the desired profitability of operations, then the system automatically switches on the lighting rate.

(30) "Profitability ratio new tech."= Profitabilitiy Table of new operations(Profitability of new operations/Desired profitability of new operations
)
Units: Dimensionless
The profitability ratio of new technologies is either equal to 0 or to 1 depending on the profitability of operations. When operations are as or more profitable than the desired profitability of operations, then the system automatically switches on thenew technologies laying rate.

(31) Pulse Quantity=0
Units: Dimensionless*Month
The quantity added to the input at the pulse time.

(32) Pulse Time=0
Units: Month
The time at which the pulse increase in the input occurs.

(33) Quantity available=Lit Capacity
Units: Tbpssec

The Quantity available represents the total capacity in the system that can be supplied. It is equal the Lit capacity.

(34) Quantity Demanded=200*Input Demand*input dimension
Units: Tbpssec
Quantity Demand is assumed to be equal at time zero 1/3 of capacity available. This is an arbitrary number that we believe should represent the actual low demand for bandwidth in the long haul portion of the network relative to the abundant supply generated by the large networks.

(35) Ramp End Time=1e+009
Units: Month
The end time for the ramp input.

(36) Ramp Slope=0
Units: 1/Month
The slope of the linear ramp in the input.

(37) Ramp Start Time=0
Units: Month
The time at which the ramp in the input begins.

(38) SAVEPER = TIME STEP
Units: Month
The frequency with which output is stored.

(39) Sine Amplitude=0
Units: Dimensionless
The amplitude of the sine wave in the input.

(40) Sine Period=10
Units: Month
The period of the sine wave in the input.

(41) Sine Start Time=0
Units: Month
The time at which the sine wave fluctuation in the input begins.

(42) Step Height=0
Units: Dimensionless
The height of the step increase in the input.

(43) Step Time=0
Units: Month
The time at which the step increase in the input occurs.

(44) Supply Demand Table ([(0,-10)-(10,40)],(0,40),(0.5,20),(1,0),(3,-7),(5,-9),(10,-9))
Units: Dimensionless

This is a lookup function. In this function we assume that when the ratio of supply and demand is equal 0, then the price increases 4 times above the equilibrium price. As the ratio increases, lower is the price increase. When the ratio reaches 1 (supply = quantity demanded), then the price remains at equilibrium. Above 1, then the price gradualy is reduced until it reaches a level of 1. This is the floor for price, since no capacity can be supplied when the price is equal to zero or negative.

(45) TIME STEP = 1
Units: Month
The time step for the simulation.

(46) Unused Capacity= INTEG (-Lighting rate, 400)
Units: Tbpssec
According to data gathered in our interviews with bandwidth traders and industry players, we understand that there is approximately a 40% of total layed capacity that has not been yet lit.

(47) Variable costs=10
Units: USD/Tbpssec
This is the variable costs of lighting the unused capacity which has already been layed.

(48) Variable costs of new technologies=5
Units: USD/Tbpssec
The variable costs of new technologies is assumed to be 50% lower than the variable cost of old technologies.

INTERVIEWS (end of March – Early April 2001)

- Andrew Hyman – PriceWatherhourse Coopers – Risk management
- Brad Bradshaw – Neoninc – Business Development (Regional network)
- Michael Smith – Lightrade – Neutral pooling point
- Stephen Kamman – CIBC World Markets – Equity Research – Telecom infrastructure
- William Sanders – Telcap – Editor & Conference organisation – Capacity 2001
- James Hawthorn – Enron Broadband Services – Head of Risk Management
- Greg Jenkins – El Paso Global Networks – Chief Executive Officer

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[ii] A. Michael Noll, Introduction to telephones ande telephone systems, Boston, Third edition, ARTECH HOUSE, 1998, p. 344.
[iii] In this paper, when we will speak about bandwidth trading we will be refering specifically to the trading of circuits on an exchange.
[iv] Barclay T. Leib, “The Futures of Bandwidth Trading”, *Derivatives Strategy.com*, August 2000, p. 2.
[v] Sharon Crow, “Pooling of interests”, Capacity, TELCAP LTD, November – December 2000, p. 21.
[vi] Interview with Mr. Greg Jenkins, El Paso Networks, Chief Executive Officer, April 19, 2001.
[vii] Interview with Mr. James Hawthorn, Enron Broadband Services, Head of Risk Management, April 10, 2001.
[viii] Raymond Niles, Benjamin Morton, “Enron Corporation”, Equity research, SALOMON SMITH BARNEY, January 2001.
[ix] Shira Levine, “Telcos in denial?”, *America’s network*, February 15, 2001.
[x] Interview with Mr. William Sanders, Telcap Ltd., Editor & Conference organisator, April 9, 2001.
[xi] EBS has a 12-strand fiber network in place including 4,200 miles of built fiber, additional contracted capacity, and further capacity under swap agreements.
Curt Lautner, Philip Salles, Andy DeVries, “Enron Corp.”, Equity research, CREDIT SUISSE FIRST BOSTON, January 2001.
[xii] You too can be a market maker”, *The Bandwidth desk*, SCUDDLER PUBLISHING GROUP, March 9, 2001, p. 5
[xiii] Grahame Lynch, “Bandwidth trading edges towards legitimacy”, *America’s network*, http://www.americasnetwork.com/issues/2000issues/20000801/20000801_bandwidth.htm, August 2000.
[xiv] Idem.
[xv] CompTel is the main association of telecommunications companies.
[xvi] “You too can be a market maker”, *The Bandwidth desk*, SCUDDLER PUBLISHING GROUP, March 9, 2001, p. 5
[xvii] Idem.
[xviii] Steve Kamman, “Disruptive Change in the network means disruptive change in network equipment”, industry research, CIBC WORLD MARKETS, January 2001, p.10.
[xix] Ibid, p. 17.
[xx] On this point, I have no confirmation from industry participants. This is therefore an assumption would need to be confirmed by industry players.