Upstream Internet Connectivity, Antitrust and Cyber-geography

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30 April 2002

Preliminary Version

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1. Introduction

While a rich and varied economic debate has developed on the issues of liberalisation of the telecom market and its relation to the costs, and therefore diffusion, of the Internet, less attention has been, until recently, devoted to its less known side: the upstream connectivity required by the Internet Service Providers to reach the rest of the Internet. The main source of information on this market is found in the debates accompanying the antitrust inquires into the main backbone proposed mergers, and in the preliminary work for the recent EU Directive on "Access to, and Interconnection of, electronic communication networks and associated facilities" [Official Journal 2002].

In the Internet infancy, connectivity between different networks was mainly a technical problem and was taking place on a co-operative base at public exchanges, however, recently, commercialization and a progressive wave of mergers and acquisitions, have deeply changed the way information packets travel across the different networks composing the Internet. In particular, while major backbones still exchange traffic free of charge amongst themselves, they started charging for transporting information from smaller providers, who can only achieve global Internet connectivity by using these backbones. Also, the evolution towards quality and delay sensitive Internet applications, i.e. Video on demand, voice over I.P[1]. and secure e-commerce transactions, is prioritizing the quality aspects of the Internet connectivity. While quality in the Internet is expressed by an array of properties of the information transmission process, it is strongly related to the type and number of connections each network has with the dominant backbones.

Many are the issues competition authorities need to scrutinise before understanding if there is any scope for antitrust action or regulation in this industry. The analytical tasks faced by competition authorities are particularly daunting for the market of Internet connectivity. This is particularly so

[1] Internet Protocol.

when it comes to defining the relevant market, both in terms of product space and of geographical extension; ascertain the degree of market power of single competitors; monitor the evolution of prices and their geographic differentials; evaluate the existence of entry barriers; and detect anti-competitive behaviour or quality based non-price discrimination. The main problem being the elusive nature of the commodity traded, wholesale transmission of information packets, along routes which are often recalculated at each step (hop), of the transmission process. While, indeed, it is easy to calculate the traffic exchanges for traditional telephony, which travel along a dedicated circuit, and to verify the associated economic transactions, new and different tools are required to trace Internet traffic flows when, for example, even a single e-mail from Cambridge to the NHH in Bergen is decomposed in many sub-messages which may, or may not, reach the final destination traveling across different routes and networks while some of the network crossing are for a fee and others take place for free.

The estimation of market concentration in the Internet Backbone can provide very different conclusions depending on the measuring approach used. Four main approaches have been used[2] based on measurements of*: revenues, traffic, routing and network architecture*. A revenue approach presents serious problems due to the mixing of revenue data from very different Internet segments, and is particularly misleading for vertically integrated backbones. Traffic based market share measurements are particularly challenging, given the proprietary structure of the backbones. Routing techniques for the estimate of backbone market shares are based on an annual survey counting the upstream interconnections of ISPs carried by Boardwatch[3] but have been criticised for not considering the relevance of these connections. Finally a network architecture based approach[4] considers International Internet Connectivity based on deployed and operational bandwidth running the I.P.

[2] For a comparison of these approaches see Abramson [2001].
[3] Boardwatch ISP directory..provides a count of the upstream interconnection for the providers, this have been used by the DoJ in its main antitrust inquiries .
[4] This data are collected by Telegeography, Inc.

In this paper we explore an indirect route to complement existing metrics techniques. In recent years new *Online Internet Transit* (OIT) trading places have emerged on the market. Among these are Band-X, RateXchange, InterXion, Arbinet, Asia Pacific Exchange and Enron. The main characteristic of the OITs is that they allow bandwidth trading through a centralised process with transparent prices while providing Quality of Service information. The immediate consequence of the appearance of these market operators is that while data on pricing and quality of IP transit were often specified in bilateral contracts and kept confidential, now prices are becoming available and can be used for benchmarking the industry. For example the Band-X trading place provides daily prices for monthly Internet transit at different bandwidths, from its trading floors in London and New York.

The potential competitive impact of *OITs* on the entire transit market is of extreme relevance: a lowering of the Internet access prices could enhance Internet penetration, since unconnected consumers might be willing to do so at a reduced price. Increased penetration rates are a precondition for e-commerce and the provision of e-services expansion, and this will have an more general impact on society as a whole, for example by providing information opportunities independently of the geographical area, as long as there is a good Internet connectivity. ISPs, which operate in a highly competitive market, could benefit from the increased demand while enjoying reduced uncertainty and volatility of their costs, and investors and financial institutions would be able to protect themselves from the financial risks through a liquid and transparent market and forward prices. Regulators finally will be able to obtain relevant information for benchmarking the interconnection conditions in the backbone industry.

A subtler issue concerning regulators, and therefore final users, relates to the quality of the interconnection provided. Quality differentials are an indicator of market power asymmetries since degraded quality of interconnection can be a powerful form of non-price discrimination in a concentrated industry. Cremer, Rey and Tirole (2000) indeed modelled these aspects of quality competition for the backbone market and analysed a "targeted degradation" strategy where the

larger backbone lowers the quality of interconnection to its smaller rivals. Interconnection quality depends indeed on many aspects of the network like its capacity, architecture and the number of peering, private and public, agreements. Indeed the core of the debate on the backbone market revolves around a mainly technical question, “How hierarchical is the Internet Backbone?”. This question is crucial since it defines the vertical boundaries of the relevant market to analyse, which in turn affects the determination of the geographical ones: *how connected are the different national regional markets for Internet transit, and where should we draw a line when appraising their competitiveness?*

Different studies give contrasting answers about the vertical degree of the backbone hierarchy, leading to opposite antitrust prescriptions. However the recent investment wave following the liberalisation of the European Telecoms market has dramatically redesigned the Internet connectivity maps. The most recent Industry reviews by Oftel [OFTEL 2001] and OECD [OECD 2002], suggest indeed that there has been a change in the formerly vertical U.S.- centric backbone architecture. The rapidly changing geography of the cyberspace requires therefore a continuous scrutiny since its forms, links and borders define the need for, or the irrelevance of, public intervention in this crucial market on which new attention has been devoted since the recent EU *Access and Interconnect Directive.*

After a brief review of the Features of the European Backbone market and the related antitrust investigations we will focus on the following issues:

- We consider the transit markets in the London and New York on-line trading floors. By comparing the connectivity prices in the two markets we find that Europe is a connectivity market on its own, unchallenged by the US’ one. Indeed, the low price levels prevalent on the European market would make it uneconomical for a local ISP to buy Internet transit from a US hub. This is relevant in defining the geographic scope of transit markets which is a preliminary step in antitrust investigations.

- We then focus on the quality indexes to see whether the price convenience of European ISPs to connect in London implies a lower connection quality. We find on the contrary that the quality of UK based transit is at least as good as its American counterpart. This reflects the changes recently occurred on the Internet connectivity map, which seems to be loosing its single-headed hierarchical structure, to acquire a more polymorphic architecture.
- Having found that the European and US are separate markets we analyse whether the price variability in these markets is explained by quality differentials. We do not find any statistically[5] significant effect of quality on prices. This somehow puzzling result might indicate the presence of some degree of market imperfection. Since we work with on-line data this could also reflect the well-known brand associated reputational effect characterising virtual trading environments. However, a word of caution is here required, as our results do not capture a potentially important link between the reliability of transit services and their price. This link can only be investigated by collecting and analysing data on the variance of quality indicators and its relation to quoted prices. This is part of our on-going research effort. The perspective relevance of such an analysis of the quality variance is confirmed, at this stage of our research effort, by the preliminary examination of graphic evidence on the recent temporal profile of qualitative indicators.

2. The Internet supply side

The supply side of the Internet has players that can be divided into functional categories[6]:

- *Internet Service Providers* (ISP's). These provide access to the net through personal, business, or institutional accounts.
- *Network Access Points*, (NAPs) and *Internet Exchange Poin*ts, (IXPs). These form the physical interfaces between networks and can be further divided into public and private bilateral ones.

[5] We run a set of regressions on transit prices against different quality Indicators and we found that quality indicators do not have stastically significant effects on prices.
[6] It is however important to keep in mind that overlap of these functions are often observed, also because of the recent trend in vertical integration, and mergers in the industry.

- *Internet Backbone Providers* (IBPs). They carry data traffic, across long distance on fiber optic cables. At each node they provide routing of the information packages to direct each incoming message to the next step of its path. Backbones are usually classified as Tier 1, 2 and 3 depending on their relevance and connectivity strength. This hierarchical classification is however under scrutiny, both because of the appearence of new technologies and beacuse of the rapid expansions of the connectivity maps of non U.S. backbones which are now often able to offer end to end connectivity, without necessarily depending on the original Tier 1 U.S. ones[7].

Each single network is connected along two dimensions with the rest of the net: by sharing the same *Transmission Control Protocol/Internet Protocol (TCP/IP)*, the communication protocol providing a common language for computers to exchange information, and through the physical network interconnection points. Traffic growth and commercialization has led much of this interconnection from being carried at NAP's to move towards exchanges at bilateral interfaces.

2.1. Linkages

Consider an end user, A, he connects to a Point of Presence (POP) of its Internet Service Provider. This connection can take place through dial-up, ASDL, Cable TV, or dedicated access. If the information exchange, communication, is between A an other end user and /or web site, B, connected to a different ISP , then A's ISP needs to lease lines to transfer A's message from its POP to either a NAP or an Internet Exchange Point. If such point is shared by the sender's and the receiver's ISPs, then the path is decided, otherwise the IP protocol will evaluate the path, for each single information packets, to reach the B's ISP's Point of Presence. This structure of direct or indirect connections between ISPs, NAPs and IXPs can be repeated many times depending on the actual distance, in the network topology, between the two users, A and B. Long Distance connection is finally provided by backbone operators. The entire route is recalculated at each router, and the actual transmission process is carried by many different ISPs located at different hierarchical levels. The multi-ownership of different segments, of the routes used to exchange

[7] For a detailed analysis of the development and contruction of these end to end netwroks see OECD [2002].

information between different end points of the Internet, is one of the features of the Internet architecture generating difficulties in understanding its pricing structure.

2.2. The price of Internet Connectivity

While the rapidly expanding number of IXPs, particularly in Europe simplifies the information package routing, by reducing the number of links and the average distance travelled, the connectionless nature of the Internet still makes the price formation process extremely more complex than in traditional telephony.

Interconnection charges among backbone operators have been predominately of the *settlements-free* type, for *peering*[8], while money is usually paid for *transit arrangements*[9], (see Kende 2000). The transformations taking place in the Backbone market in terms of capacity, switching technology and mergers are changing the incentive compatibility of existing pricing systems and regulatory authorities are becoming increasingly interested both in the possible emergence of market failures and in the interaction between existing regulation and interconnection pricing.

The upstream connectivity costs for an ISP can be divided into two main classes, the bandwidth costs required to connect to peering or exchange points and the *transit charges* when the data traffic leaves the original network outside a peering agreement. On many key routes bandwidth prices, relevant for reaching the Internet connectivity point, have been dramatically reduced as a result of technical innovation and stronger competition. On the other hand data on pricing of IP *transit* are often specified in bilateral contracts and kept confidential. However, some of these prices are becoming available from OIT traders such as Band-X. An ISP in need of connectivity can buy it from one of these locations and its cost is determined by the sum of the online selling price and the cost of connecting to the nearest trading place.

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[8] "Peering has a number of distinctive characteristics. First, peering partners only exchange traffic that originates with the customer of one backbone and terminates with the customer of the other peered backbone. …As part of a peering arrangement, a backbone would not, however, act as an intermediary and accept the traffic of one peering partner and transit this traffic to another peering partner. " Kende (2000)

[9] Transit arrangements occur when one backbone pays another backbone to deliver traffic between its customers and the customers of other backbones.

2.3 Interconnection Quality

Commoditization of Internet transit, facilitated by the emergence of a transparent trading place, usually provides higher incentives towards product differentiation. This shows, in particular, with the efforts to improve quality and reliability of the connectivity supplied. Quality depends on many aspects of a network like its capacity, architecture and the number of peering, private and public, agreements. There are, however, some simple ways of testing the quality of a connection and build quality indexes. In particular Band-X provides a quality index of the IP connectivity based on the network statistics described below. *" The monitoring metrics used are: -'Traceroute' which measures the* ***number of hops*** *(or routers) which traffic passes through to get to a destination and back. This figure should ideally be as small as possible.- 'Ping' is used to provide* ***packet loss*** *information, which indicates how much traffic is being lost, usually an indication of congestion or problems occurring on the network. This should be zero in a network performing properly. This metric also delivers the* ***round trip time*** *in milliseconds for the traffic to travel to and from a remote site. Again, the shorter the time, the better. -**Throughput** - the rate at which information travels across the IP network, is measured by examining the transfer rate for replies to HTTP requests for information on specific websites. "* [Source www. Band-X.com].

The quality of I.P. connectivity provided by a backbone is used more and more frequently to asses the potential degree of market power by different competition authorities since degraded quality of interconnection is seen as a powerful form of non price discrimination in a concentrated industry. Similar considerations have been central in antitrust investigations as we shall see in the analysis of the proposed merger by MCI-WorldCom and Sprint discussed below.

2.4 Antitrust analysis for the backbone market

One growing concern among antitrust authorities relates to the possibility of abuse of market power. One sign in this direction has been identified in the different interconnection charges levied to small and larger providers, a process started in 1997 by UUNET's decision of setting minimum traffic requirements for free peering with smaller ISP's. Cave (1999) analysed the possible problems

and/or desirability of having some degree of market power and a hierarchical structure in the backbone. The denial of free peering to small ISPs is, in facts, at the same time solving a free riding attitude, that could potentially lead to inefficiencies and congestion, and posing a threat of anti-competitive behaviour. Cave(1999) discussed possible regulatory measures including: obligation to peering, regulation of transit prices, monitoring/prohibition of vertical integration between IBPs and ISPs and price transparency. Of course these types of heavy interventions may induce distortions and are particularly worrying in the case of the Internet, which has shown spectacular growth and diffusion in absence of regulation. It is however of paramount relevance to assess the effects of the changes in the backbone market and their regulatory implications.

2.5 A non US-centric Backbone market?

In December 1999 the European Commission launched the *e*Europe initiative with the objective to speed up the process of bringing Europe on-line. The *e*Europe plan defined its three main objectives, of cheaper, faster and secure Internet and the European Parliament endorsed the *e*Europe action plan identifying unbundled access to the local loop as a short term priority to bring about a substantial reduction in the costs of using the Internet. However high speed access to the local loop is not sufficient to achieve, per se, the *e*Europe objectives. Indeed one of the main problems in securing a fast and cheap Internet access arises, not in the final connections between users and ISPs, but in the costs and quality of the connection between ISPs and the rest of the Internet. This issue has emerged in the drafting of the recent Directive on Access and Interconnection. In 1998 the association of European ISP's, EuroISPA (1998), pointed out that it was, in facts, common for many European ISPs to lease bandwidth to the United States to route intra-European traffic, as this was often commercially convenient[10] though technically inefficient.

In recent years there has, however, been a rapid transformation in the long distance telecommunication market: data traffic represents now more than 50% of the overall distance traffic and it is increasingly transmitted over the IP network. Entrants in the backbone market have

deployed in the last four years more than 10,000 route miles of fibre network and the amount of bandwidth which can be provided on a given strand of fiber is increasing enormously because of the new ways of exploiting fiber such as the dense wave division multiplexing (DWDM). Table 1, below, provides the number of completed and planned data traffic route miles outside the U.S. for some of the major backbone competitors.

Table 1: Completed and Planned non-U.S. Route Route Miles

Network	Completed non-U.S. Route Miles	Planned non-U.S. Route Miles
360Networks	31,000	42,700
Global Crossing	NA	80,000
Level 3	3,591	4,750
Qwest	37,825	37,825
Williams Communications	NA	31,000
WorldCom	22,000	22,000

Source Dain Rauscher Wessels, (2001)

A recent assessment of the impact of this investment wave on the competitiveness of the backbone market in the United Kingdom has been recently published by Oftel[11]. The vertical boundaries of the market have been drafted by using the *test of the hypothetical monopolist*[12] leading Oftel to the conclusion that Internet connectivity constitutes a market on his own. The definition of the geographic extension of the market for Internet connectivity identified three possibilities for an ISP based in the U.K to buy connectivity: in the U.K., elsewhere in Europe or in the U.S. Oftel found that the additional costs faced by a British ISP to buy connectivity outside the U.K. is high enough

[10] In 1998, for example, the monthly cost for a 2Mbps connection between London and Paris was of 38.000 $ while the same capacity connection between London and Virginia (the closest extra-European exchange point) was of 30.000$ even though Virginia is almost 25 times further away from London than Paris, Euroispa (1998).

[11] *Effective competition review of Internet connectivity* , Oftel (2001).

[12] From the Oftel document : " A product is considered to constitute a separate market if a hypothetical monopoly supplier could impose a small but significant, non-transitory price increase without losing sales to such a degree as to make this unprofitable. If such a price rise would be unprofitable, because consumers would switch to other products, or because suppliers of other products would begin to compete with the monopolist, then the market definition should be expanded to include the substitute products." Oftel 2001.

to make the U.K. Internet connectivity market competitive. This finding, conflicting with the earlier EuroISPA statements about the convenience of acquiring U.S.-based connectivity shows the effects of the recent evolution of the European backbone industry often described as *fiber glut*. In particular Oftel found over 20 suppliers of Internet connectivity, in the U.K. and failed to identify an operator as having a dominant position in terms of market volume. In its review[13], Oftel reached the conclusions that the wholesale IP transit market in the U.K. is effectively competitive and wholesale prices are falling. This conclusion, together with the OECD most recent study of the Backbone market, are, interestingly, conflicting with the results of the antitrust investigations on the WorldCom –Sprint proposed merger analysed below. Our preliminary analysis of the price and quality data from on-line bandwidth trading floors confirms the conclusion reached by Oftel and the OECD. For example, in Table 2 we present trading data for a typical monthly contract for 10 Mbps of bandwidth in Band-X's London and New York trading floors, as recorded on the 23/04/2002.

Table 2: Connectivity markets for typical 10 Mbps contracts in London and New York

		London (last year as of 23/04/2002)			**New York (last year as of 23/04/2002)**		
		Price on 23/4/2002	Quality Index	Quality/Price Ratio	Price on 23/4/2002	Quality Index	Quality/Price Ratio
EU	Average	2,165	67.14	55.70	2,430	28.38	20.31
	Var	136,904	71.52	167.40	64,800	33.70	4.20
	st. dev.	370	8.46	12.94	255	5.81	2.05
	Best	1,749	76.12	74.38	2,250	32.48	21.76
US	Average	2,165	57.18	47.31	2,430	107.98	77.17
	Var	136,904	48.37	108.43	64,800	640.82	102.65
	St. dev.	370	6.95	10.41	255	25.31	10.13
	Best	1,749	65.36	63.82	2,250	125.88	84.33
Globe	Average	2,165	79.60	65.53	2,430	44.02	31.55
	Var	136,904	107.42	171.66	64,800	63.85	5.98
	St. dev.	370	10.36	13.10	255	7.99	2.44
	Best	1,749	90.87	86.43	2,250	49.67	33.28

Source: Our calculations on data provided by X-band. **Notes:** The quality/price ratio is calculated as the product of the relative historical quality index (calculated over the last year) by the inverse of the ratio between relevant current price and best current price for connectivity at the stated bandwidth in the two online trade-floors.

It is worth noting that connectivity at 10 Mbps is cheaper in London than in New York (the average

[13] Oftel's review focussed on the intermediate level of Internet connectivity.

and best prices being $2,165 and $1,749 respectively in London, as against $2,430 and $2,250 in New York. Moreover, the historical quality index of connectivity (as calculated by Band-X) is substantially better in London for global connectivity and for connectivity with the EU. The only exception being connectivity specifically with the US. In this case New York maintains an edge with an average quality index that is almost twice as high as that for London.

The importance of the actual physical location of the ISP's connection to a backbone is confirmed by our quality/price index. Again London proves far better for European and Global connectivity at 10Mbps, while New York is the best market for US connectivity. On the whole these results would seem to indicate a marked change from the situation of the second half of the 1990s when a European ISP was often better off by buying bandwidth in the US even if its main interest was in connectivity with the EU. These results seem to confirm that the European market is currently characterised by a relatively larger supply of physical capacity at least at the 10Mbps level. The same exercise could be replicated for a number of bandwidths. In tables 3 and 4, for example, we present the results for 100Mbps and 1Gbps.

Table 3: Connectivity markets for typical 100 Mbps contracts in London and New York

		London (last year as of 23/04/2002)			**New York (last year as of 23/04/2002)**		
		Price on 23/4/2002	Quality Index	Quality/Price Ratio	Price on 23/4/2002	Quality Index	Quality/Price Ratio
EU	Average	17,522	70.07	58.60	18,800	28.38	21.90
	Var	4,676,345	38.23	23.53	1,280,000	33.70	10.12
	st. dev.	2,162	6.18	4.85	1,131	5.81	3.18
	Best	14,571	76.12	63.19	18,000	32.48	24.15
US	Average	17,522	58.78	49.06	18,800	107.98	83.25
	Var	4,676,345	47.57	17.79	1,280,000	640.82	213.46
	St. dev.	2,162	6.90	4.22	1,131	25.31	14.61
	Best	14,571	65.36	53.18	18,000	125.88	93.58
Globe	Average	17,522	79.62	66.13	18,800	44.02	33.99
	Var	4,676,345	143.23	21.28	1,280,000	63.85	17.20
	St. dev.	2,162	11.97	4.61	1,131	7.99	4.15
	Best	14,571	90.87	72.03	18,000	49.67	36.93

Source: Our calculations on data provided by X-band. **Notes:** The quality/price ratio is calculated as the product of the relative historical quality index (calculated over the last year) by the inverse of the ratio between relevant current price and best current price for connectivity at the stated bandwidth in the two online trade-floors.

Table 4: Connectivity markets for typical 1Gbps contracts in London and New York

		London (last year as of 23/04/2002)			New York (last year as of 23/04/2002)		
		Price on 23/4/2002	Quality Index	Quality/Price Ratio	Price on 23/4/2002	Quality Index	Quality/Price Ratio
EU	Average	164,130	68.80	62.60	182,000	32.48	26.63
	Var	445,267,039	62.61	0.73	na	na	na
	st. dev.	21,101	7.91	0.85	na	na	na
	Best	149,209	74.39	63.20	182,000	32.48	26.63
US	Average	164,130	57.51	52.19	182,000	125.88	103.20
	Var	445,267,039	79.76	1.99	na	na	na
	St. dev.	21,101	8.93	1.41	na	na	na
	Best	149,209	63.82	53.18	182,000	125.88	103.20
Globe	Average	164,130	75.09	67.89	182,000	49.67	40.72
	Var	445,267,039	257.19	34.24	na	na	na
	St. dev.	21,101	16.04	5.85	na	na	na
	Best	149,209	86.43	72.03	182,000	49.67	40.72

Source: Our calculations on data provided by X-band. **Notes:** The quality/price ratio is calculated as the product of the relative historical quality index (calculated over the last year) by the inverse of the ratio between relevant current price and best current price for connectivity at the stated bandwidth in the two online trade-floors.

The conclusion that bandwidth traded in London is substantially cheaper than in New York is confirmed. Moreover, it is confirmed that London is currently more convenient in terms of quality, and therefore of quality/price than New York for global and European connectivity. It is also confirmed that Internet connectivity to the US is cheaper and qualitatively better on the New York market. Finally, bandwidth markets seem strongly influenced by physical and geographical factors. ISPs with a definite interest in regional connectivity (i.e. in connectivity either to the US or to Europe), are better served by the bandwidth-trading floor closer to the prevalent destination of their communication needs.

Admittedly, these are preliminary results and as such they should be considered. In particular we would like to convey a word of caution on their robustness. In particular the reader should be aware that on-line bandwidth trading is still in its infancy and therefore the prices and quality indexes here presented might be unrepresentative. Moreover, the result presented here might not be entirely robust to a change in the bandwidths analysed. The quality index used is an historical one (i.e. accounts for the quality performance over one year). This has the advantage of conveying

information on the qualitative reliability of the service, but might be influenced by past technical problems/conditions not entirely relevant to today's operators. The analysis can and should be repeated for other bandwidths, for different contract lengths, and with quality indexes calculated for shorter periods before one can draw conclusive results. Yet, we think that they are valuable in two respects. Firstly, they provide what could be defined as an informed guess on the geographical stratification of backbone market that confirms the current prevailing view. Secondly, they provide an example of the richness of information that can be gathered (provided sufficient research funding is available) from on-line sources on the structure and functioning of the Internet backbone capacity market.

2.6 The proposed merger between MCI/WorldCom and Sprint

The two most relevant antitrust cases discussed in the industry have been the merger between MCI and WorldCom in 1998 and the rejected merger between MCI-WorldCom and Sprint in 2000. After an extensive investigation into the merger proposal, on the 28th of June 2000 the European Commission adopted the decision that " The notified concentration consisting of the merger between MCI-WorldCom and Sprint is declared incompatible with the common market and the functioning of the EEA Agreement." [Official Journal of the European Commission (2000)]. Similarly on the 26th of June 2000 the U.S. Department of Justice stated " The proposed merger of WorldCom and Sprint will cause significant harm to competition in many of the nation's most important telecommunications markets. By combining two of the largest telecommunications firms in these markets, the proposed acquisition would substantially lessen competition in violation of Section 7 of the Clayton Act ......The merger would lead to higher prices, lower service quality, and less innovation than would be the case absent its consummation. The United States therefore seeks an order permanently enjoining the merger". [U.S. DoJ 2000 page 3]

The dominant position of WorldCom has indeed been attained through a very active acquisition policy. The DoJ enquiry describes some of the more than 60 acquisitions operated by this company:

for example in 1995 WorldCom acquired the network service operations of Williams Telecommunications, with its 11,000 mile fiber optic network, in 1996, through the acquisition of MFS Communications Company, WorldCom obtained the control of UUNET, the world largest Internet backbone provider. In 1998 WorldCom acquired Compuserve a leading Internet provider and ANS, AOL's primary Internet backbones network. Other acquired backbones were GridNet, Unicom-Pipex, InNet, NL Net and Metrix Interlink. As a result of the leadership position reached in these years the WorldCom acquisition of MCI in September 1998 has been accompanied by the imposition, by the US DoJ and the EU Commission, for MCI to divest its Internet assets to Cable & Wireless.

The major source of disagreement between the Commission and the two defendant companies, concerned the hierarchical nature of the Internet. The Commission stressed that a hierarchical structure was clearly exposed by the evidence that top level providers achieve their connectivity entirely by settlement-free peering mainly at private peering points, whereas smaller providers need to purchase transit from top-tier network to achieve global connectivity. If connectivity is crucial in defining market leadership the physical expression of market shares is given by traffic flows. The ratio between traffic flows of the different networks have therefore been used to evaluate market shares as reported in Table 4, below, together, for reference, with a revenue based market share distribution obtained by Probe Research (Pappalardo 2001).

Table 5 Backbone Market Shares

Top tier backbones	Market Shares (Revenues year 2000) Source (probe Research)[14]	Market Shares (traffic ratios) Source EU.
GTE	6.3%	[0-10]%
Sprint	6.5%	[5-15]%
C&W	3.5%	[0-10]%
MCI WorldCom	27.9%	[32-36]%
AT&T	10%	[5-15]%

[14] See Pappalardo, D. "The ISP top dogs" *Network World Fusion* , 30 May 2001.

From these estimates the new merged entity would have had a market share between [37-51]% against the next competitor's one not being larger than 15%. The European Commission concluded that the proposed merger would have led to the emergence of a top level network provider, able to act almost independently of its competitors and customers and to determine its own, and its competitors, prices and the technical developments in the industry.

The U.S. Department of Justice enquiry provides an alternative estimate of the Tier 1 market shares and the effects of the merger: *"The Herfindahl-Hirschman Index ("HHI"), ... indicates that this market is highly concentrated. The HHI in terms of traffic is approximately 1850; post-merger, the HHI will rise approximately 1150 points to approximately 3000. The proposed merger threatens to destroy the competitive environment that has created a vibrant, innovative Internet by forming an entity that is larger than all other IBPs combined, and thereby has an overwhelmingly disproportionate size advantage over any other IBP."*

Finally concerning the issue of the threat of quality degradation the European inquiry estimated that the traffic remaining on net for the newly merged company will be between 40 and 80 percent compared to a percentage of no more than 32% for the other connectivity providers. These would then be forced to exchange around 20% of their traffic with the new dominant player and this size asymmetries would imply that a degradation of the quality interface will have a worse effect on the smaller size networks than on the larger one .

Quality issues have been considered in both the European and American enquiries also from a dynamic prospective in relation to both market tipping and potential entry in the industry. Since the existing free-peering rules require an entrant, or existing partners, to be of considerable size the enquiries found that the merger would have generated both an endogenous market tipping process in favour of the dominant backbone together with a formidable barrier for potential entrants in the top tier backbone market.

4 Conclusions.

We have seen in this paper that different analysis of the Internet backbone market provided different answers about its degree of concentration. This variability is mainly due to the paucity of existing data as opposed to that required to design the vertical and horizontal borders of the relevant market, and different market definitions provide opposite antitrust prescriptions.

We argued for the relevance of using online transit prices to monitor indirectly the evolution of the market, by-passing, in this way, the difficulties of mapping the borders and hierarchies in the Internet backbone structure. Many of the relevant questions have been addressed by using the available information on online prices and quality. This data indicates a changing structure of the Internet Connectivity Map, showing the emergence of a less hierarchical and multiheaded backbone structure with separate U.S. and European transit markets.

Concerning future research, a very promising developments arise from research in Cybergeography, the discipline devoted to the mapping of this physical-virtual world. An empirical analysis of traffic flows can be based, for example, on software like *traceroute* or *tracemaps* which allow the visualization of the paths that data packets take through the Internet, recording all the "hops" (routers) along the way. This helps the understanding of the hierarchies of Internet interconnection, since “Traceroute reveals the hidden complexity of data flows, traversing ten, twenty or more nodes, usually owned and operated by competing companies, to reach a given destination” (Dodge 2000)[15]. In this filed the *Cooperative Association for Internet Data Analysis*, (CAIDA) plays a relevant role in developing tools to analyse and visualise data about connectivity and performance in the Internet. The aim is to construct a global Internet topology and measures of the performance of specific paths through the Internet. We have seen that the first relevant question assessed in the antitrust hearings is about connectivity and, by sending out packets of data from a source to different destinations, it is possible to verify many aspects of the actual connectivity of the Internet. Among the most interesting characteristics, of a route taken by a given group of packets

are the Round Trip Time (RTT) and the data path, describing how a packet reaches the destination from its origin. On the base of this information it is possible to analyse "frequency and pattern of routing changes". This sort of analysis is of particular relevance for the Internet, since it measures when and how often alternative paths are used for the same source to destination route. An extensive analysis of a relevant number of these path data, enables the understanding of the specific role played by a given backbone or a traffic exchange point. Table 6 below, derived from Claffy et al. (1999), describes the information retrievable using this method. The authors, using samples covering 20,588 end destinations, determined the frequency with which an individual backbone provider (identified by an Autonomous system number, AS) appeared in a path and the relative depth of those appearances, both in terms of number of backbones and the number of hops crossed from the source. The traditional analysis of market concentration through HHI Index could be greatly improved if applied to these data. Moreover the daily availability of these data provides a great opportunity to maintain a close scrutiny of the evolution of this industry. We are currently engaged in a preliminary analysis of visual evidence on the qualitative features of the transit market, of the kind presented in Appendix 2.

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[15] The recent OECD study OECD[2002] of the Internet backbone provides very interesting results

Table 6

Name	AS[16]	AS Depth[17]	IP Depth[18]	Frequency[19]
CERFnet	1740	0	2	18941
Cable & Wireless USA	3561	1.9	5.6	8028
Sprint	1239	1.2	5.1	6363
UUNET Technologies, Inc.	701	1.3	5.8	6071
Internet Systems, Inc.	6196	1.2	4.2	3608
Compass Communications	7336	2.8	9.2	2561
Defense Research and Engineering Network	668	0.8	4.3	1326
UUNET Technologies, Inc.	702	2.3	12.2	1285
Verio	2914	1.3	7.5	1057
Los Nettos	226	1	4.1	910
BBN Planet	1	1.7	8	804
Telia Network Services	1833	2.6	10.6	758
IBM	2685	0.6	4.3	697
European Unix Network (EU.net)	286	2	6.8	639
AT&T	7018	1.4	6.5	553
TeliaNet Sweden	3301	3.4	12.2	500
Sprint International	4000	3.1	7.5	477
Primenet Services	3549	2	5.4	463
PSINet Inc.	174	1.6	6.5	444
European Unix Network (EU.net)	194	0.1	0.4	441

Source Claffy et al. (1999)

In this example, CerfNet/AT&T, Cable & Wireless (which purchased InternetMCI's backbone in 1998), Sprint, and UUNET play a major role in transporting packets across the Internet. It is clear

on the flattening of the backbone hierarchies by intensively using traceroutes softwares.

[16] Dominant Autonomous Systems.

[17] Average number of ASes a message passes through before reaching this AS.

how this type of network statistical explorations are becoming an essential tool in understanding the hierarchical structure of the backbone industry required for antitrust investigations.

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[18] Average number of IP addresses a message passes though before reaching (the destination machine in) this AS.
[19] Total number of times this AS occurred in the data (from the set of all destinations and intermediate routers).

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Appendix 1

Table A1, below, derived from the Oftel review and integrated with companies web sites information, provides brief profiles of the large firms supplying Internet connectivity within the U.K..

Table A1 Main Internet Connectivity Operators in Europe

Provider	Network coverage
360networks	360networks is constructing a network to link 11 European countries, to provide long-haul connectivity among 35 European cities and to extend its network 18,000 km by mid-2001. The company is also buying 330km of dark fibre strands on rings in six cities: Geneva, Lyon, Marseilles, Milan, Paris and Strasbourg.
AboveNet	AboveNet has 197 GBS total capacity, 497 peering agreements. European presence in Vienna, London, Paris, Frankfurt and Amsterdam
BT Ignite	A GBP 4 billion investment is due in 2000–2003 to extend the existing 50 000km pan-European IP backbone by 20 000km, using Cisco 12000 series routers to provide multiple 10Gbit/s trunks. The network covered Denmark, Ireland, Norway, Spain and Sweden by January 2001.

	company acquired 22 ISPs, providing itself with local presence and customer bases in 12 European countries.
Carrier1	Carrier1 operates a pan-European fibre network connecting 12 countries, extending over 10 000km and connecting POPs in 20 European cities. It is in the process of constructing six city ring fibre networks and planned to build at least another 14 in 2000–2001.
COLT Telecom	The COLT Internet Backbone provides high-speed connectivity between 12 European cities and on to the USA and the rest of the world. The European peering points were Colt is present are: LINX (London), DE-CIX (Frankfurt), MAE-FFM (Frankfurt), AMS-IX (Amsterdam), BNIX (Brussels), PARIX (Paris), SFINX (Paris), ESPANIX (Madrid), CIXP (Geneva), TIX (Zurich), MIX (Milan), VIX (Vienna), DGIX Stockholm).
Concert	The existing 2.4Gbit/s backbone network covers 21 cities in 17 countries. AT&T and BT have said they will invest USD3 billion in the Concert joint venture to 2005, in order to build an IP backbone linking about 60 cities by the end of 2000, and about 100 cities outside the USA and the UK by the end of 2001.
Deutsche Telekom	Deutsche Telekom currently operates a nationwide IP backbone in Germany with 74 nodes. Following the end of its partnership with Global One, the company announced plans to invest 4 billion marks over five years on its own pan-European fibre networks, aiming to install 90 POPs in 40 countries and 150 000km of fibre.
EasyNet	Easynet is a pan-European Internet Service Provider operating in the

	United Kingdom, France, Germany, Belgium, Spain, Switzerland, the Netherlands, and Italy. The recent merger with ipsaris, means that it has 3,500 route kilometres of lit fibre cable, with approximately 350,000 kms of optical fibres throughout the UK.
Energis	Energis operates 6500km of fibre-optic network in the UK and a continental European backbone network of 12 000km, linking 18 POPs.
France Telecom	France Telecom is in the process of constructing a new European backbone network, which is due to stretch 20 000km and connect 40 POPs in 16 European countries by the end of 2001. It will interconnect with other national and regional networks, giving total coverage of 250 European cities and access to the networks of France Telecom's Equant and Global One subsidiaries.
Global Crossing	Global Crossing operates a backbone network serving cities in Belgium, France, Germany, Italy, the Netherlands, Switzerland and the UK. It connects with GTS's Atlantic Crossing 1 (AC-1). The company intended to expand its VoIP backbone to 15 additional US cities as well as to Amsterdam, Brussels, Copenhagen, Frankfurt, London and Paris by the end of 2000.
GTS	GTS operates a network consisting of three major components: a pan-European IP-optimised backbone a number of fibre-optic MANs in Western and Eastern Europe; and Gemini AC-1, a transatlantic backbone cable. The backbone network extended 17 500km by May 2000.

Interoute	Interoute is constructing a 20 900km pan-European IP network that will link 70 European cities in 17 countries and will have 200 POPs. The first phase of the network, due for completion in mid-2001, will consist of eight rings connecting 46 cities in nine European countries with 18 000km of cable. There are plans to migrate all circuit-switched voice traffic onto the new network by the end of 2001.
KPNQwest	KPNQwest is in the process of constructing a pan-European fibre-optic backbone, based on seven EuroRings and connected via a transatlantic link to Qwest's network in North America and Asia. The EuroRing network, when complete, will reach approximately 20.000km and will link 59 business centres in Western, Central and Eastern Europe. It will have around 450 POPs throughout the region.
Level 3	Level 3 is constructing a three-ring European inter-city IP network. Ring 1 covers 1800 miles and links gateways in Amsterdam, Brussels, Frankfurt, London and Paris; Ring 2 is the inter-city loop through Germany; Ring 3 will add an additional 1300 miles. On completion, the total network will link 13 local city networks and extend 5300km.
NETs (Tiscali Group)	In December 1999 Tiscali bought NETs, a broadband telecoms infrastructure provider based in France. NETs is now building a 30,000 km European fibre-optic backbone, which will connect over 100 European cities by the end of 2001. In January 2000, Tiscali acquired CD-Telekomunikace which holds exclusive rights to the laying and operation of fibre-optic cable along the entire rail network

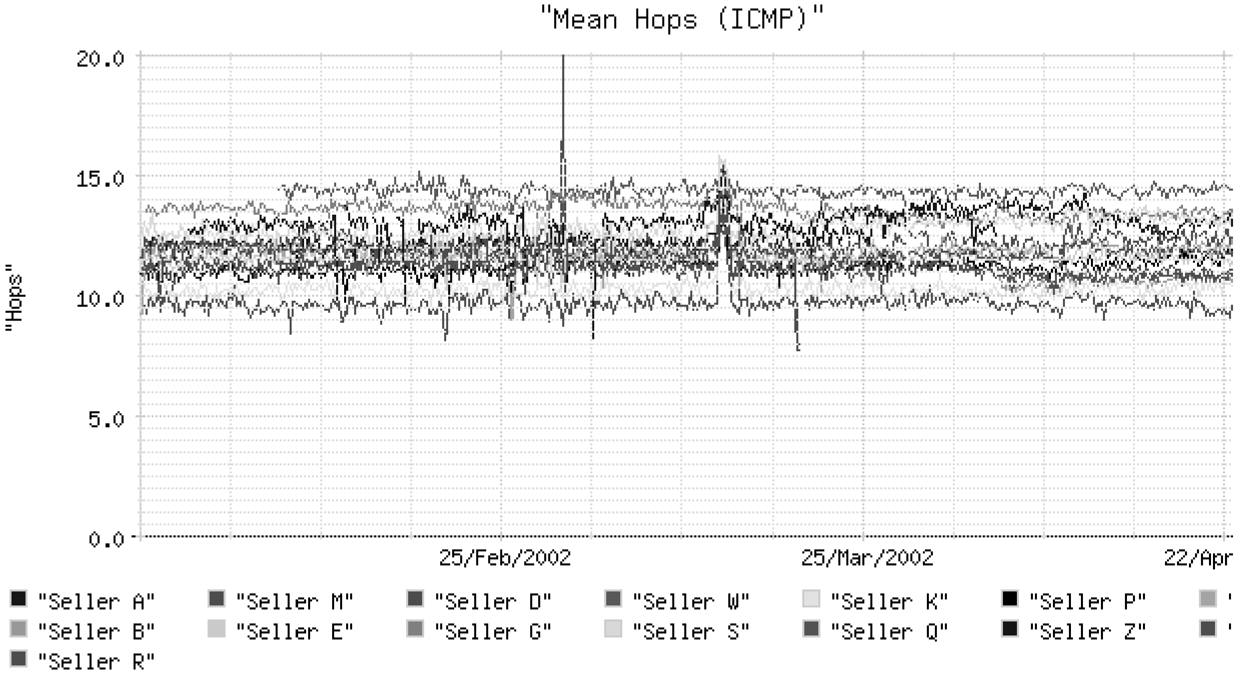
	of the Czech Republic.
PSINet	A long-term network upgrade is currently underway in Europe, replacing PSINet's E3 infrastructure with STM-1 and above. The final IP backbone network will reach over 21 000km and link at least 30 major European cities.
Teleglobe	The company's pan-European network reached around 7700km by the end of 2000. Its network construction programme involves building a number of DWDM, fibre-optic rings. By the end of 2000 Teleglobe was aiming to connect 30 European metropolitan areas with 26 000km of fibre.
Telenor	A pan-European IP network (Nextbone) directly connects Oslo via STM-1s to Frankfurt, New York and Stockholm. Connections at Frankfurt and Stockholm link the STM-1 network to three European rings with 45Mbit/s capacity. The largest connects Amsterdam, Frankfurt, London and Stockholm. The two smaller rings connect Copenhagen, Helsinki and Stockholm, and Frankfurt, Milan and Zurich. A further 45Mbit/s extension to Paris is planned.
Telia	Telia operates a 30 000km IP network covering 15 European countries. Its core 'Viking Ring' backbone network came into operation in early 1999, and links Frankfurt, Hamburg, London, Paris and Stockholm. In June 2000, Telia announced that it will construct a new 1400km OC-192 element to the 'Viking Ring' in western France.

WorldCom/UUnet	WorldCom operates a wholly owned pan-European network spanning over 12 800km. WorldCom's subsidiary UUNET operates an IP network within Belgium, France, Germany and the Netherlands. The network reaches over 200 POPs.

Source: Analysys/Oftel and companies web sites.

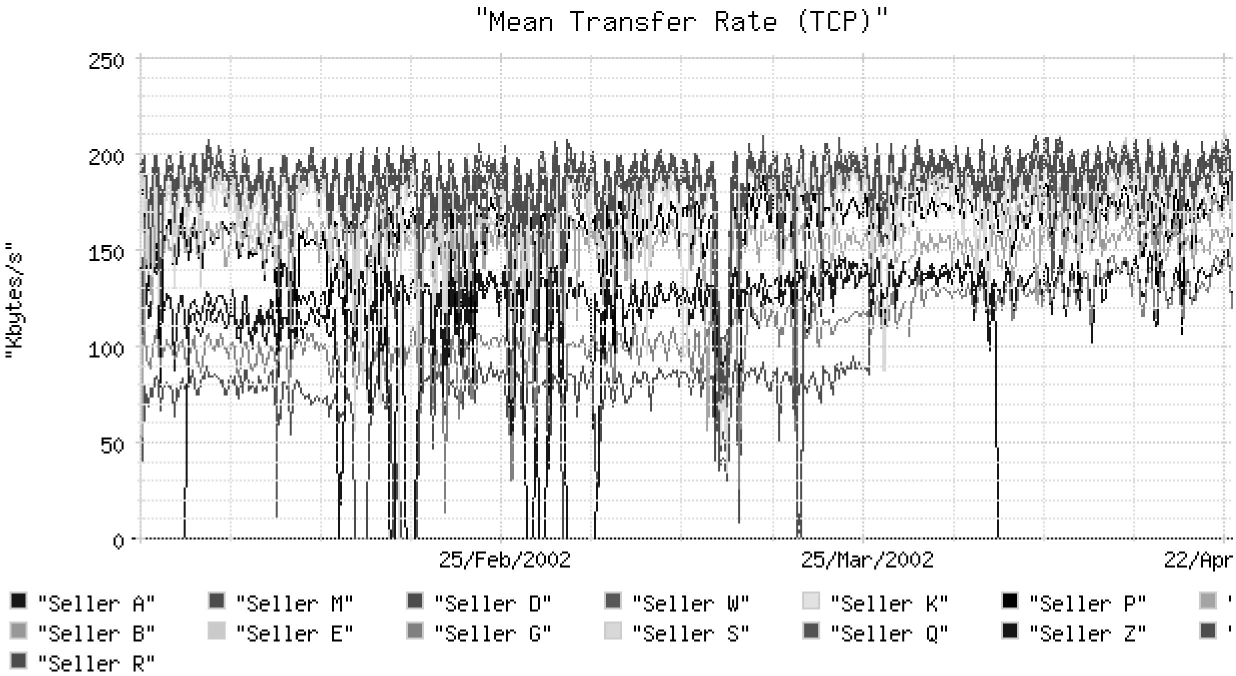
Appendix 2: Visual snapshots on quality from Band-X trade floors

Figure A1: London - Network performance data for Europe from 30-Jan-2002 to 30-Apr-2002.



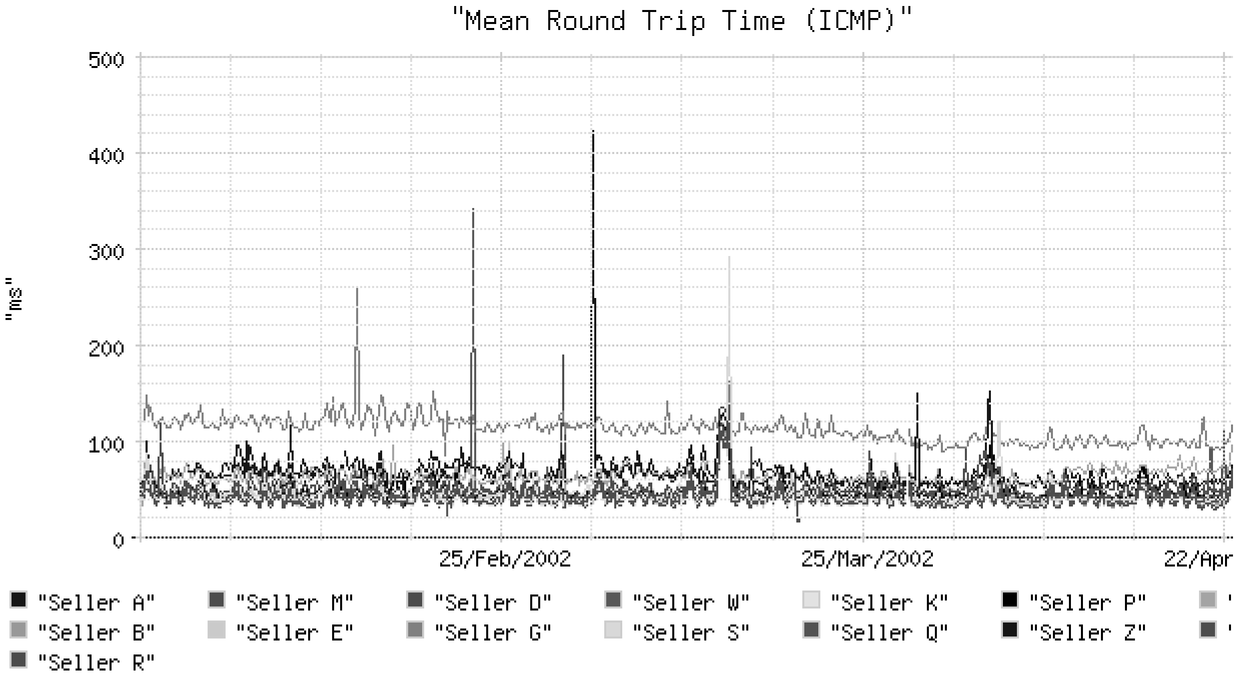
From Figure A1 we find enough differentiation in the number of Hops which describes that the set of interconnections and peering agreements can be quite diverse among the sampled operators.

Figure A2: London - Network performance data for Europe from 30-Jan-2002 to 30-Apr-2002.



In this figure we notice a strong qualitative convergence over the last three months.

Figure A3: London - Network performance data for Europe from 30-Jan-2002 to 30-Apr-2002.



The existence of a quality outlier (seller G) might indicate quality degradation. Seller G is also the second-worse in the Hops shown in figure A1. In this case the high RTT can be explained as a result of a worse set of peering agreements leading to a higher number of Hops.

Figure A4: London - Network performance data for North America from 30-Jan-2002 to 30-Apr-2002.

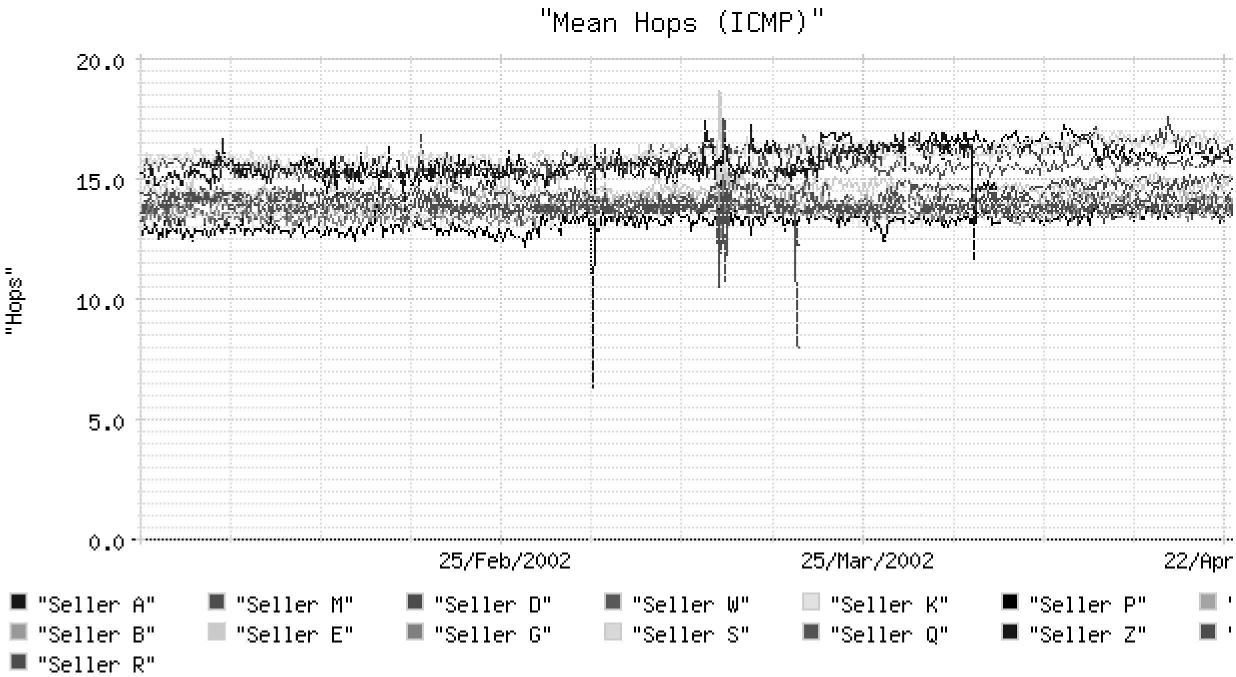


Figure A5: London - Network performance data for North America from 30-Jan-2002 to 30-Apr-2002.

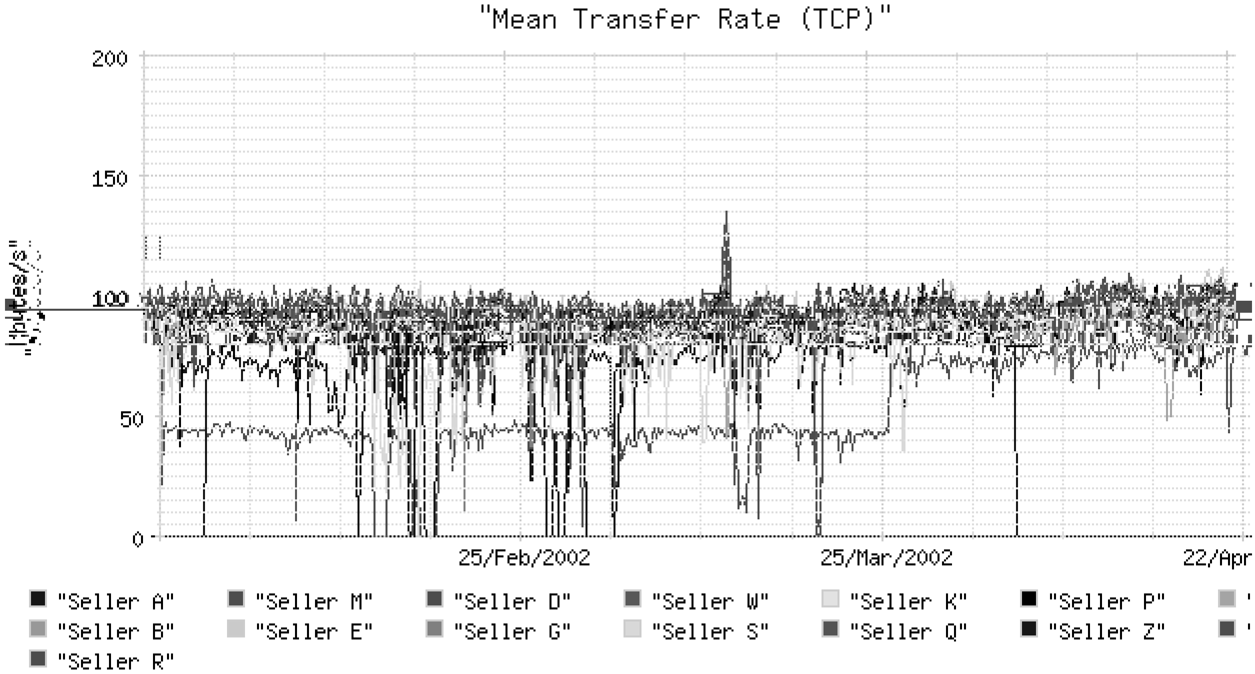


Figure A6: London - Network performance data for North America from 30-Jan-2002 to 30-Apr-2002.

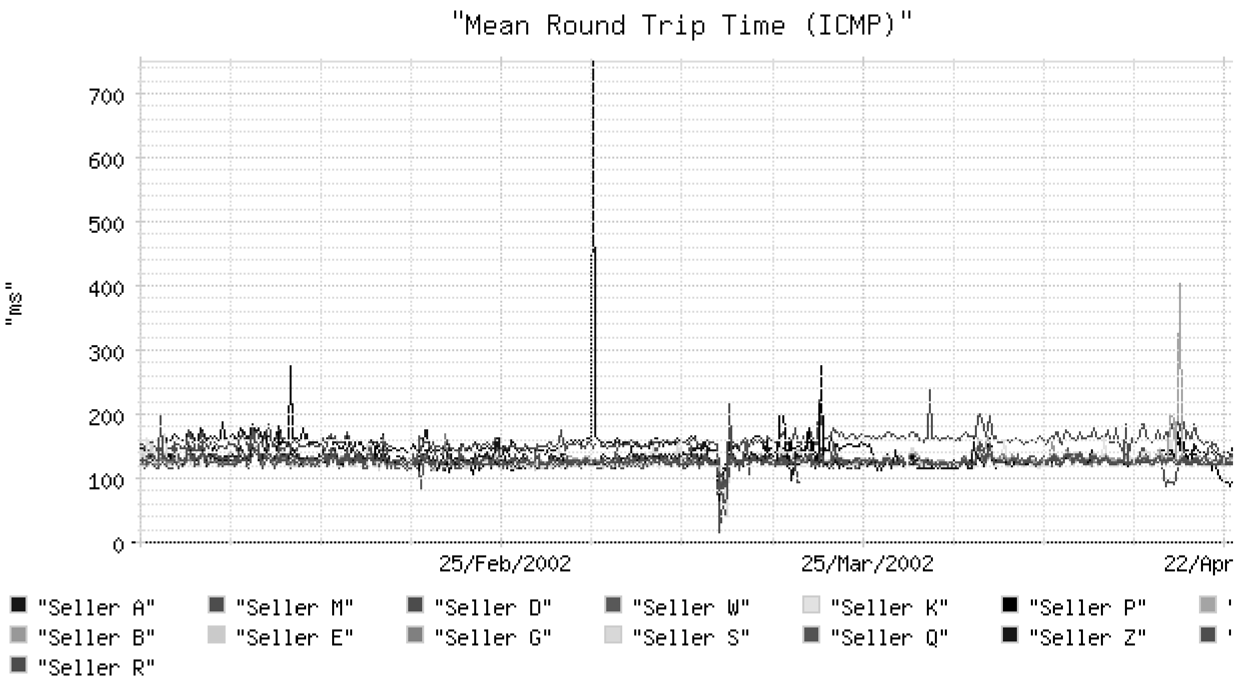


Figure A7: New York - Network performance data for Europe from 30-Jan-2002 to 30-Apr-2002.

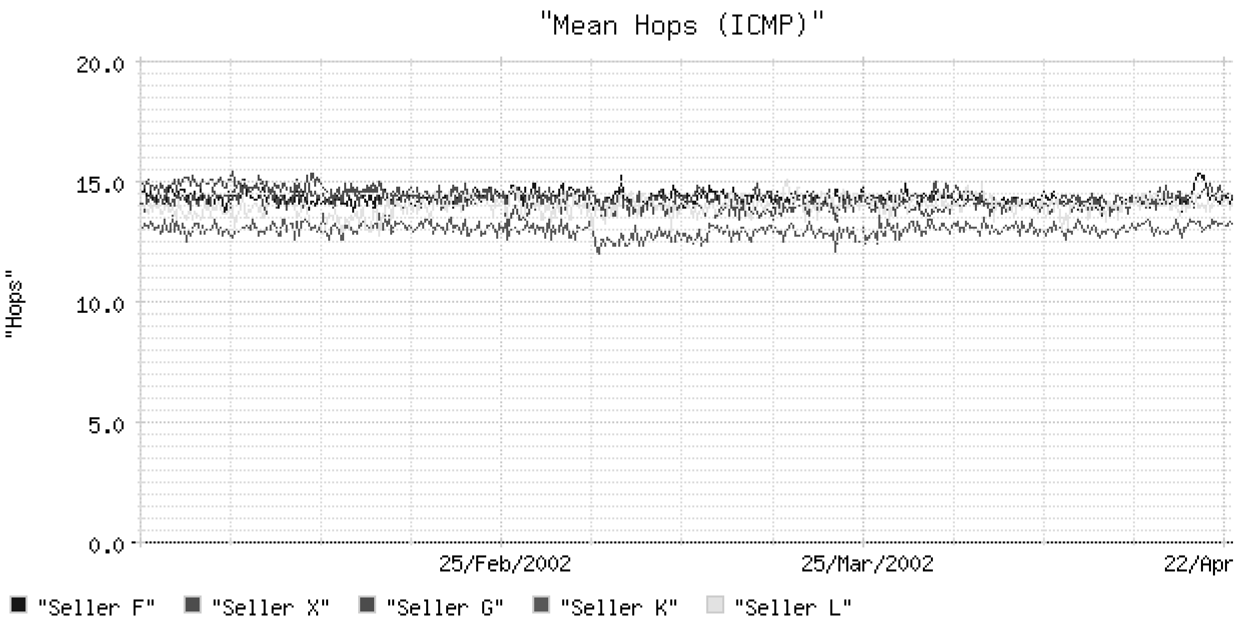


Figure A8: New York - Network performance data for Europe from 30-Jan-2002 to 30-Apr-2002.

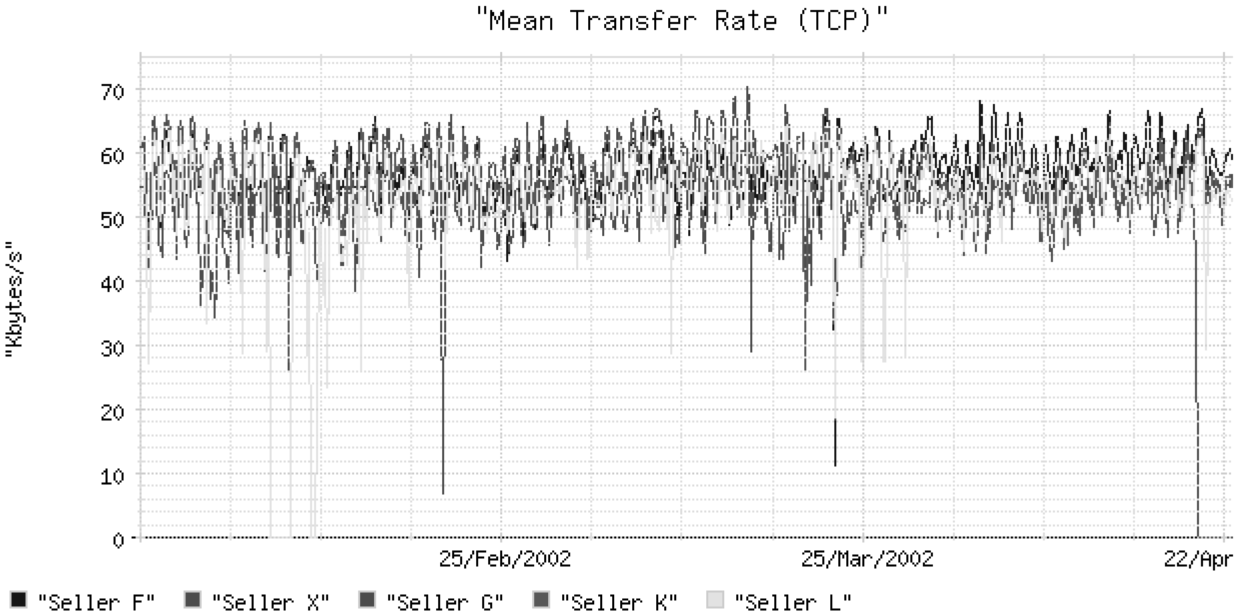


Figure A9: New York - Network performance data for Europe from 30-Jan-2002 to 30-Apr-2002.

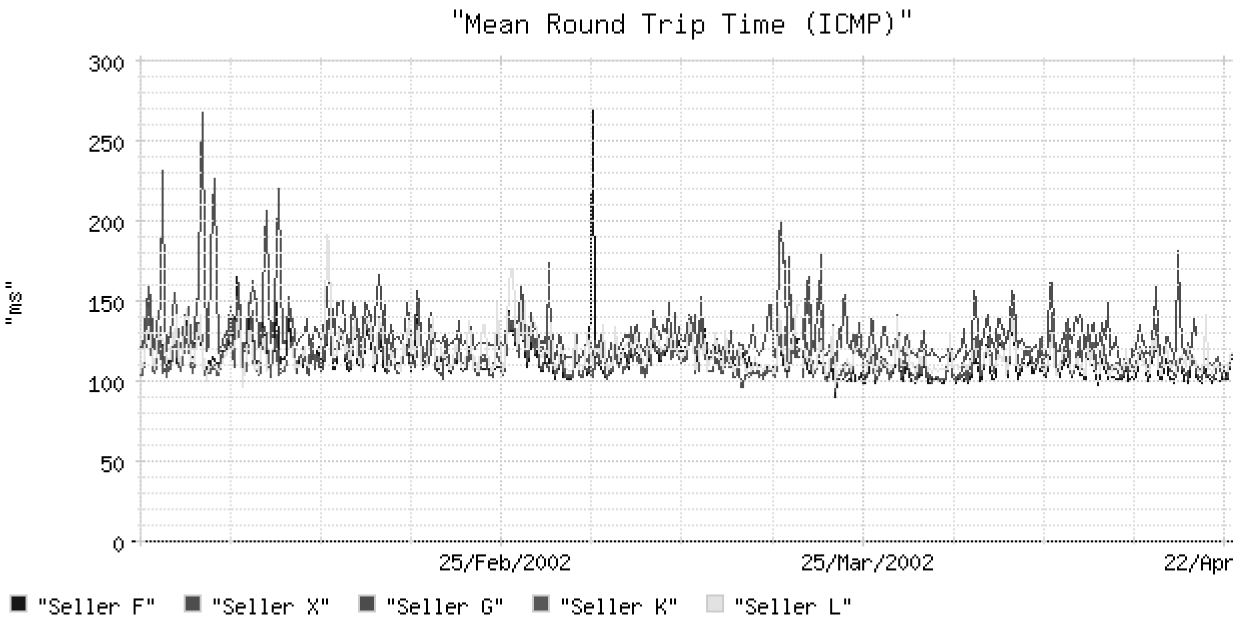


Figure n+9: New York - Network performance data for North America from 30-Jan-2002 to 30-Apr-2002.

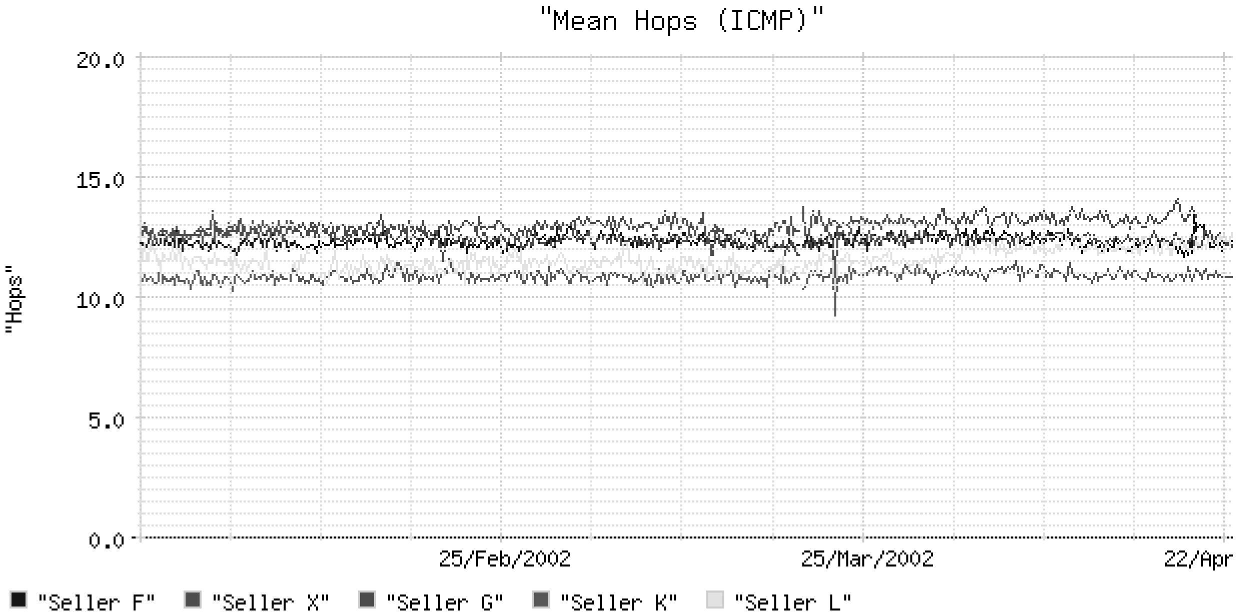


Figure n+10: New York - Network performance data for North America from 30-Jan-2002 to 30-Apr-2002.

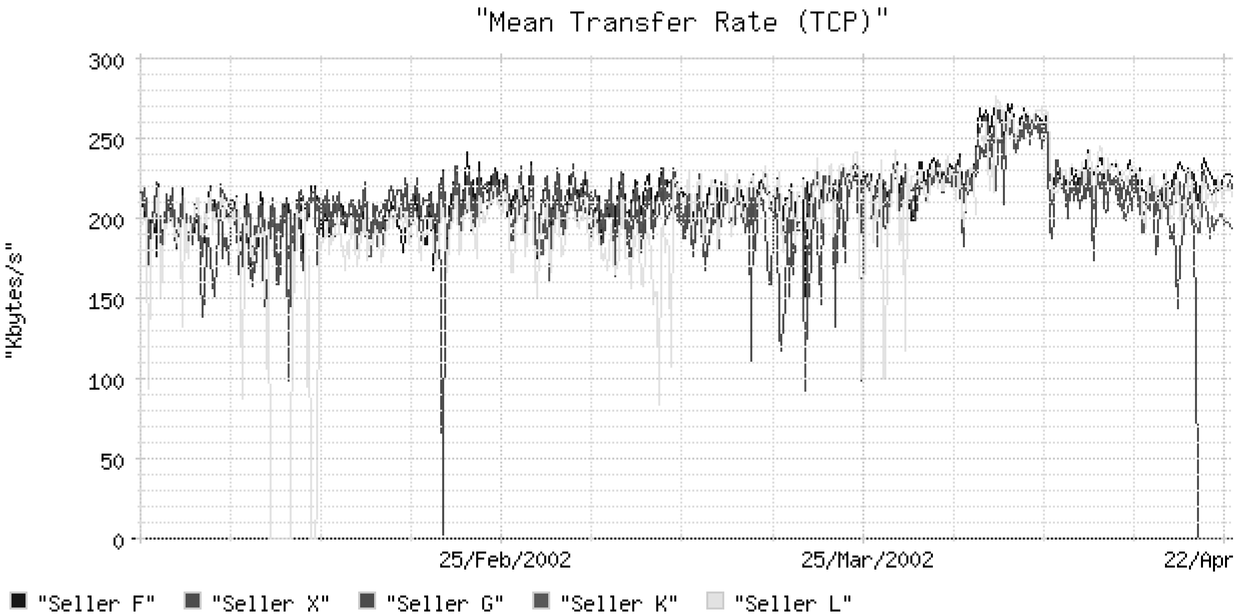


Figure n+11: New York - Network performance data for North America from 30-Jan-2002 to 30-Apr-2002.