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Effects of ISP Interconnection Agreements on Internet Competition:
The Case of the Network Access Point as a Cooperative Agreement
for Internet Traffic Exchange

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Introduction

This paper presents and analyzes the main aspects of the historical development and the current issues at stake in the South American Internet access market. We have studied the interconnection schemes for the exchange of local and regional traffic in the South American region, trying to identify the main incentives large ISPs have for improving the financial conditions under which interconnection agreements occur, usually at the expense of smaller ISPs. In fact, the model of cooperative agreement for the exchange of domestic (national) traffic has been adopted all through the region; the Internet access market has benefited from the cost reduction and the improvement in the quality of service that the operation of a NAP has brought in each country. We have also contacted representatives of the cooperative exchange points (also called Network Access Points or NAPs) at Latin American NAPs Second Meeting in Buenos Aires, Argentina[1].

The most important achievement of this work is the understanding of the basics upon which the stability of the exchange points is founded. This is especially critical for the growth of Internet in South America. We have identified come crucial aspects such as the characteristics of the interconnection agreements and the payments ISPs make to the NAP administration.

We have developed a sufficiently detailed understanding of important issues such as the impact of new forms of interconnection such as secondary peering agreements and multi-homing on the stability of Internet growth in the context of the fast developing and ever more complex South American Internet access markets. We have collected information on the structure of exchange points in different countries in the region to study the ISPs patterns of behavior arising from the new interconnection agreements, in particular, and the changes in the traditional hierarchy induced by new contract forms, in general. Such agreements are essentially bilateral agreements at the exchanges, a relatively new feature in South and Central America. For that purpose we have developed theoretical models using bargaining theory and have also dealt with cost allocation problems at cooperative exchange points.

The structure of the paper is as follows: in Chapter 1 we summarize the main questions and the main conclusions achieved. In Chapter 2, we describe, to the best of our information collection, the current state of the access markets in different countries, mainly in Argentina, Chile, Brazil and Colombia, where NAPs have existed longest in the region. In Chapter 3, we present the main conclusions of a theoretical model of interconnection agreements evolution whose purpose is to identify the incentives that a large ISP has for exerting its market power upon the smaller ISPs. We have reasons to believe that the stability of NAPs is an aspect that should concern governments in order for them to promote the development of the Internet retail market in a region with low penetration of Internet deployment.

[1] Organized by CABASE, Cámara Argentina de Bases de Datos y Servicios en Línea in Buenos Aires, Argentina, the 21st of August, 2003.

We turn our attention, in Chapter 4, to a specific problem which may become an important concern for those involved in the administration of cooperative exchanges: the procedures for cost allocation. All NAPs in the region are cooperative enterprises born out of the common interest of competing ISPs. Currently the traffic at a NAP, which is not switched at the exchange, is just a fraction of the traffic in and out of every country,.In short, the cost recovery method is not an issue for the NAP administrators. Nevertheless, the growth of Internet, propelled by government-funded programs and new commercial ISPs, will demand a more rational approach to the allocation of cost among members of a NAP. We present the current practices and explore a traffic-based theoretical method. Finally, in Chapter 5, we use Nash bargaining theory to gain some insights on the possibility of interconnection between NAPs. The need in the region for cost reduction has prompted some NAP administrators to explore the possibility of directly exchanging traffic instead of routing international traffic across the US Internet backbones. This issue is of important concern especially for the southern countries.

In spite of having counted on the collaboration of various NAP Executive Officers as they provided useful information about the main characteristics of their exchanges, traffic data and traffic flows were not available in any country studied. The public web page of NAP Chile provides information on the three main indicators ISPs are legally obliged to publish and the NAP Colombia web site provides information on the growth of total traffic at the NAP; such information stops short of providing a clear picture of traffic interest in the region. In the final session of the second meeting of Latin American NAP administrators held in Buenos Aires, several representatives spoke about the need for regional interconnection as they mentioned the high costs of international capacity and the increasing congestion as sources of concern for the optimal operation of their exchanges. In the upcoming months a trial connection will be set up between Argentina and Chile; this experiment will allow both, NAP Chile and NAP Cabase, to quantify the traffic between the two countries and will open the path for a series of regional interconnections among the NAPs in the region.

Chapter 1
A Summary of Findings

Internet is a network of networks that provides seamless communication to Internet subscribers who communicate with each other and access enormous amounts of information from all over the world. The provision of access to Internet is very different from the beginnings of telephone service provision in most countries. A myriad of Internet Service Providers (ISPs) allows millions of users to get connected to the net. No single entity or firm controls the access to Internet services as it was the case - and still is in some countries - of the access to the telephone public network. ISPs provide its customers the ability to obtain on-line information through the network.

Internet is a system of autonomous interconnected networks. Routing and a robust system of addresses bind these networks together in spite of their independent pricing policies and service definitions. The Interior Gateway Protocol (IGP) provides integrity to the routing protocol. The Exterior Gateway Protocol (EGP) assures a larger routing domain for the collection of networks.

The development of Internet has seen an upgrading of the address space from Ipv4 to Ipv6. A higher degree of transparent interactions between two networks has been reached with the utilization of Network Address Translation techniques. Routing has also been improved specially with the definition of BGP4 (Border Gateway Protocol 4) which supports less hierarchical routing arrangements. The result of improved addressing and routing protocols is the decrease in the market power traditionally exerted by core ISPs and the greater flexibility for small ISPs to enter into interconnection agreements with other ISPs therefore bypassing the core ISPs.

The two most significant agreements so far are peering contracts and customer contracts. Peering agreements are interconnection arrangements between ISPs. Under a peering arrangement an ISP accepts traffic destined to its customers and does not accept transit traffic destined to another ISP´s customers. A customer agreement is one in which an ISP purchases transit from an ISP and gets its subscribers communicated to the rest of the Internet. A peering agreement usually implies no charges among ISPs, so it is considered a Bill and Keep (B&K) agreement. Under B&K ISPs do not charge each other for traffic being delivered into the other network.

A peering contract involves address advertising, settlements and peer monitoring of interconnection features. A customer contract is a bilateral agreement between two ISPs. These two types of agreements help to consolidate the hierarchical structure observed in the Internet. Less complex routing tables, a limitation on routing arbitrage, the reduction in connection costs and an improvement in the accountability of providers quality of service are usually listed as the benefits of the hierarchical structure.

However the hierarchical structure is the dominant feature of Internet structural organization, Internet is not purely hierarchical. Secondary peering or the ability of local and regional ISPs to exchange their local and regional traffic with other ISPs, multi-homing or the ISPs practice of being a customer to multiple backbones and some examples of non-customer transit contracts are clear instances of disruptions of the hierarchical organization.

As an illustration of the ISP market developing in South America and given the enormous growth in Internet traffic, since the late 1990s several ISPs in different countries decided to rely on a local traffic exchange point instead of having their traffic routed through the large ISPs routers and gateways in the U.S. The result has been a reduction in costs for all ISPs; such reduction has attracted new ISPs to the market and, therefore, to the exchange. A typical exchange is called NAP or Network Access Point and is a cooperative agreement. NAPs exist in Argentina, Chile, Colombia, Perú and Brazil and are scheduled to initiate operation in Ecuador and Venezuela.

The less developed ISP markets in South America reveal a profound contrast with its North American counterparts and some important characteristics are worthwhile analyzing. There is a complete dependence on US IBPs for the exchange of traffic originated at a country and destined to a neighboring country. To benefit from lower costs and better response times the South American Internet Service Providers have chosen to locally conform NAPs. The exchange of traffic whose source and destination are located within a country is achieved at national NAPs, of which there is usually one in each country, with the exception of Brazil. The NAPs are cooperative agreements whose financial sustainability depends on a flat-fee tariff structure in some NAPs or a capacity fee in the rest. The members of an exchange jointly designate NAP administrative bodies and are entitled to the same decision-making rights in board meetings. The most developed NAP at regional level are: NAP Cabase in Argentina, NAP Chile, NAP Colombia, and the four NAPs in Brazil.

Our work has focused on the impact of new forms of interconnection agreements such as secondary peering arrangements and multi-homing on the stability of Internet growth in the region. We also have identified the main regulatory, technical and economical factors promoting the development of ISP markets in the most developed economies in the South American region.

As of today, there has been no regulatory intervention in the Internet access market with the exception of the Chilean market where the Chilean Department of Transportation and Telecommunications, through its Telecommunications Sub Secretariat, has regulated the interconnection between ISPs. The Secretariat must guarantee, among other things, the efficient use of resources, and the users' non-discriminatory access to contents, independently from network access providers. In turn, every content provider must be free to choose its hosting provider. The regulatory norms constrain ISPs to establish and accept connections among themselves to send domestic traffic. Established connections should guarantee quality access to users, equivalent not only to their own ISP, but also to the ISP at which interconnection was asked. The regulation allows also the establishment of traffic exchange points for domestic traffic. The Sub Secretariat controls also network functioning by keeping quality indicators for each ISP. These indicators include: number of users, number of content providers, rate of packets lost, delay levels in data delivery (latency), and levels of link occupation, published in a common web page. Another case involving government intervention is Venezuela. In Venezuela, the NAP was born two years ago promoted by Casetel (Chamber of Telecommunications), Conatel (National Telecommunications Regulatory Commission) and the Venezuelan Chamber of Electronic Commerce. The NAP is a result of Conatel´s institutional mission to promote Internet deployment in the country.

The technical and economics literature about the Internet markets in South America is very scarce. This is even more serious when searching for information about the Internet wholesale market; in spite of the few sources our personal interviews with NAP administrators, directly or at the Second Latin American NAP Meeting, unveil some critical issues that both ISPs and NAPs face in the short term. On the one hand, the peering agreements at NAPs exhibit contradictory features that may render the exchanges unstable; currently, many peering agreements are being held between ISPs that exhibit disproportionate differences, a fact that is the opposite to set of conditions peering agreements are based on. On the other hand, the flat-fee pricing structure and even the capacity based prices for cost recovery at NAPs seem to give wrong incentives to the participants; it is possible that NAP development is being slowed down because ISPs aggregate traffic before reaching the exchange in spite of the fact that a NAP has spare capacity to get new ISPs connected. More ISPs connected means more benefits to the existing multilateral agreement as long as equipment and facility capacity is timely updated.

Chapter 2

Evolution of internet traffic exchange in South America:

Network Access Points (NAP) structures and agreements among Internet Service Providers (ISPs)

2.1. The Origin of Exchange Points

The origin of Internet traffic exchange points may be traced back to the points built up in the United States at the beginning of the 90s. As regional Internet traffic increased everywhere, similar schemes were adopted. In fact, the exchange system among few Internet Service Provider (ISPs) was ineffective, as in many cases --before local exchange points were set up-- traffic would travel thousand miles, although its recipient was a few kilometers away. The use of international channels was then an effective exchange method at global level, but proved to be inefficient [9]. More regional Network Access Points (NAP) were therefore created, as well as exchange policies, like peering and transit agreements.

As far as South America is concerned, NAPs have been and are being conformed. They have adopted the English denomination, but Internet Exchange Points are also called IXP. Most NAPs in South America have developed following a similar pattern: syndicates of Internet access providers and of data transmission companies getting together to set up a country's NAP. In such cases, NAPs were born without government intervention and both its operation and functioning have not been controlled by regulatory bodies. In two South American countries NAPs have been created somehow differently: in Chile, for example, regulation played an important role constraining big ISPs to make local interconnections for Chilean Internet traffic exchange; and in Venezuela, the government itself has promoted the constitution of a NAP [10].

Thanks to those exchange points, ISPs have lowered their operational costs and improve network functioning, thus offering better services to their clients. Such points have been used to exchange only domestic traffic because nowhere has been possible to handle international bandwidth with a NAP, which may be explained because other ISPs are interested in providing international transport [10].

2.2 Interconnection Agreements among Internet Service Providers

The use of exchange points or NAPs to exchange local traffic, and the existence of agreements --mainly transit agreements-- for outgoing international traffic, characterize the agreements among ISPs. The framework of such exchange agreements is the country in which such companies operate; but most of the international regional traffic has to be routed through backbones in the United States, at considerable costs due to the use of bandwidth in intercontinental networks.

In general terms, there are two types of agreements among ISPs. Under the first one, called peering agreement, two similar ISPs exchange traffic originated in one but destined to the other. To be eligible for this type of agreement, ISPs must share similar characteristics, so the volume to be exchanged must be fairly equal in terms of volume and type. Therefore, costs derived from information packet transportation from one ISP to the other are compensated by traffic costs flowing in the other direction [1]. Under peering agreements ISPs are connected at several geographical locations. In order to route traffic between two ISPs engaged in this type of agreement, a technique known as Hot Potato Routing is used, whereby traffic goes to the other network as soon as possible. That means that if ISP_1 and ISP_2 have a peering agreement a packet traveling from ISP_1 to ISP_2 will leave ISP_1 in the geographical location closer to its original location [1].

By means of this type of agreement, and in order to be able to communicate with all network users, there should be a connection with every ISP in the market. By means of the second type of agreement, called transit agreement, one ISP buys access to another ISP, usually larger, which in turn accepts and routes all the traffic originated from and destined to the first one. This type of agreement foresees an associated payment, set forth when negotiating interconnection [1].

2.3. NAPs in South America

NAPs are domestic connection points of the ISPs networks within a country. NAP disposition allows Internet traffic originated from and destined to a given country to use local channels only [2]. Having NAP means, firstly, saving money in the use of links, as it substitutes international with national links, and, secondly, reducing delay times.

To optimize Internet exchange, ISPs have chosen NAP as a strategy in South American countries. Unlike North American practice, these NAPs are connected to ISPs under a cooperative frame, i.e., participating ISPs jointly designate NAP administrative bodies, and are entitled to the same decision-making rights in board meetings. In North America NAP are usually owned by one company which renders the interconnection service to ISPs and other telecommunication companies.

Currently, the most developed NAP at regional level are: NAP Cabase in Argentina, NAP Chile, NAP Colombia, and the NAP group in Brazil. The remaining South American countries have less developed NAP or have not created one yet.

2.3.1. NAP Cabase Argentina

NAP Cabase Argentina[2] began operations on April 1, 1998, with 12 founder members; currently it has 39. This NAP was created by the *Cámara Argentina de Bases de Datos y Servicios en Línea, Cabase* (Argentinean Chamber of Data Base and On-line Services) [3], as a non-profit body which gathers Argentinean telecommunications, and on-line and Internet service providers. This NAP was created without government intervention, and with a large participation of small ISPs. Cabase contracted with Comsat Argentina the tasks of NAP operation, but its operation and management are still Cabase's responsibility. The existence of this NAP has brought most convenient operational costs for ISPs, and improvement of quality of service for users.

This NAP was created when Argentinean communication authorities opened the country to international traffic. Data access and e-mail companies (whose clients were mainly companies) operated with a X.25 network. From the moment of migration to Internet Protocol (IP) and the arrival of Internet, Argentinean regulations allowed access from these companies to Telintar, the only company that could operate data with international connection; but Telintar did not allow local connection. Three Argentinean ISPs decided then to joint efforts to interconnect themselves, solving the local connection issue. Before that, one ISP had to pay an expensive international access to communicate with other ISPs at local level.

After one year of negotiations, ISPs decided to enter one local interconnection neutral agreement. As of today, mid 2003, Argentinean ISPs have approximately 71.500 dial-up connections, that is 90% of

[2] Members of NAP Cabase: Arte Gráfico Editorial Argentino S.A., Asociación Civil Ciencia Hoy (retina proyect), AT&T, Comptia/Aspic (asp industry consortium) , Comsat Argentina S.A., Cps Comunicaciones S.A., Diginet/ Diveo, Dka S.A., Equant Argentina, Fibertel S.A., Global Crossing, Impsat S.A., Interlink, Intermediasp (Intermedia Comunicaciones S.A. + Interlink Network srl), Iplan Networks (NSS S. A.), Metrored, Telecomunicaciones, Movicom Bellsouth, Net Express S.A., Netizen S.A., Netv, Network Accesspoint srl, Nosis, Laboratorio de investigación y desarrollo S.A., Optiglobe S.A., Pnud Proyecto ARG/98/032, RCC Red Cooperativa de Comunicaciones, SES Sistemas Electrónicos S.A., Sinectis, Sion, Structured Intelligence arg. S.A., Technisys Informatica srl, Techtel S.A., Telecom Argentina S.A., Telefónica Data, Teleglobe Argentina S.A., Velocom, Via Networks Argentina, Winstar Argentina S.A., XL Sistemas S.A.

[3] http://www.cabase.org.ar

the country's connections. ADSL bandwidth connections are around 120.000, and those by modem cable are approximately 73.000. Thanks to these connections, NAP handles almost 100% of Internet domestic traffic, while for international traffic each ISP has its own outgoing traffic providers [10]. To be eligible as a NAP Cabase member, companies must be Cabase members, have an added value or telecommunications license, and own an Autonomous System Number.

Satisfied such requirements, the ISP signs with the NAP an interconnection agreement, which terms are the same for all ISPs. This particularity has raised problems because some ISPs refuse to accept some of the clauses. However, NAP administration believes that keeping the same contract has been determinant for its growth. The agreement provides that every ISP must advertise its domestic routes, but there is not an obligation to advertise its international routes. Decisions are made together, and there is a technical sub commission in which every company is represented by a professional technician. Setting up and maintenance are coordinated by a third party.

Cabase's approach to financial sustainability lies on the concept of NAP points. Depending on the capacity needed by each ISP from NAP, the latter determines the amount of NAP points to each ISP. ISP's monthly payments depend on the amount of NAP points. One NAP point not only includes the connection capacity, but also the kind of installation needed by each ISP. It is worth mentioning that connectivity bandwidth was not considered as a parameter to determine costs, because one ISP connecting with a larger bandwidth is somehow improving NAP operation with other ISPs [10].

Originally, the equipment required to start operations was donated by a data routing equipment provider. Currently, each new ISP must pay NAP Cabase an entrance fee, whereas the monthly operational cost is divided among all members. None of the 12 founder members paid an entrance fee. Foreign companies have recently asked Cabase for access to its NAP; but, the administration policy provides that such access is limited to ISPs operating in Argentina, that is, ISPs exchanging local traffic.

As a result, Cabase is creating an International Internet Exchange or IIE. This exchange point will be limited to international carriers exchanging international traffic, and it will allow each carrier not only to administrate private routing policies, but also to decide with whom to connect and under what conditions. Beneath this initiative lies the purpose of converting IIE into a traffic exchange point for southern South American countries.

2.3.2. NAP Chile

NAP Chile aims at interconnecting Internet access providers in Chile. It was born in September 1997 as a stock company, conceived as a syndicate, and was originally created by six independent ISPs to prevent international outgoing of domestic IP traffic[4]. From this ISPs group the *Asociación de Proveedores de Internet* (API) was born[5].

Chile has Internet domestic exchange points that gather and exchange traffic from two or more ISPs; they are known as Traffic Exchange Points or TEPs [8]. Such connections are non-discriminatory, and must accept all ISPs' domestic traffic, without restrictions, interchanging also routes with ISPs connected to other TEPs. It should be mentioned, however, that in order to accept such connections the relevant technical aspects must be complied with, and equipment must be managed according to international standards [8].

Such TEPs also manage quality indicators not only of TEP connections with ISPs, but also of connections among TEPs. This quality measuring is made regardless of the amount of international traffic handled [8]. In the case of ISPs not connected to any TEP, the latter must provide information about its indicators. For this measuring the intervention of a third party --that is, somebody alien to such ISP-- is necessary. [8].

It is important to mention that there must be full connection among TEPs, if they are less than five. If they are more than five, each one must be connected, at least, to another three [2]. TEPs existing in Chile are NAP Chile, ENTEL, NAP de Telefónica Mundo, Global One, AT&T, Equant, Impsat, and Chilesat.

NAP Chile's entrance policy has been to allow participation of other ISPs with independent international links. On the other hand, to guarantee non- discrimination, ISPs must accept and establish connections among them to send domestic traffic. Therefore, to comply with the domestic connection requirement, every ISP must be physically connected to and entitled to route exchange, at least with one TEP [8]. In this case, the existing agreement among ISPs connected to a TEP should be a peering agreement. But they may agree on other connection topologies, provided that the domestic traffic be exchanged by authorized providers [7].

[4] Memoirs of the First Latin American NAPs Meeting, Cartagena, Colombia, October 22-24, 2001 - Report of NAP Chile.
[5] Members of NAP Chile : AT&T LA Chile, BellSouth, CMET, CTC Mundo, CyberCenter, E-Money, Global-Net, Global-One, GTD Internet, IFX Networks, Impsat, INFOPYME S.A. Empresa del Grupo Tecnológico Sonda, NETGlobalis, NewPlanet, Nivel5, Telefónica Internet Empresas, Terra Networks, SurNET.

Interconnection Regulation

Chile has been the only South American country where regulations have been designed to solve the problem of Internet interconnection. Specifically, the Chilean Department of Transportation and Telecommunications, through its Telecommunications Sub Secretariat, has taken actions to regulate ISPs' interconnection in Chile. According to some 1999 and 2000 regulatory guidelines the Telecommunications Secretariat must guarantee, among other things, the efficient use of resources, and the users' non-discriminatory access to contents, independently from the network access providers. In turn, every content provider must be free to choose its hosting provider, a situation that leads to free competition [7].

The mentioned guidelines look for non-discriminatory Internet access service, in terms of quality, constraining ISPs to establish and accept connections among themselves to send domestic traffic. Red tape for ISPs includes written request, and a copy to the Sub Secretariat. Established connections should guarantee quality access to users, equivalent not only to their own ISP, but also to the ISP at which interconnection was asked. The regulation allows also the establishment of the TEPs for the exchange of domestic traffic.

The Sub Secretariat also controls network functioning by keeping quality indicators for each ISP. These indicators include: number of users, number of content providers, rate of packets lost, delay levels in data delivery (latency), and levels of links occupation, published in a public web page [7]. The rate of packets lost is the percentage of packets sent to a specific destiny but lost and therefore unable to receive an answer during a certain period of time. Latency is the time spent by a packet while leaving and going to another specific point of the Internet [8].

Internet traffic through NAP Chile

Under existing regulations, NAP Chile provided that all ISPs should measure, among others, occupation rate, latency, and packets lost rate, to be able to determine the amount of traffic handled.

ISPs with the largest average of annual traffic volume are: AT&T (37,4 Mb), IFX Networks (35,4 Mb), Terra Networks (28,8 Mb) and GlobalOne (25,8 Mb). Among them, ISPs IFX Network (22,9 Mb) and AT&T (17 Mb) have also the largest annual average of incoming traffic. At the same time, ISPs with the largest annual average of outgoing traffic are AT&T (20,4 Mb), Terra Networks (15 Mb) and GlobalOne (14,6 Mb). It is worth mentioning that NAP Chile exchanges 35% of Chile's traffic.

ISPs with the largest annual average of latency values are Surnet (41 ms), PSInet (20 ms), GlobalOne (17 ms), and IFX Network (16ms). Finally, measurement of annual average of lost packets rate lead us to estimate that ISPs with most problems of this type are Bellsouth and Worldcom, 70% each, followed by GTD Internet with 47%.

2.3.3. NAP Colombia

NAP Colombia was born in 1998 as a cooperative body, thanks to an agreement signed by 12 ISPs (founders) that, led by the Colombian Chamber of Informatics and Telecommunications, CCIT, acquired infrastructure and contracted an operation that allowed all ISPs involved, to benefit from a common exchange point[6].

NAP Colombia is responsible for the concentration and routing of all communications of Internet access provider companies connected to it in order to avoid international connection costs previously derived from the connection to their servers. Communication concentration and routing services are rendered under equal conditions and opportunities for all entitled NAP operators.

It is estimated that the total traffic sent by such operators through NAP represents 90% of all domestic traffic. Data traffic has increased approximately 200% per year since 1999 when it was created. Thus, there is a current exchange through ISPs parties to NAP of approximately 3.5 Terabytes per month. This allows ISPs to save approximately one million dollar a year, as they are not using international bandwidth to route domestic traffic [10]. The services offered by NAP Colombia are: physical infrastructure for Internet traffic exchange, web sites, router collectors (a router provided by NAP to which all operators may peer), mailing lists, and router placement for all members.

NAP provides also information about traffic volume, speed, traffic relationships, time of use, congestion levels, and of any operational aspect required. It also updates information about Internet development and growth in Colombia, identifying technical capacities offered, and its traffic and demand [2]. All information and statistics derived from NAP operation must be furnished to all parties to the agreement, at the same time, and under the same conditions and means, without any discrimination or preference. Therefore all members have the right to receive and request the same information supplied to the others, as well as a certification thereof. For this companies the only possible NAP interconnection agreement is the open peering agreement, i.e., all ISPs must publish and be aware of each ISP's routes and their clients'.

[6] Members of NAP Colombia**:** Andinet.com, AT&T, Colomsat S.A., COMSAT Internacional, Diveo, Emtelco S.A., EEPP de Medellín, Equant, ETB, IBM, Impsat, InterRed, Telefónica, Teleglobe

NAP Administrative Council acts as decision-making body. If technological changes are implemented by NAP, the technical subcommittee -conformed by technicians in charge of NAP members' infrastructure- issues recommendations to be approved by said Administrative Council and carried out by NAP. Before operations started with ISPs, the founder members set forth an entrance fee to cover infrastructure expenses. NAP operating costs are financed with a monthly payment set forth by NAP members, which purpose is to cover projected expenses.

CCIT celebrated an outsourcing agreement with Intesa de Colombia which provides NAP operation, that is, maintenance, control, and traffic measuring. In order to perform an adequate control, Intesa has its Integrated Services Center (ISC), which is basically a location where the information generated by NAP machines is monitored. NAP infrastructure consists of three racks of working equipment. Such equipment is owned by all ISP (level 2 routers) and by NAP (2 switches and one level 3 router). Every ISP is directly connected to another ISP by switches, and has an additional connection to the level 3 router.

NAP was originally operated with level 3 technology, which lead to the fact that all ISPs were connected under peering agreements (implicit on direct connection to NAP). However, due to traffic increase through the level 3 router, speed problems appeared as the router was working at full capacity. Consequently, NAP members migrated to level 2 technology, and although it was a technological set back, it allowed each ISP to set up its equipment according to its own traffic requirements. This new scheme may generate interconnection agreements other than peering, but transit agreements have not been signed yet. While using level 3, the router identified NAP traffic type and quality. In other words, it was possible to measure traffic amount generated by voice, data, video, etc. For the time being, it is not possible to obtain this data as a whole; each ISP is responsible for this measuring.

Provided that all the quality requirements requested by NAP be complied with, NAP is capable of adapting itself to every ISP's technology (it accepts different equipment trademarks). Moreover, NAP administration may suggest ISPs to update or change equipment, or to enlarge their capacity if they recurrently reach the established limit --which is 70% of its installed capacity for each ISP-- at peak hours.

Recent ISP statistics gathered by NAP took into account traffic sent, latency, and information lost for every ISP. Latency measuring ranges between 3 and 12 ms for all ISPs. The maximum level of latency established by NAP is 30 ms, calculated taking into account that latency on delivery of information between Bogotá and Medellín is 15 ms. Total is the result of multiplying this latter figure by 2. NAP measures average traffic of each ISP every 5 minutes, every hour, and every day. This data is transcribed to graphics that include ISP's incoming and outgoing traffic. The curve of incoming traffic is above that of the outgoing traffic, which means that consultation exceeds publication.

The original tariff scheme for each ISP was calculated on monthly operational costs, and equally divided among all ISPs. But it did not fairly reflect traffic variations from one ISP to the others. Therefore NAP had to design new schemes. The one currently implemented by NAP is the following: monthly costs, when 70% is incurred, are equally divided among all ISPs; the remaining 30% is estimated by traffic measurements, and proportionally assigned to each ISP's total traffic. Its application required the design of a new system that measures traffic sent by each ISP every 10 minutes.

Total Internet traffic passing through NAP Colombia has gradually increased during the period June 2002-June 2003, from a total of 4.800 Gb to approximately 8.100 Gb., which means a total traffic increase of about 60% during this last year.

2.3.4. NAP Peru

NAP Peru is a non-profit civil association (more similar to a cooperative), born on August 25, 2000. It is an independent company, created by competitive bidding, for which each operator suggested one or two companies with absolutely no stock relationship with any NAP member -to guarantee independence.

Thanks to this interconnection network, functioning has eased, because faster local traffic exchange does not interfere with international exchange, easing it too. This is so, because international bandwidth is not shared with national traffic. Another benefit is the reduction of costs derived from time of connection, final destination, and network and infrastructure used for the interconnection.

This NAP has 7 members; five founders rotate at the presidency. It was originally conformed by Telefónica Data, Telefónica del Perú, ATT (former Firstcom), Infoductos (RCP), BellSouth, and COMSAT. Subsequently Diveo and Impsat joined the group, with voice but not voting right. There are also a technical and an administrative committee, which the American Chamber of Commerce currently administers. A large number of clients come from Telefónica Data and it is estimated that there are approximately one million Internet users in Peru, 80% of which use this company.

NAP Peru is physically located at the American Chamber of Commerce. Its administration and operation was originally entrusted to INICTEL (Peruvian Institute for Telecommunications Research and Training), but they were recently transferred to GMD (Graña y Montero Digital), a private company. Its technical and operational structure consists of one administrator-operator and four operators who rotate from time to time to guarantee 24 hours service. INICTEL (now GMD) designates a technical coordinator and one administrative coordinator.

The main problem faced by this NAP is the result of its original legal framework (an association instead of a company), because it does not reflect the existing traffic disparity. Under the original rules all the parties had to connect with the same capacity, and if links were saturated they had to increase their capacity on equal basis. But this restriction to conform to bandwidth harms small traffic operators. Since NAP Peru is currently saturated, sometimes it is preferable, for speed sake, to route traffic to international links. Therefore, it has been decided to increase interconnection links to 30 Mb. But this action may push out members with less traffic because of higher interconnection costs, which in turn may lead to financial difficulties.

On the other hand, to NAP Peru may connect only ISPs partners, like Telefónica del Peru, AT&T, Bellsouth, ComSat, RCP, Impsat and Diveo. They convene peer-to-peer exchange agreements, and traffic exchange by means of different routes (BGP). This exchange is originally done under peering agreements among connected Internet providers. At the beginning is on "everybody vs. everybody" basis, thus, each provider should have "n-1" BGD sessions in its router, being "n" the number of members at NAP Peru. Information flux is made according to final destination. In the latter scheme the provider's router with AS1 has a BGP peering with every other provider; therefore, routing flux is point by point with each of the NAP provider router members.

Among the NAP members, the two more important are Telefónica del Perú (80% of Peruvian Internet traffic) and AT&T (15% of the country's Internet traffic). Telefónica del Perú recently increased its speed to 12 Mbps. It may be said then that traffic handled by NAP has increased and therefore its members presently use 10 Mbps links towards central switches. No special measurements are taken from this traffic to identify its nature (data, video, voice, etc.)

For such clients, NAP basically hosts routers and exchange infrastructure for local traffic transportation, thus avoiding international linking. Link monitoring and the assurance of uninterrupted node operation is also carried out. In case of failure, a report is produced in less than five minutes, offering 99.999% availability. Measurements are not, however, classified according traffic type (voice, video, data, etc). Quality criteria of the services rendered by NAP include bandwidth and latency between the exchange central node and the provider's exchange router.

The following parameters are also considered when evaluating quality of service: traffic analysis from each ISP to NAP (outgoing traffic for ISPs) and from NAP to each ISP (ongoing traffic to ISP). Total traffic is also calculated from data level transiting throughout the two switches which conform the NAP. Each ISP is connected to each one of these switches (one backs up the other in case of failure: redundant switches). Delay measurements are also made calculating the time spent by the information, sent or received by each ISP in its loop back interface. Other measurements are those of equipment resources used by NAP Peru. The NAP has two switches and one router, and the resources monitored are the use of CPU and memory.

Software called MRTG is used to collect this information. Such program is carried out in Linux platform. All this information is collected every day at 12h30, as the period of time elapsed from 8h00 a.m. to 8h00 a.m., the following day, is considered a sample window to determine the bandwidth assigned to each ISP (from that time on NAP receives larger amounts of transit data). Environmental temperature, UPS voltage level and equipment's fuel are also controlled, and assistance is given to all members in configuration tasks. Finally, scripts and control programs are developed (basically using MRTG and similar). In order to obtain these services, operational costs --which amounts to $3 000 per month-- are equally divided among members. Another fee that has to be paid is the entrance fee to NAP, equivalent to $15.000, payable once.

If other ISPs request access to this operation, they should have an AS number and use BGP, own an international outgoing, and keep the same speed as the remaining members. The minimum capacity required to interconnect to NAP is 2Mbps. As a result, Peruvian smaller ISPs usually route their Internet traffic through transit nodes in the United States [10].

2.3.5. NAP de las Americas and NAP Brazil

NAP Brazil is located in Sao Paulo. It is administered and operated by Terremark Latin America (Brazil) Ltd, together with FAPESP (*Fundaçáo de Amparo á Pesquisa do Estado de Sáo Paolo*). In addition, Terremark owns and operates NAP de las Americas, the world's 5th network access point Tier-1, and the model for data centers, TerreNAP(sm), that the company is developing in San Paulo, Brazil (NAP do Brasil), in Madrid, Spain (NAP de las Americas, Madrid), and in other emerging markets. However, NAP Brazil and NAP de las Americas are completely independent.

NAP de las Americas is a neutral complex with the latest technology, which furnishes interconnection to Internet and other access service providers (ISPs), and supplies optical fiber network connectivity between Latin America, Europe, Asia and Africa, and the United States.[7] NAP de las Americas operates in Miami, Florida, since July 2001[8]. Terremark financed the necessary infrastructure to operate this NAP. NAP Brazil uses instead FAPESP[9] facilities and some FAPESP's expenses are covered by Terremark.

For its technical and operational functioning, NAP de las Americas has approximately 60 people trained and certified on the latest technology, and provides 24 hours service, seven days a week, 365 days a year. NAP Brazil has instead only 6 people because its operation is fairly small. However this number tends to increase, as its operational center is also in Miami. Among the services offered by such NAP are information placement, peering, and data services. Such placement includes physical space to its clients at NAP operations center. Another service rendered is the access to peering agreements, when its clients acquire peering ports. Each party privately carries out such agreements, and other similar commercial agreements, among ISPs present at NAP. NAP de las Americas acts simply as a facilitator and operates the peering structure and the meeting points used by its clients during the implementation of such agreements.

[7] http://www.terremark.com

[8] Members of NAP de las Americas: Advanced Communications Network, Amzak, AT&T IP, Azultel, Bacardi, Belgacom, Belize Telecom, Boliviatel, CAF (Corporacíon Andina de Fomento), Caribbean Network Management, CCD Communications, Centennial Florida Switch, Codetel, Cogent, Conectron, Coverall North America, Crescent Heights, Deutsche Telekom *(T-Systems),*Digitel Networks, Diveo, Dominion Telecom, Dynegy Connect, e-life Group Corporation, El Salvador Telecom, Embratel Americas, Emergia USA *(Telefónica),* Entel Bolivia, Entel Chile, EPIK Communications, Exergy, E-xpedient, ez2rent.com, FIU AMPATH/Internet2, Flag Telecom, Florida Broadband, FPL Fibernet, FPPI, France Telecom, Genuity, Global Crossing, Heritage Communications, IBW, IDT Telecom, IFX Communications Ventures, IM1 Webhosting, Imart, Information Services Extended, Innovative Communications, InterDOM, InterNAP, Interplex, Intrado, Latin America Nautilus USA, Level 3, Matrix Internet Corp. *(Caribe.net)*, MedNAP, Metromedia Fiber Network Services, MetroRed Honduras, MetroRed Telecomunicaciones, Mirror Image Internet , NAP Host, Navega.com, Netideal, NewCom, NTT/Verio, NUI Telecom, OCTET Group, On Fiber (Telseon), Operadora Protel, Optenet, Orbitel *(Cinco Telecom),*PC Universe, Progress Telecommunications, QWest Communications, Reach Services (USA) Inc., Reality Networks, Salnet, Savvis, Savvydata, SBC Internet Services, Site Manageware, Sprint , Swisscom AG, SXP, SysteComm, TelCove, Telecom Argentina, Telecom Italia, Telecom Network, Inc., Teleglobe, Teleware, Telstra Wholesale Trading, The Treaty, Time Warner Telecom, Trimax Technologies, Tyco Telecommunications, U.S. State Department DTS-PO, VeriSign, Vox, Webhosting.net, WebUseNet, Williams Communications, WIP Telecom, Worldcom, XO Communications, Xtec.

[9] (FAPESP is the Brazilian equivalent to NSF in the United States),

Another service is the selling of cross connections at different speed for those clients who may interconnect among themselves. Finally, it offers system monitoring, services and other kind of installations used by its clients once connected to NAP. These services are offered to its clients, who are divided in four categories: network service transporters or providers, service providers (hosting companies), and government companies and bodies.

If any other ISP applies for peering service, in the case of NAP de las Americas, it would need at least the related circuit, and a port in the relevant Terremark structure. And in the case of NAP Brazil, it would have to use one of the entrances handled by Terremark, paying an extra cost for it. This extra cost is used for the exchanging operation. At the beginning and for 9 months after the creation of NAP de las Americas, there was not much network traffic exchange. But it is estimated that by mid 2002 there was an approximate exchange from 100 to 200 Mbps. This traffic growth pattern is almost logarithmic. Terremark estimates that it currently processes 500 Mbps, and expects to exceed 1Gbps at the end of the year. This last figure includes also traffic by peering in NAP Brazil. Total traffic going through NAP does not considerably exceed such figure because there are not current cross connections carried out under agreements different from peering agreements.

It could be stated that most of such traffic figures are data packets (Internet Protocol, IP). But since there is a certain number of providers servicing South American and European regions, traffic has increased due to voice over IP (VoIP). It is worth mentioning that Terremark does not classify traffic according to the type of application. On the other hand it is evident that this traffic varies from one ISP to the other.

There is another type of data collection, which includes counting packets and SLA monitoring. Packets are counted every 5 minutes, a period of time which is considered enough. If frequency were increased, it would not be possible to obtain additional information. NAP clients with two simultaneous connections are offered 99.999% availability to connect with other clients having also two connections. Those with one connection may obtain 99.5% availability. However, larger percentages may be handled in some cases. The maximum latency offered is 21 μs from one port to another. SLA also includes connectivity monitoring capacity from every client's switch. Thereby, errors that could cause dropping in a peering connection --in which though the port is working, it is not active-- may be detected. Clients receive assistance service in case of functioning problems, as well as to identify peering needs, transit sell, and similar ISPs' functions.

There are other NAPs in Brazil, namely RSIX (Porto Alegre), ANSP (Academic Network at Sao Paulo), and Diveo NAP (Sao Paulo), described hereunder.

NAP RSIX (Porto Alegre)

NAP RSIX operates in the data processing center of *Universidad Federal de Rio Grande do Sul*. One of its objectives is to facilitate agreements and network connection at low costs for public and private institutions. This NAP is a neutral point where different operators may exchange traffic among different backbones, having at least one point of presence in Brazil.

Some of its first members are RNP (*Rede Nacional de Ensino e Pesquisa*), Rede Tche (*Rede Academica Estadual*), UFRGS (*Universidade Federal do Rio Grande do Sul*), Impsat and Unisinos (*Univesidade do Vale do Rio dos Sinos*). Subsequently, the main national universities and other *Sistemas Autonomos Academicos* (Academic Autonomous Systems) joined the group [10].

Multilateral agreements are celebrated among these members, favoring such members having at least 3 participants in its network[10]. On the other hand, members are required to use protocol BGP4 and have at least 2 Mbps capacity [10].

NAP ANSP

ANSP was created on 1988 thanks to a nuclear physics professor, president of the FAPESP's Conselho Superior. Originally it had connections that allowed universities and research institutions in Sao Paolo access to information in United States laboratories [10]. Ten years later this network offered NAP services, thus promoting traffic exchange between backbones and content providers. This NAP was also called *Ponto de Troca de Tráfego*, PTT (Traffic Exchange Point) [10]. This NAP owns an international connection carried out directly with Global Crossing (GBLX) at 155 Mbps, therefore connected also to AMPATH (American Path), and with Abilene [10].

DIVEO - NAP

DIVEO NAP was created in 2001 and it's the only private NAP in Brazil. Its goal is the exchange of Internet consumers and companies in Brazil. It was born also to improve network efficiency and performance. DIVEO NAP is connected to NAP ANSP and to other operators like Embratel and Global One, among others. It aims at implementing a regional strategy, point by point, diversifying network

[10] This is the case of UFRGS

exchange by using protocol BGP4. On the other hand, it aims at connecting most Latin American Autonomous Systems in order to establish traffic on a local basis [10]. Diveo's coverage area includes cities like Brasilia, Campinas, Curitiba, Porto Alegre, Rio de Janeiro, Sao Paulo and Belo Horizonte [10].

Other South American countries

In the remaining South American countries, Internet connection is carried out by ISPs directly to international backbones; this is the case of Venezuela. This scheme makes information delivery channels inefficient because local contents that may be exchanged within the same country have to travel towards the international backbone and go back to its country of origin to be delivered to its final destimation. It increases delay costs due to information transportation and it also increases the risk of loosing information packets. Countries like Ecuador, Panama, Venezuela and Paraguay are currently promoting ISPs and economical studies to consider the possibility of creating a local NAP.

In Venezuela, CASETEL (*Cámara de Empresas de Servicios de Telecomunicaciones* - Chamber of telecommunication services companies), a private institution created in 1980, gathers 47 companies that offer telecommunication services within the country. The NAP was born two years ago, promoted by CASETEL, CONATEL (*Comisión Nacional de Telecomunicaciones* - National Telecommunications Commission) and the Venezuelan Chamber of Electronic Commerce [12].

Participants at NAP CASETEL would then be those ISPs qualified by CONATEL, entitled to the same conditions, rights and obligations. Companies would incur costs after one year of operations, provided that each one builds up its won connection [12]. NAP administration would be run by a committee conformed by its members, though NAP operation would be entrusted to CASETEL [12]. Before carrying out this project, certain aspects like equipment and installation supply must be defined, by means of a competitive bidding. The evaluation of different guidelines set forth in other Latin American NAPs, and applicable in Venezuela, would also have to be made. It is worth mentioning that this project has not been accepted by all relevant chambers [12].

2.4. Future trends

Recently, South American ISPs have begun discussions the future existence of a regional NAP, although there are no developments so far. One of the purposes of such exchange point is to gain bargaining power when establishing traffic exchange or contracting bandwidth with a network like the one managed US large IBPs. This negotiation power would increase with the existence of a common point at regional level [10].

One of the factors preventing the execution of such project is the existence of different levels of Internet development in South America. Countries with a more developed Internet access market acquire international traffic at lower costs than less developed countries. It is the case, for example, of Argentina, Chile and Brazil, where this service may be contracted at amounts between US$ 350/Mbsp and US$700/Mbps. In contrast, in Colombia the same service could cost up to US$2.900.

Therefore, there is not an evident economic benefit from using one common connection point at equal cost for all members, because it could be --in some cases-- higher than the current price, with no important improvement in service quality. Consequently, Internet providers prefer to maintain their own international connections, aware that international exchange costs tend to decrease, due to the fact that existing network and infrastructure with international connection capacity towards the United States has not been fully used yet. [10].

On the other hand, regulation has been and will continue to be a vital subject in the Internet market development. So far regulations have been mostly the natural result of market forces, but there is a tendency to tighten them because of disagreements in negotiation procedures among some ISPs. The billing agreements, so far existing between North American backbones and Latin American ISPs illustrate the foregoing. Most of these providers don't have peering agreements with backbones, and therefore must assume all or almost all the exchange costs. It is possible that in the near future a main data center may be created in Latin America, and act as a hub for traffic of this part of the continent. It would reduce costs, as it would use to a less extent the interconnection established with the backbone. This scheme would allow Latin American operators to have greater bargaining power with IBPs. This power could grow to the point of conforming an exchange point that could make a peering agreement with one of the backbones, benefiting Latin American ISPs. This group negotiation could be one of the goals to be reached by smaller ISPs. So, one hub becomes an attractive alternative to develop new tendencies in the Internet market. Such hub would be the result of the union of content providers, Latin American ISPs, and, if possible, other countries' NAPs. Since Internet, as it is well known, tend to develop free of frontiers, regulations, if any, should promote the increase of traffic and users. Regulations, therefore, are strategic tools that benefit operators.

Another way to strengthen the ties between the South American countries is the possibility of NAP interconnection. According to a Chilean expert[11], the most important element for this idea to succeed is the will NAP Cabase and NAP Chile may have for initiating a direct connection between the two countries. NAP Chile members have agreed to run some trial period with NAP Cabase. The exchange

[11] Juan Pablo Redard, NAP Chile representative at the Latin American NAPs Second Meeting in Buenos Aires, Argentina

of traffic will be among networks with a regional prefix, which must be IP addresses in the two countries. Strategic and technical reasons are exhibited to justify such connection despite the traffic level may not yet justify the economics of the interconnection.

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Chapter 3

Modeling the evolution of interconnection agreements between ISPs

The looser arrangement the Internet is moving forward to allows for smaller ISPs to reach interconnection agreements for traffic exchange; the incentives of larger ISPs to degrade peering agreements are reduced when more secondary agreements are in place. Besen et al. [1] have proposed a bargaining model to understand the incentives that core ISPs have to refuse a peering agreement with smaller ISPs; they assume there are N homogenous customers in the market, served by n core ISPs.

In our case, the non fully developed national markets in South America show a similar evolutionary characteristic: first, ISPs got connected to the Internet, purchasing transit from large backbones and paying for international bandwidth for any traffic they needed to deliver; eventually, after realizing that the cost they were facing for switching and delivery of their domestic (national) traffic was excessively high, many ISPs in different countries decided to join in a cooperative agreement from which they created an exchange point also called Network Access Point or NAP. NAPs have been operating in many South American countries for several years[12].

A typical NAP brings together ISPs different in size, range of services provided and geographical coverage. The contractual agreement says that any two ISPs are bound by a peering agreement for the exchange of local (national) traffic. Traffic in and out of the country has to be delivered by alternative communication paths. It is common that small ISPs purchase transit from other larger ISPs, which in turn purchase access to Internet from IBPs, or from IBPs directly. As can be observed a diverse array of transit and peering agreements is in place for the Internet access market to properly function in those countries.

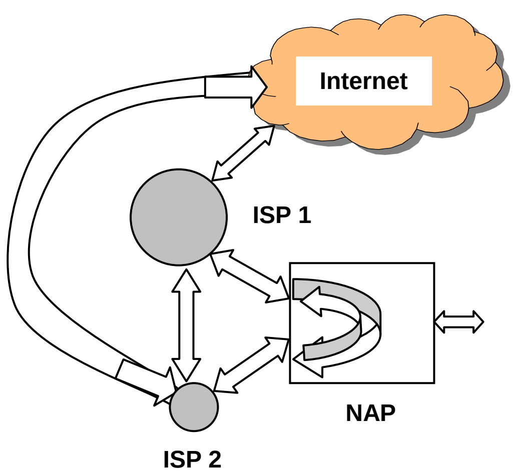
Our main concern is based upon the observation that in a NAP all agreements are peering agreements[13] in spite of the fact that ISPs are different by any measure used, in contrast with the literature consulted and the practice observed that peering is achieved between ISPs of similar characteristics. In some cases the agreement can be seen as one where a partial peering is in place; this means that the traffic of a small ISP is delivered at no cost to a restricted part of the network of the larger ISP. Any traffic from the small ISP reaching the rest of the network is charged under a transit

[12] A description of NAPs in many South American countries can found in the second chapter of this work.
[13] Ibid.

agreement. [3]. In practice, in the South American region even though small ISPs have peering agreements with large ISPs for the exchange of national traffic, they do not necessarily have transit agreements for their international traffic. This fact leads us to believe that the particular structure observed in those markets is worth being studied in order to assess important aspects of the market such as the stability of the exchange points and the bargaining position of small ISPs when faced with demands from larger ISPs.

3.1. A model of bargaining

In our model we consider two ISPs connected, as many others are, to a NAP. We will call them ISP1 and ISP2; ISP1 is a large ISP, which perhaps is also an important international player of the Internet access market and ISP2 is a small domestic ISP, which has a transit agreement with ISP1 for its non-domestic traffic. Each ISP has a direct connection to an IBP, which may be a Tier-1 ISP[14]. In other words, ISP2 is multi-homed to Internet carriers to improve the quality and the reliability of its access to the Internet cloud. Figure 3.1 illustrates the situation.



Such situation is typical of many of the studied countries[15] in South America. In fact, the small ISPs can be considered a distinct group from that of the large ISPs. Large ISPs have a more diverse range of services and usually are international players. So we can consider that ISP1 is a representative of the large ISPs and ISP2 is a representative of the small ISPs. All agreements at the NAP are peering agreements.

The technical and economical literature on Internet interconnection agreements says that peering agreements are possible when ISPs are of similar measure; the typical measures used are [Norton]: (i) geographic coverage, (ii) network capacity, (iii) traffic volume, (iv) size of the customer base, or (v) position in the market.

[14] It is common that small ISPs have a second (back-up) connection to an IBP.
[15] Interviews with the Operations Directors of NAPs in the region.

The peering agreements at NAPs do exist in spite of the fact that some or all of the measures mentioned above do not coincide when the interconnection agreement between a pair of ISPs, one from each group, is considered. It is therefore relevant to ask whether there are any incentives for large ISP to unilaterally terminate their peering agreements with small ISPs. Such termination is initiated when a large ISP asks a small ISP for a change in the nature of their interconnection contract demanding that the small ISP pays either a transit fee or a peering fee.

We will use a bargaining model [4] to describe the ISPs behaviors after PSI1 has informed ISP2 about its intention to change the agreement. We assume that an ISP's utility is a function of the number of customers or more exactly is a function of its market share and the quality of service. More specifically, if there are N customers and ISPk has a fraction α_k of it, then the utility of ISPk is $N*\alpha_k*f(q)$, where f(q) is the utility of its representative customer.

Contrary to the assumptions in Besen et. al. [1], we will not consider here that an ISP may be blocked from reaching all customers of another ISP should a threat to disrupt the connection arise when ISPs are bargaining over a new agreement. Instead, we will assume that negotiations start before the contract term expires and that the threatened ISP has alternatives to the threat. Consequently, we can assume that the utility function that an ISP's representative customer enjoys is a function of the quality of service.

Any customer of an ISP can certainly distinguish between two main destinations for his Internet traffic; we will suppose this customer knows if he is trying to access Web sites or electronic addresses which are located somewhere in his own country[16]. On the other hand he is also able to know whether his Internet session (Web surfing, e-mail, ftp downloads, etc.) is being held with a server located in another country. The two sets of destinations use different paths of communication once traffic leaves the customer's network; domestic traffic has to be routed through the ISP's own network or the NAP, whereas international traffic uses the international connections to IBPs. So it is reasonable to think of the utility function as a function of the quality of each type of traffic. An ISP's utility function is $f_i(q) + f_n(q)$, where f_i is the utility derived from the quality of its international access (e-mail, downloads, etc.) and f_n is the utility derived from the quality of its domestic access. We also assume there are only two level of service quality, high and low, represented by q^h and q_l, respectively.

What would happen when ISP1 threats ISP2 to change the interconnection agreement at the NAP from a peering agreement to a different kind? Which are ISP2's alternatives?

[16] A lot of Internet use is Web surfing on Web sites not located under the national domain (for instance, .ar for Argentina, .co for Colombia, .br for Brasil) so users are able to perceive the geographical difference in site location.

We will consider two possible situations:

a. ISP2 terminates its peering agreement with ISP2 at the NAP; alternatively, ISP2 signs a transit agreement with a third party, ISP3, for the exchange of domestic traffic, including ISP2's traffic with ISP. ISP1 keeps its transit agreement for international traffic with ISP1.
b. ISP2 terminates its transit agreement with ISP1 and gets a new transit contract with a third party, ISP3; ISP2 keeps its interconnection agreement with ISP1 at the NAP but agrees to change it from a peering agreement to a paid peering [5].

We assume that ISP2´s cost of connection to ISP1 is less than its cost to connect to ISP3, that the quality of service provided by ISP3 is lower than the quality of service provided by ISP1 and that managing local traffic is less expensive than managing international traffic.

In situation a we assumed that the transit agreement for international traffic between ISP2 and ISP1 is still in place. ISP2 pays a fee T to ISP3 and the quality of service deteriorates because ISP2's traffic to and from ISP1 goes through a transit network, which could probably increase traffic latency. As a consequence, ISP2's response to ISP1´s threat is to sign a transit interconnection agreement with ISP3 for the delivery of its traffic destined to ISP1's customers. If ISP k serves a portion α_k of the customer population then the disagreement point is

$$D_1: \quad N\alpha_1(f_i(q^h) + f_n(q_l))$$

$$D_2: \quad N\alpha_2(f_i(q^h) + f_n(q_l)) - T$$

The utility to be shared by the ISPs when the interconnection agreement is in place is

$$U = N\alpha_1(f_i(q^h) + f_n(q^h)) + N\alpha_2(f_i(q^h) + f_n(q^h)) - N\alpha_1(f_i(q^h) + f_n(q_l)) + T - N\alpha_2(f_i(q^h) + f_n(q_l))$$

which is just the difference between the value created when there is a peering agreement at the NAP and the value jointly created when ISP2 seeks a third party for transit to ISP1´s network.

Nash´s bargaining solution to this problem just states that the payoff to any player is half of the utility U plus his utility at the disagreement point:

$$U_1: \quad \frac{1}{2}U + D_1$$

$$U_2: \quad \frac{1}{2}U + D_2$$

When customers are served under the peering agreement, they are willing to pay up to $P_k = N\alpha_k (f_i(q^h)+f_n(q^l))$. Therefore the incremental utility that ISPk would have as a result of reaching an agreement is $U_k - P_k$.

For ISP1, $U_1 - P_1$ is $\frac{1}{2}[N\alpha_2(f_n(q^h) - f_n(q_l))] - \frac{1}{2}[N\alpha_1(f_n(q^h) - f_n(q_l))] + \frac{T}{2}$

and for ISP2, $U_2 - P_2$ is $\frac{1}{2}[N\alpha_1(f_n(q^h) - f_n(q_l))] - \frac{1}{2}[N\alpha_2(f_n(q^h) - f_n(q_l))] - \frac{T}{2}$

$U_1 - P_1$ represents the transfer from 1 to 2 as a result of reaching an agreement. It is s decreasing function of $\alpha_1 - \alpha_2$ and takes a value T/2 when α_1 is equal to α_2. So, if customer bases are similar then ISP1 will be willing to pay up to half of the cost of ISP2's alternative connection in order for 1 to retain its relation with 2. This is basically implied by the fact that ISP1´s customer base is comparable to ISP2's. Similarly ISP2 would expect T/2 from ISP1.

However, what is close to reality is that ISP2's market fraction be smaller than ISP1's. If there is going to be no transfers from one party to another - in other words if there is going to be a bill and keep agreement – then the relation between the markets fraction should be

$$\alpha_1 = \frac{T}{N(f_n(q^h) - f_n(q_l))} + \alpha_2$$

If degradation of the quality of service for the domestic traffic is very serious then ISP1's customer base will not have to be very different from ISP2´s customer base in order fro ISP1 to expect to gain from his threat to ISP2. However, as long as ISP2 manages to keep the quality of its domestic connection, ISP1 will not have as much bargaining maneuverability as it would if the quality of the domestic connection were reduce.

According to situation b., another course of action would have ISP2 disengaging from its international transit contract to ISP1 and seeking an alternative provider for its international traffic. This includes the possibility that ISP2 uses more heavily its connection to the IBP or purchases transit from a third ISP. We will also assume that the peering agreement at the NAP is kept but as a paid peering agreement [5].

ISP2 would incur in a new cost T^{int}_3 to get international transit for its traffic instead of the old agreement with PSI1 at a fee T^{int}_1. The new agreement at the NAP would cost t^n to ISP2; this is a paid peering.

The disagreement point is

$$D_1: \quad N\alpha_1(f_i(q^h)+f_n(q^h))-T_1^{\text{int}}+t^n$$
$$D_2: \quad N\alpha_2(f_i(q_l)+f_n(q^h))+T_1^{\text{int}}-T_3^{\text{int}}-t^n$$

The utility to be shared by the ISPs when the interconnection agreement is in place is

$$U = N\alpha_1[f_i(q^h)+f_n(q^h)]+N\alpha_2[f_i(q^h)+f_n(q^h)]-N\alpha_1[f_i(q^h)+f_n(q^h)]-T_1^{\text{int}}+t^n$$
$$-N\alpha_2[f_i(q_l)+f_n(q^h)]+T_1^{\text{int}}-T_3^{\text{int}}-t^n$$

which is just the difference between the value created when there is a peering agreement at the NAP and the value jointly created when ISP2 has ceased its transit agreement with ISP2 and has arranged for an alternative connection while maintaining its peering agreement with ISP1 at the NAP under a paid peering agreement.

Nash´s bargaining solution to this problem just states that the payoff to any player is half of the utility U plus his utility at the disagreement point:

$$U_1: \quad \frac{1}{2}U+D_1$$
$$U_2: \quad \frac{1}{2}U+D_2$$

When customers are served under the peering agreement, they are willing to pay up to $P_k = N\alpha_k (f_i(q^h)+f_n(q^l))$. Therefore the incremental utility that ISP_k would have as a result of reaching an agreement is $U_k - P_k$.

For ISP1, $U_1 - P_1$ is $\frac{1}{2}[N\alpha_2(f_i(q^h)-f_i(q_l))]+\frac{1}{2}T_3^{\text{int}}-T_1^{\text{int}}+t^n$ and for ISP2, $U_2 - P_2$ is $\frac{1}{2}[N\alpha_2(f_i(q_l)-f_i(q^h))]-\frac{1}{2}T_3^{\text{int}}+T_1^{\text{int}}-t^n$

Interestingly enough in this situation there is no dependence on the fraction of customers that ISP1 serves. The amount of the negotiated payment from ISP1 to ISP2, $U_1 - P_1$, depends on the degradation of service quality on the international link. We would expect such degradation to occur when ISP2 decides to rely only on its backup connection to the IBP.

ISP1 will exert an advantageous bargaining position whenever the alternative international connection has a similar cost to the one ISP1 may provide to ISP2; that is true if we assume that any payment obtained by a paid peering agreement is just a fraction of the payments made when international transit agreements are signed. Intuition does provide some guide to understand that result: if, as a result of ISP2´s decision to disengage from its transit agreement with ISP1, the quality of service perceived by its customers is reduced, and if the alternative for access to the Internet cloud has a similar price than the current connection then ISP1 has an advantageous position.

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Chapter 4

Traffic-based allocation methods for pricing of multilateral cooperative agreements at Internet traffic exchanges

Interconnection agreements allow for network interoperability making it possible for an Internet Service Provider, or ISP, to provide seamless communications to its customer base. Since interconnection is at the core of Internet operation, interconnection agreements and their financial settlements become crucial for Internet growth.

Interconnection agreements between ISPs may adopt different ways. Major categories for models of interconnection agreements among ISPs are: bilateral agreements, third party administrator and cooperative agreements [6].

An exchange point allows ISPs to deliver traffic destined to other ISP's customers whether a third party is in charge or the ISP has joined a cooperative agreement. It is also a way for ISPs to save on interconnection costs because each ISP gets connected to a central facility for the exchange of traffic instead of laying as many connections as ISPs it has to connect to.

Flat fees are widely used for economic payments derived from agreements [2]. In essence, a flat-fee interconnection agreement is a non usage-sensitive pricing method. Flat fees provide operators with a simple financial settlement without incurring additional expenses for traffic measurement. While flat fee agreements are attractive, there could be incentives for abusive behavior. For instance, firms may aggregate traffic before it reaches an interconnection point and split the fee of interconnection [2]. Therefore, we consider it necessary to explore the effects of usage-sensitive cost allocation mechanisms on the stability of multilateral interconnection agreements. Traffic-based cost allocation [5] may provide the grounds for the utilization of usage-sensitive payment methods in the exchange model of ISPs interconnection.

We want to focus on a situation in which several ISPs share the use of a facility exchange, participating in a multilateral cooperative agreement. The exchange is called NAP, Network Access Point or IXP, Internet Exchange Point[17]. A NAP may provide not only interconnection among its connecting ISPs but also the possibility that such an interconnection may be used as bilateral agreements between pairs of

[17] This is mainly the model adopted throughout South America as each country, with the exception of Brazil, has one NAP or is in the process of consolidating one national NAP. In Europe the denomination IXP is more popular. Chapter 2 of this work presents the current situation of cooperative agreements in some South American countries.

ISPs. In addition, a NAP may provide transit services for other operators not connected directly to the NAP. The administration of a NAP is usually a board whose representatives come from each member ISP.

We assume that the participants have already paid for the set-up costs (last mile, equipment, etc.) and the membership fee; thus, the NAP administration has to decide how to allocate the monthly costs incurred by the operation of the exchange among its members.

4.1. Traffic-based cost allocation in a multilateral cooperative agreement

Figure 1 shows a set of N ISPs connected to an exchange facility. ISPs have already paid a membership fee and use the exchange for routing their traffic to other ISPs also connected to the exchange. The interconnection equipment at the exchange is one of several technological choices [6].

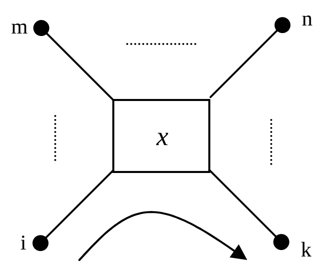

Figure 1

In many instances the operational costs incurred by the NAP are not based on the traffic each ISP delivers to and receives from the exchange[18]. In other cases determining the fees an ISP has to pay is based on a mix of the link capacity from the ISP to the exchange and the total traffic that the ISP has delivered to and received from the exchange[19].

When a flat fee is used, it usually prescribes a payment equal to the total cost (monthly cost) divided by the number of members as the NAP is just trying to recover its costs. In this case every ISP pays exactly the same regardless of the amount of its traffic exchanged with the NAP [3].

When the NAP administration knows how much capacity will be used by every ISP, it can assess the amount of resources to be used and the level of traffic going through the exchange. It is customary that NAP administrators inform its customers that the traffic delivered to the exchange cannot be greater

[18] This is the case of most of South American NAPs for most of the time they have been operating; some of them have recently adopted capacity-based charges.
[19] LINX or London Internet Exchange uses a mix of flat and traffic-based fees; both are based on port capacity.

than 75% of the ISP’s nominal capacity, [6], [7]. Any use in excess of such threshold will deteriorate the quality of service offered to the other ISPs. Consequently, it is also frequent that a NAP decides to charge a differential capacity-based fee. If traffic is not measured then the administration faces a situation in which any violation of the maximum traffic allowed per ISP cannot be detected.
AMS-IX in Amsterdam [1], PARIX in Paris [10] and Cabase [4] in Argentina use such a method. Their tariffs exhibit the monthly fee to be paid to the exchange in accordance to the required capacity but they do not include any penalties for exceeding the maximum amount of traffic allowed.

In Colombia, NAP Colombia [9] uses a two-part tariff; it charges a fixed fee which is aimed at recovering 70% of the monthly operational cost and a traffic-based fee to recover the rest. The fixed fee is (0.7*CT)/N, where CT is the total cost and N is the number of ISPs connected to the NAP. The traffic-based fee is 0.3 *CT *α_i, where, for ISP i, α_i is the proportion of i’s traffic to the total traffic handled by the NAP in a month. The NAP also charges USD 25000 to any ISP seeking to become a member. A similar fee in London – charged by LINX – is USD 7750 (EUR 7750) and in Milan – charged by MIX – is EUR 7746. So in addition to the clear incentive for traffic aggregation that the current tariff at NAP Colombia exhibits, there is also an entry barrier to potential new members who would prefer to be transit customers of ISP’s who are already members of the NAP.

Another method combines a fixed fee per port and a fee per utilization up to a maximum value beyond which a penalty is applied. The method demands that traffic be measured; it is usually max(traffic in, traffic out) the value used to determine use. MIX in Milan [6] and LINX [7] in London use this idea.

Any ISP connected to MIX must pay an annual fee which depends on the bandwidth required for connection to the exchange. This is called the nominal bandwidth. The nominal bandwidth, in turn, is used by the NAP and an equivalent point-based measure is obtained. The following table shows the relation between the nominal bandwidth and the point scale used by MIX [6].

Mbits	**Points**	**Mbits**	**Points**
4	1	100	10
8	2	155	12
12	3	310	15
16	4	620	18
34	6	1000	20
68	8		

The tariff is then obtained as the product of the number of points by the euro value of a point; for 2003 the value of a point is approximately EUR 3200.

Every month MIX uses a procedure to calculate the real bandwidth used by each ISP; if the real bandwidth is greater than the nominal value then the administration calls upon the ISP to remind it of its commitment to keep its traffic within the agreed limit. In case of a new violation, MIX will reduce the ISP real bandwidth to the nominal value.

Under this method traffic aggregation will not impact negatively the operation at the exchange. It is possible for several ISPs to aggregate traffic and to take advantage of the decreasing marginal cost of contracted capacity at the exchange.

More recently a two-part payment has been used. A fraction α of the total cost is recovered through a traffic or capacity independent fee. The rest of the cost is recovered using a proportional method. If C represents the total cost and x_i is the total traffic of ISP i (x_i is the sum of i's inbound and outbound traffic) then i will pay $[(1 - \alpha)*C* x_i] / \Sigma x_i$.

When capacity is considered one method uses the Base Port Fee[20] concept. The Base Port Fee is the monthly zero percent utilization price for a port. Different values are used depending on the capacity of every port an ISP uses. In addition to this fee, the Average Measured Traffic, calculated as the ratio of the number of bits passed through the port to the number of seconds in a month, is also used to calculate a traffic-based fee. For ISP i the number of bits passed through the port x_i is actually the maximum of the bits in and the bits out of the port, $x_i = \max(x_i^{out}, x_i^{in})$.

If an ISP is using a port of capacity Q, its payment to the exchange is:

$P(Q,x_i)$ = Base Port Fee (Q) * (1 + Average Measured Traffic(Q, x_i) * Ceiling factor(Q))

Both the Base Port Fee and the Ceiling Factor are determined by the exchange governing body so as to keep the total income from the port fees approximately constant.

London LINX [4] is a good example of the application of such method. It offers two types of ports; the capacity chosen by an ISP will determine the base fee. If the required port is 100 Mb the tariff is: FP = BPF-FE + (AMT * BPF-FE * 0.0275); on the other hand, if the capacity is 1 Gb the tariff is: FP = BPF-Gb + (AMT * BPF-Gb * 0.00215).

[20] As is the case of LINX.

BPF-FE (*Base Port Fee*) for both port sizes and the constants in the formulas are chosen so that LINX's monthly income is approximately constant.

Those formulas apply when the real capacity does not exceed 75% of the nominal capacity. If, during its monthly operation, an ISP exceeds such a value the administrator will charge an extra amount which can be seen in the following table [7].

Services	Payment Schedule	Price		
Current Services		***GBP***	***EURO***	***USD***
Joining Fee	*one-off*	*5,000*	*7,750*	*7,750*
Membership Fee	quarterly	1,250	1,938	1,938
Base Port Fee (BPF-FE)	July 2003	300	465	465
Base Port Fee (BPF-Gb)	July 2003	946	1466	1466
100Mb Excess Port Charge (over 75%)	per instance	2,200	3,410	3,410
1Gb Excess Port Charge (over 75%)	per instance	5,900	9,145	9,145
Private Interconnect Service (intrasite)	one-off	1,800	2,790	2,790
Route Server	n/a	n/a	n/a	n/a
Use of Space at TeleCity Bonnington House (per U)	monthly	83	129	129
Use of Space at Telehouse East (per U)	monthly	100	155	155
Support and on-site attendance (excess charge)	per instance	1,000	1,550	1,550
Deprecated Services		***GBP***	***EURO***	***USD***
Use of Space at Telehouse North	monthly	100	155	155

Prices are for July 2003 (Source: LINX [7])

The current method used by LINX improves the control upon traffic into and out of the exchange because any ISP's payment depends not only on the contracted capacity but also on the level of traffic.

There is a strong incentive for the use of 1 Gb capacity ports; traffic aggregation is now a matter of strategic of business ability: any ISP seeking to aggregate others' traffic will have no advantages over other members of the exchange so it will have to carefully negotiate its transit agreements to smaller ISPs or other customers. LINX is therefore able to efficiently manage the exchange and assure its clients the quality of its services.

4.2. Traffic-based cost allocation: the external method

As noted by Bailey [2] a cost allocation rule that assigns the same cost to every member of the exchange provides incentives for ISPs to aggregate traffic from other ISPs before traffic reaches the exchange. If those ISPs, not connected directly to the NAP, got connected the fee paid by those already subscribed would be reduced if the NAP still has spare capacity.

The external method for cost allocation [5] is a traffic-based method for cost recovery in network operation. Accordingly, in a multilateral environment any financial settlement satisfying the axioms of additivity, sustainability and no transit is stable in the sense that costs are fully recovered, there are no incentives for a subset of the participants to provide an interconnection exchange on their own, and no participant finds it profitable to route traffic destined to another node through a third node in order to profit from a reselling activity.

The external method uses traffic as a basis for allocating fixed costs; the latter means that in order for a cooperative agreement to allocate costs to its members the set up costs – which may be considered fixed in the sense that they are not traffic sensitive – are distributed according to a traffic-based rule[21].

In an Internet exchange facility, traffic is usually measured and reported on a monthly basis. The cost incurred by the NAP to exchange such traffic is the cost to be allocated to the NAP members. Although the method's original idea is to allocate the cost of setting up a cooperative agreement (in this case, for instance, the location, the routers and other equipment), the monthly operational cost CT can be used as the total cost to be allocated [3]. The total cost is the sum of the members' set up costs, C_i. Each C_i is called a member's private cost. When a NAP uses a flat fee it charges CT/N to every ISP. CT/N can be considered the private cost when the external method is applied.

[21] Traffic based methods include the proportional method – in which cost is assigned to a participant in proportion to the ratio between her traffic to the total traffic exchanged at the NAP –, the private cost method – a version of which would assign to any participant the NAP´s monthly operational cost divided by the number of participants – and the quadratic and the external methods.

Once this subtle modification of the method is in place, we study the effects of traffic increases on the stability of the agreement. Assuming that all traffic delivered to the exchange is switched and sent to its destinations then, as long as the capacity is not exceeded, the external method allows for a redistribution of costs when more traffic is delivered to the exchange by one of the exchange participants, its allocated cost changing accordingly. The method is based on the possibility of a periodical traffic measurement. The ISP delivering the additional traffic into the exchange will experience an increase in its payment to the exchange administrator due to the additional traffic it handles.

The allocation rule of the external method says that the connecting cost C_i of customer i be shared among all of his correspondents in proportion to their traffic with i, so that user i bears no share of his own connecting cost. This idea is used to allocate a NAP operational costs in the following manner: instead of considering the connecting costs C_i (I =1,…,N) –which are supposedly already paid for – it is assumed that the total monthly cost C divided by the number of members N, is used as the cost that needs to be modified using a usage-sensitive rule.

Let us assume that the total traffic between two nodes i and j is represented as X_{ij} [22], and denote as X^j the total traffic between j and all other nodes, $\sum_k X_{kj}$. The cost allocated to node i by the external cost method is:

$$E_i = \sum_j \frac{X_{ij}}{\sum_l X_{lj}} C/N \quad l, j = 1,...,N. \;\; \forall i = 1,...,N$$

(If X_{ij} and X^j are replaced by $(X_{ij})^2$ and $(X^j)^2$ in the previous expression we obtain the quadratic method)

$X^j = \sum_i X_{ij}$ represents the traffic exchanged by every node *j* with the remaining nodes of the network and the traffic direction is not relevant at this point, so $X_{ij} = X_{ji}$ for every pair of nodes *i*, *j*. We will assume that C is the cost to be allocated and C/N represents the “connection cost” of every node[23].

[22] It includes traffic in and traffic out.

[23] We will assume that the (third party) administrator uses C/N as the allocation method and wishes to find an alternative which deviates the payments from C/N satisfying the axioms mentioned above.

4.3. Effects of the application of capacity-based and traffic-based cost allocation methods

Using the external method for the allocation of the operational monthly cost C, we would like to observe the changes in the cost allocated to ISP *i* (monthly fee) when traffic changes. For instance, we would like to know what the cost change for *i* is when the traffic x_{ik} in route *i-k* grows.

$$\frac{\partial E_i}{\partial X_{ik}} = \frac{\partial}{\partial X_{ik}}\left[\frac{X_{i1}}{\sum_l X_{l1}} C_1 + \frac{X_{i2}}{\sum_l X_{l2}} C_2 + \ldots + \frac{X_{iN}}{\sum_l X_{lN}} C_N\right]$$

$$= \frac{\partial}{\partial X_{ik}}\left[\frac{X_{ik}}{\sum_l X_{lk}} C_k\right] = C_k \frac{\sum_l X_{lk} - X_{ik}}{(\sum_l X_{lk})^2} = C_k \frac{\sum_{l \neq i} X_{lk}}{(\sum_l X_{lk})^2} > 0$$

This expression means that node *i* will be charged an additional extra cost due to the new traffic between *i* and *k*. This is consistent with the charge due to the use of the exchange. On the other hand, for any other node m, which has not increased its traffic level into the exchange the change is:

$$\frac{\partial E_m}{\partial X_{ik}} = \frac{\partial}{\partial X_{ik}}\left[\frac{X_{m1}}{\sum_l X_{l1}} C_1 + \frac{X_{m2}}{\sum_l X_{l2}} C_2 + \ldots + \frac{X_{mN}}{\sum_l X_{lN}} C_N\right]$$

$$= \frac{\partial}{\partial X_{ik}}\left[\frac{X_{mk}}{\sum_l X_{lk}} C_k\right] = C_k \frac{-X_{mk}}{(\sum_l X_{lk})^2} < 0$$

The net cost change must be is *zero* since total fees must be equal to total costs; to see this notice that

$$\sum_h E_h = \sum_h \sum_j \frac{X_{hj}}{\sum_l X_{lj}} C_j \quad h = 1,\ldots,N$$

so the total change is

$$\frac{\partial \sum_h E_h}{\partial X_{ik}} = C_k\left[\frac{\sum_{l \neq i} X_{lk}}{(\sum_l X_{lk})^2} - \sum_{l \neq i} \frac{X_{lk}}{(\sum_l X_{lk})^2}\right] = 0$$

If we find the change in E_i due to the growth in the traffic between i and h then we have:

$$\frac{\partial E_i}{\partial X_{ih}} = C_h \left[\frac{\sum_{k \neq i} X_{kh}}{(\sum_k X_{kh})^2} \right] \qquad E_i = \frac{X_{ih} C_h}{\sum_k X_{kh}} + \sum_{j \neq h} \frac{X_{ij}}{\sum_k X_{kj}} C_j$$

$$\frac{\partial E_i}{\partial X_{ih}} = C_h \left[\frac{a_i}{(a_i + X_{ih})^2} \right] \qquad E_i = \frac{X_{ih} C_h}{a_i + X_{ih}} + B$$

where

$$a_i = \sum_{k \neq i} X_{kh} \qquad B = \sum_{j \neq h} \frac{X_{ij}}{\sum_k X_{kj}} C_j$$

It is clear now that i´s allocation is a concave function bounded by C_h + B when traffic between i and h increases and the cost grows asymptotically to the bound; i´s marginal cost is a convex decreasing function.

If we want to observe the effect on i´s cost allocation of the traffic between h and l (none of which is i) then:

$$\frac{\partial E_i}{\partial X_{lh}} = -\left[\frac{X_{ih} \cdot C_h}{(X_{lh} + \sum_{k \neq l} X_{kh})^2} \right] \qquad E_i = \frac{X_{ih} C_h}{X_{lh} + \sum_{k \neq l} X_{kh}} + B$$

$$\frac{\partial E_i}{\partial X_{lh}} = -\left[\frac{X_{ih} \cdot C_h}{(X_{lh} + a_l)^2} \right] \qquad E_i = \frac{X_{ih} C_h}{X_{lh} + a_l} + B$$

In this case i´s allocation is a convex decreasing function asymptotically bounded by 0, the lowest possible cost. The marginal cost is a concave increasing negative function. What this means is that as long as there is more traffic between h and l (both different from i) i captures a benefit; this is reflected in the decreasing form of the cost allocation function.

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Chapter 5
Interconnection negotiation between two NAPs

Using Nash's bargaining [4] theory we develop and analyze a model that explains the interconnection between two NAPs (Network Access Points) located in different regions and with different market characteristics. The equilibrium solution will directly depend on the degree of risk aversion and the analyzed parameters within the model; the player with a greater income and with the highest degree of risk aversion will be the one that has to pay a highest portion of the interconnection. Players payoffs at equilibrium will solely be differentiated by the degree of risk aversion that each player has.

5.1. Background

An Internet Service Provider or ISP could not deliver its service offer if it is not connected to other ISPs or information and contents networks. ISPs are not only obliged to compete for the access market but also forced to cooperate among themselves.

The Internet hierarchical structure shows many local and regional ISPS at the bottom. Their services include hosting, e-mail and access to Internet. On the next level are the national ISPs which usually cover larger geographic regions than the local ISPs. National ISPs offer transit service to smaller ISPs. At the top of the hierarchy are the largest networks which offer full connectivity to Internet; they are usually called Internet Backbone Providers. The largest IBPs are also called Tier-1 providers. Every ISP is a client of one or several larger ISPs to whom they buy access to the rest of the net.

The wholesale market or market for access is made up of ISPs and IBPs or carriers that sell capacity and have access to regional and local markets.

In order for a young Internet access market to develop, the nascent ISPs had to connect to large ISP or IBPs for their traffic to reach destinations out of their networks scopes. When several ISPs realized their local traffic had to travel enormous distances to reach destinations geographically situated some tens of meters away, they understood that local connectivity, at least for the exchange of local traffic, was necessary. In short, regional markets developed Network Access Points or NAPs; a NAP is a physical location equipped with the necessary communications facilities for the exchange of Internet traffic. This arrangement reduced the traffic delay time and helped improved the overall perceived quality of the service.

According to Huston [2], quality and cost are inversely proportional to the distance that information has to traverse. A NAP allows for savings in costs and improvement of quality because traffic does not have to go through a third party network whose switches are located thousand of miles away from the traffic sources or destinations.

Agreements at NAPs are generally peering agreements although their facilities might allow for other types of agreements. A peering agreement is an economic agreement between two ISPs for the mutual delivery of traffic at no expense[24]. Nevertheless traffic destination is bounded to customers of each other, which means that no ISP involved in a peering agreement will serve as a transit network to other ISP.

In this paper we assume that two NAPs, perhaps two regional NAPs, have connected to each other; this connection will reduce the cost of using international channels reaching IBPs for the exchange of regional traffic[25].

5.2. A bargaining model

We will assume that two exchange points or NAPs are seeking to share the cost of their interconnection; if C_x is the interconnection cost then the two NAPs will have to decide how much of that amount each will pay.

It is clear that the common objective of the two agents is somehow binding them to compromise.

Players will be called B and M and we will assume that each has a set of strategies whose representative element is (S_B, S_M); S_B is the amount that B will offer to pay for maintaining the connection and S_M is a similar amount for M; in any case we should have that $S_M + S_B \le C_x$.

[24] They are also known as SKA (Sender Keeps All) agreements.

[25] At the Second Latin American NAP Meeting (NAPLA 2003) in Buenos Aires, attendants proposed a trial period to assess the feasibility of regional NAP interconnection. As proposed, there will be a link connecting NAP Chile and NAP Cabase in Argentina. Both NAP administrations expect to reduce the burden of capacity charges that their members incur in when exchanging traffic with other South American countries.

Supongamos que el jugador B decide pagar x; esto tiene como efecto que el jugador B pague $C_x - x$, en cuyo caso el perfil de estrategias es $(S_B, S_M) = (x, C_x - x)$.

We also suppose that one of the players, for instance B, is currently receiving a payment k from M; this is typical of a situation where a settlement is first reached in which one of the players is larger in size than the other and the connection was started as an experiment to investigate the actual benefits the two NAPs and its members would obtain from the interconnection.

The utility functions for B and M are

$$U_B(S_B, S_M) = [k - (C_x - S_M)]^p$$
$$U_M(S_B, S_M) = [(C_i - k) - (C_x - S_B)]^q$$

where $(C_i - k)$ represents the savings that M would get when changing from an international connection at cost C_i to a connection to B at cost k. Here $0 \le p \le 1$ y $0 \le q \le 1$. The benefit to a player can be understood as either his income or his savings from the interconnection.

Two conditions are necessary for the players to enter the bargaining process; first, in order for M to be willing to negotiate with B, the cost of its international link should be larger that the combined cost of its current payment to B plus the negotiated payment, which means that $C_i \ge k + C_x$; second, since x represents B´s willingness to pay, then x should be in the interval $[0, C_x]$.

As a function of x the utility values are [3]

$U_B = (k - (C_x - (C_x - x))^p$; $U_B = (k - x)^p$
$U_M = (C_i - k - (C_x - x))^q$; $U_M = (R + x)^q$

with $R = C_i - k - C_x$.

5.3. Results

Nash bargaining solution Q will be the result of maximizing $F(U_B, U_M) = U_B * U_M$. In this case,

$\delta F(U_B U_M)/\delta x = -p(R + x) + q(k - x) = 0$

and $x_Q = \dfrac{qk - pR}{p + q}$; this is B´s payment to M.

Since $0 \le x \le C_x$ then $0 \le \frac{qk - pR}{p+q} \le C_x$ so we should have that $\frac{R}{k} \le \frac{q}{p} \le \frac{C_i - k}{k - C_x}$ for an agreement point to exist.

$\frac{q}{p} > 0$ means $\frac{C_i - k}{k - C_x}$ must also be positive. This happens if and only if $C_i \ge k \; and \; k \ge C_x$.
The solution x_Q, therefore depends on the net benefits to each party, k and R, as well as on the coefficients of risk aversion p and q. As expected, the larger the risk aversion coefficient for a player, the less demanding the solution will be on him.

On the other hand, since $\frac{\partial x_Q}{\partial k} = 1$, B´s payment or transfer to M as a result of the bargaining process is higher, the higher the price of the current capacity agreement. The higher the savings M obtains from getting domestic routing of its traffic, which is just the connection to B, the higher his payment to B as a result of bargaining. This is just so because $\frac{\partial x_Q}{\partial R} < 0$.

In summary, transfers are dependant on the risk condition of players and the perceived benefits from the interconnection. Replacing x_Q in the utility expressions of both players yields, Q, the equilibrium utility in the plane (U_B, U_M):

$$Q = \left[\left(\frac{p(C_i - C_x)}{p+q} \right)^p, \left(\frac{q(C_i - C_x)}{p+q} \right)^q \right]$$

A useful exercise is to observe Q changes as a function of changes on p or q. This can be seen in Figure 1. We have normalize the utility values to a scale in units of $(C_i - C_x)$, which is the difference from the cost of international transit and the value of the direct connection between B and M. Each surface shows the utilities of B and M. U_B is bounded by $C_i - C_x$ and such value corresponds to a highly risk averse M and a neutral B. When both risk coefficients are equal, the payment is the same with the highest payment at $(C_i - C_x)/2$ for each at p=q=1.

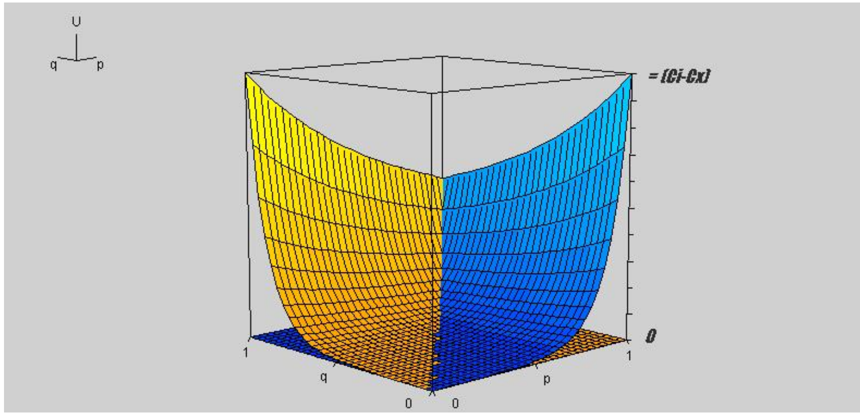

Figure 1

Figure 2 shows three situations where the joint utility is maximized; these are points where one or both players are risk-neutral. Besides, if both players are risk-neutral then they will equally share the difference C_i-C_x.

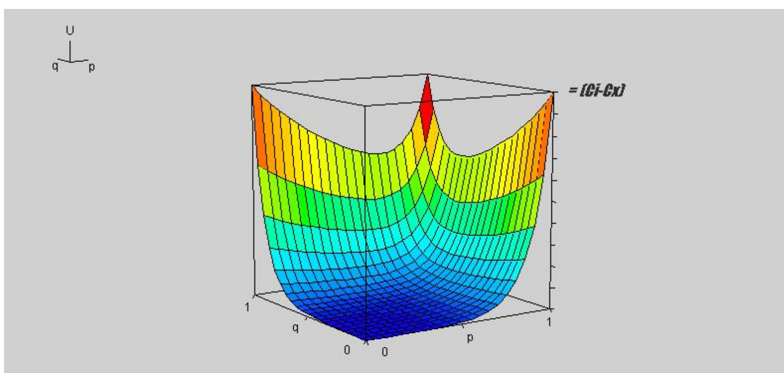

Figure 2

5.4. An indecisive ISP

I an interconnection between to regional NAPs is achieved an ISP whose options for the local exchange of traffic include connecting to either NAP, will face the decision of which NAP to join. The ISP will join the NAP that affords the highest return in terms of benefits obtained.

We will cal such ISP an indecisive ISP and B and M the two NAPs. Both, B and M, have their own assessment of the potential connection of the ISP to its facilities. If we model such assessment as the probability, (from the point of view of a NAP administration) that the ISP will join a given NAP, then let α be such probability in the case of B and let β be the probability that the ISP joins M, from M´s viewpoint. We will also assume that existing signaling from the ISP is such that β = 1- α, which means that B and M have common beliefs about the ISP's decision. The expected utility functions of B and M are [3]:

$$E[U_B]= \alpha(k - x + I_B)^p + (1-\alpha)(k - x)^p$$
$$E[U_M]= \beta(R + x + I_M)^q + (1-\beta)(R + x)^q$$

Since β = 1- α, then $E[U_M]= (1-\alpha)(R + x + I_M)^q + \alpha(R + x)^q$.

The expected utility function of B considers the income I_B brought in by the ISP in case the ISP decides to be its member.

When α = 1, that is, when ISP is certain about connecting to B, x_Q is:

$$x_{Q(\alpha=1)} = \frac{q(k+I_B)-pR}{p+q}$$

Since ISP will certainly get connected to B, x_Q is the highest payment B would offer. On the contrary, when ISP is definitely certain to be a member of NAP M its offer x_Q can be as high as:

$$x_{Q(\alpha=0)} = \frac{qk-p(R+I_M)}{p+q}$$

As can be seen, if ISP joins M, M´s offer is lower than B´s when the ISP joins B. This says that whoever gets the most benefits is willing to offer a higher transfer or a higher portion of the interconnection costs at the bargaining table.

Utilities change due to the fact that a new ISP is getting connected, no matter what end it chooses. The change in utility is $p\mathbf{I_B}$ and $q\mathbf{I_M}$ for B and M respectively. Utilities expressions can be obtained for each NAP at the extreme probability values, that is, α =1 and α= 0.

$$Q_{(\alpha=1)} = \left[\left(\frac{p(C_i-C_x)+pI_B}{p+q}\right)^p, \left(\frac{q(C_i-C_x)+qI_B}{p+q}\right)^q\right]$$

$$Q_{(\alpha=0)} = \left[\left(\frac{p(C_i-C_x)+pI_M}{p+q}\right)^p, \left(\frac{q(C_i-C_x)+qI_M}{p+q}\right)^q\right]$$

The expression when α is not either 0 or 1 is much more complex; nevertheless, we can say that x_Q is an increasing function of α. So if we interpret α as the perception that B has about the ISP being its member then B should be more willing to accept a higher portion of the connection cost the more it is inclined to think the ISP will opt for signing as a member of B.

5.5. Conclusions

We have used the classical Nash approach to understand the bargaining situation between two NAPs which have found it in their best interest to interconnect; such interconnection is being a topic of discussion in South America given the enormous costs that ISPs incur when routing traffic towards neighboring countries.

One important factor in the settling of how much of the total connection cost each party will pay for is the risk aversion degree of the decision makers. The decision making process at NAP administration must take into account the voices of all its members or, at least, of a great majority of the members because of the cooperative nature of the agreement. A simple experiment based on the applocation of a questionnaire to ISPs administrators [1] shows that a more established and organized administration (or board) is more risk averse than its counterpart when the latter is a younger less organized body. Therefore when there is no previous connection and the connection is sought by both parties, the more established NAP will assume a lower portion of the interconnection cost.

If negotiations between NAPs in South America start sometime in the near future, we can foresee that national NAPs in Argentina, Chile and Colombia will have a strategic advantage because they have been operating longer than other NAPs in the region.

As an anecdotal closing we can mention that NAP Chile has proposed to run some trials for the interconnection of NAPs Chile and Cabase (Argentina)[26]; the Chilean administration is willing to pay for the connection (the cost of the international capacity between the two countries) so both NAPs will be able to know the real traffic flows between the two countries.

[26] As recently proposed by the NAP Chile Operations Director at the Second Latin American NAP Meeting (NAPLA 2003) in Buenos Aires. August 2003.

5.6. References

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