Internet Interconnection Co-ordination Issues

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1 Introduction

This a discussion paper: it does not present a finished part of my research, but I've tried to capture in a few pages (so that people actually read it) the essence of my PhD research project and its current status, so that the paper may form a base on which to discuss during the Promovendies meeting.

1.1 Internet Interconnection

The Internet is a large system of interconnected networks (that is why it is called internet). Data travels over this network in the form of packets. The Internet Protocol (IP) describes how these packets should be sent, forwarded and received over the Internet. A data packet generally traverses a large number of networks during its journey from source to destination. As each network is administered by an Internet Service Provider (ISP), the agreements between ISPs about their interconnections are essential to the provision of services to their customers. The following figure provides a schematic representation of two kinds of relationships between ISPs, *peering* and *transit*:

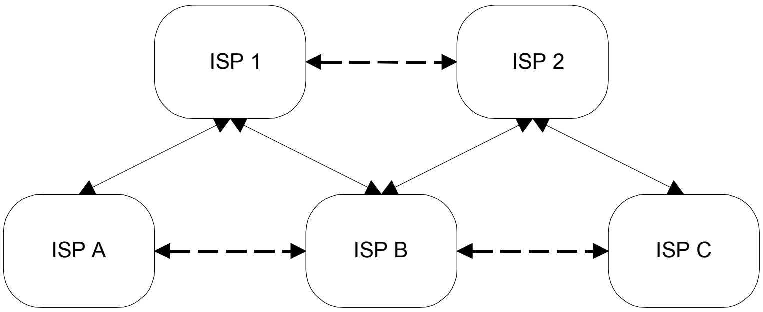

Figure 1: Peering and transit relations between ISPs

We will make use of the following definitions[Norton2001]:

- *Peering* is the business relationship whereby ISPs reciprocally provide to each other connectivity of each other's transit customers.
- *Transit* is the business relationship whereby one ISP provides (usually sells) access to all destinations in its routing table

In Figure 1, peering relationships are represented by dashed lines and transit relationships by solid lines. An ISP typically starts with buying transit from one or more upstream ISPs, in order to secure access to the entire Internet. After this, an ISP will seek peering agreements with other ISPs, usually of similar size and reach, in order to reduce the cost of its transit connection(s).

1.2 Co-ordination Issues

ISPs are not just in the business of selling access to their networks: their business is rather selling access via their networks to the entire Internet. This is a result of *network externalities*: the value that a consumer derives from a product or service increases as a function of the number of other consumers of the same or compatible products or functions[Econ1996]. ISPs' customers expect the highest possible value from their ISP subscription, i.e., access to the entire Internet. It is therefore necessary for ISPs to interconnect with one another to exchange traffic destined for each other's end users. In the telephony world, this interconnection is co-ordinated by the ITU (International Telecommunications Union) and by various regulatory offices, like OPTA in the Netherlands and

Oftel in the UK. In the Internet world, there is no such central co-ordination. Each ISP makes its own, independent decision about its peering and transit relationships. These decisions are influenced by many factors, both technical and commercial. As an example of the latter, in 1997 UUNET attempted to end peering with a number of smaller backbones and instead charge them for transit[Kende1999], because peering with these smaller backbones conflicted with UUNETs image of top-level ISP. Because of peering disputes (like the UUNET case) and other commercial strategies, the Internet topology grows less transparent. A recent study[Labo2001] shows that more than five percent of the currently routed Internet address space lacks global connectivity.

In more theoretical terms, the co-ordination of interconnecting ISPs can be seen as a *network organisation* [Powell1991]. ISPs are involved in an intricate latticework of (peering and transit) relationships with other ISPs, mostly competitors and these relationships are essential to their functioning.

1.3 Co-ordination and Quality of Service

In Internet terms, the term "Quality of Service" (QoS) is mostly used in differential terms: an ISP may differentiate between several service levels in the connections it offers to its customers. For instance, an ISP may guarantee real-time connections for a certain service level, or only indicate that Internet traffic of class A will always get priority over traffic of class B. ISPs may attempt to use QoS services as a means to differentiate themselves from their competitors[Kende1999]. Consumers, on the other hand, will expect to be able to use these services not only to communicate with other customers of the same ISP, but also with customers of other ISPs. This asks for more co-ordination from ISPs: not only must ISPs agree on a common QoS technology with their direct interconnection partners, but all ISPs on the Internet path between the communicating partners must agree on the technology and on the relevant QoS parameters. This all means that the relationships between ISPs will grow in complexity because a whole new set of QoS-related interconnection parameters that has to be agreed upon.

2 Research Design

The *goal* of this research is twofold:

- As a scientific goal, we would like to be able to understand how the interaction between ISPs (with regard to their interconnection relationships) can be used to explain the nature of the resulting network.

- As a more practical goal, we would like to contribute to the provision of QoS by ISPs to their customers by defining ways to co-ordinate the ISPs' interconnection agreements with regard to QoS.

This research is further structured as follows:

1. Internet Topology

Results of this part should be a map that shows which ISPs interconnect with which other ISPs. Relevant features of this map are e.g.

- Number of peering and transit partners of ISPs
- Internet diameter: how many networks does an Internet data packet typically traverse?
- Relative size and number of connections of ISPs (related to market power)

Raw data for this part can be obtained from RIPE's Test-Traffic project[RIPE-TT].

2. Current Internet Interconnection practice

This part should result in a description of the dynamic processes that shape the interconnection between ISPs. The information for this part will come from literature review, (informal) communication with ISPs and maybe a formal series of interviews.

3. Model development

In this part, a model is sought such that the inter-ISP dynamic processes can be fit into it, in a way that the Internet topology (in a qualitative or maybe quantitative way) follows from it. This model should follow Powell's ideas (see Section 1.2) and probably concepts from self-organising systems theory ([SOSFAQ]) and social network analysis (see, e.g., [Hanne2001]).

4. Application to Internet QoS

By modifying the model developed in the previous part for the changes in the inter-ISP dynamics that result from QoS services, the changes to the resulting topology can be studied. This will hopefully demonstrate the usefulness of the model by applying it to a slightly different domain.

3 Current Status

Up to now, most attention has been given to the first and second part. Analysis of the RIPE data results in eye candy like the map in Figure 2.

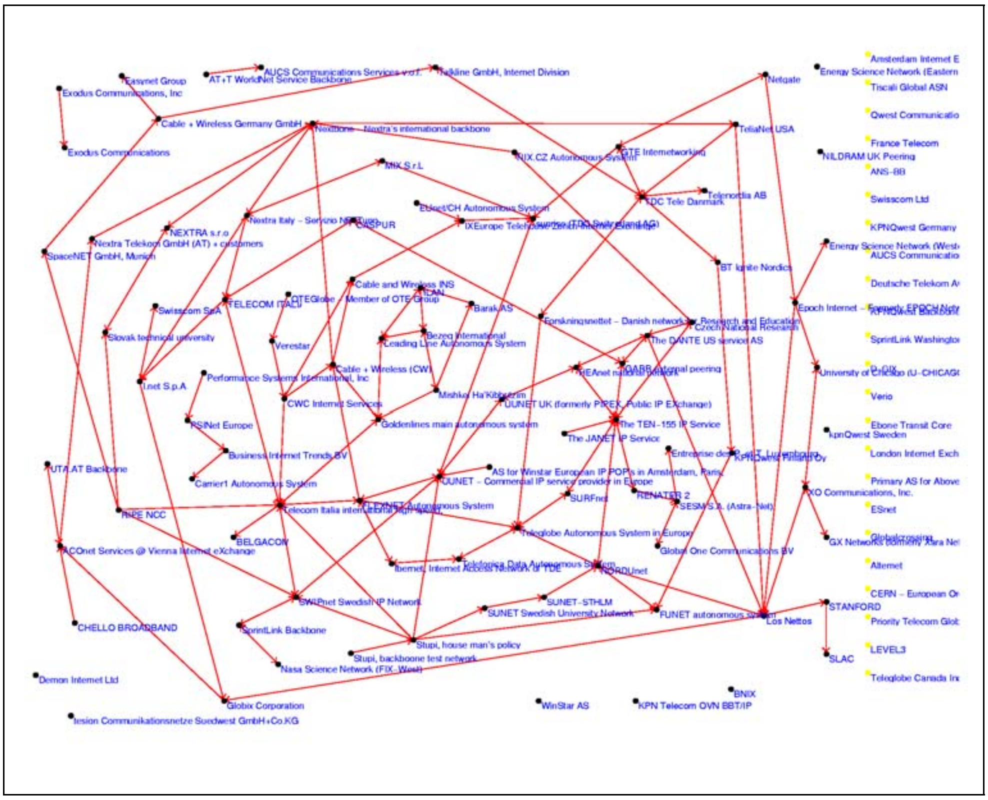

Figure 2: ISP interconnection map

In this picture, ISPs with more than 17 connections to other ISPs have been moved to the right. Their connections are not shown.

This map shows the connections between (mostly European) ISP's on March 1, 2001 at 15:00. Such maps can easily be produced for any moment in time since 1999, so that the dynamics of ISP interconnection can be visualised and analysed.

Currently, most attention is going to the third part: how to capture the drivers of ISP interconnection in a model that can be used to explain or predict the resulting topology.

References

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