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A Quote-Driven Market for Service Providers in Telecommunications Networks

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Abstract

This paper describes a quote-driven market mechanism for a telecommunications network through which multiple service providers can act as brokers of bandwidth between a network provider and its end-users. A comparative study is proposed to evaluate this approach and to compare it with the more widely studied auction-based market mechanisms. The aim is to assess the practicality of this form of automated trading in the telecommunications domain, and to provide criteria from which to judge differing market-based approaches.

1 Background

There has recently been an explosion in research into automated trading using agent-based technology focused on the telecommunications domain. Applications have included load control [1, 3], bandwidth allocation [2, 6, 10] (see figure 1) and optimal route-finding [4, 5]. While some of this research hints at the possibility of multiple service providers, the market models being used do not necessarily reflect the type of markets which currently exist, nor which might be required in the future. In particular, most of the research has taken place in the context of purely auction-based markets which require a centralised (and trusted) auctioneer, leading to security and integrity issues as well as the necessity for synchronisation between the market participants. The attraction of using auction-based markets has arisen in part because such markets are relatively straightforward to analyse [8] and

Figure 1: Reprinted with kind permission of the IMPACT Project.

have provable properties such as *pareto efficiency* and *coalition stability* [9]. While such properties may be desirable from the point of view of the consumer, service providers acting as intermediaries require incentives to participate in the market that may come from the ability to take on varying degrees of risk for which adequate profit-making potential needs to be in place. Most of the research currently being carried out considers either a cooperative market place [1, 5] or self-interested agents in isolation [10], rather than the relative attractions of different market mechanisms.

In section 2, this paper outlines a proposal for a more flexible, and perhaps more realistic, market scenario in which service providers are brokers of bandwidth between a network provider and users (or clients). The service providers are in direct competition for the clients' business and must attempt to trade profitably both by ensuring adequate profit margins and by maintaining a sufficient market share. Service providers are exposed to risks such as leasing more bandwidth than they can sell and selling more bandwidth than they have leased (going short), both of which have a negative impact on their profits. Furthermore, this

paper sets out a framework within which to evaluate the proposed market scenario. By fixing the behaviours of the producers (i.e., the network provider) and the consumers (i.e., the clients) in the market, the quote-driven market scenario can be compared with an auction-based mechanism. The details of this framework and which measures are proposed as evaluation metrics are given in section 3. A discussion of this and future research concludes the paper.

2 Quote-driven market scenario

The essence of the quote-driven market is that service providers are *market makers* in bandwidth having to deal both externally with the network provider and customers, and internally with other service providers. To simplify the understanding of the market mechanism, and the analysis, the telecommunications market will be considered at an abstract level. The market is composed of one network provider (NP), multiple service providers (SPs) and many more clients or users (Us). The commodities being traded are amounts of bandwidth between fixed sources and destinations (s-d pairs) for limited periods of time.

The idea is that the SPs lease bandwidth from the NP in large chunks and for fixed periods, and lease it on to the Us in smaller chunks and for unspecified periods. However, there is a great deal of uncertainty about how much of their leased resources will be in use at any one time, and the SPs must balance their leases against the uncertainty of demand and adjust their prices accordingly. An SP's profits depend on how effective it is at both competing in the market and managing its risks; for example, if an SP has a large amount of unused bandwidth on a particular route, by lowering the price, perhaps even to below cost, at least it stands a better chance of attracting whatever business is available on that route.

The market is composed of three separate types of interaction: between the NP and the SPs, between the SPs and the Us, and between the SPs themselves; this is illustrated in figure 2. All of these interactions adhere to the strict communication protocols now described.

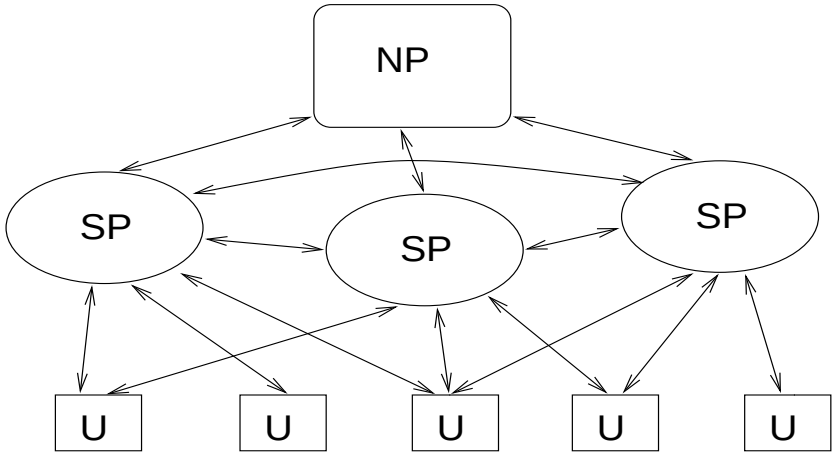

Figure 2: Interactions in quote-driven market.

2.1 Network provider/service provider interaction

Since the NP is the sole supplier of bandwidth in the market, each SP must communicate with the NP to negotiate leases for particular s-d pairs. This interaction takes the following form:

1. `SP specifies the s-d pair, units of bandwidth and length of lease.`
2. `NP quotes a price.`
3. `SP either accepts terms and lease commences, or declines.`

Thus the SP must decide the amount of bandwidth it requires, and for how long, and requests a quotation from the NP. If the price is acceptable, the deal is done and the lease commences. Once a lease exists, the SP is committed to paying for that bandwidth whether or not it is leased on to users or other SPs. An SP which leases excess bandwidth on a route is said to be *running a long position* in that s-d pair.

2.2 User/service provider interaction

Whether users search for the cheapest deal around, or prefer to stick to a single SP, their interaction for each connection is the same:

1. U requests the price for a particular s-d pair.
2. SP quotes a price.
3. U either accepts terms and connects, or declines.

As opposed to an auction-based mechanism whereby each SP submits a bid for each connection, in this scenario the user dictates the number of alternative prices he sees and from which SP to obtain a quote. For example, a user might keep track of those SPs with the most competitive prices and only ask these for quotations in future. Since the market is inherently asynchronous and discreet, the user may ask several SPs in parallel, or may not intend to deal at all, but merely check current prices with an SP. Once a deal has been agreed, a connection commences and the user pays the agreed rate for each second it remains connected.

2.3 Service provider/service provider interaction

This interaction potentially offers to increase liquidity in the market, since in some sense it allows the SPs to escape from unprofitable leases. The interaction is based on having to quote *two-way prices*, that is, both sale and purchase prices, differing only by a fixed *trading spread*. The quoting SP is obliged to deal at these prices, if the other SP so wishes. Each interaction involves one SP asking for a quote from other, and having the chance to deal, and then being asked a price in return. This means that both SPs are exposed to the risk of obtaining a new position, but also have the opportunity to offload a position which is no longer profitable. This interaction takes the following form:

1. SP_1 requests a quote specifying an s-d pair, units of bandwidth and length of lease.
2. SP_2 quotes a two-way price, its bid and its ask.
3. If SP_1 wishes to deal on this price, it states whether it is buying or selling and the deal takes place.
4. SP_2 requests a quote specifying an s-d pair, units of bandwidth and length of lease.
5. SP_1 quotes a two-way price, its bid and its ask.
6. If SP_1 wishes to deal on this price, it states whether it is buying or selling and the deal takes place.

Parameters for the trading spread will clearly affect how successful this particular interaction is at helping maintain a stable market. As with all interactions, there is no requirement to deal, so this mechanism may be used to simply check another SP's current price; however, an SP who choses to do this exposes itself to quoting a price in return.

2.4 Book-keeping

All prices are quoted in terms of the cost in pence per second, for the given size of the transaction. For the NP/SP and SP/SP interactions, the number of units of bandwidth is specified in the quote; however, in the U/SP interaction each quote is based on a fixed size of one unit of bandwidth (i.e., just one connection). It is assumed that all transactions commence at the next available second. For example, if a user accepts the price quoted by an SP at time t_i, their connection commences at t_{i+1} and lasts until the user disconnects. Similarly all leases start at the next second and last for the specified whole number of seconds.

Because of the uncertainty of the duration of users connections, the SPs will not be able to guarantee the amount of their leased capacity which is available for connection in the coming second, although they may have some predictive model of it. Furthermore, since the SPs can only maximise their profits by leasing *all* their leased bandwidth, sometimes they may be in a situation where they have actually leased out more capacity than they have control over. In such a case, the SP will be said to be *running a short position* in that particular s-d pair. The implications of this are described in section 2.5 below.

An SP's profit (or loss) is calculated from the difference between its outgoings, i.e., the cost of leases with the NP, and its income received from connections successfully completed. Although this can be estimated on a per second basis, it is more likely that an SP's pricing strategy will be adjusted on a larger time-scale. It therefore makes more sense for an SP to examine its profit and loss position at regular intervals, perhaps of the order of minutes, and to adjust its pricing strategy accordingly.

2.5 Short positions

If an SP gets into a situation whereby it has leased a capacity C units (for a particular route) from the NP but has accepted $C + \delta$ calls for connection, it is said to be running a short position. In normal circumstances, there should be sufficient capacity in the network to cover this position, so rather than refuse to connect the calls, the SP must *borrow* sufficient capacity from the NP to cover its short position. Naturally, the rate for this transaction will be set by the NP, and to discourage the SP from going short, the rate will be higher than the normal price for this service. However, it is only necessary for the SP to borrow for the number of seconds for which it remains short and, because it cannot agree the price but must accept whatever is set by the NP, this also leads to uncertainty in its expected profit. Alternatively, the SP could opt to randomly disconnect calls so as to restore its position, but this may incur a hefty penalty; for example, the market might be set up so that calls which are disconnected do not generate any revenue at all. Thus an SP must balance the uncertainty of going short against the risk of having to cover a short position at unknown cost.

The profitability of running short positions is heavily dependent on the price set by the NP as borrowing costs. For example, if these were no different from normal leasing costs, it would make no sense ever to run the risk of long positions, since the SP could simply borrow exactly the amount of bandwidth it has allocated at each second. It is not clear what level of penalty should be imposed by the NP for covering short positions; it is hoped that through experimentation, suitable levels will be established. From the point of view of the NP, the market should be both active and reliable. By adopting a suitable pricing policy both for long- and short-term leases, and for borrowing costs, it should be able to maintain these conditions.

3 Framework for comparative study

The aim of proposing an alternative market scenario for competing service providers is twofold. Firstly, to assess its viability as a mechanism—can such an interface from NP to users be made to work? do the service providers have any incentive to participate in such a market? Secondly, to compare and contrast the behaviour of the market scenario with more widely studied mechanisms such as an auction-based approach.

In order to study the market mechanism itself, it is necessary to fix several parameters. In particular, the NP requires a pricing structure for leases which can be applied in both a quote-driven and an auction-based market. Similarly, the requirements of the users both in terms of acceptable levels of service (set-up delay, possibility of disconnection) and of price limits need to be set. It is also necessary that the SP themselves whether making two-way markets or simply participating in an auction use similar models to assess their risk/reward trade-offs. With these external constraints on the market fixed, three variations of the market mechanism will be considered: an auction-based market, and quote-driven markets both with and without inter-service provider trading.

Using this framework, various aspects of the market can be evaluated through simulation studies. Some general properties may be assessed such as price volatility, liquidity, throughput and profitability. Other properties more particular to the telecommunications domain include communication overheads (inter-agent message-passing), call set-up delays, call rejection through unacceptable pricing and disconnection rates in overloaded situations.

4 Discussion and future work

This paper has set out a framework from which to investigate the impact of the market mechanism in the context of multiple service providers competing in a telecommunications market. There are two strands to this research. The first is to examine the practicality of treating a network in terms of a society of competing agents. This is an important question to address—while there are many researchers actively investigating market-based approaches to this area [2, 5, 10], it seems unlikely that industry will allow automation of this kind without a good understanding of its implications both in terms of profitability and stability. This research aims to answer some of these questions by comparing the relative merits of different market mechanisms.

The second strand is more general and is to analyse the pros and cons of the different mechanisms themselves. While the analytic properties of auctions are well-known, there are hidden costs to adopting this approach; for example, the necessity of synchronisation, both of time and of products traded, may lead to a decrease in the amount of trades which can take place; other factors include lack of confidentiality of prices and trust in the auctioneer [7]. The comparison proposed in this paper may go some way towards identifying more general criteria for evaluating market mechansims.

Future work will attempt to generalise the simplified model of the telecommunications market. In particular, it seems reasonable to assume that SPs trade bandwidth between different trunk nodes in the network, rather than a fixed set of source-destination pairs. Once the impact of the chosen market mechanism is better understood, its extension to more complex trading scenarios will be undertaken.

References

[1] Å. Arvidsson, B. Jennings, L. Angelin, and M. Svensson. On the use of agent technology for in load control. In *Proceedings of 16th International Teletraffic Congress*, 1999.

[2] J. Bigham, L. G Cuthbert, and Z. Luo. A distributed and decentralised architecture for control of connection admission to a telecommunications network. In *IMPACT Conference*, pages 2–2, 1999.

[3] E. L. Bodanese and L. G Cuthbert. A multi-agent approach for channel allocation in cellular networks. In *IMPACT Conference*, pages 1–1, 1999.

[4] M. J. Gibney and N. R. Jennings. Dynamic resource allocation by market-based routing in telecommunications networks. In *Proceedings of the 2nd International Workshop on Multi-Agent Systems and Telecommunications*, pages 102–117, Paris, France, 1999.

[5] M. J. Gibney, N. R. Jennings, N. J. Vriend, and J. M. Griffiths. Market-based call routing in telecommunications networks using adaptive pricing and real bidding. In *Proceedings of the 3rd International Workshop on Multi-Agent Systems and Telecommunications*, pages 50–65, Stockholm, Sweden, 1999.

[6] A. L. G. Hayzelden, J. Bigham, and Z. Luo. A multi-agent approach for distributed broadband network management hayzelden. In *Proceedings of the Fourth International Conference and Exhibition on the Practical Application of Intelligent Agents and Multi-Agents (PAAM'99)*, London, UK, 1999.

[7] J. A. Rodríguez-Aguilar, F. J. Martín, P. Noriega, P. Garcia, and C. Sierra. Towards a test-bed for trading agents in electronic auction markets. *AI Communications*, 2000.

[8] J. S. Rosenschein and G. Zlotkin. *Rules of Encounter*. MIT Press, Cambridge, MA, 1994.

[9] T. W. Sandholm. Distributed rational decision making. In G. Weiss, editor, *Multiagent systems*, pages 201–258, Cambridge, MA, 1999. MIT Press.

[10] N. Vulkan and C. Priest. Automated trading in agents-based markets. In *UKMAS Workshop*, Hewlett-Packard Laboratories, Bristol, 1999.