Broadband network structure and natural monopoly

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Abstract

Although the supposition that cable television service, like fixed-line telephone, has natural monopoly characteristics is no longer universally held (Beil et al. 1993, Hazlett 1996, DiLorenzo 1996) the discourse around tax-funded new generation networks occasionally suggests that natural monopoly conditions do apply to residential broadband service. This paper considers how the nature of each of the three services could affect the costs involved in network expansion. Cable television is a relatively high bandwidth application with considerable scope for an increase in demand for essentially one-way traffic whereas voice telephony is a low bandwidth application with a trivial upper bound on the demand. Broadband Internet on the other hand is a potentially quite high bandwidth application with no obvious upper bound on the demand and with strongly bidirectional traffic in part because of the popularity of peer-to-peer distribution of content (Plissonneau et al. 2005). The hypothesis of this work is that the versatility of broadband networks in terms of the content that they support, distinguishes them in a fundamental and important way from the older networks (Cooper and Madden 2008).

Further, Internet traffic patterns can be modelled by graphs that are fundamentally different from those for television (a simple star graph) or voice telephony. Whether scale-free (Albert and Barabási 2002, Briscoe et al. 2009) or otherwise (Willinger et al. 2009), the actual structure of the demand for traffic must influence investment decisions and hence the debate (Marcus and Elixmann) on how new generation networks and universal access should be funded and regulated.

1 Introduction

The provision of cable television is still thought by some (Wen 2008) to exhibit natural monopoly characteristics, in spite of a substantial literature arguing the contrary (Beil et al. 1993, Hazlett 1996, DiLorenzo 1996). Perhaps the widespread use of cable infrastructure for providing Internet access has contributed to a perception that natural monopoly characteristics would apply in broadband Internet access as well (Atkinson 2009). The first part of this paper will argue that this seems quite unlikely to be the case.

In the OECD (Picot and Wernick 2007) but also elsewhere (Mutula and Mostert 2010) there has been a push for government involvement in rolling out advanced broadband networks. The rationale for public intervention comprises two thrusts:

- natural monopoly as an argument for the efficiency of a single provider, to be regulated by the authorities; and
- welfare arguments for the subsidy of access by large groups of consumers that might otherwise be left behind by development.

The framework of Faulhaber (1975, 2005) will be used to discuss these approaches. Finally, the paper considers the very nature of demand on broadband networks and briefly discusses the impact of the structure of the network (traffic).

When several utilities can provide a service or product to a consumers $1, \ldots, N$ with heterogeneous demand functions, following Faulhaber (1975), there are economies of joint production whenever

$$C\left(q^S\right) + C\left(q^T\right) \geqq C\left(q^{S\cup T}\right) \quad \text{whenever} \quad S \cap T = \emptyset \tag{1}$$

for all demand levels, where $C\left(q^U\right)$ is the cost, which is assumed to be homogeneous for all suppliers, of supplying the demand of a subset $U \subseteq \{1,\ldots,N\}$ of the consumers. Under these circumstances, the arrangement of a single supplier for all consumers has no disadvantage over many suppliers and if (1) is replaced by

$$C\left(q^S\right) + C\left(q^T\right) > C\left(q^{S\cup T}\right) \quad \text{whenever} \quad S \cap T = \emptyset \tag{2}$$

then the single supplier is strictly more efficient than several suppliers and the polity can hope to regulate a situation with monopoly supply to the advantage of consumers.

The discussion in this paper is restricted to wire-line broadband access. The reason is that the expansion of wireless broadband is subject to an obviously different dynamic than wired networks and that the supply of wireless connectivity is restrained very much by spectrum capacity (Hazlett 2001).

2 Monopoly characteristics in cable and broadband

Cable television networks seem a likely candidate for satisfying (2) and thereby satisfying the condition for a natural monopoly environment. Since the service is essentially unidirectional, the cost of joining two separate networks, providing the same content, is quite low. Suppose disjoint subsets A and B of consumers are each served by a separate cable network. Each network will have its infrastructure as well as distribution equipment and administrative overheads. The joining of the network serving A to the network serving B could consists of any connection from B that delivers the content to a suitable point on the defunct network for A and nothing more. The cost of splicing the connection to the existing network for B would be minimal and require no substantial redesign of the network for B. This is because of the unidirectionality and the fact that the consumers A have absolutely no effect on the older consumers B of the new network serving $A \cup B$.

How is the provision of broadband Internet access different from cable television? First, in the example above the joining of networks serving A and B is not quite as simple where broadband access is concerned, for the adding of customers A to the old network for B can result in the entire network for B having to be upgraded to provide upstream capacity for consumers A. Further, cable television supplies (with the exception of pay-per-view and similar services) the full range of content to every premise. This is of course very far from true for Internet access. Broadband networks do not deliver the Internet to every premise, but rather just *access* to the Internet. This access cannot be duplicated locally, as a cable television service can.

Faulhaber and Hogendorn (2000) point out that the cost structure in broadband provision arise in three ways:

(i) cost per unit of actual usage;

(ii) a cost per actual user; and

(iii) a cost per potential user.

The cost (iii) arises in broadband and cable television networks in a similar way. It is simply the cost of placing potential customers within reach of the network. In the case of wired networks, this will typically be by running the network down the potential user's street or bringing it to some point close to them and the cost of connecting the service provider to the Internet backbone. Cost component (ii) is approximately constant for cable television as well as for broadband networks.

The component (i) is absent on cable television networks but is highly significant for broadband networks since it determines the investment required (Faulhaber and Hogendorn 2000) on the network as well as fees paid for connecting to the public Internet. Furthermore, there is a complex interaction between (i) and (ii) and (iii). High volume demands for a specific level of pricing will reduce the number of potential and actual users on the network as the quality of service degrades. Cable television is, of course, simply not subject to this effect. Network effects are also present in broadband networks (Cooper and Madden 2008) but absent for to cable television. Even for national or urban networks, where most content is consumed from the external (public) network, the demand for strictly local services such as video conferencing and peer-to-peer downloads (Plissonneau et al. 2005) will increase as the number of actual users go up.

3 Arguments for subsidy

As Faulhaber (1975, 2005) has shown, a simple example in the supply of water can satisfy (2) but fail to be subsidy-free. When the supply cannot be made free of subsidy, there are groups of consumers that can defect and obtain service more efficiently than with a single supplier. In this case, the only option for obtaining a socially desired outcome with a single supplier will involve some degree of coercion. Where entry to the market is not restricted, this coercion is most easily effected using tax-funded subsidies to consumers, including those in possible defecting coalitions. This makes the single supplier a somewhat curious vehicle for achieving social goals. Indeed, since the demand for broadband use has few obvious upper limits (who does not want to project a high-resolution live image of their favourite hometown or holiday location on the living-room wall?) a social solution faces many difficulties including public demand for ever higher subsidies. Broadband access is however far from unique as an industry subject to politicised regulation and subsidy (Joskow 2007).

Heikki et al. (2008) have compared the broadband strategies of Sweden and Finland and have found near equally rapid expansion of broadband services in the two countries, in spite of the contrast between Sweden's decision to construct a tax-payer funded national network (three years before the Finnish strategy appeared) and Finland's tolerance for local monopolies in the first phase of its plan. This example can be read as an argument that publicly funded national networks are a harmless alternative but it is perhaps worth keeping in mind that well-intentioned early regulation of television in the United States resulted in quite wasteful use of spectrum and other resources (Robinson 2010) that is only now being cleaned up.

4 The structure of the broadband network

It is tempting to think of the Internet and broadband access infrastructure in terms of other traditional infrastructure developments. The analogy is not entirely apt, however. Physical infrastructure is just that – physical. There is no way to reach Sydney from San Francisco other than by crossing the Pacific. Should a million people in Sydney wish to access data or a service on a server in San Francisco, the operators of the latter can quite easily locate a mirror or cache in Sydney and thereby reduce by a considerable amount the infrastructure required. A large (or the larger) share of Internet traffic has as its aim simply to access a publicly available service and is completely unlike telephone traffic which is strictly between fixed (but possibly mobile) locations. Goth (2010) and others report the large extent to which content and access providers are innovating in order to manage the so-called *middle mile*. Regulatory interventions, especially regarding network neutrality, are likely to become increasingly more complex but this should perhaps be seen as a symptom of the dynamic and flexible nature of the Internet rather than as a defect.

The topology of the Internet has over recent year become a popular research topic and the behaviour of agents on the network is amenable to economic analysis (Kleinberg and Raghavan 2009). Furthermore, the network topology has regulatory implications because it impacts on the cost of constructing and running the facility (Werbach 2009). The efforts of network providers to reduce congestion and manage cost will keep the topology in flux and Yoo (2010) argues that regulation of innovation like private peering will be harmful.

Scale-free random graph models of the Internet (Albert and Barabási 2002) have gained a respectable following. However, as Willinger et al. (2009) have argued very persuasively, modelling or even description of the Internet is fraught with difficulty. Host counting is traditionally a popular basis for mapping the Internet but virtualisation has now made it normal for dozens or hundreds of servers using different operating systems and having different IP addresses to populate the same single computer or rack in a server farm.

5 Conclusion

Although the argument above suggests that cable television could present natural monopoly characteristics, a study by Levin and Meisel (1991) found that prices were significantly lower in markets in the US with competing cable systems than in those with a single franchise, which runs counter to the expectation where (2) is satisfied. It would also suggest that new entrants would be deterred from seeking entry to existing markets, which is also not really the case Hazlett (1995). As we have pointed out, the case for broadband access is much more weak and Section 2 it was emphasised out how broadband provision differs fundamentally from cable television. Mindful of the Negroponte Switch[1] (Hazlett 2001) one can hardly avoid cautioning against the hasty assembly of a public consensus to subject broadband provision to overly prescriptive regulation and politically determined investment choices.

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[1] Most of us grew up in an era where voice telephony was strictly from wires in the ground and television purely over the air and now live in a world where the opposite is the case.

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