Evaluating Impacts of Oversubscription on Future Internet Business Models

Anand Raju*, Vânia Gonçalves, Sven Lindmark, and Pieter Ballon

IBBT-SMIT, Vrije Universiteit Brussel, Pleinlaan 9,
1050 Brussels, Belgium
`{vania.goncalves,pieter.ballon}@vub.ac.be`
`{Anand.Raju,Sven.Lindmark}@ibbt.be`

Abstract. Network oversubscription has long been used by Internet Service Providers (ISPs). While high oversubscription ratios can hamper the end user experience, low oversubscription rates may result in an under-utilization of resources. This paper investigates the impacts of oversubscription, both from a technical (OpEx, Energy footprint etc.) and from a value network point of view (Control and Value creation etc.). A multi-parameter sensitivity analysis of a power model is performed to establish that the choice of oversubscription ratio by an ISP can have a serious impact on their operational energy and capital expenditures. As a next step, a set of business model parameters are operationalized in order to evaluate and establish long-term and short-term impacts of network oversubscription on business stakeholders. Key findings include that there is a need to establish a fit between the technical and business gains of network oversubscription, and that is possible only when an ISP leverages its control and influence over its customer base to better understand and anticipate the network usage, thereby being able to promptly adapting the overall network oversubscription ratios.

Keywords: Future Internet, Business Models, Impact Assessment, Oversubscription, Internet Service Provider.

1 Introduction

Internet Service Providers (ISPs) often oversubscribe their inter-connection network by overbooking the shared infrastructure among their customers. While being cost-efficient, it is also one of the reasons for lower access rates delivered to customers as compared to the rates advertised in their Service Level Agreements (SLAs). As a result, there has been an ongoing, intensely political debate over the nature and impacts of network oversubscription in the literature, much of which considers the choice of oversubscription as a business decision and not a technical decision [5]. However, in reality, oversubscription can be seen as an effective tool used by ISPs to mitigate such implications by finding a fit (in terms of optimal oversubscription ratio) that is symbiotic to end users and long-term economic goals, and at the same time confirming their corporate social responsibility.

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* Corresponding author.

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So far, little work has been done to systematically and objectively map the individual ISP's direct incentives to oversubscribe (e.g. related to energy consumption and operational expenditure) and the impacts of oversubscription on all stakeholders within the ISP's value network. This paper aims to operationalize the impacts of network oversubscription on a single firm, i.e. an ISP, in terms of energy consumption and operational expenditures, as well as, the impact on stakeholders pertaining to the ISP's value network in terms of value creation and control.

In an attempt to provide a holistic view of impacts of choosing and adapting to an optimal oversubscription ratio of a single ISP, Section 2 introduces a comprehensive multi-parameter sensitivity analysis of access power model. It reveals that the choice of oversubscription ratio by an ISP can have a serious impact on the energy footprint of its operation in a given service area. In Section 3 we introduce and elaborate a business model ontology, which is then used for assessing the business impacts of network oversubscription. Building on the results, we then operationalize the business model parameters to evaluate the control and value of an ISP within its value network. The main conclusions are summarized in Section 4.

2 Impacts of Oversubscription on an ISP

Considering the rapid development in design and delivery of access technologies, estimating the power consumption using a generic power model becomes a challenging proposition. These power models [1] are likely to be misinformed as they often fail to assess the impact of underlying variables like oversubscription present in the network. In this work, instead of proposing a power consumption model for an access network, we adapt one of the power models proposed in [1] as represented in (1) and estimate the extent to which the choice of oversubscription by an ISP impacts the overall operational energy footprint of his deployments and resulting savings due to reduction in energy bills and carbon footprint etc.

$$\frac{P_{FTTEx}}{N} = \left(P_{NT} + 2.\frac{P_{RN}}{N_{RN}} + 2.\frac{P_{CN}}{R_{CN}}\right) \tag{1}$$

The evaluation metric (P/N) here expresses the power-per-subscriber as a function of number of subscribers and power consumption of access equipment in a particular region. (P_{NT}; N_{NT}), (P_{RN}; N_{RN}) and (P_{CN}; N_{CN}) represent the power consumption and subscriber base sharing the Network Termination, Remote Node and Central Node respectively. An additional factor of 2 is introduced in order to account for additional cooling and power losses. According to [7], the power model for an FTTEx type of deployment in (1) is reduced to the following:

$$\frac{P_{FTTEx}}{N} = \left(P_{NT} + 2.\frac{P_{RN}}{N_{RN}} + 2.\frac{P_{CN}}{\frac{a.R_{CN}}{r.N_{RN}+a.r_p}}\right) \tag{2}$$

Model also assumes the network aggregation rate (a) as unity and the overall capacity of a Central Node Switch (R_{CN}) is 400Gbps. In order to attain an advertised access rate R (=20Mbps), the throughput capacity of each port is estimated as r_p = 1Gbps. In order to benchmark and cross compare the impacts the power ratings of P_{NT}, P_{RN} and P_{CN} are recorded as 7W, 1465W, and 3000W respectively from Table1 in [7]. However it is to be noted that the power ratings taken directly from the device manual often provide the nameplate rating instead to actual power rating, which may add further sensitivity to our analysis. Finally, the number of subscribers served by each network element is approximated to 960 for a remote node (N_{RN}).

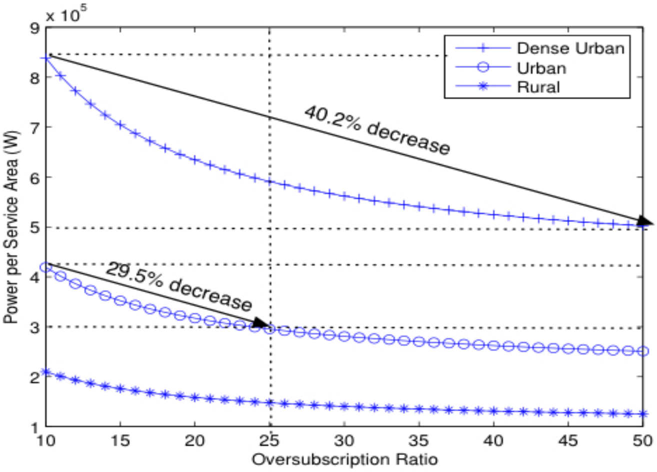


Fig. 1. Power-per-Subscriber in a service area in Watts (y-axis) as a function of variable Oversubscription rates (x-axis)

Oversubscription in access network is introduced when the network configuration meant to serve N subscribers with a peak access rate R, instead supports M (≥ N) subscribers thereby sharing the allocated bandwidth intended for N subscribers [1], resulting in an oversubscription ratio of $\rho = \frac{M-N}{N}$. Assuming R (20Mbps) as the advertised access rate, we have $R = r\,(\rho + 1)$, where r is the average bit access rate. Using the power ratings, power-per-subscriber metric and oversubscription ratio in the equation (2), we have:

$$\frac{P_{FTTEx}}{N} = \left(25 + \frac{288}{\rho+1}\right) \qquad (3)$$

Consistent with the findings in [1], we delimited the range of the oversubscription ratio from 10 to 50, however it must be noted that some aggressive oversubscription models employed by ISPs may have oversubscription ratios up to 200. Figure 1, gives an overview of sensitivity analysis performed on the power model in response to the parameters ρ and N. The Y-axis represents power-per-subscriber in a service area with subscriber density N varying from $(2^{14},2^{13},2^{12})$ for a (dense urban, urban, rural) subscriber base. We summarize our findings in Table 1, where an increase in the oversubscription ratio from 10 to 50, reduced the power consumption in a service area by 40 percent. Further increasing the oversubscription ratio to 200, the overall energy footprint reduces to 48 percent of original value.

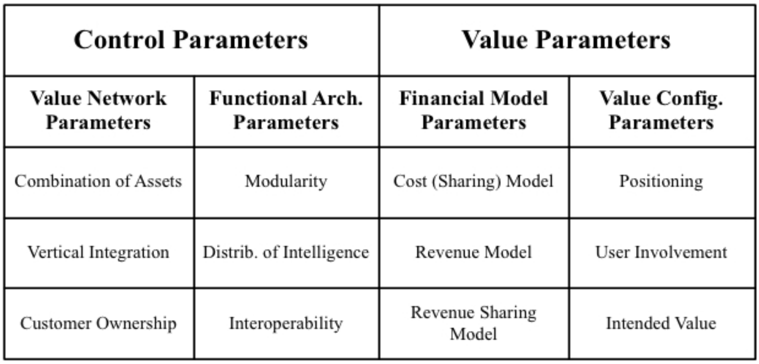
Table 1. Impact of Oversubscription in terms of subscribers (N= 2^{12})

Oversub. Ratio	Rural (Watts)	Urban (Watts)	Dense Urban (Watts)	Greening (%)
10	51.1(N)	51.1(2N)	51.1(4N)	-
25	36.0(N)	36.0(2N)	36.0(4N)	29.5
50	30.6(N)	30.6(2N)	30.6(4N)	40.2
200	26.4(N)	26.4(2N)	26.4(4N)	48.1

In hindsight, high energy savings may come at the cost of heavy oversubscription and loss of QoS, which may have other business implications (cf. Section 3). Hence, ISPs must be extremely cautious while choosing the oversubscription ratios for their networks. That being said, an intelligent choice of ratio (say $\rho = 25$) might serve the purpose of providing a network access, which is both energy aware and quality conscious.

3 Impact of Oversubscription on the Value Network Design

While there are many proposed frameworks in the literature for defining individual firms' business models, see e.g. [3][4], the key business model parameters related to control and value creation within the value network are best captured in the business model ontology [2] presented in Figure **2**. The framework mainly consists of four abstract layers in which the business models operate under the constraints of three design metrics in each layer. On the one hand, the ontology encapsulates the dimensions of value creation termed as Value Parameters (which relate to aspects such as the value proposition and the financial model). And on the other hand, it captures the functional architecture and value network design parameters termed as Control Parameters.



Control Parameters		Value Parameters	
Value Network Parameters	**Functional Arch. Parameters**	**Financial Model Parameters**	**Value Config. Parameters**
Combination of Assets	Modularity	Cost (Sharing) Model	Positioning
Vertical Integration	Distrib. of Intelligence	Revenue Model	User Involvement
Customer Ownership	Interoperability	Revenue Sharing Model	Intended Value

Fig. 2. Business Model Configuration Parameters

Thus these four layers consist of: (1) The value network: the architecture of actors and roles in the future marketplace; (2) The functional model: the architecture of technical components in the future technological system; (3) The financial model: the

Table 2. Business model parameters and definitions

Business model parameter	Definition
Combination of Assets	Overviews business actors that are in control of resources and assets
Vertical Integration	Represents if the resulting value network would be integrated or disintegrated.
Customer Ownership	Identifies the direct commercial relationship with the customer
Modularity	Refers to the design of systems and artifacts as sets of discrete modules that connect to each other via predetermined interfaces.
Distribution of Intelligence	Refers to the distribution of processing power, control and management of functionality across the system in order to deliver a specific application or service.
Interoperability	Related with the ability of systems to directly exchange information and services with other systems originating from different sources.
Cost Sharing Model	Refers to the anticipated costs for the design, development and exploitation of a product or service
Revenue model	Describes the way a business, monetizes its services and assets
Positioning	Distinguishes between the complementarity and substitutability between products and services
User involvement	Determines the extent to which is customer involvement essential to guarantee adoption
Intended value	Refers to the basic attributes that the product or service possesses which constitute the intended value to be delivered to the customer.

architecture of financial streams determining the future business case; (4) The value proposition: the architecture or general outline of the future product or service. Table 2 elaborates each business parameters captured in Figure 2.

Complementary to the quantitative assessment in Section 2, in the following, we present a qualitative assessment of key business model parameters that are operationalized for long and short-term business implications. In order to examine the implications of oversubscription on the value network design, each business model parameter (see Table 2) is operationalized from a control and value point of view.

Combination of Assets and Vertical Integration: In this context, we consider these main resources as the network elements at the access layer required to provide connectivity to end customers. The ISP would assume full control over these assets and could adjust at all times the maximum number of subscribers served by each network element. Exploiting this control over assets, an ISP can achieve efficiency gains thanks to increase in energy savings, lower equipment deployment and maintenance costs, later translated into operational savings.

Customer Ownership: Traditionally, it is an ISP that interacts and serves the end customers. It also assumes full control over the service and revenue flow from the end customers. In hindsight, not only an ISP has a guaranteed revenue stream but also a clear view on customer behavior and expected demand patterns, using which an ISP can predict the degree of resource utilization and hence can oversubscribe its network more effectively.

Modularity: The network architecture within the access layer is currently to some extent modular and not too complex. The complexity of the network architecture is mainly perceived in the interactions between different layers (access and end user or access and core layers) since management and troubleshooting at one layer is often more difficult when a problem occurs at a lower layer. Greening (lowering the energy consumption in) the network access layer as proposed in Section 2 could lower the resulting QoS. However, problems pertaining to QoS will negatively impact the end customers; its modularity in the architectural design will enable the ISPs to take prompt decisions to assuage these impacts.

Cost (Sharing) Model: Given that present day communication networks are oversubscribed, lower investments in new networking elements can be assumed. Although, our current research does not quantify such savings, we could refer that similar instances of network oversubscription are also prominent in wireless networking cases, where for e.g., in the case of femto cell deployments, impacts of oversubscription on ISP cost structure are clearly identified and estimated in [6].

Table 3. Impact of Oversubscription on ISP Cost Model [6]

Number of users per Femto BS	Area per Femto BS (m^2)	No. of Femto BS (for 10,000 Users)	CapEx (M€)	Savings (%)
4	200	2500	2.50	-
8	400	1250	1.25	50.0
16	800	625	0.62	75.0
32	1600	313	0.31	87.4

With an oversubscribed Femto BS serving up to 32 simultaneous users instead of 4 users, an ISP can save up to 87.4% in terms of capital investments. These substantial gains in CapEx show a high business relevance of network oversubscription at least from an ISP point of view. Still this case differs from the case analyzed in section 2 due to differences in technology, which, for instance, imply that the number of subscribers served by a FTTEx network element (e.g. router) could be higher but at the same time the simultaneity factor would also be higher. This would limit the use of an optimal oversubscription ratio without degrading QoS. Even though we cannot expect the same CapEx savings rate, it is safe to assume that choosing oversubscription in our case would still translate into CapEx savings with a relevant impact on an ISP's cost structure.

Intended Value: The value proposition of greening the network access consists mainly in optimising cost/quality of the service provided. Towards the end customer, the intended value of the service is expressed by a minimum number of outages and delivering the expected quality. Therefore, the key objective lies in choosing the optimal oversubscription ratio, which would guarantee lowering energy costs without degrading QoS. According to the results presented in Table 1, an oversubscription ratio of 25 would satisfy this objective. This value could then be incrementally adjusted according to monitoring activities and customer involvement, resulting in small deviations of power savings depending on subscriber base and period of time. Taking as example the FTTH offer of two French operators (100Mbs advertised download rate), operator A (Figure **3**) presents an average oversubscription ratio of 29 while operator B (Figure **4**) presents an average oversubscription ratio of 63. Although operator's B oversubscription is not too high (if compared with ratios of 200), the customers' perceived quality of service could not be acceptable for rich media applications. In addition, the higher the deviation between the advertised and the actual download rates, the higher the customers' perception of unfulfilled QoS.

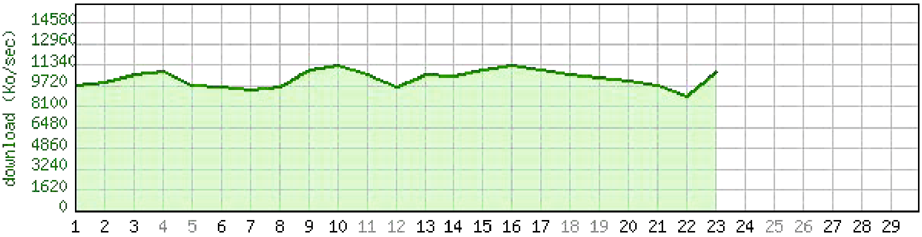


Fig. 3. Monthly sample download access rates of Operator A [8]

Fig. 4. Monthly sample download access rates of Operator B [8]

4 Synthesis and Implications

The previous sections assessed the impacts of oversubscription both from a technical and a value network point of view. The technical analysis showed that the choice of oversubscription ratio by an ISP has a serious impact on their operational energy and expenditures. In fact, oversubscribing a network can reduce the power consumption for a service area by 40 percent, which in turn has other indirect impacts like reduction of carbon footprint. Therefore, if societal (environmental) costs are also taken into consideration, a higher degree of oversubscription could be preferable than what would have been the case if only based on business decisions.

The business model parameters evaluated in order to establish long-term and short-terms impacts of network oversubscription are summarized in Table 4. One of the key findings of our assessment is that there is a need to establish a strategic fit between the technical and business gains of network oversubscription, this is possible only when an ISP leverages on his control and influence over its customer base to better understand and anticipate the network usage thereby being able to promptly adapting the overall network oversubscription ratios.

In conclusion, given the non-cumulative nature of network bandwidth requirement, oversubscription based business models and design choices will continue to prevail. However, unexpected peaks in demand for bandwidth (due to events like Super Bowl etc.) can critically paralyze the entire delivery mechanism. Also, there is clearly a gap

Table 4. Operationalization of business model parameters

Parameter	Operationalization Strategy	Key Implications
Combination of Assets and vertical integration	Which business actors are in control of networking resources? Would a vertically integrated value network contribute towards positive or negative impacts?	ISP in control over assets allows for achieving efficiency gains. Introducing further actors (e.g. NIP) will likely lead to less oversubscription and lower energy gains.
Customer Ownership	How customer ownership (direct or intermediated) structure looks like? What is the impact of customer ownership in terms of control over the ecosystem?	ISP owns customers, which allows for optimization of oversubscription based on customer behavior and demand patterns.
Modularity	How will the complexity of network architecture and interdependencies between network elements hinder or deter resolving the issues pronounced by network oversubscription?	The modularity of network design (considering mainly access network) allows ISP to balance QoS and savings.
Cost Model	What is the impact in terms of capital investments from ISPs while oversubscribing their networks and serving more customers with limited infrastructure?	Cost savings pertain mainly to the ISPs. In addition to energy cost savings, capital cost will be reduced.
Intended value	From an intended customer value perspective, what are the major impacts for involved stakeholders (ISPs and end users)?	Oversubscription is a key means toward operational excellence, which has to be carefully traded off with QoS.

between headline (advertised) bandwidth and actual bandwidth accessed by the End Customer, and therefore ISPs must take precautionary steps to inform and educate their End Users regarding network oversubscription – its relevance and its importance from technical and business standpoints. Regulators on the other hand, should revise the existing guidelines for marketing the delivery rates by ISPs thereby assuaging and addressing the mutual distrust between the ISP and End Customers.

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