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An Internet periphery study: Network centrality and clustering for mobile access in Bhutan ☆

Emanuele Giovannetti [a,b,*], Sebastian Sigloch [c]

[a] Institute for International Management Practice, Anglia Ruskin University, East Road, Cambridge CB1 1PT, United Kingdom
[b] Department of Economics, University of Verona, Italy
[c] LAIBS, Anglia Ruskin University, Cambridge, United Kingdom

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ABSTRACT

This paper explores the upstream network connectivity structure of Bhutan's monopolistic supplier of broadband mobile access. It is claimed that the presence of a hierarchical and well interconnected network, matched with a price-matching promise, may provide a crucial early mover's advantage against the second country's mobile provider, and entrant into the broadband mobile access segment. An upstream mobile connectivity dataset based on a large number of traceroutes was generated using Portolan, an Android's smartphones application. These data were used to perform an Internet Periphery Analysis highlighting the role played by existing connection agreements between Bhutan's incumbent network and other key international Internet providers. These international operators emerge as critical and central nodes for the Bhutanese interconnection network, a role providing them with a favourable bargaining position along the Internet end to end connectivity chain. The analysis identifies the need for regulatory authorities to address features of the hierarchical structure of network connectivity, in order to ensure cost-based network access, a precondition for entry and fair competition in the broadband mobile market.

1. Introduction

Internet connectivity in developing countries is more expensive and of lesser quality than in developed ones as subscribers in developing countries pay up to five times more than those in developed countries for high-speed Internet access (ITU, 2011). Access to mobile broadband is also less affordable in developing countries, as the International Telecommunications Union (ITU) estimated that, in 2013, the price of an entry-level mobile broadband plan represents between 11.3% and 24.7% of the monthly per capita Gross National Income (GNI) in the developing countries compared to the 1.2–2.2% in the developed ones.

Notwithstanding these high costs, in developing countries mobile broadband remains significantly more affordable than fixed broadband, as a 1 GB post-paid computer-based mobile-broadband plan requires 18.8% of per capita monthly GNI compared to the 30.1% required for a post-paid fixed-broadband plan with the same amount of data (ITU, 2013).

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* Corresponding author. Tel.: +44 1223 698233.
E-mail address: Emanuele.giovannetti@anglia.ac.uk (E. Giovannetti).

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Further differences between developed and developing countries are found when focussing on connection speeds. Akamai (2013) estimated that, within a sample of Asian countries, South Korea, Japan and Hong Kong all had average connection speeds above 10 Mbps while Indonesia, Vietnam, Philippines and India had an average connectivity below 2 Mbps. Moving from average country speeds to connectivity in rural areas, these differences become significantly larger.

Against this backdrop of high costs and slow connectivity, mobile access to the Internet remains of strategic relevance for countries without an established fixed telephone infrastructure, as the required capital investment to build a mobile infrastructure is usually lower than that needed to construct a fixed network, particularly when reaching remote areas. This is because in a fixed network, the costs increase directly with the number of customers, as each subscriber has a dedicated line. This is not the case for mobile networks where the access network and base stations are not dedicated to individual subscribers.[1] The per-household-reached wireless cost advantage, defined as the costs of reaching a given household with wireline technology, less the cost of reaching the same household with wireless technology was estimated by Bazelon (2010) to exceed 7500 USD in the rural counties of the USA.

An ITU project connecting 14 Bhutanese villages in two different sites (Limukha, servicing 44 households in 6 villages and Gelephu, covering 40 households in 8 villages), found that the preferred technology had to be wireless given the mountainous terrain, the demographic distribution (such as sparse population in pockets along valleys) and the lack of infrastructure such as roads or stable commercial power. The estimated cost per connection was 3570 USD (Tobgyl, 2003).[2] Another additional advantage of investing in wireless networks is that, it is usually easier, both from a technical and a regulatory point of view, to implement entry and competition in the mobile sector than in the fixed one due to lower barriers to entry.

Bhutan is a low-income country which joined the Internet as late as 1999, and is currently opening to competition in the broadband mobile access market.[3] After a brief overview of the current state of competition in the Bhutan's mobile and Internet access sectors, this paper discusses the results of an experiment designed to assess the main features of the country's mobile Internet connectivty. This analysis is done from an “Internet Periphery” perspective (Gregori, Improta, Lenzini, Rossi, & Sani, 2014) exploring the steps and properties of the supply chains for broadband mobile Internet access.[4]

These structural features of Bhutan's Internet connectivity play a key role in determining both the quality and final costs of broadband mobile access. This analysis is of particular specific relevance as it is performed just before the second Bhutanese mobile operator, *Tashi Cell*, is launching its 3G Internet access services,[5] after an initial period of monopoly in the supply broadband mobile access by the incumbent operator, *B-Mobile*. The analysis of these connectivity features provides the backdrop against which the entrant and the regulator will need to assess the possibility of fair competition, as the entrant's operations will require multiple interconnections with the incumbent network.

Quality and pricing of mobile Internet access clearly depend on many different factors, arising both from demand and supply conditions.[6] The supply ones are jointly determined by competitiveness at retail level and by the providers' costs, mainly accruing along the relevant supply chains as, after the initial network investment, the main costs in providing Internet mobile access depend on the complex set of interconnection charges and peering agreements taking place along the supply chain. These originate at the individual mobile access point and end at the target destination, usually a content provider.[7]

Using a crowdsourced smartphone technique, this paper produces primary data to explore these network features from the final user perspective. The analysis will focus on the structural properties of the graph generated by the observed interconnection links.[8]

This analysis is an essential step to identify where the potential interconnection bottlenecks may arise, affecting the feasibility and success of mobile broadband competition. This could also become useful in assessing the emergence of different competitive conditions in upstream Internet access at different geographic locations, for example along the urban/rural divide, and in evaluating the potential need for geographically diversified conditions for the regulations of access to take into account the underlying network differences.[9]

The role played by structural network metrics, capturing the centrality of given nodes, in shaping the outcomes of economic competition, has been studied by Choi, Galeotti, and Goyal (2014). These authors discussed the game theoretical

[1] The costs difference between fixed and wireless lines in densely populated areas in India was assessed by wireless connectivity expert Professor Jhunjhunwala, from IIT Madras, as follows: with a fixed local exchange in the vicinity an extra copper landline for a final user to the local exchange would cost 850 USD, while to set up a mast that connects through wireless different users would cost only 85 USD per user. Both these costs can treble in rural areas with low population densities and this difference increases significantly, making wireless more convenient in the absence of a pre-existing wired network in the vicinity. (Personal communication with Professor Ashok Jhunjhunwala).

[2] However, if the number of customers was to be increased by 50% the cost per wireless connection would have gone down to 2530 USD.

[3] See Kezang and Whalley (2004) for a fascinating account of the development of telecommunications in Bhutan.

[4] See Maitland, Bauer and Westerveld (2002) for a value chain approach to analyse telecommunications mobile data market in Europe and Li and Whalley (2002) on the evolution and complexity of the value chains in the telecommunications sector.

[5] TashiCell launched its 3G service on the 3rd of December 2013 (Tashi, 2014).

[6] See Giovannetti and Ristuccia (2005) for an early analysis of the relation between prices and quality in the upstream Internet backbone.

[7] See Faratin et al. (2007) for an analysis of the pattern of the evolution of AS interconnection in the Internet and Lippert and Spagnolo (2008) for an analysis of the interconnection decisions from a strategic point of view.

[8] Sgroi (2008) studied the role of complexity in the evolution of the world wide web and D'Ignazio and Giovannetti (2009, 2014) used complexity metrics to assess competitiveness and interconnection decisions in the Internet.

[9] See Bourreau, Cambini and Hoernig (2012) for a discussion on differential geographic access regulation.