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Working with CAIDA's (and other) DATA, Bottlenecks and Affordability a study in Tamil Nadu

Sebastian Sigloch[1], Emanuele Giovannetti[2] Shailaja Fennell[3]

[1] Anglia Ruskin University & Switch (CH)
[2] Anglia Ruskin University, & Hughes Hall, University of Cambridge
[3] Centre of Development Studies, University of Cambridge

Working with CAIDA's data since 2004

- Visited CAIDA in 2004, after Regulatory economics conference in San Diego.
- Used CAIDA Customer Cones data to:
  - Construct Market concentration indexes (HHI) "*Journal of Competition Law & Economics,* D'Ignazio & Giovannetti, (2006)
  - Estimate the effects of Customer cones asymmetry on the probability of bilateral Peering between LINX members "*International Journal of Industrial Organization* D'Ignazio & Giovannetti, (2009)
- Used CAIDA's data on AS relations
  - to estimate the role of clustering coefficient in digital goods value chain *International Journal of Production Economics* D'Ignazio & Giovannetti, (2014)
- Used CAIDA's Panel data set on Disconnection (Dahmdere & Dovrolis, 2012)
  - to estimate the impact of trust and asymmetry, on disconnectivity as a repeated game punishment strategy to support coordination (equivalent of price wars), *International Journal of Forecasting* D'Ignazio & Giovannetti (2015)
- Urged ITU to look at CAIDA's data in relation to innovation ecosystems
  - in Giovannetti, E. (2017) "Digital Divide and Digital Multiplier: A Paradigm Shift through Innovation", in Lehr and Sharafat eds (2017) *International Telecommunication Union,*
- Currently merging CAIDA's data with Portolan data to study affordability and bottlenecks in Tamil Nadu in Mobile Internet Access

Ongoing work

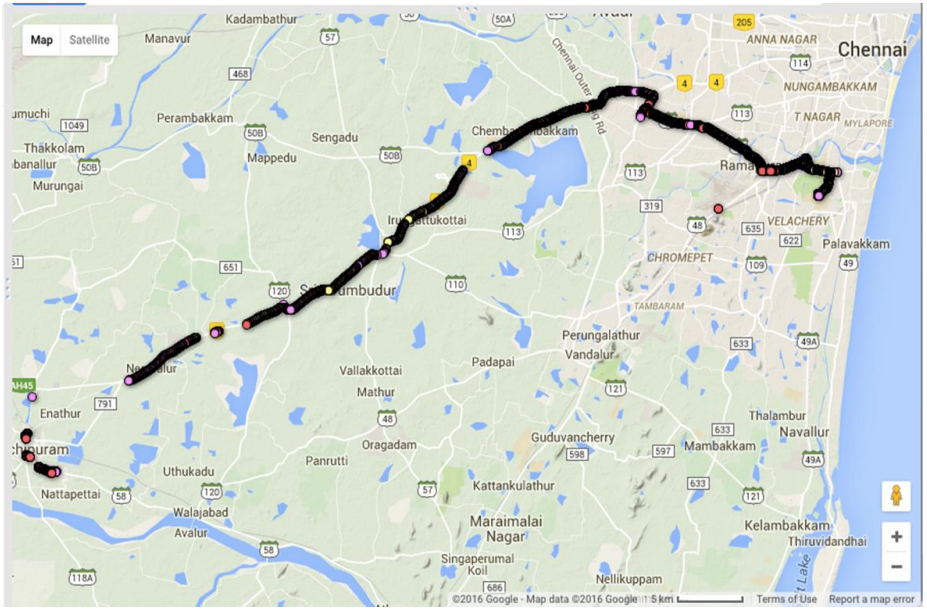
- Integrating CAIDA data on AS Ranking and commercial relations with Portolan traceroutes data to visualize upstream connectivity bottlenecks for three competing Tamil Nadu Mobile providers.
- Estimating impact of Hierarchical structuring on affordability of Mobile Internet Access, two stages:
  1. Estimate proxies for a degree of hierarchical structuring, based on clustering, eigenvector centrality and in & out-degrees
  2. Estimate impact of these proxies on affordability/ price per Mb in advertised mobile plans

Economic Logic

- The degree of Upstream vertical structuring reflects market power in the upstream/ Input/ connectivity. Markets for Mobile Access providers.
- This (SMP) may lead to incentives to set higher input costs, reflected on final consumer prices.
- Competition among final Mobile access providers is reduced by disparities in these costs.
- Use CAIDA's and Portolan's data to proxy them in an econometric model

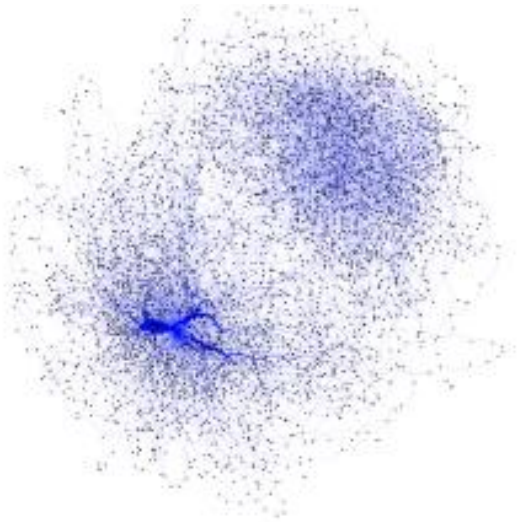
Field data collection

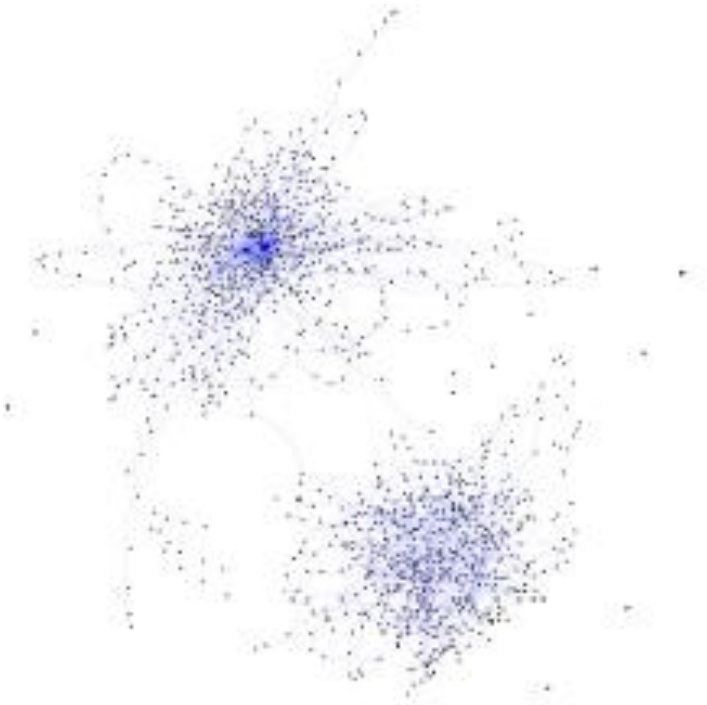
- Three major Tamil Nadu mobile broadband providers (Aircel, Bharti Airtel and Vodafone).
- Mobile sourced primary data collection using the Portolan (2015) Network Sensing Architecture.
- Traceroute data collection between 1st and 5th March 2015.Covering the urban area of Chennai and the 45 miles west rural regions between Chennai and Kancheepuram.
  - 57,122 unique Paris traceroute observations.
  - 731,200 Internet Protocol address hop observations.



The 3 Networks at IP granularity

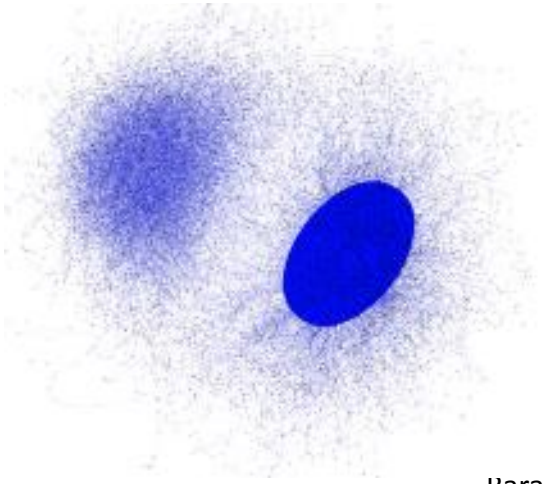
Aircell Network
N Number of vertices in network: 8647.
M Number of edges in network: 11411.





Bharti Airtel Network
N Number of vertices in network: 600.
M Number of edges in network: 803.

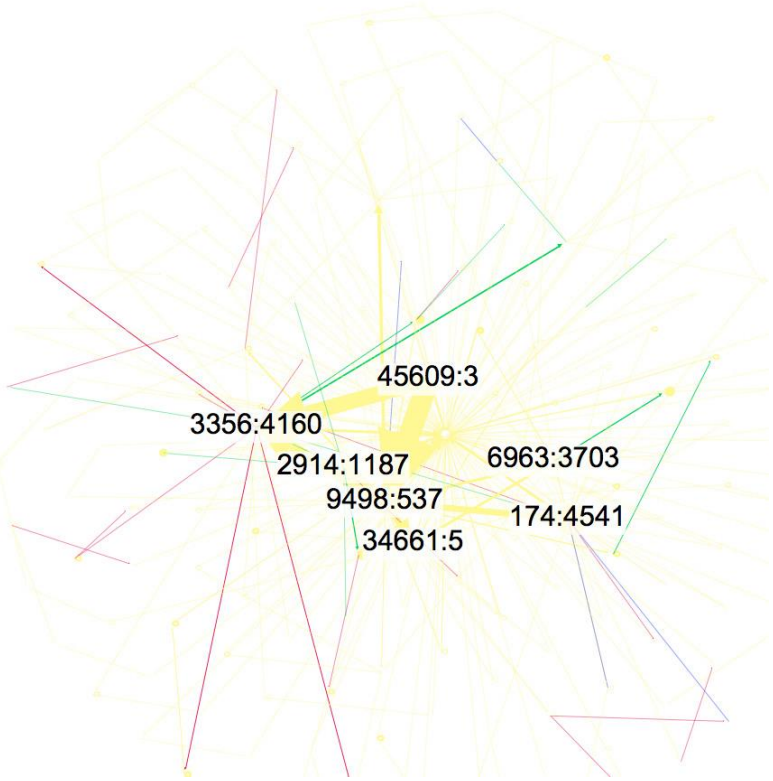
Vodafone Network
N Number of nodes in network: 7509.
M Number of edges in network:. 10390



Barabási-Albert Model B graph visualisations per mobile broadband operator at IP granularity

Merged with CAIDA Data

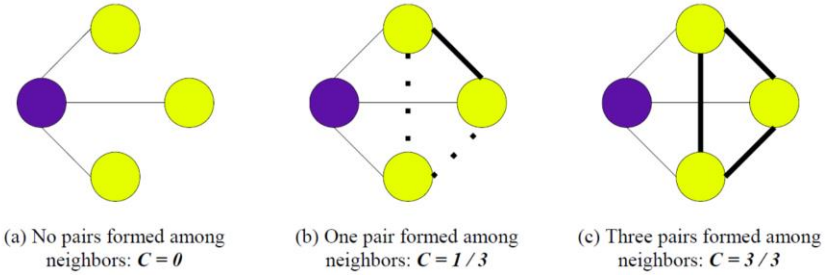
- Field data fused with additional secondary ones:
- The CAIDA (2016b) AS-Relationship dataset, which covers the inferred Customer Cones from publicly available Border Gateway Protocol (BGP) data.
- Example:
- Bharti Airtel Ltd. (AS9498:537) the analysis exposed a direct connection to Level 3 Communications Inc. (AS3356:4160), a major Tier-1 *Internet Service Provider*.



Bharti Airtel graph visualisation with relationship colouring. Red edges: p2c link.
Green edges: p2p link. Blue edges: c2p link.
Yellow edges: #N/A

Capturing Hierarchical Network Structuring from the data using:

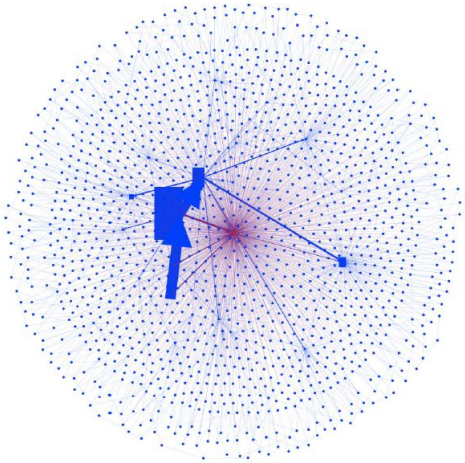
1. **Clustering Coefficient**: measuring how well connected among themselves a node's neighbors are.
   - when related to connectivity allows us to measure hierarchical network structuring (Vázquez, Pastor-Satorras and Vespignani, 2002). Power law degree distributions, as indicator of hierarchical structuring (Faloutsos, Faloutsos and Faloutsos, 1999). Study on Bhutan Giovannetti and Sigloch (2015).
2. **Eigenvector Centrality**, a metric to measure vertex direct and indirect influence.
   - Helps to study information flows in networks (Borgatti, 2005), where degree differences determine centrality (Bonacich, 2007). Linked to Google Pagerank. Key in the game theroretic anaysis of endogenous network formation and on bargaining power.



(a) No pairs formed among neighbors: $C = 0$

(b) One pair formed among neighbors: $C = 1/3$

(c) Three pairs formed among neighbors: $C = 3/3$



$G_{Vodafone\_AS}$

Eigenvector Centrality

small = red, high = blue.

Estimating the impact of hierarchical structuring on affordability

- In a two stage model we first estimate proxies for hierarchical structuring for the three networks
  - The estimated parameter of a log-log regressions between (weighted in & out) connectivity with clustering coefficient and eigenvector centrality.
- And then we use these proxies as explanatory variables, to estimate the effects of each mobile broadband operator networks' hierarchical level on affordability
  - The key affordability dependent variable of interest – the price per Megabyte of price plans, derived from a secondary price plan database

Results for Different models depending on in/ out degree

Both proxy metrics, either based on clustering coefficient or on eigenvector centrality, show that a higher hierarchical structuring of a mobile broadband operator network result in an **increase** of the price per Megabyte, hence in a **decreased** affordability.

For proxies based on out-degree

- 1% Increase in, Clustering Coefficient-based proxy for hierarchical structuring leads 1.24% increases in price per megabyte (reduction in affordability).
- 1% Increase in Eigenvector Centrality-based proxy increases price per megabyte by 1.39% (reduction in affordability).

For proxies based on in-degree

- 1% Increase in Clustering Coefficient proxy (increase in level of hierarchical structuring) increases price per megabyte by 5.68%.
- 1% Increase in Eigenvector Centrality proxy (In the model with in degree showing a decrease in level of hierarchical structuring) decreases price per megabyte by 6.11%.

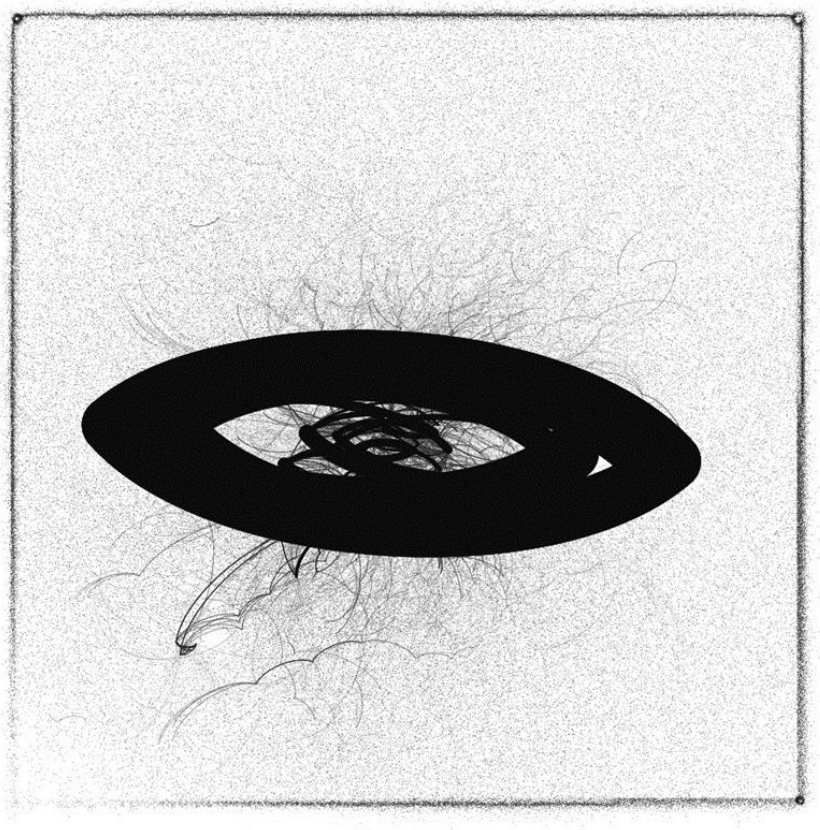
Next Steps/ Metrics to reach policy makers and regulators

- Mobile broadband is a key driver for achieving the Sustainable Development Goals (SDGs) (Lehr & Sharrafat, 2017).
- Using CAIDA and more data to understand upstream market structure and its influence on costs and competitiveness.
- ITU-D, SG1 Relevance of Mobile Internet Access Cost in "Enabling environment for the development of telecommunications/ICTs"
  - in particular QUESTION 4/1 on Economic policies and methods of determining the costs of services related to national telecommunication/ ICT networks, including next-generation networks)

More metrics

- Refine geo-location analysis, to be fused with periphery crowd-sourced data, Portolan (Gregori et al., 2014)
  - Critical for geographic scope of market definition
  - Focus on degree of essential facility, through unavoidability of bottlenecks are key to assess
  - Significant Market Power
  - Shifting between Ex-ante/ ex post regulation
- Addressing Productivity paradoxes.
  - How can we use these metrics on Internet Quality/Use to be used in relation with productivity and possibly can we use them, to proxy for product innovation/ process innovation? At least for the ICT sector?

'The Eye' - Total 731,200 observations at IP granularity using the Barábasi-Albert Standard Model with thick edges, elaborated using Gephi (2016). By Sebastian Sigloch



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Thanks

Emanuele

Anglia Ruskin University and
Hughes Hall, University of Cambridge
Giovannetti@cantab.net

UNIVERSITY OF CAMBRIDGE

Anglia Ruskin University