On routing controls in ISP topologies: A structural perspective

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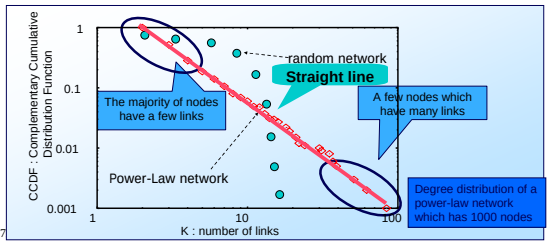
Contents

Power-Law networks

- The connectivity of nodes in the Internet follows power-law
- The probability that a node is connected to k other node : $P(k) \approx \alpha k^{(-\gamma)}$
  - A few nodes which have many links
  - Most nodes which have only a few links



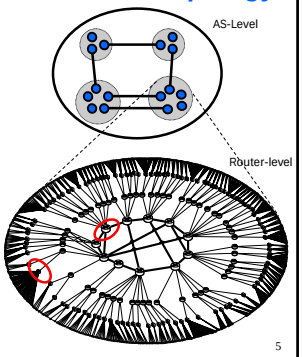
Related works

- Modeling power-law topology
  - BA (Barabasi-Albert) model
    - » Nodes are added incrementally (Incremental growth)
    - » Added nodes are connected to the larger degree nodes without considering physical distance (Preferential attachment)
- Evaluating the distributions of link/node load
  - BA model based
  - Minimum hop routing based

- **Only the degree distribution does not determine the network structure**
- **Other various routings have been proposed**

Modeling of Internet router level topology

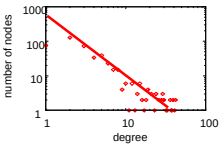
- Power-Law arise [1]
  - for maximizing network throughput
  - under the router's technical constraints
- Modeled like Figure.
  - At smaller-degree nodes
    - » Links can have large capacity for backbone
  - At larger-degree nodes
    - » Links must have small capacity for aggregating

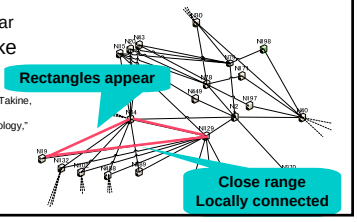


[1] L. Li, D. Alderson, W. Willinger, and J. Doyle, "A first–principles approach to understanding the Internet's router–level topology," in *Proceedings of SIGCOMM*, Aug. 2004.

ISP networks

- Sprint network
  - ISP network
  - Following power-law
  - 467 nodes
  - 1292 links
- Highly clustered [2]
  - The rectangles appear
- Locally connected like a bottom Figure



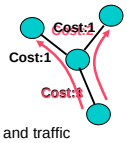


[2] Shin'ichi Arakawa, Ryota Fukumoto, Tetsuya Takine, Masayuki Murata, "Analyzing and modeling router-level internet topology," *IEICE Tech. Rep.*(IN2005-95), pp. 43–48, Oct. 2005

Objectives

- Investigate
  - How structural characteristics of Internet's power-law topologies affect the performance of the routing mechanisms
  - Difference between ISP topology and BA model topology
- Evaluate the load distribution of Internet router level topologies from the view point of structural properties
  - Minimum hop routing
  - Optimal routing
    - » takes huge time to calculate routes
  - Our heuristic routing

Heuristic routing method



- Select routes following two policies
  - Avoiding the higher-degree nodes
    - » At larger-degree nodes, links have small capacity and traffic concentrates due to router's technology constraints
  - Selecting larger capacity links
- Incrementally determine the route of each node-pair
  - After we obtain the route of a node-pair
    - » The remaining costs of all links are updated based on the selected routes
    - » Added by following expression : $\alpha C_{\max} / C$
      (α is parameter, $C_{\max}$ is maximum link capacity, and C is link capacity)

Simulation model

- Network models
  - ISP router level topologies
    - » Sprint topology, AT&T topology
  - BA model topology
- Traffic model
  - Each node-pair generates the same amount of traffic
- Link capacity
  - Determined based on the technical constraint of router
    - » Maximize the throughput with minimum hop routing
- Routing method
  - Minimum hop routing
  - Optimal routing
    - » Minimum the maximum link utilization using flow deviation method
  - Heuristic routing

Comparison of network throughput

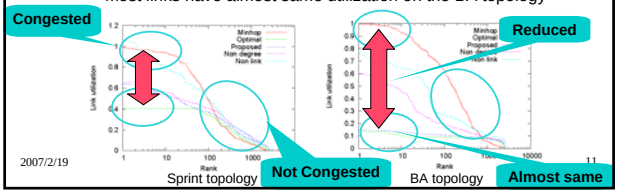
- The network throughput
  - The amount of traffic that the network can accommodate
- Optimal ratio
  - The ratio of Optimal routing to Minimum hop routing
- Results
  - ISP topologies have lower network throughput
  - ISP topologies have lower Optimal ratio

The network throughput [Gbps]

	Sprint	AT&T	BA
Minimum hop	256.85	117.8	364.26
Proposed	405.82	248.95	2444.75
Optimal	627.65	337.34	2706.27
Optimal ratio	2.44	2.87	7.43

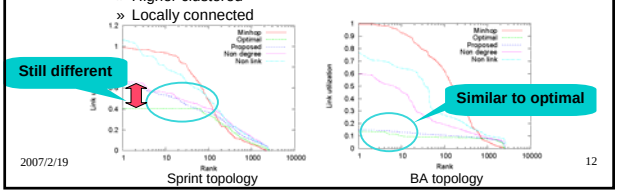
Comparison of link load distribution (1/2)

- Minimum hop routing (red line)
  - Some links are congested
  - The most links are not congested at all
  - BA topology has larger variation of link utilization
- Optimal routing (green line)
  - The utilizations are significantly reduced
  - Most links have almost same utilization on the BA topology



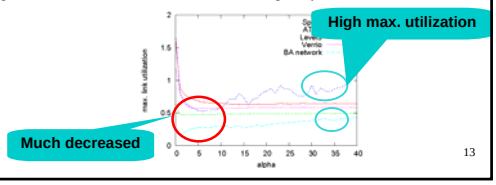
Comparison of link load distribution (2/2)

- Our heuristic routing (blue line)
  - High utilization links are still different from optimal routing on Sprint topology
  - Similar distribution to the optimal routing
- Effects of optimal and heuristic routing
  - Not significant in the Sprint topology
  - ISP topology have following characteristics
    - » Higher clustered
    - » Locally connected



The impact of parameter settings

- Parameter alpha gives priority for selecting routes
  - Large alpha causes shorter hop routes
  - Small alpha causes high bandwidth routes
- When the alpha is between 1 and 10
  - Maximum link utilization is much decreased
- Only on the BA topology and the Level3 topology
  - High maximum link utilization under large alpha



The relation between parameter alpha and maximum link utilization

- The BA topology and the Level3 topology
  - Large-degree nodes are located at “center” of the topologies
  - “Center” means where other nodes reach the nodes within a few hop count
    - The larger alpha causes the shorter hop routes
    - Traffic concentrate to the larger degree nodes at center of topology

⇨ **Maximum link utilization increase under large alpha**

- The Sprint, AT&T, and Verio topology
  - Large-degree nodes are not located at center of the topologies

Average hop count from maximum degree node to the other nodes

Sprint	AT&T	Verio	Level3	BA
2.89	3.99	3.50	2.22	2.15

Conclusion and future works

- Conclusions
  - We evaluated several routing methods on ISP topologies
    - » Minimum hop routing
    - » Optimal routing
    - » Our heuristic routings
  - Effects of Optimal routing method are not significant in the Sprint topology
  - Since ISP topology have following characteristics
    - » Higher clustered
    - » Locally connected
  - Our heuristic routing method achieve the similar distribution of link/node load to optimal routing
- Future works
  - Evaluating with more realistic traffic demand
  - Evaluating scalability our heuristic routing method