Queue Dynamics in Complex Networks

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In the Ambient Networks

- Topologies are hardly captured
  - Dynamic interaction of devices, and no centralized management
- Researches of Complex networks are focused
  - Complex networks are formed based on the interaction between individuals of the network
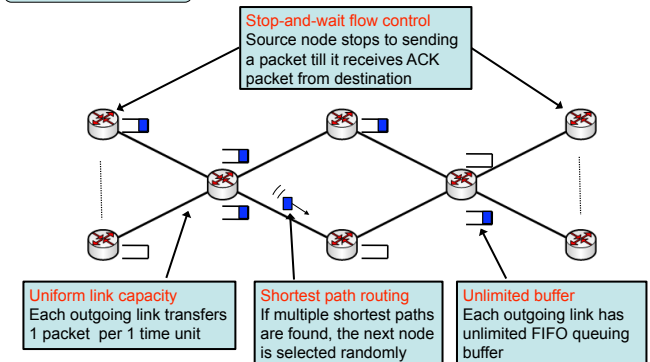
The Internet as One of Complex Networks

- Self-organization in the Internet
  - Autonomous systems (ASs) interconnect under no-centralized control
  - ASs are governed by architects based on each strategies
- Many models complex networks are proposed
- However, existing models can't capture characteristics of the Internet
  - ISP router-level topologies have different structures from model-based topologies

Research Purpose

- Difference in structure leads to difference in performance
  - The power-law degree distribution is not enough to discuss performance of networks
- We focus on the relationships between structure of topology and packet-level behavior
  - each of nodes has end-to-end flow control functionality
- Investigation of the optimal structure for efficient packet forwarding

Network Model

Stop-and-wait flow control
Source node stops to sending a packet till it receives ACK packet from destination

Uniform link capacity
Each outgoing link transfers 1 packet per 1 time unit

Shortest path routing
If multiple shortest paths are found, the next node is selected randomly

Unlimited buffer
Each outgoing link has unlimited FIFO queuing buffer

- Using 2 topologies having different structures
  - The number of nodes and links are same
  - AT&T Topology···Measured router-level topology of AT&T
  - BA（AT&T）Topology···Generated by BA model

Evaluation of Queue Dynamics

- Long-range dependence (LRD) in queue length
  - Hurst Parameter (H) represents the strength of LRD ($0.5 < H < 1$)
 - Estimating Hurst parameters of all links with R/S plot
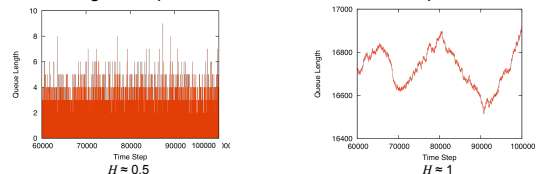
$H \approx 0.5$ Example of queue length fluctuation $H \approx 1$
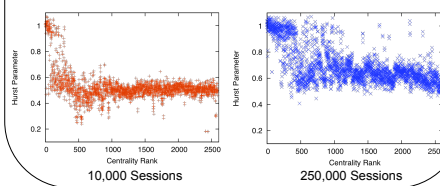
Simulation Result

BA topology

- When the number of sessions is small (10,000 Sessions)
  - High H values are observed at the links on which packets tend to concentrate
- When the number of sessions is large (250,000 Sessions)
  - Strong LRD are observed at many links

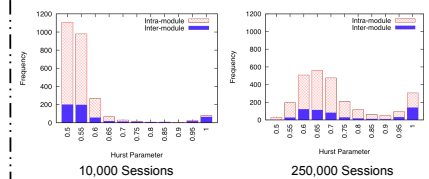10,000 Sessions   250,000 Sessions
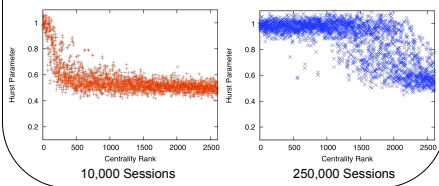
AT&T topology

- When the number of sessions is small
  - It yields similar feature of the BA topology
- When the number of sessions is large
  - The number of links which have large H value does not increase
  - The AT&T topology prevents queue length from fluctuation against increased traffic

10,000 Sessions   250,000 Sessions

Comparison the structures

- Why the AT&T topology prevents fluctuation?
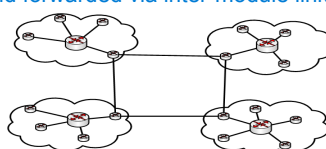 - Comparing the structures of the 2 topologies

BA topology

- The BA topology has many "Connector Hubs"
  - Hub nodes have many links connecting to other modules
- Hub nodes transfer a large amount of packets between modules

AT&T topology

- The AT&T topology has many "Provincial Hubs"
  - Hub nodes have many links connecting to the nodes in the same module
  - The AT&T topology has a few inter-module links
- Packets are aggregated at hub nodes, and forwarded via inter-module links

Effects of AT&T topology

- When the number of sessions is small, almost the links which has high H value are inter-module links
- As the number of sessions gets higher, intra-module links having high H value increase
  - However, H value of many links does not change

10,000 Sessions   250,000 Sessions

Conclusions and future works

- Comparing the queue dynamics of the 2 topologies
- In the AT&T topology, Inter-module links prevents other links from fluctuation
- Future works
  - Evaluation
    - heterogeneous link capacity
    - more complex flow control like TCP