Overlay Network Symbiosis: Evolution and Cooperation

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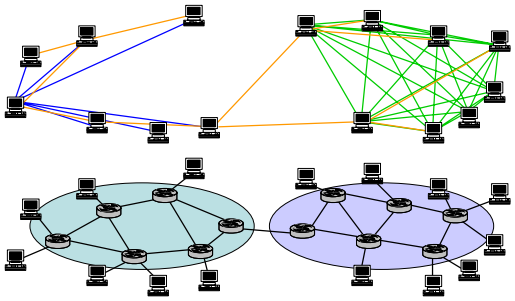
Competition among Overlay Networks

- Overlay networks try to maximize their application-level QoS and compete for the physical resources

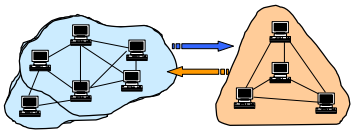


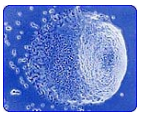
Overlay Network Symbiosis

- Collective performance can be enhanced by symbiosis
- By exchanging control information, overlay networks can
  - avoid flapping of paths
  - construct better topology
- By exchanging application-level messages, they can
  - enhance application-level QoS
    - higher probability of successful search
    - more candidate peers for a better provider peer
  - enhance system-level QoS
    - faster and more reliable message forwarding
    - higher rate of message dissemination
    - higher resilience against network failures

Overlay Network Symbiosis

- Overlay network = organism
  - *evolves and expands* when a new node joins
  - *shrinks* when a node leaves
  - *interacts* with each other through direct and/or indirect communications
  - *changes* its structure





Symbiotic colony composed of E. coli and Dictyostelium.

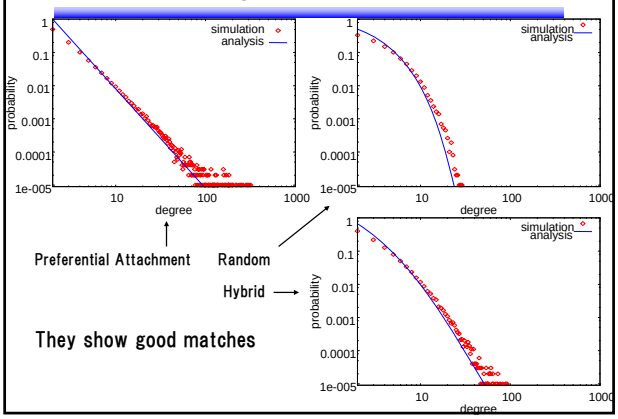
Objectives

- To achieve better cooperation
  - Topology: evolution mechanism
    - Preferential attachment of Barabasi and Albert
    - Random model
    - Hybrid of PA and random
  - Connection: selection of cooperative nodes
    - Degree-dependent
    - Random

Analysis of Evolution and Degree Distribution

Preferential Attachment	Evolution	$\frac{\partial k(i,t)}{\partial t} = m\frac{k(i,t)}{S(t)}$
	Degree Distribution	$P(k,t) = 2m^2 k^{-3}$
Random	Evolution	$k(i,t) = m\log t - m\log i + m$
	Degree Distribution	$P(k,t) = \frac{1}{2}e^{1-\frac{k}{2}}$
Hybrid	Evolution	$\frac{\partial k(i,t)}{\partial t} = \frac{(2-\alpha)m}{\alpha S(t)}\left(\frac{t}{i}\right)^{\frac{\alpha}{2}} + \frac{(1-\alpha)m}{\alpha N(t)}$
	Degree Distribution	$P(k,t) = \frac{2}{(2-\alpha)m}\left\{\frac{(2-\alpha)m}{\alpha k + (1-\alpha)2m}\right\}^{1+\frac{2}{\alpha}}$

Degree Distribution

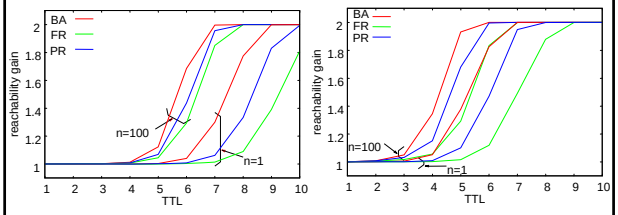


Property of Connected Networks

- Two 5000-nodes networks
  - Preferential attachment
  - Random
  - Hybrid (α=0.5)
- Connected by inter-overlay links
  - Random
  - High-degree
- Measures
  - Reachability gain
    The average number of nodes that a message reaches
  - Load gain
    The average number of messages that a network processes

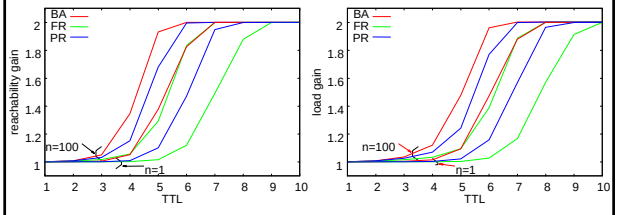
Reachability Gain

- The high-degree connection is more effective than the random connection
- The BA network benefits more than the others

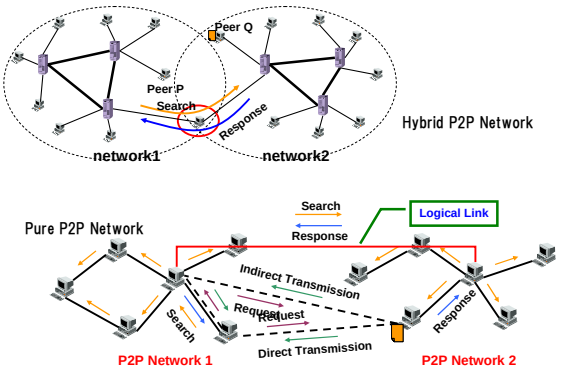


Load Gain

- Higher reachability is obtained at the sacrifice of the higher load



Cooperative P2P Networks



Conclusions

- A BA network benefits much when it is connected with a BA network with inter-overlay links between high-degree nodes
- Future works include considering more dynamic networks
- Bio-model based analysis