LLR: A Construction Scheme of a Low-Diameter, Location-Aware, and Resilient P2P Network

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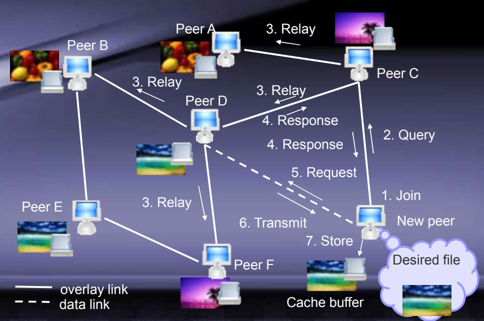
Outline

Backgrounds

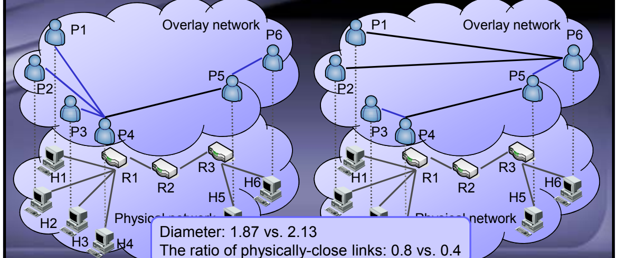
- Decentralized-unstructured P2P file-sharing system
  - most popular in the current Internet
  - e.g., Gnutella, KaZaA
  - There is no server that maintains meta information on peer and file locations
    - A peer finds its desired file by flooding a query in a P2P overlay network
- The structure of an overlay network affects
  - efficiency of file search and retrieval

Query flooding in unstructured P2P overlay network



Importance of overlay network

- Efficient overlay network
- Inefficient overlay network



Diameter: 1.87 vs. 2.13
The ratio of physically-close links: 0.8 vs. 0.4

Low-diameter → High reachability
Location-awareness → Fast search and retrieval

Related works

- Barabasi-Albert (BA) model [3]
  - Construction method of a low-diameter overlay network
    - Preferential Attachment (PA)
      - A node gets a link from a new node in proportional to its degree
    - Degree distribution follows a power-law
  - Problems
    - Characteristics of an underlying physical topology are not considered
    - Centralized control
- Location-Aware Topology Matching (LTM) [5]
  - Construction method of a location-aware overlay network
    - A connection with a distant neighboring peer tends to be disconnected
  - Problems
    - Diameter of an overlay network is not considered
    - A new peer to connect is randomly selected like as Gnutella

[3] A.-L. Barabasi and R. Albert: "Emergence of Scaling in Random Networks", Science, 286, (1999).
[5] Y. Liu, X. Liu, L. Xiao, L.M. Ni and X. Zhang: "Location Awareness in Unstructured Peer-to-Peer Systems", IEEE Transactions on Parallel and Distributed Systems, vol. 16, no. 2, pp. 163-174, 2005.

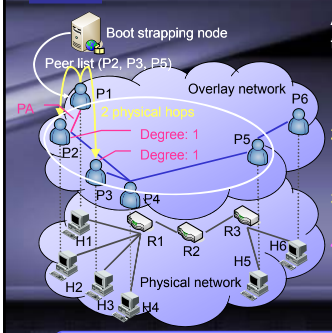
Research object

- Construction of a low-diameter and location-aware overlay network
  - Construction method
    - A new peer connects to a high-degree and physically-close peer at a join phase
  - Rewiring method
    - A peer disconnects an inefficient neighboring peer, then connects to more efficient peer
  - Failure recovery method
    - A peer conducts failure recovery when it detects a link failure

Common objectives
A peer tries to connect to a high-degree and physically-close peer to shorten search and retrieval latency and find out more provider peers

Construction method

- PA among physically-close peers based on modified BA model [7] -



A new peer selects m peers to connect as follows

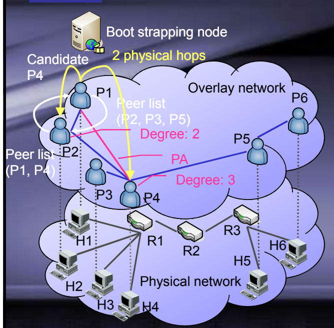
1. Obtain set S_p of candidate peers from a bootstrapping server
2. Calculate the physical distance to each peer in S_p using traceroute
3. Obtain set S_c of physically-close peers
4. According to PA, select m peers in S_c

$$P_r(d_j) = \frac{d_j}{\sum_{k \in S_c} d_k}$$

[7] R. Albert and A.-L. Barabasi: "Topology of Evolving Networks: Local Events and Universality", Physical Review Letter, 85, 24 (2000).

Rewiring method

- Refinement of the overlay network -



A peer conducts a rewiring method when it obtains a new candidate as a neighboring peer

- Calculate set S_w of peers that are the most physically distant among the current neighbors
- Calculate set S_m of peers that are physically close
- According to PA, select a peer in $S_w US_m$

$$P_r(d_j) = \frac{d_j}{\sum_{k \in S_w \cup S_m} d_k}$$

If the selected peer is not the current neighbor, the rewiring is done

Failure recovery method

- Determination of a new peer to connect -

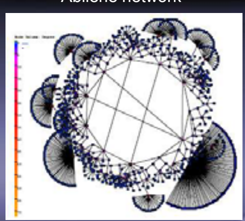
- A peer conducts failure recovery when it detects a link failure
  - The failure recovery method is the same as the construction method except for the following settings
    - set m=1
    - start from step 3
      - A peer uses locally cached information on peers and their physical distance

Simulation experiments

- Model -

- Simulation model
  - Physical topology
    - Real networks: Abilene, Sprint
    - Power-law degree distribution
  - Number of Peers
    - Abilene: 698, Sprint: 6478
    - Peers are on leaf nodes
      - We regard end users as peers
  - The inter-arrival time between two successive peer participations
    - Exponential distribution whose average is 120 seconds

Abilene network



Simulation experiments

- Model -

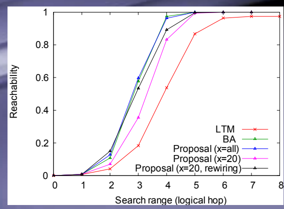
- Construction method of an overlay network
  - LLR (3 cases)
    - no limitation on the number x of peers initially obtained from a bootstrapping node
    - x=20
    - x=20 with the rewiring method
  - BA
  - LTM

Simulation experiments
- Model -

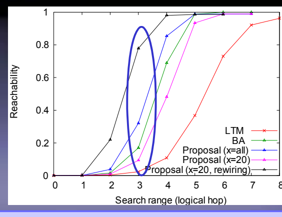
- Evaluation criteria
  - Reachability
    - number of peers to which a query message emitted by a peer reaches / number of peers in the overlay network
    - To evaluate search efficiency
  - Neighbor distance
    - number of physical hops between peers connected logically
    - To evaluate what extent an overlay network considers an underlying physical network
  - Resilience to failures
    - random disappearance of peers
    - attacks from malicious users

Simulation results
- Reachability -

Abilene network



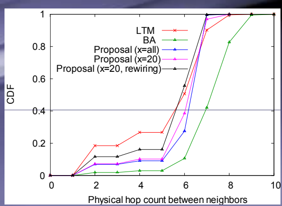
Sprint network



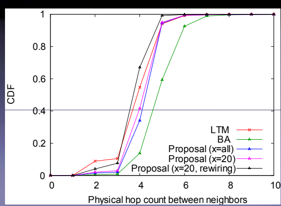
Effectiveness of rewiring method
- Reachability is improved by the rewiring method
even if a new peer knows only 20 candidates at a join phase
- Especially in Sprint, the reachability becomes higher than BA by 0-60%

Simulation results
- Neighbor distance -

Abilene network



Sprint network



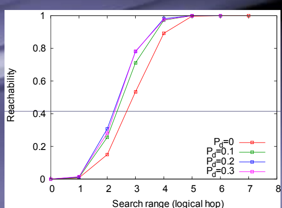
Effectiveness of LLR
LLR can construct an overlay network where logical neighbors are physically close with each other as with LTM

Evaluation scenario for resilience to failures
- random peer disappearances -

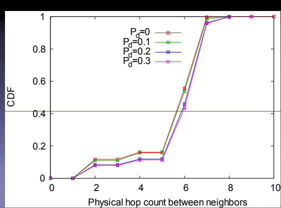
- Every time a new peer joins, we conduct a disappearance event at probability ***Pd***
- When the disappearance event occurs
  - A peer is randomly selected and removed from an overlay network
  - We change ***Pd*** as 0, 0.1, 0.2, and 0.3

Simulation results
- Resilience to failures (random disappearances, Abilene) -

Reachability



Neighbor distance



Neighbor distance
•Even if ***Pd*** increases, the neighbor distance does not change much ...ures, because the number of peers decreases and consequently the diameter of the overlay network decreases

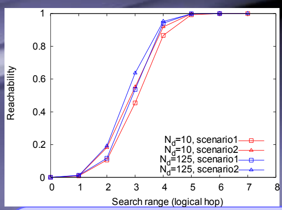
Evaluation scenario for resilience to failures
- attacks from malicious users -

- We remove ***Nd*** peers in a descending order of degree after all peers joined
  - Scenario 1
    - We try to recover from the attack by the recovery method
  - Scenario 2
    - We rebuild an overlay network from the initial condition by adding peers that remained after the attack one by one
  - Time for recovery in scenario 1 and time for reconstruction in scenario 2 is the same
- If those two networks have similar properties
  - LLR is resilient to attacks
- We change ***Nd*** as 10 and 125

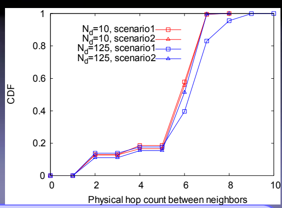
Simulation results

- Resilience to failures (attacks from malicious users, Abilene) -

Reachability



Neighbor distance



Neighbor distance

- If the scale of attacks is small (*Nd*=10), there is almost no difference
- Even in the case of massive attacks (*Nd*=125), the deterioration is at most 0.2

Conclusions and future works

- Conclusions
  - We proposed LLR: construction scheme of a low-diameter, location-aware, and resilient P2P network
  - We showed the following characteristics through simulation experiments
    - Reachability is improved by 0-60% compared with BA model
    - Neighbor distance becomes short as with LTM
    - Failure resilience is accomplished against both random disappearances and malicious attacks
- Future works
  - Load balancing among peers
    - Query messages tend to concentrate on high-degree nodes
    - By introducing caching mechanism, we expect to reduce the load on a high-degree peer