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

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Outline

- Background
  - Unstructured P2P overlay network
  - What is an efficient overlay network?
- Related works
  - BA model
  - LTM
- Proposed scheme
  - LLR: construction scheme of a low-diameter, location-aware, and resilient P2P network
- Simulation experiments
- Conclusions and future works

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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

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Query flooding in unstructured P2P overlay network

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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

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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

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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

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

[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_u 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 $S_u \cup S_m$

$$P_r(d_f) = \frac{d_f}{\sum_{k \in S_u \cup S_m} d_k}$$

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

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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

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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

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Simulation experiments
- Model -

- Evaluation criteria
  - Reachability
    - $\dfrac{\text{number of peers to which a query message emitted by a peer reaches}}{\text{number of peers in the overlay network}}$
    - 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

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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%

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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

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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

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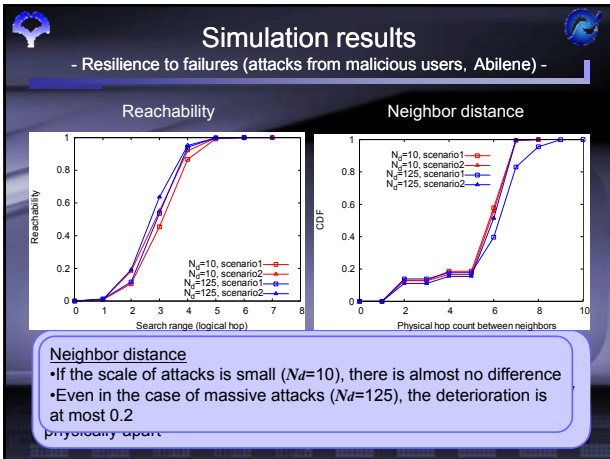
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Evaluation scenario for resilience to failures
- attacks from malicious users -

- 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 (N_d=10), there is almost no difference
- Even in the case of massive attacks (N_d=125), the deterioration is at most 0.2

physically apart

Conclusions and future works

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- **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

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