Mobile P2P Networks for Highly Dynamic Environments

Kei Takeshita, Masahiro Sasabe, and Hirotaka Nakano
Osaka University, Japan

Outline
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  - Classification of P2P networks
- Background
  - Problem of the structured P2P networks over mobile ad hoc networks
  - Link disconnections
- Related work
  - MADPastry
- Proposed method
- Conclusion & Future Work

P2P network
- P2P networks are classified into unstructured and structured
  - Unstructured P2P networks
    - Find a destination node by flooding
    - Induce a high amount of traffic into the network
  - Structured P2P networks
    - Find a destination node by unicast
    - DHT enables such a unicast-based routing
    - Keep low search costs with an increase in network size

Structured P2P networks are more scalable to the network size

Objective
- Improving success ratio of object search in highly-dynamic mobile P2P networks
- Understand how the link disconnections happen in the network-layer routing protocols
- Propose an application-layer approach to tackle the link disconnection problem

Problem of the structured P2P networks over mobile ad hoc networks
- Success ratio of object search deteriorates as node velocities become high
  - Object: file, service etc.
- What causes the problem?
  - Link disconnections at the network layer
    - The next-hop node does not exist in its wireless transmission range due to its movement
    - They frequently occur under highly dynamic environments
- Unicast packet transfer is not reliable in MANETs

Behavior of routing protocols in the network layer when link disconnections occur
- Proactive Routing Protocols (e.g. OLSR)
  - Maintain lists of destinations and their routes by periodically distributing routing tables
  - If link disconnections occur, the node abandons sending the packet
- Reactive Routing Protocols (e.g. AODV)
  - In case the link disconnection occurs at D→E:
    Node D re-finds the route to node E by flooding
  - In case the link disconnection occurs at A→B, B→C, or C→D:
    The node rejects the packet
How to reduce the link disconnections

- Increase the link reliability at the network layer
  - AODV-BR, AOMDV etc.
  - Limited reliability improvement
- Send multiple queries
  - Send multiple queries for each search
    - Induce additional traffic that reduces the advantage of structured P2P networks
- Reduce the hop count to the destination node
  - Clustering ⇒ MADPastry
  - Replication ⇒ Proposed method

Clustering method

- Clustering using Landmark keys
  - Landmark keys are preassigned
  - A node whose nodeId is the closest to the landmark key becomes a cluster head
  - Sends beacon to members of the cluster
  - Non cluster-head nodes store physical hop count to each cluster head based on received beacons ⇒ belong to the nearest (minimum hop count) cluster
- Changes cluster from 3 to B

Problem of clustering method

- Changing cluster results in a temporal churn
  - The corresponding node leaves and rejoins the network
  - Since it has responsible pointers (the pair of objectId and IP address) whose objectIds are the closest to its nodeId, it must update pointers

Simulation - MADPastry with considering pointer exchange

- Assess the overheads and risks of cluster changes that were not evaluated in Ref. [*1]
- Simulation environments
  - Number of nodes: 250
  - Number of objects: 1000
  - Query interval: 10 s/query in each node
  - Mobility model: Random Waypoint Model
  - Simulation time: 3600 s, use the latter 2000 s
  - Number of cluster: 16
  - Transmission range: 250 m
  - Node density: 100 node/km²

Related work

Simulation result – MADPastry considering pointer exchange

- Metric: Success ratio of object search
  - w/o pointer exchange: ratio of the number of queries reaching nodes whose objectIds are the closest to searching objectId
  - w/ pointer exchange: ratio of the number of queries reaching nodes that have the corresponding pointers

- Success ratio of object search deteriorates as the node velocity increases
  - Pointer exchanges fail more and more in highly dynamic environments
How to reduce the link disconnections

- Increase the link reliability at the network layer
  - AODV-BR, AOMDV etc.
  - They can slightly improve the reliability
- Send multiple queries
  - Send multiple queries for each search
  - They induce additional traffic that reduces the advantage of structured P2P networks
- Reduce the hop count to the destination node
  - Clustering ⇒ MADPastry
  - Replication ⇒ Proposed method

Sharing pointers among nodes in a cluster (1/2)
- Each node sends its responsible pointers to other nodes in the same cluster
  - Using the periodic beacon messages of MADPastry
  - Each node stores the pointers received or overheard
  ⇒ All nodes in a cluster can reply to a query whose destination belongs to the same cluster

Sharing pointers among nodes in a cluster (2/2)
- Effects of pointer sharing
  - Success ratio of object search is increased by reducing the overlay hop count
  - Overall Traffic is increased by flooding in clusters to replicate pointers
  - Decreased by reducing the overlay hop count

Simulation Results (success ratio of object search)

- The effect of pointer sharing increases as the node velocity becomes high
- The success ratio of object search of the proposed method is about 6% lower than that of flooding when the node velocity is 5.0 m/s
- Since flooding does not rely on physical topology

Simulation Results (overall traffic)

- Flooding requires at most third times as much overall traffic as the proposed method
- Overall traffic of the proposed method becomes lower than that of MADPastry as the node velocity increases
  - (reduction of forwarded queries inside clusters > increase of the beacon size)
Discussion - negative aspects of pointer replications

- Duplicate responses caused by overhearing
  - They can be avoided by caching received or overheard responses to the query at each node
- Pointer inconsistency
  - When an object holder changes or leaves the network, a node with the corresponding pointer may be unaware of the event
  - It can be alleviated by maintaining replicated pointers in a soft-state manner

Discussion - What is “highly dynamic environment”?

- Network dynamics depends on not only node velocities but also transmission range, parameters of the network routing protocol, etc.
  - Link disconnections may frequently occur even when the nodes move slowly

<table>
<thead>
<tr>
<th>Transmission range [m]</th>
<th>250</th>
<th>50</th>
</tr>
</thead>
<tbody>
<tr>
<td>Node velocity [m/s]</td>
<td>5.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Node density [node/Km²]</td>
<td>100</td>
<td>2500</td>
</tr>
</tbody>
</table>

These two environments have the same degree of network dynamics

Conclusion

- Improving success ratio of object search in highly-dynamic mobile P2P networks
  - Propose an application-layer approach to tackle the link disconnections
  - Deploy pointer replications
  - Proposed method could improve the success ratio of object search up to 40% compared with MADPastry

Future Work

- Further reductions of overall traffic without deteriorating the success ratio of object search
  - Each node does not send pointer information by flooding
  - Each node stores all pointer information in overheard or received packets
  - Formulate a new metric to model the network dynamics