Comparison and Evaluation of Application Level Multicast for Mobile Networks

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Two papers dealing with different aspects:

A Comparison of Network and Application Layer Multicast for Mobile IPv6 Networks
(A. Garyfalos, K. Almeroth, J. Finney)

An Evaluation of Scalable Application Multicast Built Using Peer-to-peer Overlays
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Motivation:

- Need a way to address fast moving nodes in mobile environment
  - High mobility => high network resource usage
  - Idea: address a group of nodes instead of all or one: multicast
    - Multicast: one-to-group addressing – hierarchical groups
    - Unicast: one-to-one addressing - what about node moving out of range? Rebuilding routing tables takes time
    - Broadcast: one-to-all addressing – high network stress
  - Current solution: IP multicast working on Network Layer
    - BUT: high complexity, not designed for mobile environment
  - New approach: Application Layer Multicast (ALM)
Application Layer Multicast (ALM):

Designed for easier use than IP multicast BUT not for mobile networks

- Idea: management of groups and packets shifted from IP routers on Network Layer to end hosts on Application Layer,
  construct Overlay on current network

- Claims to be independent of characteristics of underlying network,
  disregards node movement

- Questions:
  Is this the final solution to problems of mobile networks ???
  How will ALM and Mobile IP work together ?
  How can ALM be implemented ?
Peer-to-peer overlays for ALM:

- Structured p2p overlay networks can be used to implement Internet-scale application level multicast
- Provide efficient routing in namespace by assigning parts of namespace to nodes:

```
myfoo.com
  ↓
demyfoo.com us.myfoo.com fr.myfoo.com ...
  ↓
sales.de.myfoo.com commit.de.myfoo.com treasury.de.myfoo.com ...
  ↓
a.sales.de.myfoo.com ...
```
Protocols for p2p overlay networks: CAN, Chord, Pastry, Tapestry ...  
Multicast approach: *Flooding* or *Tree-building*  
Routing approaches: *d-dimensional hypercube* or *Cartesian hyperspace*  
Scalable and self-organising  
Problems:  
- Highly complex with many different adjustable parameters (Network-aware routing, Landmark-based Placement ...)  
- Each protocol uses different approach  
- No evaluation on performance of 4 combinations for mobile networks and how to measure it  

Question: Even with this approach, will ALM work in mobile environment?
Impact of mobility on ALM:

- ALM may work well in wired networks but faces new problems in mobile IP:
  - Only concerned with network failure, not designed for node mobility
  - Mobile network consists of many different nodes (heterogeneous)
  - Need to care for node's capabilities (low battery etc.)
  - Depends on end hosts which WILL be less robust in mobile networks

=> Maybe ALM is not the final solution for mobile IP but has to evaluated

Question: Can peer-to-peer overlay networks be beneficial for ALM?
Approaches for peer-to-peer overlay networks:

- Content Addressible Network (CAN) Overlay Network
  - Nodes organized in groups in network space
  - Each node takes ownership of network portion, maintains routing table to neighbours
  - Routing: message forwarded to neighbour closer to destination

- Pastry Overlay Network
  - Uses 128-bit namespace to assign random nodeID to nodes
  - Routing: sends message to node whose nodeID is numerically closest to destination key by comparing a variable number of the ID's bits
  - Exploits network locality to reduce routing delays by measuring RTT when building routing tables
Approaches for peer-to-peer overlay networks - Multicast:

- Overlay-Per-Group implementations (Flooding):
  - Lookup function for joining clients requires distributed name service
  - CAN Flooding: broadcast algorithm - nodes forward messages to all neighbours
  - Pastry flooding: broadcast algorithm – node forwards message to all entries in node’s routing table

- Tree-Per-Group implementations:
  - HERE: Scribe used (generic application-level multicast infrastructure)
  - Uses reverse path forwarding to build multicast tree per group, identified by groupID
  - Scalable, failure-tolerant decentralized algorithm
Evaluation:

- Which one is better: IP Multicast or Application Layer Multicast?
- Important aspects of performance and metrics used to measure:
  - Network performance: \textit{Relative delay penalty (RDP)}
    \[ RDP = \frac{ALM \text{ link cost}}{IP\text{multicast link cost}} \]
    - smaller value means ALM is better
    - 4 components for mobile receivers:
      - IP multicast – home subscription (receiver is in home network)
      - IP multicast – remote subscription (receiver in foreign network)
      - ALM – reverse tunneling (packets tunneled through home agent)
      - ALM – optimized routing (packets go directly to receiver)
- Link stress: number of identical packets received by nodes
- Robustness: amount of packet loss in network

• Simulation model for comparison IP multicast vs. ALM:
  - 500 nodes, of which 10 – 200 are receivers
Results for comparison IPM - ALM:

- Robustness:
  - Equal values for slow movement
  - Losses for ALM with fast movement
  - Loss rate increase faster for ALM

=> packet loss through mobility (additive path), ALM worse
Results for comparison IPM - ALM:

• RDP:

stationary: stationary nodes (1): ALM (rt) over IPM (hs) (2): ALM (or) over IPM (rs)
(3): ALM (rt) over IPM (or) (4) ALM (or) over IPM (hs)
(1) = fast movement, (2) = slow movement

=> ALM performance better with fast movement, IPM superior for less mobile nodes
Results for comparison IPM - ALM:

Link Stress:

- Mcast(rm) always
- ALM(REV) worst case scenario
- ALM(OPT) better than REV

=> ALM causes overhead, packets traverse link 1.7 times more than IPM
Conclusions for comparison IPM - ALM:

- **Robustness**: no advantage to IP Multicast for low mobility, BUT: add. Packet loss for ALM by increased node speed

- **RDP**:
  - low mobile nodes cause IP Multicast to perform better than ALM by factor 4-5, with high mobility factor decreases to 2
  - Metric depends on user behaviour: localized movement => smaller gain for IP Multicast

- **Link Stress**: with ALM about 1.7 times higher, generally increases with group size

=> **OVERALL**: Concerns confirmed. IP Multicast outperforms ALM in all aspects

Though no protocol support needed for ALM, questionable if it will ever work
Evaluation of ALM using peer-to-peer overlays:

- CAN and Pastry used for p2p overlay, each with flooding and tree-building
- Simulation model setup:
  - packet-level event simulator on five network topologies with 5000 routers and 80,000 end nodes
  - Two sets of experiments, (1) with single group, (2) with 1500 groups
- Same criteria used for measurement:
  - Relative Delay Penalty (RDP)
  - Link Stress
  - Duplicates
Results for evaluation of ALM using peer-to-peer overlays CAN:

- CAN results:
  - Enabling landmark-based assignment largest improvement for RDP
  - Flooding results:
    - Delay penalty independent from routing table size
    - Link Stress:
      - showed best numbers with landmark-based placement
      - 80,000 members joining a group causes more link stress and grows with routing table state size than sending a message to 80,000 members
  - Duplicates: impact neglectable
Results for evaluation of ALM using peer-to-peer overlays - Pastry:

- Pastry results:
  - Two optimizations used, topology-aware node ID assignment (TOP) and topology-aware routing table construction (TART)
  - Flooding results:
    - RDP: Best results by combining TOP and TART, which reduces RDP by 60%
    - Link Stress: Average reduced to 30%
    - Duplicates: Increasing the number of matching bits $b \Rightarrow$ better performance
      BUT duplicates rise enormously (up to factor 1000)
      - No problem, routing tables can be repaired at low costs
Results for evaluation of ALM using peer-to-peer overlays - Pastry:

- Tree-based results:
  - RDP: same results like flooding
  - Link Stress: even lower than with flooding
- Outcome:
  - Best combinations for p2p overlays:
    - for single large group: Pastry with Flooding & TOP
    - for many groups Pastry with tree-based & TART
Conclusion:

- ALM alone is no solution and performs even worse in mobile environment than IP multicast
- When using peer-to-peer overlay networks to provide ALM performance is much better but still worse than IP multicast
  - As Per-group-overlays (flooding) has many disadvantages, use tree-per-group multicast with Pastry
- Hybrid solution suggested with ALM for inter-domain and IPM for intra-domain
- ... or find another, better approach
Thank you for your interest!

[f1], [f2], [f3]: A. Garyfalos, K. Almeroth, J. Finney - A Comparison of Network and Application Layer Multicast for Mobile Ipv6 Networks, MSWiM’03 San Diego 2003