Mobile P2P After 5 Years – Where are we and where are we headed?

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Avaya Labs Research
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## MP2P Highlights 2004 - 2008

<table>
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<tr>
<th>Year</th>
<th>Location</th>
<th>Organizers</th>
<th>Sessions / Main Topics</th>
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<tr>
<td>MP2P’04</td>
<td>Orlando</td>
<td>Jiannong Cao, Maria Papadopouli, Y. Charlie Hu, Cecilia Mascolo</td>
<td>File Sharing, Routing, Networking Issues</td>
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<td>MP2P’05</td>
<td>Hawaii</td>
<td>Maria Papadopouli, Jiannong Cao, Y. Charlie Hu, Cecilia Mascolo</td>
<td>Information Sharing, Routing, Middleware</td>
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<td>MP2P’06</td>
<td>Pisa, Italy</td>
<td>Kurt Tutschku, Frank-Uwe Andersen, Li Li, Maria Papadopouli</td>
<td>Theoretical Foundations, Applications of MP2P, DHTs in MANETs</td>
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<td>MP2P’07</td>
<td>White Plains, NY</td>
<td>Kurt Tutschku, Li Li, John Buford</td>
<td>P2P in Ad Hoc &amp; MANETs, Platforms, Applications</td>
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<td>MP2P’08</td>
<td>Hong Kong</td>
<td>Kurt Tutschku, Li Li, John Buford</td>
<td>Caching and Load Sharing, P2P SIP, Security</td>
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Topics

• MP2P-1: Mobility in Internet scale P2P overlays
  – Why: P2P overlays support applications which are of interest to mobile users
  – Mobility in large P2P structured overlays
  – Multi-homed Device Roaming
  – Device heterogeneity, adaptivity, power-limits
  – Overlays to support mobility in future Internet

• MP2P-2: P2P overlays + MANETs
  – Why: P2P overlay might be useful abstraction for applications using MANETS
  – P2P overlay routing for MANETs

• MP2P-3: Hybrid
  – Why: Devices will run in both types of networks
  – Mobile devices in multi-overlay topologies (e.g., Internet, PAN, MANETs)
Mobility in Large P2P Structured Overlays

- Over 50 different structured overlay algorithms proposed
  - Logarithmic degree, constant-degree, one-hop, variable hop
- Most evaluated for stability under churn using 1 hour node lifetime or longer
- But, roaming scenarios could shorten node lifetime
  - Native layer address changes are effectively leave-join sequences
- Node lifetime also effected by energy limitations of devices, device usage patterns, and network connection costs
- Higher churn rate means higher bandwidth for structure overlay maintenance
Transition Rates Due to Roaming

802.11n
(Source: R. Stacey, Intel)

<table>
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<tr>
<th>Channel Model D</th>
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<tbody>
<tr>
<td>Over-the-air Throughput (Mbps)</td>
</tr>
<tr>
<td>Range (m)</td>
</tr>
<tr>
<td>legacy 1x1-20 MHz</td>
</tr>
<tr>
<td>2x2-20 MHz</td>
</tr>
<tr>
<td>2x2-40 MHz</td>
</tr>
<tr>
<td>2x3-40 MHz</td>
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</table>

UWB vs 802.11n
(Source: D. Leeper, Intel)

Theoretical Maximum Capacity vs Range for Equivalent UWB and 802.11n Channels

<table>
<thead>
<tr>
<th>WiMax</th>
<th>802.11n</th>
<th>UWB</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 km</td>
<td>100 transitions/hour</td>
<td>400 transitions/hour = 6.7 transitions/min</td>
</tr>
<tr>
<td>Driving at 20km/hour</td>
<td>4 transitions/hour</td>
<td>20 transitions/hour</td>
</tr>
<tr>
<td>Walking at 1 km/hour</td>
<td>0.2 transitions/hour</td>
<td>20 transitions/hour</td>
</tr>
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</table>
Mobility in Large P2P Structured Overlays

• Known techniques for mobility-induced churn
  – Nodes with Mobile IP use Home Address (HoA) in overlay
  – Nodes with fixed addresses act as virtual home agents
  – Quarantine mobile nodes (overlay clients)
  – Stealth nodes (participate in overlay on outgoing messages)

• Evaluation continuing
  – Difficult to evaluate since it requires simulation with both network layer and 100K+ peers
Mobility in Large P2P Structured Overlays

How Does the Overlay Work If > X% of Devices are Mobile?

• **Worst case: all nodes are mobile**
  – To maintain acceptable levels of churn, some % need to use home address (HoA) in overlay
    • Adds additional delay for all messages
  – Or overlay operator could provide super peers to act as home peers for mobile peers
    • Could help those nodes which are roaming far from their HoA

• **Mobile node transitions to another network lead to lost packets during the transition**
  – Possible solutions are
    • Bi-casting the packets to both old and new CoA (care-of address),
    • Buffering packets at the HoA.
How Does the Overlay Work If > X% of Devices are Mobile?

• What about low latency handoffs/Fast MIPv6 and pre-registration?
  – Reduces transition component of delay:

![Diagram showing overlay layers and time components](image-url)
How Does the Overlay Work If > X% of Devices are Mobile?

• Effect on node overlay address
  – Some algorithms compute overlay address from IP address and use this relationship in routing table maintenance to save space in the messages
    • 128 Bytes vs 8 byte

• Effect on proximity awareness
  – Many multi-hop overlays use proximity to select neighbors to reduce hop delay
  – If HoA is used for proximity determination then proximity benefit will be reduced
    • Assume measurement is based on RTT to IP address in overlay routing table
How Does the Overlay Work If > X% of Devices are Mobile?

• Effect on relaying
  – TCP relays are used in overlays for media streaming
  – Relays increase throughput and reduce E2E delay if in mid-stream position
    • Determined through probing
  – If HoA is used for relay selection then relay benefit will be reduced

• NATed mobile nodes also depend on relays for NAT traversal
  – Selection of relay effect delays
  – Is it reasonable to assume that Mobile Nodes will be NATed?
    • These nodes could be gateways for a PAN with sensors and other personal devices
How Does the Overlay Work If > X% of Devices are Mobile?

• Effect on topology-sensitive use
  – A number of types of overlays use topology awareness
    • Improve E2E routing or to
    • Form ALM trees with least delay
  – Topology measurements will be effected
Multi-Homed Peers

WiMax = 100x 802.11n range

- Peer registers in overlay using WiMax connection
- Uses 802.11 for higher-bandwidth transfers with other peers
  - Can first exchange IP address on 2nd interface
- Redundancy
  - Packets which aren’t acked on primary path can be re-sent on wide-area interface
  - Packets can be sent simultaneously on all available interfaces
Overlays to Support Mobility in Future Internet

• Several proposals for the future of the Internet are proposing overlays which are tied in to the infrastructure and support network services including mobility

• Examples
  – SpovNet
  – Service-Aware Transport Overlay (SATO)

• Also IETF HIP WG is designing “HIP-Bone” which provides an overlay using HIP addressing
  – Intended to leverage HIP features include mobility transparency
Device Heterogeneity

- Most overlays assume peers are homogeneous
  - Some have “super-peers”
- For mobile case, network bandwidth varies by type of wireless network and distance from access point
Distribution and Density

• Suppose there are two wireless technologies that have L and H bandwidth capacity respectively
  – Overlay may have peers using different wireless technologies
  – Peers may be close or far to the access point

Certain regions of the network may be heavily L or H

What is the performance over the range?

Density of L and H peers may vary
Heterogeneity vs Adaptivity

• Heterogeneity
  – Different devices in the overlay have different capacities for CPU, storage, access BW
  – These capacities for each device are relatively stable over time

• Adaptivity
  – In a given access network, access BW varies
    • Distance from access point / base station
    • Interference
    • => could be frequent transitions between H-, M-, and L- states
  – Devices support multiple network interfaces
    • Devices roam and encounter different access BW
    • => If multi-homed, transitions could be masked by high bandwidth interface

• => There are few transitions between H-, M-, L- states.
Open Issues

• Heterogeneity
  – Recognize capacity
  – Use it to determine peer role in overlay
  – Design role-specific maintenance and lookup algorithm

• Adaptivity
  – Dynamically recognize capacity
  – Use it to budget maintenance and lookup traffic
  – Design overlay algorithms that adapt
Example: Variable Hop Overlays

- **What?**
  - Each peer in the overlay has bandwidth budget that is allocated to routing table maintenance
  - Higher budget means more routing table updates are exchanged, leading to higher routing table accuracy
  - Each peer manages its budget independently

- **Why?**
  - Devices have heterogeneous resources and access network capacity
  - Latency matters
  - Many nodes have the capacity for more routing table accuracy
  - Doesn’t penalize the low bandwidth nodes
Variable Hop Overlay

• Examples
P2P and MANETs

• The underlay design assumptions for most P2P overlays are quite dissimilar from the routing architectures proposed for MANETs
  – MANETs characterized by low bandwidth, higher error rate of the wireless medium, and low computation power of each node
  – Energy preservation is also a vital consideration in the protocol design
• DHT might provide a useful abstraction for some applications
  – Not clear that unstructured overlays have a significant value add
• If MANET is small then flooding/broadcast could be used as alternative to the usual DHT overlay routing
P2P and MANETs

• Survey of recent work
  – Discusses: Ekta, MPP, Gnutella optimization for Manet, FastTrack over AODV, and MADPastry

• Issues
  – Given a cross-layer approach provides better performance and reduces network overhead
    • is it better to integrate the layers or to have 2 layers with an interlayer protocol?
  – Is it worth to implement a DHT abstraction in a Manet environment, even if in a cross-layer fashion?
    • Less benefit as mobility increases and as size of MANET shrinks
## P2P and MANETS

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<tbody>
<tr>
<td>To provide an efficient DHT substrate in Manet</td>
<td>To provide a protocol suite for efficient P2P applications in a Manet</td>
<td>Optimization of an unstructured P2P protocol for Manet usage</td>
<td>To provide a common framework where P2P file sharing and ad-hoc networks are integrated</td>
<td>To provide a DHT substrate explicitly designed for Manet</td>
<td></td>
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<table>
<thead>
<tr>
<th>P2P overlay protocol</th>
<th>Pastry</th>
<th>Gnutella-like</th>
<th>Gnutella</th>
<th>FastTrack</th>
<th>Pastry</th>
</tr>
</thead>
<tbody>
<tr>
<td>P2P protocol typology</td>
<td>DHT-based</td>
<td>unstructured</td>
<td>unstructured</td>
<td>unstructured (supernode usage)</td>
<td>DHT-based</td>
</tr>
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<table>
<thead>
<tr>
<th>Routing algorithm</th>
<th>DSR</th>
<th>DSR (modified)</th>
<th>OLSR</th>
<th>AODV</th>
<th>AODV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Routing alg. typology</td>
<td>reactive</td>
<td>reactive</td>
<td>proactive</td>
<td>reactive</td>
<td>reactive</td>
</tr>
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</table>

| Main design principle | Integrated approach at network layer | A protocol suite with a vertical interlayer communication protocol. Reusing of existing protocol as far as possible. | Cross-layer interface to synchronize on shared data structure and to react to events generated at different layers. | Integrated approach at network layer | Integrated approach at network layer to provide indirect-routing functionality |

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<th>Performance evaluation</th>
<th>Comparison with a Gnutella-like behaviour</th>
<th>Comparison with the ORION system</th>
<th>Comparison with the legacy Gnutella behaviour</th>
<th>Comparison with the layered approach with and w/o supernodes</th>
<th>Comparison with Pastry and a Gnutella-like behaviour</th>
</tr>
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</table>

| Prototype implementation | Yes (Linux based) | No (SDL specification) | No | No | No |
Hybrid Cases

• Hybrid Ad Hoc – Infrastructure case
  – A kind of federated overlay problem (see next slide)

• Why?
  – Provide E2E continuity for applications
Approaches

1) All peers in PAN/BAN overlays participate in Internet overlay
   - Peer overlay address uniqueness across overlays to avoid collisions in the address space
     • Could use a hierarchical address scheme
   - Maintaining visibility of data across the two overlay networks.
     • Peers in an PAN/BAN determine what data of theirs is to be visible in global DHT
     • Explicit put to global DHT

2) A peer in the PAN/BAN DHT acts as a gateway (GW) to the global DHT
   - GW peer has a unique identifier in the global DHT
   - Requests to the global DHT get routed through the GW peer
   - GW Peer may change due to power and use
Conclusion: MP2P 09

- Peer-to-peer overlays for MANETs and sensor networks
- Hybrid P2P architectures for integrated MANETs and wide-area networks
- Large-scale heterogeneous P2P systems
- Mobility in federated overlay architectures
- Impact of network mobility on P2P systems and services (mobile IP / MANET)
- P2P-based information sensing and fusion
- MP2P performance & measurement studies
- Semantic routing & overlay routing in MP2P
- Delay tolerant MP2P systems
- Resource and service discovery in MP2P
- Resource exchange mechanisms in MP2P
- Peer access and control in mobile environment
- Data exchange and rendering techniques for mobile P2P devices
- Secure communication protocols for MP2P
- Nature-inspired algorithms for MP2P
- Novel MP2P applications & services
- Theoretical issues on mobile information diffusion
- MP2P SIP
- MP2P messaging systems, monitoring systems, searching systems, games, etc.
- Location dependent MP2P services
- MP2P over different bearer services: 2.5/3G (GPRS/UMTS) / 802.11 (WLAN)
- MP2P & operator/provider requirements
- Reliability and carrier-grade performance of MP2P services
Thank you!