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

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MP2P Highlights 2004 - 2008

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

Topics

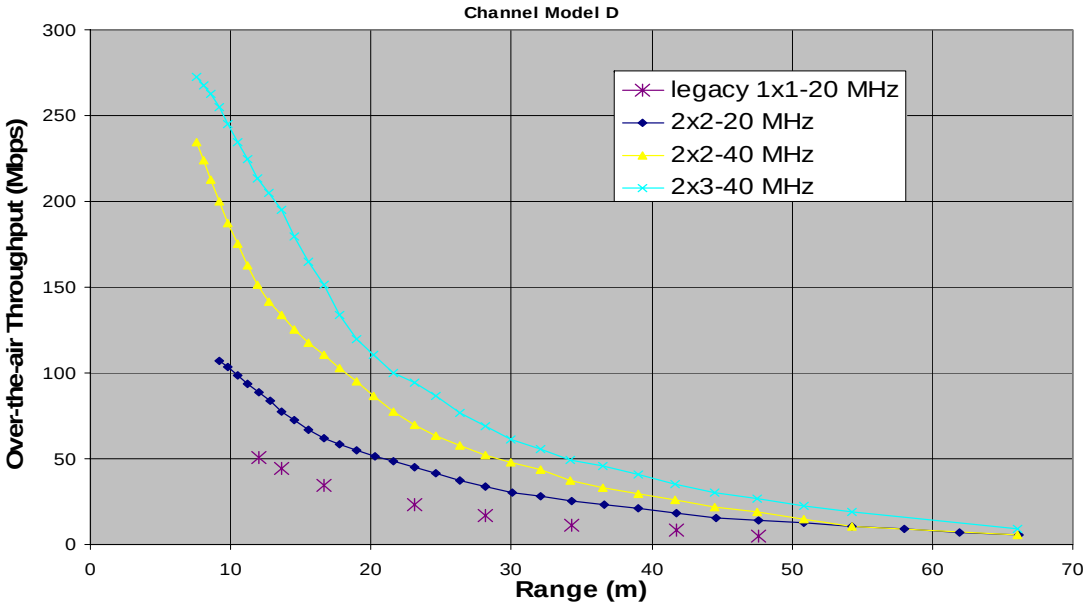
- MP2P-1: Mobility in Internet scale P2P overlays
  - Why: P2P overlays support applications which are of interest to mobile users
  - Mobility in large P2P structured overlays
  - Multi-homed Device Roaming
  - Device heterogeneity, adaptivity, power-limits
  - Overlays to support mobility in future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

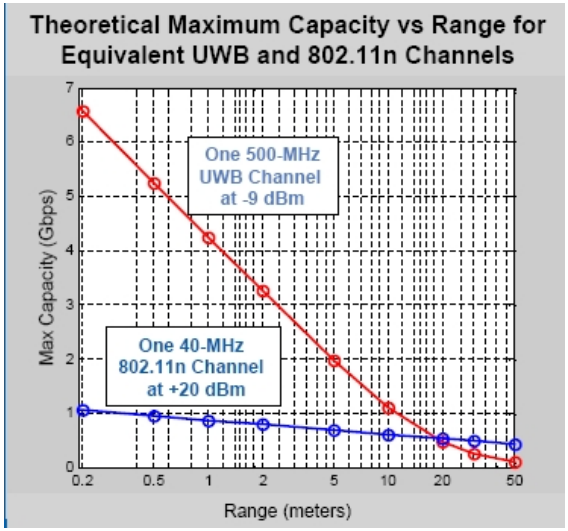
- Over 50 different structured overlay algorithms proposed
  - Logarithmic degree, constant-degree, one-hop, variable hop
- Most evaluated for stability under churn using 1 hour node lifetime or longer
- But, roaming scenarios could shorten node lifetime
  - Native layer address changes are effectively 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)



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



	WiMax 5 km	802.11n 50m	UWB 10m
Driving at 20km/hour	4 transitions/hour	400 transitions/hour = 6.7 transitions/min	2000 transitions/hour or 0.55 transitions/sec
Walking at 1 km/hour	0.2 transitions/hour	20 transitions/hour	100 transitions/hour

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

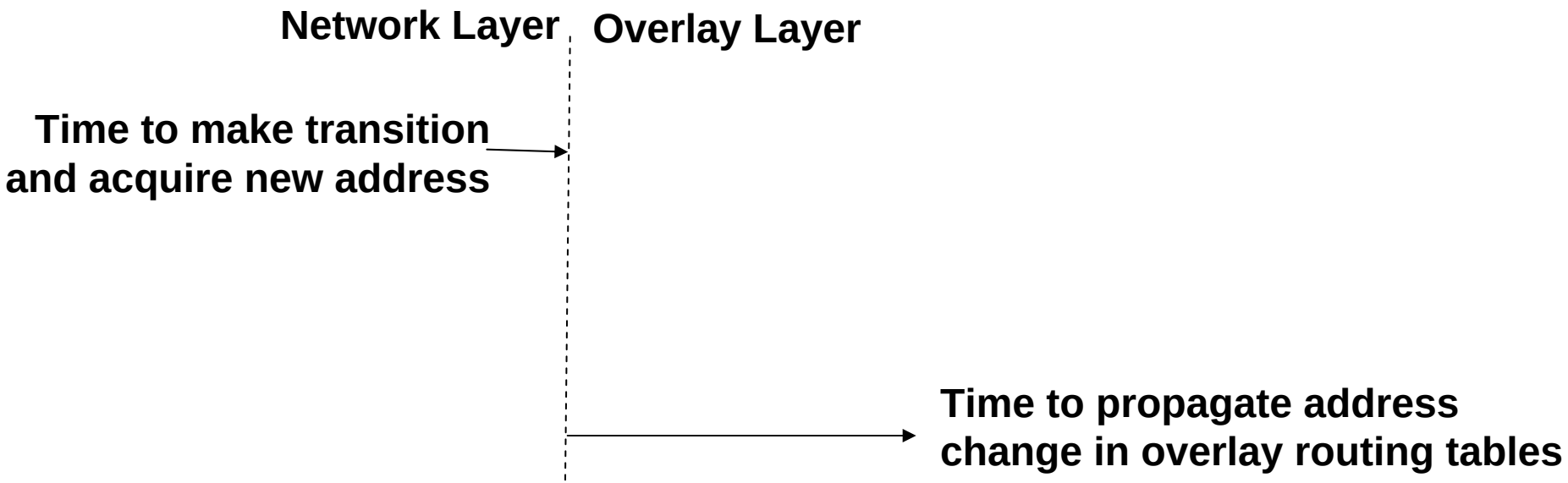
- H.-C. Hsiao, C.-T. King, Bristle: A Mobile Structured Peer-to-Peer Architecture. *International Parallel and Distributed Processing Symposium* (IPDPS'03), 2003.
- O. Landsiedel, S. Götz, K. Wehrle. Towards Scalable Mobility in Distributed Hash Tables. *Sixth International IEEE Conference on Peer-to-Peer-Computing*, Cambridge, UK, August / September 2006
- A. MacQuire, A. Brampton, I. Rai, L. Mathy. Performance Analysis of Stealth DHT with Mobile Nodes, *Fourth IEEE Workshop on Mobile Peer-to-Peer 2006*.

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
  - Possibile 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:



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

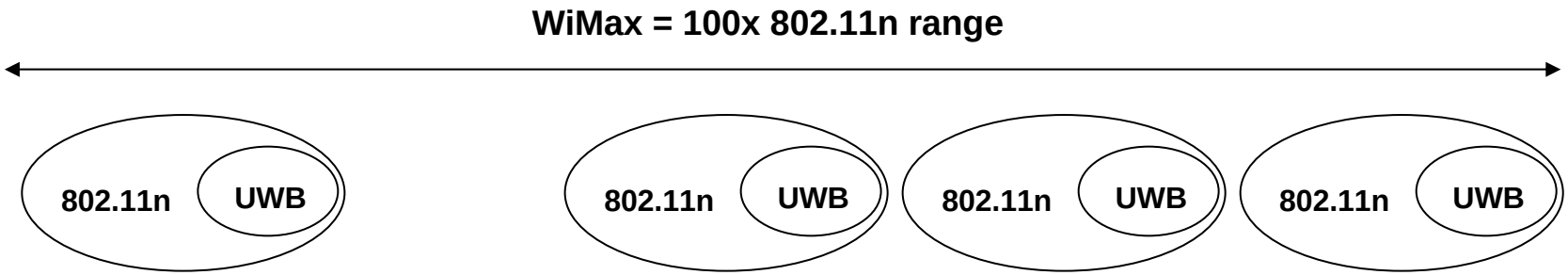
How Does the Overlay Work If > X% of Devices are Mobile?

- 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
    - J. Buford, A. Wang, X. Hei, Y. Liu, K. Ross. Discovery of In-Band Streaming Services in Peer-to-Peer Overlays. IEEE Globecom 2007, Nov. 2007.
  - 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-sensitve 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



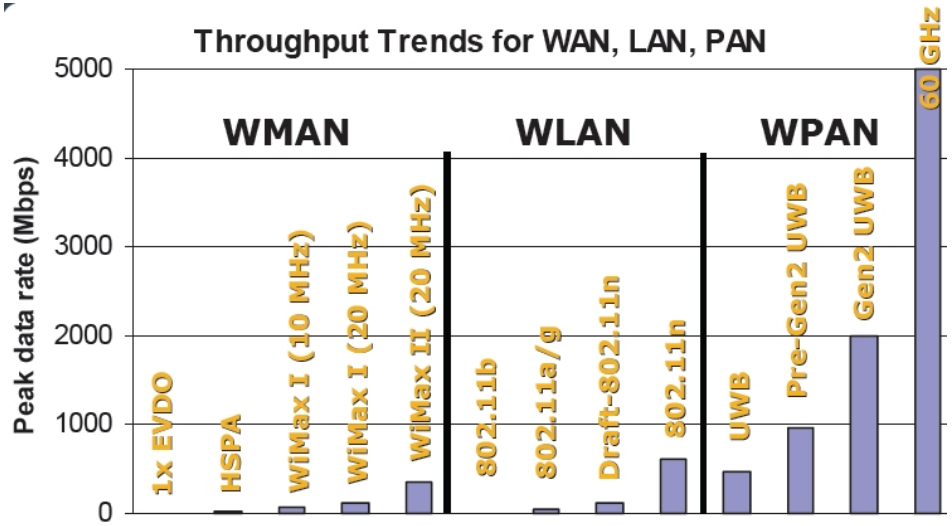
- Peer registers in overlay using WiMax connection
- Uses 802.11 for higher-bandwidth transfers with other peers
  - Can first exchange IP address on 2nd interface
- Redundancy
  - Packets which aren't acked on primary path can be re-sent on wide-area interface
  - Packets can be sent simultaneously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

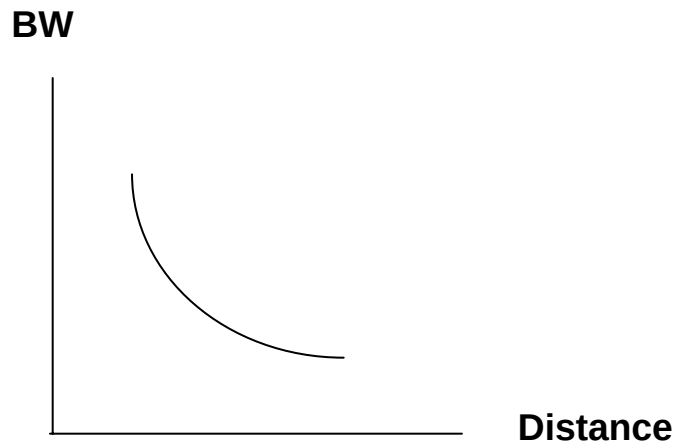
Overlays to Support Mobility in Future Internet

- 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

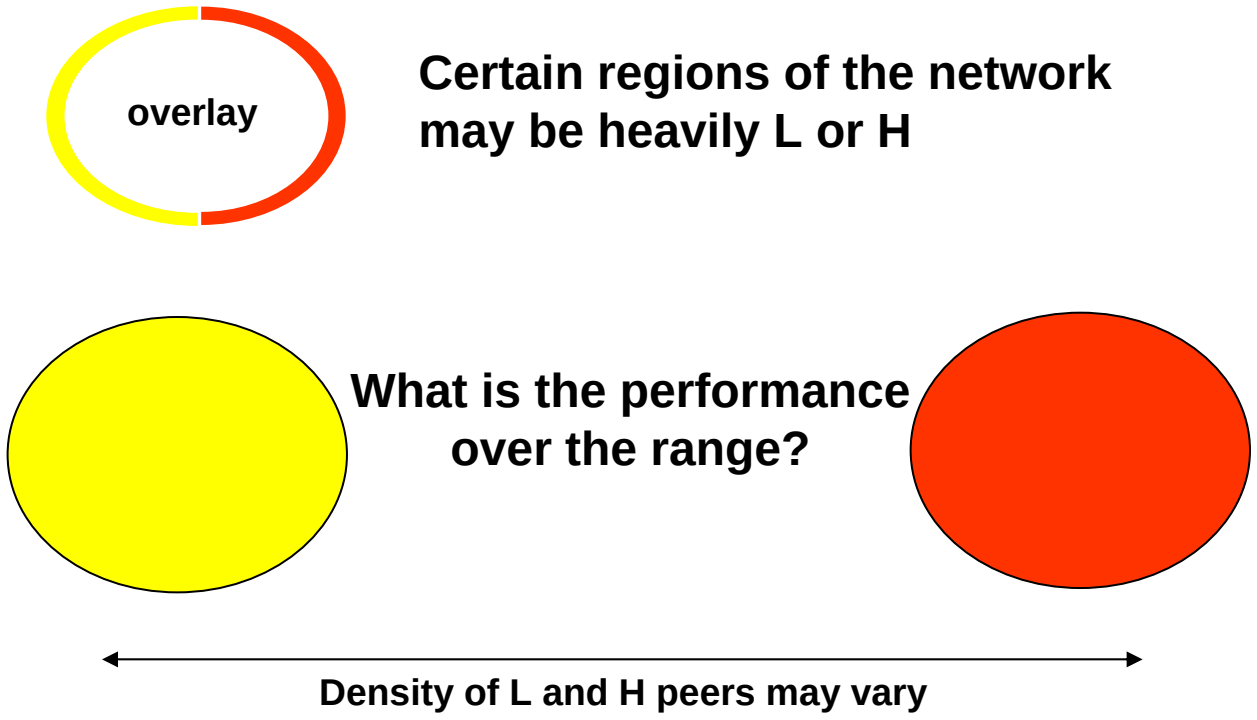
- Most overlays assume peers are homogeneous
  - Some have “super-peers”
- For mobile case, network bandwidth varies by type of wireless network and distance from access point





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



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

- 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

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
  - Jinyang Li, Jeremy Stribling, Robert Morris and M. Frans Kaashoek. Bandwidth-efficient management of DHT routing tables. In the Proceedings of the 2nd USENIX Symposium on Networked Systems Design and Implementation (NSDI '05), Boston, MA, 2005.
  - A. Brown, M. Kolberg, J. Buford. An Adaptable Service Overlay for Wide-Area Network Service Discovery. IEEE Globecom 2007 Workshop - Enabling the Future Service-Oriented Internet. Nov. 2007
  - A. Brown, J. Buford, M. Kolberg. Tork: A Variable-Hop Overlay for Heterogeneous Networks. Fourth Workshop on Mobile Peer-to-Peer 2007. March 2007

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
  - M. Bisignano, G. Di Modica, Tomarchio, Orazio; L. Vita. P2P over Manet: a comparison of cross-layer approaches. 18th International Conference on Database and Expert Systems Applications, 2007. DEXA '07. 3-7 Sept. 2007, 814 - 818
  - 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

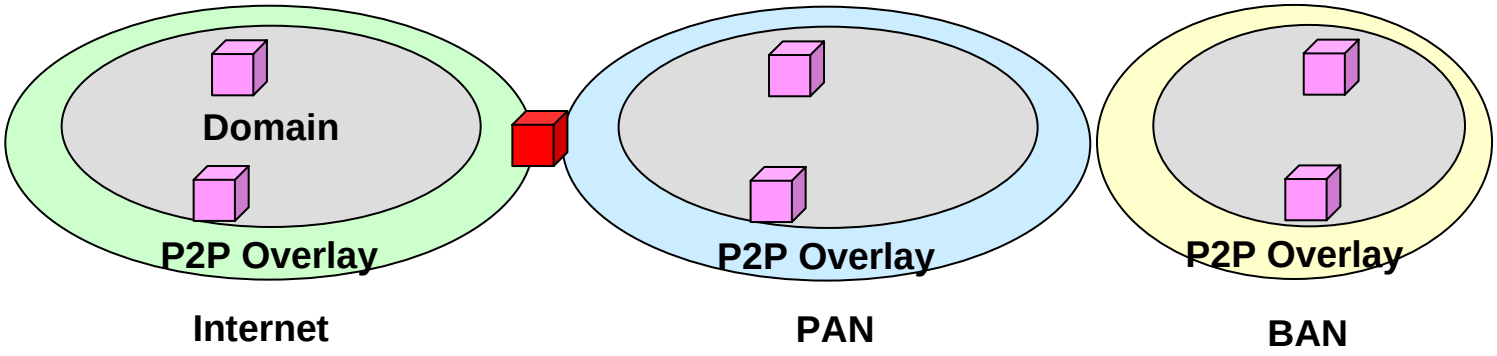
P2P and MANETS

	Ekta [11]	**MPP** [7, 6]	**Gnutella over Manet** [4]	**FastTrack over AODV** [15]	**MADPastry** [17]
Main goal	To provide an efficient DHT substrate in Manet	To provide a protocol suite for efficient P2P applications in a Manet	Optimization of an unstructured P2P protocol for Manet usage	To provide a common framework where P2P file sharing and ad-hoc networks are integrated	To provide a DHT substrate explicitly designed for Manet
P2P overlay protocol	Pastry	Gnutella-like	Gnutella	FastTrack	Pastry
P2P protocol typology	DHT-based	unstructured	unstructured	unstructured (supernode usage)	DHT-based
Routing algorithm	DSR	DSR (modified)	OLSR	AODV	AODV
Routing alg. typology	reactive	reactive	proactive	reactive	reactive
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
Performance evaluation	Comparison with a Gnutella-like behaviour	Comparison with the ORION system	Comparison with the legacy Gnutella behaviour	Comparison with the layered approach with and w/o supernodes	Comparison with Pastry and a Gnutella-like behaviour
Prototype implementation	Yes (Linux based)	No (SDL specification)	No	No	No

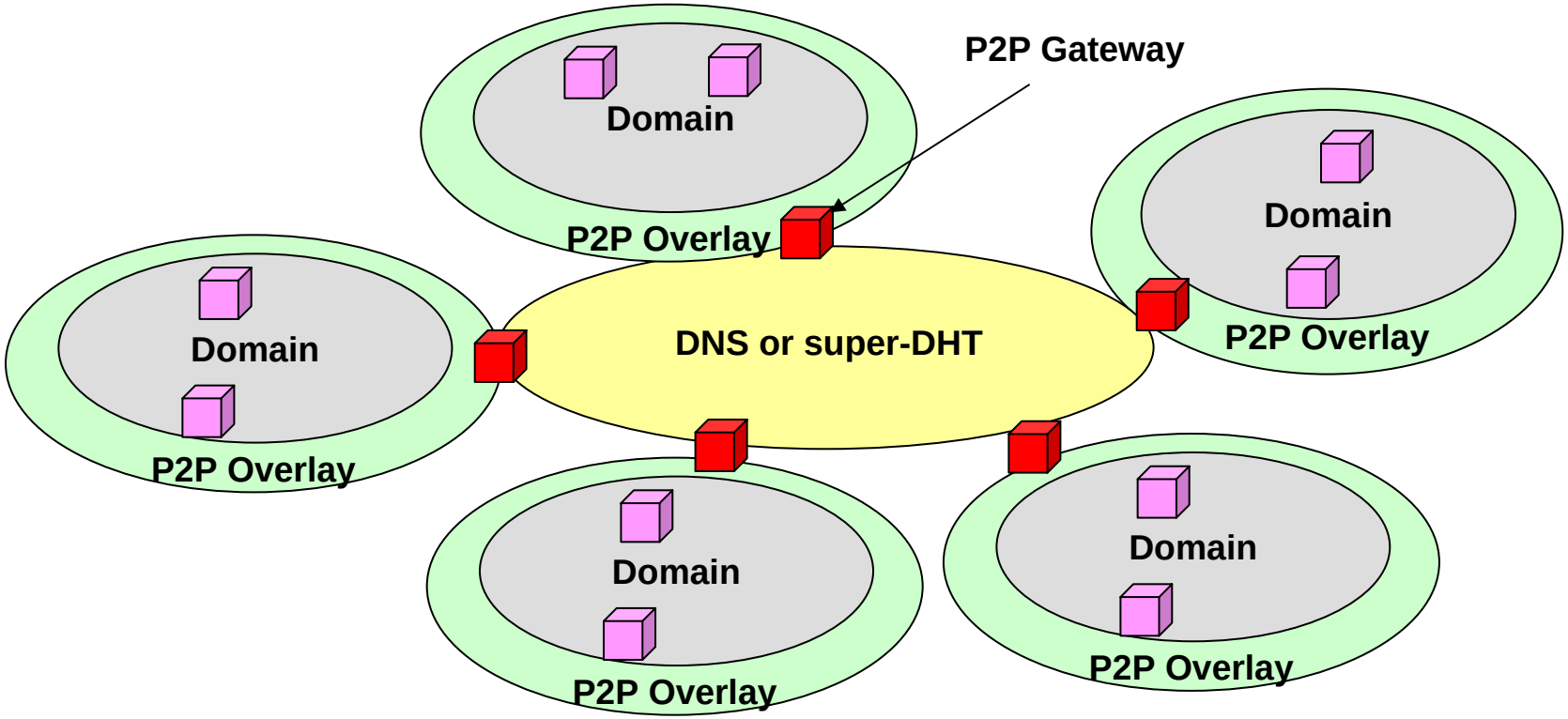
Source: M. Bisignano, G. Di Modica, Tomarchio, Orazio; L. Vita. P2P over Manet: a comparison of cross-layer approaches. 18th International Conference on Database and Expert Systems Applications, 2007. DEXA '07. 3-7 Sept. 2007, 814 - 818

Hybrid Cases

- Hybrid Ad Hoc – Infrastructure case
  - A kind of federated overlay problem (see next slide)
- Why?
  - Provide E2E continuity for applications



Federated Overlay



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!