Mobility- and Topology-aware Peer-to-Peer Infrastructures for Location Based Services

Jochen Schiller, Rolf Winter

Computer Systems & Telematics
Freie Universität Berlin
[schiller, winter]@inf.fu-berlin.de

New Topics for LBS

- Powerful mobile devices
- Short range communication
- Ad-hoc applications, spontaneous interaction
- Provider/operator independent applications
- Light-weight applications
- Relative locality sufficient for many applications
- Social aspect might be important
- Low cost info provider

- Examples:
  - tourist information system
  - ad-hoc gaming
  - friend finder

ScatterWeb Nodes

- Embedded Sensor Board
  - Luminosity sensor
  - Noise detection
  - Vibration sensor
  - PIR movement detection
  - Microphone/speaker
  - IR sender/receiver
  - Precise timing
  - Communication using 868 MHz radio transceiver
  - Simple programming (C interface)

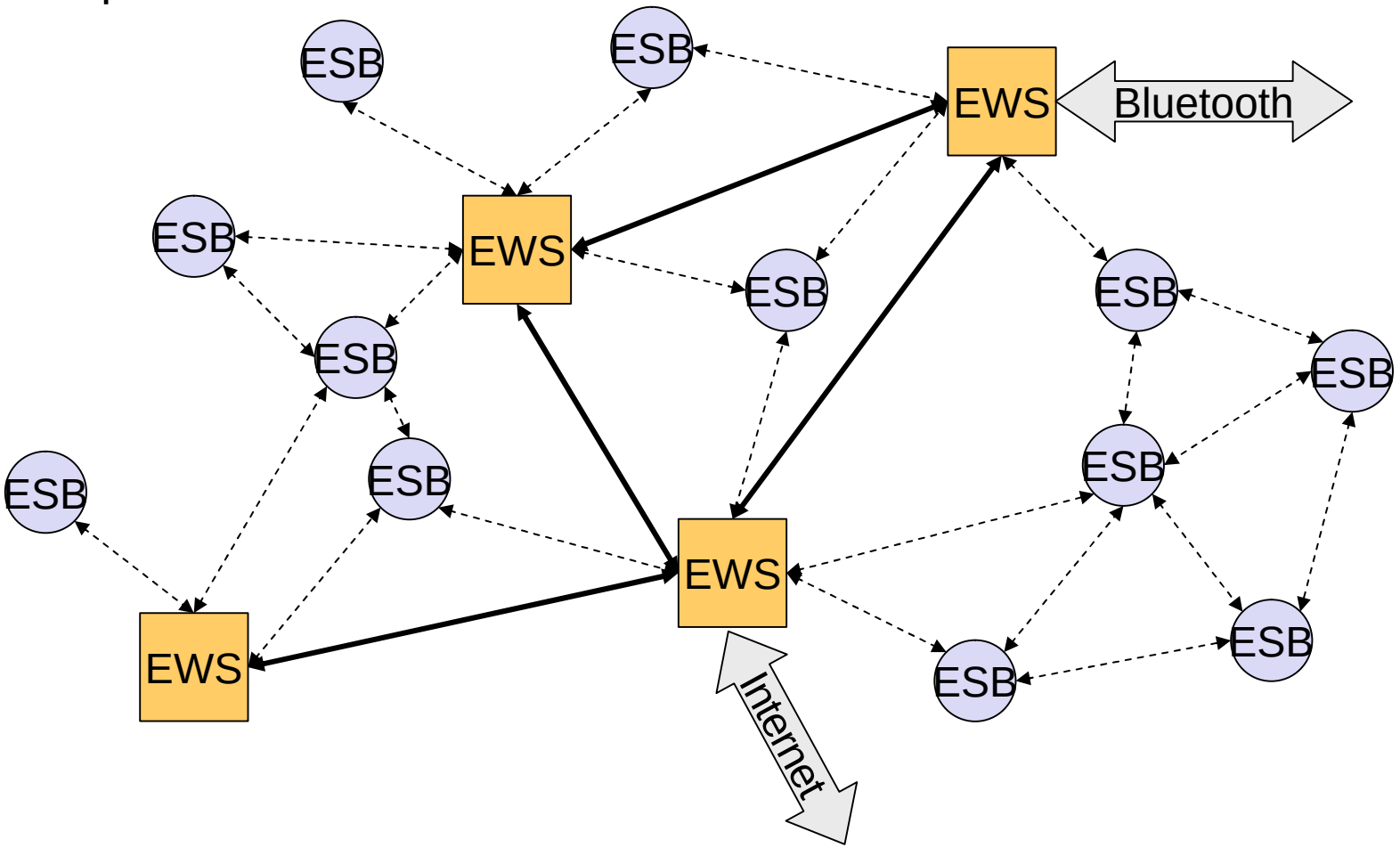
Further information:
www.scatterweb.net

Embedded Sensor Board

Modular Sensor Node

ScatterWeb

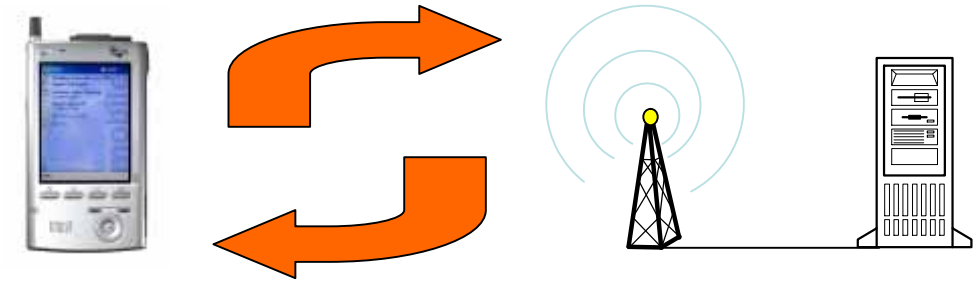
- Interoperation between sensor network and web server



Communication Paradigms

Classical approach (centralized):

Client-Server:



- Single point of failure
- Bottleneck
- Administration
  → Cost

Business model support

Emerging approach (decentralized):

Peer-to-Peer:

- Self-organizing
- Self-configuring
- Robust against failure
- Load distribution

Community support

Peer-to-Peer (P2P) Paradigm

- *Overlay* network of “equal” peers
- Self-organizing
- No central server and/or administration
- Peers can „directly“ talk to each other (on the overlay)

Issues:

- Peer discovery
- Data dissemination and retrieval

} P2P substrate‘s main task

- Discrepancy between overlay topology and underlying topology
- Mobility
  → Topology changes over time

} Problematic for LBSs without common localization means

Common Localization

Localization with the help of…

- GPS

- Cell information
  (Mobile phone)
- Localized short-range radios
  (e.g. DriveBy InfoFueling)

A P2P Substrate for LBS

Structured Peer-to-Peer overlay (DHT based)

Desired properties:

- Topological localization (overlay and underlay)
- Relative location to others

Advantages:

- No extra hardware is required on the client side (e.g. GPS receiver)
- No infrastructure is required (satellite system, access points)

Disadvantages:

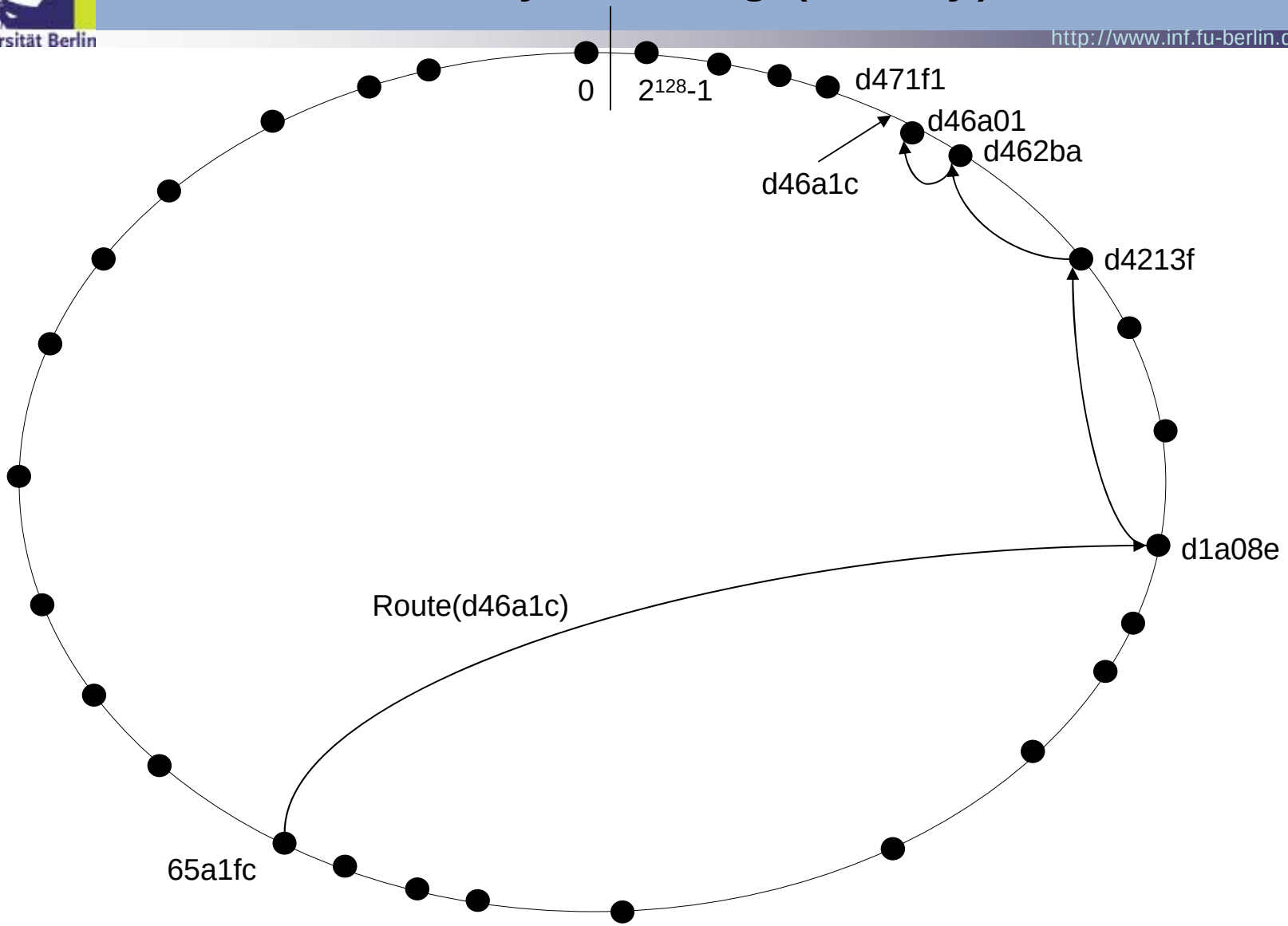
- Absolute localization is not possible

Problem of current approaches : Overlay does not reflect the physical topology
→ Not suitable for LBS

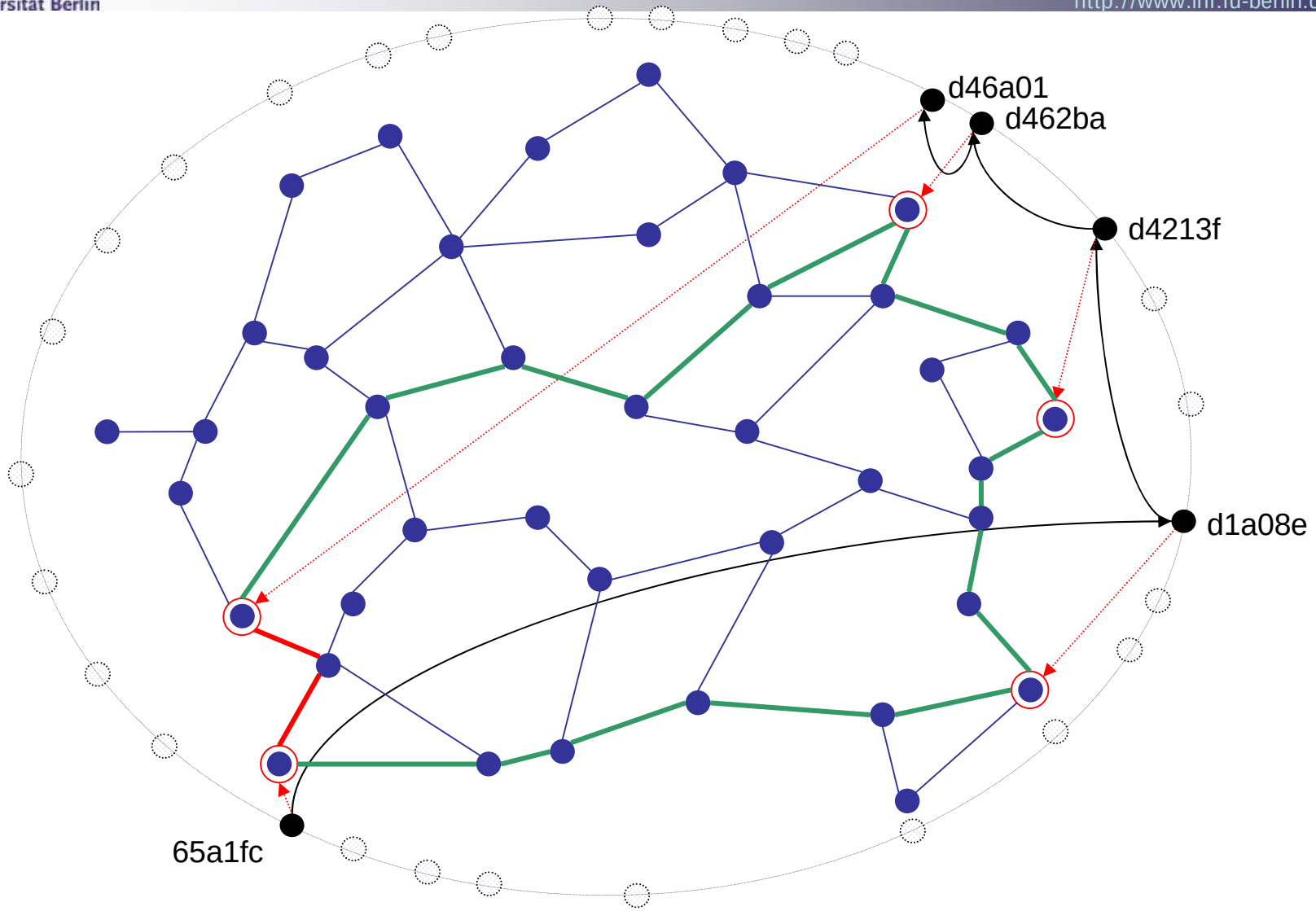
Distributed Hash Tables

- Each participating node is assigned a hash ID (e.g. hash on node's IP address, etc.)
- Every object also has a hash ID in the same ID space
- Object is stored on node whose ID is closest to object's ID
- Each node keeps track of only a certain number (typically O(log n)) of other nodes
- All DHTs provide one basic operation: **lookup(key)** → **node**
- Key lookup in O(log n) overlay hops

Overlay Routing (Pastry)



Overlay vs. Physical Topology (Overlay stretch)



The Two Major Problems

1.

There is no relation between the overlay ID and the underlying topology

2.

Lookup processes can have an highly inefficient overlay stretch

Topology Awareness the "Dynamo Way"

Dynamo has two different approaches:

A. Random Landmarking

- Landmark measurement to temporary landmarks (landmark keys)
- Assignment of own ID according to the closest landmark

<not resilient against node mobility>

B. Closest Neighbor Prefix Assignment

- *Neighbor detection phase (part of Pastry's join procedure)*
- *Assignment of own ID according to closest neighbor*

Mechanisms

Random Landmarking:

- "Landmark gravitation range" used to distribute ID equally during bootstrap
- Intelligent landmark caching
- Adaptive landmark re-measurement periods in mobile networks
- Fine-grained → mobility-resilient

Closest Neighbor Prefix Assignment:

- *Gravitation range similar to RLM during bootstrap*
- *More coarse-grained → less overhead*

Overlay ID Interpretation

- The prefix corresponds to a node‘s location. In other words nodes with a common overlay ID prefix are close to each other.

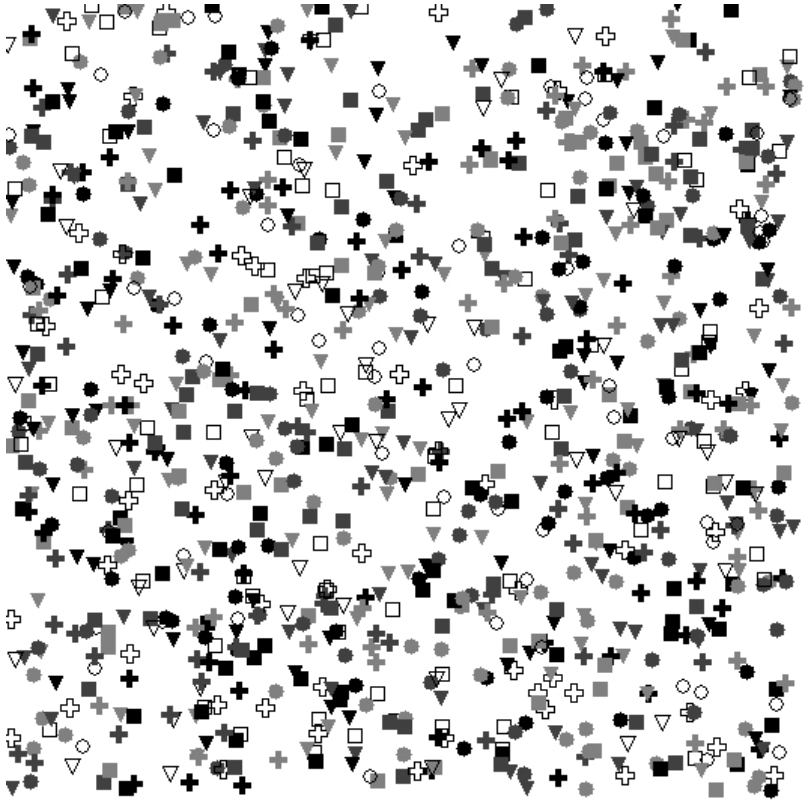
- The rest of the overlay ID could

  … be further split up and associated with a meaning (semantics, categorization, profiling).

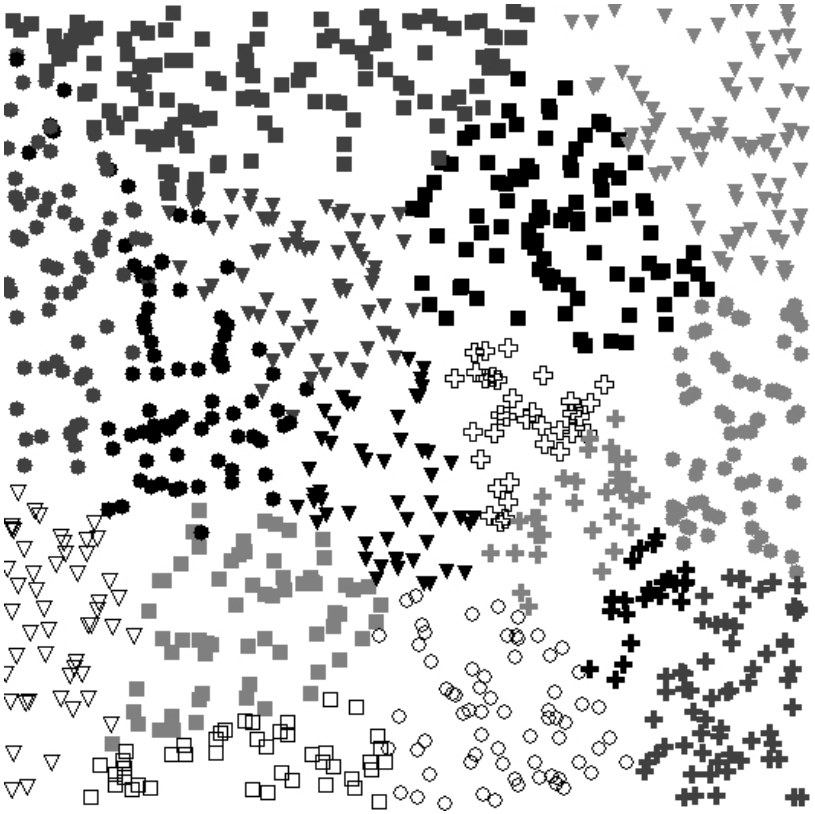
  … represent an object (files, profiles, applications, resources…).

Topology Map

Pastry

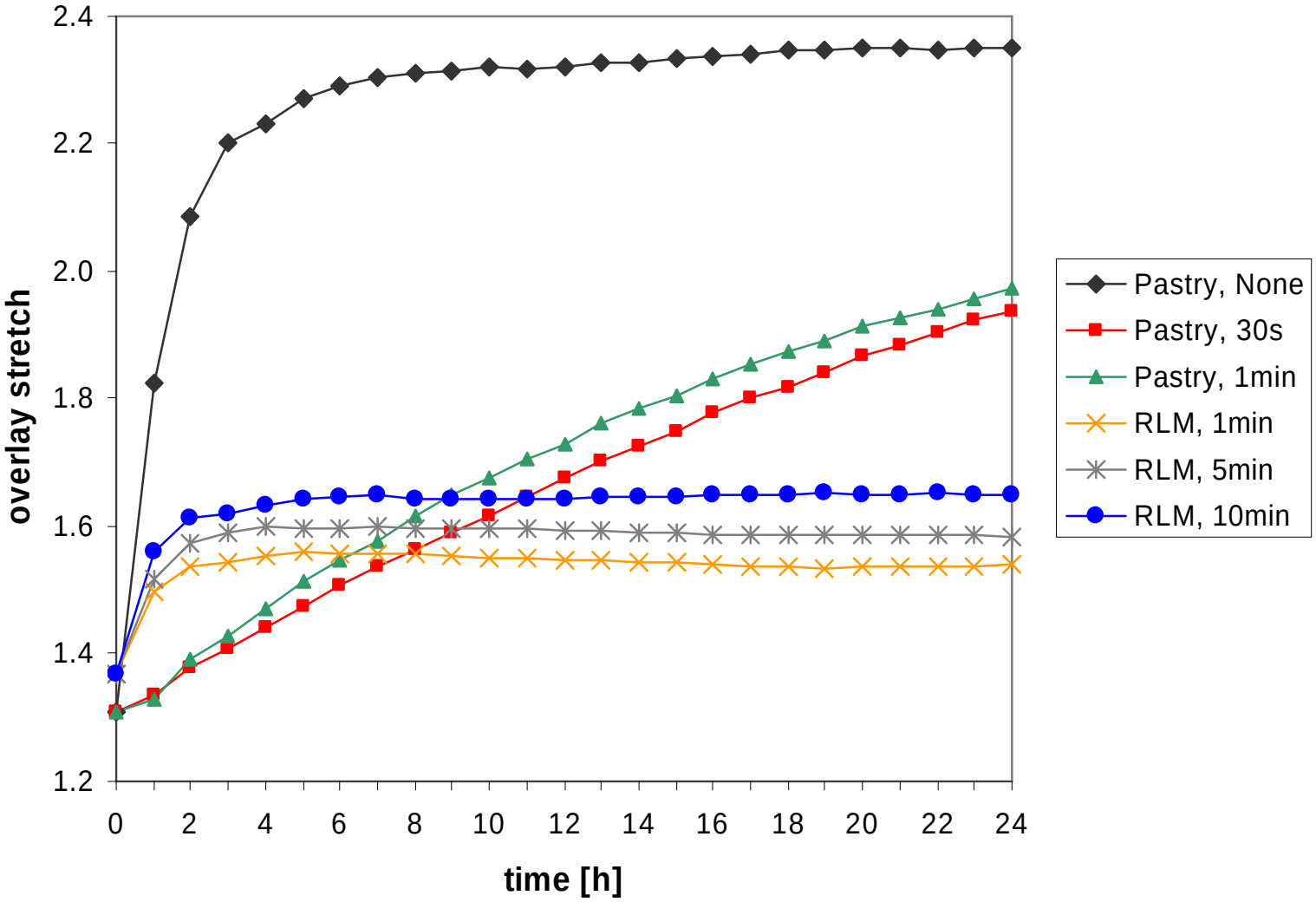


DynaMO

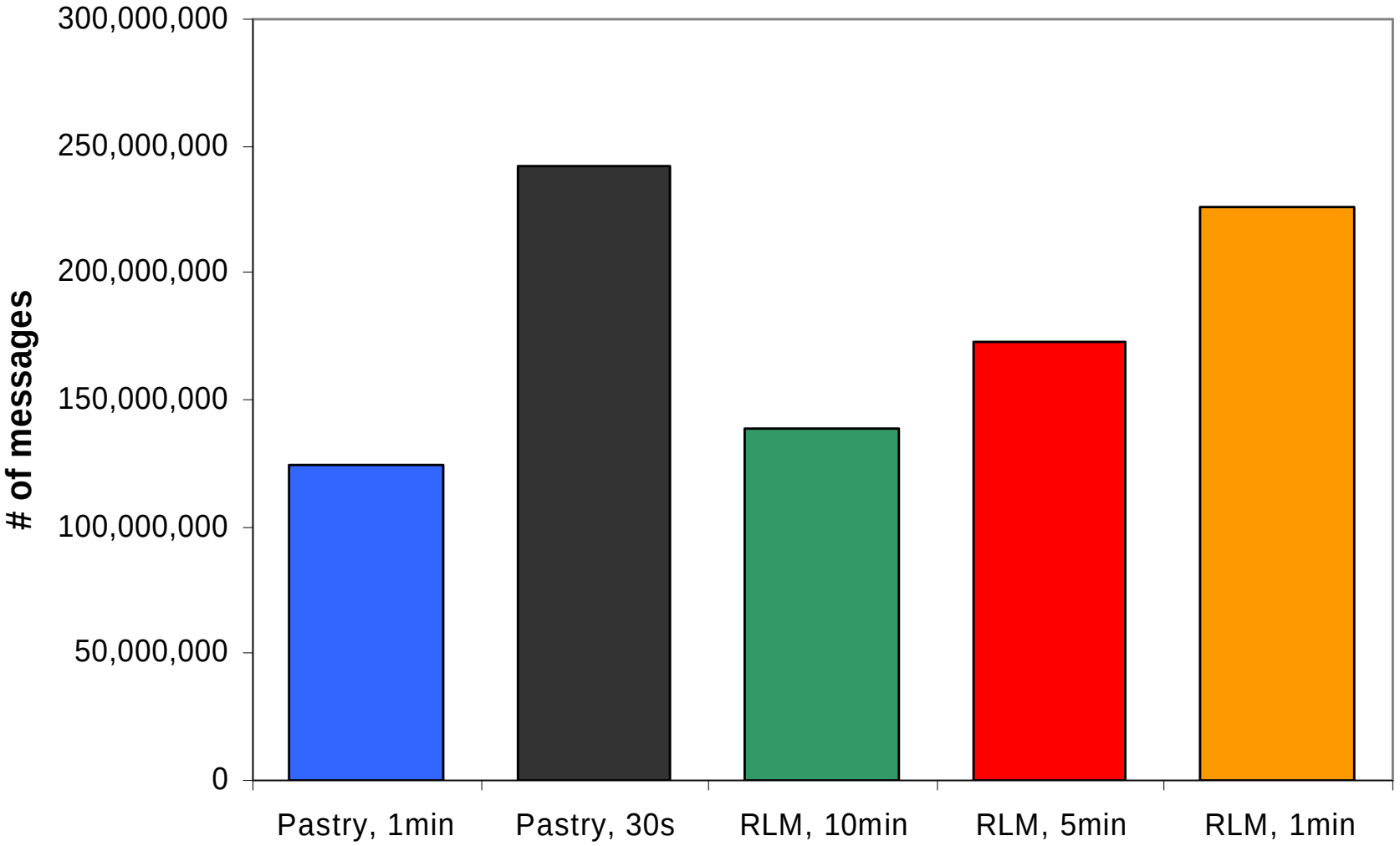


Equal symbols and shades represent equal overlay ID prefixes

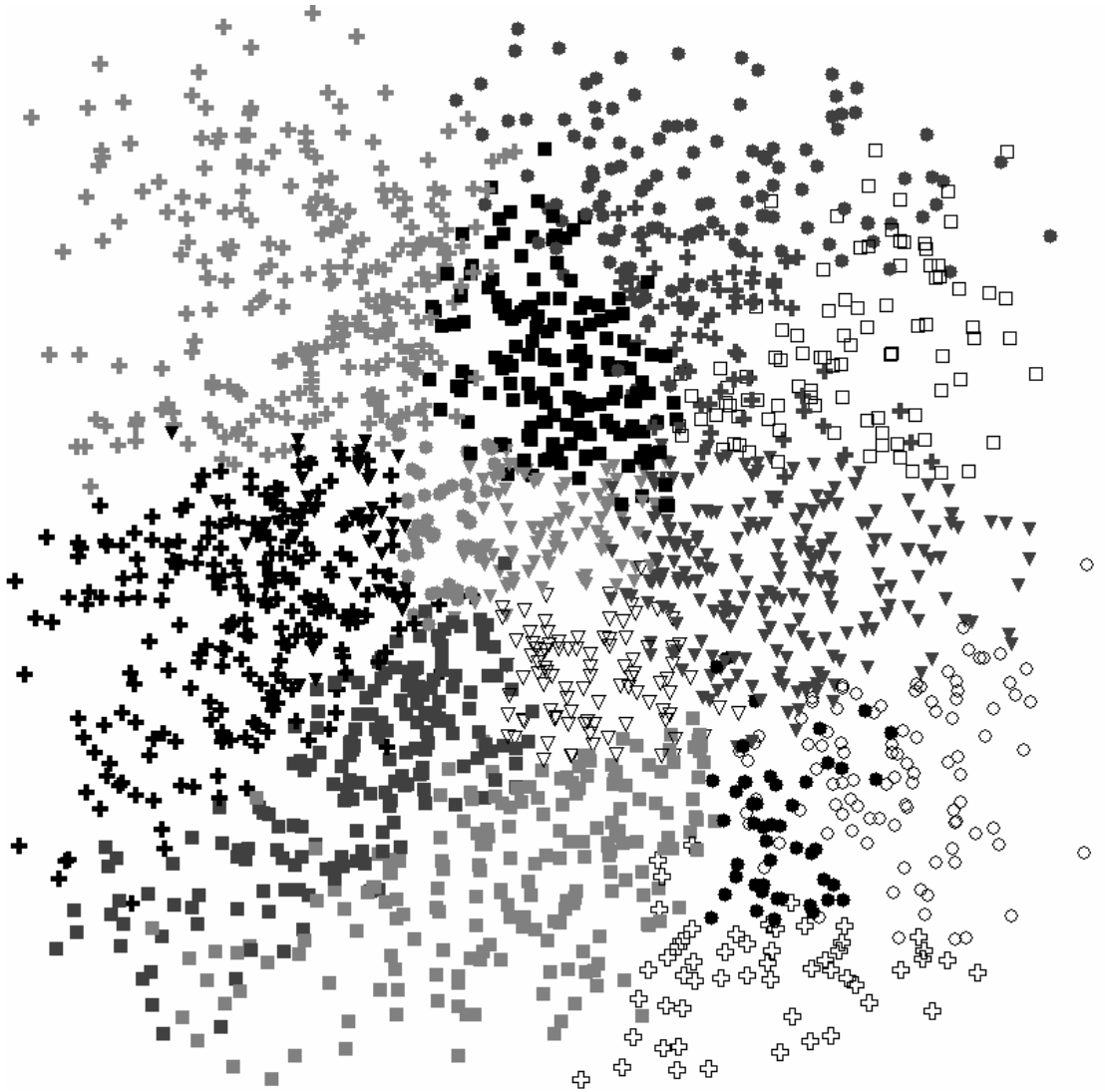
Mobility I: Overlay stretch



Mobility II: Overhead



Mobility III: Topology



Application scenarios

- Applications were locality plays an important role: (Relative or fuzzy) **Location Based Services**. „Is anyone near me who…?“ **not** „Does anyone currently on highway 10 know…?“
- Applications with high lookup rates: Monitoring applications (certain sensornetworks etc.)
- Applications which require a higher QoS, since paths in the physical network are shorter compared to Pastry
- Applications which mainly interact with their own (common prefix) cluster nodes and only infrequently with nodes of other clusters (applications with social implication: mobile gaming etc.)

Conclusion

- New features of mobile devices enable new LBS infrastructures
  - Ad-hoc, short-range communication, peer-to-peer
  - Low-cost, flexible, robust
- Peer-to-Peer infrastructures have to take into account
  - physical topology
  - node mobility
- DynaMO provides
  - ID clustering resulting in zones (locality)
  - Strong mobility & degression resilience
  - Less communication overhead compared to current approaches
  - Lightweight implementation

Future Work

Short-term:

- Implementation of DynaMO on Windows Mobile 2003 PDAs and ESB/2 sensorboards (www.scatterweb.net)

Long-term:

- Designing a component which maps cooperation onto communication patterns under QoS constraints
- Load balancing strategies
- Application of multicast, concast, anycast etc.
- Location awareness

Publications

R. Winter, T. Zahn, J. Schiller, Topology-Aware Overlay Construction in Dynamic Networks

Proc. of 3rd International Conference on Networking, Guadeloupe, France (DOM), 2004

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10th International Workshop on Future Trends in Distributed Computing Systems, China, 2004

Winter, R., Zahn, T., Schiller, J., DynaMO: Applying Topological Locality to the Construction of Dynamic, Mobility-Aware Overlays,

Technical Report B 03-04, Freie Universität Berlin, February 2004