Evaluating Mobility Pattern Space Routing for DTNs

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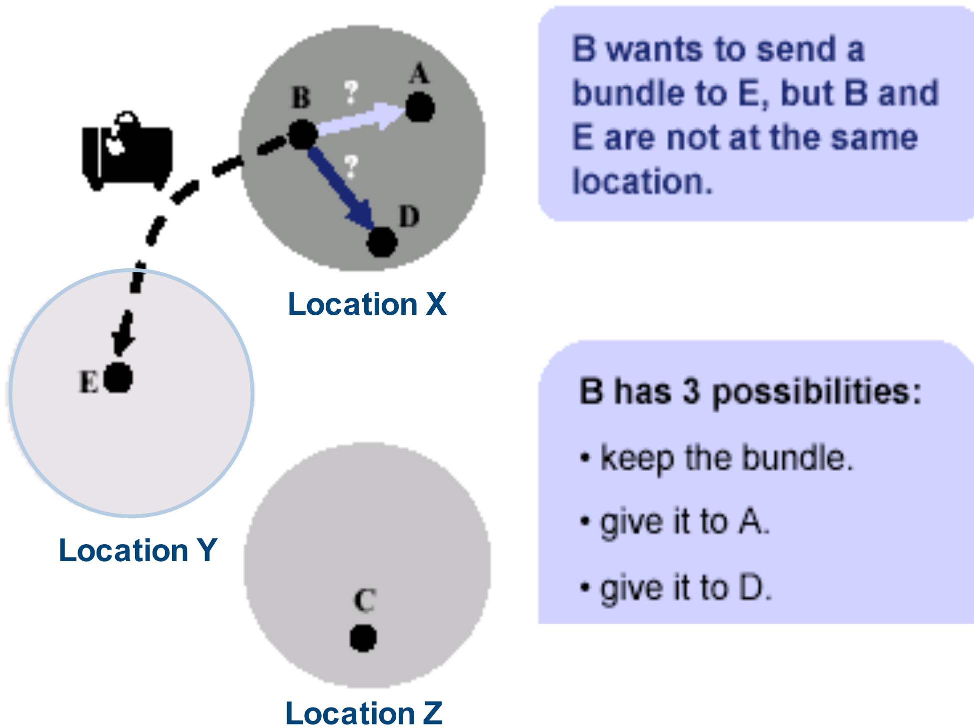
- Main Contribution
  - Euclidean virtual space for DTN (Delay Tolerant Networks) routing
    - Space built on mobility patterns
  - Evaluation using “real” mobility traces

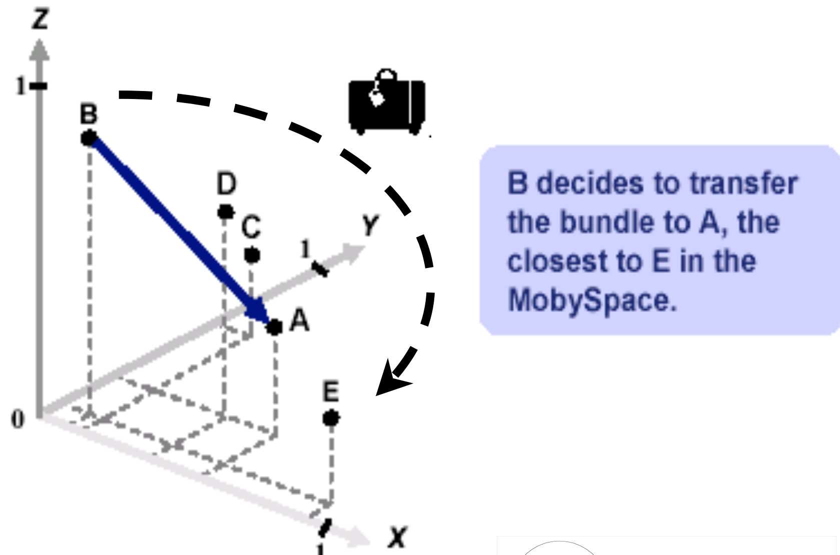
- Outline
  - Problem statement
  - Routing proposition
  - Dartmouth data
  - Simulation results

- Problem of routing
  - **Routing is a challenge in DTNs** (Delay Tolerant Networks) [Lindgren, Burgess, Wang, Widmer, …]. Regular ad hoc routing protocols fail because topology suffers from connectivity disruptions:
    - Partitions
    - Long-delay links
  - Example:



- Our contribution: MobySpace [WDTN]
  - Routing decisions are taken using nodes' **mobility patterns.**
  - Give bundles to nodes that we believe are **more likely** to deliver them.
  - Use of a **virtual Euclidean space** to make routing decisions.

- MobySpace usage
  - A node's mobility pattern defines its position in the virtual Euclidean space.
  - To route a bundle, a node passes the bundle to the neighbor whose position is closest to the destination's.



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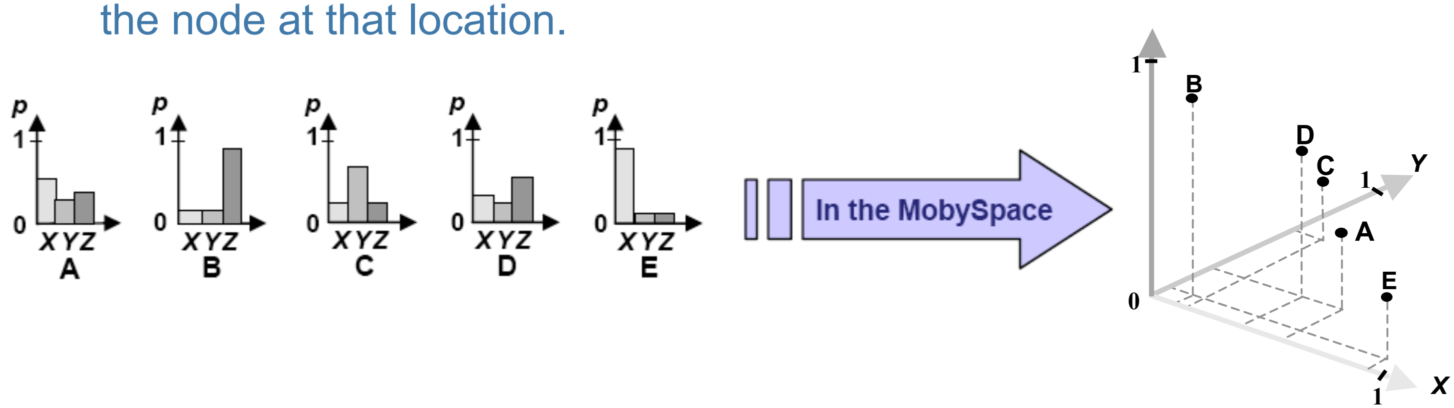
MobySpace concept

- A MobySpace is defined by:
  - The number of dimensions
  - The meaning of the dimensions (a probability, a frequency, etc…)
  - A distance function

- Examples of MobySpace:
  - **Frequency of visit based:** Each dimension in the MobySpace represents a physical location. Each coordinate corresponds to the probability of finding the node at that location.



  - **Contact based:** Each dimension in the MobySpace represents the frequency of contacts between two given nodes.

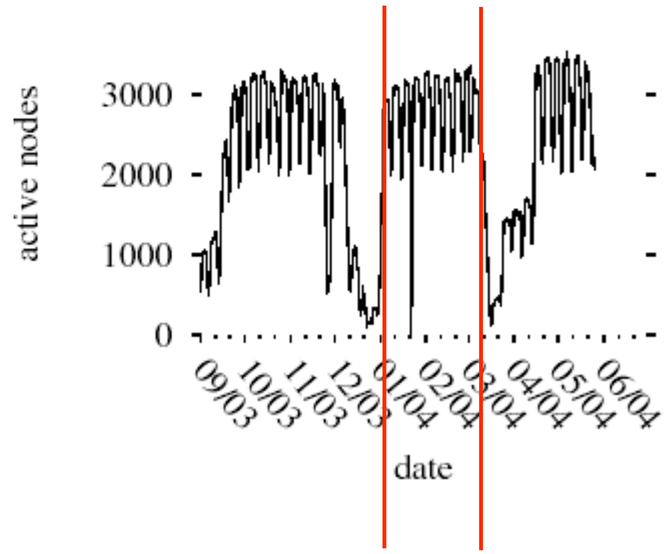
- Dissemination of mobility patterns
  - The mobility pattern of the destination needs to be known.
  - Mobility patterns may be difficult to share between nodes.
- Nature of mobility patterns
  - Mobility pattern of nodes may change too rapidly.
  - The mobility pattern might not capture some essential information.
    - E.g. time of day
- Single copy scheme
  - May suffer in a lossy environment.

MobySpace evaluated

- The frequency of visit based MobySpace
  - Each dimension in the MobySpace represents a physical location. Each coordinate corresponds to the probability of finding the node at that location. (≠ geographical routing)
- Motivation
  - Nodes' frequencies of visits to locations have been observed to follow a power-law distribution in a certain number of cases. [Dartmouth,UCSD].

- Dartmouth Wi-Fi access network [Kotz]
  - One of the largest data collection efforts
  - Between 2001 to 2004
    - 13,000 MAC addresses
    - 550 APs (academic buildings, library, sport infrastructures, administrative buildings, student residences, etc…)

- Mobility data used
  - Users' sessions (pre-processed by Song et al.)
  - January 26th 2004 and March 11th 2004 (Spring semester prior to spring break)
  - Hypotheses to obtain DTN-like data
    - APs considered to be locations
    - Connection to a same AP = contact



Simulation parameters

- General settings:
  - 45 days of Dartmouth traces replayed
  - 300 mobile nodes sampled from 5545 (computational reasons)
  - 536 locations (No sampling)

- Traffic generation:
  - 100 random mobile nodes are *active* (*i.e.*, generate traffic)
  - Each active node sends 5 bundles to different destinations
  - Active nodes are present the first week
  - Nodes have knowledge of their mobility patterns

- 5 global runs
  - Student *t* distribution to compute 90% confidence intervals

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Routing comparisons

- **Epidemic routing**
  - Bundles are flooded in the network. It is the optimum in terms of delays and delivery but leads to high buffer and radio utilization.
- **Opportunistic routing**
  - A source waits to meet the destination in order to transfer its bundle. It involves only one transmission per bundle.
- **Random routing**
  - Like MobySpace but random node preferences as opposed to preferences defined by mobility patterns.
- **Hot potato routing**
  - At any time, a node may transfer the bundle to a neighbor chosen at random. Loops are avoided.

Simulation results

- Summary:

	Delivery ratio (%)	Delay (days)	Route length (hops)
Epidemic	82.0	12.5	7.1
Opportunistic	4.9	15.9	1.0
Random	7.2	16.6	3.12
Potato	10.7	19.1	72.7
MobySpace	14.9	18.9	3.8

- Lessons:
  - MobySpace outperforms the other single copy protocols in delivery ratio
  - Potato engenders many more transmissions
  - MobySpace is next to Epidemic in delivery ratio, while only using selected contact opportunities

Simulation results

- With "most active" users:
  - Users that are present all 45 days (835 users)
  - Summary:

	Delivery ratio (%)	Delay (days)	Route length (hops)
Epidemic	96.7	3.1	7.9
Opportunistic	10.7	17.6	1.0
Random	14.0	17.9	3.5
Potato	38.9	19.1	317.0
MobySpace	50.4	19.5	5.1

- Lessons:
  - Results are globally improved
  - MobySpace far outperforms other single copy protocols

Conclusion and future work

- Conclusion
  - Proposition of MobySpace, a routing scheme for DTN that uses a virtual space constructed upon nodes' mobility patterns.
  - Evaluation with real mobility traces
  - MobySpace outperforms the other single copy schemes we evaluated in delivery ratio while keeping a low number of transmissions

- Ongoing and future work
  - Introduction of controlled flooding mechanisms
    - we expect a gain in delay and delivery ratio
  - Definition of other kinds of MobySpace
  - Study using other data sets

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