DTN Routing in a Mobility Pattern Space

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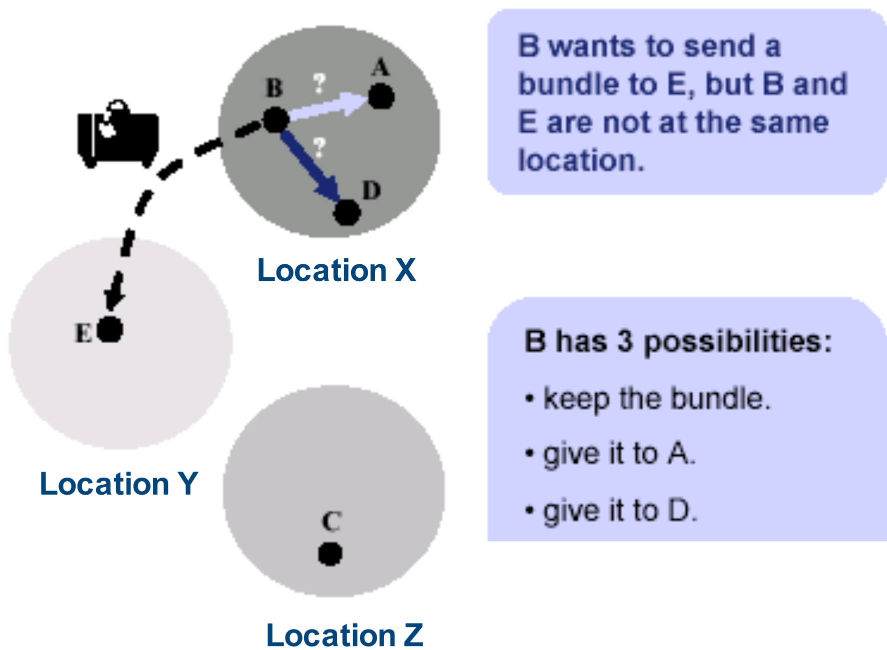
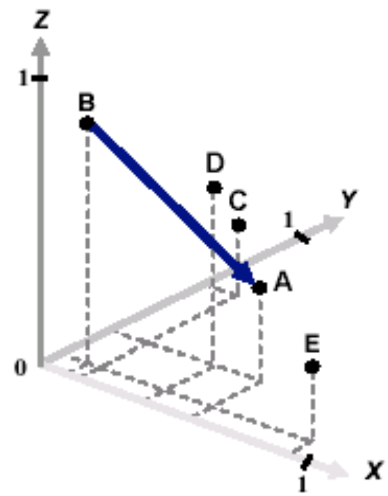
- Outline
  - Problem statement
  - Proposition
  - Case study
  - Simulation results
  - Conclusion and perspectives

- Problem of routing
  - Routing is a challenge in DTNs (Delay Tolerant Networks). Regular ad hoc routing protocols fail because the topology suffers from connectivity disruptions:
    - Partitions
    - Long delay links
  - Example:



- Main idea
  - Routing decisions are taken using nodes mobility patterns.
  - Give bundles to nodes that are *more likely* to deliver them.

- Concept of MobySpace
  - We propose to use mobility patterns of nodes to define their position in a virtual Euclidean space, their MobyPoint.
  - To route a bundle, a node passes the bundle to the neighbor whose MobyPoint is closest to the destination's.



B decides to transfer the bundle to A, the closest to E in the MobySpace.

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

- Examples of MobySpace
  - Frequency of visit based
    - Each dimension in the MobySpace represents a location in the physical space. 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.

- Possible limits
  - Handling of mobility patterns
    - Mobility patterns may be difficult to share between nodes.
    - The mobility pattern of the destination needs to be known.
  - Nature of mobility patterns
    - Mobility pattern of nodes may too rapidly change.
    - Mobility pattern specific problems may occur.
  - Single copy protocol
    - may suffer from packet loss

- **The frequency of visit based MobySpace**
  - Each dimension in the MobySpace represents a location in the physical space. Each coordinate corresponds to the probability of finding the node at that location.
- **Motivation**
  - Nodes' frequency of visits to locations follow a power-law distribution in a certain amount of cases. [Dartmouth,UCSD].

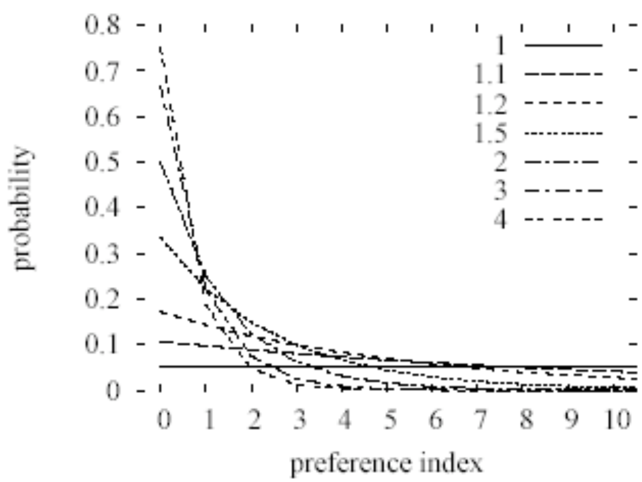
- Mobility model
  - power-law based
    - For the probability to find a node to be found at a location:

$$P(i) = K\left(\frac{1}{d}\right)^{n_i}$$

    - K is chosen such as:

$$\sum_i P(i) = 1$$

    - Example of distributions:



- **Comparison to:**
  - Epidemic routing
    - Bundles are flooded in the network. It is the optimum in terms of delays but leads to high buffer and radio utilization.
  - Opportunistic routing
    - A node waits to meet the destination in order to transfer its bundle. It involves only one transmission per bundle.
  - Random routing
    - At any time, a node may transfer the bundle to a neighbor chosen at random. Loops are avoided.

- **Distance functions:**
  - Euclidean

$$d_{ij} = \sqrt{\sum_{k=1}^{n} (x_{ik} - x_{jk})^2}$$

  - Canberra

$$d_{ij} = \sum_{k=1}^{n} \frac{|x_{ik} - x_{jk}|}{|x_{ik}| + |x_{jk}|}$$

  - Cosine angle separation

$$s_{ij} = \frac{\sum_{k=1}^{n} x_{ik}.x_{jk}}{\sqrt{\sum_{k=1}^{n} x_{ik}^2 . \sum_{r=1}^{n} x_{jr}^2}}$$

  - Matching
    - number of coordinates that are similar for two nodes.

- Parameters
  - 50 mobile nodes
  - 25 locations
  - Pause time at each location is uniformly distributed on [5s,15s]
  - Nodes generate bundles every 30s toward each of the others during the first 500s
  - Simulation ends when all the bundles have arrived
  - Mobility patterns do not change and are known globally

- Results
  - Average bundle delay (seconds)

Discrimination level of nodes mobility patterns

	d = 1.1	d = 1.5	d = 2
Epidemic	10.9	13.2	16.2
Opportunistic	123.3	287.4	550.2
Random	117.8	160.0	203.3
MobySpace	103.0	59.1	54.6

  - Route lengths (hops)

	d = 1.1	d = 1.5	d = 2
Epidemic	3.7	3.7	3.8
Opportunistic	1	1	1
Random	44.5	55.9	69.8
MobySpace	3.3	3.2	3.2

- MobySpace with partial knowledge
  - The goal is to reduce network overhead
  - Results
    - Average bundle delay (seconds)

Number of main components	d = 1.1	d = 1.5	d = 2
1	110.7	69.2	75.1
2	107.2	62.2	57.2
3	107.2	60.0	54.9
4	106.2	60.0	54.5
25	103.0	59.1	54.6

    - Route lengths do not vary significantly

- **Conclusion**
  - Introduction of the formalism of Euclidean Space based on mobility patterns of nodes for DTN routing
  - First validation of a MobySpace leading to encouraging results

- **On going and future work**
  - Validation on real data
    - Feasibility study (Paper Submitted)
  - Other kind of MobySpace
  - Control flooding