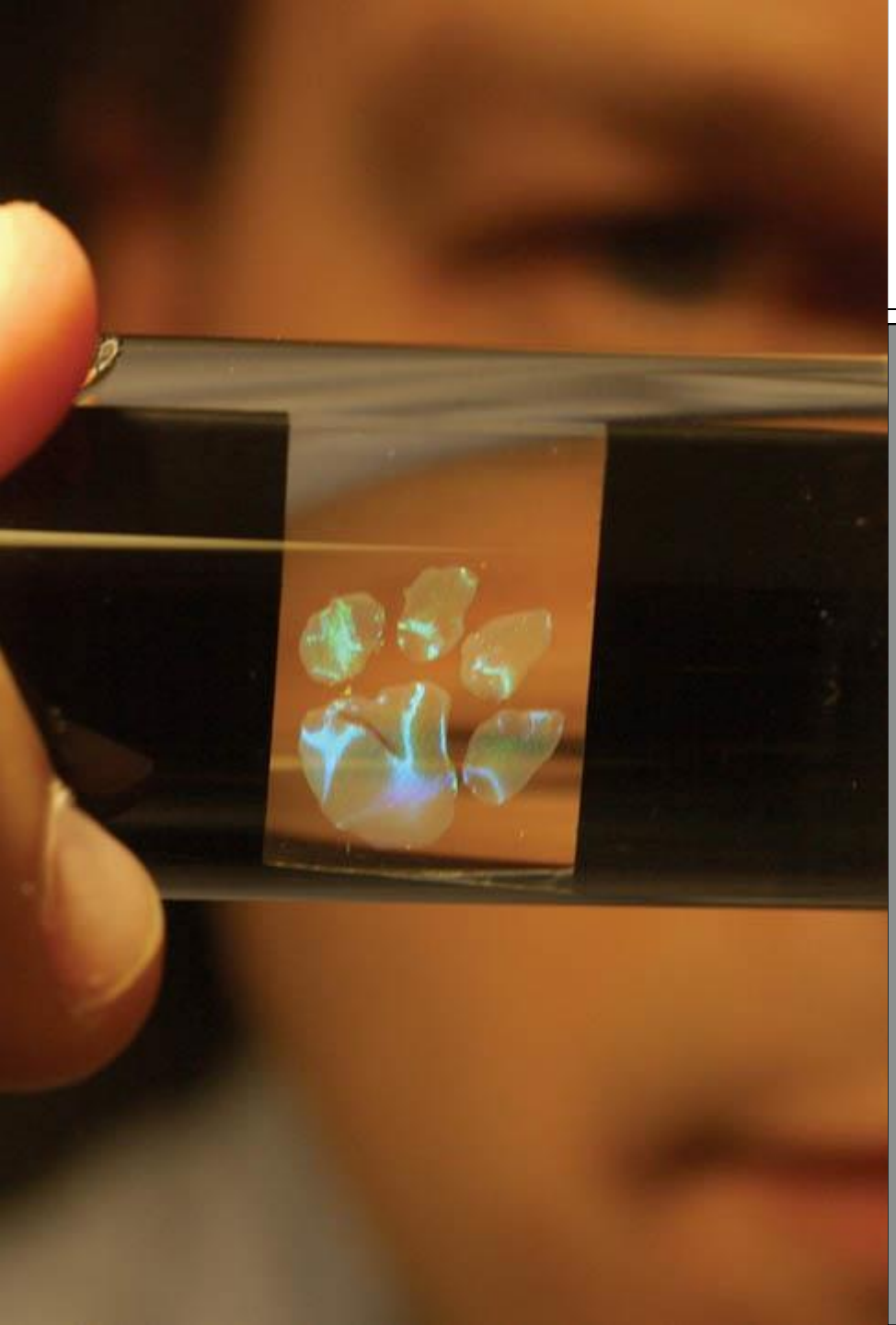

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DSearching: Distributed Searching of Mobile Nodes in DTNs with Floating Mobility Information

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Outline

- Introduction
- Related work
- System design of DSearching
- Evaluation
- Conclusion

Introduction

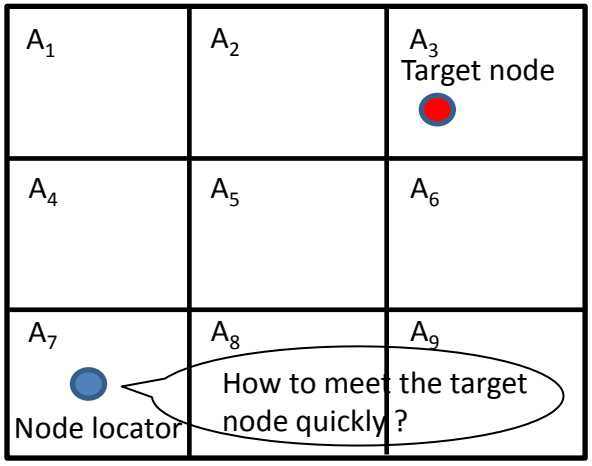
- Rapid development of mobile devices
  - Laptops, tablets, smart phones, and sensors
- These devices form a delay tolerant network
  - Alleviate the necessity of infrastructure
  - Nodes communicate when move close
  - Suitable for rural areas, exploit unused contact opportunities

Introduction (cont.)

- Distributed network
  - Without a central controller
  - Without infrastructure for communication
- Nodes move autonomously in the network
  - May not follow instructions to move to a place
  - Example 1: sensors on animals
  - Example 2: malicious nodes in the network
  - Example 3: device holders may feel troublesome

Introduction (cont.)

- Node searching is **beneficial**
  - Update and repair sensors on animals timely
  - Locate malicious nodes timely
  - Support other services



Introduction (cont.)

- Node searching is also **non-trivial**
  - No central controller to guide node movement
  - No infrastructure to collect node location information
  - Information transmission follows the "delay tolerant" manner

- Proposed solutions
  - Summarize node mobility information
    - Nodes can generate transient location records
    - Nodes usually present mobility pattern
  - Exploit mobile nodes to distribute mobility information in the network to facilitate node searching

Related Work

- Infrastructure-based methods [MobiSys'04 Sensys'05, Adhoc-Now'09]
  - Relying on central station/infrastructure to collect node location/mobility information
  - Drawbacks:
    - Not applicable to the DTN scenario
- DTN Routing methods [SIGCOMM'07, INFOCOM'10, MobiHoc'08]
  - Focus on routing a packet to a node, which can be adapted for node searching by following the forwarding route
  - Drawbacks:
    - Low efficiency since packet holders do not actively move toward the target node

Design: Problem Definition

- A DTN with n nodes
  - N_i, $i = 1,2,3,\cdots,n$
- The whole DTN is split into sub-areas
  - Each sub-area contains one landmark, e.g., a popular place
  - The area between two landmarks is evenly split
  - No overlap among sub-areas
- Node searching
  - Enable the locator to find the sub-area where the target node resides in quickly

Design: Node Mobility

- Transient visiting record (VR)
  - Generated when entering a new sub-area
  - Shows where the node was before entering the new sub-area

$$VR: < N_i, A_{new}, A_{prev}, Time, T_s, Seq >$$

  - A_{new} and A_{prev} represent the current and the previous sub-area, respectively
  - T_s is the TTL of the VR, e.g., half day

- Purpose of VR
  - Providing the information on where the target node currently is
  - Enabling the locator to know where the target moves to from A_{prev}

Design: Node Mobility

- Long-term mobility pattern table (MPT)
  - St
  - Tr
  - Accumulated on each node along moving in the network

Rank	Sub-areas	Staying Prob.	Next Sub-areas (Prob.)	Seq
1	A_5	0.50	$A_8(0.8)$, $A_2(0.2)$	1
2	A_2	0.25	$A_1(0.7)$, $A_3(0.3)$	1
3	A_6	0.15	$A_5(1)$	1
…	…	…	…	…

m A_m

- Purpose of MPT
  - Providing the information on the node's pattern on transiting among sub-areas

Design: Distribute Mobility Info.

- Why distribute mobility information?
  - It is generated by each node, not the locator
  - Information forwarding is slow in DTN
  - Rely on mobile nodes to carry such information to other places in the network to make it easy to be accessed
  - Facilitate the locator to search for the target

Design: Distribute Mobility Info.

- Distribute visiting record (VR)
  - When a new VR is generated, it is copied to selected encountered nodes

$$VR: < N_i, A_{new}, A_{prev}, Time, T_s, Seq >$$

  - Ensure that the VR has a high probability to appear in the previous sub-area, i.e., A_{prev}

A node's probability to stay in A_{prev}: $Pt_r(A_{new} \rightarrow A_{prev}) * Ps_r(A_{prev})$

  - Purpose: enabling the locator to know the next sub-area to search after arriving at A_{prev}, i.e., leaving a scent on the trail

Design: Distribute Mobility Info.

- Distribute mobility pattern table (MPT)

Rank	Sub-areas	…
1	A_5	…
2	A_2	…
3	A_6	…

Define the sub-area a node stays for the most as its home sub-area

Each row represents the mobility pattern in one sub-area

The row for the home sub-area is stored in every sub-area

The rows for other sub-areas are stored in corresponding sub-areas

Design: Distribute Mobility Info.

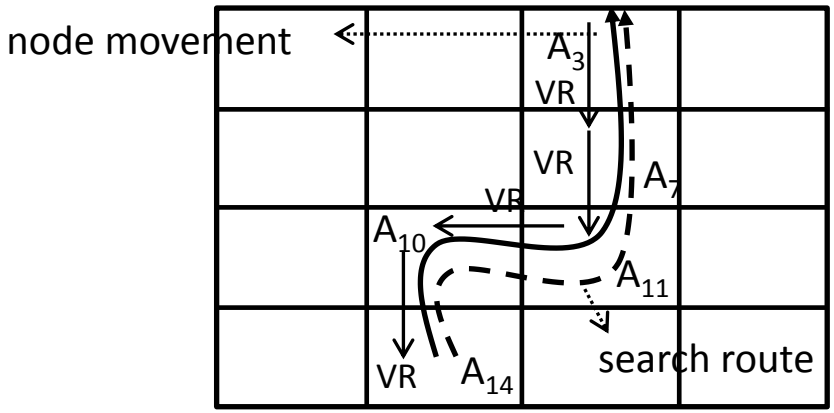
- Distribute mobility pattern table (MPT)
  - How to store a row in a sub-area?
  - Nodes are moving, not fixed

  Solution:
  - Store the row in the nodes whose home sub-area is the sub-area
  - Overall probability to stay in the the sub-area > Th_t

- Purpose:
  - When the locator arrives at a sub-area, if it cannot find a VR to know the next sub-area to search, it relies on MPT to search around to retrieve valid VRs

Design: Node Searching

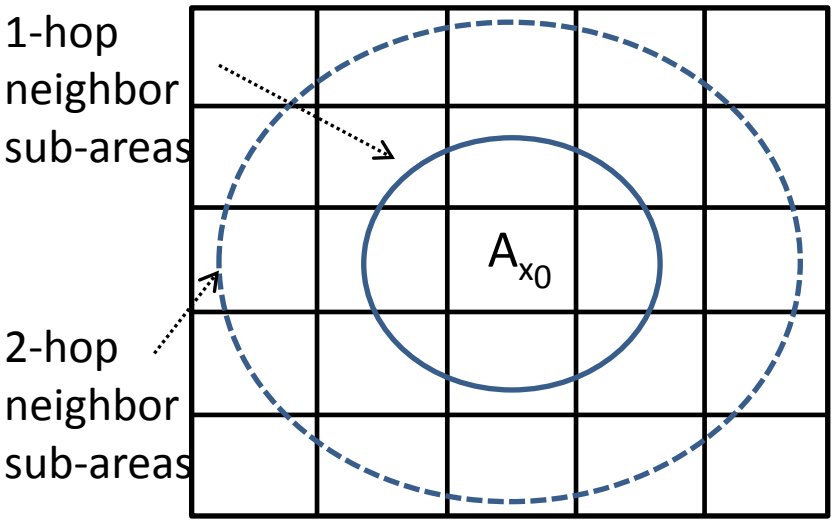
- Startup
  - Search randomly
  - When obtaining the MPT row for the target's home sub-area, the locator searches toward the home sub-area
- Following VR
  - Whenever one or more valid VRs of the target node are found, the locator moves to the A_{new} in the latest VR for search



Follow the VR chain to search the target node

Design: Node Searching

- Searching with MPT
  - It is possible that when arriving at a sub-area, a valid VR cannot be obtained
  - In this case, the MPT row stored in the sub-area is used to search around to retrieve a valid VR



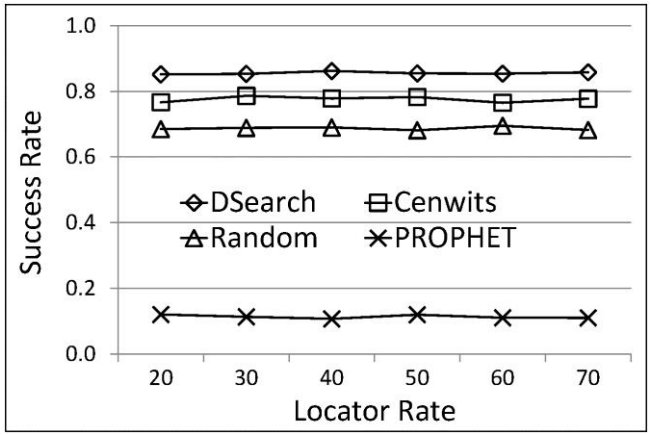
First search the 1-hop neighbor sub-areas, then 2-hop

The searching direction and start sub-area is determined by the MPT info. : **minimize** the expected steps to retrieve a valid VR

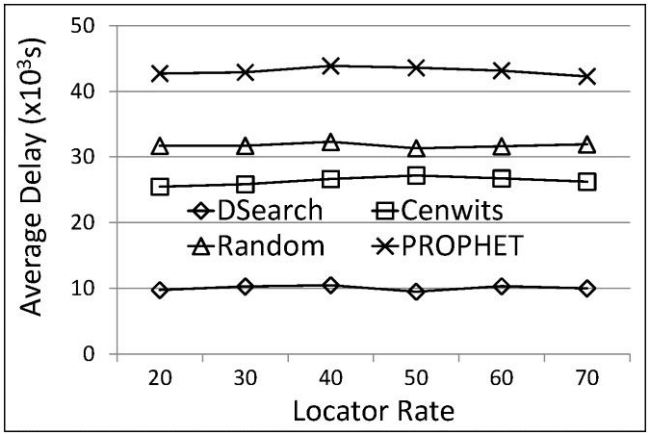
Performance Evaluation

- Simulator
  - Event driven simulator
- Node Mobility Traces
  - Dartmouth trace (DART): AP association records of mobile devices on campus [ref]
  - DieselNet AP trace (DNET): AP association records of buses in a college town [ref]
- Comparison Methods
  - Cenwits: encountering based method
  - PROPHET: following the routing algorithm PROPHET
  - Random: searching randomly

Experiment with Different Locator Rates (DART)

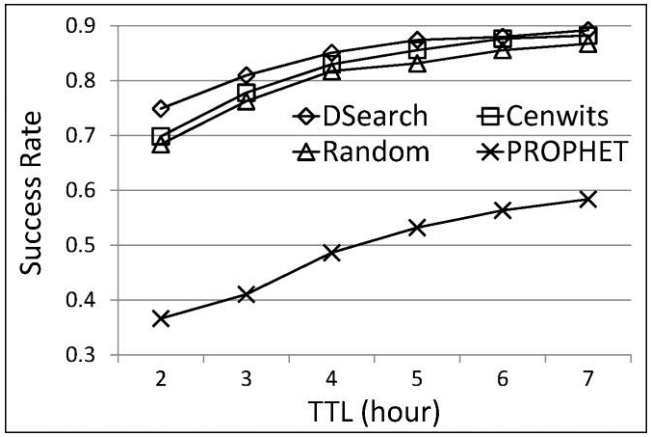


Success rate:
DSearch>Cenwits>Random>PROPHET

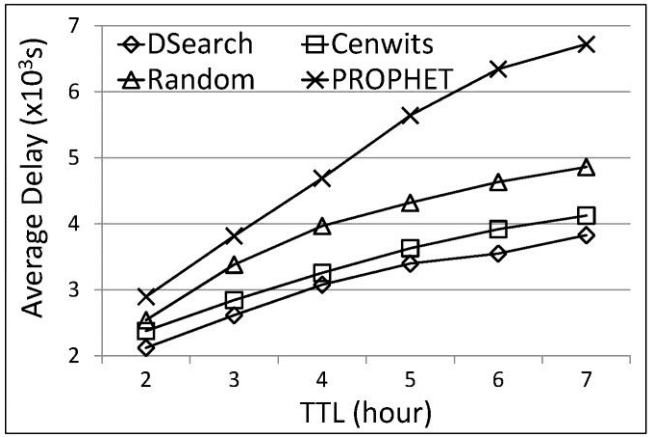


Ave. delay:
Dsearch<Cenwits<Random<PROPHET

Experiment with Different TTLs (DNET)



Success rate:
DSearch>Cenwits>Random>PROPHET



Ave. delay:
Dsearch<Cenwits<Random<PROPHET

Conclusions

- We proposed DSearching, a distributed node searching algorithm for DTNs using node mobility information
  - Summarize node information using both transient visiting records and long-term mobility patterns
  - Distribute node mobility information to mobile nodes for easy access
  - Use both the two types of information to search the target node along the actual path it traversed

Thank you!

Questions & Comments?

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