University at Buffalo
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Department of Computer Science and Engineering

Orbital Mobility Profile based Routing

in Intermittently Connected Mobile Ad hoc Networks (ICMAN)

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Key Concepts

- Users' movements are often socially influenced
- "hubs" – places of social interest to users
- User mobility – an "orbit" involving a list of hubs
- Mobility profile – a list of hubs likely to be visited

Remarks

- User mobility profiles exist but difficult to obtain
- Usefulness for routing in MANET and ICMAN *and Mobile* wireless applications

Recent Results on Mobility Profiling

- CSE Dept. TR # 2005-27, SUNY Buffalo, 2005

Related Publications on SOLAR in MANET

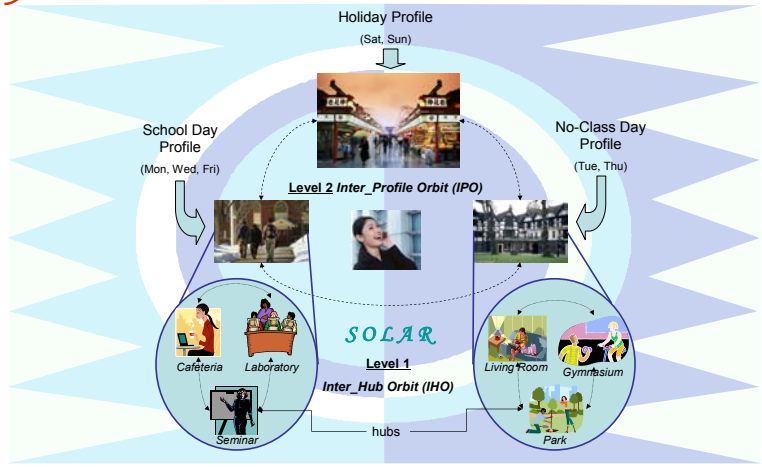
- Paper in Elsevier Journal on Ad hoc Networks, '05
- Paper in IEEE Broadnets '05
- Poster in ACM Mobihoc '05

Visit Project SOLAR's Website for More Information

http://www.cse.buffalo.edu/~joyghosh/solar.html

Mobility Traces

- AP based traces collected by APs: User/MAC ID, AP's ID, times of association, disassociation, roaming etc.
  - E.g., Traces from Dartmouth and ETH Zurich
- AP based traces collected by devices (PDAs, Laptops, etc.) carried by wireless users and uploaded to database servers.
  - E.g., Traces from UCSD
- User contact based traces without location information
  - E.g., Experiments by Intel Research at Berkeley (HAGGLE)
- User location based traces collected by GPS or other devices carried by wireless users (not much available yet)



Orbital Mobility Profiling

- Obtained a daily list of hubs visited by each user
- Considered a N-dimensional plane → N is the total number of hubs, and each hub list generates a point in the plane
- Clustered hub lists using the *Expectation Maximization* (EM) algorithm based on the *Mixture of Bernoulli's* distribution
- Defined each mobility profile to be the cluster mean, that is, a *weighted (or probabilistic) hub list*
- User mobility aptly described via a *probabilistic mixture of profiles*
- Profiling techniques applied to traces from ETH Zurich
  - collected for 1 year from 4/1/04 till 3/31/05
  - 13,620 mobile users, 391 Access Points, 43 Buildings (hubs)

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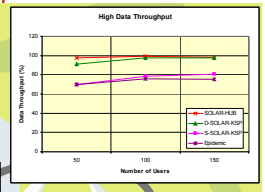
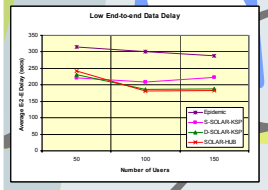
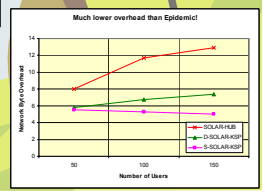
Profiles shown useful for *hub-level location prediction*
- on average, 20% more accurate than statistical prediction

Benefits of Profile-based Routing







Simulation Parameters
- Simulation Time: 3000secs
- Terrain Size: 2000m x 2000m
- Number of hubs: 15 (50m x 50m)
- Radio Range: 125m
- Cache Size: 200 packets
- Cache Timeout: 400secs
- Traffic: 30 CBR (120 packets each)
- Data Payload: 1460 bytes per packet

Hub-level Routing Strategy

- Deliver packets to the hubs visited by destination
- Intermediate users store-carry-forward the packets
- Packet stored in a hub by other users staying in that hub (or using a fixed hub storage device if any)
- Mobility profiles used to obtain delivery probabilities (DP), not the visit probability, of a user to a given hub
- Fractional data delivered to each hub proportional to the probability of finding the destination in it

Routing Protocol – SOLAR-HUB
- Source transmits up to *k* copies of message
  - *k*/2 to neighbors with higher DP to "most visited" hub
  - *k*/2 to neighbors with higher DP to "2nd most visited" hub
- Downstream users forward up to *k* users
  - with higher DP to the hub chosen by upstream node

User-level Routing Strategy

- Deliver packets to the destination itself
- Intermediate users store-carry-forward the packets
- Mobility profiles used to compute pair wise user contact probability (CP) to form weighted graph
- Apply modified Dijkstra's to obtain *k*-shortest paths (KSP) with corresponding Delivery probability (DP)

Routing Protocol – S-SOLAR-KSP (*static*)
- Source only stores set of unique next-hops on its KSP
- Forwards only to max k users of the chosen set that come within radio range within time T

Routing Protocol – D-SOLAR-KSP (*dynamic*)
- Source always considers the current set of neighbors
- Forwards to *max k* users with higher DP to destination

Applications of Orbital Mobility Profiles

- *Anomaly based intrusion detection* → unexpected movement (in time or space) sets off an alarm
- *Customizable traffic alerts* → alert only the individuals who might be affected by a specific traffic condition
- *Targeted inspection* → examine only the persons who have routinely visited specific regions upon re-entrance.
- *Environmental/health monitoring* → identify travelers who can relay data sensed at locations with no APs

Challenges in Routing in ICMAN

- May not have an end-to-end path from source to destination at any given point in time (intermittently connected)
- Conventional MANET routing strategies fail
- User mobility may not be deterministic or controllable
- Devices are constrained by power, memory, etc.
- Applications need to be delay/disruption tolerant

Future Work

- Collect and analyze user location-based traces
- Apply advanced clustering/profiling techniques
- Optimization techniques for profile information management
- Design and analyze routing algorithms
- Experimenting with Applications