Profile-cast: Behavior-Aware Mobile Networking

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Outline

- A new communication paradigm: message delivery to users with similar *behavior (Profile-casting)*
- Background: Delay Tolerant Networks (DTN)
- Similarity-based profile-cast protocol
- Evaluation
- Future work and conclusion

Contribution: Show-casing the potential of a behavioral-aware communication paradigm in mobile networks.

Profile-cast Paradigm

- The introduction of portable/personal communication devices leads to a tight user-device coupling.

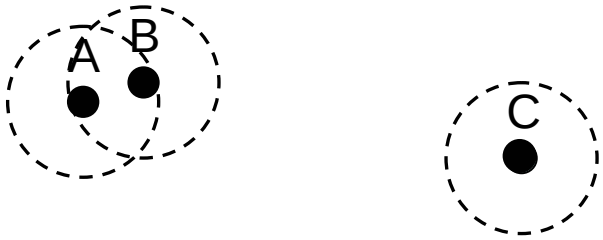
- How can the user-device coupling be leveraged to design new services?

Profile-cast Paradigm

- We focus on message delivery to a group of hosts with similar behaviors (profile-cast)
  - (VS multi-cast) Group membership is implicit
- We use mobility profile as an example
  - Targeted announcement
  - Lost-and-found
  - (VS geo-cast) Definition of user group based on long-run mobility characteristics

Background (DTN)

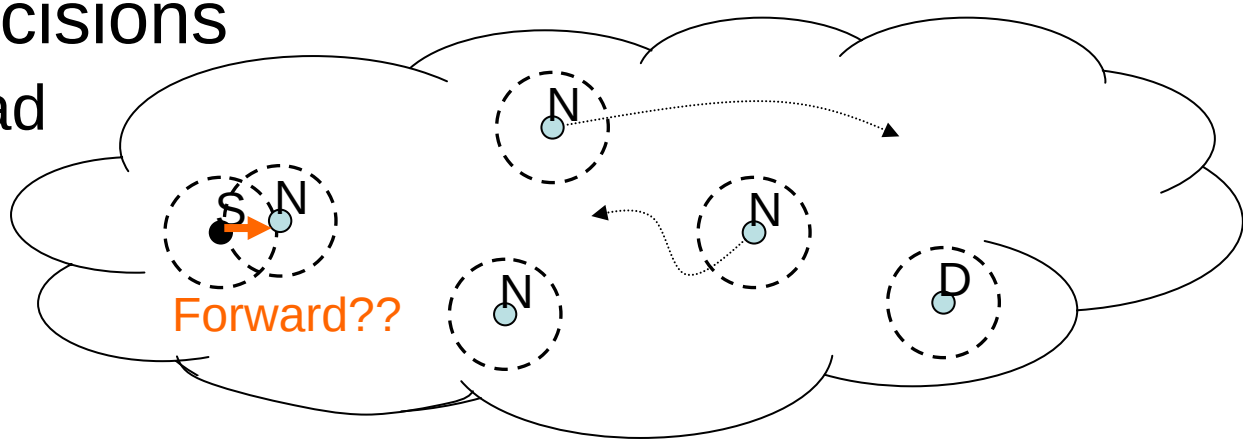
- Delay Tolerant Networks (DTNs) are mobile network with sparse, intermittent nodal connectivity.
- Messages are stored in memory and moved across the network with nodal mobility



- Encounter events provide the communication opportunities among nodes

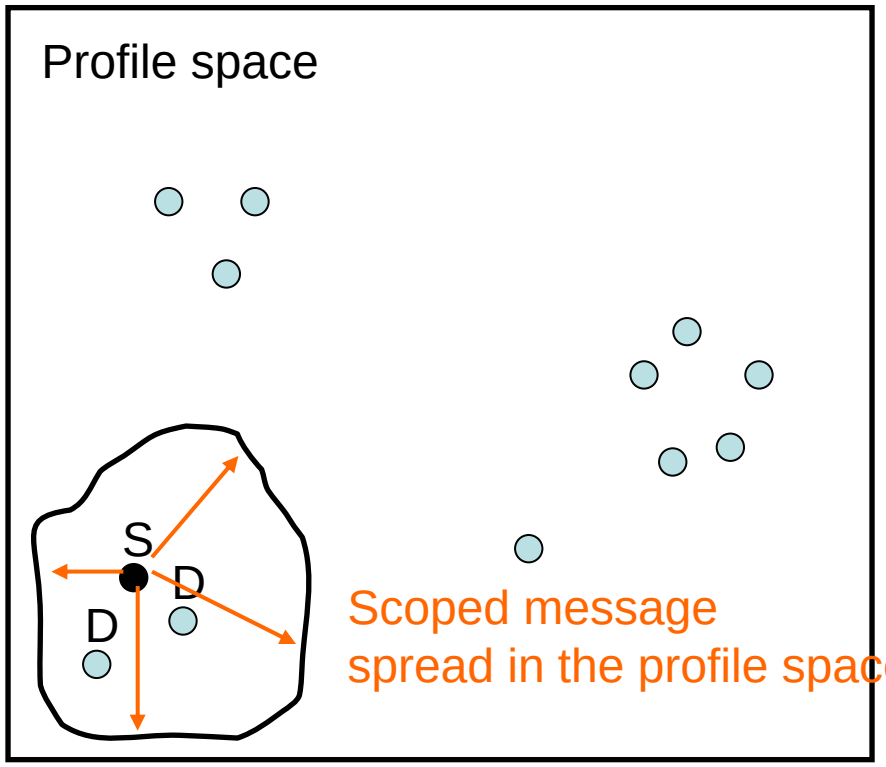
Background (DTN)

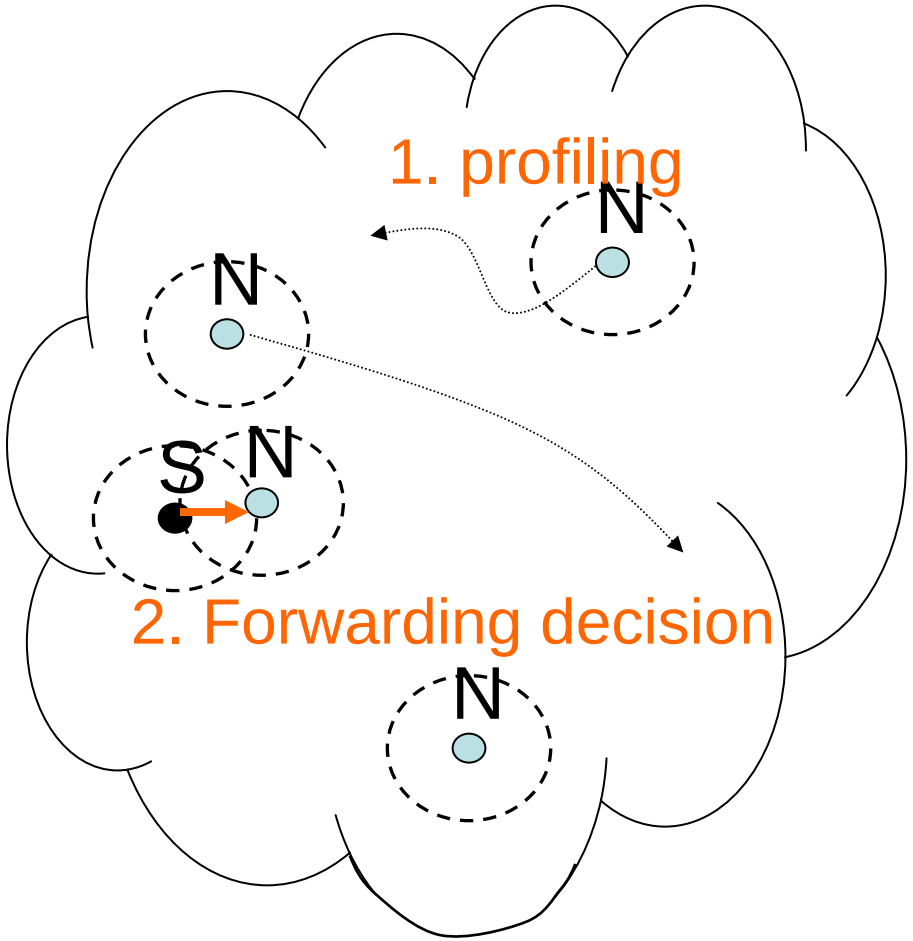
- DTN routing protocols are de-centralized
  - Each node relies on local information to make forwarding decisions
    - High overhead for directory-based services



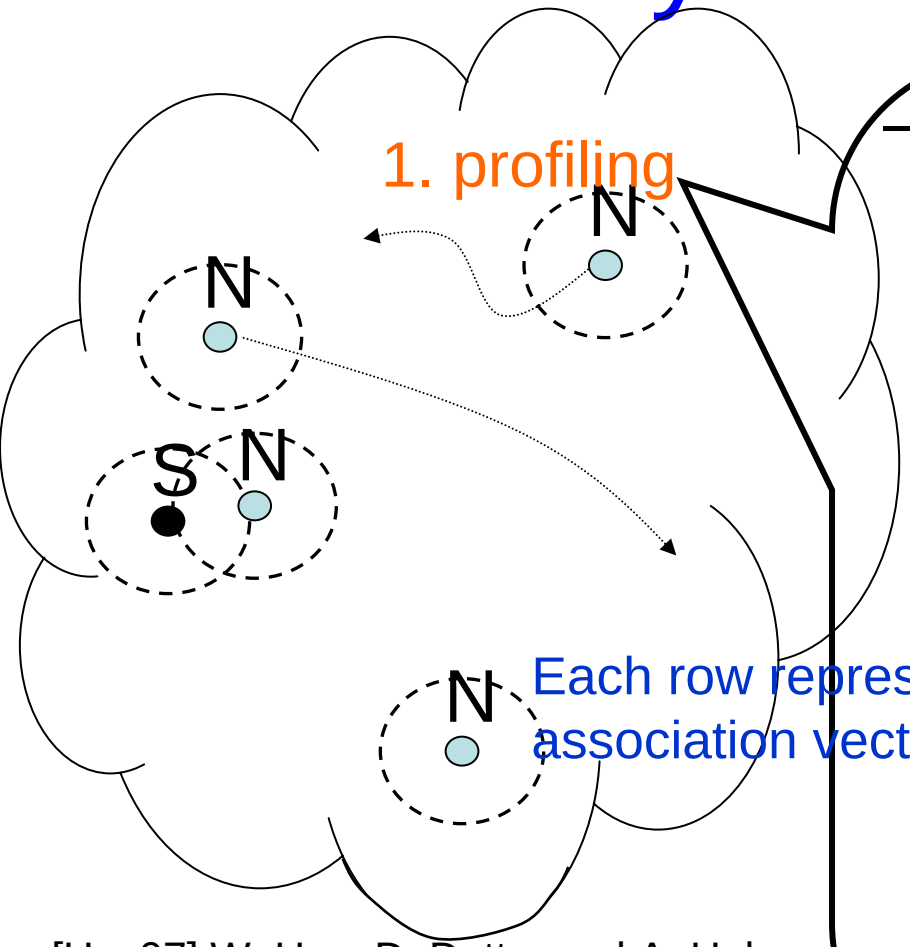
  - The decisions have direct impact on performance
    - Delivery probability
    - Overhead (transmission and storage)
    - Delay

Similarity-based Profile-cast

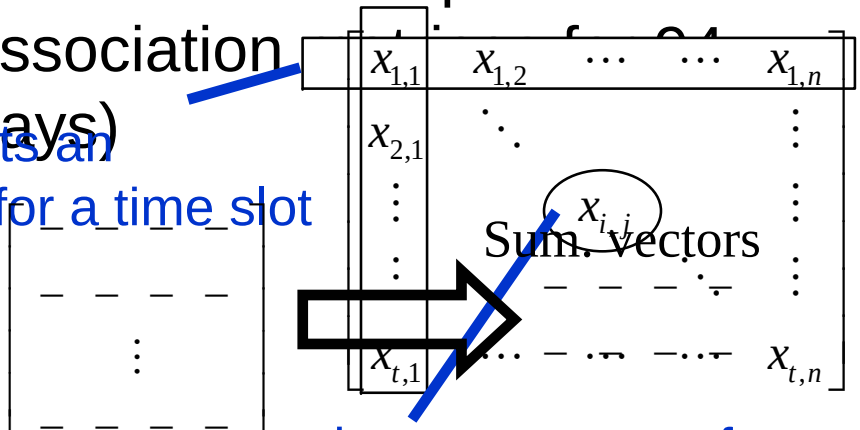




Similarity-based Profile-cast



- Profiling user mobility[Hsu07]
  - The mobility of a node is represented by an *association matrix*.
  - Singular value decomposition provides a summary of the matrix (A few *eigen-behavior* vectors are sufficient, e.g. for 99% of users at most 7 vectors describe 90% of power in the association [illegible] days)

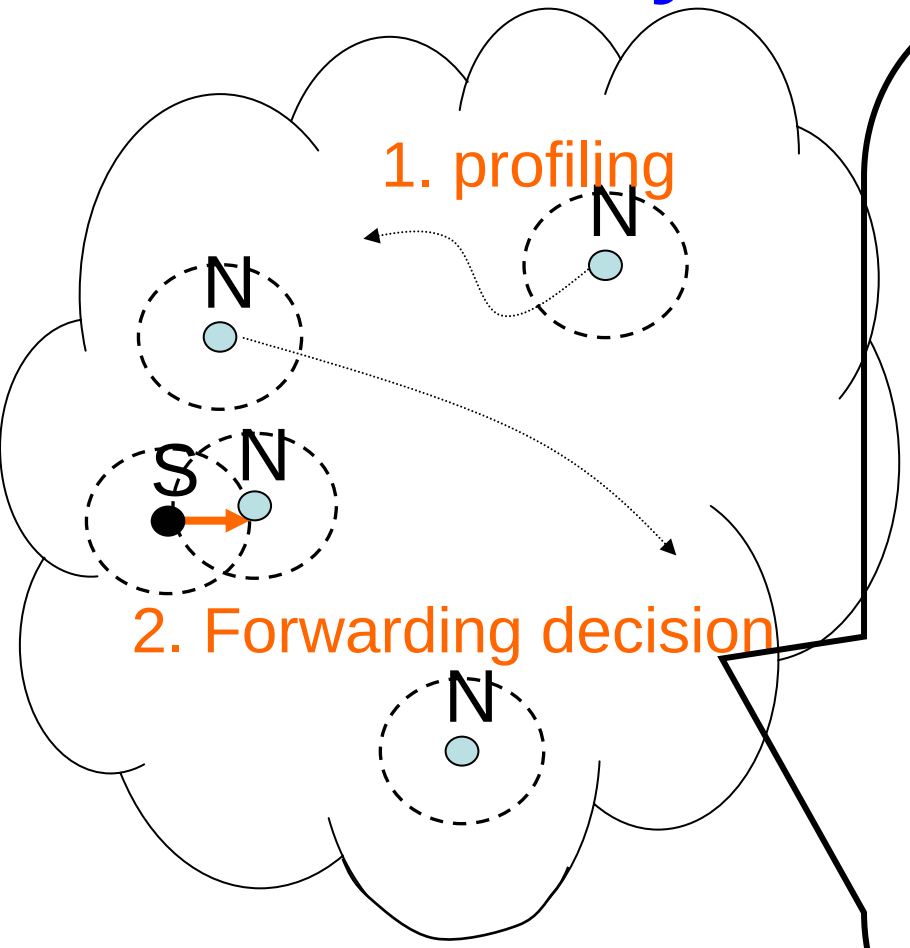


Each row represents an association vector for a time slot

An entry represents the percentage of online time during time slot *i* at location *j*

[Hsu07] W. Hsu, D. Dutta, and A. Helmy, "Extended Abstract: Mining Behavioral Groups in Large Wireless LANs," in Proceedings of MOBICOM 2007.

Similarity-based Profile-cast



- Determine user similarity
  - Nodes exchange their eigen-behaviors and the corresponding weights at encounter
  - Similarity of user mobility are evaluated by weighted inner products of eigen-behaviors

$$Sim(U,V) = \sum_{\forall i,j} w_i w_j \left| u_i \cdot v_j \right|$$

  - Message forwarded if Sim(U,V) is higher than a threshold (recall that the goal is to deliver messages to nodes with similar profile)

Similarity-based Profile-cast

- This is a different approach to disseminate messages in DTN
  - Use *behavior* as the target as opposed to IDs[1][2]
  - Avoid persistent exchanges of control messages[2]; nodes profile itself silently
- The idea is related to the Mobility Space routing[3] or social network-based routing[4], but the goal is different

[1] A. Vahdat and D. Becker, ”Epidemic Routing for Partially Connected Ad Hoc Networks”
[2] A. Lindgren, A. Doria, and O.Schelen, ”Probabilistic Routing in Intermittently Connected Networks”
[3] J. Leguay, T. Friedman, and V. Conan, ”Evaluating Mobility Pattern Space Routing for DTNs”
[4] E. Daly and M. Haahr, ”Social Network Analysis for Routing in Disconnected Delay-Tolerant MANETs”

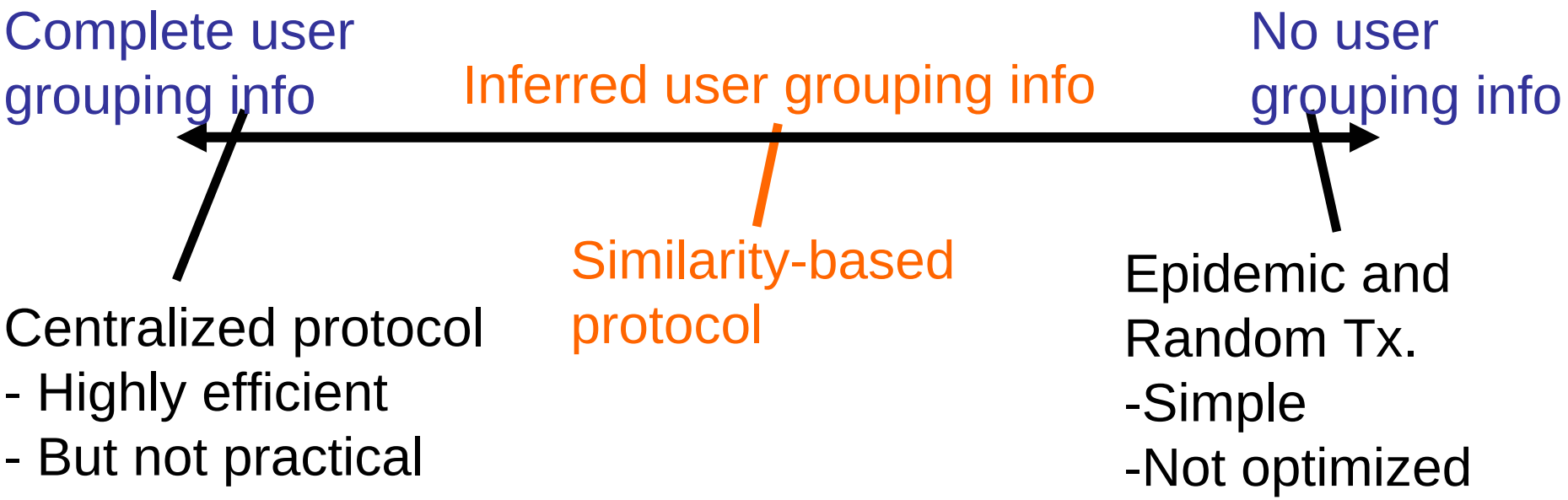
Evaluation

- Based on USC WLAN trace for realistic user mobility[1] (2006 spring, 94 days, 5000 users)
- We use hierarchical clustering to identify 200 distinct groups based on mobility profile.
- We pick groups with 5 or more members and randomly pick 20% of the members in these groups as senders

[1] W. Hsu and A. Helmy, MobiLib USC WLAN trace data set. Download from http://nile.cise.ufl.edu/MobiLib/USC_trace/

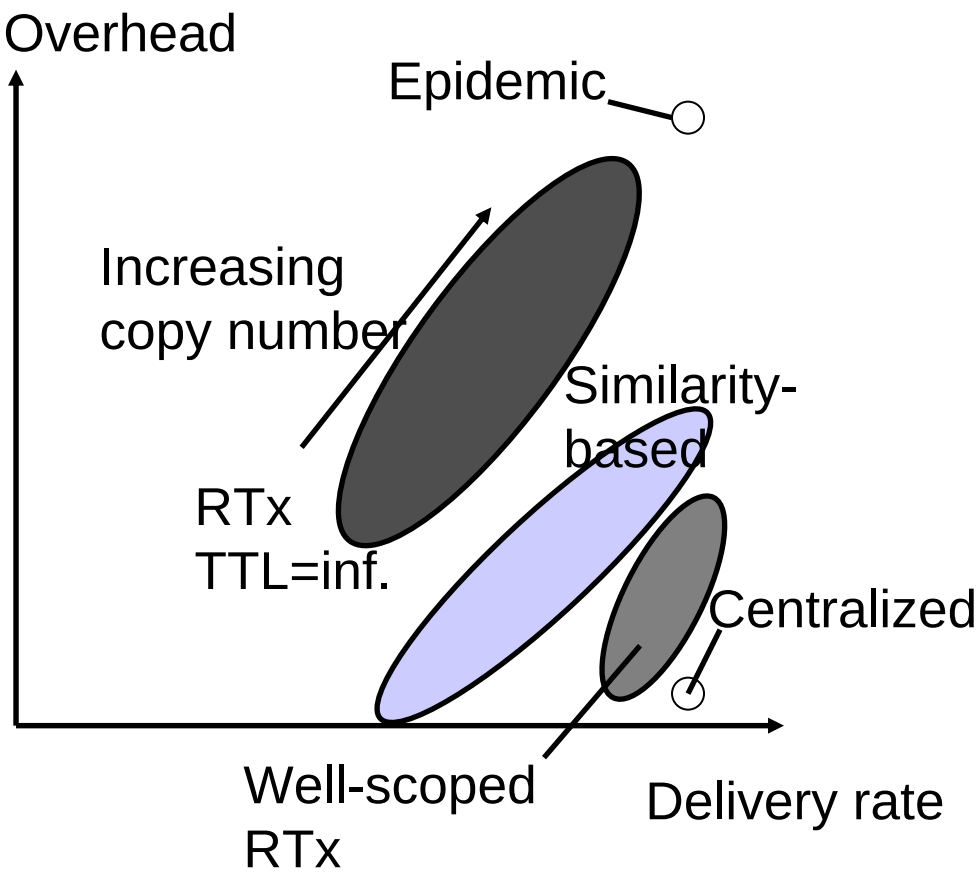
Evaluation

- Spanning the spectrum of grouping knowledge



Evaluation - Result

- Goal: get as close to the centralized as possible
  - RTx without TTL limit degenerates to flooding as number of copies increases
  - Similarity-based has better delivery ratio-overhead tradeoff and low delay
  - Well-scoped RTx has longer delay



(darker color => longer delay)

Future Work

- Can we send to a specified target profile not necessarily similar to the sender?
- Can we specify the target profile in different contexts?
  - Affiliations, interests, etc.

Conclusions

- Tight user-device coupling in mobile networks enables behavior-aware service/protocol design
- Behavior-aware protocol design shows good potential for performance improvement

Thank you!!

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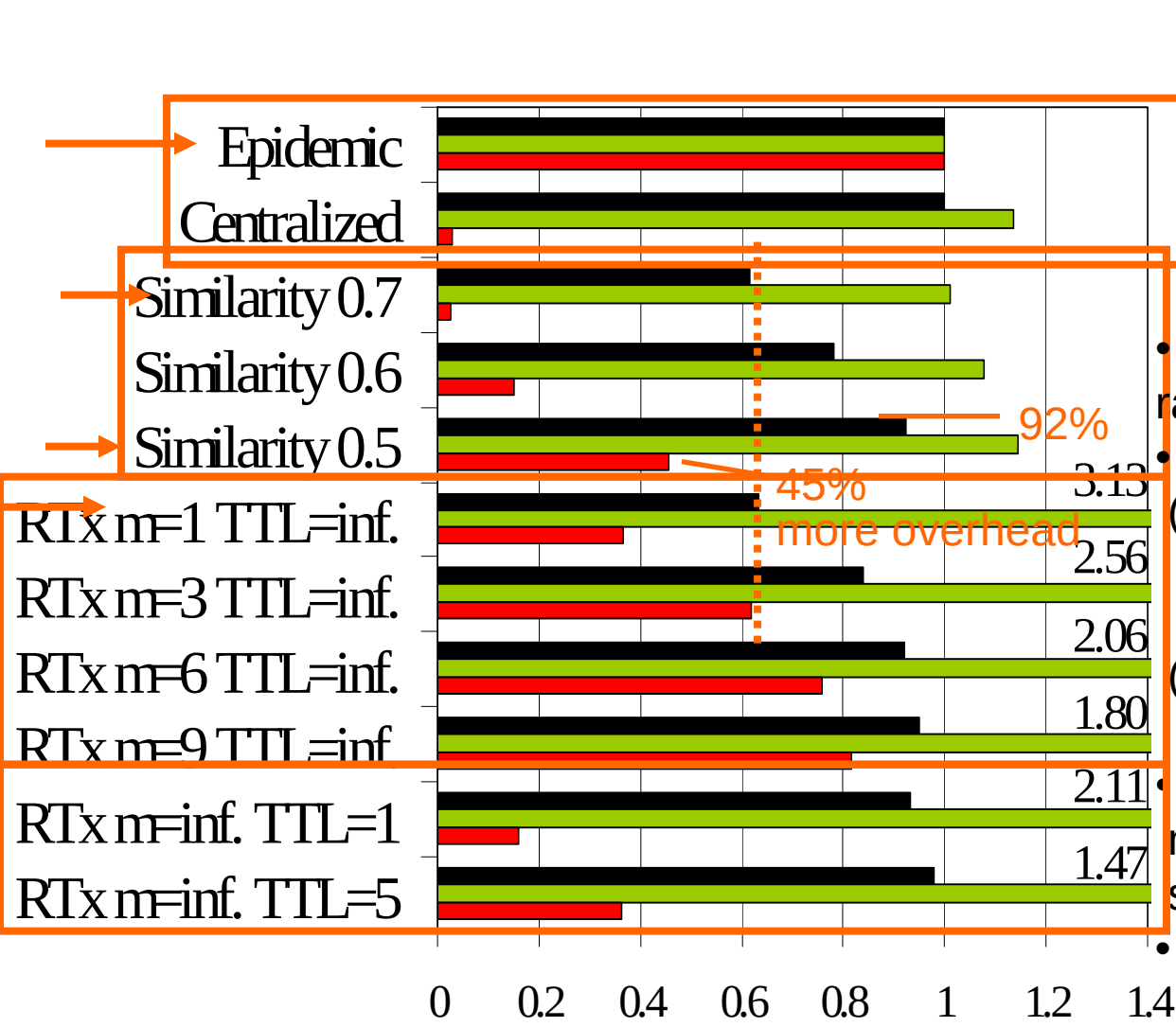
http://nile.cise.ufl.edu/MobiLib

Evaluation - Result



- Centralized: Excellent success rate with only 3% overhead.
- Similarity-based:
  (1) 61% success rate at low overhead, 92% success rate at 45% overhead
  (2) A flexible success rate – overhead tradeoff
- RTx with infinite TTL: Much more overhead under similar success rate
- Short RTx with many copies: Good success rate/overhead, but delay is still long