Opportunistic Forwarding in Healthcare Scenarios

McGill
Department of Electrical and Computer Engineering,
3480 University St, Montreal QC, H3A 2A7 Canada

Shohreh Shaghaghian, Divya Alok Sharma, Mark Coates
shohreh.shaghaghian@mail.mcgill.ca,
divya.a.sharma@mail.mcgill.ca, mark.coates@mcgill.ca

NSERC CRSNG
Healthcare Support through
Information Technology Enhancement

Motivation

In some healthcare senarios, providing a stable communication infrastructure is not possible

- emergency or disaster situations
- prohibition of high-power electromagnetic waves

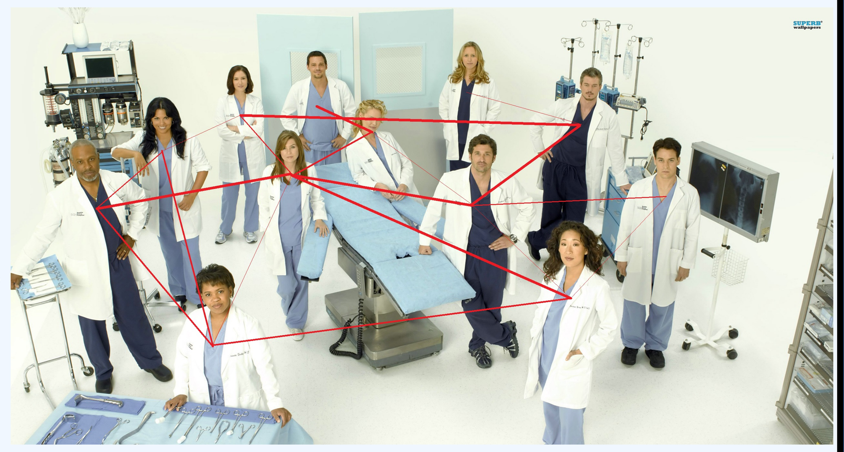
Practical Scenarios [1] **:**

- detect clinical deterioration through patient montoring in hospital
- enhance first responders' capability to provide emergency care in large disasters through automatic electronic triage
- improve life quality of elderly through smart enviroments
- enable large-scale field studies of human behavior and chronic disasters

Opportunistic networking is a good candidate for mobility and continuity of service even in the absence of any stable communication infrastructure.

Main Characteristics:

- node mobility
- random movement pattern
- no pre-determined end-to-end routes
- store-carry-forward fashion



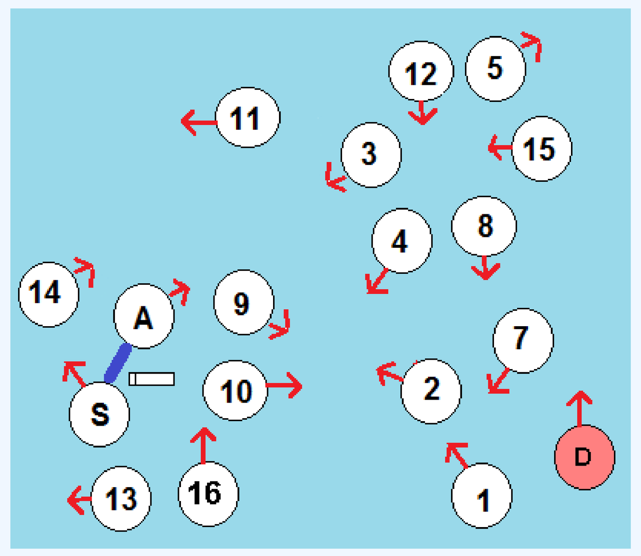
©ABC TV Show: Grey's Anatomy

Main Question:

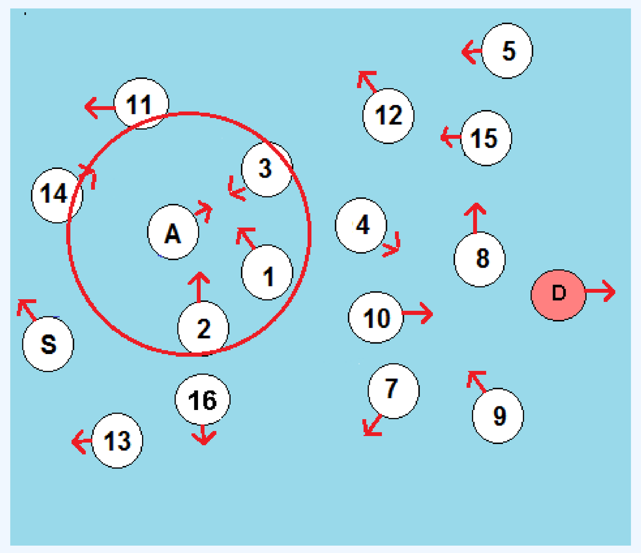
- WHEN to forward a message and to WHOM

Background

- replication based forwarding : Epidemic [2]
- history based forwarding : Prophet [3]
- social based forwarding : SimBet [4], Bubble [5]



$t = 1$



$t = 2$

Epidemic Routing:
A forwards the packet to 1, 2 and 3.

Prophet:
A forwards the packet to 1 because it has recently been in touch with the destination.

SimBet:
A forwards the packet to 1 and 2 because they have had 'similarity' with the destination in terms of shared neighbors.

BubbleRap:
A forwards the packet to 3 as well as 1 because 3 has been in contact with a lot of people.

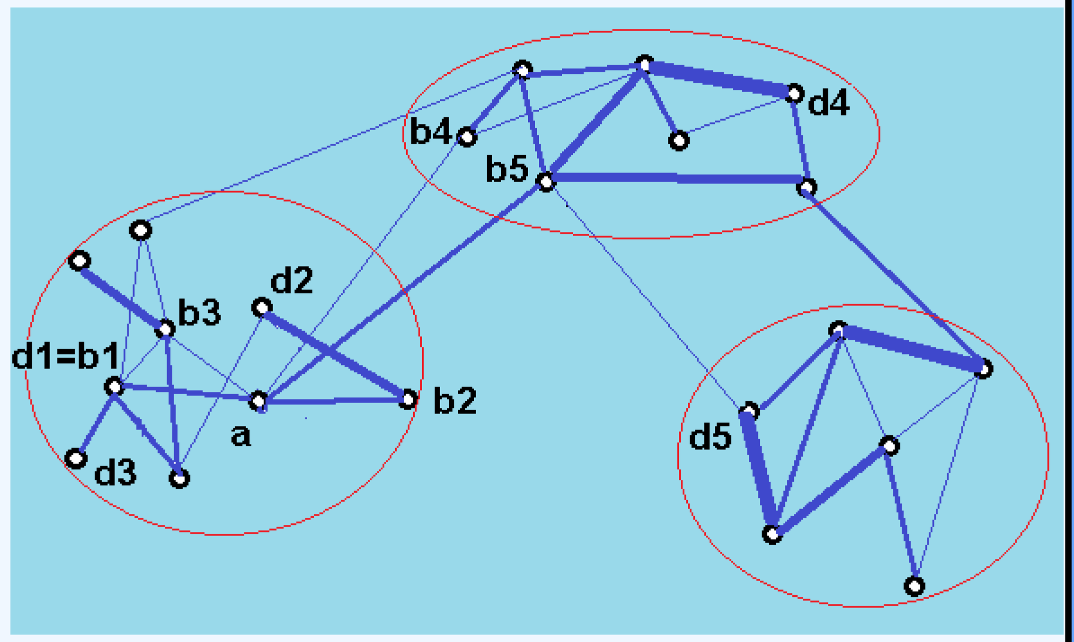
Contact Graph Algorithm

Aggregated Contact Graph:

- assign a weight w_{ab} to encounters between each pair of nodes (a, b) based on their contact history
- divide the contact graph into communities

Goal:

- Node a has a message and wants to pick a node b from its neighbourhood set $N_a = \{b1, b2, b3, b4, b5\}$ to relay the message to a destination $d \in \{d1, d2, d3, d4, d5\}$
- $C_a : community(a)$
- $C_b : community(b)$
- $N_a : neighbourhood(a)$
- $N_b : neighbourhood(b)$



Forwarding decisions based on:

- neighbourhood
- community
- degree centrality of nodes

- if $d = d1 \Rightarrow$ deliver message to $b1$ since $b1 = d1$
- if $d = d2 \Rightarrow$ choose $b2$ since $d \in C_a = C_b, w_{bd} > w_{ad}$ (more often contacts)
- if $d = d3 \Rightarrow$ choose $b3$ since $d \notin (N_a \cup N_b), |N_b| > |N_a|$ (more popularity)
- if $d = d4 \Rightarrow$ choose $b4$ since $C_a \neq C_b, d \in C_b$ (same community)
- if $d = d5 \Rightarrow$ choose $b5$ since $d \notin (C_a \cup C_b), w_{bd} > w_{ad}$ (more often contacts)

Simulation Setup

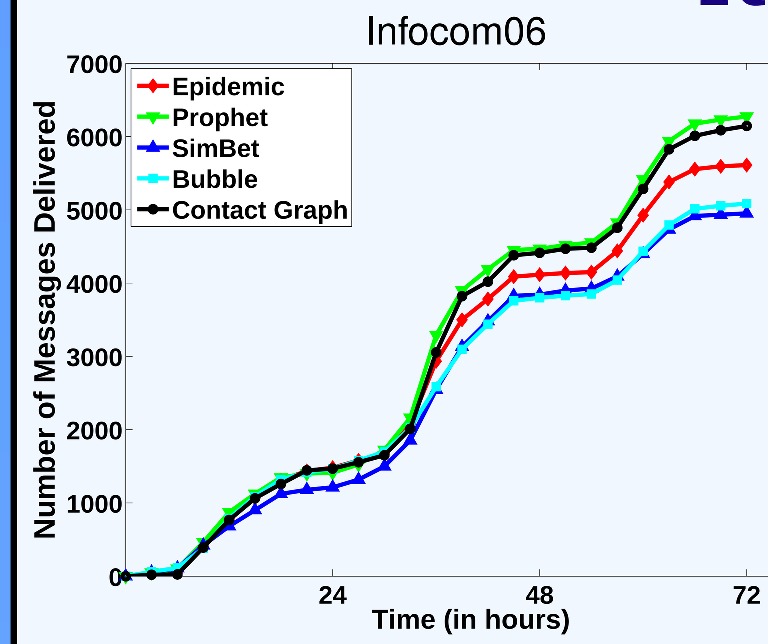
- nodes equipped with a Bluetooth interface with a transfer rate of 2.1 Mbps
- messages of size 4MB generated at intervals of 30 seconds
- unlimited buffer capacity
- no restriction imposed on the time to live (TTL)

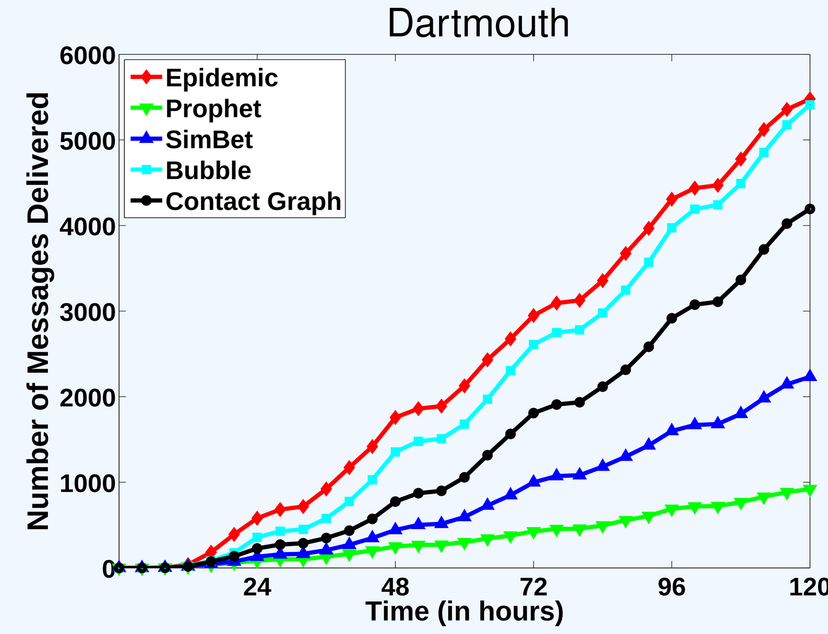
Performance Metrics

- delivery ratio $= \frac{\text{number of messages delivered}}{\text{number of messages generated}}$
- delivery overhead ratio $= \frac{\text{number of messages transmitted}}{\text{number of messages delivered}}$
- average hop count for delivered messages
- buffer occupancy

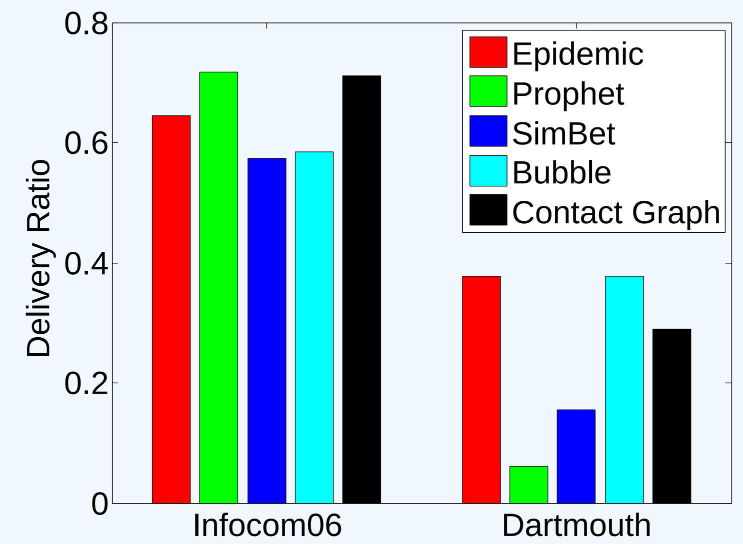
Parameter	Infocom06	Dartmouth
duration(days)	3	14
number of nodes	78	1811
number of nodes (largest component)	65	1803
number of communities (largest component)	8	29
modularity	0.511	0.892

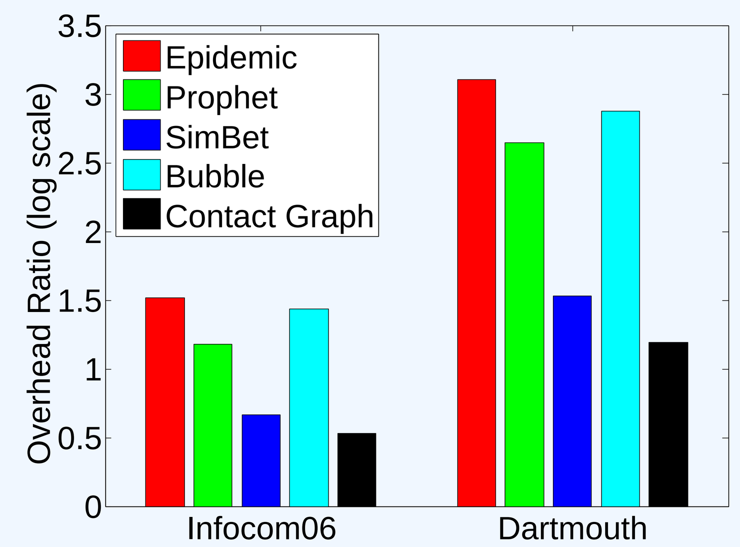
Results

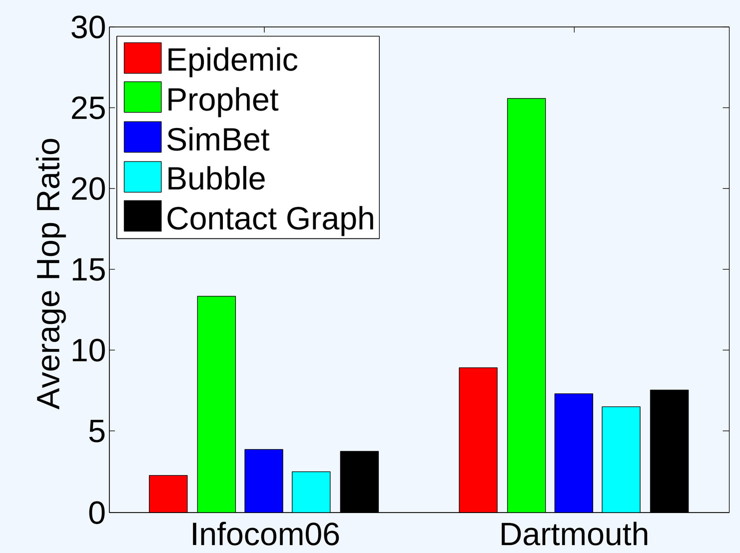


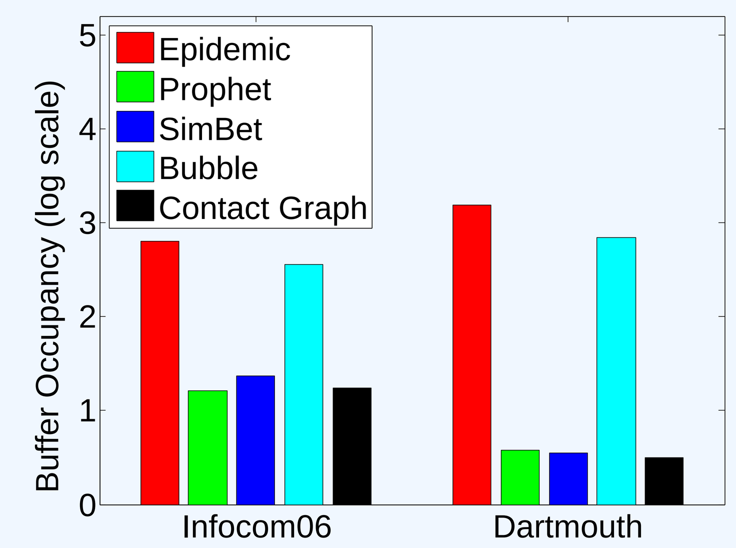


- small network (Infocom06): improvement in delivery performance, consuming much fewer resources, lowest overhead ratio.
- large network (Dartmouth): lower delivery ratio compared to replication-based forwarding, consuming much fewer resources, lowest overhead ratio.









References

[1] J. Gil Ko, C. Lu, M. Srivastava, J. A. Stankovic, A. Terzis, M. Welsh "Wireless Sensor Networks for Healthcare, " Proc. IEEE, Sep 2010.
[2]A. Vahdat and D. Becker, "Epidemic Routing for Partially Connected Ad-Hoc Networks, " Tech. Rep., Duke University, 2000.
[3] A. Lindgren, A. Doria, and O. Schelen, "Probabilistic Routing in Intermittently Connected Networks, " SIGMOBILE Mob. Comput. Commun. Rev., vol. 7, Jul. 2003.
[4] E. M. Daly and M. Haahr, "Social Network Analysis for Routing in Disconnected Delay-Tolerant Manets , " in Proc. 8th ACM Int. Symp. on Mob. Ad-Hoc Net. and Comput., Montreal, Sep. 2007.
[5] P. Hui, J. Crowcroft, and E. Yoneki, "Bubble Rap: Social-based Forwarding Delay Tolerant Networks, " in Proc. 9th ACM Int. Symp. on Mob. Ad-Hoc Net. and Comput., Hong Kong, May 2008.
[6]D. A. Sharma and M. Coates, "Contact Graph based Routing in Opportunistic Networks," IEEE Global Conf. on Signal and Info. Proc., Dec. 2013 (accepted).