

Measuring a Human Contact Network for Epidemiology Research

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Contact Networks

Specify physical proximity interactions over time

Used by

National Institute of Health
Center for Disease Control

Key in determining how to limit disease spread
e.g. vaccinations

Epidemiology's Problem

Not enough data!

Pen-and-paper and survey methods
are inaccurate
have limited coverage

The Alternative

Use technology to get more fine grained and accurate data

Previous work has used cell phones and RFID on small populations

The Deployment

8-hour day at a U.S. high school
- closed network environment

850 participants
- students, teachers, staff

5+ school buildings
170 location nodes

the motes

CrossbowTelos
Rev B 2004/09/27
8350-0380-01
02-23-081



The Code

Over 1000 motes
broadcasting periodic beacons

Mote type	Number	Beacon interval	TX Power
participant	850	20 sec	-16.9 dBm
location	170	20 sec	-11 dBm

Data Format

source bcn_seqno rssi local_seqno

Preparation

Program 1000+ notes

Place 170 location notes the night before

Prepare batches of 10 to 15 notes for teachers to distribute to students

Brief the school

D-Day

In at 6:30 am, out by 9 pm

Distribute motes, pouches, and assent forms

Participants write down the time and start the mote by inserting the second battery

4 pm - motes start to come back





The Rest of This Talk

Pre-deployment considerations
working with epidemiologists
working with human subjects

Post-deployment woes
node resets and disconnections

Epidemiology Considerations

Trade-off between
time resolution of data and coverage

20 seconds is good enough

Human Subject Considerations

Opting in and out

user button vs. batteries

Indicate state of the mote

red vs. yellow LED

The Deployment

8-hour day at a U.S. high school

850 participants

5+ school buildings

D-Day Outcome

792 traces from participants

Total of 3 million contact entries

But During the Deployment ...

Batteries fell out

Batteries were taken out

Students played with the reset button

Motes were accidentally bumped against desks

Students banged motes against hard surfaces

Students swung motes by the lanyards

Motes were rubbed together

... to see what happens

Node reboots

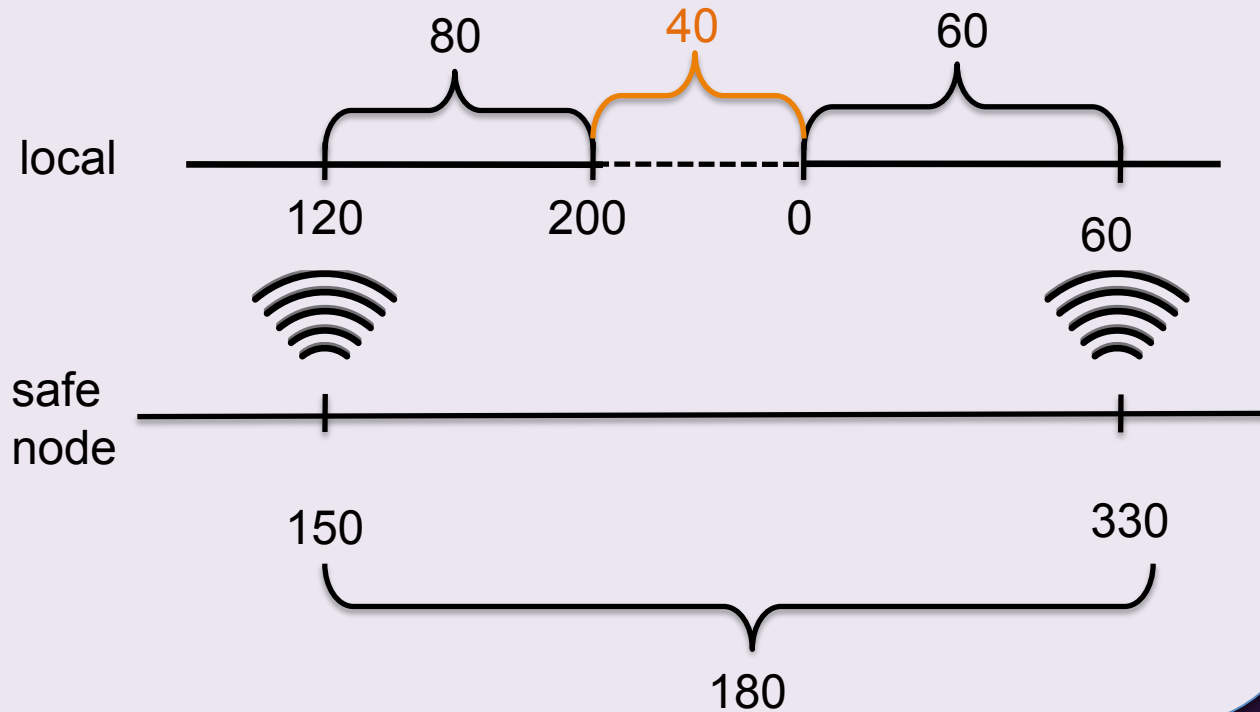
272 nodes with uninterrupted data traces
a.k.a. 'safe notes'

520 nodes with a total of over 1500 reboots

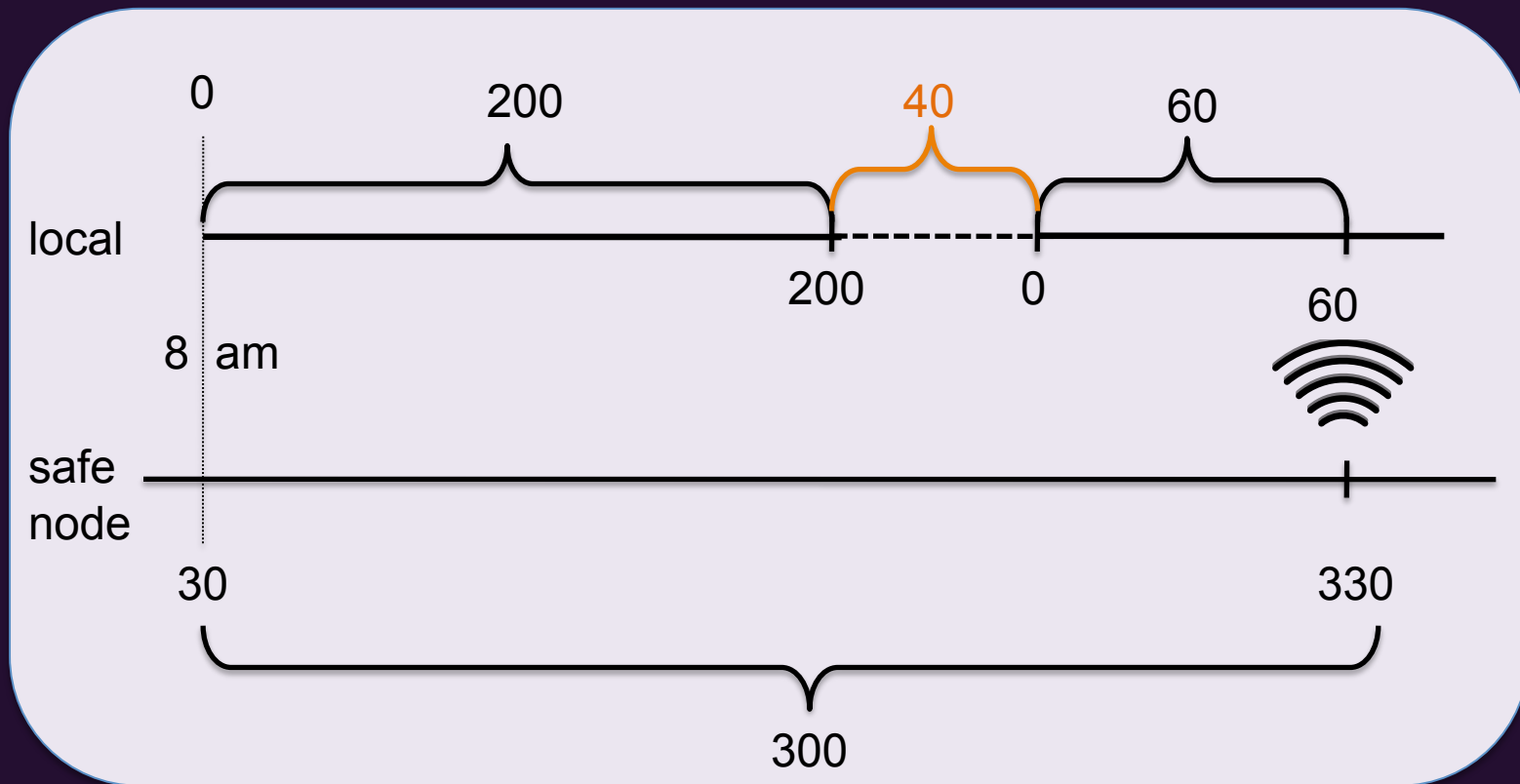
Hardware Resets

source	bcn_seqno	rss	local_seqno
450	300	220	370
789	414	223	370
450	301	221	371
450	302	220	0

Extended Disconnection



Extended Disconnection, case 2



Global Time

No time synchronization code on the motes

Only need relative time
to place all subject interactions in context

Tactic: choose a popular mote!

Global Time, p2

Everyone likes food...

93.6% of participants received a beacon from one mote in the dining area

it became the global reference clock

Global Time

mote 101 example

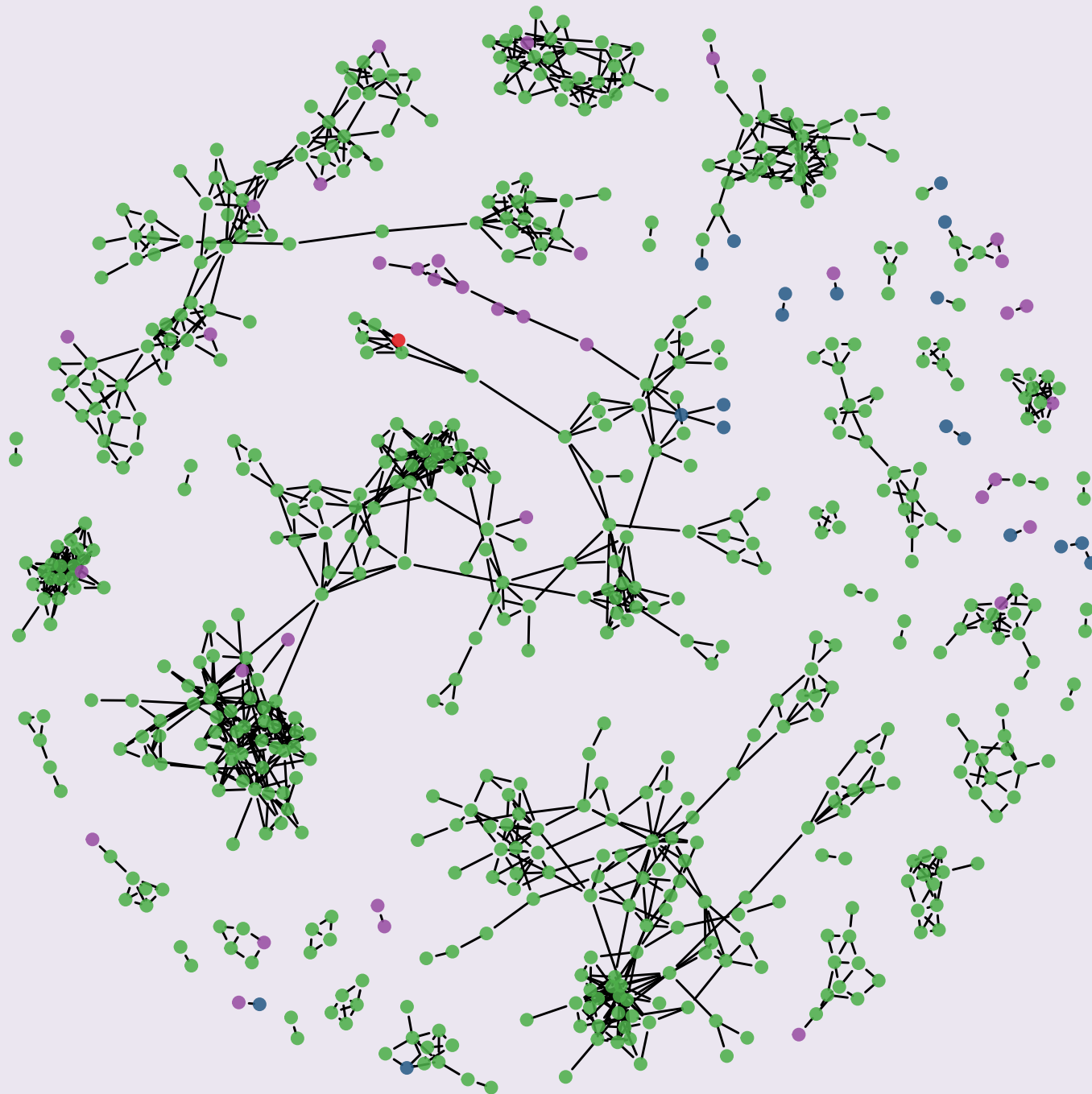
source	bcn_seqno	local_seqno	global
450	10	0	1700
.....			
.....			
10055	1750	50	1750

Global Time, result

A lookup table

Node ID	Global time at start
101	1700
102	1800
...	...
145	???

You did all this work, so what?



Takeaways

Sensor networks provide an opportunity to improve the understanding of disease spread.

Large-scale deployments can benefit from standard tools for mass programming.



Discussion