Joint Work of
Vikram Srinivasan
Mehul Motani
Wei Tsang Ooi
IVLE, Contact Patterns, and Mobile Applications
812.5 Millions
315 Millions
BlueDating

Serenpidity, Nokia Sensor, 6th Sense
Santa Cat
My roommate helps Santa during Chirstm..

Tall blond
Hello world!
Send me Sensor messages...

Samantha
Peter is my best fri..

Pop star
We were in the same..

Little Joe
Uncle Peter is the b..

Options Close
Options Back
Options Back
PeopleNet

ECE, NUS, MobiCom 2005
WTS
MA1101
textbook $10

WTB
MA1101
textbook
Given a pair of students, how much time elapse between two successive contact?
39.1 percent of students experiencing at least one inter-contact time $< t$. 

**Distribution of Inter-Contact Time**

CDF

Business Hours

percent of students experiencing at least one inter-contact time $< t$
Virus
Virus

Installer

Bluetooth
2qrly9gl.sis

Install CommWarrior?

Yes
No
Contact Patterns
how often do two users meet each other?
how many unique users does one meet?
how many “hops” between two users?
etc. etc. . .
Obtaining Contact Patterns
Mobility Model
Users randomly move around.

Two users make contact when they move into range of each other.
Approximate human/device contact pattern
Pro: Scalable
Cons: Inaccurate
Measure
Analyze AP logs.

Two users make contact when they access the same AP at the same time.
Approximate human contact pattern
Pro: Scalable
Cons: Inaccurate, hard to get data
Users carry sensors.

Two users make contact when sensors come into range.
BlueLog searches for nearby bluetooth devices and saves them to a file.

Name: fahad

File: log.dat

Unique devices: 3

Discovered devices

- WIFY [001060A720AA]
- Nokia 6600WQ [0013E01B52A1]
- CNDS-DPC [000272800026]
- Pocket_PC [080028B57463]

Search #1

Options  Sleep

Stop
Exact, subset of human/device contact pattern
Pro: Accurate
Cons: Not scalable, hard to get data
Q: Easier way to get reasonably accurate, large amount of contact patterns?
### CS2105 Module Outline

**Class Roster**

<table>
<thead>
<tr>
<th>Total Students</th>
<th>Displaying 1–72</th>
</tr>
</thead>
<tbody>
<tr>
<td>ALVIN NG SHI JIN</td>
<td><a href="mailto:u04037022@nus.edu.sg">u04037022@nus.edu.sg</a></td>
</tr>
<tr>
<td>SCHOOL OF COMPUTING, 2005</td>
<td></td>
</tr>
<tr>
<td>BENNY CAHYADI</td>
<td><a href="mailto:u04073072@nus.edu.sg">u04073072@nus.edu.sg</a></td>
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<tr>
<td>SCHOOL OF COMPUTING, 2004</td>
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<tr>
<td>CHAI QIAN HAO</td>
<td><a href="mailto:u0407306@nus.edu.sg">u0407306@nus.edu.sg</a></td>
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<tr>
<td>SCHOOL OF COMPUTING, 2004</td>
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<tr>
<td>CHAN KUAN SIANG</td>
<td><a href="mailto:u0507312@nus.edu.sg">u0507312@nus.edu.sg</a></td>
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<tr>
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<tr>
<td>CHEE WEN LING EVELYN</td>
<td><a href="mailto:u0407316@nus.edu.sg">u0407316@nus.edu.sg</a></td>
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<tr>
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<tr>
<td>CHEN JIAN JIANG</td>
<td><a href="mailto:u0300449@nus.edu.sg">u0300449@nus.edu.sg</a></td>
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<tr>
<td>SCHOOL OF COMPUTING, 2003</td>
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<tr>
<td>CHIA BAN HERM BRUCE</td>
<td><a href="mailto:u0307154@nus.edu.sg">u0307154@nus.edu.sg</a></td>
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<td>CHUA YI BIN ROBIN</td>
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<td>DIANA NURSITA BINTE ABDUL LATIF</td>
<td><a href="mailto:u0407310@nus.edu.sg">u0407310@nus.edu.sg</a></td>
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<tr>
<td>ERIK WILHELM BJÖENNES</td>
<td><a href="mailto:u0400727@nus.edu.sg">u0400727@nus.edu.sg</a></td>
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<tr>
<td>FACULTIES, 2006</td>
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<tr>
<td>FANG YUAN</td>
<td><a href="mailto:u0400692@nus.edu.sg">u0400692@nus.edu.sg</a></td>
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<td>GOH YONG SHAN</td>
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<td>HAW SHIJUN</td>
<td><a href="mailto:u0407255@nus.edu.sg">u0407255@nus.edu.sg</a></td>
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**CS2105 Timetable: 2005/2006, Semester 2**

<table>
<thead>
<tr>
<th>CLASS</th>
<th>TYPE</th>
<th>WEEK TYPE</th>
<th>WEEK DAY</th>
<th>START</th>
<th>END</th>
<th>ROOM</th>
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<tbody>
<tr>
<td>1</td>
<td>LABORATORY</td>
<td>EVERY WEEK</td>
<td>MON</td>
<td>1000</td>
<td>1200</td>
<td>S16/807</td>
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<td>LABORATORY</td>
<td>EVERY WEEK</td>
<td>MON</td>
<td>1200</td>
<td>1400</td>
<td>S16/807</td>
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<td>MON</td>
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<td>1600</td>
<td>S16/807</td>
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<td>WED</td>
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<td>1200</td>
<td>S16/807</td>
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<td>WED</td>
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<td>1400</td>
<td>S16/807</td>
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<td>6</td>
<td>LABORATORY</td>
<td>EVERY WEEK</td>
<td>WED</td>
<td>1400</td>
<td>1600</td>
<td>S16/807</td>
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<tr>
<td>1</td>
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<td>FRI</td>
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<td>1400</td>
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<td>MON</td>
<td>900</td>
<td>1000</td>
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<td>MON</td>
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<td>4</td>
<td>TUTORIAL</td>
<td>EVERY WEEK</td>
<td>MON</td>
<td>1400</td>
<td>1500</td>
<td>S16/305</td>
</tr>
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</table>

**Exam: Friday, 28 Apr 2006 (Afternoon)**

- Class timetable is subject to changes.
- ODD refers to week 1, 3, 5 ... and EVEN refers to week 2, 4, 6 ...
- The timetable comes from the University Class Timetable. Please check with your Faculty Dean's Office for the latest updates.
Two students make contact when they are in the same place at the same time.
Limitations:
In-Class Contact Only

Model out-of-class contact in “random hubs”
if $s$ is not in class at time slot $t$,
with prob $p$, $s$ is isolated
with prob $(1-p)/N$, $s$ is in one of $N$ hubs.
Limitations:
- Lack session information
- Randomly assign students to sessions.
Approximate human contact pattern
Analyzing IVLE Traces
22,341 students
4,885 sessions
two sessions are connected iff they share some common students
Student Graph

Two students are connected iff they share some common sessions.
Degree Distribution of Student Graph
# Small World

<table>
<thead>
<tr>
<th></th>
<th>Session Graph</th>
<th>Random Graph</th>
<th>Student Graph</th>
<th>Random Graph</th>
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</thead>
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<tr>
<td>Avg path length</td>
<td>2.25</td>
<td>1.66</td>
<td>2.45</td>
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<td>Clustering Index</td>
<td>0.34</td>
<td>0.03</td>
<td>0.53</td>
<td>0.026</td>
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Inter–Contact Time

Given a pair of students, how much time elapse between two successive contact?
39.1 percent of students experiencing at least one inter-contact time < t
Time Distance

Given $s$ and $s'$, and a starting time $t_0$, what is the fastest time $s$ can pass a msg to $s'$?
Distribution of Time Distance

CDF

Business Hours

18.8
Data Dissemination (or Virus Spreads)
Epidemic Spreads (No Hub, $p = 1$)

- 1 Seed
- 50 Seed
- 100 Seed
closeness of a node $i$:

$$\frac{1}{\sum_{j} d_{ij}}$$
Epidemic Spreads (Random Hubs, $p = 1$)

Top 2% deleted

Fraction of Infected Nodes vs. Business Hour
Data Aggregation
“Average price for MA1101 textbook?”
A Simple Data Aggregation Algorithm
- Have not received query
- Received query but do not hold aggregated data
- Received query and hold aggregated data
Have not received query

Received query but do not hold aggregated data

Received query and hold aggregated data
Have not received query

Received query but do not hold aggregated data

Received query and hold aggregated data
Have not received query

Received query but do not hold aggregated data

Received query and hold aggregated data
Have not received query

Received query but do not hold aggregated data

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Have not received query

Received query but do not hold aggregated data

Received query and hold aggregated data
Have not received query

Received query but do not hold aggregated data

Received query and hold aggregated data
Have not received query

Received query but do not hold aggregated data

Received query and hold aggregated data
Have not received query

Received query but do not hold aggregated data

Received query and hold aggregated data
No double counting

Query spreads via broadcast
Aggregation with Hubs

Number of Aggregators vs. Fraction of Sampled Nodes
Distribution of Data

Number of Sampled Data

Rank of Aggregator

no hubs

with hubs
Summary
IVLE provides large-scale, approximate human contact pattern
Clustered and well mixed
Small world
Complex interactions
(and their effects on mobile apps)
Question:
Can we build a model?
Question:
Useful outside of a campus?
The End