Familiar Strangers:
Understanding metropolitan patterns of daily encounters

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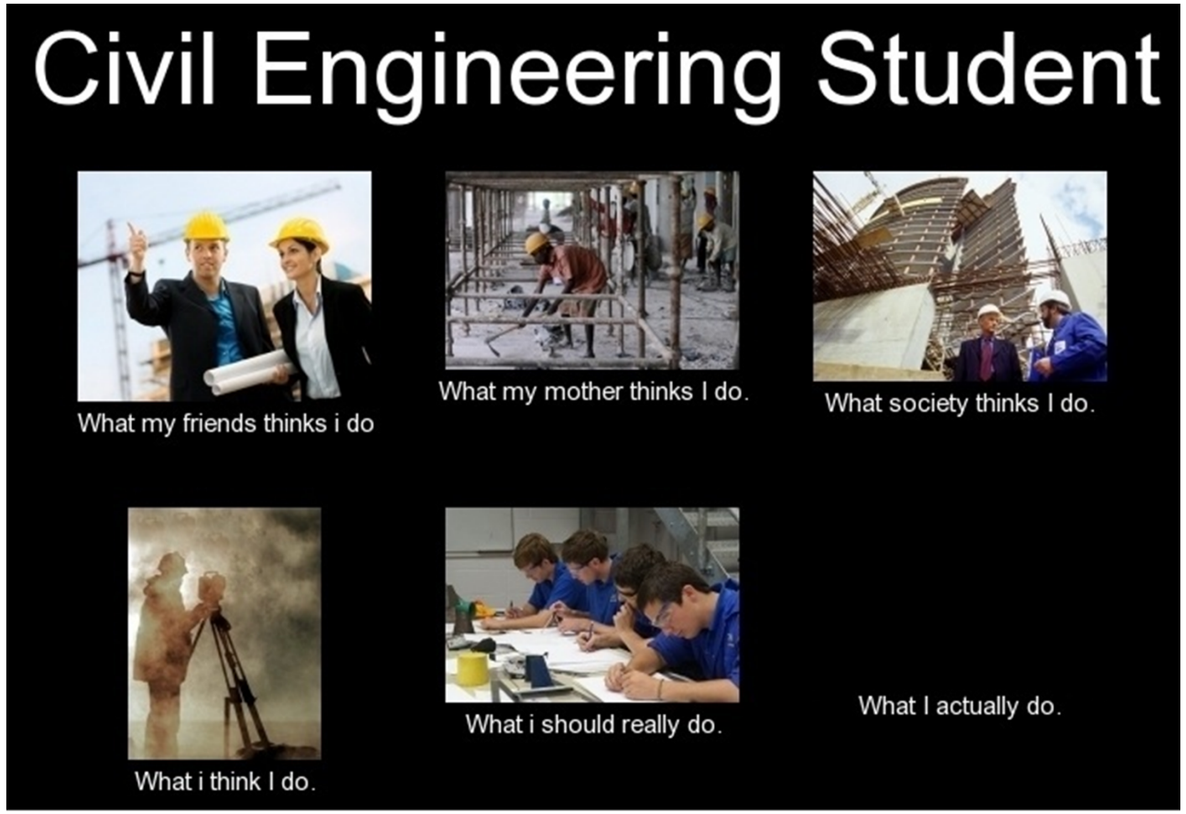
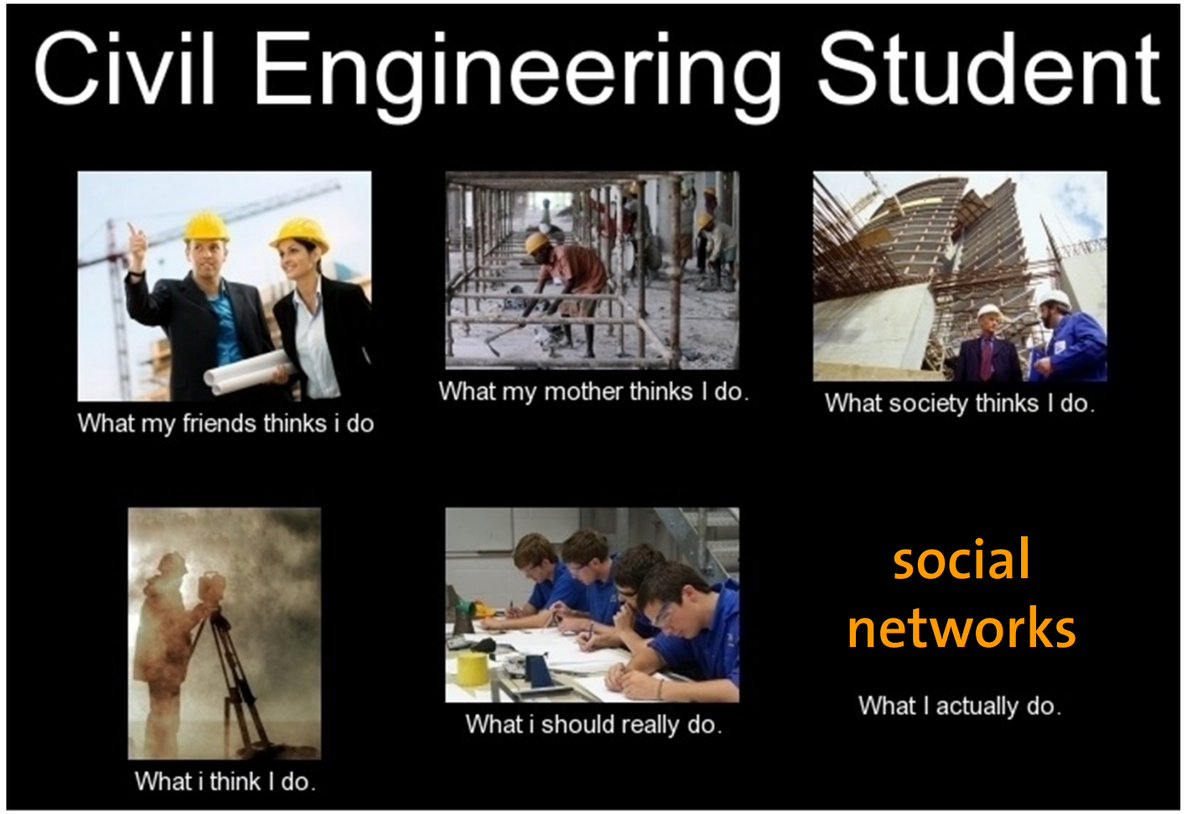
June, 7, 2013, Copenhagen, NetSci2013

Myself



Outlier!

Myself



!Outlier

Stanley Milgram

Stanley Milgram

http://en.wikipedia.org/wiki/Stanley_Milgram

Stanley Milgram

Born	August 15, 1933 New York City
Died	December 20, 1984 (aged 51) Manhattan
Cause of death	Heart failure[1]
Education	Queens College, New York (1954) M.A. Harvard University (1960) Ph.D.
Known for	Milgram experiment Small world experiment Familiar stranger

Stanley Milgram's experiment

Milgram, S. (1974) The frozen world of the familiar stranger. Psychology Today 17, 70-80.

Stanley Milgram's experiment

The frozen world

1970s
a train station

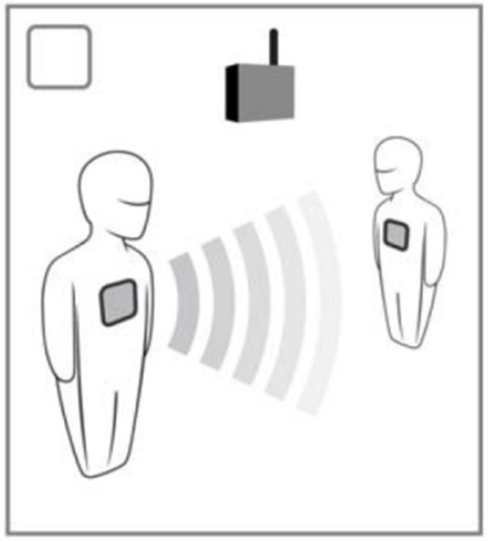
of the familiar strangers

Milgram, S. (1974) The frozen world of the familiar stranger. Psychology Today 17, 70-80.

Stanley Milgram's experiment

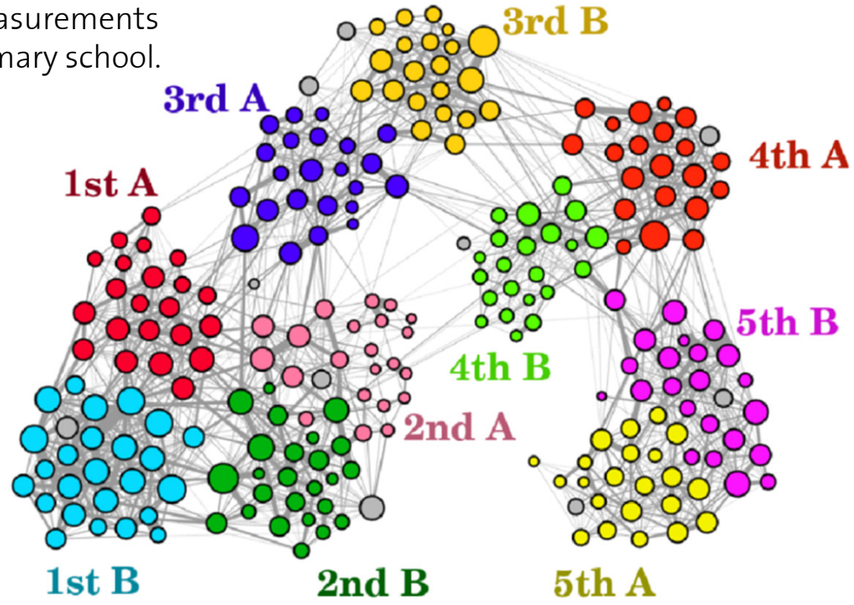
- "Familiar strangers" are those who urbanites meet everyday in public settings, such as a subway station, and with whom they never speak or otherwise acknowledge the other's existence.
- Comfortable anonymity
- **Physical proximity**

Physical proximity (Except taking photos)



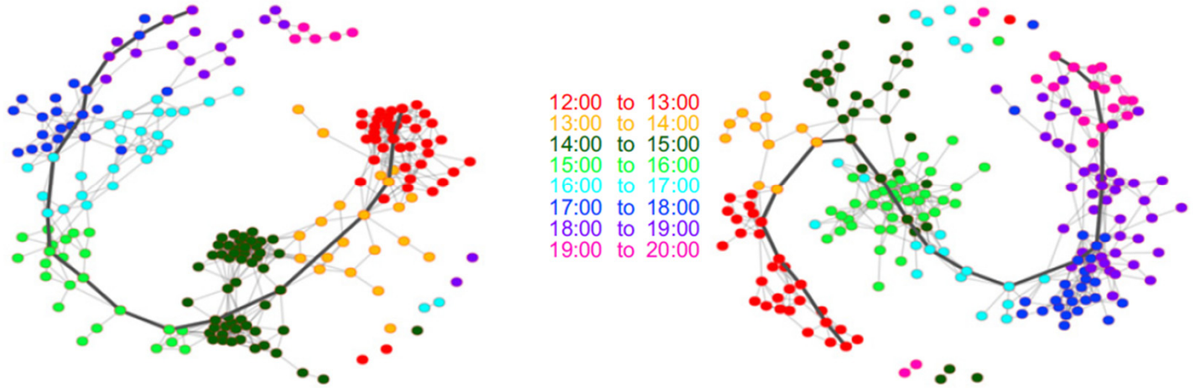
Cattuto C, et al. (2010) Dynamics of person-to-person interactions from distributed RFID sensor networks. PloS One 5(7):e11596.

Stehlé J, et al. (2011) High-resolution measurements of face-to-face contact patterns in a primary school. PloS one 6(8):e23176.

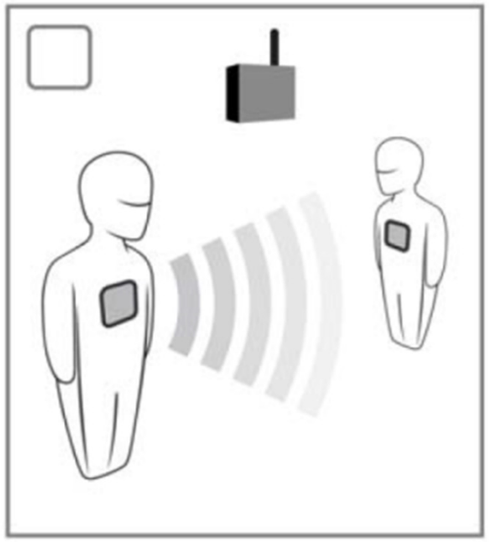


Bluetooth
RFID
Wi-Fi
...
Active data collection

Isella L, et al. (2011) What's in a crowd? Analysis of face-to-face behavioral networks. J Theor Biol 271(1):166-180.



Physical proximity



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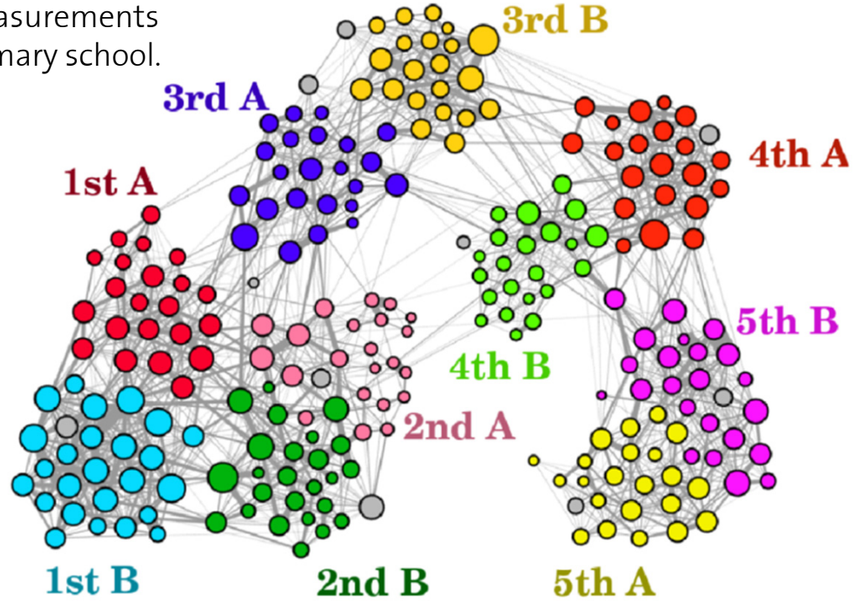

Limited in scale: schools, conferences, exhibitions...

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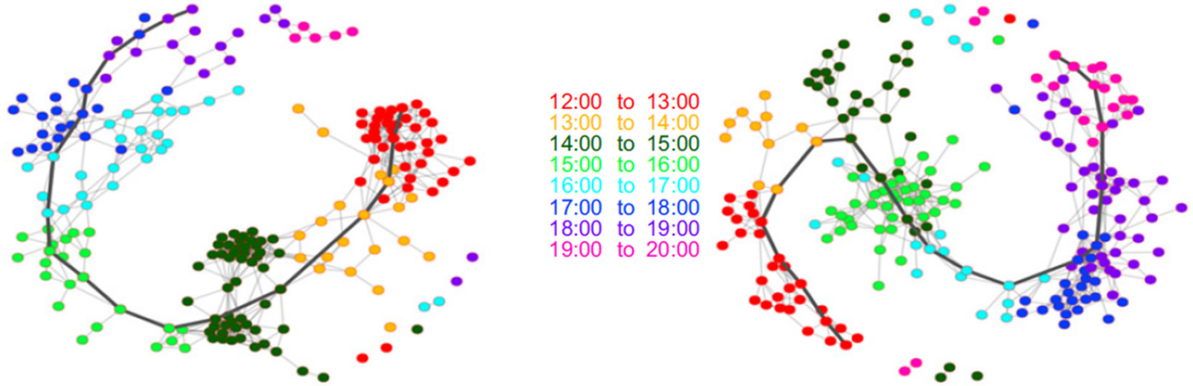

How to tie them together?

- **Think of data to capture physical proximity**
- Active data collection?

Physical proximity ←-----→ Familiar strangers

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- Large scale (city)
- Accurate
- Long time observation

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How to tie them together?

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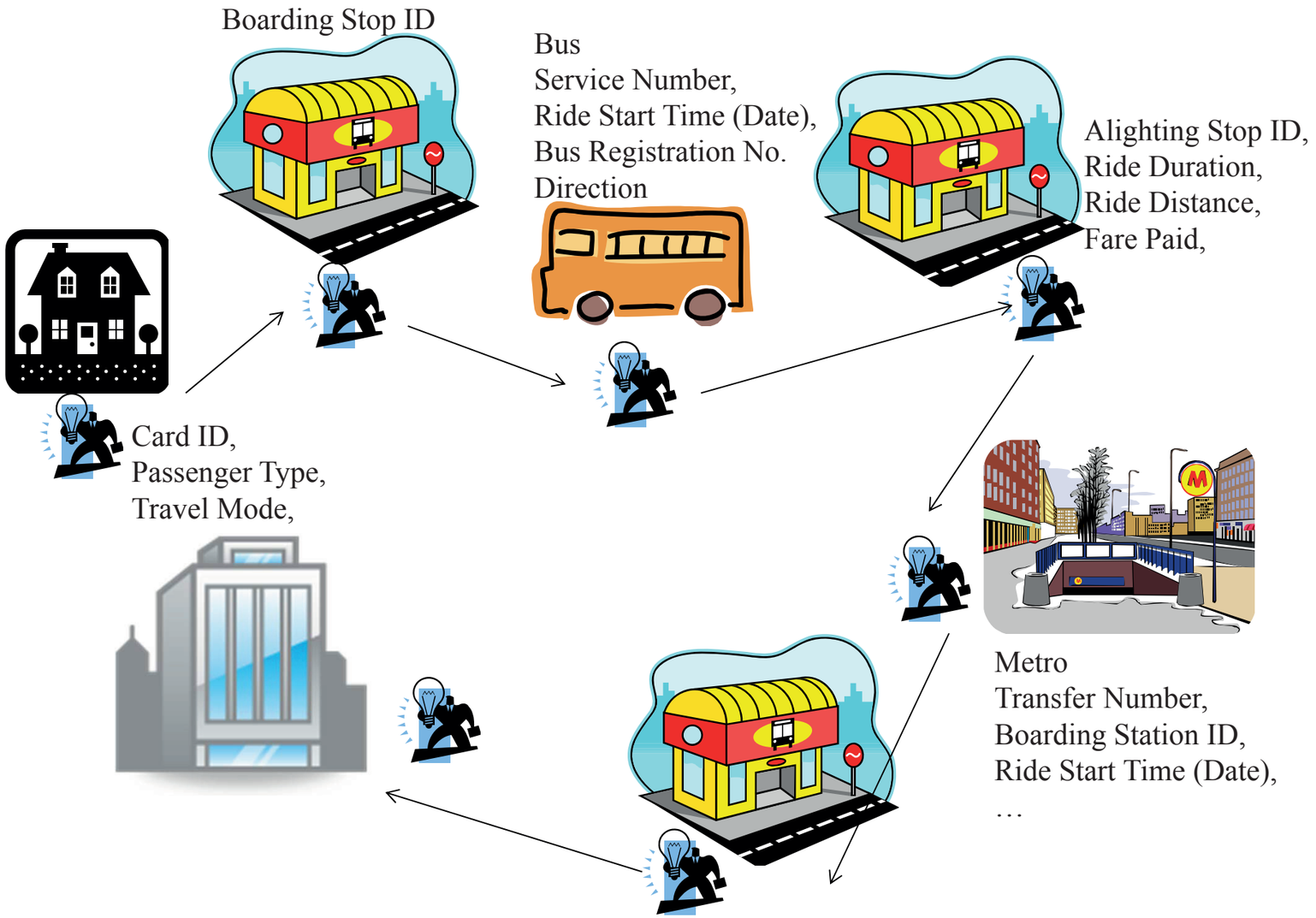
- Active data collection?
- Large scale (city)
- Accurate
- Long time observation

- **Public transit smart card!**
- **The EZ-link data in Singapore.**

How to tie them together?



What do we get from smart card data?

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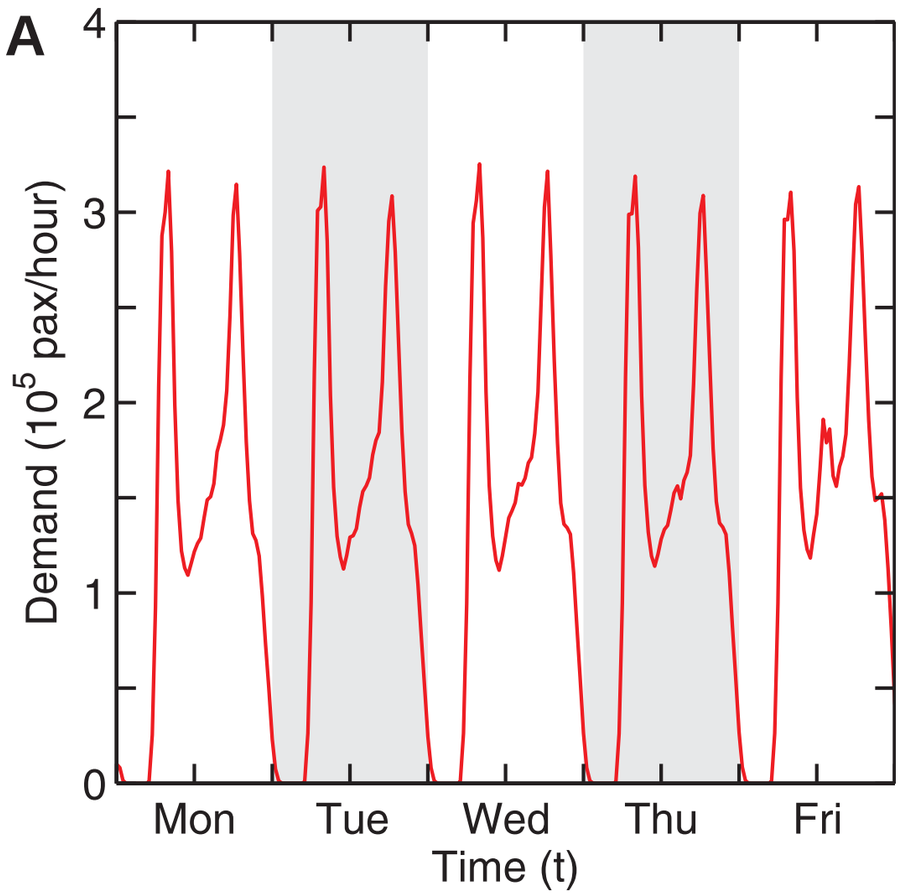
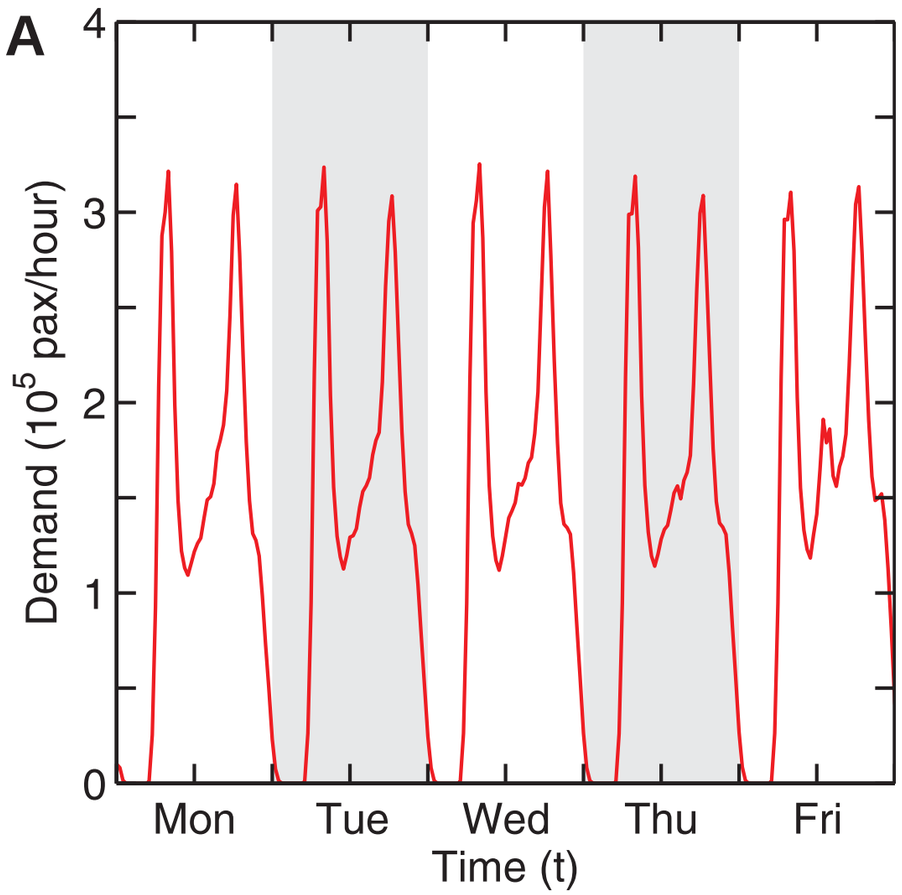


Simple statistics

But this is not what we want

What do we get from smart card data?



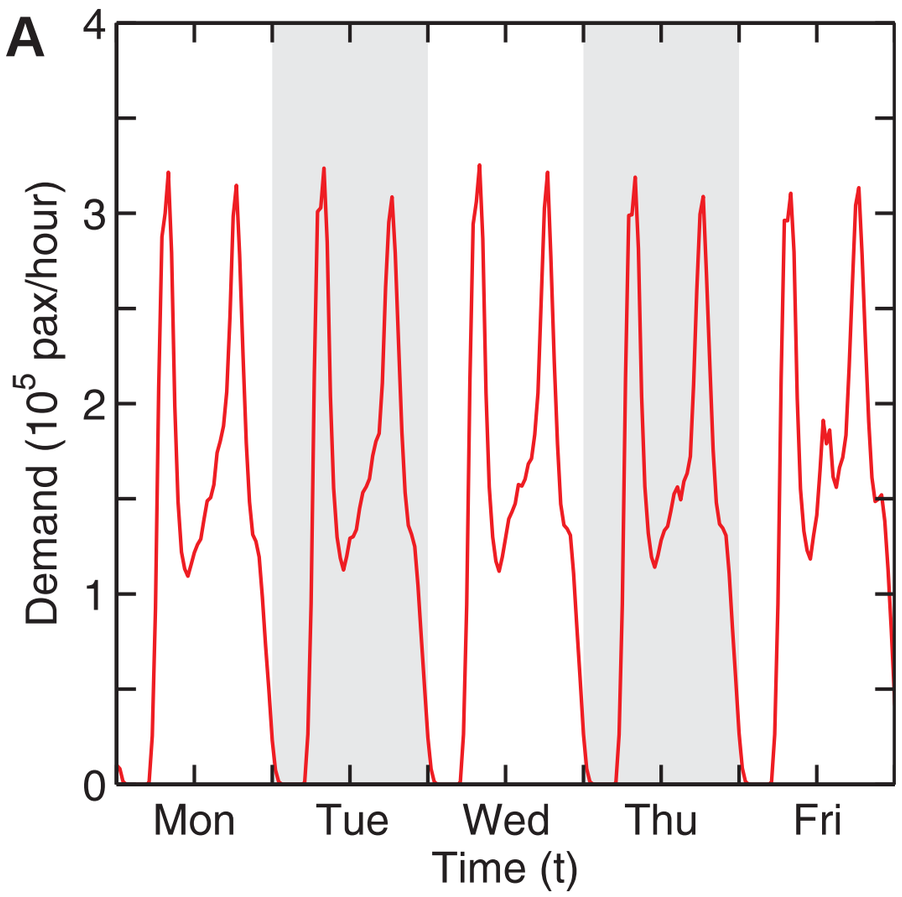
Simple statistics

But this is not what we want

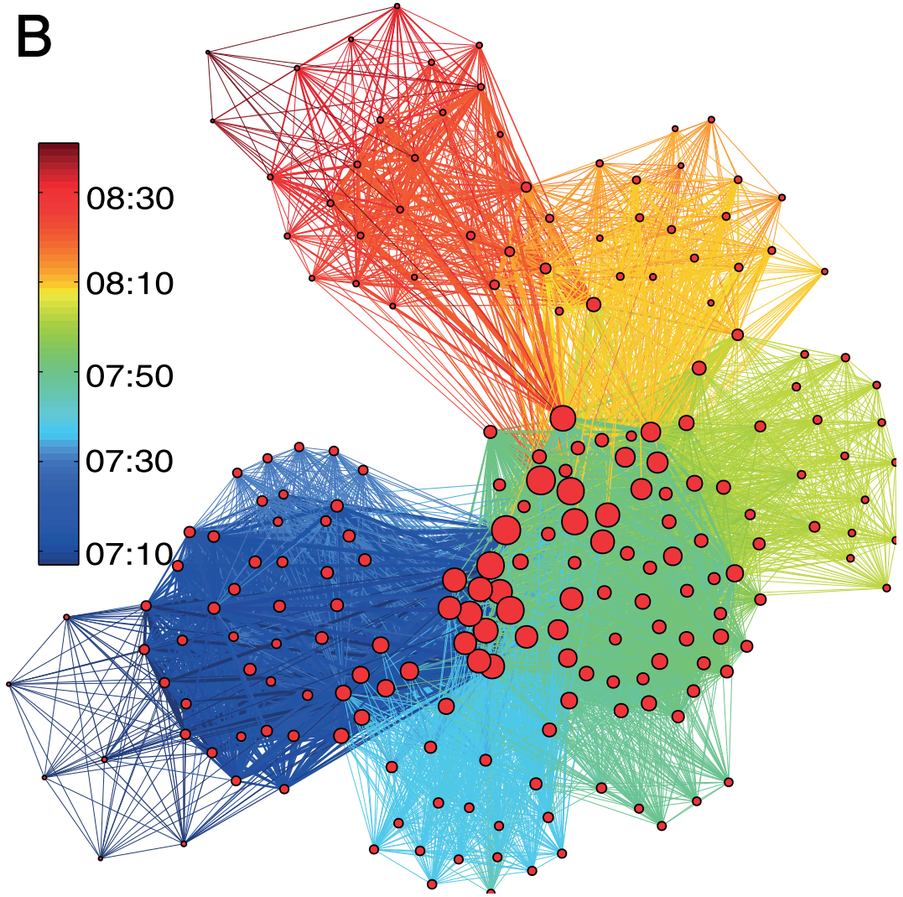
We want something complex

Like a network

What do we get from smart card data?

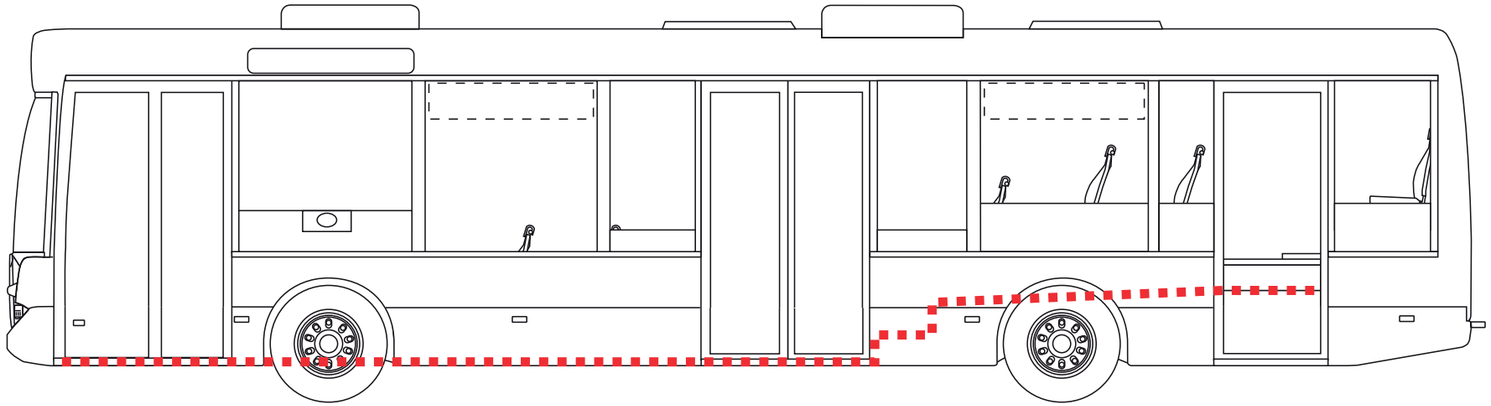


physical proximity?



How do we convince you and ourselves?

- Why bus is a good proxy to capture physical proximity?

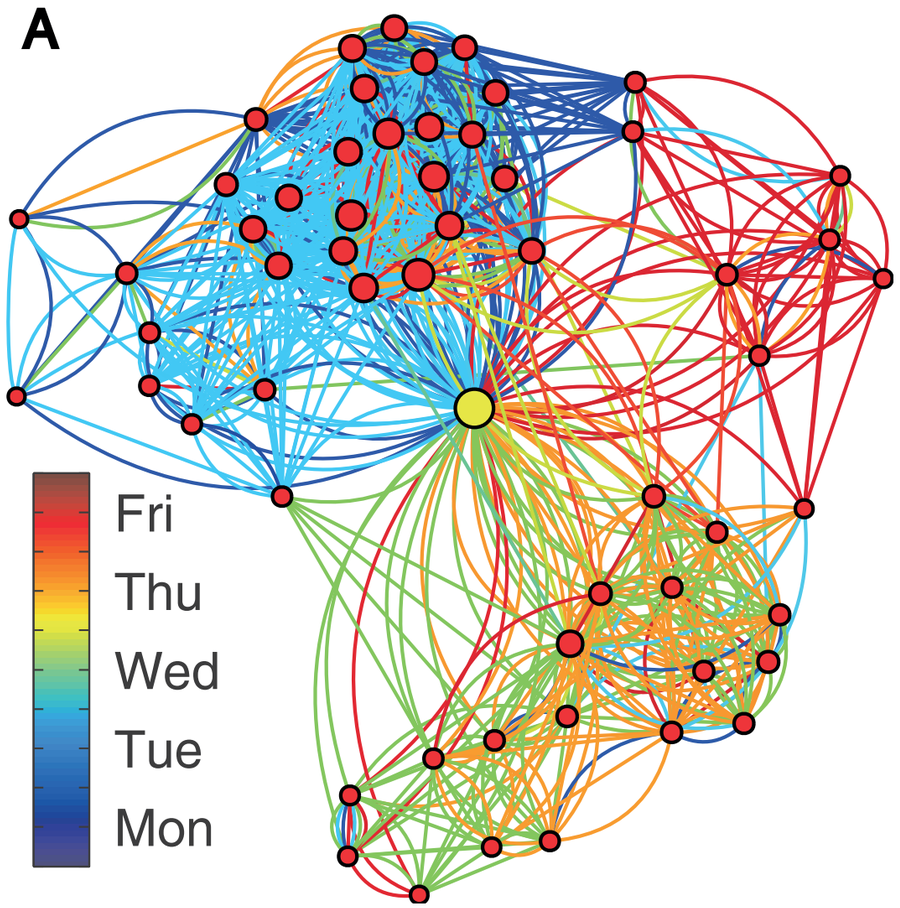


http://sgwiki.com/wiki/Buses

Find “familiar strangers”

- Find “the others” you have encountered more than once.

- “Once” over the study period:
  - perfect stranger
- “More than once”:
  - we assume he/she is a familiar stranger to you



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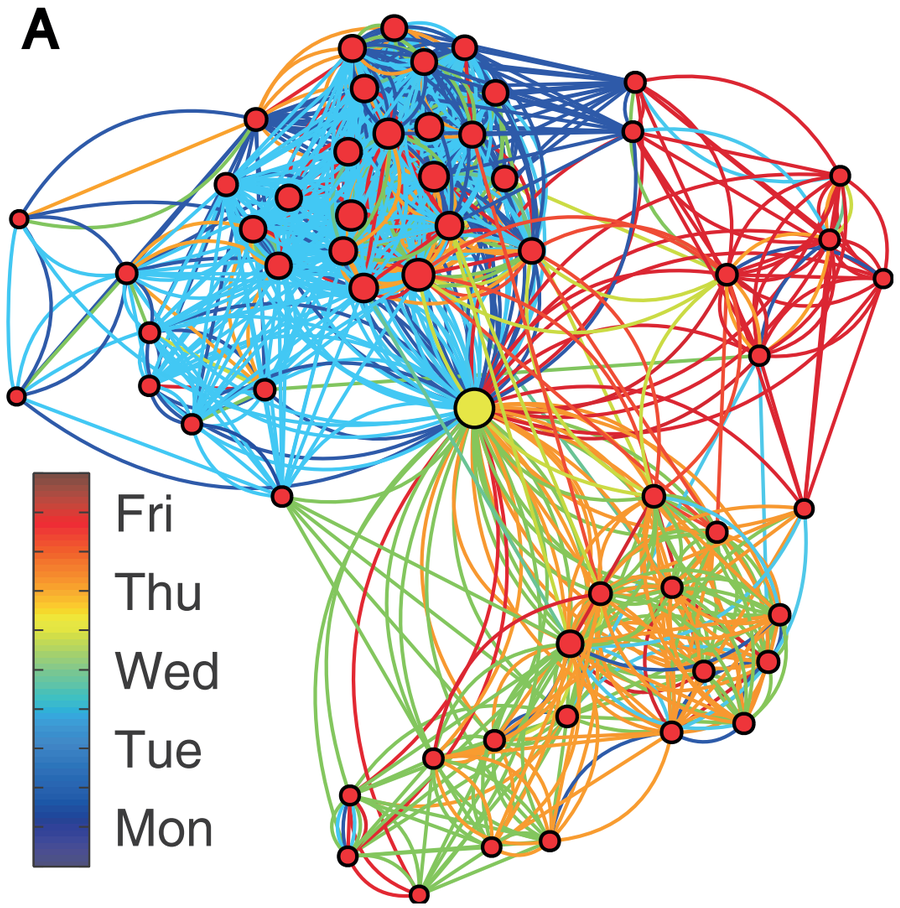
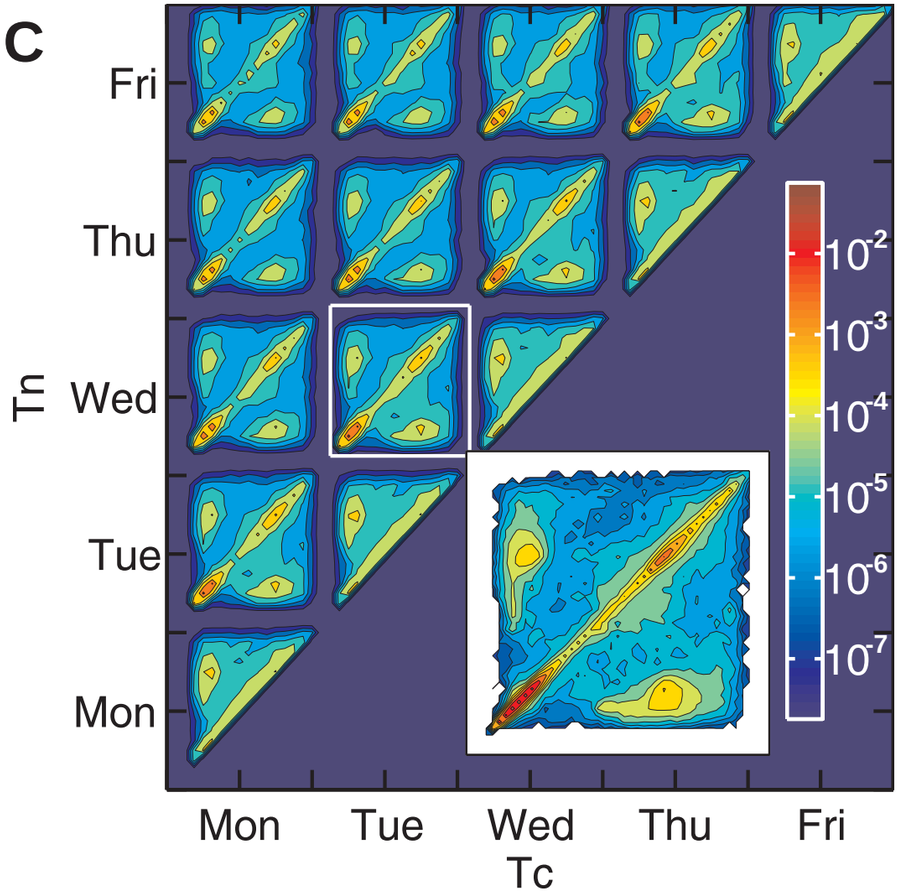
- **FSs are FSs**
- **What’s the law behind?**

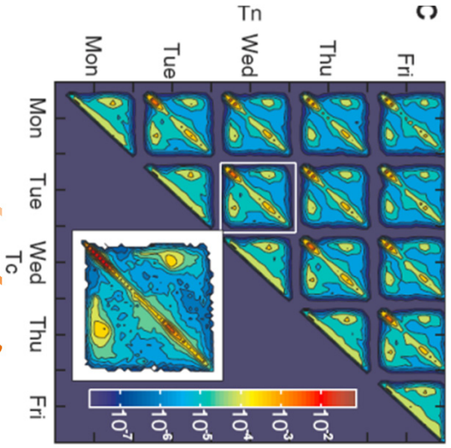


Time-of-day and day-to-day variation

- Probability density $P\left(T_c, T_n\right)$
- 2d plot shows the density of the current and the next encounter



$$P\left(D_c, D_n\right) = \begin{bmatrix} 0 & 0.141 & 0.086 & 0.061 & 0.046 \\ 0 & 0 & 0.148 & 0.091 & 0.062 \\ 0 & 0 & 0 & 0.145 & 0.085 \\ 0 & 0 & 0 & 0 & 0.135 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$



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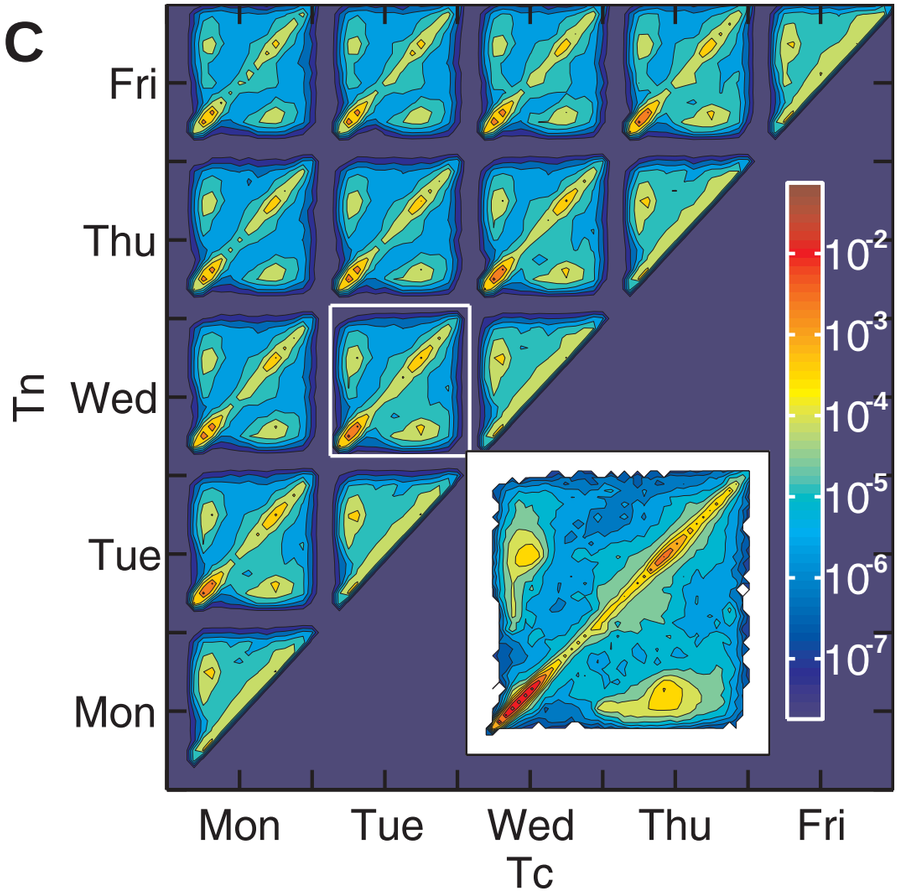
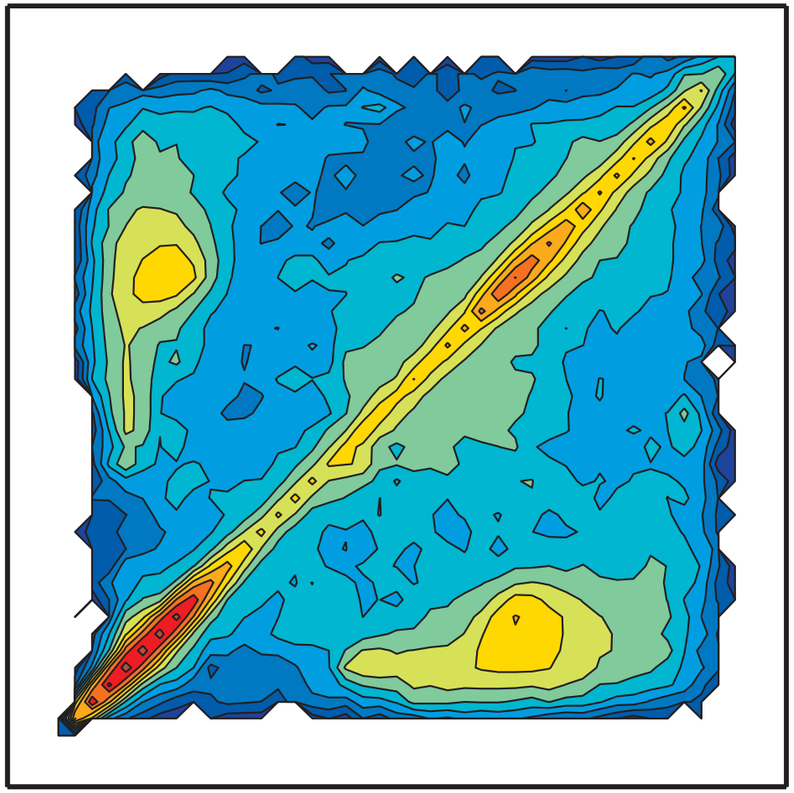
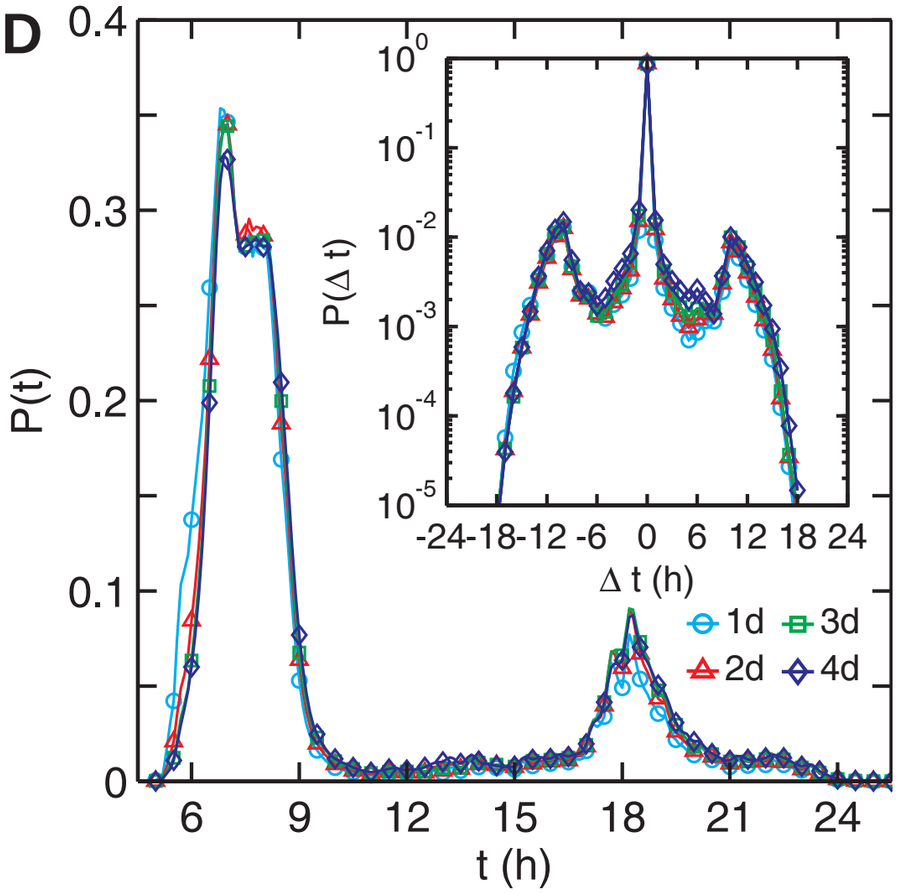




Time-of-day and day-to-day variation

- Have to check

- Two dimensions:
  - Over day (merge t_c and t_n)
  - **Collective regularity morning/afternoon**
  - On the diagonal ($\mathrm{mod}\left(t_c - t_n, 24\right)$)



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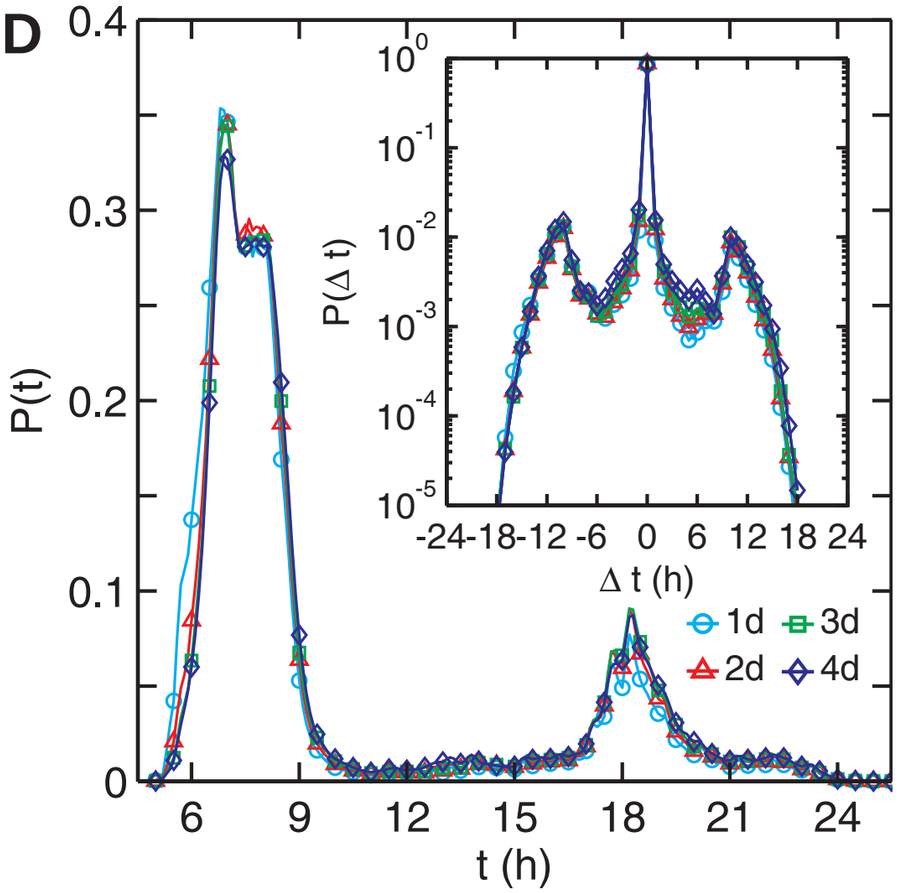
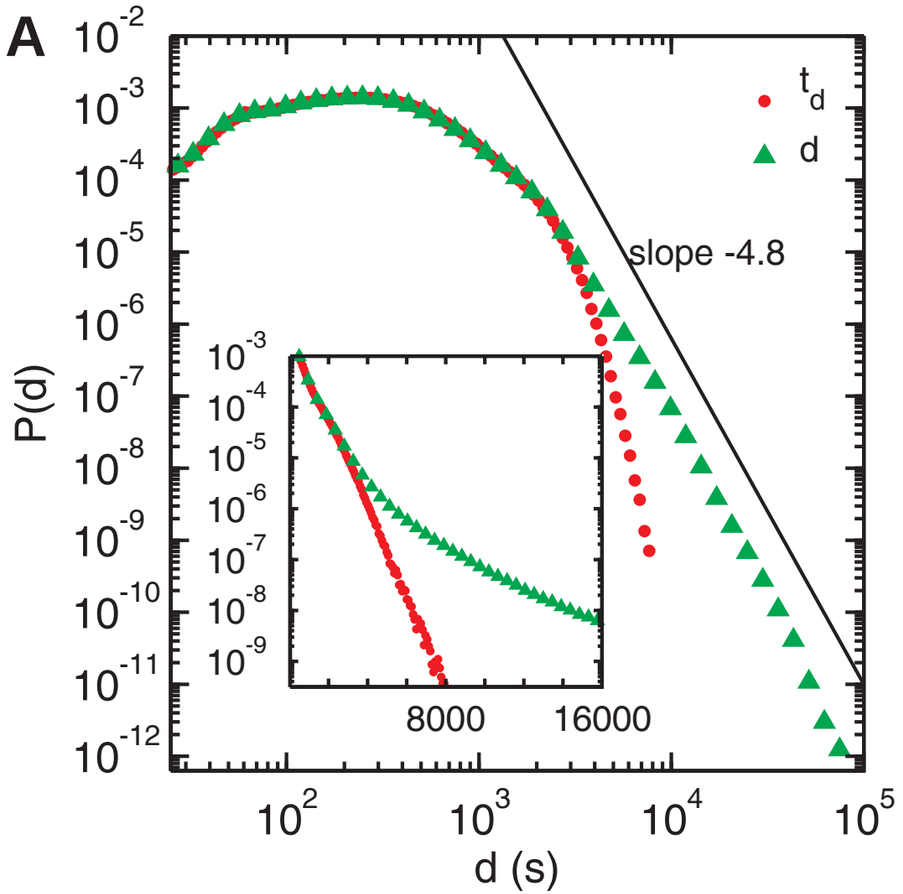
- **Taken together, we find**
- **reproducible temporal patterns**



What is the consequence?

- Distributions of …
- Duration of each encounter t_d
- **Exponentially decaying tail**

- Duration of $d(i,j) = \sum_{k=1}^{f_e(i,j)} t_{d,k}(i,j)$
- **Sum of total duration between** (i,j)



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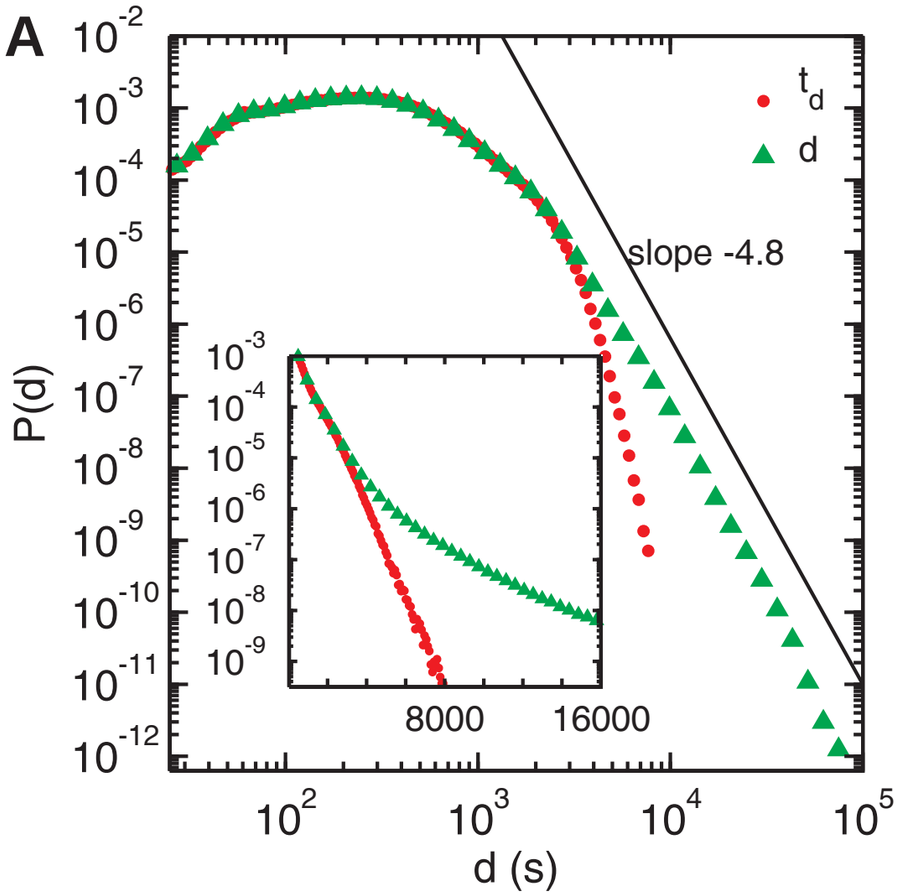
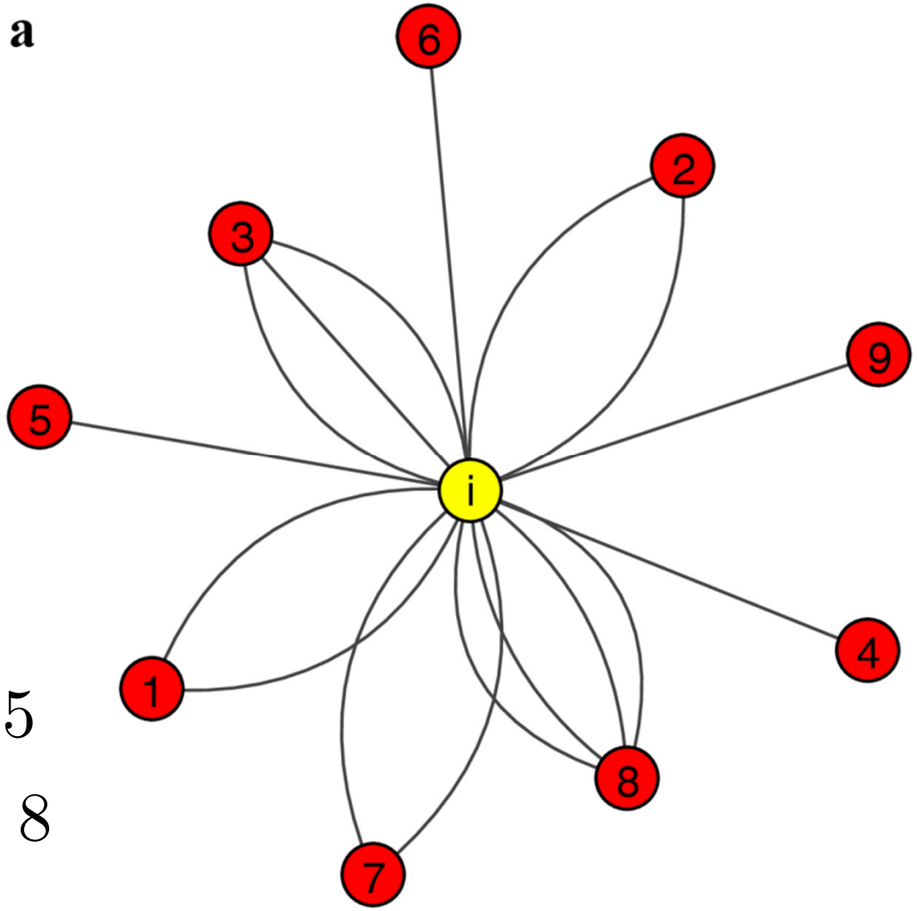
- Duration of $d(i,j) = \sum_{k=1}^{f_e(i,j)} t_{d,k}(i,j)$
- **Sum of total duration between** (i,j)
- **Power-law tail**
- **Evidence of paired regularity**

- **Measurement?**



What is the consequence?

- On individual level
- Number of familiar strangers: k_i
- Personal weight: $w_i \equiv \sum_{j \in N(i)} \left(f_e(i,j) - 1 \right)$

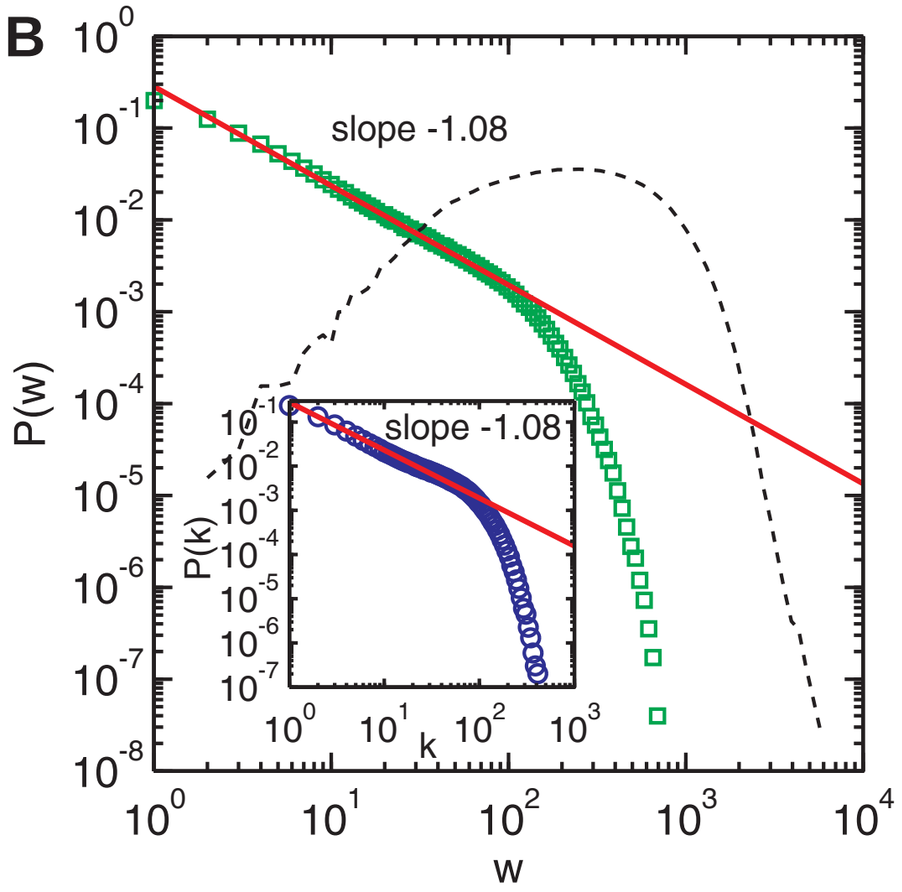


$k_i = 5$

$w_i = 8$

What is the consequence?

- On individual level
- Personal weight: $w_i \equiv \sum_{j \in N(i)} \left(f_e \left(i, j \right) - 1 \right)$
- Follows a power law with high cut-offs,



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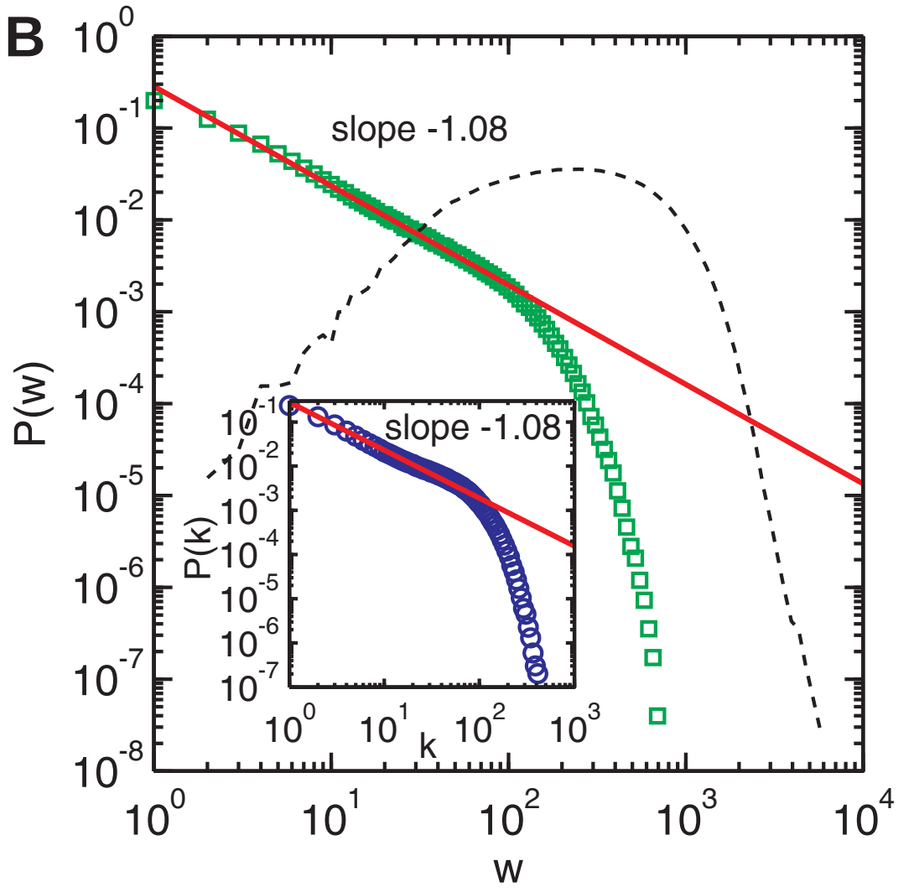
- Personal weight: $w_i \equiv \sum_{j \in N(i)} \left(f_e \left(i, j \right) - 1 \right)$
- Follows a power law with high cut-offs,
- **Great variation**
- **Encounter patterns might be influence by individual behavior patterns (regularity).**



Measure individual regularity

- Rescaled personal weight:

$$r_i = \frac{w_i}{T_i}\left(\text{hour}^{-1}\right)$$

How often do you recognize fss in one hour?

Measure individual regularity

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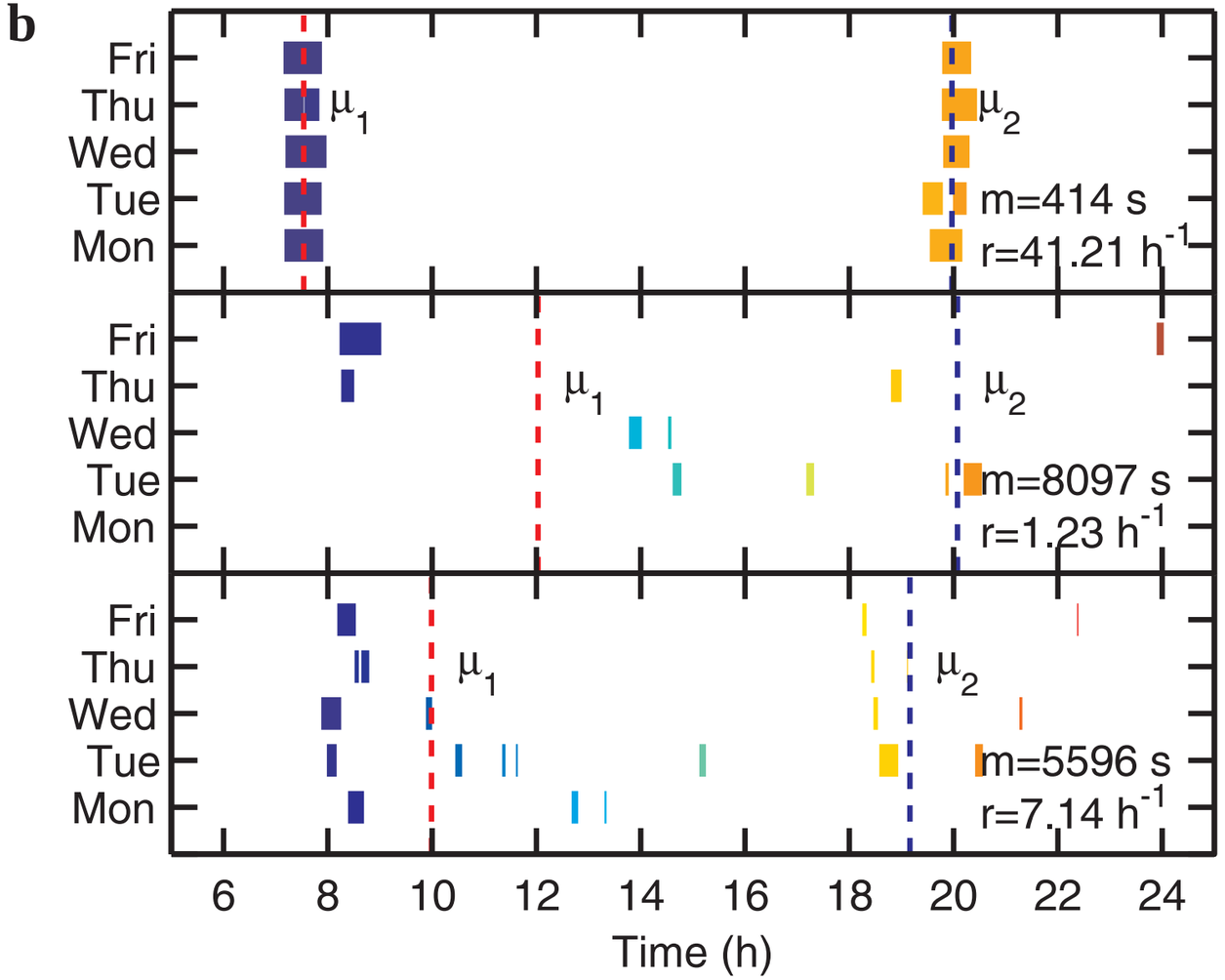
$$r_i = \frac{w_i}{T_i}\left(\text{hour}^{-1}\right)$$

How often do you recognize fss in one hour?

- Absolute trip difference:

$$m_i = \sum_{k=1}^{2} \sum_{t \in S_k} \frac{\left| t_j - \mu_k \right|}{n}$$

How regular you are?



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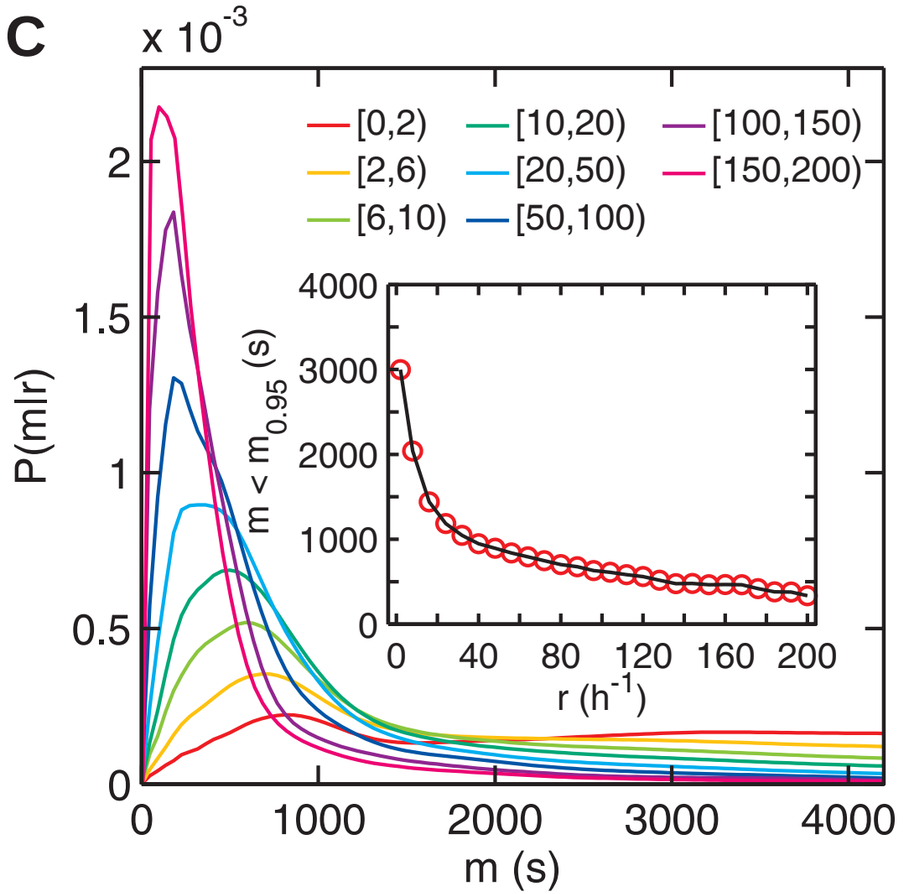
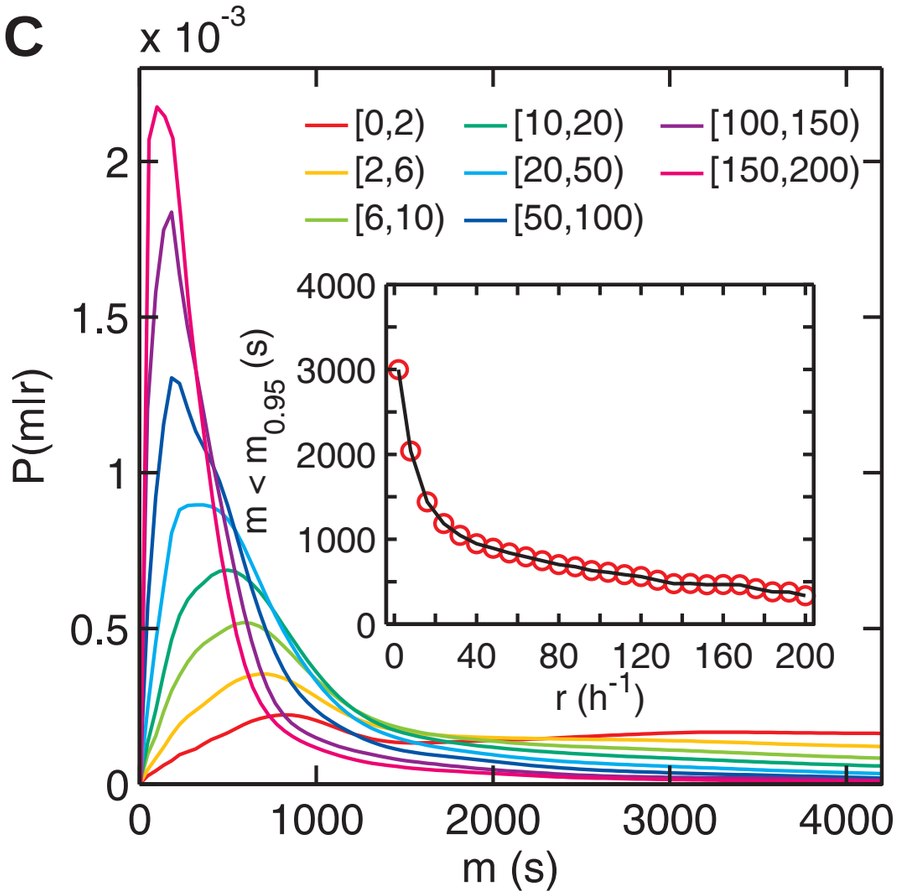


Measure individual regularity

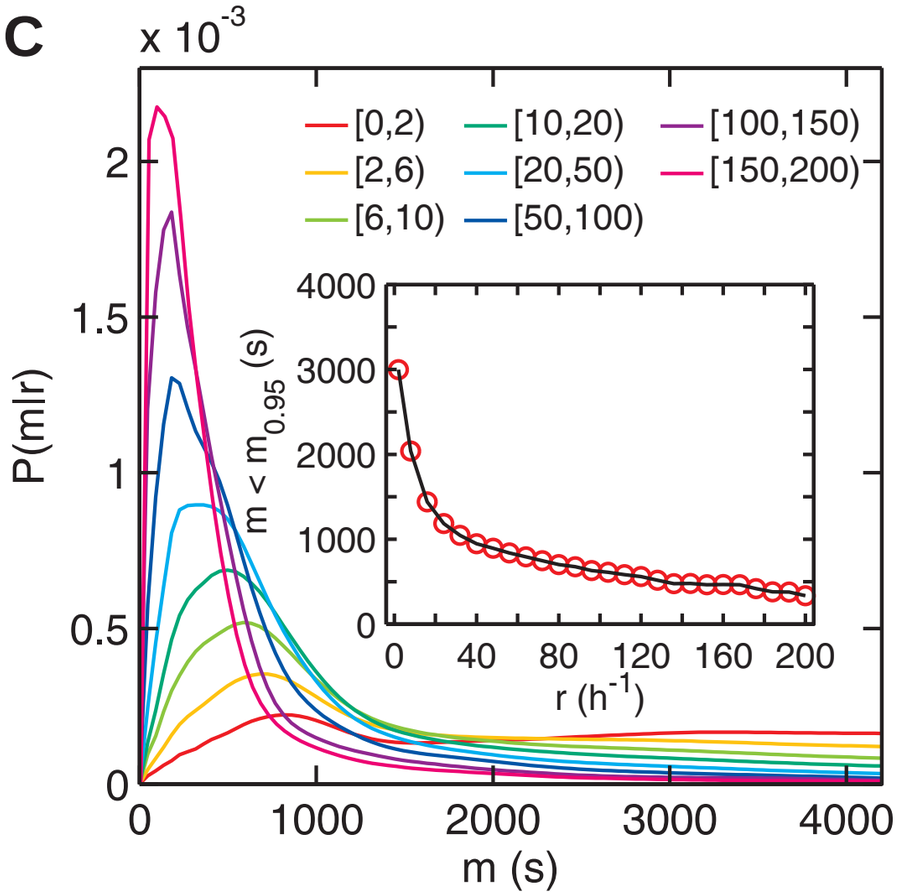
- Individuals with higher r_i tend to have less skewed $P(m)$

- Those with lower r_i display a more skewed distribution



Measure individual regularity

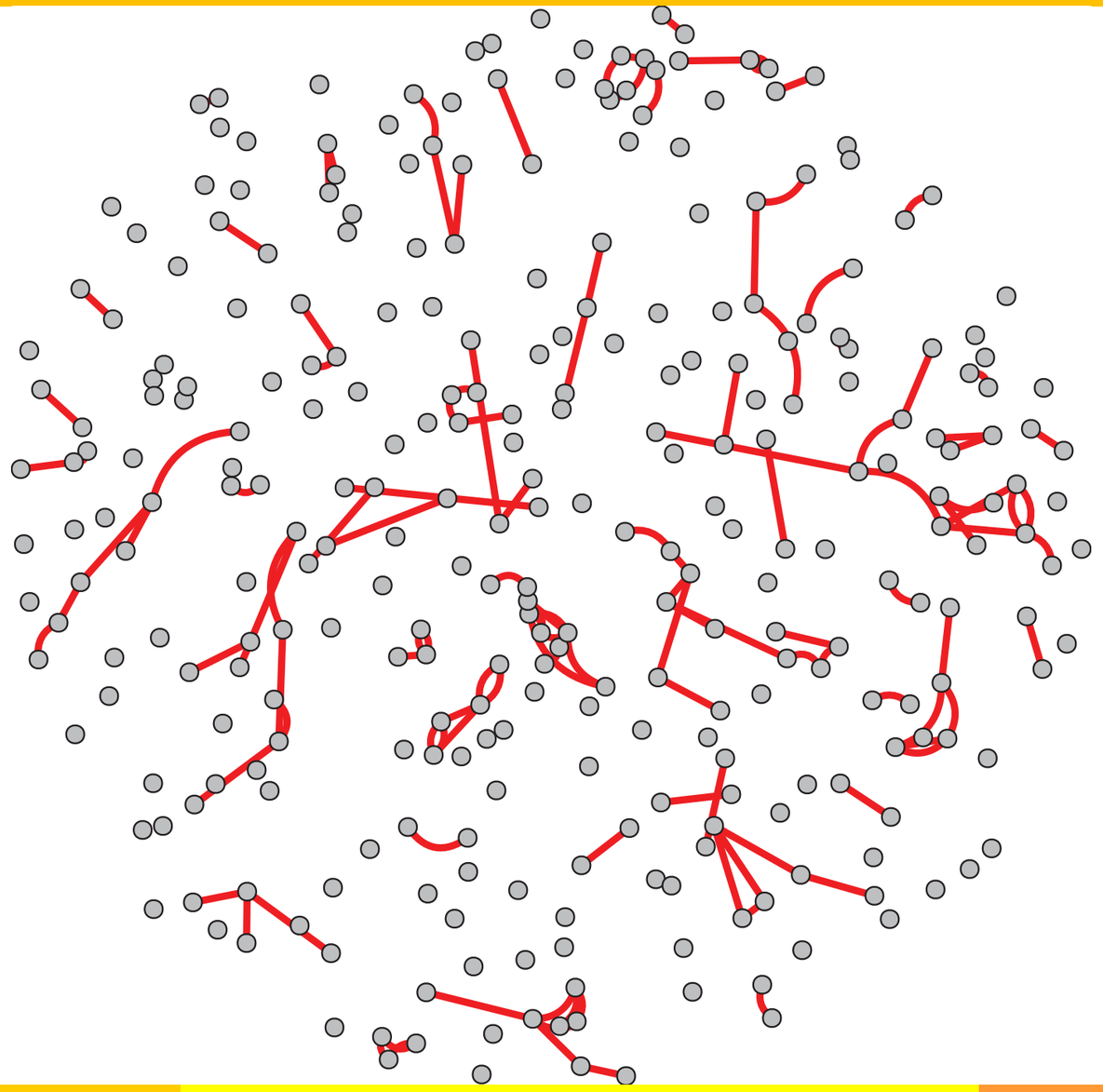
- Individuals with higher r_i tend to have less skewed $P(m)$
- Those with lower r_i display a more skewed distribution
- **A larger encounter likelihood of an individual is strongly rooted in his/her behavioural regularity**



A world of familiar strangers

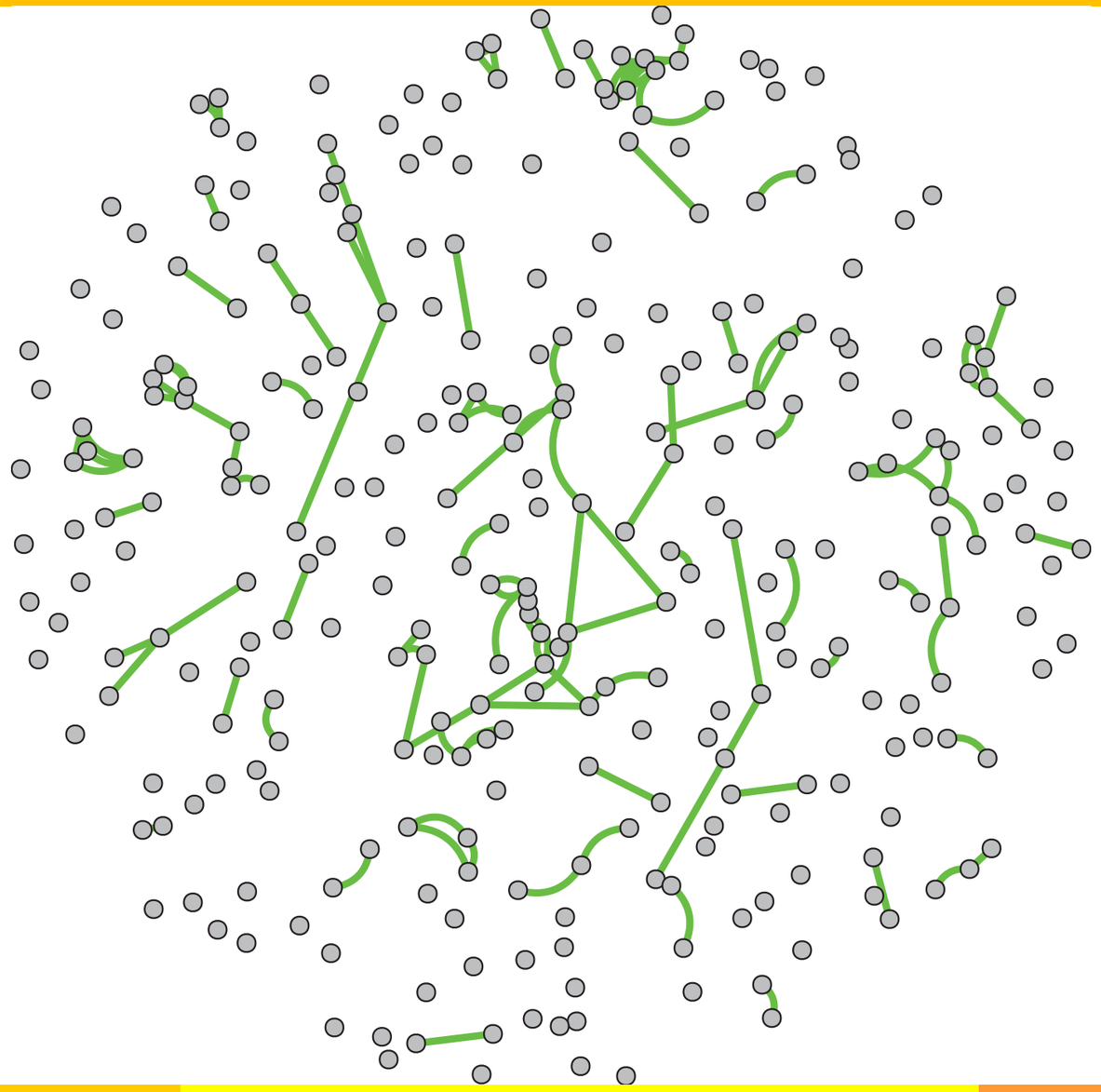
- **We all living in a world of familiar strangers**

A world of familiar strangers



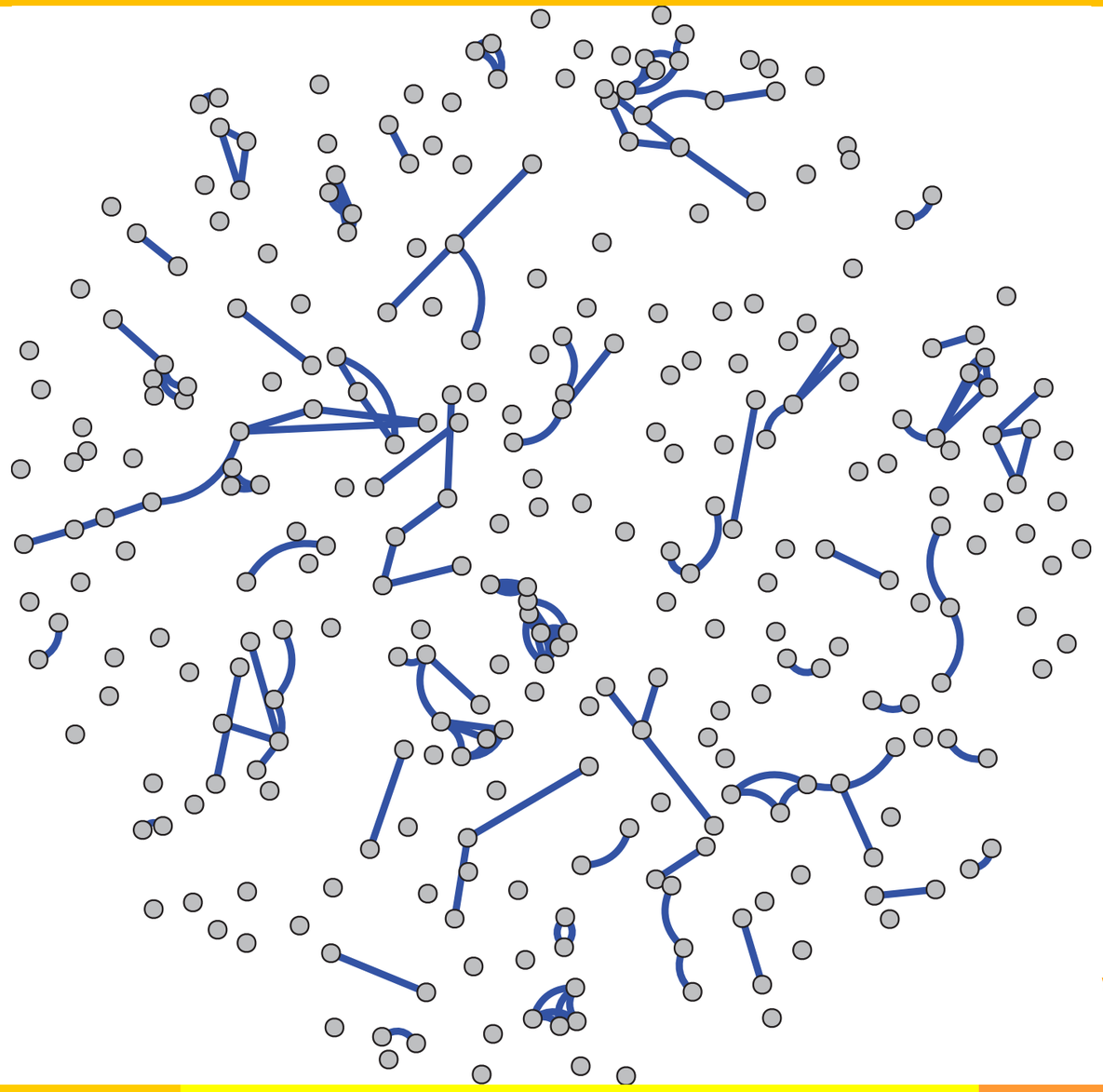
Monday

A world of familiar strangers



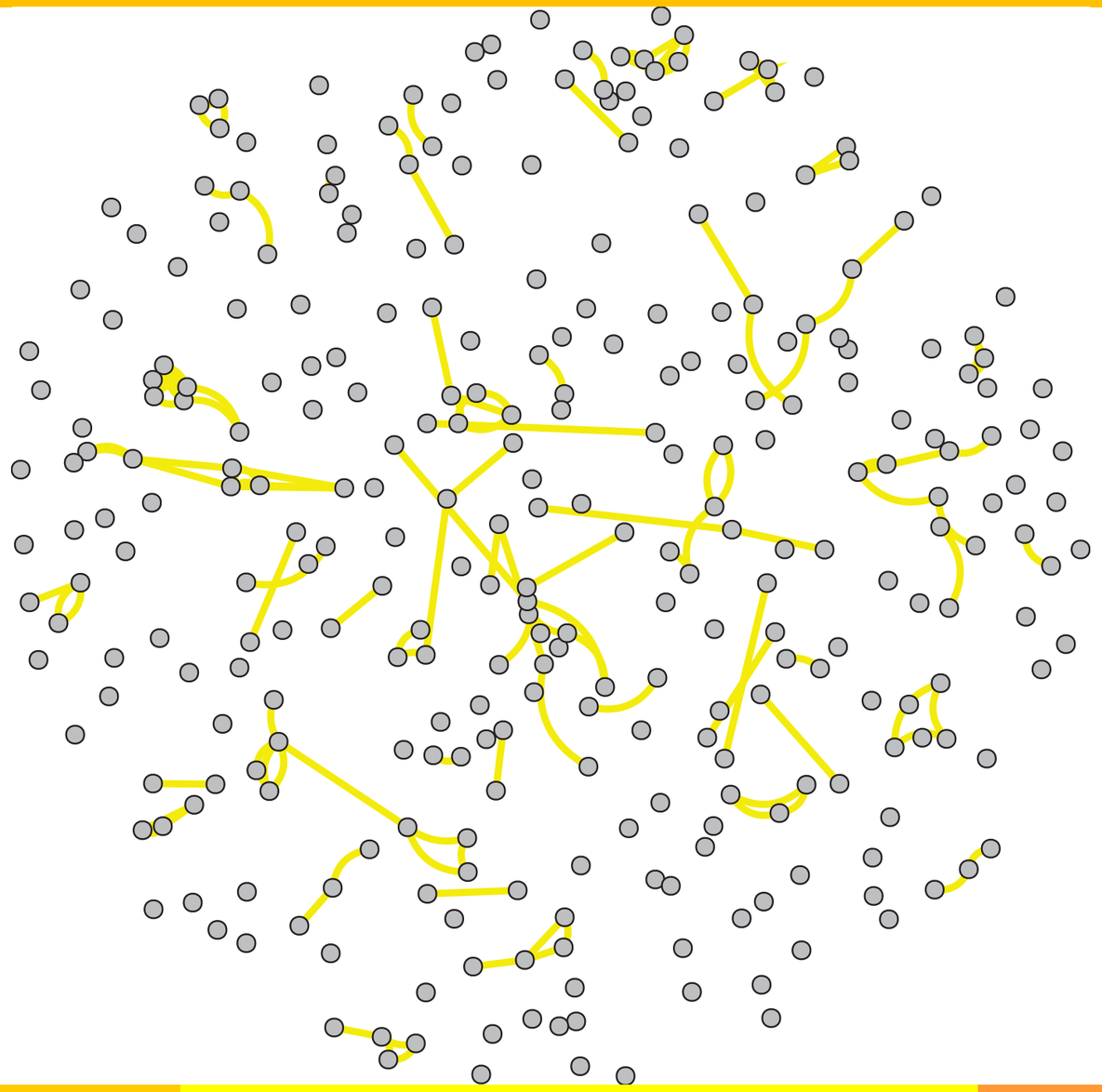
Tuesday

A world of familiar strangers



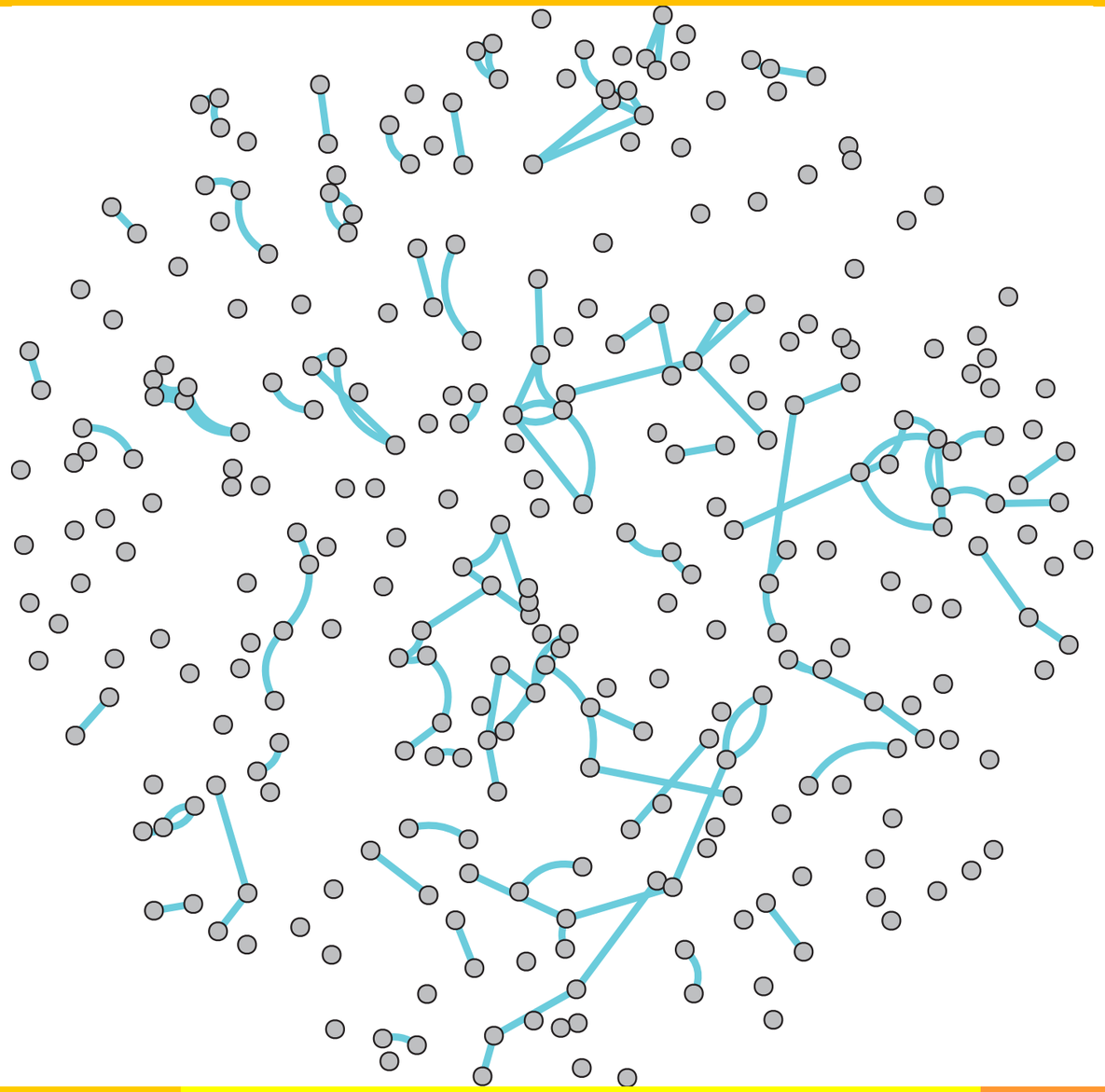
Wednesday

A world of familiar strangers



Thursday

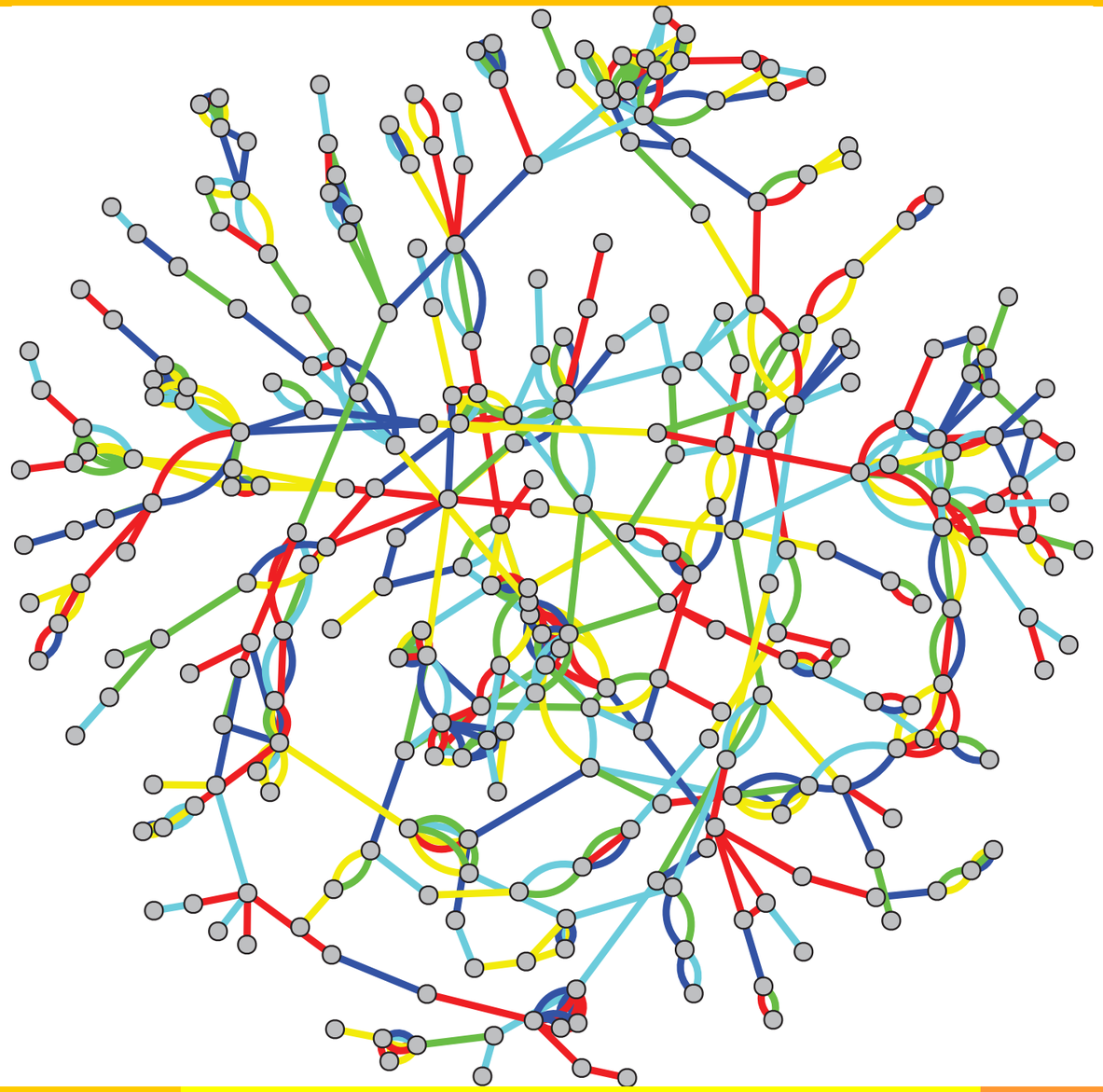
A world of familiar strangers



Friday

A world of familiar strangers

The frozen world

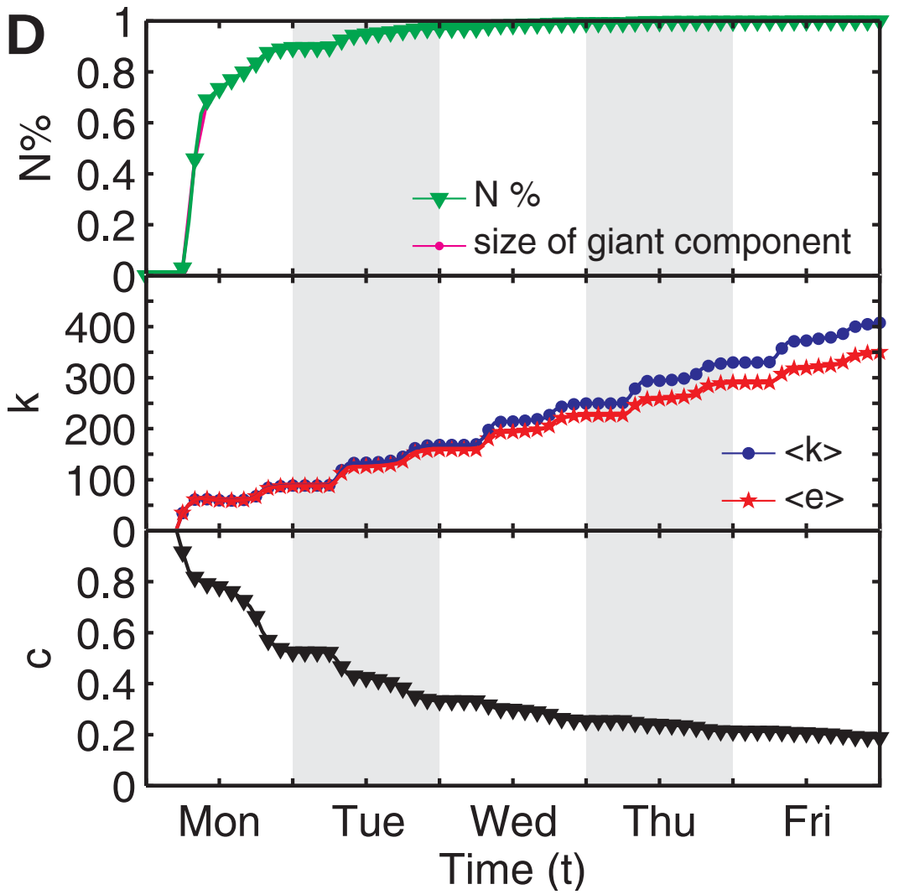


of the familiar strangers

Mon-Fri

A world of familiar strangers

- A large social network over the population
- **Diameter: 6**
- **Characteristic path length: 2.95**
  - **(random: 2.63)**
- **Average clustering coefficient: 0.19**
  - **(random: 4.5×10^{-4})**
- **Small-world**
  - Watts DJ & Strogatz SH (1998) Collective dynamics of 'small-world'networks. Nature 393:440-442.



A world of familiar strangers

- After all the stupid analysis
- Linking you with familiar strangers:

A world of familiar strangers

- Linking you with familiar strangers:
- **Stage 1: when geography allows people to be available to one another**

Grannis, R. (2009). From the ground up: Translating geography into community through neighbor networks. Princeton University Press.

A world of familiar strangers

- Linking you with familiar strangers:
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A world of familiar strangers

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- **Stage 3: when people intentionally encounter and interact with one another**

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A world of familiar strangers

- Linking you with familiar strangers:
- **Stage 1: when geography allows people to be available to one another**
- **Stage 2: when people unintentionally encounter one another or engage in passive interactions**
- **Stage 3: when people intentionally encounter and interact with one another**
- **Stage 4: when people engage in activities indicating mutual trust or a realization of shared norms and values**

Grannis, R. (2009). From the ground up: Translating geography into community through neighbor networks. Princeton University Press.

A world of familiar strangers

- What will happen afterwards?

A world of familiar strangers

- What will happen afterwards?

Thank you!

Sun Lijun

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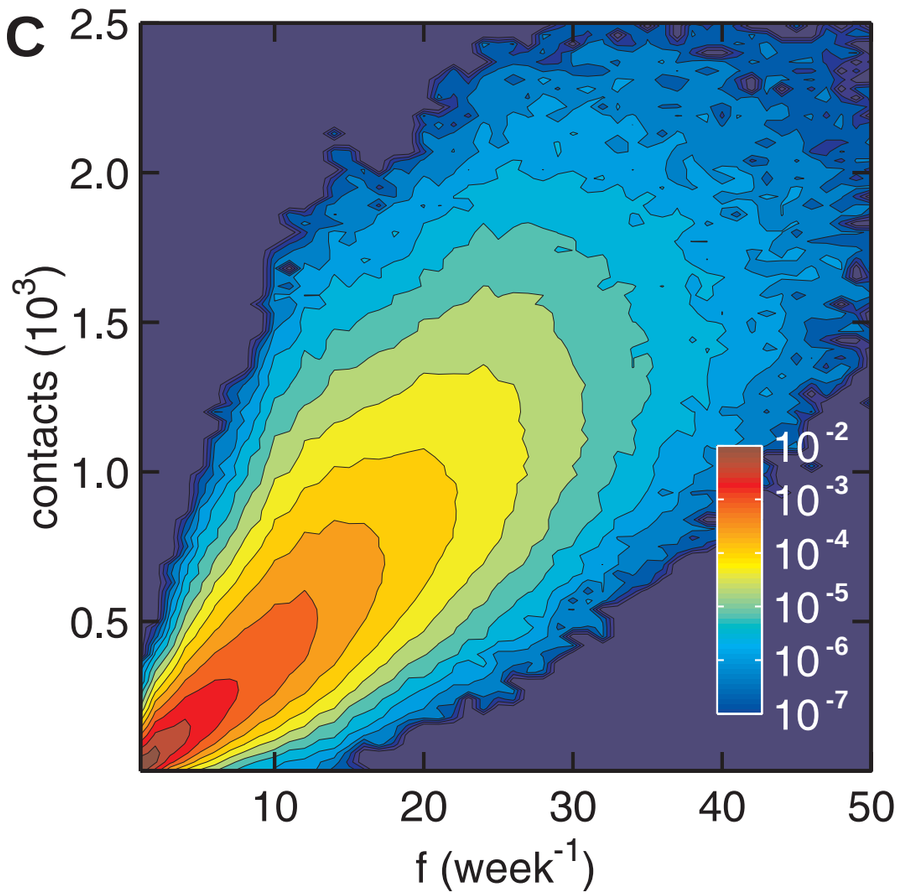
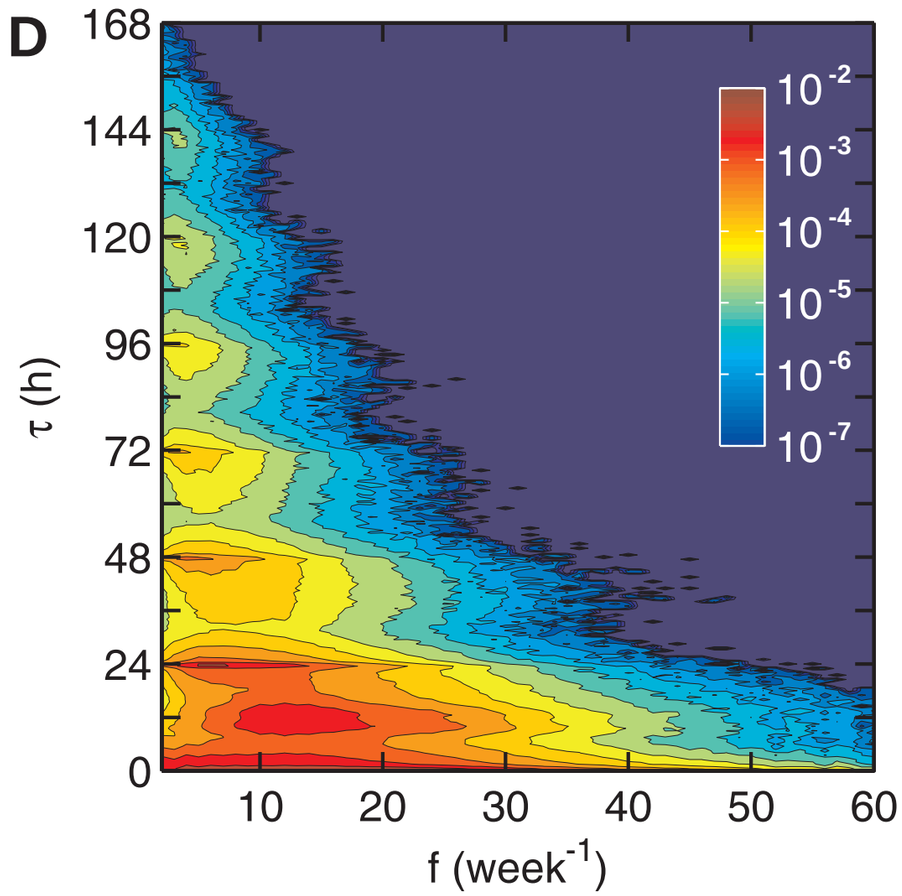
lijun.sun@ivt.baug.ethz.ch
https://sites.google.com/site/sunlijun1988/
June, 7, 2012, Copenhagen, NetSci2013

Appendix

- Why bus is a good proxy to capture physical proximity



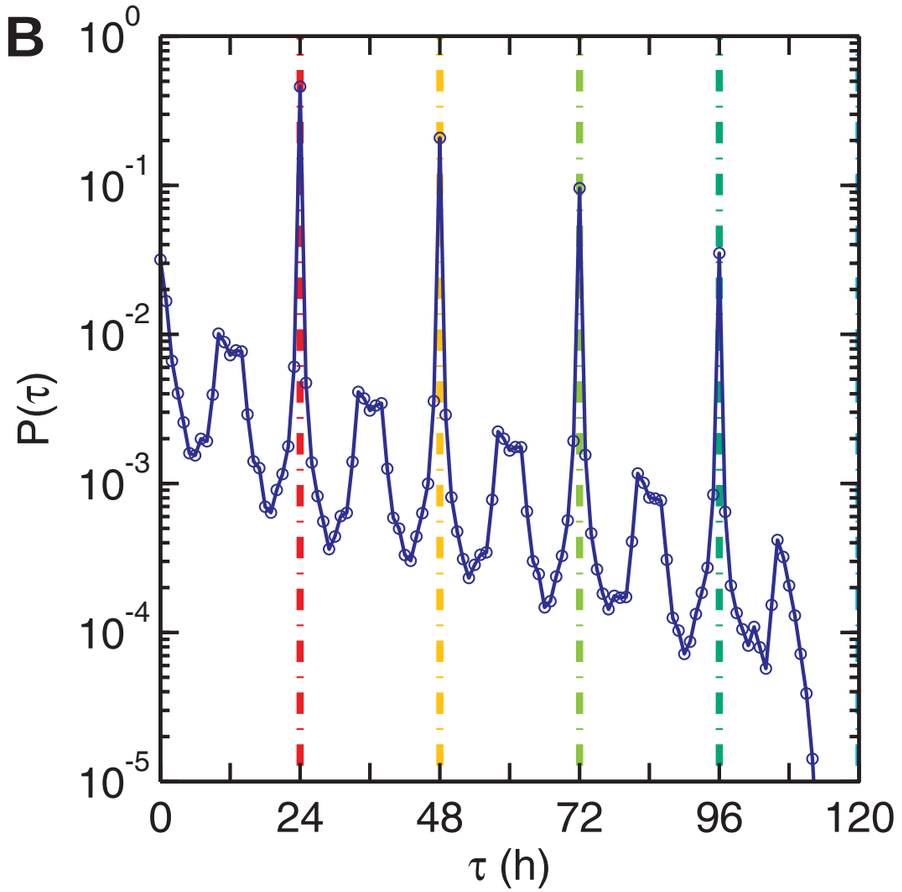


Appendix

- $\tau = t_n - t_c$: inter-encounter interval
- the time interval between successive encounters

- Prominent peaks at 24h, 48h, 72h, 96h
- 1d, 2d, 3d, 4d

- Decreasing pattern



Appendix

- As a result of various preference and constraints on individual behavior, spatial-temporal patterns and collective regularity can be found in daily life, such as morning/evening peak in transportation, crowdedness in shopping malls and supermarkets at weekends and in restaurants at dinning time.
- Transit use is only one of these social activities with limited time allocation and specific locations.
- The physical proximity does not necessarily indicate a more intense social contact such as talking to each other, but implies diverse interactions, from not noticing each other, to fleeting eye contact and a close observation.
- How to measure the familiarity in the passive "FS" network and how to define the threshold of familiarity on social diffusion processes. (beyond this study and maybe future work)