# Mining Second Life:

## *Characterizing User Mobility in a Popular Virtual World*


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# Introduction

# Long term objective



- Study content distribution on mobile ad hoc networks
  - Human mobility traces/model
  - Overlay construction mechanism
  - Data dissemination mechanism

# Human mobility: Related works



- Study the real world
  - Chaintreau et al. work [4]
  - Measure the contact between human pocket devices
  - Costly procedure
  - Limited population size
  - Limited scenarios (conferences, campuses...)

# User mobility in Second Life

# What is Second Life (SL)



- A Networked Virtual Environment that mimics the real world
  - Provides a virtual environment in which people can move according to a land map to interact and live in community
  - Consists of thousands of servers, each server hosts one or several “lands“ (size = 256x256m2)
  - User mobility in SL
    - Moving speed: [0, 11.4]m/s (standing, walking and “flying“)
    - Moving in group or community
    - Moving around interest point (shop, bank, club..)
    - Almost similar to the real world

# Mining Second Life: approaches (1)



- Virtual Sensor Devices
  - SL provides a way to create objects using Linden Script Language (LSL)[1]
  - Objects can detect people in range (96m) and communicate to external HTTP server to send data.
  - Limitation in detection capacity: 16 people
  - Limitation in HTTP messages per user per day
  - Private lands in SL restrict the execution of LSL script and object deployment

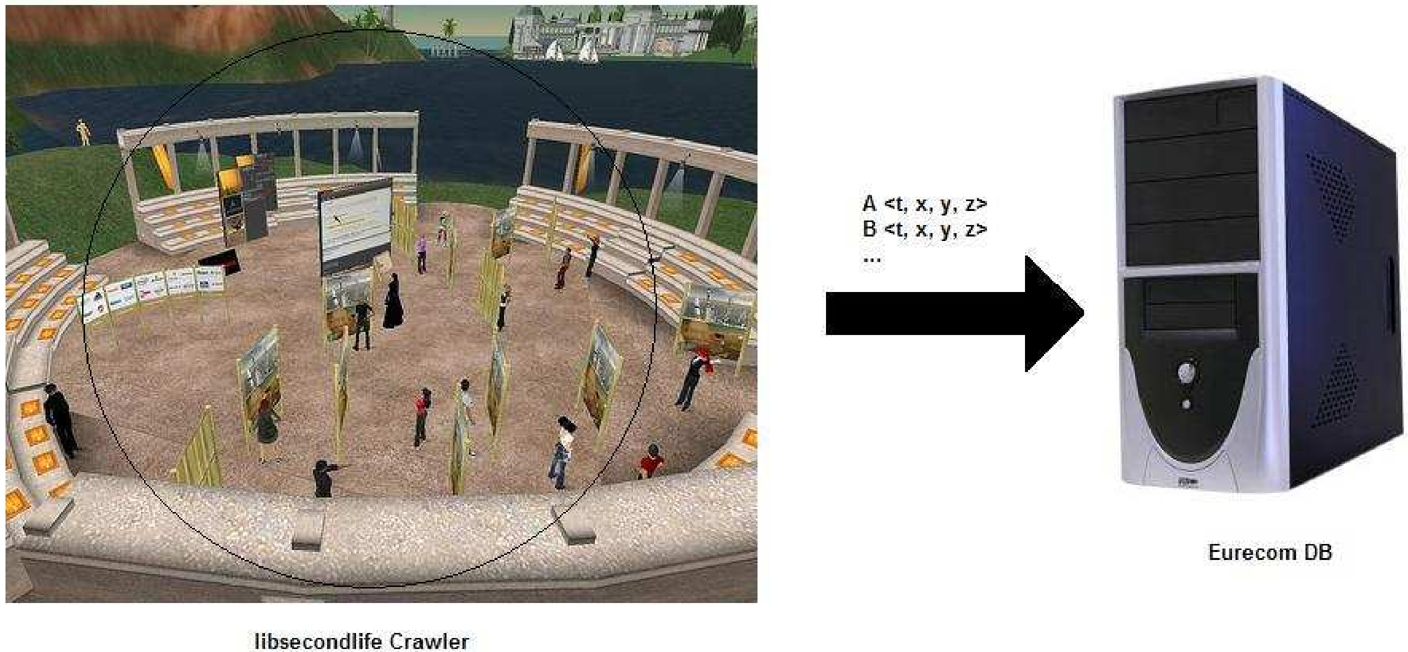
# Mining Second Life: approaches (2)



- External Crawler
  - We developed a lightweight SL client using `libsecondlife`
  - This “crawler“ connects to SL as a normal user
  - Any accessible land can be monitored in its totality
  - The maximum sensing range covers the whole target land and part of adjacent lands.
  - Users mobility data are collected and stored in Eurecom DB for post-processing

# Crawler component





# Measurement Results

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# Measurement methodology

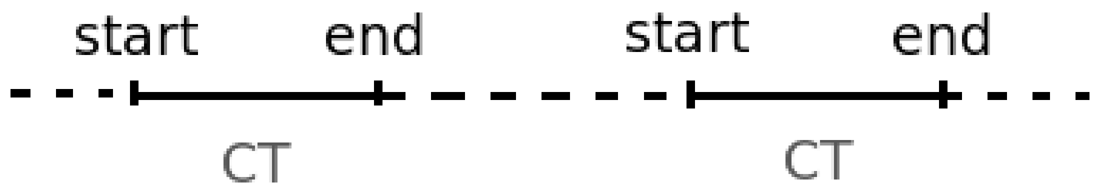


- Our crawler was launched on some selected lands from August 2007
  - Time granularity (intervals for snapshot of the users' coordinates) $\tau = 10$ sec.
  - To study the contact opportunities between people we set a communication range $r$
    - $r_b = 10$ meters (bluetooth)
    - $r_w = 80$ meters (wifi 802.11a at 54 Mbps).
- Choosing a target land in the SL is not an easy task:
  - a large number of lands host very few users;
  - lands with a large population are usually built to distribute virtual money: no mobility
  - automatic synchronization to events is very difficult: we did it manually

# Temporal analysis (1)



- Temporal Analysis: we use metrics as from the work of Chaintreau [3]
- *Contact time* $(CT)$*:* the time interval in which 2 users are in direct communication range, given $r$;
- This metric represents the contact opportunities between users



# Temporal analysis (2)



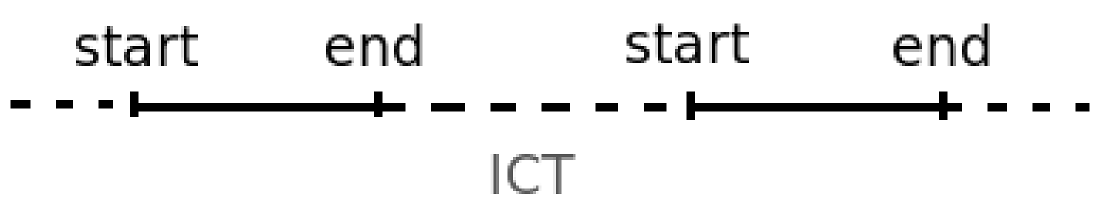
- *Inter-contact time ($ICT$):* the time interval between two contact periods of a pair of users. Let

$$[t^1_{(v_i,v_j)s}, t^1_{(v_i,v_j)e}], [t^2_{(v_i,v_j)s}, t^2_{(v_i,v_j)e}], \ldots [t^n_{(v_i,v_j)s}, t^n_{(v_i,v_j)e}]$$

be the successive time intervals at which user $v_i$ and $v_j$ are in contact; ICT between the $k^{th}$ and the $(k+1)^{th}$ contact is:

$$IC^k_{(v_i,v_j)} = t^{k+1}_{(v_i,v_j)s} - t^k_{(v_i,v_j)e}$$

- This metric represents the waiting time for meet again between users



# Spatial analysis (1)



- *This analysis is very difficult to achieve using traces from related works [3] which loses the spatial information.*
- These metrics help understanding graph theoretic properties of network snapshots
- We denote $G(t_k) = G(v_i^{t_k}, e_{i,j}^{t_k})$ a snapshot of the communication graph formed by users at time $t_k$:
  - *Node degree:* $d_i^{t_k}$ the number of neighbors of a given node $n_i$
  - *Network diameter:* $D(G(t_k))$ the longest shortest path of the largest connected component of the graph $G(t_k)$
  - *Zone occupation:* we divide a land in several square sub-cells $LxL$ and compute the number of users per sub-cell.

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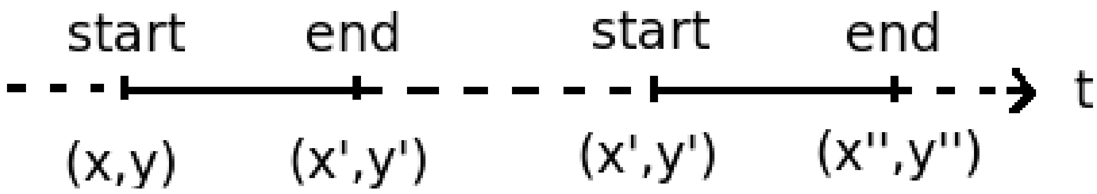
# Spatial analysis (2)



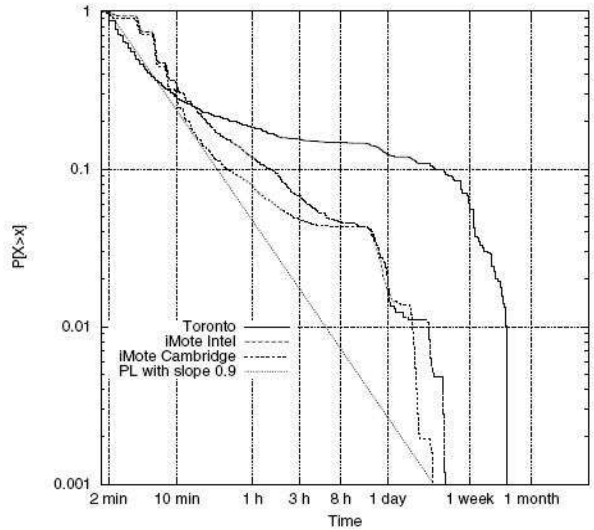
- We study the travel length and time for each user in SL to understanding how much they move
  - *Travel length:* the total distance traveled by user $v_i$ until leaving the land.
  - *Travel time and Effective travel time:* login time and moving time for user $v_i$ on the land.



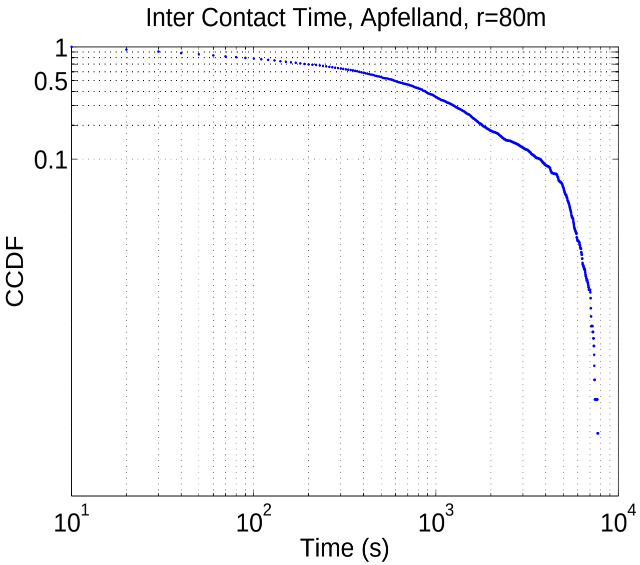
# Inter-contact time (1)



- In general, the inter-contact time CCDF exhibits 2 phases: a power law followed by an exponential cut-off phase [3, 5] .




(a) Chaintreau work



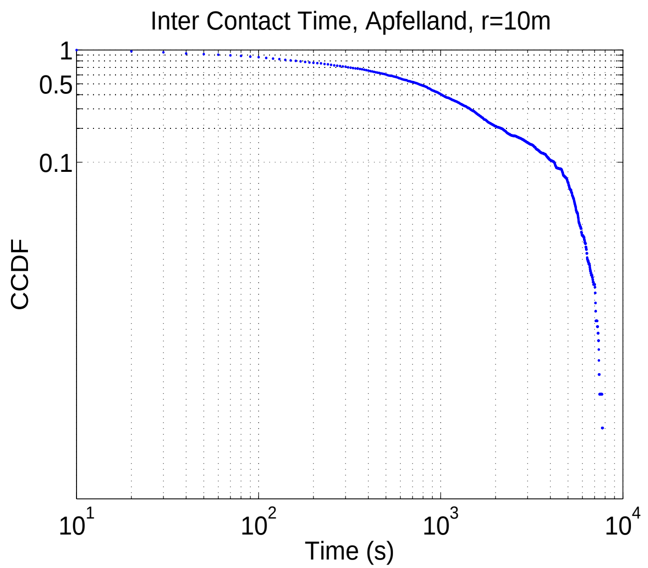

(b) SL Apfelland ICT

Figure 1: ICT CCDF

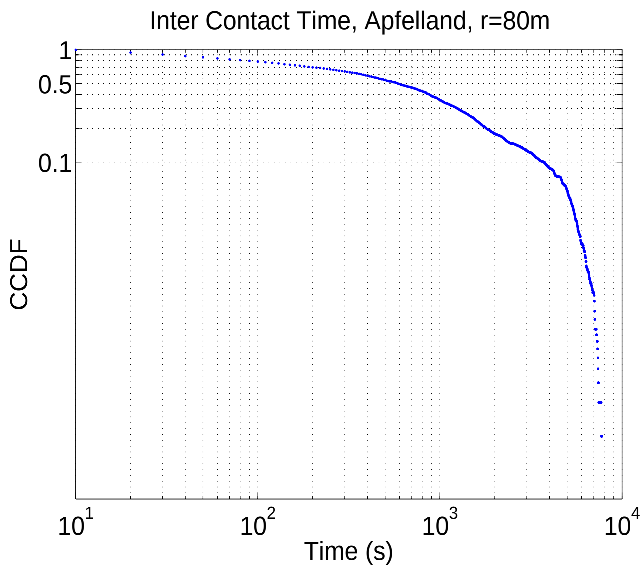
# Inter-contact time (2)



- Inter-contact time is reduced when contact range is wider, but the power law is still there...




(a) r=10



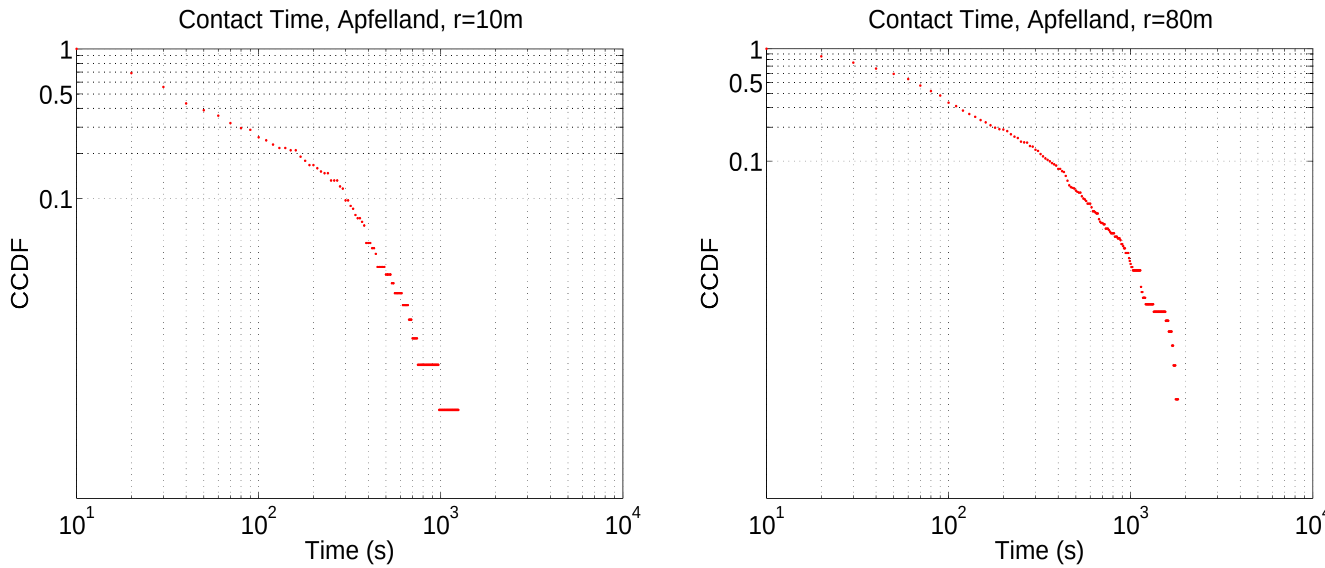

(b) r=80

Figure 2: ICT CCDF

# Contact time



- Intuitively, the contact time increases when the radio range is wider.

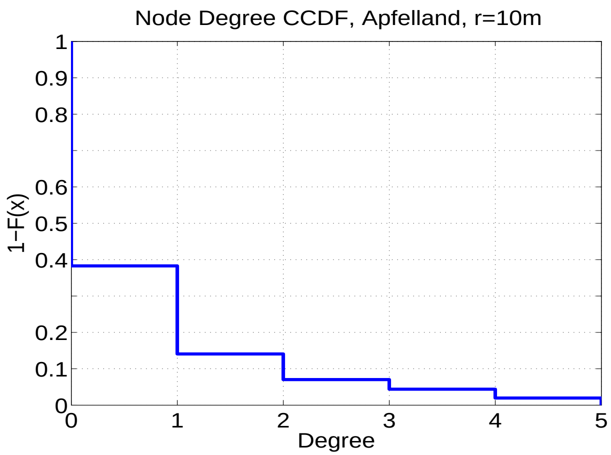



(a) r=10m (b) r=80m

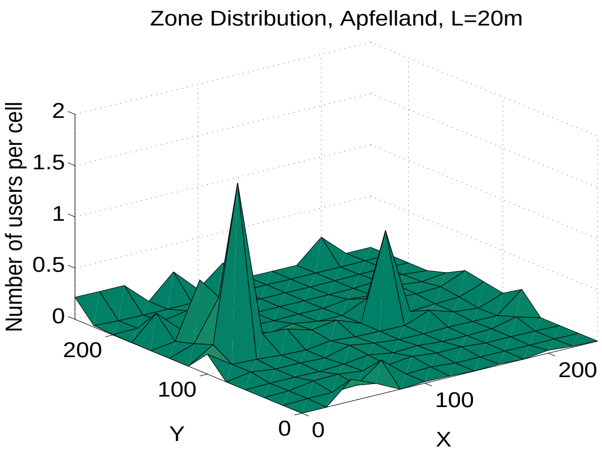
Figure 3: CT CCDF

# Node degree and point of interest (1)






(a) Node degree

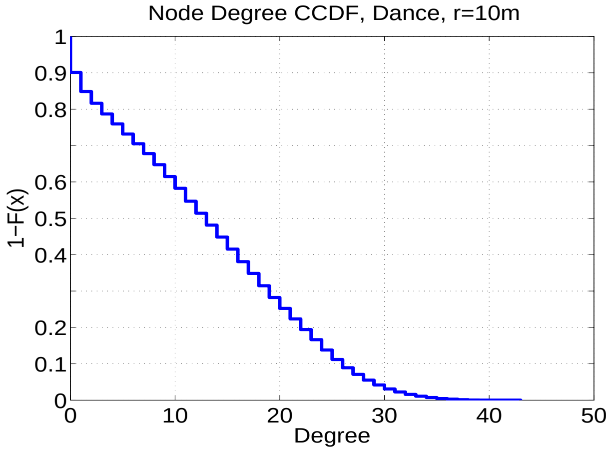



(b) Zone occupation

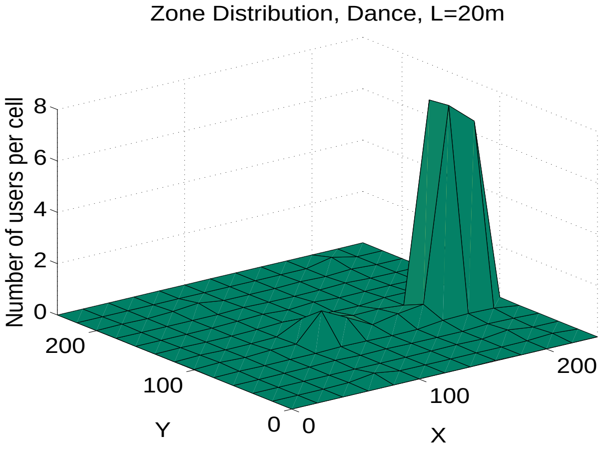
Figure 4: Apfelland - A SL German-speaking land

# Node degree and point of interest (2)






(a) Node degree

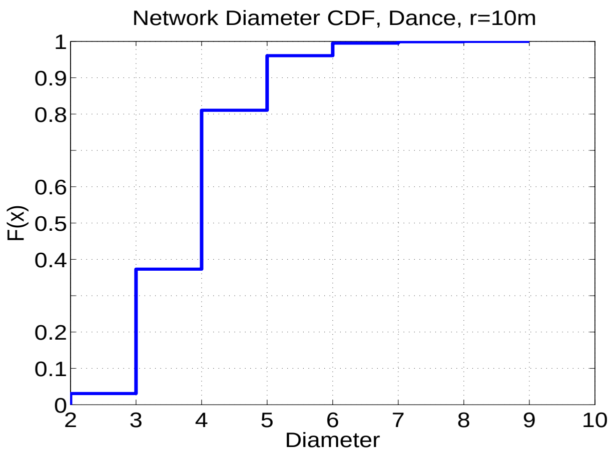



(b) Zone occupation

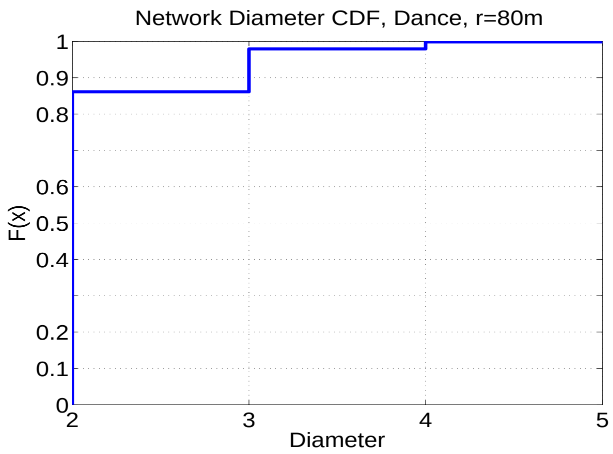
Figure 5: Dance Island - A SL discotheque

# Network Diameter






(a) r=10




(b) r=80

Figure 6: Dance Island - Network Diameter

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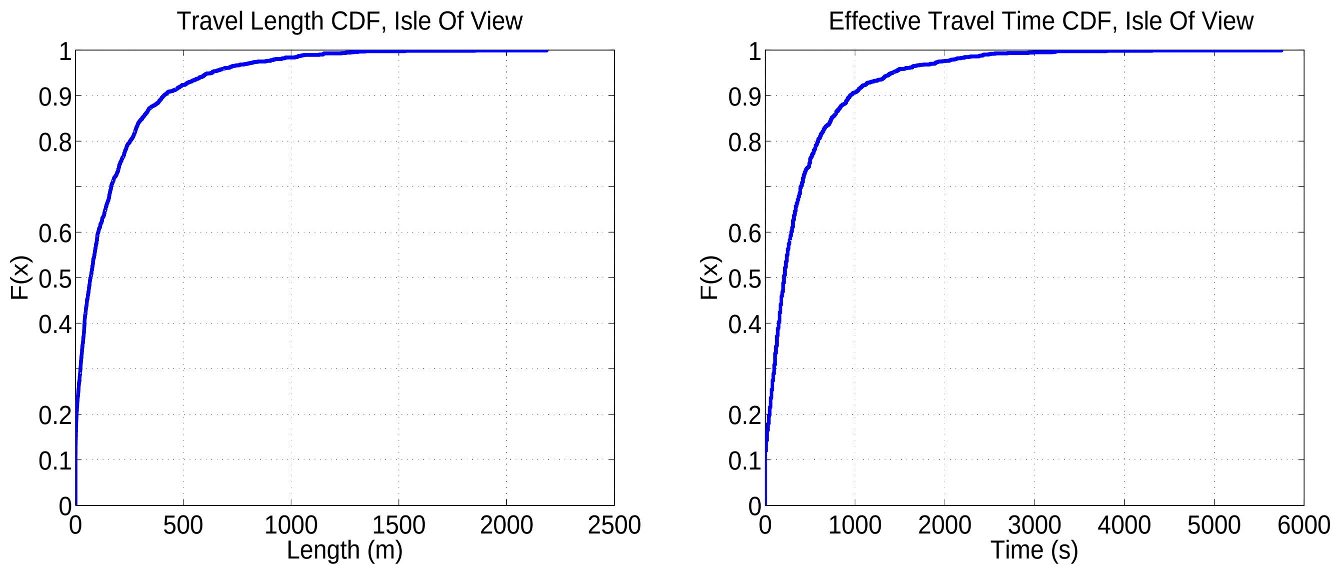
# User mobility



- The mobility in most cases is not high except a small fraction of users.




(a) Travel length (b) Travel time

Figure 7: Node mobility

# Conclusion

# Conclusion



- A novel methodology to capture spatio-temporal dynamics of human mobility
- No requirement of costly devices (PDA, GPS)
- Traces can be used to perform trace-driven simulations
- Not bound to a specific wireless technology
- Potentially scale up to a very large number of participants (depends on SL)
- Capability to measure both spatial and temporal metrics

# Questions

# References



[1] Lsl: http://wiki.secondlife.com/wiki/lsl_portal.

[2] Second life: http://www.secondlife.com.

[3] A. Chaintreau, P. Hui, J. Crowcroft, C. Diot, J. Scott, and R. Gass. Impact of human mobility on opportunistic forwarding algorithms. *IEEE Transactions on Mobile Computing*, 6:606–620, 2007.

[4] A. Chaintreau, A. Mtibaa, L. Massoulie, and C. Diot. The diameter of opportunistic mobile networks. In *Proc. of CoNEXT*, 2007.

[5] T. Karagiannis, J.-Y. L. Boudec, and M. Vojnović. Power law and exponential decay of inter contact times between mobile devices. In *Proc. of MOBICOM*, 2007.

[6] J. Krumm and E. Horvitz. The microsoft multiperson location survey. Technical report, Microsoft Research, MSR-TR-2005-13, 2005.