Mining Second Life:

*Characterizing User Mobility in a Popular Virtual World*

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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
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
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
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

![](image)
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:

\[
I C_{(v_i,v_j)}^k = t_{(v_i,v_j)s}^{k+1} - t_{(v_i,v_j)e}^k
\]

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

```
start - - - - - - - - end
ICT
start - - - - - - - - end
```
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 $G(t_k) = G(v_{i,t_k}^{t_k}, e_{i,j}^{t_k})$ 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.
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.

![Travel Time Diagram](image)
In general, the inter-contact time CCDF exhibits 2 phases: a power law followed by an exponential cut-off phase \([3, 5]\).

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...

![Figure 2: ICT CCDF](image.png)
Intuitively, the contact time increases when the radio range is wider.

Figure 3: CT CCDF
Introduction

User mobility in Second Life

Measurement Results

- Measurement methodology
- Temporal analysis (1)
- Temporal analysis (2)
- Spatial analysis (1)
- Spatial analysis (2)
- Inter-contact time (1)
- Inter-contact time (2)
- Contact time
- Node degree and point of interest (1)
- Node degree and point of interest (2)
- Network Diameter
- User mobility

Conclusion

Figure 4: Apfelland - A SL German-speaking land
Node degree and point of interest (2)

Figure 5: Dance Island - A SL discotheque
Network Diameter

Figure 6: Dance Island - Network Diameter
The mobility in most cases is not high except a small fraction of users.

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


