Predicting Encounters in Opportunistic Networks

Radu-Ioan Ciobanu, Ciprian Dobre

University Politehnica of Bucharest
Faculty of Automatic Control and Computers
Bucharest, Romania

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Introduction

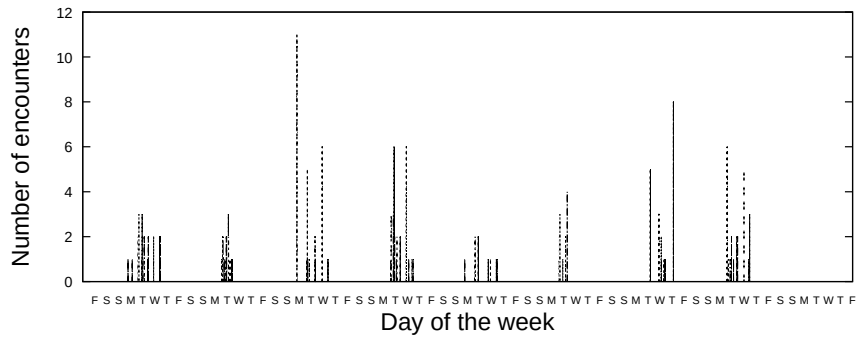
- **Opportunistic networks**
  - human-carried mobile devices
  - store-carry-and-forward
  - challenge: when and to whom is a message relayed?
- **Solution**
  - predict the future encounters of a node
  - analyze its past encounters
  - approximate the time series as a Poisson distribution

Mobility Traces

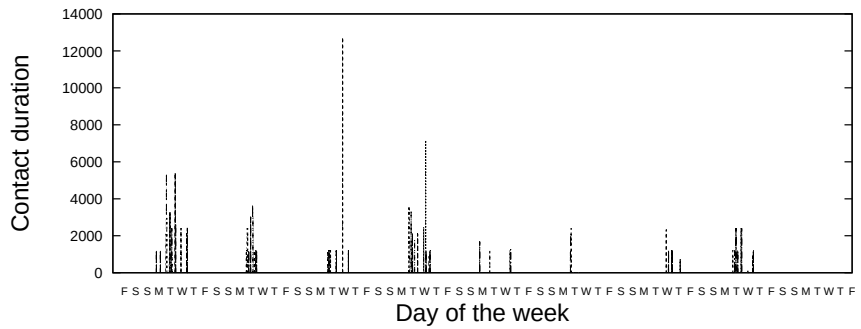
- Analyze predictability using mobility traces
- **UPB 2012**
  - social tracing experiment performed for 64 days with 66 participants (chosen from all study years) at the University Politehnica of Bucharest
  - HYCCUPS Tracer application for Android phones (scans Bluetooth and AllJoyn)
  - academic environment $\rightarrow$ small enclosed space with lots of contact opportunities and high degree of predictability
  - Facebook social information collected
  - followed a previous trace entitled UPB 2011 (35 days, 22 participants)
- **St. Andrews**
  - mobile sensor network with 27 participants, duration of 79 days (Tmote Invent devices)
  - experiment performed in and out of the town of St. Andrews
  - discovery beacons sent at every 6.67 seconds
  - open and largely distributed environment, with a lower degree of predictability
  - collected information about social relationships on Facebook

Predictability

- The behavior of students and teachers at the university is regular → highly predictable
- Analyze UPB 2012 in terms of total number of encounters and contact duration → some patterns are easily seen



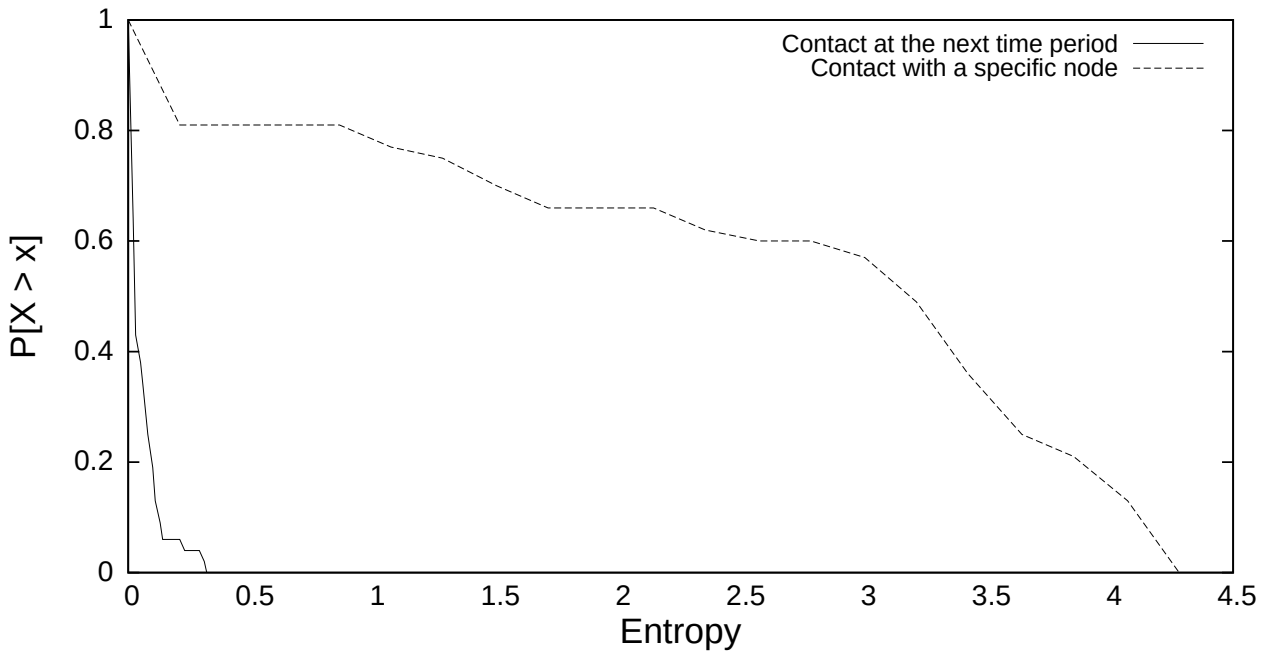
(a) Total encounters per day (random node)



(b) Total contact durations per day (same node)

Predictability (2)

- Verify nodes' behavior using Shannon's entropy
- Can't compute entropy using the probability of encountering node N at the next time interval → split the computation in two parts:
  - probability of the next encounter being with node N → high entropy
  - probability of a contact taking place at the next time interval → mostly predictable (< 0.35)



Node Behavior Prediction

- Try to predict the number of encounters per time interval (one hour)
- Model the encounter history as a Poisson distribution
- The λ parameter computed using the max likelihood method $\rightarrow$ average of encounters per hour:
  - per the entire experiment
  - per day of the week
  - per hour of a day of the week
- Tested using Pearson's chi-squared test (0.05 level of significance)

Node Behavior Prediction (2)

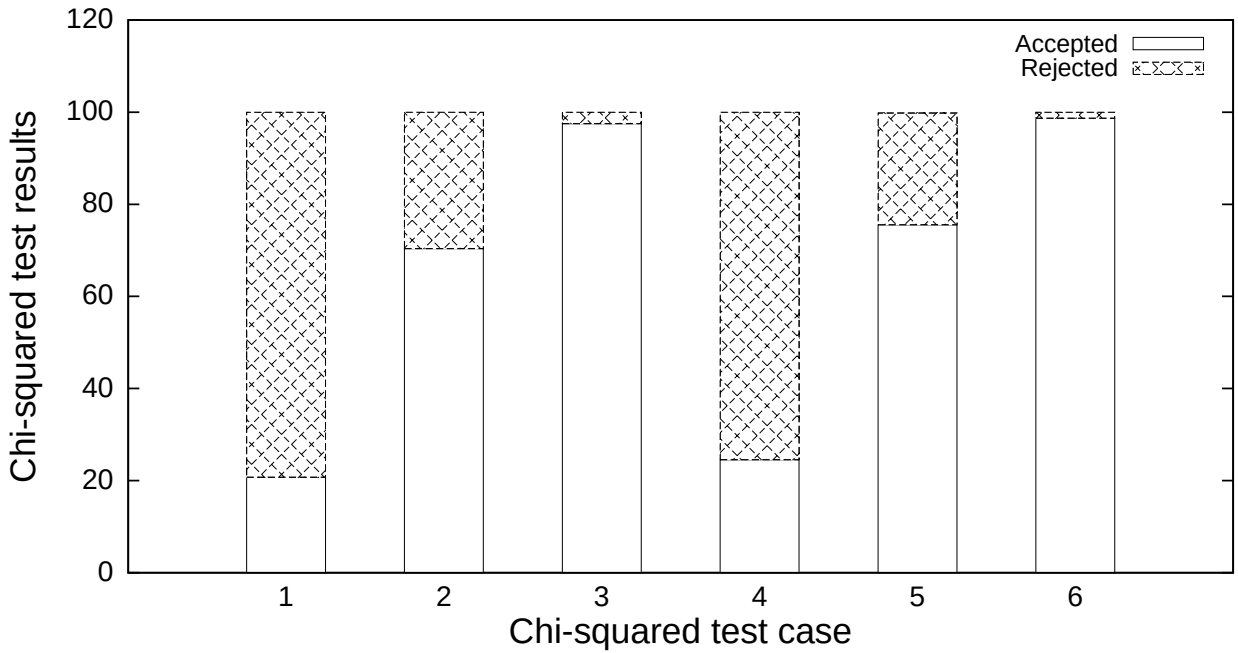


Figure: UPB 2012. Datasets 1, 2 and 3 are computed using the total number of encounters and varying the max likelihood (1 - for the entire experiment, 2 - per weekday, 3 - per hour of a day of the week). Datasets 4, 5 and 6 are computed using unique encounters.

- St. Andrews $\rightarrow$ 12.39% rejected on the best case
- UPB 2011 $\rightarrow$ 0.11% rejected on the best case

Node Behavior Prediction (3)

- Removed last two weeks from UPB 2012, compared Poisson prediction with actual values

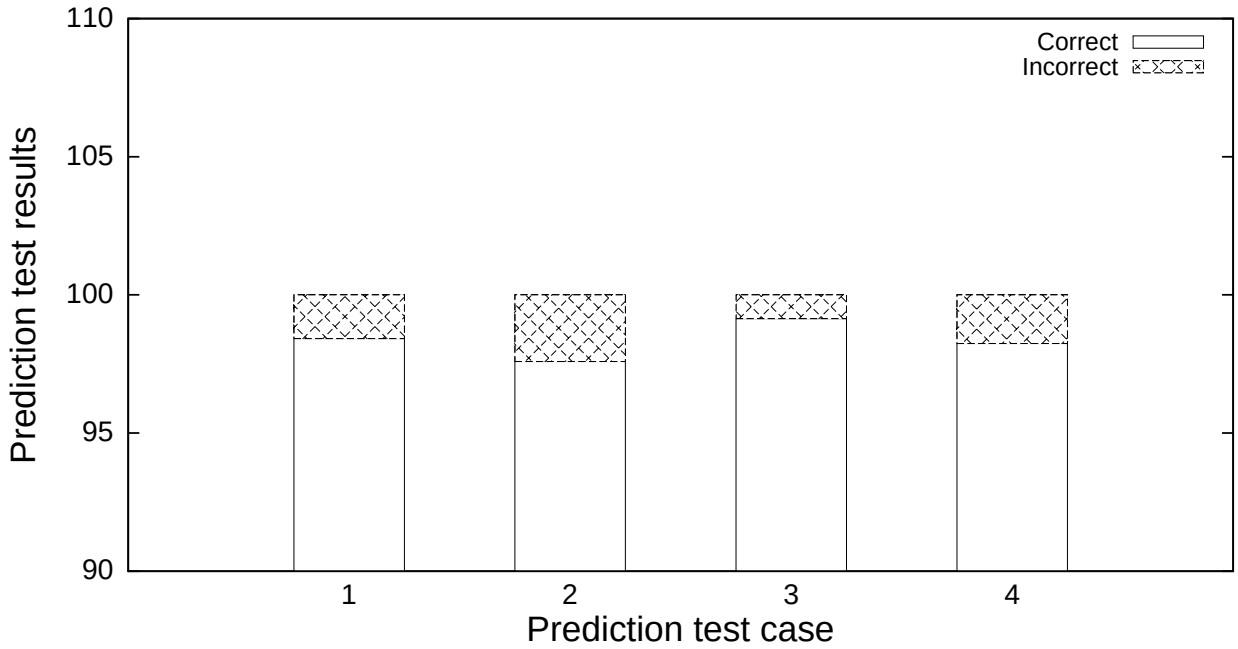


Figure: UPB 2012. Prediction success of the Poisson distribution. 1 - next to last week, total contacts; 2 - next to last week, unique contacts; 3 - last week, total contacts; 4 - last week, unique contacts

Conclusions

- Analyzed a mobility trace (UPB 2012) from the point of view of node encounters and contact durations
- Showed that the history of contacts in terms of the number of encounters can be modelled as a Poisson distribution with very good predictability results
- Proved that these assumptions hold for different traces (St. Andrews, UPB 2011)
- Future work: combine predictability with social information to also predict the nodes that will be encountered in the next hour (not only their number)

Thank You!