Precise Location Prediction Algorithms Using Improved Random Walk-based and Generalized Markovian Mobility Models

Károly Lendvai, Péter Fülöp, Sándor Szabó, Tamás Szálka
lendvaik@hit.bme.hu, fulopp@hit.bme.hu, szabos@hit.bme.hu, szalkat@mcl.hu
Budapest University of Technology and Economics, Department of Telecommunication2, Magyar tudósok körútja, Budapest 1117, Hungary

Outline

- Motivation
- Mobility modeling approaches
- Random Walk Model Extension
- Proposiotion of a Markovian model with memory extensions
- Accuracy measurement results

Motivation

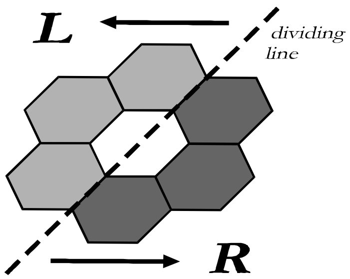
- Mobile and cellular network dimensioning
- Dynamic resource allocation in cells
- Justifying CAC decisions and QoS parameter tuning
- Predicting user distribution and motion drifts in network
- Estimating number of users in current and adjacent cells

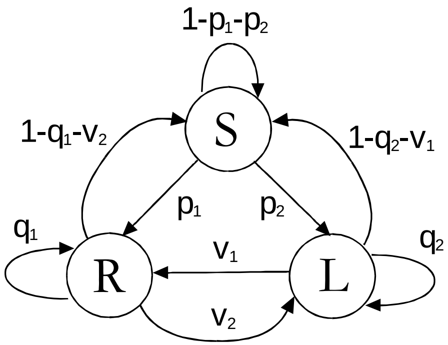
Traditional mobility models

- Fluid models
- Random walk based algorthims
  - Traditional 2 dimensional RW model
  - RW model extended with exponential cell dwell time and variable velocity
  - Handover Vector based on historical handoff trace

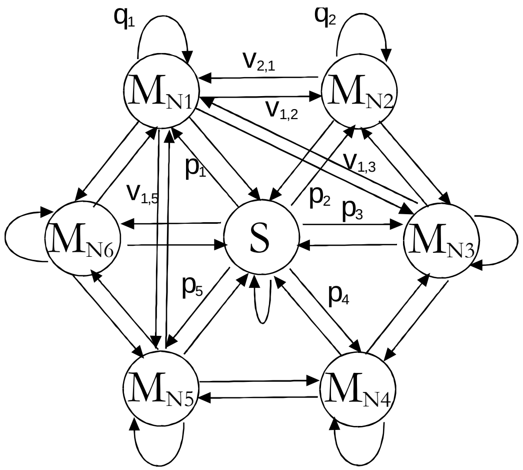
Markovian approaches

- 3-state Markov model (M3)
  - neighbour cells separated into 2 groups
  - stay (S), left-move (L) right-move (R)





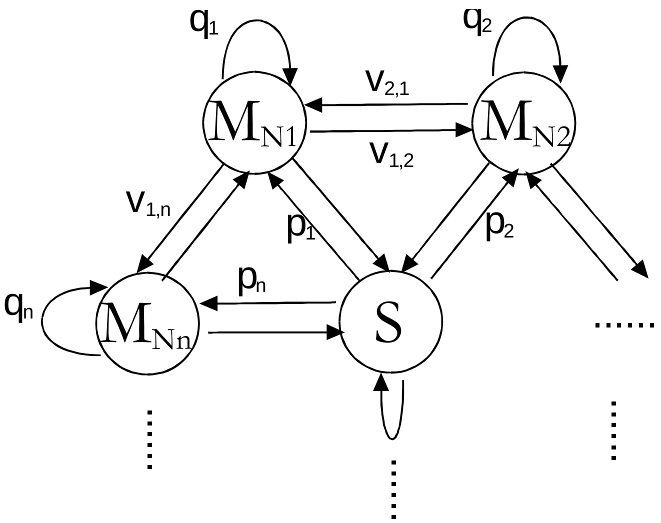
- 7-state Markov model (M7)
  - All neighbour cell as separated Markov state



Markovian approaches

- n-state Markov model (Mn)
  - common model, n neighbour

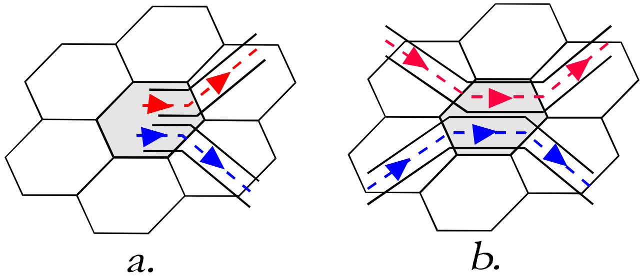
$$\Pi = \begin{bmatrix} 1-\sum_{m=1}^{n} p_m & p_1 & p_2 & \cdots & \cdots & \cdots & p_n \\ 1-q_1-v_{1,2}-v_{1,n} & q_1 & v_{1,2} & \cdots & \cdots & \cdots & v_{1,n} \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ 1-q_i-v_{i,i+1}-v_{i,i-1} & \cdots & \cdots & v_{i,i-1} & q_i & v_{i,i+1} & \cdots \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ 1-q_n-v_{n,1}-v_{n,n-1} & v_{n,1} & \cdots & \cdots & \cdots & v_{n,n-1} & q_n \end{bmatrix}$$



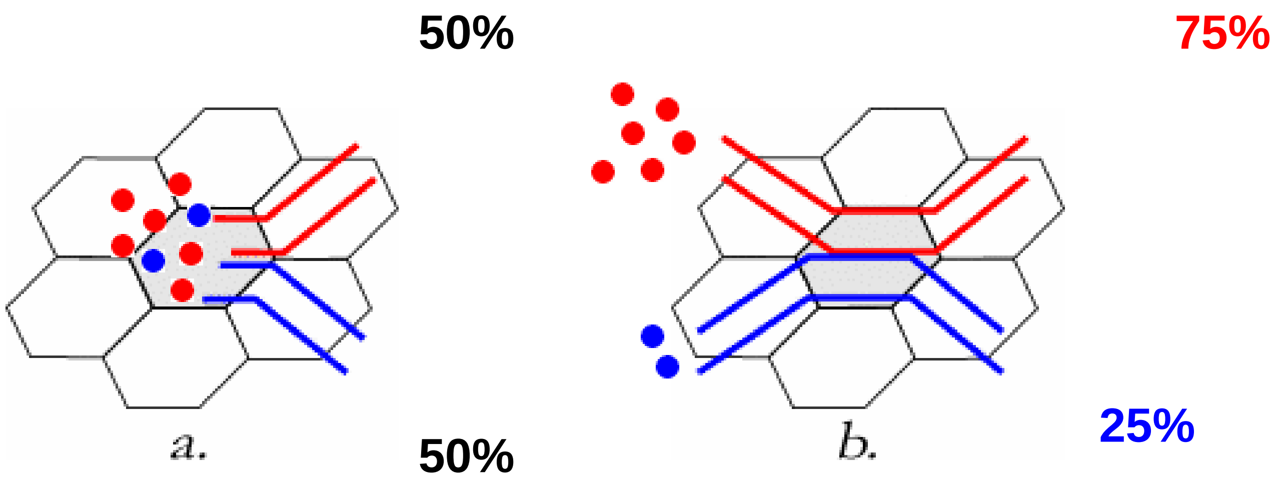
$$N_i(t+1) = N_i(t) \cdot P_S(i) + \sum_{j, C_j \in S_{adj}^{i}} N_j(t) \cdot P_{M_i}(j)$$

Markovian approaches with memory extensions

- Direction level memory
  - Differentiating outgoing directions (M3, M7)
- Time level memory
  - Recently visited cell-series



Analyzing time level memory

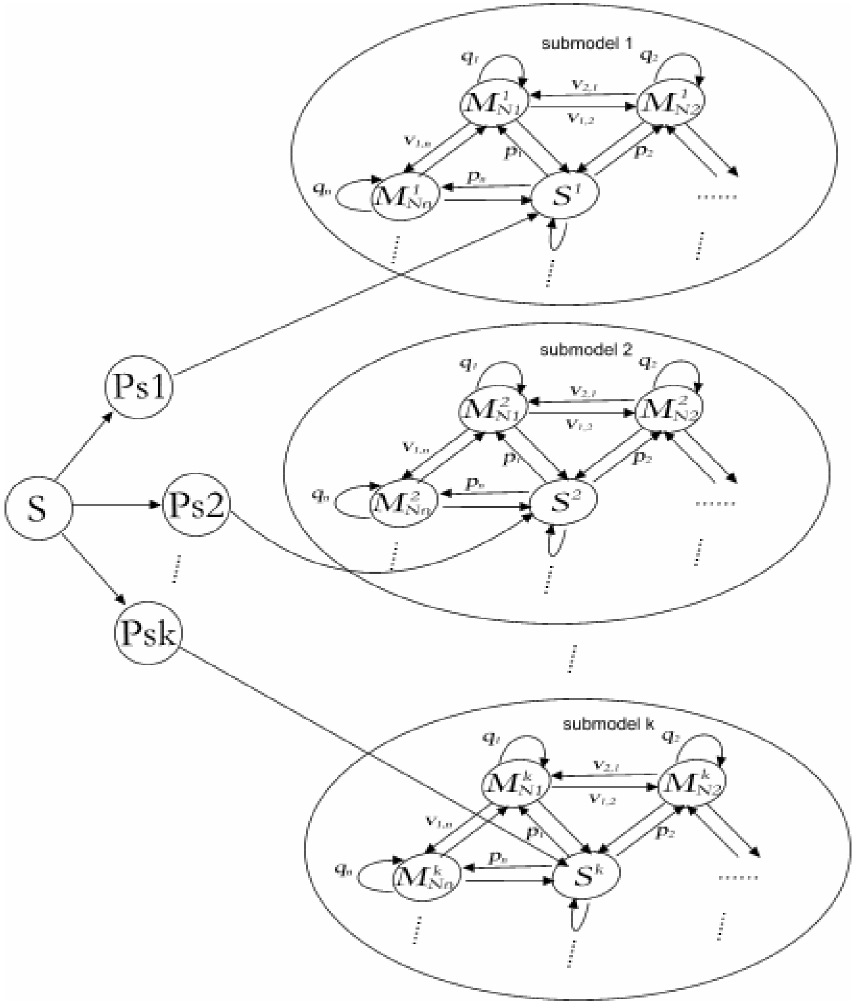


- Prediction **a**: outgoing users on two touching roads without memory **- inaccurate!**
- Prediction **b**: outgoing users on two touching roads with memory – prediction puts every user on the appropriate road

Extended Markov model with memory

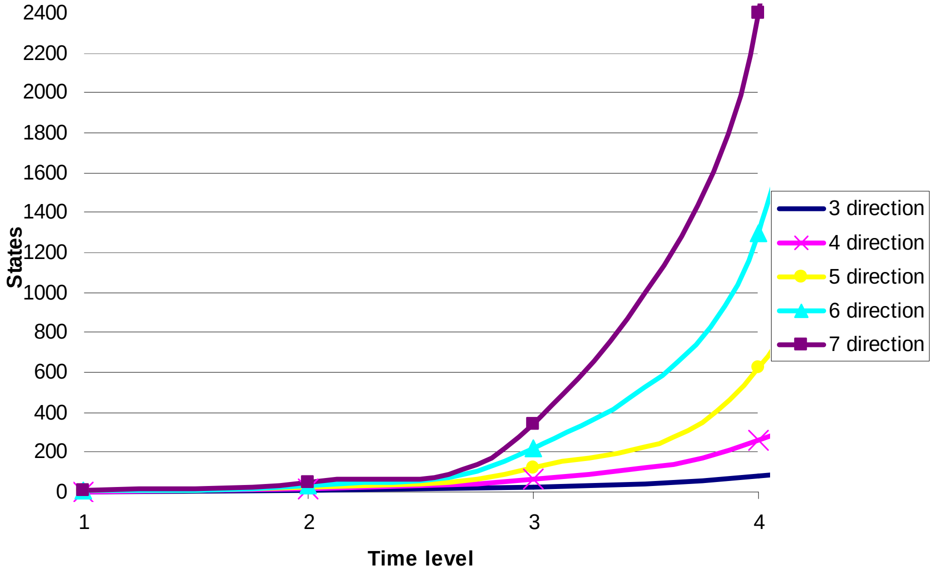
- Time level memory
  - Path States

    (Ps1, Ps2,…,Psk)
  - Parallel sub-Markov models for different paths



Accuracy measurement results

The increase of number of states in case of different direction levels (3,4,5,6,7 states), and different time levels (1,2,3,4)



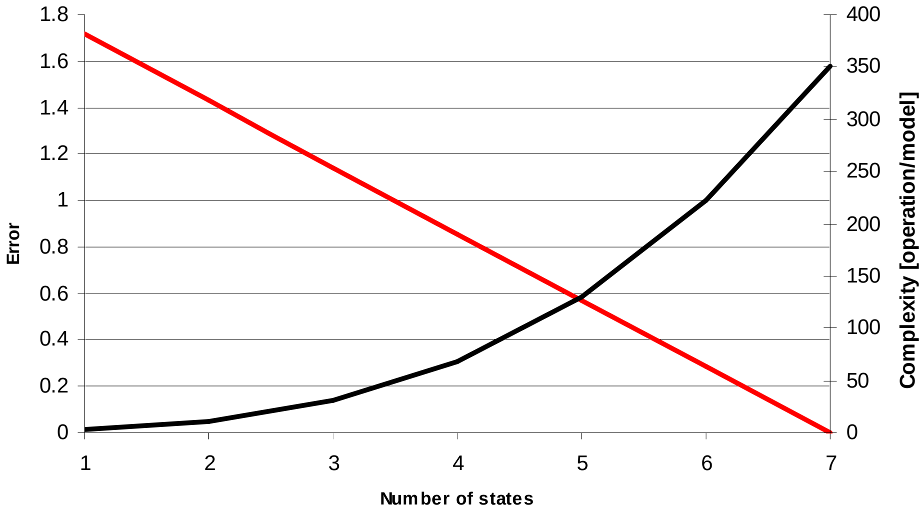
Mathematical complexity >

$$\sigma(M^3 + M + \frac{1}{M})$$

Theoretical Worst Case Error >

$$1 - \frac{1}{N/M} + \frac{1}{N/M} * ((N/M) - 1)$$

Theoretical Worst Case Error vs. Mathematical complexity



Conclusion / Summary

- Random Walk model extension
- Markov-Chain based method for prediction
    - Direction Level (M3, M7, Mn)
    - Time Level

➡ efficient CAC or other QoS decisions

- Future Improvements
    - quantity calculations for time level Markov model
    - model error calculations

THANK YOU!

lendvaik@hit.bme.hu,
fulopp@hit.bme.hu,
szabos@hit.bme.hu,
szalkat@mcl.hu