Evaluating Filtering Strategies for Decentralized Handover Prediction in the Wireless Internet

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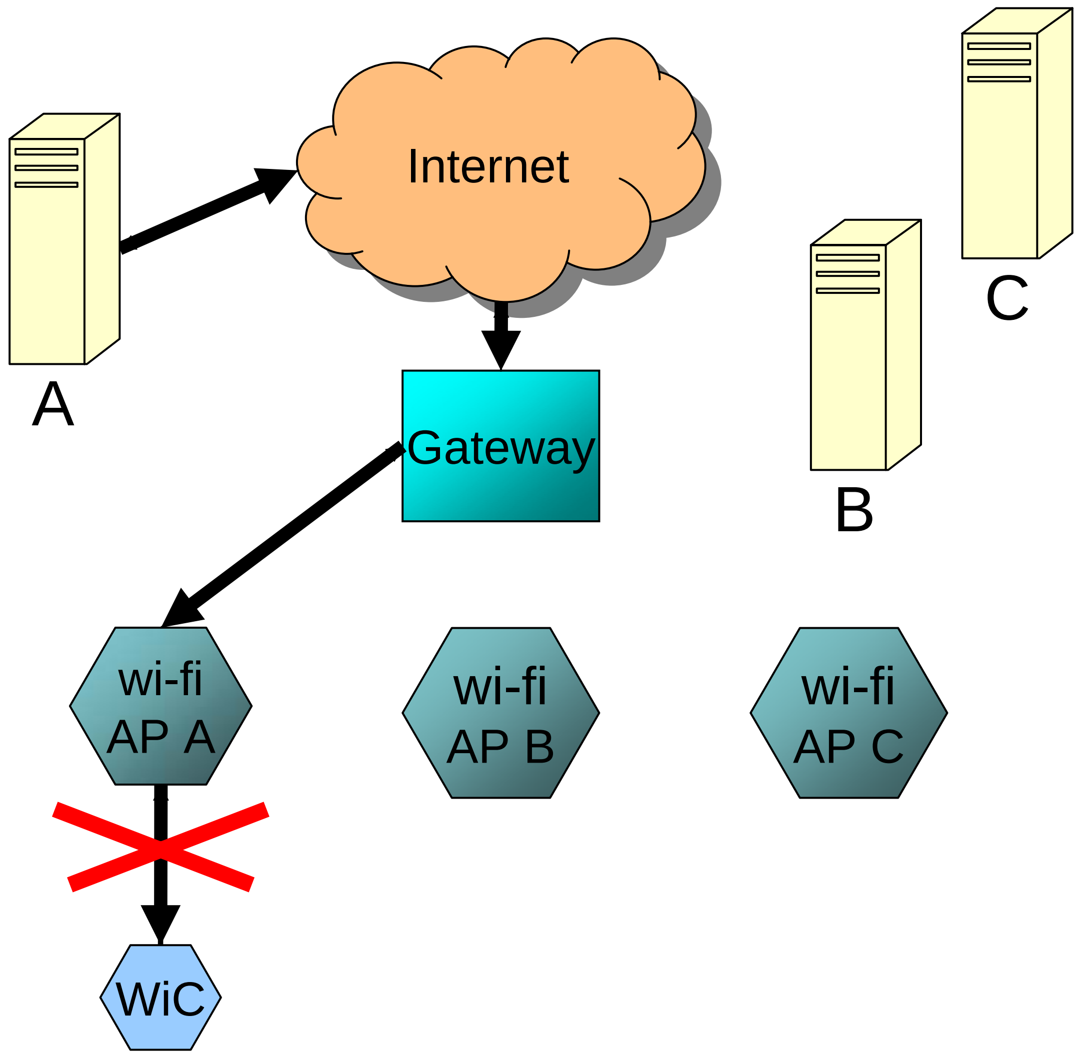
Agenda

- Wireless Internet
- Avoid continuous service interruption when a Wireless Client (WiC) performs an handover
  - Handover prediction
  - Mobility prediction
- Low-pass filters to improve Handover/Mobility predictor performance
- Experimental results

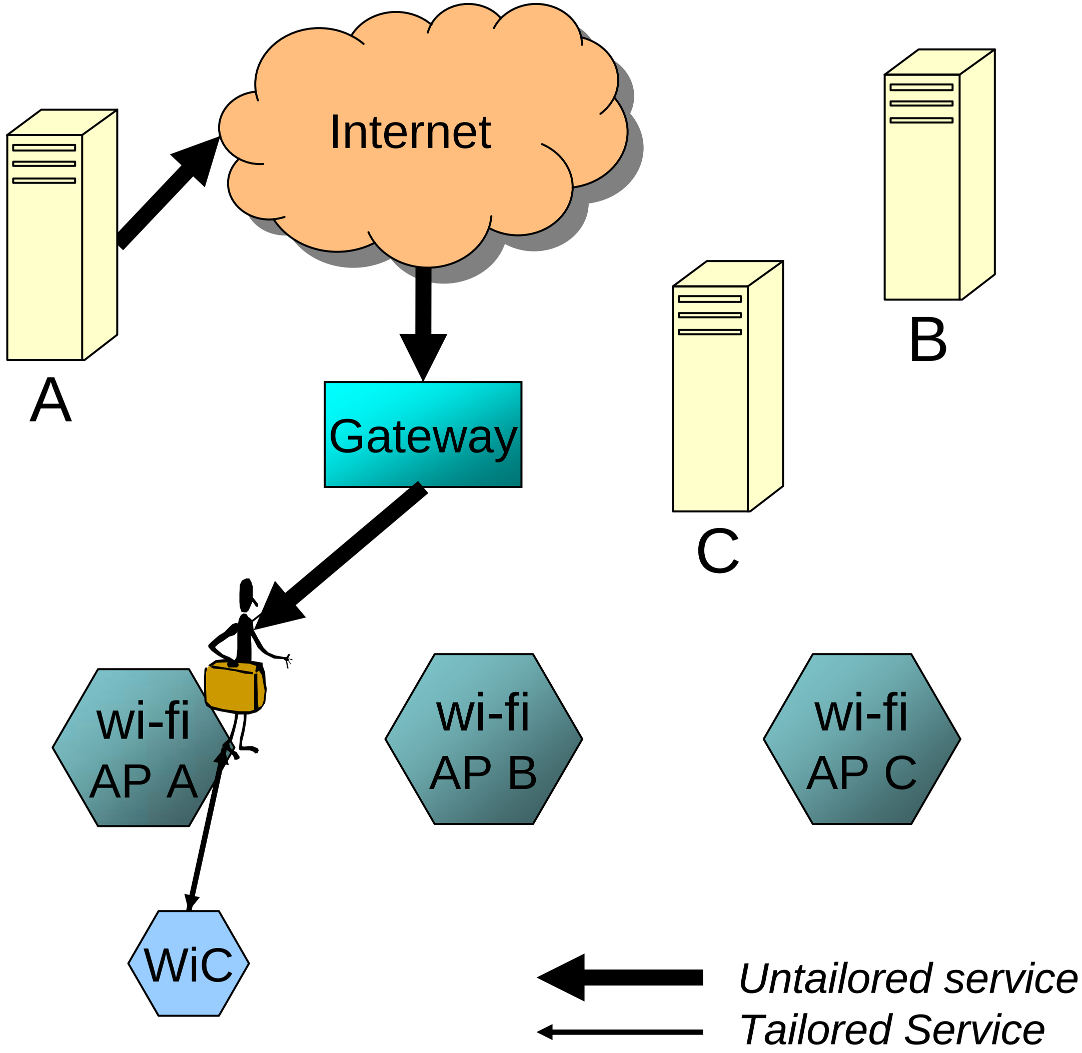
The Wireless Internet

- Limited and heterogeneous WiC hardware and software
- Limited wireless bandwidth
- Limited WiC battery life



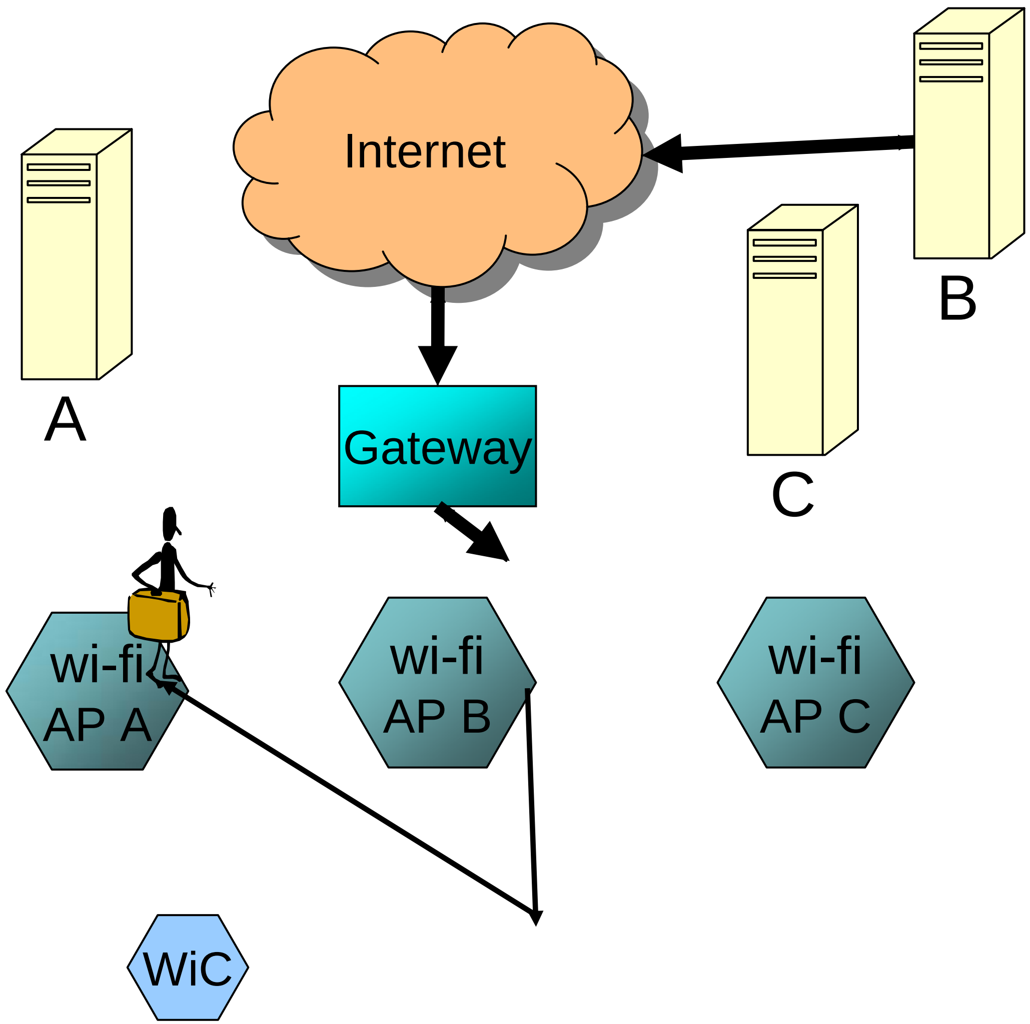
The Wireless Internet + Proxy

- Mobile agent based proxy tailors services to WiC software/ hardware capabilities and bandwidth availability
  - e.g., audio/video streams downsampled to actual capabilities of each WiC



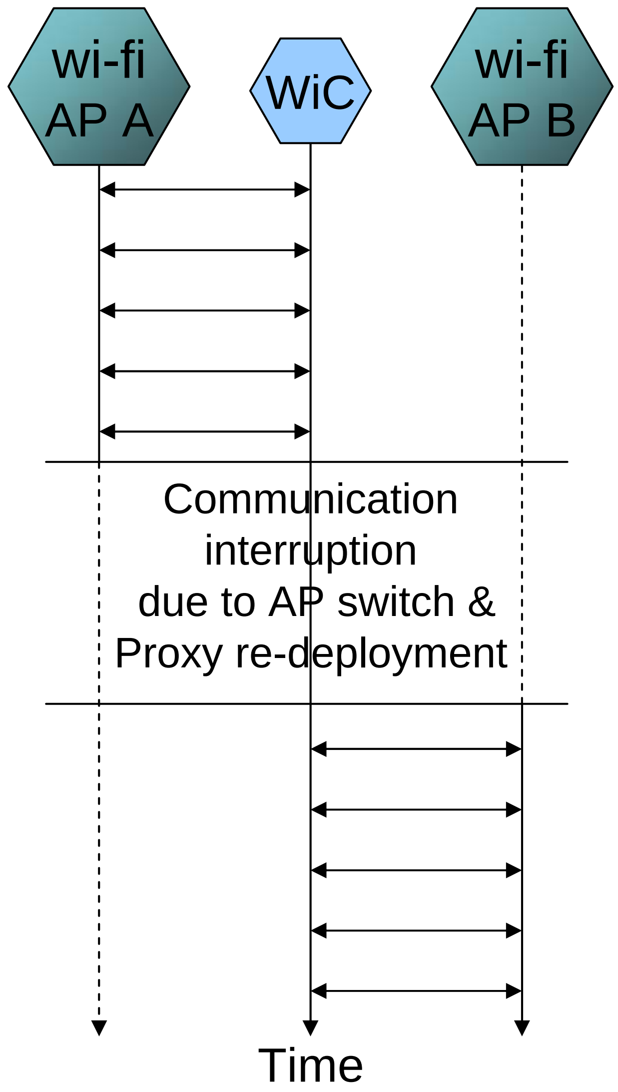
WiC Handover

1. WiC changes AP
2. WiC triggers proxy migration
3. Proxy rebinds to service
4. Proxy supplies service to WiC



Service Interruption

- Hard handover
  - WiC communicates with only one AP at a time
  - proxy-WiC communication link interruption during AP switch



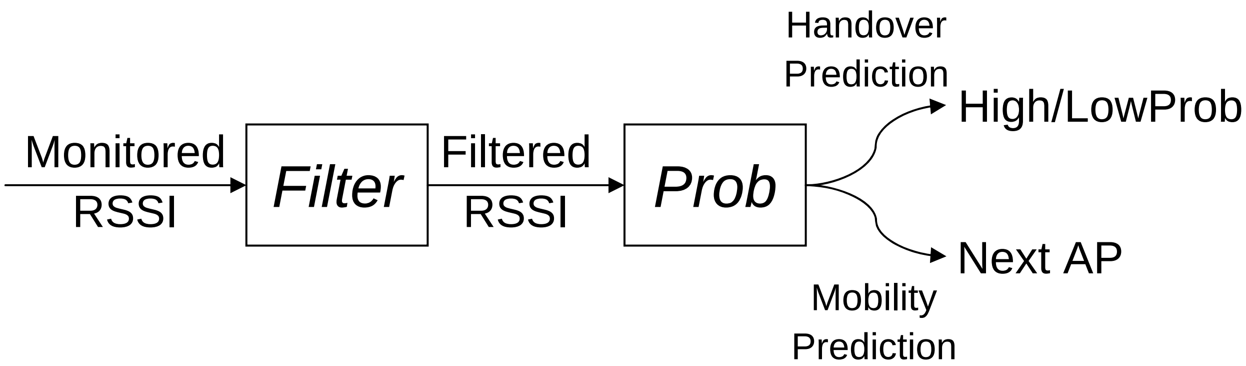
- Adaptive management:
  1. client-side adaptive buffering
  2. tailoring proxy proactive re-deployment

Handover/Mobility Prediction

- Need to predict:
  - when WiC handover starts (Handover Prediction)
  - which is the most probable next AP (Mobility Prediction)
- Handover triggering based on visible AP RSSI (Received Signal Strength Indication)

⇒ Handover/Mobility prediction based on monitoring and comparing visible AP RSSI

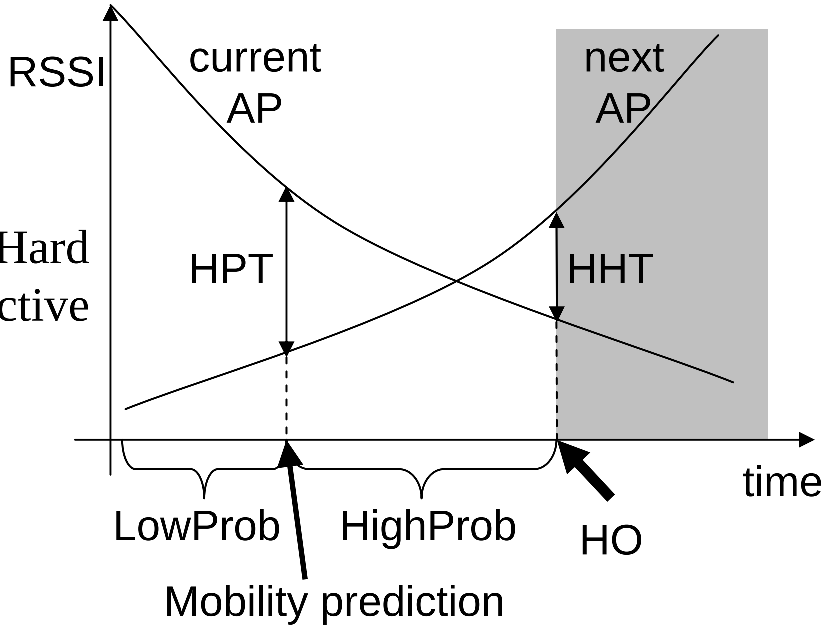
  - visible AP: AP signal reaches WiC

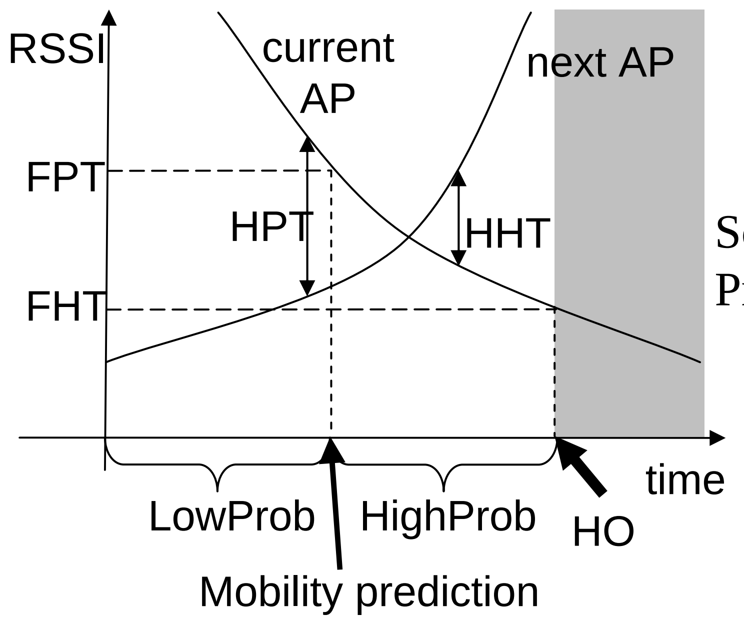


Prob Module: Handover Strategies

- Reactive: when signal is lost
- Proactive: before signal is lost
  - Hard Proactive: compares visible AP RSSI
  - Soft Proactive: HP + current AP RSSI is below a threshold

Hard Proactive



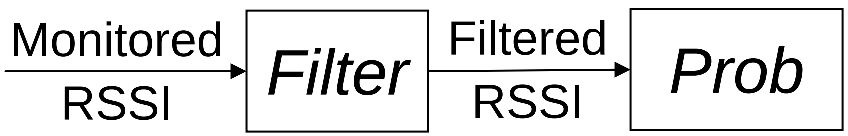


Soft Proactive

Filter Module

- Signal noise may trigger too many Prob changes and AP predictions
  - useless system perturbations may affect performance, e.g., triggering too many tailoring proxy migrations
- Filter acts as a low-pass filter on actual RSSI sequence ➔ RSSI sequence becomes more regular

- Main goal: low-pass filter RSSI fluctuations while limiting actual-to-filter RSSI delay



Exploited Filters

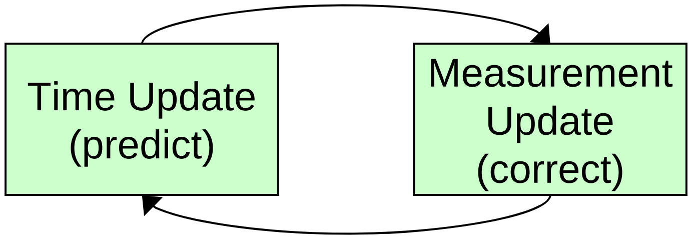
- Grey Model:
  - RSSI samples → first order differential equation
  - 15 historical RSSI samples

$$RSSI(i) = \left(r_1(1) - \frac{u}{a} \right) e^{-ai} + \frac{u}{a}$$

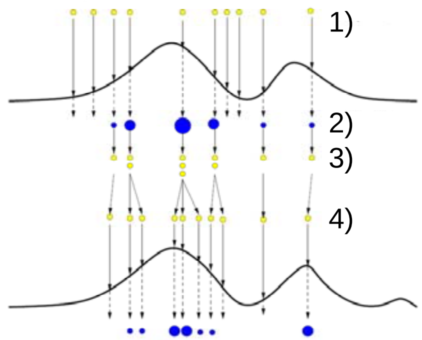
- Fourier Transform
  - RSSI samples → frequency samples
  - 4 historical time samples
  - first harmonic for signal regeneration

$$f(t_n) = \tfrac{1}{2} A_0 + \sum_{p=1}^{M} [A_p \cos(\omega_p t) + B_p \sin(\omega_p t)]$$

- Discrete Kalman Filter
  - Predict and Correct
  - Process/Signal noise standard deviation: Q=1.6, R=6.0

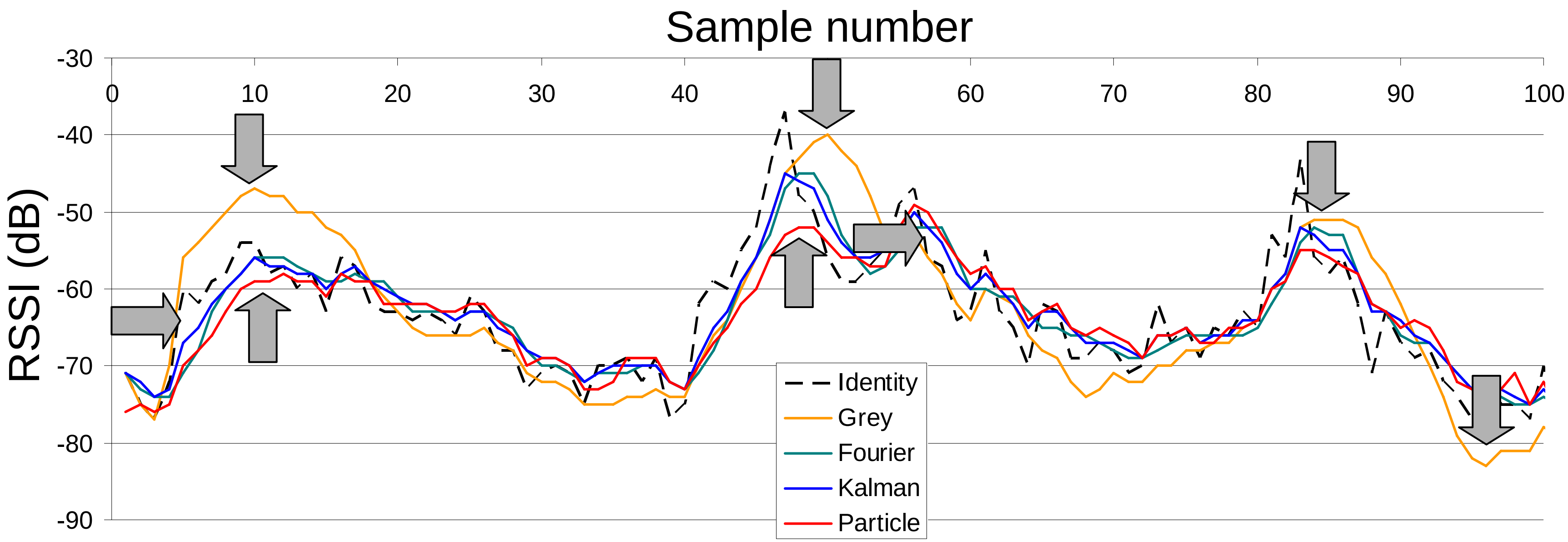


- Particle Filter
  - no normal distribution for signal noise
  - Q=1.6, R=6.0, 250 particles
  - heavy computational load



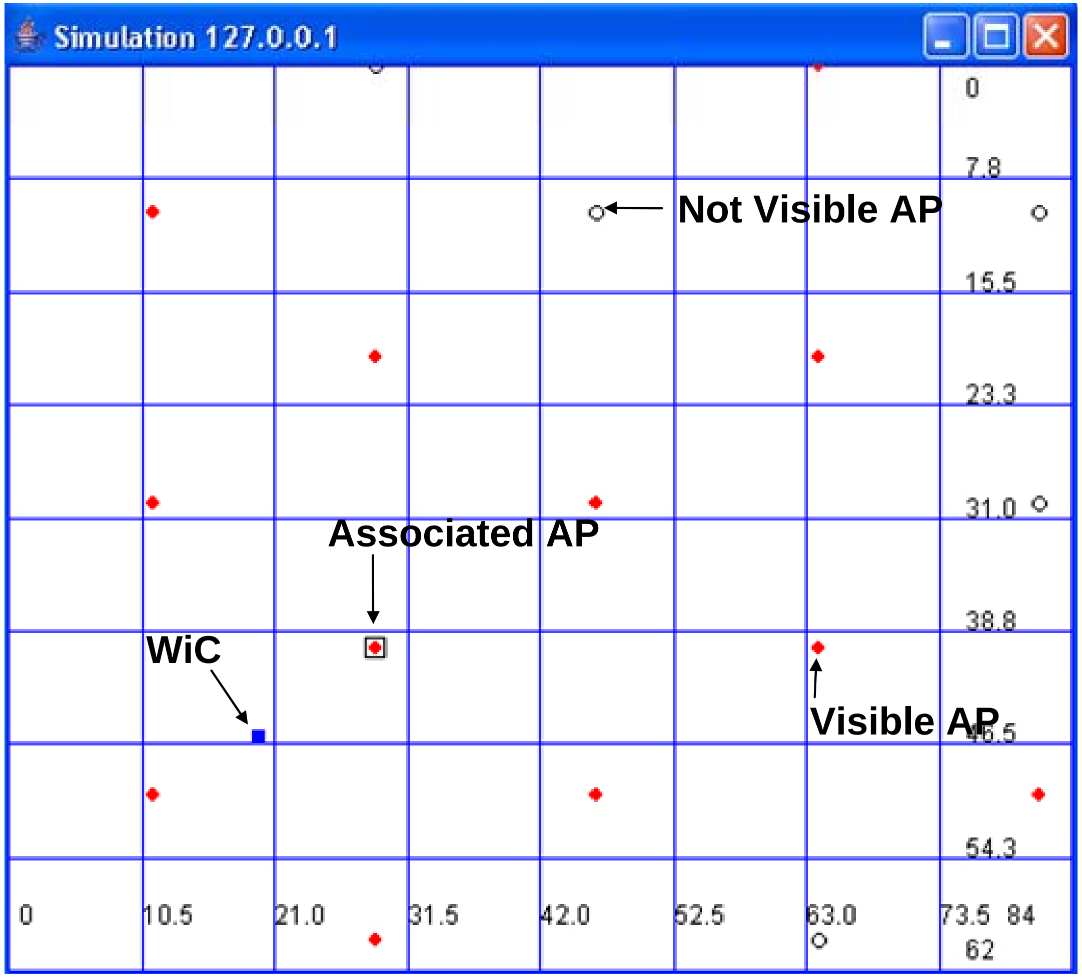
Filter behavior

- Goals: filter RSSI fluctuations and follows RSSI sequence
  - Grey: less fluctuations but amplifies RSSI growth
  - Fourier, Kalman: rarely slower, but without overestimations
  - Particle: occasionally non-negligible delay



Simulated Environment

- Random Waypoint model
- WiC speed between 0.6 and 1.5 m/s
- RSSI standard deviation at 3 dB



Performance Indicators (1)

- hit rate
  - how many handovers are correctly predicted
- efficiency
  - the capability to predict only handovers the actually occur
- stability
  - the ability to minimize Prob state changes

- Goals
  - maximize hit rate
    - to proactively manage handovers
  - maximize efficiency and stability
    - to minimize overhead due to useless predictions (mobility prediction) and useless Prob Module state changes (handover prediction)

Performance Indicators (2)

- Handover Prediction
  - $\text{hit rate} = \left(\frac{HPpre}{HPopt}\right) * 100$
  - $\text{efficiency} = \left(\frac{HPopt}{HPtot}\right) * 100$
  - $\text{stability} = \left(\frac{PC}{PCopt}\right) * 100$

HPpre: time interval in HighProb in the 4-second interval before an actual handover
HPopt: time interval an optimal predictor should stay in HighProb

HPtot: total time elapsed in HighProb state

PC: number of actual Prob changes
PCopt: optimal number of Prob state changes

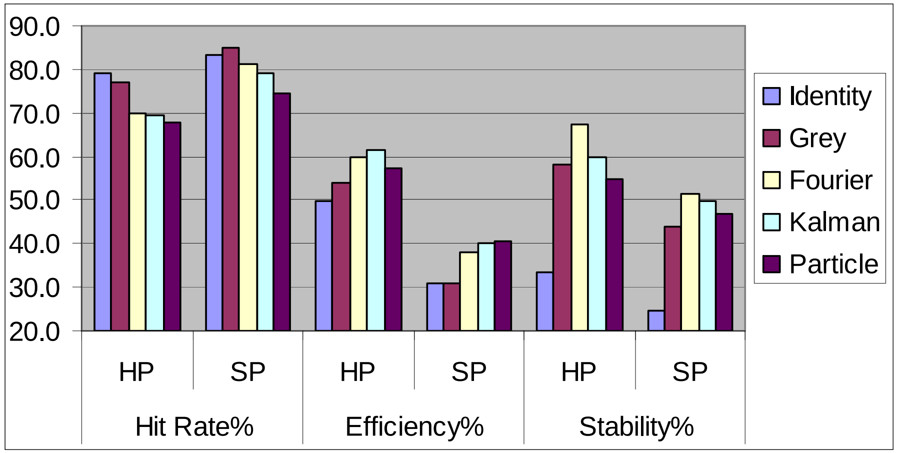
- Mobility Prediction
  - $\text{hit rate} = \left(\frac{CP}{NH}\right) * 100$
  - $\text{efficiency} = \left(\frac{CP}{NP}\right) * 100$

CP: correctly predicted handovers
NH: total number of actual handovers

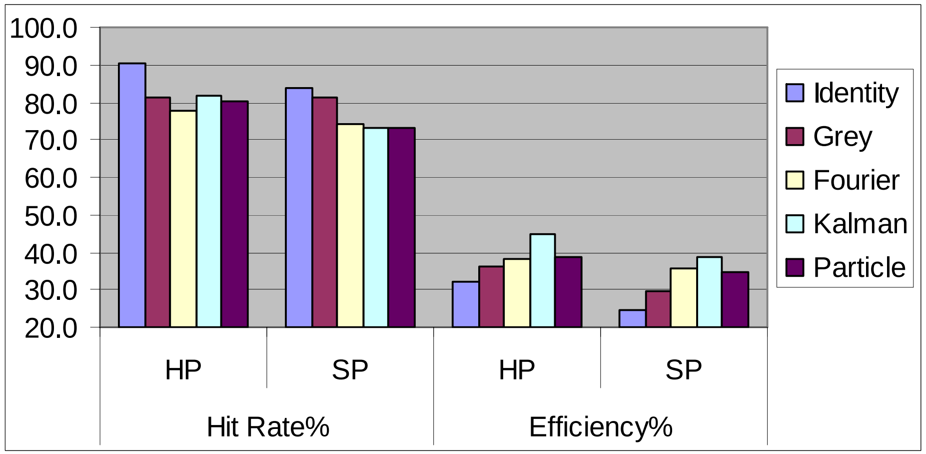
NP: number of triggered predictions

Experimental Results

- Results specifically point out filter contributions
  - greater Prob module setting could achieve greater performance
- low-pass filters significantly improve stability
  - Grey achieves a good hit rate
  - Fourier and Kalman achieve good efficiency and stability
  - Particle performance are limited; moreover its computational load is too high



Handover Prediction



Mobility Prediction

Conclusions & Ongoing work

- There is **not an outperforming filter**
- Filters **dynamically selected** at service provisioning time to improve either hit rate (Grey) or efficiency (Fourier and Kalman)
- WiC performs handover/mobility prediction in a lightweight, portable, and **completely decentralized** manner, only based on RSSI

- Evaluate filter performance with more refined RSSI evolution models
  - WiC velocity inferred exploiting RSSI evolution
- In-the-field performance in a multimedia deployment scenario

Any question?

- Acknowledgements:
  - Work supported by MIUR FIRB WEBMINDS and CNR Strategic IS-MANET Projects

- Web references for software and additional documents:
  - http://lia.deis.unibo.it/Research/SOMA/MobilityPrediction/
  - http://lia.deis.unibo.it/Staff/CarloGiannelli/