Velocity Effects on RSM-based Handover Decision

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Abstract

The velocity at which MTs travel will have an influence on the handover process in terms of handover delay.

This analysis provides a mathematical model for the (minimum) experienced handover delay if the handover process employs a radio-signal-measurement based decision scheme using low-pass filtering and hysteresis margins.

It will provide lower bounds on the required overlapping of adjacent radio cells to enable a seamless handover.

In consequence, TGr should include MT's velocity and handover delay in the list of metrics.

Motivation

- **Seamless handover (bounded delay) essential for various applications, e.g.:**
  - VoIP
  - High Speed Train Scenario (Transrapid)
- **Provider requirements stress this ability [1]**

- **Delay influenced by several aspects, e.g.:**
  - Knowledge on neighborhood (e.g. to reduce scanning time); TGk [2]
  - “Protocol mechanisms”; optimized by TGr
  - Overlapping area of adjacent APs
  - Velocity ???

- **Handover algorithms based on measuring the signal strength employing**
  - Averaging / low-pass filtering (reduce short-term fading effects)
  - Hysteresis margin (reduce oscillation between APs)

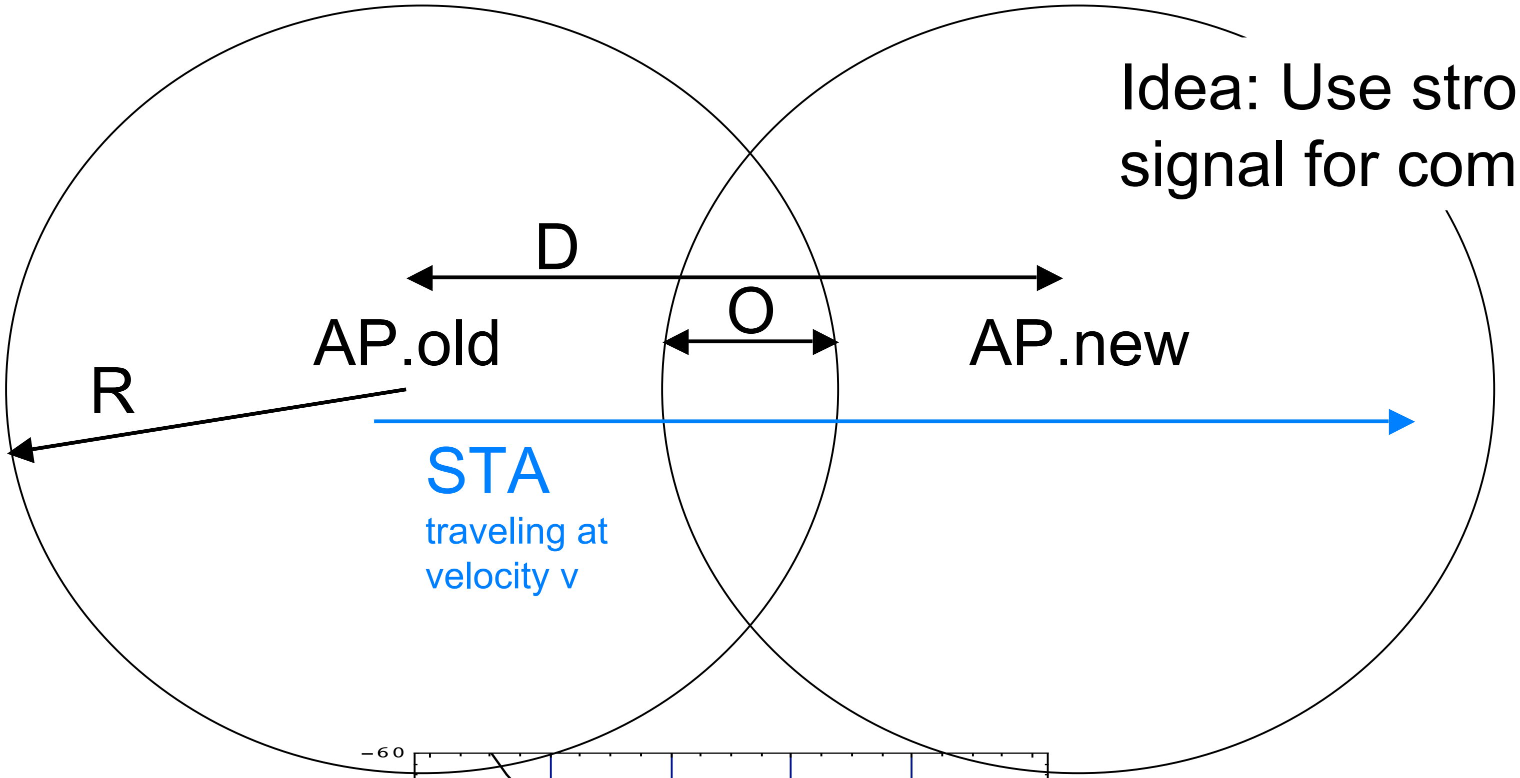
Goal

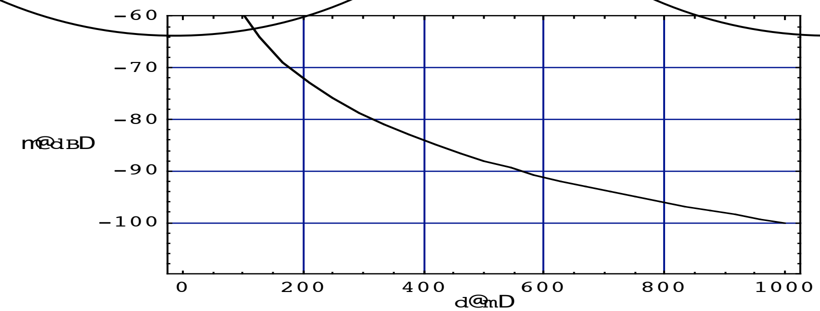
- **Analyze effect of velocity on the latter RSM-schemes to**
- **exploit associated handover delay and**
- **reveal requirements on overlapping region to minimize delay (--> network dimensioning)**

- **In consequence show**
  - Handover delay essential metric
  - MT's velocity shall be a parameter for experiments

Scenario & Handover Algorithm

Idea: Use strongest signal for communication





Ideal AWGN channel:
μ(x) := K1 - K2 Log10[x]

Roadmap

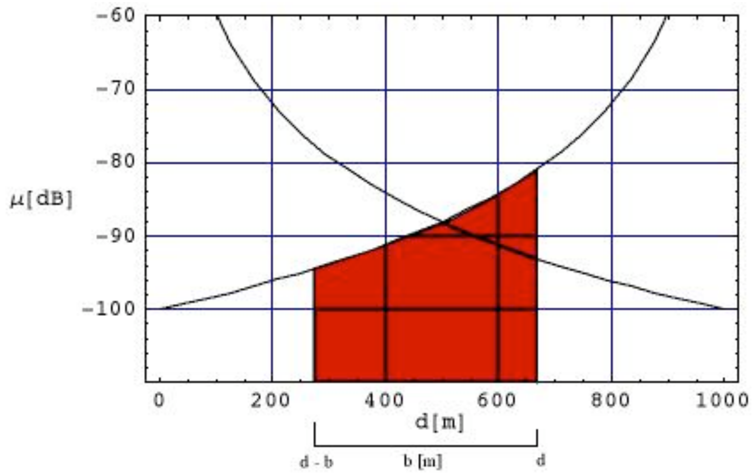
- **Open question:**

  Does the overlap of adjacent radio cells required for a seamless handover depend on the mobiles velocity?

  TGt: Should "mobile velocity" (speed on how to change tunable attenuators) be a parameter for a certain metrics (e.g.: handover delay)?

- **Steps:**
  - Determine handover delay
    - Effect of signal averaging a.k.a. low-pass filtering
    - Effect of hysteresis margin
  - Use the latter delay to determine the overlapping required for a seamless handover

HO Delay due to Averaging the signal



- **Averaging a.k.a. Low-Pass Filtering**

$$\mu_{i,avg}(d,b) = \frac{1}{b}\int_{d-b}^{d} \mu_i(x)\,dx$$

can be transformed into an integration over time as T = b / v

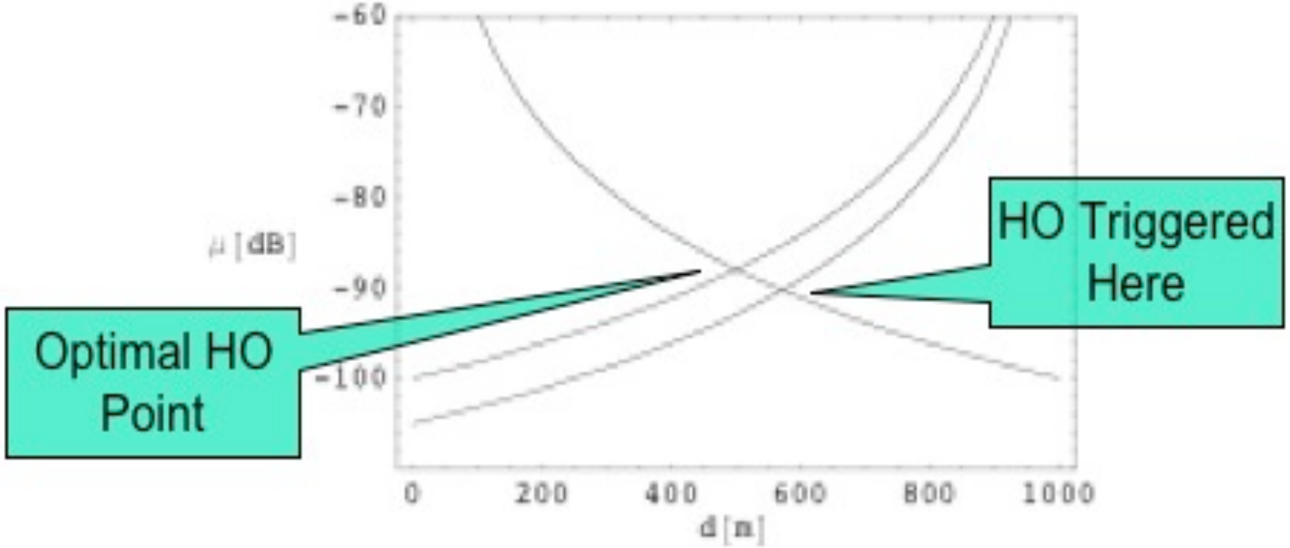
- **Associated Delay**

$$0 = \mu_{1,avg}(d,b) - \mu_{0,avg}(d,b)$$

==>

$$\delta_{avg} = \frac{d - D/2}{v} = \frac{T}{2}$$

HO Delay due to Hysteresis Margin



- **Hysteresis Margin**
- **Associated Delay**

$$h = \mu_1(d) - \mu_0(d)$$

==>

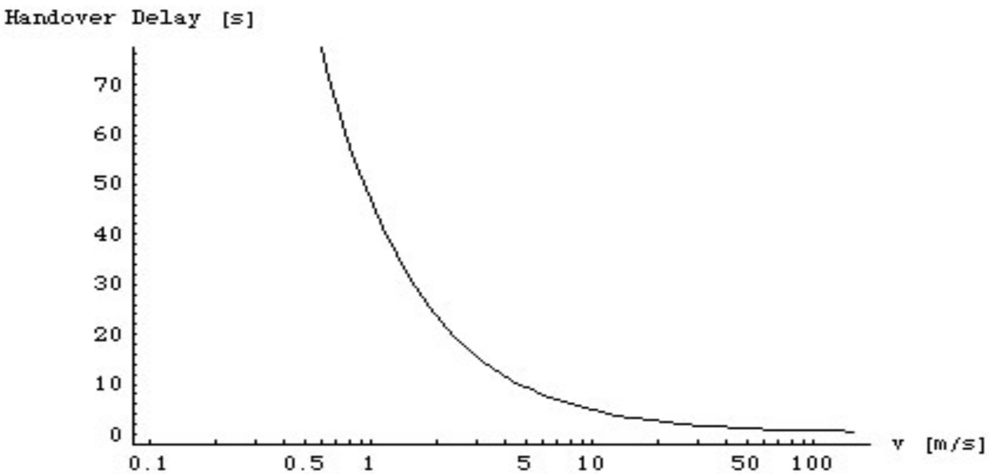
$$\delta_{hyst} = \frac{d - D/2}{v} = \frac{D}{2v} \frac{-1 + e^{h/K_2}}{1 + e^{h/K_2}} \leq \frac{D}{2v}$$

Total Handover Delay

- **Total Delay: linear combination**

$$\delta_{tot} = \frac{T}{2} + \frac{D}{2v}\ \frac{-1 + e^{h/K_2}}{1 + e^{h/K_2}} \le \frac{T}{2} + \frac{D}{2v}$$

- **Example: High Speed Train [3,4]:**
  - D=1km
    h=4dB
    T=600ms
  - Delay at 500 km/h:
    630 ms



Overlapping for Seamless Handover

- **As distance = delay * velocity**

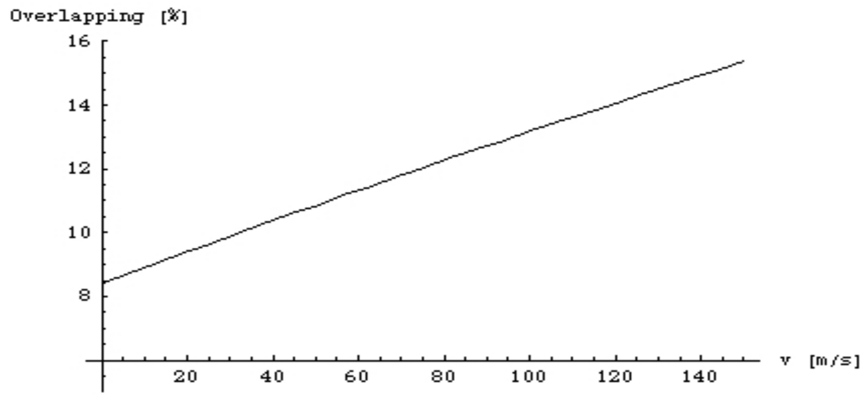
$$O/2 \geq v\,(\delta_{tot} \quad)$$

- **Normalize overlapping to cell diameter**

$$p = \frac{O}{2R}$$

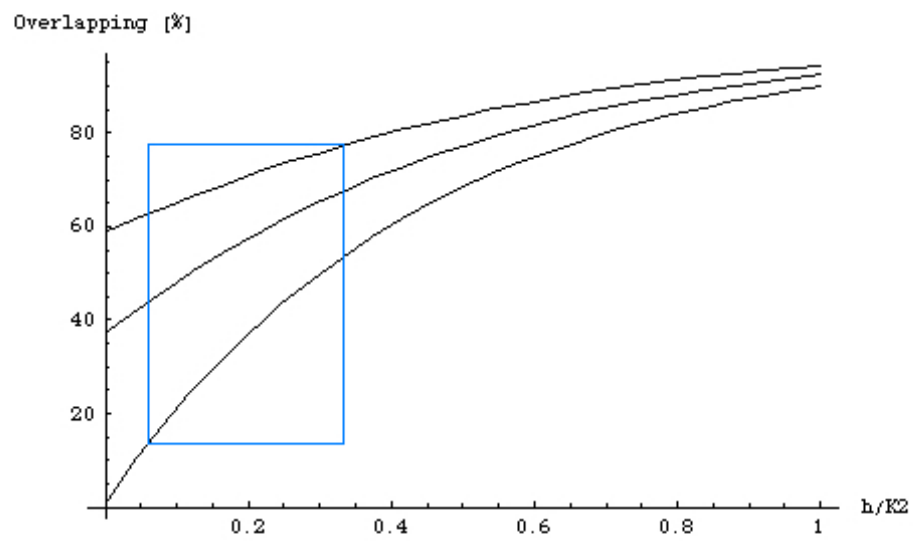
$$\frac{Tv - D + 10^{h/K_2}(D + Tv)}{2^{(h+K_2)/K_2}\, 5^{h/K_2} D + (1 + 10^{h/K_2})T_v} \leq px \qquad px \leq 1 - \frac{2}{1 + 10^{h/K_2}} + \frac{v(T - \quad)}{D}$$

- **Example: High Speed Train [3,4]**
  - D=1km
  - h=4dB
  - T=600ms



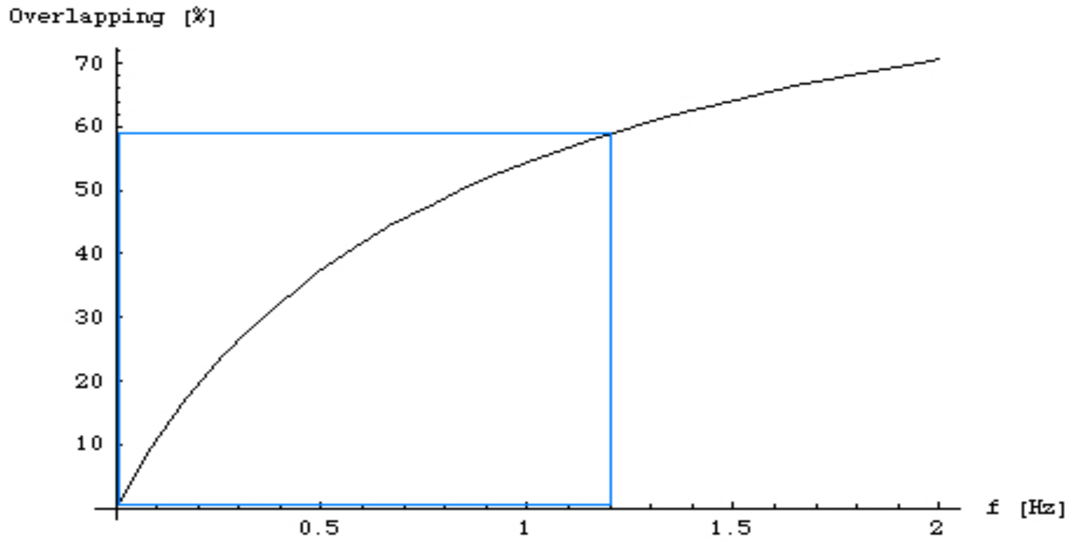
Normalization using HO-Frequency

- **Handover rate / frequency parameter of application scenario**
  - f = v / D
  - E.g.:
    - Pedestrian f = 0.006 Hz
    - Transrapid f = 0.150 Hz
    - Office environment f = 1.2 Hz
- **Limit range of h / K2 [3,5,6]**
  - Ericson Tech. Doc.:
    3 ≤ h ≤ 5 [dB]
  - Zonoozi and Dassanayake:
    15 ≤ K2 ≤ 50 [dB]



Dynamic Adaptation of Hysteresis Margin

- For high velocities a.k.a high handover frequencies, reducing the hysteresis margin seems feasible since oscillation in between two APs is rather unlikely (Consider: h -> 0)



- Decrease of overlapping for low ho frequencies by one magnitude
- Not noticeable for high ho frequencies

Conclusion & Contributions

- **Conclusion:**
  - Solemnly employed RSM-based handover algorithms should be supported by other decision schemes in order to guarantee a seamless handover (esp. for small overlapping regions)
  - Dynamically adapting the hysteresis margin to the velocity results in rather small performance improvements

- **Contributions:**
  - Conducted detailed analysis on how the velocity effects the handover delay associated with a RSM-based HO decision
  - Provided lower bounds for the overlapping area of two adjacent cells guaranteeing seamless handover
    --> can be used for network dimensioning
  - Results generalized according to the handover frequency describing the application scenario
  - TKN-Tech-Report detailing the described analysis [7]

Relevance wrt. TGt

- **Velocity of MTs has influence on Performance of WLAN systems**

- **Consider following metrics and their correlation**
  - Handover Delay
  - MTs' velocity (better: handover frequency)
- **Applicable Use Cases**
  - Voice (+)
  - Video (rt-data) (+)
  - Data (non-rt) (+/-)

- **Performance evaluations involving handover should conduct experiments employing various speeds (at least specify the latter)**

References

[1] B. Ford, C. Cook, and R.B. Miller. Service Provider Requirements for 802.11n Detailed. doc.: IEEE 802.11-05/109r2.

[2] 802.11k Radio Resource Measurement -- Draft. IEEE P802.11k/D2.0, February 2005.

[3] “Signal strength measurements in TEMS mobiles (GSM) white paper,” Ericson, Tech. Rep., 2002.

[4] WIGWAM - Wireless Gigabit With Advanced Multimedia Support. online: www.wigwam-project.com

[5] M. Zonoozi and P. Dassanayake, “Handover delay in cellular systems,” in Proc. of Personal Wireless Communications, 1997. IEEE International Conference on, Mumbai, India, December, 17-19 1997, pp. 24 – 27.

[6] A. Aguiar and J. Gross, “Wireless channel models,” Technical University of Berlin - Telecommunication Networks Group, Einsteinufer 25, 10587 Berlin Germany, Tech. Rep. TKN-03-007, April 2004. [Online]. Available: www.tkn.tu-berlin.de.

[7] M. Emmelmann, “Influence of Velocity on the Handover Delay associated with a Radio-Signal-Measurement-based Handover Decision,” Technical University of Berlin - Telecommunication Networks Group, Einsteinufer 25, 10587 Berlin Germany, Tech. Rep. TKN-05-xxx, 2005. Accepted for publication.