

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

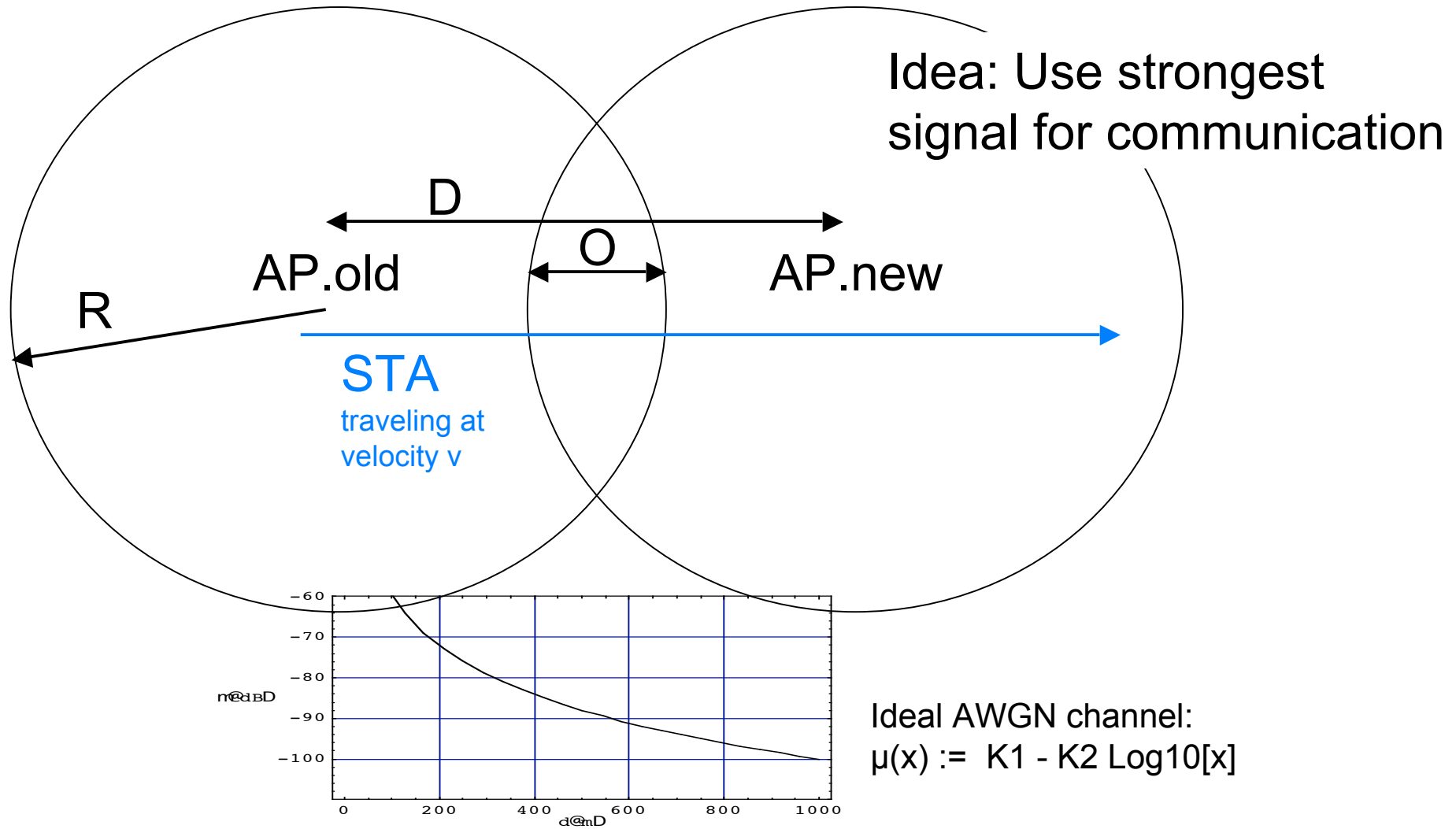
- **Seamless handover (bounded delay) essential for various applications, e.g.:**
 - VoIP
 - High Speed Train Scenario (Transrapid)
- **Provider requirements stress this ability [1]**
- **Delay influenced by several aspects, e.g.:**
 - Knowledge on neighborhood (e.g. to reduce scanning time); TGk [2]
 - “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



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:**

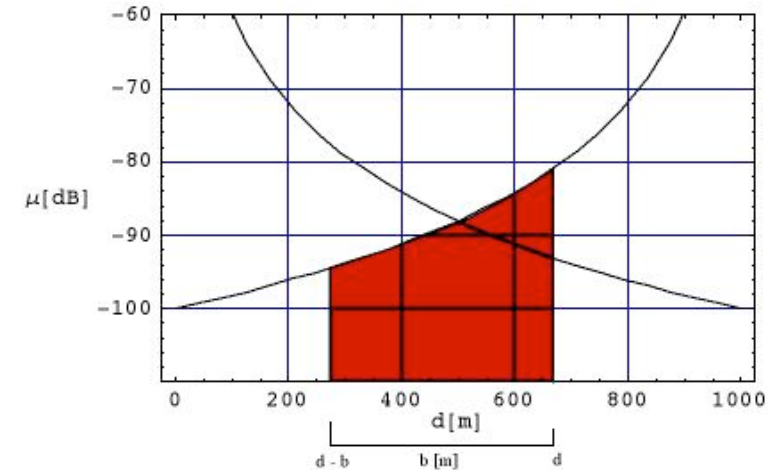
- Determine handover delay
 - Effect of signal averaging a.k.a. low-pass filtering
 - Effect of hysteresis margin
- Use the latter delay to determine the overlapping required for a seamless handover

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 $T = b / v$



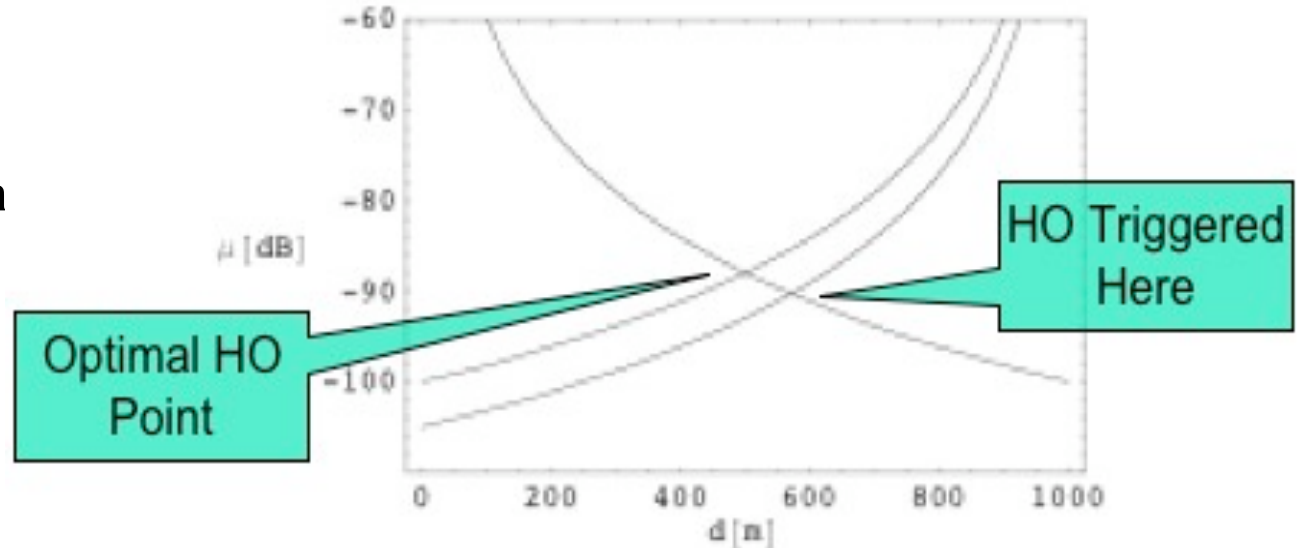
- Associated Delay

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

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

HO Delay due to Hysteresis Margin

- Hysteresis Margin



- Associated Delay

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

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

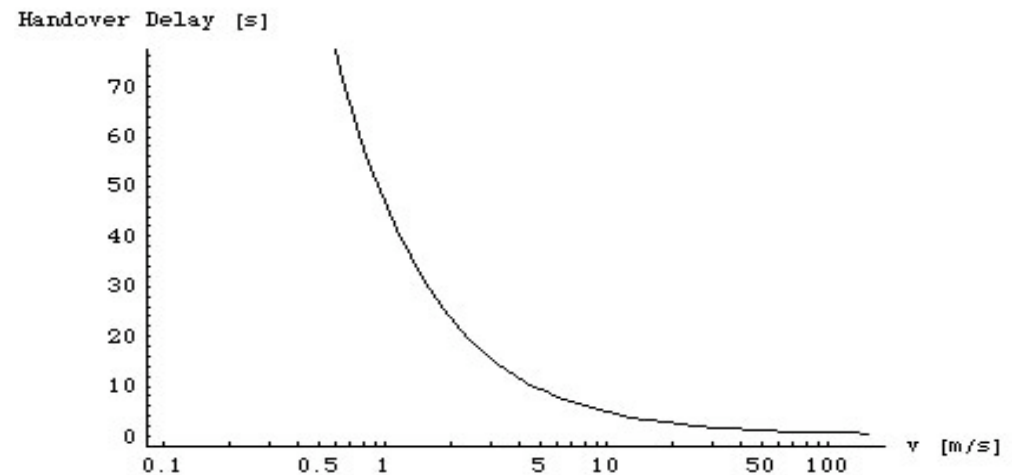
Total Handover Delay

- **Total Delay: linear combination**

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

- **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

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

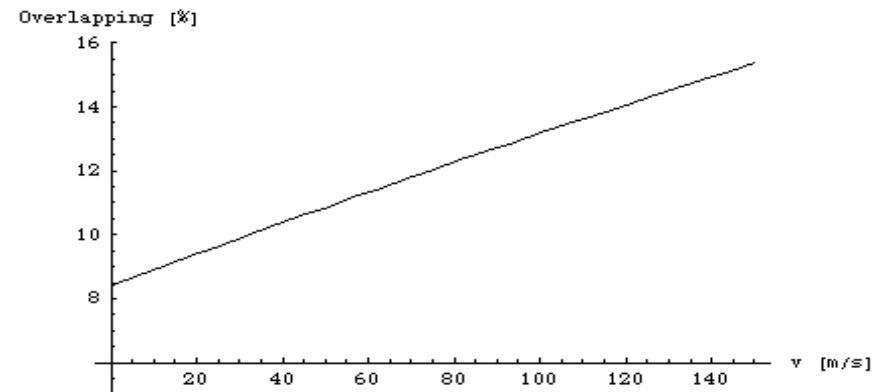
- Normalize overlapping
to cell diameter

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

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

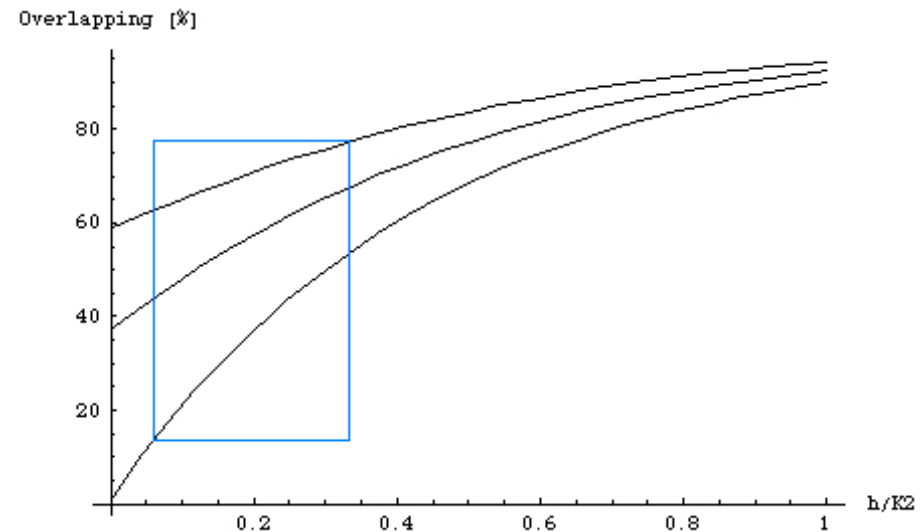
- **Example: High Speed Train [3,4]**

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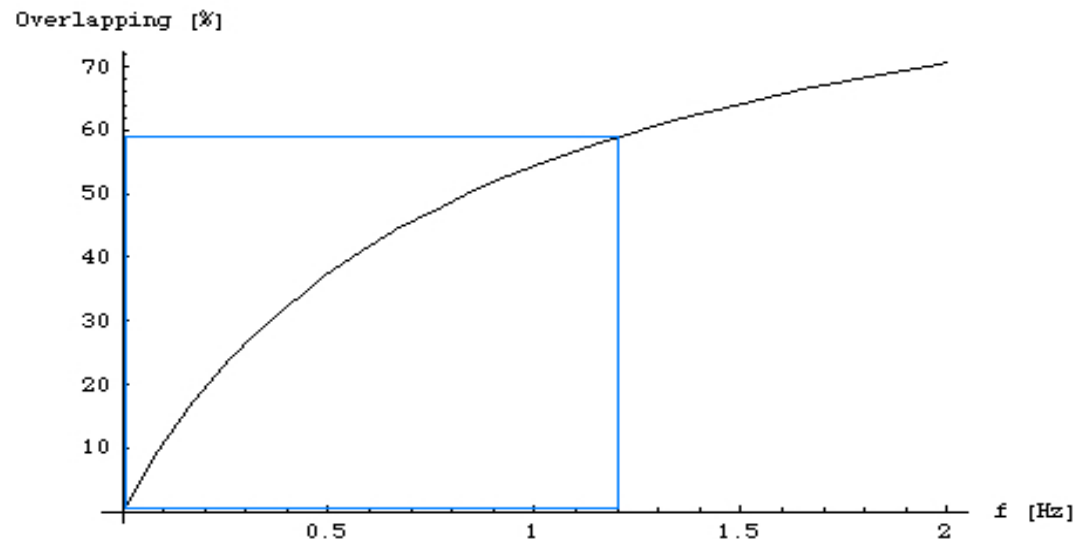
Normalization using HO-Frequency

- **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.:
 $3 \leq h \leq 5$ [dB]
 - Zonoozi and Dassanayake:
 $15 \leq K2 \leq 50$ [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: $h \rightarrow 0$)



- 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.
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- [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.