Velocity Effects on RSM-based Handover Decision

Authors: Marc Emmelmann
Company: Technical University Berlin
Address: Einsteinufer 25 10587 Berlin Germany
Phone: +49-30-314-24580
email: emmelmann@ieee.org

Date: 2005-03-15

This work was conducted under the contract of TELEFUNKEN Radio Communication Systems GmbH within the framework of the WIGWAM [4] project founded by the German Ministry of Education and Research.

Notice: This document has been prepared to assist IEEE 802.11. It is offered as a basis for discussion and is not binding on the contributing individual(s) or organization(s). The material in this document is subject to change in form and content after further study. The contributor(s) reserve(s) the right to add, amend or withdraw material contained herein.

Release: The contributor grants a free, irrevocable license to the IEEE to incorporate material contained in this contribution, and any modifications thereof, in the creation of an IEEE Standards publication; to copyright in the IEEE’s name any IEEE Standards publication even though it may include portions of this contribution; and at the IEEE’s sole discretion to permit others to reproduce in whole or in part the resulting IEEE Standards publication. The contributor also acknowledges and accepts that this contribution may be made public by IEEE 802.11.

Patent Policy and Procedures: The contributor is familiar with the IEEE 802 Patent Policy and Procedures <http://ieee802.org/guides/bylaws/s4h-bylaws.pdf>, including the statement “IEEE standards may include the known use of patent(s), including patent applications, provided the IEEE receives assurance from the patent holder or applicant with respect to patents essential to compliance with both mandatory and optional portions of the standard.” Early disclosure to the Working Group of patent information that might be relevant to the standard is essential to reduce the possibility for delays in the development process and increase the likelihood that the draft publication will be approved for publication. Please notify the Chair <stuart.kerry@philips.com> as early as possible, in written or electronic form, if patented technology (or technology under patent application) might be incorporated into a draft standard being developed within the IEEE 802.11 Working Group. If you have questions, contact the IEEE Patent Committee Administrator at <patcom@ieee.org>.
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:
\[ \mu(x) := K_1 - K_2 \log_{10}[x] \]
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

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

can be transformed into an integration over time as \( T = \frac{b}{v} \)

- Associated Delay

\[ 0 = \mu_{1,\text{avg}}(d, b) - \mu_{0,\text{avg}}(d, b) \]

\[ \Rightarrow \delta_{\text{avg}} = \frac{d - D/2}{v} = \frac{T}{2} \]
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

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

- 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
  \[ = \text{delay} \times \text{velocity} \]
  \[ O/2 \geq v(\delta_{\text{tot}}) \]

- Normalize overlapping to cell diameter
  \[ p = \frac{O}{2R} \]
  \[ \frac{T_v - D + 10^{h/K_2}(D + T_v)}{2(h + K_2)/K_2} \leq p_x \]
  \[ \leq 1 - \frac{2}{1 + 10^{h/K_2}} + \frac{v(T - D)}{D} \]

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

- **Handover rate / frequency parameter of application scenario**
  - \( f = \frac{v}{D} \)
  - E.g.:
    - Pedestrian \( f = 0.006 \) Hz
    - Transrapid \( f = 0.150 \) Hz
    - Office environment \( f = 1.2 \) Hz

- **Limit range of \( h / K_2 \) [3,5,6]**
  - Ericson Tech. Doc.: \( 3 \leq h \leq 5 \) [dB]
  - Zonoozi and Dassanayake: \( 15 \leq K_2 \leq 50 \) [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


