Novel Channel Estimation for OFDM-based WLAN Receivers

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Abstract

- Wireless Local Area Network (WLAN) deploying
- Most of WLAN standards are Orthogonal Frequency Division Multiplexing (OFDM)
- One of the most critical issues is the channel estimation
- So, this paper deals with the efficient channel estimation problem at the receiver
- Novel smoothing-assisted channel estimation scheme is proposed for the OFDM-based WLAN systems
Orthogonal Frequency Division Multiplexing (OFDM)
- Popular technique for achieving high rate
- Combating multipath fading in the wireless communication

Wireless Local Area Network (WLAN)
- A wireless computer network that links two or more devices using a wireless distribution method within a limited area
- Most modern WLANs are based on IEEE 802.11 standards, marketed under the Wi-Fi brand name.

Channel estimation
- Crucial to the performance of systems
- Representatively, there are LS and MMSE
In this paper, a smoothing-assisted channel estimation scheme is proposed for the OFDM-based WLAN systems. The scheme uses preamble and pilot information. The simulation results show that the proposed scheme exhibits good performance. The novel scheme is only based on the IEEE 802.11a standard defined WLAN systems.
Frame format of 802.11 a

- SS: the preamble of ten short symbol and SS consists of 16 samples
- LS: the preamble of two long symbol and LS consists of 64 samples
- GI1: guard interval for the LS

(Packet structure of 802.11a standard)
Frame format of 802.11 a (cont’d)

- Automatic gain control (AGC) and signal detection are completed at some arbitrary point in time relative to the start of the preamble.
- The time sync and frequency offset estimation starts at some unknown discrete sample of the preamble.
- Two of the LSs are used for channel estimation.
- The data carrying part consists of a variable number of OFDM symbols.
The proposed channel estimation is based on the smoothing of the past data and the current data. Therefore, it is called the smoothing-assisted channel estimation scheme.

The received signal is given by:

\[ r(n) = S(n) \otimes h(n) + N(n) \]

where \( \otimes \) denotes convolution, \( N(n) \) indicates additive white Gaussian noise (AWGN).

The correlation function is defined as:

\[ R^{rS_{LS}}(n) = \frac{1}{N_{LS}} \sum_{i=0}^{N_{LS}-1} r(i - n) \cdot S^{LS^*}(i) \]
Channel Estimation Scheme (2)

- Between the received signal $r(n)$ and the locally generated LS signal $s^{LS}$
  - $R^{rS^{LS}}(n) = R^{SS^{LS}}(n) \otimes h(n) + N(n)$

- In an idea case, during every one period of the LS
  - $R^{SS^{LS}}(n) = \begin{cases} 
  R^{S^{LS}S^{LS}} = \frac{1}{N_{LS}} \sum_{i=0}^{N_{LS}-1} S^{LS(i)} \cdot S^{LS*}, & n = 0 \\
  N(n), & n \neq 0 
\end{cases}$

- To reduce the estimation variance
  - $\hat{R}^{rS^{LS}}(n) = \frac{1}{2}(R_1^{rS^{LS}} + R_2^{rS^{LS}})$

- Respectively, two correlation value denotes the correlation function during the first and the second LS preamble period
Channel Estimation Scheme (3)

Through a N-point fast Fourier transform (FFT) operation

\[ FFT(\hat{R}^{r_{LS}}(n)) = FFT(R^{SS_{LS}}(n)) \cdot H^{LS}(f) + N(n) \]

The composite channel frequency response at the \( k \) th subcarrier

\[ H^{LS}_k = \sum_{l=0}^{N_p} h_l e^{-j2\pi k \tau_l f_k} \]

From FFT equation the channel estimation at the \( k \)th subcarrier

\[ \hat{H}^{LS}_k = [FFT(R^{SS_{LS}}(n))]_k^{-1} \cdot [FFT(\hat{R}^{r_{LS}}(n))]_k \]

The least square channel frequency response

\[ \hat{H}^{P}_{k_p,j} = \frac{R^{P}_{k_p,j}}{S^{P}_{k_p,j}} \]
The channel frequency response

\[ \tilde{H}_{k,1} = \beta (\tilde{H}_k^{LS} e^{-j\phi_k}) + (1 - \beta) \tilde{H}_k^{LS} \]

- The smoothing factor, \( \beta \in [0.5, 1] \), is determined by the SNR and Doppler frequency.

\[ \tilde{H}_{k,(i+1)} = \beta \hat{H}_{k,j} \cdot e^{-j\phi_k(1+j)} + (1 - \beta) \hat{H}_{k,j} \]

- OFDM symbol can be smoothing, it is taken as predication of the current transfer factor.

\[ \hat{S}_{k,(j+1)} = \frac{R_{k,(1+j)}}{\tilde{H}_{k,(1+j)}} \]

- Detected by the demodulator.

\[ \hat{H}_{k,(1+j)} = \frac{R_{k,(1+j)}}{\hat{S}_{k,(j+1)}} \]

- The estimation of the channel frequency response of all the pilot subcarriers of the (i+2)th data carrying part OFDM symbol.
Simulation results

- Channel models

<table>
<thead>
<tr>
<th>Name</th>
<th>Rms delay spread (nsec.)</th>
<th>Maximum delay (nsec.)</th>
<th>Characteristic</th>
<th>Environment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Channel A</td>
<td>50</td>
<td>390</td>
<td>Rayleigh</td>
<td>Office NLOS</td>
</tr>
<tr>
<td>Channel E</td>
<td>250</td>
<td>1760</td>
<td>Rayleigh</td>
<td>Large open space NLOS</td>
</tr>
</tbody>
</table>
Simulation results (cont’d)

Performance

< MSE performance of the proposed scheme>

< Symbol error rate performance of the system >
Conclusion

- An effective channel estimation and channel updating procedure is proposed for the design and implementation of the OFDM-based WLAN receivers.
- Performance evaluation shows that the designed WLAN system with practical system performance under the BRAN channels.
Thank you for giving your attention!