FRAME DELAY AND LOSS ANALYSIS FOR VIDEO TRANSMISSION OVER TIME-CORRELATED 802.11a/g CHANNELS

Victoria Sgordoni, Pierre Ferré, Angela Doufexi, Andrew Nix, David Bull

Presented by Victoria Sgordoni
What is it about

• Cross-layer performance of 802.11a/g MAC and PHY layers
• Frame Loss Rate (FLR) and MAC-to-MAC frame delay

• We demonstrate it is vital to use a spaced-time correlated channel model to replicate the bursty nature of packet errors

➤ How is the ARQ retransmission mechanism affected by the fading wireless channel?
➤ What may be the effects on video transmission?
The time-correlated errors issue

- Several studies of 802.11 MAC performance, but based on static channel models with PHY layer PER independent of time.
- The bursty nature of packet errors in a wireless channel is well known
- **Very few address the correlation of errors in the time-varying fading channel**
  - Frame delay is severely underestimated
Our contribution

• To estimate MAC-to-MAC frame delay, FLR and error burst lengths, we simulate the transmission of a series of equal length packets (user definable).
• Assume unicast operation

What is Novel:

• To replicate the bursty nature of packet errors, we implement an accurate time-correlated channel model.
• We study the impact of Doppler spread on the effect of ARQs on FLR and frame delay and their time pattern.
• We compare results based on time-correlated packet errors with results for errors independent in time.
The time-varying channel model

- Multipath fading model based on a TDL, with each tap experiencing Rayleigh fading, modeled as a function of terminal velocity, carrier frequency and Doppler spectrum.
- The spaced-time autocorrelation of fading envelope is controlled by a Jakes PSD for each tap.
- The instantaneous signal is attenuated appropriately to model any mean SNR level desired.
- Channel was modeled with a single Rayleigh fading tap, for max Doppler frequencies of 4, 24 and 80Hz (correspond to terminal speeds 0.5, 3 and 10m/sec for a 2.4GHz carrier).
The MAC-PHY simulator

- Packets arrive at transmit MAC at CBR and encapsulated in MAC frames 1:1
- Queue in the transmit buffer for transmission
- For each packet sent $s(k)$ we use the channel impulse response $h_c(t_k,r)$ at the exact time of transmission. At receiver:
  \[ r(k) = s(k) \otimes h_c(t_k,r) \]
- Packet retransmitted till ACK' d or till the ARQ retry limit.
Transmission duration

- The transmission duration of each frame is calculated considering the 802.11 MAC CSMA/CA protocol, IFS timings and the ARQ retransmission mechanism. (The MAC DCF Basic Access scheme is assumed.)

- For $N$ retransmissions the total transmission delay is:
  \[ T_{tx} = N \times (DIFS + T_{Data} + SIFS) + \sum_{i}^{N} T_{Bo,i} + T_{ACK}, \quad N \leq maxARQ \]
Total Frame Delay and Frame Loss Rate

- The simulator estimates total delay for each frame from MAC-to-MAC.

  \[ \text{Total frame delay} \quad T_{\text{tot}} = T_{\text{tx}} + T_{Q} \]

- FLR at the transmit MAC defined:

  \[ \text{FLR} = \frac{\text{no. lost frames}}{\text{no. unique transmit frames}} \]
Total delay per frame

- Plots for 1500 frames of size 800 bytes, for maxARQ=4 and mean SNR=10dB

- Total frame delay reaches
  - for slow fading channels (4Hz) 160ms
  - for fast fading channels (80Hz) 27ms

- Lost frames time pattern
Simulation Parameters

- Frames arriving at CBR = 1Mbps
- Frame length fixed – results here for 800 bytes
- Simulated 1500 frames – about 10 sec of data
- maxARQ limit = 0, 4, 16
- Modeled 8 PHY link-speeds – results here for link-speed 3
- Channel was modeled with a single Rayleigh fading tap, for max Doppler frequencies of 4, 24 and 80Hz (correspond to terminal speeds 0.5, 3 and 10m/sec for a 2.4GHz carrier).
- Mean SNR 2 – 25 dB

- For comparison we also simulate uncorrelated packet transmissions/retransmissions
Frame Loss Rate vs. SNR

- The improvement in FLR is better for higher Doppler, for a given maxARQ. ARQs are more effective when the channel decorrelates fast.

- FLR appears better when errors are independent in time
Total frame delay PDF

- Total delays estimated are significantly greater than when packet errors are uncorrelated (200 ms and 27 ms).
- For a given mean SNR and $\textit{maxARQ}$, the total frame delay decreases for higher Doppler. The number of required ARQs is lower for fast changing channels.
Frames delayed excessively for video

If total MAC-to-MAC delay > threshold, e.g. 100ms, frame is treated as lost by the video decoder. We compute the effective FLR % at the decoder.

- The effective FLR decreases for higher Doppler for the same maxARQ
- At low SNR there is a trade-off between lost frames and excessively delayed frames.
Conclusions

- It is necessary to include a **time correlated channel model**, otherwise FLR and frame delay are severely underestimated.
- If the **channel coherence time** is low (i.e. a fast changing channel), the probability of error may improve significantly after several **retransmissions** and the ARQ mechanism is more effective.
- Retransmissions can lead to an increase in **delay** and jitter which is **unacceptable for video applications**.
- For a video application, it is possible to **determine the best maxARQ value** for any given Doppler frequency and mean SNR.
Thank you!