Performance Analysis of the IEEE 802.11 Distributed Coordination Function


*Presented by*

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DCF

- Random Access scheme based on CSMA/CA
- Collision – exponential back off rule
- Packet transmission ways
  - Basic mechanism
  - RTS/CTS
Basic Access Mechanism
RTS/CTS Access Mechanism
Assumptions

• Earlier works – simulation / analytical models with simplified back off rule assumptions
• In this work, simple model with exponential back off model
• Basic Assumptions
  • Ideal channel conditions (no hidden nodes & capture)
  • Constant independent transmission probability independent of no of retransmissions suffered
  • Finite no. of terminals at saturation condition
  • Fairly large WLAN (>10)
Performance measure

20 stations, CWmin=32, CWmax=256
Throughput Analysis

• Packet transmission probability
  – For single station with Markov model
  – Does not depend on access mechanism

• Saturation throughput for basic, RTS/CTS, hybrid access methods
\[
\tau = \sum_{i=0}^{m} b_{i,0} = \frac{b_{0,0}}{1-p} = \frac{2(1-2p)}{(1-2p)(W+1) + pW(1-(2p)^m)}
\]

for \(m=0,\)

\[
\tau = \frac{2}{W + 1}
\]

\[
p = 1 - (1 - \tau)^{n-1}
\]

\[
\tau(p) = \frac{2}{1 + W + pW \sum_{i=0}^{m-1}(2p)^i}
\]
\[ P_{tr} = 1 - (1 - \tau)^n \]
\[ P_s = \frac{n\tau(1 - \tau)^{n-1}}{P_{tr}} = \frac{n\tau(1 - \tau)^{n-1}}{1 - (1 - \tau)^n} \]
\[
S = \frac{E[payload \ information \ transmitted \ in \ a \ slot \ time]}{E[length \ of \ a \ slot \ time]} = \frac{P_s P_{tr} E[P]}{(1 - P_{tr})\sigma + P_{tr} P_s T_s + P_{tr} (1 - P_s) T_c} \]
\[
E[P^*] = E[E[max(P_1, \ldots, P_k)|k]] = \frac{\sum_{k=2}^{n} \binom{n}{k} \tau^k (1 - \tau)^{n-k} \int_0^{P_{max}} (1 - F(x)^k) dx}{1 - (1 - \tau)^n - n\tau(1 - \tau)^{n-1}} \]
\[
E[P^*] = \int_0^{P_{max}} (1 - F(x)^2) dx \]
\[
\begin{align*}
T_s^{bas} &= H + E[P] + SIFS + \delta + ACK + DIFS + \delta \\
T_c^{bas} &= H + E[P^*] + DIFS + \delta \\
T_s^{rts} &= RTS + SIFS + \delta + CTS + SIFS + \delta + H + E[P] + SIFS + \delta + ACK + DIFS + \delta \\
T_c^{rts} &= RTS + DIFS + \delta \\
T_s &= T_s(P) = T_s^{bas} F(P) + T_s^{rts}(1 - F(P)) \\
&= T_s^{bas} + O_{rts}(1 - F(P)) \\
T_c^{rts/cts} &= RTS + DIFS + \delta = \alpha - O_h \\
T_c^{rts/bas} &= \alpha + \int_0^\bar{P} \left(1 - \frac{F(x)}{F(P)}\right) dx \\
T_c^{bas/bas} &= \alpha + \int_0^\bar{P} \left(1 - \frac{F^2(x)}{F^2(P)}\right) dx
\end{align*}
\]
Model Validation

- Event driven custom simulation program in C++
- Results compared with 802.11 DCF simulator
- FHSS PHY, 1Mbps, 802.11 MAC spec frame sizes, packet payload size 8184 bits
Maximum saturation throughput

\[ S = \frac{E[P]}{T_s - T_c + \frac{\sigma(1 - P_{tr})/P_{tr} + T_c}{P_s}} \]

\[ \tau = \frac{\sqrt{n + 2(n-1)(T_c^* - 1)}/n - 1}{(n-1)(T_c^* - 1)} \approx \frac{1}{n\sqrt{T_c^*/2}} \]

- \( \tau \) depends only on \( n, m, W \)
- For \( m=0 \), \( W_{opt} \approx n\sqrt{2T_c^*} \)
- \( m, W \) hardwired; \( n \) estimate
• Max throughput of both access mechanism very close, independent of $n$

• For sufficiently large $n$

\[
S_{\text{max}} = \frac{E[P]}{T_s + \sigma K + T_c (K(e^{1/K} - 1) - 1)}
\]

Independent of $n$

• RTS/CTS less sensitive to $\tau$
\[ S = \frac{E[P]}{T_s + \sigma \frac{1 - P_{tr}}{P_s P_{tr}} + T_c \left( \frac{1}{P_s} - 1 \right)} \]
RTS/CTS threshold

– Highly dependent on PHY
– Decreases as $n$ increases

Lower value of $W$, greater performance impairment in basic access and advantageous to RTS/CTS
• Assumption: p independent of retransmission number
• No of retransmission increases as initial backoff window $W$ reduces and as $n$ increases
Conclusion

• Simple analytical model to analyze performance of DCF
• Comparison with simulation results
• RTS/CTS marginally dependent on system parameters, solution to hidden node problem
• But, assumptions not valid in most WLANs