A Scalable Rate Adaptation Mechanism for IEEE 802.11e Wireless LANs

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Introduction

• ARF has been the most widely deployed rate adaptation scheme on 802.11 WLAN market

• ARF can malfunction when it is used over IEEE 802.11e EDCA

• This paper design and evaluate a new rate adaptation scheme, called Scalable Auto Rate Fallback (S-ARF)
Background:

IEEE 802.11e EDCA

- EDCA is designed to provide *prioritized services* by differentiating the parameter values of each access category (AC)

<table>
<thead>
<tr>
<th>Access category</th>
<th>CWmin</th>
<th>CWmax</th>
</tr>
</thead>
<tbody>
<tr>
<td>AC_BK</td>
<td>aCWmin</td>
<td>aCWmax</td>
</tr>
<tr>
<td>AC_BE</td>
<td>aCWmin</td>
<td>aCWmax</td>
</tr>
<tr>
<td>AC_VI</td>
<td>aCWmin/2</td>
<td>aCWmin</td>
</tr>
<tr>
<td>AC_VO</td>
<td>aCWmin/4</td>
<td>aCWmin/2</td>
</tr>
</tbody>
</table>

- The shortened range of CW for voice AC may increase a frame collision probability
Background:
Related work

• ARF
  – Perform at next lower rate when two consecutive ACKs are missed
  – Perform at next higher rate when ten consecutive ACKs are received

• Due to shortened CW range for voice AC,
  – TX failures are to be due to *collisions*, not due to bad channel condition → unnecessary fallback
  – *Increased collision* makes ten consecutive ACKs a *rare* event → hard to recover
Background: Related work

• CARA & RRAA
  – Use RTS/CTS exchange to distinguish collisions from frame errors
  – Exchanging RTS/CTS before transmitting DATA reduces collisions
    • RTS/CTS frame is much smaller than DATA frame

• In case of VoIP
  – The size of VoIP frame is comparable to that of RTS/CTS frame
  – RTS/CTS exchange cannot be the solution
ARF over 802.11e

- Two-dimensional discrete Markov chain
- State \( \{r, s\} \)
  - \( r \): TX rate
  - \( s \): consecutive successful TX count
- \( S_{r,s} \): Stationary distribution
- Average TX rate:
  \[
  E[r] = \sum_{\forall r, s} S_{r,s} \times r
  \]
ARF over 802.11e (cont.)

• Average TX PHY rate chosen by ARF as number of contenders increases
• Voice category chooses lower TX PHY rates
  – Due to increased collisions
• Erroneous decision even when only two stations exist

![Graph showing the average transmission rate (Mbps) against the number of stations.](image)
Scalable-ARF

• Goal
  – Overcome the malfunction of ARF without using RTS/CTS exchange

• Operation
  – To determine frame error cautiously
    • Increase $C_{\text{err}}$ when $C_{\text{fail}}$ reaches $T_{\text{limit}}$
    • Lower TX-rate when $C_{\text{err}} \geq F_{\text{TH}}$
  – To recover responsively
    • Reset $C_{\text{succ}}$ only if $C_{\text{err}}$ was added
    • $C_{\text{succ}}$ is increased by $(C_{\text{fail}} + 1)$
Performance Evaluation

Simulation Setup

• NS2 simulator with TKN EDCA module
• 802.11b PHY in indoor environment
  – Empirical BER-SNR curves by Intersil
  – Shadowing model with path loss exponent 4
• Star topology with saturated traffic
• Comparisons in terms of TX rate and aggregate throughput
  – ARF scheme
  – S-ARF(2): $T_{\text{limit}} = 2$, $F_{th} = 4$
  – S-ARF(4): $T_{\text{limit}} = 4$, $F_{th} = 8$
Performance Evaluation

Result (1/2)

• Average TX rate w.r.t. number of contenders

• ARF cannot choose high TX rate even when contenders are small
  – Analogous to ARF analysis

• S-ARF can select high TX rate up to a moderate number of stations
Performance Evaluation

Result (2/2)

- Aggregate throughput of voice flows w.r.t. number of voice flows
  - 4 background video flows

- S-ARF shows much scalable performance than ARF
Conclusions

- **Contributions**
  - Reveal the malfunction of ARF over 802.11e
    - Using analytical model
  - Design new rate adaptation scheme
    - Performs consistently well compared to ARF

- **Future work**
  - Optimization/adaptation of operational parameters