A Dynamic Rate Adaptation with Fragmentation MAC Protocol against Channel Variation for Wireless LANs

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Outline

• Introduction
  – Motivations
  – Goals
• Concept Model
• FaRM MAC Protocol
• Simulation Results
• Conclusions
Introduction

Motivations
Goals
Multi-rate in IEEE 802.11

- IEEE 802.11 provides several transmission rates
  - How to select a proper rate is not specified
- Each rate uses different modulation method

<table>
<thead>
<tr>
<th>Rate (Mbps)</th>
<th>Modulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>DBPSK</td>
</tr>
<tr>
<td>2</td>
<td>DQPSK</td>
</tr>
<tr>
<td>5.5</td>
<td>CCK 5.5</td>
</tr>
<tr>
<td>11</td>
<td>CCK 11</td>
</tr>
</tbody>
</table>
Theoretical BER in AWGN Channel

Bit Error Ratio (BER) vs. SNR (dB)

- DBPSK
- DQPSK
- CCK5.5
- CCK11

DBPSK: 2.27E-5
DQPSK: 3.43E-4
Fixed Rate (1 Mbps)

\[ \text{PER} = 1 - (1 - \text{BER})^L \]

Packet Error Ratio (PER)

Packet Length \((x 10^4 \text{ b})\)

- High SNR (10dB)
- Low SNR (7dB)
Fixed SNR (10 dB)

\[ \text{PER} = 1 - (1 - \text{BER})^L \]

- PER: Packet Error Ratio
- BER: Bit Error Rate
- L: Packet Length (bit)

Graph showing the relationship between Packet Error Ratio (PER) and Packet Length (bit) for different data rates: 1M, 2M, 5.5M, and 11M.
Motivations

- Channel quality is *good*
  - Use higher data rate

- Channel quality is *bad*
  - Use shorter packet size
    - Higher rate
  - Use lower data rate
Method

- Adapt to the variation of channel condition
  - Make a policy which combines
    - Fragmentation
    - Rate selection
Goals

• Maximize network throughput
• Decrease packet delay time
  – Reduce transmission time (media occupation time)
• Make transmission robust
### Previous Researches

<table>
<thead>
<tr>
<th>Feature</th>
<th>OAR(^1)</th>
<th>D-Frag(^2)</th>
<th>FaRM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Channel quality-aware</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Rate decision</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Fragment and length decision</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Fragmentation</td>
<td>Fixed trans. time</td>
<td>Fixed trans. Time</td>
<td>Dynamic</td>
</tr>
</tbody>
</table>


Concept Model
Concept Model

Fading Channel Model (Rayleigh, Nakagami, …)

p.d.f.

SNR-BER Mapping

BER₁, BER₂

Channel Modeling (Finite-State Markov Chain)

Length of MSDU

Link-Adapted and Robust

Packet Length Determination

L₁₋R₁, L₂₋R₂, …, Lₙ₋Rₙ

SNR

L₁₋R₁

(p.d.f.)

BER₁, BER₂

Packet Length Determination

Length of MSDU

L₁₋R₁, L₂₋R₂, …, Lₙ₋Rₙ

Link-Adapted and Robust

Packet Length Determination

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Length of MSDU

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Link-Adapted and Robust

Packet Length Determination

Length of MSDU

L₁₋R₁, L₂₋R₂, …, Lₙ₋Rₙ
Finite-State Markov Chain

- Interval assigned to $s_K$
- Interval assigned to $s_{K-1}$
- Interval assigned to $s_2$
- Interval assigned to $s_1$

FSMC Packet Length Determination

- Received Power
- Time

$P_{1,1}$ $P_{1,2}$ $P_{2,1}$ $P_{2,2}$ $P_{2,3}$ $P_{3,2}$ $P_{3,3}$ $P_{3,4}$ $P_{4,3}$ $P_{K-1,K}$ $P_{K,K}$

State 1 State 2 State 3 ... State K

- FC Model
- CCDF
- L-R
- Packet Length Determination
Complementary Cumulative Distribution Function (CCDF)

Data Length (b)

CCDF (1 - CDF)

Initial SNR: 11
Rate: 1 Mbps
Packet Length Determination

- Select the best length for all transmission rates

\[
T_{\text{tran.}} = \left[ \left( \frac{L'}{R} + T_{\text{overhead}} \right) \times \left[ \frac{L}{L'} \right] \right] \times \frac{1}{P_{\text{success}}}
\]

\[L' \in L, \quad \min(T_{\text{tran.}})\]
Link-Adapted Fragment-Rate Matching

Current Rate: $R_i$
Length of MSDU: $L$

Given:
$L_1 - R_1, L_2 - R_2, \ldots, L_n - R_n$

$R_b \leftarrow R_i$
$L_b \leftarrow L$

$L_b < L_{i+1}$

$T(L_{i+1}, R_i) > T(L_{i+1}, R_{i+1}) + T_{overhead}$

$L_b < L_i$

END

$\text{true}$
$\text{false}$
$\text{true}$
$\text{false}$
Link-Adapted Fragment-Rate Matching

\[
T(L_i, R_{i-1}) > T(L_i, R_i) + F_{\text{overhead}}
\]

\[
L_b < L_{i-1}
\]

\[
R_b \leftarrow R_i
\]

\[
L_b \leftarrow L
\]

\[
R_b \leftarrow R_{i-1}
\]

\[
L_b \leftarrow L_i
\]
FaRM MAC Protocol

FaRM Protocol
Extension
FaRM Protocol

Sender

RTS

Fragment0

Fragment1

Receiver

CTS

ACK0

SNR0

SNR1

Tempory NAV

NAV (Fragment0)

NAV (Fragment1)

NAV (CTS)

NAV (ACK0)

Length of MSDU

BER

FC Model

FSMC

SNR-BER

Packet Length Determination

L-R

Length of MSDU

L-R

L-R

L-R

BER

BER
Simulation Results
Simulation Scenario and Settings

Rayleigh fading channel

Average frame size: 1024 Bytes
Speed: 18 m/s
Simulation Time: 80 seconds
Simulator: NS2 2.27
Throughput

Time (Second)

Throughput (Mbps)

FaRM
RBAR
Error frame count
Transmission delay
Conclusions
Conclusions

• FaRM could adapt to the variation of channel condition by
  – Rate decision
  – Frame fragmentation

• Throughput and delay time can be improved by FaRM
Thanks for your time