A Relay-Aided Media Access (RAMA) Protocol in Multirate Wireless Networks

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Outline

- Introduction
- Background and related works
- Motivation
- Relay-Aided Media Access (RAMA) Protocol
- Simulation Results
- Conclusion
Introduction

- In WLAN, transmission rate is dependent on Signal-to-Noise Ratio (SNR)
  - When the SNR is sufficiently high, higher data rates can be explored
  - IEEE 802.11 supports multirates, e.g. 11a : 6,8,12,18,…, and 54 Mbps
- Signal attenuation over radio link typically varies as $d^n$ for $2 < n < 6$, where $d$ is the distance between the sender and the receiver
- Objective
  - Replace one low-rate link with two much higher rate links to improve transmission rate
  - An enhanced multirate IEEE 802.11 protocol is introduced
Background

- Basic Mechanisms in IEEE 802.11
  - Distributed Coordination Function (DCF)
  - 2-way and 4-way handshaking
  - Network Allocation Vector (NAV)

RTS/CTS access mechanism in DCF
Related Work

- **Receiver-Based AutoRate (PBAR) protocol**
  - Receiver selects the appropriate rate for data frame during RTS/CTS frame exchange
  - Maximum possible transmission rate is selected by analyzing the PHY BER of received RTS frame
  - A reservation subheader is inserted preceding data transfer
    - For modifying the NAV value

NAV set by other nodes in RBAR
Motivation

- **Shannon formula**
  \[ R = W \log(1 + \text{SNR}) \]

- **Propagation model** [6]
  \[ P_r = K \frac{P_t}{d^n} \]

- **Goal**: reduce transmission time
  \[ T_{AC} + T_{CB} + \text{SIFS} < T_{AB} \]

- $R$ : transmission rate
- $W$ : bandwidth
- $P_r$ : received power
- $P_t$ : transmitted power
- $K$ : constant
Motivation

It is possible to improve transmission rate by replacing one low-rate link with two high-rate links.
RAMA Protocol Concept

- When node C finds that A is communicating with B at low bit rate
  - C produces an *invitation* frame and sends it according to DCF
- After A receives the invitation from C
  - A will record it in its Relay List
  - Other relay candidates C’ will cancel their invitation from AB after hearing the invitation from C
- When A sends data packets to B, it will use C as a relay node
  - When C receives the relayed frame from A, it *forwards* that immediately after SIFS
RAMA Protocol – Invitation Trigger

- Conditions
  - The communication pairs are both RAMA capable
  - 4-way shaking (RTS/CTS) is used
  - Invitation is sent at the basic rate
    - All possible relay nodes can hear
  - Relay condition is satisfied
  - Data frame is followed immediately by ACK frame
  - Addresses is not changed during relay transmissions

Format of invitation frame
RAMA Protocol – Invitation Trigger

- Solving hidden terminal problem - Serve Table
  - A node does not send an invitation during backoff interval (BI) after it sends out an invitation or acts as relay for the pair
  - Double corresponding BI when it sends out invitation and finds that the pair of nodes still communicate with low rate

<table>
<thead>
<tr>
<th>TABLE II</th>
<th>SERVE TABLE IN RELAY NODE</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;SrcToRelay, DstToRelay&gt;</td>
<td>T1</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>
RAMA Protocol – Relay Transmission

- After exchange RTS/CTS, sender checks the Relay List to see if there is an entry corresponding to the destination.
- If there is one entry for this transmission and relay condition satisfied, sender transmits data frame to relay node using relaying.
- The stale entry will be flashed periodically after receiving ACK frames from receiver.
RAMA Protocol – Relay Transmission

At this time, with \( (R_{AB}, R_{AC}, R_{CB}) \), A found that the relay condition is satisfied and so send DATA to C.

This duration includes the time needed for C→B.

\[ \text{RTS}[\text{Rate}=R_{AB}', \text{Length}=L] \]

\[ \text{CTS}[\text{Rate}=R_{AB}, \text{Length}=L] \]

\[ \text{DATA}[\text{duration}=L/R_{AC}+\text{SIFS}+L/R_{CB}+\text{SIFS}+D_{ACK}] \]

\[ \text{DATA}[\text{duration}=L/R_{CB}+\text{SIFS}+D_{ACK}] \]

Contention free

\[ \text{ACK}[\text{NAV}=0] \]

\( R_{AB}' \) is selected based history
\( R_{AB} \) is the actual rate A can use to reach B.
Energy Efficiency of RAMA

- Only compare the energy consumption during data transmission
  - Energy consumed in signaling is omitted
- Total energy consumption (RAMA):
  \[(P_t + P_r + P_i)t_1 + (P_t + P_r + P_i)t_2\]
- Total energy consumption (original DCF):
  \[(P_t + P_r + P_i)t\]
- Because \(T_1 + T_2 < t\)

\[\Rightarrow P_{\text{RAMA}} < P_{\text{DCF}}\]
Simulation

- Using NS-2 to evaluate two protocol
  - RAMA and PBAR
- Network area is 250m x 250m
- All reported results are averaged over ten runs of 50-s simulation

### Important Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
<td>2.4GHz</td>
</tr>
<tr>
<td>Range for 11M</td>
<td>125m</td>
</tr>
<tr>
<td>Range for 5.5M</td>
<td>175m</td>
</tr>
<tr>
<td>Range for 2M</td>
<td>200m</td>
</tr>
<tr>
<td>Range for 1M</td>
<td>250m</td>
</tr>
<tr>
<td>Carrier Sensing Range</td>
<td>550m</td>
</tr>
<tr>
<td>INITIAL_INTERVAL</td>
<td>2s</td>
</tr>
<tr>
<td>MAX_INTERVAL</td>
<td>128s</td>
</tr>
<tr>
<td>RTS Threshold</td>
<td>100bytes</td>
</tr>
<tr>
<td>Packet Size</td>
<td>1500bytes</td>
</tr>
</tbody>
</table>
UDP Throughput

Static scenario

Mobile scenario
UDP Delay

Static scenario

Mobile scenario
TCP Throughput

Static scenario

Mobile scenario
TCP Delay

Static scenario

Mobile scenario
Hidden Terminal

Hidden terminal scenario.
Hidden Terminal

UDP Throughput with HT

TCP Throughput with HT
Multihop Scenario

UDP throughput under multihop scenario.
Conclusion

- Improvement for multihop and multirate is exploited in this paper
  - Problem definition
  - Analysis
- A RAMA protocol is developed to take the advantage of the existence of multihop high-rate links for throughput enhancement
  - Invitation Trigger
  - Relay Transmission
- Simulations show the improvement for throughput and delay in both static and mobile scenario