An Intelligent Modulation Controller with Fuzzy Function for IEEE 802.11 Multi-Rate/Range Transmission

Shiann-Tsong Sheu, Jenhui Chen, and Yung-Da Wang

Dept. of Electrical Engineering, Tamkang Univ.
Tamsui, Taipei Hsien,
Taiwan, R.O.C.
Outline

- IEEE 802.11 Network
- Multi-rate and Multi-range Transmission
- MAC Delay & Packet Error Rate
- Fuzzy Rate Controller
- Simulation Model
- Simulation Results
IEEE 802.11 Network

- shared wireless access network connects mobile hosts to internet
- Data rate can be up to 11Mbps
- The highest data rate is depending on the link quality and the transmission distance
IEEE 802.11 Network

- The DSSS PHY
  1. 1Mbps uses Differential Binary Phase Shift Keying (DBPSK)
  2. 2Mbps uses Differential Quadrature Phase Shift Keying (DQPSK)
  3. 5.5 , 11Mbps uses complementary code keying (CCK)

- The FHSS PHY
  1. uses 2- or 4-level Gaussian Frequency Shift Keying (GFSK) modulation
Multiple Data Rates

- IEEE 802.11b PLCP sublayer supports
  - 2 / 5.5 / 11 Mbps

- A higher data rate may incurs a higher packet error rate

- Every mobile host needs to decide a proper transmission rate to deliver packets
Multiple Data Rates

- Higher rate is the best choice?
- When we need the lower rate?
Transmission Range vs. Data Rate

- Different rates can be derived by using different modulation techniques.
- Low speed data rate provides a longer transmission distance.
What Rate We Need

- High speed data rate improves throughput
- Low speed data rate guarantees packet error rate
Average MAC Delay

Analysis parameters:

- 0.001 packet arrival rate
- 200 bytes data payload
Packet Error Rate vs. Transmission Distance

- The PER is measured under different transmission distances.
- There are some gray areas.
- Problem: how to choose a proper data rate to minimize the packet error rate?
Fuzzy Rate Controller

- Choose the proper transmission rate to transmit packets will derive the maximal network utilization.
- We use fuzzy control to choose data rate to accommodate the varying channel condition and transmission distance from time to time.

\[ \text{Rate}(t) = \text{Rate}(t-1) \& \text{action} \]

**Diagram:**
- RSSI strength
- MAC delay
- PER
- Intelligent Modulation Controller
- **Action:** up, fix, down
- \[ \text{Rate}(t) = \text{Rate}(t-1) \& \text{action} \]
In IEEE 802.11, RSSI values are measured in the range from 0 through RSSI maximum. This parameter can be obtained by the PHY sublayer from antenna when receiving a PPDU.

- Max. RSSI value = 63,
MAC delay and PER
Membership Functions
Rule Table

- Max–Min scheme is used to generate the fuzzy results
- Results indicate how to switch speed rate: un-change, raise or slowdown

<table>
<thead>
<tr>
<th>RSSI</th>
<th>PLR</th>
<th>MD</th>
<th>Rate Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>S</td>
<td>H</td>
<td>H</td>
<td>↓</td>
</tr>
<tr>
<td>S</td>
<td>H</td>
<td>M</td>
<td>↑</td>
</tr>
<tr>
<td>S</td>
<td>H</td>
<td>L</td>
<td>↓</td>
</tr>
<tr>
<td>S</td>
<td>M</td>
<td>H</td>
<td>↑</td>
</tr>
<tr>
<td>S</td>
<td>M</td>
<td>M</td>
<td>↑</td>
</tr>
<tr>
<td>S</td>
<td>M</td>
<td>L</td>
<td>↓</td>
</tr>
<tr>
<td>S</td>
<td>L</td>
<td>H</td>
<td>↑</td>
</tr>
<tr>
<td>S</td>
<td>L</td>
<td>M</td>
<td>↓</td>
</tr>
<tr>
<td>S</td>
<td>L</td>
<td>L</td>
<td>↓</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>RSSI</th>
<th>PLR</th>
<th>MD</th>
<th>Rate Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>F</td>
<td>H</td>
<td>H</td>
<td>↓</td>
</tr>
<tr>
<td>F</td>
<td>H</td>
<td>M</td>
<td>↓</td>
</tr>
<tr>
<td>F</td>
<td>H</td>
<td>L</td>
<td>↓</td>
</tr>
<tr>
<td>F</td>
<td>M</td>
<td>H</td>
<td>↑</td>
</tr>
<tr>
<td>F</td>
<td>M</td>
<td>M</td>
<td>↑</td>
</tr>
<tr>
<td>F</td>
<td>M</td>
<td>L</td>
<td>↓</td>
</tr>
<tr>
<td>F</td>
<td>L</td>
<td>H</td>
<td>↑</td>
</tr>
<tr>
<td>F</td>
<td>L</td>
<td>M</td>
<td>↓</td>
</tr>
<tr>
<td>F</td>
<td>L</td>
<td>L</td>
<td>↓</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>RSSI</th>
<th>PLR</th>
<th>MD</th>
<th>Rate Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>W</td>
<td>H</td>
<td>H</td>
<td>↓</td>
</tr>
<tr>
<td>W</td>
<td>H</td>
<td>M</td>
<td>↓</td>
</tr>
<tr>
<td>W</td>
<td>H</td>
<td>L</td>
<td>↓</td>
</tr>
<tr>
<td>W</td>
<td>M</td>
<td>H</td>
<td>→</td>
</tr>
<tr>
<td>W</td>
<td>M</td>
<td>M</td>
<td>→</td>
</tr>
<tr>
<td>W</td>
<td>M</td>
<td>L</td>
<td>→</td>
</tr>
<tr>
<td>W</td>
<td>L</td>
<td>H</td>
<td>→</td>
</tr>
<tr>
<td>W</td>
<td>L</td>
<td>M</td>
<td>→</td>
</tr>
<tr>
<td>W</td>
<td>L</td>
<td>L</td>
<td>→</td>
</tr>
</tbody>
</table>
Simulation Model

◊ 100m X 100m square area
◊ The considered data rates and the associated transmission ranges:
  ◊ 2Mbps - 150m
  ◊ 5.5Mbps - 80m
  ◊ 11Mbps - 50m
◊ Destination is randomly selected form all mobile hosts.
◊ Packet arrival rate is 0.001.
◊ Average packet length is 200Bytes.
Simulation Results

- **Graph 1: Throughput**
  - X-axis: Number of Nodes
  - Y-axis: Throughput
  - Lines for different bit rates: 11Mbps, 5.5Mbps, 2Mbps, Fuzzy Control

- **Graph 2: Average MAC Delay**
  - X-axis: Number of Nodes
  - Y-axis: Average MAC Delay (ms)
  - Lines for different bit rates: 11Mbps, 5.5Mbps, 2Mbps, Fuzzy Control
Conclusions

- The proposed fuzzy controller can provide
  - low packet error rate
  - low access delay
  - maximal channel utilization