Flexible and Modular Support for Multicast Rate Adaptation in WLANs

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Outline

• **Introduction**
  – Contributions
  – Rate adaptation techniques
  – MAC layer virtualization: WMP

• **System description**
  – Transmission period
  – Feedback protocol
  – Rate adaptation algorithms

• **Experiments**
  – Testbed description
  – Results

• **Conclusions**
Introduction: Contributions

Design a *new rate adaptation system* for *multicast communications* in wireless LAN

*Implementation* within a *modular architecture* based on MAC layer virtualization
Introduction: Rate Adaptation Systems

- Dynamic adaptation of the transmission rate
- Performance enhancement
  - Increased goodput
  - Reduced delays
- Multicast scenario:
  - Commercial solutions use the lowest available data rate
  
  Not suitable for multimedia content delivery
Introduction: Rate Adaptation Systems

Rate Adaptation System

- Multicast applications
- Rate adaptation algorithm
- MAC layer
- Feedback protocol
  - Selected rate
  - Measurements
  - Feedback Protocol Reconfiguration
Introduction: MAC Layer Virtualization

- **Wireless MAC Processor (WMP)**
  - Special-purpose processor for executing MAC programs
  - MAC program described by an eXtended Finite State Machine (XFSM)
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The AP transmits $N$ multicast data frames.

The $i$-th frame is transmitted with rate $r_{ji}^i$. 
System Description: Feedback protocol

Rate adaptation algorithm

Transmission period

Feedback protocol

Statistics update

Computation of the Joint Reception Probability $P_r$

Selection of the transmission rates $(r^1_j, ..., r^N_j)$
System Description: Rate Adaptation Algorithm

$P_{r_j}$ is the **Joint Reception Probability** of the rate $r_j$

- Probability that a multicast data frames transmitted with rate $r_j$ will be received by every station of the multicast group
Rate Adaptation Algorithms

- Linear increase / Multiplicative decrease

\[ j = \text{index of}(R_r(e)) \]

\[
r_r(e+1) = \begin{cases} 
R[j+1], & T(e)/T(e-1) \leq 1 \\
R[j-2], & T(e)/T(e-1) > 1 
\end{cases}
\]

- Best Throughput

\[ r_b(e+1) \leftarrow \max_{r_j} \left\{ r_j \mid S_j = \max_{r_k} \left\{ S_k \right\}, S_k = P_k \cdot r_k \right\} \]

- Limited Losses

\[ r_b(e+1) \leftarrow \max_{r_j} \left\{ r_j \mid P_j \geq x, 0 < x < 1 \right\} \]
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Experimental methodology

- 1 AP, 9 fixed STAs and 1 mobile node
- Mobile node located in 18 positions:
  - Ranging from 3m to 55m from the AP
Experimental methodology

- We compare 4 systems:
  - Best throughput, limited losses and lin. inc./Mult. Dec.
  - Fixed transmission rate (6 Mb/s)
- For every position:
  - 5 repetitions with each system
  - 100000 multicast data frames of 1470 bytes (UDP) for each repetition
Experimental results: Throughput

Average throughput (Mb/s) vs Mobile node positions

- Fixed rate
- Best throughput
- Limited losses
- Lin. inc. /Mult. dec.
Experimental results: Delays

![Graph showing average delay (ms) for different conditions across mobile node positions.]

- Fixed rate
- Best throughput
- Limited losses
- Lin. inc. /Mult. dec.

Legend:

- Blue dashed line: Fixed rate
- Red dashed line: Best throughput
- Green dashed line: Limited losses
- Black dots: Lin. inc. /Mult. dec.
Experimental results: Losses

Mobile node positions

Average losses (%)

- Fixed rate
- Best throughput
- Limited losses
- Lin. inc./Mult. dec.

Fixed rate (mobile station)
Best throughput (mobile station)
Limited losses (mobile station)
Lin. inc./Mult. dec. (mobile station)
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Conclusions

• Modular and flexible rate adaptation system:
  – Feedback protocol runs inside WMP
  – Three rate adaptation algorithms based on frame reception correlation

• Experimental results:
  – Throughput improves up to 250%
  – Delay decreases up to 5 times
  – Losses comparable to fixed rate solution