PLUS-DAC: An Admission Control Scheme for IEEE 802.11e Wireless LANs

Kiran Kumar Gavini

Kanwal Rekhi School of Information Technology
Indian Institute of Technology, Bombay

M Tech. Project Presentation

Guided by
Prof. Varsha Apte and Prof. Sridhar Iyer
Introduction

According to Infonetics Research

“Spending on VoIP, or next-generation networking equipment, will jump from $1.71 billion in 2004 to nearly $6 billion by 2008.”

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“voice over 802.11 handsets will reach 500,000 units by 2006.”

Need for QoS

- Increasing realtime traffic in Wi-fi Networks.
- Need for Protection and Guarantees to the traffic.
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Quality of Service

- measure of overall experience of an application
- achieved by giving importance through “Controlled Unfairness”

Requirements

- For a good quality VoIP
  - uni-directional end to end latency < 150ms
  - Packet loss < 10%
- Bandwidth Requirements
  - VoIP (e.g. G.711, G.723 Codec) < 100 Kbps
  - Video conferencing (e.g. H.261 and h.263) < 400 Kbps
  - MPEG Video 1-4 Mbps
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QoS in IEEE 802.11 WLANs

- IEEE 802.11 designed for Best Effort Data Traffic. Doesn’t provide QoS.
- Task Group E is going to finalize a QoS extension to the base standard called IEEE 802.11e
- service differentiation based on priorities.
- Transmission Opportunity (TxOP)
- Hybrid Coordination Function.
  - Contention Based Channel Access (EDCA)
  - Controlled Channel Access (HCCA)

EDCA

- Multiple Access Categories (AC) with in each Station
- Different EDCA Parameters specific to access category
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**EDCA**

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EDCA Station Model

**legacy 802.11 STA**

- single priority
- Backoff entity
- backoff (DIFS) (CWmin) (CWmax)

**802.11e QoS STA (four Access Categories)**

- high priority
- AC 3
- backoff (AIFS) (CWmin[3]) (CWmax[3])
- AC 2
- backoff (AIFS) (CWmin[2]) (CWmax[2])
- AC 1
- backoff (AIFS) (CWmin[1]) (CWmax[1])
- AC 0
- backoff (AIFS) (CWmin[0]) (CWmax[0])

When More than one AC tries to access in the same slot the higher AC transmits and the lower AC back offs (Virtual Collision)

**Transmission**

- Backoff Entity
QoS Control and TSPEC

**QoS Control**

- Additional two byte field added to MAC header for QoS related information.
- Identifies the Traffic category (TC)
- A frame sent by non-AP station contains *queuesize*

**TSPEC**

- Ported from RSVP.
- Typical Parameters
  - Mean Data rate
  - Nominal MSDU Size
  - Min. PHY rate
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EDCA suffers at high load due to increased collisions.

**Problem Statement**

**Admission Control**
- Given that there are N[TC] flows of each traffic category existing in Basic Service Set (BSS), whether the new flow of a particular TC should be admitted or not? (Without effecting the guarantees given to the existing flows).
- Load measure
- State Information and its Distribution.

**Bandwidth Reservation**
- Stations do not have clear knowledge of available bandwidth in WLANs. (Equivalent Measure?)
- Should not be static.
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Partitioning based Distributed Admission Control (Xiao)

**Procedure at Access Point (AP)**

- Available Time limit for each AC is calculated by BW Partitioning.
- TxTime is calculated by looking into the header of the frames being transmitted.
- Calculate the TxOPBudget of each AC as follows
  \[
  TXOPBudget[AC] = \max(\text{ATL}[AC] - \text{TxTime}[AC] \times \text{SurplusFactor}[AC], 0)
  \]
- Transmit the TxOPBudget[AC] through Beacon.

**Admission Control at the Station**

Reject new flows when TxOPBudget[AC] is zero.
Example Scenario

Consider Beacon Interval is 100 ms. ATL[3] = 70ms, ATL[2] = 20ms, ATL[0] = 10ms

Note
- If average occupation of audio traffic is 30ms. Hence 40ms in every beacon interval is unused.
- We can reduce this effect by partitioning the unused TXOP.
- Further, we can adapt the partitioning ratios dynamically.
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PLUS-DAC: Proposed Scheme

Goal
To achieve better channel utilization while still satisfying the QoS requirements.

Key Idea
Give importance to traffic categories having sufficient load and priority and have not utilized the channel to the required extent.

- Consider Queue Size at each of the Station as a measure of load and estimate TXOP required to service the load.
- Partition the cumulative unused TXOP based on priority, load and utilization measures.
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Mechanism

- An AP assisted scheme.
- The AP records the amount TXOP used by that traffic category in the previous beacon interval by looking at duration-id in MAC header.
- AP records the buffered queue length for each access category by looking at the QoS Control field of frame sent by non-AP stations and estimates the load.
- The priority for TXOP partitioning will be decided by AP, may be based on policy.
- The unused time will be partitioned based on different normalized weights calculated from the above values.
- The the available TXOP partitioning forms the TXOP_Grant for each traffic category.
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PLUS-DAC: Proposed Scheme

**Priority Weight (pw[i])**

Fraction of TXOP assigned by the Administrator at the QAP. Forms the Default partitioning of the available TXOP.

**Utilization Weight (uw[i])**

\[ uw[i] = \frac{TXOP \text{ used by traffic category, } i}{Total \ TXOP \ used} \]

**Load Weight (lw[i])**

\[ lw[i] = \frac{TXOP \ required \ to \ service \ the \ queues \ of \ traffic \ category, \ i}{Total \ TXOP \ required \ to \ service \ all \ the \ queues} \]
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\]
**TXOP Grant Calculation**

**Effective weight**, $ew[i]$, of each traffic category, $i$, is calculated as,

$$ew[i] = pw[i] \cdot \left( \frac{0.5 + \alpha \cdot lw[i]}{1 + \alpha \cdot uw[i]} \right)$$

- $\alpha$: balance factor
- $pw[i]$: priority weight
- $lw[i]$: load weight
- $uw[i]$: utilization weight

**TXOP Grant**

We estimate the $TXOP Grant[i]$ for each traffic category, $i$, as,

$$TXOP_Grant[i] = Total_{TXOP\_Available} \times ew'[i]$$

- $ew'[i]$ is the normalized effective weight.
- $TXOP\_Grant[i]$ is sent to all the stations as a part of the beacon frame.
ew[i] Variation

**Note**

- ew[i] for voice decreased and gradually became constant priority is still respected.
- For CBR traffic, ew[i] increased (0.3) and became constant once it accepted enough flows.
- For Data traffic ew[i] value is constant. Though it has load requirement, priority is less.

NOTE: The ew[i] is used to partition only the unused time. Hence the admitted flows are protected.
**ew[i] Variation**

- **Note**: The ew[i] is used to partition only the unused time. Hence the admitted flows are protected.

- **Effective Weight**

  - **Audio**
  - **Video (CBR)**
  - **Data**

- **Simulation Time (sec)**

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- For CBR traffic, ew[i] increased (0.3) and became constant once it accepted enough flows.
- For Data traffic ew[i] value is constant. Though it has load requirement, priority is less.
The nominal TXOP $\Delta[i]$ required for an incoming traffic stream can simply be calculated as,

$$
\Delta[i] = \frac{\lambda[i] \times T_{Beacon}}{R}
$$

where:
- $\lambda[i]$ : arrival rate
- $R$ : PHY transmission rate
- $T_{Beacon}$ : length of beacon interval

Admissibility Condition

A request for a new flow belonging to traffic category, $i$, can be admitted if the following inequality is satisfied.

$$
TXOP_{Grant}[i] \geq \Delta[i]
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Simulation Setup

- Extended the FHCF ns2-patch to support Admission Control
- Single BSS and AP is the sole Receiver
- Exponential On/Off audio traffic (high priority)
- VBR and CBR Video traffic (medium priority)
- Poisson Data traffic (low priority)
- Traffic stream per station is assumed to be flow.
- Simulation Duration is 200ms.
- starts with low load and gradually increases the load in the BSS.
Simulation II

Simulation Scenarios
- High priority scenario: Audio, VBR and CBR video traffic.
- Low priority scenario: Audio, CBR video and data traffic.

Observed Parameters
- Mean Latency
- Mean Jitter
- Mean Bandwidth per stream
- Total Bandwidth
- Packet loss ratio
- Latency Distribution
## Simulation Parameters

### Description of Traffic Stream

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Audio</th>
<th>H.261 video</th>
<th>MPEG4 video</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Packet Size (bytes)</td>
<td>160</td>
<td>660</td>
<td>1000</td>
<td>1500</td>
</tr>
<tr>
<td>Arrival Period (ms)</td>
<td>4.7</td>
<td>26</td>
<td>2.5</td>
<td>12</td>
</tr>
<tr>
<td>Sending rate (Kbps)</td>
<td>64</td>
<td>200</td>
<td>3200</td>
<td>1000</td>
</tr>
<tr>
<td>AIFS (µs)</td>
<td>25</td>
<td>25</td>
<td>25</td>
<td>34</td>
</tr>
<tr>
<td>(CW_{min})</td>
<td>7</td>
<td>31</td>
<td>31</td>
<td>127</td>
</tr>
<tr>
<td>(CW_{max})</td>
<td>15</td>
<td>63</td>
<td>63</td>
<td>1023</td>
</tr>
</tbody>
</table>

### PHY and MAC Parameters

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>SIFS</td>
<td>16 µs</td>
</tr>
<tr>
<td>DIFS</td>
<td>34 µs</td>
</tr>
<tr>
<td>Slot Time</td>
<td>9 µs</td>
</tr>
<tr>
<td>CCA Time</td>
<td>3 µs</td>
</tr>
<tr>
<td>Beacon Interval</td>
<td>500 ms</td>
</tr>
<tr>
<td>PHY Rate</td>
<td>54 Mb/s</td>
</tr>
<tr>
<td>Min. bandwidth</td>
<td>24 Mb/s</td>
</tr>
<tr>
<td>MAC header</td>
<td>38 bytes</td>
</tr>
<tr>
<td>PLCP header</td>
<td>4 bits</td>
</tr>
<tr>
<td>Preamble Length</td>
<td>20 bits</td>
</tr>
</tbody>
</table>
Observations

- EDCA performed slightly worse than the admission control schemes. But experienced latency and jitter are well below the QoS limits.
- This is because we are using Strict EDCA.
- The bandwidth requirements of Audio traffic are very minimal.
Mean Latency and Mean Jitter (H.261 VBR Video)

High Priority Scenario

Observations

- Latency and Jitter of the VBR traffic are worse when compared to audio.
- This is a result of increase in bandwidth requirements.
- The values are still well inside the QoS limits. (strict EDCA!)
Introduction

Proposed Scheme

Simulation

Conclusion and Future Work

Throughput Characteristics (H.261 VBR Video)

High Priority Scenario

Observations

- per stream bandwidth is almost same for all the schemes: requirements of accepted flows are satisfied.
- SDAC has accepted only Half as many flows as that of PLUS-DAC.
- EDCA achieved better VBR throughput than SDAC, as no calls are blocked (strict EDCA!!).
Mean Latency and Latency distribution (MPEG Video)

**Observations**

- Bandwidth requirements of MPEG are significant.
- Admission control schemes admitted only few flows, and performed better.
- Without admission control only 20% of the packets experienced a delay of less than 100ms.
Throughput Characteristics (MPEG CBR Video)

High Priority Scenario

**Observations**

- Per stream throughput of both the admission control schemes is same and constant: Admitted flows are protected.
- SDAC admitted only one flow to PLUS-DAC’s four.
- High total throughput of EDCA is not useful, as loss and delay requirements cannot be satisfied.
Observations

- PLUS-DAC experienced delay and packet loss at high load.
- But the values are still within the limits.
- This is because the low priority flows will disturb the traffic at high load.
Observations

- Per stream throughput of PLUS-DAC is slightly worse than SDAC - result of packet loss.
- Total throughput of PLUS-DAC is high. Accepted Eight flows opposed to SDAC’s two.
- PLUS-DAC achieves better utilization while protecting the flows satisfactorily.
Observations

- The per stream throughput of the admission control schemes is similar.
- Total throughput of PLUS-DAC is low. Accepted only three flows opposed to SDAC’s six.
- The Bandwidth is used up by high priority flows by the time data flows arrive.
Total Throughput (Both scenarios)

In the High Priority Scenario, EDCA achieves throughput but could not satisfy the latency and loss requirements. PLUS-DAC admits more flows than SDAC by reallocating the unused bandwidth. PLUS-DAC achieves better channel utilization, while satisfying the QoS requirements.

In the Low Priority Scenario, PLUS-DAC shows an improvement in throughput compared to EDCA and SDAC.
Summary of Work done

- Extensive study of QoS provisioning in IEEE 802.11e standard.
- Studied the admission control problem for QoS in 802.11e LANs.
- Implemented the partitioning based admission control by Xiao in ns2 and analyzed it.
- Proposed a new scheme, PLUS-DAC for intelligent admission control, which strictly adheres to the standard with minimal overheads.
- Implemented PLUS-DAC in ns2 by extending FHCF ns2 patch.
- Evaluated PLUS-DAC with various metrics and compared it with the previous scheme, and with pure EDCA, within many scenarios.

submitted paper to MICC-ICON 2005
Conclusion

- EDCA suffer at high load due to increase in collisions.
- Admission control and bandwidth reservation improve the QoS guarantees.
- Bandwidth partitioning should not be static and purely based on priority.
- Attention to the current load and utilization in the network is necessary for better channel utilization.
- PLUS-DAC achieves significant improvement in the channel utilization, while satisfying the QoS guarantees simultaneously.
Future Work

- Policing and scheduling of packets at each of the stations can be done by deferring the channel access to misbehaving QSTAs in a manner similar to that of virtual collision.
- PLUS-DAC could be extended to HCCA.
- Policy controller can be enhanced to support various admission control policies.
For Further Reading I


For Further Reading II

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The Network Simulator - ns2.  
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url: http://www-sop.inria.fr/planete/qni/fhcf/.
For Further Reading III

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An Enhanced HCF for IEEE 802.11e Wireless Networks.
In *MSWiM’04*.

Antonio Grilo, Mario Macedo, and Mario Nunes.
A Scheduling Algorithm for QoS Support in IEEE 802.11e Networks.
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Antonio Grilo and Mario Nunes.
Performance Evaluation of IEEE 802.11e.

Lamia Romdhani, Qiang Ni, and Thierry Turletti.
A Survey of QoS Enhancements for IEEE 802.11 Wireless LAN.
THANK YOU
QoS in IEEE 802.11 WLANs

problems with 802.11

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- doesn’t differentiate between traffic streams.
- transmission time is not in control of AP

802.11e

- IEEE 802.11 Task Group E is going to finalize a QoS extension to the base standard called IEEE 802.11e
- service differentiation based on a queue model.
- provisions for traffic negotiation are available.
- suffers at high load.
Summary

- Details about IEEE 802.11e are presented.
- The details about the algorithms implemented and proposed scheme are explained.
- The complete details about the Simulation, along with the observations are presented.

- PLUS-DAC achieves significant improvement in the channel utilization, while satisfying the QoS guarantees simultaneously.