An Efficient Call Admission Control for IEEE 802.16 Networks

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Introduction

- IEEE 802.16 is a PHY and MAC layer specification for broadband wireless access in LAN and MAN
- High Bandwidth and long range deployment
- Native support for Quality of Service for voice, video and data
Motivation

- 802.16 MAC supports different services such as UGS, RTPS, NRTPS, BE, which require various levels of QoS guarantees.
- 802.16 standard does not specify any scheduling or admission control
  - But Call Admission Control (CAC) is a very important part of the 802.16 network which can determine the correctness of the QoS Provisioning and efficiency of the network
  - In this paper, we propose an efficient CAC for 802.16 network
Typical Deployment Topology

WirelessMAN: Wireless Metropolitan Area Network

Source: Nokia
Uplink Scheduling Services

- Four services are supported in IEEE 802.16 networks
  - Unsolicited Grant Service
    - Fixed size data packets on a Periodic basis.
    - Example: Voice over IP
  - Real time polling Service
    - Variable sized data packets on a Periodic basis
    - Example: MPEG
  - Non-Real time polling Service
    - Variable sized data packets on a Periodic basis but not real time
    - Example: High Bandwidth FTP
  - Best-Effort Service
    - Example: Internet traffic
Proposed BS Architecture

DSA New Request From SS

UGS Queue
RTSPS Queue
NRTPS Queue

Classifier

ADMISSION CONTROL

Periodic Grant Generator

BW Request

SCHEDULER

Map Generator

Classifier

RTSPS Queue
NRTPS Queue
BE Queue

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Proposed SS Architecture
## Connection Request Parameters

<table>
<thead>
<tr>
<th></th>
<th>Nominal grant interval $C_i^{UGS}[ngi]$</th>
<th>Tolerated grant jitter $C_i^{UGS}[tpj]$</th>
<th>Maximum traffic rate $C_i^{UGS}[maxrate]$</th>
<th>RPS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>UGS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>RTPS</strong></td>
<td>Nominal polling interval $C_i^{RTPS}[npi]$</td>
<td>Tolerated polling jitter $C_i^{RTPS}[tpj]$</td>
<td>Minimum traffic rate $C_i^{RTPS}[minrate]$</td>
<td>Max</td>
</tr>
<tr>
<td><strong>NRTPS</strong></td>
<td>Nominal polling interval $C_i^{NRTPS}[npi]$</td>
<td>Tolerated polling jitter $C_i^{NRTPS}[tpj]$</td>
<td>Minimum traffic rate $C_i^{NRTPS}[minrate]$</td>
<td></td>
</tr>
<tr>
<td><strong>BE</strong></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>

- BE: Best Effort
Admissibility Test

- **Hyper Interval (HI):** Since connections come with different parameters, *HI* is used for testing admissibility of requests. This makes sure that QoS requirements are met at every periodic interval of the corresponding service class type. *HI* of different service classes are defined as follows.

\[
\begin{align*}
H^{\text{UGS}}(N) & = \forall_i \text{ LCM} \left( C^n_{\text{UGS}}[ngi] \right), \quad 1 \leq i \leq N^{\text{UGS}} \\
H^{\text{RTPS}}(N) & = \forall_i \text{ LCM} \left( C^n_{\text{RTPS}}[npi] \right), \quad 1 \leq i \leq N^{\text{RTPS}} \\
H^{\text{NRTPS}}(N) & = \forall_i \text{ LCM} \left( C^n_{\text{NRTPS}}[npi] \right), \quad 1 \leq i \leq N^{\text{NRTPS}}
\end{align*}
\]

The *HI* of all the connections across the three service classes are calculated as follows:

\[
H(N) = \text{LCM} \left( H^{\text{UGS}}, H^{\text{RTPS}}, H^{\text{NRTPS}} \right)
\]
BW-based CAC

The available Bandwidth is given by

\[ BW_{avail} = BW - \sum_{s \in \{UGS, RTPS, NRTPS\}} \sum_{i=1}^{N^s} C^s_i[rate] \]

where \( C^s_i[rate] = C^s_i[maxrate] \) when \( s \in UGS \), \( C^s_i[rate] = C^s_i[minrate] \) otherwise and \( BW \) is the total link bandwidth.
Our QoS-CAC

- Overview
  - Our algorithm admits connections only if it can provide QoS guarantees to all the previously admitted connections along with the newly arrived connection request.
  - A new connection request is classified into a particular queue depending on the associated Service Class type.
  - Service Class Queue Priority Order (highest to lowest)
    - UGS, RTPS, NRTPS, BE
QoS-CAC: Admission Decision of various connection requests

- **UGS Connection:**
  - If the request is of type UGS then it should satisfy the necessary condition: the requested slots based on its maxrate within its ngi should be less than or equal to the total number of slots that can actually be accommodated within the tgj based on BW i.e.

\[
\left\lfloor \frac{C_{i}^{UGS}[ngi] \times C_{i}^{UGS}[maxrate]}{slot\_size} \right\rfloor 
\leq \left\lfloor \frac{C_{i}^{UGS}[tgj] \times BW}{slot\_size} \right\rfloor
\]

- Then it assigns required number of slots starting from 

\[tgj\]
UGS CAC Illustrated

Contiguous Allocation

Non-Contiguous Allocation

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RTPS Connection

• If the request is of type RTPS then it should satisfy the necessary condition: the number of required slots within the npi as per its minrate should be less than or equal to the total number of slots that can actually be accommodated within the npi as per the total bandwidth. i.e.

\[
\left( C_{i}^{RTPS[\text{npi}] \times C_{i}^{RTPS[\text{min rate}]}} / \text{slot size} \right) \leq \left( C_{i}^{RTPS[\text{npi}] \times BW} / \text{slot size} \right)
\]
RTPS Connection

- Then it checks that enough number of slots are available for bandwidth request: enough number of bw request slots should be available within $tpj$
RTPS CAC Illustrated

Hyper Interval

NPI

TPJ

Request slots

Data slots

Hyper Interval

NPI

TPJ

Request slots

Data slots
NRTPS Connection

• Similar is the case with NRTPS except that the values taken by the parameters are large when compared to the RTPS connections.
Need for BW Estimator

- In RTPS and NRTPS connection, admission of a connection is based on its minrate.
- But they have a variable bandwidth requirement
  - Always allocating minrate will have performance impact on nrtps application
  - Always allocating maxrate will result in low utilization of resources of 802.16 system
  - Thus, a bw estimator at the SS which monitors the queue length and changes the bw requirement accordingly
  - BR : ratio of change of queue length between two successive observation to the monitoring interval.
Bandwidth Estimator Agent (BEA) for RTPS and NRTPS connections

- \( \text{minrate} \leq BR \leq \text{BW}_{\text{thr}} \): BEA sends a bandwidth request for \( \text{minrate} \)
- \( \text{BW}_{\text{thr}} < BR \leq \text{maxrate} \): BEA sends a bandwidth request for \( BR \)
- \( \text{maxrate} < BR \): BEA sends a bandwidth request for \( \text{maxrate} \)
Only UGS connections

Codec chosen is G.711
Acceptance Ratio is 100% until arrival rate is 38/sec
Only RTPS connections

Minrate = 128kbps, maxrate=256kbps, npi=1sec, tpj=0.5sec
Acceptance ratio falls much quicker than UGS because of high Bw requirement
## Mixed Traffic Classes

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Channel Capacity</td>
<td>32 Mbps (QPSK)</td>
</tr>
<tr>
<td>Symbol Rate (MBd)</td>
<td>16</td>
</tr>
<tr>
<td>Frame Duration</td>
<td>1 ms</td>
</tr>
<tr>
<td>Physical slots per frame</td>
<td>4000</td>
</tr>
<tr>
<td>Slot size</td>
<td>1 byte</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Codec</th>
<th>G.711</th>
<th>G.721</th>
<th>G.728</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bit rate (Kbps)</td>
<td>64</td>
<td>32</td>
<td>16</td>
</tr>
<tr>
<td>ngi (ms)</td>
<td>20</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>tpj (ms)</td>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Duration (sec)</td>
<td>180</td>
<td>180</td>
<td>180</td>
</tr>
</tbody>
</table>

System Parameters used in Simulation

UGS Traffic Parameters

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## RTPS, NRTPS, BE parameters

<table>
<thead>
<tr>
<th>Service type</th>
<th>maxrate ( kbps )</th>
<th>minrate ( kbps )</th>
<th>npi (sec)</th>
<th>tpj (sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>RTPS</td>
<td>128</td>
<td>64</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>RTPS</td>
<td>256</td>
<td>128</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>RTPS</td>
<td>512</td>
<td>256</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>NRTPS</td>
<td>128</td>
<td>64</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>NRTPS</td>
<td>256</td>
<td>128</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>NRTPS</td>
<td>512</td>
<td>256</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>BE</td>
<td>32</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
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<td>64</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>BE</td>
<td>128</td>
<td>-</td>
<td>-</td>
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</tr>
</tbody>
</table>
Experimental Results

All classes of Traffic allocated Maxrate

All classes of Traffic allocated Minrate

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Experimental Results

All classes of Traffic with Bandwidth Estimator

BW_thr midway between min and max
Acceptance Ratio of all classes increase except for NRTPS (compared to maxrate case)
Comparison with BW-CAC

- BW-CAC admits connections only based on available bandwidth
  - Can admit more connections than QoS-CAC
  - But connections might miss deadlines
- Hence we define a Figure of Merit (FOM) to compare the two CACs:

\[
\text{FoM} = \frac{\text{Utilization} \times (\text{No\_of\_conn\_admitted} - \text{No\_of\_conn\_miss\_deadlines})}{\text{Total\_no\_of\_conn\_requests}}
\]
Experimental Results
Conclusion

- Presented an architecture for BS and SS of 802.16 system
- Presented the Call Admission Control algorithm for UGS, RTPS and NRTPS connections
- Proposed a method for estimating BW to increase system utilization
- Proposed a composite Figure of Merit for comparing QoS-CAC with BW-CAC
- QoS-CAC is more suitable for 802.16 network which provide bandwidth, delay and jitter guarantee to different connections.
REFERENCES


Thank you

Questions??