Implementation and Evaluation of a MAC Scheduling Architecture for IEEE 802.16 WirelessMANs

by
Abhishek Maheshwari

under the supervision of
Dr. Bhaskaran Raman

28th May 2006
Outline

- Motivation
- IEEE 802.16 MAC
- Problem Statement
- Related Work
- Scheduling Architecture
- NS-2 Implementation
- Simulation Analysis
- Conclusions
- Future Work
Motivation

- Features
  - Large spamming area (up 30 miles)
  - Data rate (variable and high up to 75 Mbps)
  - Large frequency band (2-11 GHz)
  - NLOS
  - Mobility
  - TDD and FDD modes
  - PMP and Mesh networks
  - Half and Full duplex modes
  - Easy deployment
Motivation

- Applications
  - Disaster recovery places
  - WiFi backhaul
  - QoS for VoIP and other real-time applications
  - Wireless access to rural areas
  - A replacement of DSL
  - Web access at home and commercial places
IEEE 802.16 Architecture

- Base Station (BS)
- Subscriber Station (SS)
- Only BS-SS communication
- TDMA MAC style
- Uplink (SS to BS) and Downlink (BS to SS)
IEEE 802.16 MAC

- Connection formation through management messages
- Request-Grant mechanism for slot allocation
- Slots are specified in UL-MAP
- Each SS sends data in specified slots
- Three ways – contention, piggyback and use granted slots
Problem Statement

- Scheduling Architecture for slots allocation
- Evaluation of scheduling architecture
- Comparative performance analysis with and without bandwidth contention period

Why simulations

- Deployed architecture is not available
- Easy and fast first level testing through simulations
IEEE 802.16 MAC QoS

- Four Flows types
  - UGS – CBR traffic (VoIP without silence)
  - rtPS – VBR traffic (VoIP with silence, video traffic)
  - nrtPS – non real-time traffic (FTP)
  - BE – traffic with no QoS (telnet, http)

- Slots allocation
  - GPC – per connection bandwidth allocation
  - GPSS – per SS bandwidth allocation
Related Work

- Supriya (05) – Qualnet, GPSS, weighted max-min fair allocation (uplink) and WFQ (downlink) with constant weight
- Chu(02) – GPSS, WRR (uplink) without mentioned weights, No results
- Hawa(02) – PWFQ without priority and weight mentioned
- Moraes(05) – SSs priority, Transmission + TDMA, two versions for uplink slots
- Ganz(03) – strict priority with overall bandwidth allocation module
- Oh(05) – optimal contention period, 2 times the number of users, one b/w request in each frame
Weighted Fair Queuing (WFQ)

- Bit-by-bit round robin
- $F(i,k,t) = \max\{F(i,k-1,t),R(t)\} + \frac{P(I,k,t)}{w(i)}$
- Round number – the index of round in bit-by-bit round robin scheduling
- Packet served in finish time order
- Update round number on each packet arrival or departure
- Scheduling is done based on weights and length of flow queue
Scheduling Architecture

Design Goals
- Delay bound for real-time (UGS and rtPS flows) traffic
- QoS to all applications (number and type of flows only matters)
- GPC slots allocation mode
- Easy to implement

Design Decisions
- WFQ as downlink and uplink scheduling algorithm
- Bit-wise-bit fair allocation
- Guarantee time bound on packet transmission
- Protects responsive flows against unresponsive flows also called flow isolation
Scheduling Architecture

- Classifier
- Connections Queues
- SS Uplink
- SS
- Data Uplink Period
- Downlink Period
- CID 1
- CID 2
- CID 3
- CID 4
- ……….. CID N
- NBWC
- Broadcast Channel
- Downlink Period
- Ranging
- Bandwidth
- CID 1
- CID 2
- ……….. CID N
- BWC
- BS Downlink
- WFQ
- UL-MAP
- BS Allocation Module
- GPC allocation mode
- BS
- IP Packets
- Packets from BS
- Packets to Link Layer
- Packets from SS
- Packets to Link Layer
- Classify the packets based on flowID

28th May 2006
Abhishek Maheshwari
Thesis Defense
Other Details

- Each SS can have as many flows and maintains the same number of MAC level queues
- BS has only one MAC level queue
- Admission control
- Forever loop and polling time
  - Connections do not have any packets
  - BS does not allocate slots for connections
  - Polling time – Every connection should be able to communicate its queue information to BS within this time
  - Unicast request slots from ranging period
  - Choice of polling time depends on number and types of flows and their weights
NS-2 Implementation Details

- Supported features
  - Interface between MAC and LL
  - TDD frame structure
  - GPC mode bandwidth allocation
  - RANG-REQ, REG-REQ, BW-REQ, CONN-REQ
  - RANG-RSP, REG-RSP, CONN-RSP
  - IEEE 802.16 MAC frame structure
  - All four uplink scheduling services
  - MAC level packet association based on flowID
Modified NS-2 Node

Entry

port classifier

Protocol Agent

Routing Agent

Link Layer

addr classifier

ARP

WFQ

802.16 MAC

802.11 PHY

Channel

802.16 MAC

Old architecture

Propagation and antenna models

28th May 2006
Abhishek Maheshwari
Thesis Defense
Simulation Analysis

- Assumptions
  - Only IEEE 802.16 MAC CPS layer
  - No DCD and UCD
  - No guard timer for synchronization
  - No admission control
  - No ARQ/ACK mechanism
  - IEEE 802.11 PHY layer

- What we want to evaluate
  - Effect of one type of flow on other type of flow
  - Comparative performance analysis of BWC and NBWC modes
  - Choice of bandwidth contention period for BWC mode
Flow Specifications and Weights

- UGS – CBR traffic with 28 Bytes packet and 22.4 Kbps rate (G.729 codec)
- rtPS – Video traces with 64 Kbps (H.263 codec)
- nrtPS – FTP traffic from ns-2
- BE – Telnet traffic from ns-2

Weights are in the ratio of minimum reserved bandwidth of flows

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>UGS</td>
<td>22.4</td>
</tr>
<tr>
<td>rtPS</td>
<td>64.0</td>
</tr>
<tr>
<td>nrtPS</td>
<td>100.0</td>
</tr>
<tr>
<td>BE</td>
<td>10.0</td>
</tr>
</tbody>
</table>
## Parameter Choices (uplink flows)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data rate</td>
<td>11 Mbps</td>
</tr>
<tr>
<td>Basic rate</td>
<td>1 Mbps</td>
</tr>
<tr>
<td>Slot time</td>
<td>8 micro sec</td>
</tr>
<tr>
<td>Frame length</td>
<td>10 msec</td>
</tr>
<tr>
<td>Uplink frame</td>
<td>8 msec</td>
</tr>
<tr>
<td>Downlink frame</td>
<td>2 msec</td>
</tr>
<tr>
<td>Ranging period</td>
<td>100 slots (=0.8 msec)</td>
</tr>
<tr>
<td>Bandwidth contention</td>
<td>100 slots (=0.8 msec)</td>
</tr>
<tr>
<td>Data uplink slots (BWC)</td>
<td>800 slots (=6.4 msec)</td>
</tr>
<tr>
<td>Data uplink slots (NBWC)</td>
<td>900 slots (=7.2 msec)</td>
</tr>
</tbody>
</table>
Delay Analysis of UGS flows

- UGS delay increases after a fix number of rtPS flows
- UGS flows are not able to send queue information to BS in contention manner
Delay Analysis of UGS flows

- Increment in delay is linear for nrtPS flows
- UGS queues relatively non-active than nrtPS queues
Delay Analysis of UGS flows

- UGS delay is constant with BE flows
- Packets are very rare in BE flows thus fewer BE connection take part in contention
Delay Analysis of UGS flows

- UGS delay is more affected by nrtPS flows
Delay Analysis of rtPS flows

- rtPS delay is irregular but lies in a certain range
- rtPS flows needs more slots to convey queue information to BS
Delay Analysis of rtPS flows

- rtPS delay increases in NBWC mode also with nrtPS flows
- rtPS delay increases linearly after a certain number of nrtPS flows in BWC mode
Throughput Analysis of rtPS flows

- With UGS flows sudden decrement in throughput then stable
- UGS flows occupy the slots which were previously allocated to nrtPS flows
For rtPS and BE flows total throughput is same
For nrtPS flows NBWC mode throughput is higher
Total Throughput in BWC and NBWC modes

- Total throughput achieved for nrtPS flows is more in NBWC mode.
Total Throughput in BWC and NBWC modes

- Similar to throughput of nrtPS flows graph
- Throughput of NBWC mode is higher than BWC mode
Optimum value of Bandwidth Contention

- For 30 UGS flows delay is minimum at 100 slots
- rtPS delay is not very regular
Comparison between BWC and NBWC modes

- **Average UGS delay**
  - Almost constant but higher in BWC mode with BE flows
  - Linear increase with nrtPS flows but with higher slop in BWC mode
  - Almost constant up to a certain number of rtPS flows than linear increment in BWC mode while constant in NBWC mode

- **Average rtPS delay**
  - Irregular delay behavior of rtPS flows in BWC mode
  - Delay is more in BWC mode in all cases
Comparison between BWC and NBWC modes

- nrtPS throughout
  - Decreases linearly with rtpS and BE flows in both modes
  - Sudden decrement then stable with UGS flows in both modes

- Total throughout
  - Similar to nrtPS throughput
  - Almost constant with BE flows in both modes
  - Lies in certain range with rtPS flows in both modes
  - Sudden decrement then stable with UGS flows in both modes

- NBWC mode perform better or equivalent with BWC mode
## Parameter Choices (downlink flows)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data rate</td>
<td>11 Mbps</td>
</tr>
<tr>
<td>Basic rate</td>
<td>1 Mbps</td>
</tr>
<tr>
<td>Slot time</td>
<td>8 micro sec</td>
</tr>
<tr>
<td>Frame length</td>
<td>10 msec</td>
</tr>
<tr>
<td>Uplink frame</td>
<td>2 msec</td>
</tr>
<tr>
<td>Downlink frame</td>
<td>8 msec</td>
</tr>
<tr>
<td>Ranging period</td>
<td>25 slots (=0.2 msec)</td>
</tr>
<tr>
<td>Bandwidth contention</td>
<td>25 slots (=0.2 msec)</td>
</tr>
<tr>
<td>Data uplink slots (BWC)</td>
<td>200 slots (=1.6 msec)</td>
</tr>
<tr>
<td>Downlink slots</td>
<td>1000 slots (=8.0 msec)</td>
</tr>
</tbody>
</table>
Delay Analysis

Average Delay of 30 MCS flows (downlink direction)

Average Delay of 20 rTPS flows (downlink direction)

28th May 2006

Abhishek Maheshwari
Thesis Defense
Throughput Analysis

- Expected output
- Linear decrement with BE and rtPS flows
- Sudden decrement then stable with UGS flows
Conclusions

- Simple approach
  - Only minimal required modules
  - WFQ well known for 20 decades now
  - One module with two copy

- NBWC mode
  - completely remove the bandwidth contention period
  - Remove the possibility of collision at BS
  - Overhead is less compared to BWC mode

- Performance
  - Delay is less in all case in NBWC mode
  - Throughput is higher because of removal of bandwidth contention period

- Drawback
  - Forerver loop
  - Polling time concept
Future Work

- ARQ/ACK mechanism implementation
- Fragmentation
- HTTP traffic as BE flow
- Classification of packets
- Order of bandwidth contention period
- Polling time calculation
- Dynamic variation in framesize
Acknowledgements

- Ayush Ghai and Nihit Purwar
- Alexander Sayenko
- Dr. Sridhar Iyer
Thank You 😊

Questions ?