A Novel Architecture for IEEE 802.16m Subscriber Station for Joint Power Saving Class Management

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Introduction

- IEEE 802.16m amends the IEEE 802.16 WirelessMAN-OFDMA specification to provide an advanced air interface for:
  - the requirements of IMT-Advanced next generation mobile networks
  - To Support Enhanced Power Saving Strategies [1]
Power Saving Mechanism in IEEE 802.16e

- Sleep mode is a state in which an MS conducts pre-negotiated periods of absence from the Serving BS air interface.
- A Power Saving Class (PSC) is defined according to a group of Medium Access Control (MAC) layer connections that have common traffic demand properties and can follow a common algorithm for determining the sleep interval.
- SS negotiates sleep-mode with BS per active Power Saving Class Identifier (PSC_ID) belonging to a PSC.
One Device Multiple Applications Simultaneously Accessing Internet over WiMAX.

QoS Class BE
Power Saving Class A
PSC_ID 1

QoS Class rtPS
Power Saving Class B
PSC_ID 1

QoS Class BE
Power Saving Class A
PSC_ID 2

QoS Class UGS
Power Saving Class B
PSC_ID 3

01/09/2009
QoS Class BE
Power Saving Class A
PSC_ID 4
MOTIVATION

All connections simultaneously active only for 3.3%!

Potential power saving can be achieved, if the listening intervals could be synchronized across the PSC_IDs.

Voila! Device is sleeping 12% of the time!

Details in [5]
Problem Statement

• To design an architecture and mechanism for Joint Power Saving Class Management that optimizes the sleep mode management efficiency as the number of active connections increase in IEEE 802.16m MAC
State transitions in the proposed architecture

[Diagram showing state transitions between connected state, active mode, and idle state for different PSC_IDs.]
Sleep-Mode Manager allows the SS to manage the sleep mode of all the PSC_IDs belonging to a single QoS class by aggregating the traffic characteristics of all individual connections.
Advantages of the Proposed Architecture

- The overhead of management messages is minimal as sleep is not negotiated on a PSC_ID basis.
- Changes in parameters for sleep mode do not require deactivation or activation of PSC.
- The parameters can be directly negotiated with sleep-manager.
- Robust system is available for adaptive power management according to changing traffic.
Analytical Modeling

Case 1
- Sleep Cycle
- Listening Interval
- Transmission/Reception Mode

$t_u$ $w_{n-1}$

Case 2
- Sleep Cycle
- Listening Interval
- Transmission/Reception Mode

$w_{n-1}$ $t_d$

Case 3
- Sleep Cycle
- Listening Interval
- Transmission/Reception Mode

$t_u$ $w_{n-1}$ $t_n$

Case 4
- Sleep Cycle
- Listening Interval
- Transmission/Reception Mode

$w_n$ $t_d$
Average Probability of the Unavailability Period

\[ \lambda_u^i = 0.125 \]
\[ \lambda_d^i = 0.025 \]
\[ t_{\text{min}} = 2 \]
\[ t_{\text{max}} = 64 \]
\[ L = 1 \]
Extension of the unavailability period of QoS Class

- We define a Threshold Factor $T_i$, for $i = 1, 2, 3, 4, 5$
- Maximum frame time for which the unavailability period of the QoS Classes (UGS, ertPS, rtPS, nrtPS and BE) can be extended
- These values are selected, considering the latency and jitter requirements of the respective QoS class, such that

$$T_1 < T_2 < T_3 < T_4 < T_5$$
The duration of extension of the unavailability period of the QoS class is then determined from a value given as $t_{ext}^j$, where $j$ represents each QoS Class (UGS, ertPS, rtPS, nrtPS, BE) and calculated as

$$t_{ext}^j = \max(t_k \forall k, k \in n, T_j), j \in QoS \ Class$$

The value by which the total unavailability can be extended is calculated as follows

$$t_{ext} = \min(t_{ext}^j, \forall j, j \in QoSClasses)$$
**Simulation Parameters**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transmission Power</td>
<td>15.0 dBm</td>
</tr>
<tr>
<td>MAC Frame Duration</td>
<td>20 ms</td>
</tr>
<tr>
<td>TDD Downlink Duration</td>
<td>10 ms</td>
</tr>
<tr>
<td>DCD/UCD Interval</td>
<td>5 sec</td>
</tr>
<tr>
<td>DCD/UCD timeout interval</td>
<td>25 sec</td>
</tr>
<tr>
<td>Simulation period</td>
<td>25 sec</td>
</tr>
</tbody>
</table>

DL connections with exponential traffic $\lambda = 1$ and random on-off time with on time percentage of 0.3
Results

Percentage of time in transmit mode of the SS for DL connection

Mainly due to MOB_SLP-REQ and MOB_SLP-RSP messages

1.2% lesser than individual PSC_IDs

Percentage time in transmit mode of the SS for DL connection
Number of MOB_SLP-RSP messages received with increasing number of active PSC_IDs

Results contd...

4.8:1
Number of MOB_SLP-REQ messages transmitted with increasing number of active PSC_IDs

Results contd...

No. of MOB_SLP-REQ messages sent

5.3 : 1
Conclusion

• Introduction of soft-sleep mode at SS considerably reduces the management message exchanges between SS and BS
• The Joint Power Saving Class Management Architecture helps maximize the unavailability interval
• Percentage of time the SS is in transmit mode is reduced, leading to better power conservation
• The architecture enables the parameters of the sleep algorithm to be adapted to dynamic changes in traffic pattern while ensuring their QoS constraints
References

1. IEEE 802.16m-07/002r4, “IEEE 802.16m System Requirements Document”
THANK YOU !!

ACKNOWLEDGEMENT:
Supported by Microsoft Research India,
This work has been carried out at IIIT-Bangalore.