Exploiting MAC Flexibility in WiMAX for Media Streaming

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Outline

- Introduction
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- Tweaking MAC of WiMAX
- Feedback-based Adaptive MAC
- Simulation Model and Results
- Conclusion

Introduction

- WiMAX [2]
  - an access technology that uses multiple channels for a single transmission
  - provides bandwidths of up to 350 Mbps. [1]
- Bottlenecks for media data
  - bandwidth
  - unreliable wireless link.
- Proposed method
  - dynamically construct the MAC packet data units (MPDU) for streaming media over unreliable wireless channel
  - maintain a high throughput.
  - the robustness of MPDUs is obtained by CRC code bits

System Model

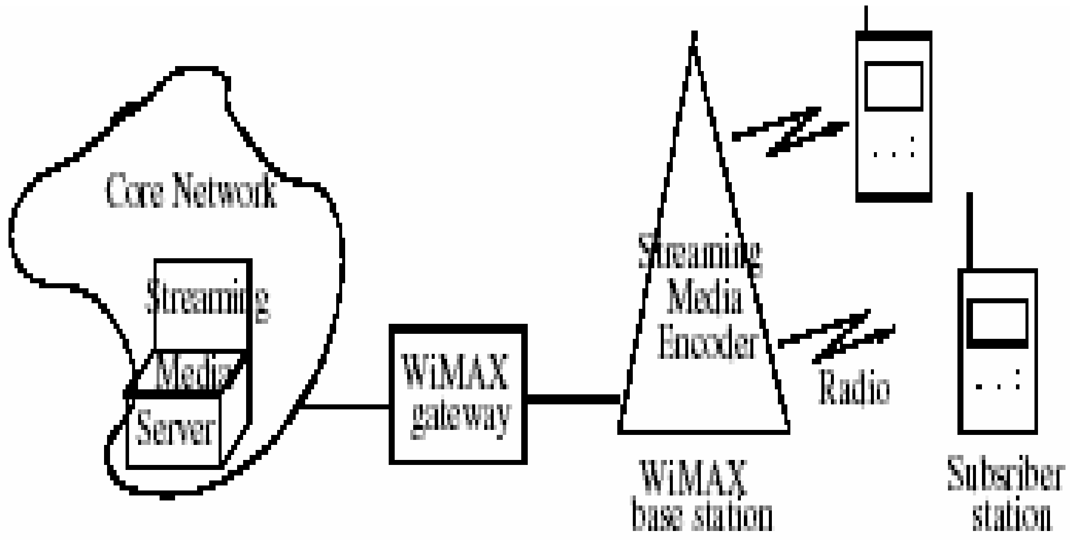


Figure 1. Network architecture

Tweaking the MAC of WiMAX

- The MAC layer of 802.16a [3] comprises three sublayers which interact with each other through the service access points (SAPs).
- The service specific convergence sublayer:
  - transform or map external network data
- The MAC common part sublayer:
  - pack MSDUs into the payload fields of MPDUs
- Privacy sublayer:
  - provides authentication, secure key exchange and encryption on the MPDUs formed from the MSDUs and passes them over to the physical layer

MAC Layer with SAPs

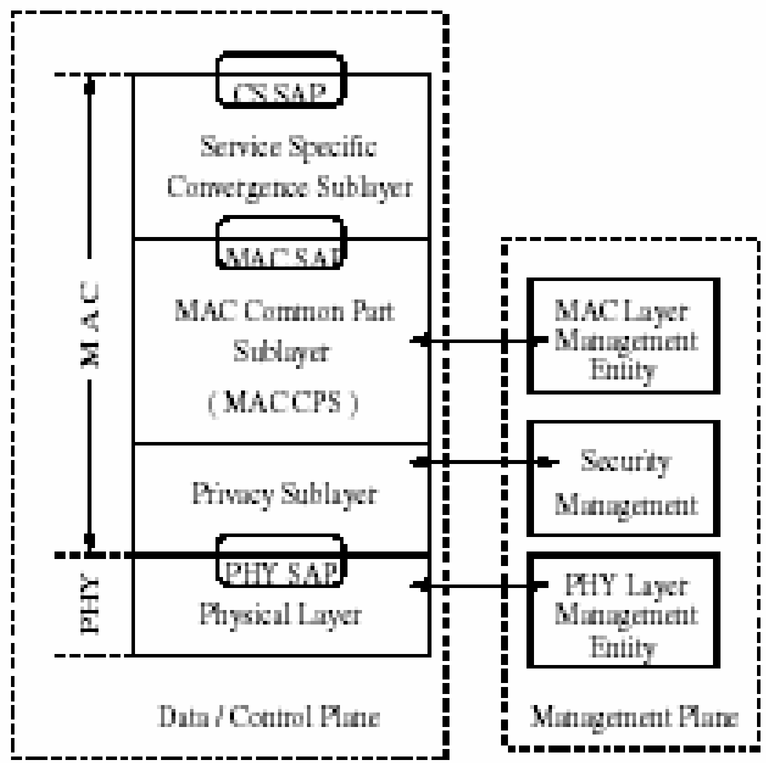


Figure 2. 802.16a MAC layer with SAPs

Aggregation and Fragmentation of MSDU

- Common part sublayer (CPS)
  - controls the on-air timing based on consecutive frames that are divided into time slots.
  - modifies the size of the MPDUs by changing the size of the payload, depending on the feedback and physical layer slots
- Sizes of frames and the individual slots in frames
  - be varied on a frame-by-frame basis
- Payload
  - is obtained either by aggregation or fragmentation of the upper layer data units.

Aggregation of MSDU

- The CPS is capable of packing more than one complete or partial MSDUs into one MPDU.

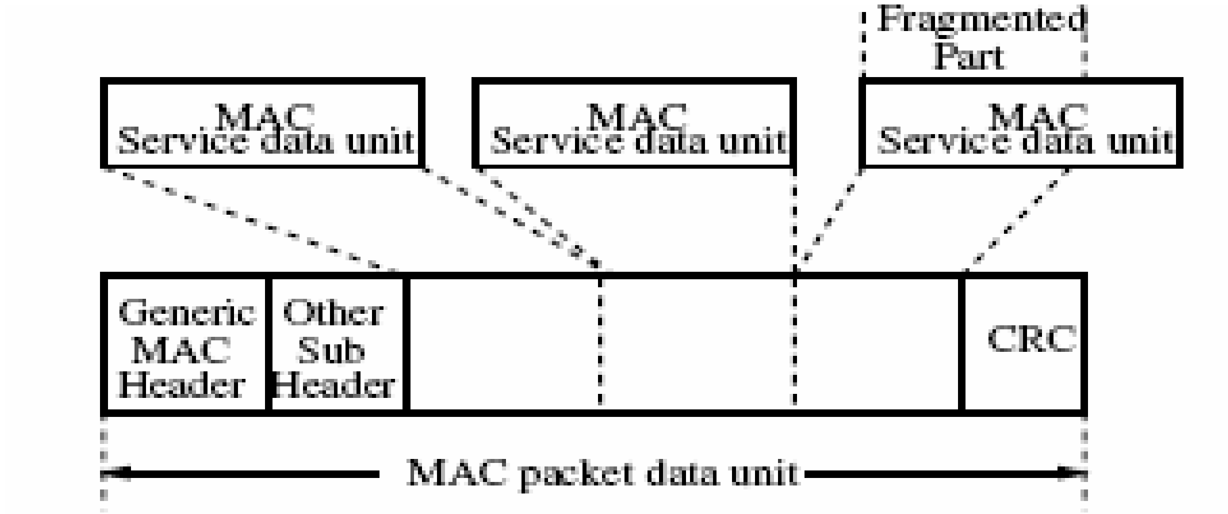


Figure 3. Multiple MSDUs form a MPDU

Fragmentation of MSDU

- The CPS can also fragment a MSDU into multiple MPDUs.

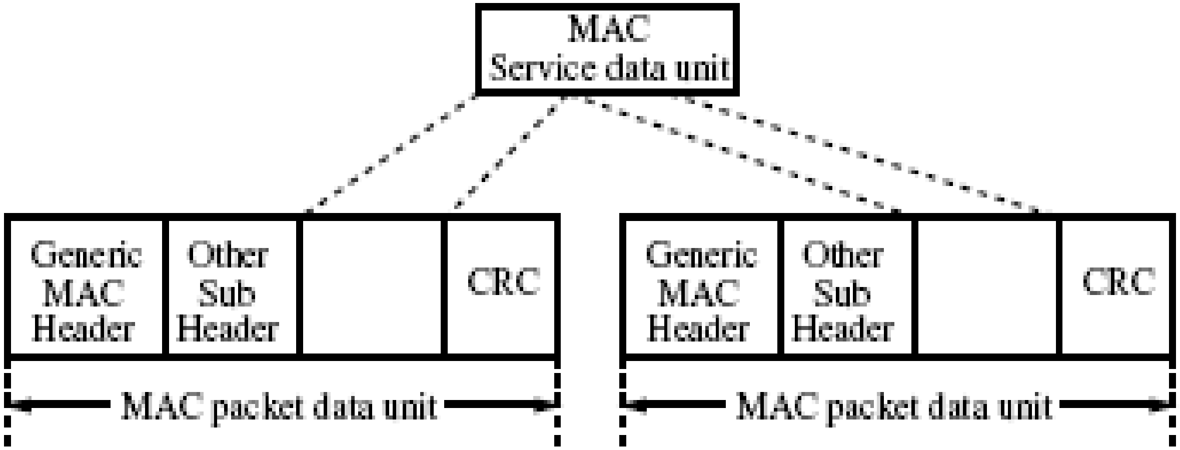


Figure 4. Single MSDU forms multiple MPDUs

Optimal MPDU size

- The sizes of the MPDUs are constantly modified based on the channel state information.
- There is a trade-off between the goodput (information bits/total bits transmitted) and the delay.
- If a MPDU is large, the transmission time is large but the overhead due to headers is less which helps in maintaining a high goodput.
- If the MPDU is dropped or corrupted due to bad channel condition, the retransmission of the large MPDU, which will introduce delay in the transmission.

Optimal MPDU size (conts.)

- If the bad channel condition persists, there will be more retransmissions of large MPDUs, resulting in severe degradation of goodput
- The main disadvantage of having small MPDUs is the low goodput due to low payload/overhead ratio.
- Then we propose dynamically changing the MPDU size in response to the channel conditions.

Feedback-based Adaptive MAC

- Classify video frames as important and not so important and propose to treat them differently.
- We propose six types of feedback- each of which depends on the state of the received MPDU and its importance level.

Feedback types

Feedback type	Feedback classification
1	MPDU received correctly
2	MPDU received with errors, but correctable
3	MPDU received with errors, and uncorrectable
4	MPDU dropped, timeout in receiver MAC occurred
5	Receiver MAC buffer full last stored frame is important
6	Receiver MAC buffer full last stored frame is not so important

Table 1. Different feedback possibilities

Packet Restore Probability

- a probability that the receiver would be able to detect and possibly correct the errors

Payload (N bits)	CRC (M bits)

- the resulting bit loss probability is given by [1],

$$b = \sum_{i=M+1}^{M+N} C_i^{M+N} {b_p}^i (1 - b_p)^{M+N-i} \frac{i}{M+N} \qquad (1)$$

  where b_p is the bit loss probability before decoding and b is the decoded bit error probability.

- The restore probability of such a MPDU is given by, $p = (1 - b)^{(M+N)}$.

Three schemes to manipulate packet restore probability:

- **Decreasing payload keeping CRC fixed:**
  decrease the payload size to N’ keeping the CRC field fixed, the resulting bit loss probability after decoding is given by,

$$b' = \sum_{i=M+1}^{M+N'} C_i^{M+N'} {b_p}^i (1 - b_p)^{M+N'-i} \frac{i}{M+N'} \qquad (2)$$

then p’, the new packet restore probability , is given by

$$p' = (1 - b')^{(M+N')} \qquad (3)$$

without any loss of generality, it can be said that, for N’<N, P’>P, i.e., with a decrease in payload, packet restore probability increases.

Three schemes to manipulate packet restore probability:

- **Increasing CRC keeping payload fixed:**

  the resulting bit loss probability decreases and packet restore probability of MPDUs increases.

- **Increasing both payload and CRC:**

  increasing payload only will increase the resulting bit error probability, so we must also increase the CRC to compensate for the increased payload.

Connection Set-up and transmission

- **Phase 1:** *Subscriber station requests connection request:*
  - Ranging request packet (RNG-REQ)
  - Service flow parameters
- **Phase 2:** *Base station confirms connection:*
  - Ranging response
  - Agreed service flow parameters
  - Connection ID
- **Phase 3:** *Base station starts transmission of MPDUs:*
  - MPDUs be transmitted depended on the type of feedback received.

The action taken by the base station

- ***Feedback type 1:***
  - increase MPDU payload
  - decrease CRC for not so important MPDU
- ***Feedback type 2:***
  - increase CRC for important MPDU
  - keep payload and CRC fixed for not-so-imp MPDU
- ***Feedback type 3:***
  - decrease payload of MPDU
  - increase CRC of MPDU
- ***Feedback type 4:***
  - same as Feedback 3, but the increment/decrement is more
- ***Feedback type 5:***
  - stall transmission until further request received
- ***Feedback type 6:***
  - skip transmission of next few *not so important* frames
  - important frame(s) is/are transmitted

Simulation Model- Channel Model

- Assumed a four-state Markov model for the channel.

BER: bit error probability

State	BER
good	0.045
fair	0.060
medium	0.070
bad	0.085

Simulation Model- Parameters

- It is necessary to figure out the exact increase/decrease in payload and CRC if the goodput is to be optimized.
- Example
  - Payload : CRC :: 500:50 ,

    the best goodput is obtained for 1 byte payload increase.
  - Payload : CRC :: 500:100 ,

    the best goodput is obtained for 5 bytes payload increase .
- It can be concluded that the increase/decrease will also depend on the ratio of the payload to CRC.

Different ratios of payload / CRC

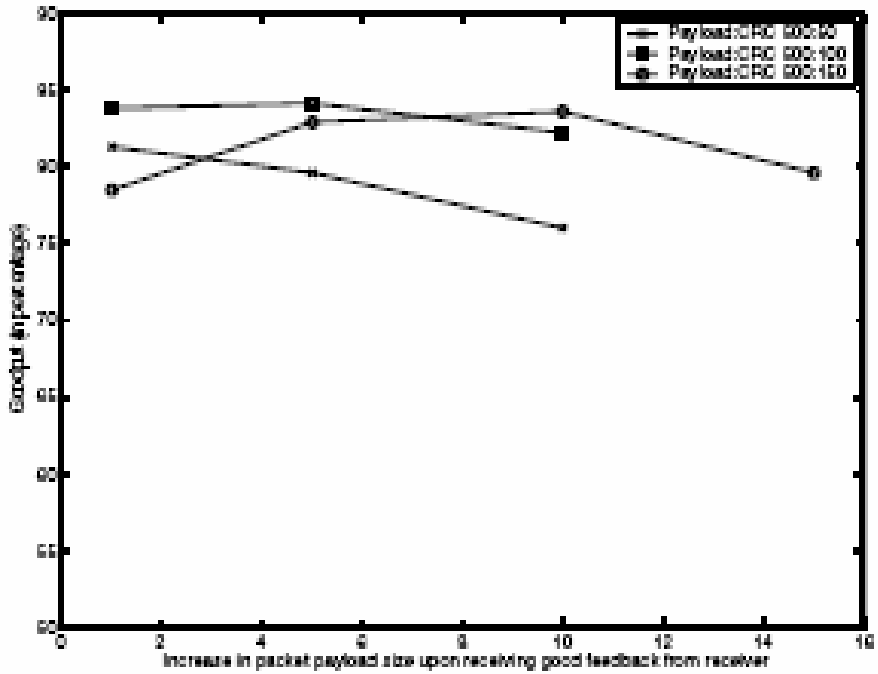


Figure 5. Goodput with payload increment

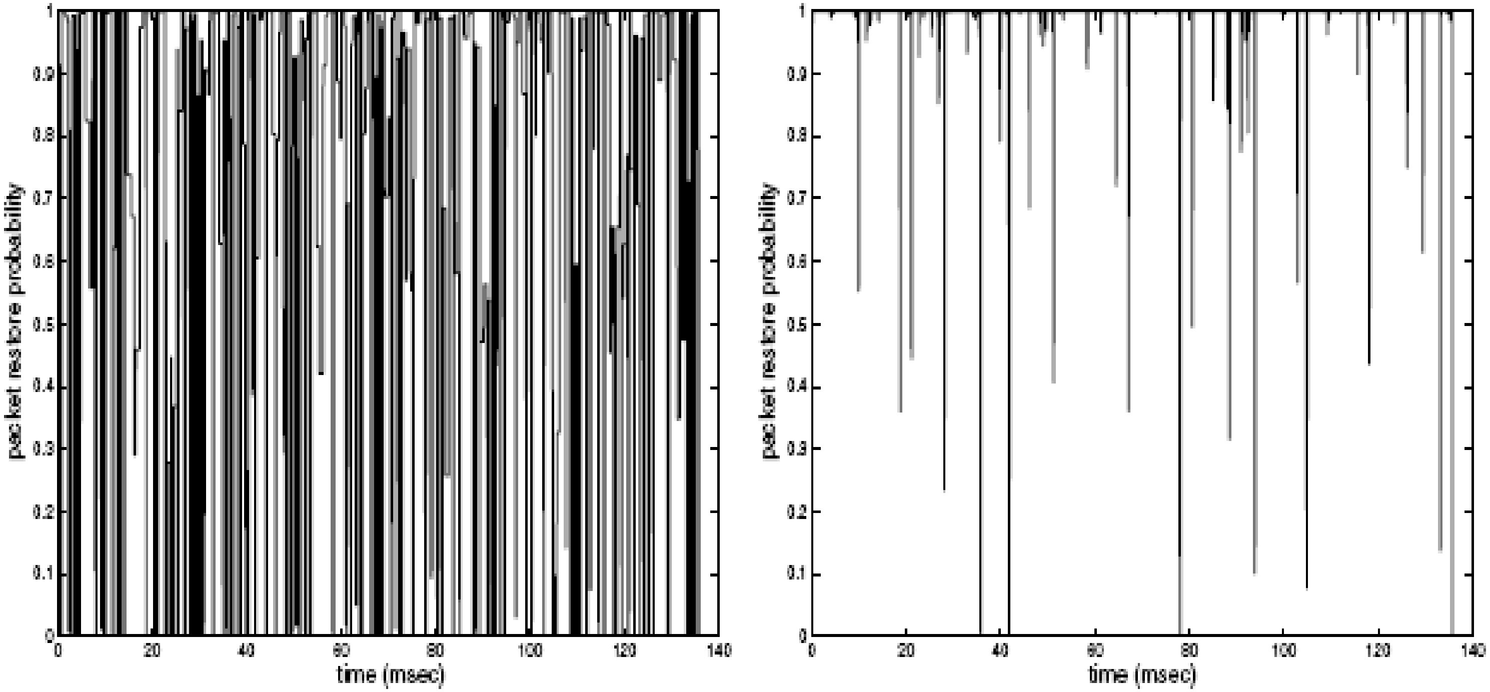
Different feedback types and sizes in payload / CRC

Payload:500 bytes CRC:50 bytes Header: 5 bytes

Feedback type	Payload (imp)	Payload (not-imp)	CRC (imp)	CRC (not-imp)
1	+1 Byte	+1 Byte	+0 Byte	-1 Byte
2	+0 Byte	+0 Byte	+2 Byte	+0 Byte
3	-50 Byte	-50 Byte	+5 Byte	+1 Byte
4	-75 Byte	-75 Byte	+10 Byte	+1 Byte

Table 2. Change in payload and CRC

Packet restore probability for non-adaptive and adaptive schemes



Goodput comparison

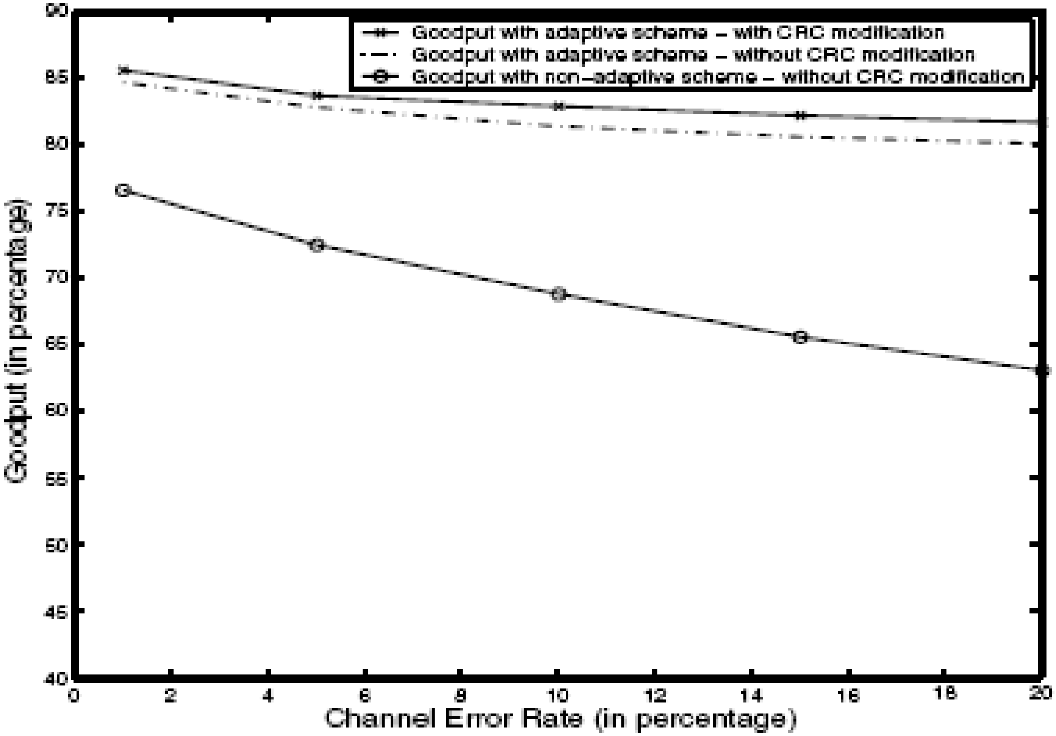


Figure 8. Goodput comparison

MPDU drop comparison

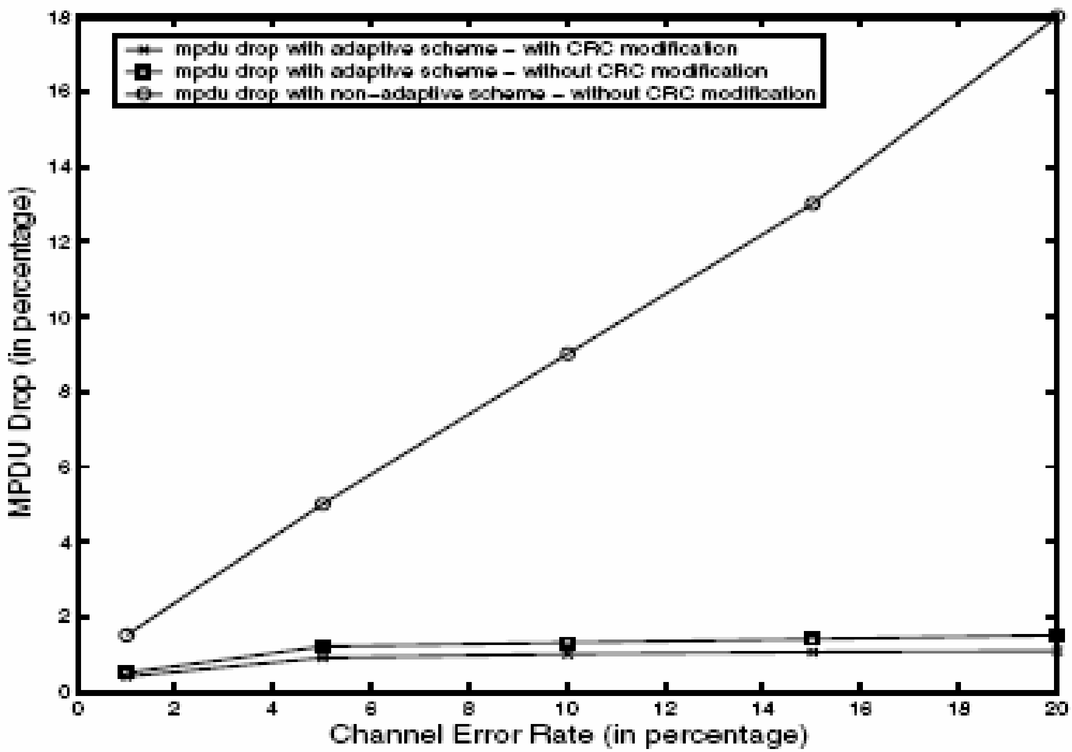


Figure 9. MPDU drop comparison

Goodput for different channels

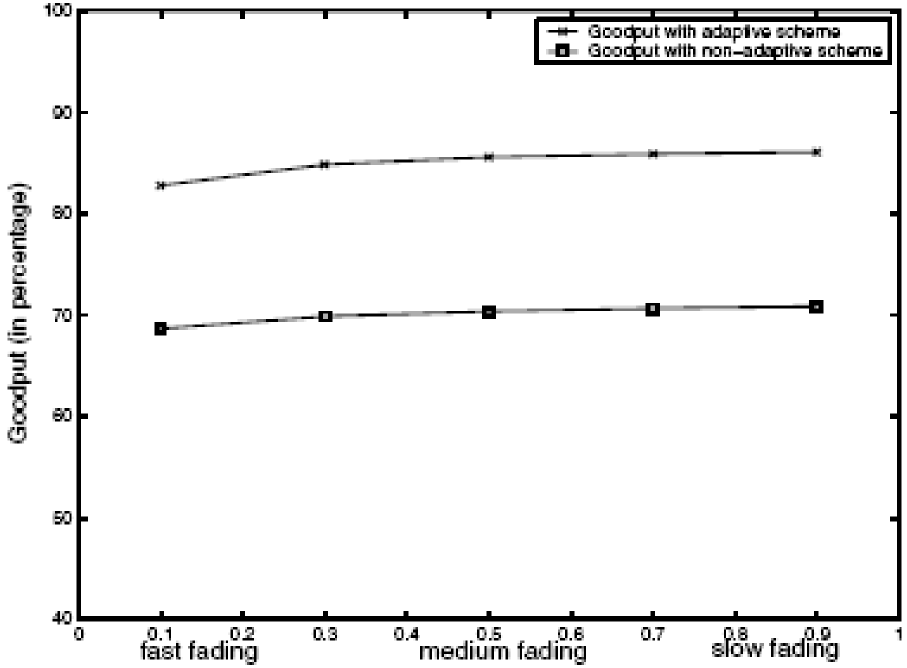


Figure 10. Goodput for different channels

MPDU drop for different channels

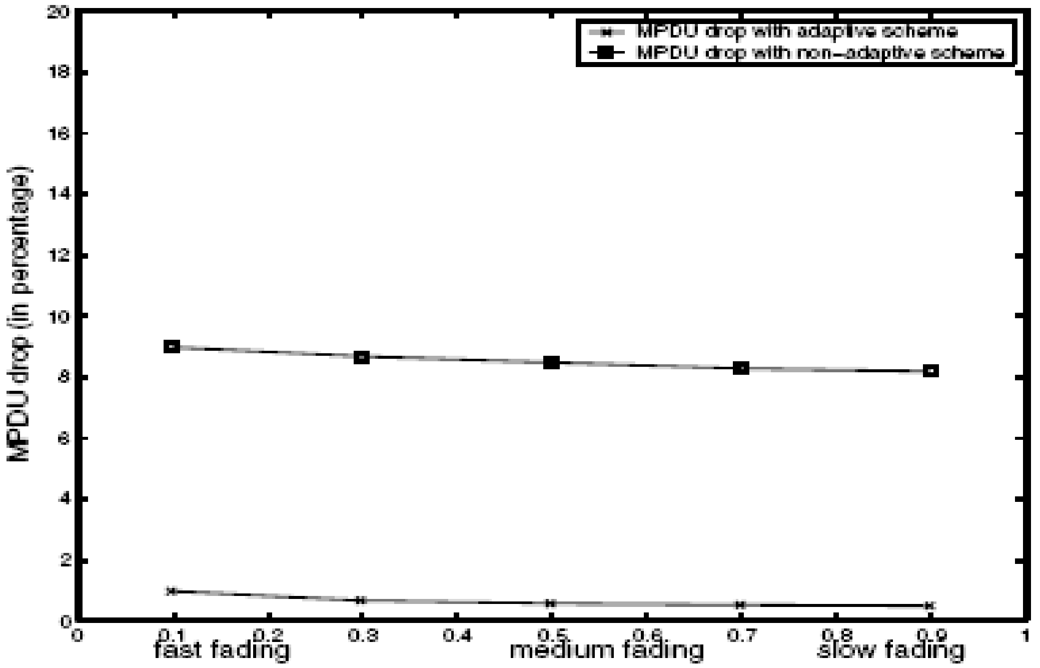


Figure 11. MPDU drop for different channels

Conclusion

- We exploited the flexible features in the MAC layer of 802.16a and proposed that the size of MPDUs be made adaptive to the instantaneous wireless channel state condition.
- Based on the type of feedback received, variable size MPDUs were constructed either by aggregation or fragmentation of MSDUs.
- Packet restore probability, goodput, and dropping probability of MPDUs were defined as the performance metrics.

References

- [1] S.J. Vaughan-Nichols, “Achieving wireless broadband with WiMax”, IEEE Computer, Volume: 37, Issue: 6, June 2004, pp. 10-13.
- [2] IEEE Std. 802.16-2001 IEEE Standard for Local and MANPart 16:Air Interface for Fixed Broadband Wireless Access Systems, IEEE Std 802.16-2001, 2002.
- [3] IEEE Std. for Local and MAN Part 16:Air Interface for Fixed Broadband Wireless Access Systems-Amendment 2: MAC Modifications and AdditionalPhysical Layer Spec. for 2-11 GHz, Std 802.16a-2003 (Amendment to IEEE Std 802.16-2001), 2003.