Evaluation Procedure for 802.16 MAC Protocols

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Purpose:

To jumpstart a debate within IEEE 802.16 on how the current set of 802.16.1 MAC proposals should be evaluated.

Evaluation Procedure for 802.16 MAC Protocols

Contents

Introduction

- This is in response to the Call for Contributions on MAC-Layer Modeling (IEEE 802.16.1m-00/02) and the Call for Evaluations, Improvements, and Mergers (IEEE 802.16-00/11).
- Purpose of this document
  - To define a general process for modeling, simulation, and evaluation of the current set of 802.16.1 MAC proposals (Documents IEEE 802.16.1mc-00/09 and IEEE 802.16.1mc-00/10)
  - To jumpstart a debate on how the current set of the MAC proposals should be evaluated.
- This document includes :
  - A brief overview of differences between two proposals
  - An evaluation model
  - A range of parameter values and traffic models for simulations
  - A procedure for performance evaluation.

Comparison of the Two Proposals

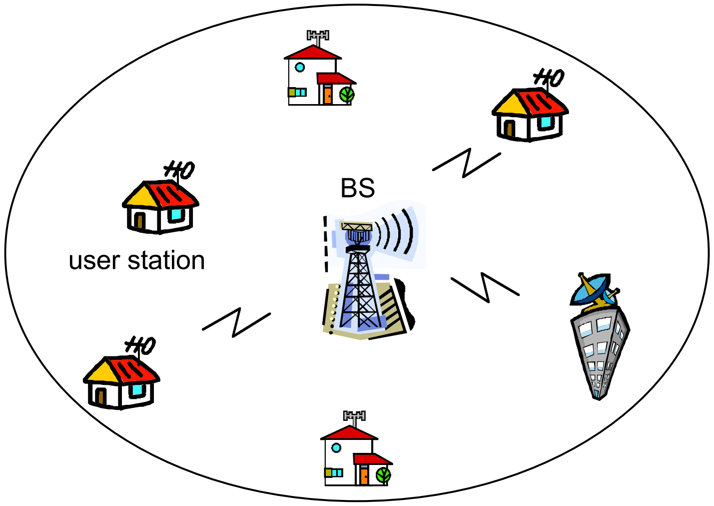
- Two proposals for the LMDS MAC protocol :
  IEEE 802.16.1mc-00/09 and IEEE 802.16.1mc-00/10

- A brief description of the two proposals w.r.t.
  - Framing and formatting
  - Initialization/registration procedure
  - Bandwidth request/allocation procedure
  - Contention resolution scheme
  - QoS support and data unit handling capabilities

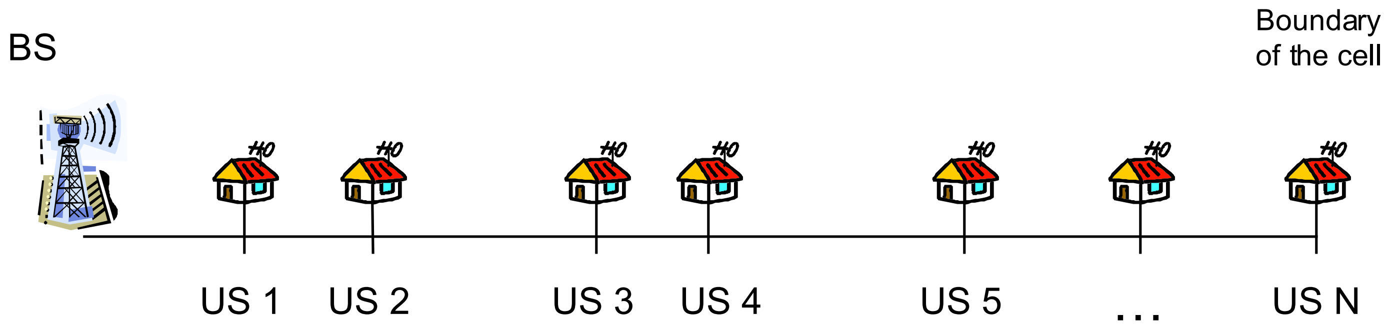
- The two proposals share a number of similar concepts.

System Models

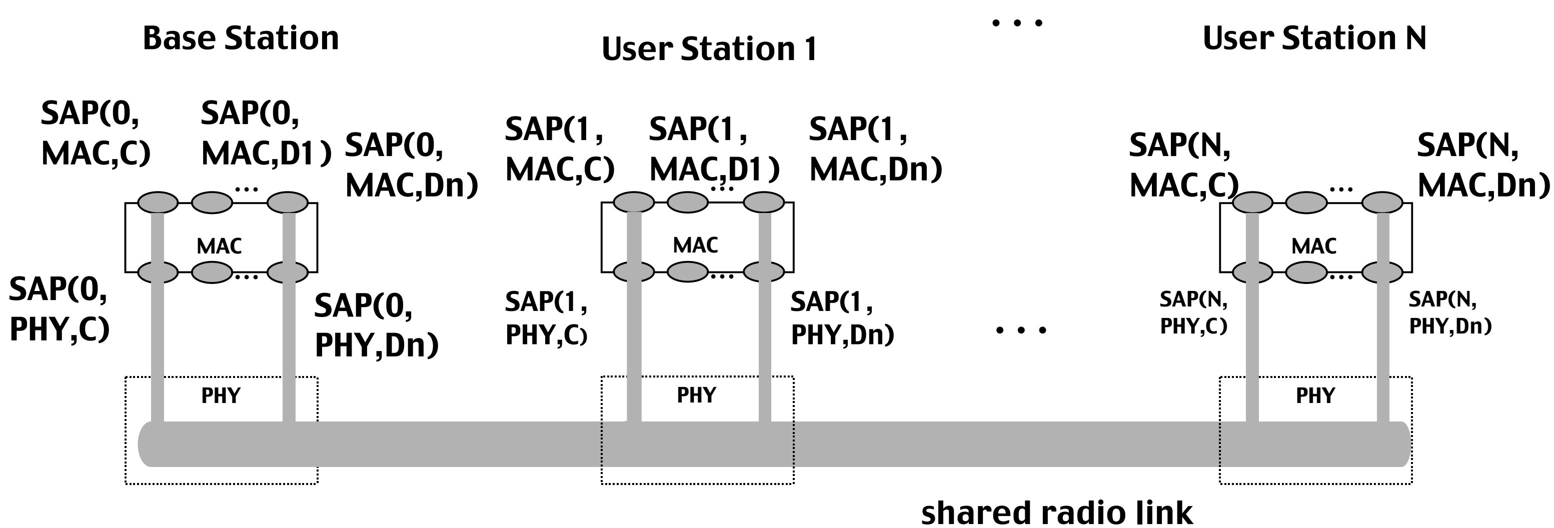
- Evaluation of the LMDS MAC protocols in a wireless access network(a cell)



- Logical topology of the stations



❑ Definition of Service Access Points (SAP)



SAP(0,MAC,C) : SAP for Control information at MAC layer in the Base Station

SAP(*k*,MAC,*Dn*) : SAP for Data connection *n* at MAC layer in the User Station *k*

SAP(*k*,PHY,*D1*) : SAP for Data connection *1* to PHY layer in the User Station *k*

Simulation Parameters

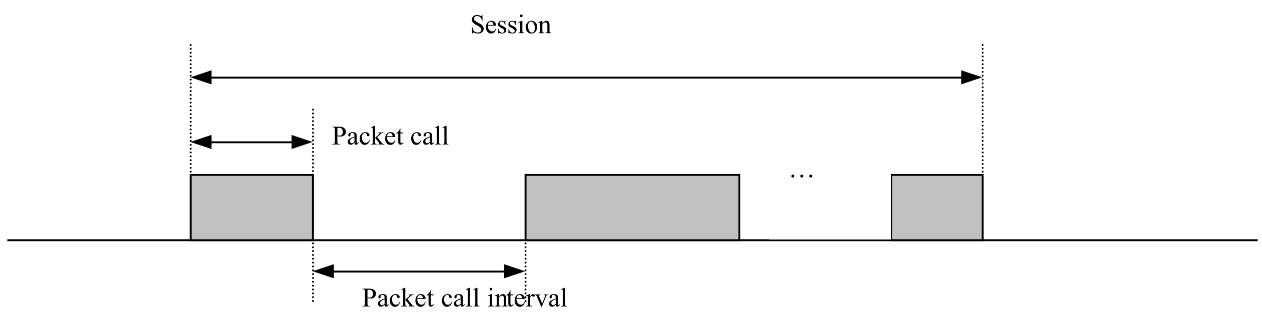
- Some of the simulation parameters

Simulation Parameters	Values
Cell radius, *r*	0.5 km, 1 km, 1.5 km, 2 km
Number of sectors in a cell	1, 3, 6
Number of channels in a sector	1
Duplexing schemes	TDD, FDD
Ratio of uplink slots to downlink's in TDD	10% ~ 50% ~ 70%
Number of user stations in a sector	30, 60, 90, 120, 150
Downstream data transmission rate	2 Mbps, 9 Mbps, 45 Mbps, 155 Mbps
Aggregated upstream data transmission rate	2 Mbps, 9 Mbps, 45 Mbps, 155 Mbps
Propagation delay	3.3 μsec/km
Bit error ratio	10E-4, 10E-6, 10E-9
Initial back-off parameter	1 (window size = 2)
Maximum back-off parameter	15 (window size = 32K)
Length of simulation run, *T*	Depends on the statistical confidence of output
Length of the run prior to gathering statistics	5 % of the simulation time

Input Traffic Model

- 5 Traffic types
- For bursty traffic source
  - Class A : bursty traffic (e.g. Internet telnet service data or E-mail type data)
  - Class B : bursty and bulky traffic (e.g. Web browsing, file transfer type data)
  - Class C : sporadic data traffic (e.g. Web traffic on the upstream link)
- For smooth traffic source
  - Class D : constant data rate traffic (e.g. CBR data, circuit simulation)
  - Class E : variable data rate traffic (e.g. compressed voice/video)

- Definition of session for bursty data traffic
  - Packet call in the session represents a collection of IP packets, such as packets from a web page.



- Class A
  - Poisson arrivals of sessions (arrival rate λ_A)
  - Geometrically distributed number of packet calls per session with mean 114
  - Geometrically distributed interval time between packet calls with mean 1 second
  - One packet per packet call
  - Geometrically distributed packet sizes with mean 90 bytes
- Class B
  - Poisson arrivals of sessions (arrival rate λ_B)
  - Geometrically distributed number of packet calls per session with mean 5
  - Geometrically distributed interval time between packet calls with mean 120 seconds
  - Geometrically distributed inter-arrival time between packets with mean 0.01 second
  - Pareto distributed number of packets per packet call with parameters α=1.1, k =2.27 (mean=25), where Pareto distribution with parameters α and k is given as

$$F(x) = \begin{cases} 1 - (\frac{k}{x})^{\alpha} & \text{when } x \geq k > 0, \\ 0 & \text{when } x < k \end{cases}$$

  - Fixed packet sizes of 480 bytes

- Class C
  - Poisson arrivals of sessions (arrival rate λ_B)
  - Geometrically distributed number of packet calls per session with mean 5
  - Geometrically distributed interval time between packet calls with mean 120 seconds
  - Geometrically distributed inter-arrival time between packets with mean 0.01 second
  - Pareto distributed number of packets per packet call with parameters $\alpha=1.1$, $k=2.27$ (mean=25)
  - Fixed packet sizes of 90 bytes

- Class D
  - Deterministic arrival of packet. Rate is dependent on an application
  - Fixed packet sizes of 53 bytes

- Class E
  - Arrivals of packets by Markov Modulated Poisson Process (arrival rates λ_{E1} and λ_{E2})
  - Geometrically distributed packet sizes with mean 180 bytes

Measures and Evaluation Procedures

- Delivered Bandwidth
- Initial Registration Delay
- Bandwidth Request Delay
- MAC Transit Delay
- Access Network Transit Delay
- Delays with respect to the Number of Stations
- Flexible Asymmetry
- Fairness

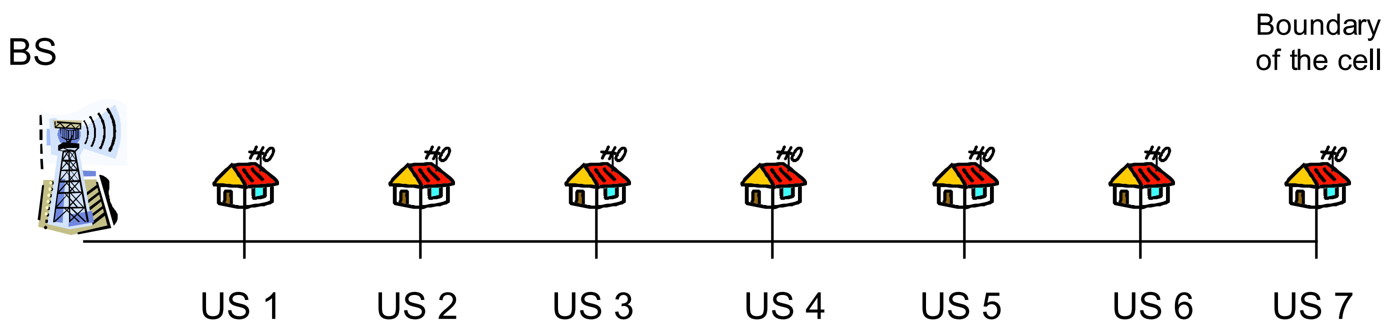
- Needs a simulation model of the PHY layer.

Bandwidth Request Delay

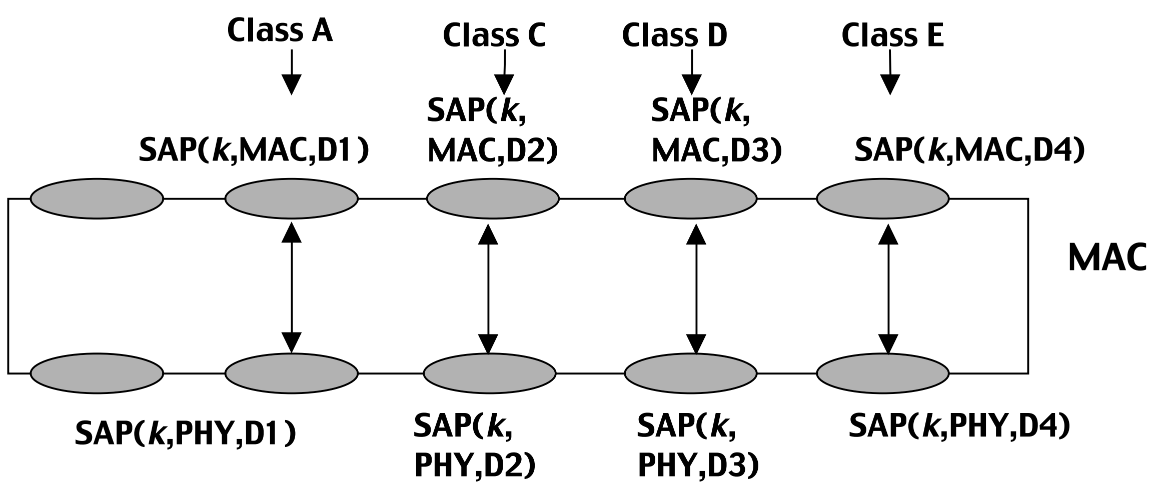
- Both explicit and implicit (piggybacking, poll me bit, bandwidth stealing) bandwidth request mechanism should be implemented.
- The FIFO scheduling policy is assumed for servicing registration or bandwidth requests in the BS.

- Evaluation Procedure

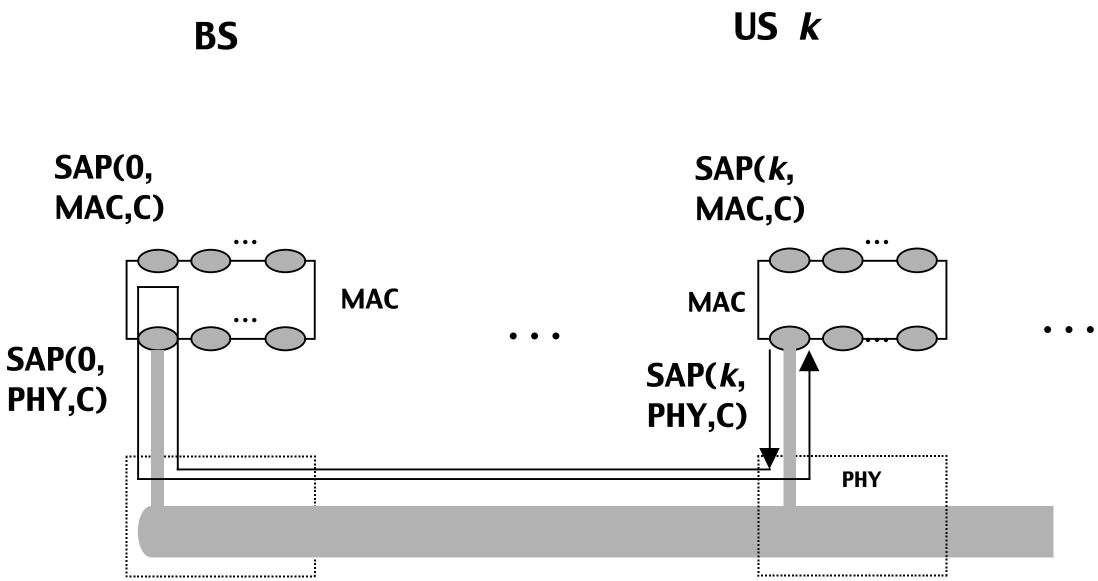
1. Choose 7 user stations that belong to the same sector and are located at $i*r/7$ km from the BS.



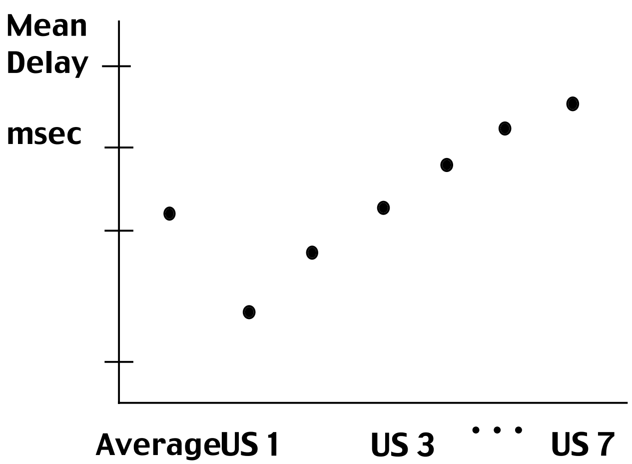
2. Associate Class A service to connection D1 at SAP(k, MAC, D1) which is assumed to map to SAP(k, PHY, D1). Likewise associate Class C, Class D, and Class E service to connection D2, D3 and D4, respectively, as shown below.



3. All user stations in the cell generate Classes A, C, D, and E traffic according to the parameters of the traffic classes.
4. Generate a bandwidth request each time a new session of Class A or C arrives.
5. Measure the time difference between the instance at which the request is made at SAP(k, PHY, C) and the instance at which the grant is received at SAP(k, PHY, C). Count the number of collisions, if any.

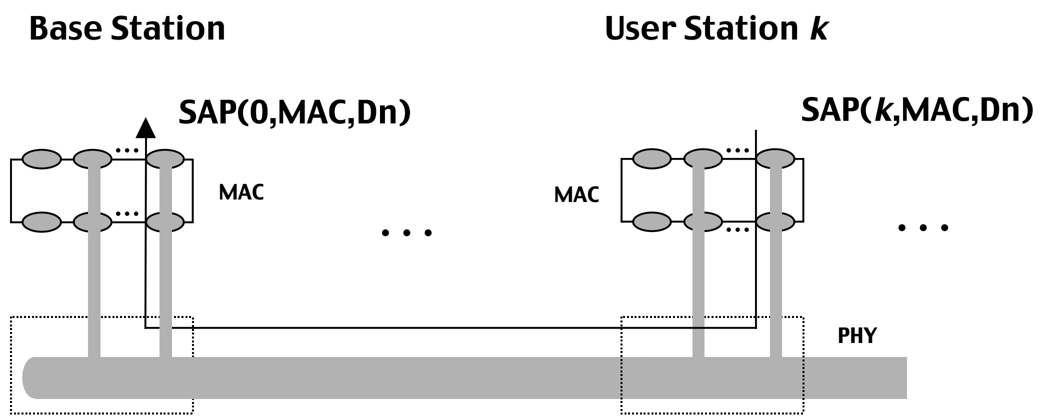


6. Repeat steps 4~5 for a simulation of duration *T* seconds and compute the mean.
7. Repeat steps 4~6 for each of the other 6 user stations.
8. Plot a graph of the mean registration delay for each of the 7 user stations along with the average of the 7 values.
9. Plot a graph of the number of collisions for each of the 7 user stations along with the average of the 7 values.
10. Let the registration request rate increase at all user stations and repeat steps 4~6.
11. Plot a line graph of the mean delay vs. the offered load, that is, the sum of bandwidth requests by all the user stations.



Access Network Transit Delay

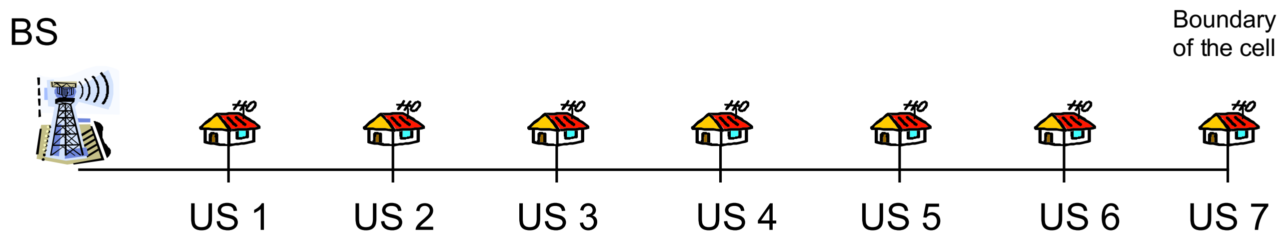
- Definition of the access network transit delay
  - The time difference between the instance at which the first bit of a service data unit crosses SAP(k, MAC, D*) and the instance at which the last bit of the same service data unit crosses SAP(0, MAC, D*).



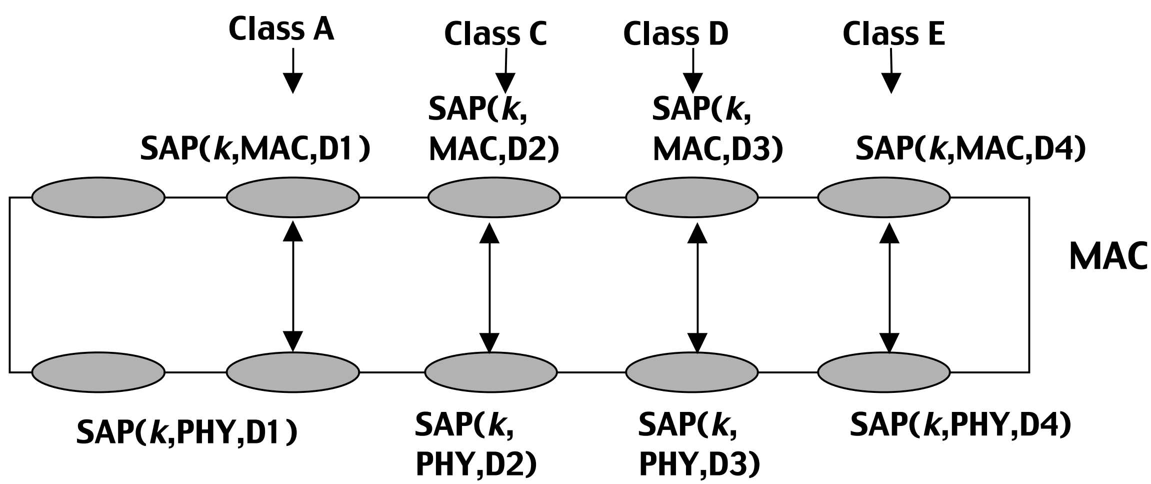
  - This time includes the bandwidth request delay, contention resolution delay (if necessary), the messaging delay including fragmentation/concatenation, and the propagation delay.
  - We assume a constant amount of time is needed to frame a single message, regardless of the message type.

❑ Evaluation Procedure

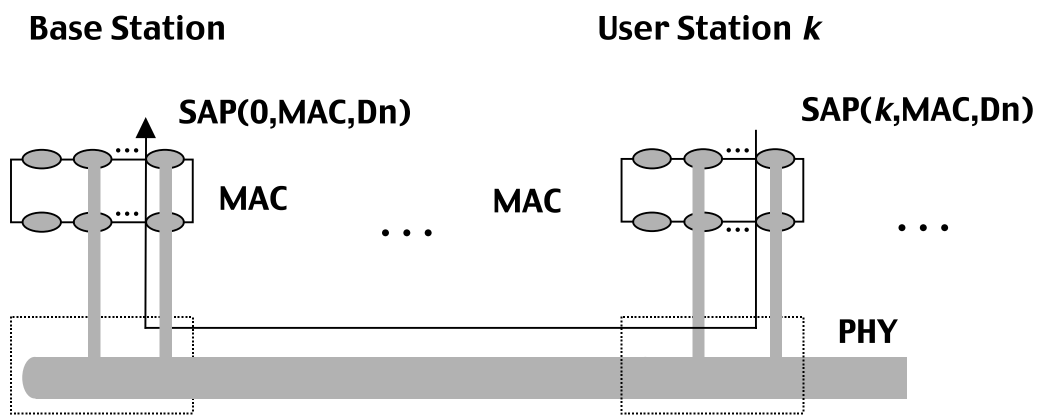
1. Choose 7 user stations as before.



2. Associate Class A service to connection D1 at SAP(*k*, MAC, D1), and Class C, D, and E service to connections D2, D3, and D4 at SAP(*k*, MAC, D2), SAP(*k*, MAC, D3), and SAP(*k*, MAC, D4), respectively.

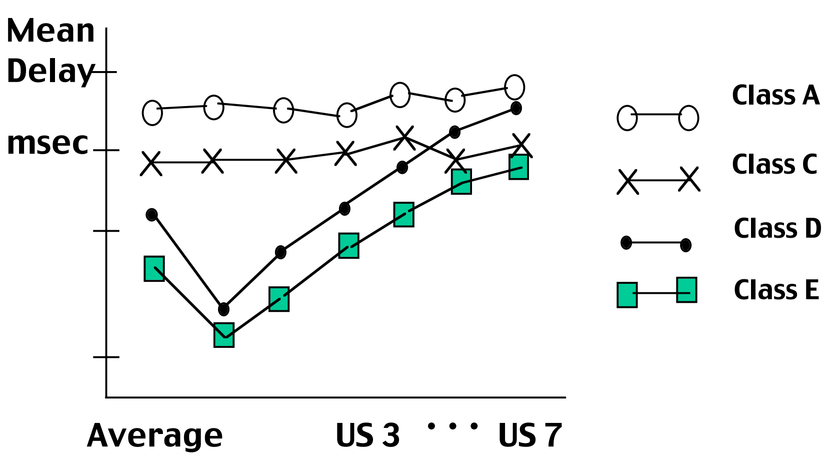


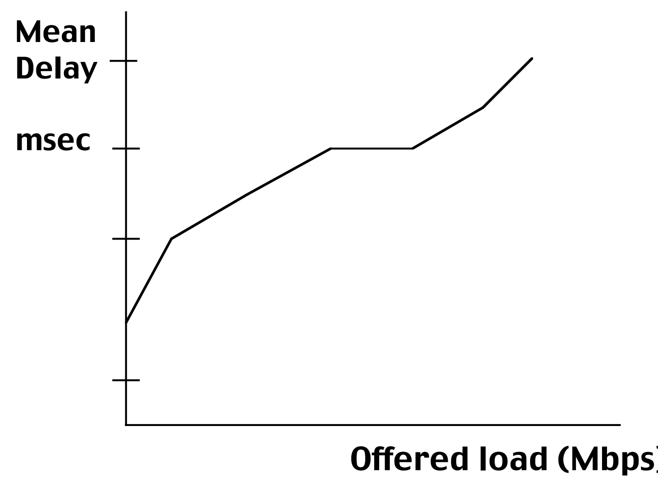
3. All user stations in the cell generate Classes A, C, D, and E traffic according to the parameters of the traffic classes.
4. Measure the time difference between the instance at which the first bit of a service data unit crosses SAP(k, MAC, D*) and the instance at which the last bit of the same data crosses SAP(0, MAC, D*) for each connection.



5. Repeat steps 3~4 for a simulation of duration T seconds and compute the mean and the variation of delay for each connection.
6. Repeat steps 3~5 for each of the other 6 user stations.

7. Plot a graph of the mean transit delay for each of the 7 user stations along with the average of the 7 values.
8. Plot a graph that shows the coefficient of variation of the MAC transit delay for Class D vs. station number.
9. Let the registration request rate increase at all user stations and repeat steps 3~5.
10. Plot a line graph of the mean delay vs. the offered load, that is, the sum of bandwidth requests by all the user stations.

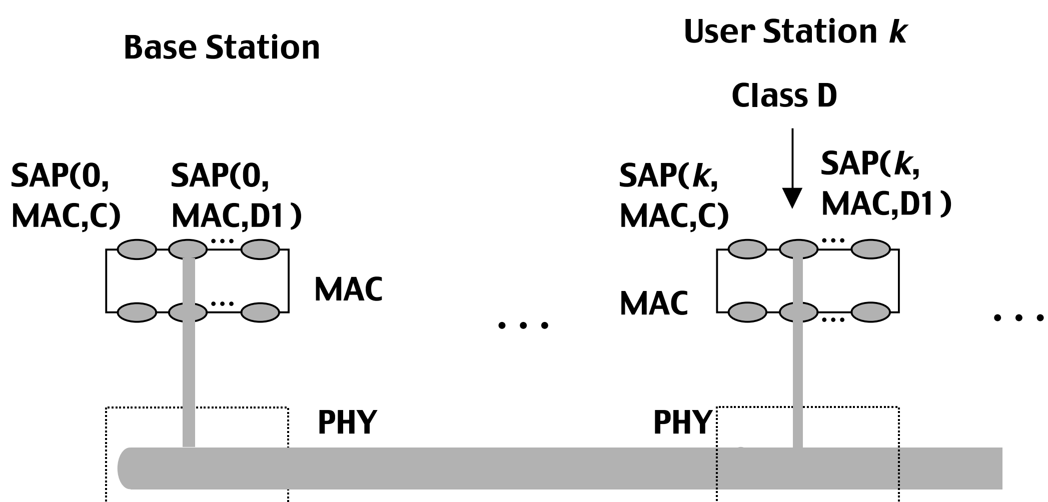




Delivered Bandwidth

- According to the functional requirement document, the 802.16 protocol shall be optimized to provide the peak capacity from 2 to 155 Mbps to a user station "sufficiently" close to the base station.

- Measurement of the delivered data rate



- Experiment A:
  1. Choose a user station k that is away from the base station by about 1/3 of the cell radius.
  2. Feed Class D traffic at SAP(k, MAC, D1). Increase the data rate from 0 Mbps to 155 Mbps while other user stations do not generate a traffic.
  3. Measure the amount of received data at SAP(0, MAC, D1), and measure the elapsed time.
  4. Plot the received (delivered) bandwidth vs. generated traffic.

- Experiment B:
  1. User station k keeps generating data at the rate of 155 Mbps and the aggregated traffic volume from the remaining user stations increases from 0 Mbps in 2 Mbps increments.
  2. Measure the amount of received data at SAP(0, MAC, D1) from user station k, and measure the elapsed time.
  3. Plot the received bandwidth vs. the offered load, that is, the total traffic from all the user stations.

Flexible Asymmetry

- The MAC protocol shall support for flexibility between delivered upstream and downstream bandwidth.
- Repeat the experiments so far as the ratio of aggregated upstream bandwidth to downstream varies 3:7, 4:6, 5:5, 6:4, 7:3, etc..
- Measure and plot the bandwidth of downstream when the aggregated upstream bandwidth varies from 2 Mbps to 155 Mbps. Check which protocol gives higher downstream bandwidth and smooth change.

Fairness

- The graphs of delays at 7 stations show the performance variation of the MAC protocols with respect to distance. The preferred protocol should give smaller difference in the amount of various delay times regardless of the distance of the user station from the base station.