

Asia Future Internet Mobile/Wireless School

# QoS and Mobility in Multicast/Broadcast Services (MBSs) in Mobile WiMAX Systems

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# Outline

- ▶ Multicast Broadcast Service (MBS) in Mobile WiMAX
- ▶ Mobility issue in MBS
- ▶ Location Management Area (LMA)-based MBS Handover
- ▶ Performance Analysis
- ▶ Numerical Results
- ▶ Conclusion

# WiMAX

- ▶ WiMAX (Worldwide Interoperability for Microwave Access)
  - ▶ Industrial forum to promote IEEE 802.16-based network deployment
- ▶ Mobile WiMAX
  - ▶ Extended to support mobility
  - ▶ Handover, sleep/idle mode
  - ▶ Multicast Broadcast Service (MBS)

# Broadcasting Paradigm Shift

▶ TV / Satellite Broadcasting

↓ Need for regional broadcasting arises

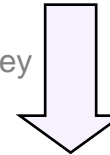
▶ Regional Broadcasting

↓ Need for various, specialized, differentiated contents arises

▶ Cable Broadcasting

↓ Users are eager in watching broadcast service anywhere they are

Users are eager in watching broadcast service anytime they are available by storing and scheduling contents



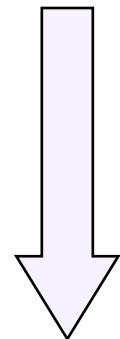
▶ Mobile Broadcasting

▶ IPTV Broadcasting

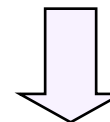
Need for feedback on the contents from content providers or users arise



▶ IPTV Broadcasting with Return Channel



Need for receiving the specific contents either in dedicated manner or in shared manner arise

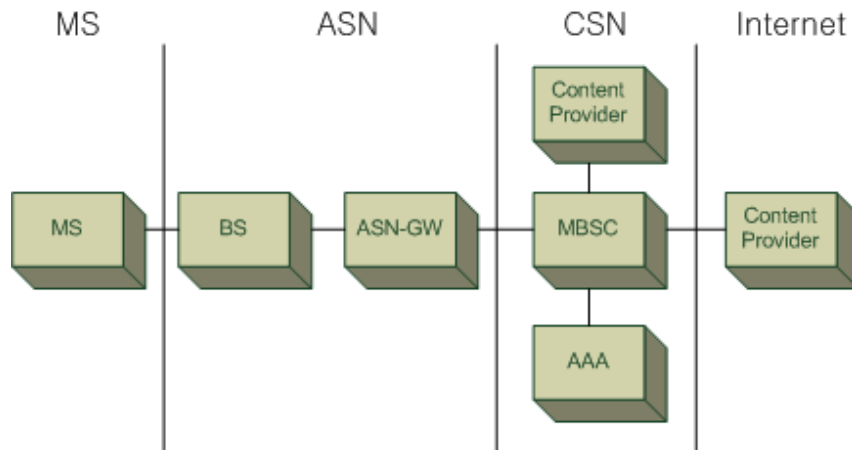


▶ Mobile IPTV Broadcasting

- 3GPP MBMS
- 3GPP2 BCMCS
- **Mobile WiMAX Multicast Broadcast Service (MBS)**

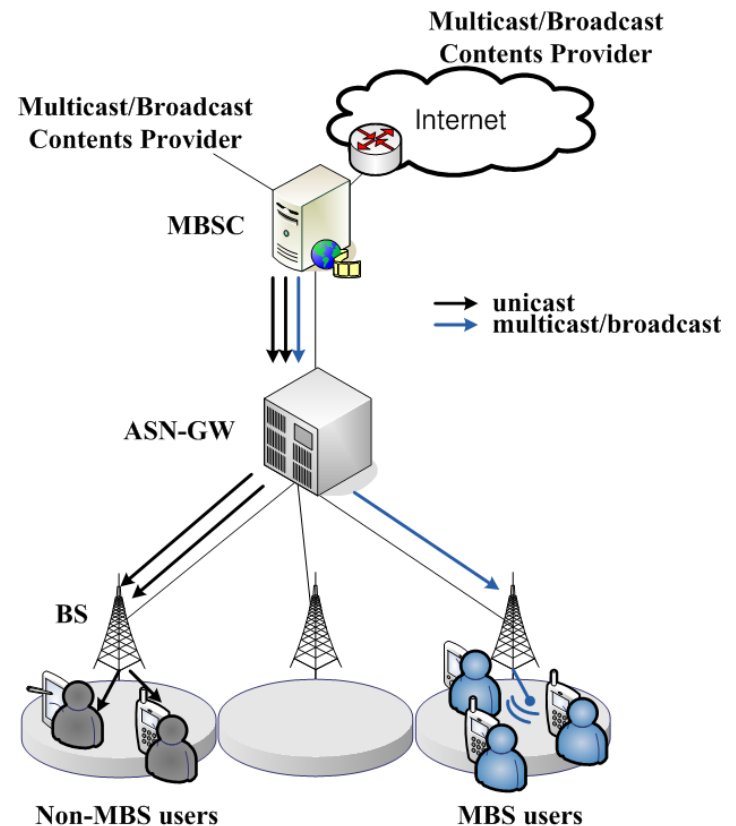
# Mobile WiMAX MBS

## Network Reference Model



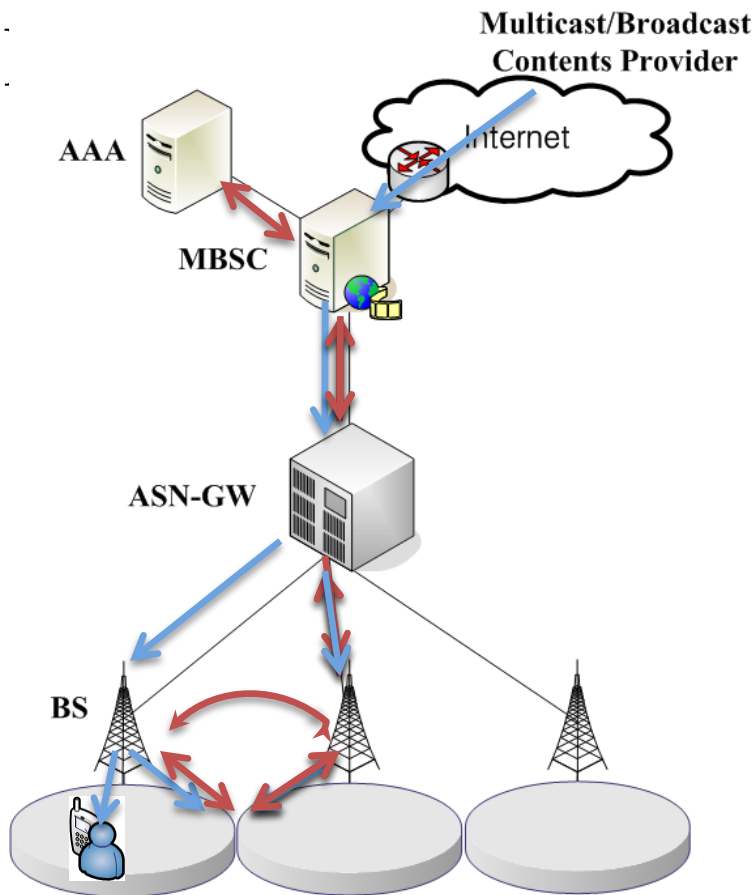
- MS - Mobile Station
- BS - Base Station
- ASN - Access Service Network
- ASN-GW - Access Service Network Gateway
- CSN - Connectivity Service Network
- MBSC - Multicast Broadcast Service Controller
- AAA - Authentication, Authorization, Accounting

## Deployment Scenario

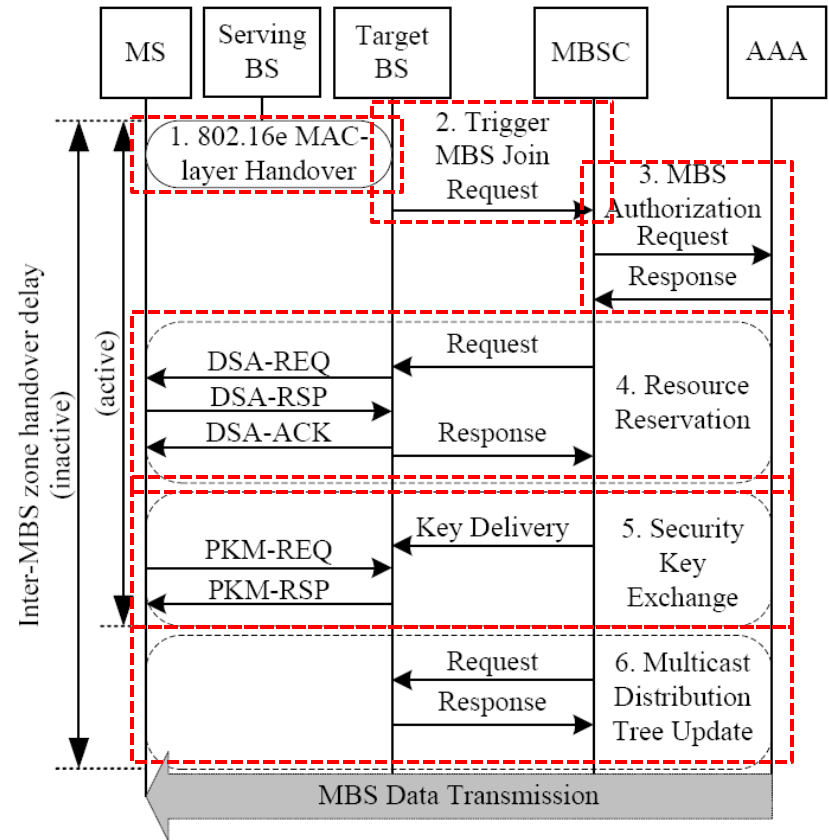


# Mobility Issue

► “Service disruption” due to

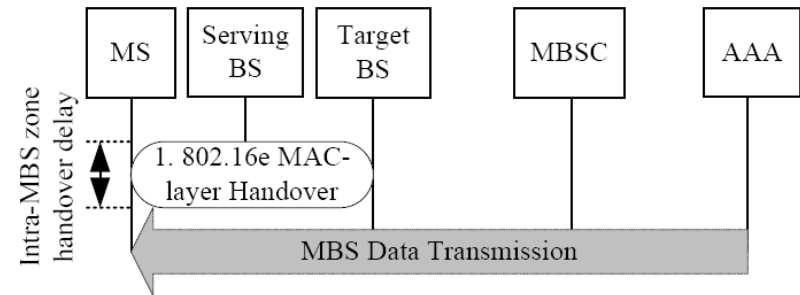
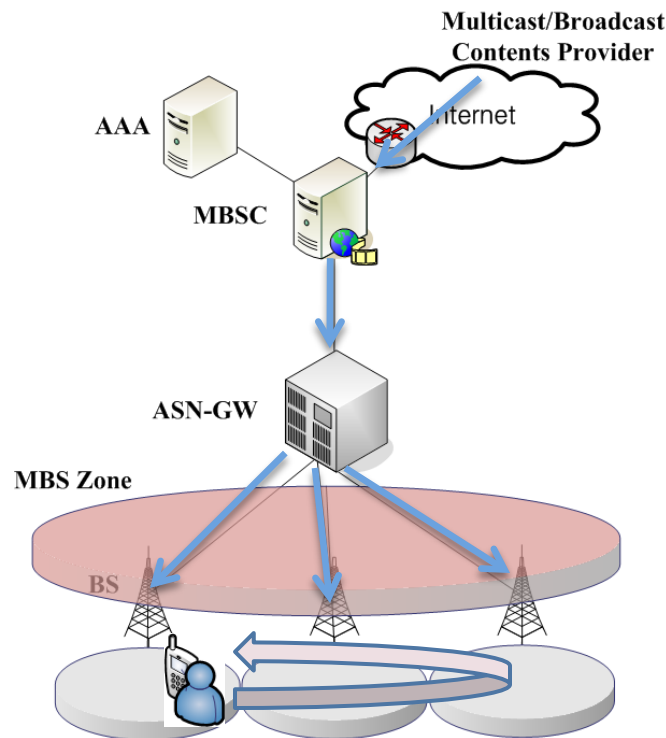


Break the connection!



# MBS Zone

- ▶ IEEE 802.16e defines an MBS zone, which is a group of adjacent BSs transmitting the same MBS contents.



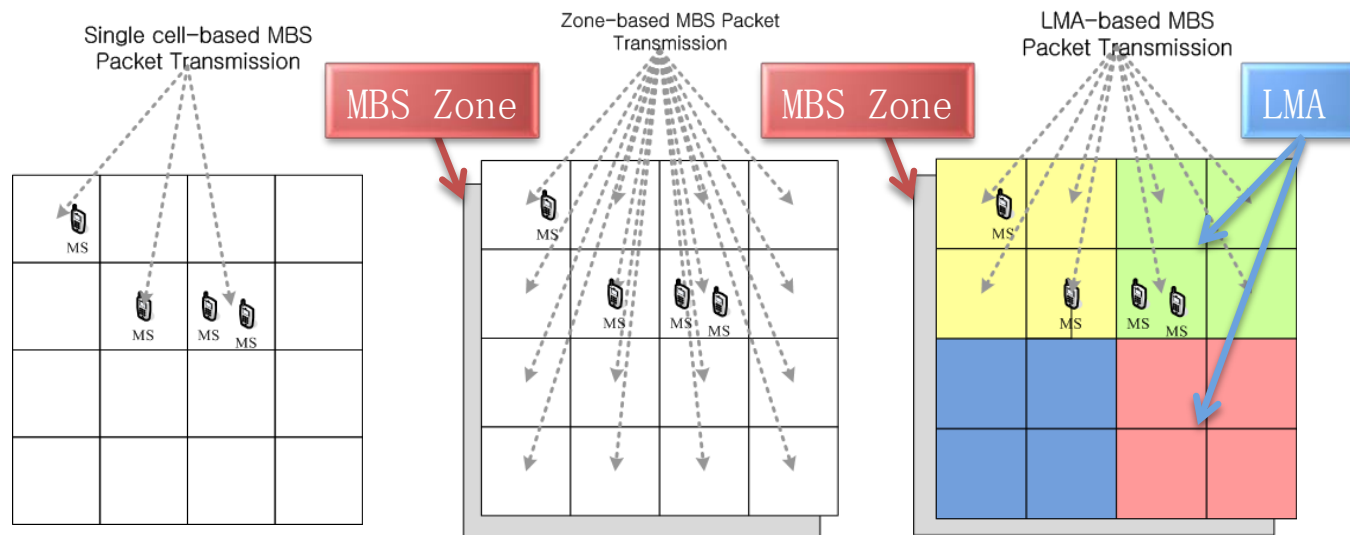
Intra-MBS zone handover delay

# Characteristics of MBS Zone

- ▶ Handover delay is minimized while MSs are moving within an MBS zone.
  - ▶ The larger MBS zone provides the better quality of MBS.
- ▶ The handover delay cutback comes at the cost of the amplified MBS traffic.
  - ▶ Bandwidth may be wasted since all BSs in the same MBS zone transmit MBS packets regardless of the existence of MBS users.
- ▶ Handover Delay vs. Wireless Bandwidth Usage
  - ▶ Two conflicting criteria in MBS.

# LMA-based MBS handover

- ▶ Location Management Area (LMA)
  - ▶ An MBS zone is partitioned into multiple LMAs.
    - ▶ A single BS  $\leq$  LMA  $\leq$  A whole MBS zone
  - ▶ Transmit MBS data packets only to the LMAs in which MBS users currently reside.
    - ▶ Save bandwidth by utilizing the location information of MBS users.

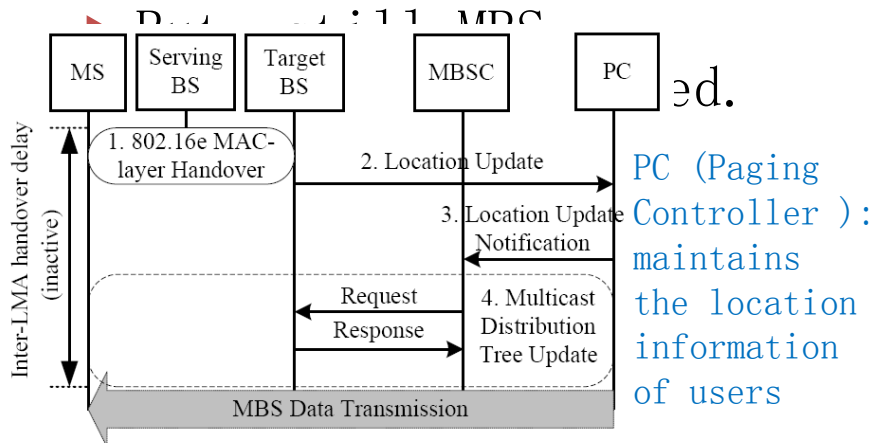
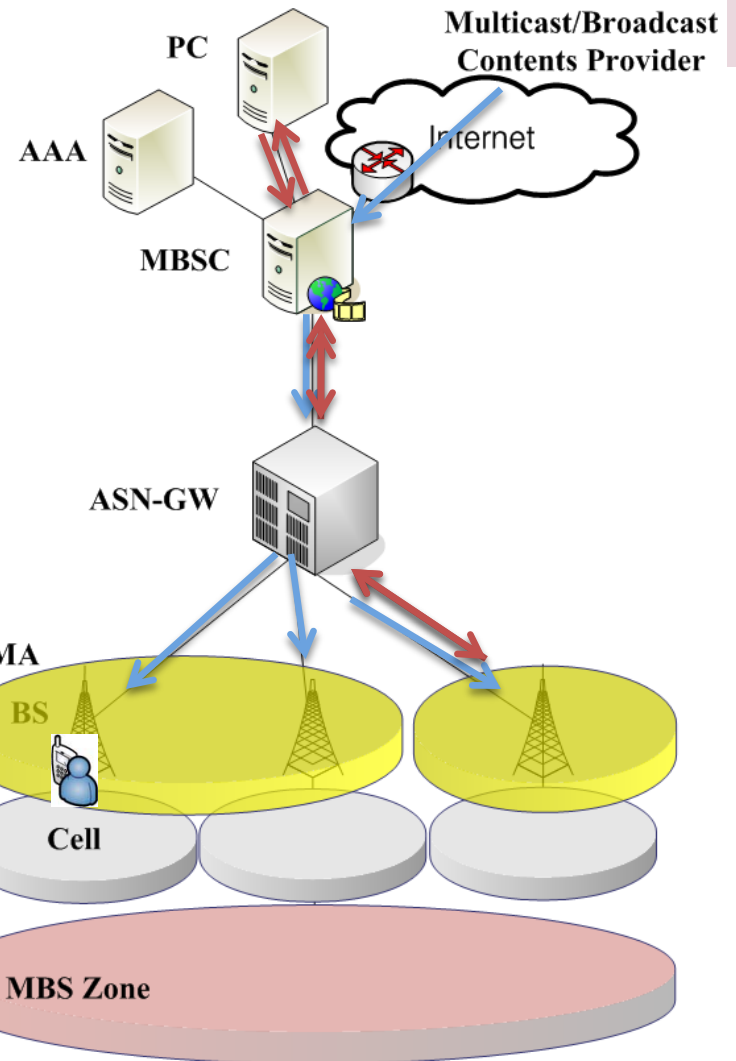


# Delay of Inter-LMA Handover (1/2)

- ▶ Inter/intra-LMA handovers still belong to the intra-MBS zone handover.
  - ▶ No need to create new connection.
  - ▶ No need to make new security association
- ▶ The delay of intra-LMA handover = the delay of intra-MBS zone handover
- ▶ Inter-LMA handover delay depends on the existence of MBS users in the target LMA.
  - ▶ If there is an MBS user in the target LMA (Active LMA),
    - ▶ MBS traffic is already available
    - ▶ No additional signaling is required
    - ▶ Same as the delay of an intra-LMA handover.

# Delay of Inter-LMA Handover (2/2)

- ▶ If there is no user in the target LMA (Inactive LMA),
  - ▶ After multicast distribution tree update between MBSC and BSs, MBS traffic can be received.



Inter-LMA handover delay (inactive)

# Performance Analysis

## ► Assumptions

### ► Residence time

- The MBS session duration time follows an exponential distribution with mean  $1/\lambda_s$ .
- The residence times in an MBS zone, an LMA, and a cell follow exponential distributions with mean  $1/\lambda_z$ ,  $1/\lambda_l$ , and  $1/\lambda_c$ , respectively ( $1/\lambda_z \geq 1/\lambda_l \geq 1/\lambda_c$ ).

### ► Session popularity

$\beta_i$  can be drawn from a cut-off Zipf-like distribution  $\beta_i = \frac{\Omega}{i^\alpha}$ , where  $\Omega = \left( \sum_{i=1}^S \frac{1}{i^\alpha} \right)^{-1}$ .

$$\lambda_i = \beta_i \lambda^*.$$

### ► User distribution

Let  $p(k, i, R)$  denote the probability that there are  $k$  users subscribing the  $i$ th most popular session in a region with area  $A$ . We have

$$p(k, i, A) = \frac{(\lambda_i A)^k e^{-\lambda_i A}}{k!}. \quad (8)$$

# Disruption Time (1/2)

## ▶ Disruption Time in the original MBS zones (MZ)

### ▶ Random variables:

▶ Z1: number of inter-MBS zone handovers (inactive zone)

▶ Z2: number of inter-MBS zone handovers (active zone)

▶ Z3: number of intra-MBS zone handovers

▶ The average service disruption time for i-th pop  $T_{MZ,i} = E[Z_{1,i}] \cdot D_{Z1} + E[Z_{2,i}] \cdot D_{Z2} + E[Z_{3,i}] \cdot D_{Z3}$  are

$$\begin{aligned} \text{unit ha} = & \frac{\lambda_z}{\lambda_s} [e^{-\lambda_i A_z} \cdot D_{Z1} + (1 - e^{-\lambda_i A_z}) \cdot D_{Z2}] \\ & + \frac{(\lambda_c - \lambda_z)}{\lambda_s} \cdot D_{Z3}. \end{aligned} \quad (15)$$

# Disruption Time (2/2)

## ▶ Disruption Time in the LMA-based MBS zones (LMA)

### ▶ Random variables:

- ▶ L1: number of inter-LMA handovers (inactive LMA)
- ▶ L2: number of inter-LMA handovers (active LMA)
- ▶ L3: number of intra-LMA handovers

### ▶ The average service disruption time for $i$ -th popular session in LMA ( $D_{L1}$ , $D_{L2}$ , and $D_{L3}$ are

$$\begin{aligned} \text{uni } T_{LMA,i} &= E[Z_{1,i}] \cdot D_{Z1} + E[Z_{2,i}] \cdot D_{Z2} + E[L_{1,i}] \cdot D_{L1} \\ &+ E[L_{2,i}] \cdot D_{L2} + E[L_{3,i}] \cdot D_{L3} \end{aligned} \quad (16)$$

$$\begin{aligned} &= \frac{\lambda_z}{\lambda_s} [e^{-\lambda_i A_z} \cdot D_{Z1} + (1 - e^{-\lambda_i A_z}) \cdot D_{Z2}] \\ &+ \frac{(\lambda_l - \lambda_z)}{\lambda_s} [e^{-\lambda_i A_l} \cdot D_{L1} + (1 - e^{-\lambda_i A_l}) \cdot D_{L2}] \\ &+ \frac{(\lambda_c - \lambda_l)}{\lambda_s} \cdot D_{L3}. \end{aligned} \quad (20)$$

# Bandwidth Usage

- ▶ Bandwidth Usage = (the number of cells transmitting MBS packets) / (the total number of cells in a network)
- ▶ Bandwidth usage  $U_{MZ,i} = (1 - p(0, i, A_z))$  session in MZ
- ▶ Bandwidth usage for  $i$ -th popular session in LMA

$$U_{LMA,i} = (1 - p(0, i, A_l))$$

▶  $A_z$  : area of MBS zone

▶  $A_l$  : area of LMA

# Unit Handover Delay Analysis

## ▶ Unit Handover Delay

- ▶  $D_{Z1}$  : inter-MBS zone handover delay (inactive LMA)
  - ▶  $D_{Z2}$  : inter-MBS zone handover delay (active LMA)
  - ▶  $D_{Z3}$  : intra-MBS zone handover delay
  - ▶  $D_{L1}$  : inter-LMA handover delay (inactive LMA)
  - ▶  $D_{L2}$  : inter-LMA handover delay (active LMA)
  - ▶  $D_{L3}$  : intra-LMA handover delay
- $T_{A-B}$ : The average time required to send a message between nodes A and B.
  - $T_{ho}$ : The average time required to complete an IEEE 802.16e MAC-layer handover.
  - $P_{auth}$ : The average processing time to perform the MBS Authorization at AAA.
  - $P_{conn}$ : The average processing time to establish a multi-cast connection at MS.
  - $P_{key}$ : The average processing time to set up a security key at MS.
  - $P_{mu(A)}$ : The average processing time to perform a multicast distribution update at node A.
  - $P_{lu(A)}$ : The average processing time to perform a location update at node A.

## Handover delays

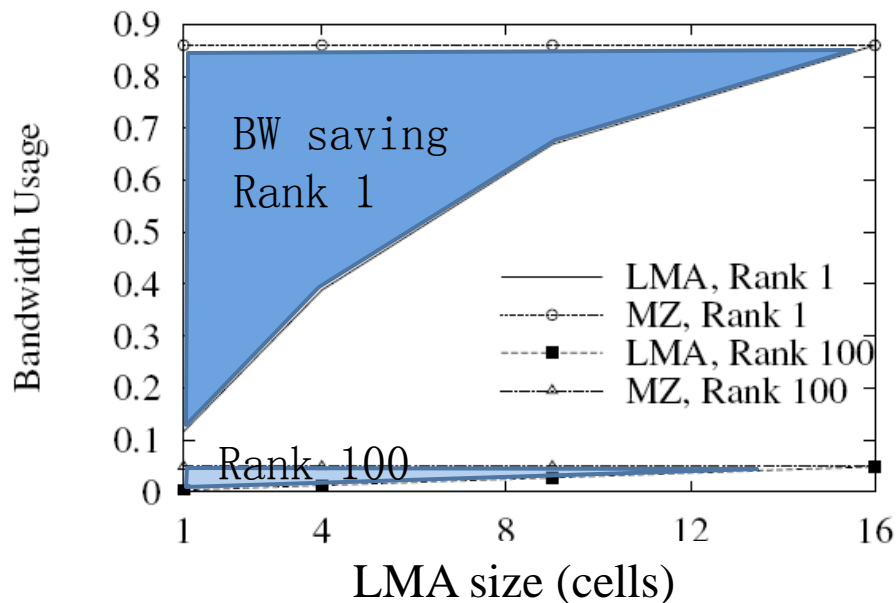
Delay		Expression
Type	Step	
$D_{Z1}$	1	$T_{ho}$
	2	$T_{BS-MBSC}$
	3	$2T_{MBSC-AAA} + P_{auth}$
	4	$2T_{BS-MBSC} + 2T_{BS-MS} + P_{conn}$
	5	$T_{BS-MBSC} + 2T_{BS-MS} + P_{key}$
	6	$2T_{BS-MBSC} + P_{mu(MBSC)} + P_{mu(BS)}$
$D_{Z2}$	1	$T_{ho}$
	2	$T_{BS-MBSC}$
	3	$2T_{MBSC-AAA} + P_{auth}$
	4	$2T_{BS-MBSC} + 2T_{BS-MS} + P_{conn}$
	5	$T_{BS-MBSC} + 2T_{BS-MS} + P_{key}$
$D_{Z3}$	1	$T_{ho}$

Delay		Expression
Type	Step	
$D_{L1}$	1	$T_{ho}$
	2	$T_{BS-PC} + P_{lu(PC)}$
	3	$T_{MBSC-PC} + P_{lu(MBSC)}$
	4	$2T_{BS-MBSC} + P_{mu(MBSC)} + P_{mu(BS)}$
$D_{L2}$	1	$T_{ho}$
$D_{L3}$	1	$T_{ho}$

# Effect of the LMA/MBS Zone Size (1/2)

## ▶ Bandwidth Usage

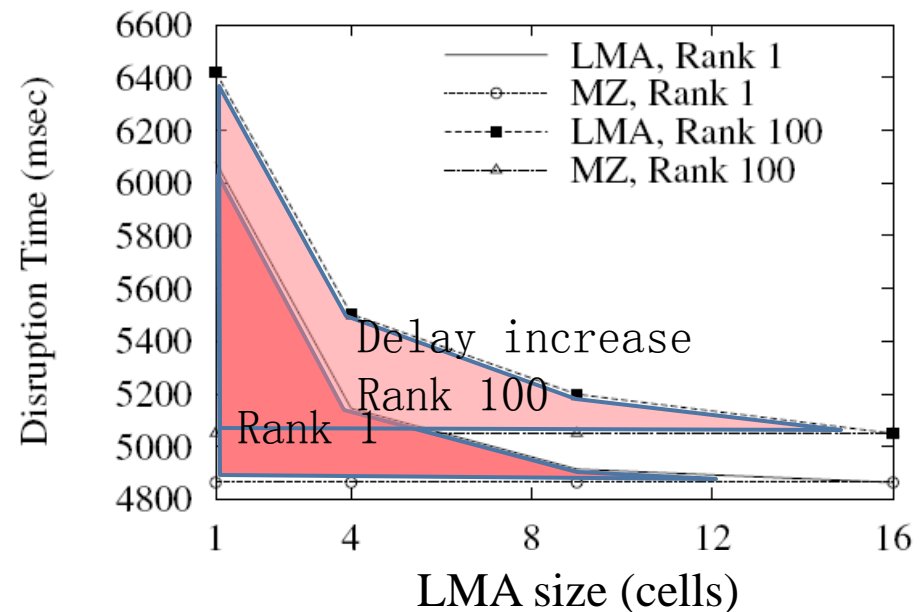
- ▶ LMA substantially outperforms MZ.



The size of MBS zone : 16 cells

## ▶ Disruption Time

- ▶ Delay of LMA increases up to 25% (rank 1) or 27%

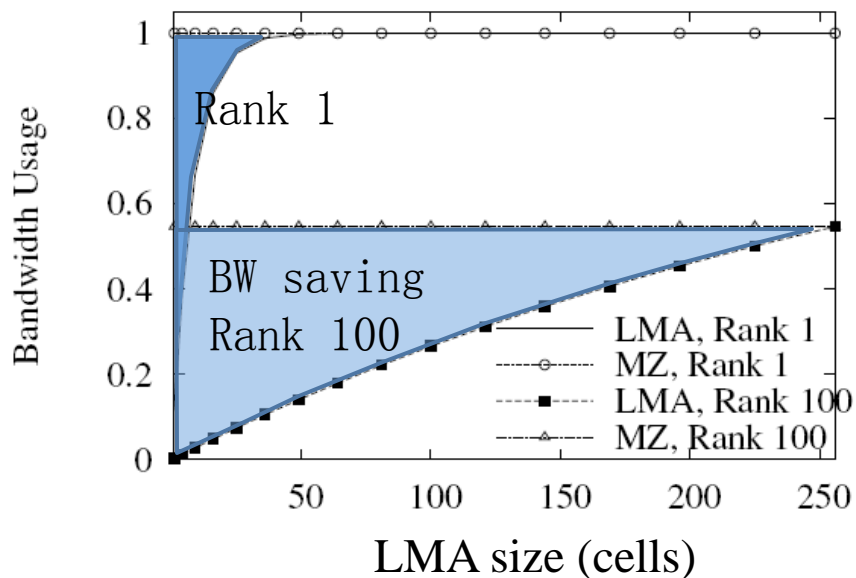


( $\alpha=0.8$ ,  $\lambda^*=1$  user/cell, and  $v=60$  km/h)

# Effect of the LMA/MBS Zone Size (2/2)

## ▶ Bandwidth Usage

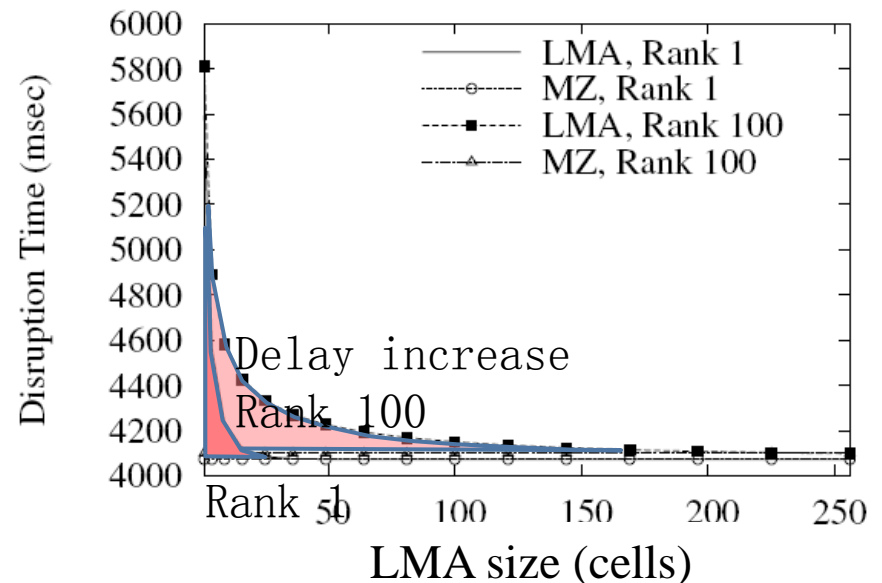
- ▶ LMA substantially outperforms MZ.



The size of MBS zone : 256 cells

## ▶ Disruption Time

- ▶ Delay of LMA increases up to 37% (rank 1) or 42% (rank 100)



( $\alpha=0.8$ ,  $\lambda^*=1$  user/cell, and  $v=60$  km/h)

# Bandwidth Delay Metric (BDM)

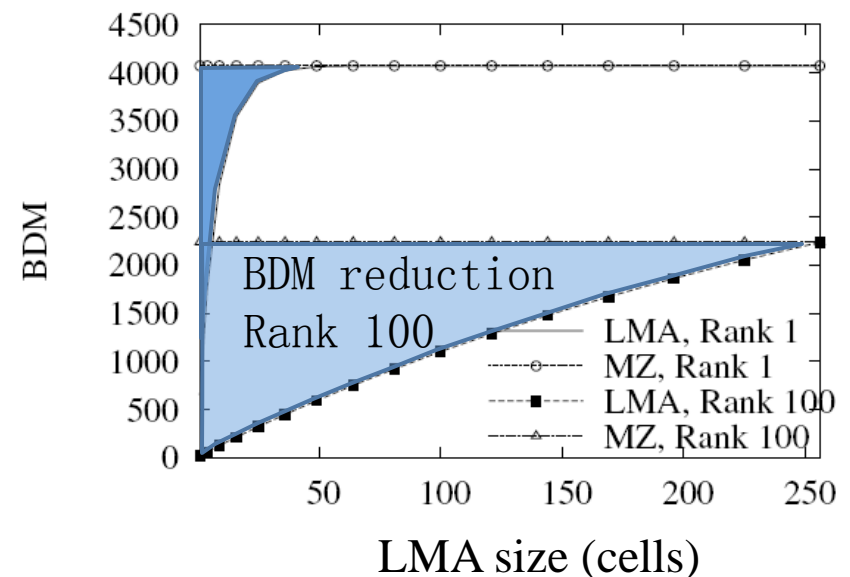
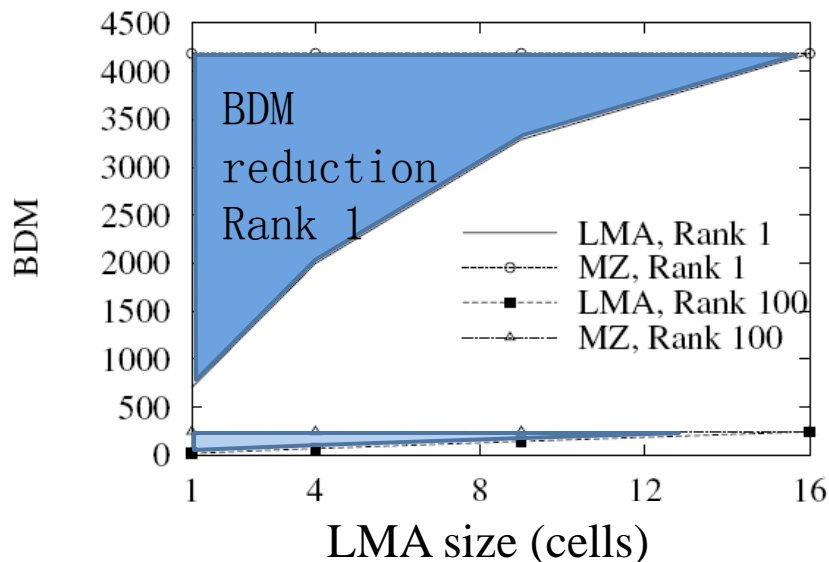
## ▶ 16-cell MBS zone

## ▶ 256-cell MBS zone

▶ Generally LMA exhibits lower BDM than MZ.

▶ Impact of reducing bandwidth usage is greater than that of increasing delay.

▶ For small (large) MBS zones, the higher (lower) ranker session highlights the advantages of LMA.

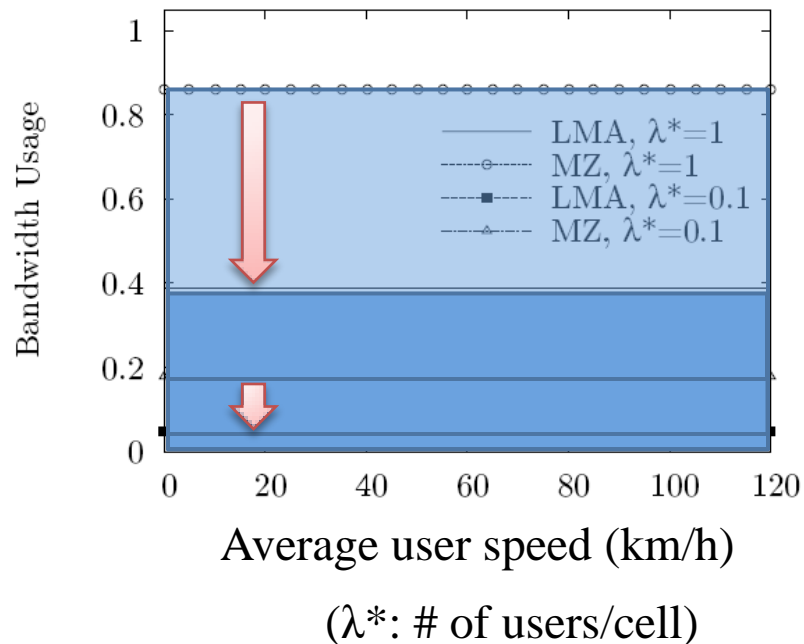


( $\alpha=0.8$ ,  $\lambda^*=1$  user/cell, and  $v=60$  km/h)

# Effect of the average velocity

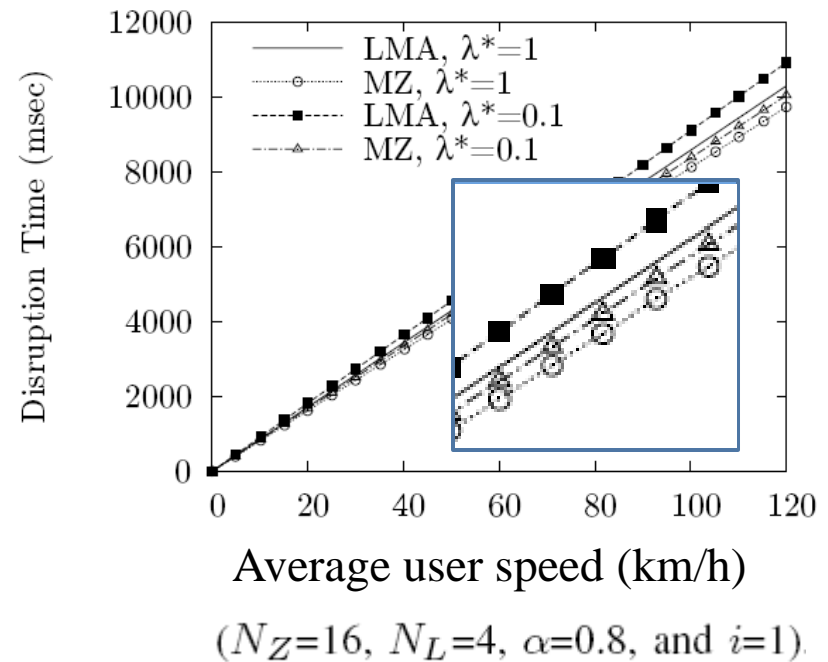
## ▶ Bandwidth Usage

- ▶ Depends on not user speed, but user distribution.



## ▶ Disruption Time

- ▶ LMA is slightly worse than MZ
- ▶ 6% or 9% increase



# Conclusion

- ▶ Cell-based broadcast/multicast service
  - ▶ suffers from frequent service disruption.
- ▶ MBS zone
  - ▶ MZ minimizes delay, while the waste of wireless bandwidth increases.
- ▶ LMA-based MBS
  - ▶ Our LMA reduces substantially the bandwidth usage compared to MZ, while the service disruption time increases slightly.