Radio Resource Management in MBMS Enable 3G and Beyond Mobile Cellular Networks

Christophoros Christophorou (UCY)
Andreas Pitsillides (UCY)
Nicola Benucci (3G, UK)

http://www.NetRL.ucy.ac.cy
Outline

• Multimedia Broadcast Multicast Service (MBMS) System
  – Multicast Distribution Tree and MBMS content delivery
  – 3G Multicast Vs MBMS
• Radio Resource Management (RRM)
  – RRM Challenges in MBMS
  – RRM Challenges in MBMS – Issues under consideration
• MBMS Future Trends
• Current work
• Future work
• Conclusions
Multimedia Broadcast Multicast Service (MBMS) System

- MBMS (Multimedia Broadcast Multicast Service) provided UMTS Network with a powerful tool to offer broadcast and multicast services (e.g. Mobile TV) efficiently, with the main benefit of **significant Core- and Radio- resource saving**.

  - Introduced in UMTS Release 6 specifications

  - With MBMS the same stream of data is transmitted from a single source entity to multiple recipients allowing the **Core-Network** and **Radio-Network resources** to be **shared**, with an **emphasis** on **radio resource efficiency**.
Multicast Distribution Tree and MBMS content delivery

- After an MBMS service is announced, UE must initiate a **Join procedure** in order to register itself to MBMS Service Group.
  - When procedure finished each node in **Core Network** has a list of downstream nodes to know where it should forward data:
    - GGSN list contains all SGSNs to which data should be forwarded;
    - SGSN list contains all RNCs to which data should be forwarded.
  - results in set-up of Multicast distribution tree, but does not result in the establishment of bearer plane (resources are NOT allocated yet).

Multicast Tree is constructed up to the RNCs!!!

How is the MBMS Service content going to be distributed to the MBMS users in the RAN???

This is RNC’s issue taken care after MBMS Session Start!!
When MBMS content ready to be distributed, **MBMS Session Start Procedure is initiated:**
- a request to **activate all necessary bearer resources** in the **Core Network** and the **UTRAN**.

In **UTRAN** for **radio resource efficiency**, two types of transmission modes can be used for the distribution of MBMS Service content in a Cell:
- **Point-to-Point Transmission** mode (one DCH established for each UE in the Cell)
- **Point-to-Multipoint Transmission** mode (one FACH covering the whole Cell and shared by all the UEs within)

Which transmission mode is going to be adopted is decided by the RNC (according to standards based on a UE Counting Threshold).

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**Multicast Distribution Tree and MBMS content delivery**

- One replication of the MBMS Content transmitted using FACH to all the UEs in the Cell
- Two replications of the MBMS Content transmitted using one DCH for each UE in the Cell
- One Common Channel shared by all the UEs in the Cell
- It’s up to RNC to replicate and distribute the data stream accordingly
- One Dedicated Channel for each UE in the Cell

**UEs joined to the same MBMS service**
3G Multicast Vs MBMS

Existing Multicast approach in 3G Networks prior to MBMS Vs MBMS approach used
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Radio Resource Management (RRM)

• RRM in Wireless\Cellular Networks is a set of algorithms devoted to:
  – Achieve optimal usage of the radio interface resources
  – Guarantee Quality of Service (QoS)
  – Maintain the planned coverage area
  – Offer high capacity

• RRM involves strategies and algorithms for controlling parameters such as
  – Transmit power,
  – Channel (radio resource) allocation,
  – Handover criteria
  – Link Adaptation (Modulation and error Coding scheme used)
RRM Challenges in MBMS

• To provide MBMS services many technical challenges:
  – Mobility and Handoff
    • mobile node should **seamlessly handover** to a new Cell or another Radio Access Network technology during reception of an MBMS service.
  – Radio Resource Allocation
    • Efficient allocation during an MBMS Service distribution in the Radio Access Part of a heterogeneous network environment is of great importance in order to **increase capacity** and moreover revenue.
Challenge 1: Handover Control in UTRAN

Introduction of MBMS bearer services in 3G Networks introduced handover between different kind of resources (handovers from P-t-P (DCH) to P-t-M (FACH) and vice versa transmission mode Cells)

3GPP did not specified a specific algorithm for these kind of handovers!!!

- Existing handover approach for triggering a handover, as described in TR 25.922 is as follows:
  - The UE performs a handover when Common Pilot Channel (CPICH) signal strength (Ec/No) of a Neighbouring Cell (Cell 2) exceeds CPICH signal strength (Ec/No) of Current Cell (Cell 1) within a predefined threshold (AS_Rep_Hyst).

- Existing handover algorithm implemented for legacy UMTS services
  - Based only on DCHs characteristics where power control can be applied
  - Power control is not applied to FACH
    - Fixed amount of transmission power (capacity) allocated so as to cover whole Cell.
    - Leaving its coverage area will result in progressive signal strength degradation and finally total ‘collapse’ of the throughput.
  - Efficient for handovers between DCHs but inefficient for handovers between FACH and DCH
RRM Challenges in MBMS – Issues under consideration (Previous work)

- Applied existing handover algorithm to execute a “from P-t-M to P-t-P” and vice versa handovers but due to the time-varying interference (No) caused in the Cells the handover executed either:
  - Inside FACH coverage area (Case 1)
    - Underutilization of FACH resources
  - Outside FACH coverage area (Case 2).
    - Degradation on the MBMS Service QoS

A new handover approach for executing these types of handovers is essential!!!
Solution proposed:

- **Main idea:** Handover should be executed (switch from DCH to FACH and vice versa) at a point:
  - As close as possible to the P-t-P BS (in order to reduce the total downlink power in the P-t-P Cells to the minimum required)
  - But not outside of the FACH effective coverage (since once outside its coverage area will result in degradation of the FACH received signal strength and even worse the loss of the connection).

- **This point can be depicted as the FACH coverage limit (P-t-M Cell’s Coverage limit)**
  - The point where the FACH provides the requested quality with the “minimum” Required Eb/No essential for correctly detecting the signal.
    - Required Eb/No for a Service denotes value that Signal energy per bit (Eb) divided by interference and noise power density (No) should have for achieving a certain BER so as to satisfy required QoS.
With existing handover approach currently implemented on UEs, main input in making handover decision is CPICH signal strength (Ec/No) received by UE from the BSs within reach.

Our approach uses same measurable input for triggering the handover (the Received Signal strength (Ec/No) of the CPICH transmitted from the P-t-M BS):

- The “FACH Required Eb/No” is equivalently expressed as a “CPICH Required Ec/No” value.
  - The function of CPICH in Cell, as defined by 3GPP, is to aid channel quality estimation at the Terminal for the dedicated channel, and to provide channel quality estimation reference for the common channels.
  - The “CPICH Required Ec/No” for each MBMS service is pre-estimated by the network operator during Radio Network Planning and made known to the UEs during the installation of the MBMS service application on the UEs.

Thus, the aim of the proposed approach is to execute the handover when the Measured CPICH Ec/No becomes equal to the “CPICH Required Ec/No” value.
RRM Challenges in MBMS – Issues under consideration (Previous work)

• In order to accommodate the handover delay time caused from the time the handover is triggered until the UE switches channels we introduced the “Pre-trigger Predictor (PP)” parameter.

• The PP is estimated periodically by the UE based on two parameters:
  – CPICH Alteration Rate (how fast the CPICH signal strength is increasing or decreasing)
    • Estimated by the UE during its mobility
  – Handover Delay Time
    • Pre-estimated by the network operator during Radio Network Planning and made known to the UEs during the installation of the MBMS service application.
      – The estimated value will be that much in order ensure the execution of the handover inside the FACH guaranteed coverage but not far enough from the FACH coverage limit.

• In case the “CPICH Required Ec/No” or “Handover Delay time” values change due to some reason, it is up to the application installed on the UEs to perform an update procedure (before the MBMS session start) in order to acquire any updates made.
The value of the “Pre-trigger Predictor” parameter along with the “CPICH Required Ec/No” value will form the “MBMS Handover Trigger Threshold (MHTT)” which indicates to the UE the exact time of triggering the handover in order to be efficiently executed on the FACH coverage limit.

- The UE during its mobility measures the P-t-M BS’s CPICH Ec/No and when it equals the “MBMS Handover Trigger Threshold” the handover is triggered.

- Having in mind that with the proposed approach the main input in making the handover decision is only the CPICH signal strength (Ec/No) received from the received P-t-M BS, the MHTT value will be equal to:
  - The Required CPICH Ec/No – PP if the UE is likely going to execute a “from P-t-P (DCH) to a P-t-M (FACH)” handover.
  - The Required CPICH Ec/No + PP if the UE is likely going to execute a “from P-t-M (FACH) to a P-t-P (DCH)” handover.
RRM Challenges in MBMS – Issues under consideration (Previous work)

Simulation Results: Proposed Approach Vs Existing 3 GPP Handover Approach

Scenario 1: 10 MBMS users are moving from a P-t-P Cell towards a P-t-M Cell and receiving a 64 Kbits/sec MBMS Streaming video, in a Pedestrian Outdoor environment.

Scenario 2: 10 MBMS users are moving from a P-t-M Cell towards a P-t-P Cell and receiving a 64 Kbits/sec MBMS Streaming video, in a Pedestrian Outdoor environment.

Gains obtained:
- Capacity enhancement
- MBMS Service QoS improvement
RRM Challenges in MBMS – Issues under consideration (Previous work)

Conference papers published:


Journal paper published:

Challenge 2: Radio Resource allocation in UTRAN

According to the specs currently defined by the 3GPP, the RNC on a per Cell basis counts the number of the MBMS users present in a cell and based on a **UE Counting threshold** (selection based on the worst case scenario – all the MBMS users are near the Cell’s edge) decides the transmission mode (either P-t-P or P-t-M transmission mode) that is going to be adopted within the specific Cell.

Is this really efficient???

What if all the MBMS users are located near the BS and their total number is equal to or greater than the UE Counting Threshold???

The existing approach will select a P-t-M Transmission mode and establish one FACH channel covering the whole Cell allocating **2.02 watts** while the actual Power Required if a P-t-P transmission mode is adopted is only **0.06 watts**.

This approach results in considerable capacity waste!!!

Another radio resource allocation approach is required!!!
RRM Challenges in MBMS –
Issues under consideration (Previous work)

Solution Proposed:

• **Main idea:** Instead of using a UE Counting threshold, the switching criteria between P-t-P and P-t-M transmission modes relies on the instantaneous total downlink power required by each transmission mode (*Power Counting Threshold*).

• In order to identify the optimum transmission mechanism for the distribution of the MBMS service at every given time, what the RNC needs to determine is the total power required within a cell if a P-t-P transmission mode is adopted
  – Note that the power required for a P-t-M transmission is fixed and predetermined by the network operator

• The Proposed Power counting approach is divided into two phases:
  – Initial Selection of Transmission mode
  – During the MBMS Session
RRM Challenges in MBMS – Issues under consideration (Previous work)

- **Initial selection of transmission mode:**
  - The RNC broadcasts a notification message for Power Counting Request to the UEs in the Cell
  - The UEs respond to this message by reporting back to the RNC the CPICH received signal strength (CPICH Ec/No)
    - With this information the RNC indicates the pathloss experience by each UE
  - The RNC by using the following formula estimates the total power required for a P-t-P transmission mode
    \[
    P_{Tx}^{Tot} = \sum_{i=1}^{N} \left[ \frac{R \times (Eb/No)_{DL}}{W} \times \frac{CPICH_{Tx}}{CPICH_{(Eb/No)}_i} - \alpha \times P_{Car} \right]
    \]
    Where:
    - \( N \) is the total number of UEs receiving the MBMS Service in the P-t-M Cell
    - \( R \) is the MBMS Service bit rate
    - \( (Eb/No)_{DL} \) is the DL planned Eb/No value set during the Radio Network Planning (RNP) for achieving a certain Bit Error Rate as to satisfy the required QoS
    - \( W \) is the chip rate (3.84 Msps)
    - \( CPICH_{(Eb/No)}_i \) is the measurement report received from UE \( i \)
    - \( CPICH_{Tx} \) is the initial power used for the transmission of the CPICH
    - \( \alpha \) is the orthogonality factor
    - \( P_{Car} \) is the carrier power measured at the Node_B and reported to the RNC
  - If the amount of power estimated for a P-t-P transmission is lower than the amount of power required for a P-t-M transmission then the Cell is initialized to a P-t-P transmission mode Cell
    - One DCH is established for each UE in the Cell
  - If the amount of power estimated for a P-t-P transmission is greater than or equal to the amount of power required for a P-t-M transmission then the Cell is initialized to a P-t-M transmission mode Cell
    - One FACH is established and shared by all the UEs in the Cell
RRM Challenges in MBMS – Issues under consideration (Previous work)

During the MBMS Session:
- The RNC, due to changes that can occur during the MBMS session, periodically commands a Power re-counting Request
  - If P-t-P transmission mode is used in the Cell
    - It is easy to calculate the instantaneous total downlink power of the DCH channels since the Base Station (BS) is aware of the downlink transmitted power used for each Dedicated Channel.
    - Thus the power summation of all channels participating in P-t-P mode is periodically reported to the RNC, which then checks if the condition for switching to P-t-M transmission mode is met.
      » Total DL Transmission power for P-t-P > Total DL Transmission power for P-t-M
    - If the condition is met, the RNC establishes a FACH that will be shared by all the MBMS users in the Cell and releases the all the DCHs
  - If P-t-M transmission mode is used in the Cell
    - The RNC periodically broadcast a notification message for Power Re-Counting Request to the UEs in the Cell.
    - The UEs respond to this message by reporting back to the RNC the CPICH received signal strength (CPICH Ec/No)
    - The RNC by using the same formula used during the initialization of a Cell, estimates the amount of power required for a P-t-P transmission and checks if the condition for switching to P-t-P transmission mode is met.
      » Total DL Transmission power for P-t-P < Total DL Transmission power for P-t-M
    - If the condition is met, the RNC establishes one DCH for each MBMS user in the Cell and releases the FACH.
With the first scenario, where the UEs are located near the Cell's edge (Cell 2), both algorithms execute the channel switching efficiently. However, in the case with UE Counting is that the transmission mode remains in P-t-M since the number of the UEs meets the condition to have a P-t-M transmission mode. This causes a significant amount of capacity waste since the UEs during their mobility towards the BS reduce the amount of power required considerably, making the use of a FACH redundant.

The proposed algorithm, due to its capability to dynamically adapt to the continuously varying Cell conditions, selects the most efficient transmission mode, resulting in significant power savings, thus maximizing capacity.

With the second scenario, where the UEs are located near the Base Station, the proposed algorithm, in contrast with the existing one, not only achieves efficient capacity, but also eliminates the need of channel switching, thus resulting also in less signalling overhead.
RRM Challenges in MBMS – Issues under consideration (Previous work)

Conference paper published:

RRM Challenges in MBMS – Issues under consideration (Previous work)

• Challenge 3: MBMS Service Provision in UTRAN

As currently specified by 3GPP, MBMS services can be provided in a cell either by Point-to-Point (PtP) or Point-to-Multipoint (PtM) transmission mode, but not both at the same time. Is this really efficient???

The inefficiencies of the current 3GPP Specified MBMS Service provision approach are shown in the following scenarios.
Deficiencies of Current 3GPP Specified MBMS service provision approach:

• Scenario 1: All the MBMS users are distributed at distance closer than 500 meters from the BS and a P-t-M transmission mode is justified.

Current 3GPP specified approach - One FACH established covering the whole cell’s area (1000 meters coverage → **2.0222 watts required**)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Propagation Environment used</td>
<td>Pedestrian outdoor Environment</td>
</tr>
<tr>
<td>Shadow Fading Standard Deviation</td>
<td>10dBs</td>
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<tr>
<td>MBMS application (multicast traffic sent)</td>
<td>Streaming video (64 Kbps)</td>
</tr>
<tr>
<td>Transmission Time Interval (TTI)</td>
<td>20ms</td>
</tr>
<tr>
<td>Cell radius</td>
<td>1000 meters</td>
</tr>
<tr>
<td>Channel coding</td>
<td>Convolutional</td>
</tr>
<tr>
<td>Coding Rate</td>
<td>1/3</td>
</tr>
<tr>
<td>Downlink Over to other-cell interference factor at the cell’s edge</td>
<td>1.78</td>
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Reduce power devoted to FACH to cover only the area where the MBMS users are located.

Optimal approach: FACH is dynamically adjusted to cover only the area where all the MBMS users are located (500 meters coverage → **0.1263 watts required**)

1.8959 watts less!!!

Dynamic adaptation of FACH’s coverage is considered essential to avoid any excessive use of power!!!
RRM Challenges in MBMS – Issues under consideration (Previous work)

Deficiencies of Current 3GPP Specified MBMS service provision approach:

- **Scenario 2:** The majority of MBMS users are located at distance closer than 500 meters from the BS and two UEs (UE 1 & UE 2) located near the cell’s edge are frequently leaving and re-joining the MBMS service causing a repetitive transmission mode switching between P-t-M and P-t-P.

**Optimal Approach**

- Use one FACH for supporting the MBMS users near the BS and DCHs for UE 1 and UE 2.
- The signaling and processing effort is significantly reduced, since every time UE 1 and UE 2 leave/re-join the MBMS session, only 2 DCHs will be released/re-established instead of for all the MBMS users.

Current 3GPP specified approach: Switch from P-t-M to P-t-P transmission mode and vice versa when the two UEs leave/re-join the MBMS session.

Significant signaling traffic and processing effort introduced every time a transmission mode switching is justified!!!

The co-existence of P-t-P and P-t-M transmissions within a cell is considered essential in order to minimize signaling traffic in the radio interface and processing effort in the RNC and BS!!!
RRM Challenges in MBMS – Issues under consideration (Previous work)

• Introduction of the “Dual Transmission mode cell” in which P-t-P and P-t-M transmissions:
  – Can coexist
  – Can dynamically be adapted based on the instantaneous distribution of the MBMS users within the cell
    • Shrink or expand FACH’s coverage
    • Establish or release DCHs

FACH
(Allowed to shrink or expand through time based on the instantaneous distribution and movement of the MBMS users within the cell)

DCHs
(Allowed to be released or established through time based on the instantaneous distribution and movement of the MBMS users within the cell)
Main Concept:

- Based on the users’ context reported, periodically estimate the power required for all “possible” transmission arrangements and dynamically adapt the most efficient one:
  - **Transmission arrangement 1**: All DCHs.
  - **Transmission arrangement 2**: FACH for UEs up to Z1 (inclusive) and DCHs for UEs beyond.
  - .......
  - **Transmission arrangement 11**: FACH for all UEs in the cell (i.e. up to Z10)
RRM Challenges in MBMS – Issues under consideration (Previous work)

Simulation Results: Proposed MBMS Service provision approach Vs Current 3GPP Specified MBMS Service Provision approach

80 MBMS users randomly distributed and moving randomly with a pedestrian speed (~5 Km/h) within the cell

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**Significant transmission power savings:** By utilizing the dual transmission mode cell concept, the maximum total downlink power required is reduced from 2.38 to 1.46 watts (that is 39% decrease), while the average downlink power used is reduced from 1.1819 to 0.5668 watts (that is 52% decrease).
**Considerable reduction on the aggregated processing effort required in RNC and BS for the establishment or releasing of channels:** By allowing the co-existence and the ability of P-t-P and P-t-M transmissions to dynamically adapt through time, eliminated the sudden switching between P-t-P to P-t-M transmission modes and provided a smoother and more efficient transition between them.

The total number of actions required for channel releasing is reduced from 243 to 10 (95.9% decrease) and for channel establishment is reduced from 323 to 12 (96.3% decrease).

**Considerable reduction on the aggregated signaling traffic introduced in the radio interface:** This gain came as an additional benefit of the processing effort efficiency achieved.

The aggregated downlink traffic introduced is reduced from 230400 to 36360 bits while the aggregated uplink traffic is reduced from 35840 to 5656 bits (that is 84% decrease on both downlink and uplink signaling traffic).
RRM Challenges in MBMS – Issues under consideration (Previous work)

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MBMS Future Trends

- **MBMS over HSDPA**
  - Currently there is discussion in the standards bodies for using the HSDPA (High-Speed Downlink Packet Access) for the distribution of MBMS Services in the Cells, but as of present there is nothing standardised

- **MBMS in WiMAX**
  - In the future there are high expectations for using WiMAX for the distribution of MBMS Services, but as of present there is nothing standardised

- **Multicast in Heterogeneous Networks**
  - In the future, users receiving an a multicast service will be able to access the network through a heterogeneous landscape of technologies (WLAN, WiMAX, UMTS, HSDPA, GPRS etc.)
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• Future work

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Current Work

- Radio Resource Management for multicast transmissions in Heterogeneous Networks
  - Currently working on the specifications of an Intelligent Context Aware Radio Access Technology Selection Algorithm (Running in NIS)
    - The aim of the algorithm is to optimize the pool of the available radio resources among a variety of Radio Access Technologies (RATs) (i.e. WiFi, UMTS, WiMAX, etc) belonging to the same Network Operator.
    - The algorithm, based on the instantaneous context of the users and the network, dynamically selects the RAT that will serve each user aiming to enhance capacity and performance of the whole heterogeneous network during a multicast transmission.
  - This research is ongoing and partly funded by the C-CAST project.
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• Multicast services due to their ability to deliver content efficiently to multiple users are considered by many as a ‘killer applications’, and can thus become an attractive revenue generator for operators without loss of perceived QoS for the user

• Many challenges are still facing the efficient distribution of these kind of services especially in the Radio Access part where the radio resources are limited

• BS’s transmission power is a limited resource and must be shared among all the users in a Cell

• Efficient Radio Resource Management (RRM), during the multicast service provision is very challenging
  – End-to-End QoS requirements to be fulfilled in all respects with minimum capacity (transmission power) consumption