1. Multimedia Broadcast/Multicast Service
2. Location Services
3. Other Enhancements in Release 9
• Release 9

✓ Multimedia Broadcast/Multicast Service (MBMS) location services and dual layer beamforming

✓ Enhancement of self optimization capabilities of LTE

Layer: It is synonymous with stream. For spatial multiplexing, at least two layers must be used. Up to four are allowed. The number of layers is always less than or equal to the number of antennas.
1. Multimedia Broadcast / Multicast Service

- 1.1 Introduction
- 1.2 Multicast/Broadcast over a Single Frequency Network
- 1.3 Implementation of MBSFN in LTE
- 1.4 Architecture of MBMS
- 1.5 Operation of MBMS
1.1 Introduction

- Mobile cellular networks are normally used for
  - **One-to-one** services: phone calls and web browsing
  - **One-to-many** services: mobile television

- Two types of **one-to-many** service
  - **Broadcast** services are available to **anyone**
  - **Multicast** services are only available to users who have subscribed to a **multicast group**

- Broadcast and multicast services require several different techniques from traditional unicasting, e.g.,
  - The network has to **distribute** the data using **IP multicast**
  - The **encryption** techniques have to be modified to ensure that all **subscribing users** can receive the information stream
- UMTS implements these techniques using Multimedia Broadcast/Multicast Service (MBMS), which was introduced in 3GPP Release 6.

- LTE Multimedia Broadcast/Multicast Service was introduced in Release 9.
  - LTE currently only supports broadcast services, which do not require the user to subscribe to a multicast group.

- To transmit MBMS data streams:
  - LTE uses a Multicast/Broadcast over a Single Frequency Network (MBSFN) air interface technique.
  - MBSFN was fully specified in Release 8.
1.2 Multicast/Broadcast over a Single Frequency Network

- When delivering a broadcast or multicast service
  - The radio access network transmits the same information stream from several nearby cells
- This is different from the usual situation in a mobile telecommunication system
  - In which nearby cells are transmitting completely different information
- LTE exploits this feature to improve the transmission of broadcast and multicast services, using the technique of MBSFN
Figure 17.1 Multicast/broadcast over a single frequency network.
• Using MBSFN

✓ Nearby BSs
  - Synchronized so that they broadcast the same content at the same time and on the same sub-carriers

✓ Mobile
  - Receives multiple copies of the information
    ‣ Which are identical except for their different arrival times, amplitudes and phases
  - Process the information streams using exactly the same techniques for handling multipath
  - It is not even aware that the information is coming from multiple cells
• Because the extra cells are transmitting the same information stream

✓ They do not cause any interference to the mobile

✓ Instead, they contribute to the received signal power
  - This increases the mobile’s SINR and maximum data rate, particularly at the edge of the cell where interference is usually high

✓ This allows LTE to reach a target spectral efficiency of 1 bit per second per Hz for the delivery of MBMS
  - Equivalent to 16 mobile TV channels in a 5MHz bandwidth at a rate of 300 kbps each
1.3 Implementation of MBSFN in LTE

- In LTE, the synchronized BSs lie in a geographical region known as an MBSFN area.

- MBSFN areas
  - Can overlap, so that one BS can transmit multiple sets of content from multiple MBSFN areas.
  - In each MBSFN area, the LTE air interface delivers MBMS using the channels shown in the figure.
Figure 17.2 Channels used for MBMS and MBSFN.
• Two logical channels
  ✓ Multicast Traffic CHannel (MTCH)
    - Carries broadcast traffic such as a television station
  ✓ Multicast Control CHannel (MCCH)
    - Carries RRC signaling messages that describe how the traffic channels are being transmitted
• Each MBSFN area contains
  ✓ One MCCH
  ✓ Multiple instances of MTCH
• The multicast traffic and control channels are transported using
  ✓ Multicast CHannel (MCH)
  ✓ Physical Multicast CHannel (PMCH)
• Each MBSFN area contains multiple instances of PMCH
  ✓ Each of which carries either the MCCH, or
  ✓ One or more MTCHs
• A few differences between the transmission techniques used for PMCH and PDSCH

• PMCH

✓ Implements MBSFN techniques, and always uses the extended cyclic prefix to handle the long delay spreads that result from the use of multiple BSs

✓ It is transmitted on antenna port 4, to keep it separate from BS’s other transmissions, and does not use transmit diversity, spatial multiplexing or hybrid ARQ

✓ Each instance of the channel uses a fixed modulation scheme and coding rate, which are configured by means of RRC signaling

<table>
<thead>
<tr>
<th>Antenna port</th>
<th>Release</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>R8</td>
<td>Single antenna transmission</td>
</tr>
<tr>
<td>1</td>
<td>R8</td>
<td>2 and 4 antenna transmit diversity and spatial multiplexing</td>
</tr>
<tr>
<td>2</td>
<td>R8</td>
<td>2 and 4 antenna transmit diversity and spatial multiplexing</td>
</tr>
<tr>
<td>3</td>
<td>R8</td>
<td>4 antenna transmit diversity and spatial multiplexing</td>
</tr>
<tr>
<td>4</td>
<td>R8/R9</td>
<td>4 antenna transmit diversity and spatial multiplexing</td>
</tr>
<tr>
<td>5</td>
<td>R8</td>
<td>MBMS</td>
</tr>
<tr>
<td>6</td>
<td>R9</td>
<td>Beamforming</td>
</tr>
<tr>
<td>7–8</td>
<td>R9</td>
<td>Positioning reference signals</td>
</tr>
<tr>
<td>9–14</td>
<td>R10</td>
<td>8 antenna spatial multiplexing</td>
</tr>
<tr>
<td>15–22</td>
<td>R10</td>
<td>8 antenna spatial multiplexing</td>
</tr>
</tbody>
</table>

PMCH: Physical Multicast Channel
PDSCH: Physical Downlink Shared Channel
PMCH uses a different set of reference signals from usual, known as MBSFN reference signals.

- These are tagged with MBSFN area identity instead of the physical cell identity, to ensure that the mobile can successfully combine the reference signals that it receives from different cells.

To date, MBMS is only delivered on carriers that are shared with unicast traffic.

- This is achieved using time division multiplexing.
In any one cell, each downlink subframe is allocated to the following traffic according to a mapping that is defined in SIB 2:

- Unicast traffic on the PDSCH, or
- Broadcast traffic on the PMCH

Thus a particular subframe contains either PDSCH, or PMCH, but not both.

Each broadcast subframe is allocated to a single MBSFN area.

Within an MBSFN area, each broadcast subframe carries:

- Either signaling messages on MCCH, or
- Broadcast traffic on a single instance of MTCH
• A broadcast subframe still starts with a **PDCCH control region**

✓ Only used for **uplink scheduling and uplink power control commands**

✓ Only **one or two symbols long**

✓ The **control region** uses

  - Cell’s usual **cyclic prefix duration** (normal or extended)

  - Cell specific **reference signals**

• The rest of the subframe

✓ Occupied by **PMCH**, which uses **extended cyclic prefix** and **MBSFN reference signals**
The figure shows the resulting slot structure, for the case where

✓ The control region uses normal cyclic prefix and contains two symbols

✓ Note the gap in the downlink transmission, as the cell changes from one cyclic prefix duration to the other
Figure 17.3 Example structure of an MBSFN subframe, for a 2-symbol control region using the normal cyclic prefix.
• Eventually, LTE will also support **cells** that are dedicated to MBMS

• These cells will only use **downlink reference and synchronization signals**

  ✓ The **physical broadcast channel** and **physical multicast channel** will **not** support any **uplink transmissions**

  ✓ They can **optionally** use a special slot structure in support of **very large cells**

    - In this slot structure, the **subcarrier spacing** is reduced to 7.5 kHz, which **increases** the **symbol duration** to 133.3 μs and **cyclic prefix duration** to 33.3 μs
1.4 Architecture of MBMS

- The figure shows the architecture that is used for the delivery of MBMS over LTE

- **Broadcast/Multicast Service Center (BM-SC)**
  - Receives MBMS content from a content provider

- **MBMS GateWay (MBMS-GW)**
  - Distributes the content to the appropriate BSs

- **Multicell/Multicast Coordination Entity (MCE)**
  - Schedules the transmissions from all the BSs in a single MBSFN area
Figure 17.4 Architecture for MBMS in LTE.
• BM-SC (Broadcast/Multicast Service Center)

✓ Indicates the start of each MBMS session by sending a signaling message across the SGmb interface

✓ The message describes the session’s QoS and tells the MBMS GW to reserve resources for it

✓ The message is propagated across Sm, M3 and M2 interfaces

✓ M2 interface also defines
  - Modulation scheme
  - Coding rate
  - The subframe allocation that the BSs in the MBSFN area should use
• BM-SC (Broadcast/Multicast Service Center)
  ✓ BM-SC then broadcasts the data across SGi-mb interface using IP multicast

• MBMS GW (MBMS GateWay)
  ✓ Forwards data to the appropriate BSs across M1 interface, along with a header that indicates each packet’s transmission time with an accuracy of 10 ms

• eNB
  ✓ By combining the above info with the scheduling info that it receives from the multicell/multicast coordination entity, the BS can establish the exact transmission time for each packet
1.5 Operation of MBMS

- After the mobile switches on, it reads SIB 2
- By doing this, it discovers
  - Which subframes have been reserved for MBSFN transmissions on the PMCH
  - Which subframes have been reserved for unicast transmissions on the PDSCH
- The MBSFN subframes repeat with a period of 1 to 32 frames
  - They do not clash [衝突] with the subframes used by
    - Synchronization signals
    - Physical broadcast channel
    - Paging subframes
• If the user wishes to receive broadcast services

✓ The mobile continues by reading a new system information block, **SIB 13**

✓ This lists the **MBSFN areas** that the cell belongs to

• For each MBSFN area, it also defines

✓ The **subframes** that carry **MCCH**

✓ The **modulation scheme** and **coding rate** that those transmissions will use
• The mobile can now receive the **MCCH**, which carries

  ✓ A single **RRC signaling message**

  ✓ **MBSFN area configuration**

  - This message lists the **PMCHs** that the **MBSFN area** is using

    ‣ For each PMCH, the message

    • Lists the **corresponding MTCHs**

    • Defines the following

      • The **subframes** that will be used

      • The **modulation scheme**

      • The **coding rate**

    • A **MCH scheduling period parameter** that lies between 8 and 1024 frames

---

**MCCH** : Multicast Control Channel
**PMCH** : Physical Multicast Channel
**MTCH** : Multicast Traffic Channel
**MCH** : Multicast Channel
• The mobile
  ✓ Now receive each instance of PMCH
  ✓ It still has to discover the way in which the PMCH subframes are shared amongst the various MTCHs that it carries

• The BS
  ✓ Signals this information in a new MAC control element known as MCH scheduling information
  ✓ The BS transmits this info at the beginning of each MCH scheduling period

• The mobile
  ✓ Once it has read this control element, the mobile can receive each instance of the MTCH

• If the contents of the MCCH change, the BS alerts the mobiles by
  ✓ Writing a PDCCH scheduling command using a variant of DCI format 1C
  ✓ Addressing it to the MBMS radio network temporary identifier (M-RNTI)

<table>
<thead>
<tr>
<th>DCI format</th>
<th>Release</th>
<th>Purpose</th>
<th>Resource allocation</th>
<th>DL mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>R8</td>
<td>UL scheduling grants</td>
<td>1 antenna</td>
<td>-</td>
</tr>
<tr>
<td>1</td>
<td>R8</td>
<td>DL scheduling commands</td>
<td>1 antenna, open loop diversity, beamforming</td>
<td>Type 0, 1, 2, 7</td>
</tr>
<tr>
<td>1A</td>
<td>R8</td>
<td>DL scheduling commands</td>
<td>1 antenna, open loop diversity</td>
<td>Type 2</td>
</tr>
<tr>
<td>1B</td>
<td>R8</td>
<td>Closed loop diversity</td>
<td>Type 2</td>
<td>6</td>
</tr>
<tr>
<td>1C</td>
<td>R8</td>
<td>System information, paging, random access responses</td>
<td>Type 2</td>
<td>Any</td>
</tr>
<tr>
<td>1D</td>
<td>R8</td>
<td>Multiple user MIMO</td>
<td>Type 2</td>
<td>5</td>
</tr>
<tr>
<td>2</td>
<td>R8</td>
<td>DL scheduling commands</td>
<td>Closed loop MIMO</td>
<td>Type 0, 1, 4</td>
</tr>
<tr>
<td>2A</td>
<td>R8</td>
<td>Open loop MIMO</td>
<td>Type 0, 1, 3</td>
<td></td>
</tr>
<tr>
<td>2B</td>
<td>R9</td>
<td>Dual layer beamforming</td>
<td>Type 0, 1, 8</td>
<td></td>
</tr>
<tr>
<td>2C</td>
<td>R10</td>
<td>8 layer MIMO</td>
<td>Type 0, 1, 9</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>R8</td>
<td>UL power control</td>
<td>2 bit power adjustments</td>
<td>-</td>
</tr>
<tr>
<td>3A</td>
<td>R8</td>
<td>UL power control</td>
<td>1 bit power adjustments</td>
<td>-</td>
</tr>
<tr>
<td>4</td>
<td>R10</td>
<td>UL scheduling grants</td>
<td>Closed loop MIMO</td>
<td>-</td>
</tr>
</tbody>
</table>
• 1. Multimedia Broadcast/Multicast Service
• 2. Location Services
• 3. Other Enhancements in Release 9
2. Location Services

- 2.1 Introduction
- 2.2 Positioning Techniques
- 2.4 Location Service Procedures
2.1 Introduction

- Location services (LCS) or Location Based Services (LBS), allow an application to find out the geographical location of a mobile
- UMTS supported LCS from Release 99, but they were introduced into LTE from Release 9
- The biggest motivation is emergency calls
  ✓ This issue is especially important in USA, where the FCC requires network operators to localize an emergency call to an accuracy between 50 and 300 meters, depending on the type of positioning technology used
- LCSs are also of increasing importance to the user, for applications such as navigation and interactive games
- Other applications include
  ✓ Lawful interception by the police or security services
  ✓ Use of a mobile’s location to support network-based functions such as handover
2.2 Positioning Techniques

- LTE can calculate a mobile’s position using three different techniques
  - The most accurate and increasingly common technique is the use of a **Global Navigation Satellite System** (GNSS), a collective term for satellite navigation systems such as the Global Positioning System (GPS)
  - There are two variants
    - **UE based** positioning
      - The mobile has a **complete satellite receiver** and the mobile calculates its own position
      - The network can send it information to assist this calculation, such as an initial position estimate and a list of visible satellites
    - **UE assisted** positioning
      - The mobile has a **more basic satellite receiver**, so it sends a basic set of measurements to the network
      - The network calculates its position
  - **Positioning accuracy**
    - Typically around 10 meters
✓ The second technique is downlink positioning or **Observed Time Difference of Arrival (OTDOA)**

- The **mobile**
  - Measures the **times** at which signals arrive from its **serving cell** and the nearest neighbors
  - Reports the **time differences** to the network
- The **network**
  - Calculate the mobile’s position by **triangulation**
- The **timing measurements** are made on a new set of **positioning reference signals**, which are transmitted on a new **antenna port**, number 6
- Positioning accuracy
  - Limited by **multipath**
  - Typically to around **100 meters**, has difficulty in meeting the requirements of US FCC
- It is often used as a **backup** to satellite positioning, as a mobile may not be able to receive a satisfactory satellite signal if it is surrounded by tall buildings or is indoors
• **Note**: Triangulation

• **Triangulation** may be used to calculate the **coordinates** and **distance** from the shore to the ship.

• The **observer at A** measures the angle $\alpha$ between the shore and the ship, and the **observer at B** does likewise for $\beta$.

• With the length $l$ or the coordinates of A and B known, then the **law of sines** can be applied to find the coordinates of the ship at C and the distance $d$. 

![Diagram of triangulation concept](image)
The last technique is **enhanced cell ID positioning**

✓ The network
  - Estimates the mobile’s position from its knowledge of
    ‣ The **serving cell identity**
    ‣ Additional information such as the **mobile’s timing advance**

✓ Positioning accuracy
  - Depends on the **cell size**
  - **Excellent in femtocells** (provided that the BS’s position is actually known)
  - **Very poor in macrocells**
• The figure shows the main **hardware components** that LTE uses for LCSs

• **Gateway Mobile Location Center (GMLC)**
  ✓ Receives **location requests** from external clients across **Le** interface
  ✓ Retrieves the **identity** of the mobile’s **serving MME** from HSS
  ✓ Forwards the **location request** to MME

• **MME**
  ✓ Delegates responsibility for calculating a mobile’s position to **Evolved Serving Mobile Location Center (E-SMLC)**
Figure 17.5 Architecture for location services in LTE.
Two other components can be separate devices or can be integrated into GMLC

✓ Privacy Profile Register (PPR)
  - Contains the users’ privacy details, which determine whether a location request from an external client will actually be accepted

✓ Pseudonym [假名] Mediation Device (PMD)
  - Retrieves a mobile’s IMSI using the identity supplied by the external client
The architecture uses several signaling protocols

✓ **GMLC** communicates with **HSS** and **MME**
  - Using **Diameter** applications

✓ **MME** communicates with **E-SMLC**
  - Using **LCS** application protocol (LCS-AP)

✓ **MME** can also send *positioning-related* information to **mobile**
  - Using *supplementary service* (SS) messages that are embedded into **EMM** messages on the air interface

✓ **E-SMLC** communicates with **mobile** and **BS**
  - Using **LTE positioning protocol** (LPP), the messages being transported by embedding them into lower-level LCS-AP and EMM messages

✓ **GMLC** can communicate with **external client**
  - Using a few different techniques, such as **Open Service Architecture** (OSA)
2.4 Location Service Procedures

- The figure shows how the network might respond to a location request from an external client.

- Assumptions
  - ✓ The mobile is not roaming.
  - ✓ The GMLC can communicate directly with mobile’s serving MME.
  - ✓ Use of a mobile-assisted or mobile-based positioning technique.
Figure 17.6 Mobile terminated location request procedure.
• Step (1)
  ✓ The external client asks GMLC for the mobile’s position and optionally velocity
  ✓ The client typically identifies the mobile using its IP address

• Step (2-3) GMLC
  ✓ (2) Retrieves the mobile’s IMSI from Pseudonym Mediation Device (PMD)
  ✓ (3) Interrogates the privacy profile register to establish whether the location request can be accepted
• Step (4-6) GMLC

✓ (4-5) Retrieves the identity of the mobile’s serving MME from HSS

✓ (6) Forwards the location request there (serving MME)

- As part of that message, it can specify the location estimate’s QoS in terms of
  - Positional accuracy
  - Response time

- The information being obtained either from the client or from the mobile’s subscription data
• Step (7)

✓ If the mobile is in ECM-IDLE state, then the MME wakes it up using the paging procedure, to which the mobile responds by initiating a service request

• Step (8)

✓ If the privacy information indicates that the user should be notified of an incoming location request, then the MME sends a notification message to the mobile
• Step (9-10)

✓ (9) The mobile asks the user whether the request can be accepted

✓ (10) Indicates the response to MME

• Step (11)

✓ Unless the user withholds permission, the MME selects an E-SMLC and forwards the location request there

✓ The message includes the mobile’s location capabilities, which are supplied as part of its non access stratum capabilities during the attach procedure
• Step (12)

✓ Using the mobile’s capabilities and the requested QoS
  - The E-SMLC decides the positioning technique that it will use

✓ Assuming the use of a mobile-assisted or mobile-based technique
  - E-SMLC sends the mobile a location request
  - In its message, the E-SMLC
    ‣ Specifies the selected positioning technique
    ‣ Supplies supporting information such as
      • The satellites that should be visible
      • The positioning reference signals that nearby BSs are transmitting
  - The message is transported to the mobile by embedding it into lower-level LCS-AP and EMM messages
• Step (13)
  ✓ The mobile makes the measurements that have been requested and sends a response to the E-SMLC

• Step (14-16)
  ✓ E-SMLC returns its position estimate to the client
• 1. Multimedia Broadcast/Multicast Service
• 2. Location Services
• 3. Other Enhancements in Release 9
3. Other Enhancements in Release 9

- 3.1 Dual Layer Beamforming
- 3.2 Commercial Mobile Alert System
- 3.3 Enhancements to Earlier Features of LTE
3.1 Dual Layer Beamforming

- In dual layer beamforming, the BS transmits two simultaneous data streams using the same set of resource blocks, by processing the data using two parallel sets of antenna weights.
- It can then direct the data either to two different mobiles, or to two antennas on the same mobile.
3.1 Dual Layer Beamforming

- Dual layer beamforming is first supported in LTE Release 9

✓ BS configures the mobile into a new transmission mode, mode 8, and schedules it using a new DCI format, 2B
✓ It then transmits to the mobile using either or both of two new antenna ports, numbers 7 and 8.

✓ Ports 7 and 8 use a new set of UE-specific reference signals, which behave in the same way as the reference signals used for single layer beamforming on port 5.

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<thead>
<tr>
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<td>MBMS</td>
</tr>
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</tr>
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</tr>
<tr>
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<td>R10</td>
<td>8 antenna spatial multiplexing</td>
</tr>
<tr>
<td>15–22</td>
<td>R10</td>
<td>CSI reference signals</td>
</tr>
</tbody>
</table>
3.2 Commercial Mobile Alert System


• Using this system, participating network operators can transmit three types of emergency message
  ✓ Presidential alerts about local, regional or national emergencies
  ✓ Imminent [緊迫，眉睫] threat alerts about natural disasters such as hurricanes
  ✓ Child abduction emergency alerts
• In Release 9, LTE supports CMAS by generalizing its earthquake and tsunami warning system to a **Public Warning System (PWS)** that covers both types of information.

• BS continues to send
  ✓ Earthquake and tsunami warnings on SIBs 10 and 11
  ✓ Transmits commercial mobile alerts on a new system information block, SIB 12
3.3 Enhancements to Earlier Features of LTE

- Two other enhancements that Release 9 makes to earlier features of the system

  ✓ Improves the algorithms for cell selection and reselection, to include measurements of the reference signal received quality as well as the reference signal received power

  ✓ Supports emergency calls over IMS, by adding features such as a null integrity protection algorithm

    - Null integrity protection algorithm for the sole purpose of making emergency voice calls without a UICC