Multimedia Broadcast/Multicast Services

In the past, cellular systems have mostly focused on transmission of data intended for a single user and not on multicast/broadcast services. Broadcast networks, exemplified by the radio and TV broadcasting networks, have on the other hand focused on covering very large areas with the same content and have offered no or limited possibilities for transmission of data intended for a single user. Multimedia Broadcast Multicast Services (MBMS) support multicast/broadcast services in a cellular system, thereby combining the provision of multicast/broadcast and unicast services within a single network.

With MBMS, the same content is transmitted to multiple users located in a specific area, known as the MBMS service area and typically comprising multiple cells. In each cell participating in the transmission, a point-to-multipoint radio resource is configured and all users subscribing to the MBMS service simultaneously receive the same transmitted signal. No tracking of users’ movement in the radio-access network is performed and users can receive the content without notifying the network.

When providing multicast/broadcast services for mobile devices there are several aspects to take into account, of which two deserve special attention and will be elaborated upon further below: good coverage and low terminal power consumption.

The coverage, or more accurately the data rate possible to provide, is basically determined by the link quality of the worst-case user, as no user-specific adaptation of transmission parameters can be used in a multicast/broadcast system providing the same information to multiple users. As discussed in Chapter 3, OFDM transmission provides specific benefits for provision of multi-cell multicast/broadcast services. If the transmissions from the different cells are time synchronized, the resulting signal will, from a terminal point of view, appear as a transmission from a single point over a time-dispersive channel. As mentioned in Chapter 7, for LTE this kind of transmission is referred to as an MBMS Single-Frequency Network (MBSFN). MBSFN transmission provides several benefits:

- Increased received signal strength, especially at the border between cells involved in the MBSFN transmission, as the terminal can utilize the signal energy received from multiple cells.
- Reduced interference level, once again especially at the border between cells involved in the MBSFN transmission, as the signals received from neighboring cells will not appear as interference but as useful signals.
- Additional diversity against fading on the radio channel as the information is received from several, geographically separated locations, typically making the overall aggregated channel appear highly time-dispersive or, equivalently, highly frequency selective.
Altogether, this allows for significant improvements in the multicast/broadcast reception quality, especially at the border between cells involved in the MBSFN transmission, and, as a consequence, significant improvements in the achievable multicast/broadcast data rates.

Providing for power-efficient reception in the terminal in essence implies that the structure of the overall transmission should be such that data for a service-of-interest is provided in short high-data-rate bursts rather than longer low-data-rate bursts. This allows the terminal to occasionally wake up to receive data with long periods of DRX in between. In LTE, this is catered for by time-multiplexing unicast and broadcast transmissions, as well as by the scheduling of different MBMS services, as discussed further below.

15.1 ARCHITECTURE

An MBSFN area is a specific area where one or several cells transmit the same content. For example, in Figure 15.1, cells 8 and 9 both belong to MBSFN area C. Not only can an MBSFN area consist of multiple cells, a single cell can also be part of multiple, up to eight, MBSFN areas, as shown in Figure 15.1, where cells 4 and 5 are part of both MBSFN areas A and B. Note that, from an MBSFN reception point of view, the individual cells are invisible, although the terminal needs to be aware of the different cells for other purposes, such as reading system information and notification indicators, as discussed below. The MBSFN areas are static and do not vary over time.

The usage of MBSFN transmission obviously requires not only time synchronization among the cells participating in an MBSFN area, but also usage of the same set of radio resources in each of the cells for a particular service. This coordination is the responsibility of the Multi-cell/multicast Coordination Entity (MCE), which is a logical node in the radio-access network handling allocation of radio resources and transmission parameters (time–frequency resources and transport format) across the cells in the MBSFN area. As shown in Figure 15.2, the MCE\(^1\) can control multiple eNodeBs, each handling one or more cells.

\(^1\)There is an alternative architecture supported where MCE functionality is included in every eNodeB. However, as there is no communication between MCEs in different eNodeBs, the MBSFN area would in this case be limited to the set of cells controlled by a single eNodeB.
The Broadcast Multicast Service Center (BM-SC), located in the core network, is responsible for authorization and authentication of content providers, charging, and the overall configuration of the data flow through the core network. The MBMS gateway (MBMS-GW) is a logical node handling multicast of IP packets from the BM-SC to all eNodeBs involved in transmission in the MBSFN area. It also handles session control signaling via the MME.

From the BM-SC, the MBMS data is forwarded using IP multicast, a method of sending an IP packet to multiple receiving network nodes in a single transmission, via the MBMS gateway to the cells from which the MBMS transmission is to be carried out. Hence, MBMS is not only efficient from a radio-interface perspective, but it also saves resources in the transport network by not having to send the same packet to multiple nodes individually unless necessary. This can lead to significant savings in the transport network.

**15.2 OVERALL CHANNEL STRUCTURE AND PHYSICAL-LAYER PROCESSING**

The basis for MBSFN transmission is the Multicast Channel (MCH), a transport channel type supporting MBSFN transmission. Two types of logical channels can be multiplexed and mapped to the MCH:

- *Multicast Traffic Channel* (MTCH)
- *Multicast Control Channel* (MCCH).

The MTCH is the logical channel type used to carry MBMS data corresponding to a certain MBMS service. If the number of services to be provided in an MBSFN area is large, multiple MTCHs can be configured. Obviously, as no acknowledgements are transmitted by the terminals, no RLC retransmissions can be used and consequently the RLC unacknowledged mode is used.

The MCCH is the logical channel type used to carry control information necessary for reception of a certain MBMS service, including the subframe allocation and modulation-and-coding scheme for each MCH. There is one MCCH per MBSFN area. Similarly to the MTCH, the RLC uses unacknowledged mode.
One or several MTCHs and, if applicable, one MCCH are multiplexed at the MAC layer to form an MCH transport channel. As already described in Chapter 8, the MAC header contains information about the logical-channel multiplexing, in this specific case the MTCH/MCCH multiplexing, such that the terminal can demultiplex the information upon reception. The MCH is transmitted using MBSFN in one MBSFN area.

The transport-channel processing for MCH is, in most respects, the same as that for DL-SCH as described in Section 10.1, with some exceptions:

- In the case of MBSFN transmission, the same data is to be transmitted with the same transport format using the same physical resource from multiple cells typically belonging to different eNodeBs. Thus, the MCH transport format and resource allocation cannot be dynamically adjusted by the eNodeB. As described above, the transport format is instead determined by the MCE and signaled to the terminals as part of the information sent on the MCCH.
- As the MCH transmission is simultaneously targeting multiple terminals and therefore no feedback is used, hybrid ARQ is not applicable in the case of MCH transmission.
- As already mentioned, multi-antenna transmission (transmit diversity and spatial multiplexing) does not apply to MCH transmission.

Furthermore, as also mentioned in Chapter 10, the PMCH scrambling should be MBSFN-area specific – that is, identical for all cells involved in the MBSFN transmission.

The MCH is mapped to the PMCH physical channel and transmitted in MBSFN subframes, illustrated in Figure 15.3. As discussed in Chapter 9, an MBSFN subframe consists of two parts: a control region, used for transmission of regular unicast L1/L2 control signaling; and an MBSFN region, used for transmission of the MCH. Unicast control signaling may be needed in an MBSFN subframe, for example to schedule uplink transmissions in a later subframe, but is also used for MBMS-related signaling, as discussed further below.

---

2One MCCH per MBSFN area is needed, but it does not have to occur in every MCH TTI, nor on all MCHs in the MBSFN area.
3As discussed in Chapter 9, MBSFN subframes can be used for multiple purposes and not all of them have to be used for MCH transmission.
As already discussed in Chapter 3, in the case of MBSFN-based multicast/broadcast transmission, the cyclic prefix should not only cover the main part of the actual channel time dispersion but also the timing difference between the transmissions received from the cells involved in the MBSFN transmission. Therefore, MCH transmissions, which can take place in the MBSFN region only, use an extended cyclic prefix. If a normal cyclic prefix is used for normal subframes, and therefore also in the control region of MBSFN subframes, there will be a small “hole” between the two parts of an MBSFN subframe, as illustrated in Figure 15.3. The reason is to keep the start timing of the MBSFN region fixed, irrespective of the cyclic prefix used for the control region.

As already mentioned, the MCH is transmitted by means of MBSFN from the set of cells that are part of the corresponding MBSFN area. Thus, as seen from the terminal point of view, the radio channel that the MCH has propagated over is the aggregation of the channels of each cell within the MBSFN area. For channel estimation for coherent demodulation of the MCH, the terminal can thus not rely on the normal cell-specific reference signals transmitted from each cell. Rather, in order to enable coherent demodulation for MCH, special MBSFN reference symbols are inserted within the MBSFN part of the MBSFN subframe, as illustrated in Figure 15.4. These reference symbols are transmitted by means of MBSFN over the set of cells that constitute the MBSFN area – that is, they are transmitted at the same time–frequency position and with the same reference-symbol values from each cell. Channel estimation using these reference symbols will thus correctly reflect the overall aggregated channel corresponding to the MCH transmissions of all cells that are part of the MBSFN area.

MBSFN transmission in combination with specific MBSFN reference signals can be seen as transmission using a specific antenna port, referred to as antenna port 4.

A terminal can assume that all MBSFN transmissions within a given subframe correspond to the same MBSFN area. Hence, a terminal can interpolate over all MBSFN reference symbols within a given MBSFN subframe when estimating the aggregated MBSFN channel. In contrast, MCH transmissions in different subframes may, as already discussed, correspond to different MBSFN areas. Consequently, a terminal cannot necessarily interpolate the channel estimates across multiple subframes.

As can be seen in Figure 15.4, the frequency-domain density of MBSFN reference symbols is higher than the corresponding density of cell-specific reference symbols. This is needed as the
aggregated channel of all cells involved in the MBSFN transmission will be equivalent to a highly
time-dispersive or, equivalently, highly frequency-selective channel. Consequently, a higher
frequency-domain reference-symbol density is needed.

There is only a single MBSFN reference signal in MBSFN subframes. Thus, multi-antenna trans-
mis
mission such as transmit diversity and spatial multiplexing is not supported for MCH transmission.
The main argument for not supporting any standardized transmit diversity scheme for MCH transmis-
sion is that the high frequency selectivity of the aggregated MBSFN channel in itself provides sub-
stantial (frequency) diversity.

15.3 SCHEDULING OF MBMS SERVICES

Good coverage throughout the MBSFN area is, as already explained, one important aspect of providing broadcast services. Another important aspect, as mentioned in the introduction, is to provide for energy-efficient reception. In essence, for a given service, this translates into transmission of short high-rate bursts in between which the terminal can enter a DRX state to reduce power consumption. LTE therefore makes extensive use of time-multiplexing of MBMS services and the associated signaling, as well as provides a mechanism to inform the terminal \textit{when} in time a certain MBMS service is transmitted. Fundamental to the description of this mechanism are the \textit{Common Subframe Allocation} (CSA) period and the \textit{MCH Scheduling Period} (MSP).

All MCHs that are part of the same MBSFN area occupy a pattern of MBSFN subframes known as the \textit{Common Subframe Allocation} (CSA). The CSA is periodic, as illustrated in Figure 15.5.
Obviously, the subframes used for transmission of the MCH must be configured as MBSFN subframes, but the opposite does not hold – MBSFN subframes can be configured for other purposes as well, for example to support the backhaul link in the case of relaying, as described in Chapter 16. Furthermore, the allocation of MBSFN subframes for MCH transmission should obviously be identical across the MBSFN area as there otherwise will not be any MBSFN gain. This is the responsibility of the MCE.

Transmission of a specific MCH follows the MCH subframe allocation (MSA). The MSA is periodic and at the beginning of each MCH Scheduling Period (MSP), a MAC control element is used to transmit the MCH Scheduling Information (MSI). The MSI indicates which subframes are used for a certain MTCH in the upcoming scheduling period. Not all possible subframes need to be used; if a smaller number than allocated to an MCH is required by the MTCH(s), the MSI indicates the last MCH subframe to be used for this particular MTCH (MSA end in Figure 15.5), while the remaining subframes are not used for MBMS transmission. The different MCHs are transmitted in consecutive order within a CSA period – that is, all subframes used by MCH \( n \) in a CSA are transmitted before the subframes used for MCH \( n + 1 \) in the same CSA period.

The fact that the transport format is signaled as part of the MCCH implies that the MCH transport format may differ between MCHs but must remain constant across subframes used for the same MCH. The only exception is subframes used for the MCCH and MSI, where the MCCH-specific transport format, signaled as part of the system information, is used instead.

In the example in Figure 15.5, the scheduling period for the first MCH is 16 frames, corresponding to one CSA period, and the scheduling information for this MCH is therefore transmitted once every 16 frames. The scheduling period for the second MCH, on the other hand, is 32 frames, corresponding to two CSA periods, and the scheduling information is transmitted once every 32 frames. The MCH scheduling periods can range from 80 ms to 10.24 s.

To summarize, for each MBSFN area, the MCCH provides information about the CSA pattern, the CSA period, and, for each MCH in the MBSFN area, the transport format and the scheduling period. This information is necessary for the terminal to properly receive the different MCHs. However, the MCCH is a logical channel and itself mapped to the MCH, which would result in a chicken-and-egg problem – the information necessary for receiving the MCH is transmitted on the MCH. Hence, in TTIs when the MCCH (or MSI) is multiplexed into the MCH, the MCCH-specific transport format is used for the MCH. The MCCH-specific transport format is provided as part of the system information (SIB13; see Chapter 14 for a discussion about system information). The system information also provides information about the scheduling and modifications periods of the MCCH (but not about CSA period, CSA pattern, and MSP, as those quantities are obtained from the MCCH itself). Reception of a specific MBMS service can thus be described by the following steps:

- Receive SIB13 to obtain knowledge on how to receive the MCCH for this particular MBSFN area.
- Receive the MCCH to obtain knowledge about the CSA period, CSA pattern, and MSP for the service of interest.
- Receive the MSI at the beginning of each MSP. This provides the terminal with information on which subframes the service of interest can be found in.

After the second step above, the terminal has acquired the CSA period, CSA pattern, and MSP. These parameters typically remain fixed for a relatively long time. The terminal therefore only needs to receive the MSI and the subframes in which the MTCH carrying the service of interest are located,
as described in the third bullet above. This greatly helps to reduce the power consumption in the terminal as it can sleep in most of the subframes.

Occasionally there may be a need to update the information provided on the MCCH, for example when starting a new service. Requiring the terminal to repeatedly receive the MCCH comes at a cost in terms of terminal power consumption. Therefore, a fixed schedule for MCCH transmission is used in combination with a change-notification mechanism, as described below.

The MCCH information is transmitted repeatedly with a fixed repetition period and changes to the MCCH information can only occur at specific time instants. When (parts of) the MCCH information is changed, which can only be done at the beginning of a new modification period, as shown in Figure 15.6, the network notifies the terminals about the upcoming MCCH information change in the preceding MCCH modification period. The notification mechanism uses the PDCCH for this purpose. An eight-bit bitmap, where each bit represents a certain MBSFN area, is transmitted on the PDCCH in an MBSFN subframe using DCI format 1C and a reserved identifier, the M-RNTI. The notification bitmap is only transmitted when there are any changes in the services provided (in release 10, notification is also used to indicate a counting request in an MBSFN area) and follows the modification period described above.

The purpose of the concept of notification indicators and modification periods is to maximize the amount of time the terminal may sleep to save battery power. In the absence of any changes to the MCCH information, a terminal currently not receiving MBMS may enter DRX and only wake up when the notification indicator is transmitted. As a PDCCH in an MBSFN subframe spans at most two OFDM symbols, the duration during which the terminal needs to wake up to check for notifications is very short, translating to a high degree of power saving. Repeatedly transmitting the MCCH is useful to support mobility; a terminal entering a new area or a terminal missing the first transmission does not have to wait until the start of a new modification period to receive the MCCH information.