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Title: MCH Transport Channel Mapping
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1. Introduction

Two conceptual models have been assessed as the basis for mapping the MCH transport channel onto the physical resource. In the first general approach, physical resources allocated to a specific multi-cell MCH transmission are distinguished from resources allocated to other multi-cell MCH transmissions or transport channels such as the DL-SCH on a time-division multiplexed (TDM) basis. In the second approach, time-frequency resources are allocated to different multi-cell MCH transmissions, or between MCH and DL-SCH transmissions, on a frequency division multiplexed (FDM) basis. This contribution compares the advantages and disadvantages of each approach, and makes recommendations on potential ways forward.

2. Discussion

2.1. UE Power Consumption

Figure 1 and Figure 2 illustrate the issue of UE power consumption as a function of the MCH mapping mode. Figure 1 shows an example of the TDM approach. In the figure, subframes (1ms) are allocated to either DL-SCH or MCH use, where the MCH mode is either a single- or multi-cell configuration, depending on the number of contributing cells. Multiplexing between, say two local multi-cell MCH SFN's (respectively ID's #1 and #2) or between a local SFN and a wide-area SFN is achieved by subframe multiplexing in the time-domain. A corresponding instance of the FDM approach appears in Figure 2. Here, each subframe is allocated to MCH use, but may be partitioned on an FDM basis between more than one multi-cell MCH SFN.

Unsurprisingly, delivering the same MCH data rate via the TDM and FDM options leads to increased UE activity under the FDM model. Consider for example a UE receiving a 'Mobile TV' of 256 kbps MCH from a single SFN using the TDM model of Figure 1, assuming a single reference symbol set (R1) with an L1/L2 control channel allocation of 1 OFDM symbol. As indicated in Table 1, assuming QPSK, R=1/2 operation, a maximum rate of around 6.2Mbps is sustainable in a 10MHz bandwidth. Table 1 also shows, however, that the UE could maintain the 256kbps rate while receiving only every 24th sub-frame (i.e. with a 'frame skip factor' of 24).

In order to quantify the benefit of decreased UE activity in TDM on UE power consumption, consider an LTE_IDLE mode UE accessing a multi-cell MCH transmission, neglecting any overhead radio subsystem activity (i.e. RF and baseband signal processing) due to paging etc. Table 1 further shows the relative UE power consumption as a function of the MCH frame skip factor, and fraction of the UE power consumption allocated to the radio subsystem. It can be seen that for radio subsystem power consumption fractions in the range 0.3-0.4, and neglecting quiescent radio subsystem power consumption as negligible, savings of up to 40% in UE power consumption can be achieved via TDM, even for high rate "Mobile TV" applications of 256kbps. For lower rate services, with correspondingly reduced activity factors, the TDM approach supports still further reductions in power consumption, especially when the applications subsystem (control, applications co-processing) is no longer continuously active.

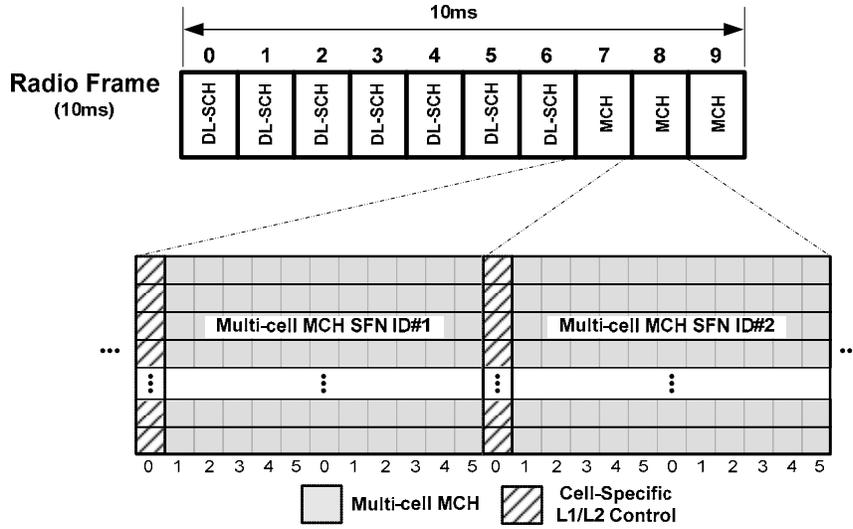


Figure 1 – Basic TDM MCH Mapping.

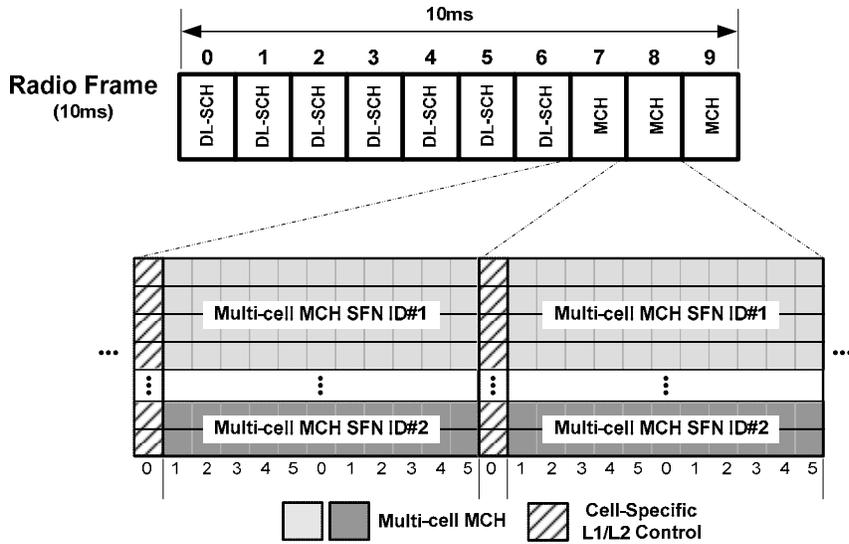


Figure 2 – Basic FDM MCH Mapping

Parameter	Units	Value
MTCH Data Rate	kbps	256
EUTRA DL Bandwidth		10
#Sub-carriers		600
Code Rate		1/2
Modulation		QPSK
# OFDMSyms/subframe	Syms	12
# L1/L2 CTL OFDMSyms/subframe	Syms	1
# MCH OFDMSyms/subframe	Syms	11
#OFDM Syms/subframe with RS	Syms	4
Inter-RS Dist.	Subcarriers	6
Total RE's	RE's	6600
Total RS RE's	RE's	400
Total MCH RE's	RE's	6200
Total MCH Coded Bits/Subframe	Bits	12400
Total MCH Inf. Bits/Subframe	Bits	6200
MCH Data Rate	Mbps	6.2

Basic Data Rates

Fractional Radio Subsystem Pow. Cons.	Frame Skip Factor				
	1	4	8	16	24
0.1	1.00	0.93	0.91	0.91	0.90
0.15	1.00	0.89	0.87	0.86	0.86
0.2	1.00	0.85	0.83	0.81	0.81
0.3	1.00	0.78	0.74	0.72	0.71
0.4	1.00	0.70	0.65	0.63	0.62

Relative UE Power Consumption

Skip Factor	Data Rate (kbps)
1	6200.0
4	1550.0
8	775.0
12	516.7
16	387.5
24	258.3

Rate vs. Frame Skip Factor

Table 1 – TDM activity factors and fractional UE power consumption.

Clearly, application of the FDM approach leads inevitably to increased UE activity – i.e. a requirement to observe a greater number of sub-frames. Since the radio subsystem cannot effectively exploit FDM to reduce power consumption, UE current drain is greater for FDM than for TDM, with relative TDM/FDM power consumption determined by the degree of time-multiplexing still applicable to FDM. In the limit, when the FDM UE is continuously active, the power consumption difference could be as large as 40%.

2.2. MBMS Resource Allocation Granularity

Some MBMS-related services, such as cell-specific information services or low-rate ‘ticker-tape’ services, could potentially be handled more efficiently if individual subframes could be sub-partitioned via FDM into MCH-specific resources. The benefit of this ‘smaller granularity’ approach is illustrated further in the Figure 3, which shows FDM enabling the allocation of individual portions of subframes for a low-rate broadcast service.

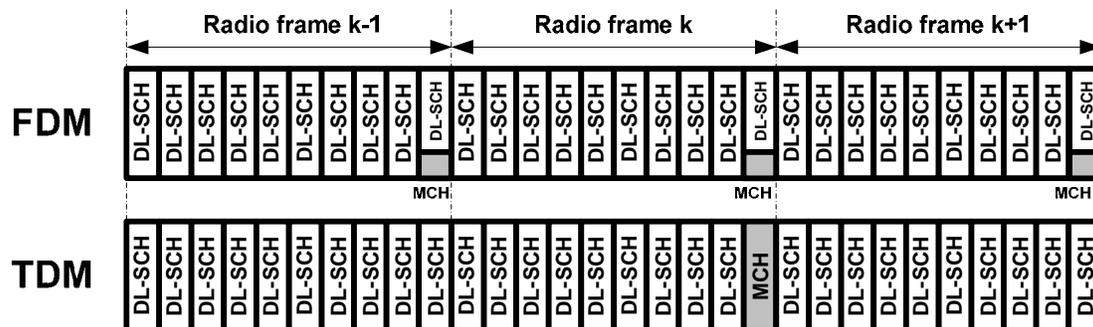


Figure 3 – FDM, TDM and resource granularity.

Nevertheless, it is also apparent from Figure 3 that for such low-rate MBMS services which are not significantly impacted by delay, a TDM allocation at a reduced rate – and, importantly, at a reduced UE activity factor which can be exploited for power consumption reduction purposes – is equally effective. In the specific example of Figure 3, an MCH-dedicated sub-frame is inserted with a frequency less than once per radio frame. In this particular example, the MCH sub-frame is inserted once every 3 radio frames, thereby providing the same resource efficiency as the FDM approach (which, in this case, has an MCH

resource allocated in combination with DL-SCH allocations every radio frame) but with the UE radio subsystem activity reduced by a factor of 3.

2.3. MBMS Dedicated Mode Operation

As discussed in [2] dual-antenna operation can provide significant enhancement of MBMS spectral efficiency, and may be essential to achieving the nominal 1bps/Hz target specified in TS 25.913. The joint session on MBMS of RAN1#47bis and RAN2#56 in Riga further concluded that in the context of Rel-6 MBMS evolution, single- and dual-antenna architectures controlled by a single LO should be supported. The same consideration can reasonably be applied to LTE MBMS.

RAN2 has not yet adopted any procedure for coordinating transmissions between a unicast/MBMS-mixed frequency layer and an MBMS-dedicated layer. Nevertheless, when accessing a companion MBMS-dedicated layer in LTE_ACTIVE mode, UE power consumption minimisation in LTE_IDLE mode suggests that the time duration of an MBMS service-specific transmission on the dedicated frequency layer should be minimised to allow minimum ‘absence’ of the UE from the unicast layer and thereby permit maximum flexibility in unicast layer scheduling. The TDM approach – by minimising the time duration of the MBMS-dedicated transmission – achieves this by minimising the absence of the UE from the unicast/MBMS-mixed layer.

3. Cell Search and Measurements

For unicast/MBMS mixed mode, initial cell search and cell measurement functions are impacted differently by TDM and FDM modes. Reference symbol (RS) provisioning is particularly important, especially if adopted as a component in multi-step initial or non-initial cell search procedures.

Figure 4 shows RS allocation to example FDM and TDM modes. In FDM mode, each subframe contains RS allocations (denoted RS_{S1} etc.) in support of frequency-localised SFN transmissions. Since they are sourced as part of a multi-cell MCH configuration, the RS sequences are a function of the multi-cell MCH SFN ID. For FDM, each subframe then contains multiple SFN-specific RS sequences, along with the cell-specific RS sequence associated with the target cell RS used for initial- or non-initial cell search. The UE is then required to discriminate between RS sources in both time (i.e. between subframes) and frequency (i.e. within a subframe, between resource blocks), without prior guidance on cell-specific SFN partitioning and therefore RS partitioning.

In the TDM case, as illustrated in Figure 4, this problem still exists but is considerably simplified. In this example, subframe k is allocated for cell-specific use – i.e. to DL-SCH or single-cell MCH use – while subframe $k+1$ is allocated to a specific multi-cell MCH. Accordingly, the UE is required solely to validate that a specific subframe has been allocated – *in its entirety* – to a multi-cell MCH SFN, and therefore should not be used to source a cell-specific measurement. Correspondingly, specific subframes may be allocated in entirety to cell specific transmissions. This provides an opportunity to considerably simplify UE measurement processing.

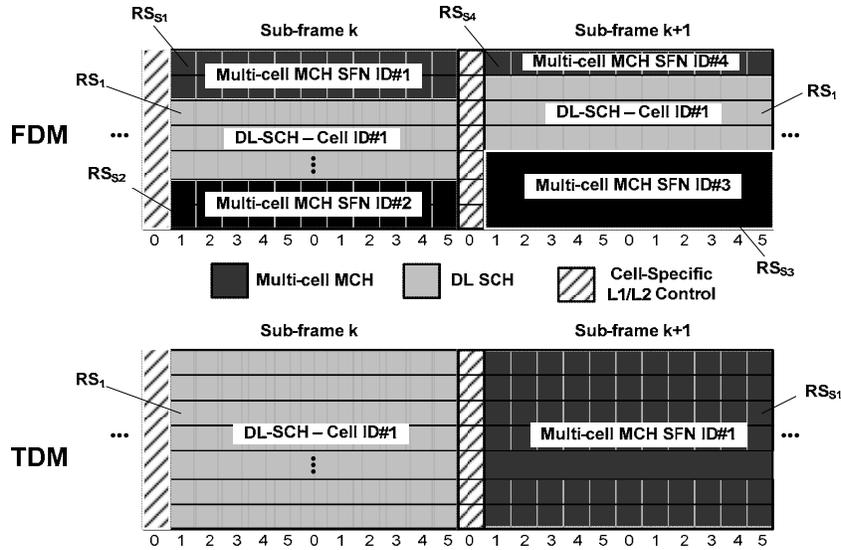


Figure 4 – Reference symbol (RS) provisioning, TDM and FDM SFN.

3.1. Frequency Diversity and Channel Estimation – FDM

Multi-cell MCH operation in FDM mode can support the two principal alternatives of localised and distributed transmission. These broad alternatives appear conceptually in Figure 5.

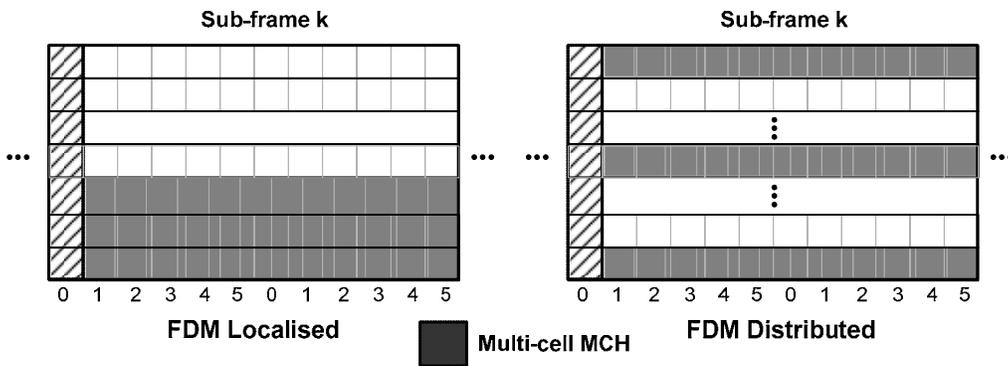


Figure 5 – FDM distributed and localised modes.

There are obvious trade-offs in the designs. For small frequency-domain allocations to a specific multi-cell MCH SFN, the distributed approach permits exploitation of full frequency diversity. In Figure 5, it is assumed that diverse allocations are made using integer numbers of resource blocks (RB's), to maximise commonality with unicast signalling. But, since reference symbols cannot be shared between SFN's, channel estimation error increases. This can be particularly significant in SFN's supporting higher order modulation (16-QAM etc.). Improved channel estimation using an FDM localised allocation reduces frequency diversity.

4. Performance

Clearly, since FDM mode does not gain as much benefit from frequency diversity as TDM mode, there is a risk of performance degradation at low doppler speeds. Figure 6 shows performance of coverage versus spectral efficiency for FDM-Localised, FDM Distributed and TDM modes in Case 1 and Case 3 5MHz deployment scenarios. Codeword lengths were considered occupying 288 sub-carriers of 1 OFDM symbol for TDM mode and 24 sub-carriers in 12 OFDM symbols for FDM-Localised and FDM-Distributed mode. Although FDM gains somewhat from diversity in time over TDM, this is insufficient to make up for the loss in frequency diversity, in particular at low doppler speeds.

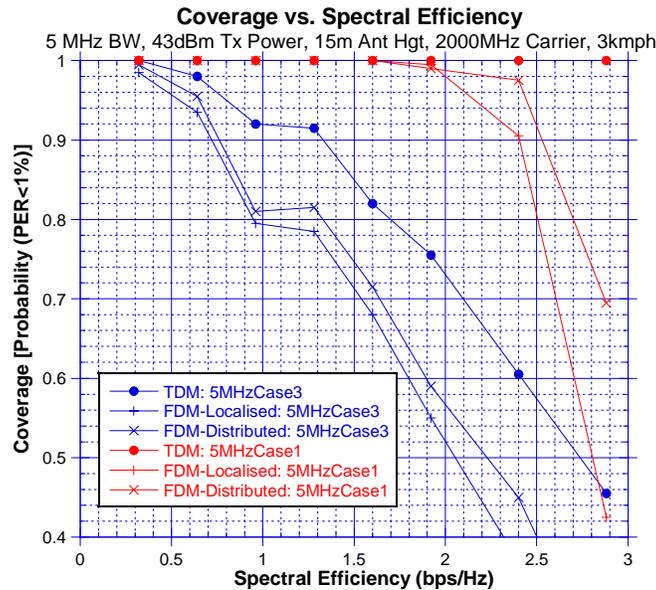


Figure 6 – Coverage versus spectral efficiency for FDM and TDM at low Doppler frequency in Case 1 and Case 3 5MHz deployment scenarios.

Figure 7 considers spectral efficiency for Case 1 and Case 3 10MHz deployment scenarios at low and high Doppler frequencies. The MCH is assigned 600 sub-carriers in a sub-frame (guard sub-carriers were neglected – this has minor impact) in TDM mode, the first 120 sub-carriers for 5 consecutive sub-frames in FDM-Localised mode and the first 120 sub-carriers for the first sub-frame, the second 120 sub-carriers for the second sub-frame and so on for 5 consecutive sub-frames in FDM-Distributed mode. As shown in the figure there is no significant difference in performance between TDM or FDM, even at high Doppler frequencies where the benefit of FDM should be enhanced over TDM.

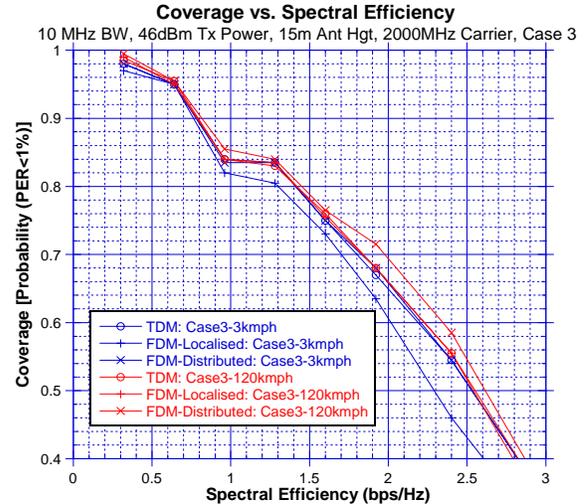
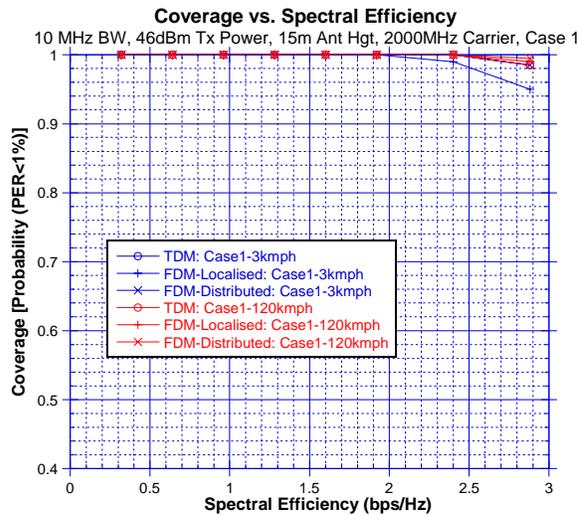


Figure 7 – Coverage vs. spectral efficiency for FDM and TDM in Case 1 and Case 3, 10MHz deployment scenarios.

5. Conclusions

In summary, while both TDM and FDM approaches can provide a feasible approach to MCH mapping, the TDM approach to MCH multiplexing offers the following advantages:

1. reduced UE power consumption
2. simplified reference symbol provisioning
3. simplified initial- and non-initial cell search
4. simplified coordination between unicast/MBMS-mixed and MBMS-dedicated layers

Accordingly, it is proposed that RAN2 adopt the following working assumptions concerning MCH transmission for the MBMS Stage 2 definition in TS 36.300:

- a) a cell may transmit multiple instances of an MCH
- b) only one single- or multi-MCH transmission (i.e. a single SFN) may be mapped to one subframe
- c) DL-SCH and MCH transport channels may not be mapped to the same subframe

6. References

- [1] R2-063145, "Operator's view on LTE MBMS scenarios of deployment", Orange, China Mobile, T-Mobile, Vodafone, NTT DoCoMo, RAN WG2#56, Riga, Latvia, Nov.6-Nov.10, 2006
- [2] R2-063421, "Impact of Single and Dual-Antenna Performance on E-MBMS", Motorola, RAN WG2#56, Riga, Latvia, Nov.6-Nov.10, 2006