Feasibility of UMTS-TDD mode in the 2500-2690MHz Band for MBMS

Alexandra Boal, Luísa Silva, Américo Correia, ADETTI, ISCTE
Lisbon, Portugal, americo.correia@iscte.pt

Abstract—**Spectrum Arrangement Scenarios for 2500-2690MHz band allocation according to ITU-R include 7 different cases, however it remains to be known whether a single scenario or several should coexist in the future. For the 7 scenarios it's necessary to get to know which are the most interesting and which will be more useful to broadcasting/multicasting using UTRA TDD (Time Division Duplex) or FDD (Frequency Division Duplex). In the 2500-2690 MHz band, we investigate the feasibility of future Enhanced-UMTS TDD mode to carry digital broadcast services such as MBMS (Multimedia Broadcast Multicast Service) and provide to a number of existing operators in the actual band, an asymmetric capacity extension, with no impact on existing frequency arrangements. The objective of this work is to choose and study the suitable scenario(s) to provide multimedia broadcast multicast services based on the UTRA TDD mode.**

Index Terms—**ACLR, ACS, Enhanced-UMTS, MBMS, UTRA FDD, UTRA TDD.**

I. Introduction

The knowledge of the received power level inside of the buildings, due to external/internal transmitters, is very important because quality of service requires strict signal to interference to be achieved. In the case of the external transmitters the coverage inside buildings must be done avoiding too much interference from in-building transmitters of other operators. In our study users are located inside buildings where interference comes from inside and outside buildings.

The Multimedia Broadcast and Multicast Service (MBMS) is a unidirectional Point To MultiPoint (PTMP) service for delivering high bitrate multimedia services to a large number of mobile users. There are two modes of operation: multicast and broadcast. A typical MBMS service is the goal replay application, whereby multiple mobile users receive, in real-time, a multimedia replay videoclip of a goal scored in a football match from, for example, a streaming server.

UMTS consists of two complementary interface modes for deployment in terrestrial networks: UTRA FDD for wide area access and UTRA TDD for high user density local area access. The two UMTS modes, FDD and TDD used in parallel will provide the user with the benefits of both radio access principles in overlapping application scenarios.

The TDD study is needed to check its advantages in public micro and pico cell environments. TDD is especially suitable for environments with high traffic density and indoor coverage, where the applications tend to create highly asymmetric traffic and require high bandwidth. The reason is that, it facilitates the particularly efficient use of the available unpaired spectrum and supports data rates of up to 2Mbps with low mobility. TDD is also ideal for corporate networks as it provides the same services on the corporate site as outside in combination with FDD for wide area coverage with separate, simplified network planning on the campus.

TDD technology supports rich applications because it offers users an increased data rate. Otherwise, synchronization difficulties and the associated interference problems are seen as the primary limiting factors [1].

However, TDD is a viable option for operating within the 2500 – 2690MHz band, because UTRA TDD allows the autonomous frequency allocation for new operators, which do not have a frequency block in the core bands.

The study on the use of UTRA TDD in the band 2500–2690MHz does not reveal any general new technical aspects and does not require the development and implementation of new concepts [5].

This paper is organized as follows. Section II describes the propagation aspects for 2.5GHz band. Section III shows the proposed scenarios for 2.5GHz band allocation. Section IV describes the interference model in the TDD and FDD systems. Section V shows the results, contains a discussion of those results and a brief conclusion of the subjects discussed in the previous sections.

II. Propagation aspects for 2.5GHz Band

There are no significant differences between the basic physical mechanisms of radio propagation in 2.5GHz, compared with 2GHz. To scale a continuous function of frequency, all effects like path loss, diffraction losses, building/wall penetration losses will be need to scale as a continuous function of frequency. The basic model assumptions concerning radio propagation developed for the 2GHz band will be re-use without much loss of accuracy [2, 3]. Comparing to the 2GHz, the path loss (PL) for the 2.5GHz bands will be larger. If the Walfisch-Ikegami-Model is still valid around 2.5GHz, we can estimate the additional PL from the frequency dependent term in this model, B*log10(f), where B=33.9 (this value is expected to be larger for 2.5GHz):

This work is co-funded by the European Commission under the framework of IST-2003 507607 Project, B-BONE – Broadcasting and Multicasting Over Enhanced UMTS Mobile Broadband Networks.

$$\Delta PL = B * \log_{10}(2.5/2.1) = 2.57dB \qquad (1)$$

Additional cable losses for the 2.5GHz signal relative to the one around 2GHz will occur at Node B sites - these are typically in the order of 1…3dB/100m, consonant the cable type and size. For cable length of up to 20m (typical for rooftop installations) the additional cable losses in 2.5GHz will be in the order of 0.3…0.6dB. These are the values used in the following calculations [6].

III. Proposed Scenarios

The feasibility analysis of enhanced UMTS FDD and TDD to carry digital broadcast/multicast services will contribute to the dissemination of the B-BONE (Broadcasting and multicasting over enhanced UMTS mobile broadband networks) project results. Co-existence between UTRA FDD and UTRA TDD within 2500-2690MHz will be considered. In the figure below, seven scenarios are shown from the several different possible scenarios [4].

TABLE I
Spectrum Arrangement Scenarios for 2500-2690MHz band allocation according to ITU-R. [5]

FUTURE BAND				
MHz ***2500***				***2690***
Portions	***A***	***B***	***C***	***D***
Scenario1	FDD UL (internal)	TDD		FDD DL (internal)
Scenario2	FDD UL (internal)	FDD DL (external)		FDD DL (internal)
Scenario3	FDD UL (internal)	TDD	FDD DL (external)	FDD DL (internal)
Scenario4	FDD DL (external)		TDD	
Scenario5	TDD		FDD DL (external)	
Scenario6	TDD			
Scenario7	FDD DL (external)			

In this work we consider the scenarios 1, 3, 4, 5 and 6 because they are the best scenarios to perform the requirements of TDD, to our case of study of B-BONE project. The study of scenario 6 is presented in the poster.

Using FDD and TDD technologies we can maximize the number of users on a system and thereby maximize average revenue per user, total revenues, and return on investment[5].

A. Scenario 1

This scenario shows a graphical representation for using the additional frequencies from 2500 - 2690MHz for UTRA FDD. In here, both FDD UL and FDD DL carriers are located in the 2.5GHz band.

With this scenario we could made the following observations:

- Provision of a wide range of symmetric or asymmetric capacity and additional UL/DL spectrum to support new, as well as existing operators (with no impact on existing frequency arrangements);
- From UE roaming and design point of view, it would be beneficial if the partitioning A/B of the 2.5GHz band could be made fixed on an as global basis as possible;
- Implementing UEs or Node B's according to the scenario 1 frequency arrangement does not require development of any new or risky implementation concepts as such;
- Propagation loss in 2.5GHz is higher and therefore cell sizes will be smaller with current UE power classes;
- 30 MHz of duplex gap between FDD UL and FDD DL bands is desirable to achieve the present interference protection levels [5].

B. Scenario 3

This scenario shows a graphical representation for utilizing the additional frequencies from 2500 - 2690MHz for UTRA FDD and TDD.

With this scenario we could made the following observations:

- Provision of a wide range of asymmetric capacity, the UL and DL bands of the "FDD internal" system can be asymmetric;
- Provision of additional UL/DL spectrum to support new, as well as existing operators (with no impact on existing frequency arrangements);
- The potential bandwidth available for both FDD and TDD within the band 2500–2690MHz may increases the potential for interference;
- The TDD band is located between FDD UL and FDD DL, the two TDD channels will experience interference with the FDD channels, caused by the other system due to the imperfect transmitter and receiver characteristics [5].

C. Scenario 4 and 5

In both scenarios, half of this band use FDD UL carriers located within Band I and other half use TDD. With these scenarios we could made the following observations:

- Provision of a DL capacity extension for existing Band operators (with no impact on present band);
- TDD allows the autonomous frequency allocation for new operators, which do not have a frequency block in the core bands;
- TDD RF performance requirements as currently formulated for the TDD core band operation if applied to the 2500-2690MHz band may result in a number of TDD/TDD interference cases;
- The FDD DL is located next to the TDD band, at least one TDD and one FDD DL channel will experience interference caused by the other system due to the imperfect transmitter and receiver characteristics [5].

D. Scenario 6

In this scenario the complete band 2500-2690MHz is used exclusively for UTRA TDD.

UTRA TDD allows frequencies to be allocated autonomously for new operators who do not have frequency blocks in the core band.

Compared with UTRA TDD operation in the core band, TDD operation at 2.5GHz will entail:

- higher propagation loss within 2500–2690MHz compared to the UTRA TDD core band which may affect the numerical values of some of the RF requirements for UR and/or node B;
- larger potential bandwidth (up to 190MHz) available for TDD, increasing the potential for interference (particularly for mechanisms related to spurious emissions and blocking);
- the possibility for prospective TDD operators within the 2.5GHz band to deploy multiple TDD carriers - this will have a positive impact on the potential for escaping interference but a negative impact on the equipment (BS, UE) feasibility regarding the projected RF requirements (e.g. ACLR, spurious emissions)[5].

IV. Interference Model In the TDD/FDD

The suggested model considers free space propagation path loss between the external antenna and the illuminated wall of the building.

The propagation losses in an indoor environment are calculated by the following expression [6]:

$$L_{indoor}(dB) = 32.4 + 20\log(f_{[GHz]}) + 20\log(d_{[m]}) + \\ + WG_e \cdot n + \max(\Gamma_1, \Gamma_2) \tag{2}$$

where $\Gamma_1 = W_i \cdot p$ and $\Gamma_2 = \alpha \cdot (d-2) \cdot p$

Relatively to the variables of the expressions, f is the 2.5GHz carrier frequency and d is the distance. The WG_e parameter is the additional loss for floor (in dB), with a value about 20dB, and n represents the number of floors among the access point and the mobile. The W_i parameter is the loss for wall (in dB) with a value between 4 and 10dB, being p the number of penetrated interior walls. For the remaining parameters the following intervals are recommended: W_e (4–10dB) and α it's about 0.6dB/m [6].

The total path loss between outdoor BS and UE inside building is determined with the following expression [6]:

$$L_{path}(dB) = 32.4 + 20\log(f) + 20\log(S+d) + \\ + W_e + WG_e \cdot \left(1 - \frac{D}{S}\right)^2 + \max(\Gamma_1, \Gamma_2) \tag{3}$$

where $\Gamma_1 = W_i \cdot p$ (4)

$$\Gamma_2 = \alpha \cdot (d-2) \cdot \left(1 - \frac{D}{S}\right)^2 \tag{5}$$

In what it concerns above the variables mentioned, we have that D and d are the perpendicular distances and S is the physical distance between the external antenna and the external wall at the actual floor. All distances are expressed in meters and the frequencies are expressed in GHz. The angle θ is determined through the following expression:

$$\sin(\theta) = D/S \tag{6}$$

When the external antenna is located at the same height as the actual floor height and $D=S$, in other words, at a perpendicular distance from the external wall, θ=90º. Relatively to the other parameters, W_e is the loss (in dB) in the externally illuminated wall at perpendicular penetrations (θ=90º) with a value about 7dB (with normal window size), the WG_e parameter is the additional loss in dB in the external wall when θ =0º and has a value about 20dB, W_i is the loss in the internal walls in dB, with a value about 7dB (concrete walls) and p is the number of penetrated internal walls. This approach is correct for LOS conditions in the micro-cells, with small values of θ, even if the path loss are larger than free space propagation close to the proximities of the external walls. α it's about 0.6dB/m [6].

There are two critical scenarios of WCDMA interference. One happens when UE from operator 1 is coming close to Node B of operator 2, located at the cell edge of operator 1 and is blocking this Node B because it's transmitting with full power. Second happens when Node B from operator 2 is transmitting with high power and therefore is blocking all of UE of operator 1 in a certain area around it, caused by dead zones because of the excessive power, and/or blocking because of the exceeded input power at the UE receiver. The influence of adjacent channels on each other can be identified as Adjacent Channel Leakage power Ratio (ACLR), Adjacent Channel Selectivity (ACS) and Adjacent Channel Interference Ratio (ACIR). Assuming values of 33dB and 45dB to ACS and ACLR respectively, the coupling C between the carriers can be calculated as

$$C = -10\log(10^{-33/10} + 10^{-45/10})dB = 32.7dB \tag{7}$$

Assuming that for UL, the interference margin is 4dB, and knowing that

$$M_i = I/P_N \tag{8}$$

then, $I = 2.5\ P_N$. For UL, the background noise level is P_N=-103.1dBm. Therefore I=-99dBm.

It's known that

$$P_r = SIR + I \tag{9}$$

SIR can be obtained in two ways: graphic analysis or through the following table:

TABLE II
DL and UL E_b/N_0 and PG values for TDD [3].

TDD	Downlink	Uplink
E_b/N_0(dB)	11.5	1.0
Processing gain(dB)	2.4	2.4

where,

$$SIR = E_b/N_0 - PG \quad [dB] \tag{10}$$

Knowing that, we can calculate P_t and considering that $P_t \leq$ 21dBm. If that doesn't happen, we are before a case of dead zone. The received level at the micro BS, must be, $P_r \leq$-93dBm, otherwise there is blocking zones.

For this work, we calculated SIR for the two processes, obtaining through the graphic analysis SIR=-14.4dB and for the other process SIR=-1.4dB.

For DL, the process is exactly equal to the UL, but considering that M_i=10dB, P_N =-100.1dB. With those values we obtained I=-90dB, SIR=9.1dB (128k bit/s), P_r =-80.9dB, and I =-90dB with SIR=3dB (64k bit/s), P_r =-87dB In these cases, $P_t \leq$ 27dBm and $P_r \leq$ -90dBm. If that doesn't happen, we are before a case of dead zone and blocking zone, respectively.

V. Discussion and Conclusions

In our simulations the chosen scenario is building where is located the department ADETTI of ISCTE (university campus of Lisbon). We considered two UMTS Portuguese operators that are operating in adjacent channels within the same area. Operator 1 has an external BS (FDD), and Operator 2 has internal BSs (TDD).

It's observed (see Fig. 1) that, in a widespread way, as closer to the BS, smaller will be the propagation losses. That happens because for increasing distance to BS, there will be, probably, higher number of obstacles (for instance, walls, doors...). However not always that happens, as it is the case of corridor, in that the distance to the BS increases, but the losses increase a little, in an almost insignificant way, very few walls and doors are crossed, therefore we can conclude that walls and doors contribute more to the increase of propagation losses than the distance alone.

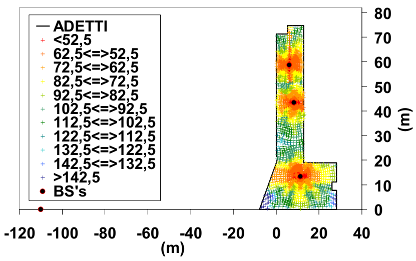

Fig. 1. Indoor Propagation Loss.

Relatively to the graph of the outdoor propagation loss (Fig.2), we can conclude that, as minor is the distance to the BS, minor will be the losses.

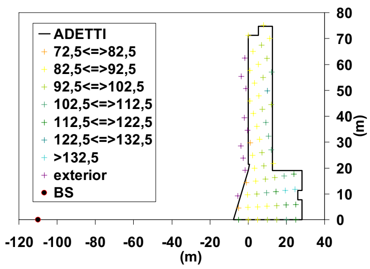

Fig. 2. Outdoor Propagation Loss.

In our simulations, the uncovered areas and the blocking zones are estimated for UL with SIR values of SIR=-14.4dB, SIR=-1.4dB and for DL SIR=9.1dB, SIR=3dB, as shown in Fig. 3, 4, 5 and 6 respectively. In these graphics, the blue is the unblocking zones, the yellow is the blocking zones and the brown is the dead zones.

When we have a user inside of the building and it is communicating with an external BS, this can cause interferences in the communication of other users covered by indoor BS, in that case we say that there is blocking. The results are so much better as less area with blocking exists and vice-versa.

In relation to the graphs for us obtained, in the case that we have UL with SIR=-14.4dB we check that we obtain better results than when SIR=-1.4dB. We conclude that, as more negative is SIR, better will be the obtained results.

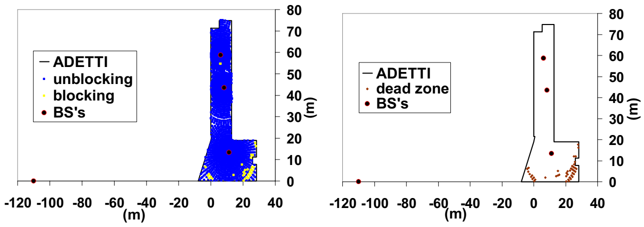

Fig. 3. Blocking zones (left) and dead zones (right) for UL with SIR=-14.4dB.

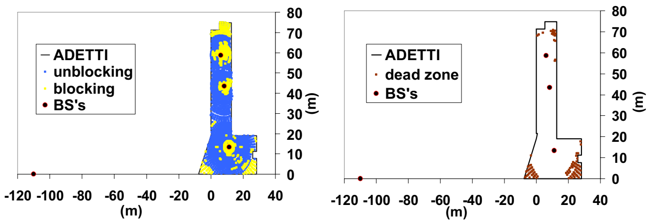

Fig. 4. Blocking zones (left) and dead zones (right) for UL with SIR=-1.4dB.

In DL case, we can conclude that as smaller is SIR, better will be the obtained results (the results of SIR=3dB are a little better than SIR=9.1dB).

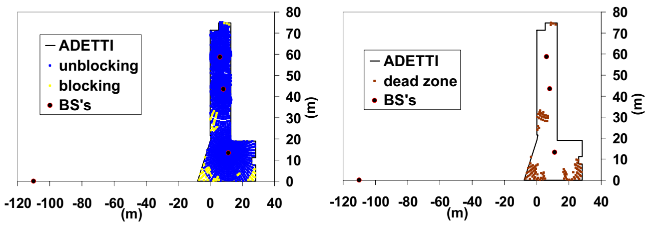

Fig. 5. Blocking zones (left) and dead zones (right) for DL with SIR=9.1dB

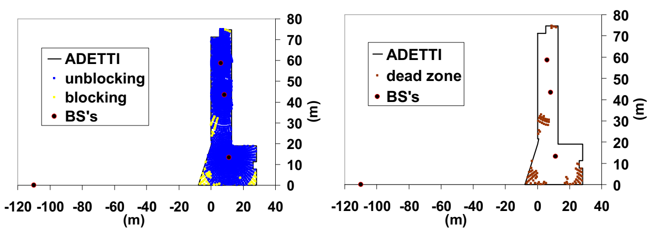

Fig. 6. Blocking zones (left) and dead zones (right) for DL with SIR=3dB.

The propagation loss predictions are based on the knowledge of topography and building height information. The applied path loss model is based on the Walfisch-Ikegami-Model. WCDMA internal interferences are estimated, taking into account ACLR and ACS. The requirements of both defined in table III, are valid when the adjacent channel power is greater than -50dBm [4].

TABLE III
ADJACENT CHANNEL LEAKAGE POWER RATIO AND ADJACENT CHANNEL SELECTIVITY PERFORMANCE REQUIAREMENTS.

Adjacency	Channel Separation	Max. Allowed ACLR		Max. Allowed ACS	
		UE	NodeB	UE	NodeB
1rst Adjacent Carrier	5 MHz	33 dB	45 dB	45 dB	45 dB

A dead zone is an area in which either in DL or in UL the user does not have enough received power to maintain the quality of service (QoS) required.

The next figures correspond to the blocking zones and the dead zones for the cases in study, but now they are expressed in percentage and it's referred to the bit rate and the channel separation (see Table III).

Through the graphs of probabilities, it's observed that the case that presents higher probability of blocking is UL with a SIR=-1.4dB, following by DL with SIR=9.1dB, DL with SIR=3dB and last UL with SIR=-14.4dB. Relatively to the dead zones, it is observed that in UL (SIR=-14.4dB) there are few dead areas. The same doesn't happen with UL (SIR=-1.4dB) and DL (with SIR=9.1dB and SIR=3dB). However, in DL with SIR=3dB we have less dead areas than DL with SIR=9.1dB.

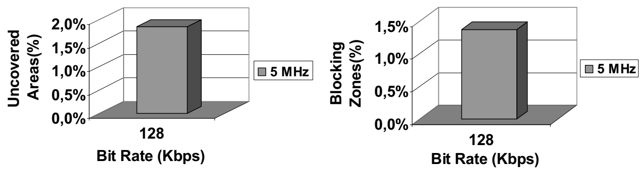

Fig. 7. Uncovered areas (left) and blocking zones (right) for UL with SIR=-14.4dB.

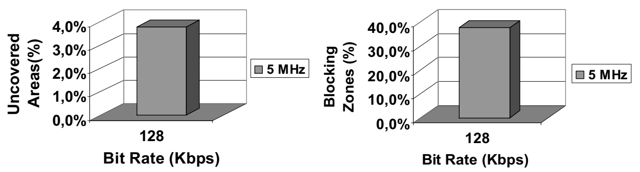

Fig. 8. Uncovered areas (left) and blocking zones (right) for UL with SIR=-1.4dB.

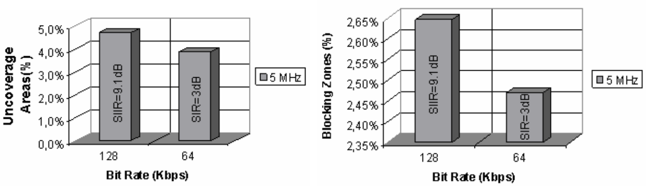

Fig. 9. Uncovered areas (left) and blocking zones (right) for DL with SIR=9.1dB and SIR=3dB.

Regarding SIR we can conclude that the worse case is when the BS has one antenna, that is, in the UL SIR=-1.4dB, and the DL SIR=9.1dB. Therefore, it is essential that the BS has two antennas, as is the case of the SIR=-14.4dB in the UL and the SIR=3dB in the DL. However, when we compare the graphs of the DL with the UL, there is a visible difference, in the case of the BS having 1 or 2 antennas. This difference is not so evident relatively to the DL graphs, this is because in the band of 2.5GHz there is a coverage problem, so the UL is the more sensitive to the number of antennas in the BS to cover the same area (the use of two or three links helps to minimize the coverage issue in broadcast services).

In order to support MBMS services (asymmetric traffic), additional DL carriers in the 2.5GHz band will be required. Nevertheless, the use of TDD is viable and allows the frequency allocation for new operators, which do not have a frequency block in the core bands [5].

REFERENCES

[1] Siemens AG 2000, "TDD and FDD for One Source".
[2] Holma, Toskala, WCDMA for UMTS, Wiley.
[3] Wacker, Laiho, Novosad, Radio Network Planning and Optimisation for UMTS, Wiley.
[4] 3GPP TR 25.889 V6.0.0, "3rd Generation Partnership Project; Technical Specification Group Radio Access Network; Feasibility Study considering the viable deployment of UTRA in additional and diverse spectrum arrangements (Release 6).
[5] Américo Correia, Ana Rita Oliveira, "Feasibility Study of the 2500-2690MHz Band for Multimedia Broadcast Multicast Service", VTC2004 Fall, Los Angeles USA, 26-29 September 2004.
[6] COST Action 231, "Digital Mobile Radio Towards Future Generation Systems".