SC-PTM or MBSFN for Mission Critical Communications?

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***Abstract*—Long Term Evolution (LTE), designed by 3rd Generation Partnership Project (3GPP) to increase the capacity of radio mobile communications, has been endorsed by multiple public protection and disaster relief organizations as a next generation technology for Professional Mobile Radio (PMR) networks, which convey business and mission critical communications. One of the main services of PMR is the group communication that can be seen as a Multimedia Broadcast Multicast Service (MBMS). LTE offers functionality to transmit this type of flows either by MBMS over Single Frequency Network (MBSFN), or Single-Cell Point-To-Multipoint (SC-PTM). In this paper, we compare MBSFN, SC-PTM and unicast transmissions in terms of radio quality, system spectral efficiency and cell coverage. Our main conclusion is that SC-PTM together with Transmission Time Interval (TTI) bundling transmissions offers a flexible solution to trade coverage off for capacity.**

I. Introduction

Business and mission critical communications are communications between professional users either from the public safety sector or operating critical infrastructures. Owing to special coverage, priority access, reliability and resilience requirements, as well as additional services for professional users, these communications are conveyed by Professional Mobile Radio (PMR) networks. Driven by the demand growth, significant changes are taking place in the PMR industry. The existing PMR technologies are indeed not well suited to provide high data rates mobile services like video and photo transfers. In this context, the adoption of commercial technologies, such as Long Term Evolution Advanced (LTE-A), for business and mission critical communications is gaining strong momentum. Thus, 3rd Generation Partnership Project (3GPP) Release 12 has started including public safety features [1].

Group communication is the main service allowed by PMR networks. The Multimedia Broadcast/Multicast Services over Single Frequency Network (MBSFN) technology is a natural enabler for such services because it offers Point-to-Multipoint (PTM) communications. In this approach, several evolved NodeB (eNB) transmit the same signal to group users and thus increase their signal radio quality. As an alternative, 3GPP Release 13 has proposed Single-Cell Point-To-Multipoint (SC-PTM), a solution based on a single eNB transmission, which aims at increasing the System Spectral Efficiency (SSE) [2]. In this paper, we compare these two approaches in terms of coverage and capacity and provide engineering rules for the deployment of group communications.

The 3GPP has first introduced MBMS for UMTS in Release 6, as a PTM content delivery to provide multimedia services over mobile networks in efficient means by taking advantage of the broadcast nature of the radio channel. MBMS has been enhanced to become evolved MBMS (eMBMS) in LTE Release 9. Its underlying transmission scheme is MBSFN, a technique by which several eNBs transmit the same signal to group users. The MBSFN operation increases the Signal to Interference plus Noise Ratio (SINR), especially at cell edge.

In MBSFN, the transmission of eMBMS data can occur in cells, in which there are no user interested in receiving the session, thus, radio resource waste can occur. Moreover, the transmitting cells should be synchronized, which imposes additional delays in session's establishment. SC-PTM has thus been proposed in Release 13 as an alternative to overcome these issues. In SC-PTM, multicast transmission is performed on a per cell basis. The SSE is thus expected to increase.

The performance of MBSFN and SC-PTM has been discussed in literature and recent 3GPP technical reports. In [3], an analytical model for the capacity and coverage estimations in MBSFN transmission were proposed. Alexiou et al. presented in [4] a study on performance and cost analysis of different MBSFN deployments but mainly focus on forward error correction impact. Different selection techniques of Modulation and Coding Scheme (MCS) have been evaluated for MBSFN assuming Channel State Information (CSI) feedback, e.g. in [5], [6]. In references [3]–[6], SC-PTM is however not considered.

Some system aspect differences between MBSFN and SC-PTM are analyzed in [1], [7]. Authors of [8], [9] focus on the gains brought by Hybrid Automatic Retransmission reQuest (HARQ). In [8], deployment strategies of MBSFN are not investigated although they have crucial impact on its performance. The 3GPP report [10] is the closest to our study. A performance comparison of SC-PTM, MBSFN and unicast transmission modes are presented. The authors show that SC-PTM outperforms MBSFN in terms of SSE, owing to the efficient use of radio resources only in cells in which there are User Equipment (UE) interested in receiving the session. However, the authors didn't consider the selection of appropriate

MCS for each MBSFN session, since the CSI feedback is not adopted by the standard. Also, the tradeoff between coverage gain ensured by MBSFN and transmission reliability in terms of outage probability has not been investigated; although this tradeoff is crucial for mission critical communications [11].

In this paper, we evaluate the performance of MBSFN, SC-PTM and unicast transmissions in different UE's distribution scenarios and network configurations, in terms of SINR distribution, SSE, outage probability and cell range. We study the tradeoff between coverage and reliability, and we provide engineering rules for the deployment of group communication services. We also show the impact of the Transmission Time Interval (TTI) bundling feature.

The rest of the paper is organized as follows: in section II, we introduce MBSFN and SC-PTM transmission modes. Next, we define the system model and parameters in section III. Section IV presents and discusses the simulation results. Finally, conclusions are summarized in section V.

II. Multicast transmission techniques

MBMS data can be delivered either by Point-To-Point (PTP) or Point-To-Multipoint (PTM) transmissions [8]. In PTP (or unicast) mode, a dedicated channel is established with each UE to carry MBMS information, while in PTM, a common channel is used to simultaneously convey the information to multiple (multicast transmission) or all (broadcast transmission) UEs requesting the corresponding data. Since it is expected that the radio resources increase linearly with the number of UEs receiving the same data in PTP transmission, PTM improves the resource allocation. However, PTM transmission efficiency mainly depends on the UE in the group with worst radio conditions. The PTM transmission of MBMS data in the radio access network uses either SC-PTM, or MBSFN. In the following sections, we introduce some aspects of these transmission modes.

A. MBSFN

The Multimedia Broadcast Multicast Service over Single Frequency Network (MBSFN) is a simulcast transmission technique introduced to support eMBMS transmission in LTE networks. In MBSFN, a time-synchronized common waveform is transmitted simultaneously from a set of eNBs using the same resource blocks. The corresponding cells form the so called MBSFN area. This area can be *static*, i.e., defined a priori by the operator, or *dynamic*. In this case, the set of transmitting eNBs is dynamically adapted to the UE group spatial distribution.

In such a transmission, the UE receives copies of the signal with different delays, amplitudes and phases depending on the distance to each eNB. Therefore, the UE may treat the multicell transmissions in the same way as multipath components of a single-cell transmission without incurring any additional complexity [1].

It can thus benefit from spatial diversity, increased useful signal power and reduced inter-cell interference (since the received signals from neighbor eNBs inside the MBSFN area will be considered as constructive signals). In order to further reduce the inter-cell interference, a set of *reserved cells* around the MBSFN area can be deployed, in which there is no transmission during active MBSFN subframes. MBSFN is designed to only support extended cyclic prefix, which reduces inter-symbol interference to the UEs. These properties lead to SINR improvement, especially at cell edge and thus increased cell coverage [5], [6]. MBSFN uses Multicast Traffic CHannel (MTCH) to convey the data on specific subframes.

B. SC-PTM

The Single-Cell Point-To-Multipoint (SC-PTM) was introduced in 3GPP Release 13 as complementary bearer type of eMBMS transmission [2]. SC-PTM reuses the eMBMS system architectures (logical entities and interfaces) and relies on PTM transmissions. However, the synchronized multi-eNB transmission is abandoned, i.e., PTM transmission is performed on a per-cell basis. If a group of users requesting the same service is distributed over several cells, involved eNBs use independently PTM for the users under their coverage and may interfere each other. Contrary to MBSFN, SC-PTM uses the Physical Downlink Shared CHannel (PDSCH), so that the multiplexing with unicast transmissions is more flexible [1]. Furthermore, SC-PTM transmission enhances coverage and transmission efficiency by enabling the HARQ retransmissions based on the uplink HARQ and CSI feedback from connected UEs [9]. SC-PTM can also activate the TTI bundling feature that consists in sequentially transmitting multiple redundancy versions of every transport block to increase the probability of good reception. We study this feature in this paper as it does not increase the transmission delay compared to HARQ.

III. System model

A. Network Model

We consider the downlink of a cellular network with omnidirectional eNBs implementing either MBSFN, SC-PTM or unicast transmissions. Let $\mathcal{X}$ be the set of all cells (or eNBs) in the network.

In MBSFN transmission, we consider several network deployment configurations assuming dynamic MBSFN areas. We designate by "SFNatr" a given configuration, where there are "a" rings of cells with active UEs requesting the considered service, "t" rings of cells transmitting synchronously the service without active UEs, and "r" rings of reserved cells. In such network, there are also "o" rings of cells which are outside the MBSFN area. Let $\mathcal{X}_a$, $\mathcal{X}_t$, $\mathcal{X}_r$ and $\mathcal{X}_o$ be the sets of eNBs inside cell rings "a", "t", "r" and "o" respectively; hence: $\mathcal{X} = \mathcal{X}_a \cup \mathcal{X}_t \cup \mathcal{X}_r \cup \mathcal{X}_o$.

In SC-PTM and unicast transmissions, the eMBMS service is transmitted in eNBs supporting active UEs, and all other eNBs act as interfering transmitters.

B. SINR Evaluation

1) Unicast: In a unicast transmission, the SINR experienced by UE m is given by:

$$\gamma_{ucst}(m) = \frac{\frac{P_0}{q_0(m)}}{\sum\limits_{b \in \mathcal{X} \setminus \{0\}} \frac{P_b}{q_b(m)} + N} \quad (1)$$

where $b = 0$ is the index of the eNB, from which m receives the highest power (i.e., the serving eNB); P_b is the transmit power of eNB b; and $q_b(m) = 10^{(L_b(m)+\xi_b(m))/10}$ is the channel loss between eNB b and UE m, where $L_b(m)$ is the distance-dependent path-loss and $\xi_b(m)$ is the shadowing modeled as a zero-mean gaussian random variable with standard deviation σ in dB; N is the thermal noise power given by: $N = N_0 W$, where N_0 denotes the white noise power spectral density, and W the system bandwidth.

2) SC-PTM: In a SC-PTM transmission, the SINR of user m is defined in the same way as for unicast transmission since all eNBs that do not serve m are interfering:

$$\gamma_{sc-ptm}(m) = \gamma_{ucst}(m) \quad (2)$$

3) MBSFN: In SC-PTM and unicast transmissions, the signals originating from all eNBs except the serving eNB are viewed as inter-cell interference. On the contrary, in MBSFN, the signal received from an eNB of the MBSFN area is part of the useful received signal, provided that the propagation delay does not exceed the cyclic prefix duration.

To account for this, we define the weight function of the useful portion of a received MBSFN signal as [3]:

$$\omega(\tau_{bm}) = \begin{cases} 0 & \tau_{bm} < -T_u \\ 1 + \dfrac{\tau_{bm}}{T_u} & -T_u \leq \tau_{bm} < 0 \\ 1 & 0 \leq \tau_{bm} < T_{CP} \\ 1 - \dfrac{\tau_{bm} - T_{CP}}{T_u} & T_{CP} \leq \tau_{bm} < T_{CP} + T_u \\ 0 & \text{otherwise} \end{cases} \quad (3)$$

where τ_{bm} is the difference in propagation delay between signals from eNB b and serving eNB 0 at UE m, i.e., $\tau_{bm} = \frac{d_{bm} - d_{0m}}{c}$, where d_{im} denotes the distance between UE m and eNB i, and c is the light propagation speed. Variable T_u is the duration of the useful part of Orthogonal Frequency-Division Multiplexing (OFDM) symbol and T_{CP} is the duration of the OFDM cyclic prefix.

Therefore, the SINR experienced by UE m can be expressed as [3]:

$$\gamma_{mbsfn}(m) = \frac{\sum\limits_{b \in \mathcal{X}_a \cup \mathcal{X}_t} \frac{\omega(\tau_{bm}) P_b}{q_b(m)}}{\sum\limits_{b \in \mathcal{X}_a \cup \mathcal{X}_t} \frac{(1-\omega(\tau_{bm}))P_b}{q_b(m)} + \sum\limits_{b \in \mathcal{X}_o} \frac{P_b}{q_b(m)} + N} \quad (4)$$

C. Spectral Efficiency

In multicast transmissions, we select the MCS based on the minimum SINR among those experienced in a group communication, from which we determine the Spectral Efficiency (SE) of the group. Other MCS selection algorithms are proposed in the literature [5], [6]. However, in the context of mission critical communications, this is the one that ensures the best coverage, owing to the fact that all UEs, even those with the lowest SINR, will receive the MBMS data. Moreover, because of the possible multicell transmission, resources are used in several cells for a given group. To take into account these two effects and to be able to compare the transmission schemes, we need to define a System Spectral Efficiency (SSE).

Let consider a user m served by the reference cell of index 0. Let G_m the group of users to which m belongs and which are served by 0. At least, let Ω_m be the group users that are served by the MBSFN area of m.

1) Unicast: In unicast transmissions, the SE (in bps/Hz), $SE_{ucst}(m)$, is derived from $\gamma_{ucst}(m)$ using some increasing function $f(\gamma)$, based on the appropriate MCS (see [12, Table 7.2.3-1], [13]). Note that SE does not depend on the rest of the group. In order to take into account the fact that the information is sent to every user separately, the SSE is defined by dividing the SE by $|G_m|$, and taking the expectation as follows:

$$SSE_{ucst} \triangleq \mathbb{E}[\frac{SE_{ucst}(m)}{|G_m|}] \quad (5)$$

where the expectation is taken over user locations, group characteristics (spatial distribution, size), cells, and channel variations.

2) SC-PTM: In this case, the MCS chosen for m depends on the smallest SINR in G_m, so that $SE_{sc-ptm}(m) = f(\min\limits_{p \in G_m} \gamma_{sc-ptm}(p))$. As SC-PTM uses a common resource for all users in G_m, we can define:

$$SSE_{sc-ptm} \triangleq \mathbb{E}[SE_{sc-ptm}(m)] \quad (6)$$

3) MBSFN: Here, the MCS chosen for m depends on the smallest SINR in Ω_m, so that $SE_{mbsfn}(m) = \frac{6}{7} f(\min\limits_{p \in \Omega_m} \gamma_{mbsfn}(p))$, where the factor $\frac{6}{7}$ accounts for the longer cyclic prefix with MBSFN. To consider the reserved resources in reserved cells, as well as the resources used in eNBs which transmit the MBSFN signal without serving any UE, the SSE in MBSFN is defined as follows [10]:

$$SSE_{mbsfn} \triangleq \mathbb{E}[SE_{mbsfn}(m)] \frac{|\mathcal{X}_a|}{|\mathcal{X}_a| + |\mathcal{X}_t| + |\mathcal{X}_r|} \quad (7)$$

D. TTI Bundling

TTI bundling is a feature highly related to HARQ, in the sense that several redundancy versions of a transport block are sequentially transmitted. There is however no feedback from the receiver. This is thus an attractive option for delay sensitive reliable group communications. TTI bundling can be adopted for SC-PTM and unicast, whereas it is not available for MBSFN. For each TTI transmission, an improvement of the BLock Error Rate (BLER) is expected, as it provides UE additional information. In [14], Ikuno et al. estimate the SINR gain for a given BLER target that can be achieved when

HARQ with Incremental Redundancy (IR) is used, compared to a transmission without HARQ. We evaluate the gain of TTI bundling based on this study assuming a fixed number of retransmissions. As a consequence, the SINR after the i-th retransmission can be written:

$$\gamma^{(i)}(m) = \gamma(m) + \gamma^{(i)}_{ttib-gain} \quad (8)$$

where $\gamma(m)$ is given by (1) or (2) depending on the transmission scheme. Figures of $\gamma^{(i)}_{ttib-gain}$ are given in [14].

IV. SIMULATION RESULTS

A. Simulation Parameters

The simulation platform considers a hexagonal urban city cellular network composed of a central cell and 10 rings of adjacent eNBs (331 omni-directionnal eNBs in total). It performs Monte Carlo simulations by varying at each snapshot channel gains and UE locations. The UEs of a group are distributed either in the central cell only (Scenario I), or in central cell as well as the first ring of adjacent cells (Scenario II). Hata model (Urban, eNB antenna height of 55 m, UE antenna height of 1.5 m) is assumed for path-loss evaluations. We vary the group size by considering 1, 2, 4, 8 or 10 UEs per cell in both scenarios (typical figures for mission critical communications). The parameters used in the performed simulations are presented in Table I.

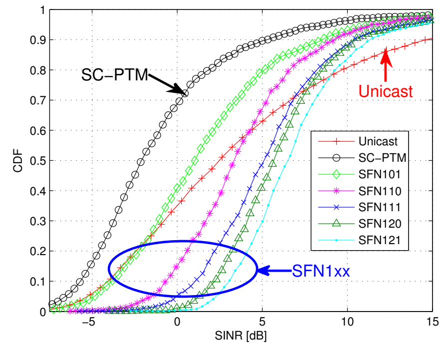
Parameter	Assumption
System model	Macro-cells, urban city
Cellular layout	331 eNBs, omnidirectional
Cell range	1 Km
Carrier frequency (f_c)	800 MHz
Duplex method and Bandwidth	FDD, 5 MHz
eNB Tx power	40dBm (10W)
Nb. of group users per cell	1,2,4,8 or 10 UE per eNB
N_0	-174 dBm/Hz
Shadowing standard deviation	6dB
TTI bundling model	IR with 1, 2, 3 re-Tx, BLER=10%
$T_{CP,mbsfn}$	16.7 µs
$T_{CP,sc-ptm}$, $T_{CP,uncst}$	5.2 and 4.7 µs
Useful signal frame length, T_u	66.7 µs

TABLE I: Simulation parameters.

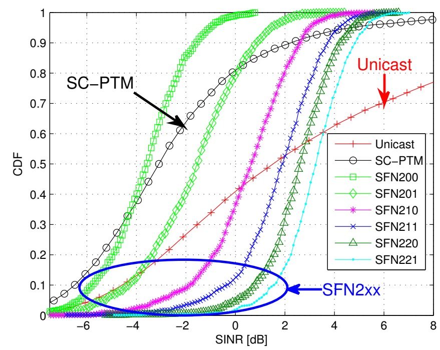
B. SINR Distributions

To compare the performance of different transmission modes, we first consider 4UE/eNB for both Scenarios I and II. Fig. 1a and 1b show the Cumulative Distribution Functions (CDF) of the SINR in unicast, and the minimum SINR in SC-PTM and MBSFN transmission modes, i.e., $\gamma_{ucst}(m)$, $\min_{p \in G_m} \gamma_{sc-ptm}(p)$ and $\min_{p \in G_m} \gamma_{sc-ptm}(p)$ in Scenarios I and II, respectively.

MBSFN benefits from the synchronous transmission from adjacent eNBs and/or the use of reserved cells as shown on Fig. 1a. We observe that the introduction of one ring of reserved cells increases the SINR by 3 dB approximately (see SFN101 vs. SC-PTM). Furthermore, an additional SINR gain of 1 to 2 dB can be obtained by transmitting the signal synchronously on same resources from eNBs of this ring (see



(a) Scenario I (4 UEs in central cell).



(b) Scenario II (4 UEs/cell in central and first ring cells).

Fig. 1: SINR CDF of different transmission modes.

SFN110 vs. SFN101). Reserving the resources of the second ring while transmitting the synchronous signal in the first one (SFN111) improves SINR with 1 to 2 dB compared to SFN110. Moreover, transmitting the synchronous signal from two adjacent rings (SFN120 and SFN 121) improves SINR by 1 to 2 dB compared to single ring transmission (SFN110 and SFN111). All in all, about 9 dB can be gained over SC-PTM with SFN121 for 50% of the groups. For a small group of 4 UEs co-located in a single cell, SFN110 is sufficient to improve the median SINR over unicast.

From Section III, we see that unicast SINR distribution does not depend on the group size, that SC-PTM SINR depends only on the number of group users in reference cell, whereas MBSFN SINR depends on the number of group users in the whole MBSFN area. As a consequence, although the group size has increased, the SC-PTM SINR distribution is not affected in Scenario II because the number of UEs per cell is constant. On the contrary, all MBSFN SINR distributions are shifted to the left. In the best case, MBSFN improves the SINR by 6 dB over SC-PTM (SFN221). SFN211 is now needed for MBSFN to outperform unicast median SINR.

As a conclusion, in terms of minimum SINR, SC-PTM may be preferred over MBSFN for groups, whose users are distributed over many cells. From our simulations we have observed that if the group is distributed over more than 2 rings around the central cell, SC-PTM outperforms SFNX00 (with

$X \geq 3$).

C. System Spectral Efficiency

Tables IIa and IIb show the mean SSE evaluated for different transmission modes (we assume here that CSI feedback and MCS adaptation is possible in MBSFN).

Transmission mode	Mean SSE (bps/Hz)
Unicast	0.36
SC-PTM	0.56
SFN101	0.14
SFN110	0.17
SFN111	0.08
SFN120	0.08
SFN121	0.04

(a) Scenario I

Transmission mode	Mean SSE (bps/Hz)
Unicast	0.36
SC-PTM	0.56
SFN200	0.30
SFN201	0.17
SFN210	0.24
SFN211	0.15
SFN220	0.17
SFN221	0.11

(b) Scenario II

TABLE II: Mean SSE of different transmission modes (4UEs/eNB).

Although unicast provides roughly a double mean SE with respect to multicast transmissions, it uses resources proportional to the number of group users in the cell. MBSFN uses four times less resources than unicast in every cell but uses more resources in the network since some eNBs without group users also transmit. it also suffers from a longer cyclic prefix. In Scenario I, the former effect does not compensate the latter one so that unicast outperforms MBSFN in terms of SSE. Among MBSFN configurations, SFN110 offers the best SSE, which suggests that reserved cells and an extra ring of transmitting eNBs are not required. SC-PTM outperforms both unicast and MBSFN in terms of SSE because it uses less resources than unicast in every cell and less resources in the network than MBSFN. The degradation of the SINR with SC-PTM observed in the previous section does not compensate these effects.

In Scenario II, users are distributed over more cells, which increases the MBSFN SSE, whereas unicast and SC-PTM SSEs are on the contrary not affected. For example, the SSE of SFN200 is now comparable to unicast. From our simulations, we observed that MBSFN performance however saturates for an increasing number of rings (SFNX00 configuration with $X \geq 3$) and never outperforms unicast. This can be explained by the unfavorable MCS selection scheme in MBSFN, which is not compensated by the use of less resources w.r.t. unicast. SFN210 is the best MBSFN configuration for the same reason as for Scenario I.

As a conclusion for this section, MBSFN performance in terms of SSE is increasing with the number of group users. Reserved cells and transmitting cells without group users should be avoided for an increased SSE. If the number of group users per cell is small, MBFSN may not outperform unicast transmission. SC-PTM outperforms MBSFN in terms of SSE. As this effect is the inverse of the one observed for SINR distributions, the transmission mode choice will depend on whether the operator wants to favor coverage or capacity.

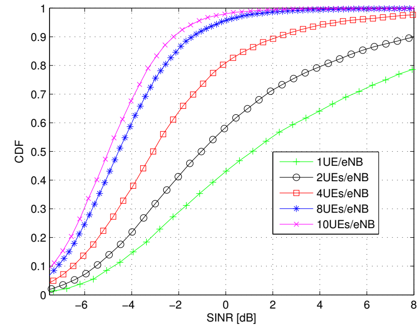


Fig. 2: Minimum SINR CDF of SC-PTM for different numbers of group users per cell.

D. Impact of Group Size

In Fig. 2, we vary the number of group users per cell and show the SINR distributions for SC-PTM. As we consider the minimum SINR for the group, it is clear that the radio quality decreases as the number of UEs increases. We also observe that the standard deviation is reduced. The degradation of the SINR implies a degradation of the SE and thus of the SSE as shown in Table III. Unicast transmission is outperformed by multicast transmissions after about 10 group users per cell.

Nb. of group users per cell	1	2	4	8	10
Unicast	1.47	0.72	0.36	0.18	0.14
SC-PTM	1.47	0.93	0.56	0.33	0.29
SFN110	0.29	0.22	0.17	0.12	0.11
SFN210	0.37	0.30	0.24	0.21	0.20

TABLE III: Mean SSE (in bps/Hz) of transmission modes for different numbers of group users per cell.

E. Cell Range

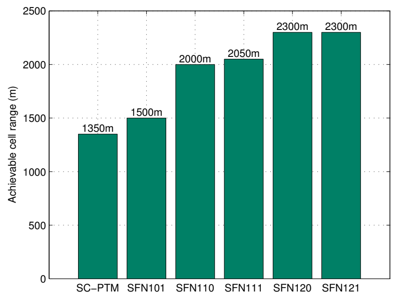
In this section, we evaluate achievable cell ranges depending on the chosen transmission modes. We first define the outage probability as the probability that a UE experiences an SINR lower than a certain threshold γ_{th} (taken as -9.5 dB in our simulations [13]). Note that we consider here individual SINR and not the minimum SINR of the group.

Fig. 3a and 3b show the achievable cell range of different transmission modes, in Scenarios I and II respectively, assuming a maximum outage of 1% (typical value for critical communication services).

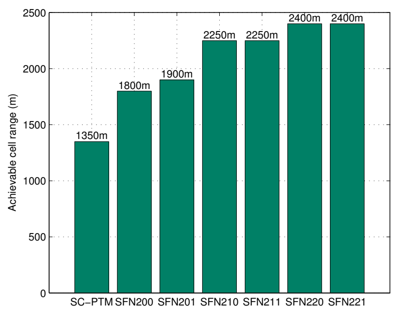
In both scenarios, we notice the significant coverage gain of MBSFN transmissions with respect to SC-PTM. Cell range of 1350 m can be achieved with SC-PTM, while MBSFN allows cell range up to 2300 m (+70%) in the best case in Scenario I. A 78% gain is achieved in Scenario II (as more rings of cells are transmitting). Moreover, the use of reserved cells in MBSFN transmissions does not improve significantly the cell coverage (e.g., SFN110 vs SFN111, SFN210 vs SFN211).

F. TTI Bundling Gain

Fig. 4 shows cell ranges with SC-PTM with or without TTI bundling compared to cell ranges with SFN110 and SFN 210



(a) Scenario I



(b) Scenario II

Fig. 3: Maximum cell range (for a 1% outage).

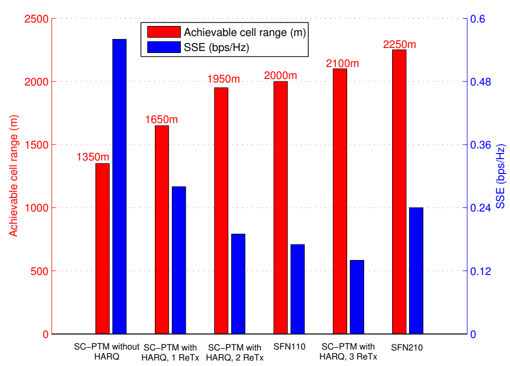


Fig. 4: Impact of TTI bundling on coverage (1% outage) and SSE.

(assuming again a maximum outage of 1%). We use equation (8) with always a fixed number of retransmissions (1, 2 or 3). MBSFN is assumed without TTI bundling. We note that SC-PTM with TTI bundling with 3 retransmissions provides a coverage gain of 750 m and 100 m compared to SC-PTM without TTI bundling and SFN110 but at the cost of a reduced SSE due to retransmissions. By playing with the number of TTI bundling retransmissions, we see that it is possible to find a tradeoff between SSE and coverage as per the operator needs.

V. Conclusion

In this paper, a performance comparison between MBSFN, SC-PTM and unicast transmissions for mission critical communications has been presented in terms of Signal to Interference plus Noise Ratio (SINR) gain, System Spectral Efficiency (SSE) and outage probability. Our main conclusions for the scenarios considered in this paper are the following: (i) in terms of minimum group SINR, SC-PTM may be preferred to MBSFN for groups, whose users are distributed over many cells; (ii) SC-PTM outperforms both unicast and MBSFN in terms of SSE because it uses less resources than unicast in every cells and less resources than MBSFN in the network; it should thus be preferred when the resource is scarce; (iii) in other scenarios, MBSFN provides huge gains in terms of cell range; (iv) the tradeoff between capacity and coverage can be tuned by varying the number of TTI bundling retransmissions with SC-PTM. We have also provided MBSFN design rules: (i) the gain provided by reserved cells in terms of coverage is negligible; (ii) Transmitting cells without group users bring significant coverage gain. As the cost in terms of SSE is huge, a single ring of transmitting cells without group users is sufficient.

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