

MBSFN coverage evaluation for AL-FEC enabled eMBMS transmission

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Abstract—In Long Term Evolution (LTE), Evolved Multimedia Broadcast/Multicast Services (eMBMS) offers functionality to transmit multimedia contents over a single frequency network (SFN) where a time-synchronized common waveform is transmitted from multiple cells for a given duration. It is called Multimedia Broadcast multicast service Single Frequency Network (MBSFN). The optimized Modulation and Coding Scheme (MCS) level will result in the acceptable coverage performance and signal quality. The MBSFN coverage is primary determined by Signal Interference Noise Ratio (SINR), Block Error Rate (BLER), and MCS. In this paper we investigate the impact of Application Layer Forward Error Correction (AL-FEC) against the selection of the MCS that will be utilized for the transmission of the MBSFN data. We examine the efficient working point between AL-FEC overhead and BLER with given MCS and SINR.

Index Terms—LTE, eMBMS, AL-FEC, MBSFN

I. INTRODUCTION

Nowadays more users surf the web, and watch multimedia contents over the mobile devices. The mobile entertainment market is expected to continuously grow in the next four years [1]. However, due to the very nature of Unicast transmission namely, the inefficient bidirectional point to point (ptp) transmission between each of the users and the network, most of the cellular operators have very limited streaming service options. This led to the development of the broadcast and multicast service over cellular network. In LTE, 3GPP has specified eMBMS, which extends LTE architecture model by newly introducing MBSFN [2] and the AL-FEC [3].

eMBMS defines two broadcast transmission schemes: Single-cell and MBSFN transmission. MBSFN allows combining of MBMS transmissions from tightly time-synchronized cells by using the same radio configuration in each of the cells with use of extended Cyclic Prefix (CP). MBSFN significantly improves the spectral efficiency compared to conventional ptp transmission.

As like any other wireless communication, due to fading and shadowing some of the packets might be lost during the delivery in eMBMS. However, unlike the Downlink Shared Channel (DL-SCH), the Multicast Channel (MCH) that transfers eMBMS data is sent in Radio Link Control (RLC) unacknowledged mode (UM). The reason MCH cannot benefit from either Hybrid Automatic Repeat-request (HARQ) or RLC retransmission is because of the broadcast characteristics. The single user's channel condition cannot represent the

channel condition of whole UEs in the same MBSFN area. Besides, it is very inefficient to retransmit lost packets to every MBSFN UE those numbers could be thousands. Therefore, in addition to physical layer (L1) Turbo code FEC [4], Raptor AL-FEC [5] plays an important role in eMBMS. AL-FEC is an application layer error control method that is used to improve the reliability of the data transmission. The MBSFN and AL-FEC together achieves effective broadcasting of High Definition (HD) multimedia contents to the UEs located in multiple cells.

In LTE systems, the receiving signal quality in the serving cell depends on the signal power, noise and interference. With given transmission power, by matching data rate, the transmitter should be adjustable to the variable receiving signal quality. Commonly, for the ptp downlink data transmissions, the eNB decides the MCS level based on a Channel Quality Indicator (CQI) feedback received from UE. However, eMBMS provides the broadcast services, where by means, eNB cannot optimize the link adaptation by CQI reports. Therefore, MCS level for Physical Multicast Channels (PMCH) should be decided and semi-statically configured for each MBSFN area prior to the service deployment. The optimized MCS level for MBSFN that ensures the required BLER based on signal quality will result in the optimized MBSFN coverage performance. It is challenging for all users at the cell boundary to receive the same power level. Either the eNB must transmit extra power to ensure users affected by shadowing received minimum requires power or transmit reduced power to minimize the interference to neighbor cells.

In this paper, after brief introduction of LTE eMBMS, we will approximate MBSFN SINR from a single cell case. And then with the SINR that we found from single cell case and target MCS level 14, we will evaluate the performance of AL-FEC against MBSFN coverage in terms of its overhead and BLER. Our goal is to select optimized SINR that meet the eMBMS throughput requirement (MCS level) as well as the required MBSFN coverage with acceptable AL-FEC overhead. This research will benefit the operator's MBSFN cell planning.

II. EMBMS OVERVIEW

In this section, we briefly introduce eMBMS architecture and its related functions. As depicted in Fig 1, eMBMS

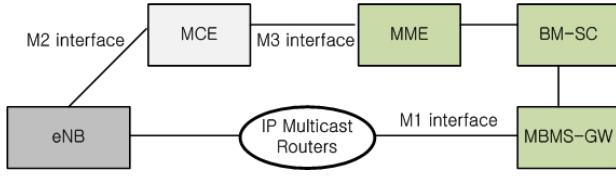


Fig. 1. eMBMS Centralized MCE architecture

requires new network entities to enable MBSFN transmission: Broadcast Multicast Service Center (BM-SC), MBMS Gateway, and Multi-cell/Multicast Coordination Entity (MCE). BM-SC is a multimedia streaming server with File Delivery over Unidirectional Delivery (FLUTE) [6] support. It manages the eMBMS subscriptions, service announcement, eMBMS sessions control, SYNC protocol, MBMS security, point to point retransmission, and AL-FEC. The MBMS Gateway is responsible for multicast IP address allocation and session management. The MBMS Gateway receives eMBMS content from BM-SC and then forwards eMBMS service traffic to the eNBs over IP multicast network. The MCE, acting as an eMBMS scheduler, allocates radio resources, performs session admission control, and manages the eMBMS services. Therefore, the scheduling of MBSFN transmission is performed through a MCE. When MCE receives a “Session Start” request from MME, it runs session admission control function to determine radio resource availability. Only if there are enough radio resources available the MCE will allocate the required radio resources. Besides the function of the new entities, eNBs will also need to support some eMBMS related PHY, MAC, and Transport layer features, including 15 kHz sub-carrier spacing, extended CP, MBSFN reference signal, PMCH physical channel, MCH Transport channel, Multicast traffic Channel (MTCH)/Multicast Control Channel (MCCH) logical channels, MCCH related BCCH broadcasting such as SIB2, SIB13, SIB16 System information, PDCCH with MBMS Radio Network Temporary Identifier (M-RNTI), RLC-UM mode, SYNC protocol, and M2 Application Part (M2AP) Interface [7].

A. MBMS channel description

The physical, transport, logical and channels associated with eMBMS are depicted in Fig 2. LTE eMBMS requires implementation of two new logical channels, MTCH and MCCH. Both the MCCH and the MTCH logical channels are multiplexed into the MCH transport channel. The eNB performs MAC-level multiplexing for different MTCHs to be transmitted on a single MCH. Multiple eMBMS services can therefore be transmitted using a single MCH (because up to 29 MTCHs can be multiplexed on one MCH instance), provided that they use the same MBSFN area. At the physical layer up to 15 MCH transport channels per MBSFN area can be time multiplexed to a PMCH within Common Scheduling Allocation Period (CSAP) interval.

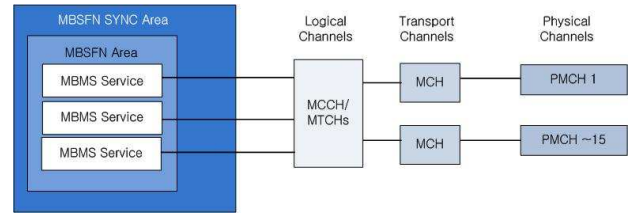


Fig. 2. Channel Structure

B. MBSFN transmission

The delay spread is generated by different multi-paths between the transmitter and the receiver when those paths have different delays. It causes Intersymbol Interference (ISI), which can cause an irreducible error floor. However, when the multiple paths of the signals with different delays are received by the UE, the receiver may be able to combine them as a single signal with different path delays. It is possible, if the signals are from tightly time synchronized cells, and are received within the CP at the beginning of the symbol.

In MBSFN operation, given the CP length of $16.7\mu s$ ensures the signals arrive within the CP, the UE receiver treats these different signals as multi-path components of a single cell transmission. The use of the extended CP ensures that the signals remain within the CP at the UE, and thus, reducing inter-cell interference by using additional symbols for extended CP. The gain from MBSFN operation is significant especially at the cell edge, where the signals from edge cells causes ISI.

III. MBSFN SINR ESTIMATION

In LTE, eNB selects the most suitable MCS according to the measured SINR so as a certain target BLER to be achieved. In this section, the propagation model and MBSFN SINR computation method are presented.

A. Propagation model for multiple RF cells

We first accomplished the model by a drive test and ATOLL software [8]. We conducted tests in urban area to develop a propagation model based on outdoor measurements for 2.3 GHz where LTE system is operating under several geographical terrains and frequency limitations. Based on the gathered radio data from the driving test, we used radio planning tool, ATOLL software which uses the Standard Propagation Model (SPM) to predict the coverage area.

The SPM incorporates an optimal model with respect to distance from the eNB. It also incorporates algorithms for eNB heights, diffraction loss, and the clutter effects. The general received power formula for the SPM is as follows;

$$\text{Received Power (dBm)} P_R = P_{Tx} - (K_1 + K_2 \times \log(d) + K_3 \times \log(H_{Tx_{eff}}) + K_4 \times \text{DiffractionLoss} + K_5 \times \log(d) \times \log(H_{Tx_{eff}}) + K_6 \times H_{Rx_{eff}} + K(\text{Clutter}) + K_{hill,los})$$

whereby:

- P_R : the received power,
- P_{tx} : the transmitted power,

- K_1 : the constant offset (dB)
- K_2 : the multiplying factor for $\log(d)$
- d : the distance from the base station to the mobile station (km);
- K_3 : the multiplying factor for $\log(H_{T_{eff}})$
- $H_{T_{eff}}$: Effective height of the transmitter antenna (m);
- K_4 : Multiplying factor for diffraction calculation
- $DiffractionLoss$: Losses due to diffraction over an obstructed path (dB)
- K_5 : the multiplying factor for $\log(H_{T_{eff}}) \log(d)$
- K_6 : the multiplying factor for $H_{R_{eff}}$
- K_7 : the multiplying factor for $\log(H_{R_{eff}})$
- $H_{T_{eff}}$: Mobile antenna height(m);
- $K_{clutter}$: the multiplying factor for clutter
- $K_{hill,los}$: Corrective factor for hilly regions (=0 in case of NLOS)

The propagation model can be tuned by modifying the K factors. The simulation area map of using ATOLL software with eNB location is shown in Fig. 3. A dot indicates the location of eNB.

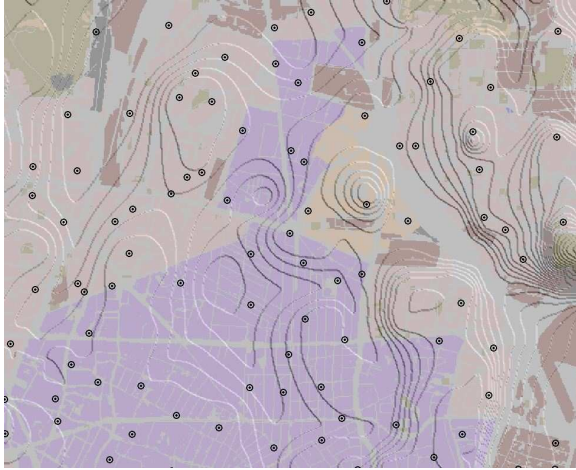


Fig. 3. Digital Map

B. SINR computation

In MBSFN the signals originating from neighbor cells within extended CP duration can be viewed as a gain. Several studies such as [9], [10], and [11] proposed analytical approaches to evaluate the MBSFN coverage. We further simplified the analytical model [9] for multi-path propagation delay by only taking into account of the signals of arriving from the N interfering cells within 70% boundary of extended CP. Thus as Fig 4 depicts, we approximate the MBSFN SINR to target user within 3.5 km.

Now consider an UE dropped in a target cell. Taking N interfering cells into account, whose signals arrive to the receiver M different paths. We are only taking into account of the signals of arriving from the N interfering cells within 70% boundary of extended CP. Taking N interfering cells into

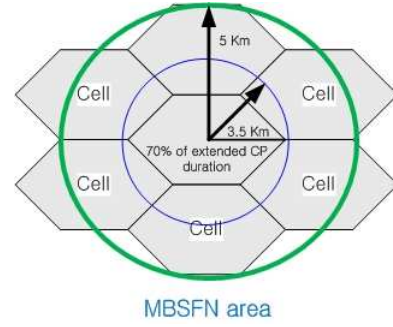


Fig. 4. Extended CP duration

account, whose signals arrive to the receiver, the average SINR expression can be found:

$$MBSFN_SINR = \frac{P_1}{P_2 + N} \quad (1)$$

where,

$P_1 = \sum_{i=1}^n RSRP_i$ (mW) within 70% CP (3.5 km) distance cells

$P_2 = \sum_{i=1}^n RSRP_i$ (mW) within 70% CP (3.5 km) distance cells + N

$N(dBm) = \text{Noise power per RE} = -174 \text{ dBm} + 7 \text{ (UE noise figure)} + 10 \times \log(15000)$

Reference Signal Received Power (RSRP) is the average power received from a single cell specific reference signal resource element. We used aforementioned the received power from our cell measurement data. For noise power term 15000 Hz is considered, since Resource Element (RE) BW in LTE is 15 KHz. Table I summarized the noise power related figures:

TABLE I
MACRO SYSTEM ASSUMPTION

Parameters	Assumptions
White noise power density	-174 dBm/Hz
UE Noise Figure	7 [dB]
UE distribution	UEs dropped with uniform density within the macro coverage area

For this calculation it assumes that the center cell in the cell formation is always on for the MBSFN. Based on these observations, we plot MBSFN SINR distribution. We plot it as a Cumulative Distribution Function (CDF) and compare it with unicast SINR in Fig 5. It demonstrate that the MBSFN SINR is higher power than the unicast SINR power in terms of the MBSFN coverage.

Table II shows the 10 percentile SINR, 5 percentile SINR, and 1 percentile SINR of both MBSFN and unicast. It indicate that for 95% the MBSFN area coverage, it requires at most 18.86 dB.

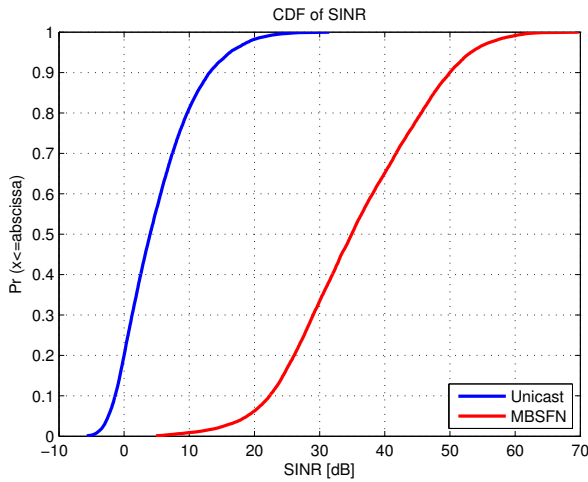


Fig. 5. SINR CDF

TABLE II
MBSFN AND UNICAST SINR COMPARISON

	10%-tile	5%-tile	1%-tile
MBSFN SINR	22.35[dB]	18.86[dB]	10.70[dB]
Unicast SINR	-1.38[dB]	-2.42[dB]	-4.07[dB]

IV. MBSFN COVERAGE SIMULATION

The evaluation of the MBSFN coverage is quite challenging, since the simulation must take into account of both the physical channel and the application layer decoding performance. The receive characteristic of eMBMS is largely determined by the LTE physical channel BLER as well as the application layer Bit Error Rate (BER).

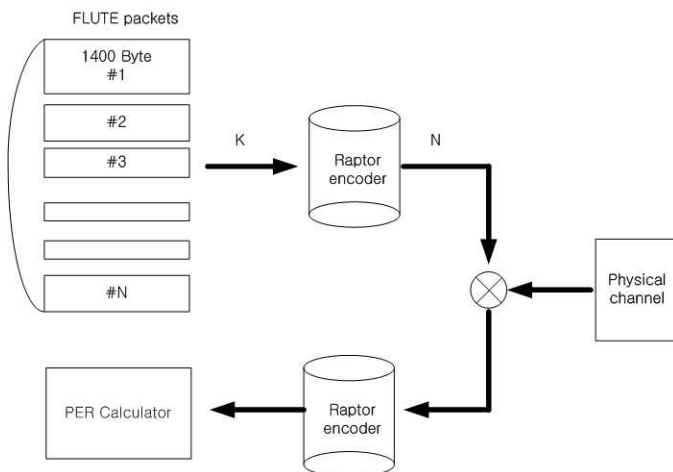


Fig. 6. AL-FEC coding illustration

The overall design of the simulation is shown in Fig 6. The simulation is largely divided into two parts. The application layer part that randomly generates bit patterns and the Raptor encoder encodes 1360 byte payload of the FLUTE packets.

The physical channel part is to simulate the over the air signal to interference and noise ratio every 1 Transmission Time Interval (TTI) which is 1ms in LTE.

In order to evaluate the impact of the mobile radio in MBSFN environment, the channel models that use standard models and technique have been defined and developed in 3GPP. We model the propagation conditions for the multi-path fading channel as an Extended Delay Spread (EDS) channel [12]. The MBSFN propagation channel profile of the EDS channel describes the propagation conditions that are used for the MBSFN performance requirements in multi-path fading channel in an extended delay spread environment. For physical layer FEC, Turbo code is assumed with 1% BLER.

With the Raptor code if there are K source symbols in a source block, the Raptor encoder generates N repair symbols for each source block. The detailed information on Raptor AL-FEC and its usage in eMBMS can be found in [3, 5, 13, 14]. For this simulation one second Dynamic Adaptive Streaming over HTTP (DASH) [15] segment is assumed. The DASH segment to be transmitted is divided into K source symbols. All source symbols associated with the DASH segment are same size, 1360 Byte. The symbol size is carefully chosen not to exceed the 1400 Byte IP Maximum Transmission Unit (MTU) while considering 40 byte IP/UDP/FLUTE overhead. The generated FLUTE packet transmission is evaluated if the received symbols can be correctly recovered. Based on that we calculate the AL-FEC overhead and determine MBSFN coverage for the EDS channel. The network parameters in Table 3 are used as reference values for the evaluation of MBSFN coverage.

TABLE III
LAB TEST SETTINGS

Parameter	Value
3gpp spec.	Release 9
Access Technology	TDD
Carrier Frequency	2.6 GHz
Cellular Layout	3 cell sites
System Bandwidth	20 MHz
Channel Models	AWGN, EPA, EDS
Doppler shift	5 Hz
Extended CP Duration	16.7 μ s
Data MCS	14
Common SF Alloc Period	32 RF
MCH Scheduling Period	320 ms
Radio Frame Allocation Period	N1
Target MCS level	14
Allocated subframe number	3, 4, 8, 9
Transport Coding	DASH/FLUTE
L1 BLER	1% ~ 20%
AL-FEC encoder	Raptor10
AL-FEC overhead	10%, 15%, 20%, 25%

V. SIMULATION RESULTS

This section provides detailed evaluation of MBSFN coverage and its AL-FEC overhead tradeoff. In order to find optimal AL-FEC overhead with target MCS level, extensive simulations are performed. In these simulation experiments, we investigated the MBSFN coverage by SINR under various channel models, L1 BLER, and AL-FEC BER.

A. AL-FEC vs. EPA and AWGN Channel models

We first compared AL-FEC overhead for the Additive White Gaussian noise (AWGN) channel and Extended Pedestrian A (EPA) channel [12]. For the target MCS level 14 with different L1 BLER 3% of EPA channel and L1 BLER 3%, 3.93% of the AWGN channels are observed. For each channels L1 BLER is varying by SINR strength. Fig 7 is plotted AL-FEC BER against AL-FEC BER overhead. In the AWGN channels of the experiment, the AL-FEC BER 0.1 % can be achieved at about 15% overhead. For the EPA channel AL-FEC BER 0.1 % can be achieved at about 24% overhead. We found that under the same long-term L1 BLER, the fading channel requires more AL-FEC overhead due to fading channel's burst error.

B. AL-FEC vs. EPA Channel model

Fig 8 is plotted AL-FEC BER against AL-FEC overhead for varying L1 BLER of EPA channels. We found increasing L1 BLER from 1.5% to 4% causes increment of AL-FEC overhead from almost 15% to 25%. Thus, it is not desirable to L1 BLER operating point over L1 BLER 1%.

C. AL-FEC vs. EDS Channel model

In this section, we consider the EDS channel model in Fig 9. The EDS channel made use of propagation conditions for the MBSFN. Fig 10 presents AL-FEC overhead for varying L1 BLER of EDS channels. From our observation on EDS channel model, we learned 1% L1 BLER is desirable. In order to obtain 0.1% AL-FEC BER for the EDS channel, we found that it can be achieved at MCS level 14 with BLER 1%.

D. AL-FEC overhead vs. SINR

In this paragraph we finally attempt to analyze desirable MBSFN coverage and impact of the AL-FEC overhead over EDS channel. From Fig 10 the observation was that 0.1% AL-FEC BER for the EDS channel can be achieved at MCS level 14 with BLER 1%. From Fig 10 we found AL-FEC for the EDS channel is 0.1% with L1 BLER 1% when SINR is 11dB. Therefore, by utilizing the SINR found from section III and MCS selection by BLER and AL-FEC overhead, we can find the desirable MBSFN coverage.

VI. CONCLUSION

For the commercial success of the eMBMS, the assurance of service availability (the percentage of the users that receive the service in an acceptable quality) for the user even with the lowest SINR value is very important. The failure of the operators to meet the demand of high quality multimedia

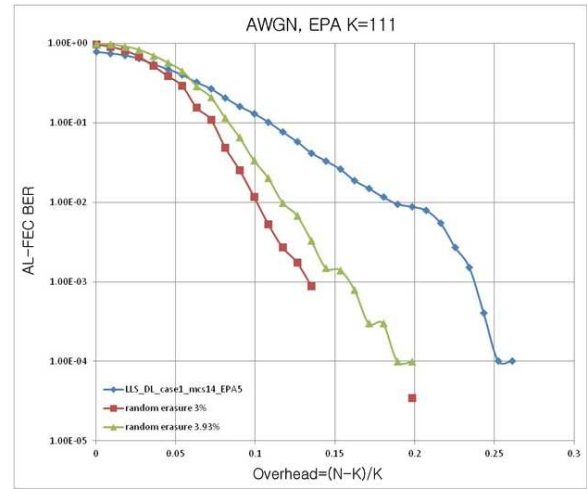


Fig. 7. AWGN and EPA channel AL-FEC overhead comparison

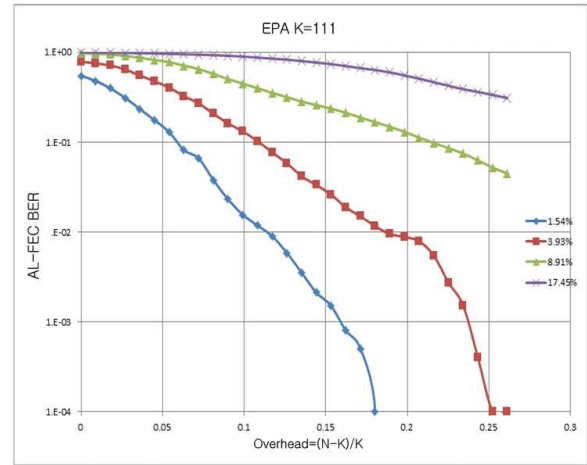


Fig. 8. EPA channel AL-FEC overhead comparison

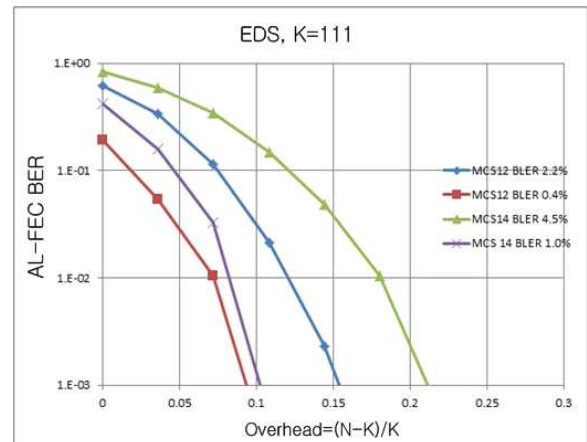


Fig. 9. EDS channel AL-FEC overhead comparison

content playback is not acceptable for the business. The major enhancement of LTE eMBMS over 3G MBMS is the improvement of overall service availability by introducing the

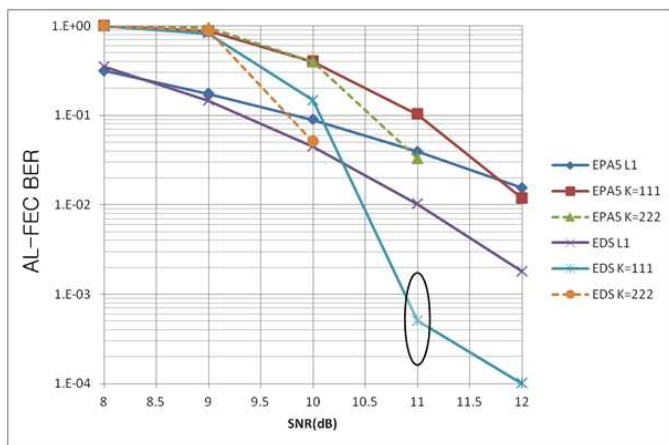


Fig. 10. EDS channel SINR

MBSFN transmission and AL-FEC to keep up with certain BLER in a rapid and significant degradation of multimedia content. In this paper we proposed a method to determine the MBSFN coverage and its AL-FEC overhead with a target MCS level and SINR. The proposed approaches can cover different cell deployment scenarios, service availability requirements, and AL-FEC overhead requirements that could exist in real world. Based on the proposed method the service provider, without the MBSFN specialized cell planning tool, can choose an optimized MCS level for the MBSFN coverage as well as the AL-FEC overhead rate. The step that follows this work could be the investigation of the interference between non-MBSFN cell and MBSFN cell at MBSFN area boundary.

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