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The impact of code allocation on the multiple access interference in WCDMA systems

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Abstract

Code allocation has a significant impact on the performance of Code Division Multiple Access (CDMA) systems. For the uplink direction, in 3G Wideband CDMA (WCDMA) cellular systems, orthogonal codes are employed to differentiate the physical channels of one transmitter and Pseudo Noise (PN) sequences are used to provide mutual randomness between the users. Since the received data spread by different codes are not perfectly orthogonal, the emerged Multiple Access Interference (MAI) is a major limitation of the system capacity. In this paper, we propose a new code allocation scheme with the aim of reducing the interference by decreasing the number of non orthogonal spreading codes used in a cell. Consequently, the new proposed scheme improves the system capacity for the uplink direction in term of accepted calls in one cell. The idea behind is to assign one scrambling code for each class of service in a cell instead of assigning one scrambling code per mobile station as in 3G WCDMA-based systems. Note that the traffic belonging to one class of service may be originated from different mobile stations. We also develop a new power control algorithm associated with the new code allocation scheme. In order to evaluate the performance, we develop analytical models for the code allocation scheme currently used in UMTS (Universal Mobile Telecommunication Systems) WCDMA-based system considered as a benchmark and for our proposed scheme. Numerical and simulation results are showing that our proposed scheme offers significant gain for the uplink capacity compared with the current scheme used in UMTS.

Index Terms

UMTS, CDMA, radio resources allocation, spreading codes, power control.

I. Introduction

CDMA is adopted as a radio access technique to be used in the third generation of mobile systems [1]–[3]. Since all mobile stations use simultaneously the entire bandwidth in CDMA technique, each mobile station (MS) multiplies its data by a higher rate code and at the receiver, the data is extracted by multiplying the received signal with the same code.

The code modulation in WCDMA system consists of two stages: channelization, then scrambling [3]. In the first stage, OVSF (Orthogonal Variable Spreading Factor) channelization codes are used to spread the data [3]–[6]. These codes separate the MSs in the downlink direction and the physical channels of one MS in the uplink direction. Each information bit is replaced with a sequence of binary elements (chip code) if it is ”1” and with the 1-complement of the chip code when it is equal to ”0”. OVSF codes are mutually orthogonal and they have a constant Euclidean distance (the number of 1’s is equal to the number of 0’s). Furthermore, they can provide different bit rates thanks to their variable length.

In the scrambling stage, Gold and Kasami sequences are used [3]–[6]. These codes are Pseudo Noise (PN) sequences and it is possible to generate an infinite number of them. Each scrambling code is assigned to one MS. Therefore, the resources in WCDMA systems are theoretically not limited. However, as scrambling codes are not orthogonal, the system capacity is limited by the Multiple Access Interference (MAI). This interference is related to the number of allocated scrambling codes, i.e., each mobile station enters a cell will add interference seen by the ongoing communications in that cell. Therefore, WCDMA systems have to use an algorithm of power control to regulate the transmission power for each MS in function of the interference in order to meet the bit rate (R) and the Quality of Service (QoS) requirements. Typically, the QoS is defined as the Signal to Interference Ratio (SIR) [1].

In this work, we propose a new scheme of spreading code allocation that reduces the interference in the uplink direction. Since the scrambling codes are not orthogonal, most of the interference seen by the base station (BS) is due to those codes. Our proposition aims to minimize the number of used scrambling codes in a cell. The traffic is seen by the BS as different classes of service in our scheme and not as different mobile stations as in UMTS code allocation scheme. We propose that the mobile stations using the same service are multiplexed by using different channelization codes. Hence, the number of scrambling codes allocated in a cell is reduced to the number of active services in that cell and is not equal to the number of mobile stations.

This paper is organized as follows. Section II presents the related works. In Section III, the scheme of code allocation used in UMTS system is detailed. We also develop a model of UMTS code allocation scheme and the associated power control algorithm. Afterwards, we present the proposed scheme of code allocation in Section IV. Analytical and simulation results are shown in section V. Finally, conclusions are presented in section VI.

II. Related works

In WCDMA systems, the physical radio channel can be defined as a union of a spreading code, frequency bandwidth, a time slot and transmission power. The allocated bandwidth and the duration of one time slot are typically assumed invariable whereas the spreading code and the level of transmission power are variable and they depend on different parameters such as the required bit rate, the QoS requirements and the instantaneous interference.

The development of efficient power control algorithm in WCDMA system based on the bit rate and QoS requirements have been extensively investigated [7]–[12]. Most of the power control algorithms proposed for a WCMDA system are based on optimizing the transmission power in function of the instantaneous interference due to the near-far effect and the lack of orthogonality between the used spreading codes. The near-far effect can be mitigated by adjusting the transmission power of mobile stations such that the BS receives theirs signals with the same strength. On the other hand, the scrambling codes bring about most of the interference since they are not orthogonal. The channelization codes can also cause interference because their orthogonality can be lost due to propagation environment. Anyhow, the impact of this interference is minor compared to the one caused by the scrambling codes. Several power control algorithms have been proposed to reduce or cancel the interference and hence improve the system capacity [13]–[15].

In [16], the authors have discussed MAI versus the dynamic spreading gain and proposed a dynamic approach to radio resource allocation and access control. In this approach, the spreading gain of non real-time traffic decreases when the MAI increases. The OVSF codes allocation in the downlink direction have been also studied [17]–[19]. However, to the best of our knowledge the relation between MAI interference and the scrambling codes allocation in the uplink direction have not been yet investigated.

In this paper, we study the impact of MAI on the system capacity using a different approach. We propose a new scheme of code allocation that decreases the number of used scrambling codes by allocating one code per service. Consequently, the new scheme reduces MAI. The UMTS scheme of code allocation is used as a benchmark. In the next section, we investigate the UMTS scheme and we analyze its performance.

III. The code allocation in UMTS

Considering the code allocation scheme in the uplink direction of UMTS system, the data streams originated from one MS and belonging to different classes of service are multiplexed into one stream that is transported on the Coded Composite Transport CHannel (CCTrCH). The latter is mapped into 1 to M Dedicated Physical Data CHannels (DPDCHs) [20]. The traffic transmitted over each one of DPDCHs is multiplied by one OVSF code. Afterward, the traffic transmitted over these channels is summed to form one data flow that will be multiplied by a unique scrambling code assigned to the corresponding MS [20], [21]. Thereby, we refer to this scheme of code allocation used in UMTS system by "All Services - one Scrambling Code" (ASSC).

Figure 1 depicts the code allocation scheme of UMTS system. Figure 1(a) shows three mobile stations where the first (denoted by MS_1) transmits only voice and the second (MS_2) transmits only data whereas the third (MS_3) transmits simultaneously voice and data. The size of arrows represents the amount of traffic generating by each MS. Figure 1(b) shows how different services from each MS are coded and multiplexed. The output data stream is mapped into several channels using different channelization codes. Finally, the traffic in these channels are summed and multiplied by the assigned scrambling code for that MS.

In order to analyze the UMTS code allocation scheme, we develop a model of power control algorithm associated to this scheme. The model calculates the level of transmission power to be used by a particular MS in function of three parameters: the required bit rate (R), the required energy bit to interference ratio E_b/I_0 and the interference seen by that MS. We consider N mobile stations distributed randomly within a cell. Each MS employs M DPDCHs which carry data with different bit rates.

For CDMA systems, the E_b/I_0 ratio required for one user is usually expressed in function of the bit rate, R, and the signal to interference ratio SIR as in [6]:

$$\frac{E_b}{I_0} = \frac{W}{R}\frac{S}{I} = G\frac{S}{I}, \tag{1}$$

where W is the chip rate, S is the transmission power and I is the interference power seen by the MS. G represents the spreading factor and it is defined as the ratio of chip rate to bit rate. Applying the relation (1) on UMTS model, the minimum E_b/I_0 required for the mobile station MS_i, $(E_b/I_0)_i$, can be written as follow:

$$\left(\frac{E_b}{I_0}\right)_i = \frac{W}{R_i}\frac{p_i h_i}{\alpha \sum\limits_{l=1,l\neq i}^{N} p_l h_l + \eta W}, \qquad i = 1, \dots, N, \tag{2}$$

where p_i is the transmission power of MS_i, h_i is the channel gain between MS_i and its serving BS, R_i is the bit rate of MS_i, α is a constant that represents the orthogonality factor between the spreading codes and η is the Additive White Gaussian Noise (AWGN) power.

From (2), we get:

$$p_i h_i = \frac{R_i}{W}\left(\frac{E_b}{I_0}\right)_i \left(\alpha \sum_{l=1,l\neq i}^{N} p_l h_l + \eta W\right). \tag{3}$$

Since each MS can transmit in multiple channels with different bit rates and different (E_b/I_0) ratios, we can rewrite (3) as follows:

$$p_i h_i = \frac{1}{W}\left(\sum_{k=1}^{M} R_{ik}\left(\frac{E_b}{I_0}\right)_{ik}\right)\left(\alpha \sum_{l=1,l\neq i}^{N} p_l h_l + \eta W\right), \tag{4}$$

where R_{ik} and $(E_b/I_0)_{ik}$ are the bit rate and the energy bit to interference ratio for channel k of MS_i. Using a vectorial representation, (4) can be written as:

$$p_i h_i = \frac{1}{W}\left(\mathbf{r}_i^T \mathbf{q}_i\right)\left(\alpha \sum_{l=1,l\neq i}^{N} p_l h_l + \eta W\right), \tag{5}$$

where $\mathbf{r}_i^T = \begin{pmatrix} R_{i1} & R_{i2} & \dots & R_{iM} \end{pmatrix}$ and $\mathbf{q}_i^T = \begin{pmatrix} \left(\frac{E_b}{I_0}\right)_{i1} & \left(\frac{E_b}{I_0}\right)_{i2} & \dots & \left(\frac{E_b}{I_0}\right)_{iM} \end{pmatrix}$. The subscript ^{T} denotes transpose of the vector.

To simplify the representation, we denote the scalar product $\mathbf{r}_i^T \mathbf{q}_i$ by γ_i. Consequently, the equation (5) becomes:

$$p_i h_i - \frac{\alpha \gamma_i}{W} \sum_{l=1, l \neq i}^{N} p_l h_l = \eta \gamma_i. \tag{6}$$

Note that $\gamma_i = \mathbf{r}_i^T \mathbf{q}_i$ $(i = 1, \ldots, N)$ depends only on the mobile station MS_i.

Finally, we obtain the following linear system:

$$\mathbf{\Pi p} = \mathbf{\Gamma} \eta, \tag{7}$$

where

$$\mathbf{\Pi} = \begin{pmatrix} h_1 & -\frac{\alpha h_2}{W}\gamma_1 & \ldots & -\frac{\alpha h_N}{W}\gamma_1 \\ -\frac{\alpha h_1}{W}\gamma_2 & h_2 & \ldots & \ldots \\ \vdots & \vdots & \ddots & \vdots \\ -\frac{\alpha h_1}{W}\gamma_N & \ldots & \ldots & h_N \end{pmatrix},$$

$\mathbf{\Gamma}^T = \begin{pmatrix} \gamma_1 & \gamma_2 & \ldots & \gamma_N \end{pmatrix}$ and $\mathbf{p}^T = \begin{pmatrix} p_1 & p_2 & \ldots & p_N \end{pmatrix}$.

Each element of $\mathbf{p}$ presents the transmission power level for one of N active mobile stations.

Based on the previous developments, the code allocation scheme used in UMTS can be discussed considering three aspects: complexity, delay performance and interference. In order to analyze the complexity, we note from equation (4) that different classes of service (delay-sensitive and delay-insensitive) are coded, interleaved and mixed together. Therefore, any change in the traffic of one stream corresponding to one class of service results in changing the spreading factor and/or the number of channelization codes. This increases the complexity of achieving dynamic multiplexing of delay-sensitive and delay-insensitive applications. Besides, heterogenous data streams belonging to different services from the same MS are multiplexed into one data stream. The multiplexing of heterogenous traffic may degrade the performance of delay-sensitive services in term of respecting the delay constraint. Finally, the users' behavior show that the majority of users use often two classes of service at most. Subsequently, this code allocation scheme uses many scrambling codes (one scrambling code for each MS) and few channelization codes. Accordingly, the hamming distance between the code sequences is decreased, and this increases the interference and consequently reduces the uplink capacity.

Considering these drawbacks, a new code allocation scheme is needed to improve the uplink capacity of WCDMA systems by allocating adequately the scrambling and channelization codes and then reducing the interference. Hence, the next section proposes a new code allocation scheme for WCDMA systems.

IV. New code allocation for WCDMA systems

To cope with the aforementioned limitations, we propose a new scheme of code allocation denoted by OSSC (One Service - one Scrambling Code). According to this scheme, the traffic is seen by the BS as different services and not as different mobile stations, contrarily to ASSC scheme described in the last section. We propose that the traffic belonging to one service and originated from different mobile stations will use one scrambling code. Consequently, the scrambling codes will identify the service, instead of identifying the MS as in ASSC scheme, whereas the channelization codes will be used to identify the MS.

The BS may indicate on the broadcast channel the assignment of scrambling codes to different classes of service. Moreover, when one MS wants to transmit data corresponding to a particular service, this MS requests a channelization code (OVSF code) from the BS. The BS responds by assigning one OVSF code for this MS using that particular service. Afterward, the MS modulates its data by using the assigned channelization code and thereafter by the scrambling code assigned to the corresponding service. Subsequently, the traffic originated from different mobile stations transmitting the same service will be multiplexed on the same scrambling code by using different OVSF channelization codes.

Our proposed scheme is presented in figure 2. The arrows in figure 2(a) represents the service type. Since there are two services only, two scrambling codes are needed in OSSC scheme. Figure 2(b) shows the scheme of code allocation. The traffic originated from different mobile stations using the same service is modulated by the same scrambling code allocated to that service. Each mobile station is identified by its unique channelization code.

The proposed scheme uses the same principle of WCDMA systems that consists of two stages: channelization and scrambling, and it tackles the limitations mentioned in section III. Since the channelization codes are assigned relying on the bit rate, QoS and other conditions, mobile stations do not need to change this code during the transmission. Consequently, the system will be less complex and the uplink traffic more homogenous.

Furthermore, the number of scrambling codes will be reduced to the number of active services in the cell.

In UMTS, different mobile stations can use the same channelization code. This does not have significant impact on the interference because firstly the channelization codes are assumed to be orthogonal and secondly they are used to differentiate the physical channels in each MS and are not used to differentiate the mobile stations. Therefore, using same or different channelization codes does not have impact on the performance comparison of our proposition with UMTS. For example, we assume 50 mobile stations transmitting simultaneously two different services where each service undergoes the same bit rate and QoS requirements for all the mobile stations. According to ASSC scheme, we need to 50 scrambling codes and 100 channelization codes if we considered, without loss of generality, that one channelization code is assigned to one service in UMTS model whereas only two scrambling codes and 100 different channelization codes have to be assigned according to OSSC scheme.

A. System model

To model the power control associated with OSSC scheme, we consider L classes of service in a cell and a unique scrambling code is assigned to each class. The capacity of a class is related to its bit rate and QoS requirements. The number of channelization codes in a class of service with R kbps is the spreading factor $G = W/R$ where the chip rate is constant. It is to be reminded that $W = 3,84$ Mcps in UMTS.

Unlike the ASSC scheme used in UMTS, the OSSC scheme could separate the MAI interference into two types of interference:

- Intra-code interference ($I_{intra-code}$): it is proportional to the cross correlation between the channelization codes under one class. Although, the assigned channelization codes are orthogonal, there could be a loss of orthogonality due the multipath delay and time offsets. Hence, the cross correlation is relatively small and the interference is weak. This interference has a minor impact on the system capacity.
- Inter-code interference ($I_{inter-code}$): it is proportional to the cross correlation between the scrambling codes. Since the scrambling codes are not orthogonal, the cross correlation is relatively high. Hence, the interference is not negligible and has a significant impact on the uplink capacity.

Thus, our model can be written as follow:

$$\left(\frac{E_b}{I_0}\right)_{ji} = \frac{W}{R_{ji}} \frac{p_{ji}h_{ji}}{\alpha_{ov}\sum_{k=1,k\neq i}^{M_j} p_{jk}h_{jk} + \alpha_{sc}\sum_{l=1,l\neq j}^{L}\sum_{f=1}^{M_l} p_{lf}h_{lf} + \eta W}, \quad j = 1,\ldots,L \quad \texttt{and} \quad i = 1,\ldots,M_j \tag{8}$$

where

- p_{ji} is the transmission power of MS_i under class j;
- h_{ji} is the path loss between MS_i using class j and BS;
- $\left(\frac{E_b}{I_0}\right)_{ji}$, R_{ji} are respectively the energy bit to interference ratio and the bit rate for mobile station i under class j;
- M_j is the number of mobile stations using class j;
- α_{ov}, α_{sc} are constants representing respectively the orthogonality factor between the OVSF channelization codes and between the scrambling codes;
- $I_{intra-code} = \alpha_{ov}\sum_{k=1,k\neq i}^{M_j} p_{jk}h_{jk}$ represents the Intra-code interference; and
- $I_{inter-code} = \alpha_{sc}\sum_{l=1,l\neq j}^{L}\sum_{f=1}^{M_l} p_{lf}h_{lf}$ represents the Inter-code interference.

Since all mobile stations in one class transmit with the same bit rate and require the same ratio (E_b/I_0), we call $\left(\frac{E_b}{I_0}\right)_{ji}$ and R_{ji} henceforth by $\left(\frac{E_b}{I_0}\right)_{j}$ and R_j where j represents the class. We re-write (8) to get:

$$\frac{h_{ji}}{\theta_j} p_{ji} - (I_{intra\_code} + I_{inter\_code}) = \eta W, \tag{9}$$

where $\theta_j = \frac{(E_b/I_0)_j R_j}{W}$ $(j = 1,\ldots,L)$ depends only on the class j.

Finally, the matrix form is

$$\mathbf{\Pi}\mathbf{p} = \eta W \mathbf{1}, \tag{10}$$

where

$$\mathbf{\Pi} = \begin{pmatrix} \mathbf{a}_1 & \mathbf{b}_2 & \ldots & \mathbf{b}_j & \ldots & \mathbf{b}_L \\ \mathbf{b}_1 & \mathbf{a}_2 & \ldots & \mathbf{b_j} & \ldots & \mathbf{b}_L \\ \vdots & \vdots & \ddots & \vdots & \ldots & \vdots \\ \vdots & \vdots & \vdots & \mathbf{a}_j & \ldots & \vdots \\ \vdots & \vdots & \vdots & \vdots & \ddots & \vdots \\ \mathbf{b}_1 & \ldots & \ldots & \mathbf{b}_j & \ldots & \mathbf{a}_L \end{pmatrix}, \mathbf{1} = \begin{pmatrix} 1 \\ \vdots \\ 1 \end{pmatrix}$$

$$\mathbf{a}_j = \begin{pmatrix} \frac{h_{j1}}{\theta_j} & -\alpha_{ov}h_{j2} & \dots & -\alpha_{ov}h_{jM_j} \\ -\alpha_{ov}h_{j1} & \ddots & \vdots & \vdots \\ \vdots & \vdots & \ddots & -\alpha_{ov}h_{jM_j} \\ -\alpha_{ov}h_{j1} & \dots & -\alpha_{ov}h_{j(M_j-1)} & \frac{h_{jM_j}}{\theta_{jM_j}} \end{pmatrix}$$

$$\mathbf{b}_j = \begin{pmatrix} -\alpha_{sc}h_{j1} & -\alpha_{sc}h_{j2} & \dots & -\alpha_{sc}h_{jM_j} \\ -\alpha_{sc}h_{j1} & \ddots & \vdots & \vdots \\ \vdots & \vdots & \ddots & -\alpha_{sc}h_{jM_j} \\ -\alpha_{sc}h_{j1} & \dots & -\alpha_{sc}h_{j(M_j-1)} & -\alpha_{sc}h_{jM_j} \end{pmatrix}$$

where $\mathbf{p}^t = \begin{pmatrix} p_{11} & \dots & p_{1M_1} & p_{21} & \dots & p_{2M_2} & \dots & p_{ji} & \dots & p_{L1} & \dots & p_{LM_L} \end{pmatrix}$ is the vector of transmission power where each element p_{ji} for $j = 1, \dots, L$ and $i = 1, \dots, M_j$ represents the transmission power required for service j of MS_i.

Accordingly, OSSC allows classifying the traffic originated from different mobile stations into homogenous traffic with the same bit rate and QoS requirements; the mobile stations MS_i ($i = 1 \dots, M_j$) using the service j are multiplexed on the same scrambling code. Also, mobile stations can be simply classified into many classes according to their priorities, bit rates, QoSs or their distances from the BS.

Code asynchronization may occur due to the transmission from several independent terminals in a cell. The potential of OSSC scheme in asynchronous environments have been investigated in [22]. It has been shown that OSSC scheme outperforms ASSC code allocation scheme whatever the ratio of asynchronization. However, the percentage of gain is reduced when the ratio of asynchronization becomes more important.

V. Numerical and Simulation results

A. Numerical results

By using MATLAB, the performance of ASSC and OSSC code allocation schemes are evaluated considering two classes ($L = 2$) of traffic and three types of mobile stations: MS_v that transmits only voice (delay-sensitive service), MS_d that transmits data (delay-insensitive service) and MS_m that transmits simultaneously voice and data. The MS_m are considered implicitly as two users: voice and data, and hence they can not seen in the results. The parameters used for the propagation and traffic models are shown in table I.

We study the system capacity in function of the orthogonality factor α because the capacity is limited by the interference that itself is proportional to the orthogonality between spreading codes. In ASSC scheme used in UMTS model, there is only one α that represents a global orthogonality factor of spreading codes. In OSSC, there are two orthogonality factors, α_{ov} for channelization codes and α_{sc} for scrambling codes. In the first implementation, we set α = 0.4 for UMTS model (using ASSC code allocated scheme) while α_{ov}= 0.1 and α_{sc}= 0.4 for OSSC. In the second implementation, we consider relatively bad orthogonality between the codes (α=0.7 for ASSC and α_{sc}=0.7, α_{ov}= 0.1 for OSSC).

The serving BS performs closed loop power control procedure as in [6], [23], [24] in order to adjust the transmission power of each mobile station in the cell whereas the algorithm of power control is based on the models (7) and (10); BS must receive all signals with the same strength. Thus, the arrival of a new mobile station into a cell increases the interference seen by the ongoing communications. Subsequently, the BS asks the active mobile stations in the cell to adjust their transmission powers. When the transmission power of one MS reaches its maximum power and the interference seen by that MS is still unacceptable, the BS rejects the new incoming MS.

The obtained results in figures 3(a) and 3(b) show that OSSC outperforms the UMTS code allocation scheme. The performance gain varies between 31% and 77% from applying OSSC scheme. Also, we observe from figures 4(a) and 4(b) that the obtained gain is more significant (higher than 60%) when the orthogonality is bad (α = 0.6 vs α_{sc} = 0.7). Thus, since OSSC uses efficiently the spreading codes (few scrambling codes and a lot of OVSF codes), the gain increases. When MAI decreases, the mobile stations in turn reduce their transmission powers and the BS can admit additional mobile stations in the cell.

B. Simulation results

The mobile stations in the previous implementations are assumed stationary. Therefore, to obtain more realistic results, we simulate the two models considering this time the mobility and the traffic variations. The simulation model, executed by OPNET, consists of a cluster of 64 hexagonal shaped cells as shown in figure 5. Handovers at the cluster boundary are handed by wrapping them around. Thereby for one cluster, the handover arrival rate and the handover departure rate are equivalent. We consider that the call duration follows an exponential distribution with a mean of $120sec$. The cell dwell time (time that a mobile spends/remains in a cell) is also considered exponential with a mean of $50sec$. Two services are considered: voice and data. Voice service represents 70% of the total traffic and data service represents 30% of the traffic. The arrival of mobile stations are modeled by a Poisson distribution with mean λ. Finally, the parameters in table I are also considered in this simulation.

In this simulation, a cell admits mobile stations as while as the conditions of power control are respected. When a mobile station enters into a cell, the ongoing mobile stations are invited to adjust their transmission powers to overcome the interference occurred from this new MS. The new MS will be rejected when the transmission power of at least one ongoing MS reaches its maximum power and the interference is still unacceptable. Figure 6(a) presents the performance of the uplink capacity in term of the handover failure ratio (the number of failure handover to the number of occurred handover) while figure 6(b) shows the call blocking ratio (the number of blocked calls to the total number of new calls) for both models (ASSC and OSSC). The results show that the obtained gain from using OSSC scheme is considerable. The call blocking ratio and the handover failure ratio in OSSC are less than that in ASSC by 20% and 50% respectively.

VI. Conclusion

In this paper, we have studied MAI effects on the uplink capacity of WCDMA systems defined as the number of simultaneous calls that can be admitted in a cell. The presented work has shown that the interference is tightly related to the number of used scrambling codes. In order to reduce the interference in the system and deal with the limitations in UMTS code allocation scheme, we have proposed a new scheme of code allocation in the uplink direction denoted by “one service-one scrambling code” (OSSC). The main idea is to multiplex traffic originated from different mobile stations using the same service under one scrambling code by using different OVSF codes (one OVSF code per mobile station).

The proposed code allocation scheme simplifies the mobile stations classification according to their priorities, bit rates, QoS or even distances from the base station. It separates MAI effects into two types of interference: interference due to the channelizations codes, and another due to the scrambling codes. Thus, the interference decreases when the number of allocated scrambling codes is small and the mutual hamming distance between the codes is high. The numerical and simulation results have shown that OSSC outperforms the UMTS system in term of the number of simultaneous admissible calls.

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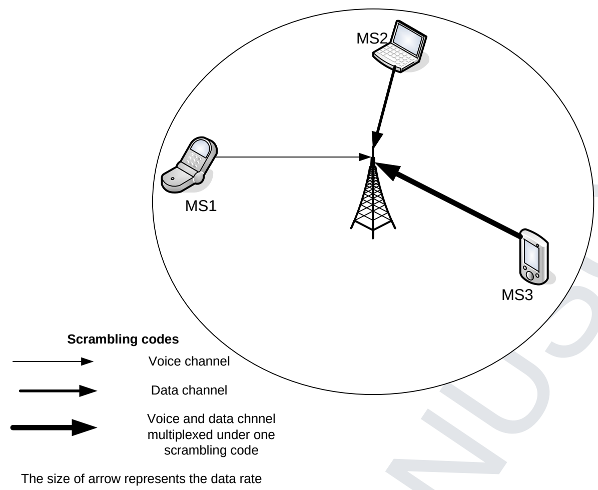
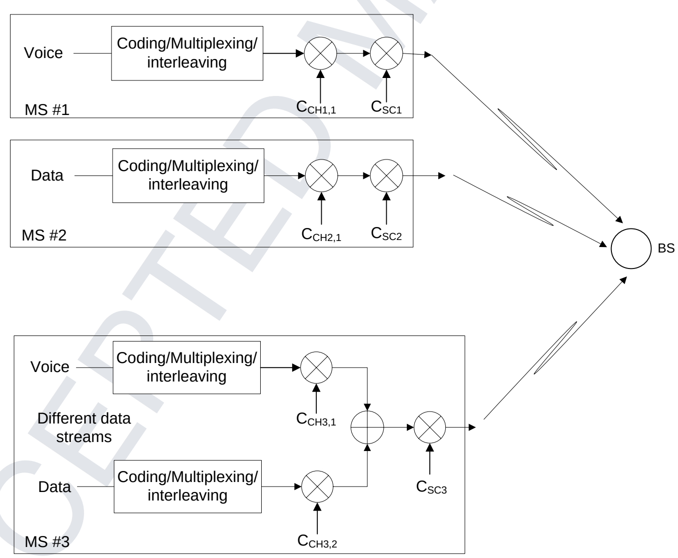
Item	Value
Chip rate W	3.84Mcps
Voice bit rate R_v	15kbps
Data bit rate R_d	30kbps
$(E_b/I_0)_{voice}$	$5dB$
$(E_b/I_0)_{data}$	$7dB$
Max transmission power P_{max}	0.05W
Path loss	d^{-4}
Noise, η	$3.98 * 10^{-21}$

TABLE I

THE PARAMETERS USED IN UMTS AND OSSC IMPLEMENTATIONS.

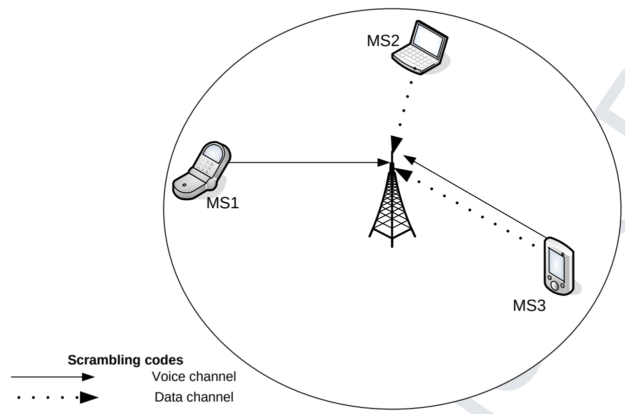


(a) Example of a cell with three mobile stations.

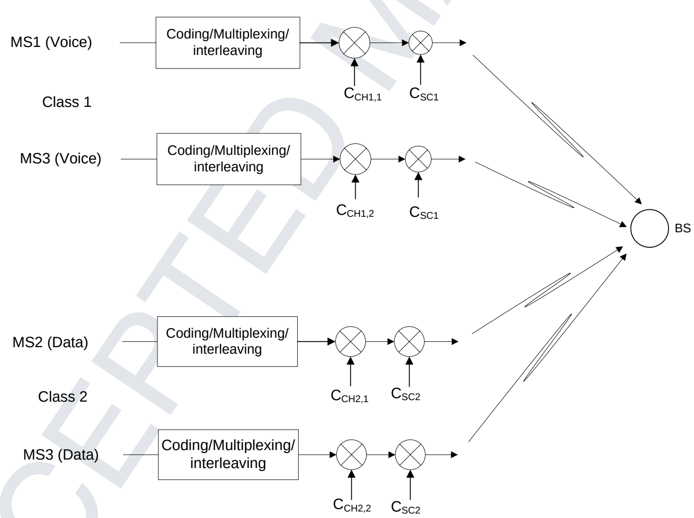


(b) The service multiplexing in UMTS. C_{SCk} is the scrambling code and $C_{CHk,j}$ is the channelization code where k is the scrambling code index and j is the channelization code index.

Fig. 1. Code allocation scheme ASSC in UMTS.

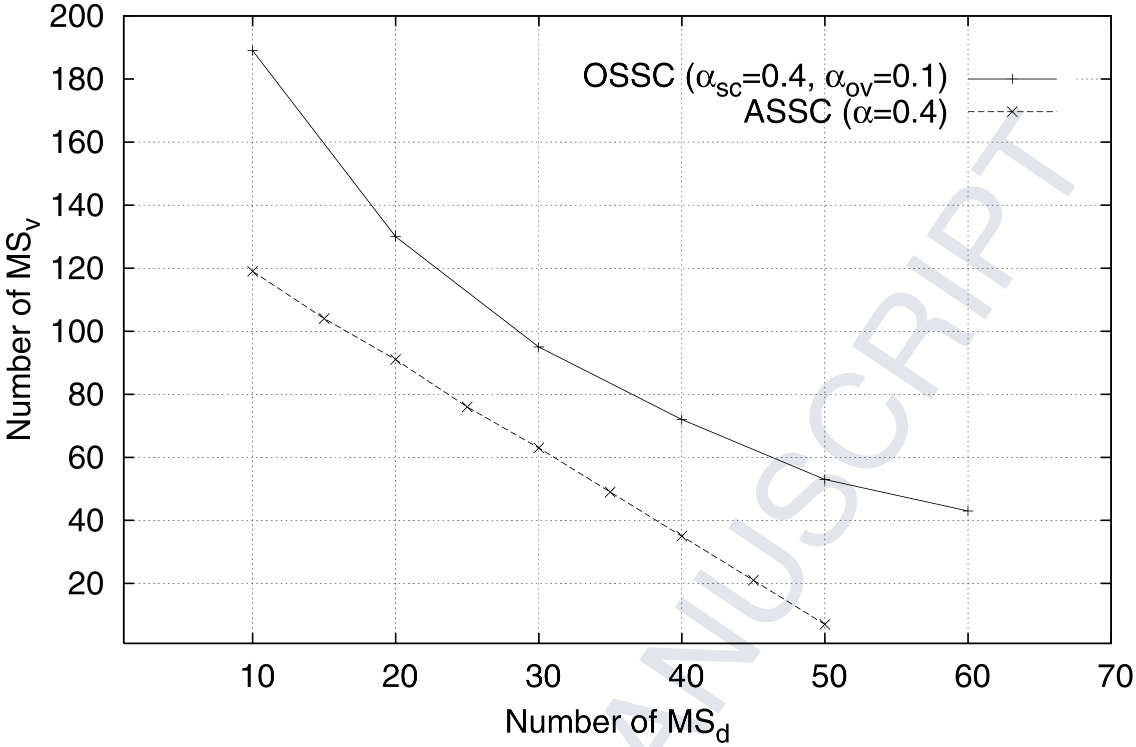


(a) Example of a cell with three mobile stations.

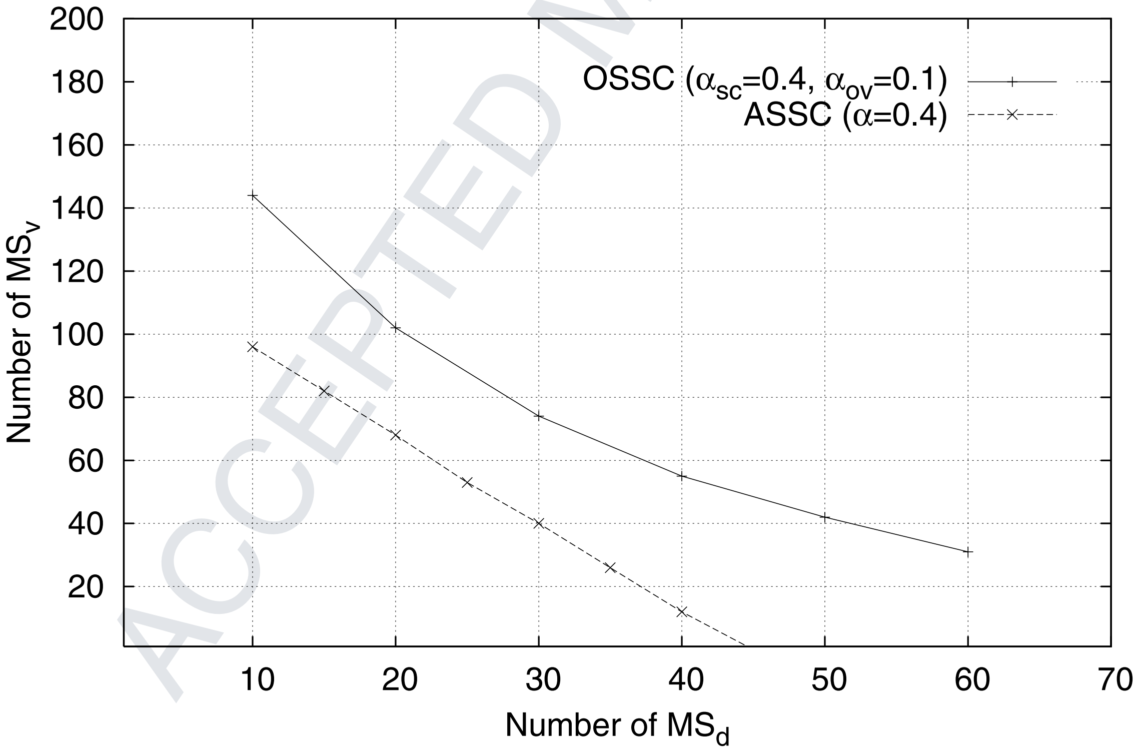


(b) The user multiplexing in OSSC scheme. C_{SCk} is the scrambling code and $C_{CHk,j}$ is the channelization code where k is the scrambling code index and j is the channelization code index.

Fig. 2. The OSSC scheme of code allocation.

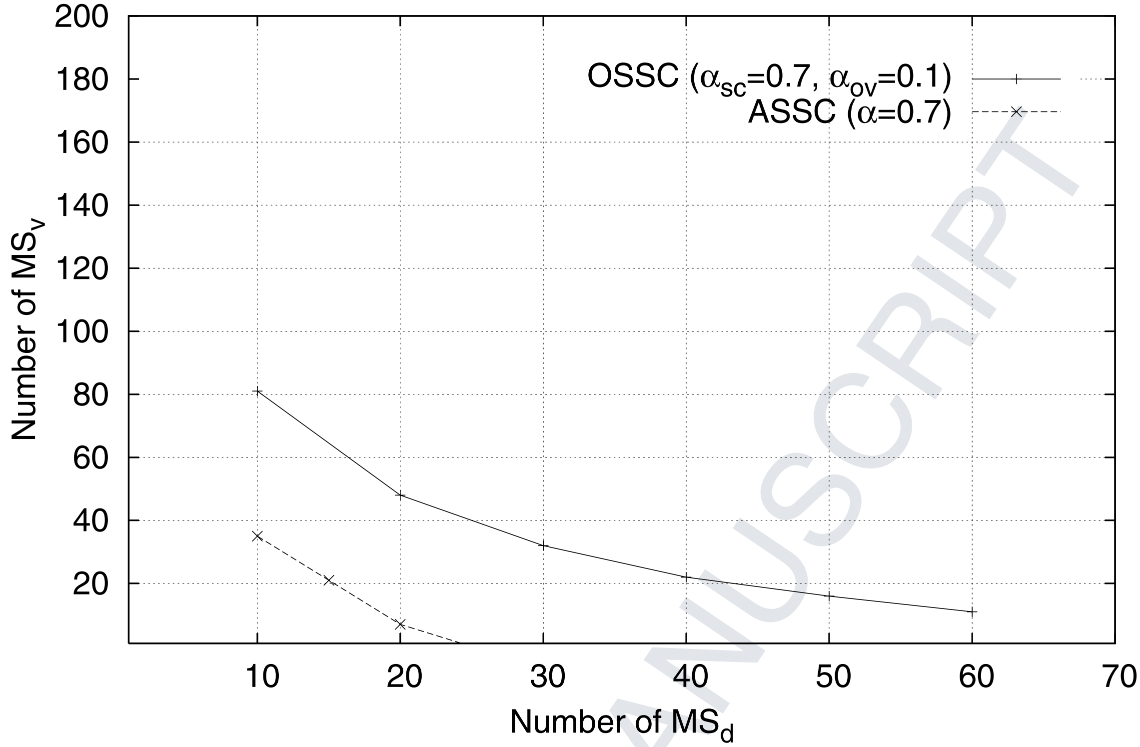


(a)

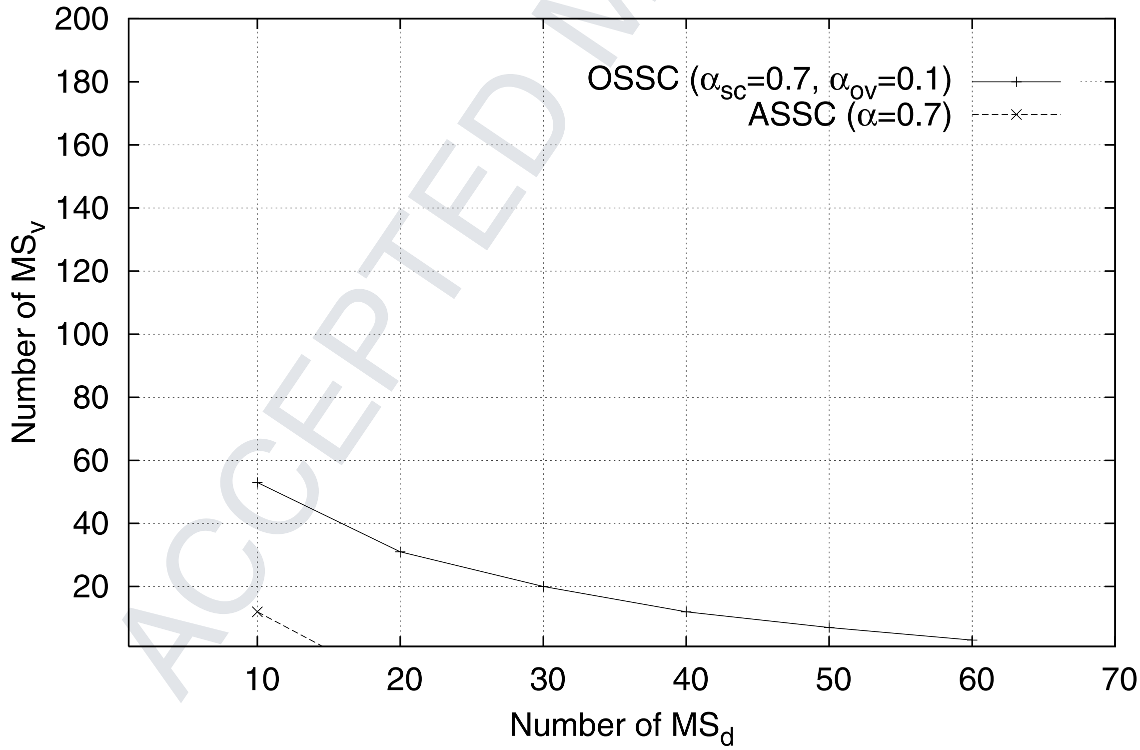


(b)

Fig. 3. The uplink capacity according to ASSC in UMTS model and OSSC. $\alpha_{sc} = 0.4$



(a)



(b)

Fig. 4. The uplink capacity according to ASSC in UMTS model and OSSC. $\alpha_{sc} = 0.7$

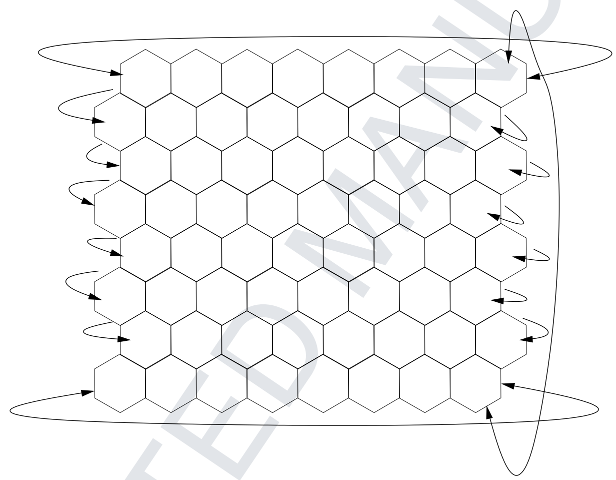
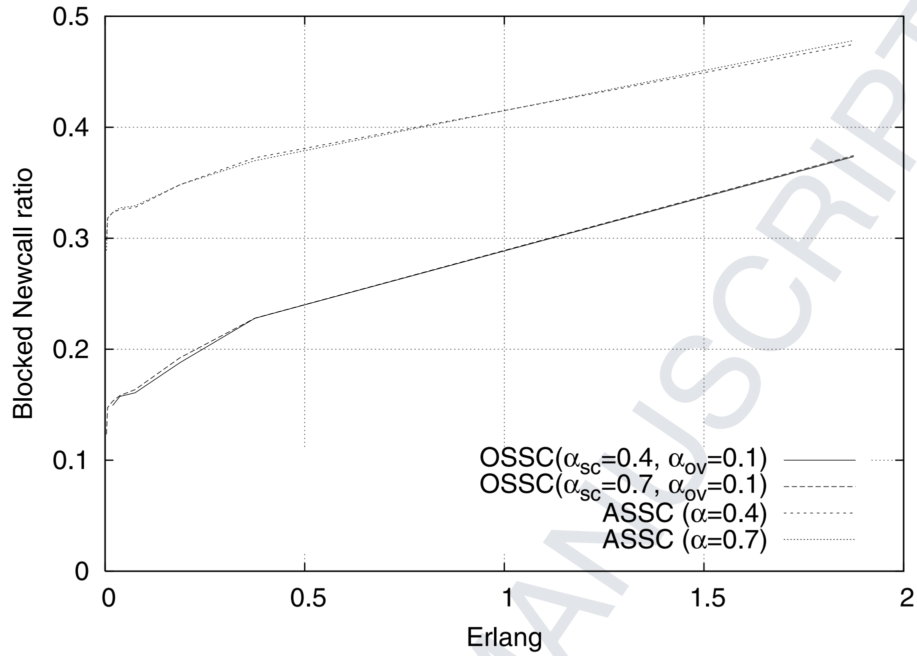
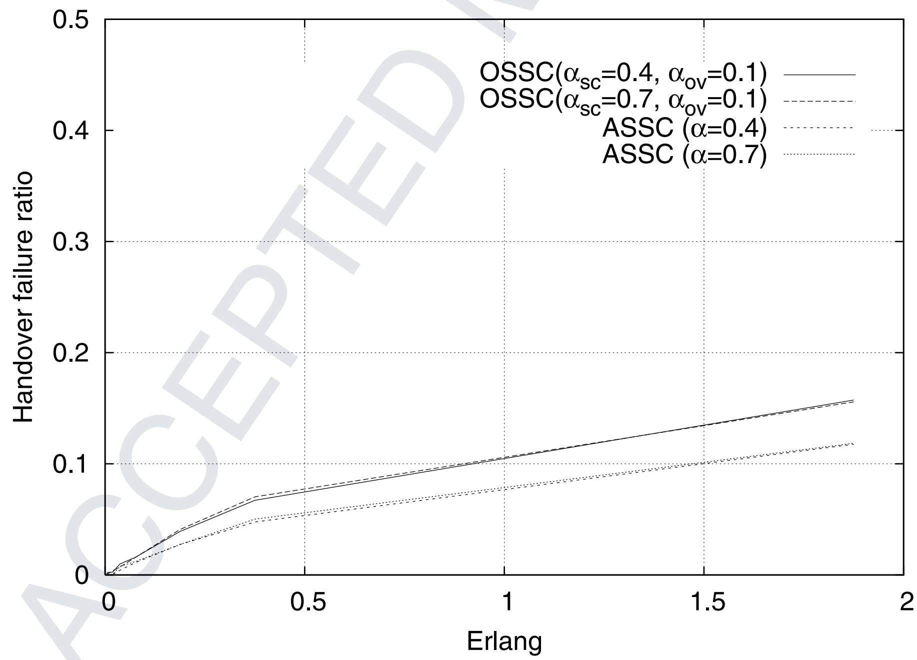


Fig. 5. Layout for a 64 cells system.



(a) The call blocking ratio



(b) The handover failure ratio

Fig. 6. The performance of ASSC in UMTS model and OSSC in term of handover failure and call blocking.