Analysis Throughput Multi-code Multicarrier CDMA S-ALOHA

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***Abstract*— This paper proposes an integrated system consisting of multi-code multicarrier code-division multiple accesses (MC-MC-CDMA) with random access scheme Slotted ALOHA (S-ALOHA), named multi-code multicarrier CDMA S-ALOHA, respectively. The performance analysis of both systems is stated as throughput. Multi-code multicarrier CDMA S-ALOHA is proposed to improve performance of multi-code CDMA or multicarrier CDMA.**

In multi-code multicarrier CDMA S-ALOHA, each user is allowed to transmit multiple orthogonal codes, so the proposed MC-MC-CDMA S-ALOHA system can support various data rates, as required by the next generation standard. In MC-MC-CDMA S-ALOHA the initial data is serial to parallel converted to a number of lower rate data streams. Each stream which consists of part of the initial data called sub-packet will be coded to a number of multiple orthogonal codes then modulated using specific spreading code for each user, and all sub stream signal are transmitted in parallel on different sub carrier.

The combination of a multi-code scheme and a multi-carrier code division multiple access (MC-CDMA) and ALOHA, called MC-MC-CDMA S-ALOHA, with dual medium, is proposed and analyzed in an AWGN channel. Each medium has different characteristics in data rate transmission. The high-rate bit transmitted data user is serial to parallel converted into low-rate bit streams and assigned with multiple-orthogonal code. Each low-rate bit stream is transmitted over L orthogonal sub-carrier.

In this paper we divide interference into different types depending on codes and sub-carriers in this system, and we carry out our analysis to obtain the BER and throughput taking into account all these types.

The performance of the system is improved as the number of assigned codes and sub-carriers increases, and also the results show that the proposed MC-MC-CDMA S-ALOHA system outperforms both multi-carrier CDMA S-ALOHA and multi-code CDMA S-ALOHA in fixed bandwidth allocation.

The results show that both systems have higher throughput for high bit rate signal transmission than multi-code CDMA S-ALOHA or multicarrier CDMA S-ALOHA. It is also shown that the throughput of both systems improve as the number of code and sub carriers, while the increase of sub packet length degrades the throughput of both systems.

Index Terms ***: Multiple-access protocols, CDMA, S-ALOHA, Multicode Multicarrier CDMA S-ALOHA.***

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I. Introduction

Future wireless system such as third generation (3G) or fourth generation (4G) will need to flexibly provide subscribers with a variety of services such as voice, data, images, and video. Because these services have widely differring data rates and traffic profiles, future generation systems will have to accomodate a wide variety of data rates such as low-data rate or high-data rate (multi-rate).

There are two general schemes that are used to accomodate the multi-rate system Code Division Multiple Acces (CDMA), namely the variable spreading gain (VSG) system scheme and the multi-code CDMA scheme [1]. The VSG system provides a variety of spreading gain for every user. The disadvantage of this system is that the spreading gain falls very low [2]. The CDMA multi-code system is able to accomodate variable data rates which is provided by multiple-code and different capacity for each of user. In a multi-code system, the spreading factor continuosly keeps constant. The disadvantage of this system is that the increase of the data rate of every user will influence the increase of interference because the carrier used to transmit the signal is the same (single-carrier) [3] .

CDMA systems have some disadvantages such as inter-symbol interference (ISI) and inter-chip inteference (ICI) [4]. The multicarrier CDMA scheme (MC-CDMA) is one approach used to overcome those problems. Essam A. Sourour and his colleagues have researched the perfomance of multicarrier CDMA systems [4]. Every data user goes through a serial-to-paralel converter and then divided into low-rate data stream or low rate data symbol. Every low rate data symbol will be transmitted by some subcarrier that have narrowand bandwidth [5,6]. In [10], the BER system multi carrier DS-CDMA and multirate traffic have been researched and analyzed.

The integrated system consisting of multi-code CDMA and multicarrier CDMA called multi-code multicarrier CDMA (MC-MC-CDMA) has been widely researched [1,3]. In [1], research was directed towards the performance of MC-MC-CDMA system for uplink communications. The work of [3] researched and analyzed the perfomance of MC-MC CDMA in single medium. The results shows that MC-MC CDMA system is better than multicarrier CDMA system and multi-code CDMA system in a certain bandwidth alocation.

This paper proposes an integrated system consisting of multi-code CDMA and multicarrier CDMA, and additionally ALOHA for dual medium traffic or dual-rate traffic. In MC-

MC CDMA ALOHA system, every user from all media will be transmitted in multiple-code through some subcarrier according to its data rate. The different characteristics of every media will influence the interference increase because of the code and subcarrier from users in the same medium and also the code and subcarrier from users in another medium.

The analyzed parameter is the throughput of MC-MC-CDMA ALOHA with dual medium or dual rate traffic in AWGN channel. The assumed system has two mediums that have different traffic profiles. The first user in medium *s* focused on code to-*m* and subcarrier to-*l* is a reference. The calculation of throughput is based on the consideration of the interference influencing from code and subcarrier in the same medium and also code and subcarrier in a different medium. The system also assumed that inter subcarrier and code from user is orthogonal.

The model of the system MC-MC-CDMA is explained in section 2. The explanation of BER is given in section 3 while section 4 discusses interference. Section 5 discusses MC-MC CDMA ALOHA, while section 6 presents the results and analysis of the calculation of the throughput with the results shown graphicly. The conclusions are provided in section 7.

II. System Model

The transmitted signal from user to-*k* and medium *s* is

$$s_k^{(s)}(t) = \sum_{m=1}^{Ms}\sum_{l=1}^{L}\sqrt{2P_k^{(s)}}\,b_{k,m,l}^{(s)}(t)\,c_{k,m}^{(s)}(t)\,cos(\omega_l t + \theta_{k,l}^{(s)}) \quad (1)$$

From equation (1), $P_k^{(s)}$ is transmission power from user to-*k* and medium *s*, $c_{k,m}^{(s)}$ is *code* to-*m* from user *k*, ω_l is subcarrier frequency to-*l* that have initial phase $\theta_{k,l}^{(s)}$, *l* is the number of subcarrier in a system (l = 1, 2, 3, ..., L), M_s is the number of sequence code that used in medium *s*, $b_{k,m,l}^{(s)}$ is transmitted data in medium s that reference in code to-*m* and subcarrier to-*l*.

$$b_{k,m,l}^{(s)}(t) = \sum_{j=-\infty}^{\infty} b_{k,m,l,j}^{(s)}\, h(t - jT_s) \quad (2)$$

$$c_{k,m}^{(s)}(t) = \sum_{j=-\infty}^{\infty} c_{k,m,j}^{(s)}\, h(t - jT_c) \quad (3)$$

$b_{k,m,l,j}^{(s)} \in \{+1,-1\}$ dan $c_{k,m,j}^{(s)} \in \{+1,-1\}$. *h(t)* is *periodic* rectangular pulse with duration T_c and T_s. *h(t)* will be 1 if $0 \le t \le T_s$ and will be 0 if $0 > t > T_s$. Frequency equation is orthogonality :

$$\omega_l = \omega_1 + (l-1)\frac{2\pi}{T_c} \quad (4)$$

When assume the transmission bandwidth is pass-band null-to-null $2/T_{c1}$ and when G_{s1} is *processing gain* for single-code single-carrier DS-CDMA

$$G_{s1} = \frac{T_b}{T_{c1}} \quad (5)$$

Spreading code duration and processing gain for multicode multicarrier are

$$T_c = \frac{M_s L + 1}{2} T_{c1} \text{ , and} \quad (6)$$

$$G_s = \frac{M_s L T_b}{T_c} = \frac{L T_m}{T_c} = \frac{T_s}{T_c} \quad (7)$$

Subtitute T_{c1} from (6) to equation (5) hence :

$$T_b = \frac{2T_c}{M_s L + 1} G_{s1} \quad (8)$$

Subtitute T_b from (8) to equation (7) so that processing gain for multi-code multicarrier CDMA system is

$$G_s = \frac{T_s}{T_c} = \frac{2M_s L}{M_s L + 1} G_{s1} \quad (9)$$

Received signal is

$$\begin{aligned} r(t) = n(t) + \sum_{i=1}^{S}\sum_{k=1}^{Ks}\sum_{m=1}^{Ms}\sum_{l=1}^{L}\sqrt{2P_s}\,b_{k,m,l}^{(s)}(t-\tau_k^{(s)}) \\ \times c_{k,m}^{(s)}(t-\tau_k^{(s)})\,cos(\omega_l t + \phi_{k,l}^{(s)}) \end{aligned} \quad (10)$$

where $\phi_{k,l}^{(s)} = \theta_{k,l}^{(s)} - \omega_l \tau_k^{(s)}$, P_s is received power and assumed for all user is in the same medium. *(s = 1, 2, ..., S)*. Assumed perfect power control for every medium. For example, P_1 is received power from medium 1 and P_2 is received power from medium 2, but P_1 is not same as P_2. $\phi_{k,l}(t)$ is the different beetween $\theta_{k,l}$ and phase that caused by time delay. $\tau_k^{(s)}$ is time delay for user *k* from medium *s*.

III. BER Approximation

Standard Gaussian Approximation (SGA) is used, so that Multiple Access Interference (MAI) from another user is assumed random. No loss of generality, assuming that desire user is first user (*k = 1*) from medium *s* with focus on code to-*m* and subcarrier to-*l*. Output from coherent matched filter in code to-*m* and subcarrier to-*l* from receiver are for user to-*1* from medium *s* is

$$z_{1,m,l}^{(s)} = \int_0^{T_s} r(t).c_1(t)\cos(\omega_l t + \alpha_{k,m}^{(s)}) \quad (11)$$

$\alpha_{k,m}^{(s)}$ is shifting phase in receiver. Output from the previous matched filter can expressed as :

$$Z_{1,m,l}^{(s)} = D_{1,m,l}^{(s)} + N_{1,l}^{(s)} + I_{tot}^{(s)} \quad (12)$$

$$\begin{aligned} Z_{1,m,l}^{(s)} = D_{1,m,l}^{(s)} + N_{1,l}^{(s)} + I_1^{(s)} + I_2^{(s)} + I_3^{(s)} + I_4^{(s)} \\ + I_5^{(s)} + I_6^{(s)} + I_7^{(s)} + I_8^{(s)} + I_9^{(s)} \end{aligned} \quad (13)$$

$N_{1,l}^{(s)}$ is AWGN with *zero mean* , $I_{tot}^{(s)}$ is total interference that caused by code and subcarrier in medium *s* and medium *i*, $D_{1,m,l}^{(s)}$ is desired signal for user to-*l* from medium *s* in code to-*m* and subcarrier to-*l*.

When assumed that the desire signal is the signal from user to-*1* comes from medium *s* in code to-*m* and subcarrier to-*l* and $\omega_l >> T_s^{-1}$ hence :

$$D_{1,m,l}^{(s)} = \sqrt{\frac{P_s}{2}}\, T_s \qquad (14)$$

Signal noise *n(t)* assumed have same spectrum for all the frequency allocated is $N_o/2$ (*two-sided spectral density*) and *zero mean*. Variance noise is given [7].

$$\sigma_n^2 = \frac{N_o}{4} T_s \qquad (15)$$

IV. INTERFERENCE VARIANCE

4.1. Interference Variance

4.1.1. Interference from user and from the same medium

(a) Interference from code and subcarrier from the same user in medium *s*.

This interference its caused by using of another code and another subcarrier from the same user in the medium *s*. In the system model, assumed that inter code and inter subcarrier in the same user have orthogonality so that interference will not occur [4]. This case will occur if there is no multipath fading. Assumed the sincronization is perfect and there is no delay path, so the interference that caused by self interference is zero. $I_1^{(s)} = 0$.

(b) Interference from the same code and the same subcarrier that is used by another user.

This interference is categorize as interference in single-code single-carrier CDMA. If assumed time delay $\tau_k^{(s)}$ distributed uniformly with one bit duration *T*, ($0 \le \tau_k^{(s)} \le T_s$).

$$I_2^{(s)} = \sqrt{2P_s} \sum_{k=2}^{K_s} \int_0^{T_s} b_{k,m,l}^{(s)}(t-\tau_k^{(s)})\, c_{k,m}^{(s)}(t-\tau_k^{(s)}) \times \cos(\omega_l t + \phi_{1,l}^{(s)})\, c_{1,m}(t) \cos(\omega_l t + \alpha_{1,l}^{(s)}) dt \qquad (16)$$

This kind of variance interference is [10]:

$$Var[I_2^{(s)}] = \sum_{k=2}^{K_s} \frac{P_s T_c^2 G_s}{6} \qquad (17)$$

(c) Interference from same code and another subcarrier that is used by another user.

This interference is inter-carrier interference.

$$I_3^{(s)} = \sqrt{2P_s} \sum_{k=2}^{K_s} \sum_{q=1, q\neq l}^{L} \int_0^{T_s} b_{k,m,l}^{(s)}(t-\tau_k^{(s)}) \times c_{k,m}^{(s)}(t-\tau_k^{(s)})\, c_{1,m}(t) \cos(\omega_l t + \phi_{k,l}^{(s)}) \times \cos(\omega_q t + \alpha_{1,q}^{(s)})\, dt \qquad (18)$$

This kind of variance is [10]:

$$Var\left[I_3^{(s)}\right] = \sum_{k=2}^{K_s} \sum_{q=1, q\neq l}^{L} \frac{6 P_s T_c^2 G_s}{4\pi^2 (q-l)^2} \qquad (19)$$

(d) Interference from another code and same subcarrier that is used by another user.

The interference caused by another code from the same subcarrier that used by another user.

$$I_4^{(s)} = \sqrt{2P_s} \sum_{k=2}^{K_s} \sum_{m'=1, m'\neq m}^{M_s} \int_0^{T_s} b_{k,m,l}^{(s)}(t-\tau_k^{(s)}) \times c_{k,m}^{(s)}(t-\tau_k^{(s)})\, c_{1,m}(t) \cos(\omega_l t + \phi_{k,l}^{(s)}) \times \cos(\omega_l t + \alpha_{1,l}^{(s)})\, dt \qquad (20)$$

Variance from this interference is

$$Var[I_4^{(s)}] = \sum_{k=2}^{K_s} \frac{P_s T_c^2}{12 G_s} (M_s - 1).(1 - \frac{\pi^2}{6}) \qquad (21)$$

(e) Interference from another code and another subcarrier that is used by another user.

The interference caused by another code and another subcarrier that used by another user.

$$I_5^{(s)} = \sqrt{\frac{P_s}{2}} \sum_{k=2}^{K_s} \sum_{m'=1, m'\neq m}^{M_s} \sum_{q=1, q\neq l}^{L} \int_0^{T_s} b_{k,m,l}^{(s)}(t-\tau_k^{(s)}) \times c_{k,m}^{(s)}(t-\tau_k^{(s)})\, c_{1,m}(t) \times \cos\left[(\omega_q - \omega_l)t + \phi_{k,q}^{(s)} - \alpha_{1,q}^{(s)}\right] dt \qquad (22)$$

The variance from this interference is

$$Var[I_5^{(s)}] = \sum_{k=2}^{K_s} \sum_{q=1, q\neq l}^{L} \frac{6 P_s T_c^2 (M_s - 1) G_s}{4\pi^2 (q-l)^2} \qquad (23)$$

4.1.2. Interference from a user in a different medium

(a) Interference from a different code and different subcarrier that is used by another user.

If assumed that user to-*k* from medium *s* that is as a reference user and integrator medium is medium *i* (*i = 1, 2, ..., S)*, where $i \neq s$ and assumed also that time delay from integrator user $\tau_k^{(i)}$ distributed uniformly with 1 bit period from integrator user is T_i, where $0 \le \tau_k^{(i)} \le T_i$.

$$I_6^{(s)} = \sqrt{\frac{P_i}{2}} \sum_{i=1, i\neq s}^{S} \sum_{k=1}^{K_i} \int_0^{T_s} b_{k,m,l}^{(i)} (t-\tau_k^{(i)}) \times c_{k,m}^{(i)} (t-\tau_k^{(i)})\, c_{1,m}(t) \, Cos\, \phi_{k,l}\, dt \quad (24)$$

Where $\phi_{k,l} = \theta_{k,l} - \omega_l \tau_k$, P_i is received power from user in medium to-*1*. G_i is processing gain from medium *i* as an integrator. T_i is bit duration from user in the medium *i*. This kind of interference is [10] :

$$Var[I_6^{(s)}] = \sum_{i=1, i\neq s}^{S} \sum_{k=1}^{K_i} \frac{P_i T_c^3 G_s G_i}{6T_i} \quad (25)$$

(b) Interference from the same code and another subcarrier.

The interference caused by another subcarrier from user in medium *i*.

$$I_7^{(s)} = \sum_{i=1, i\neq s}^{S} \sum_{k=1}^{K_i} \sum_{q=1, q\neq l}^{L} \sqrt{\frac{P_i}{2}} \int_0^{T_s} b_{k,m,l}^{(i)} (t-\tau_k^{(i)}) \times c_{k,m}^{(i)} (t-\tau_k^{(i)})\, c_{1,m}(t) \times Cos\left[\left(\omega_q - \omega_l\right)t + \phi_{k,q}^{(i)} - \alpha_{k,l}^{(i)}\right] \quad (26)$$

This kind of variance is [10] :

$$Var\left[I_7^{(s)}\right] = \sum_{i=1, i\neq s}^{S} \sum_{k=1}^{K_i} \sum_{q=1, q\neq l}^{L} \frac{P_i T_c^3 G_s G_i}{2T_i \pi^2 (q-l)^2} \quad (27)$$

(c) Interference from another code and the same subcarrier.

The interference caused by another code in the same subcarrier from the user in medium *i*.

$$I_8^{(s)} = \sum_{i=1, i\neq s}^{S} \sum_{k=1}^{K_i} \sum_{m'=1, m'\neq m}^{Mi} \sqrt{\frac{P_i}{2}} \int_0^{T_s} b_{k,m',l}^{(i)} (t-\tau_k^{(i)}) \times c_{k,m}^{(i)} (t-\tau_k^{(i)})\, c_{1,m}(t) \, Cos^2\left(\omega_l t\right) dt \quad (28)$$

Using the process like the interference that is caused by another code and the same subcarrier from another user in the same medium, so that the variance from this interference is

$$Var[I_8^{(s)}] = \sum_{i=1, i\neq s}^{S} \sum_{k=1}^{K_i} \sum_{m'=1, m'\neq m}^{Mi} \frac{P_i T_i^2}{12 G_i^3} M_i \left(1 - \frac{\pi^2}{6}\right) \quad (29)$$

Subtitute the formula of processing gain from another medium G_i to equation (29), hence :

$$Var[I_8^{(s)}] = \sum_{i=1, i\neq s}^{S} \sum_{k=1}^{K_i} \sum_{m'=1, m'\neq m}^{Mi} \frac{P_i T_c^3}{12 T_i} M_i \left(1 - \frac{\pi^2}{6}\right) \quad (30)$$

(d) Interference from another code and another subcarrier.

The interference caused by another code and another subcarrier from user and from medium *i*.

$$I_9^{(s)} = \sum_{i=1, i\neq s}^{S} \sum_{k=1}^{K_i} \sum_{m'=1, m'\neq m}^{M_i} \sum_{q=1, q\neq l}^{L} \sqrt{\frac{P_i}{2}} \times \int_0^{T_s} b_{k,m',q}^{(i)} (t-\tau_k^{(i)}) c_{k,m'}^{(s)} (t-\tau_k^{(i)})\, c_{1,m}(t) \times Cos\left[(\omega_q - \omega_l)t + \phi_{k,q}^{(i)} - \alpha_{k,l}^{(s)}\right] dt \quad (31)$$

The variance of this kind of interference is

$$Var[I_9^{(s)}] = \sum_{i=1, i\neq s}^{S} \sum_{k=1}^{K_i} \sum_{q=1, q\neq l}^{L} \frac{P_i T_c^3 M_i G_s G_i}{2 T_i \pi^2 (q-l)^2} \quad (32)$$

Subtitute the desired signal, noise signal, interference from medium *s* and interference from medium *i*, so the average Bit Error Rate (BER) equation in medium *s* is

$$BER_s = \frac{1}{L} \sum_{l=1}^{L} \frac{1}{2} erfc(\sqrt{SINR}) \quad (33)$$

$$SINR = \frac{D_1}{\sqrt{Var[\eta] + Var[I_{tot}^{(s)}]}} \quad (34)$$

$$Var[I_{tot}^{(s)}] = Var[I_1^{(s)}] + Var[I_2^{(s)}] + Var[I_3^{(s)}] + Var[I_4^{(s)}] + Var[I_5^{(s)}] + Var[I_6^{(s)}] + Var[I_7^{(s)}] + Var[I_8^{(s)}] + Var[I_9^{(s)}] \quad (35)$$

$$\begin{aligned} SINR^{-1} = {} & \frac{N_o}{2E_b} + \sum_{k=2}^{K_s} \frac{T_c^2 G_s}{3T_s^2} + \sum_{k=2}^{K_s} \sum_{q=1, q\neq l}^{L} \frac{3T_c^2 G_s}{\pi^2 T_s^2 (q-l)^2} \\ & + \sum_{k=2}^{K_s} \frac{T_c^2 (Ms-1)}{2T_s^2 G_s} \left(1 - \frac{\pi^2}{6}\right) \\ & + \sum_{k=2}^{K_s} \sum_{q=1, q\neq l}^{L} \frac{T_c^2 (M_s - 1) G_s}{\pi^2 T_s^2 (q-l)^2} \\ & + \sum_{i=1, i\neq s}^{S} \sum_{k=1}^{K_i} \frac{P_i T_c^3 G_s G_i}{3 T_i P_s T_s^2} \\ & + \sum_{i=1, i\neq s}^{S} \sum_{k=1}^{K_i} \sum_{q=1, q\neq l}^{L} \frac{P_i T_c^3 G_s G_i}{\pi^2 T_i P_s T_s^2 (q-l)^2} \\ & + \sum_{i=1, i\neq s}^{S} \sum_{k=1}^{K_i} \sum_{m'=1, m'\neq m}^{Mi} \frac{P_i T_c^3}{6 T_i P_s T_s^2} M_i \left(1 - \frac{\pi^2}{6}\right) \\ & + \sum_{i=1, i\neq s}^{S} \sum_{k=1}^{K_i} \sum_{q=1, q\neq l}^{L} \frac{P_i T_c^3 G_s G_i M_i}{\pi^2 T_i P_s T_s^2 (q-l)^2} \end{aligned} \quad (36)$$

where $E_b = P_s T_s$ and *signal to noise ratio* is $SNR = \frac{2E_b}{N_0}$.

V. The Performance Of Multi-code Multi carrier CDMA S-ALOHA

According its name, Slotted Aloha changes the protocol from continuous time to slotted time. We will observe the time as sequence slot and duration *T*, where one frame can be sent to each of the slots. In the transmission we assume that the synchronization has occurred, so that all the transmissions can start in the first slot. When a frame is to be transmitted in a time slot, that frame is queued in first time slot. Therefore, one frame competes with another frame that has the same time slot. This reduces the time of contention from two time frames to one time frame. This makes the maximum throughput from Slotted-Aloha two times larger than the maximum throughput of P-Aloha. Traffic load *(G)* will change according to the time. Note that if the number of packets that are backlogged increases, *G* will also increase. In this discussion we are assuming that the number of users is unlimitted, while the length of the packet being constant. Furthermore we also assume that when a packet arrives, that packet will be transmitted in another slot after. If a collision occurs so a node is backlogged, the backlogged node will transmit the packet in every slot with probability *q* until success. The number of simultaneous transmissiosn from the system in a slot duration has been given by the steady state probability from the Poisson process, in this case it follows that

$$P(K,G)=\frac{\left(\dfrac{G}{M_s\cdot L}\right)^K}{K!}\exp\left(-\frac{G}{M_s\cdot L}\right) \qquad (37)$$

P (K,$G_{S\text{-}Aloha}$) as a probablity in *K* user that raise *Ms.L.K* subpacket in one slot duration. $G_{S\text{-}Aloha}$ is load traffic, the average of subpacket that sent in one slot duration. The Poisson Model assumes that the number of users are unlimitted because generally gives an approximation near to a real condition in a network with many stations.

Systematically throughput value can be written in

$$S=\sum_{k=1}^{\infty}M_s\cdot L\cdot K\cdot P(K,G)\cdot P_a \qquad (38)$$

where *Ms* is the number of code in medium *s*, *L* is the number of subcarrier that is used and *K* is the number of users. *Pa* is the probability success in transmission of subpacket in the S-Aloha system. It can be written in the form

$$P_a=\left(1-\left(BER_s\right)_{mc-mc}\right)^{L_b}$$

(39)

with L_b being the length of a transmitted bit.

VI. Result And Analysis

Based on Figure 1 and 2, we can observe that the perfomance of throughput in MC-MC-CDMA S-ALOHA with single medium is better than dual medium. This is because in the dual medium system, the interference is caused not only by the code and subcarrier from the same medium but also because of the code and subcarrier from a different medium.

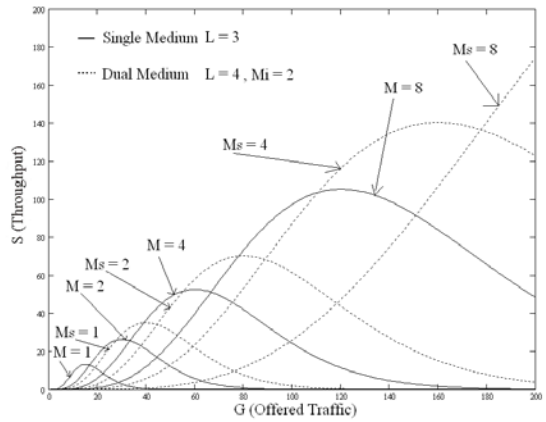

Figure 1. Throughput analysis MC-MC-CDMA S-ALOHA in single medium and dual medium system with G_s^1 = 32, G_i^1 = 64, K_s = 200, K_i = 50, L = 2, M_i = 2, dan M_s in variation

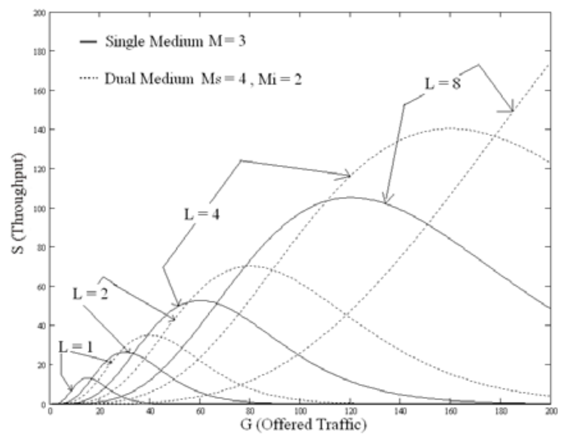

Figure 2. Throughput analysis MC-MC-CDMA S-ALOHA system in single medium and dual medium with G_s^1 = 32, G_i^1 = 64, K_s = 200, K_i = 50, M_s = 2, M_i = 2, and L in variation

VII. ConclusionS

1. Throughput system of multi-code multicarrier CDMA S-ALOHA in dual medium in the AWGN channel has been analyzed
2. Throughput system of multi-code multicarrier CDMA S-ALOHA is better than multi-code CDMA or multicarrier CDMA S-ALOHA system.
3. Throughput system of multi-code multicarrier CDMA S-ALOHA in single-medium is better than dual-medium.
4. Throughput system of multi-code multicarrier CDMA S-ALOHA increases according to the increase in the number of code in medium s (Ms), medium i (Mi) and the number of subcarrier (L).

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