Cooperative diversity in HSDPA network

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1

Abstract – **HSDPA (High speed data packet access) allows high-speed downlink data flow in WCDMA network. It uses all remaining power after power for DCH (dedicated channels which are power controlled) channels and other channels (CPICH (pilot channel), SCH (synchronization channel), PCH (paging channel),…) is reserved on Node-B since HSDPA channel is not powered controlled. This causes increased inter-cell interference for neighboring cells. In this work method, that improves performance in terms of outage probability and shares interference increase between two neighboring cells, is proposed and analyzed.**

Key words — **HSDPA, turbo coding, outage probability**

I. INTRODUCTION

HSDPA [1] uses max 15 SF16 codes from tree of downlink orthogonal codes. On every 2 ms number of codes is scheduled for each user according to uplink HS-DPCCH (High speed-dedicated physical control channel) channel, that carries CQI (channel quality indicator) bits, which is sent by each user. Number of codes that is reserved for each user depends of relative CQI users relation. One code is used for transmission of one HSDPA packet which contains 3 WCDMA slots. Also all available Node-B power left, after power required for DCH channels and all other channels is allocated, is split among the HSDPA users according to their CQI. HS-PDSCH (High speed-physical downlink shared channel) is downlink physical channel that carries HSDPA traffic. Turbo encoding [2] for user message is used prior to transmission over this channel using multiple HSDPA packets.

The case when 2 codes are allocated to user is analyzed here. Method for allocating of 2 turbo encoded packets between 2 Node-B's that are in active set of UE (user equipment) is proposed.

In section II proposed method is presented, in section III performance analysis through evaluating of outage probability is executed, in section IV is the summation of this paper.

II. DESCRIPTION OF PROPOSED METHOD

In the Fig. 1 proposed method is illustrated.

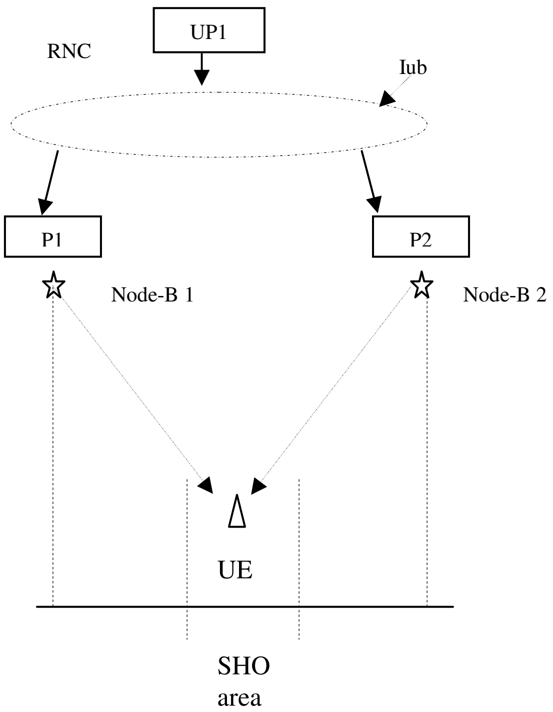

Fig. 1

The scenario that it is analyzed is next: According to CQI information from UE, 2 codes, for sending message UP1, are allocated for UE and power allocated for this transmission is P_d from Node-B 1. UE is in SHO (soft-softer handover) area and has active set with Node-B 1 and Node-B 2. Distances from Node-B 1 and Node-B 2 to the UE are the same. Message UP1 is turbo encoded and sent over packets P1, P2 using two allocated codes.

Proposition is that RNC should send user packet UP1 to Node-B 1 and Node-B 2 over Iub interface. Node-B 1 should turbo encode packet UP1 into P1, P2 and transmit just P1 packet (instead of P1, P2 in original case). Node-B 2 should turbo encode packet UP1 into P1, P2 and transmit just P2 packet. Proposed method is illustrated in Fig. 1. On this way macro diversity [3], similar as in SHO, is achieved since 2 parts of turbo-encoded message are sent over 2 independently fading channels and probability that both parts of message are in deep fading is significantly reduced. Also inter-cell interference is more evenly distributed between these two cells, because interference increase that HSDPA transfer cause is equal in both cells.

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Slow fading channel over one packet is assumed. Coherence time can be calculated as:

$$T_c = 1/f_c\,,\quad f_c = v/\lambda = \frac{v\cdot f_{sys}}{c}$$

where T_c is coherence time, v is speed of UE, f_{sys} is frequency of chip symbols in WCDMA system and c is speed of light. It can be calculated that even for large UE speed, time for one packet transmission (2 ms) is smaller than coherence time [4]. From this small analysis it can be seen that assumption about slow fading is justified.

III PERFORMANCE ANALYSIS

In the HSDPA network there is no power control, which can compensate for bad channel condition and maintain SNR on UE on target value, like it is the case in SHO. So, performance of the proposed scheme can be compared to classic HSDPA network in terms of outage probability.

In Eq. 1 the SINR value on UE before decoding is presented for original and proposed scheme.

$$SINR^O = pg\cdot\frac{P_d\cdot h^2}{I_{tot}} \text{ - original scheme}$$

$$SINR^P = pg\cdot\left(\frac{P_{s1}\cdot h_1^2}{I_{tot1}}+\frac{P_{s2}\cdot h_2^2}{I_{tot2}}\right) \text{ - proposed scheme}$$

Eq.1

where *pg* (for HSDPA value is 16) is processing gain, P_d, P_{s1}, P_{s2} are transmitted power from Node-B 1 in original scheme and from Node-B 1 and Node-B 2 in proposed scheme, I_{tot}, I_{tot1}, I_{tot2} are total interference from Node-B 1 in original scheme and from Node-B 1 and Node-B 2 in proposed scheme and h^2, h_1^2, h_2^2 are channel gains from Node-B 1 in original scheme and from Node-B 1 and Node-B 2 in proposed scheme. Power will be equally distributed between Node-B's $P_{s1}=P_{s2}$ and $P_{s1}+P_{s2}=P_d$. Total interference is the sum of the own and inter cell interference. It will be assumed that orthogonality between cell downlink codes is preserved i.e. own interference is 0. The inter cell interference is suppressed with so called de-ciphering process which results in an interference which is equal to cross-correlation between cell PN code and neighboring cell PN codes. Then this interference is effectively slow varying value which can be approximated by its mean value. According to that, inter-cell interference does not depend on fading coefficients. It will be assumed that roughly inter cell interference is the same i.e. $I_{tot1}=I_{tot2}$. This assumption is justified if the load is distributed evenly between cells.

Since there is additional power transmission in proposed scheme from Node-B 2 interference in this case is: $I_{tot1}=I_{tot2}=I_{tot}+P_d/2$. Then $SINR^P$ from Eq. 1 is:

$$SINR^P = pg\cdot\frac{P_d}{2\cdot I_{tot1}}\cdot(h_1^2+h_2^2)$$

Eq. 2

Performance of two schemes will be compared in terms of outage probabilities. In Eq. 3 outage probabilities are presented.

$$P_{out}^o = P(SINR^o<\gamma_T) = P(h^2 < \frac{I_{tot}}{pg\cdot P_d}\cdot\gamma_T = \gamma)$$

$$P_{out}^p = P(SINR^p<\gamma_T) = P(h_1^2+h_2^2 < \frac{2\cdot I_{tot1}}{pg\cdot P_d}\cdot\gamma_T = \frac{2\cdot I_{tot}+P_d}{pg\cdot P_d}\cdot\gamma_T = 2\cdot\gamma+\frac{\gamma_T}{pg}=\gamma_p)$$

Eq. 3

where γ_T is the target SNR required for wanted symbol rate. Value of γ_T is between –5 dB to 8 dB [1] or from 0.31 to 6.31 for QPSK modulation. Since UE is on the cell edge QPSK modulation is assumed. Largest outage probability for proposed scheme is obtained when γ_T =8 dB and then $\gamma_p = 2\cdot\gamma+0.4$. This value for γ_p will be used in further calculation.

Probability density function (PDF) of random variable h^2 can be calculated as chi-squared with 2 degrees of freedom since *h* is modeled as Rayleigh fading variable where $h=\sqrt{A^2+B^2}$ with *A* and *B* are normally distributed random variables with mean 0 and variance σ^2. Also h_1 and h_2 are the statistically independent random variables with the same characteristics as random variable *h*. Probability density function of random variable $h_1^2+h_2^2$ has chi-square distribution with 4 degrees of freedom. In Eq. 4 PDF and CDF (cumulative density function) of h^2 and $h_1^2+h_2^2$ are presented.

$$pdf^o(z=h^2)=\frac{1}{2\cdot\sigma^2}\cdot e^{-\frac{z}{2\cdot\sigma^2}}$$

$$cdf^o(z=h^2)=1-e^{-\frac{z}{2\cdot\sigma^2}}$$

$$pdf^p(z=h_1^2+h_2^2)=\frac{1}{4\cdot\sigma^4}\cdot z\cdot e^{-\frac{z}{2\cdot\sigma^2}}$$

$$cdf^p(z=h_1^2+h_2^2)=1-(1+\frac{z}{2\cdot\sigma^2})e^{-\frac{z}{2\cdot\sigma^2}}$$

Eq. 4

By using results from Eq.4 outage probabilities from Eq. 3 are:

$$P_{out}^{o} = P(h^2 < \gamma) = cdf^{o}(\gamma) = 1 - e^{-\frac{\gamma}{2\cdot\sigma^2}}$$
$$P_{out}^{p} = P(h_1^2 + h_2^2 < \gamma_p) = cdf^{p}(\gamma_p) =$$
$$1 - (1 + \frac{\gamma_p}{2\cdot\sigma^2})\cdot e^{-\frac{\gamma_p}{2\cdot\sigma^2}}$$

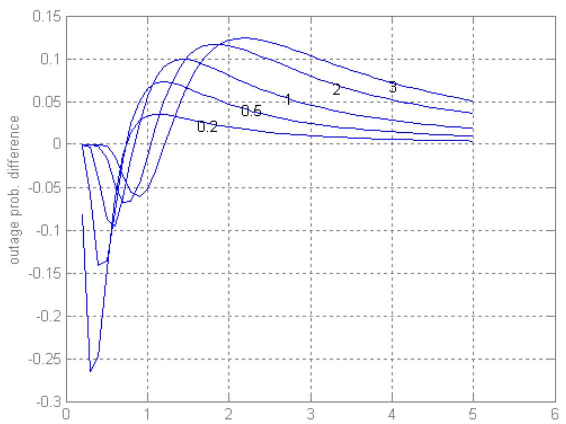
Eq. 5

Outage probability difference is:

$$P_{out}^{o} - P_{out}^{p} = (1 + \frac{2\cdot\gamma + 0.4}{2\cdot\sigma^2})\cdot e^{-\frac{2\cdot\gamma+0.4}{2\cdot\sigma^2}} - e^{-\frac{\gamma}{2\cdot\sigma^2}}$$

Eq. 6

Value of P_d^{ref} (γ =1 (Eq. 3)) is calculated from $\frac{pg\cdot P_d^{ref}}{I_{tot}} = \gamma_T$. If $P_d < P_d^{ref}$ then γ >1 else if $P_d > P_d^{ref}$ then γ <1. Value σ can be linked to distance between Node-B and UE as $\sigma = \sqrt{L/2}$ [5] where *L* is a path loss between Node-B 1 and Node-B 2 to UE. In the Fig. 2 outage probability difference is evaluated against σ and for different γ.



σ

Fig. 2

Numbers on curves on Fig. 2 represents γ values. It can be seen that for γ >1, when low power is assigned for transmission, the outage probability difference (gain) becomes higher. When too much power is assigned (γ <1) the gain tends to 0. So it can be concluded that proposed scheme is especially advantageous when too low power is assigned. Higher values of σ represent the area of interest since UE is in the cells edge. It can be seen from the Fig. 2 that if the cell is smaller (smaller values of σ) then proposed system brings more gain in terms of outage probability. Table 1. presents gain (from Fig. 2) for different values of path loss *L* for γ =1.

Table 1.

	L=8 (9dB) (σ =2)	L=18 (12.55 dB) (σ =3)	L=32 (15 dB) (σ =4)	L=50 (17 dB) (σ =5)
gain	0.08	0.042	0.03	0.02

Gain is presented in terms of outage probability decrease in compare to original case. It can be seen that reliability for achieving target SNR on UE is increased, i.e smaller outage probability is obtained when proposed scheme is used. Outage probability could be viewed as probability of retransmission. So gain in this context is decrease in retransmission probability.

IV CONCLUSION

In this work performance of new scheme for HSDPA downlink data access is analyzed and compared against original scheme in terms of outage probability for achieving target SNR on UE. It is shown that new method can effectively decrease this outage probability with the same power constrains as in original case and can also distribute interference more evenly between neighboring cells. Outage probability decrease can be in practical terms evaluated as decrease in retransmission probability.

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