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Agenda item :
Title: Principle, performance and benefits of SSDT
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1. Introduction

Site Selection Diversity TPC (SSDT) is considered as one of R99 features in WG1 and WG2. This paper presents the principle, performance and benefits of SSDT in detail.

2. Principle and benefits of SSDT

Soft hand-over (SHO) is an important technology in CDMA by which we can attain site diversity reception and smooth RL exchange avoiding intermittent connection between UE and BSs. However, as far as the downlink is concerned, multiple site transmission during SHO increases interference, which limits the downlink capacity.

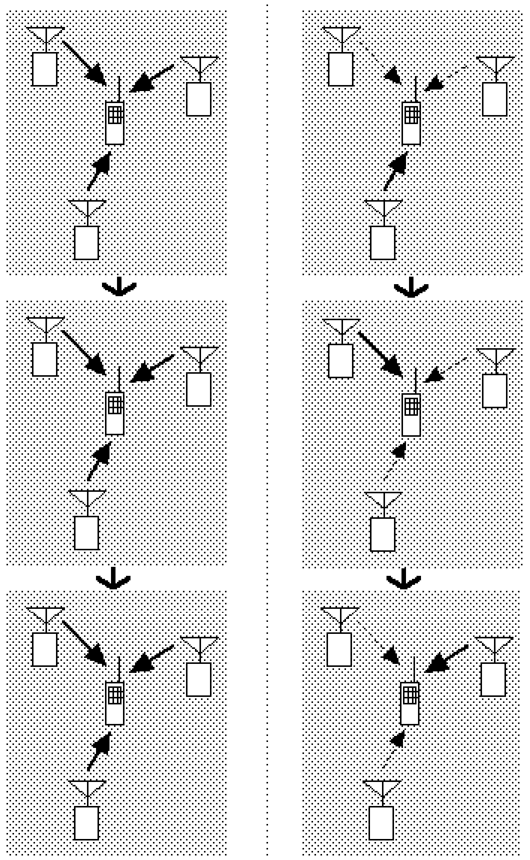
Site Selection Diversity TPC (SSDT) has been proposed to solve this problem in SHO mode. The principle of SSDT is identical to site selection diversity: the best BS (a BS having minimum path loss to UE) is dynamically chosen as a transmitting site and the other BSs switch off their DL transmission as shown in Fig.1. Since one of BSs within an active set serves the connecting UE with an adequate power, the increasing interference can be avoided.

In SSDT operation, site selection is carried out in 1~1/5 frame cycle while tracking minimum path loss BS that frequently alternates due to fast fading. This feature of SSDT discriminates itself from typical Hard Hand Over.

The other benefits of SSDT can be summarized as follows.

(a) The paths resolved by path searcher can be captured at RAKE receiver with higher efficiency than that of conventional TPC. Since only one cell site transmits DL signal in SSDT mode, UE does not need to capture the paths of all active cells. This feature also enhances system capacity.

(b) Power imbalancing among active cells does not become a problem. This is obvious because only one cell site transmits DL signal during SSDT mode.



(a) Conventional TPC

(b) Proposed TPC

Fig.1 Principle of SSDT in comparison to conventional method

3. Operation summary

Each Node-B within an active set is assigned a temporary identification number (ID) and a Node-B with the minimum path loss to the connecting UE is selected as a serving station. We call the serving station as primary station. UE measures common pilot signal strength to detect primary station and then informs the primary station ID to all Node-B's within the same active set. The primary ID is delivered periodically via FBI field of UL DPCCH. A Node-B selected as primary station transmits its dedicated channels with an adequate power and the other Node-Bs switch off their DL transmission of the dedicated channel.

Node-B manages two transmit power levels, i.e. a hidden power of P1 and real power of P2. A Node-B keeping its DL transmission off can know adequate power by referring P1 when this Node-B is chosen as the primary BS. A Node-B updates P1 assuming that it is always primary whether it is really primary or not. Dedicated channels are actually transmitted with power of P2. P1 and P2 are updated in accordance with TPC signal as shown in Table 1. Node-B initially deals with P1 and then P2, further, limits both of which so as to be within the maximum and minimum level.

Table 1 Updating method of P1 and P2

state of BTS	Contents of the TPC signal from UE	P1	P2
non primary	Down	P1 - ΔP [dBm]	Switched off
	Up	P1 + ΔP [dBm]	Switched off
primary	Down	P1 - ΔP [dBm]	= P1 [dBm]
	Up	P1 + ΔP [dBm]	= P1 [dBm]

Figure 2 shows an example of power transition in two Node-B's participating to the same active set. As seen in Fig.1, transmit power of the preceding primary BS is smoothly handed over to that of the subsequent one. This is owing to the management of the hidden power of P1.

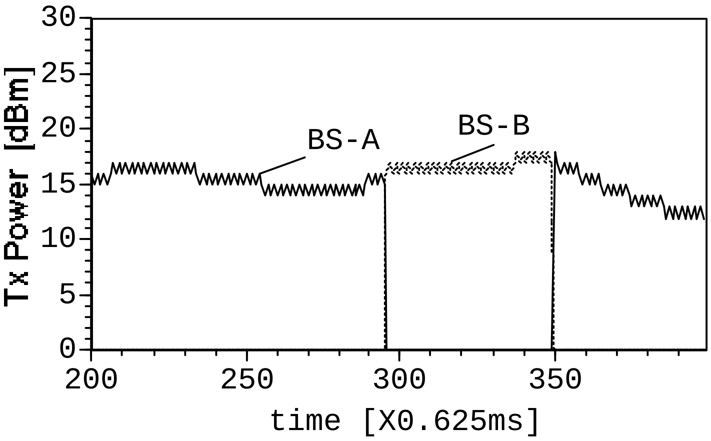


Fig.2 Power transition of two Node-Bs (BS-A and BS-B) in the same SHO situation

The ID assignment is based on the RL number of respective Node-B. Node-B should have a mapping table which describes the relationship between RL number and cell ID for SSDT operation. The mapping table does not need to be updated so frequently, and therefore the maintenance of the table should be carried out by eg. Implementation Specific O&M function. On the other hand, UE has to be explicitly informed the relationship between Node-B and cell ID by RRC messages.

The primary ID should be sent as correctly as possible and therefore code word with a long bit length is used as ID signaling. In WG1's specification, we have defined three lengths of CWs, i.e. Long/Medium/Short. The smaller the length of CW, the shorter is the cycle of site selection. The concrete settings of CWs are shown in Appendix A of the present paper.

Node-B recognizes its state as non-primary only when its UL DPCCH reception level satisfies a quality threshold (Qth). Otherwise the Node-B acts as primary even though the CW delivered by UE does not actually match its own CW. This is in order to prevent no site transmission due to wrong site selection as much less as possible. The quality threshold, Qth should be also informed to each Node-B by O&M function.

4. Performance of SSDT

Computer simulation is carried out according to ETSI and ITU-R guidelines for IMT-2000 RTT evaluation[1][2]. Simulation conditions are summarized in the following Table.

Table2 Simulation parameters and settings

Parameter	Setting
Service type	Circuit switching data, 100% activity
Slot duration	0.625 msec
Frame duration	10 msec
Information bit rate	384 kbps
Spread bandwidth	5 MHz
Carrier frequency	2 GHz
Processing gain	10.7
Cell deployment model	3 sector Vehicular model
Cell radius	1.73km
Shadowing parameters	10dB standard deviation, 20m decorrelation distance, no correlation between BSs
UE reception diversity	Yes / No
Target SINR (Signal power to Interference + Noise power Ratio)	0dB (with UE reception diversity), 3dB (without UE reception diversity)
Maximum number of connecting BSs in an active set	3
T_add, pilot RX power threshold for deciding an active set. (normalized by the maximum one.)	-5dB
Hysterisis margin	2dB
Control range of transmission power	10dBm ~ 30dBm
Transmission power of Common control channel	20dBm
FBI and TPC bit reception error probability BS	5 % in UL link primary BS, a probability greater than 5 % is set in UL non-primary BS according to path loss difference between the primary & non primary BSs.
Path and Fading model	Independent 2 or 6 path Rayleigh fading model. Respective path power ratio [8] is 0.60: 0.40 and 0.506 : 0.252 : 0.126 : 0.063 : 0.028 : 0.025

The capacity is defined as the system load in interference probability of 5%. Interfered user is defined as one cannot maintain a required SINR in average. In order to determine whether a required SINR at a UE can be maintained or not, a distribution of SINR is taken, and then the average value and variance of the distribution are both checked. System load [kbps/MHz/sector] is calculated as follow.

System load [kbps/MHz/sector] =
the number of offered MSs per sector * 384[kbps] / 5[MHz]

The counter TPC to be compared with SSDT is named as conventional TPC in which transmit power of every Node-B in the same active set is controlled equally to maintain a target SINR at a UE.

Before showing the capacity results in the subsequent sections, we would like to show the probability of no site transmission versus Qth, a quality threshold for detecting non-primary state. No site transmission necessarily takes place due to CW reception error at Node-B. Qth is defined as -X[dB] from target SINR in reverse link channel. Fig.3 shows the results for respective length of CW. The no site transmission probability can be lower than the interference probability of 5% irrespective of the length of CW and Qth setting. As shown in Fig.3, the probability can be smaller as Qth becomes larger. The larger the length of CW, the smaller the probability of no site transmission that can be achieved. The relevant range of Qth should be -15dB~0dB according to Fig.3. In the following subsection, we use Qth=-10dB.

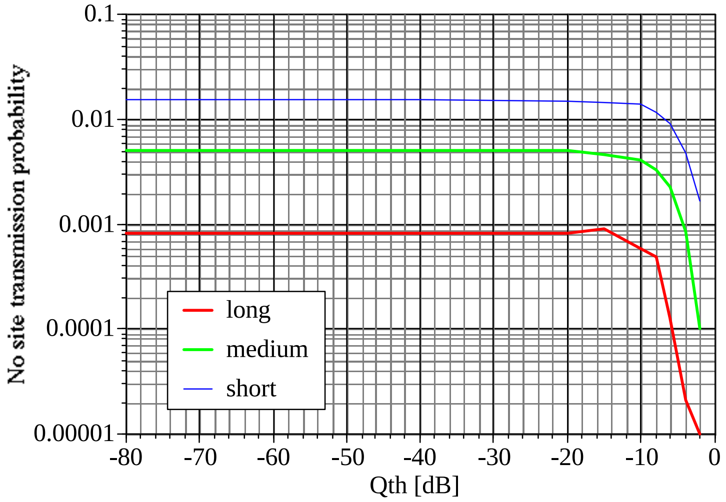


Fig. 3 No site transmission probability vs Qth

4-1. Capacity comparison under infinite RAKE fingers implementation

Initially, capacity gain of SSDT is investigated assuming 2 path Rayleigh fading channel and infinite RAKE fingers implementation. The SSDT gain is defined such that the capacity achieved by SSDT is normalized by that achieved by conventional TPC at respective UE speed. Fig.4 shows the result when we use medium length of CW and 1bit FBI.

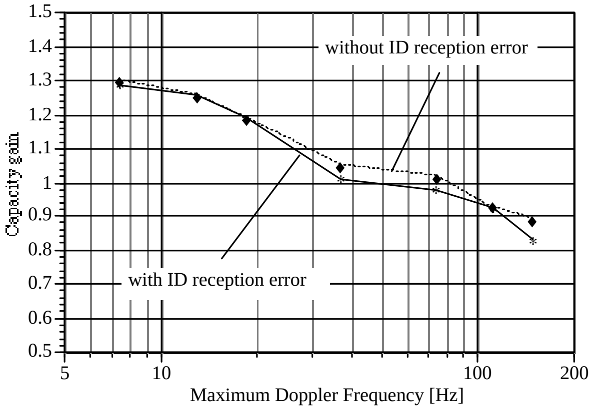


Fig.4 SSDT capacity gain to the conventional TPC. **Medium length of CW and 1bit FBI per slot are assumed.** (However, the cycle of site selection is 1 frame but not 1/2 frame) 2 Path Rayleigh fading channel. Infinite RAKE fingers and UE antenna reception diversity are implemented.

We can achieve about 30% gain in pedestrian speed of UE. As shown in Fig.4, SSDT performance becomes worse as the speed of UE increases. This is because the selection of primary BS cannot be kept correctly as the speed of UE, hence the frequency of path loss fluctuation, increases.

In Fig.3 we can find little difference in performance between the cases with ID reception error and without ID reception error. From this result, the medium length CW has high tolerance to the ID reception error.

4-2. RAKE efficiency improvement given by SSDT introduction and its impact on capacity

Since during SSDT mode only one cell site transmits its DL signal, we have a smaller the number of paths to be combined at path diversity circuit of UE compared to that needed in case of conventional TPC in SHO mode. Under restriction of the number of RAKE fingers, this feature of SSDT leads to the increase of path capturing efficiency and hence the capacity enhancement. Fig.5 shows the capacities of SSDT and conventional TPC in case of 6 path Rayleigh fading channel and 6 RAKE fingers implementation.

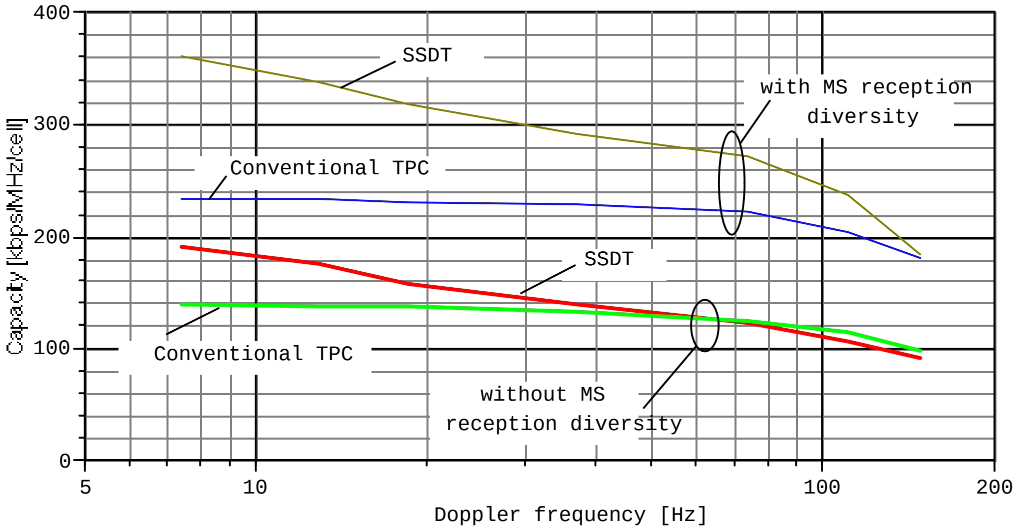


Fig.5 Capacities of SSDT and conventional TPC vs. UE speed. 6 path Rayleigh fading channel. 6 RAKE fingers and the medium length of CW in 1bit FBI are implemented. (However, the cycle of site selection is 1 frame but not 1/2 frame.)

At UE speed of 4 km/h (Doppler frequency of 7Hz), the gain of SSDT was achieved of about 55% with UE antenna reception diversity and 43% without UE antenna reception diversity. More important result is that SSDT can achieve a capacity higher than that of conventional TPC even though UE moves with high speed.

Finally, we would like to compare the performance of SSDT and conventional TPC for several cases of RAKE finger number. Table 3 shows the results. From Table 3, SSDT can achieve a capacity higher than that of Conventional TPC even though the former TPC employs the number of RAKE fingers smaller than that of the latter TPC. This result tells us that it will be possible to reduce the number of RAKE fingers by using SSDT.

Table 3 Capacity comparison between SSDT and conventional TPC in terms of the number of RAKE fingers. Unit is [kbps/MHz/Sector]

	Infinite RAKE fingers	6 RAKE fingers	5 RAKE fingers
Conventional TPC	377	233	217
SSDT	479	361	341

5. Conclusion

This paper presented the principle, performance and benefits of SSDT. The parallel operation of SSDT and Tx antenna diversity is investigated in [3] and this results in a significant capacity improvement. WG1 assumes that such an operation as well as independent operation is possible to be realized. WG1 also assumes that SSDT is a part of UE mandatory feature for R99 [4].

Reference:
[1] ETSI UMTS30.03 Ver.3.1.0, Nov. 1997.
[2] ITU-R, Rec. M.1225, Annex 2, Dec. 1997.
[3] Tdoc R1-(99)911
[4] Ad-hoc 11 Meeting Report, Tdoc R1-(99)255

Appendix A Settings of CWs (TS25.214)

Table A. Settings of ID codes for 1 bit FBI

	ID code		
ID label	**"long"**	**"medium"**	**"short"**
a	000000000000000	0000000(0)	00000
b	111111111111111	1111111(1)	11111
c	000000001111111	0000111(1)	00011
d	111111110000000	1111000(0)	11100
e	000011111111000	0011110(0)	00110
f	111100000000111	1100001(1)	11001
g	001111000011110	0110011(0)	01010
h	110000111100001	1001100(1)	10101

Table B Settings of ID codes for 2 bit FBI

	ID code (Column and Row denote slot position and FBI-bit position.)		
ID label	**“long”**	**“medium”**	**“short”**
a	0000000(0) 0000000(0)	000(0) 000(0)	000 000
b	1111111(1) 1111111(1)	111(1) 111(1)	111 111
c	0000000(0) 1111111(1)	000(0) 111(1)	000 111
d	1111111(1) 0000000(0)	111(1) 000(0)	111 000
e	0000111(1) 1111000(0)	001(1) 110(0)	001 100
f	1111000(0) 0000111(1)	110(0) 001(1)	110 011
g	0011110(0) 0011110(0)	011(0) 011(0)	010 010
h	1100001(1) 1100001(1)	100(1) 100(1)	101 101