Evaluating of Capacities in TD-SCDMA Systems When Employing Smart Antenna and Multi-User Detection Techniques

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Abstract—In TD-SCDMA systems, the Multi-User Detection (MUD) and adaptive smart antenna techniques are adopted in both uplink and downlink. Considering the complexity of cancelling inter-cell interference, the technique of MUD in this paper mainly focuses on the interference suppression of intra-cells. The adaptive smart antenna technique is adopted to suppress the interference from both intra- and inter-cells. Since these two motioned techniques are not adopted in WCDMA and cdma2000 systems, the corresponding capacity and load evaluating models for TD-SCDMA systems must be reinvestigated. In this paper, a theoretical analysis model for CDMA capacity constraints is presented firstly when employing the adaptive smart antenna and MUD techniques in both uplink and downlink, in which the factors of average beamforming interference and intra-cell MUD factors are proposed for evaluating the impacts of adopting these key techniques. Based on the theoretical model, the pole capacity and load estimation models are deduced. The simulation results demonstrate the theoretical analytical models specified for TD-SCDMA systems available. According to our proposals, the TD-SCDMA network planning and optimization can be processed efficiently.

Keywords-TD-SCDMA, Capacity, Smart Antenna, Multi-User Detection

I. INTRODUCTION

There are two radio air access interfaces in 3G CDMA systems: Frequency Division Duplex (FDD) and Time Division Duplex (TDD). TDD-CDMA system is designed for both symmetrical and asymmetrical traffics, and can work in the unpaired frequency band. Actually, it supports the flexible allocation of uplink (UL)/downlink (DL) slots in one carrier, and is adapt to the different system load between uplink and downlink. The dynamic time slots allocation for uplink and downlink make it more spectral efficient than that of symmetrical system. From the viewpoint of standardization, TDD-CDMA mode is based on the harmonization between UTRA (UMTS Terrestrial Radio Access) TDD and TD-SCDMA (Time Division-Synchronous CDMA).

There have been great interests in improving CDMA performances via utilizing the MUD technique, which has the potential to suppress the multi-access interference and to provide significant benefits in the capacity and quality of service. To data, most investigations focused on the link performance gain when employing the MUD. Considering the complexities of implementing in the downlink, MUD is not recommended to be adopted. However, from the network planning and optimization point of view, the capacity gain provided by MUD for the uplink is significant and the complexity of implementing is allowable. Consequently, the impacts on the uplink capacity should be investigated for assisting the network planning and optimizations.

The smart antenna technology, as one of the key technologies of TD-SCDMA, increases the capacity, enlarges the coverage range, and improves the quality of the signal. More benefits include the possible reduction of the delay spread, allowing higher data rates, and a reduction of the transmission power in both uplink and downlink [1]. There are two different kinds of smart antennas: a tracking beam antenna with which the maximum gain point follows the angel of arrival of the user, and a switched beam system where the antenna pattern is fixed.

Many literatures have presented to investigate the UL capacity and system load. The paper [2] shows the capacity of the FDD-CDMA system depends on the absolute background noise floor, and an increase in the background noise power directly leads to a reduction in the converge area. In [3], a new analytical approach to estimate the system capacity for the voice and circuit data services are proposed and evaluated. However, to our best knowledge, there are not many articles to investigate the UL capacity of TD-SCDMA system when employing MUD and adaptive smart antenna techniques.

Most of the published results on smart antennas in the literatures focused on the link level benefits [4][5]. A comparison of smart antennas based on the performance of physical level is presented in [4]. In [5], only the radio transmission techniques and their corresponding link level simulation results are presented. Actually, the capacity evaluation and the load estimation for uplink when employing MUD and smart antenna techniques are very important to the network planning and optimizations, which has great impacts on optimizing the radio resource management (RRM) schemes.

Due to many key techniques and TDD/TDMA utilized in TD-SCDMA systems, there are huge difference in the aspects of capacity evaluation and radio resource management (RRM) schemes from other FDD-CDMA systems, such as WCDMA and cdma2000. The capacity models for uplink and downlink in TD-SCDMA systems should be investigated further, which is the fundament for making RRM schemes work efficiently. The capacity models considering smart antenna and MUD techniques specialized for TD-SCDMA should be researched.

In this paper the smart antenna model is introduced in section II. And the UL pole capacity of TD-SCDMA based on MUD technology when employing the smart antenna technique...
is presented in section III. The system load and capacity related to the value of background noise rise is evaluated simultaneously. The downlink capacity and load model is discussed in section IV. The simulation results are shown in section V, followed by the conclusions.

II. SMART ANTENNA MODEL

The uplink capacity constraint has been analyzed in [6] while using the omni antenna for the speech voice service. When employing the smart antenna techniques, both uplink and downlink capacity constraints for multi-services should be deduced further.

The most practical antenna arrays used in the smart antenna system are the circular and linear arrays. The circular array is suitable for omni-direction cell design while the linear one is suitable for the sectorial (180°or 120°) cell design. Our research work considers the adoption of a uniform circular antenna array containing $M$ elements, where the first (reference) antenna element is located at the position of $(R, 0)$, where $R$ denotes the radius of the circular array, and the $i^{th}$ element is located at the location of $(R^*\cos 2\pi i/M, R^*\sin 2\pi i/M)$. The element spacing is equal to the typical value $0.5\lambda$, where $\lambda$ is the propagation wave length.

In a CDMA system, each user transmits in the same frequency band simultaneously. The incident signal will be a sum of the signals from the various transmitters present plus the additional background noise. Let $N$ denote the number of transmitters present. To account for multipath, let $L_n$ denote the number of multipath signal components of the $n^{th}$ transmitter. The received signal vector can be expressed as:

$$x(t) = \sum_{i=1}^{N} \sum_{j=1}^{L_n} a(\theta_{n,j}) \alpha_{n,j} e^{j\phi_{n,j}} d_n(t - \tau_{n,j}) + n(t)$$

(1)

where $\theta_{n,j}$, $\tau_{n,j}$, $\alpha_{n,j}$, and $\phi_{n,j}$ are the angle of arrival (AOA), delay time, path attenuation factor and phase of the $i^{th}$ path of the $n^{th}$ transmitter respectively. The vector $a(\theta)$ is known as the antenna response vector. $d_n(t)$ is the transmitted signal for the $n^{th}$ user. $n(t)$ represents any additional additive interference and noise presenting in the channel.

The beam pattern for the circular array can be simplified as [7]:

$$G(\alpha, \phi) = 10 \log \left( \frac{2\pi}{\lambda} \right) \left[ \sum_{m=1}^{M} \exp \left( j \frac{2\pi}{\lambda} \left[ M \alpha - m \left( \cos \left( \phi - \frac{m-1}{M}2\pi \right) \right) \right] \right)$$

(2)

where $\phi_i$ ($\phi_i \in [0^\circ, 360^\circ]$) is the direction of interfering UEs, and $\alpha$ is the direction of desired user equipment (UE); $M$ is the number of elements in antenna array. $\lambda$ is the wavelength. The antenna gain pattern is illustrated in Fig.1, which is assumed that $\alpha$ is 0 degree. The number of elements for the antenna array is assumed to be 4, 8 and 16 respectively.

III. UPLINK CAPACITY MODEL

For each class of services, the BER is assumed to be fixed at the maximum allowed level by the QoS requirement, which leads to a target $E_b/N_0$ for each class of services. This target is defined as $\Gamma_i$ for service $i$:

$$\Gamma_i = \left( \frac{E_b}{N_0} \right) = \frac{W_S}{v_i R} \left( \frac{C}{I} \right) = \frac{W_S}{v_i R} \left[ P_m G(\alpha, \phi_{mi}) \right]$$

(3)

where $P_{mi}$ is the received power at $m^{th}$ base station (BS, or called Node B) for the $i^{th}$ UE (excluding the received antenna gain); $\phi_{mi}$ is the actual angle from the UE $i$ to the BS $m$, $\phi_{mj}$ is the actual angle from the UE $j$ to the BS $m$, and $\phi_{kj}$ is the actual angle from the UE $j$ of BS $k$ to the BS $m$. $\alpha$ is the ideal direction of desired UE to the serving BS. If $\alpha$ is equal to $\phi_{mi}$, it means that there is an ideal AoA estimation and the main beam points at the desired UE. $W$ is the chip rate; $S_i$ is the ratio of occupied slots for MS $i$ in a frame. For example, for 12.2kbps speech service, it is 1/15 in UTRA TDD, while it is about 1/7.4074 in TD-SCDMA because there is near 7.4074 traffic slots in each sub-frame. $v_i$ is the speech active factor; $\beta$ is the MUD (Multi-User Detection) factor, and only the intra-cell interference suppression is considered; $R_i$ is the bit rate of UE $i$; $N$ is the average number of UEs serving in one BS. $P_{mi}$ is the thermal background noise.

In order to deduce the load and capacity for uplink easily, it is assumed that $C/I_D$ is the target $C/I$ for UE $i$, and the total average satisfied UE number is $N$. According to equation (3), the received power of UE $i$ in BS $m$ can be written as:

$$P_{mi} = \frac{C}{i \left( 1 - \beta \sum_{j=1}^{N} G(\alpha, \phi_{mi}) \right) + f \sum_{j=1}^{N} G(\alpha, \phi_{mj})}$$

(4)

where $f$ is defined as the ratio of other cell to own cell interference (not include the influence of antenna gain) in uplink. From the statistical view, the average beamforming interference factor can be stated as $\tilde{G}$:

$$\tilde{G} = \frac{\sum_{j=1}^{N} G(\alpha, \phi_{mj})}{N}$$

(5)

Consequently, the received power can be expressed as:
\[ P_{\alpha} = \frac{C}{T} P_{\gamma} \]

\[ G(\alpha, \phi) - \frac{C}{T} \left[ 1 + \beta \right] \left(N - 1 \right) + f \cdot N \]

We can define the background noise rise (r) as follows:

\[ r = \frac{I_{\text{total}}}{P_{\gamma}} = \frac{N(1 + f)P_{\alpha} - 1 = N(1 + f)}{P_{\gamma} \left[ 1 + \beta \right] \left(N - 1 \right) + f \cdot N} + 1 \]

\[ G(\alpha, \phi) = \frac{C}{T} \left[ 1 + \beta \right] \left(N - 1 \right) + f \cdot N \]

where \( I_{\text{total}} \) is the total interference in BS. According to equation (7), the uplink average satisfied UE number can be expressed as:

\[ N = (r - 1) \left( \frac{C}{T} \right) \left[ 1 + \beta \right] \left(N - 1 \right) + f \cdot (r - 1)G \]

According to equation (8), the pole capacity is:

\[ N_{\text{max}} = \lim_{r \to \infty} \frac{G_{\text{max}} + G(1 - \beta) \frac{C}{T}}{1 + \beta \left(N - 1 \right) + f \cdot (r - 1)G} \]

\[ G_{\text{max}} + G(1 - \beta) \frac{C}{T} \]

The load for uplink can be easily derived as:

\[ \eta = \frac{N}{N_{\text{max}}} = \frac{1 + \beta \left(N - 1 \right) + f \cdot (r - 1)G}{1 + \beta \left(N - 1 \right) + f \cdot (r - 1)G} \]

If considering the multi-services, the capacity \( N_i \) for service \( i \) can be expressed as:

\[ N_i = (r - 1) \left( \frac{C}{T} \right) \left[ 1 + \beta \right] \left(N - 1 \right) + f \cdot (r - 1)G \]

The uplink load factor, related to the parameters: \( f, \beta, G \) and \( G \), can be written as:

\[ \eta = (1 + \beta \sum_{i=1}^{N} \left[ 1 \right] - G_{\text{max}} / (G \cdot (C / I)_i) \} \]

In our work, it is assumed that there is the ideal AoA estimation, and the main beam points at the desired UE adaptively. Additionally, the number of elements in the smart antenna array is assumed to be 8. Hence according to equation (2), the maximum value of \( G(\alpha, \phi) \) is set 9.1dB. The target of \( C/I \) is assumed to -2.5dB. In order to only investigate the influences from the interference, it is assumed that the radio resource is unlimited.

The pole capacity as a function of MUD factor for various \( f \) (i.e. the ratio of other cell to own cell interference) values is shown in Tab.1, where \( \beta \) is assumed to 0dB.

<table>
<thead>
<tr>
<th>( \beta )</th>
<th>0.4</th>
<th>0.6</th>
<th>0.8</th>
<th>0.9</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.4</td>
<td>11.04</td>
<td>12.71</td>
<td>15.05</td>
<td>18.57</td>
</tr>
<tr>
<td>0.6</td>
<td>9.66</td>
<td>10.90</td>
<td>12.55</td>
<td>14.85</td>
</tr>
<tr>
<td>0.75</td>
<td>8.83</td>
<td>9.84</td>
<td>11.15</td>
<td>12.92</td>
</tr>
<tr>
<td>1.0</td>
<td>7.73</td>
<td>8.47</td>
<td>9.41</td>
<td>10.61</td>
</tr>
</tbody>
</table>

Tab.1 suggests that MUD factor \( \beta \) can suppress the interference from the own cell and improve the uplink capacity. If there is a big interference from the adjacent cells, i.e. the value of the parameter \( f \) is high, the capacity will decrease.

According to equation (9), if the value of \( G \) is low, then the capacity can improve, which is shown in Tab. 2 when \( G \) is assumed to -6dB.

<table>
<thead>
<tr>
<th>( \beta )</th>
<th>0.4</th>
<th>0.6</th>
<th>0.8</th>
<th>0.9</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.4</td>
<td>41.82</td>
<td>48.62</td>
<td>58.14</td>
<td>72.43</td>
</tr>
<tr>
<td>0.6</td>
<td>36.59</td>
<td>41.67</td>
<td>48.45</td>
<td>57.94</td>
</tr>
<tr>
<td>0.75</td>
<td>33.45</td>
<td>37.64</td>
<td>43.07</td>
<td>50.39</td>
</tr>
<tr>
<td>1.0</td>
<td>29.27</td>
<td>32.41</td>
<td>36.34</td>
<td>41.39</td>
</tr>
</tbody>
</table>

Compared the pole capacity in Tab. 1, the pole capacity has a huge gain when \( G \) is little. In order to maximize the capacity, the advanced radio resource management schemes should be presented to decrease \( G \). The pole capacity per BS as a function of the background noise rise value under the various \( f \) values is shown in Tab. 3, where \( \beta \) is set to 0.78.

<table>
<thead>
<tr>
<th>( \beta )</th>
<th>0.4</th>
<th>0.6</th>
<th>0.8</th>
<th>0.9</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.4</td>
<td>2.43</td>
<td>4.87</td>
<td>13.47</td>
<td>20.54</td>
</tr>
<tr>
<td>0.6</td>
<td>2.10</td>
<td>4.13</td>
<td>10.82</td>
<td>15.82</td>
</tr>
<tr>
<td>0.75</td>
<td>1.9</td>
<td>3.70</td>
<td>9.42</td>
<td>13.49</td>
</tr>
<tr>
<td>1.0</td>
<td>1.64</td>
<td>3.16</td>
<td>7.76</td>
<td>10.83</td>
</tr>
</tbody>
</table>

The theoretical analysis results in Tab. 3 show that the parameter \( r \) has a great impact on the capacity. Similar the omni-antenna system, the BNR can be used to evaluate the uplink load and can be used as the admission control threshold when the new or handover UE access the network. When the value of parameter \( r \) is more than 15dB, the capacity is approaching the pole.

IV. DOWNLINK CAPACITY MODEL

Above descriptions suggest that the basic resources in UL are the total received power. In DL, UE is located at various positions; as a consequence, BNR in DL changes in a very wide value. Therefore the factor of BNR is useless for DL. For DL dimensioning, it is important to estimate the total amount of required BS transmitting power, which should be based on the average transmission power for the user, not the maximum
transmitting transmission power for the cell edge shown by the link budget. There is no difference between FDD and TDD mode in DL load and capacity analysis. However, if the adaptive smart antenna technique is adopted, the available model should be presented for TDD-CDMA systems.

Suppose that the UE are currently in the cell having “exactly the minimum average $E_b/N_0$” required for every service, i.e. perfect power control make the system capacity largest. The link quality for the downlink $i^{th}$ MS in the cell $m$ can be expressed as:

$$\left(\frac{E_b}{N_0}\right)_i = \frac{WS_i P_{max} \frac{G}{L_m i} R_{v_i}}{(1-\alpha)P_{txTotal} + \frac{G}{L_m i} R_{v_i} + \frac{P_{txTotal} L_m i}{L_m i} + P_{si}}$$  \hspace{1cm} (13)

where $P_i$ is the transmission power at $m^{th}$ Node B for the $i^{th}$ UE; $\alpha$ is the non-orthogonality factor, when $\alpha$ is set to 1, it means the full orthogonal; $L_m i$ is the path loss from the serving Node B to UE $i$, while $L_m i$ is the path loss from the desired Node B $m$ to UE $i$. $K$ is the number of Node Bs, and $P_{txTotal}$ is the total transmission power of $i^{th}$ Node B. Solving (13) for $P_i$ is:

$$P_i = \left(\frac{E_b}{N_0}\right)_i \cdot \frac{R_{v_i}}{G_{max} WS_i} \cdot \left[ (1-\alpha) G P_{txTotal} + \frac{G}{L_m i} R_{v_i} + \frac{P_{txTotal} L_m i}{L_m i} \right]$$ \hspace{1cm} (14)

The number of UEs in $m^{th}$ BS is $N_{ms}$ than PtxTotal,m is:

$$P_{txTotal} = \sum_{i=1}^{N_{ms}} \left(\frac{E_b}{N_0}\right)_i \cdot \frac{R_{v_i}}{G_{max} WS_i} \cdot \left[ (1-\alpha) G P_{txTotal} + \frac{G}{L_m i} R_{v_i} + \frac{P_{txTotal} L_m i}{L_m i} \right]$$ \hspace{1cm} (15)

In order to estimate the downlink pole capacity, the total transmission power and the number of UEs in every BS should be assumed to be the same:

$$P_{txTotal} = \sum_{i=1}^{N_{ms}} \left(\frac{E_b}{N_0}\right)_i \cdot \frac{R_{v_i}}{G_{max} WS_i} \cdot \left[ (1-\alpha) G P_{txTotal} + \frac{G}{L_m i} R_{v_i} + \frac{P_{txTotal} L_m i}{L_m i} \right]$$ \hspace{1cm} (16)

Thus it is convenient to define downlink loading:

$$\eta_{DL} = \sum_{i=1}^{N_{ms}} \left[ \frac{\left(\frac{E_b}{N_0}\right)_i \cdot \frac{R_{v_i}}{G_{max} WS_i} \left[ (1-\alpha) G P_{txTotal} + \frac{G}{L_m i} R_{v_i} + \frac{P_{txTotal} L_m i}{L_m i} \right]}{(1-\alpha) G P_{txTotal} + \frac{G}{L_m i} R_{v_i} + \frac{P_{txTotal} L_m i}{L_m i}} \right]$$ \hspace{1cm} (17)

When the parameter $\eta_{DL}$ approaches to 1, the downlink capacity obtains its maximum value, i.e. pole capacity. Similar with the parameter $f$ in uplink, the other-to-own-cell interference ratio in downlink can be defined as the average value:

$$f_{DL} = \frac{1}{N_{ms}} \sum_{i=1}^{N_{ms}} \frac{L_m i}{L_m i}$$ \hspace{1cm} (18)

The average maximum number of successful serving UEs in each Node B is:

$$N_{max} = \frac{G_{max} WS}{\left(1 + G f_{DL} - \alpha\right) E_b \frac{R_v}{N_0 R_v}}$$ \hspace{1cm} (19)

The DL load can be expressed as:

$$\eta_{DL} = \frac{(1-\alpha) + G f_{DL} \sum_{i=1}^{N_{ms}} \left(\frac{E_b}{N_0}\right)_i R_{v_i} WS_i}{G_{max}}$$ \hspace{1cm} (20)

According to the equation (19), the pole capacity as a function of non-orthogonality factor $\alpha$ for various $f$ values is shown in Tab. 4, where $\tilde{G}$ is assumed to 0dB.

<table>
<thead>
<tr>
<th>$\beta$</th>
<th>0</th>
<th>0.2</th>
<th>0.4</th>
<th>0.6</th>
<th>0.8</th>
<th>0.9</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\eta_{DL}$</td>
<td>0.4</td>
<td>8.04</td>
<td>9.04</td>
<td>10.34</td>
<td>12.04</td>
<td>14.48</td>
</tr>
<tr>
<td>0.6</td>
<td>6.58</td>
<td>7.24</td>
<td>8.04</td>
<td>9.05</td>
<td>10.35</td>
<td>11.14</td>
</tr>
<tr>
<td>0.75</td>
<td>5.79</td>
<td>6.29</td>
<td>6.89</td>
<td>7.62</td>
<td>8.52</td>
<td>9.05</td>
</tr>
<tr>
<td>1.0</td>
<td>4.83</td>
<td>5.17</td>
<td>5.57</td>
<td>6.03</td>
<td>6.58</td>
<td>6.90</td>
</tr>
</tbody>
</table>

If $\tilde{G}$ is assumed to -6dB, the pole capacity improves, which is shown in Tab. 5.

<table>
<thead>
<tr>
<th>$\beta$</th>
<th>0</th>
<th>0.2</th>
<th>0.4</th>
<th>0.6</th>
<th>0.8</th>
<th>0.9</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\eta_{DL}$</td>
<td>0.4</td>
<td>13.13</td>
<td>16.05</td>
<td>20.04</td>
<td>28.88</td>
<td>48.11</td>
</tr>
<tr>
<td>0.6</td>
<td>12.56</td>
<td>15.20</td>
<td>19.25</td>
<td>26.25</td>
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<td>57.65</td>
</tr>
<tr>
<td>0.75</td>
<td>12.16</td>
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<td>16.98</td>
<td>22.20</td>
<td>32.04</td>
<td>41.16</td>
</tr>
</tbody>
</table>

Comparison with the analytical results between Tab. 4 and Tab. 5, it suggests that minimizing the parameter $\tilde{G}$ can improve the capacity.

V. SYSTEM LEVEL SIMULATOR

An advance static TDD system level simulator is used to evaluate the system performance according to[11]. The UL and DL are simulated simultaneously. A simulation loop consists of several simulation steps (snapshots) with the purpose of covering a large amount of all possible UEs placement in the network. In each simulation step, a single placement (amongst all the possible configurations) of the UEs in the network is considered.

Fig. 2 shows the relation of UL capacity and the BNR value. Simulation results and theoretical analysis demonstrate that BNR will approach to infinity when the system has reached its pole capacity. According to the simulation result, we can know that when BNR value is less than 6 dB, the average number of UE per cell will increase steadily. However, BNR will increase dramatically when the capacity is approaching the pole, which is same to the theoretical analysis.

At the same time, perfect power control scheme can’t make all access UE reach the $C/I$ target and most UEs will transmit the maximum allowable power. Consequently, the real network will not approach to infinity, i.e., the BNR value in the real network will not be infinity and will be less than a threshold, such as 60dB in Fig.3. Since the parameters $f$ and $\tilde{G}$ vary subject to a certain probability distribution, the simulation
result will cover with some curves of the determined values of $f$ and $\hat{G}$.

Fig. 3 shows the distribution of parameter $\hat{G}$. When the number of accessed UE per cell per slot is big, the mean value of $\hat{G}$ approaches 1.0 dBi, and the diversity of $\hat{G}$ is also close to 1.0 dBi. However, when the load is not high, the mean value and the diversity value of $\hat{G}$ become high.

Fig. 4 shows the mean value of parameter $f$ in uplink. The value of $f$ will change with the accessed UE number. When the accessed UE number is not big, the interference is not uniform and the mean and diversity values of the parameter $f$ are big. However, with the accessed UE increase, the mean value of the parameter $f$ approaches to 0.6 and the diversity of it is close to 0.

Similar to uplink, the downlink capacity is influenced by the parameters of $\hat{G}$ and $f$. The distribution of $\hat{G}$ is shown in Fig. 5. It can be seen that there is no much difference for the distribution of $\hat{G}$ between uplink and downlink.

VI. CONCLUSIONS

Our work shows that the background noise rise can still be used to estimate the capacity and load according to our proposed analytical model in TD-SCDMA systems. We compare the theoretical analytical and the simulation results, and find a very good match between them. Additionally, the parameters of $\hat{G}$ and $f$ have great impacts on the capacity, and the simulation results show that the mean and diversity values of the parameter $\hat{G}$ approach 1.0dBi and 0dBi when there is enough accessed UEs. If MUD can suppress the inter-cell interference, the capacity model for TD-SCDMA systems should be re-investigated.