and implementation, lower deployment cost, as well as channel reciprocity between uplink and downlink, and so forth [2]. Two TDD-CDMA standards have been accepted by 3GPP [3] (3rd Generation Partnership Project): TD-CDMA, and LCR (Low Chip Rate) TDD or TD-SCDMA.

Many papers have been focused on load estimation [4] and admission control [5] research, however most of them are concerned with FDD (Frequency Division Duplex) system like WCDMA. This paper analyzes the characteristics of TDD-CDMA system load firstly and deduces the expressions of slot load and beam load as well as load increment estimation formula theoretically. A novel uplink directional-load-based CAC is presented for TDD-CDMA system with smart antennas. The rest of contents are organized as follows: Chapter 2 describes load analysis of TDD-CDMA system, and then a novel CAC criterion based on directional interference or directional system load is presented and some simulation are given in Chapter 3 and Chapter 4.

## 2. TDD CDMA SYSTEM LOAD

There is a close relationship between system load control and call admission control schemes, both of which play important roles in RRM. Therefore, a load-based CAC scheme seems more reasonable by considering the trade-off between system capacity and stability. This chapter investigates TDD-CDMA system load in a slot and in a beam theoretically firstly and then presents a directional-load-based CAC algorithm based on the analysis introduced.
Compared to FDD system, TDD system load with smart antennas has lots of characteristics:

1. There is some particular interference such as interference between adjacent Node-Bs and interference between UEs in different cells in TDD-CDMA system if there is no slot synchronization and identical setting for switching points. These kinds of interferences are not considered in our investigation;
2. All active users in TDD-CDMA systems are assigned into different slots so that user number and user distribution between slots are obviously different. So, the interference based load, as well as other RRM schemes, should be calculated and estimated in each slot. The load in a slot is called as slot load;
3. Due to the decrease of user number in a slot, the inter-to-intra-cell interference ratio in TDD-CDMA system is no more a uniform distribution as that in WCDMA system. In the following system load calculation, we will see that the ratio is a significant factor in load expressions.
4. The channel reciprocity in TDD mode system is beneficial to the realization of smart antenna technology. In TDD-CDMA system with SA, the focus of load analysis should be concentrated further on the load in a certain beam, which is named beam load.

There are some assumptions in following load calculation: perfect frame synchronization, fixed and identical switching point in all the cells. At first, the ratio of bit energy to noise for uplink in TDD-CDMA system employing Multiple User Detection (MUD) technique should be expressed as:

$$\left(\frac{E_b}{N_0}\right)_j = G_{pj}\left(\frac{C}{I}\right)_j = \frac{\lfloor (W \cdot TS_j)/R_j \rfloor \cdot P_{jr}}{(1-\beta)(I_{own} - P_{jr}) + I_{oth} + P_N} \tag{1}$$

where $G_{pj}$ = $(W*TS_j)/(v*R_j)$: processing gain of UEj; $W$: chip rate; $R_j$: data rate of UEj; $TS_j$:

because slot load goes to 1 when $P_{Bt}$ trends to infinity.

$$\eta_{DL}^{T} = \sum_{j=1}^{Nc} \frac{(1-\alpha+i_j)}{k_j+(1-\alpha)} \tag{10}$$

The downlink slot load added by UEj can be calculated by:

$$DL_j^T = \frac{(1-\alpha_j+i_j)}{k_j+(1-\alpha_j)} \tag{11}$$

It is obvious that the uplink and downlink load expressions and estimation expressions are identical. Then we extend the results to TDD-CDMA system with smart antennas. From the beginning, antenna gain factor is defined to describe a users' antenna gain in a beam. Here it is indicated by the angle deviation between the direction of UEi and the beam:

$$G(\theta_i,\theta_{bj}) = G(\theta_i-\theta_{bj}) \tag{12}$$

where $\theta_i$ stands for the angle of UEi; $\theta_{bj}$ is the angle of maximum antenna gain direction of beam j; $G(\theta_i,\theta_{bj})$ means antenna gain of UEi in the observed beam as Fig.1.

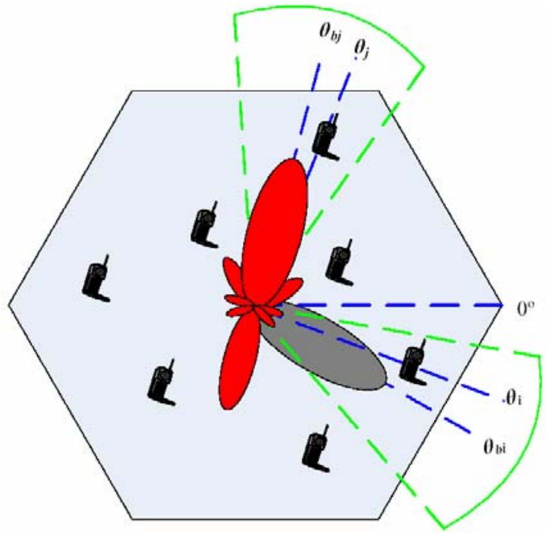


Fig.1: Illustration of $\theta_i$ and $\theta_{bj}$

If fixed-switched-beam smart antenna is utilized, there is another expression approach by beam coupling matrix can be used to reflect the value of antenna gain [4]:

$$\begin{pmatrix} P_t(\phi_{b1}) \\ P_t(\phi_{b2}) \\ \vdots \\ P_t(\phi_{bN}) \end{pmatrix} = \begin{pmatrix} W(\phi_{b1},\phi_{b1}) & W(\phi_{b1},\phi_{b2}) & \cdots & W(\phi_{b1},\phi_{bN}) \\ W(\phi_{b2},\phi_{b1}) & W(\phi_{b2},\phi_{b2}) & \cdots & W(\phi_{b2},\phi_{bN}) \\ \vdots & \vdots & \ddots & \vdots \\ W(\phi_{bN},\phi_{b1}) & W(\phi_{bN},\phi_{b2}) & \cdots & W(\phi_{bN},\phi_{bN}) \end{pmatrix} \cdot \begin{pmatrix} \overline{P}_{b1t} \\ \overline{P}_{b2t} \\ \vdots \\ \overline{P}_{bNt} \end{pmatrix}$$
$$\begin{pmatrix} P_r(\phi_{b1}) \\ P_r(\phi_{b2}) \\ \vdots \\ P_r(\phi_{bN}) \end{pmatrix} = \begin{pmatrix} W(\phi_{b1},\phi_{b1}) & W(\phi_{b1},\phi_{b2}) & \cdots & W(\phi_{b1},\phi_{bN}) \\ W(\phi_{b2},\phi_{b1}) & W(\phi_{b2},\phi_{b2}) & \cdots & W(\phi_{b2},\phi_{bN}) \\ \vdots & \vdots & \ddots & \vdots \\ W(\phi_{bN},\phi_{b1}) & W(\phi_{bN},\phi_{b2}) & \cdots & W(\phi_{bN},\phi_{bN}) \end{pmatrix} \cdot \begin{pmatrix} \overline{P}_{b1r} \\ \overline{P}_{b2r} \\ \vdots \\ \overline{P}_{bNr} \end{pmatrix} \tag{13}$$

where $P_t(\phi_{bi})$ and $P_r(\phi_{bi})$ are transmitted and received power of beam i respectively; $\overline{P}_{bit}$ and $\overline{P}_{bir}$ are their average power. The beam coupling matrix $W(\phi_{b2},\phi_{b1})$ is mapped to antenna gain.

The downlink beam load rise by user j is calculated by:

$$DL_j^B = \frac{\upsilon \cdot (1-\alpha+i_j)}{k_j+\upsilon \cdot (1-\alpha)} \sum_{n=1}^{N} \frac{\overline{P}_{bnt} \cdot W(\phi_j, \phi_{bn})}{\overline{P}_{bmt} \cdot W(\phi_j, \phi_{bm})} \tag{23}$$

## 3. DIRECTIONAL LOAD BASED CAC SCHEME

In this chapter, we extend the predictive interference-based CAC schemes [6] derived by omni directional antenna systems to smart antenna systems. The improved CAC scheme is called directional load based because the received power increment should be estimated for each individual beam based on load rise produced by the new call. However, the scheme is only used for uplink.

Let's begin with uplink BNR of all beams in the serving cell in the case that the new user is admitted into the system [7]:

$$BNR_{new}^{Bn} = BNR_{old}^{Bn} + \Delta BNR^{Bn} = \frac{I_{total}^{Bn} + \Delta I^{Bn}}{P_N} < BNR_{TH}^{Bn} \qquad \forall n \in (1, \quad 2, \quad \cdots, \quad N) \tag{24}$$

where $\Delta I^{Bn}$ is the interference increment for beam n, which is caused by admission for new user. It is expressed with beam load by means of derivative or integral method as:

$$\begin{cases} \Delta I^{Bn} = \dfrac{I_{total}^{Bn}}{1-\eta_{UL}^{Bn} - UL_j} \Delta L^{Bn} & for \quad n = m \\ \Delta I^{Bn} = \dfrac{I_{total}^{Bn} \cdot \Delta L^{Bm}}{1-\eta_{UL}^{Bn} - UL_j \dfrac{W(\phi_j, \phi_{Bn})}{W(\phi_j, \phi_{Bm})}} \dfrac{W(\phi_j, \phi_{Bn})}{W(\phi_j, \phi_{Bm})} & for \quad n \neq m \end{cases} \tag{25}$$

where the beam load and the load rise from the new call can be get from the formula (18)(19); n is the beam index, and m, generally called main beam, is the beam index in which the observed user j is located.

When an idle user wants to get served, it will send an access request to base station where the CAC scheme is implemented to search the slots satisfying both uplink and down-link QoS requirements for all active users in the slot as well as the new user. Then the radio resource in the selected slots will be allocated to the new user according to a certain rule such as least interference.

On the other hand, common downlink call admission criterion used in TDD-CDMA system with smart antennas is based on directional transmission power as indicated by (26). So it's not necessary to make admission decision based on beam load and load rise.

$$P_{new}^{Bn} = P_{old}^{Bn} + \Delta P^{Bn} < P_{TH}^{Bn} \qquad \forall n \in [1, \quad 2, \quad \cdots, \quad N] \tag{26}$$

## 4. SYSTEM LEVEL SIMULATION

A dynamic system level simulator is established using OPNET to evaluate performance gain of the improved CAC algorithm. The simulation assumptions are listed as follows:

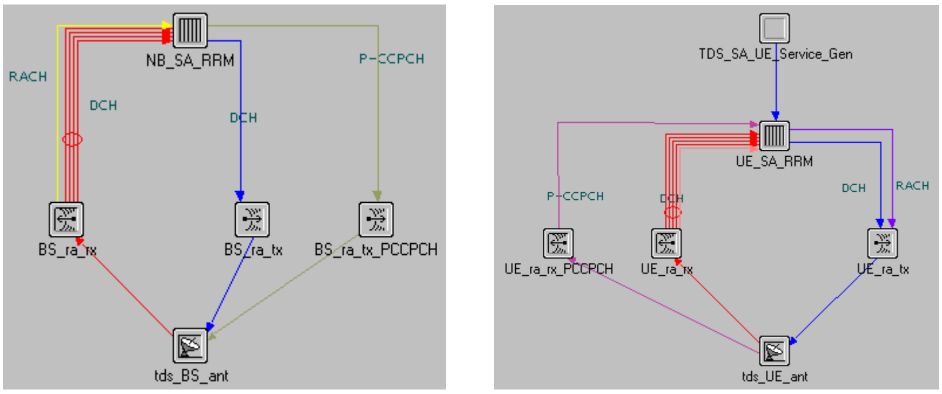


Fig.3: illustration of node structure (The left: base station, the right: mobile station)

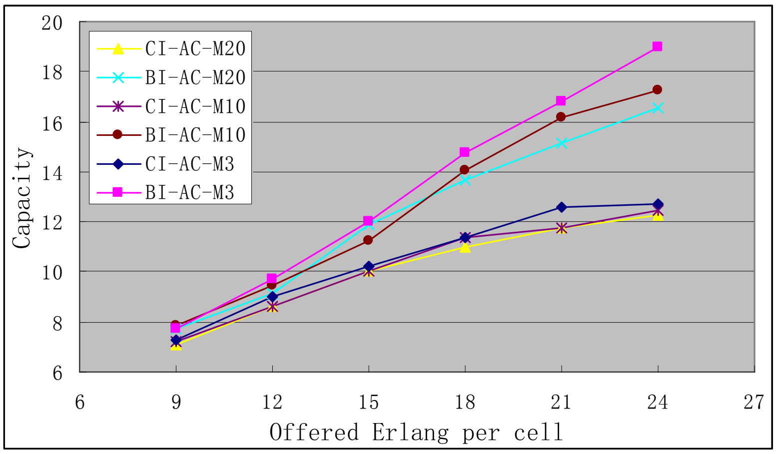


Fig.4 simulation result - system capacity

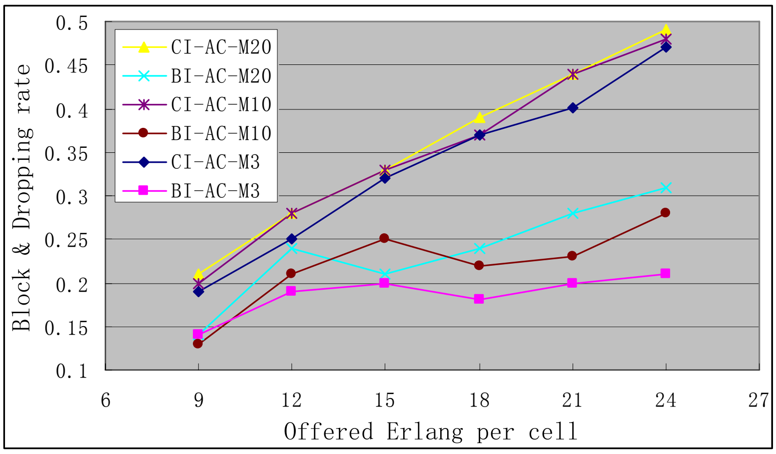


Fig.5 drop rate with user number increasing

The simulation results are shown as from Fig.4 to Fig.5. The meaning of the abbreviations in the above three figures is that CI-AC: the cell-interference-based admission control scheme; and BI-AC: the beam-interference-based one; MS stands for user motion speed whose unit as kilometer per second. It is clear from the Fig.4 that the beam-interference-based AC scheme is able to admit more calls than that of cell-based AC scheme without reference to user mobility. Fig.5 indicates a comparison of these two schemes on dropping and blocking rate. In this picture, the cell-interference-based AC scheme will block and drop more and more users with the system load increasing, but the blocking and dropping rate of the beam-interference-based