Alternative Scheme to Improve UMTS Cell Coverage and Downlink Transmit Power Distribution for Fast Moving Train Users

Loh Wai Loon and Chris Todd

University College London

Abstract: This paper provides an investigation into the UMTS cell performance of fast moving train users. A number of dimensions are customised to accommodate the needs of providing UMTS services in railway conditions. Link budget estimation in both uplink and downlink directions are implemented to compare the performance of the conventional and customised schemes in terms of the cell coverage limitation and downlink transmit power distribution in the system.

1. Introduction

In WCDMA radio network the coverage of a cell has an inverse relationship with user capacity of the cell. In the uplink, each active user appears as an interference to another user whereas in the downlink, each base station contributes a certain amount of interference to the network. As a result, noise floor of affected cells increased and hence degraded the BER as well as decreased the capacity of the cell. Given that the UEs have a maximum allowable transmit power, an increase in the required received power will result in a decrease in the maximum distance a mobile can be from the base station, thereby reducing coverage. Optimum transmit power distribution as a function of cell coverage and capacity is essential to strike a balance between the two limitations; coverage and capacity.

The well known link quality equation in WCDMA radio network dimensioning [1]:

$$p_i = \frac{P_N \dfrac{r_i R_i}{W} L_i}{1 - h_{UL}}, \tag{1}$$

with

$$h_{UL} = \sum_i \frac{r_i R_i v_i}{W}(1 + f_{UL}) \tag{2}$$

and

$$p_i = \frac{P_N \dfrac{r_i R_i}{W} L_i}{1 - h_{DL}}, \tag{3}$$

with

$$h_{DL} = \sum_i \frac{r_i R_i v_i}{W}(1 - a_i + f_{DL}) \tag{4}$$

Where p_i, required transmission power; i, number of users; P_N, noise power; r_i, required power density over the interference power density after dispreading; R_i, bit rate; L_i, path loss; W, chip rate; h, loading factor; v_i, channel activity factor; f, other-to-own-cell received interference; a, orthogonality. Equation (2) and (4) are used in analyzing the cell coverage limitation performance and Equation (1) and (3) are used in analysing the transmit power distribution in the system.

2. System Model

Figure 1 depicts the proposed network configuration to provide broadband internet access to train users. In the Uu interface, instead of having each MS to communicate to the serving cell individually, transceivers are connected to UEs to provide higher antenna gain. The gain is dependent on the transceiver, usually at 18dB. This is a big improvement in terms of antenna gain because a data terminal its antenna gain is only 2dB or lesser. The function of the gateway is to store and convert the traffic for the users into UMTS network and vice versa. This network configuration is more suitable for non-realtime applications such as file downloading, web browsing and the usage of e-mails. Since the available bandwidth of WCDMA is lesser than the bandwidth of WLAN, the mainframe is operating as a resource management between the UMTS and users by allocating available bandwidth to the users. Hence, this is an adaptive multi-rate service.

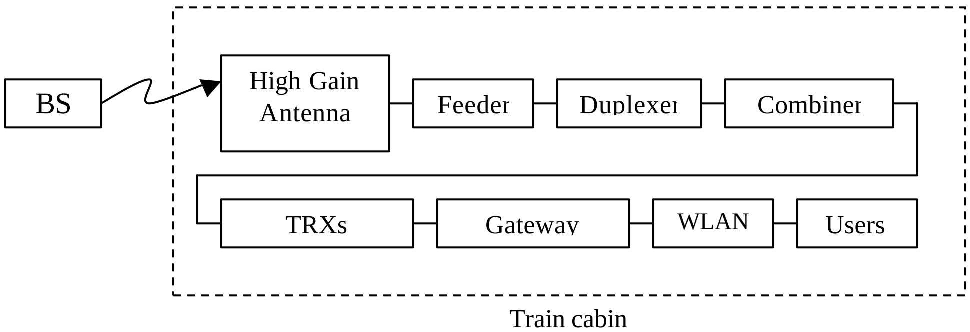

Figure 1: Train Network Configuration

3. Link Budget

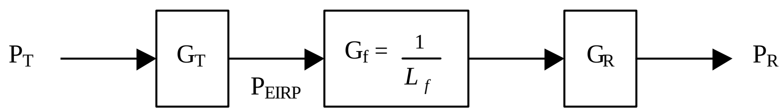

Figure 2: Transmitting and Receiving Antennas

Using Friis formula;

$$P_R = A_R P_{inc} = \frac{P_T G_T A_R}{4\pi r^2} \qquad (5)$$

For all antennas, it can be shown that the effective area $A(\theta,\phi)$ is related to the power gain $G(\theta,\phi)$ and the wavelength $\lambda = c/f$ as follow:

$$G(\theta,\phi) = \frac{4\pi A(\theta,\phi)}{\lambda^2} \qquad (6)$$

By replacing $A_R = \lambda^2 G_R / 4\pi$, we obtain:

$$P_R = \frac{P_T G_T G_R \lambda^2}{(4\pi r)^2} \qquad (7)$$

$P_T G_T$ is the EIRP (effective isotropic radiated power), G_R is the receiver gain and $(\lambda / 4\pi r)^2$ is the effect of propagation path, which causes P_R to attenuate with the square of the distance r , can be quantified by defining the free-space loss by, L_f , where

$$EIRP = 10\log_{10} P_T G_T \qquad (8)$$

$$G_R = 10\log_{10} \frac{4\pi A_R}{\lambda^2} \qquad (9)$$

$$L_f = 20\log_{10} \frac{4\pi r}{\lambda} \qquad (10)$$

In the simulation, Okumura-Hata's propagation model for macro cell with base station antenna height of 30m, mobile antenna height of 1.5m and carrier frequency of 1950MHz is chosen to assess L_f [2].

$$L_{Urban} = 137.4 + 35.2\log_{10}(r) \qquad (11)$$

$$L_{Suburban} = 129.4 + 35.2\log_{10}(r) \tag{12}$$

4. Downlink Transmit Power Distribution

Mathematically, the total base station transmission power can be expressed using the following equation [1]:

$$P = \frac{P_N \sum_{i=1}^{K} \frac{r_i R_i v_i}{W} L_{m,i}}{1 - \sum_{i=1}^{K} \left[\frac{r_i R_i v_i}{W} \left((1 - a_i) + \sum_{n=1, n\neq m}^{N} \frac{L_{m,i}}{L_{n,i}} \right) \right]} \tag{13}$$

$$h_{DL} = \sum_{i=1}^{K} \left[\frac{r_i R_i v_i}{W} \left((1 - a_i) + f_{DL,i} \right) \right] \tag{14}$$

$$f_{DL,i} = \sum_{n=1, n\neq m}^{N} \frac{L_{m,i}}{L_{n,i}} \tag{15}$$

where P, total downlink transmission power of the BS; P_N, noise spectral density of the receiver front-end; r_i, required transmit power at BS m for the connection i, i = 1,…,K,; R_i, bit rate; v_i, channel activity factor; W, chip rate; $L_{m,i}$, path loss from the serving BS m to user i; $L_{n,i}$, path loss from another BS n to user i; N, number of relevant neighbouring BSs; a_i, orthogonality factor.

Each train could be classified as a group of users who are using the same service with the same bit rate and quality requirement. Thus

$$P = \left\{ \frac{P_N \frac{rRv}{W} KL}{1 - \left[\frac{rRv}{W} K(1 - a + f_{DL}) \right]} \right\}_1 + \ldots\ldots + \left\{ \frac{P_N \frac{rRv}{W} KL}{1 - \left[\frac{rRv}{W} K(1 - a + f_{DL}) \right]} \right\}_X \tag{16}$$

where X is the number of train.

5. Comparison and Result

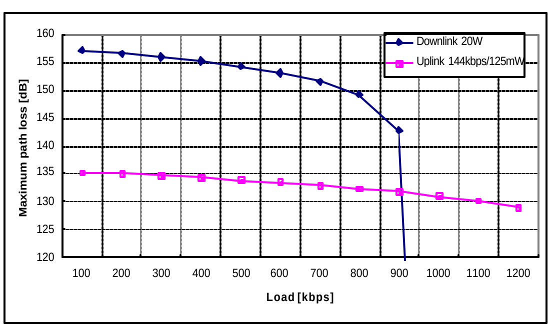

Figure 3: Relationship between UL and DL using conventional scheme

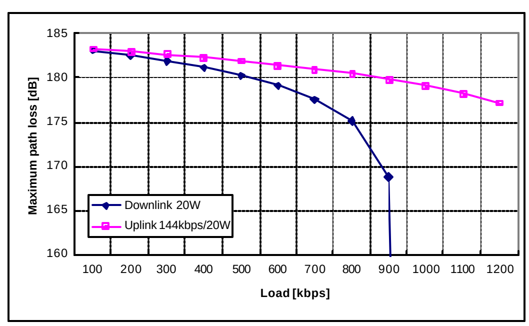

Figure 4: Relationship between UL ad DL using customised scheme

Figure 3 shows that uplink is coverage limited whereas downlink is capacity limited. Figure 4 shows an improvement in the uplink coverage while downlink is now both coverage and capacity limited. Therefore the customised scheme has contributed to the improvement of the overall coverage performance. Table 1 shows the comparison numerically. It is assumed that there is no SHO gain due to the minimum overlapping between cells, 8dB and 0dB in-car loss for the conventional and customised schemes respectively and 7.3dB log normal fading margin.

	Conventional		Customised	
h_{UL} and h_{DL}	r_{Urban} (km)	$r_{Suburban}$ (km)	r_{Urban} (km)	$r_{Suburban}$ (km)
0.50	0.83	1.39	16.89	28.51
0.75	0.79	1.33	13.87	23.41
0.99	0.75	1.26	5.56	9.38

Table 1: Numerical Comparison between Conventional and Customised Schemes

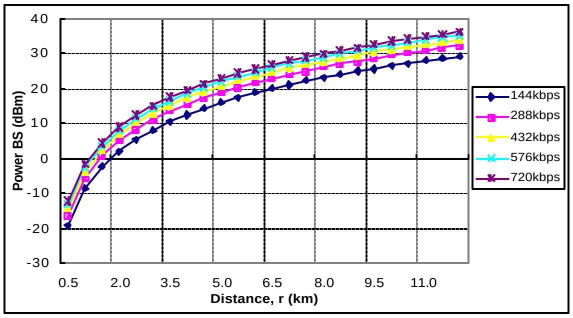

Figure 5: Power BS as a function of distance away from BS

	r (km)	R (kbps)	Speed (kmph)	Power (dBm)
Train A	5	288	130	19.12
Train B	15	288	130	35.91

Table 2: Numerical Comparison between Train A and Train B

Figure 5 shows that the overall performance of the cell could be improved if most of the users are near to the cell. This scenario is taken as a guide line for two trains moving side by side in different directions along the tracks. If the total capacity of both trains is greater than the maximum capacity of the BS, RNC requires to optimise the downlink transmit power distribution in terms of the distance from the BS. Doppler effects is taken into consideration in determining the Eb/No required by the train.

6. Conclusions

It has been shown that by increasing the EIRP and G of the UE antenna, it will bring a significant improvement in coverage area. Uplink and downlink load factors, h is used as a parameter to determine the maximum coverage area of a cell by predicting the traffic of the serving area. A good network planning in terms of capacity, the site density should be sufficient to permit capacity upgrades without the requirement for interleaving new cell, example by including additional carriers, downlink transmit diversity or cell sectorisation.

WCDMA is a power sharing concept. Optimum radio resource management on transmit power distribution is required to provide minimum power with maximum capacity in return. By optimizing the uplink and downlink transmit power, it will decrease the noise floor of the cell and interference to neighbouring cells respectively. Hence, providing overall capacity improvement.

7. References

[1] Sipila, K., Honkasalo, Z., Laiho-Steffens, J. and Wacker, A., 'Estimation of Capacity and Required Transmission Power of WCDMA Downlink Based on a Downlink Pole Equation', *Proceeding of VTC2000*, Spring 2000, pp. 1002-1005.

[2] Lee, J. and Miller, L., 'CDMA Systems Engineering Handbook', Artech House, 1998.

[3] Holma, H. and Toskala, A., 'WCDMA for UMTS', John Wiley & Sons, Ltd., 2000.

[4] Laiho, J., Wacker, Achim., Novosad, T., 'Radio Network Planning and Optimisation for UMTS', John Wiley & Sons, Ltd., 2002.

[5] Shapira, J. and Padovani, R., 'Spatial Topology and Dynamics in CDMA Cellular Radio', Proc. 42nd IEEE VTS Conf., Denver, CO, May 1992, pp. 213-216.

[6] Sopholes J. Orfanidis, 'Electromagnetic Waves and Antennas', Rutgers University, November 2002.

[7] 3GPP Technical Specification 25.101, UE Radio Transmission and Reception (FDD).