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RESEARCH ARTICLE

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Performance analysis of WCDMA wireless access standard

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Abstract Based on the transmitting power of a mobile station and the maximum cell capacity, the analysis of a wideband code-division multiple access (WCDMA) standard and the comparison of the corresponding parameters with CDMA2000 or evolution-data only (EV-DO) are given in this paper. The result proves that the mobile station of WCDMA cannot provide the required transmitting power on the specified frequency band and data rate, and the symmetrical capacity in an up-downlink cannot meet the requirement of a mobile Internet. It is questionable for the International Telecommunication Union (ITU) to select the frequency band of 2 GHz for vehicular mobile telecommunication and unreasonable to distribute it over the downlink and uplink channels symmetrically. Only CDMA2000 1X EV-DO or enhanced data rate for GSM evolution (EDGE), which adopts the Time Division Multiple Access (TDMA) mode, can provide the high-speed data rate for a wireless access.

Keywords WCDMA, electromagnetic radiation, transmit power, cell capacity, data rate

1 Introduction

The wideband code-division multiple access (WCDMA) standard, submitted in 1998, would have been implemented commercially around the year 2000 for 3G services. Its detail was greatly affected by the information bubble of that year. Some operators in Japan and in Europe had deployed their WCDMA commercial networks at around 2001 and 2003, respectively. According to the current statistics, the situation of WCDMA networks was not as good as expected to have it progress. Meanwhile, the CDMA2000 standard, proposed mainly by the United States, should follow the direction from CDMA2000 1X to CDMA2000 3X in its official publication around 1999, and though, the CDMA2000 1X EV-DO (evolution-data only) standard was published not long after the deployment of CDMA2000 1X networks according to the reality of its application. In the CDMA2000 1X EV-DO standard, Time Division Multiple Access (TDMA) is applied to downlink instead of CDMA and the average data rate in a vehicular mobile environment achieves a rate of 600 kb/s. It runs well in practice and then gains a rapid development. According to Ref. [1], the appearance of 1X EV-DO might cause 3X technology to fade out of the markets, but no final decision has been given so far. The inventor of the CDMA mode converting the key parts of CDMA2000 1X to TDMA fully proved a great change in the understanding of the CDMA mode applying for variable high-rate wireless access among American mobile operators and Qualcomm. It is worthy to study the cause of the embedded transformation and the rationality through comparing the differences among these standards. Furthermore, it is unreasonable for the International Telecommunication Union (ITU) to distribute the frequency band over the downlink and uplink channels symmetrically in 3G systems based on the requirements of mobile Internet and the appearance of 1X EV-DO.

On the basis of the capacity research of a CDMA wireless link, it is known that the capacity in the uplink is almost equal to that in the downlink, which is inadequate to provide 3G mainstream services like mobile Internet. From the research done on the cellphone transmitting power, it is impossible for a cellphone to provide a data rate higher than 32 kb/s in a vehicular environment at 2 GHz. The CDMA technology cannot support variable rate data communication. All of the reasons given above resulted in the sudden change of the CDMA2000 standard implementation.

In this paper, the 3G standard is introduced followed by the performance analysis of WCDMA in the aspects of cellphone transmitting power and the maximum cell capacity; furthermore, it is compared with the CDMA2000 standard. Some reasonable and personal suggestions about creating a 3G network will be given in the last part.

2 3G standards in brief

The prime target of the 3G standard is to provide a peak data rate of 144 kb/s, 384 kb/s and 2 048 kb/s in the wireless

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environments of a vehicle, pedestrian and indoors, respectively. The corresponding radius is approximately 10 km, 300 m and 10 m. Obviously, the last two have lower value for application. Providing variable wireless-access data rate for multiple users is the core requirement of the 3G standards. Currently, the dominant 3G standards include WCDMA, CDMA2000 and TD-SCDMA.

Table 1 gives the major parameters of WCDMA, which in essence is FDD -WCDMA, and CDMA2000 standard, which is applied to both 900 MHz for mobile communication and 2 GHz for personal communication. Indeed, it might be possible to combine the two radio access networks (RAN) at 900 MHz and 2 GHz separately with the same core network (CN) in a CDMA2000 system.

CDMA2000 1X is compatible with the IS-95 because of the same chip rate and wouldn't trigger something unreasonable since the drastic increase of the cost of a mobile station (MS) used by a low-speed data and voice user in WCDMA system for its chip rate is 3.84 Mchip/s.

1X EV-DO is a new standard based on CDMA2000 1X RC3 and these two have similar values of uplink parameters because of the low demand for uplink data rate by mobile Internet. The prominent change happens in the downlink, introducing TDMA mode for user identification, preamble W_n^{64} for user channel distinguishing, W_n^{16} in time slots occupied by certain user for user sub-channel and modulation types like QPSK, 8PSK, 16QAM for the variable data rate. Each user Spread factor (SF) per user is decided by the base station (BS) according to the condition of the signal transmission fading and SF ≈ 80-2.

The primary difference between EV-DV and EV-DO is that the former can transmit signals of voice, low-speed data and high-speed data on one carrier only. Its radio configuration is set similarly with CDMA2000 1X for voice and low-speed data transmissions, leaving the remaining Walsh code channels to form two TDMA mode channels for high-speed data transmission. The corresponding data rate (R_b) can be divided into eighteen levels: 81.6 kb/s, 158.4 kb/s,…, 3 091.2 kb/s, the encoding ratio of Turbo error corrective code is 1/5 and the modulation types selected are QPSK, 8PSK, 16QAM. The relevant parameters of EV-DV will be defined in the so called CDMA2000 RC10. Although high speed downlink packet access (HSDPA) defined in WCDMA R5 has a similar mode with EV-DO, saying its R_b will be up to 10 Mb/s, the demand for transmitting power is surprising and would result in a wide electromagnetic wave pollution. Moreover, it is doubtful whether people will need such a high rate mobile wireless data access service and pay for it willingly. The bandwidth of WCDMA is so wide that it is hard to assign HSDPA channels, showing the unreasonableness of the ITU to deploy frequency band over the up–down link symmetrically.

3 Performance analysis of radiation intensity of the electromagnetic wave from MS in WCDMA

Given the distance between the MS and the BS and the electromagnetic wave environment, MS transmitting powers surge heavily among 3G standards because of the great difference of technology and frequency band, resulting in different radiation intensities of electromagnetic wave thus affecting the surroundings. Furthermore, according to the standard rules, a 3G system should be worked at 2 GHz, the low part of the microwave frequency spectrum and characterized by a line-of-sight transmission. Compared with the 2G system at 900 MHz, its transmitting power has to multiply by ten times and the diffraction and penetrating abilities are poor. According to the data, the loss of penetrating a wall is up to 10 dB to 15 dB in practice, which means that the transmitting power will have to be increased from 10 to 31.6 times than before. Thus, it is natural to form an uncovered area, where calls are often interrupted. The practice of a GSM system to use 1.8 GHz and the personal handphone system (PHS) has also proved that merely increasing transmitting power is unable to overcome the problem. From this view, 2 GHz is only suitable for pedestrian mobile communication with a coverage radius that is less than 500 m other than an ideal frequency band for vehicular communication within an extensive area. It is difficult for 2 GHz, appointed by the ITU as the frequency band, to serve the 3G mobile communications under the vehicular, pedestrian and indoor environments, causing an unreasonable use of radio spectrum resources and the high costs of network building. The statistical data [2] from NTT DoCoMo company shows that about 2/3 of the traffic of WCDMA networks happen indoors, which means that the networks are left little to spare for most of their service periods under vehicular environment and have the characteristic of a pedestrian mobile communication system like the PHS. As a result, WCDMA systems need more micro-cellular base stations and have to increase the costs of network building. These are the essential features of 2 GHz systems. Next, we will compare the radiation intensity of an electromagnetic wave from MS in WCDMA with CDMA2000 systems by uplink budget.

Table 1 Major parameters for WCDMA and CDMA2000

	Chip rate /(Mchip·s^{-1})	RF bandwidth /MHz	Modulation type	Spread factor
FDD-WCDMA	3.84	5	QPSK	Uplink: 256-4 Downlink: 512-4
CDMA2000 1X	1.228 8	1.23	Uplink: 2 × 2PSK Downlink: 2 × 2PSK QPSK	43-2

FDD: frequency division duplex

3.1 Uplink budget

The MS transmitting power required by each communication standard can be obtained from a wireless uplink budget. Generally, the absolute error of the calculation is larger, though, it is feasible if the data are used for comparison between the different standards. The maximum path loss (MAPL) in an uplink can be expressed as [3]

$$\text{MAPL} = \text{EIRP} - L_b + G_A - L_f - L_m + G_s - L_p - R_s \quad (1)$$

where the effective isotropic radiated power (EIRP) = 23 dBm for the MS maximum transmitting power, 0.2 W in IS-95; $L_b = 0$ dB for penetration loss; $G_A = 17$ dB [4] for BS receiving antenna gain; $L_f = 3$ dB for BS feeder loss; $L_m = 5.4$ dB for fading margin to compensate radiowave propagation fading, at 900 MHz and larger at 2 GHz; $G_s = 4.0$ dB for soft handover gain; $L_p = 3$ dB for body loss, i.e., half of the MS transmitting power is absorbed by the human body; R_s is the receiver sensitivity and can be derived from

$$R_s = dFN_{th}R_b \frac{1}{1-\mu} \quad (2)$$

where $d = (E_b/N_t)_r = 4.5$ dB for threshold of the receiving signal bit error rate where $N_t = N_0 + I_0$ in which N_0 is the spectral density of additive white Gaussian noise (AWGN) and I_0 is the spectral density of self-interference caused by CDMA; $F = 4$ dB for receiver noise figure; $N_{th} = -174$ dBm/Hz for spectral density of the thermal noise; R_b for the user data rate, which differs much in different standards; $\mu = N/N_{max}$ for the load factor in the uplink where N is the number of users calling and N_{max} is the maximum number of users.

Note that d depends on the error checking correcting (ECC) types ruled by standard. The nominal code rate (R_{CECC}) is 1/3 for voice modulation in WCDMA and CDMA2000. But in fact, the actual code rate in WCDMA is 1/2.5 for introducing the method of punching, so d increases lightly. In order to compare, we set d to 4.5 dB. R_b is given in Table 2 for voice communication [5,6].

Table 2 Values of R_b

	$R_b/(\text{kb}\cdot\text{s}^{-1})$	R_b/dB	R_s/dB	MAPL/dB
WCDMA	19.5	42.9	−118.6	151.2
CDMA2000	9.6	39.8	−121.7	154.3

The WCDMA standard for the user data rate is 12.2 kb/s for voice communication, and $R_b = [12.2 \times (1+0.22) + 2.4] \times 1.13 = 19.5$ kb/s where 0.22 comes from the rate matching in the uplink, 2.4 kb/s is channel associated signaling and 1.13 comes from dedicated physical control channel (DPCCH).

3.2 Transmission range in the uplink

The maximum transmission range in an uplink i.e. coverage radius R can be obtained from calculated MAPL and the radiowave propagation models that are complex in general. In this paper, we chose Okumum hata model [3], which is suitable for the macro-cellular network environment ($R > 1$ km) and its frequency band is in the range of 150 MHz to 1 500 MHz. The formula of the path loss estimation for radiowave propagation at 900 MHz is given in Eq. (3), where $h_B = 30$ m for the height of BS antenna and $h_M = 1.5$ m for the height of MS antenna.

$$L_{900} = \begin{cases} 126.4 + 35.2\lg d \text{ dB} & \text{for urban areas} \\ 116.5 + 35.2\lg d \text{ dB} & \text{for suburbs} \end{cases} \quad (3)$$

With the value of the MAPL introduced into L_{900} in Eq. (3), the maximum transmission range d km in CDMA2000 can be derived as the MS maximum transmitting power is given to be 0.2 W (See Table 3). The channel bandwidth in CDMA2000 is 1.23 MHz, which can be applied to the 900 MHz frequency band while WCDMA cannot do that.

Table 3 Maximum transmission range of MS

	d_{900}/km		d_{2000}/km	
	Urban areas	Suburbs	Urban areas	Suburbs
WCDMA			2.0	5.4
CDMA2000	6.2	11.9	2.4	6.4

Similarly, the formula of the path loss estimation for the radiowave propagation at 2 GHz can be derived from COST-231 hata model [3] as follows

$$L_{2000} = \begin{cases} 140.8 + 35.2\lg d \text{ dB} & \text{for urban areas} \\ 116.5 + 35.2\lg d \text{ dB} & \text{for suburbs} \end{cases} \quad (4)$$

where the conditions are the same with L_{900}. The results are listed in Table 3.

From Table 3, the transmission range of the MS has a big drop in 2 GHz. China Unicom has already deployed CDMA2000 1X system at 900 MHz and the implementation of WCDMA service at 2 GHz is in the near future. If WCDMA MS needs to achieve the same coverage as CDMA2000 1X at 900 MHz, its transmitting power should be increased 17.5 dB (56 times) and 12.1 dB (16 times) in urban districts and suburbs respectively. Furthermore, the radiowave penetration loss will introduce an extra 10 dB increase at 2 GHz and here it is not concluded.

3.3 Transmit power required by 144 kb/s

As a matter of convenience, we chose voice data rate as the standard for comparison. The 3G communication standard defines a data rate of 2 Mb/s, 384 kb/s and 144 kb/s in the mobile environments of indoor, pedestrian and vehicular, respectively. In theory, the corresponding coverage radius should be smaller than 10 m, 300 m and larger than 10 km, which means that the number of BS will be increased significantly, if the user data rate goes up to 384 kb/s or even higher causing high costs of building the network, and the poor market competitiveness for limited service. Here, the increment of the MS transmitting power is concerned when the user data rate is up to 144 kb/s. There are two measures to reach 144 kb/s. One is code channel binding, by which the increment of the MS transmitting power is proportional to the number of bound channels. The other is the decreasing spread factor, by which the self-interference caused by a high-speed data channel deepens timely and then calls for excellent-performed receivers. Obviously, the former is a better choice for CDMA2000 1X. The increment of transmitting power can be obtained using the same process in Table 2. The results are listed in Table 4. Note that the data rate is 153.6 kb/s other than 144 kb/s in the CDMA2000 standard.

Table 4 Values of R_b when data rate is 144 kb/s

	WCDMA	CDMA2000
$R_b/(\mathrm{kb\cdot s^{-1}})$	144 + 2.4	153.6
R_b/dB	51.7	51.9
R_{CECC}	1/3	1/4
ΔR_b/dB	8.8	12.1

Comparing R_b in Table 4 and Table 2, it is easy to get the value of the increment when the data rate is increased in WCDMA and CDMA2000 systems, respectively.

Table 5 lists the increment ΔP_T of the MS transmitting power at a data rate of 144 kb/s in the uplink for WCDMA and CDMA2000 system at 2 GHz, respectively, relative to CDMA2000 at 900 MHz for voice communication. The numbers in the brackets are the corresponding multiple. The ΔP_T approximately reduces by 3 dB at the rate of 64 kb/s, so by reducing the coverage radius can debase the requirement of the transmitting power. However, it might affect the moving speed and increase the costs of network building. The values of MS transmitting power in the CDMA2000 and WCDMA systems in Table 5 are astonishing since the maximum transmitting power of the MS in IS-95 is 0.2 W. Generally, it is impossible for a cellphone to support uplink high-speed data considering the reliability of the cellphone and human health, which is also the major cause of the decline of the CDMA2000 3X standard. Currently, it is unclear what measures will be taken on WCDMA to deal with the tickler.

Table 5 Increment of transmit power

	ΔP_T/dB	
	Urban areas	Suburbs
WCDMA	23.3(427)	20.9(123)
CDMA2000	26.5(446)	21.1(129)

4 Research for maximum cell capacity for WCDMA

Based on the cell capacity calculation of a wireless up-downlink for a mainstream 3G communication system, a maximum wireless access R_b can be obtained, which decides whether the 3G systems practically satisfy the demand of the standards.

4.1 Cell capacity in uplink

Eq. (5) gives the expression of N_{max} [3] i.e., the maximum number of CDMA cell users in the uplink. We take the parameters in IS-95 instead of CDMA2000 to compare with WCDMA in voice communication. For the convenience of comparison with the data communication, voice activating factor α in IS-95 and voice intermittent transmitting factor DTX in WCDMA are both set to 1.

$$N_{max} = \frac{\dfrac{W}{R_b}}{kd(1+n)} + \frac{1}{1+n} \tag{5}$$

where W for chip rate; $k = 1$ for self-interference coefficient when IS-95 and WCDMA use asynchronous address code; $d = 4.5$ dB for demodulation threshold of signal-to-noise ratio; $n = 0.5$ for adjacent cells interference factor; R_b and R_{ECC} are listed in Table 6 and note that only the numbers in the brackets are actual values after punching for R_{ECC}.

Table 6 N_{max} in uplink for IS-95 and WCDMA

	IS-95	WCDMA
k/n	1/0.5	1/0.5
W/MHz	1.228 8	3.840 0
Uplink $R_b/(\mathrm{kb\cdot s^{-1}})$	9.6	19.5
Downlink $R_b/(\mathrm{kb\cdot s^{-1}})$	10.4	20.9
N_{max} (N_{rel})	31(18)	47(28)
$R_{brel}/(\mathrm{kb\cdot s^{-1}})$	$9.6\times18=172.8$	$12.2\times28=341.6$
BW (voice)/kHz	39.7(68.0)	106.4(178.6)
BW_r/MHz	1.23	5.00
R_{ECC}	1/3	1/3(1/2.5)
E_{mf}	1.000	0.768

The value of N_{max} for IS-95 which has been widely used is very close to that in Ref. [1], which also means N_{max} in Table 6 has a practical value for reference. Note that the bandwidth of WCDMA is four times that of IS-95, but its increment of N_{max} is smaller.

However, N_{max} is not the actual cell capacity because cell self-interference will increase in time and the required transmitting power P_{TR} will go up exponentially along with the rise of the users. P_{TR} can be express as

$$P_{TR} = P_T\frac{1}{1-\mu} \tag{6}$$

where $\mu = N_{rel}/N_{max} = 0.6$ and N_{rel} is given in brackets. In general, the directional antenna is used to support multi-sector communication in many systems to increase the cell capacity.

Table 6 also lists the average bandwidth per voice channel (BW/voice) and the utilized bandwidth in brackets corresponding to N_{rel}. The result is poorer for WCDMA due to the higher dummy rate for rate matching and a lower spectrum utilization of chip modulation E_{mf}, which can be expressed as E_{mf} = chip rate/occupied bandwidth and listed at the bottom.

The maximum cell uplink data rate R_{brel}, actually after code channel binding, can be derived from multiplying N_{rel} with the voice data rate seen in Table 6. Apparently, if there is one voice user, it is difficult for these two standards to provide an uplink wireless access data rate at 384 kb/s and impossible for the MS to provide a higher transmitting power which is in direct proportion to the number of binding code channels.

It is feasible to increase the R_{b} of a certain user by reducing the SF which is listed in Table 7 where $\mathrm{SF_u}$ is for uplink and $\mathrm{SF_d}$ for downlink. N_{cq} is equivalent to the number of voice user when SF is small and it can be expressed as the ratio of the maximum SF to the smaller SF. When the data rate is up to 64 kb/s and 144 kb/s in the uplink of WCDMA, it will occupy the capacity of four and eight voice users respectively, and then the total number of users declines dramatically. The transmitting power is four and eight times of that in voice communication, causing self-interference that increases in time.

Table 7 Value of SF corresponding to R_{b}

$R_{\mathrm{b}}/(\mathrm{kb\cdot s^{-1}})$	WCDMA	
	$\mathrm{SF_u}$ (N_{cq})	$\mathrm{SF_d}$ (N_{cq})
12.2	64	128
64	16(4)	32(4)
144	8(8)	16(8)
384	4(16)	8(16)

A new rising problem is that the received power for a certain code channel with a small SF would multiply, which might drown out the other signals with a larger SF. Thus, it is a better choice for CDMA2000 1X to realize high-speed wireless access R_{b} through code channel binding. Furthermore, increasing R_{ECC} is an alternative way, and here it is ignored because the d will increase along with the R_{ECC}.

4.2 Cell capacity in downlink

The major purpose of 3G standards is for wireless Internet. Thus, the cell capacity in a downlink is a crucial index in the 3G standards, and one of the keys to a successful future in 3G communication. It is worth demonstrating that the cell capacity in a downlink is at least ten times of that in uplink in the 3G standards. The greatest flaw for a CDMA is self-interference, which limits the cell capacity primarily. Based on the received signal to noise ratio (SNR) in a downlink, it can be derived as follows

$$\frac{E_{\mathrm{b}}}{N_{\mathrm{t}}}=\frac{\dfrac{mP_{\mathrm{t}}}{L_{\mathrm{p}}NR_{\mathrm{b}}}}{FN_{\mathrm{th}}+\dfrac{(k+n)P_{\mathrm{t}}}{L_{\mathrm{p}}W}-\dfrac{mP_{\mathrm{t}}}{L_{\mathrm{p}}NW}}\geqslant d \tag{7}$$

$$N_{\max}\approx\frac{m\left[\dfrac{W}{R_{\mathrm{b}}d}+1\right]}{k+n}$$

where mP_{t} for total transmitting power of traffic channels where the range of m is from 0.71 to 0.76 [7] and here, $m=0.76$; L_{p} for wireless link loss; $k=0.5$ for synchronous address code in downlink.

The physical significance of Eq. (7) is clear that the numerator is the bit energy of the receiver, $kP_{\mathrm{t}}/(L_{\mathrm{p}}W)-mP_{\mathrm{t}}/(L_{\mathrm{p}}NW)$ in the denominator is the cell self-interference produced by one cell and $nP_{\mathrm{t}}/(L_{\mathrm{p}}W)$, the interference introduced by adjacent cells, the value of which can be adjusted by n, where the range of n is from 0.04 to 1.778. Here, $n=1.778$ [3].

According to Eq. (7), the maximum number of voice users in a downlink can be obtained with the relevant parameters given above. Table 8 only lists the results of IS-95 and WCDMA system because of the same allocation shared by CDMA2000 and IS-95. Note that there are three kinds of $N_{\max}$ in Table 8, corresponding to $n=0.04$, 0.6 and 1.778, respectively. When $n=0.6$, the calculated $N_{\max}$ for IS-95 is almost equal to the result in Refs. [1,3,8], which means the estimations have practical value for reference. Yet, it is worthy of further study if the $N_{\max}$ can be used as the actual number of cell users while we only take 60% of $N_{\max}$ for reference generally.

Table 8 Maximum number of users in downlink

	IS-95	WCDMA
$N_{\max}$	62/30/14	93/45/22
$R_{\mathrm{bmax}}/(\mathrm{kb\cdot s^{-1}})$ ($n=0.6$)	288	549
R_{CECC}	1/2	1/3

The result of Eq. (7) explains that $N_{\max}$, and also the cell capacity, are decided by the self-interference in CDMA systems. In other words, increasing the BS transmitting power, to be followed by the rise of self-interference, cannot increase the cell capacity. The maximum numbers of cell users in an up–downlink in IS-95 are approximately equal. So is the case with WCDMA. That is to say, it is hard for WCDMA to realize its original design intention-wireless Internet with high speed. In order to satisfy the requirement, R_{b} in downlink should be more than ten times of that in uplink. Therefore, 3G standards are merely suitable for voice communication. Table 8 still gives the cell maximum wireless access $R_{\max}$ after code channel binding. Note that R_{bmax} is not tailored for only one or two users, because the 3G system is more commonly shared by multiple users.

Adjusting the SF in the downlink is another way to change the user wireless access rate. Table 7 lists $\mathrm{SF_d}$ corresponding to different R_{b} and the equivalent number of voice users, from which a same conclusion as uplink is drawn for downlink. Thus, for 3G primary standards, it is impossible to provide the nominal user a wireless date rate of 384 kb/s and 2 Mb/s in a mobile environment of pedestrian and indoor, respectively. A certain user can acquire a wireless access data rate of more than 144 kb/s only given few users in a cell.

5 A reasonable mobile communication mode for high-speed wireless access

There is no self-interference in the TDMA spread spectrum system, in which the SF can be used to adjust R_b for the chip rate is fixed. In the down link, the BS could work at the maximum transmitting power P_T. In order to satisfy the requirement of a received bit error rate (BER), R_b can be increased by smaller SF under conditions of short communication distance and fine transmission environment and declined by a large SF in fading channels. In addition, the user data rate could be improved through slot binding and selection modulations of 8PSK and 16QAM, which are adopted for data transmission only in CDMA2000 1X EV-DO downlink, not for a CDMA system due to self-interference. EV-DO sharing the same wireless allocation with CDMA2000 1X R3 in the uplink, the user data rate is up to 2.4 Mb/s in downlink and 600 kb/s on the average for a vehicular environment. TDMA is a reasonable mode for reaching a high data rate in an EV-DO downlink while the CDMA mode is kept up in the uplink because of the lower demand of data rate. The operation and rapid development of the EV-DO networks have firmly proved the rationality of the mode and the later published EV-DV standard for data and voice communication also uses TDMA mode to transmit high-speed data.

The GPRS system, based on GSM, announces its maximum wireless access R_b is up to 172 kb/s while actually R_b is about 10–20 kb/s in uplink and 30–40 kb/s in downlink. The primary limitation is E_f, the spectrum utilization of GMSK modulation, which is low, approximately $(270\ \text{kb/s})/(270\ \text{kHz} \times 3) \approx 0.3\ \text{b/(s} \cdot \text{Hz)}$ as well as the MS transmitting power in uplink. Generally, the transmitting power is proportional to the R_b, frequency band and E_p, the power utilization ratio of modulation.

The EDGE system uses an 8PSK modulation and its E_f is about $(270\ \text{kb/s})/[(270\ \text{kHz}/\log_2 8)(1+\alpha)]$. $E_f = 2\ \text{b/(s} \cdot \text{Hz)}$ when $\alpha = 0.5$, leading to R_b six times that by GMSK modulation with the same bandwidth. Note that the required SNR of 8PSK is three times of that by QPSK with the same BER because of its lower E_p. EDGE announces that its maximum user data R_b is up to 475 kb/s, or rather, in downlink because cell phone is hard to provide the required transmit power.

Comparing the above two wireless access modes, the spread spectrum TDMA system is preferable with SF to adjust the transmitting date rate and RAKE receiver to collect multipath propagation power.

6 Conclusions

According to the analysis and calculation made above, a WCDMA cell phone hardly bears the required transmitting power. The WCDMA system plans to provide a high-speed R_b at 2 GHz where propagation loss is at 14.4 dB or twenty-eight times larger than that at 900 MHz in urban areas and 9 dB or eight times in the suburbs, causing environmental pollution by electromagnetic wave radiation along with the big rise in the transmitting power. Furthermore, it is impossible for the CDMA system to provide a variable high-speed R_b demanded by 3G standards due to its characteristics, e.g., small and almost equivalent capacity in up-downlink which is merely suitable for voice communication. Also, the bandwidth and transmitting power that restricts R_b and the limitation imposed by transmitting power which is even more prominent in uplink. The advantage of adjusting the transmitting date rate by variable SF and increasing E_p by RAKE receiver make TDMA mode with variable SF more suitable for 3G services.

From the study above and the 3G application in recent years, it concludes that CDMA2000 1X and EV-DO at 900 MHz can reduce the transmitting power and satisfy the requirement of vehicular mobile Internet service. It is unreasonable for the ITU to select 2 GHz as frequency band for vehicular mobile communication and distribute it over up-downlink symmetrically. In this paper, we have also analyzed some technical deficiencies of WCDMA, casting doubt on the realization of the expected data rate under three environments defined by the 3G standards and the application value under the coverage radius. It needs to think twice before implementing WCDMA.

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