FDD Techniques Towards the Multimedia Era

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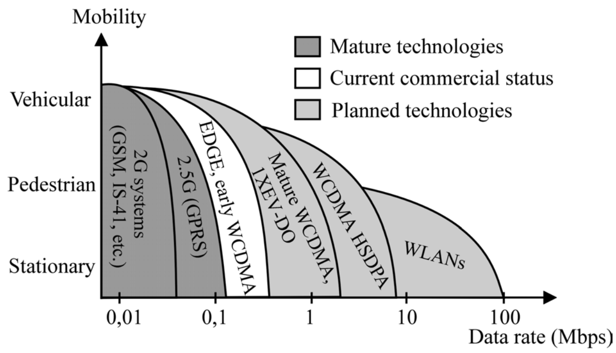
INTRODUCTION

Global rendering of personalized multimedia services is the key issue determining the evolution of next-generation mobile networks. The determinant factor of mobile multimedia communications feasibility is the air-interface technology. The Universal Mobile Telecommunications System (UMTS) evolution, based on wideband code-division multiple access (WCDMA), constitutes a major step to the target of truly ubiquitous computing: computing anywhere, anytime, guaranteeing mobility and transparency. However, certain steps are still required in order to achieve the desired data rates, capacity, and quality of service (QoS) of different traffic classes inherent in multimedia services.

A view of data-rate trends of applied and future mobile communications technologies is shown in Figure 1. UMTS, being in its premature application stage, is currently providing rates up to 64/384 Kbps (uplink [UL]/downlink [DL]). It was initially designed to provide rates up to 2 Mbps under ideal conditions, which seems not enough from a competitiveness point of view compared to WLANs (wireless local-area networks) that aim to easily reach 2- to 10-Mbps data rates with the possibility of reaching 100 Mbps (Simoens, Pellati, Gosteau, Gosse, & Ware, 2003). Hardware, software, installation, and operational costs of 3G (3rd Generation) systems could be proven unjustified and unprofitable if they cannot cope with at least a certain share of data rates over 2 Mbps. This article focuses on the characteristics, application, and future enhancements (planned in 3GPP Release 5 and 6 or under research) of WCDMA-FDD (frequency-division duplex) toward high-quality multimedia services.

Figure 1. Data-rate trends of mobile communications technologies (see also Honkasalo, Pehkonen, Niemi, & Leino, 2002)



GSM: Global system for mobile communications
GPRS: General packet radio services
EDGE: Enhanced data for GSM evolution
1XEV-DO: CDMA 1X evolution - data only
HSDPA: High speed downlink packet access

CDMA BACKGROUND

CDMA, in contrast to FDMA (Frequency Division Multiple Access) and TDMA (Time Division Multiple Access), poses no restrictions to the time interval and frequency band to be used for the transmission of different users. All users can transmit simultaneously while occupying the whole available bandwidth (Figure 2). They are separated by uniquely (per user) assigned codes with proper low cross-interference properties. Thus, while interuser interference is strictly avoided in TDMA and FDMA systems by assigning different portions of time (time slots [TSs]) or bandwidth to different users, respectively, interuser interference, referred to as multiple-access interference (MAI), is inherent in CDMA techniques and is the limiting capacity factor (interference-limited systems).

Figure 2. FDMA, TDMA, and CDMA principles

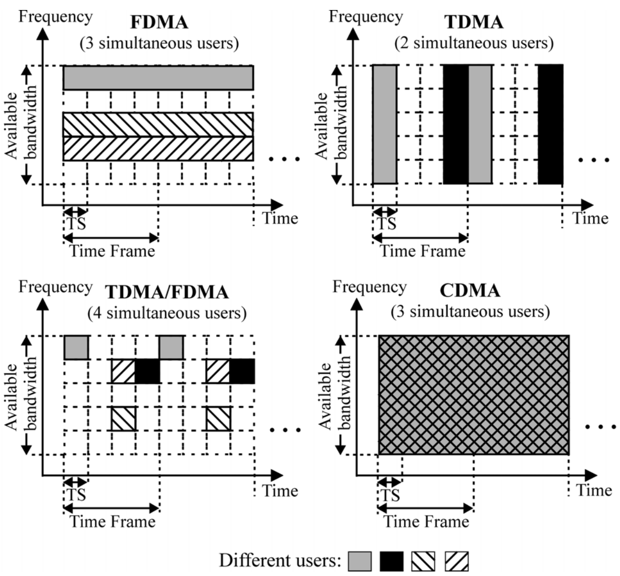
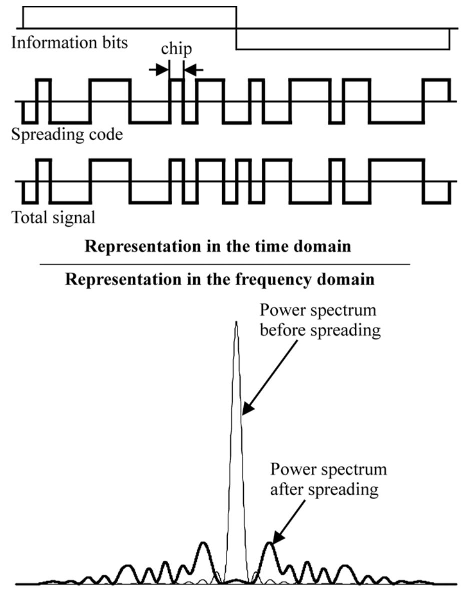


Figure 3. DS/CDMA principle



Although CDMA has been known for several decades, only in the last two decades has interest peaked regarding its use for mobile communications because of its enhanced performance compared to standard TDMA and FDMA techniques. Greater capacity, exploitation of multipath fading through RAKE combining, soft handover, and soft capacity are some of CDMA's advantages (Viterbi, 1995). The first commercial CDMA mobile application was IS-95 (1993). The real boost of CDMA applications, though, was the adoption of the WCDMA air interface for UMTS.

CDMA is applied using spread-spectrum techniques, such as frequency hopping (FH), direct sequence (DS), or hybrid methods. The DS technique, which is used in UMTS, is applied by multiplying the information symbols with faster pseudorandom codes of low cross-correlation between each other, which spreads the information bandwidth (Figure 3). The number of code pulses (chips) used for spreading an information symbol is called the spreading factor (SF). The higher the SF, the greater the tolerance to MAI is. A simplified block diagram of a CDMA transmitter and receiver is given in Figure 4. The receiver despreads the signal with the specific user's unique code followed by an integrator or digital summing device. Coexistent users' signals act as additive wideband noise (MAI).

With properly selected codes (of low autocorrelation), multipath propagation can turn into diversity gain for CDMA systems as soon as multiple paths' delays are spaced more than the chip duration (these paths are called resolved). In such a case, a RAKE receiver is employed (Figure 5), which performs a full reception procedure for each one of the resolved paths and properly combines the received signal replicas. In any case, discrimination between CDMA users is feasible with conventional receivers (no multiuser receivers) only when an advanced power-control method is engaged. Otherwise the near-far effect will destroy multiple-access capability.

There is no universally accepted definition for what is called WCDMA. From a theoretical point of view, a CDMA system is defined as wideband when the overall spread bandwidth exceeds the coherence bandwidth of the channel (Milstein, 2000). In such a case, the channel appears to be frequency selective, and multipath resolvability is possible. Compared to narrowband CDMA, beyond multipath exploitation, WCDMA presents enhanced performance through certain advantages, such as a decrease of the required transmitted power to achieve a given performance, greater tolerance to power-control errors, fading-effects reduction, the capability to transmit higher data rates and multimedia traffic, and so forth.

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