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WCDMA

In our last hot topic, we reviewed the future positioning of TD-CDMA including the rationale of taking the existing DECT time multiplexing structure to front end a CDMA air interface. The benefit of the time division duplex is the ability to provide full duplex services in non-paired frequency allocations, the benefit of the time division multiplex is to provide some additional flexibility in terms of bandwidth on demand negotiation and to provide adaptive interference management (ie interference managed locally as part of the negotiation process between base station and handset).

In this article, we set out the present evolutionary path of W-CDMA and CDMA 2000 showing how the traffic mix will be managed in terms of active rate adaption, error rate and latency control, and how TD-CDMA fits in to this overall picture.

Our five elements of the traffic mix are voice, image, video, file transfer and transaction processing. We can divide this traffic into error sensitive and/or error tolerant, delay sensitive and delay tolerant traffic (sometimes also described as elastic or inelastic traffic).

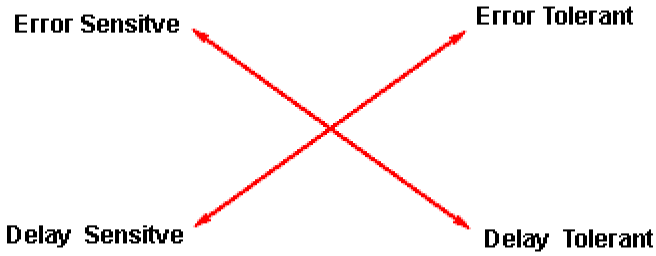

Figure 1

Generally, the traffic characteristics are as follows:

Error Sensitive
Video
Image Transfer
File Transfer
Transaction Processing

Error Tolerant
Voice

Delay Sensitive
Voice
Transaction Processing
Video

Delay Tolerant
Image Transfer
File Transfer
Voice Messaging

Figure 2

Note that the only traffic that can truly be considered to be error tolerant is voice (although it is delay sensitive). Transaction processing is both error sensitive and delay sensitive – it is delay sensitive because transactions are often deterministic in nature – for example an authentication challenge requires a response within a defined time period.

Delivering deterministic services will be a key requirement for 3G air interfaces. The problem for deterministic services delivered over wireless is that the channel quality varies over time. We have to find ways of ensuring that the application rather than the radio channel drives the information rate delivered to the user. We can use power control as a mechanism for disguising the variability of the radio channel, however power control now has two functions, one, to correct for a varying RF environment, two to adapt to rapid changes in information rate.

Here we need to define the difference between multi-rate and variable rate multiplexing.

Multi-rate is where a number of users co-sharing a channel have widely differing information rates. Remember that in CDMA, the ratio of the information rate to the spreading rate determines the coding gain. As the information rate increases, coding gain decreases (and more power is needed to preserve the orthogonality of the codes – their 'distance' from one another).

Variable rate is where the data rates for an individual user vary on a frame by frame basis – for example in an ATM application where simultaneous speech, whiteboarding, image processing and video streaming can result in substantial and rapid changes in information rate. Note also that each individual type of traffic has very individual transport requirements in terms of error and delay sensitivity.

This is the provenance behind the introduction of traffic codes in 3G air interfaces in addition to conventional channel codes and user codes. The challenge both at channel code, user code and traffic code level is to maintain code orthogonality in the presence of widely varying user data rates.

At this stage, we need to step back and remind ourselves of the various properties that codes exhibit.

Let's start with maximal length sequences, (M sequences). The definition of a maximal length sequence is the longest/largest code that can be generated by a given shift register or a delay element of a given length (N). Provided 'N' is large, M sequences are more or less indistinguishable from a pure random code.

The properties that interest us in M sequences are auto correlation and cross correlation. Auto correlation is the degree of correspondence, ie similarity between a sequence and a phase shifted replica of itself. We may use this for example to achieve synchronisation. Cross correlation is the measure of agreement between 2 different codes – the more unalike two codes are, the more 'distance' or discrimination can be achieved.

The good thing about shifting an M-sequence in time is that it's correlation with time shifted versions of itself is almost zero. It is used for example in IS95 to identify base stations (each base station and handset is identified by a unique off-set of its PN binary sequence).

We can then refine our choice of codes depending on the properties that we want. Gold codes for example provide a sub-set of shift register connections that result in a set of codes with 'known bounds' to their cross correlation (ie a known distance between them). It's rather like specifying the 'Q' of a filter in the frequency domain.

We can for example, end up with a set of codes that exhibit perfect orthogonality. Walsh codes are one example, (used in IS95 CDMA to provide channel separation). Walsh codes have zero correlation with each other provided all users co-sharing the channel are co-synchronised within a fraction of a chip length (the cross correlation between different shifts of a Walsh code may not be zero because some of the codes are just time shifted versions of themselves).

Walsh codes are used on the downlink in CDMA (base to mobile) to provide the mechanism for establishing traffic channel and paging channel discrimination. The pilot channel provides the synchronisation needed. The effect is to provide additional selectivity in the downlink. On the uplink, the modulated bit stream is mapped on to 6 bit symbols – each 6 bit symbol represents one of the 64 Walsh codes. The base station uses this additional information to provide some coding gain on the uplink (sensitivity).

With third generation W-CDMA and CDMA 2000, the challenge is to match particular code properties to the traffic being transported. This has generated the requirement for multiple length orthogonal codes – codes of variable length that maintain their orthogonality in the presence of widely varying information rates.

One option is to use tree structured orthogonal codes, a rather grand description for a series of Walsh codes that have been edited to remove those codes which are a time shifted version of other codes in the set (sometimes described as mother codes).

This solves the orthogonality issue but not the power control issue related to rapidly changing information rates.

In W-CDMA, this is addressed by (surprise, surprise), a time division multiplex.

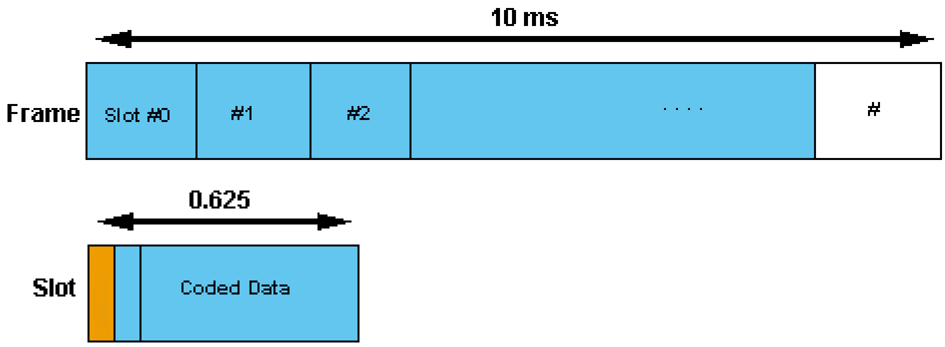

FIG 3 Pilot channel and transmit power control (TPC).

Each 10 ms frame is sub-divided into 16 time slots, each slot has it's own pilot symbol and a power control field, the base station measures the signal to interference ratio and sends back a power control command (every 0.625 m/s), i.e. the user data rates can change on a frame by frame basis, the power control is being adjusted on a slot by slot basis.

There are several mechanisms at work here. The orthogonal variable spreading factor codes provide channelisation for different users at varying user data rates and/or channelisation for different services at varying data rates supplied to an individual user.

The short term changes in data rate cause fluctuations in the spreading ratio but these are compensated by the power control which keeps a constant signal to interference ratio between all users (and all services) de-correlated at the receiver.

Note though that the power control now has two jobs to do, to compensate for changes in the radio channel **and** changes in the information rate.

The matching of information rate to the physical channel is done in two ways. 'Static matching' takes the information rate (or information rate upper and lower bounds) prescribed at the time a transport channel is added, or redefined, 'dynamic matching' then matches the instantaneous user bit rate as it varies on a frame by frame basis.

However, the additional variable which is of special common to us is bit error rate. We have established that a substantial percentage of our traffic mix is error and/or delay sensitive. Our radio channel, (compared to it's wireline equivalent) not only suffers from relatively high bit error rates (1 in 10^3 against 1 in 10^{10} or 1 in 10^{11} for wireline) but worse, these error rates are variable. Variable bit error rates go against our objective of delivering deterministic services (services with a known and relatively unvarying end to end latency).

A partial solution is to provide adaptive coding (a rate 1/3 convolutional code for low delivery services with error rates of 1 in 10^3 or a 1/3 convolutional code with outer Reed Solomon coding for 1 in 10^6 bit error rate). The additional coding for the lower bit error rate however absorbs additional channel energy. An alternative is to add a 'send again' protocol, ie a non-transparent transport layer but this introduces variable delay.

As we stated in our last hot topic, TD-CDMA adds in an additional time division duplex (so it will work in non-paired spectral allocations) and a time division multiplex that allows for localised adaptive interference management and/or more flexibility in terms of rate adaption.

Remember also that adaptive interference management and adaptive channel allocation (localised allocation of bandwidth on demand) (already inherent in DECT and PHS air interfaces), potentially also allow users to communicate **without reference** to the core network (self-sustaining self-regulating micronets or piconets).

In our next hot topic, we will address the positioning of these self-regulating micronets and piconets with other localised RF connectivity solutions (including Bluetooth and recent up-grades of IEEE 802).

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