TSKS03 Wireless Systems

Solutions for the exam 2014-06-03

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1

The following are listed in the report that this question is based upon:

On-Off Keying:
Uses a non-zero signal to represent binary 1 and an all-zero signal to represent binary 0.

Pulse-Position Modulation:
Uses a pulse of duration that is shorter than the signalling interval, and where the position of the pulse within the signalling interval corresponds to the information it represents.

Edge-Position Modulation:
Here it is the position of the edge of a pulse within a signalling interval that determines what information the pulse represents.

2

A CRC code is a kind of check-sum calculation. The encoder uses a linear feedback shift-register, which is fed with the information. What is sent is that information, followed by the parity bits that are the final contents of the shift-register. The receiver also has a linear feedback shift register, and it does the same thing with the received bits, but includes the parity bits in its input. If the resulting contents of the feedback shift-register is all zero, then the received sequence is a codeword in the CRC code.

The purpose of using CRC codes in UMTS is to provide error detection of transport blocks. That is usually the purpose of using CRC codes. The report that this question is based on does not specify what is to be done in case errors are detected by the CRC code. However, CRC codes are usually combined with some version of ARQ. The report does state, however, that HARQ is used in the enhancement HSDPA of UMTS.

3

These are the four types of bursts:

Normal burst:
This is used for normal communicaton over traffic and control channels. One part of this burst is a training sequence that is used to estimate the channel.

Frequency correction burst:
This burst is used to synchronize the frequency reference of the mobile.

Synchronization burst:
This burst is used to synchronize the timing of the mobile.

Access burst:
This is the first burst used when a user takes a subchannel in use. Its purpose is initial adjustments, since the mobile has no knowledge of the communicatoin situation ath that time.

4

The following three impacts may not be the only possible three answers to this question. Each impact is worth one point and the fourth point is given based on overall quality of the answer.

Fading:
The impulse response and frequency response of the radio channel varies with time when a user moves due to multi-path transmission. This actually also happens or when objects in the vicinity move, However, the fastest and largest variations are due to the movements ov the user. This fading means that the quality of the transmission varies between sub-bands and over time.

Doppler shift:
Movements towards or away from the base-station gives rise to doppler-shift, i.e. the spectrum of the signal is shifted. This increases the need for frequency syncronization.

Changed average quality of the channel:
Movements away from the basestation that is serving the user and towards another basestation reduces the received power. This results in that the user needs to increase its sender power, which both speeds up the battery drainage and increases the interference to other basestations, especially, the one that the user is approaching. At some point, the user would be better off if the communication would take place via the other basestation, which means that we need handover.

5

MIMO is an acronym for Multiple Input Multiple Output. Multiple refers to the number of antennas. It means that both the sender and the receiver use more than one antenna, placed in so called arrays. Related acronyms are SIMO, MISO and SISO, where S is short for single and again refers to the number of antennas. There will then be one channel between each sender and receiver antenna. If the antennas in the arrays are placed sufficiently far apart (in the order of a wavelength), then these individual channels can be modeled as independent (or at least uncorrelated) in terms of fading. Three possible ways of utilizing MIMO:

Spatial multiplexing
: With M sender antennas and N receiver antennas, $\min\{M, N\}$ separate communications can take place at once, i.e. we have $\min\{M, N\}$ effective channels available.

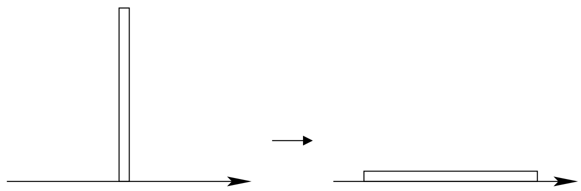
Diversity
: The SNR of each of the $\min\{M, N\}$ effective channels varies over time, independent of each other. However, the probability of two or more of them being bad at the same time is a lot smaller than the probability of one of them being bad. By sending the same information over more than one of the effective channels, we can average out the effect of fading. There are several different ways to achieve this.

Beamforming
: By using several sender antennas to transmit differently phase-shifted versions of the same signal, we can direct most of the sender power in an intended direction. This increases the received power for the intended receiver. In a multi-user scenario this also reduces the interference for other receivers that are not in that particular direction. As a result, the SINR (Signal to Interference and Noise Ratio) is reduced compared to not using beamforming. Beamforming can also be used at the receiver end, by adding the received signals differently phase-shifted. This reduces the SINR further.

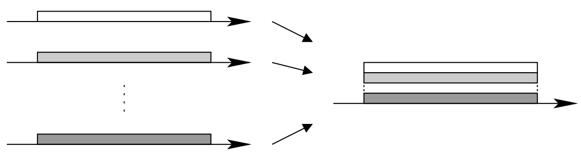
As a side-note, today researchers consider something they call Massive MIMO, which is believed to become part of future mobile communication systems. Here, hundreds or even as many as a thousand antennas are considered at the base station, and one or possibly two antennas on each mobile unit. As long as communication takes place in frequency bands at a few GHz, the wavelength is a few dm, and it does not make sense to place antennas a few dm apart on a mobile phone. It could make sense on a laptop or a smallish computer-like equipment. For it to make sense to place more than one antenna on a mobile phone, we would need at least one order of magnitude larger carrier frequencies, so that the wavelength is at most a few cm. Beamforming utilizing the multi-path property of radio channels can then be used to target a specific point in space where the intended receiver is, while essentially not causing any interference to other receivers. This is based on channel estimation, and using that to achieve constructive interference at the intended receiver, while essentially having destructive interference at other receivers.

6

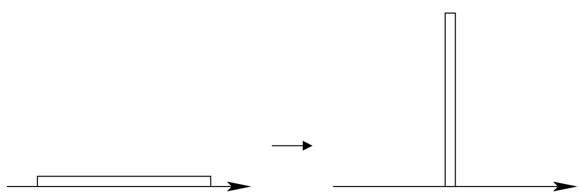
Each user represents his data with a narrow-band signal. That signal is multiplied by a so called spreading sequence that consists of ± 1 in a psedo-random fashion. The resulting signal is a broad-band signal.



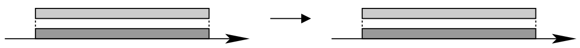
Each user has his own spreading sequence, and each users signal then occupies the same frequency band. The broad-band signals are sent over a common channel that adds them together (possibly scaled), which gives us a received signal that is a linear combination of the different users broad-band signals.



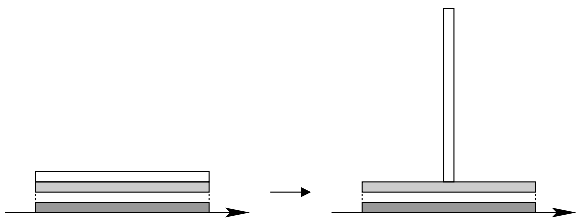
In the receiver, when we want to extract a certain users narrow-band signal from the received signal, we multiply the received signal by that users spreading sequence. The effect on the wanted part of the signal is obvious, since the original narrow-band signal of that user is then multiplied twice by 1 or by -1 (once in the sender and once in the receiver), which means that we get the original signal back. This is refered to as despreading of the signal.



The signal is disturbed by the other users signals. Each other users original narrow-band signal is first multiplied by his own spreading sequence (in the sender) and then by the wanted users spreading sequence (in the receiver). The result is that that signal is multiplied by the product of two spreading sequences. The spreading sequences are chosen in such a way that the product of two different spreading sequences is a new spreading sequence with the same spreading properties as the original ones. Thus the other users signals are still spread after the despreading of our wanted signal.



The power of the broad-band signal of a user is the same as that of the narrow-band signal of that user, since we multiply by ± 1. But, since it is spread over a larger frequency band, the "height" (power spectral density in the interesting frequency band) of the broad-band signal is considerably smaller than that of the narrow-band signal. Thus the other users disturb the wanted signal as a fairly small noise.



When there are many users around, that noise can approximately be treated as white Gaussian noise.

7

a. An M-sequence is produced by a binary feedback shift register, where the feedback network is given by a primitive polynomial over the binary field, which gives us a sequence of period $2^m - 1$, where m is the length of the shift register. m is then also the degree of the polynomial.

b. Gold sequences are generated using two M-sequences of the same length, a so called preferred pair. One of them is a decimated version of the other, by taking every q-th element. Demands:
- feedback register length $m \neq 0 \mod 4$.
- we have either $q = 2^k + 1$ or $q = 2^{2k} - 2^k + 1$,
- $k = 1$ for odd m and $k = 2$ for even m.

The set of Gold sequences then consists of
- the two M-sequences and all shifts of them
- all sums of shifted versions of the two M-sequences.

c. The generation of Kasami sequences are also based on decimation of an M-sequence. Let x be an M-sequence, from a shift-register of even length, m, and let y be a decimated version of x, where every s-th element is taken, where we have $s = 2^{m/2} + 1$. Then y has period $2^{m/2} - 1$. The small set of Kasami then consists of
- the M-sequence x and all shifts of it
- all sums of shifted versions of the two sequences.

8

a. Power control:
We start with the problem. This has primarily to do with the uplink. Ideally, subchannels used by different users should be orthogonal. Each subchannel would then be possible to filter out individually. In that case, different users would not interfere with each other. In practice, due to oscillator uncertainty and timing uncertainty, and sometimes also design choices, the subchannels are not completely orthogonal, and thus users do cause interference to each other. The other part of the problem is called the near-far effect, and is due to the fact that different users experience different channels. This is to a large extent due to different distances between the different users on one hand and the basestation on the other, and that is the reason for the name. It is also due to multi-path propagation and shadowing. If all users use the same sender power, then since they experience different channels, the corresponding received powers will be different. Since the channels are not completely orthogonal, users with good channels will cause unacceptable interference to users with bad channels. The solution to the problem is power control, which aims at obtaining the same received power from all users at the basestation, by adjusting each user's sender power. This is done in the following way. The basestation estimates the received power for each user, and individually orders each user to increase or decrease its sender power. The result is twofold: Each received user signal experiences approximately equally much interference from other users. Also, each mobile phone uses approximately as little power as needed for the situation, thus increasing the battery life of the phone compared to not using power control.

b. Handover
In cellular systems, the users are allowed to move. Radio signals get weaker (on average) the further away you are from the base station, and the signal strength

also varies due to multi-path transmission and shadowing. Therefore, staying connected to the same base station all the time can result in bad communication quality and ultimately to lost communication. A user may very well move from a point where the communication quality is best through one base station to a point where the communication quality is best through another base station. In that event, the system can transfer the communication from the first to the second base station. This process is called handover or handoff. The basestations often use directional antennas to separate the surrounding area into separate sectors. Then handover is also used when a user moves from one sector to another. Depending on the load of the system, handover can also be used to move users from a crowded cell to a neighbouring less crowded cell in order to facilitate more users, even though a user might not get the best possible channel.

c. **Multiple Access**
The primary purpose of access methods is to allow several users to share a common channel. If we have a channel with bandwidth B, then each time interval of duration T contains approximately $2BT$ dimensions. Access methods are therefore supposed to share those $2BT$ dimensions between the users. The number of potential users is normally much bigger than the number of simultaneous users at every time instance. The most important application of access methods today is mobile telephony. Both the GSM network and the 3G network use such methods. Since these are radio applications, we have frequency selective fading. This means that the used access method should be insensitive to this type of fading. In the GSM network, a combination of FH-CDMA and TDMA is used, while the 3G (UMTS) network uses DS-CDMA with a very high spreading factor, and 4G (LTE) uses scheduling. Access methods have been used for several years within wire bound telephony, but the methods are then usually referred to as multiplex methods.

9

You do not need to explain your answers in this task. All that is needed is a true or a false. However, a short explanation or comment is given here for some claims.

a. **True**. Packing data is the primary purpose of source coding.

b. **True**.

c. **False**. Kasami sequencies are pseudo-nose sequencies, usually used as spreading sequencies.

d. **False**. Gold sequencies are generated using two binary linear feedback shift registers, based on two different primitive polynomials.

e. **False**. Hard handover is quite the opposite. You communicate through one base station at a time, and the handover is done by simply switching from one base station to another.

f. **True**. M is for minimum as in small bandwidth.