Engineering Tripos Part IIA, 3F4: Data Transmission, 2019-20

Module Leader
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Lecturers
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Timing and Structure
Lent term. 16 lectures

Prerequisites
Knowledge of 3F1 assumed.

Aims
The aims of the course are to:

- Cover a range of topics which are important in modern communication systems.
- Extend the basic material covered in the Engineering Part IB Communications course to deal with data transmission over baseband (low frequency) channels as well bandpass (higher frequency) channels.
- Analyse the effects of noise in some detail.
- Understand the technique of convolutional coding to protect information transmitted over noisy channels.
- To understand basic congestion control protocols (TCP/IP), and routing algorithms used in the Internet.

Objectives
As specific objectives, by the end of the course students should be able to:

- Understand the different components of a communication network, in particular the role of the physical layer versus the network layer.
- Be able to represent waveforms as vectors in a signal space.
- Appreciate that pulses may be shaped to control the bandwidth of a signal and reduce inter-symbol interference, and be aware of the limits on transmission rate if ISI is to be avoided.
- Be able to describe and analyse demodulation of digital bandpass modulated signals in noise.
- Calculate the probability of error of various modulation schemes as a function of the signal-to-noise-ratio.
- Appreciate how equalisation can correct for undesirable channel characteristics and be able to design simple equalisers.
- Understand the principles of Orthogonal Frequency Division Multiplexing for communication over multi-path wideband channels
- Understand the need for coding, i.e., adding redundancy to control the effects of transmission errors.
- Understand the principles of convolutional coding, and be able to design a Viterbi decoder for convolutional codes.
- Understand the operation of congestion control protocols (TCP/IP) and routing algorithms used in the internet

## Content

### Fundamentals of Modulation and Demodulation (7L)

- Introduction: The overall communication network and the roles of the physical layer and the network layer
- Signal Space: representing waveforms as elements a vector space
- Baseband modulation: Desirable properties of the pulse for PAM; Nyquist criterion for no inter-symbol interference; Eye-diagrams
- Modelling the noise as a Gaussian random process. Additive White Gaussian Noise (AWGN)
- Optimal demodulation and detection at the receiver in the presence of AWGN: Matched filter demodulator, optimal detection using the maximum-a-posteriori probability (MAP) rule
- Passband modulation: QAM, M-ary FSK (Orthogonal signalling)
- Performance analysis of modulation schemes (PAM, QAM, Orthogonal signaling etc.): probability of detection error and bandwidth efficiency

### Advanced Topics in PHY-layer (3L)

- Brief discussion of coded modulation
- Equalisation techniques to deal with inter-symbol interference: ZF and MMSE equalizers
- Orthogonal Frequency Division Multiplexing (OFDM)

### Channel Coding (3L)

- Introduction to error correction and linear codes
- Convolutional codes: State Diagram and Trellis representations, Viterbi decoding algorithm
- Distance properties of convolutional codes using the transfer function derived from state diagram; free-distance of convolutional codes.

### Network Algorithms (3L)

- Congestion control in the Internet: window-based congestion control: TCP-Reno; slow-start, congestion avoidance
- Routing algorithms in the Internet: Dijkstra's algorithm, Bellman-Ford and the similarities to the Viterbi algorithm

### Further notes

The syllabus for this module was updated (with significant changes) in 2017-18. A list of relevant past Tripos questions is available on Moodle.

### Coursework

#### Digital transmission systems

**Learning objectives:**

- To investigate, using a hardware simulation of baseband transmission channels, the phenomenon of inter-symbol interference, and to measure bit error rate (BER) due to noise
- To use the eye diagram as a diagnostic tool, and to understand its limitations.
- To compare the measured dependence of BER on signal-to-noise Ratio (SNR) with theoretical predictions,
and explain the differences by considering how the assumptions made in the theoretical analysis compare with the real situation.

**Practical information:**

- Sessions will take place in EGETL, during week(s) [xxx].
- This activity involves preliminary work-- reading the lab handout [estimated duration: 1 hour].

**Full Technical Report:**

Students will have the option to submit a Full Technical Report.

**Booklists**

For Physical-layer communications (first 13L):


For network algorithms (last 3L):


**Examination Guidelines**

Please refer to [Form & conduct of the examinations](http://teaching.eng.cam.ac.uk/content/form-conduct-examinations) [4].

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