Engineering Tripos Part IIA, 3F4: Data Transmission, 2021-22

Module Leader

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Lecturers

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Lab Leader

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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 commuication network and the roles of the physical layer and the network layer
- Signal Space: representing waveforms as elements a vector space
- 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
- Baseband modulation: Desirable properties of the pulse for PAM; Nyquist criterion for no inter-symbol interference; Eye-diagrams
- 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 (4L)

- 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 (2L)

- [redacted]

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

NOTE: This lab is being redesigned for the year 2020-21 and will be released in Week 2 of Lent Term. There will be an option to do the lab remotely for those needing to self-isolate or studying remotely.

The information below refers to the previous version of the lab, and will be updated in due course.

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 EIETL, 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):

- B. Rimoldi, Principles of Digital Communication: A Top-Down Approach, Cambridge University Press, 2016]
- R. Gallager, Principles of Digital Communication, Cambridge University Press, 2008
- U. Madhow, Fundamentals of Digital Communication, Cambridge University Press, 2008

For network algorithms (last 3L):

- R. Srikant and L. Ying, Communication Networks, Cambridge University Press, 2014.

Examination Guidelines

Please refer to Form & conduct of the examinations [2].

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