Engineering Tripos Part IIA, 3F4: Data Transmission, 2017-18

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
- 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: Djikstra's algorithm, Bellman-Ford and the similarities to the Viterbi algorithm

Further notes

The syllabus for this module has been revised for 2017-18, and therefore the lecture notes, examples papers etc. will be different from previous years. A list of relevant past Tripos questions will be provided towards the end of the module.

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 EIETL, during week(s) [xxx].
- This activity involves preliminary work-- reading the lab handout ([estimated duration: 1 hour]).
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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 [4].

UK-SPEC

This syllabus contributes to the following areas of the UK-SPEC [5] standard:

Toggle display of UK-SPEC areas.

GT1

Develop transferable skills that will be of value in a wide range of situations. These are exemplified by the Qualifications and Curriculum Authority Higher Level Key Skills and include problem solving, communication, and working with others, as well as the effective use of general IT facilities and information retrieval skills. They also include planning self-learning and improving performance, as the foundation for lifelong learning/CPD.

IA1

Apply appropriate quantitative science and engineering tools to the analysis of problems.

KU1

Demonstrate knowledge and understanding of essential facts, concepts, theories and principles of their engineering discipline, and its underpinning science and mathematics.

KU2

Have an appreciation of the wider multidisciplinary engineering context and its underlying principles.

D4

Ability to generate an innovative design for products, systems, components or processes to fulfil new needs.

E1

Ability to use fundamental knowledge to investigate new and emerging technologies.

E2

Ability to extract data pertinent to an unfamiliar problem, and apply its solution using computer based engineering tools when appropriate.

E3

Ability to apply mathematical and computer based models for solving problems in engineering, and the ability to assess the limitations of particular cases.

E4

Understanding of and ability to apply a systems approach to engineering problems.

P1

A thorough understanding of current practice and its limitations and some appreciation of likely new developments.

P3

Understanding of contexts in which engineering knowledge can be applied (e.g. operations and management, technology, development, etc).

P8

Ability to apply engineering techniques taking account of a range of commercial and industrial constraints.

US1

A comprehensive understanding of the scientific principles of own specialisation and related disciplines.

US2

A comprehensive knowledge and understanding of mathematical and computer models relevant to the engineering discipline, and an appreciation of their limitations.

US3

An understanding of concepts from a range of areas including some outside engineering, and the ability to apply them effectively in engineering projects.

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