Inferring messages in non-linear optical fibres with memory

Sina Kuhbanani[1,2], Felippe Alves[1,3], Egor Sedov[2,4], Sergei Turitsyn[2], **David Saad**[1]

[1]Aston University, Birmingham, United Kingdom

Optical communication networks carry roughly 90% of global internet traffic and are central to modern society and the economy. To mitigate transmission noise and maximize throughput, a range of coding techniques are employed. A standard strategy is mapping data onto complex-valued modulation symbols transmitted over optical fibres, the specific variant we study here is the Quadrature Amplitude Modulation (QAM). To improve signal-to-noise ratio in the presence of thermal and amplification noise, the average transmission-power is amplified. The wave propagation follows a non-linear Schrödinger equation, which induces non-linear effects and results in Inter-Symbol Interference (ISI), particularly as the average transmission-power increases, causing an increase in decoding errors. Characterising and mitigating these effects are crucial for supporting high internet throughput.

The main challenge is that inferring jointly a large number of interacting transmitted variables from the received signals is intractable and a principled approximation is required to develop an effective and tractable algorithm. Our approach is to separate the interaction into primary and secondary effects, and addressing their impact using different modelling tools. More specifically, our assumption is that closer variables (consecutive transmitted symbols in the sequence) dominate the ISI and their interactions should be therefore considered individually, while the impact of the remaining variables could be modelled probabilistically via a mixture model-based distribution function. This encapsulates the impact of the remaining variables as part of the inference algorithm. To carry this out we determine symbol triplets, of three consecutive symbols, which account for the close-range interaction between symbols and employ distributed probabilistic message passing techniques between them, specifically, generalised message passing and the Viterbi algorithms.

Comparing the performance of the suggested framework with alternative techniques on transmission data we demonstrate the efficacy and efficiency of the approach under a range of transmission scenarios and conditions, including low and high-power transmission, and multi-channel transmission. We show a significantly lower bit error rate of up to 35% in specific cases. Moreover, the framework can be used for optimising throughput by changing symbol probability, termed probabilistic shaping, and can be adapted for a range of modulation schemes.

I will explain the problem, the probabilistic approach taken and its potential for addressing similar problems in other domains.