Bio-inspired Computing: Exploring the Use of Slime Mould *Physarum Polycephalum* as a model for a distributed, intelligent network.

Problem:

Many large-scale network systems have poor fault tolerance, and intelligent routing protocols, whilst effective at dealing with some of these problems, can suffer from issues of scalability (Lio et Al). Networks are typically constructed to minimise cost and maximise informational throughput, which often does not allow for changes in the environmental conditions. Protocols such as the Virtual Router Redundancy Protocol have been built to handle failures, but at the cost of the network bandwidth, and the node must be manually fixed (or a new one added) in order to restore effectiveness.

Hypothesis:

By modelling networked systems using principles underlying existing biological networks we can examine adaptive, environmentally responsive approaches to network failure. These networks have evolved to overcome problems such as scalability and fault tolerance. *Physarum Polycephalum* has been shown to exhibit interesting graph-solving (Tero et al), computational (Jones, Adamatzky) and fault-tolerant (Tero, Jones, Gunji) behaviours, whilst composed only of a simple single-celled organism. Through analysis of *Physarum,* we can understand more about creating intelligent networks that exhibit emergent behaviours. In analysing the behaviour of *Physarum* using cell simulation software (such as Compucell 3D), a fault tolerant network can be modelled and tested.

Simulation:

The computer simulations will explore the effects of moving and changing so-called 'routing' cells on the transport properties of the network, looking at different adaptive models for the system. The systems modelled by Jones and Gunji et al model cytoplasmic flow as a flow of information, examining changes in the network nodal structure due to environmental change (eg addition of agents, moving of food etc.). The starting point of this stage will be to model Gunji and Jones' simulations, then develop the models used.

Motivations:

There are a number of bio-inspired networks to draw on for inspiration in this project, including MIT's Paintable Computer, and the ant-inspired bio-networking architecture (Suda et al, Bio-inspired computing and communication).

Outcome:

The intended outcome of this project would be a largely qualitative analysis, supported by evidence from network simulations. The analysis of the simulation will compare the construction of existing large-scale networks to the adaptive structure modelled by *Physarum.* The conclusion will also compare the use of *Physarum* to the use of other biological networks as a model for fault tolerance, and compare the relative merits of each.

Start Point:

Exploration of cellular modelling software using existing simulations, design of simulation to test fault-tolerant properties, based on the mathematical models of *Physarum* behaviour described in Taro, Jones and Gunji.

Timeline:
November - preliminary reading and literature review, initial exploration of software
December 5th - full project outline and experimental design
December to January - construct simulations, run experiments
February 1st - finish experimental work, analysis of results
February - further reading, comparisons with other bio-inspired networks
March - write-up

Resources:

Tero et al (2010): Rules for Biologically Inspired Adaptive Network Design, Science, Jan 22, 2010, Vol.327(5964), p.439

Lio et al (2007): Bio-Inspired Computing and Communication, First Workshop on Bio-Inspired Design of Networks, BIOWIRE 2007 Cambridge, UK ,Springer

Jeff Jones (2016) Applications of multi-agent slime mould computing, International Journal of Parallel, Emergent and Distributed Systems, 31:5, 420-449

Gunji et al (2008) Minimal model of a cell connecting amoebic motion and adaptive transport networks, Journal of Theoretical Biology 253 (2008) 659– 667

William Butera (2002), Programming a Paintable Computer, PhD thesis for the Media Arts and Sciences Program, MIT

Michael Joseph Broxton (2005), Localization and Sensing Applications in the Pushpin Computing Network, MA thesis, School of Electronic and Computer Engineering, MIT