Intelligence for Wireless Networks

Nicholas J. Kaminski – kaminskn@tcd.ie
Research Fellow
EUCNC 5G Testbed and Hands-On Experimental Research Workshop
29 June 2015
The Problem

- Communication systems complexity is on the rise
  - Increased density, heterogeneity
  - Multiple paradigms for resource usage

Solution

- **Pervasive intelligence**
  - Beyond centralized – agents should work together autonomously
  - Still needs management
  - Need to become beekeepers of Networks

Emerging Intelligence

• Ernst Mayr, *The Growth of Biological Thought* 1982
  • “Systems almost always have the peculiarity that the characteristics of the whole cannot (not even in theory) be deduced from the most complete knowledge of the components, taken separately or other partial combinations. This appearance of new characteristics in wholes has been designated as emergence.”

• Two parts of Interactions:
  1. Distribution of goals
  2. Structure/mechanisms for interaction

• Examples from several disciplines
  • Biology, Urban Planning, Economics, Mathematics, Telecommunications
Telecoms Interactions Example

• **Complexity Theory**
  • Entropy, measures of complexity
  • Graph based modelling of interaction structures

• **Agent-Base Modelling**
  • Game of Life, Boids
  • Cellular Autonmata

• **Network Scenarios**
  • Channel Assignment

Macaluso, I.; Cornean, H.; Marchetti, N.; Doyle, L., "Complex communication systems achieving interference-free frequency allocation," *Communications (ICC), 2014 IEEE International Conference on*, vol., no., pp.1447,1452, 10-14 June 2014
Macaluso, I.; Cornean, H.; Marchetti, N.; Doyle, L., "Complex communication systems achieving interference-free frequency allocation," *Communications (ICC), 2014 IEEE International Conference on*, vol., no., pp.1447,1452, 10-14 June 2014
Building Bees

• **Bee Qualities**
  • Discrete, Simple Individuals
  • Common overall goal
  • Defined interaction structure

• **Behaviour Based Robotics**
  • Brooks and Mataric
  • Several behaviours operating simultaneously to reach a goal
  • Each behaviour focuses on single aspect of goal
  • Behaviours combined as weighted sum

http://www.wired.co.uk/news/archive/2012-10/03/robot-bee-brains
Behaviour Based Radio Bees

• **Goal:**
  • Construct groups of radios that work together in an autonomous, but guided manner (likes bees)

• **Behaviour Based Robotics!**
  • Composition of several behaviours tailored to particular subtasks
  • Allows behaviours for guidance actions

• **Problems:**
  • Domain space mapping
  • Behaviour Selection
Example Behaviour: DESYNC

- Time updating behaviour
  - Slots are organized in a phased fashion
  - Nodes listen for slot start beacons
  - Beacon time in each node is adjusted to the midpoint of adjacent nodes
  - Allows distributed TDMA in one-hop networks

Example Behaviour Radio System

- **Scenario:**
  - Opportunistic, one-hop radio network

- **Behaviours:**
  - Distribution – DESYNC
  - Avoidance – Make way for interruptions
  - Aggregation – Basic frequency rendezvous protocol for finding friends
  - Dispersion – Channel reassignment for leaving occupied channels

- **Goal:**
  - Examine the control of interactions through tuning of behaviours

Controlling the Reaction to New Comers

• No explicit protocol was used for new nodes to join a network
• Joining is instead controlled by the Avoidance behaviour
  • Nodes listen before transmitting
  • Nodes wait for ACKs before continuing
• Details of waiting for ACKs control the openness of the society
  • If individual ACKs are required for each packet, the network is open to joins
  • If group ACKs (one ACK for X number of packets) are allowed, the network is closed to joiners

Open Society

Lock Out

Importance of Experimentation

• Recall that emergence arises from the interactions within a complete system
  • The realities of RF communication certainly contribute here
  • Implementation offers the best available method to capture interactions in a realistic environment

• Simulations often provide misleading results
  • Interactions are shaped by real limitations or phenomena (finite delays, radio hardware linearity limitations, etc.)
  • Simulations tend to use approximations or assumptions that reshape the nature of these interactions
Impact of FIRE Platforms

• FIRE Opens an new set of platforms to examine the design of emergent intelligence in radio systems
  • Large scale platforms provide the environments necessary to assess the scalability of the approaches
  • Experimentation tools and services allow straight forward interfacing to facilities
Further Steps

- Guided emergent intelligence for radio systems is in early stages
  - Only initial investigations of approach exist
- Much more investigation is needed
  - Selection and testing of individual behaviours
  - Creation of effect controlling mechanisms
  - Validation of approaches for deployment
- FIRE offers the platforms needed
- Provides potential solutions for looming problems
Thank You