Example

Decentralised, Evolving, Large-scale Information Systems (DELIS) FP6 FET IP

Kick-off meeting

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An Example to Clarify

Consider a job delegation scenario:

- A network of many peer nodes
- Jobs arrive at the nodes
- A node i may pass node j a job
- Node j may perform the job or ignore it
- If j does the job credit goes to node i only even though j expends the effort (a cost)
- For an ignored job no node gets credit

A desirable property

If we assume that:

- the behaviour of nodes obtaining high credit tend to get copied to other nodes
- new nodes periodically enter the system (with variants of behaviour)

It would be desirable to minimise the number of ignored jobs

Candidate Solutions

Scenario bears *some* comparison with models of the evolution of cooperation and altruism

- “Reciprocal Altruism” Trivers (1971)
- “Evolution of cooperation” Axelrod (1980)
- “lattice topologies” Nowak & May (1992)
- “Image scoring” Nowak & Sigmond (1998)
- “Tag based” Riolo et al (2001)

Evaluation

- Reciprocation requires repeated interactions with the same uniquely indefinable individuals, memory of past interactions and has low noise tolerance
- Strict topologies like a lattice might not be practical and these studies did not promote high levels of cooperation anyway
- Image scoring, spreading information about the behaviour of nodes (“gossip”), more promising, in fact detailed work already independently done at Bologna in the BISON project (Jalasity, Montresor, Babaoglue) demonstrates its effectiveness.

A very simple PD tags model

- agents (nodes) marked with a tag (a binary string of length L)
- single bit codes behaviour (strategy)
- resource donation = Cooperate (1)
- resource non-donation = Defect (0)
- each agent is paired with a random other to play a round of PD

The Prisoner's Dilemma

Given: $T > R > P > S$ and $2R > T + S$

Player 1 / Player 2	C	D
C	R, R	S, T
D	T, S	P, P

Result is all defection

If we assume that:

- strategies and tags of agents obtaining high credit tend to get copied
- periodically agents randomly mutate tag and strategy bits

Then the result of this evolutionary process will be all defection – since a defector never gets less credit from an interaction than its partner. This is an ESS the Nash Equ.

Biasing by Tag

- But if we bias partner selection to those with matching tags (if any exist)
- We get unstable yet high levels of cooperation
- Produced via a dynamic group formation and dissolution process
- Remember: tags mutate and are copied just like strategies

Results

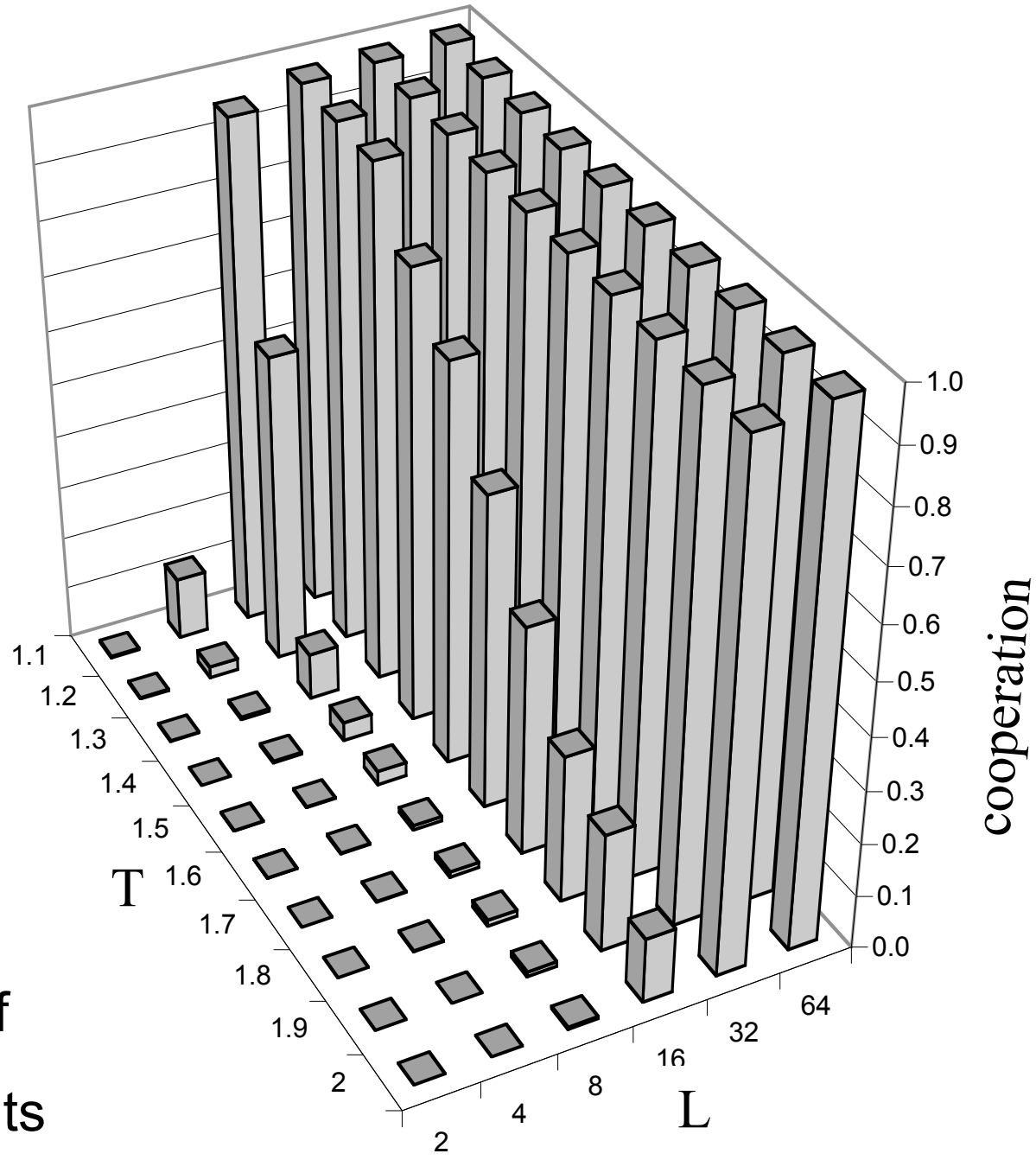
Cooperation increases:

- as T decreases
- as L increases

Each bar an average of 5 runs to 100,000 generations with different initial random number seeds

T = temptation payoff

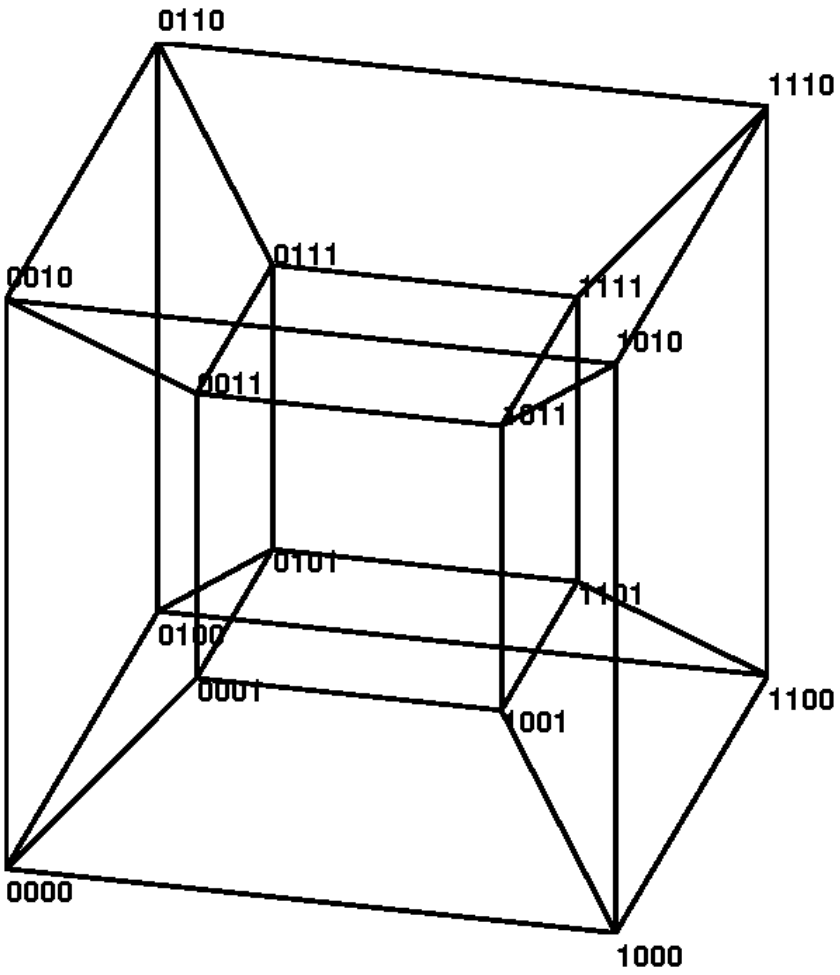
L = length of tag in bits



What's happening?

- We can consider agents holding identical tags to be sharing the corner of a hyper-cube
- Interaction is limited to agents sharing a corner (identical tag bits)
- Therefore cooperative "groups" are emerging in these corners

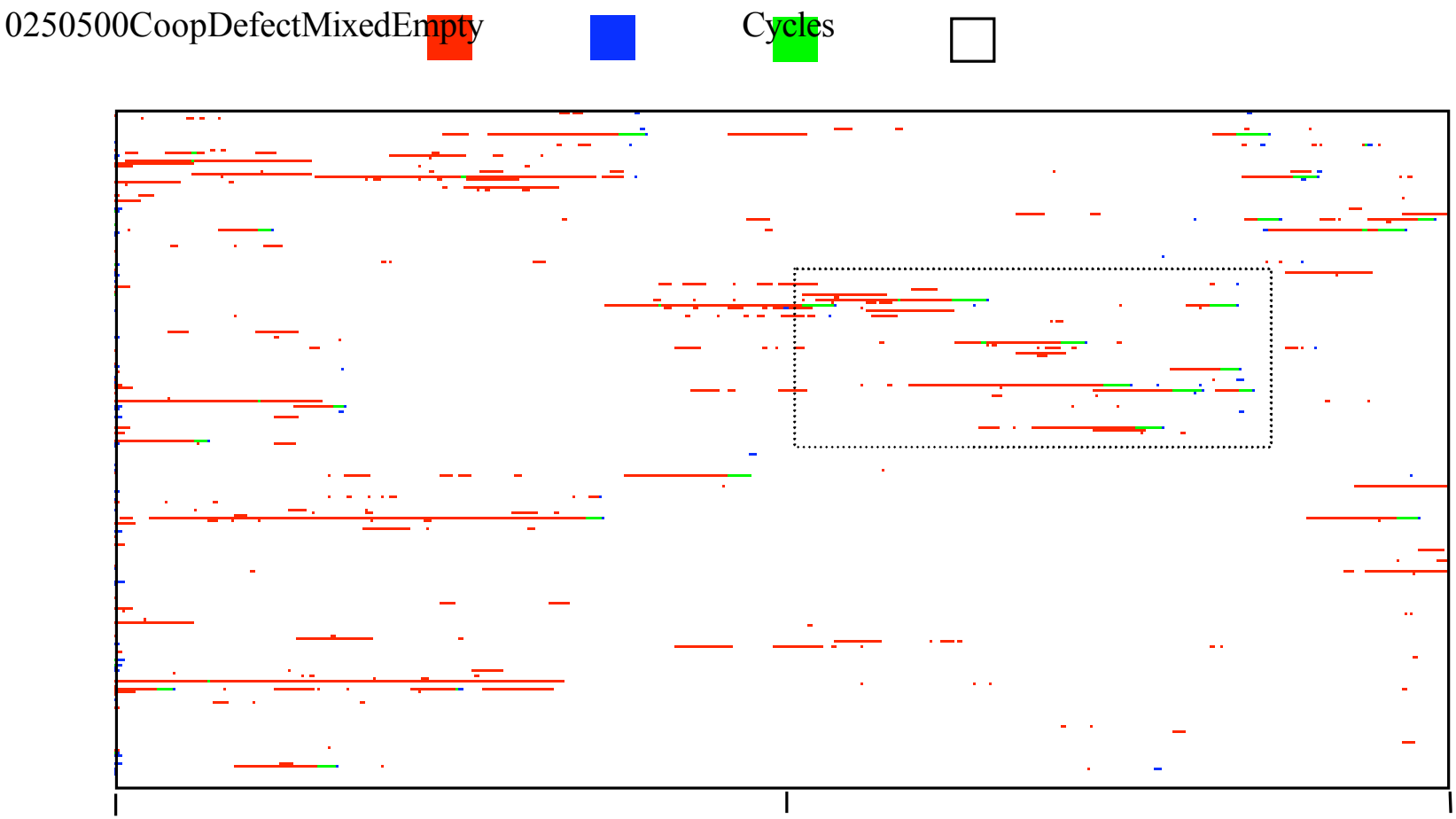
A hypercube for 4 bit tags



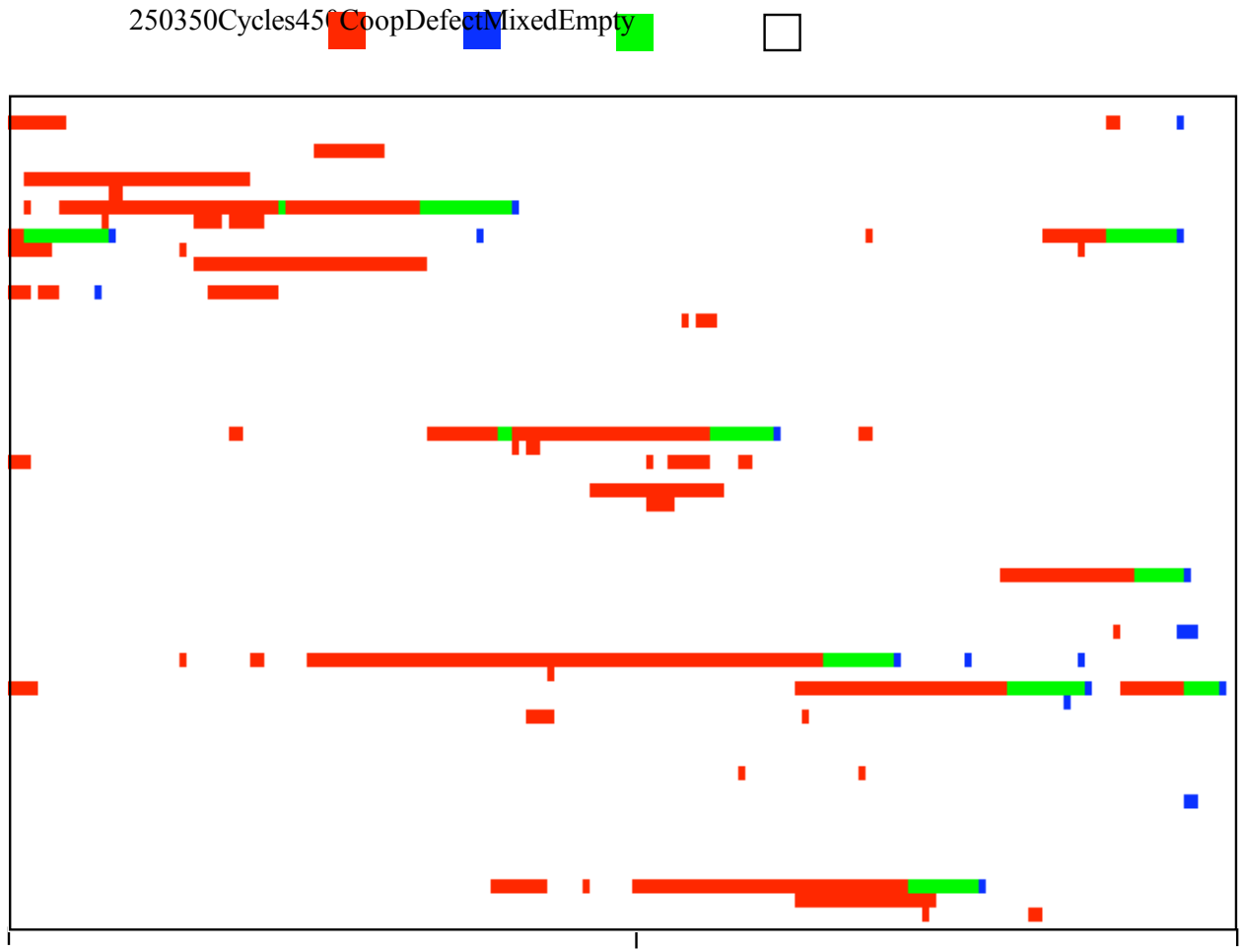
To visualise the process in time we produce a graph in which each horizontal line represents a single unique corner of the hypercube (set of unique tag bits)

We colour each line to indicate if it is occupied by all cooperative, all defective, mixed or no agents

Visualising the process



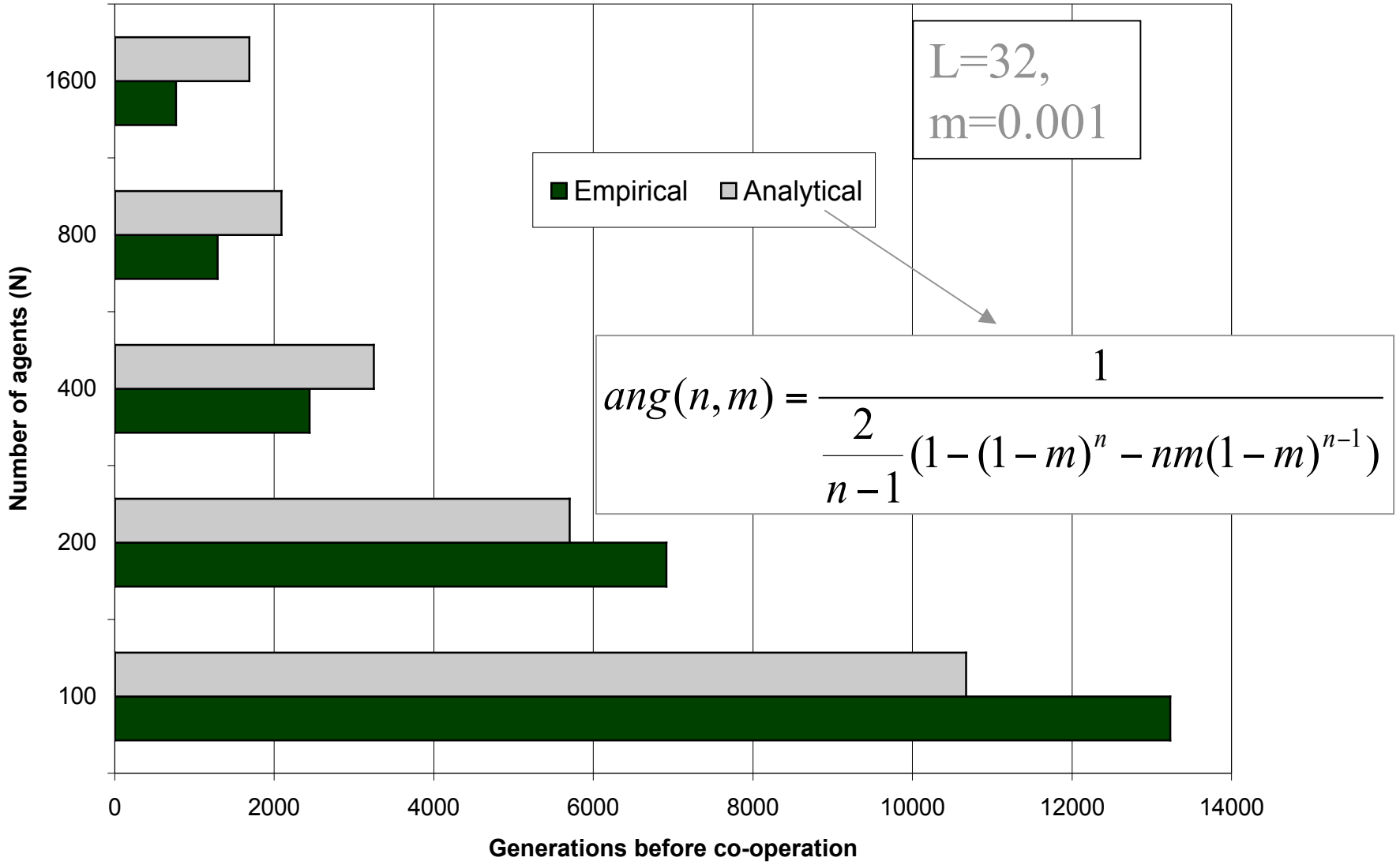
Visualising the process



What's happening?

- Defectors only do better than cooperators if they are in a mixed group (have cooperators to exploit)
- But by exploiting those cooperators they turn the group into all defectors quickly
- Agents in an "all defective group" do worse than agents in an "all cooperative group"
- Agents within an all cooperative group will out perform an all defective group – mutation of tag bits spreads the cooperative strategies to neigbouring corners of the hypercube

Reverse scaling property



Possible next step

- These results are all very well but does the dyadic PD really capture the salient features of original stated problem?
- To operate there has to be an efficient (scalable) way to pair agents with matching tags (currently this is assumed not emerged)
- Does it make sense to model nodes following this kind of evolutionary process over time?
- The promising results but open questions suggests next step – apply in a simulation scenario more closely resembling the original problem

Summary

- Here I have outlined in a little detail just one possible problem area (cooperative resource sharing) and one potential novel mechanism (tags), *my own current obsession*
- I have done this to indicate the kind of method we intend to follow – importing ideas from other areas using simulation
- Of course there are many others, much work has already been done within the BISON project eg: Ant algorithms, Gossip based protocols etc.

References and Links

- Trivers, R. L. (1971) The evolution of reciprocal altruism. Q. Rev. Biol. 46:35-57.
- Axelrod, R. (1980) The evolution of cooperation. Basic Books, New York.
- Nowak, M. & May, R. (1992) Evolutionary Games and Spatial Chaos. Nature, 359:826-929.
- Nowak, M. & Sigmund, K. (1998) Evolution of indirect reciprocity by image scoring. Nature, 393:573-577.
- Riolo, R., Cohen, M. D. & Axelrod, R. (2001=, Cooperation without Reciprocity. Nature 414,:441-443.
- Bison publications http://www.cs.unibo.it/bison
- My stuff on tags http://www.davidhales.com