Abstract—The routing and flow control problems in communication networks are considered in this progress report. The problem is cast into an agent/resource allocation model referred to as a computational ecology. To achieve this, data packets are considered as agents and outgoing links from nodes as resources. The report covers the basic theoretical computational ecology model as well as its application to telecommunication networks. Further work and applications of the computational ecology model are also discussed.

Index Terms—Computational Ecology, Routing, Flow control

I. INTRODUCTION

Various models have been developed to deal with the problem of routing and flow control in communication networks. For efficient data transfer data need to travel along optimal paths concerning the path ‘length’ and path congestion. The approach taken here is one of an agent/resource allocation model considering data packets as agents and the outgoing links from a node as resources [1]. This approach allows for the routing and flow control problem to be collapsed into a single mathematical model. Link selection becomes a function of traffic levels as well as best paths. The approach proves to achieve superior results compared to static routing and also to certain dynamic routing protocols as can be seen in [1].

II. ROUTING

Routing concerns itself with finding the optimal paths from one node in a network to another. Optimality of a path is based on optimizing a suitable metric or combination of metrics.

III. COMPUTATIONAL ECOLOGY MODEL

A. Overview

The computational ecology model as introduced by Hogg and Huberman is an agent/resource allocation model describing the macro evolution of an agent based system. Agents are individual units in the system with a certain degree of ‘intelligence’ or ability to act and make decisions influencing the system. Typically an agent can be a computer program, a human or a simpler unit. Resources are the sources used by the agents such as processing time or link capacity etc. Agents compete for and select resources. These selections are based on some preference or reward to the agent and this is modeled by probability functions and payoff vectors.

A discretized version of the dynamic model derived by Hogg and Huberman in [3] is described by the equation

\[ f_i(k+1) = f_i(k) + \alpha (\rho_i(k) - f_i(k)) \] (1)

where
- \( f_i(k) \) the fraction of agents using resource \( i \) at time \( k \)
- \( \alpha \) the degree of change of \( f_i(k) \)
- \( \rho_i(k) \) the probability of agents preferring resource \( i \) to other resources

B. Extended Model with Reward Mechanism

Hogg and Hubermann found that in the case of delay and uncertainty of information the model could exhibit chaotic behavior [4] and introduced a stabilizing mechanism [2]. This mechanism alters equation (1) to take the following form as can be seen in [1].

\[ f_{rs}(k+1) = f_{rs}(k) + \alpha (f_{sr}^{res}(k)\rho_{rs}(k) - f_{rs}(k)) + \gamma (f_{rs}^{res}(k)\eta_s(k) - f_{rs}(k)) \]

\[ f_{rs}^{res}(k) = \sum_r f_{rs}(k) \]

\[ f_{sr}^{res}(k) = \sum_r f_{rs}(k) \]

\[ \eta_s(k) = \sum_r f_{rs}^{res}(k)G_r(k) \] (2)

where
- \( f_{rs} \) fraction of agents with strategy \( s \) using resource \( r \)
- \( f_{sr}^{res} \) fraction of agents using resource \( r \)
- \( f_{sr}^{str} \) fraction of agents using strategy \( s \)
- \( \gamma \) rate of change of strategies
- \( G_r \) payoff function of resource \( r \)
Fig. 1 Conceptual diagram of a node indicating the different agent groups and available resources (links)

Using the model corresponding to eq.2, introduces different strategies into the original model. Simply explained a strategy is a bias added to a payoff.

IV. COMPUTATIONAL ECODYM APPLIED TO THE ROUTING PROBLEM

For the specific case of applying the computational ecology model to the routing problem, packets are considered as agents and outgoing links as resources. Modeling is done individually at each node and only local information is assumed to be immediately available to the decision process.

Considering a single node, packets with the same destination are grouped together as seen in Fig. 1 and considered as an agent group. Eq. 2 is continually computed at each node and a data rate equal to \( f_{r}^\alpha(k) \) is sent via link \( r \) at time \( k \). The payoff function is of importance as this term allows integration of information concerning topology and congestion into the model. \( G \) would typically take a functional form

\[
G = g \left( \frac{C_r}{C_a}, \frac{B_r}{B_a}, H_r \right)
\]

(3)

where

- \( C_r \) the capacity of link \( r \)
- \( C_a \) the capacity of other links
- \( B_r \) average buffer length at link \( r \)
- \( B_a \) average buffer length of other links
- \( H_r \) number of hops from current to destination node

The probability of preferring one resource to the others, \( \rho \), carries information of congestion in the network and would take a form

\[
\rho = p \left( f_{rs}, \frac{C_r}{C_a} \right)
\]

(4)

The model is run continually at all nodes and adapts to any disturbances continually.

V. RESEARCH AIDS

Currently a thorough simulation of the principle is being implemented as effects of protocols and network dynamics needs to be taken into account more comprehensively. Other applications of the computational ecology model are also looked at and the author has had some success applying the model to the optimal assignment problem.

VI. CONCLUSION

The computational ecology model seems a viable concept for routing in communication networks with Yamasaki and Ushio finding promising results using simulation. Additional and thorough verification is however necessary. The model as applied by Yamasaki and Ushio need refining and much adaption to be compatible with existing protocols.

REFERENCES


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