Proposal
to Examine Flow
on a Rectangular Grid

1. Background

The basic problem of traffic flow appears in several guises, specifically, in vehicular traffic on road networks and in packet flow through electronic networks. This proposal is to study flow in the abstract, and will refer to the mobile entities as “tokens”, which move along “vectors”, and the points of connection as “nodes”. When tokens are moving in one direction through a node, it is assumed that flow in the other direction is blocked. In the case of vehicular traffic, the tokens are vehicles, the nodes are road segments, and the nodes are intersections. In the case of electronic networks, the tokens are packets, the vectors are network connections and the nodes are packet switches.

This proposal is to use a rectangular grid as the underlying topology. This is more general than it perhaps sounds, as the degree of difficulty of any vector need not be the same. The degree of difficulty of any vector may be described as an impedance. The use of impedance, rather than resistance or length, is done in order to capture time-dependent behavior (that is, flow is time-dependent, and phase information is likely important).

The specific problem is to try to delineate a set of rules, which may be applied by an intelligent node, to increase the flow through the node. The use of a set of rules to be applied locally is due to the scaling of complexity when progressively larger sections of the network are considered.

2. Problem to Be Solved

A rectangular grid of 100 by 100 lines of vectors will be constructed. That is, 100 lines of vectors will run vertically, and 100 lines of vectors will run horizontally. Nodes are where these lines of vectors cross. A single vector is a connection from one node to another. Tokens are introduced onto the grid along the edges. The distribution of tokens, as a function of line number and as a function of time, is a variable.

The degree of difficulty a token has in traveling along any vector is a variable. A single (complex) quantity, or a more structured quantity may be chosen. This degree of difficulty may describe latency between nodes (“length”), or it may describe bandwidth between nodes (“number of lanes”).

The means of control of a node is another variable, indeed, it is the variable of primary concern in this study. A set of heuristic rules will be developed and tested. The node will be expected to select from a prioritized list of rules, depending upon the situation as known to the node. The rules are expected to be parameterized by data collected locally.

For example, parameters will most likely include the number of tokens attempting to cross the node, and the ratio of the number of tokens in each direction at the node.

The heuristics will be generated by the node by applying a Bayesian estimation to the values of variables as determined by data locally available to the node. Information may be exchanged between nodes, but any such communication will be between nearest neighbors only. This restriction to nearest neighbors is predicated upon the observation that tokens move between nearest neighbors, and that communication among nodes must not have any bottlenecks.

3. Computation

This problem may be scaled in several ways. First and most obvious I suppose, is the size of the grid of nodes may be increased. This allows the detection of the size of the grid which removes the effects of the edges.

The second scaling is by testing the effects of different distributions of tokens introduced along the edges. The spatial and temporal distributions may both be explored.

The third scaling is by varying the degree of difficulty of each vector. Recalling that this is assumed to be a complex impedance rather than a simple resistance, a two dimensional search must be allowed. Also, individual nodes may be assumed to be non-blocking. Or, the number of phases (or dead-time) may be studied.

The fourth scaling is in the degree of difficulty of computing the heuristics used locally by each node in its local effort to maximize its own utilization. Whether maximum flow, or minimum latency, of tokens is the best measure is another variable.

Thus, overall, there is a several dimensional parameter space to be explored in addition to the simple size of the grid itself.