Fairness Metric and its Shortcomings

The fairness metric is a measure of the minimum percentage of each group’s demand that must be satisfied. It is calculated by setting the ratio of the power that each group received divided by the power demanded to be greater than or equal to a percentage. This metric forces all the groups to have at least threshold of their demanded power met. A low percentage value indicates that there is high variability in the percentage of power that each group gets. A high percentage value indicates that group will have low variability in the percentage of power received. For the original LP model, the fairness metric was 63%. This indicates that at least 63% of the power demanded by each group was satisfied. Since this is true, the variability is relatively moderate. The majority of the groups were supplied close to this number of 63%, but there was one outlier of around 75%. This result implies that this group is essential to the other groups meeting their power demands.

Our metric stresses that groups get at least a certain percentage of power demanded, but there is no upper constraint except for maximum capacity. This means that with an ‘a’ value of 60%, every group will get at least 60%, but one could get 60% and another could get 90%. Another concern is smaller groups that demand less power. While these groups will get the same percentage of power, 40% less power in a small group could be much more detrimental than that of a larger group. One final concern, is that our metric doesn’t concern the individual nodes of each group. There are no implications of this being a problem in this scenario, but if each of those nodes are cities and two nodes have 100% and the other has 20%, while the group still has 60%, one city is scavenging for power.

Linear Programing Model for Fairness

The original LP model was changed to formulate a model that maximizes the fairness metric described earlier. The variable, a, represents the percentage of demand that each group must receive. The goal of this model is to maximize fairness, so the objective is maximize “a”. This maximizes the percentage of demand that is satisfied for each group. In order to complete this model, two constraints are added. First, the fairness metric must within the range 0 and 1. Secondly, for each group, the percentage of the demand satisfied must be greater than or equal to “a”. This is displayed as the last constraint in the LP model, and is written as the summation of yi, representing demand satisfied in a group must be greater than or equal to ‘a’ times the summation of di, representing demand for each group.

*Parameters:*

*A = set of arcs*

*N = set of nodes*

*= maximum capacity of each arc,*

*= maximum demand of each node,*

*= set of nodes in group j*

*Variables:*

*=flow on arc a,*

*=demand satisfied at node i,*

*a = minimum percentage of demand that each group received*

*Linear Program:*

*s.t*

Fairness Metric Implementation

The result of the optimization model yielded a fairness metric of 0.603. This indicates that enough power was distributed to each group to satisfy 60.3% of their demand or more. The total demand satisfied was constant at 99 units of energy. This fairness metric distributed the power more evenly among the groups, unlike the solution to the first problem.

Trade-off Curve of Fairness and Demand Satisfied

Integer Linear Model to Increase Network Capacity

*Parameters:*

*A = set of arcs*

*N = set of nodes*

*= maximum capacity of each arc,*

*= maximum demand of each node,*

*t = maximum number of hours spent on installing bolts*

*Variables:*

*=flow on arc a,*

*=demand satisfied at node i,*

*= number of bolts added to arc a,*

*Linear Program:*

*s.t*

Trade-off Curve of Time and Power Delivered