Allocation of corridors using max-min fairness criteria

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Problem Definition

- Multiple exchanges share the network for transportation of power. The network is meshed. Each branch as well as corridor has MW capacity limits, directional in nature. The exchanges inject and withdraw power at nodes of the network.

- The flows should meet the requirement of a transportation network viz., conservation of MW flow at each node or a bus.

- At certain times in a day corridors get congested.

- Lack of availability of corridors i.e., congestion in transportation network translates to loss of business for a exchange.

- Relevant question is if a network is congested then how to share the corridors among the exchanges in a fair manner.

Assumption

- In what is presented, laws of Physics, especially, KVL is ignored. This is because of the existing limitations of the regulatory framework.

- It can be addressed by improving PX management mechanism but is outside the scope of this presentation.

  - For example, PJM through LMP mechanism handles such issues as a matter of routine.

Pareto Optimality and Fairness

- In the context of competitive market equilibrium, Amartya Sen states that a state of affairs is defined as Pareto efficient or Pareto Optimal if it is the case that compared to it no one's utility can be raised without reducing someone's utility.

- Pareto efficiency is completely unconcerned with distribution of utility (or of income or anything else) and is quite uninterested in equity.

- A good corridor sharing mechanism should be both Pareto efficient and fair.

Pareto Efficeincy

- We define a measure called payoff or utility for an exchange as the volume of trade in MWs (considering both buyers and sellers) allocated to the exchange.
- We also define characteristic function for the exchange as the maximum volume that can be allocated to the exchange if it was using exchange exclusively.
- If acting alone, it does not create congestion, then it is the unconstrained optimal from bid matching.
  - Otherwise, it is constrained optimal due to congestion on the network.
- We say that an allocation is Pareto efficient if payoff of an exchange cannot be increased without reducing payoff of another.
  - If the allocations are Pareto efficient, then sum of the pay offs of the exchanges is maximized subject to network flow and capacity constraints.
- Pareto efficiency is not bothered with distribution of payoff or fairness within.

Notion of Regret

- Regret associated with corridor allocation for an exchange can be equivalenced to the loss in MW volume of business for the exchange.

- When will multiple exchanges compete for corridor ?

  - This happens when no alternative route can be shown to exist for flow of power, thus leading to curtailment in traded volume.

  - Hence, fair corridor allocation algorithm should model alternative routing to optimally use the network.

  - Since, each exchange has incomplete information (no information on requirements of other exchanges), this is to be done centrally say by NLDC.

Outline of Algorithm

- Each exchange submits its unconstrained solution i.e., injections, withdrawal schedules on network assuming a seamless network to NLDC.

- NLDC ascertains feasibility of it. If no congestion is seen, it allocates trade in full. Otherwise, it evaluates characteristic function for the exchange.

- If superimposition of trades leads to congestion, it proceeds to allocate corridors in a fair manner.

Is the congestion real?

- The first step for the algorithm is to model the set of Pareto efficient solutions. It implies that no alternate routing can be done to clear the trades without compromising requirements of another exchange.
- This step establishes genuineness of congestion and that it is not a perceived consequence of imperfect mechanism design.

Max-min Fairness

- A vector x in set X is said to max-min fair if increasing some component x_i must be at the expense of decreasing some already smaller or equal component x_j.

- A vector x in set X is said to min-max fair if decreasing some component x_i must be at the expense of increasing some already large or equal component x_j.

- Traditionally, Max- min fairness has been used in the context of resource allocation.

- Min-max fairness has been used in the context of cost allocation.

Applications of Max-min fairness

- Max-min fairness is used routinely in data networks.
- It aims at allocating as much as possible to users with low rates, and, at the same time, not necessarily wasting resources.
- It was used in the windows flow control protocol, then became very popular in the context of bandwidth sharing policies for ABR services in ATM networks.
- It is now widely used in the various areas if networking and microeconomics.
- Reference: Radunovic et. al., A unified framework for max-min and min-max fairness with applications. IEEE Trans. On Networking, Oct 2007, pp. 1073-1083.