Network Science Center at West Point

Cooperation in Information Networks

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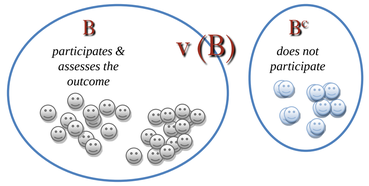
Cooperative game theory sets the context of the simulations where nodes are considered players in a network flow game and their cooperation/competition helps to determine their contributions (altruistic or selfish) to the network's performance. Various flow management schemes for a simple network are analyzed for their (altruistic and selfish) contribution.

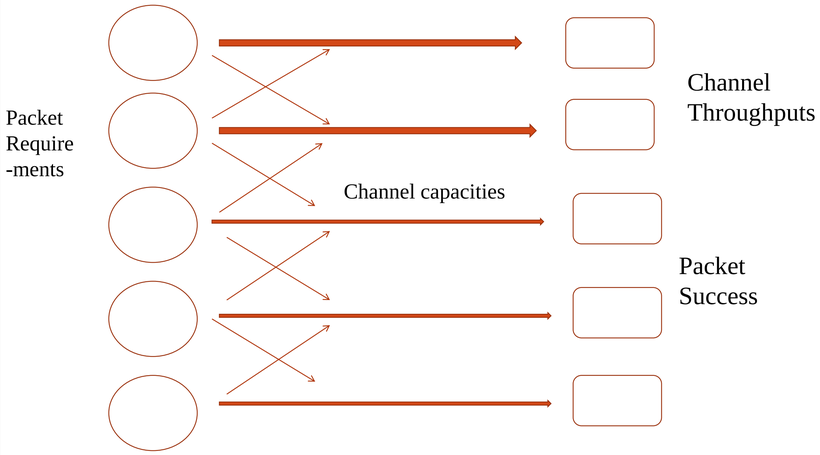
- A **cooperative game** is a set of players **T** with an **outcome** for each subset **B ⊂ T** and a **payoff (utility) function** for each outcome
- Associates a value **v (B)** to the outcome when **B** participates



DEFINITION: A **subset team game** is a set of players **T** with an **outcome** for each subset **B ⊂ T** and a **utility function** *for each outcome and each subset* **A ⊂ B**.

- Associates a value $v_A(B)$ to each subset **A** of participating players **B**

Simple (Communication) Network Flow Simulations

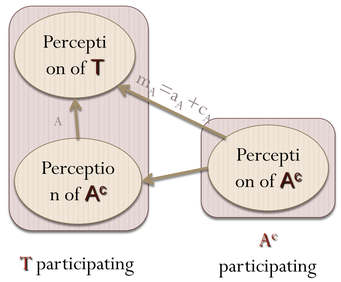


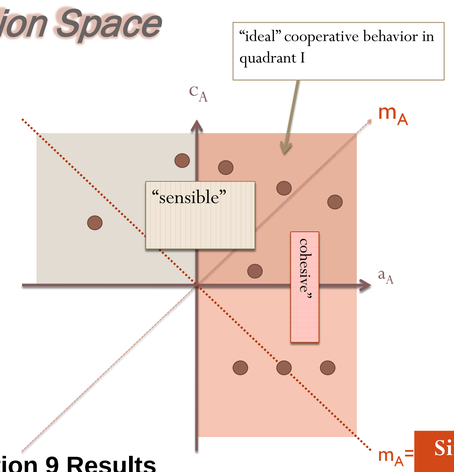
Parameters of the Network Simulations

- 20-node system
- Local sharing of channels is allowed
- Nodes know local parameters (links, capacities and requirements)
- Nodes do not know the algorithms/schemes of neighboring nodes
- Algorithms are uniform (even though nodes do not use this) – no mixed strategies
- Simulations of 10 different flow algorithms based on node strategy, node intelligence and node cooperation
- Flow might be communication (or not)

Measuring Player Contributions

Cooperation Space



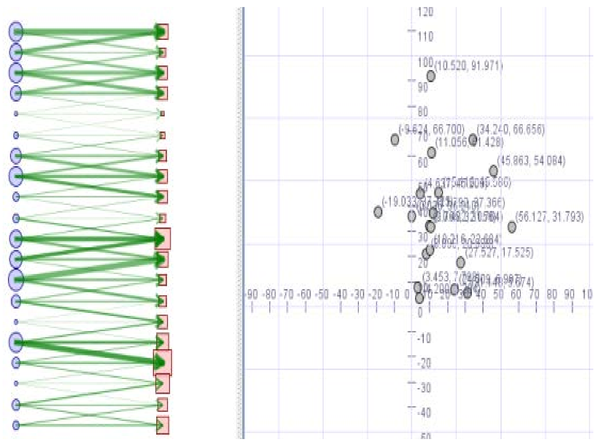


Example (Notional) Flow Data

Node #	Requirements	Capacities
1	40	70
2	20	40
3	10	30
4	70	80
5	90	10
6	20	70
7	30	20
8	50	90
9	60	40
10	80	80
11	80	50
12	0	60
13	10	10
14	70	0
15	40	90
16	100	50
17	30	20
18	50	30
19	60	100
20	90	60

- Decide on "value" or "utility" function vA(B)
  - Should make sense for individuals and for subsets of players
- Compute vT (T), vAc(Ac), and vAc (T)
  - Must consider two outcomes: with all of T participating, and with only Ac participating
- Use metrics to either
  - assess cooperative nature of the team
  - adjust behavior of players based on these metrics

Simulation 9 Results



Simulation Results

	GAME SCORE traffic passed out of 1000
Sim 1: No local awareness – each channel attempts to take care of its own requirement	**680**
Sim 2: Complete local awareness --- uses all throughput (near optimal) --- Some requirements can't be met on this heavy loaded network through local sharing	**900**
Sim 3: Completely selfish (greedy) --- tries to use local channel with highest capacity	**560**
Sim 4: Completely cooperative --- even division of load on all local channels	**781**
Sims 5: Mostly selfish --- most throughput on high channel and little on another channel	**640**
Sim 6: Mostly cooperative, but dumb (25-50-25)	**747**
Sim 7: Mostly selfish and pretty smart --- uses highest excess capacity	**560**
Sim 8: Smart and selectively cooperative – uses own channel and then seeks help when failing	**810**
Sim 9: Cooperative and Strategic – uses local channels in proportion to capacity	**869**
Sim 10: Cooperative, Strategic, & Intelligent – uses local channels in proportion to excess capacity	**842**

Cooperative Algorithms

Simulation	Selfish Contribution	Altruistic Contribution
2	47.3	3.8
4	41.1	4.8
6	39.3	4.0
8	42.6	1.0
9	45.7	2.2
10	44.3	5.4

Greedy Algorithms

Simulation	Selfish Contribution	Altruistic Contribution
3	29.4	-0.6
5	33.6	-1.0
7	29.5	-1.0