# 高级算法

# Advanced Topics in Algorithms


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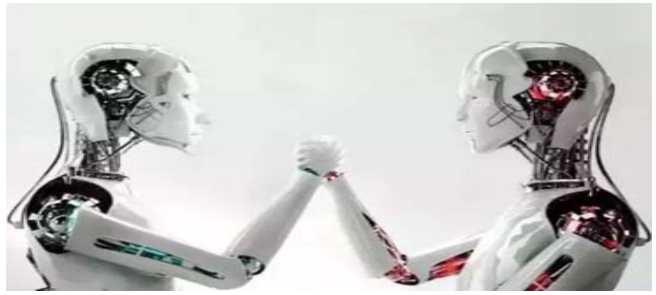
# Intelligence

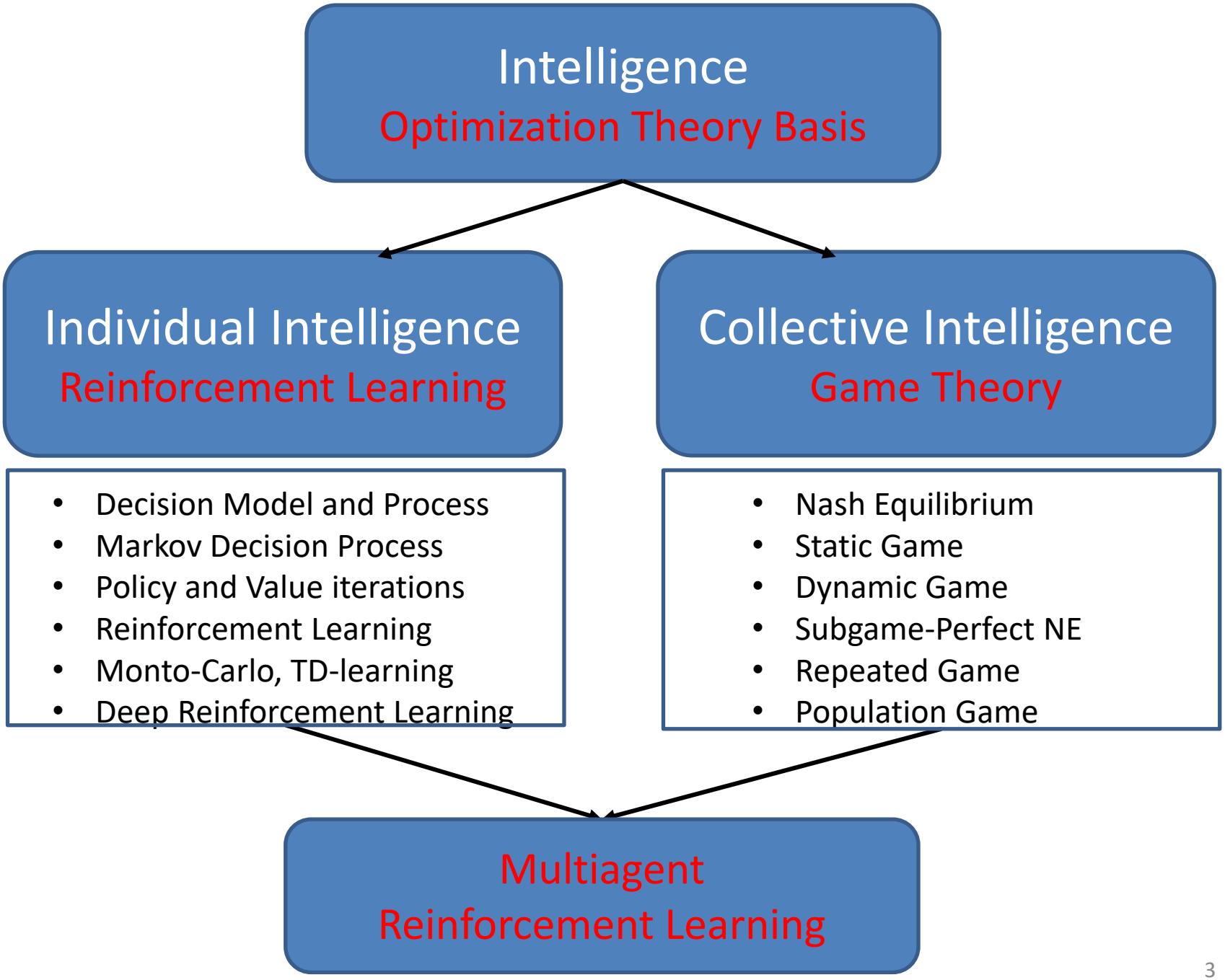
## Individual Intelligence
Reinforcement Learning

## Collective Intelligence
Game Theory

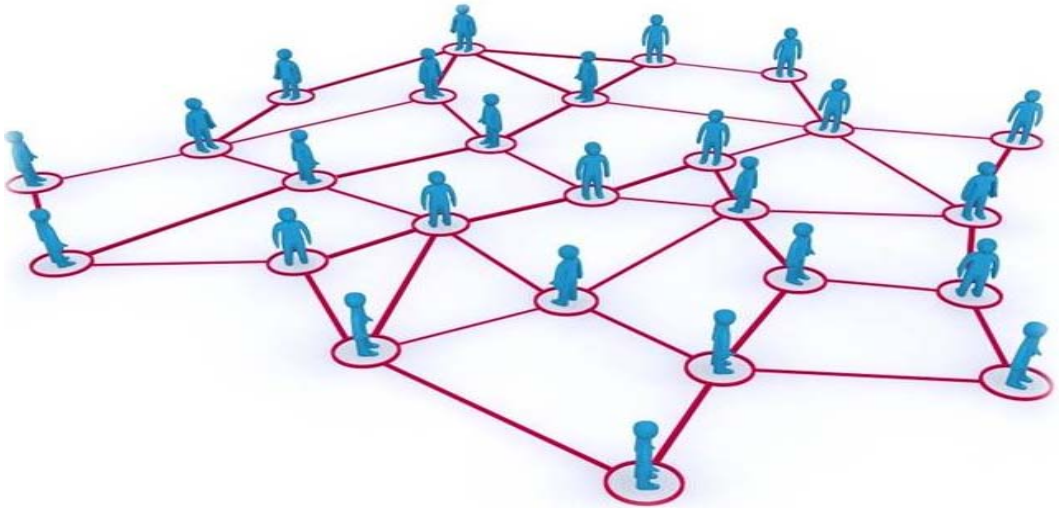
**AlphaGo**

**Pluribus**

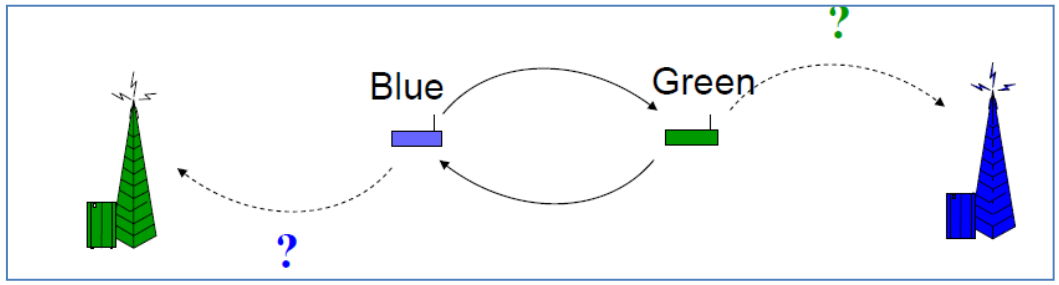




Intelligence
Optimization Theory Basis
Individual Intelligence
Reinforcement Learning
Collective Intelligence
Game Theory
• Decision Model and Process
• Markov Decision Process
• Policy and Value iterations
• Reinforcement Learning
• Monto-Carlo, TD-learning
• Deep Reinforcement Learning
• Nash Equilibrium
• Static Game
• Dynamic Game
• Subgame-Perfect NE
• Repeated Game
• Population Game
Multiagent
Reinforcement Learning

# Exploit Social Trust For Cooperation: A Social Group Utility Maximization Framework



# Packet Forwarder's Dilemma



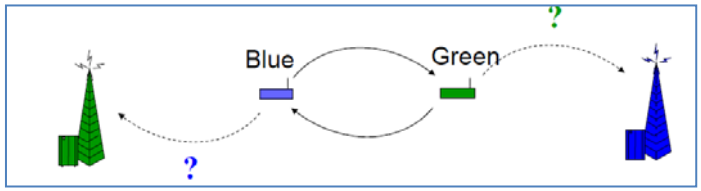

Forwarding has an energy cost of *c* *(c<< 1)*
Successfully delivered packet: benefit of 1 for packet owner

If Green **drops** and Blue **forwards**: (1,-c)
If Green forwards and Blue drops: (-c,1)
If both forward: (1-c,1-c)
If both drop: (0,0)

Each user is trying to selfishly maximize it's individual net gain

What can we predict?

# Packet Forwarder's Dilemma




Non-Cooperative Game:

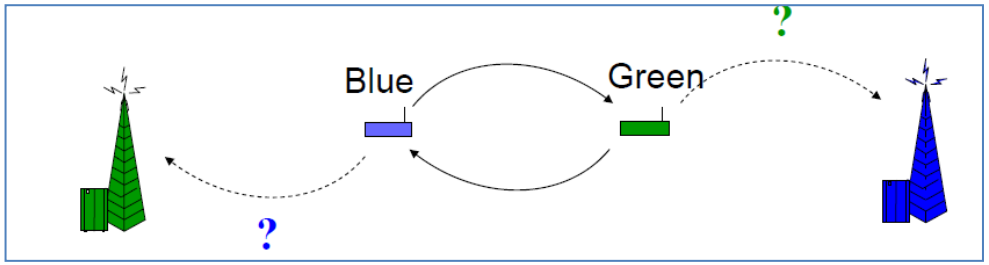
Players: Green, Blue

Actions: Forward (F), Drop (D)

Payoffs: (1-c,1-c), (0,0), (-c,1), (1,-c)

| Blue \ Green | Forward | Drop |
|---|---|---|
| Forward | (1-c, 1-c) | (-c, 1) |
| Drop | (1, -c) | (0, 0) |

# Packet Forwarder's Dilemma




| Blue \ Green | Forward | Drop |
|---|---|---|
| Forward | (1-c, 1-c) | (-c, 1) |
| Drop | (1, -c) | (0, 0) |

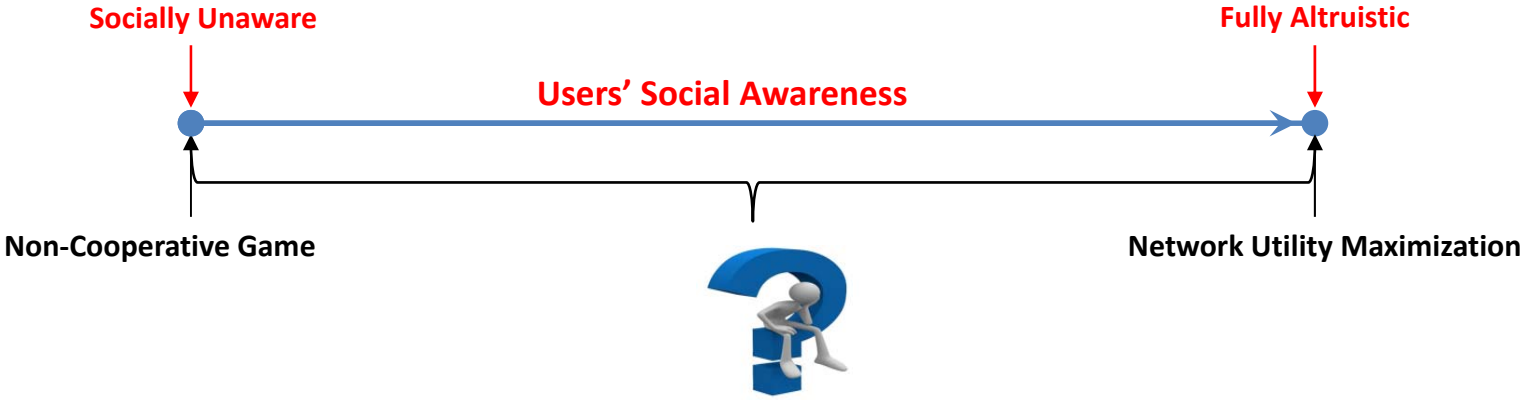
NE of the game

**Sometimes being fully rational/selfish may lead to tragedy of commons!**

# From Non-cooperative Game to Network Utility Maximization

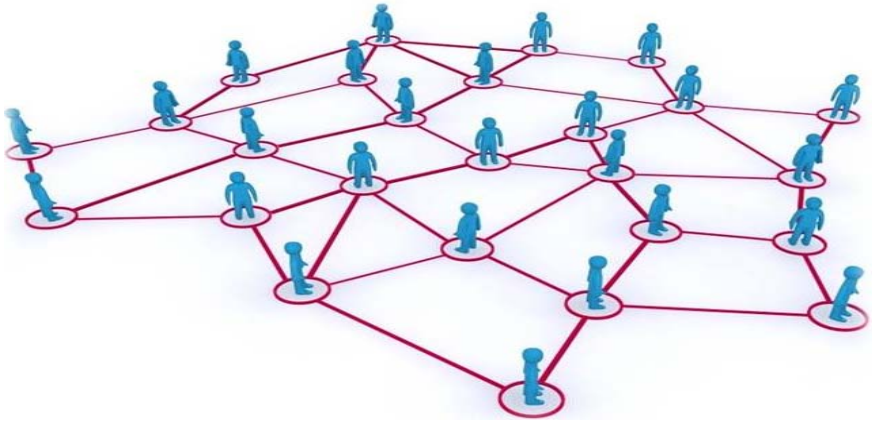
- Non-cooperative game (NCG)
  - Each user is selfish, aiming to maximize its individual utility
  - Widely applied to model strategic interaction among network entities
- Network utility maximization (NUM)
  - Users are altruistic, aiming at social welfare maximization
  - Extensively studied for network resource allocation
- NCG and NUM are two extreme cases: socially oblivious or fully social-ware

Question: What is between these two extremes?

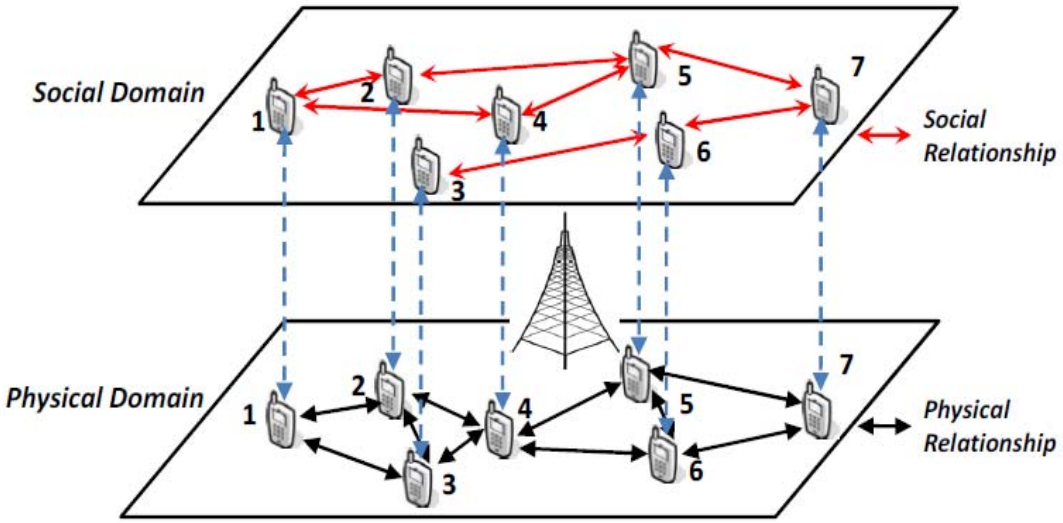


# Mobile Social Networking

- A new paradigm for mobile social networking; offer rich flexibility in modeling the continuum between NCG and NUM
  - Hand-held mobile devices are operated by human beings
  - People have diverse social relationships and care about their social neighbors at different levels (e.g., family, friends, acquaintances)
  - Explosive growth of online social networks opens up a new avenue to integrate social interactions for cooperative network design

# Social Network Overlays Mobile Network




- Physical-social coupling among mobile devices
  - Physical domain: physical coupling subject to physical relationship
  - Social domain: social coupling due to social ties among users

# Physical Graph Model

- A set of wireless users N={1,2,…,n}
- Feasible strategy set $X_i$ : User-specific, due to heterogeneous physical constraints, e.g., channel selection, power level selection

- Physical graph $G^p$={N,E$^p$}
  - Two users are connected by a physical edge if they have physical coupling
  - Capture the physical relationships among the users, e.g., interference
  - $N_i^p$: the set of users having physical coupling with user $i$

- Individual user utility $U_i(x)$
  - User's payoff under strategy profile $x$ , e.g., achieved data rate or QoS requirement satisfaction
  - Depend on the underlying physical graph, e.g., interference graph

# Social Graph Model

- Exploit social tie for enhancing mobile networking
  - Knowledge of human social ties can be leveraged, e.g., kinship, friendship, or colleague relationship

- Social graph $G^s$={N,E$^s$}
  - Two users are connected by a social edge if they have social tie
  - Capture the social coupling among the users
  - $N_i^s$: user $i$'s social group, i.e., the set of users having social ties with it
  - $a_{ij}$: strength of the social tie from user $i$ to user $j$ with $0 \leq a_{ij} \leq 1$

- Social group utility

$$S_i(x) = \underbrace{U_i(x)}_{\text{User i's utility}} + \underbrace{\sum_{j \in N_i^s} a_{ij}\ U_j(x)}_{\text{weighted sum of utilities of social neighbors of user i}}$$

  - Each user is social aware and cares about users having social tie with it

# Social Group Utility Maximization Game

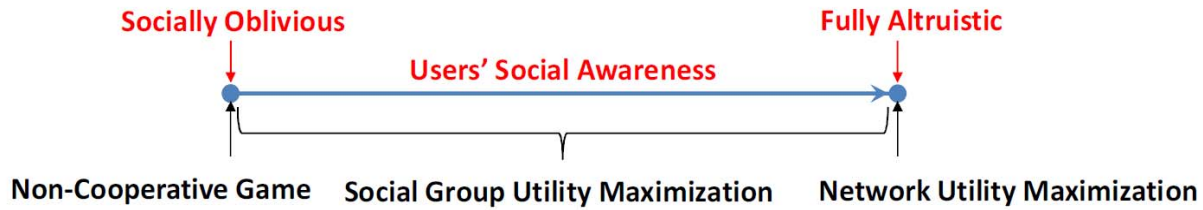
- Distributed decision making among users
  - Each user aims to maximize its own social group utility
- Social group utility maximization (SGUM) game
  - N → player set
  - $X_i$ → strategy space of player $i$
  - $S_i(x)$ → payoff function of player $i$
- Social-aware Nash equilibrium (SNE)

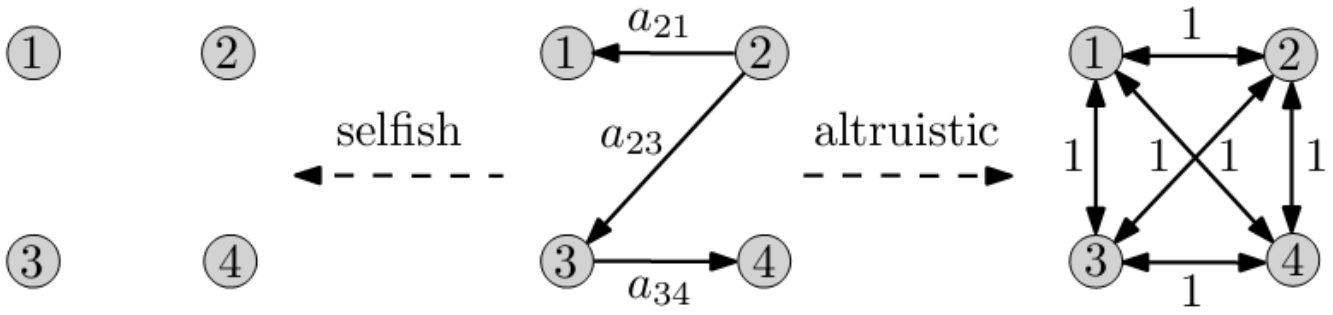
$$x_i^{SNE} = \underset{x_i \in X_i}{\operatorname{argmax}} S_i(x_i, x_{-i}^{SNE}), \forall i \in N$$

  - $(x_1^{SNE}, \ldots, x_n^{SNE})$ is a SNE if no user can improve its social group utility by unilaterally changing its strategy

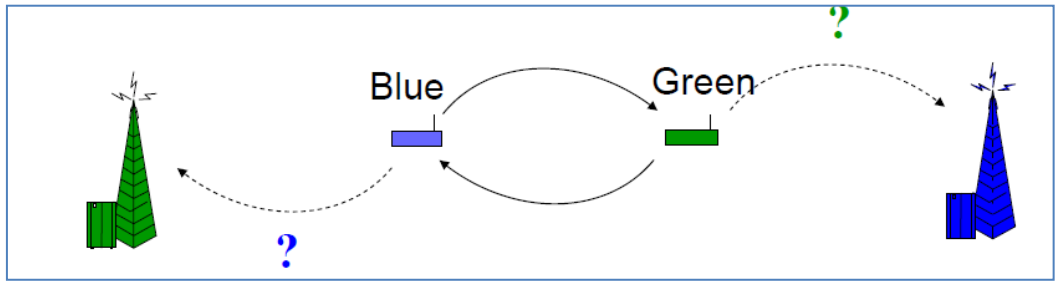
# Social Group Utility Maximization Game

- SGUM provides rich modeling flexibility
  - If no social tie exists (i.e., $a_{ij} = 0, \forall i, j$), SGUM degenerates to NCG as $S_i(x_i, \boldsymbol{x}_{-i}) = u_i(x_i, \boldsymbol{x}_{-i})$
  - If all social ties have the maximum strength (i.e., $a_{ij} = 1, \forall i, j$), SGUM becomes NUM as $S_i(x_i, \boldsymbol{x}_{-i}) = \sum_{j=1}^{n} u_j(x_j, \boldsymbol{x}_{-j})$
  - Span the continuum space between NCG and NUM



# Packet Forwarder's Dilemma: Revisited

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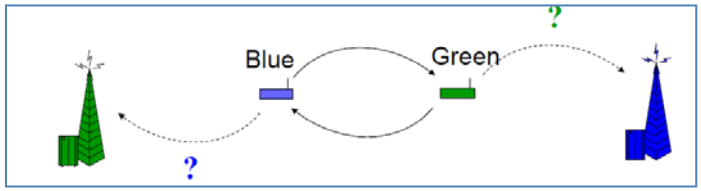
Suppose Blue and Green have a social tie of w

# Packet Forwarder's Dilemma: Revisited




**SGUM game**

| Blue \ Green | Forward | Drop |
|---|---|---|
| Forward | 1+w-c-wc, 1+w-c-wc | w-c, 1-wc |
| Drop | 1-wc, w-c | 0, 0 |

**If w>c, then (Forward, Forward) is social-aware NE!**

**A little social trust leads to efficient outcome!**

# Extensions

- Study SGUM for more applications and investigate the impact of negative social ties (e.g., malicious user)