The Challenges that Society Brings to Engineering Designs…

…and the games they play…

Jason R. Marden

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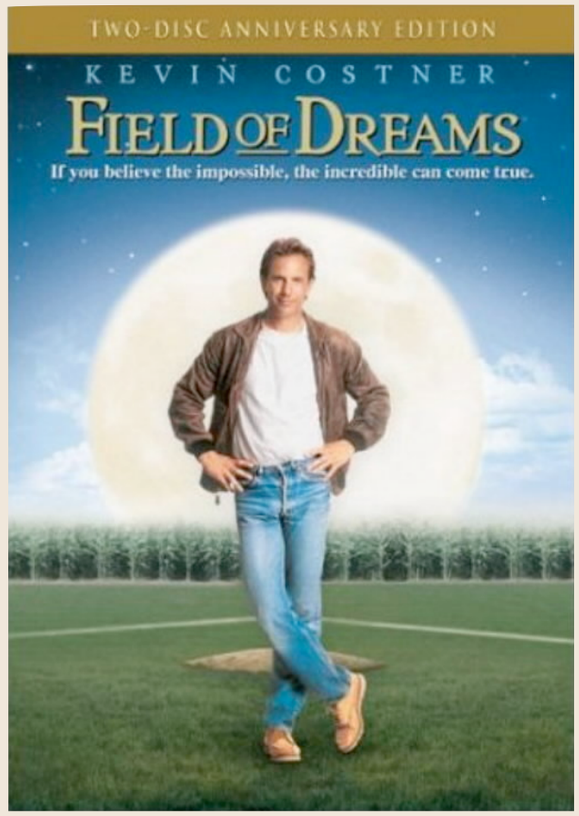
University of California, Santa Barbara
(ECE 149 - Game Theory)

Field of Dreams…



if you build it, they will come…

Field of Dreams…

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Field of Dreams…

if you build it, they will come…

but will they use it efficiently?

Goal: Determine "most" beautiful contestant

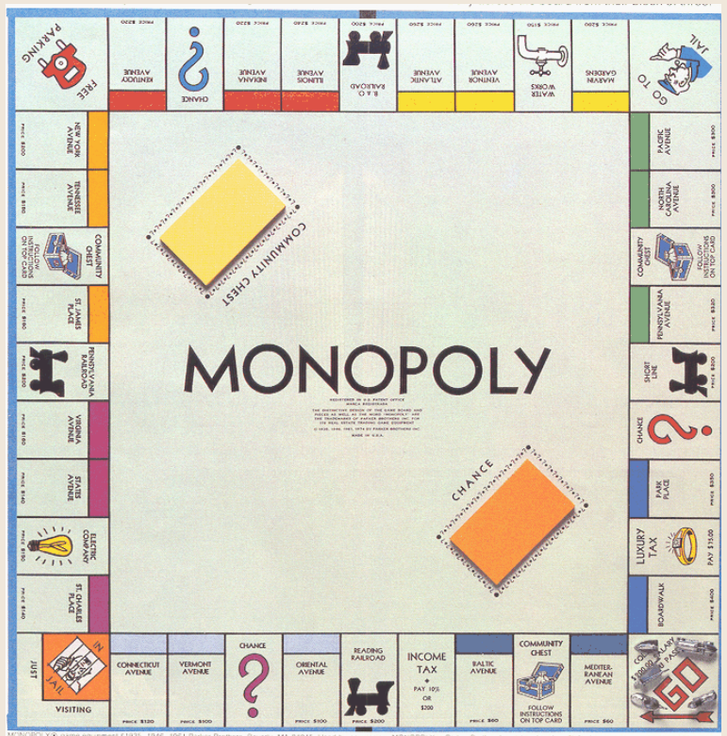
Photo courtesy of the John W. Hartman Center for Sales, Advertising and Marketing History, Duke University

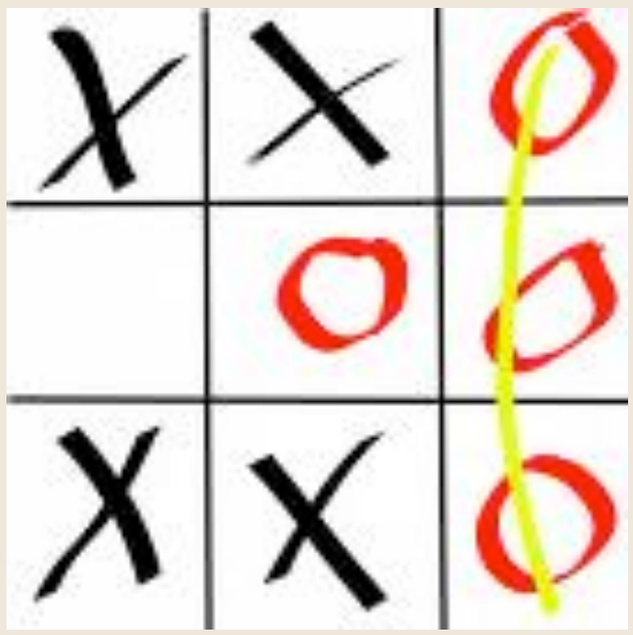
Goal: Determine "most" beautiful contestant

Photo courtesy of the John W. Sherman Center for Sales, Advertising and Marketing History, Duke University

Game Theory = Study/Influence Social Behavior

Game theory: Popular perception





Game Theory = Analysis/Influence Social Behavior

microscopic interactions → macroscopic phenomena

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microscopic interactions → **macroscopic phenomena**

↕

decision makers
choices
conditional preferences

} **"game"**

Game Theory = Analysis/Influence Social Behavior

microscopic interactions → **macroscopic phenomena**

decision makers
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} **"game"**

DMs = white/black
choices = moves
preferences = win

Game Theory = Analysis/Influence Social Behavior

microscopic interactions → **macroscopic phenomena**

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} **"game"**

DMs = drivers
choices = routes
preferences = minimize time

Game Theory = Analysis/Influence Social Behavior

microscopic interactions → **macroscopic phenomena**

↕

decision makers
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} **"game"**

Social Norms?

QWERTY vs DVORAK

traditional keyboard	optimized keyboard

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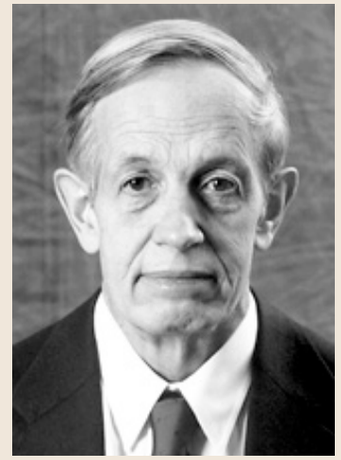

John Nash
(Nobel Prize 1994)

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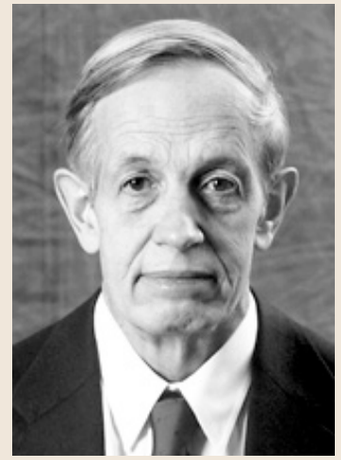

John Nash
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A Beautiful Mind

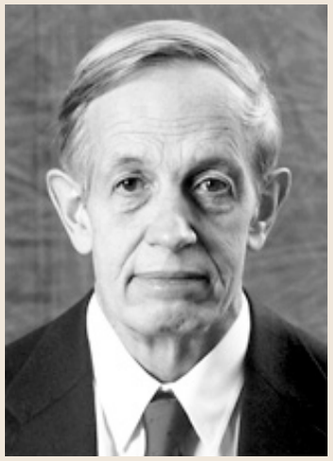
Beautiful mind

microscopic interactions → macroscopic phenomena

decision makers
choices
preferences

emergent behavior?
efficient?
coordination?

emergent behavior?
efficient?
coordination?



John Nash
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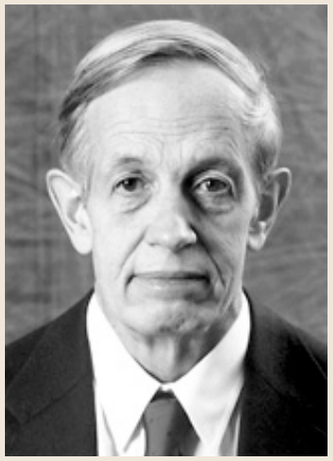
"Nash equilibrium"

Emergent behavior = Conditionally optimal choices

(i.e., best choice given choices of other DMs)

emergent behavior?
efficient?
coordination?



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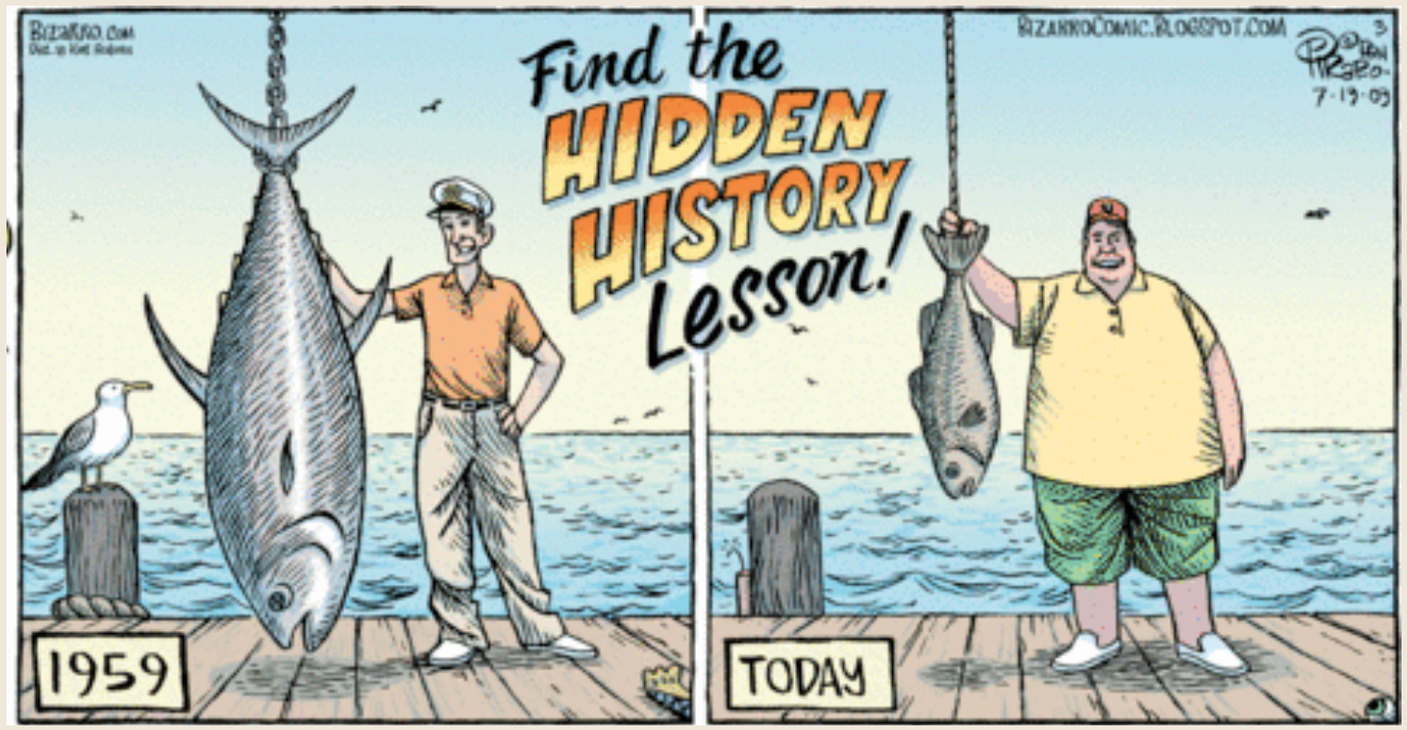
Grand Banks Fisheries

- 1950s: Endless supply of cod fish
- 1960-1970: Advancements in fishing technology
- 1990s: Collapse due to low cod populations



emergent behavior?

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Social Norms

society could adopt inferior convention

emergent behavior?
efficient?
coordination?

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Social Norms

Transportation Systems

uninfluenced traffic
can be suboptimal
(tolls not necessarily for $)

emergent behavior?
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Not Efficient Behavior!

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Social Norms

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Not Efficient Behavior!

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efficient?
coordination?

There are many mechanisms you are exposed to on a daily basis that are in place to influence your behavior

(auctions)

(overbooked flights)

(school assignments)

There are many mechanisms you are exposed to on a daily basis that are in place to influence your behavior

success story

(auctions)

(overbooked flights)

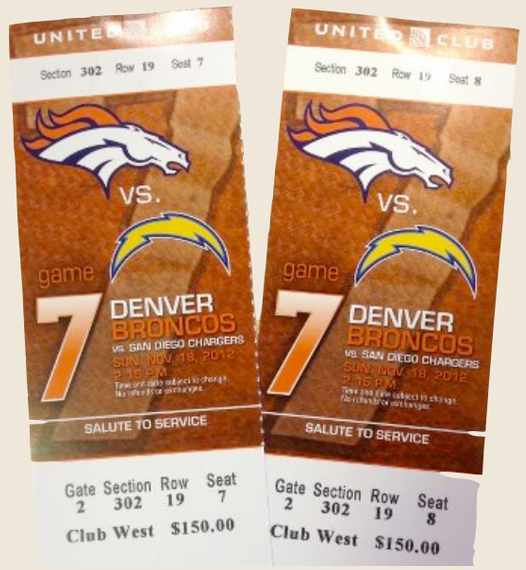
(school assignments)

Auctions

100

150

250



choices = how much $ to bid

preference = win tickets at lowest possible cost

Auctions

100

150

250

objective = optimize surplus or revenue (uncertainty)

system choice = report? who wins? payments?

Auctions

100

150

250

BIDS

80

70

175

Auctions

BIDS

100

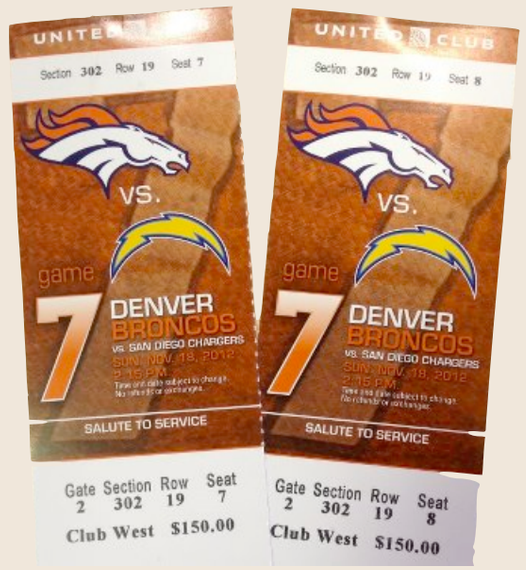
80

150

70

250

175



WINNER

Auctions

100

BIDS

80

70

150

175

250

WINNER

PAYS: $80 (second highest price)

Auctions

100

150

250

BIDS

80

70

175

WINNER

PAYS: $80 (second highest price)

Why not have Ned pay his bid $175?

There are many mechanisms you are exposed to on a daily basis that are in place to influence your behavior

(auctions)

success story

(i) optimizes social surplus

(ii) optimal to bid true value

William Vickrey (1961)
(Nobel Prize 1996)

There are many mechanisms you are exposed to on a daily basis that are in place to influence your behavior

(auctions)

OPEN Enrollment

Boulder Valley School District
Excellence and Equity

(school assignments)

(i) not efficient for BVSD

(ii) not efficient for parents

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(auctions)

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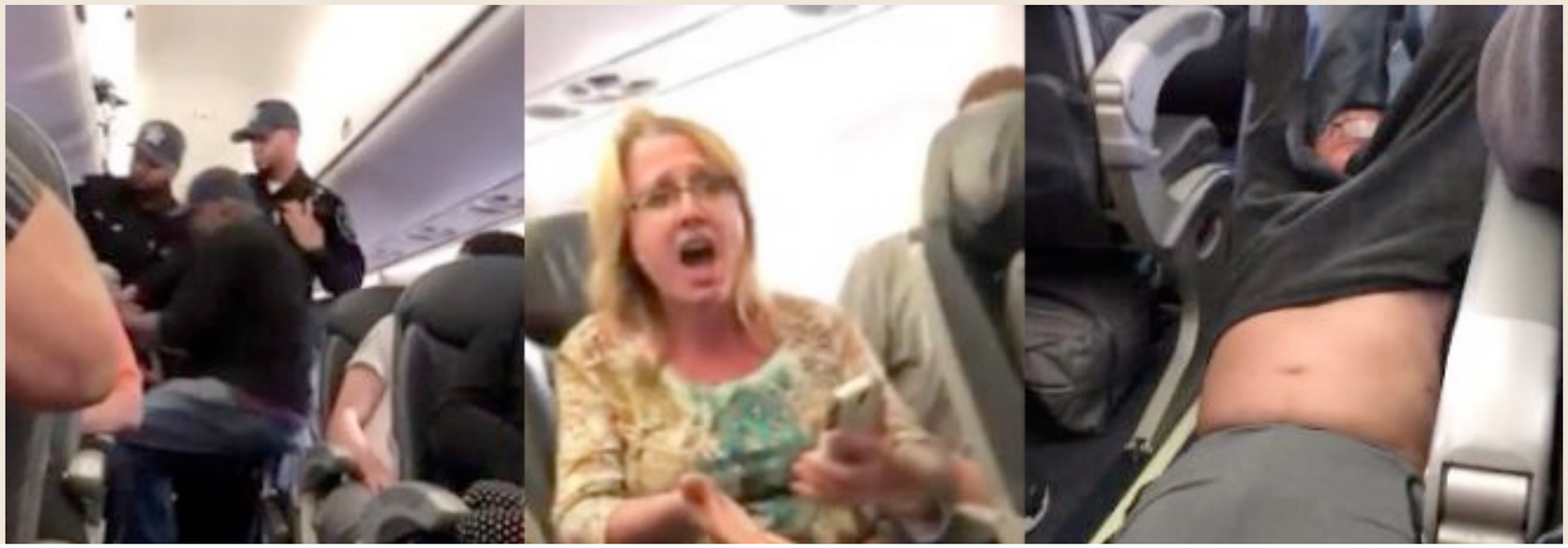
There are many mechanisms you are exposed to on a daily basis that are in place to influence your behavior

United Airlines

There are many mechanisms you are exposed to on a daily basis that are in place to influence your behavior



United's way of bumping 'is very inefficient,' says auction expert

By Ethan Wolff-Mann

m.yahoo.com — United's way of bumping 'is very inefficient,' says auction expert Yahoo Finance Wednesday, April 12, 2017 Ethan Wolff-Mann With a proper auction, there is no such thing as involuntary bumping. Source: APAfter a viral video emerged this week of United Airlines (UAL) dragging a paying customer off a plane, some outraged consumers attacked the airline industry's practice of overbooking.Not all airlines overbook, with JetBlue (JBLU) being a notable exception.

3 MONTHS AGO | Who shared? | Wrong byline?

microscopic interactions → **macroscopic phenomena**

decision makers
choices
preferences

emergent behavior?
efficient?
coordination?

simplifying assumptions

transportation network

driver behavior models

emergent behavior?
efficient?
coordination?

simplifying assumptions

transportation network

driver behavior models

system demand

$c_h(x) = x$

congestion functions

S

D

unit flow of traffic

$c_l(x) = 1$

simplifying assumptions

transportation network

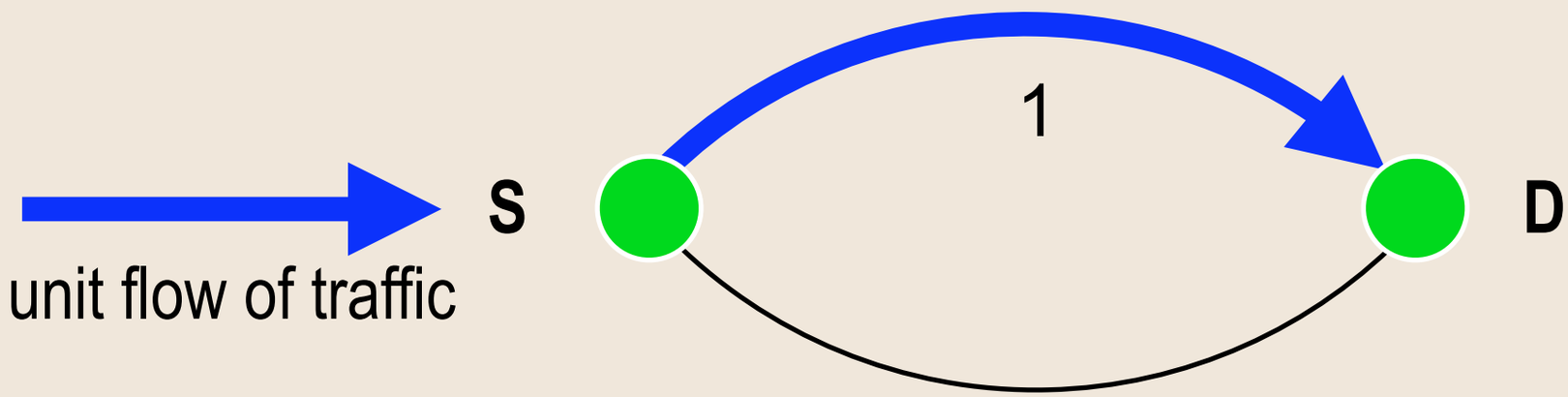
driver behavior models

system demand

$c_h(1) = 1$

$c_h(x) = x$

congestion functions



$c_l(x) = 1$

simplifying assumptions

transportation network

driver behavior models

system demand

congestion functions

$c_h(0.5) = 0.5$

$c_h(x) = x$

1/2

S

D

unit flow of traffic

1/2

$c_l(x) = 1$

$c_l(0.5) = 1$

simplifying assumptions

transportation network

driver behavior models

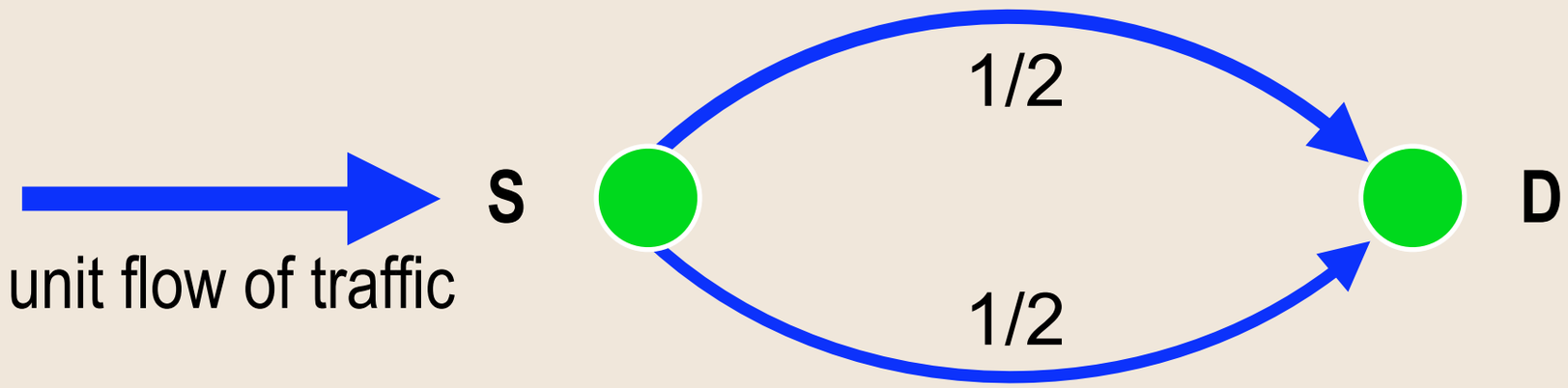
drivers seek to minimize own experienced congestion

system demand

congestion functions

$c_h(0.5) = 0.5$

$c_h(x) = x$



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Motivation:

- Uninfluenced systems often exhibit poor system behavior

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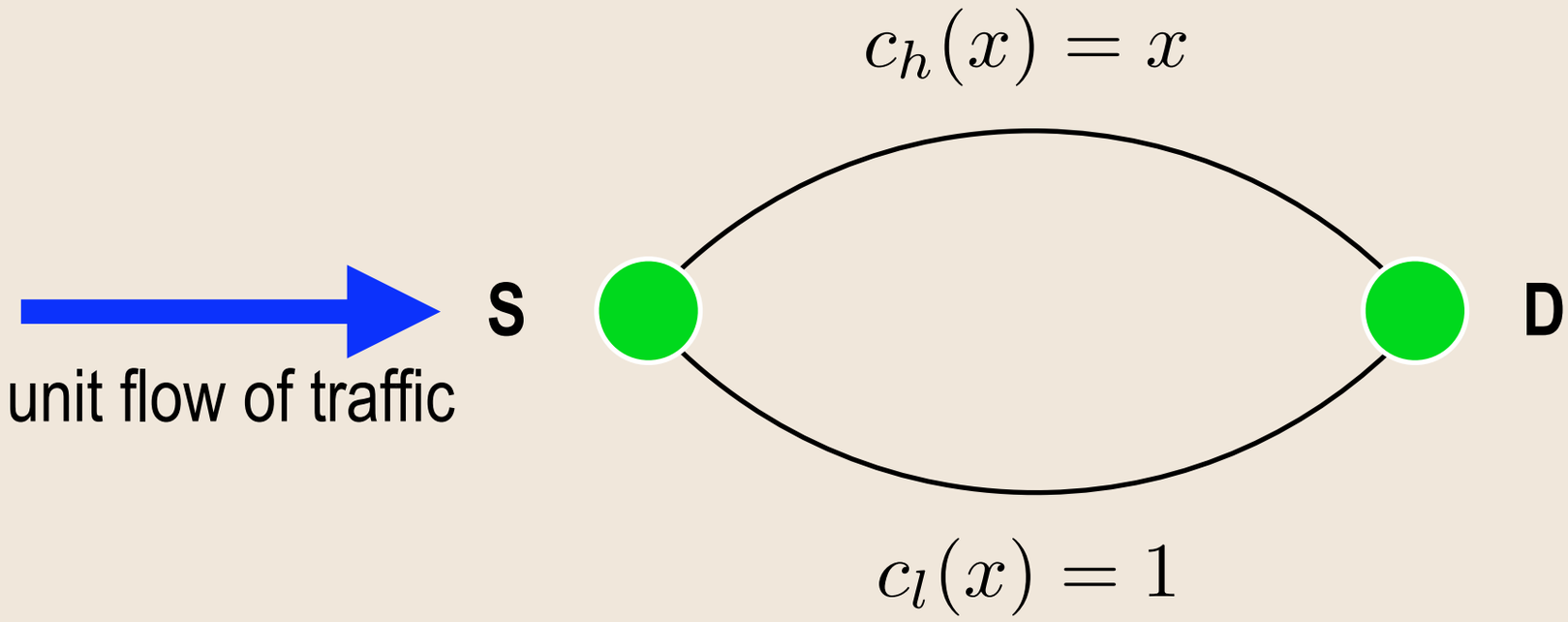

system optimal outcome **vs.** self-interested outcome

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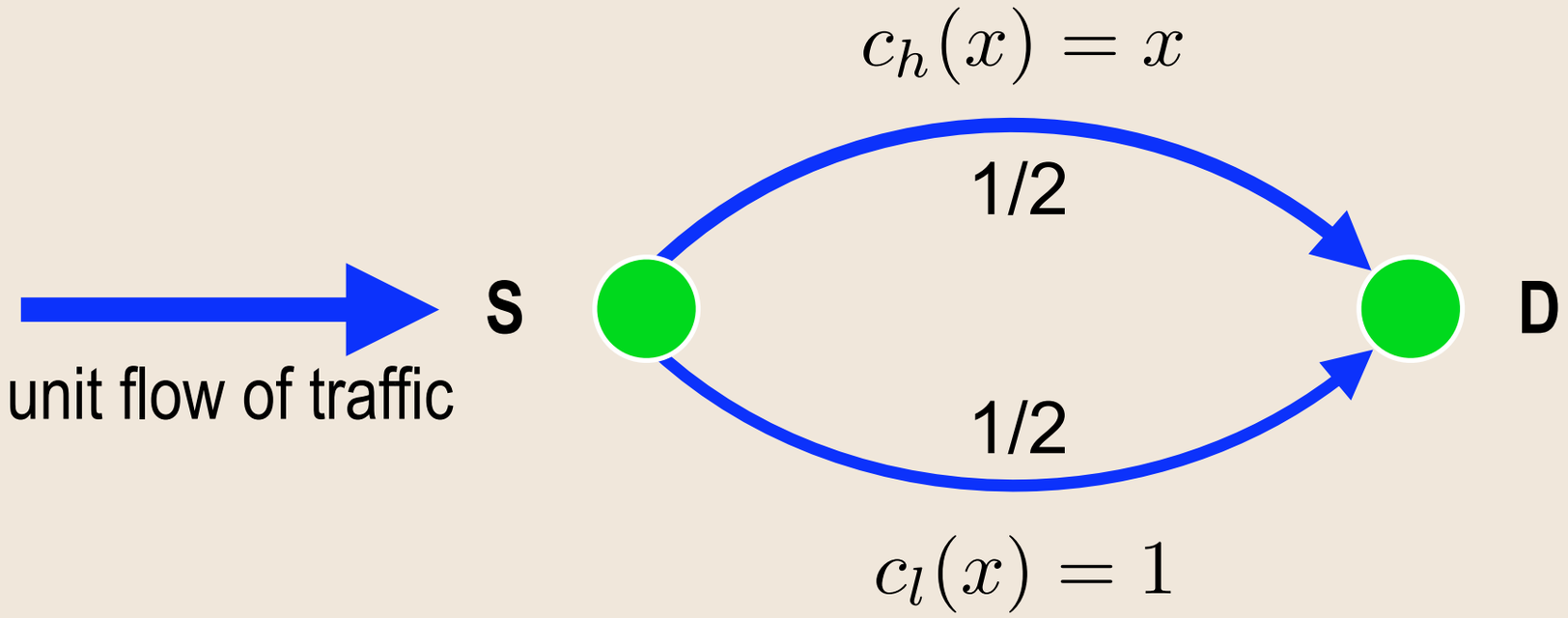

system optimal outcome **vs.** self-interested outcome

3/4

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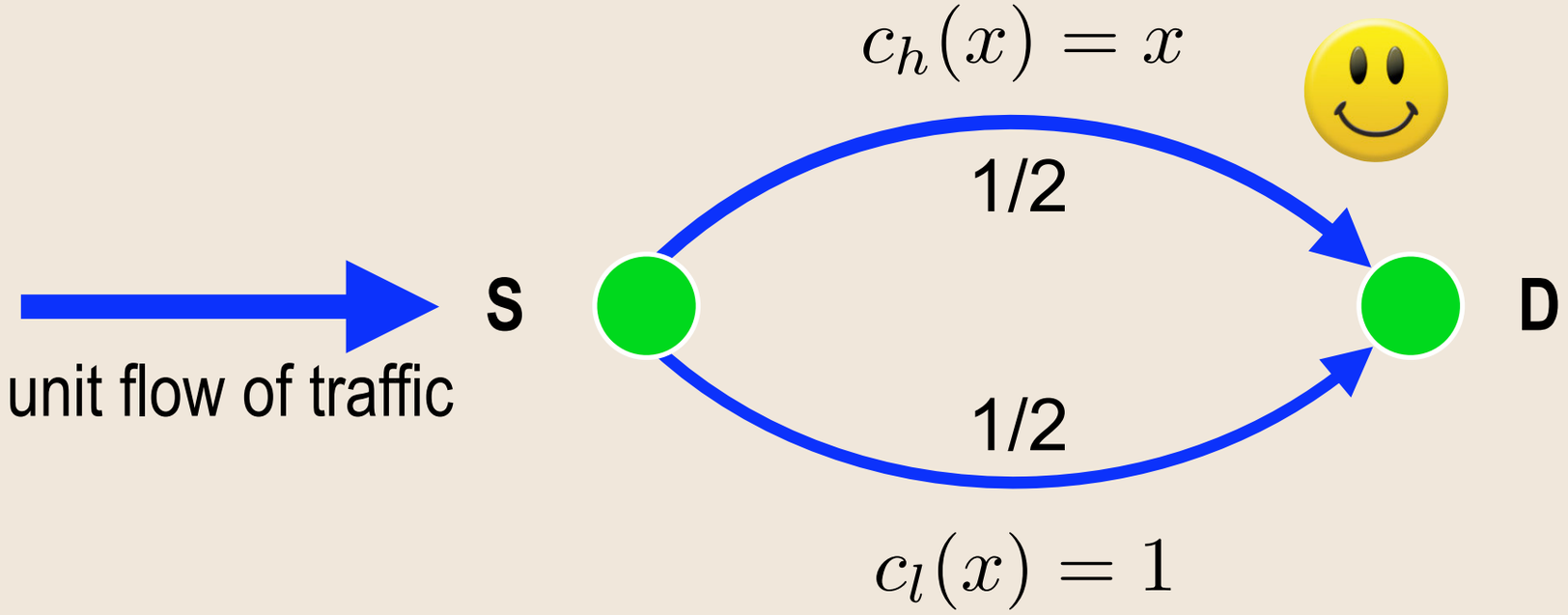

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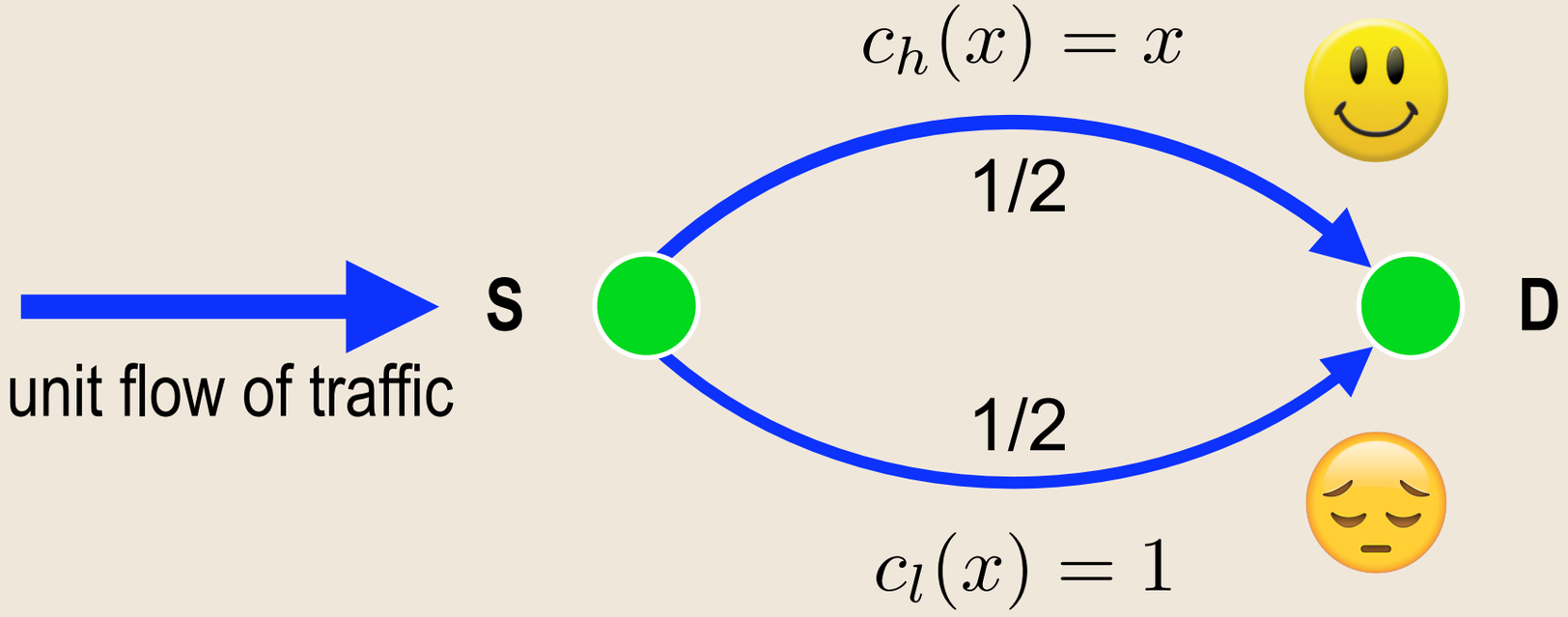

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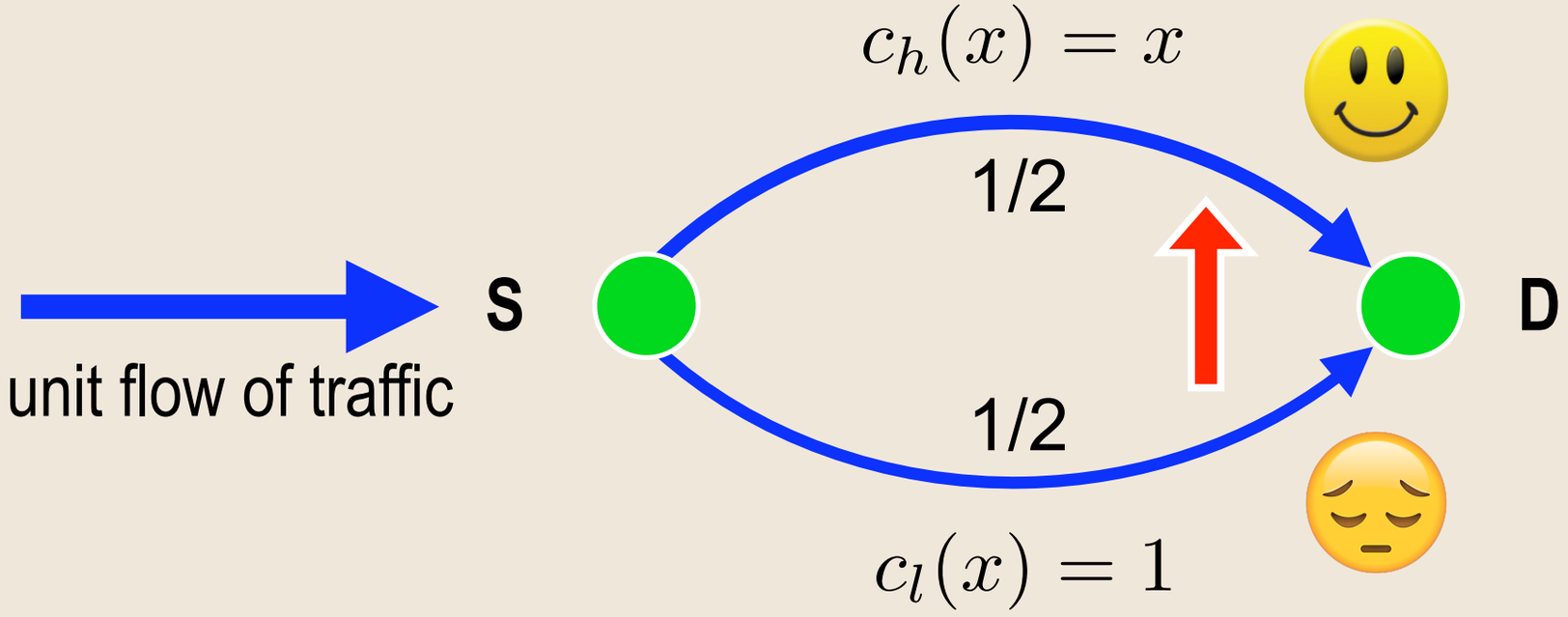

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3/4

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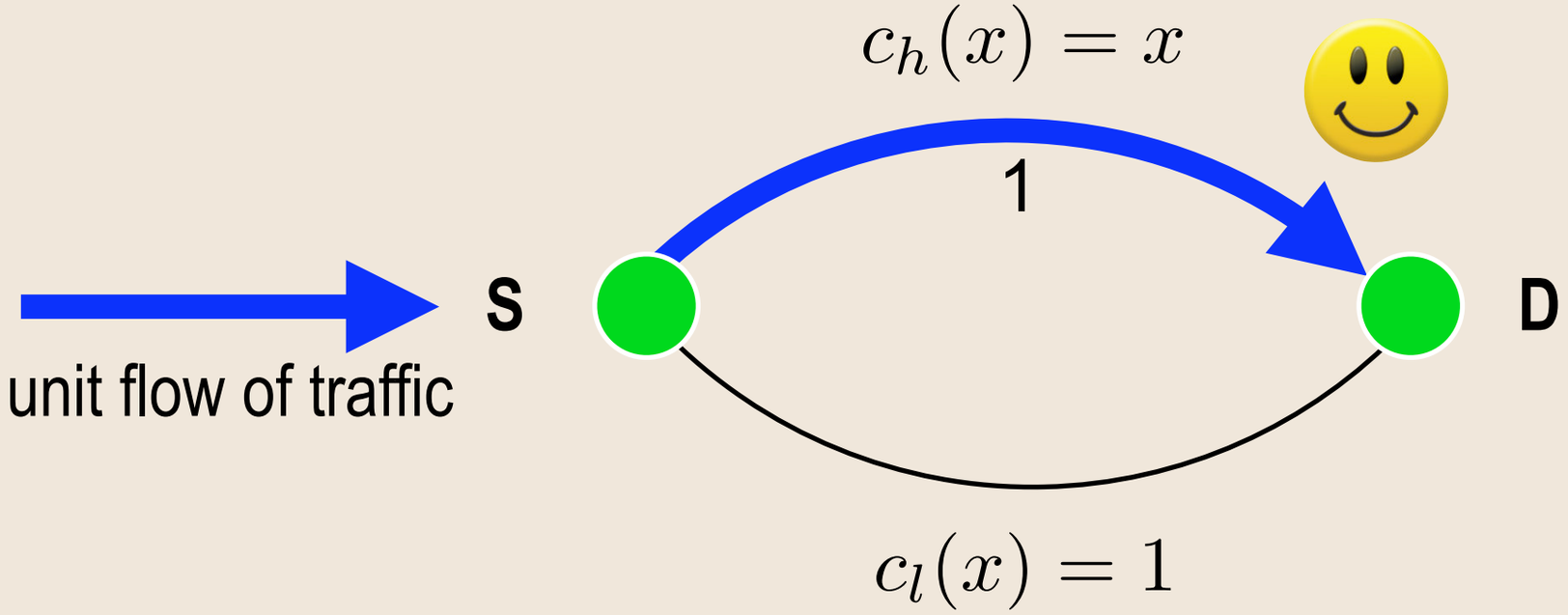

system optimal outcome **vs.** self-interested outcome

3/4 **1**

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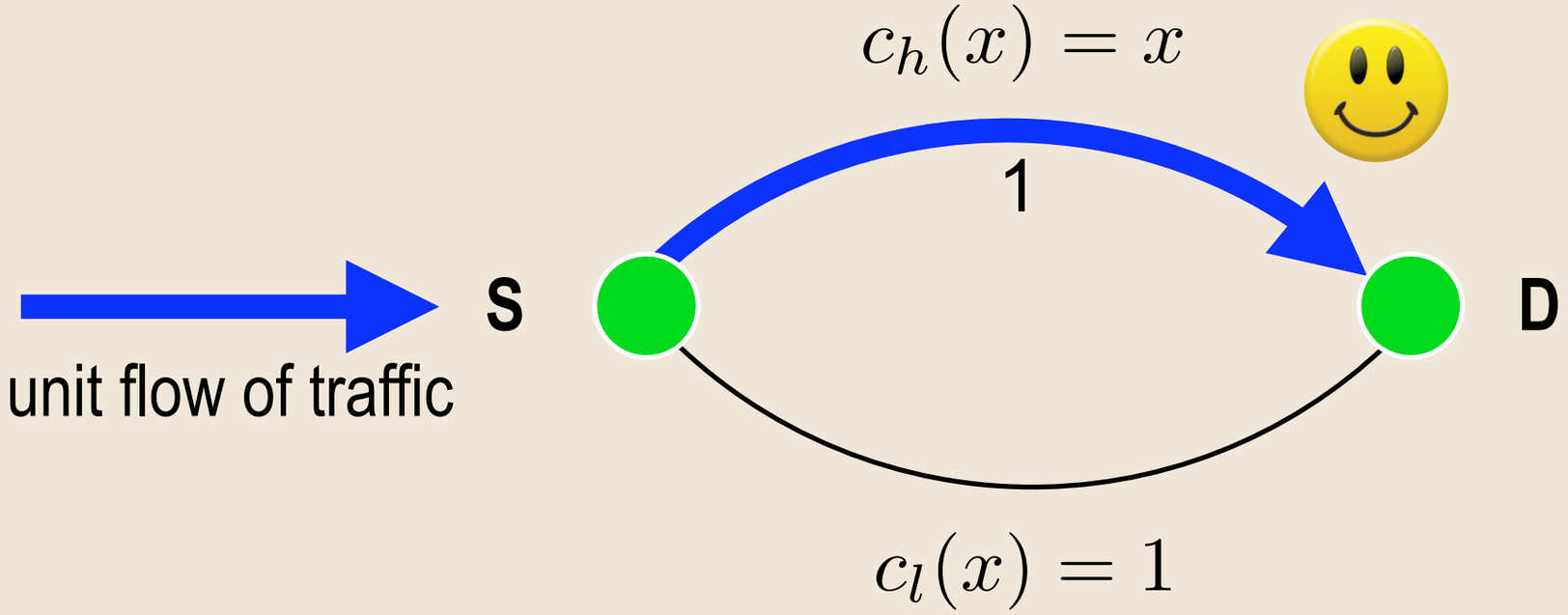

system optimal outcome **vs.** self-interested outcome

3/4

self-interested outcome
33% worse than optimal outcome

1

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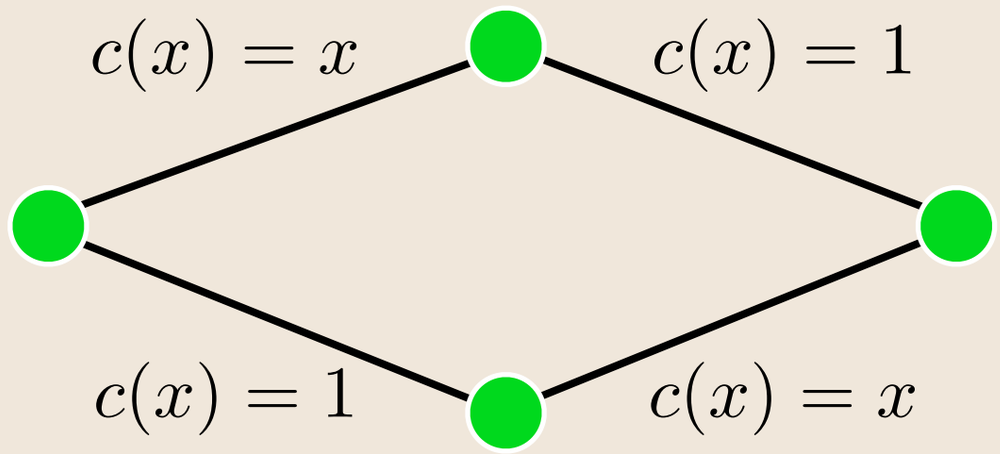

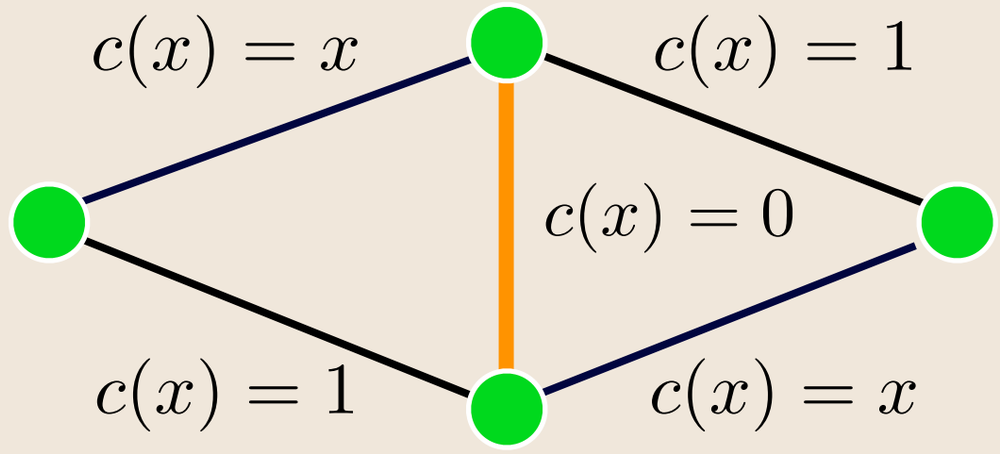

original network **vs.** original network + extra edge

Motivation:

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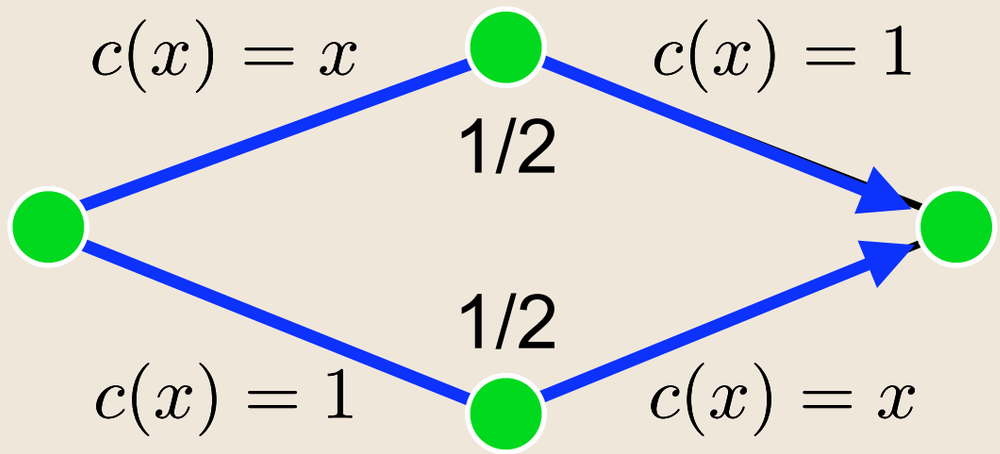

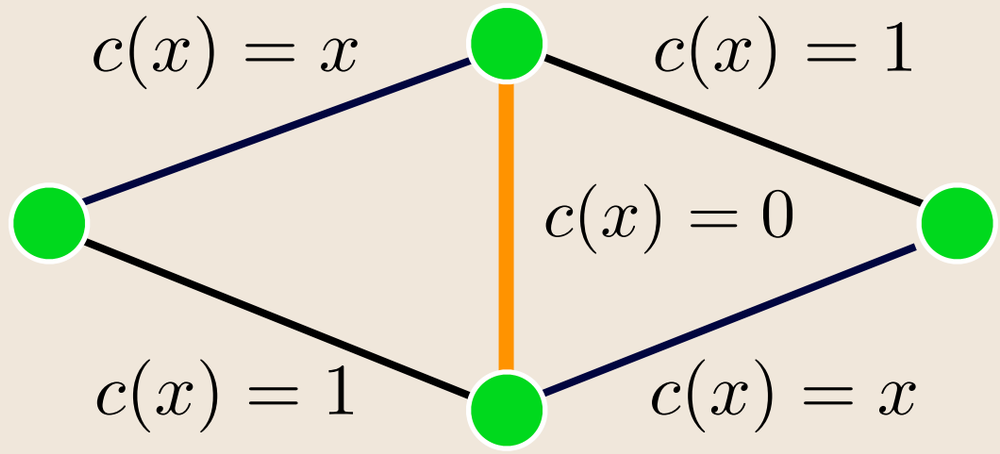

original network **vs.** original network + extra edge

1.5

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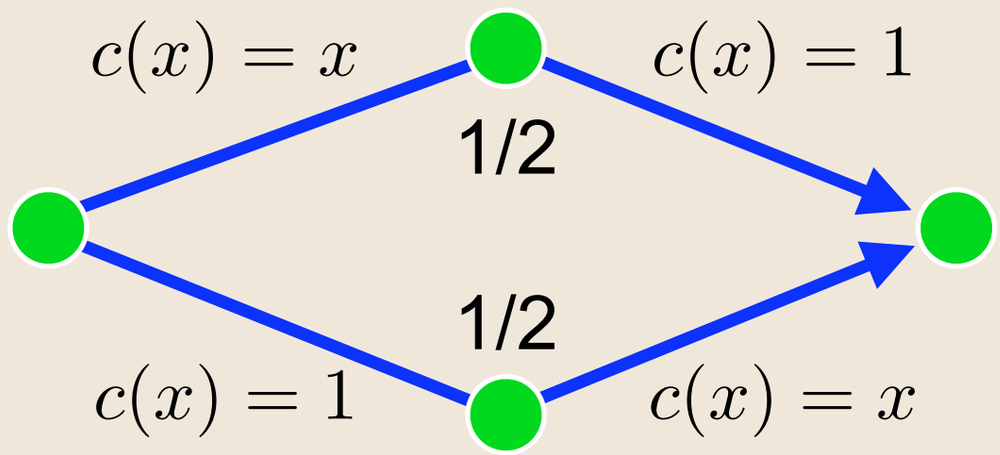

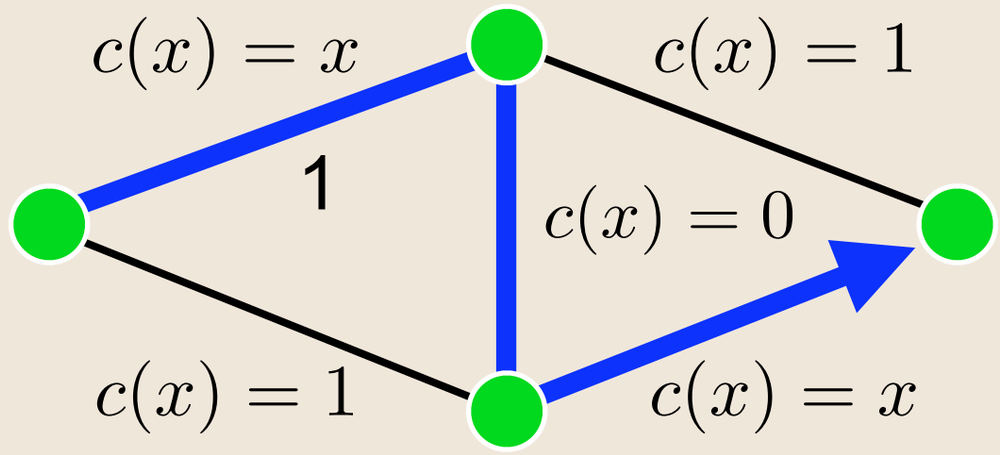

original network **vs.** original network + extra edge

1.5 **2**

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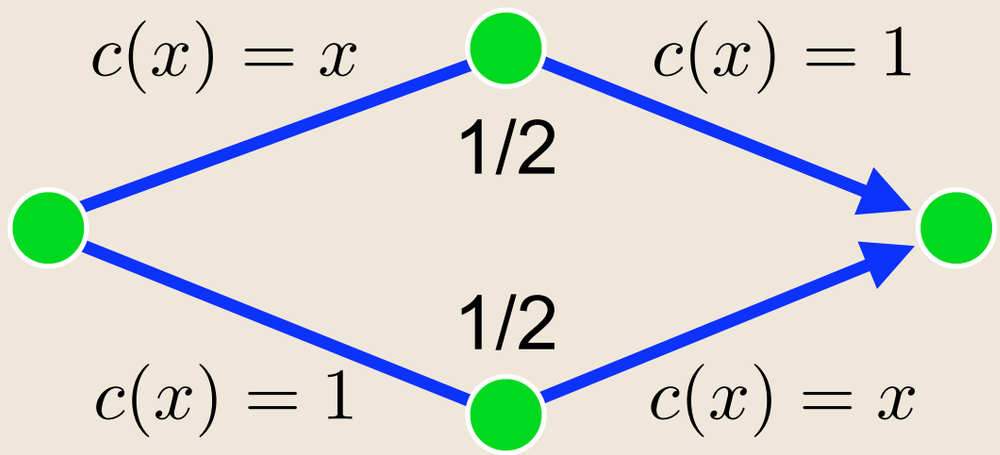

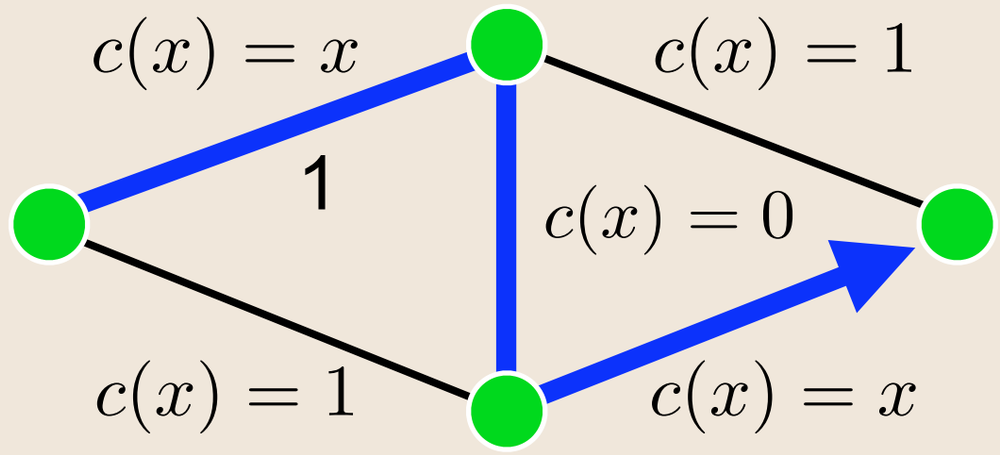

original network **vs.** original network + extra edge

1.5

additional resources resulted
in 33% worse system performance

2

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Research Thrust: Develop methodologies for robust social coordination to improve system-level performance (taxes)

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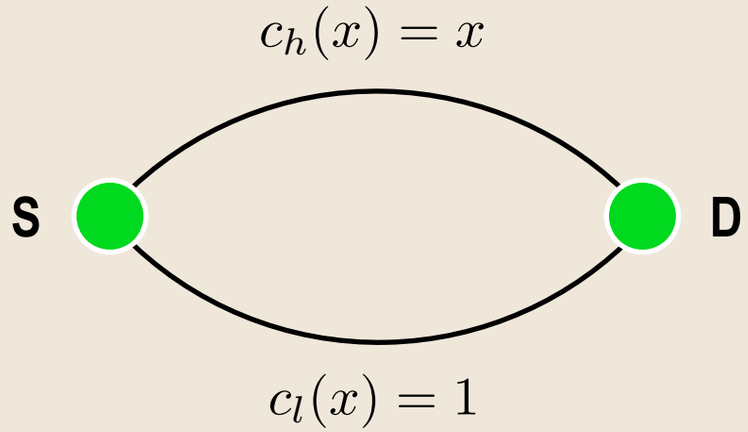

simplified models provide us insight to challenges and opportunities in realistic setting

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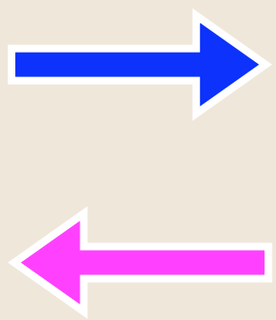
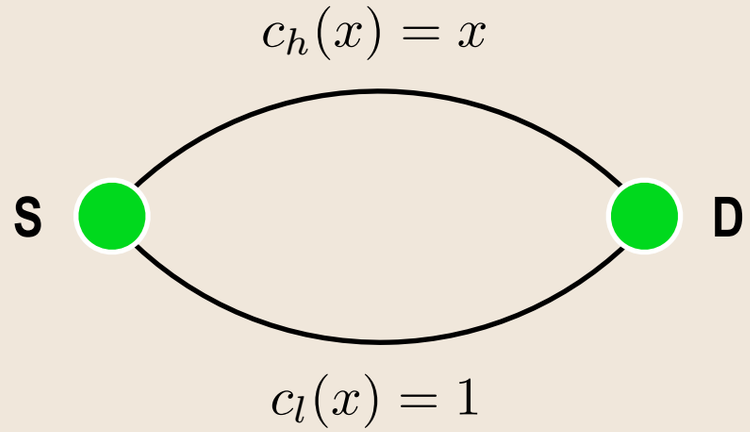
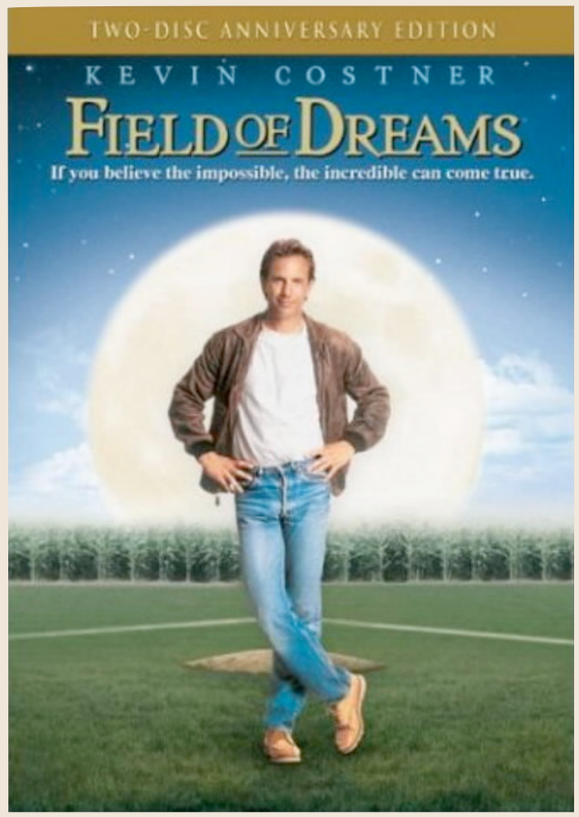




identify salient features of
robust coordinating mechanisms

Field of Dreams…



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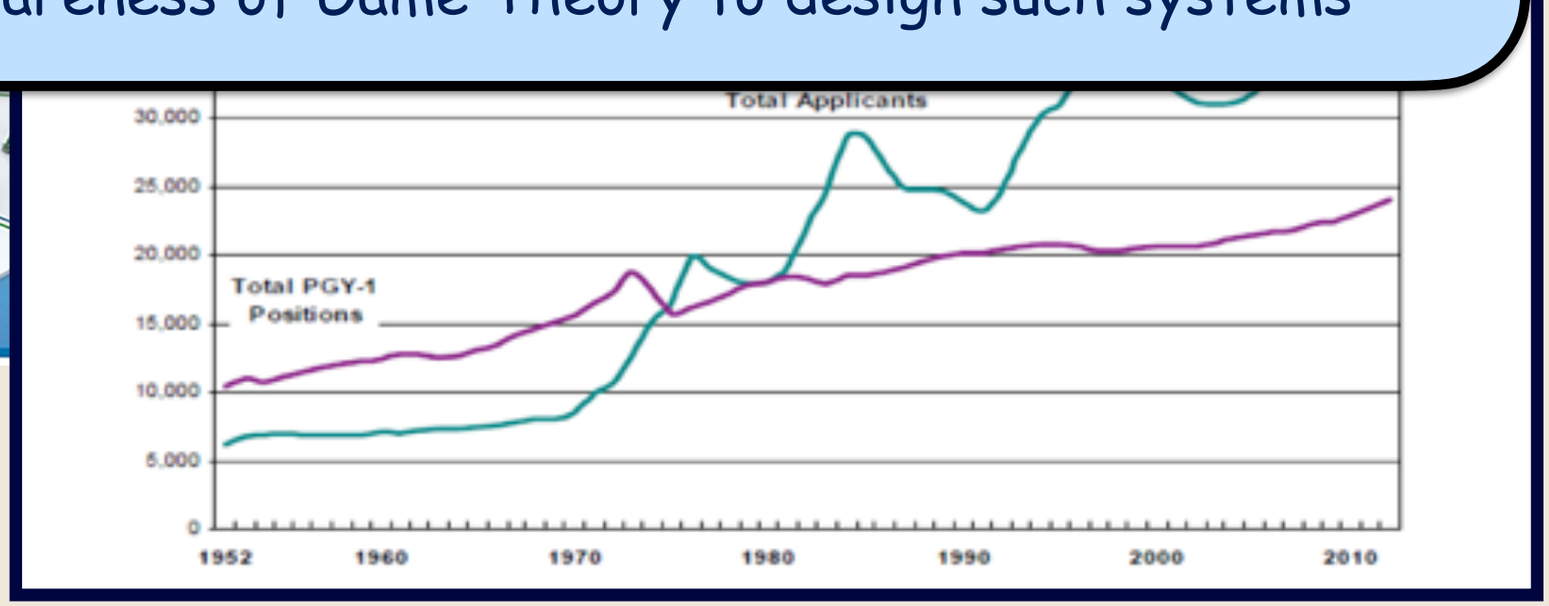
Take away points:

- Ensuring "systems" utilized efficiently is challenging
- Natural choice need not be good choice
- Deriving mechanism requires thorough theoretical analysis
- Game theory is instrumental in the design of good mechanisms
- Engineers need awareness of Game Theory to design such systems



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(avoid situations like this)

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Thank You