Agent-Based Modeling In Services Science

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Agent-based Modeling & Simulation in Services Science

(1) Service sector innovation

: How to create new value-added services?

(2) Service Oriented Architecture (Computing)(SOA/SOC)

(3) Modeling and Measurement of Quality of Service

: Customer Satisfaction, Agent-based Customer Relationship Management

(4) The Emerging Power of Complex Network Analysis

: Economics of Networks

(5) New Market Algorithms in a Networked World

: e-Market Models

:Congestion control in networked services

(6) Network Design with Smart Agents

Introduction to Services Science

- The weight of service industries has been increasing.
- The service industries have failed to achieve demonstrative increases in productivity through innovation.
- Hopes are being pinned on the service industries to become a key player in the rehabilitation of the world economy.

"*Service innovation*" based on the development and adoption of ICT (Information, Communication Technology

Needs for Service Innovation

- It is essential for service industries to raise labor productivity.
- Service industries need to do business abroad.
- The development of markets and the creation of demand through innovation should create the new markets for services.

Service Sector Shares in GDP

Sectoral Share of GDP at Current Market Prices, 1980, 1990, 2000

(Percent)

	Agriculture			Industry						Services		
				All Industry			Manufacturing only					
	1980	1990	2000	1980	1990	2000	1980	1990	2000	1980	1990	2000
China	30.1	27.0	15.9	48.5	41.6	50.9	44.2	37.0	44.3	21.4	31.3	33.2
Hong Kong	0.8	0.3	0.1	31.7	25.3	14.6	23.7	17.6	5.8	67.5	74.5	85.3
Indonesia	24.8	19.4	16.9	43.4	39.1	47.3	11.6	20.7	26.0	31.8	41.5	35.8
Korea	14.9	8.5	4.6	41.3	43.1	42.7	29.7	28.8	31.5	43.7	48.4	52.7
Malaysia	…	15.2	8.6	…	42.2	51.7	…	24.2	34.3	…	42.6	39.7
Philippines	25.1	21.9	15.9	38.8	34.5	31.1	25.7	24.8	22.6	36.1	43.6	52.9
Singapore	1.3	0.4	0.1	38.1	34.4	34.3	29.1	27.1	26.5	60.6	65.3	65.6
Taiwan	7.7	4.2	2.1	45.7	41.2	32.4	36.0	33.3	26.3	46.6	54.6	65.6
Thailand	23.2	12.5	9.1	28.7	37.2	41.7	21.5	27.2	33.4	48.1	50.3	49.2
Japan		3.0	2.0		41.0	36.0		28.0	24.0		56.0	62.0

Source: ADB, Asian Development Outlook 2001. World Bank, World Development Indicators 2001.

What Kinds of Services?

- Goods-related services industries
  - *Distribution service*
    - Wholesale, retail, transport, storage, and etc
  - *Knowledge-based business services*
    - Communications services, finance and insurance services, property and business services
- Service industries
  - *In-person services*
    - education services, health and community services, cultural and recreational services, accommodation, cafes and restaurants, personal and other services
  - *Public service: Governmental services, defense*

(John Houghton, Nick Pappas, and Peter Sheehan 1999)

Innovation in Service Sectors

- Areas of innovation
  - Product innovation
  - Process innovation
  - Organizational innovation
- Different nature of innovation in services
  - High ICT spending
  - Dependent on protection by copyright and trademark.
  - Different from R&D-dependent innovation in manufacturing
- Engines of innovation in services
  - Competition as a result of deregulation and liberalization

<Report by Nobuaki Takada/NRI at Tokyo Club for Global Studies, 2003>

Evolution toward a Service Economy

Factors on the users' side:

Individuals:

- Graying of the population.
- Participation of housewives in the labor force.
- Increasing need for continuing education.

Businesses:

- Core competency and outsourcing.

Government:

- Fiscal reformulation

Factors on the suppliers' side:

- Manufacturers focusing on after-sale services, such as maintenance and leasing
- Companies spinning off head office administration departments to create shared-service companies

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Some Directions of Service Innovation

Product innovation

- Creating new service content.
- Requires developing technology to create new services or developing technologies and know-how to offer efficient services.

Process innovation

- Building systems that can meet diverse needs.
- Chain operations.

Develop New Services Technologies with ICT

(ICT:Information/Communication Technology)

- Ubiquitous network technologies -- IC cards, RFID (Radio Frequency Identification), etc.
- Data mining
- Sensor technology
- Other information processing technology

New Services with ICT:Some Examples in Japan

- Combining crime-prevention sensors and telecommunications technology.
- Based on the information and communications infrastructure.
- Developed technologies in such areas such as

  :remote sensing,

  :image processing,

  :geographical information system (GIS),

  and other applications

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YAMATO TRANSPORT CO.,LTD.

- Based on the combination of a physical distribution and delivery system and an information system.

  “cool home delivery” such as fresh foods

  “time designation delivery”

  “cash-on-delivery”

- Challenging the government-run postal business

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7-ELEVEN JAPAN CO.,LTD.

- Convenience stores supported by sophisticated physical distribution and information systems.
- Offering a various services in addition to selling merchandise.

Services Available at SEJ Outlets

- **Copying**
- **Fax transmission**
- **Photo developing**
- **Parcel delivery**
- **Sale of postage stamps, post cards, and revenue stamps**
- **Sale of waste disposal stamps**
- **Sale of ski lift tickets**
- **Printing of New Year's cards**
- **Sale of automobile third party liability insurance**
- **Magazine subscriptions**
- **Pick-up of merchandise ordered via the Internet, etc.**
- **Sale of catalog gifts**
- **Sale of various prepaid cards**

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- Barbershop chain operator.
- Based on the concept of ¥1,000 (300 NT$) and 10 minutes (usually ¥ 4,000 and 50 minutes)
- Eliminate shampoos, face shaves, and massages.
- Designed a shop system, including utensils and barber's chairs, that allows efficient and inexpensive service.
- Opened other shops in Singapore also.

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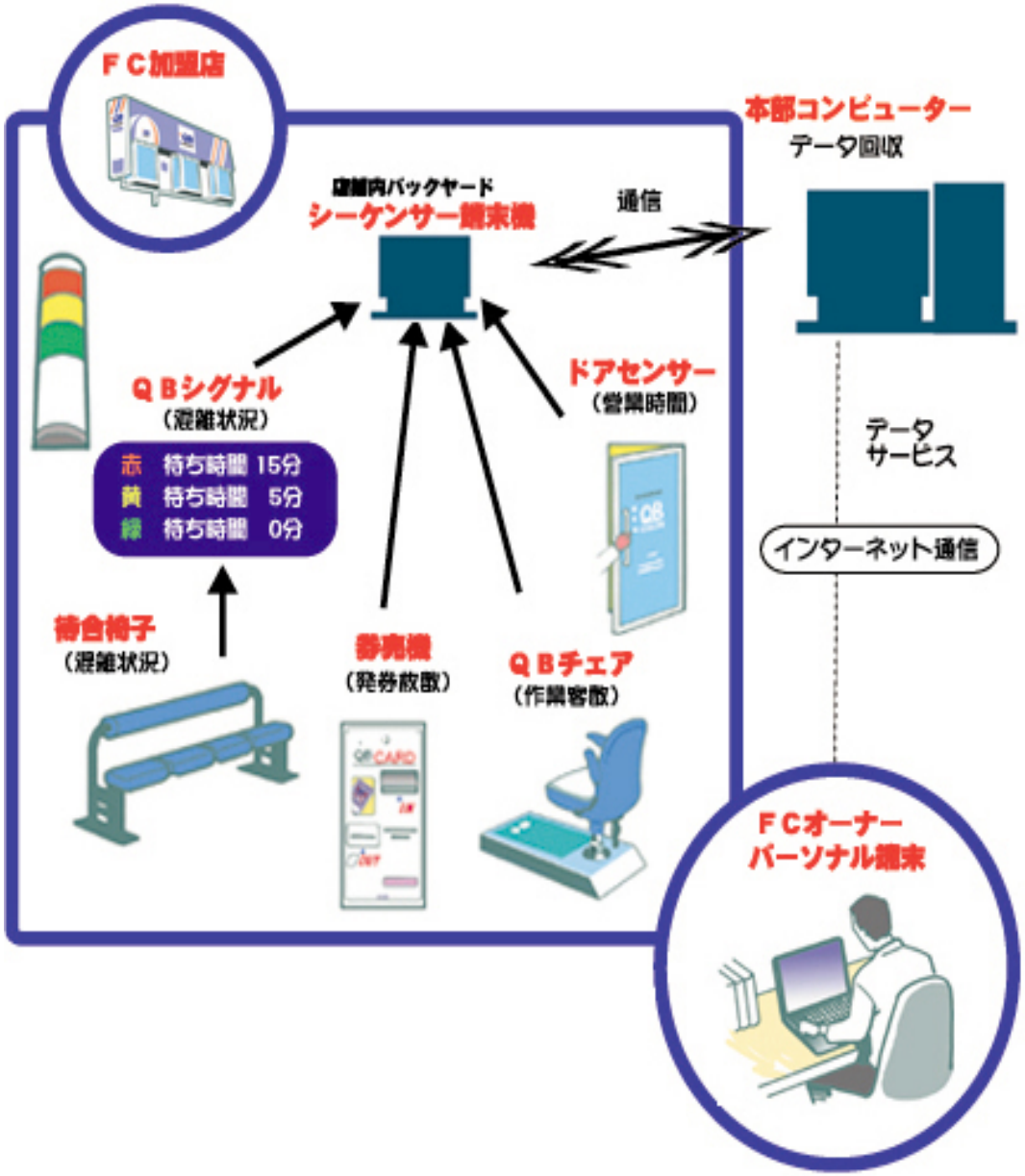

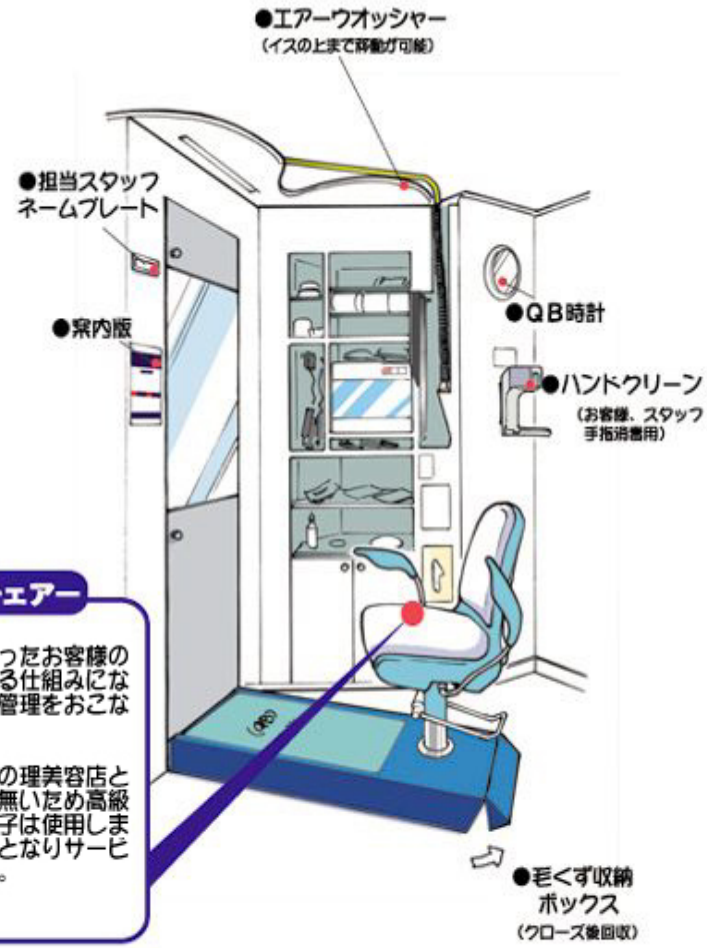

ＱＢチェアー

され、座ったお客様の
把握できる仕組みにな
的な顧客管理をおこな

終了、他の理美容店と
髭剃りが無いため高級
ク式の椅子は使用しま
スト削減となりサービ
されます。

Applications of Toyota-Kanban Model

- Dry cleaning and laundry industry:
  Adopting the “kanban” method to process small lots of various types of clothing resulted in improved finishing, fewer delivery errors, and less damage to clothing, which is the core of the Toyota model, sharply reduced waiting time for patients.

- Hospitals:
  Reforming operations based on the concept of eliminating waste.

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:Congestion control in networked services

(6) Network Design with Smart Agents

What are Service-Oriented Architectures (SOA)?

- **An SOA is:**

  :An architectural style that represents business functionality as implementation-neutral, standards-based shared services

  : A collection of shared services

  : A set of architectural principles that define how autonomous systems interoperate

  :A set of network-accessible operations and associated resources abstracted as a “service”

  :A major component of Net-Centricity

- **Characteristics of SOA:**

  : Shared services

  : Loosely coupled

  : Location transparent

  : Interoperable

Service Oriented Architecture (DoD)

Invoke

ıd)

Service Produ

Data and applications available for use, accessible via services. Metadata added to services based on producer's format.

- **Describes** content using metadata
- **Posts** metadata in catalogs for discovery
- **Exposes** data and applications as services

Service Consumer

Automated search of data services using metadata. Pulls data of interest. Based on producer registered format and definitions, translates into needed structure.

- **Searches** metadata catalogs to find data services
- **Analyzes** metadata search results found
- **Pulls** selected data based on metadata understanding

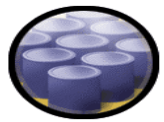
(Post) *Publish*

abled Infrastru

Discover (Find)

Service Registries

Messaging Services



Data Services

Transformation Services

Service Oriented Computing (SOC)

- Service Oriented Computing (SOC) research theme focuses on a new emerging paradigm for distributed computing and e-business processing.
- It treats individual ICT systems and software components as independent services geared for integration, and uses them as fundamental elements to build agile networks of collaborating service applications distributed within and across organizational boundaries.
- Current SOC technologies include Web Services and Grid Services.

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: Customer Satisfaction, Agent-based Customer, Relationship Management,..

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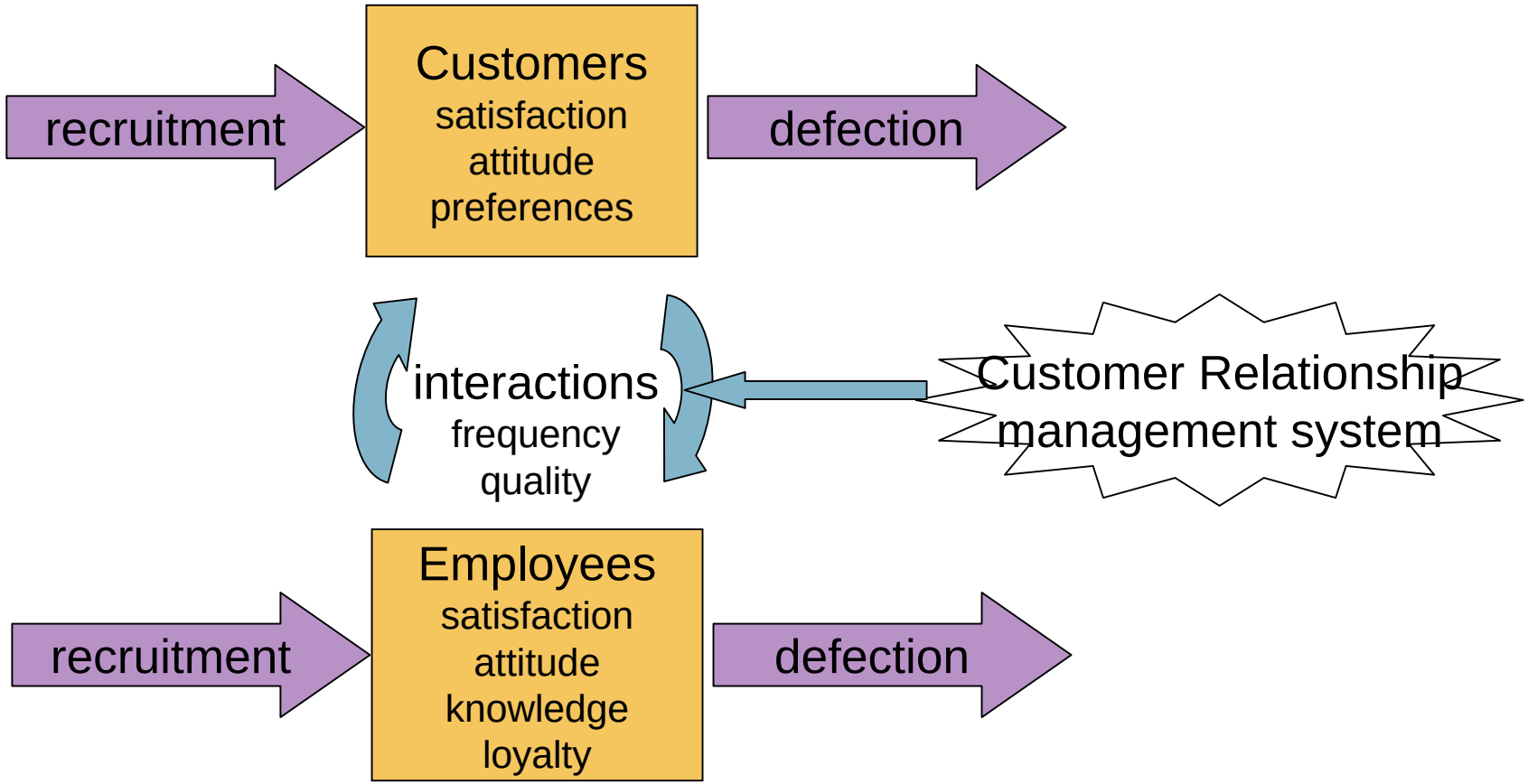
Customer Relationship Management Systems



Essential Elements for Consumer Model

- Cognitive process for the individual customers
- Social network channelling information between individuals
- ABM(Agent Based Modelling) provides a natural framework

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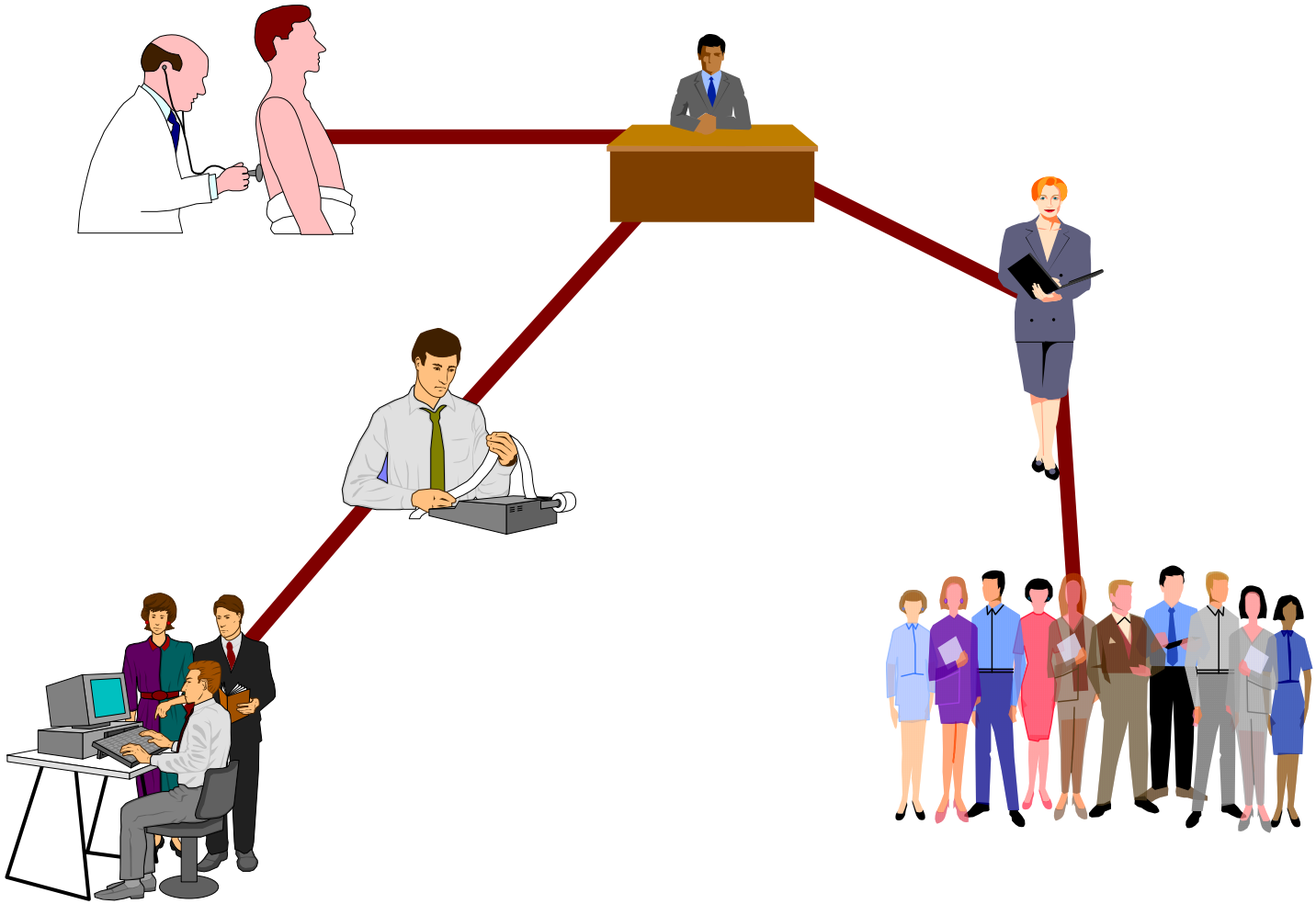
Networked Services



The Economics of Networks

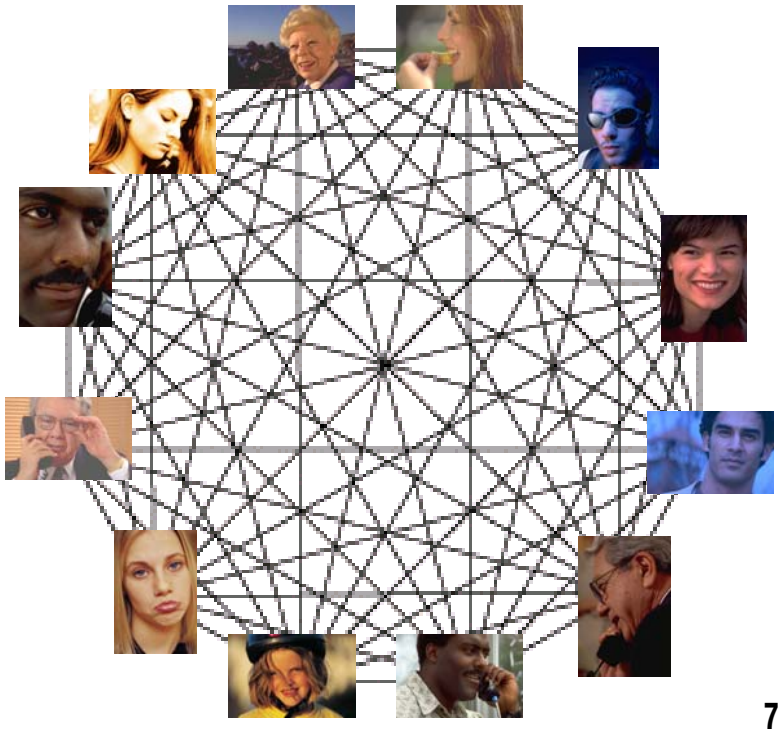
The economies of networking are gradually replacing the economies of scale.

(Meheroo Jussawala, 1989)

Network effects are commonly mistaken for economies of scale, which result from business size rather than interoperability. To help clarify the distinction people speak of demand side vs. supply side economies of scale. Classical economies of scale are on the production side, while network effects arise on the demand side. Network effects are also mistaken for economies of scope.

The Network Effect

The **network effect** is a characteristic that causes a good or service to have a value to a potential customer dependent on the number of customers already owning that good or using that service.



The Network Effect: Metcalf' Law

Metcalfe's law states that the value of a telecommunications network is proportional to the square of the number of users of the system (n^2).

First formulated by Robert Metcalfe in regard to Ethernet, Metcalfe's law explains many of the network effects of communication technologies and networks such as the Internet and World Wide Web.

Reed's Law

In contrast, Reed's law asserts that Metcalfe's law understates the value of adding connections. Not only is a member connected to the entire network as a whole, but also to many significant subsets of the whole.

These subsets add value independent of either the individual or the network as a whole. Including subsets into the calculation of the value of the network increases the value faster than just including individual nodes.

- Social capital increases exponentially through Internet connectivity

$$2^N - N - 1$$

Negative and Positive Network Effects

- Positive networks effects are obvious.

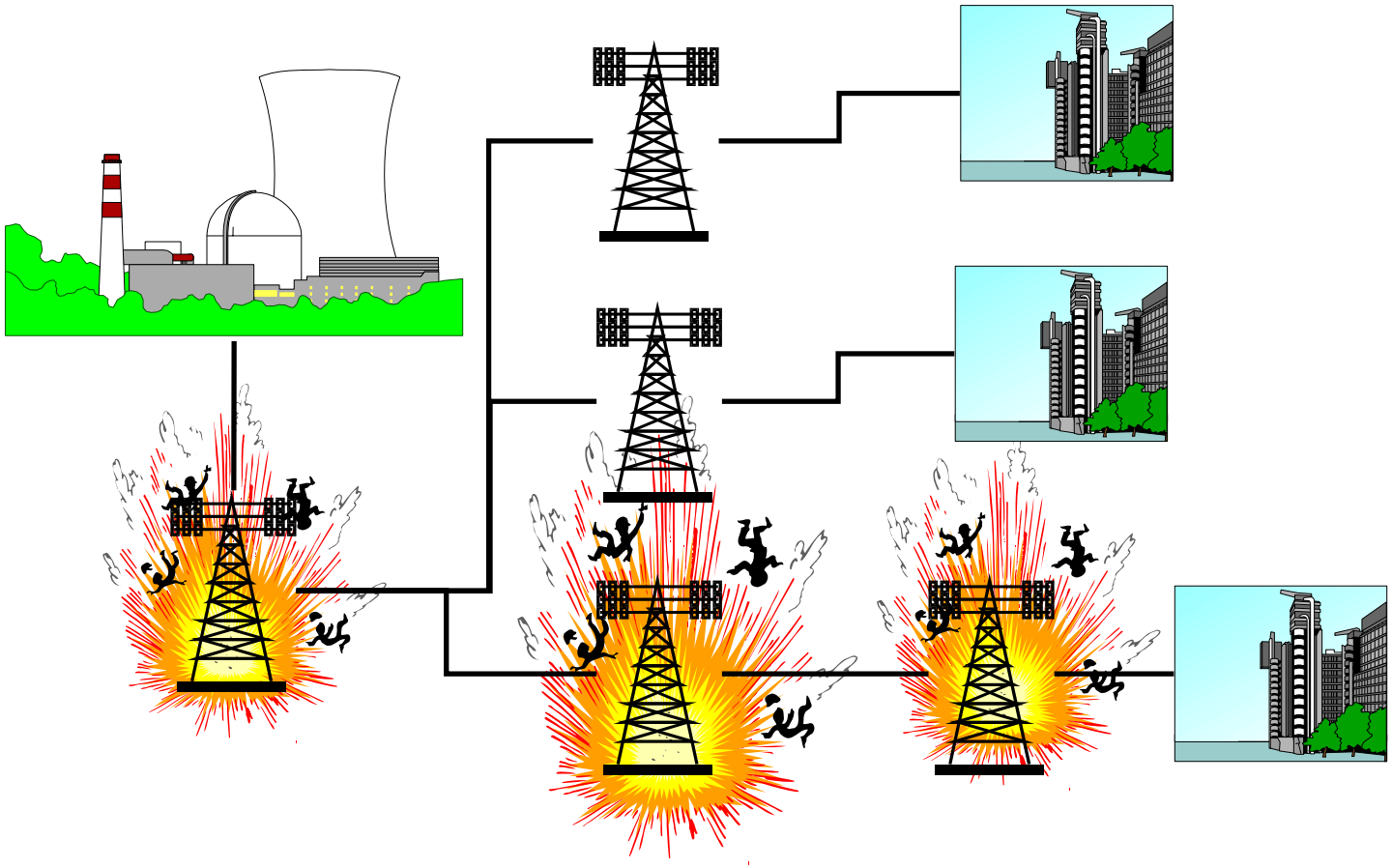
  : More people means more interaction.

- Wikipedia itself depends on positive network effects.

- Negative network effects result from resource limits.

  : Consider the overloads the daily-life trafficsf, or the conestion of bandwidth. In this case, more persons begin to decrease the value of a network.

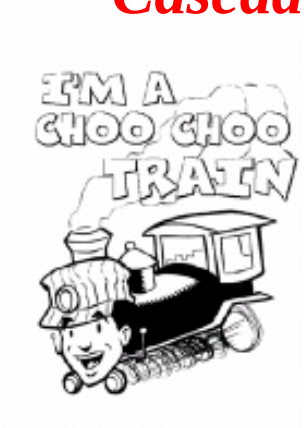
Cascading Failures in Complex Networks

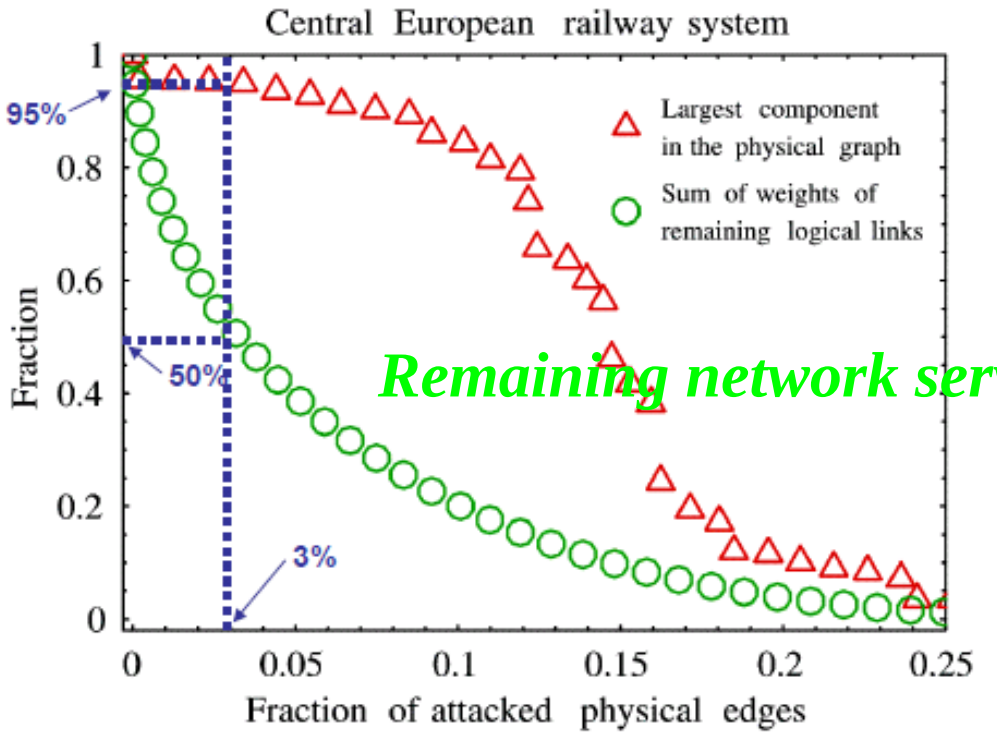


Agent-Based Research in Complex Networks

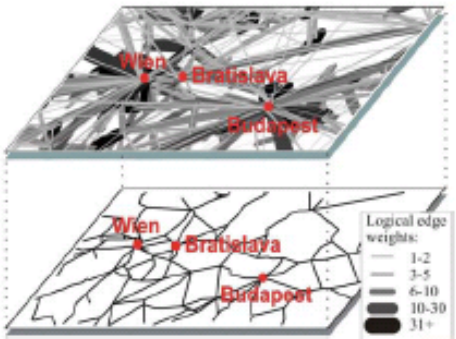
Robustness: Railway system

Cascade Failure: Remaining networks functionality





Remaining network service



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Revolution in Algorithms for New Markets

- New markets defined by
  - Google
  - Amazon
  - Yahoo!
  - e-Bay

- Massive computational power available for running these markets in a centralized or distributed manner

- Important to find good models and algorithms for these markets

: Algorithmic and economic aspects of the Internet and complex networks

What is Needed Today?

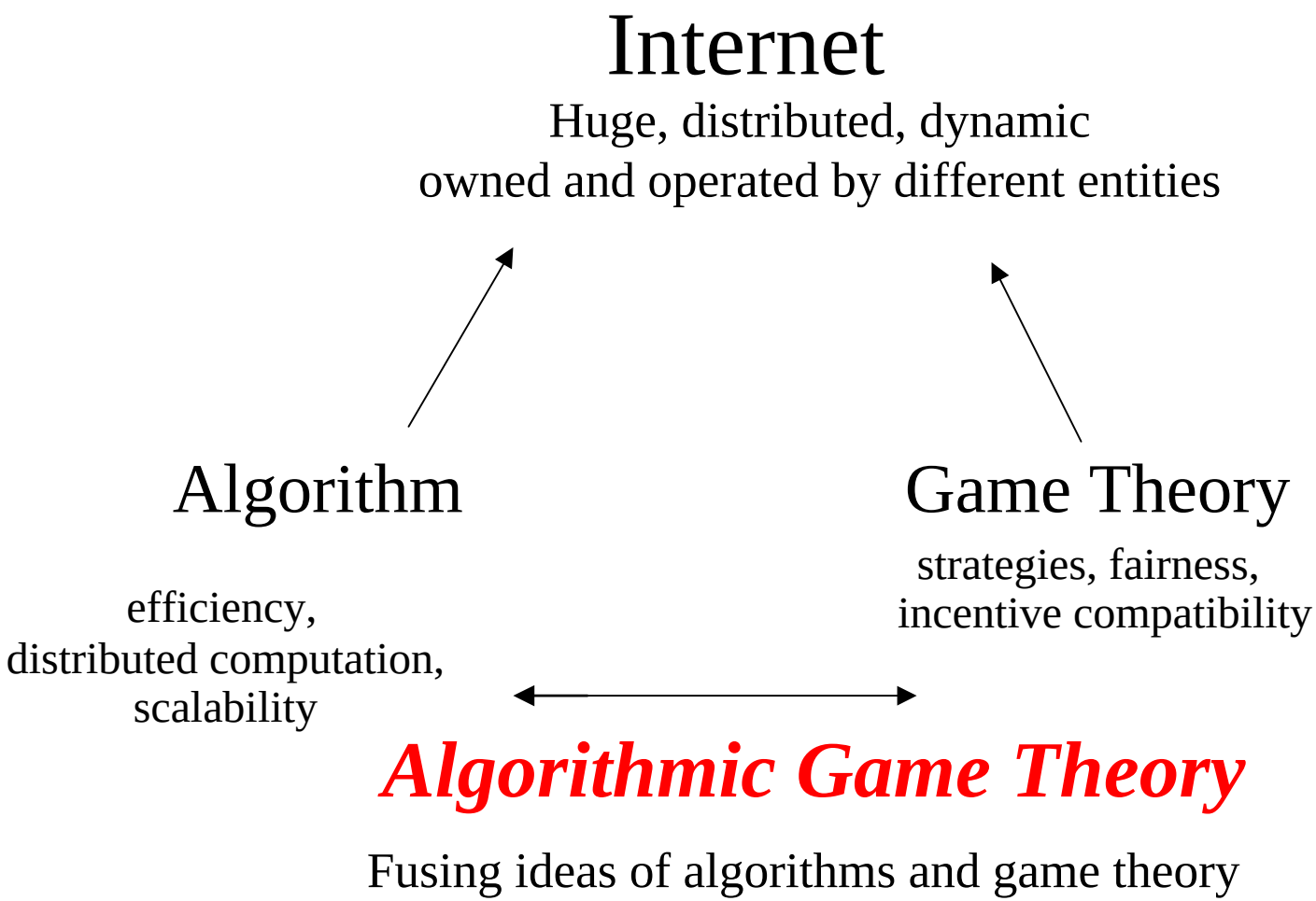
- An inherently algorithmic theory of market equilibrium
- New models that capture new markets
- Started with combinatorial algorithms for traditional market models
- New market models emerging

: Incentive/ Decentralized Search algorithms for complex networks

- Beginnings of such a theory, within

Algorithmic Game Theory

Algorithmic Game Theory



The Price of Anarchy (1)

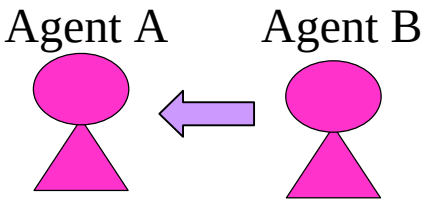
Coordination versus competition

- Equilibria of selfish agents are not efficient
- Pareto optimal is usually not Nash equilibrium

- Price of anarchy: Quantify inefficiency in terms of a global objective

$$\text{Price of Anarchy} = \frac{\text{objective function value at NEP}}{\text{optimal objective function value}}$$

The Price of Anarchy (2)



A modified coordination game

	H	M	L
H	5,5	0,0	12,0
M	0,0	2,2	0,0
L	0,12	0,0	10,10

- Pure strategy Nash equilibria include (H,H) and (M, M), but not (L,L)
- The efficient outcome is (L, L)

Price of Anarchy=5(or 2)/10=1/2 (or1/5)

-How can we improve the price of anarchy without the central authority?

-What mechanisms one can use to improve the overall system performance?

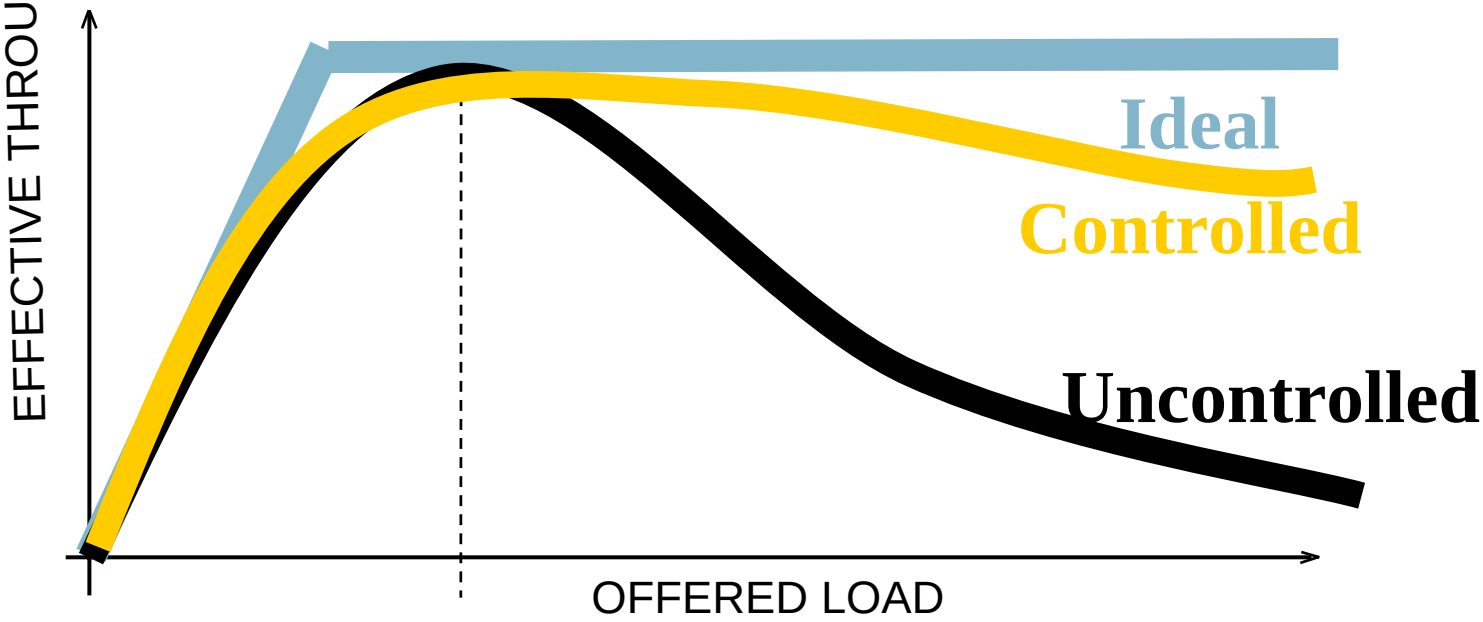
Congestion Control in Networked Systems

- Congestion avoidance and congestion recovery should receive attention
- For the quality of service, there are no perfect solutions, at least not for the foreseeable future
- It is possible to deliver differentiated levels of best effort service

Congestion Control with Agent-based Modeling

- Congestion control with Agent-Based Modeling
  - penalty for dynamically shared resources
  - Similarities with the highway system
  - The influence of routing guidance on the congestion
- Quality of service in Internet
  - a heterogeneous network that uses different lower layer technologies
  - the best effort service
- Service quality - not precisely defined
- Parameters used are
  - delay, jitter, bandwidth, reliability,..

Merits of Controlled Services

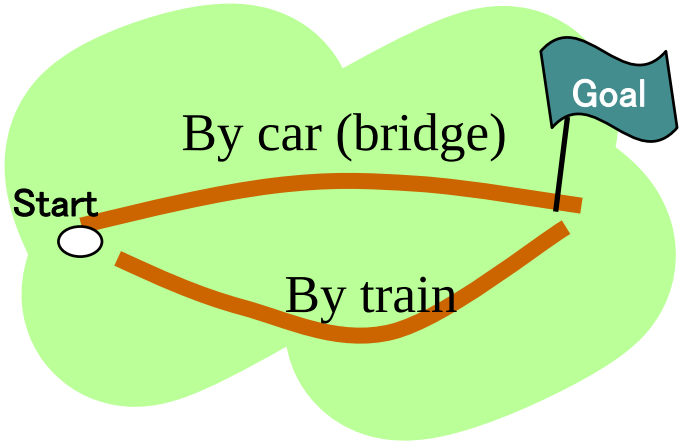


PROBLEMS CAUSED BY OVERLOAD

- Loss of efficiency
- Unfair allocation of resources among competing users
- Various types of loops and deadlocks

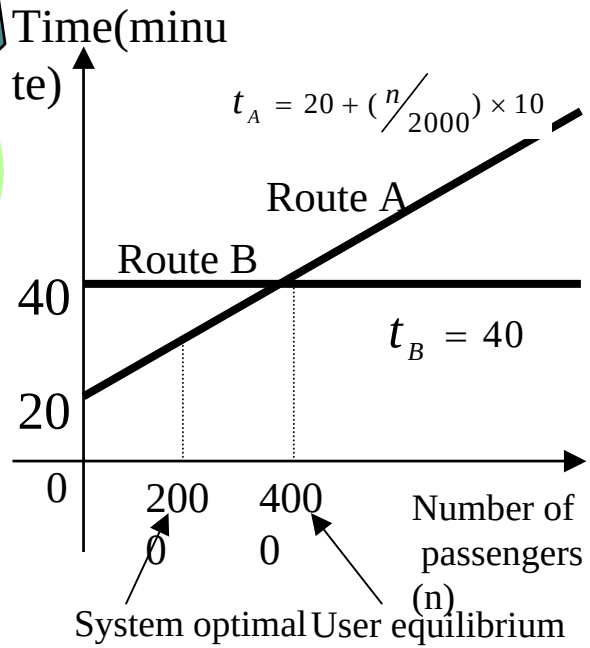
Some Examples

- **Congestion problem**



Strategies:

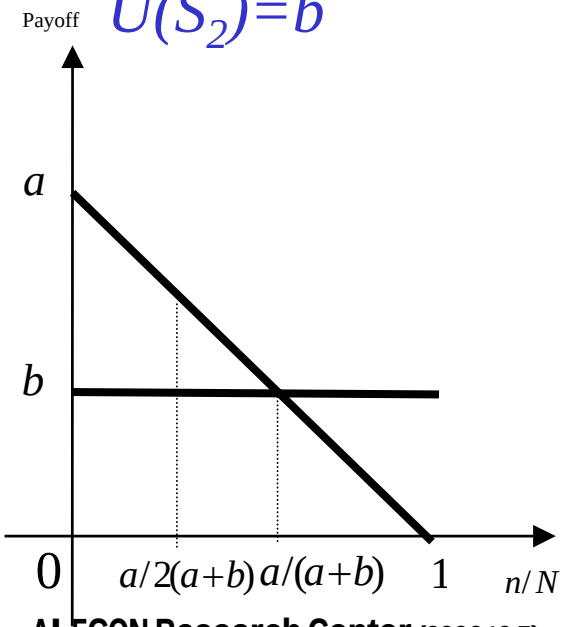
S_1 : use a car S_2 : use a train



payoff=benefit - time

$U(S_1)=a(1-n/N)$

$U(S_2)=b$



- **Market entry games**

Agents

User Equilibrium

- Users optimize their own travel times: Wardrop 1952

> A flow is a **user equilibrium** (**UE**) iff nobody can switch to a path with smaller travel time

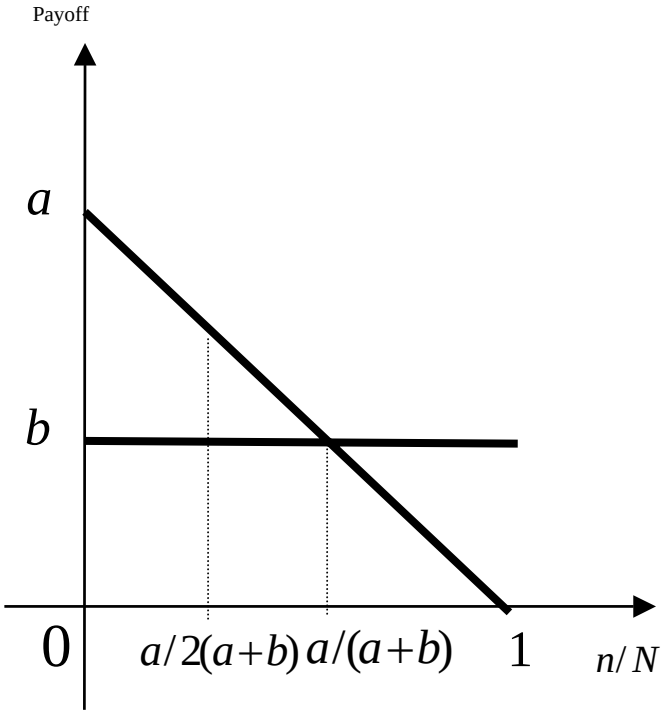
- Travel times of users between the same OD pair are equal

- **UE** always exists and is essentially unique

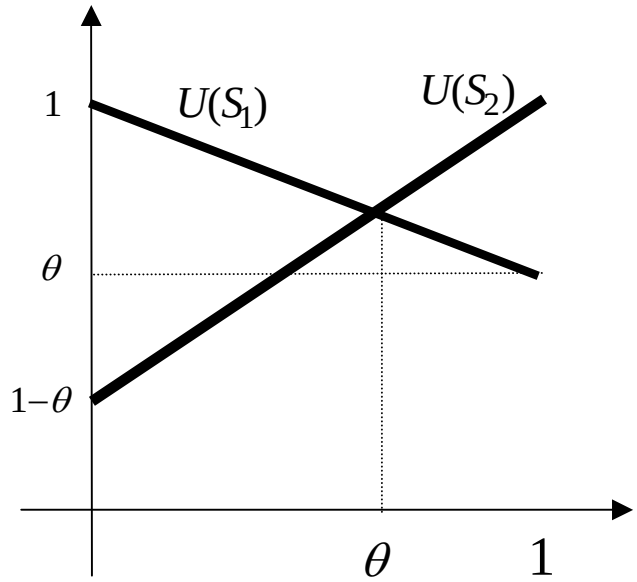
Beckmann, McGuire & Winsten 1956

Nash Equilibrium and Pareto-Optimal

Payoff scheme (1)



Payoff scheme (2)



Average utility $E=pU(S_1)+(1-p)U(S_2)$
$=a(p-p^2)+b$

Average utility is maximum at $p=a/2(a+b)$

Both Nash equilibrium and Pareto-optimal is achieved at $p=\theta$

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Open Problems :

Smart Agents Using ICT

(ICT:Information/Communication Technology)

- Smart intersections
- Smart highways
- Smart 'skyways'
- Smart dispatch of urban emergency vehicles
- Smart routing of people and vehicles

- **Congestion control receive much attention**
- **What wisdom for avoiding congestion will be emerged in networked smart agents equipped with ICT?**

Actual Urban Traffic Study (1)

2002 Urban Mobility Study

http://mobility.tamu.edu/ums

(Moses, 2003)

> "The bad news is that even if transportation officials do all the right things, the likely effect is that congestion will continue to grow. . . "

- Total congestion "bill" in 2000 was $67.5 billion

  (= 3.6 billion hours delay + 5.7 billion gallons gas)

	1982	2000
time penalty for peak period travelers	16 hours	62 hours

Actual Urban Traffic Study (2)

- In traffic networks the ratio between the equilibrium and the social optimum was observed to be significantly smaller in practice

- Divide into two cases:
  - Limited Congestion (Low traffic)
  - No Fixed Costs (Heavy traffic)

Actual Urban Traffic Study (3)

How Efficient are Equilibria?

Some computational studies show that equilibria are typically efficient

Examples:

→ Vehicular Traffic Networks Jahn, Möhring, Schulz & S.-M. OR'05

For seven "real world" instances, the total travel time of equilibria was 2%, 2%, 4%, 7%, 10%, 14% and 15% larger than a system optimum (average $\approx 7.5\%$)

→ Telecommunication Networks Qiu, Yang, Zhang & Shenker SIGCOMM'03

Can that be formalized with theoretical bounds?

The Effects of Smart Automobiles (1)

Intelligent transportation systems

Empirical observation:
People travel (between 6% and 19%) too much distance because of an unfavorable selection of their route.

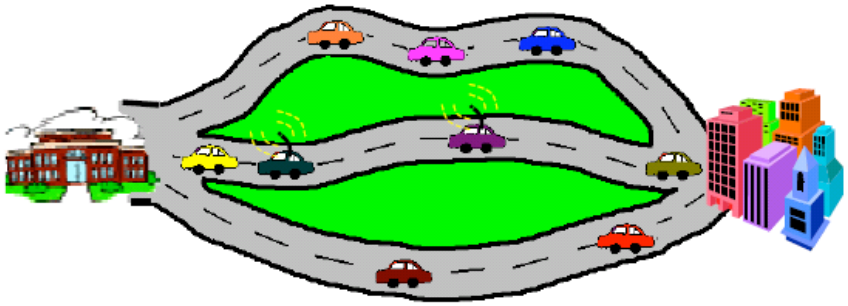
[e.g., Beccaria & Bolelli 1992, Lösch 1995]

Introduction of ITS:

Based on shortest path calculation, either completely off-line or with "dynamic" traffic information

The Effects of Smart Automobiles (2)

Shortest path routings: wanted effects

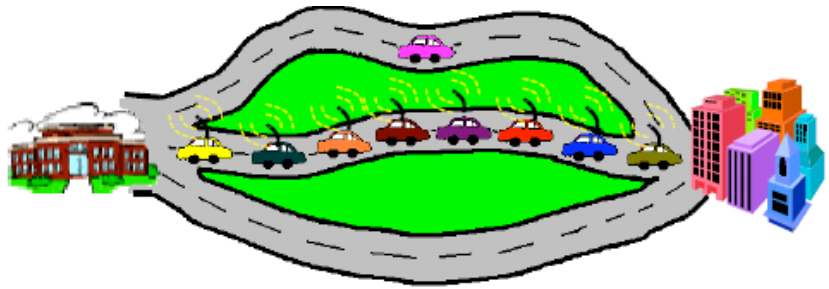


Improved network performance, but …

[Kaufman et al. '91, Lee 94]

Shortest path routings: unwanted effects

… the same simulations show the performance decreases as soon as many cars use the system.



Performance evaluation of route guidance systems

- The **Price of Anarchy** measures the impact of lack of Central Coordination — Papadimitriou 2001
- Let inst($\mathcal{T}$) be the set of instances with latencies drawn from $\mathcal{T}$

Price of Anarchy is $$\max_{\text{inst}(\mathcal{T})} \frac{C(\textbf{UE})}{C(\textbf{optimum})}$$

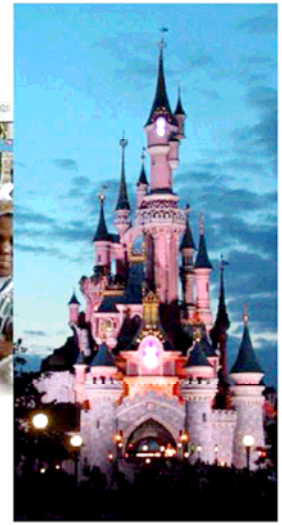
- Previously, this *price* was evaluated using **SO** as solution concept — Roughgarden, Tardos, Correa, Schulz, St., . . .
- But it is a *pessimistic* measure because **SO** cannot be achieved!

Our Goal with Network Design with Smart Agents

selfish users	central planner	our goal
optimize own travel time	optimize system welfare	
fair, not efficient	efficient, not fair	fair, efficient

Smart Networks Design with Genetics Approach

- **Smart Business Networks, Ubiquitous Web of Services,…**
- **How mutual trust can be built and sustained without knowing the motives of others, and without sharing goals.**
- ***Smart Networks Design with Genetics Approach***



search Center (2006.10.5)

Publicizing: New Society (ESHIA) and Journal

Journal of Economic Interaction and Coordination

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An international society for the advancement of economic science, called the *Society for Economic Science with Heterogeneous Interacting Agents (ESHIA)*, will begin its operations on at the beginning of 2006. Accommodating a vibrant inter-disciplinary area, the society aims to bring together researchers active within the agent-based approaches in solving economic and social problems. For more information please visit www.es-hia.org

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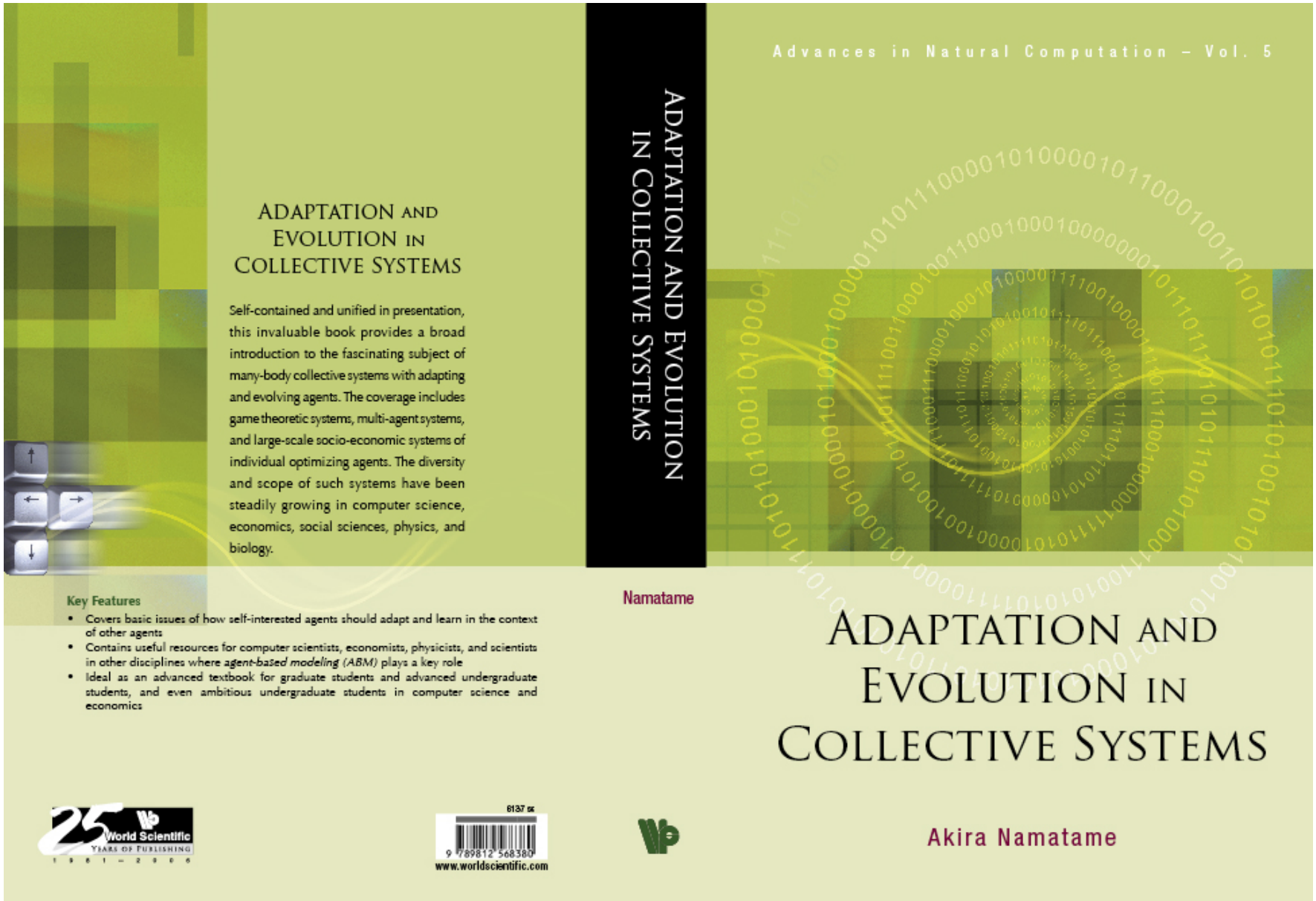
Publicizing New book: World Scientific, 2006



Thank you!! and
Question time