The Era of Supernetworks

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We Are in an Era of Supernetworks

Supernetworks are Networks of Networks.
Supernetworks Underpin Our Economies and Societies

Networks allow for the Flow of People, Products, Energy, and Information Across Regions and the Globe.
A Supply Chain is an Example of a Supernetwork

Supply chains have revolutionized the production, storage, and distribution of products and serve as critical infrastructure networks for economic activities.
Examples of Supply Chains
I utilize mathematical and operations research techniques of optimization, game theory, and dynamical systems to gain insights into the behavior of network systems.
Network Components

The components of networks as a theoretical (modeling, analysis, and solution) construct include: nodes, links, and flows.

We use such a representation to conceptualize, formulate, and study network systems in the real-world.
Representation of Supply Chains as Supernetworks

Supply Chain - Transportation Supernetwork Representation

- Financial Network
- Logistical (Product Supply Chain) Network
- Physical Transportation Network

Two-way information exchanges between specific decision-makers

Transaction cost information
Demand or order information
Travel time information
Unexpected issues information

Real-Time Information System
Why Behavior Matters and Paradoxes
Network Models from Analysis to Design Must Capture the Behavior of Users

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The Braess Paradox Illustrates Why Capturing the Behavior of Users on Networks is Critical
Assume a network with a single O/D pair (1,4). There are 2 paths available to travelers: 
$p_1 = (a, c)$ and $p_2 = (b, d)$.

For a travel demand of 6, the equilibrium path flows are 
$x_{p_1}^* = x_{p_2}^* = 3$ and

The equilibrium path travel cost is 
$C_{p_1} = C_{p_2} = 83$.

$c_a(f_a) = 10f_a, \quad c_b(f_b) = f_b + 50, \\
c_c(f_c) = f_c + 50, \quad c_d(f_d) = 10f_d.$
Adding a new link creates a new path $p_3 = (a, e, d)$.

The original flow distribution pattern is no longer an equilibrium pattern, since at this level of flow the cost on path $p_3$, $C_{p_3} = 70$.

The new equilibrium flow pattern network is

$x^*_{p_1} = x^*_{p_2} = x^*_{p_3} = 2$.

The equilibrium path travel cost: $C_{p_1} = C_{p_2} = C_{p_3} = 92$. 

$$c_e(f_e) = f_e + 10$$
The 1968 Braess article has been translated from German to English:

"On a Paradox of Traffic Planning,"

The Braess Paradox Around the World

1969 - Stuttgart, Germany - The traffic worsened until a newly built road was closed.

1990 - Earth Day - New York City - 42\textsuperscript{nd} Street was closed and traffic flow improved.

2002 - Seoul, Korea - A 6 lane road built over the Cheonggyecheong River that carried 160,000 cars per day and was perpetually jammed was torn down to improve traffic flow.
Broadway between 42nd and 47th Street was converted to a pedestrian plaza.
Other Networks that Behave in a Similar Manner

The Internet and Electric Power Networks!
The Internet has transformed the ways in which individuals, groups, organizations communicate, obtain information, access entertainment, and conduct their business and social activities.

In 2012, there were over 2.4 billion users. In 2018, the number of Internet users has surpassed 4 billion users, more than half of the world’s population.
Envisioning a New Kind of Internet – ChoiceNet
We were one of five teams funded by the US National Science Foundation as part of the Future Internet Architecture (FIA) project. Our project: *Network Innovation Through Choice* envisions a new Internet architecture *ChoiceNet*.

**Team:**

- University of Massachusetts Amherst: Tilman Wolf, Anna Nagurney
- University of Kentucky: Jim Griffioen, Ken Calvert
- North Carolina State University: Rudra Dutta, George Rouskas
- RENCI/UNC: Ilya Baldin
Some Weaknesses of Current Internet

- The Internet architecture lacks in mechanisms to introduce competition and market forces.

- Existing economic models cannot be deployed in today’s Internet: no mechanisms in order to create and discover contracts with any provider and to do so on short-time scales, and time-scales of different lengths.

- Routing of messages may be inefficient and the capacity is not well-utilized in the network.
ChoiceNet Foci: *Choices* and *Network Economics*

Choice criteria can include:

- privacy
- minimization of risk
- even *reducing environmental impact*.

Transparency is associated with ChoiceNet and having more refined routing options *can also assist in cybersecurity*. 
ChoiceNet Principles

*Competition Drives Innovation!*

**Services are at core of ChoiceNet**  
("everything is a service")

Services provide a benefit, have a cost  
Services are created, composed, sold, verified, etc.

*Encourage alternatives* Provide building blocks for different types of services

*Know what happened* Ability to evaluate services

*Vote with your wallet* Reward good services!

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Supernetworks
ChoiceNet

- **ChoiceNet** / economy plane enables new business models in the Internet
  - Very dynamic economic relationships are possible
  - All entities get rewarded.

**Examples**
- Movie streaming
- Reading a newspaper online in a coffee shop (short-term and long-term contracts)
- Customers as providers.
Muchas Gracias!

For more information, see: http://supernet.isenberg.umass.edu