On Analyzing Self-Driving Networks: A Systems Thinking Approach

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Session Outline

1. The Problems: Motivating Systems Thinking
2. The Solution: What Is Systems Thinking?
3. Systems Thinking For The Internet and Future AI-Driven SDNs
Motivating Systems Thinking

A system is always composed of elements, interconnections, and purpose.
Properties of Complex Adaptive Systems

Tightly Coupled
“Everything influences everything else”;
“You can’t just do one thing”

Dynamic
Change occurs at many time scales

Exhibit Tradeoffs
Long term behavior is often different from short term behavior

Counterintuitive
Cause and effect are distant in time and space
Problems Due to Non-Systemic Thinking in Complex Adaptive Systems

"The significant problems we face cannot be solved at the same level of thinking we were at when we created them."
- Albert Einstein
Mental models dictate how we perceive reality based on our values, expectations, & experiences.

Unintended Consequences

Policy Resistance

Symptom Treatment

”There’s always an easy solution to every problem that is neat, and plausible, but wrong.” — H. L. Mencken

Optimizing the parts rather than the whole

Mercedes

measures taken to improve a situation can directly make it worse due to policy resistance arising from people adapting
What Is Systems Thinking?

“Systems Thinking is the art and science of linking structure to performance, and performance to structure—often for purposes of changing structure (relationships) so as to improve performance”—Richmond.
Open loop vs. closed loop thinking
System-as-a-cause thinking

Every influence is both a cause and an effect (due to feedbacks)
“If you are not aware of how you are part of the problem, you can’t be part of the solution.”

**Exogenous point of view**
Sam is always mean to Pam.
It’s all his fault. If he would be nicer, Pam’s life would be better.

**Endogenous point of view**
Maybe there is something Pam is doing, which is causing Sam to be mean…

*Exogenous*: originating externally;  *Endogenous*: originating internally
System thinking tools

Qualitative tools

Causal loop diagrams

a framework for seeing interrelationships rather than things; can help in identifying reinforcing (R) and balancing (B) processes.

Quantitative tools

Stock and flow diagrams

Unlike causal loops, stock and flow diagrams provide information about rates of change and accumulations.

System dynamics is grounded in control theory and the modern theory of nonlinear dynamics and offers many other rigorous tools.
Systems Thinking For The Internet and Future AI-Driven Self-Driving Networks

Instead of optimizations based on closed-form analysis of individual protocols, network operators need data-driven, machine-learning-based models of end-to-end and application performance based on high-level policy goals and a holistic view of the underlying components. Instead of anomaly detection algorithms that operate on offline analysis of network traces, operators need classification and detection algorithms that can make real-time, closed-loop decisions. Networks should learn to do it themselves. This paper...
Endogenous causes of Internet’s problem

Paradoxes of Internet Architecture

Srinivasan Keshav
University of Waterloo

“Systems are perfectly designed to achieve the results they are currently achieving.” — Deming

Three fundamental problems with the Internet today.

1. Spam.
2. Privacy and Security
3. Quality of Service

Keshav points out that these problems stem out from the same Internet’s architectural elements responsible for its success.
System archetypes are feedback structural templates that can be used for diagnosing vexing long-term problems.

Fixes That Backfire
A quick solution with unexpected long-term consequences
IPv4 NAT; Bufferbloat

Limits to Growth
Improvement accelerates and then suddenly stalls
IPv4

Shifting the Burden
Systems unconsciously favor short-term, addictive solutions
IPv4 NAT; cross-layer design; Tussles in cyberspace

Tragedy of the Commons
Shared unmanaged resource collapses due to overconsumption
Spectrum commons;

Success to the Successful
Things get better for “winners” and worse for “losers”
Network neutrality Walled gardens

System archetypes

IPv4 NAT; cross-layer design; Tussles in cyberspace
Ethical and security policy challenges

There are ethical choices in every single algorithm we build.

The question of agency—i.e., “who will take the ethical decision?”—also looms large for self-driving networks.

“No problem stays solved in a dynamic environment.”—Russell Ackoff
Concluding remarks

Systems thinking helps us make sense of interdependency in complex system and the holistic behavior of a system by understanding the feedback loops at play.

With the rise of interest in self-driving networks, which will become part of the larger Internet, there is a need to rigorously look at how these technologies will affect—positively as well as negatively—all the stakeholders.

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