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Outline

1. Introduction
2. A Brief History of the Internet
3. The Early Internet Vision
4. The Future Vision
5. What Have We Created?
6. My Five Golden Rules for Modeling
1. Introduction
“What is the Internet?”

• The father of Larry Garwood, my ophthalmologist, asked him,
  “What is the Internet?”

  • Larry answered:
    “It’s everything, past, present and future.”

  • And so his father challenged him …
    “I was in the Canadian navy in World War II.
    I commanded assault landing craft LCA 1375!”

  “Go and find it on your Internet.”
What Makes the Internet Tick?

1. The People: Hundreds of millions of people make their work available to others on the net.

2. The Culture: There is tremendous power in the early Internet’s culture of openness, sharing and trust.

The Internet Creates Communities!
The Internet Has Dramatically Changed Some Fundamentals

It has:

• Reduced the barrier of distance
• Increased the reach of an individual
• Increased the number of people you can interact with
• Increased the speed of interaction
• Increased anonymity
• Reduced cost of communicating
• Expanded the quantity of accessible info.
The Internet Has Removed Barriers for Interaction

• Political
• Economic
• Social
• Cultural
• Racial
• Physical handicaps
• Physical appearance.

“On the Internet, nobody knows you’re a dog.”

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The Internet ...

- Creates communities
- Provides access to vast stores of knowledge
- Amplifies one’s power to affect things
- Facilitates accountability
- Enables event reporting to travel the globe at the speed of light
- Raises doubt regarding the
  - quality of information
  - authentication of an information source.
The Internet has Fundamentally Changed Our ...

- Institutions
- Business practices
- Behavior
- Attitudes
- Social interactions
- Educational processes
- Political processes
- Work and entertainment habits.
2. A Brief History of the Internet
Let’s Go Back to the Beginning
1969 Was an Incredible Year!

• The first man landed on the moon
• The Woodstock Festival took place
• The Mets won the World Series
• Charles Manson went on a killing spree
• The Internet was born, and nobody noticed!!
Before the Beginning!

- **1957**  Sputnik launched
- **1958**  ARPA formed as a response
- **1959-62**  Len Kleinrock creates a mathematical theory of packet networks at MIT
Before the Beginning!

- 1957  Sputnik launched
- 1958  ARPA formed as a response
- 1959-62 Len Kleinrock creates a mathematical theory of packet networks at MIT
- 1960-64 Paul Baran at RAND proposes sending segmented messages in data networks
- 1962  JCR Licklider 1st Director of ARPA IPTO; gives his vision of a galactic network

and nobody cared!!
Before the Beginning!

- **1965** Doug Englebart develops the mouse and concepts of hypertext
- **1965** Larry Roberts/Tom Marill connect MIT Lincoln Labs with SDC over a dial-up line and publish paper on experiment in 1966
- **1965** Donald Davies coins the word “packet”
- **1966** Robert Taylor joins ARPA and brings Roberts there to develop ARPANET
- **1967** Davies creates 1-node NPL packet “net”
- **1967** Wes Clark suggests use of a mini-computer as a network packet switch to unburden networking tasks from the host
The Arpanet Beginning

- 1967 Many researchers supported by ARPA

“So you want me to do research? Buy me a Big computer… …with all the power everyone else has!”

ARPA’s reply:
“Here’s an offer you can’t refuse …..
Join a NETWORK!”
The Arpanet Beginning

- 1967  ARPA gathers the “gang”
- 1968  Roberts publishes ARPANET plan
- 1968  RFP for a network goes out
- 1968  BBN wins the contract under Frank Heart’s leadership & Bob Kahn’s system design
- 1968  Kleinrock’s lab at UCLA selected to be the first node and serve as Network Measurement Center
- 1969  (Jan-Aug) BBN & UCLA are Busy!
- 1969  UCLA puts out Press Release
"As of now, computer networks are still in their infancy. But as they grow up and become more sophisticated, we will probably see the spread of 'computer utilities' which, like present electric and telephone utilities, will service individual homes and offices across the country."

Leonard Kleinrock
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—from Leonard Kleinrock, 1969
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- 1969  8/29 BBN sends first switch (IMP) to UCLA
- 1969  9/2  First data moves from UCLA Host to UCLA switch
The 1969 IMP
We Decided to Keep a Log

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<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>Message</th>
</tr>
</thead>
<tbody>
<tr>
<td>29 Oct 69</td>
<td>2100</td>
<td>LOADED OP PROGRAM CON FOR BEN BARKER</td>
</tr>
<tr>
<td></td>
<td>22.30</td>
<td>Talked to SRI Host to Host</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lettpcup program (SIC running after sending a host to host message to IMP)</td>
</tr>
</tbody>
</table>

First Message on the Internet - ever!
But What WAS the First Message Ever Sent on the Internet?

- Was it “What hath God Wrought” (Morse 1844)?
- Or “Watson, come here. I want you.” (Bell 1876)?
- Or “One Giant Leap for Mankind” (Armstrong 1969)?
- It was simply a LOGIN from the UCLA computer to the SRI computer.

- We sent an “L” - did you get the “L”? YEP!
- We sent an “O” - did you get the “O”? YEP!
- We sent a “G” - did you get the “G”?
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We sent a "G" -- did you get the "G"?

We sent an "L" -- did you get the "L"?
Growth of the Internet

- 1969 10/29 First Internet message
- 1969 Howie Frank assists topology design
- 1969 UCLA’s Steve Crocker RFC #1 Host-Host Protocol and the NWG
- 1970 ARPANET spans US: UCLA <-> BBN
- 1970 UCLA team releases NCP
- 1971 BBN TIP - direct terminal access
- 1972 Ray Tomlinson introduces net email
- 1972 First public demo of ARPANET
- 1972 Norm Abramson’s packet radio Alohanet connected to ARPANET

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Growth of the Internet

- 1973 ARPA deploys SATNET – 1st international connection
- 1973 Cerf and Kahn design TCP
- 1973 Bob Metcalfe develops Ethernet idea
- 1975 ARPANET mgt transfers to DCA
- 1978 TCP splits into TCP and IP driven by Danny Cohen (since 1973), David Reed and John Schoch to support real-time traffic. This allows the creation of UDP.
- 1980 CSNET funded by NSF in response to a proposal by Larry Landweber, Dave Farber, Tony Hearn and Peter Denning
- 1981 IBM introduces their first PC
Growth of the Internet

- 1983: ARPANET standardizes on TCP/IP
- 1983: DCA splits MILNET from ARPANET
- 1984: DNS introduced: Paul Mockapetris and Jon Postel
- 1986: NSFNET at 56 Kbps for supercomputers; Dave Mills writes the initial software. Steve Wolff in charge.
- 1988: NSFNET upgraded to T-1 backbone
- 1988: Robert Morris unleashes 1st Internet worm
- 1989: UCLA celebrates 20th anniversary
- 1990: ARPANET replaced by NSFNET
- 1991: Tim Berners-Lee’s WWW made available on the Internet
Growth of the Internet

- 1991  NSF opens Internet to commercial use
- 1992  Internet Society formed
- 1992  NSFNET upgraded to T-3 backbone
- 1993  Marc Andreessen Mosaic browser
- 1994  Cantor & Siegel introduce spam
- 1994  BBN celebrates 25th anniversary
- 1995  dot.com boom starts with faith that a “new economy” is beginning
- 1996  Telecom Act deregulates data networks
- 1996  More email than postal mail in USA
- 1997  Internet2 consortium is established
- 1997  IEEE releases 802.11 (WiFi) standard
Spam!

- It surfaced as a critical and widely publicized event in April 1994 when two Arizona-based attorneys arguably became the two most hated individuals in the history of the Internet. It was Lawrence Canter and Martha Siegel, the famous "green card lawyers" who "spammed" the Internet.
Green Card Lottery 1994 May Be The Last One!
THE DEADLINE HAS BEEN ANNOUNCED.

The Green Card Lottery is a completely legal program giving away a certain annual allotment of Green Cards to persons born in certain countries. The lottery program was scheduled to continue on a permanent basis. However, recently, Senator Alan J. Simpson introduced a bill into the U. S. Congress which could end any future lotteries. THE 1994 LOTTERY IS SCHEDULED TO TAKE PLACE SOON, BUT IT MAY BE THE VERY LAST ONE.

PERSONS BORN IN MOST COUNTRIES QUALIFY, MANY FOR FIRST TIME.

The only countries NOT qualifying are: Mexico; India; P.R. China; Taiwan, Philippines, North Korea, Canada, United Kingdom (except Northern Ireland), Jamaica, Dominican Republic, El Salvador and Vietnam.

Lottery registration will take place soon. 55,000 Green Cards will be given to those who register correctly. NO JOB IS REQUIRED.

THERE IS A STRICT JUNE DEADLINE. THE TIME TO START IS NOW!!

For FREE information via Email, send request to
cslaw@indirect.com
Growth of the Internet

- 1998: Blogs begin to appear
- 1998: VOIP equipment begins rolling out
- 1999: UCLA celebrates 30th anniversary
- 1999: Napster rolls out
- 2000: dot.com bubble begins to burst
- 2001: Napster forced to suspend service
- 2003: Flash mobs gain popularity
- 2003: World Summit on the Information Society (WSIS) 1st meeting in Geneva
- 2004: UCLA celebrates 35th anniversary
Growth of the Internet

- **2004** USA phone Revenue:
  mobile = fixed line = $50 billion
- **2004** USA leads in avg minutes for a cell call
  USA = 15-20, Korea = 8, Japan = 6, Britain = 5, World = 3
- **2004** Camera-enabled phone sales exceed combined sales of digital + film camera
- **2005** 812 million cell phones sold
  219 million laptops sold
- **2005** Google is the darling of the Internet
- **2005** Peer-to-Peer Grows; Supreme Court Decision supports RIAA et al.
- **2005** Grokster closes down
Growth of the Internet

• 2005 (WSIS holds 2nd meeting in Tunis.
  • On November 16, WSIS agreed to keep ICANN under USA authority and created the Internet Governance Forum which provides a forum for all stakeholders to raise concerns and issues.
  • Next meeting in Athens in late 2006.

• 2005 AT&T disappears
  • In 1983 it was the world’s largest corporation with assets > $125 billion.
  • On November 18, it ceased to exist as an independent company; SBC bought AT&T.
  • It employed some of the world’s best scientists and worst managers and died of stupidity.

• 2005 AT&T reappears
  • SBC renames itself as AT&T.
Some of the Internet Personalities

The Early Pioneers

The Implementers

The Value Adders

The Launchers

The Billionaires

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3. The Early Internet Vision
Did you see this coming?

Remember my 1969 Vision

The Press

Me
So What Was My Early Internet Vision?

- The Internet technology will be everywhere
- Always accessible
- Always on
- Anyone can plug in any device anywhere
- Invisible
The Internet *Almost* Got it Right

**Yep**  The Internet technology will be everywhere

**Yep**  Always accessible

**Yep**  Always on

**Nope**  Anyone can plug in any device anywhere

**Nope**  Invisible

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What Did the Internet Get Wrong?

• The Internet model grew up assuming that
  • the end user,
  • his device,
  • its IP address,
  • his location
• are always tightly coupled.

This is no longer true: the nomads are taking over
Enablers for the Dark Side

• The Internet allows anyone to reach hundreds of millions of users easily, quickly, at essentially no cost (in money or effort), anonymously.

• This is a perfect formula for enabling the dark side of the Internet.
4. The Future Vision
Infocom 2000

My Vision of the Future
Infocom 2000:
The Vision Has Three Phases

1. Advanced Network Technology
2. Nomadic Computing
3. Smart Spaces
Extending My Internet Vision: The Internet’s Next Five Phases

Phase 1: Nomadic Computing
Phase 2: Embedded Technology (or Smart Spaces/Smart Nets)
Phase 3: Ubiquitous Computing
Phase 4: Convergence
Phase 5: Software Agents
Phase 1: Nomadic Computing

In Your Office You Have ...

- A High performance workstation
- Access to high speed networks
- Support from an IT Systems Administrator

You lose the last 2 as soon as you go on the road!

We need a portable network administrator.
The system support to provide the nomadic user with trouble-free Internet service from any device, any place, at any time.
Phase 2: Embedded Technology: Smart Spaces & Smart Networks

- Our environment will be **alive** with technology all around us
  - In the walls
  - In my desk
  - In my belt
  - In my eyeglasses
  - In my refrigerator
  - In my automobile
  - In my fingernails
  - In my hotel room.

- Thousands of processors per human
  - Logic, memory
  - Communications
  - Actuators, sensors
  - Cameras,
  - Microphones, speakers
  - Displays.
Phase 2: Embedded Technology: Smart Spaces & Smart Nets

Small intelligent devices embedded in the physical world and connected to the Internet
What WILL be Connected?

Let’s Look at Some Recent Chip Deployments

- 150 million computational platform microprocessors
- 300 million embedded microprocessors
- 600 million digital signal processors
- 7,000 million embedded microcontrollers!
What WILL be Connected?
What WILL be Connected?
Phase 3: Ubiquitous Computing

- **Sequence of technologies:**
  - Dial-up access
  - Copper DSL
  - Cable modems
  - Satellite access
  - Cellular 3G, 4G etc
  - WiFi
  - WiMax
  - Fiber.
Phase 3: Ubiquitous Computing

Internet service availability wherever the nomad travels on a global basis
Phase 4: Convergence

Content
Function
Services

The Future Vision
Three Disruptive Forces

Digitization of Practically Everything

Explosion of Broadband

Devices are Getting Smarter… A Lot Smarter… Really, Really Fast
Let’s Focus on the Mobile Device
It is a Content Rendering Device
On The Road

- A person who carries a digital watch, a 2-way email pager, cell phone, MP3 player, PDA, camera, GPS and notebook computer is carrying:
  - 8 displays,
  - 6 keyboards,
  - 5 speakers,
  - 3 microphones,
  - 8 clocks,
  - 8 batteries and 7 chargers
  - 4 communication devices.

This is Ridiculous!
Let’s Converge Them Into One Device

- Pager
- Camera
- Portable MP3/Video
- GPS Device
- Television
- Phone
- Camcorder
- PDA
- PC
- Watch
- Walkie-Talkie
- FM Radio
- Game Console
- Rolodex

All This Garbage I Carry Around
Let’s Converge Them Into One Device
The Device Earlier Known as the Cell Phone Will Become a Communicating Multifunction Rendering Device
A Converged Phone

Those keyboards are getting smaller

But My Fingers Are Not!
The Screens Are Getting Smaller

And My Eyes Are Getting Weaker
How Far Have We Come in 35 Years?

Honeywell DDP-516 Interface Message Processor

circa 1969

Connected to Internet via 50 kbps leased line

PalmOne Treo

circa 2004

Connected to Internet via 50 kbps GPRS link

From Henry Samuei at UCLA 35th Internet Anniversary Symposium
Mismatch?

Whoa !!
What is the Mobile Device?

- **Traditional View**
  - It’s a Phone
- **Hollywood View**
  - It’s a Tiny TV
- **Silicon Valley View**
  - It’s a PDA
- **Game Industry View**
  - It’s a GameBoy
- **Correct View**
  - It’s a Whole New Medium!
The Fourth Screen is Here and Always With You

Movie Screen → TV Screen → PC Screen → Phone Screen
New Services

Multi-Billion Dollar Industries

- Ring-back tones (fan tones)
- Music Streaming
- Full Song Downloads
- Music Video Downloads
- Full Video Downloads
- Gaming
- Gambling
- Sports.
From Convergence to Divergence
With Convergence Comes Divergence

- Bluetooth earpiece
  - Implanted pacemaker
- The advanced nerd
- Head-mounted displays
- Minority Report
- Things you didn’t anticipate
Yet More Divergence in the Environment

The Intelligent Car
Phase 5: Software Agents

- Intelligent **software agents** will be deployed across the network whose function it will be to:
  - Mine data
  - Act on that data
  - Observe trends
  - Carry out tasks dynamically
  - Adapt to their environment.

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So What’s the Infrastructure Vision?

Start With Mine From 1969:

- The Internet technology will be everywhere
- Always accessible
- Always on

We Got That Far

We Are On Our Way to the Next Steps:

- Anyone can plug in any device anywhere
- Invisible

Now Let’s Expand That Vision:
An Expanded Vision of the Future

- Armies of Nomads dashing about
- Small pervasive devices ubiquitously embedded in the physical world,
  - Providing the capabilities of
    - actuators, sensors, logic, memory, processing, communications, speakers, microphones, cameras, displays, etc.
- Intelligent software agents deployed across the network
  - whose function it is to
    - mine data, act on that data, observe trends, carry out tasks dynamically and adapt to their environment.
- Considerably more network traffic generated not so much by humans, but by these embedded devices and these intelligent software agents.
An Expanded Vision of the Future (cont)

- Large collections of self-organizing, independent yet cooperative adaptive systems that can operate in unpredictable environments.
- Vast, fast networks.
- Huge amounts of information flashing across these global networks instantaneously, with this information undergoing enormous processing and informing the sophisticated decision support and control systems of our society.

The Internet will essentially be a pervasive global nervous system.
5. What Have We Created?
Let’s Look At The “Elephant” In The Room!

We are creating a vast, complex, organic system whose behavior is hardly under our control!
Let’s Look At The “Elephant” In The Room!

Complexity!

• So how do we begin to understand how such a complex system will behave?
• We are hitting a “Complexity Wall”
• It will impair our ability to move ahead
• It makes us vulnerable to:
  • unforeseen behavior
  • Failures
  • Attacks
  • High costs.
The Elephant: Complexity

- Understanding Complexity
- Controlling complexity
Where Does it Appear?

Type Of Parts

<table>
<thead>
<tr>
<th>Heterogeneous</th>
<th>Homogeneous</th>
</tr>
</thead>
<tbody>
<tr>
<td>Complex</td>
<td>Simple</td>
</tr>
<tr>
<td>Good Luck !</td>
<td>Complex</td>
</tr>
</tbody>
</table>

Number of interacting parts

Small

- Complex
- Simple

Vast

- Good Luck !
- Complex
What is Complexity?

Really hard to define

- A new field involving large systems having many interacting parts that lie between
  - Deterministic mathematical solutions
  - Statistical averaging solutions

It can refer to the

- Emergence of very intricate, seemingly planned constructs from initial randomness.
- Emergence of chaotic behavior from seemingly deterministic initial conditions.
Scope of Complexity

• What does this area cover? Basically anything complex with interacting parts
• Researchers in this science come from many areas:
  • physics,
  • biology,
  • economics,
  • medicine,
  • philosophy,
  • sociology,
  • computing,
  • engineering,
  • game theory,
  • chemistry,
  • mathematics,
  • AI,
  • and many others.
What Fields Does it Cover?

- Artificial Life
- Cellular Automata
- Chaos
- Complex adaptive systems
- Emergent behavior
- Fractals
- Genetic Algorithms
- Gur algorithm
- Insect algorithms
- Packet networks
- Neural networks
- Nonlinear dynamics
- Percolation theory
- Small world networks
- Synchronization
- Swarms.
Networks Are All Over the Place

- WWW
- Internet
- Electric Power Grids
- Transportation systems
- Biological networks
- The Brain
- Social networks.
Failed

Networks Are All Over the Place

- Power Grid Failure
  - August 2003 blackout that darkened ½ of the USA (NE & MidWest)
- SS7 Software Failure
  - January 1990, the SS7 software of an AT&T switching node rippled through over 100 switching nodes. The failure caused a 9-hour outage, affected 60,000 people and cost in excess of $60 million
- BGP Storms
  - July and September, 2001, CODE RED and Nimda viruses disrupted the Internet routing infrastructure
- WorldCom UUNET network failure
  - October 3, 2002, a faulty routing table in one router caused millions of users several hours of delay for email and connections.
- Oyster Smartcard in the UK crashes
  - March 10, 2005 due to a failed IT monitoring system
- Early days of the Internet
  - Christmas lockup
  - Store and forward lockup
  - Piggyback lockup
Some Source of Failures

- Protocol errors
- Implementation errors
- Complex protocols that interact in unforeseen ways
- Flow control
- Random faults
- Cascading failures
- Malicious attacks.
Highly Structured Systems
Blessing or Curse?

• A.M. Radio
  - Poor reception
  - Slowly gets worse with distance

• F.M. Radio
  - Good reception
  - Catastrophically gets worse at critical distance

• The more you optimize, the worse will be the system performance when you overload it

• This tends to be true for many highly structured systems
  - Congestion systems
  - Error correcting codes
  - The one horse shay
Understanding Complexity

• We thought that man-made systems could be understood and analyzed.
• We thought that natural systems, that we did not build, would be far more difficult to understand.
• But now, complexity of the man-made systems has removed our arrogantly assumed advantage.
• The key to understanding is to seek macroscopic behavior.
  • Knowing behavior of components does not necessarily help us predict behavior of the system.
  • Similarly, we may be able to predict the system behavior even if we do not know the component behavior.
• The interaction among the components in a large system can generate greater or less complexity than the components themselves.
• We must look for organizing principles.
Some Example Networks
The Internet Router Network
**Nodes:**
trophic species

**Links:**
trophic interactions

**Food Web**

1st Tropic Level
Mostly Phytoplankton

2nd Tropic Level
Many Zooplankton
Cellular Network
International Web Cache
These nets exhibit the “small world” effect, namely,

- Highly clustered
- Small distance between any 2 randomly chosen nodes
- Scale-free links
Internet Resilience and Fragility

• Can we maintain Internet functionality under
  • random failures
  • frequent attacks by computer hackers

• The **good news** is that so far the Internet has proven rather resilient against **random failures**. This is due to:
  • Error tolerance in the protocols
  • The crucial role of its scale-free topology
  • Random removal of nodes usually affects small nodes rather than hubs since small nodes significantly outnumber hubs.

• The **bad news** is that scale-free networks are rather vulnerable to **coordinated hacker attacks**. Indeed, the absence of a tiny fraction of the most-connected nodes will cause the network to break into pieces.
Towards a Theory of Network Science

- This “robust-yet-fragile" feature is characteristic of complex systems throughout engineering and biology.
- Uncover the laws that govern the underlying dynamical processes, e.g., Internet traffic or cell reaction kinetics.
- Understand how the two layers of complexity - architecture and dynamics - evolve together.
- Can we find common features beyond power laws that complicated systems in engineering and biology share using simple models and general principles?
- These are all formidable challenges for engineers, physicists, biologists and mathematicians alike, inaugurating a new era that Stephen Hawking recently called "The Century of Complexity."
6. My Five Golden Rules for Modeling
My Five Golden Guidelines to Research

1. Conduct the 100-year test.
2. Don’t fall in love with your model.
4. Understand your own results.
5. Look for “Gee, that’s funny!”
"Why do so few scientists make significant contributions and so many are forgotten in the long run?"

“If you don't work on important problems, it's not likely that you'll do important work.”

1. The 100 Year Test

• Hamming once asked me,

“What progress of today will be remembered 1000 years from now?”

Will your work be remembered 100 years from today?
2. But Don’t Fall in Love With Your Model

The Real World

Mathematical Model of The Real World

Solution to the Mathematical Model

Approximation
3. Beware of Mindless Simulation
Ask the Obvious Questions
4. Understand Your Own Results
Response Time
Throughput
Loss

Network Cloud

Input: $\lambda$
Capacity: $\gamma_0$
Throughput: $\gamma$
Loss: $\lambda - \gamma$

Response Time: $T$

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Response Time vs Throughput

Now let’s ask a good question:

Do you want to operate here? Or here?

T(\gamma)

Response Time

\gamma(\lambda)

Throughput

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Let me define a new metric of performance:

$$\text{POWER} \triangleq \frac{\text{Throughput}}{\text{Response Time}}$$

The main result is that power is max when

$$\frac{dT(\gamma)}{d\gamma} = \frac{T(\gamma)}{\gamma}$$

**Max Power Point**

4. Understand Your Own Results
Let’s Dig Deeper on Understanding

For M/M/1 this gives max Power at $N^* = 1$

Response Time vs Throughput

Why?

4. Understand Your Own Results
Use Your Intuition

Only 1 customer
in the system

Insight:
Just keep the pipe full!

\[ T = \text{Min} \]
\[ \text{Eff} = \text{Max} \]
4. Understand Your Own Results

- Our intuition says put *exactly* one person in the queueing system
  - This was from “deterministic” reasoning.
- We can’t actually do that in general
- BUT our earlier result said that we should adjust the system to achieve an *average* of one person in the queueing system, i.e.,

\[
\text{At Max Power} \quad N^* = 1
\]

for M/M/1

*Gee, that’s funny!*
5. Gee, that’s funny!
5. Gee, that’s funny!
What can we say for M/G/1?

More on Modeling

• Moving the frontier is tough (we mislead our students)
• Once you do it, you will be able to repeat it (students don’t believe us)
• Teach your students to understand their results!
• Generalization usually comes when you can see the simplicity of a solution
• Keep your interest in related areas, areas where something might happen.
Thank You

www.lk.cs.ucla.edu