

# Realizing the Wireless Internet

**Leonard Kleinrock**

**Professor, UCLA Computer Science Dept**

**Keynote Lecture**

**WCNC**

**Hong Kong**

**March 13, 2007**

# Outline

- 1. Introduction**
- 2. A Brief History of the Internet**
- 3. A Brief History of Wireless**
- 4. The Early Internet Vision**
- 5. The Future Vision**
- 6. My Five Golden Guidelines for Research**

# 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.”

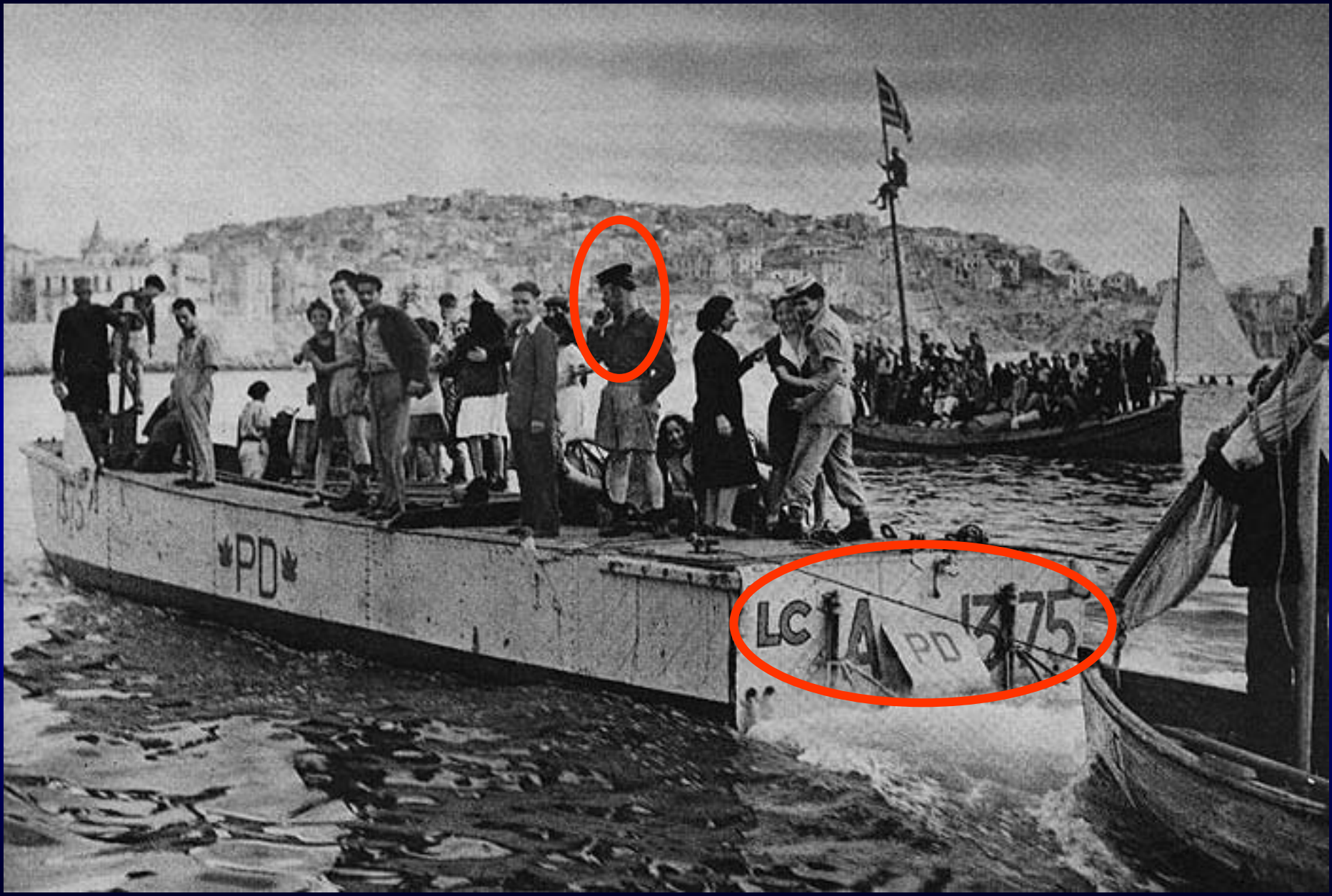












# What Makes the Internet Tick?

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 !**

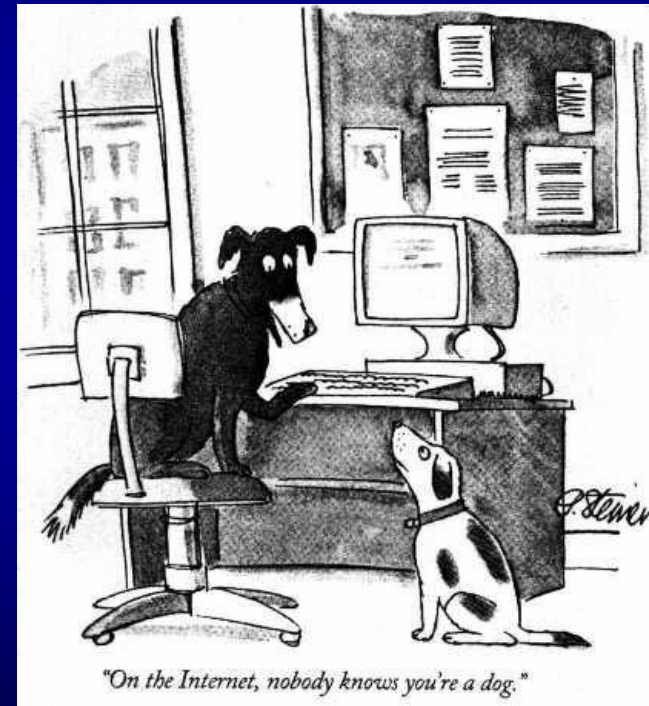
# The Internet Has Dramatically Changed Some Fundamentals

## 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.”**

## **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 1<sup>st</sup> Director of ARPA IPTO; galactic network vision of social interaction through networking of computers.



**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



Researcher

“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, or  
lose your funding!**



# 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

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Dial: "UCLA-585"

**Ucla  
Press  
Release**

Thursday, July 3, 1969

**July 3, 1969**

**“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**

Computer networks are not an entirely new concept, notes Dr. Kleinrock. The SAGE radar defense system of the Fifth Air Force was one of the first, followed by the airlines' SABRE reservation system. At present time, the nation's electronically switched telephone system is the world's largest computer network.

However, all three are highly specialized and single-purpose systems, in contrast to the planned ARPANET system which will link a wide assortment of different computers for a wide range of unclassified research functions.

"As of now, computer networks are still in their infancy," says Dr. Kleinrock. "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."

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**My 1969 vision ...**

**“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.”**

**Web-based  
IP Services**

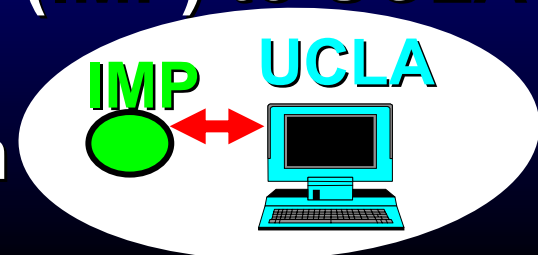
**Always On  
Invisible**

**Ubiquitous**

... are not an end... notes Dr. Kleinrock. The  
... system of... of the first, followed by the  
... ABRE reserved... present time, the nation's electronically  
switched telephone... largest computer network.  
However, ... specialized and single-purpose systems, in con-  
trast to... system which will link a wide assortment of different com-  
puter... range of unclassified research functions.  
... now, computer networks are still in their infancy," says Dr. Kleinrock.  
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- 1969 (Jan-Aug) BBN & UCLA are Busy!
- 1969 UCLA puts out Press Release
- 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

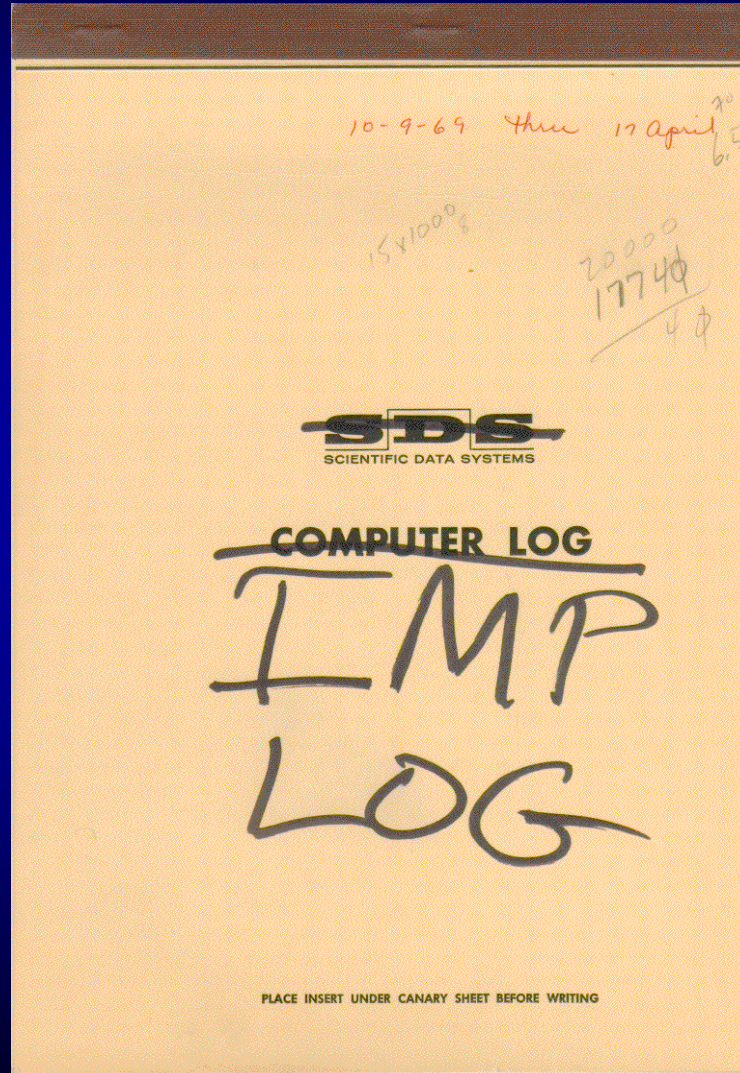






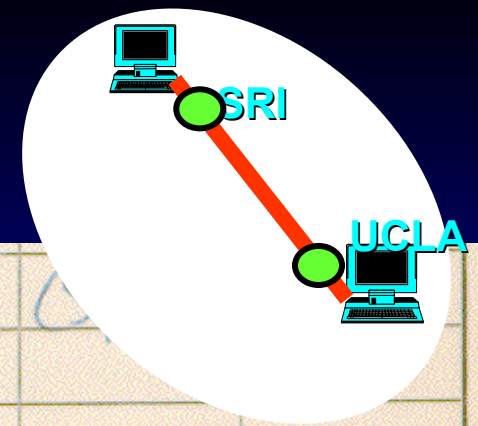


# We Decided to Keep a Log





# An Important Entry in Our IMP Log



29 OCT 69 100  
LOADED OP. PROGRAM  
E012 BEN BARKER  
BBN

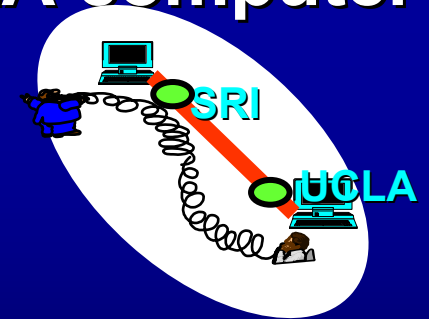
12:30 Talked to SRI  
Host to Host CS@

Left op. imp program CS@  
running after sending  
a host dead message  
to imp.

**First Message on the Internet  
- ever!**

# But What WAS the First Message Ever Sent on the Internet?

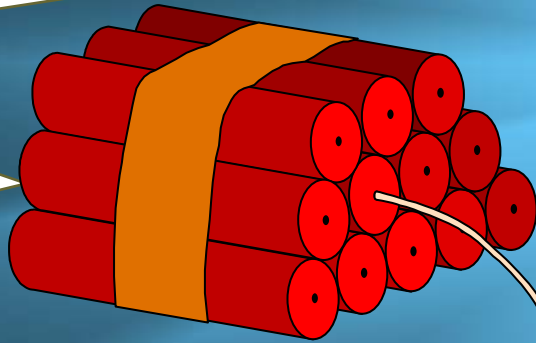
- Was it “What hath God Wrought” (Morse 1844)?
- Or “Watson, come here. I want you.” (Bell 1876)?
- Or “One Giant Leap for Mankind” (Armstrong 1969)?
- It was simply a **LOGIN** from the UCLA computer to the SRI computer.



- 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”?

# But What WAS the First Message Ever Sent on the Internet?

- What



**Crash!**

# But What WAS the First Message Ever Sent on the Internet?

- What

**LO!**



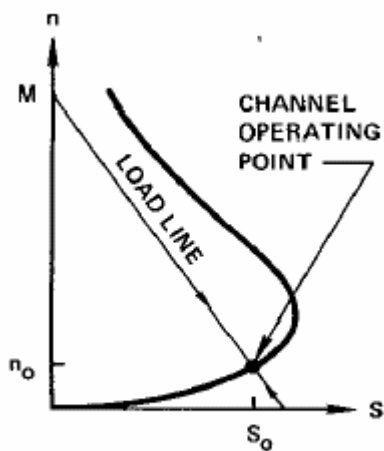


# Growth of the Internet

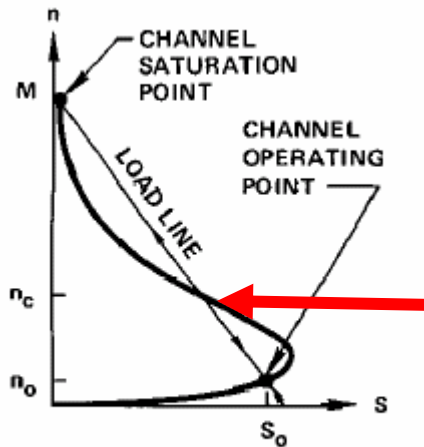
- **1969**      **10/29 First Internet message**
- **1969**      **Howie Frank assists topology design**
- **1969**      **UCLA's Steve Crocker RFC #1  
Host-Host Protocol and the NWG**
- **1970**      **ARPANET spans US: UCLA <-> BBN**
- **1970**      **UCLA team releases NCP**
- **1971**      **BBN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

# Enter the Wireless Networks

- 1972 Norm Abramson's packet radio Alohonet connected to ARPANET
- 1973 ARPA deploys SATNET -- 1st international connection
- 1973 First analysis of slotted Aloha: performance, stability



(a) A STABLE CHANNEL



(b) AN UNSTABLE CHANNEL

$$S = Ge^{-G}$$

Kleinrock, L. and S. Lam, "Packet Switching in a Slotted Satellite Channel", *AFIPS Conference Proceedings*, Vol. 42, National Computer Conference, New York, June 1973, AFIPS Press, Montvale, New Jersey, pp. 703-710, 1973

# Enter the Wireless Networks

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- 1973 ARPA deploys SATNET – 1st international connection
- 1973 First analysis of slotted Aloha: performance, stability
- 1974 First analysis of CSMA

$$S = \frac{Ge^{-aG}}{G(1+2a) + e^{-aG}}$$

Kleinrock, L. and F. Tobagi, "Carrier Sense Multiple Access for Packet Switched Radio Channels", Conference Record, *International Conference on Communications*, Minneapolis, Minnesota, pp. 21B-1 to 21B-7, June 1974.

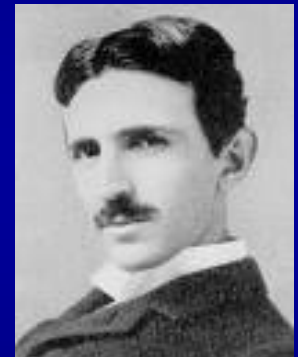


# 3. A Brief History of Wireless

# Who Made These Predictions?

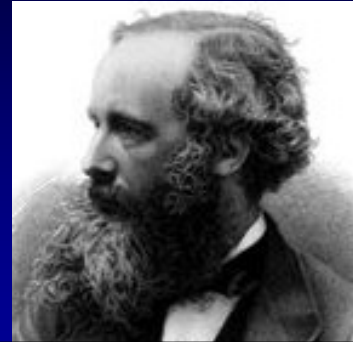
- “It will be possible for a business man in New York to dictate instructions, and have them instantly appear in type at his office in London or elsewhere.
- “He will be able to call up, from his desk, and talk to any telephone subscriber on the globe.
- “An inexpensive instrument, not bigger than a watch, will enable its bearer to:
  - hear anywhere,
  - on sea or land,
  - music or song,
  - the speech of a political leader,
  - the address of an eminent man of science,
  - or the sermon of an eloquent clergyman,
- delivered in some other place, however distant.
- “In the same manner any picture, character, drawing, or print can be transferred from one to another place.
- “The wireless art offers greater possibilities than any invention or discovery heretofore made, and ... we can expect with certitude that in the next few years wonders will be wrought by its application.”

**Nikola Tesla  
In 1908**



# The Giants of Wireless Communication

- James Clerk Maxwell



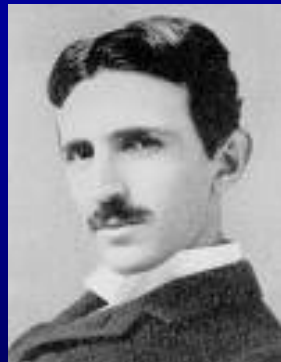
“Mathematicians ... will even be doubtful whether the ideas as expressed in symbols had ever quite found their way out of the equations into their minds.”

- Heinrich Hertz



“I do not think that the wireless waves I have discovered will have any practical application.”

- Nikola Tesla



“Today’s scientists have substituted mathematics for experiments, and they wander off through equation after equation, and eventually build a structure which has no relation to reality.”

- Guglielmo Marconi



“Have I done the world good, or have I added a menace?”

# Radio Timeline

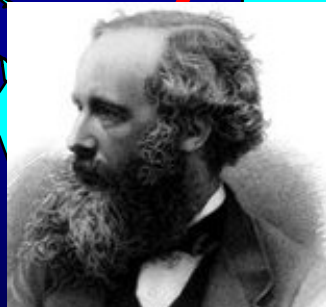
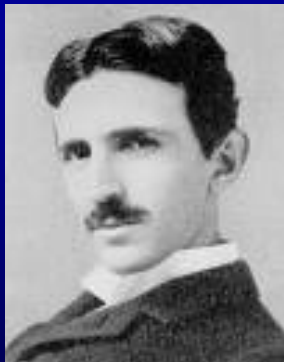
- **1864:** Maxwell mathematically predicts the existence of radio waves.
- **1878:** David E. Hughes sends/receives Morse Code, discovering radio waves.
- **1885/6:** Hertz proves existence of radio waves using a primitive transmitter and receiver.
- **1891:** Tesla is granted U.S. Patent revealing the basic techniques for greatly improving radio transmitter performance.
- **1893:** Tesla demonstrates "wireless telegraphy"
- **1894:** Alexander Popov builds his first radio receiver in Russia, the first non-laboratory radio service.
- **1894:** Oliver Lodge transmits radio signals at Oxford University
  - One year after Tesla
  - One year before Marconi

# Radio Timeline

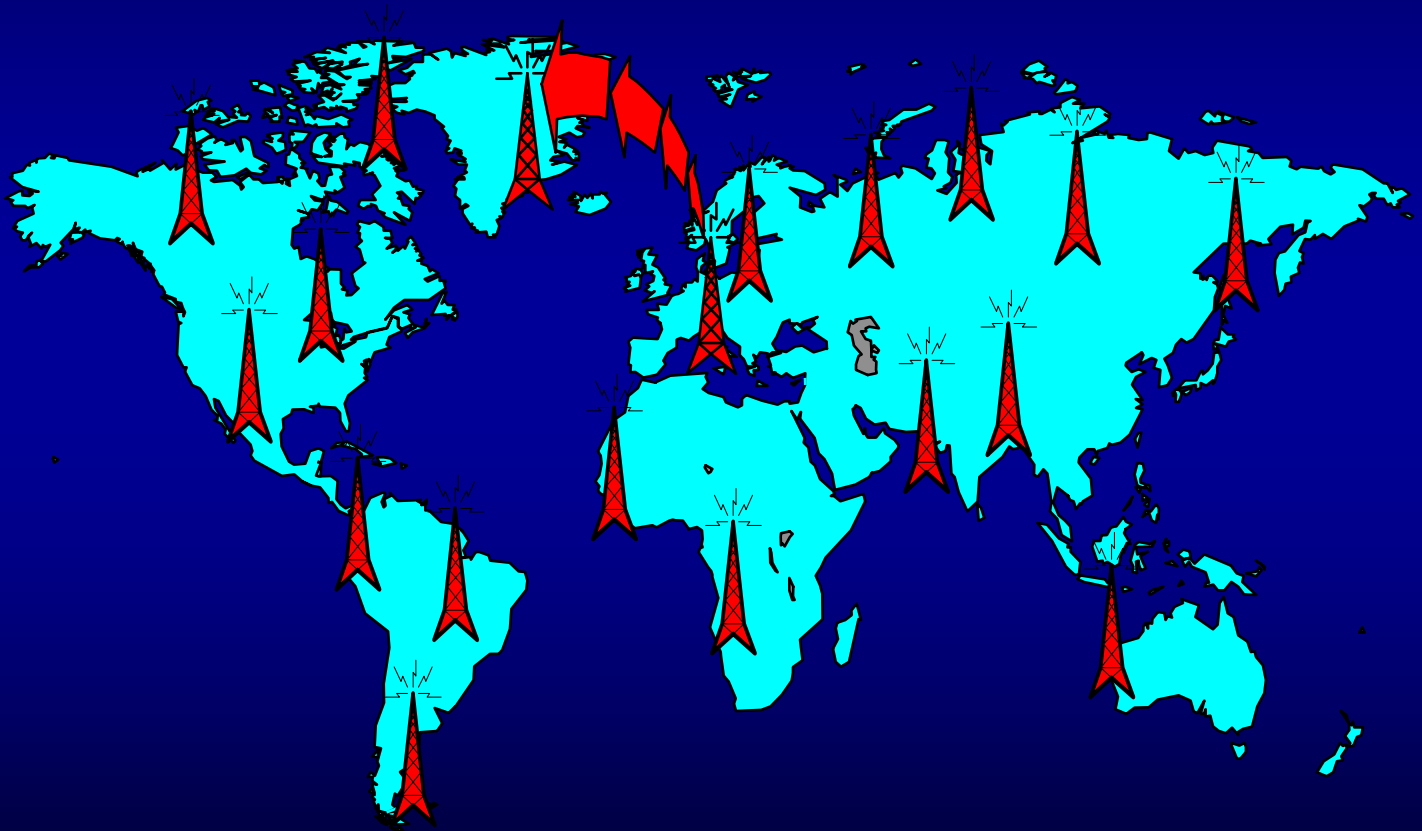
- **1895:** Marconi transmits wireless signals a distance of about 1 mile
- **1896:** Tesla transmits wireless signals over distances of up to 30 miles.
- **1897:** Marconi is granted a British patent, establishes the world's first radio station and what later becomes the Marconi Wireless Telegraph Company
- **1898:** Popov effects ship-to-shore communication over a distance of 6 miles
- **1901:** Marconi receives the first trans-Atlantic radio signal.
- **1906:** Lee de Forest invents the Audion, now known as the vacuum-tube triode.
- **1909:** Marconi wins the Nobel Prize in physics
- **1933:** Edwin Armstrong patents FM

# Radio

Newfoundland



# Radio

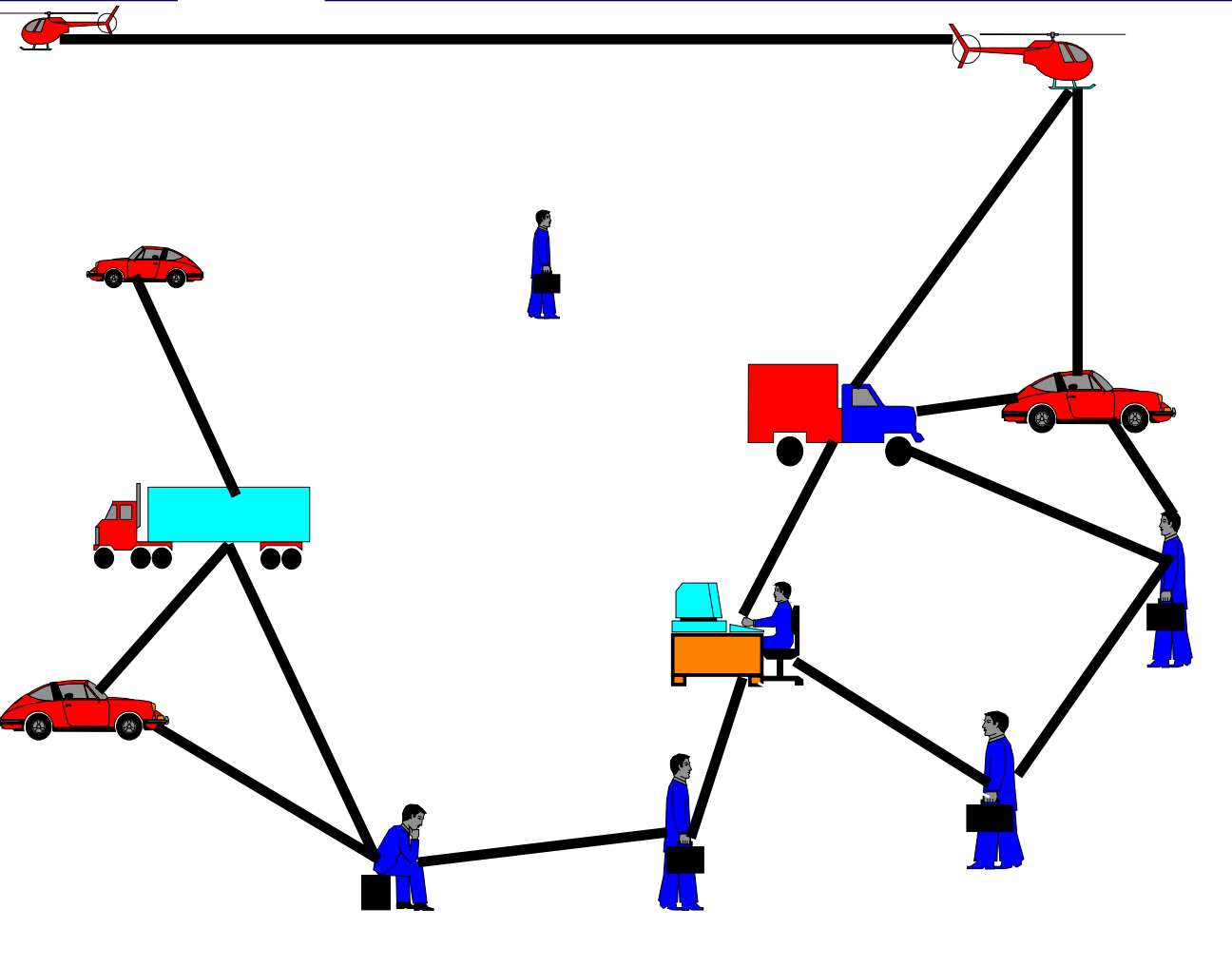






# Packet Radio

• 1970's >> 1990's: ARPA



250 >> 10 cu in

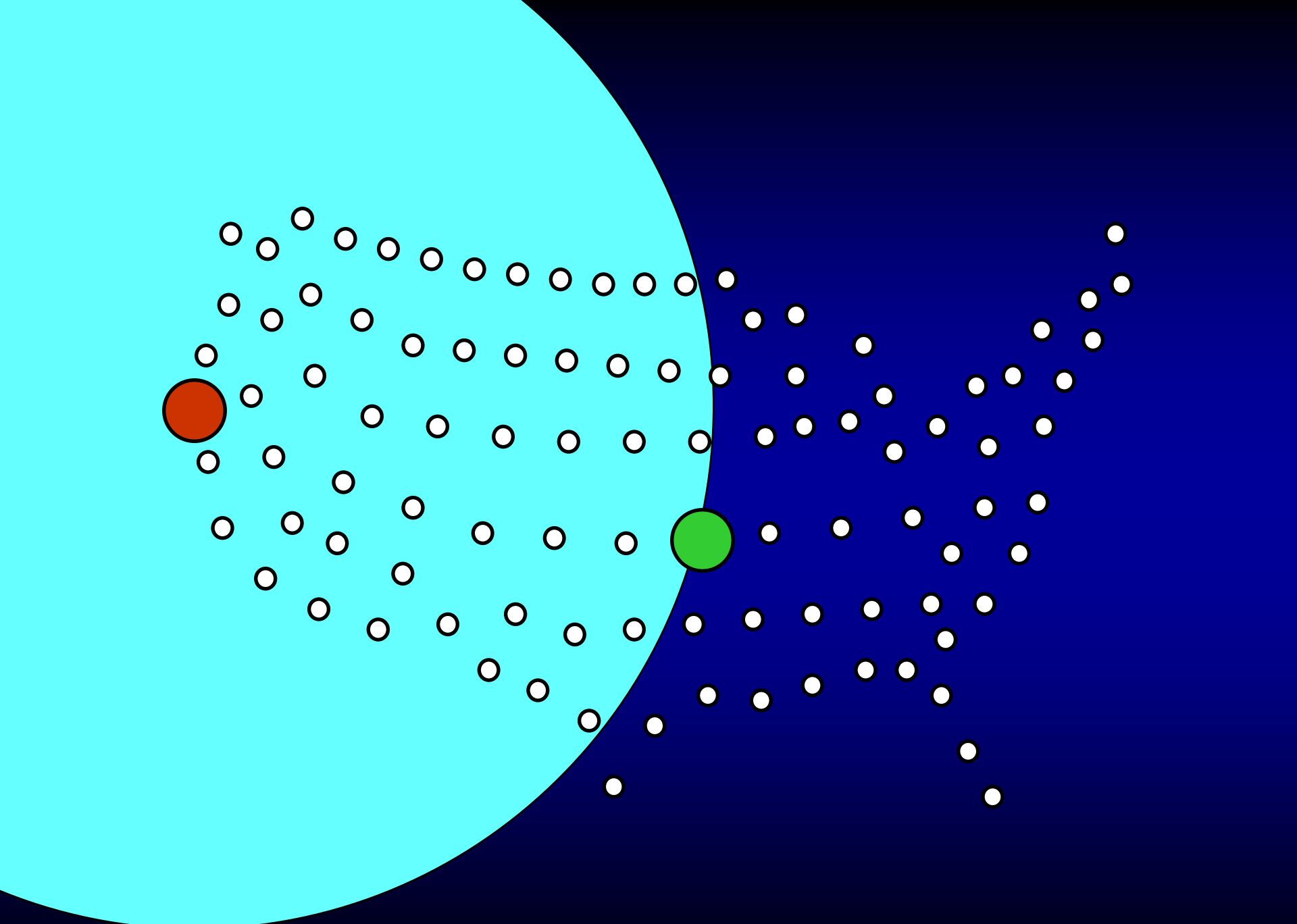
25 >> 1 watt

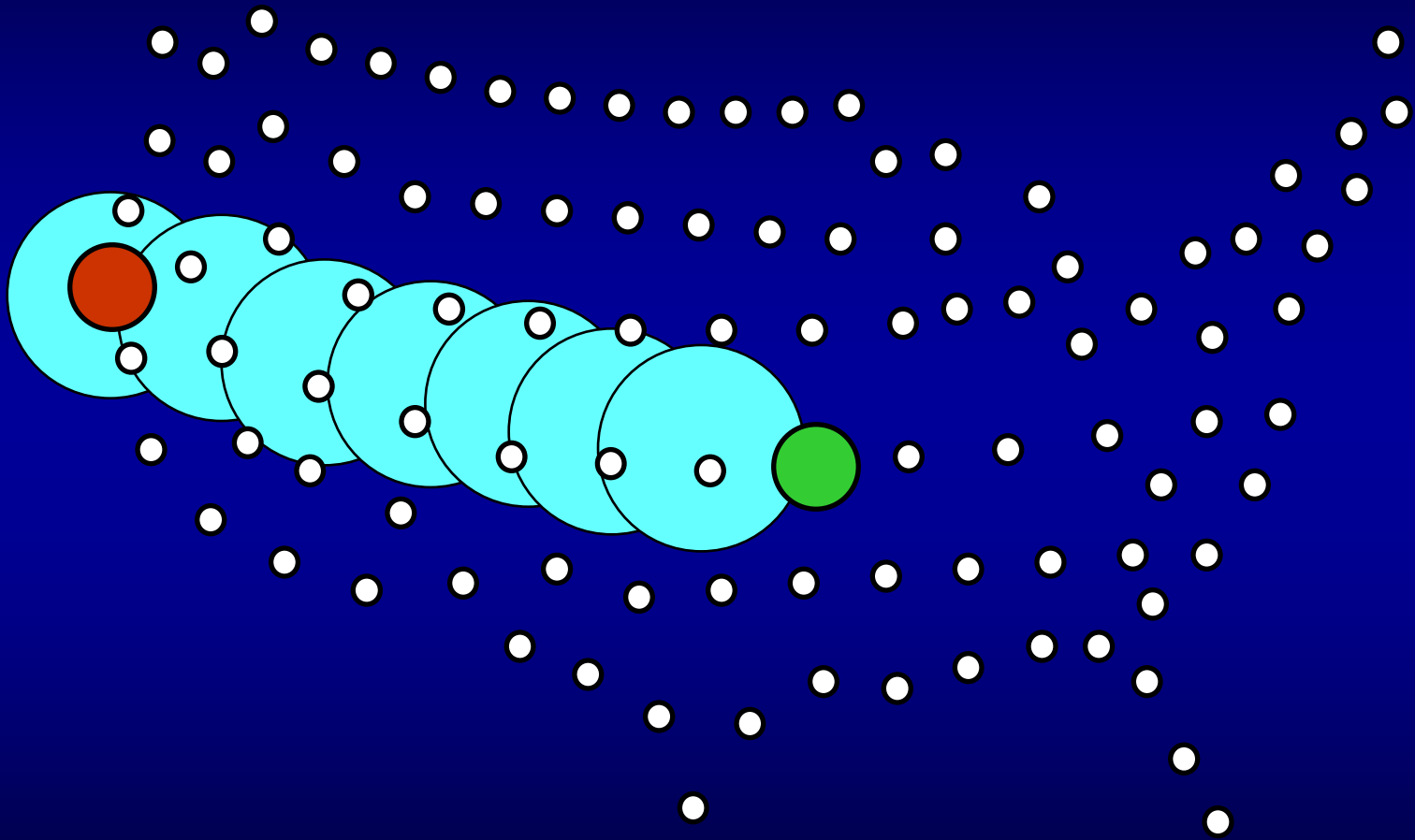
25 >> 1 lb

# Packet Radio

3G  
PCS  
GPRS  
EVDO  
TD-SCDMA  
3GPP  
3GPP2  
HSDPA  
WiFi  
WiMax  
Mesh nets  
Sensor nets  
IP Services



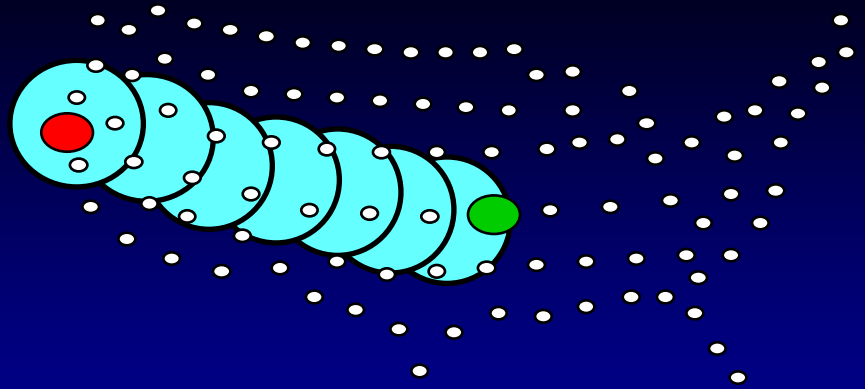




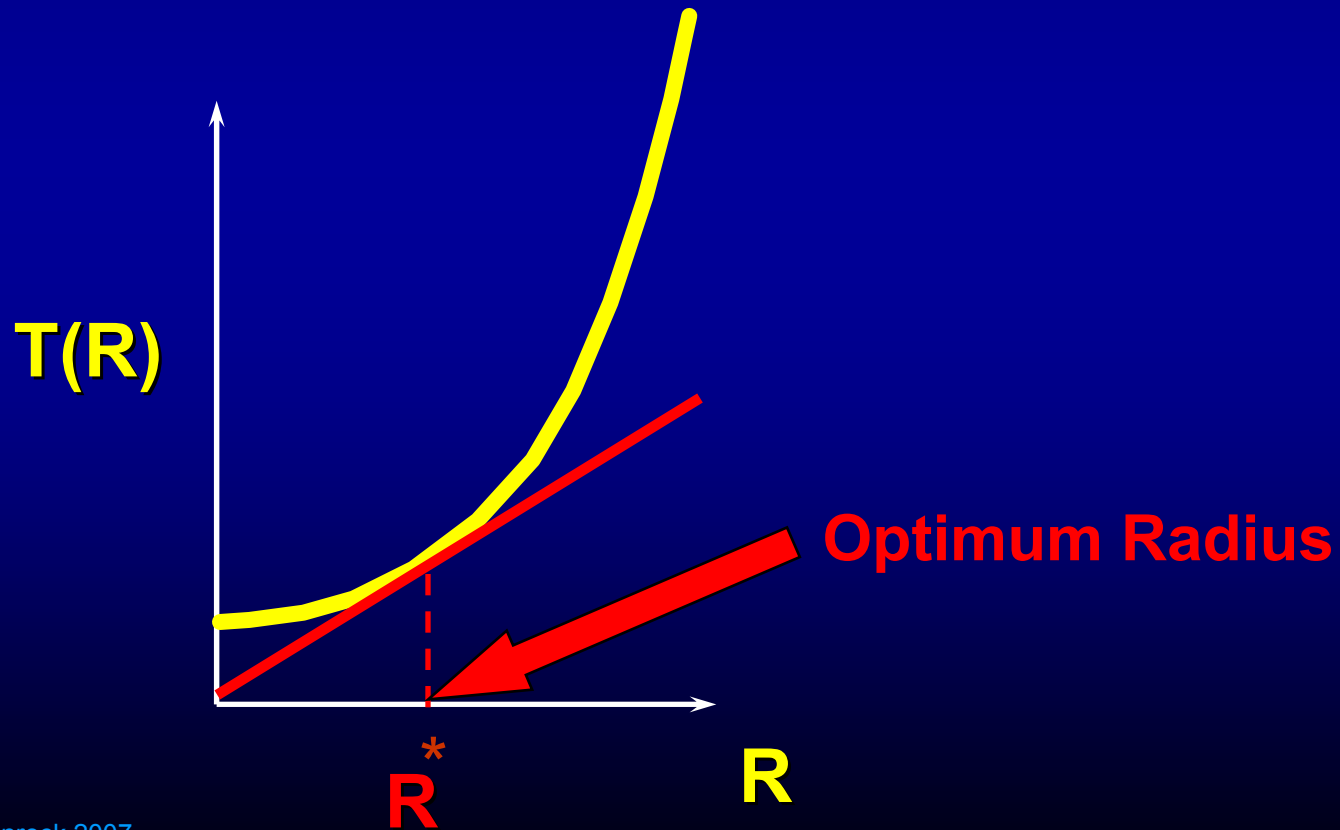
# Giant Stepping in Packet Radio

- Multihop
- Each hop covers distance  $R$  (Tx Radius)
- Total distance to cover is  $D$  ( $D \gg R$ )
- Delay per hop =  $T(R)$
- Big  $R$ , more interference, fewer hops
- Small  $R$ , less interference, more hops
- Total Delay =  $T(R)[D/R]$
- Choose  $R=R^*$  to minimize total delay
- $dT(R)/dR = T(R)/R$  optimality condition

Reference: Kleinrock, L. "On Giant Stepping in Packet Radio Networks,"  
UCLA, Packet Radio Temporary Note #5, PRT 136 , March 1975.



$$dT(R)/dR = T/R$$



# 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 1<sup>st</sup> Internet worm
- **1989** UCLA celebrates 20<sup>th</sup> 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 Andreesson Mosaic browser
- **1994** Cantor & Siegel introduce spam
- **1994** BBN celebrates 25<sup>th</sup> 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.**

• From: Laurence Canter (nike@indirect.com)  
Subject: Green Card Lottery- Final One?  
Newsgroups: alt.brother-jed, alt.pub.coffeehouse.amethyst  
View: Complete Thread (4 articles) | Original Format  
Date: 1994-04-12 00:40:42 PST

# The First Spam email

**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](mailto:cslaw@indirect.com)

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[cslaw@indirect.com](mailto:cslaw@indirect.com) telephone (602)661-3911 Fax (602) 451-7617

# Growth of the Internet

- **1997** Leiner, et al publish “The Past and Future History of the Internet” <http://www.isoc.org/internet/history/brief.shtml>
- **1998** Blogs begin to appear
- **1998** VOIP equipment begins rolling out
- **1999** UCLA celebrates 30<sup>th</sup> 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) 1<sup>st</sup> meeting in Geneva
- **2004** UCLA celebrates 35<sup>th</sup> 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 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
- **2005 Google maps and Google Earth appear**
- **2005 Web 2.0 technologies (e.g., social networks, blogs, wikis) heat up**

# Growth of the Internet

- **2005** MySpace has more page views than Google
- **2006** Is Google evil?
- **2006** YouTube purchased by Google for \$1.65 billion
- **2006** Nanotechnology showing up
- **2007** AT&T largest US Carrier again!
- **2007** 2007 Mobile TV, ads, apps and content

# The Personalities Who Brought Us All This Technology

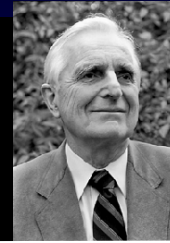
# Some of the Wireless Personalities



## The Early Pioneers

# Some of the Internet Personalities

## The Early Pioneers



## The Implementers



## The Value Adders



## The Launchers



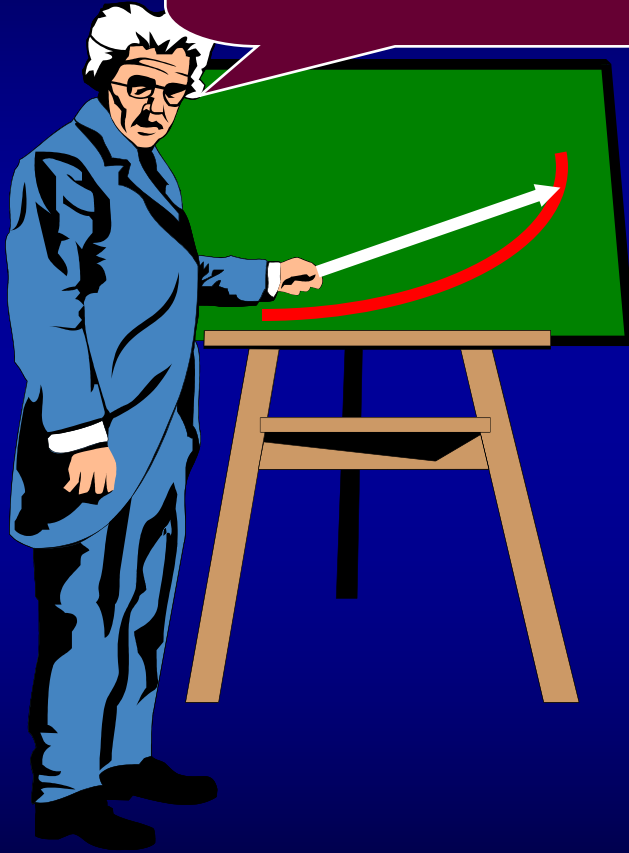
## The Billionaires



# 4. The Early Internet Vision

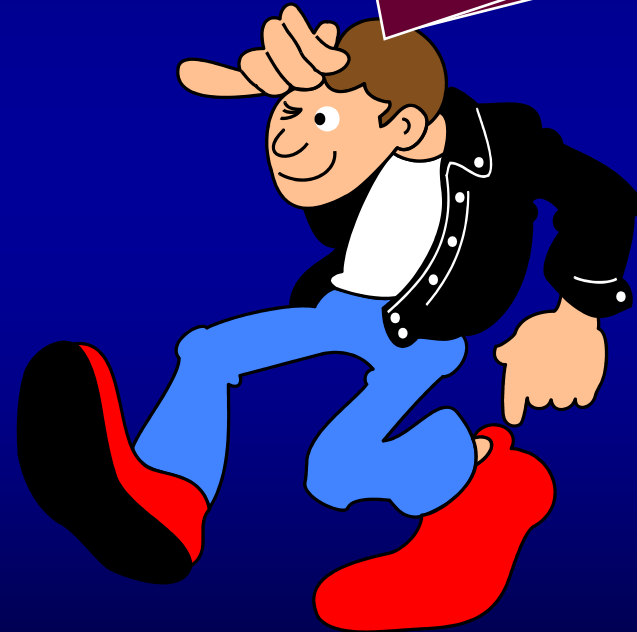


Did you see  
this coming?



The Press

Remember  
my 1969 Vision



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

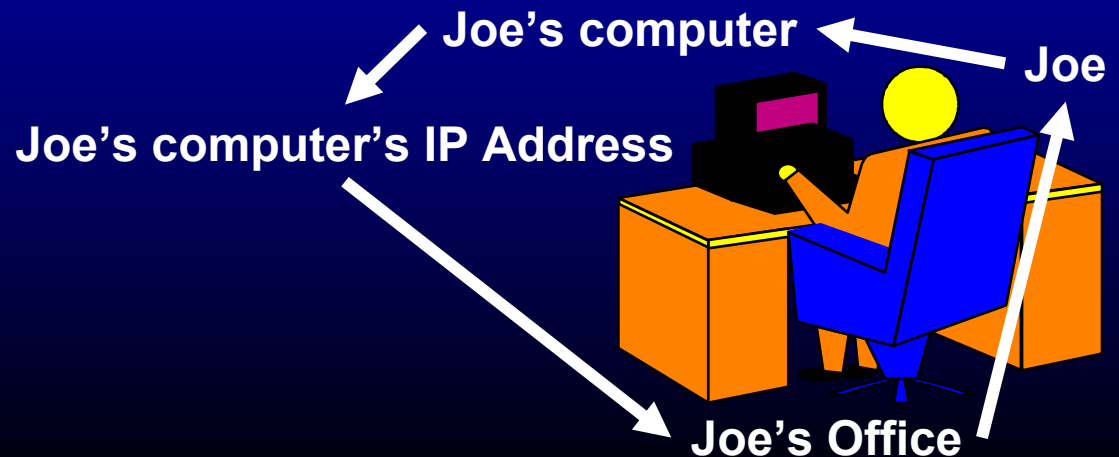
**Nope** Anyone can plug in any device anywhere

**Nope** Invisible

# 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.

## **5. The Future Vision**

**The Edge Evolves**



# **Extending My Internet Vision: The Internet's Next Five Phases**

**Phase 1: Nomadic Computing**

**Phase 2: Embedded Technology (or  
Smart Spaces/Smart Nets)**


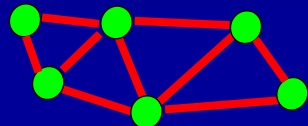
**Phase 3: Ubiquitous Computing**

**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.



# Phase 1: Nomadic Computing

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?





# What WILL be Connected?



# Phase 3: Ubiquitous Computing

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

# Computing Goes Un-tethered

- **WiFi** spreading
- **Cellular** pervasive
- **Ultra Wide Band** showing on product roadmaps
- **Cognitive Radio** emerging in Standards
- **RFID** use in inventory management
- **IEEE Zigbee** moving forward in pervasive low-cost sensor networks
- **Near Field Communication** finding its way into almost touch transaction-based computing

# Phase 3: Ubiquitous Computing

Internet service availability  
wherever the nomad travels on  
a global basis

# Phase 4: Convergence

Content  
Function  
Services

# 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



Rolodex



FM Radio



Game Console



Walkie-Talkie



Camcorder



PDA



watch



PC

# The Converged Smart Phone

## Features

- Phone
- Messaging
- Calendar
- E-mail
- Internet  
Access
- Camera
- Music Player
- Game Player
- Wireless  
Headset

## Future Enhancements

- Touchscreen
- Large, high resolution screen
- Powerful processor
- Vast storage space
- Considerable battery life
- Intuitive input system
- Video Phone
- Movie Player
- Mobile TV
- GPS Mapping
- Compass
- Accelerometer
- Wi-Fi Connectivity
- Software defined radio
- Pocket-size

# 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





# 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.



# Motivated Wireless Ads

Sign up customers (e.g., students)

Offer them cash for watching ads they request

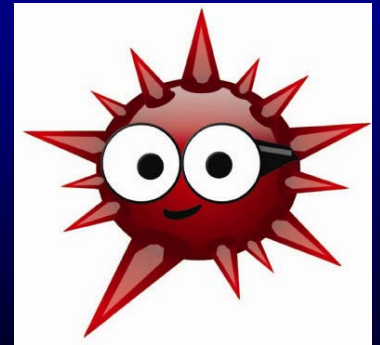
15 second ads download to their cellphone at night

Advertisers choose demographic and location

Customer clicks on icon immediately after watching an ad:

This generates the cash (\$1 per ad)

This satisfies advertiser that ad was viewed.



<http://www.blowfishworks.com/>



# Wireless Heart Implant

- The Medtronic Chronicle monitors blood pressure and other conditions inside the hearts of patients suffering heart failure.
- The goal is send a wireless alert to warn patients, their doctors and caregivers when they are in danger at a point before they need to be hospitalized.

Friday, March 2, 2007 Medtronic's Chronicle Fails

## Monitoring Your Heart via the Internet

*FDA to Review One of the First  
In a Wave of New Implants  
That Track Vitals Wirelessly*

By THOMAS M. BURTON  
And ANNA WILDE MATHEWS



**Pressure Gauge:** The Chronicle is an implantable sensor under FDA review for patients with congestive heart failure.

quickly building up fluids that could pool in the lungs, a potentially life-threatening situation. Depending on the patient's condition and how hectic the doctor's office is, the device could be set to send reports weekly, or even once or twice daily. The de-

reports weekly, or even once or twice daily. The de-

# Wireless Sensor for Diabetics

- Peripheral neuropathy
- Pressure sensor



Pressure  
Alert  
Shoe



Pressure  
Sensor



Wireless  
Processor



MediNode  
Cellphone  
PDA, iPod



**MediSens Wireless, Inc.**  
27621 San Valle, Mission Viejo, CA 92692



# Valentine's Day: Feb 14, 2007

- 50-mile backup on Pennsylvania's I-78



- Gov. Ed Rendell said the recent fiasco on Interstate 78 included a "total breakdown in communications."



# **Valentine's Day: It Could Have Been Better**

- **With picture phones that now include GPS, drivers could have informed officials and they could have pieced together detailed mile-by mile photo maps -- "mashed up" with Google maps of precisely where the worst conditions were!**

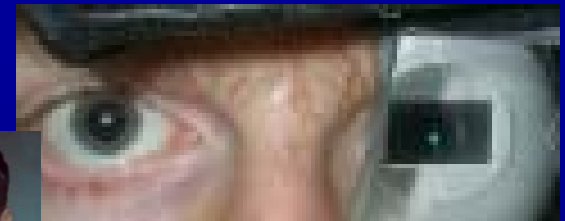
# Location-Based Services

- **The obvious location-based services - the ones available today - are**
  - Basic mapping
  - Direction finding
  - Yellow Pages-style listings
- **New location-based services:**
  - Mashup services that let users create, tag, and annotate their own maps
- **Passive Service:**
  - “This is a quality restaurant”
  - “This is City Hall”
- **Active Services:**
  - Note left for spouse to buy milk here
  - “Family or friends are nearby”
  - “Interesting performance going on in this auditorium”
  - Ad from a store offering a discount now
- **Camera phone that can read bar codes**
- **Cameras that can read coupons on your cellphone**

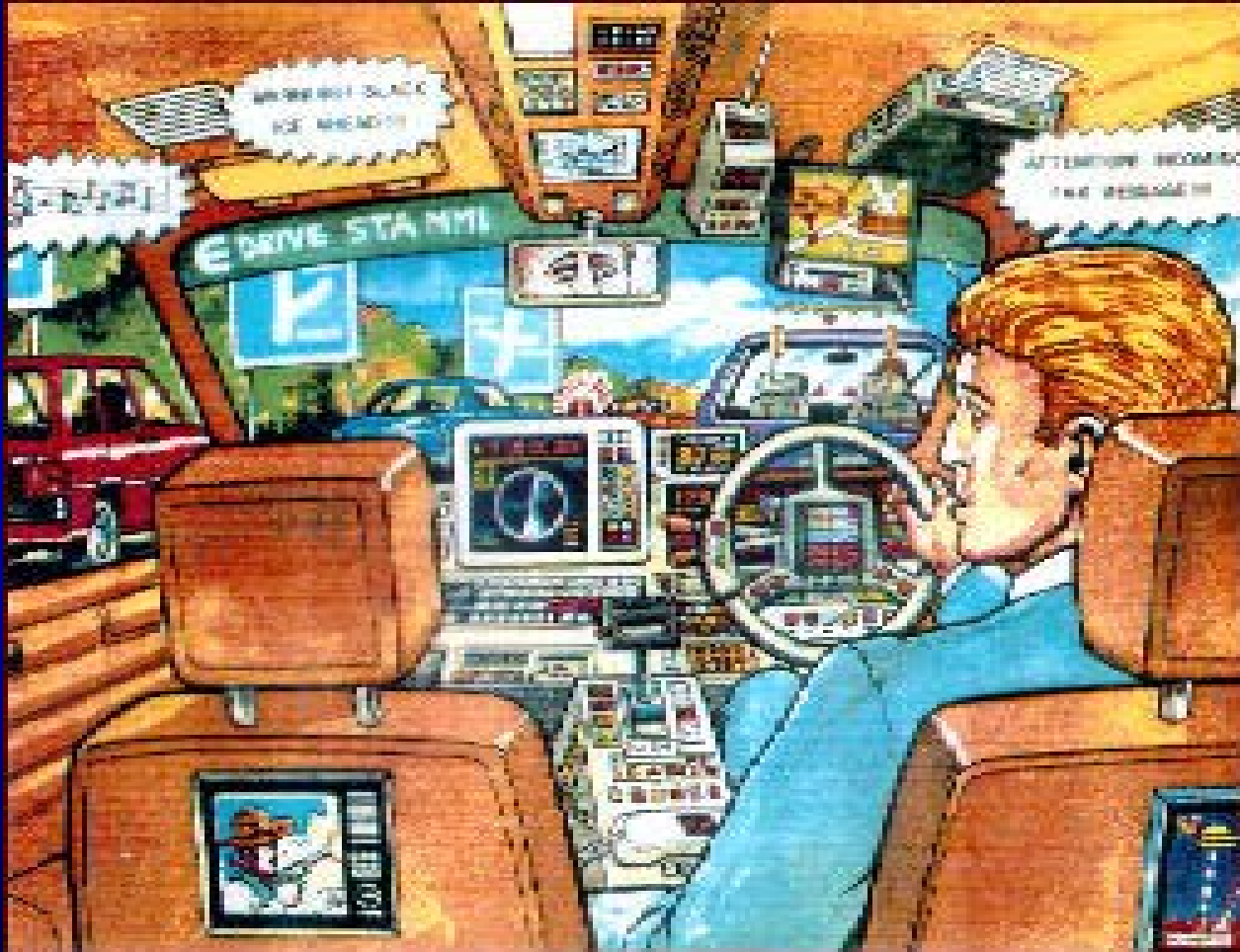
# From Convergence to Divergence

# 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.

# 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.**

# **6. My Five Golden Guidelines for Research**

# **My Five Golden Guidelines to Research**

- 1. Conduct the 100-year test.**
- 2. Don't fall in love with your model.**
- 3. Beware of mindless simulation.**
- 4. Understand your own results.**
- 5. Look for "Gee, that's funny!"**

# Richard Hamming



**"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."**

**Richard W. Hamming, "You and Your Research", March 7, 1986.**

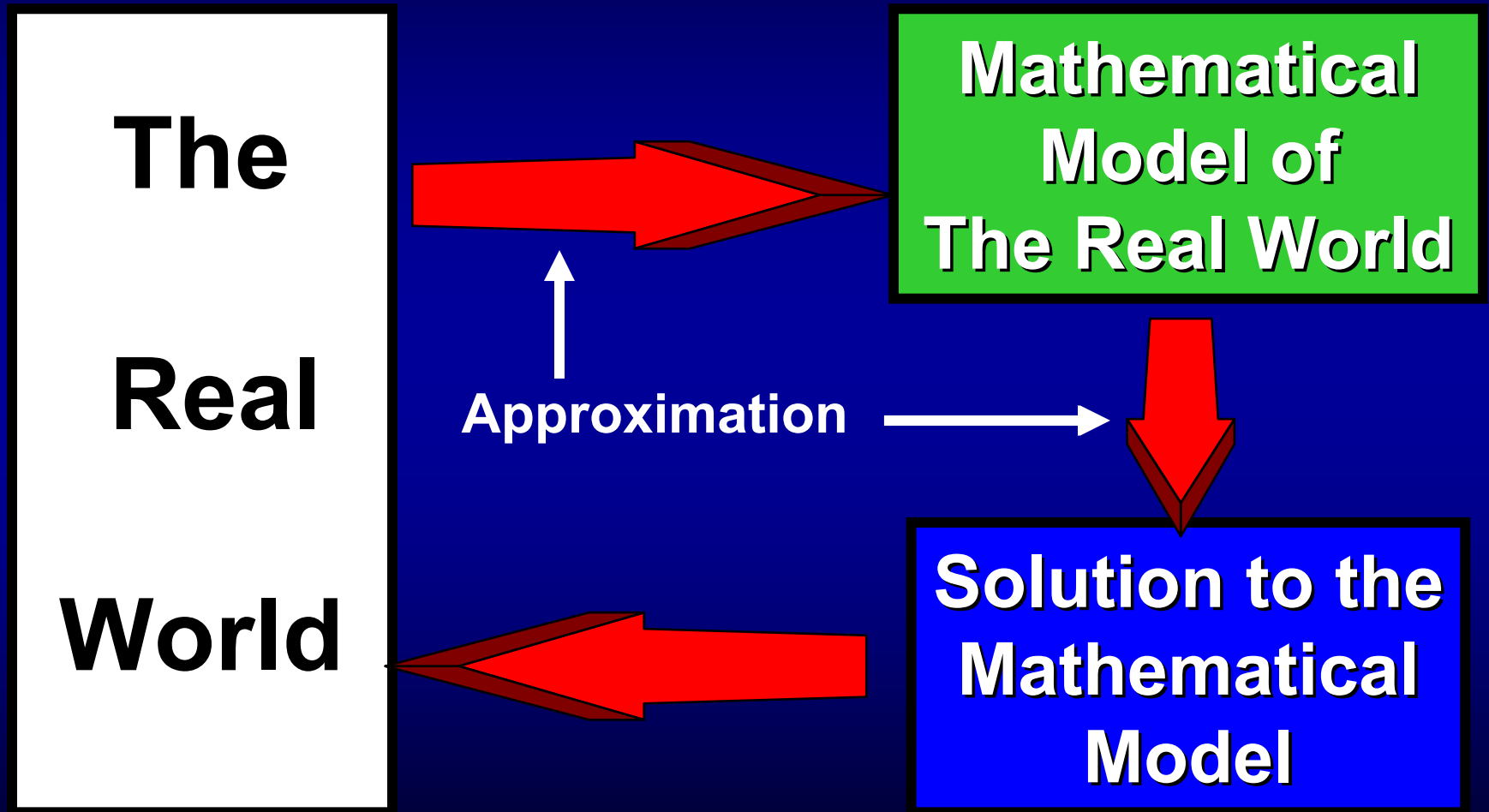
# 1. The 100 Year Test

- 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





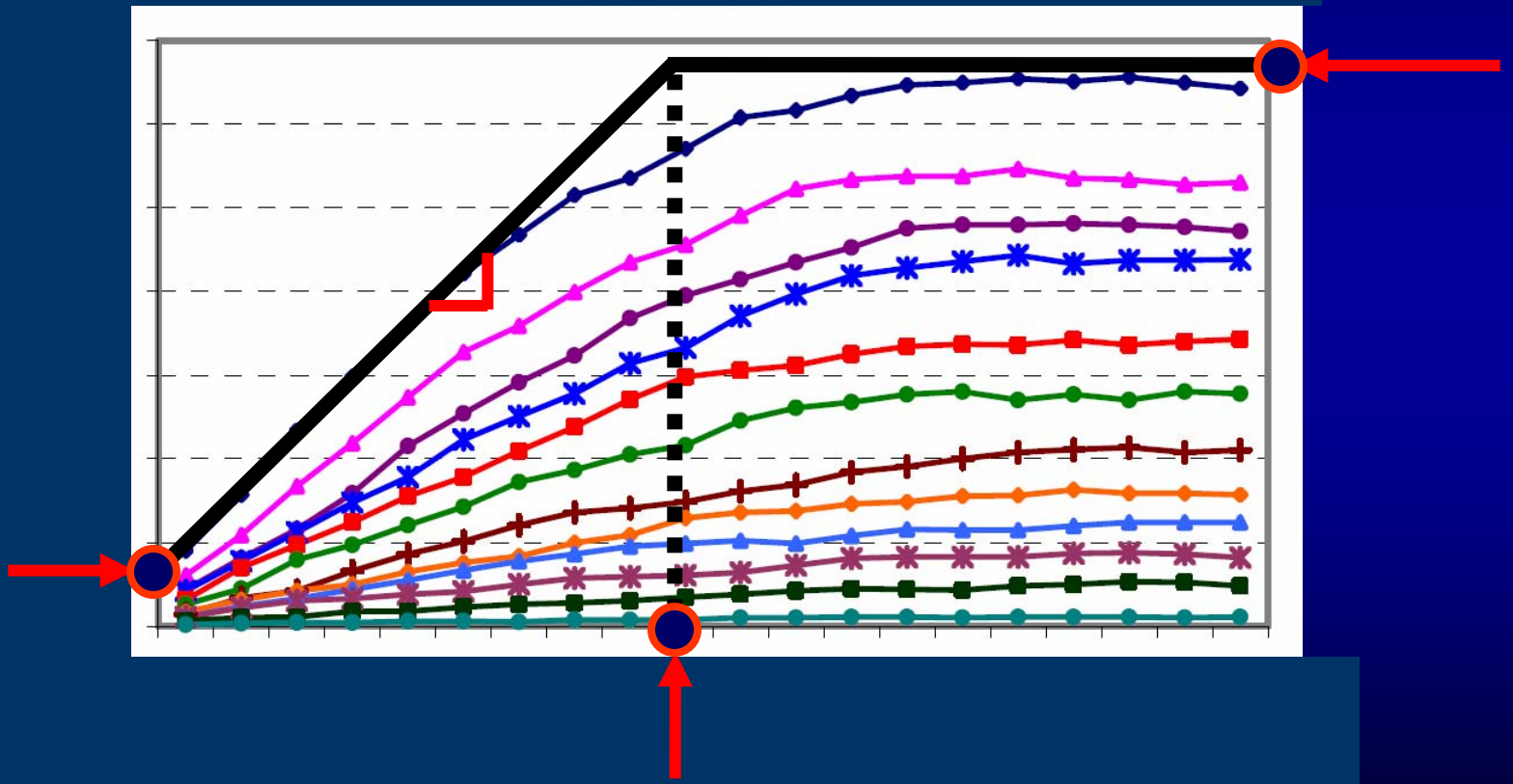


# Michael Faraday

- "I could not imagine much progress by reading only, without experimental facts and trials ... I was never able to make a fact my own without seeing it. " (Faraday: 1827)
- Faraday performed in his brain the work of a great mathematician without using a single mathematical formula" (Hermann von Helmholtz : April 5, 1881 )

# 3. Beware of Mindless Simulation

## Ask the Obvious Questions

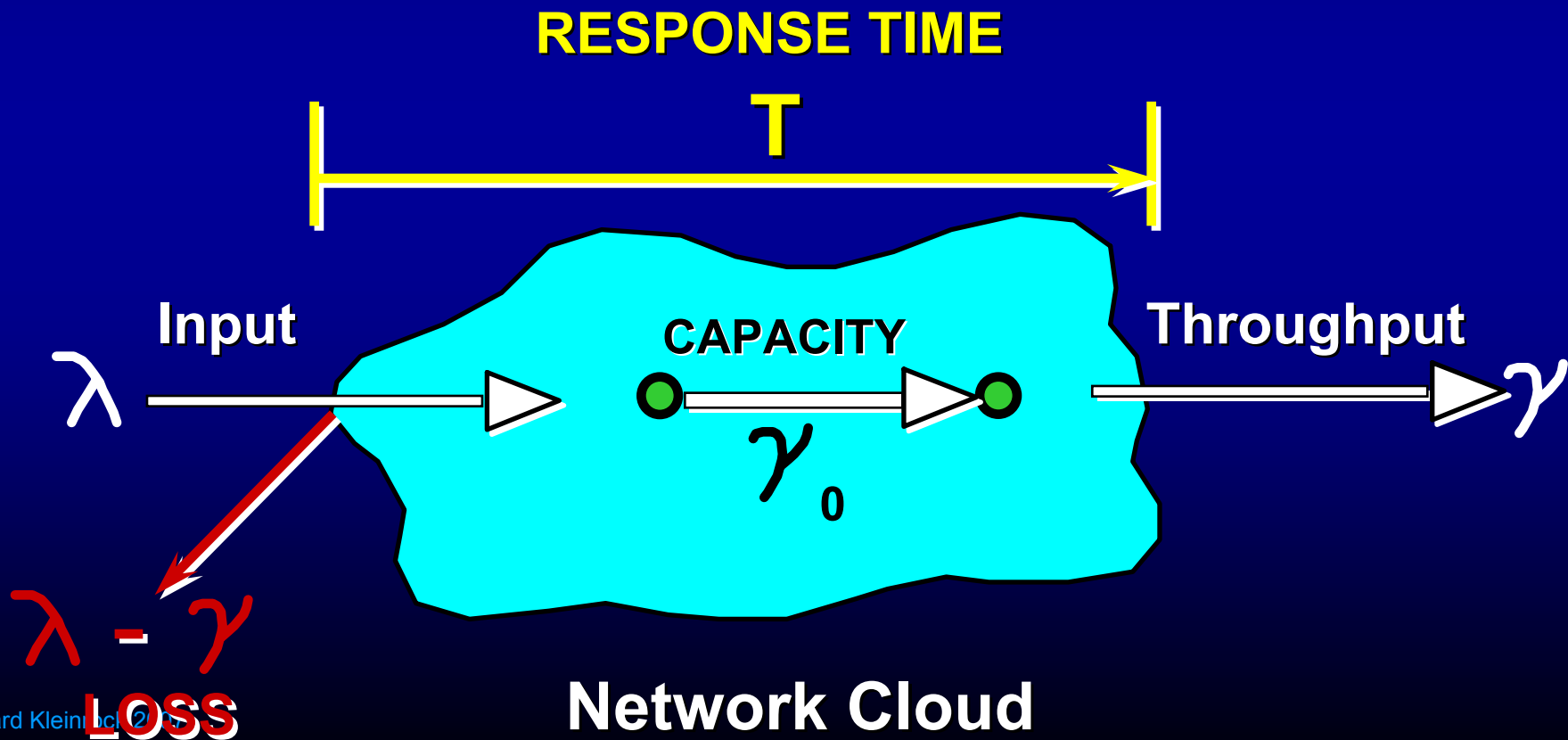


# 4. Understand Your Own Results

# Response Time

# Throughput

# Loss



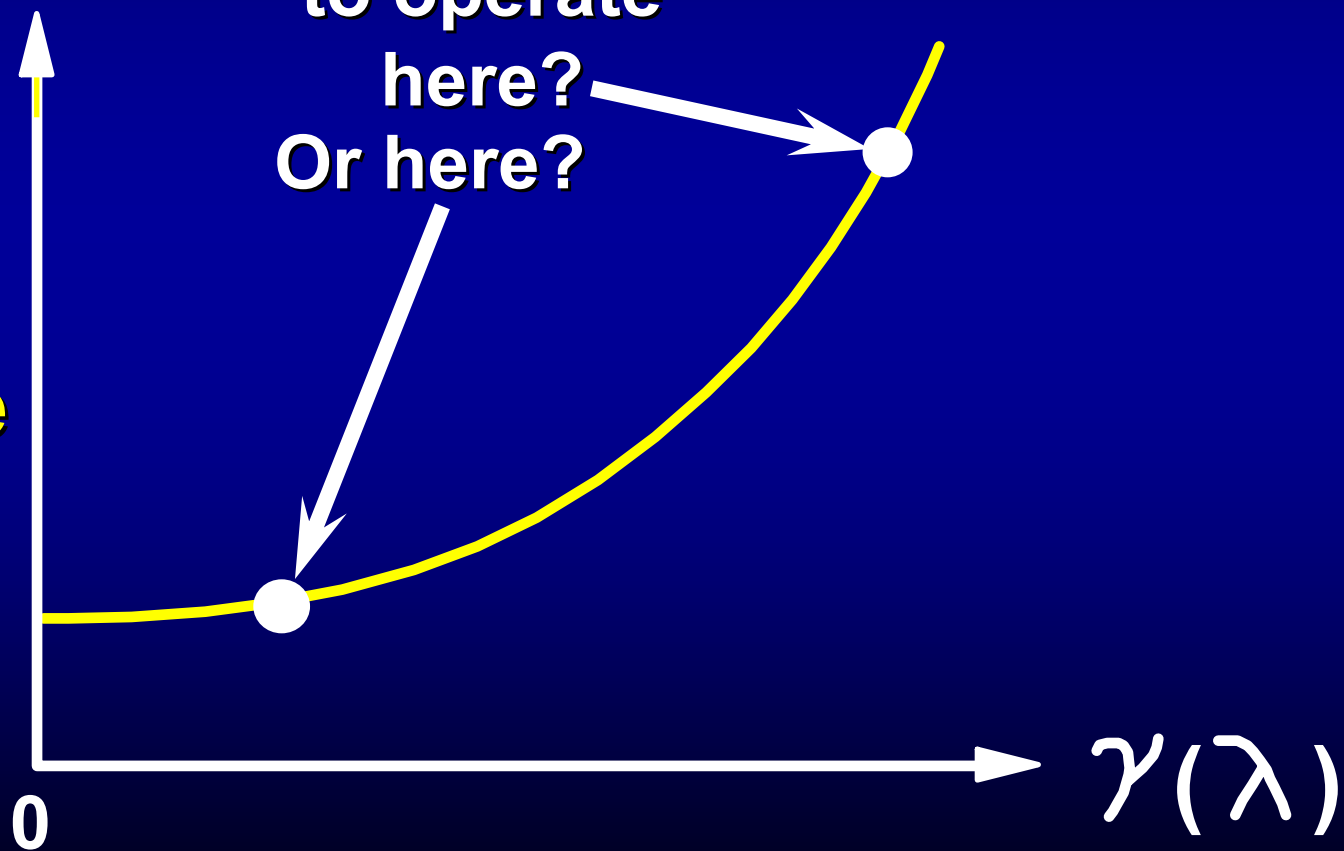
# Response Time vs Throughput

Now let's ask a good question:

Do you want  
to operate  
here?  
Or here?

$T(\gamma)$

Response  
Time



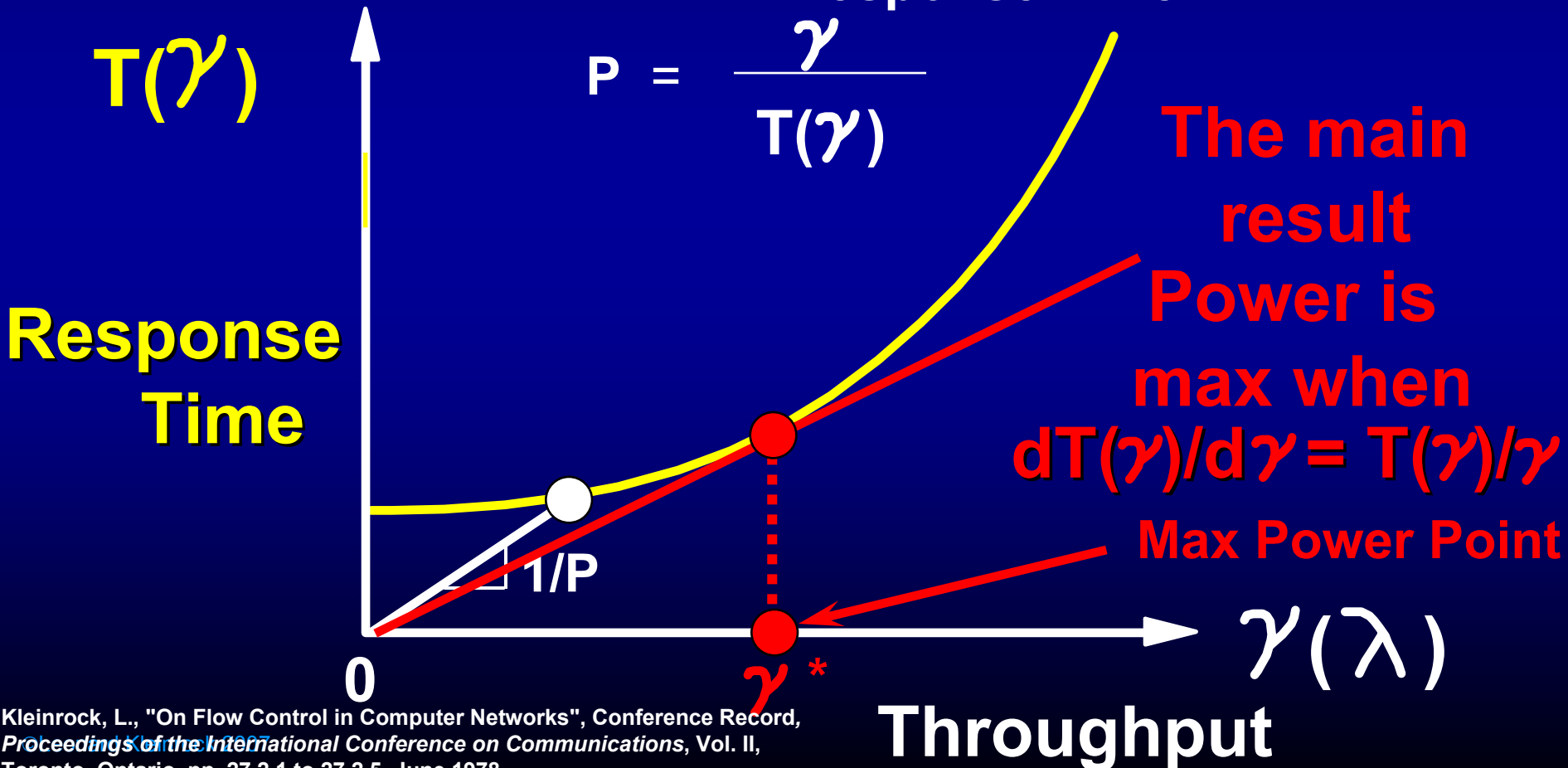
$\gamma(\lambda)$

Throughput

# 4. Understand Your Own Results

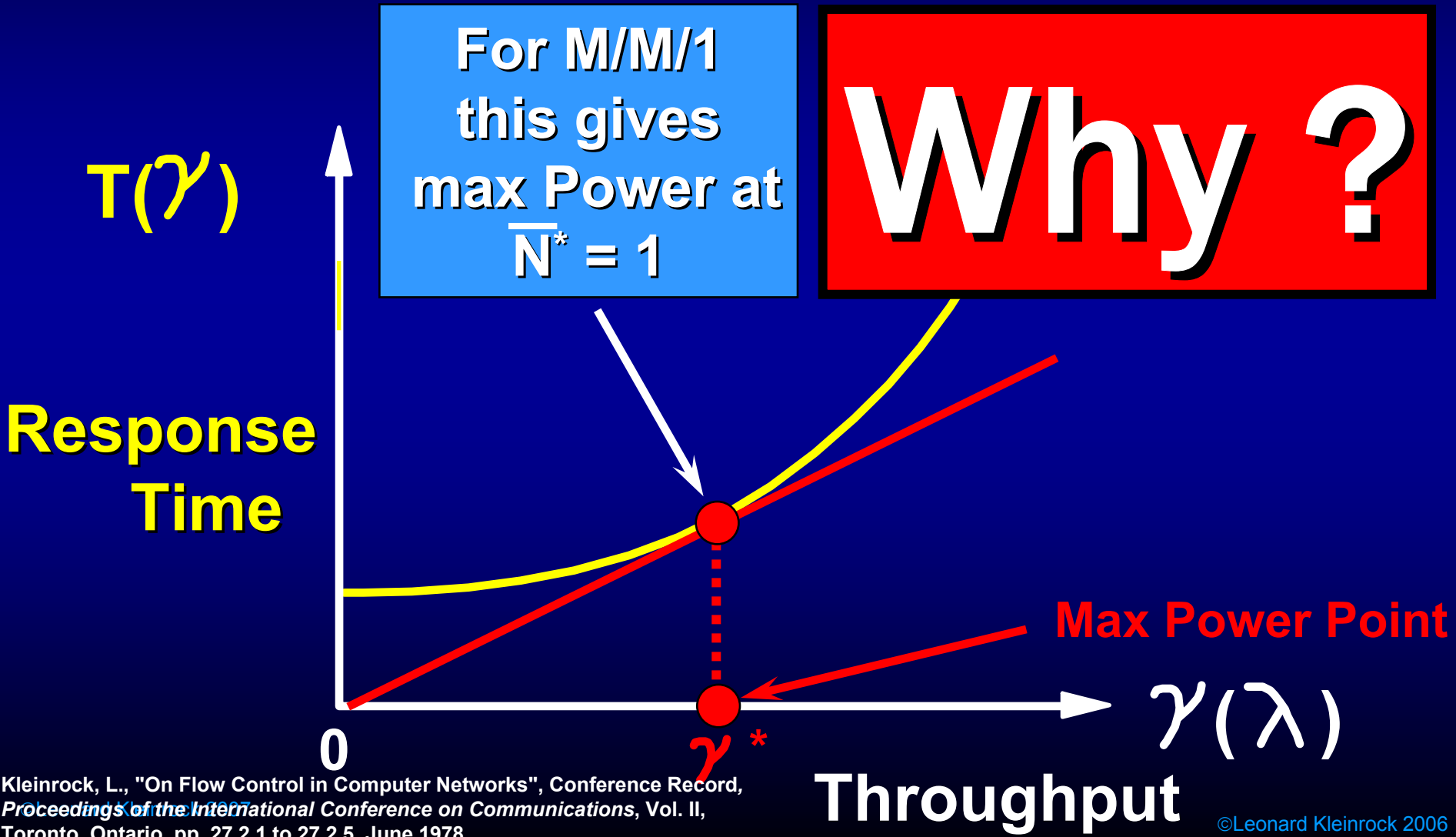
Let me define a new metric of performance:

$$\text{POWER} \triangleq \frac{\text{Throughput}}{\text{Response Time}}$$
$$P = \frac{\gamma}{T(\gamma)}$$



# 4. Understand Your Own Results

## Let's Dig Deeper on Understanding

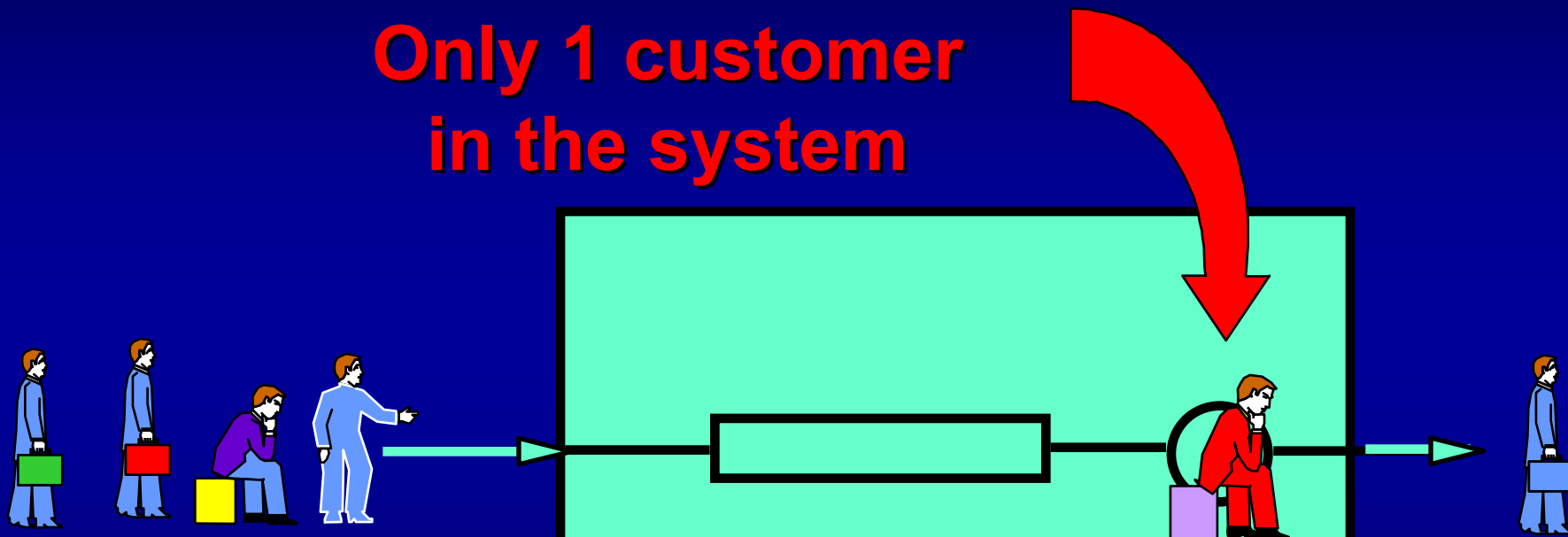


Kleinrock, L., "On Flow Control in Computer Networks", Conference Record, Proceedings of the International Conference on Communications, Vol. II, Toronto, Ontario, pp. 27.2.1 to 27.2.5, June 1978.



# 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.,

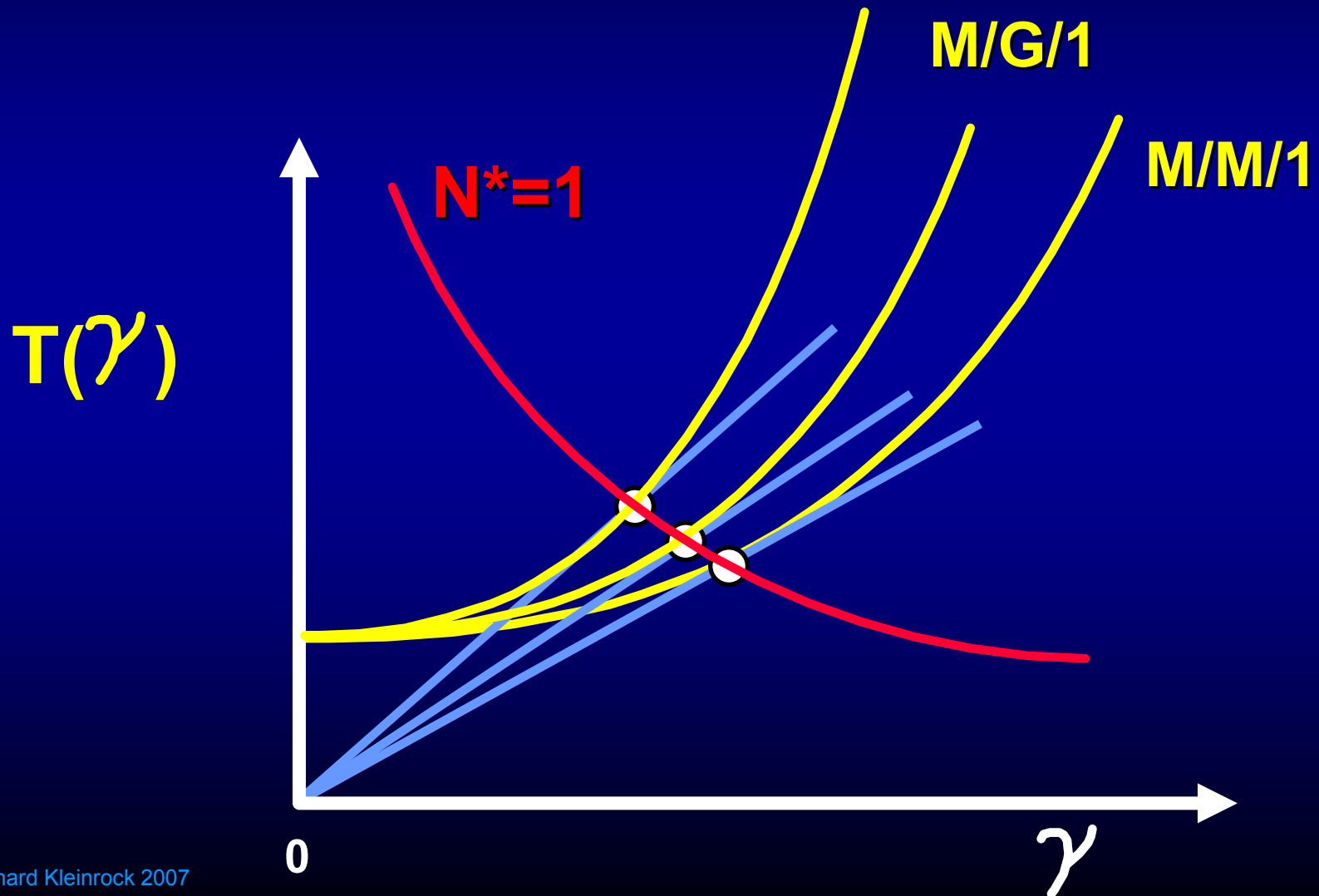
At Max Power  
 $\bar{N}^* = 1$   
for M/M/1

Gee, that’s funny!

# 5. Gee, that's funny!

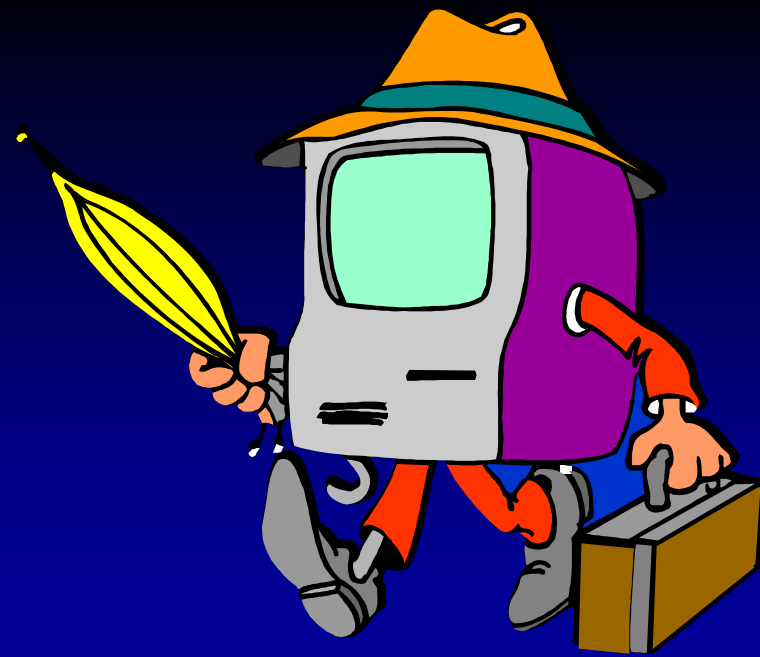
# 5. Gee, that's funny!

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](http://www.lk.cs.ucla.edu)