

Realizing the Wireless Internet

Leonard Kleinrock

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Keynote Lecture

WCNC

Hong Kong

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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 !”

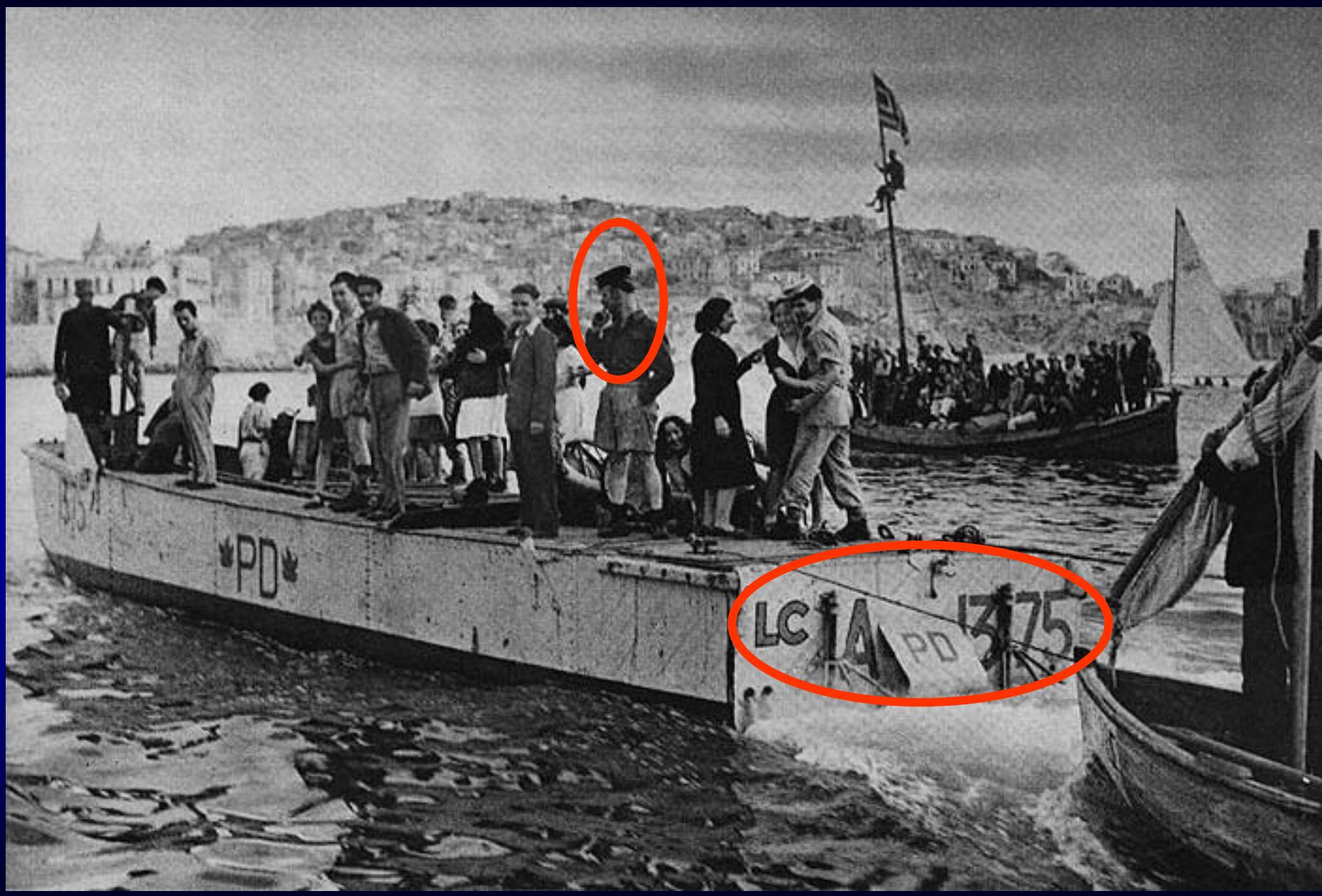
“Go and find it on your Internet.”











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 !**

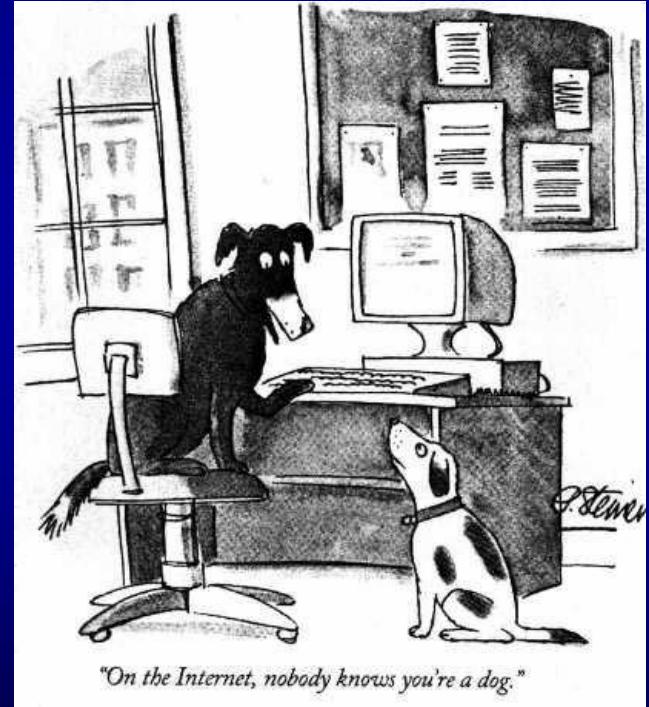
The Internet Has Dramatically Changed Some Fundamentals

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."

**"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 1st 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

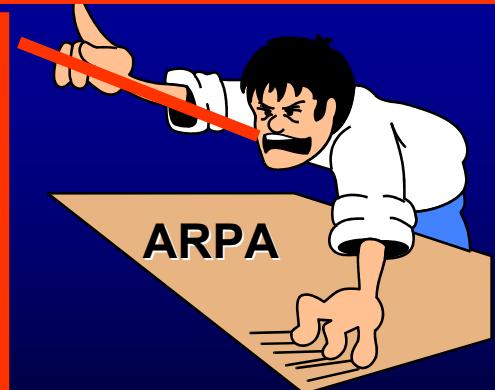


Researcher

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

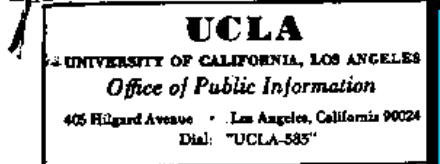
**ARPA’s reply:
“Here’s an offer you
can’t refuse**

**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



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."

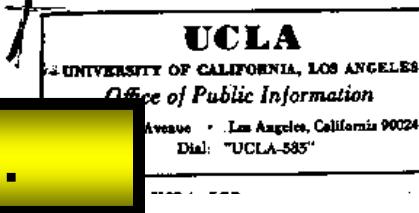
Leonard Kleinrock

Computer networks are not an entirely new concept, notes Dr. Kleinrock. The SAGE radar defense system of the Fifies 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 ARPA 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."

My 1969 vision ...



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."

Web-based
IP Services

Always On
Invisible

Ubiquitous

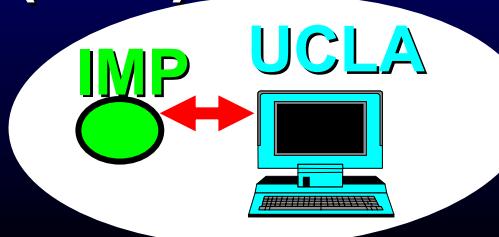
... are not an entity in themselves," notes Dr. Kleinrock. The ABLE system of M.I.T. is the first, followed by the SABRE reservations system. At the present time, the nation's electronically switched telephone system is the largest computer network.

However, he says, "There are many specialized and single-purpose systems, in contrast to the general purpose system which will link a wide assortment of different computers and serve a wide range of unclassified research functions.

"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."

The Arpanet Beginning

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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



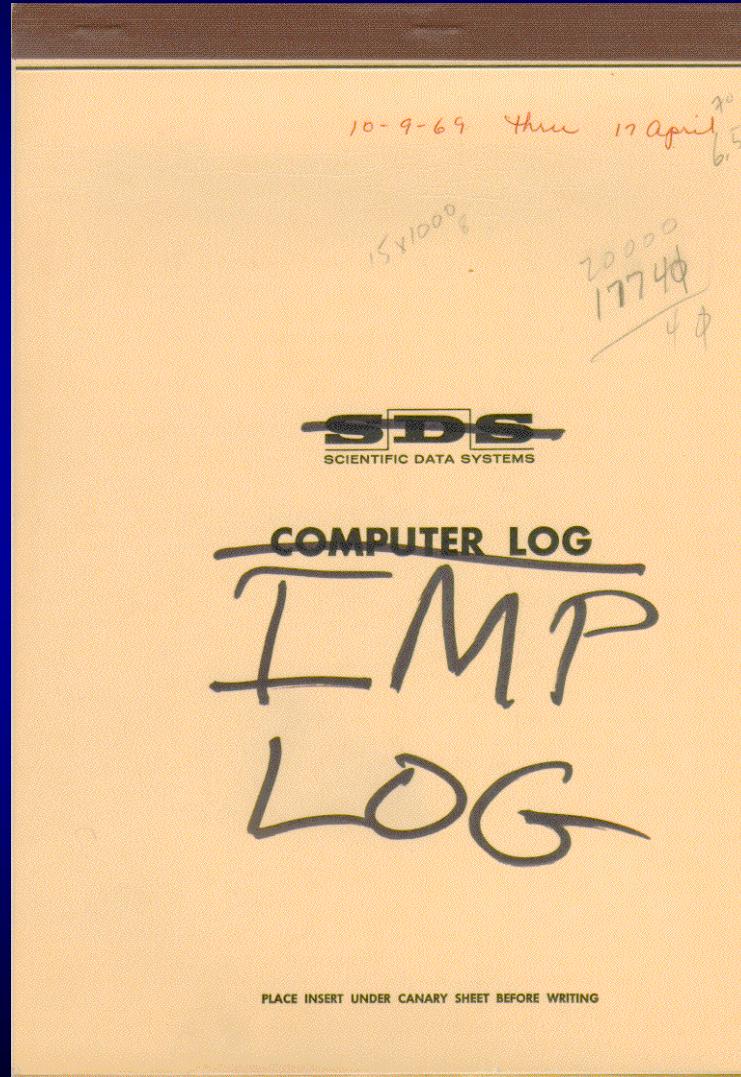
The 1969 IMP



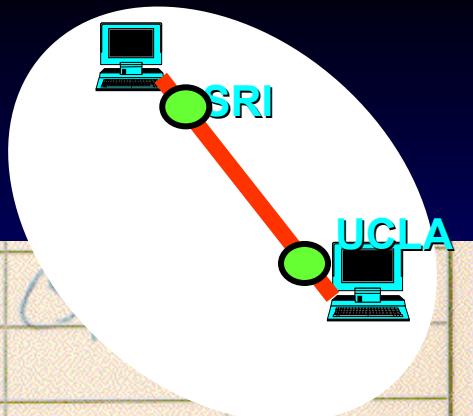
The 1969 IMP



We Decided to Keep a Log



An Important Entry in Our IMP Log



29 OCT 69 1100 LOADED OP. PROGRAM C
FOR BEN BARKER
BBN

22:30 talked to SRI
Host to Host

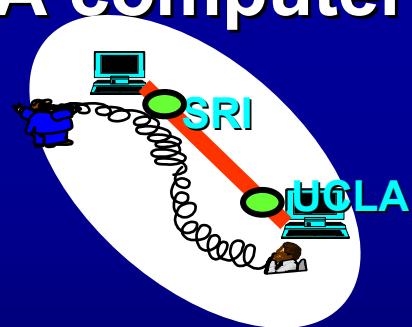
CSC

Left op. program (CSC
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?

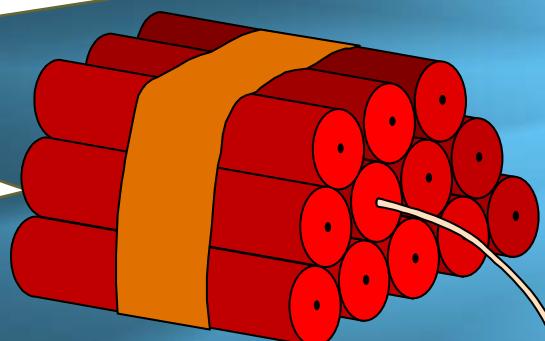
- Was it “What hath God Wrought” (Morse 1844)?
- Or “Watson, come here. I want you.” (Bell 1876)?
- Or “One Giant Leap for Mankind” (Armstrong 1969)?
- It was simply a **LOGIN** from the UCLA computer to the SRI computer.



- 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 over the Internet?

- What was it?



Crash!

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

- What was it?

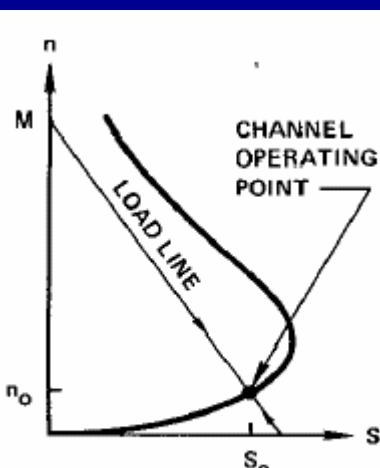
LO!

Growth of the Internet

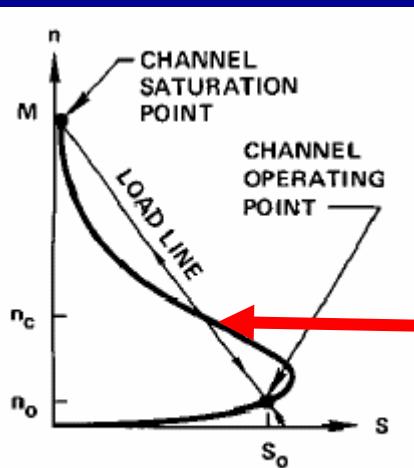
- 1969 10/29 First Internet message
- 1969 Howie Frank assists topology design
- 1969 UCLA's Steve Crocker RFC #1 Host-Host Protocol and the NWG
- 1970 ARPANET spans US: UCLA <-> BBN
- 1970 UCLA team releases NCP
- 1971 BBN TIP - direct terminal access
- 1972 Ray Tomlinson introduces net email
- 1972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

Enter the Wireless Networks

- 1972 Norm Abramson's packet radio Alohanet 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

- 1972 Norm Abramson's packet radio Alohanet connected to ARPANET
- 1973 ARPA deploys SATNET – 1st international connection
- 1973 First analysis of slotted Aloha: performance, stability
- 1974 First analysis of CSMA

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

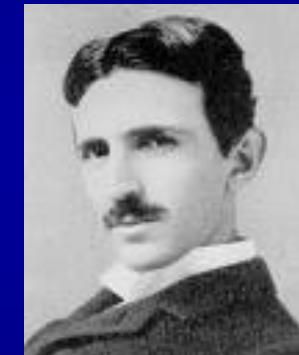
Kleinrock, L. and F. Tobagi, "Carrier Sense Multiple Access for Packet Switched Radio Channels", Conference Record, *International Conference on Communications*, Minneapolis, Minnesota, pp. 21B-1 to 21B-7, June 1974.

3. A Brief History of Wireless

Who Made These Predictions?

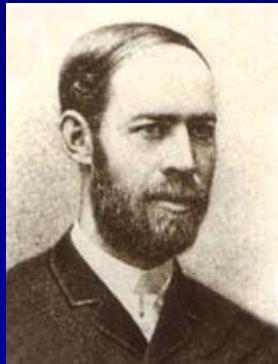
- “It will be possible for a business man in New York to dictate instructions, and have them instantly appear in type at his office in London or elsewhere.
- “He will be able to call up, from his desk, and talk to any telephone subscriber on the globe.
- “An inexpensive instrument, not bigger than a 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

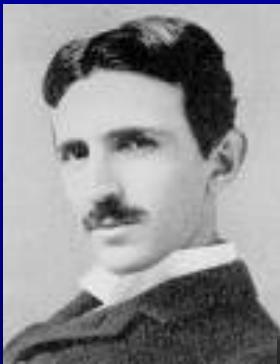
- James Clerk Maxwell



- 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

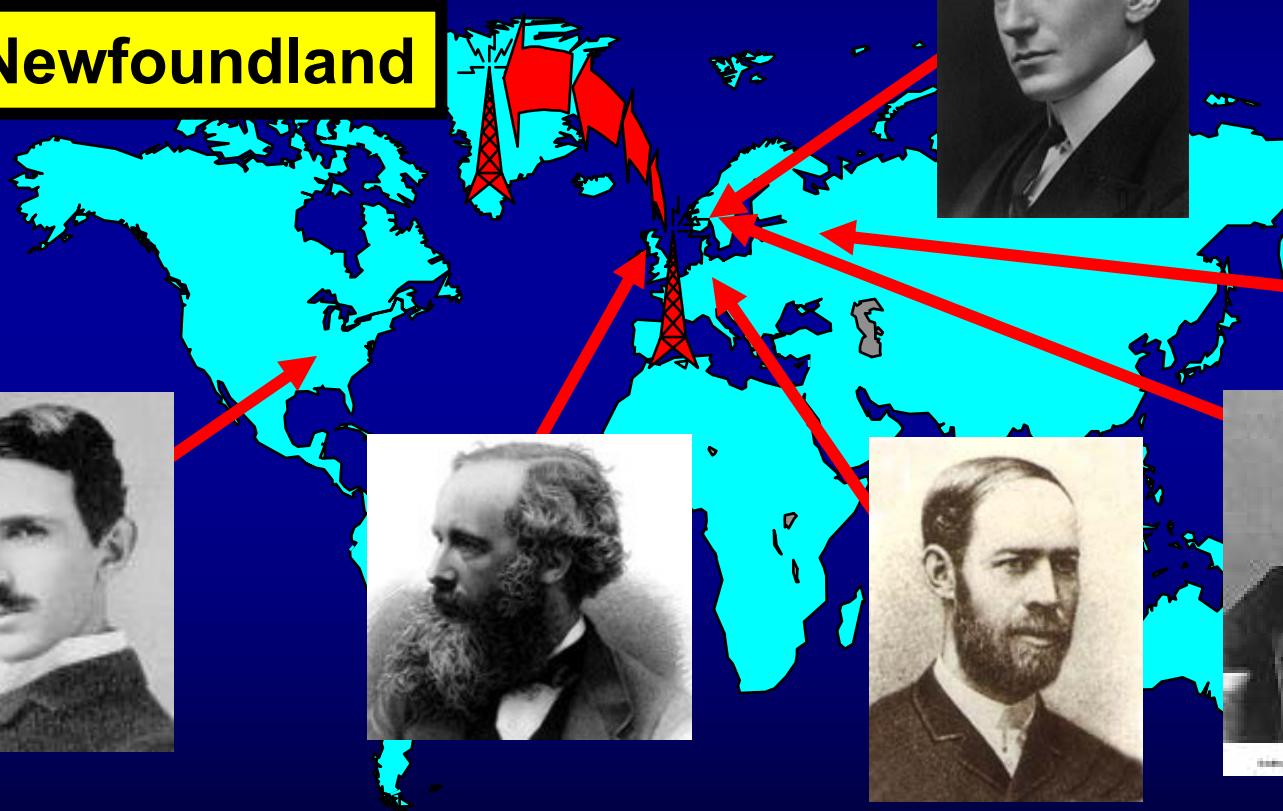
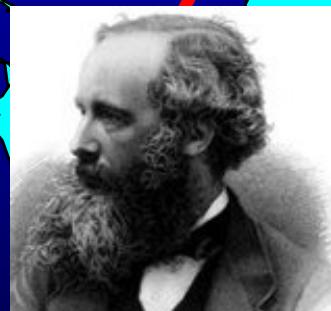
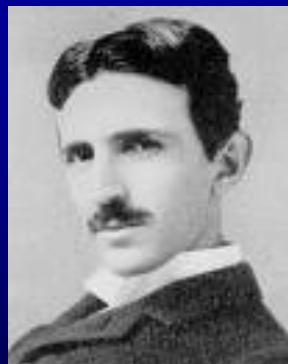
- 1864: Maxwell mathematically predicts the existence of radio waves.
- 1878: David E. Hughes sends/receives Morse Code, discovering radio waves.
- 1885/6: Hertz proves existence of radio waves using a primitive transmitter and receiver.
- 1891: Tesla is granted U.S. Patent revealing the basic techniques 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

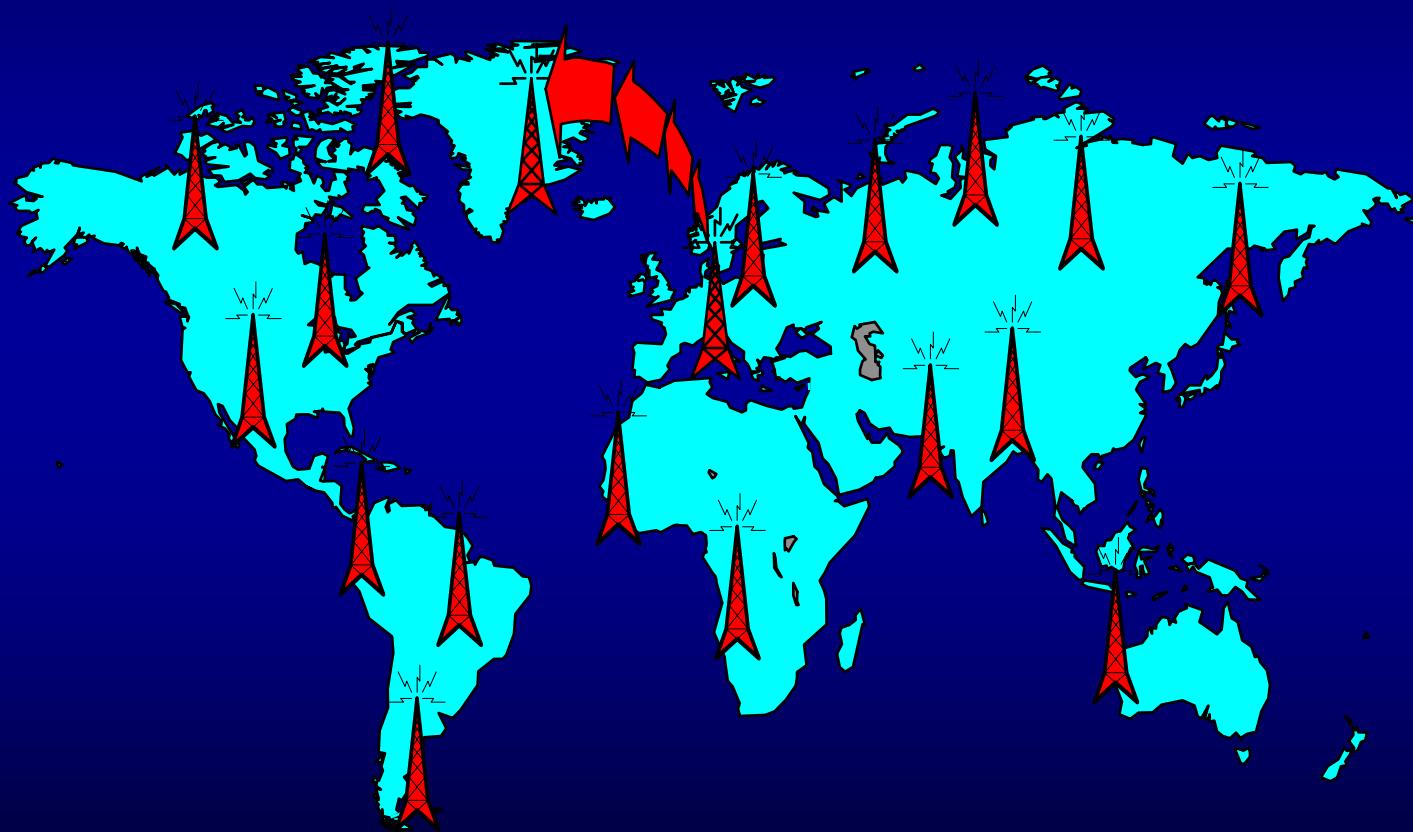
- 1895: Marconi transmits wireless signals a distance of about 1 mile
- 1896: Tesla transmits wireless signals over distances of up to 30 miles.
- 1897: Marconi is granted a British patent, establishes the world's first radio station and what later becomes the Marconi Wireless Telegraph Company
- 1898: 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

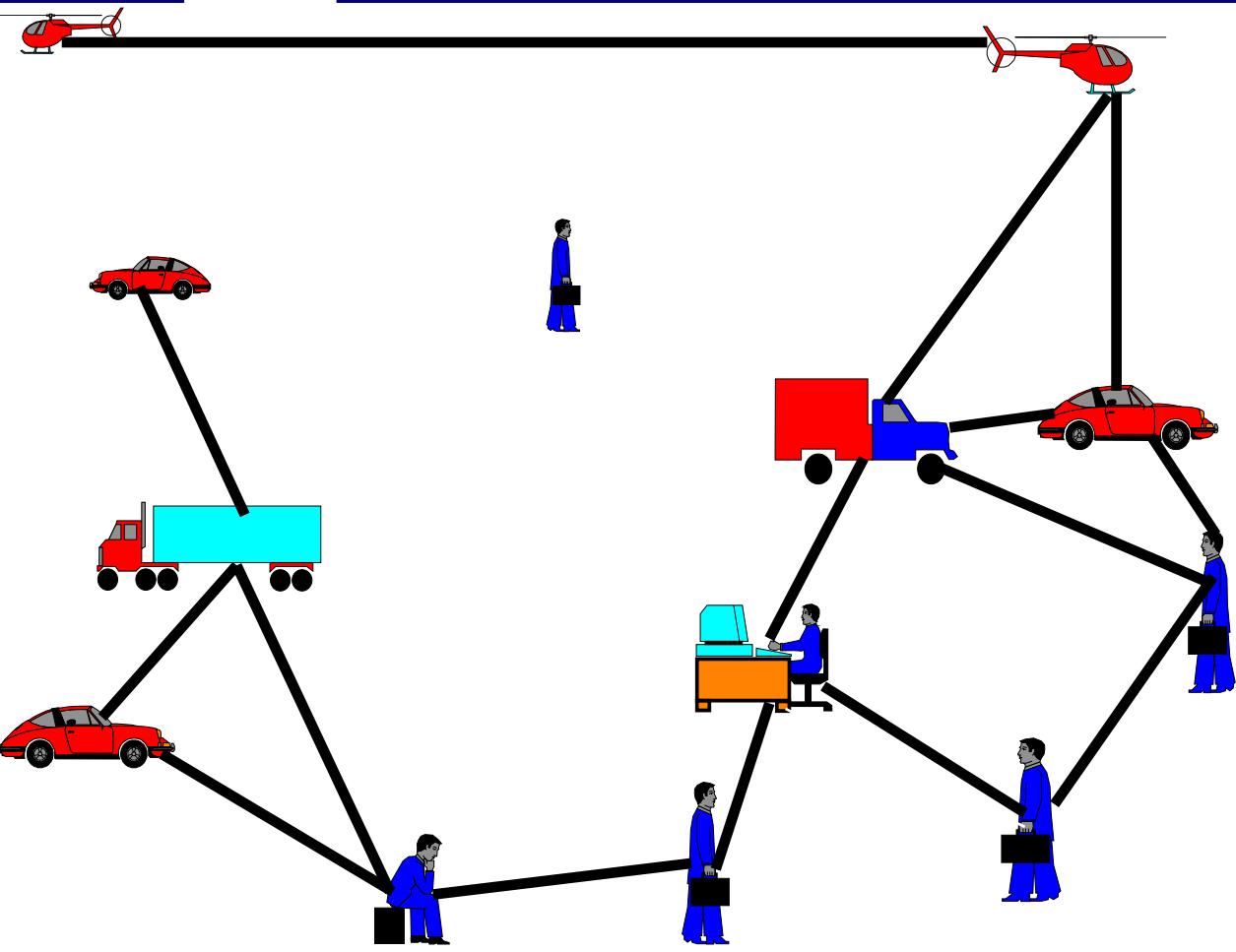


Radio



Packet Radio

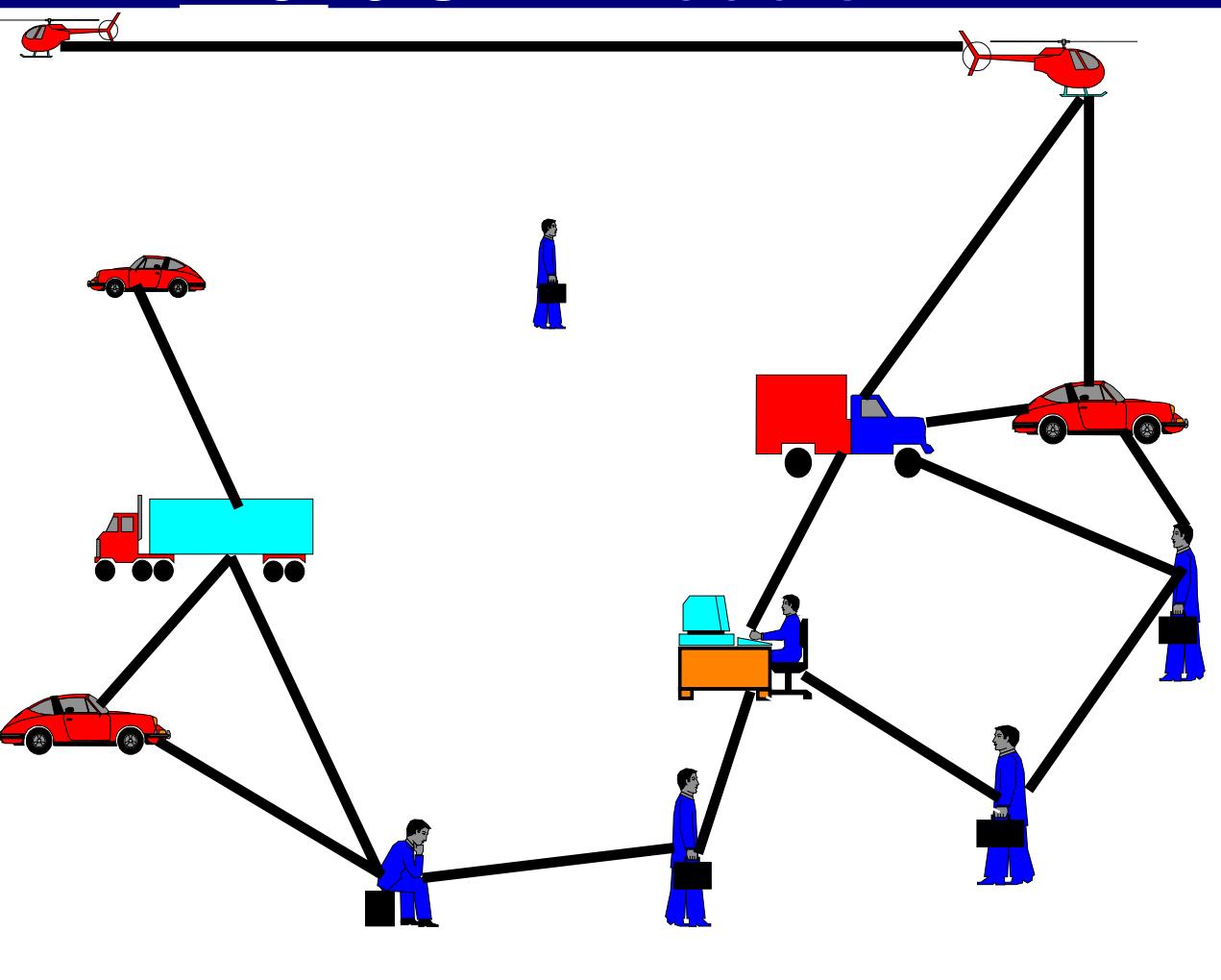
- ## • 1970's: ARPA



250 cu in
25 watts
25 lbs

Packet Radio

- 1970's >> 1990's: ARPA



250 >> 10 cu in

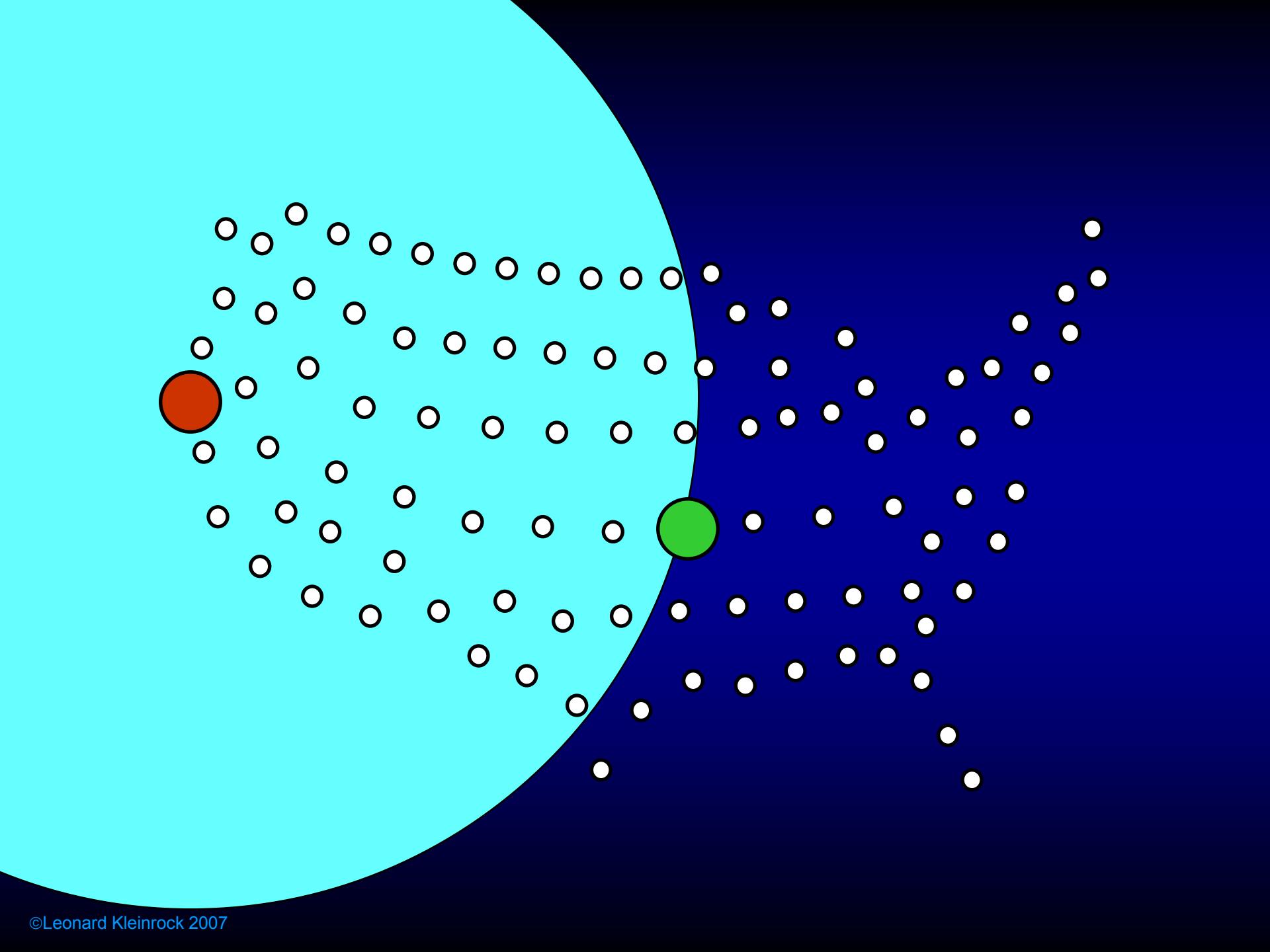
25 >> 1 watt

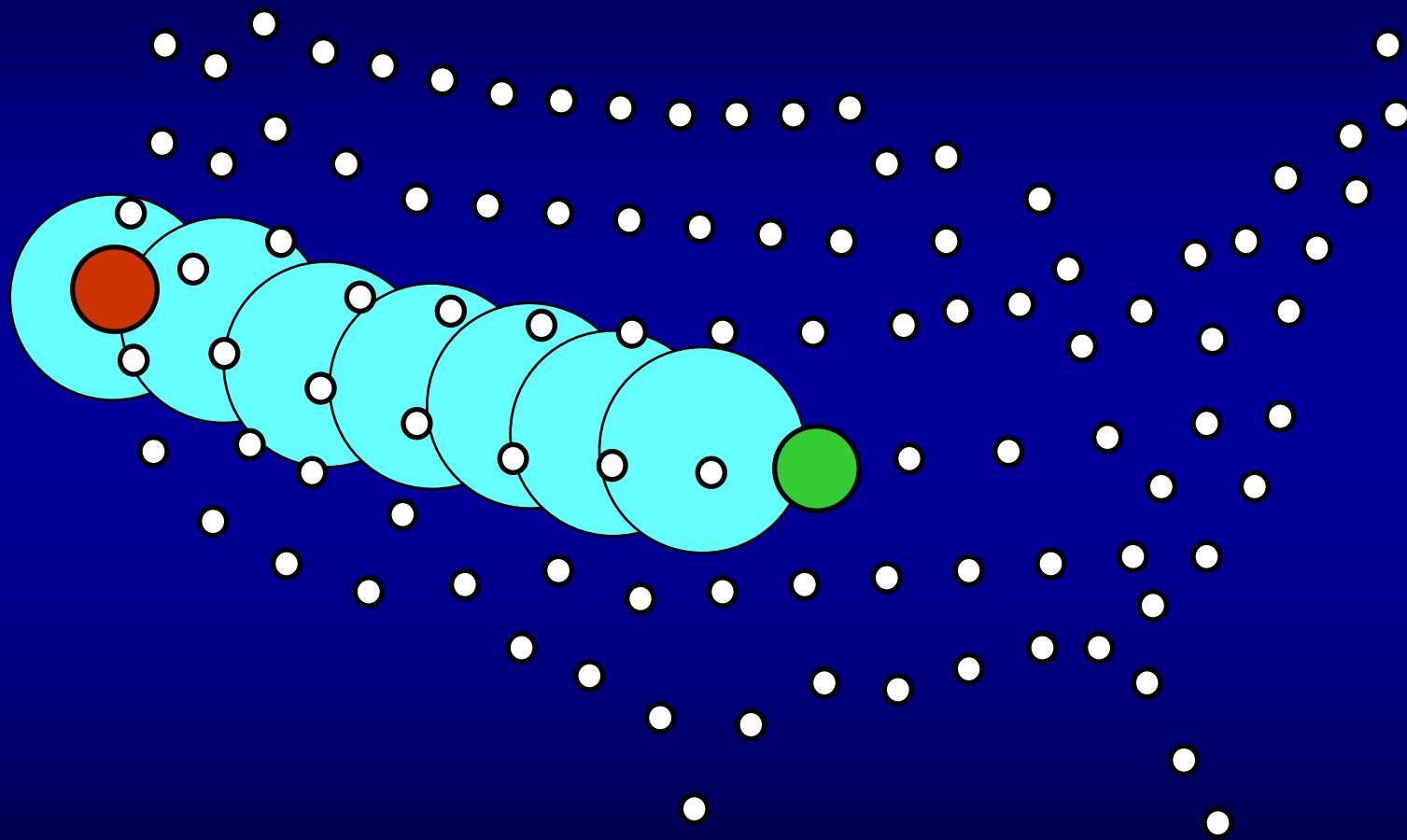
25 >> 1 lb

Packet Radio

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



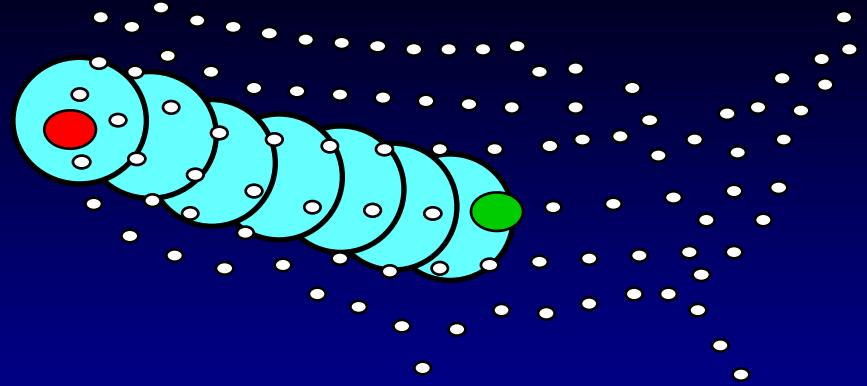




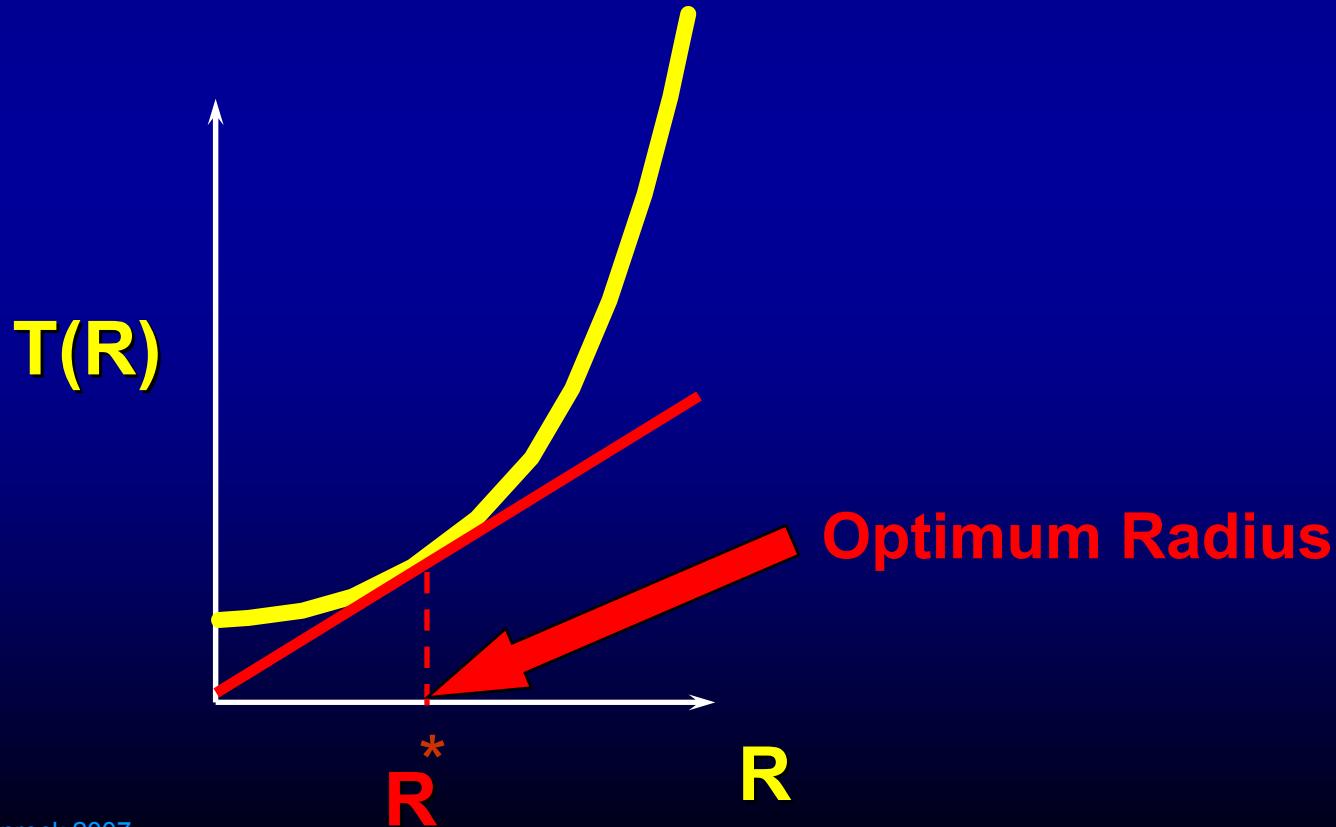
Giant Stepping in Packet Radio

- 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 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 Andreeson 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.

- 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**

**Canter & Siegel, Immigration Attorneys
3333 E Camelback Road, Ste 250, Phoenix AZ 85018 USA
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 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 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



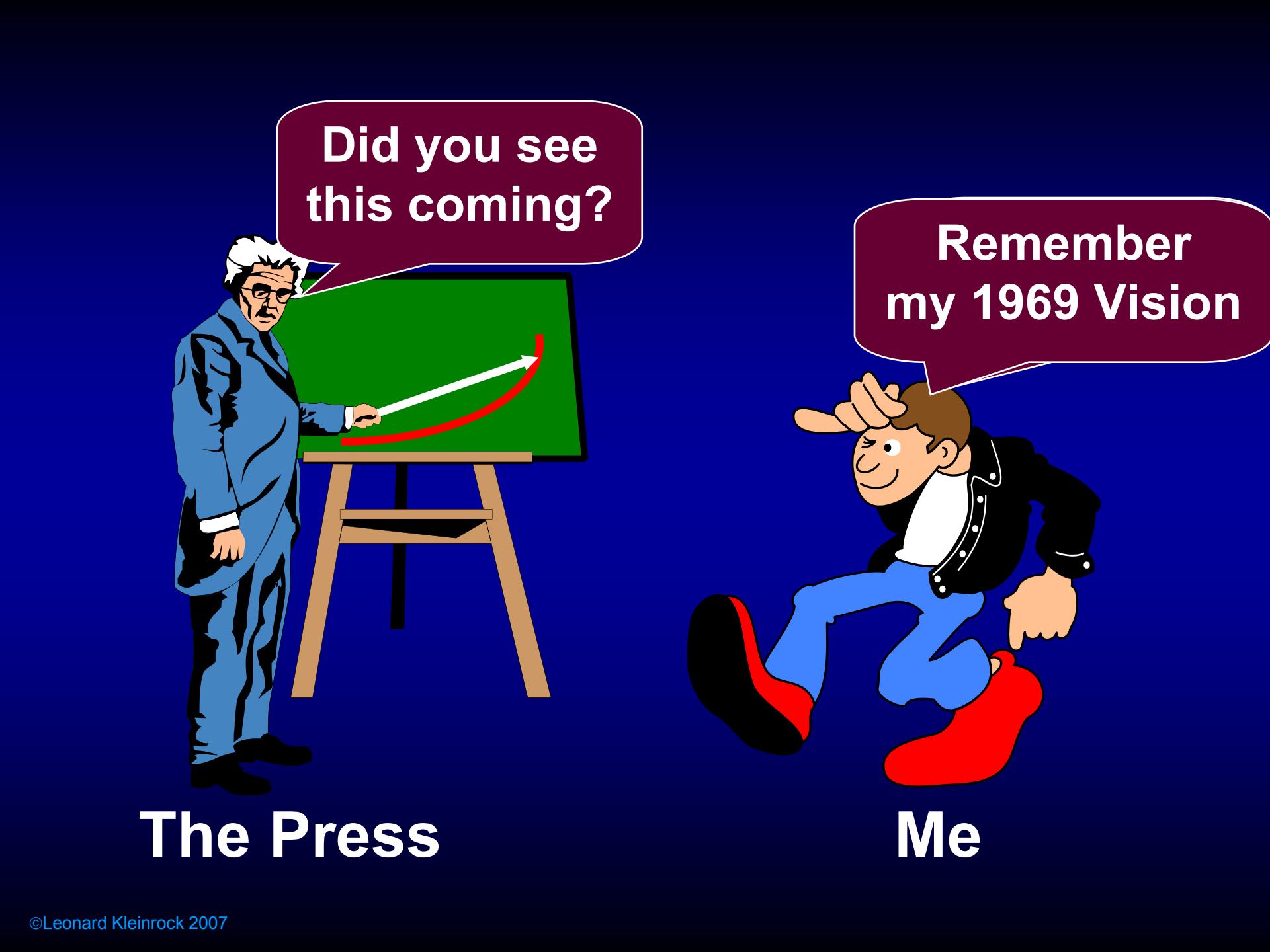
The Launchers



The Billionaires



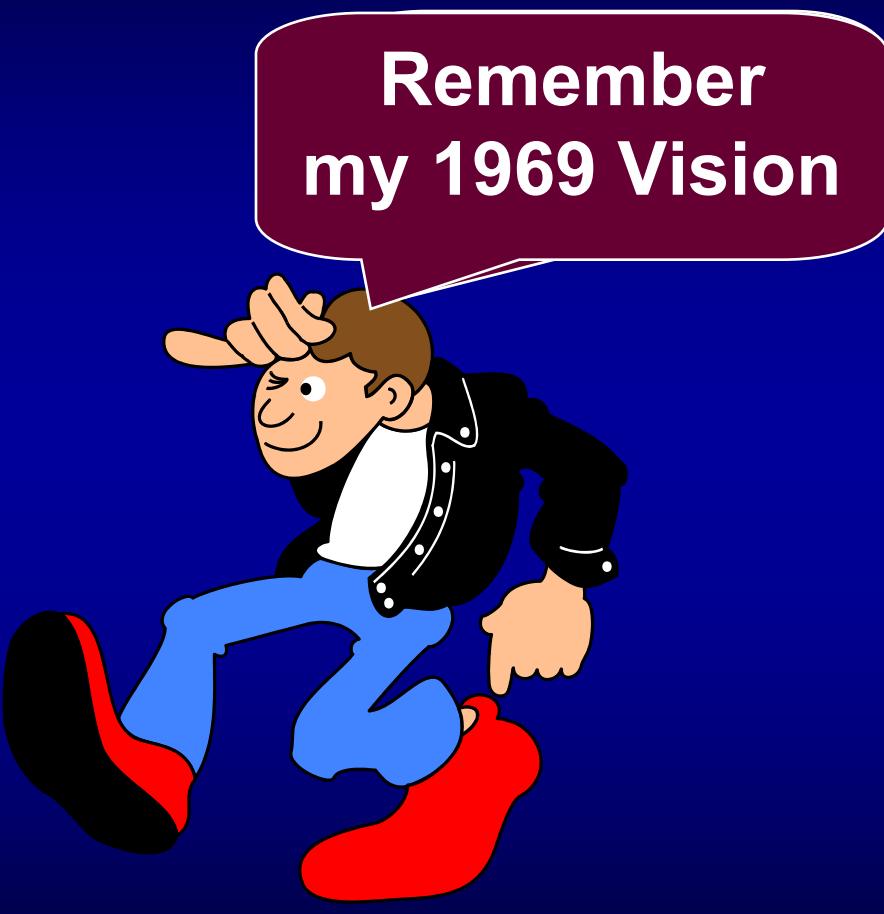
4. The Early Internet Vision



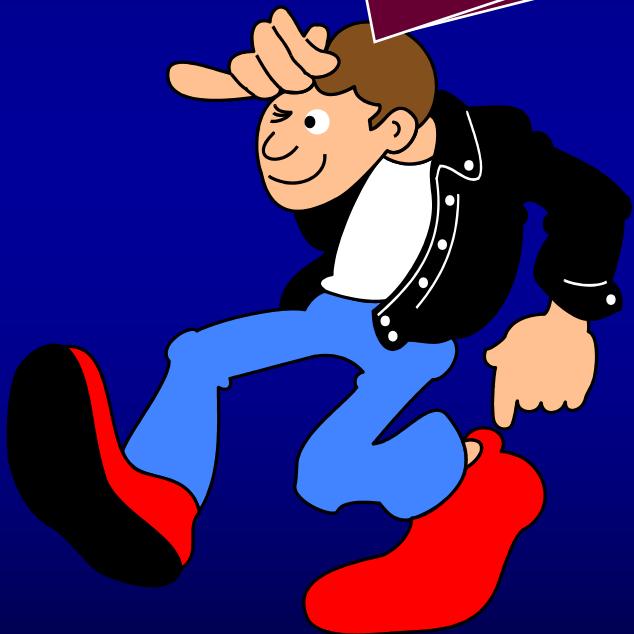
Did you see
this coming?



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**

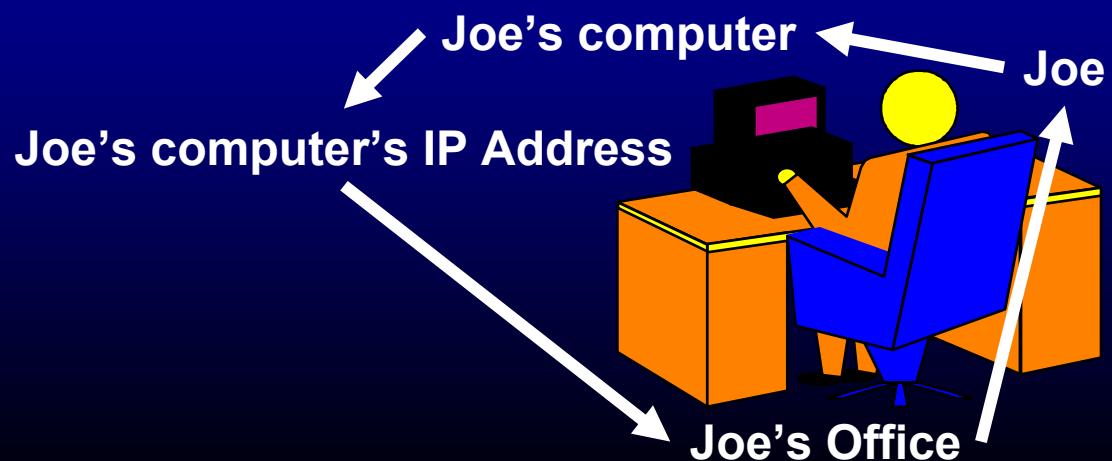
The Internet Almost Got it Right

- 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

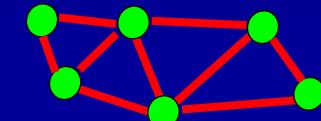
Phase 4: Convergence

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

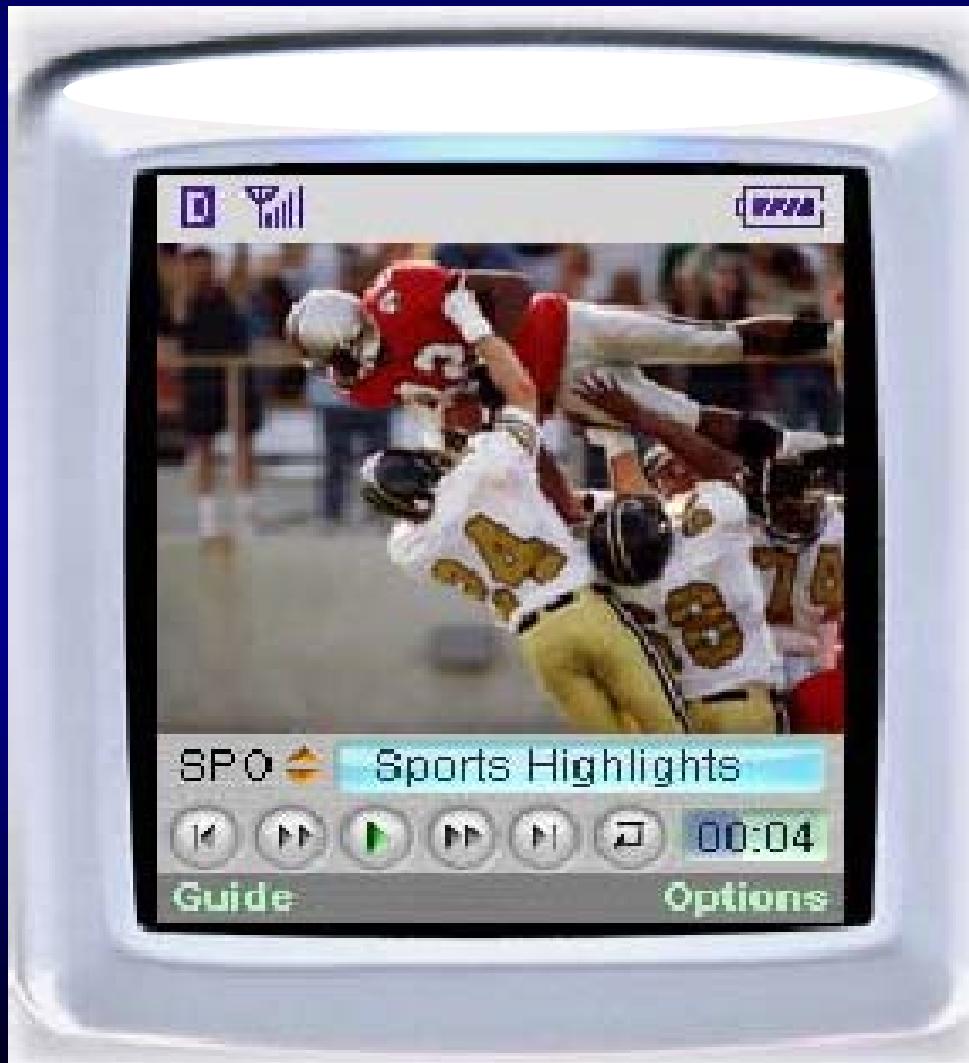
Phase 4: Convergence

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



watch



PC



PDA

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



PalmOne Treo
circa 2004



Connected to Internet via
50 kbps leased line



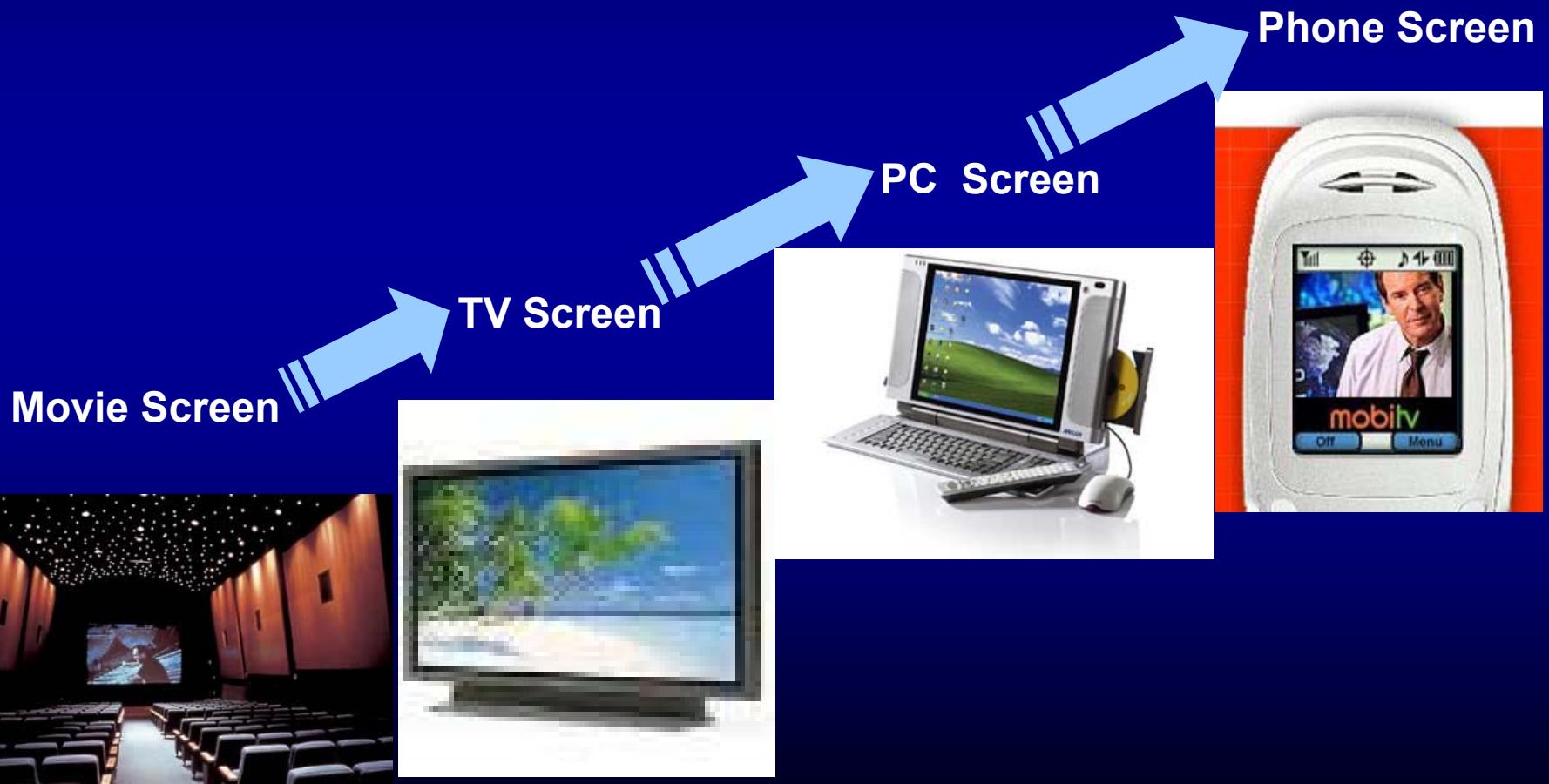
Connected to Internet via
50 kbps GPRS link

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



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

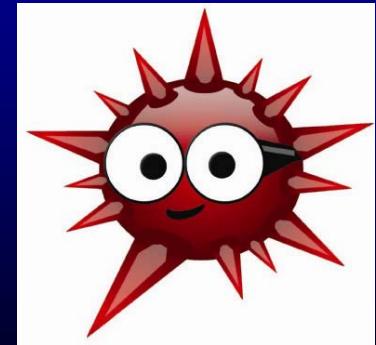
15 second ads download to their cellphone at night

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-

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!

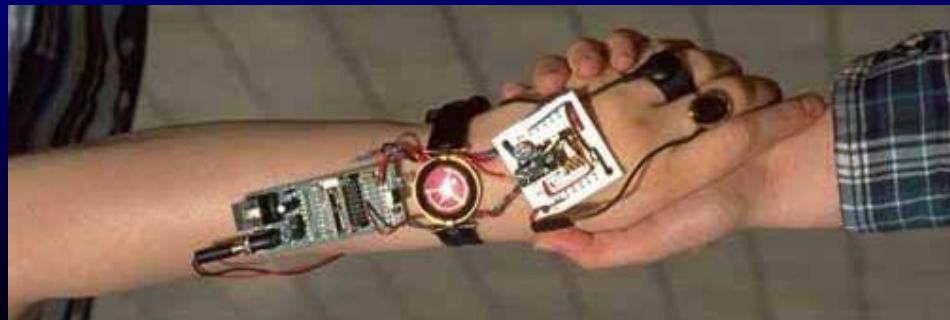
Location-Based Services

- 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

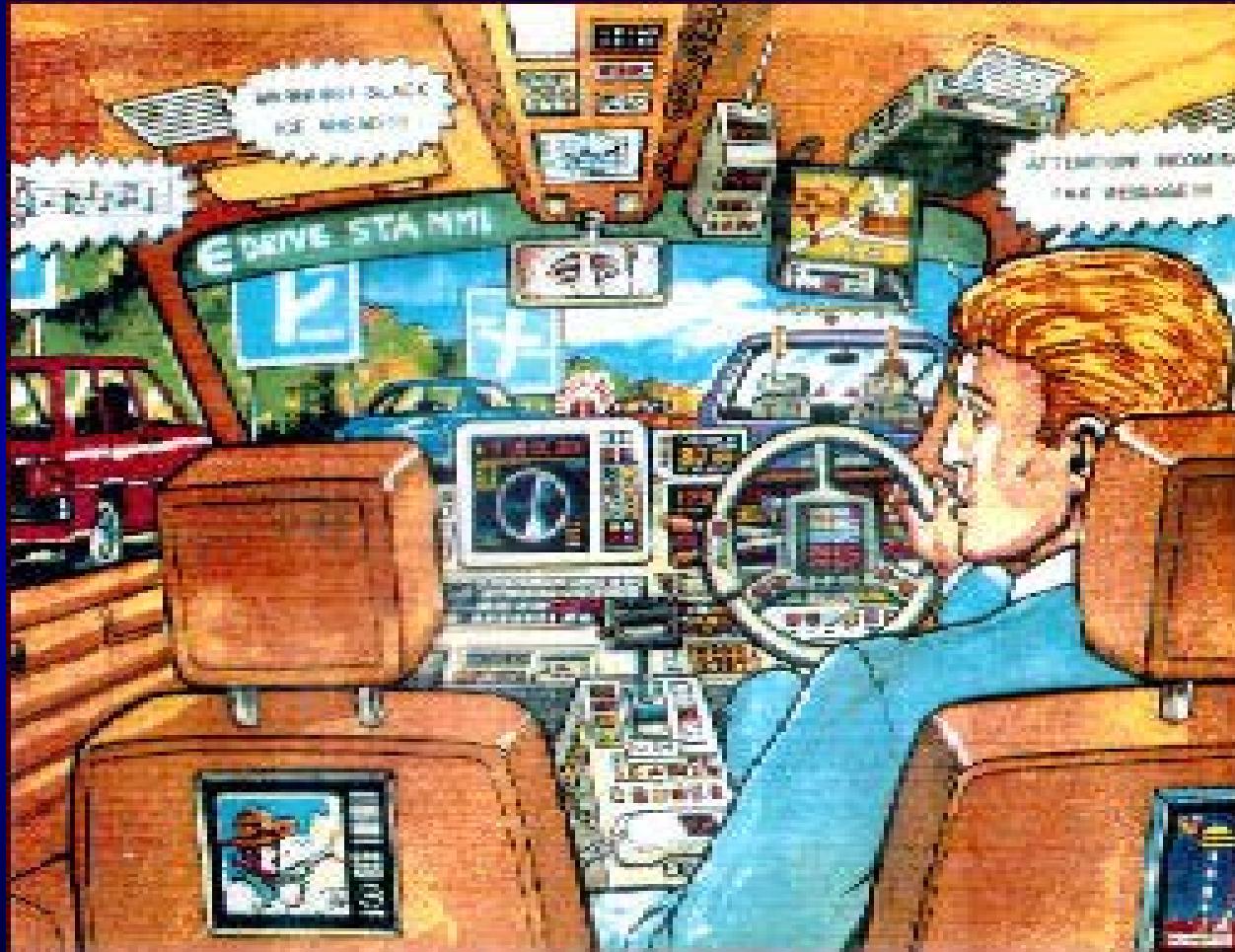
From Convergence to Divergence

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.

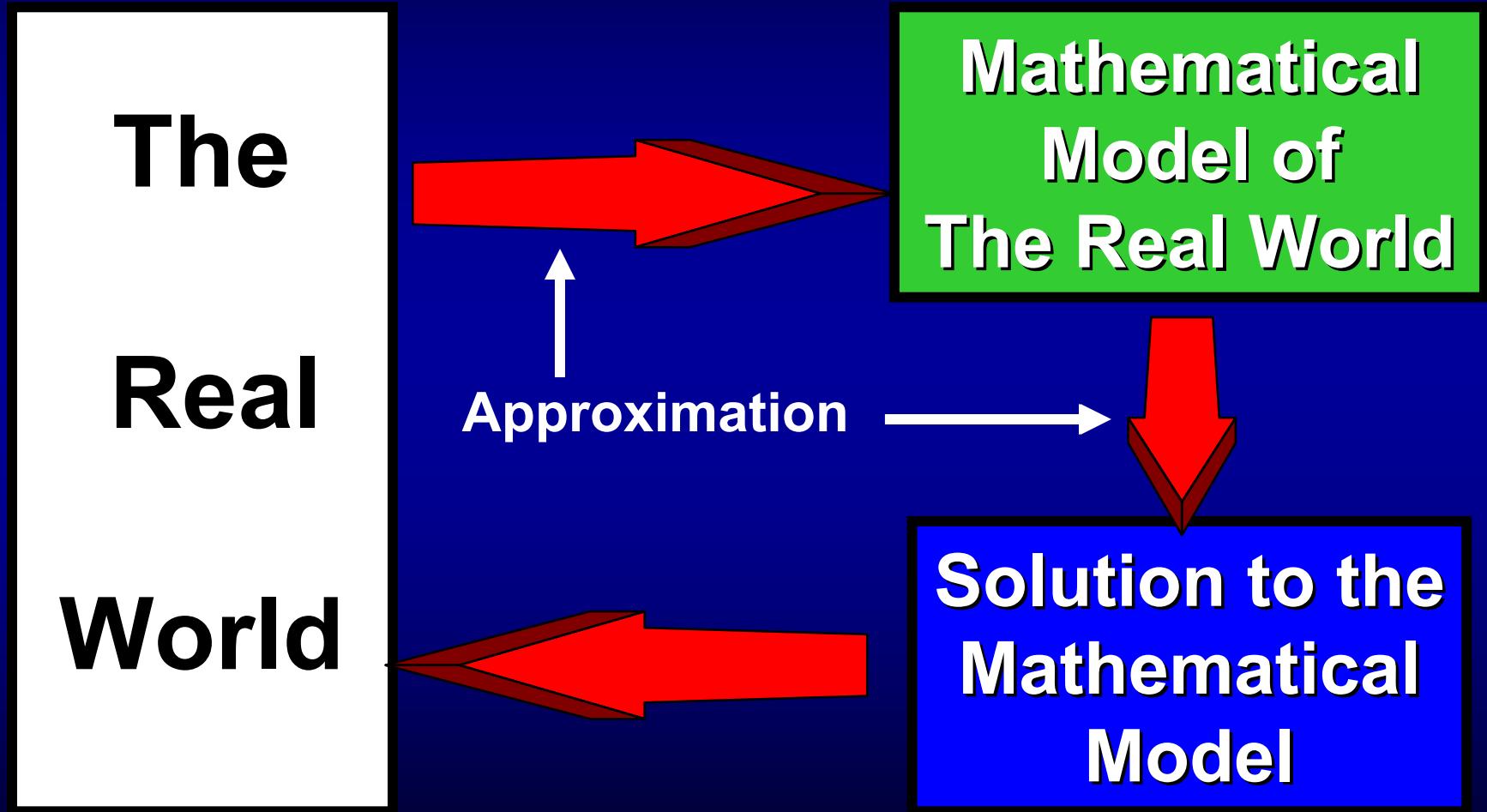
1. The 100 Year Test

- 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

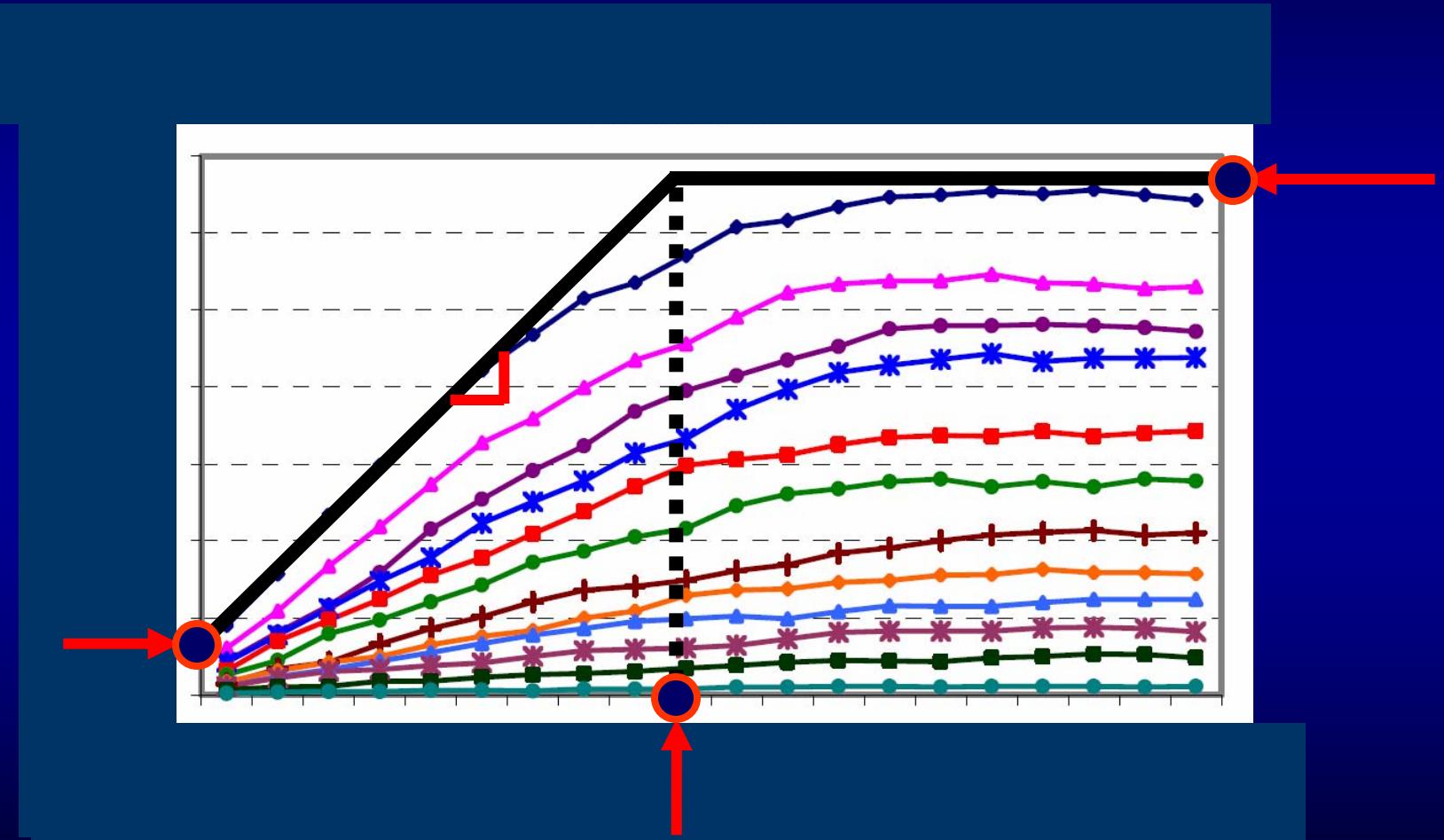




Michael Faraday

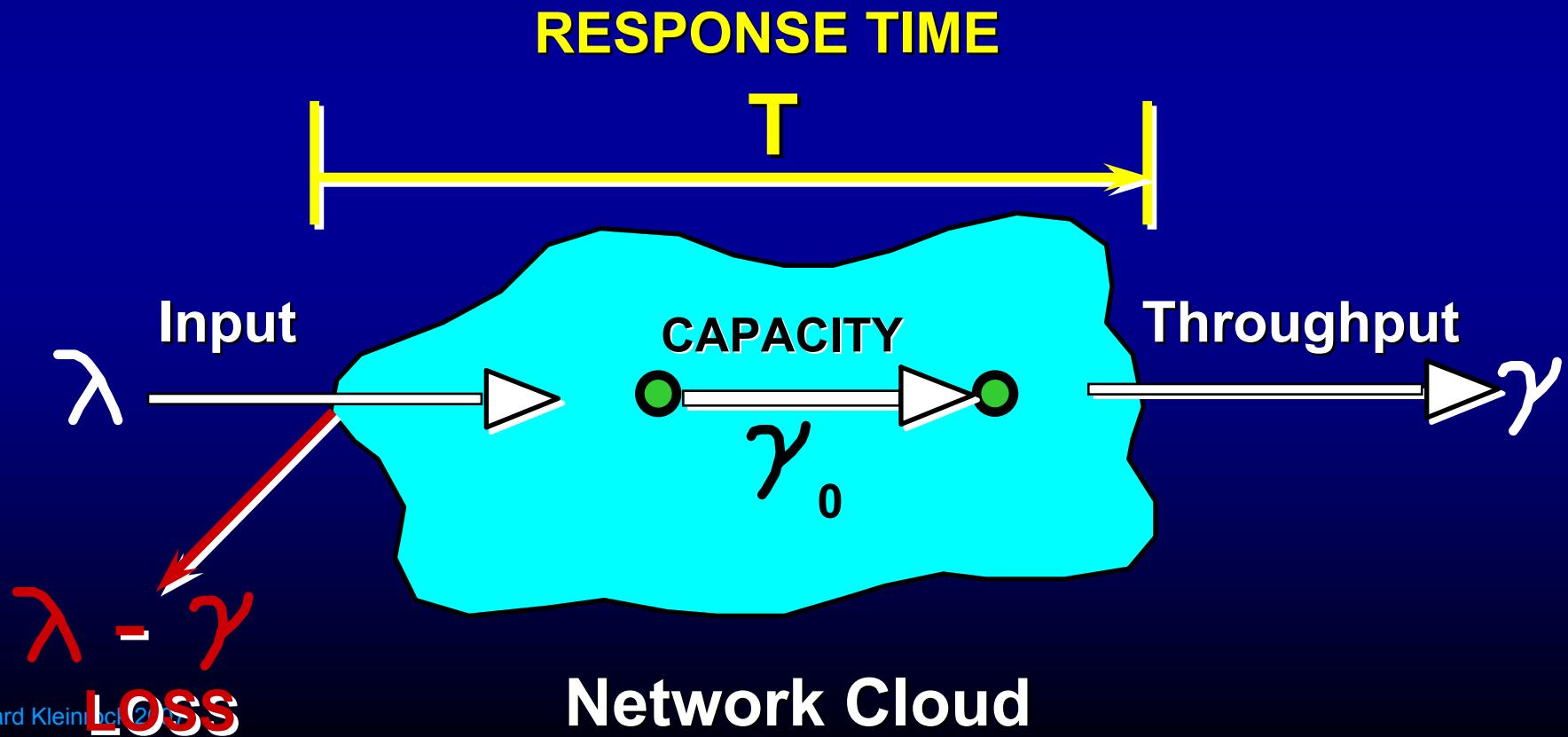
- "**I could not imagine much progress by reading only, without experimental facts and trials ... I was never able to make a fact my own without seeing it. “ (Faraday: 1827)**
- **Faraday performed in his brain the work of a great mathematician without using a single mathematical formula” (Hermann von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

3. Beware of Mindless Simulation Ask the Obvious Questions



4. Understand Your Own Results

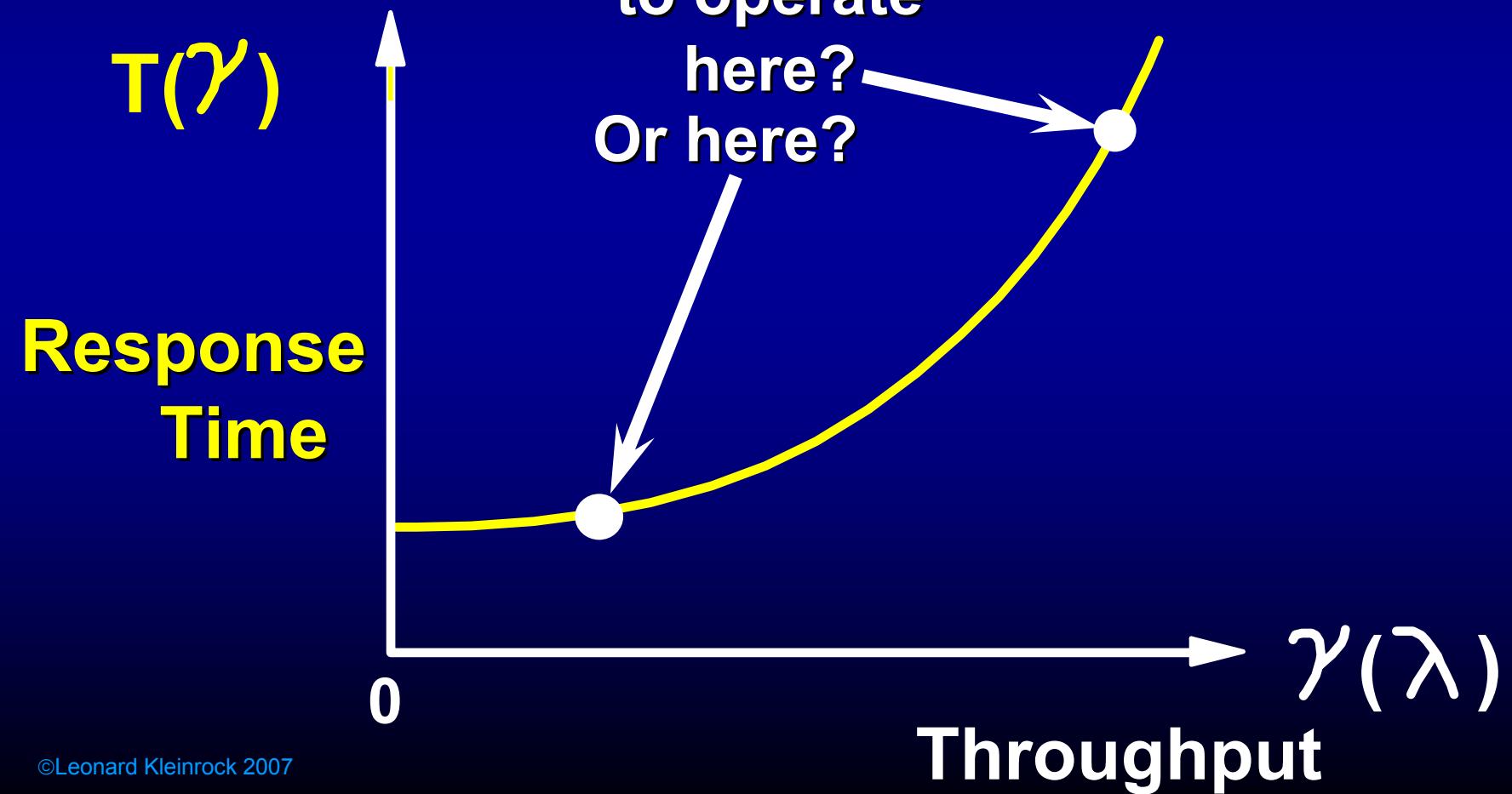
Response Time Throughput Loss



Response Time vs Throughput

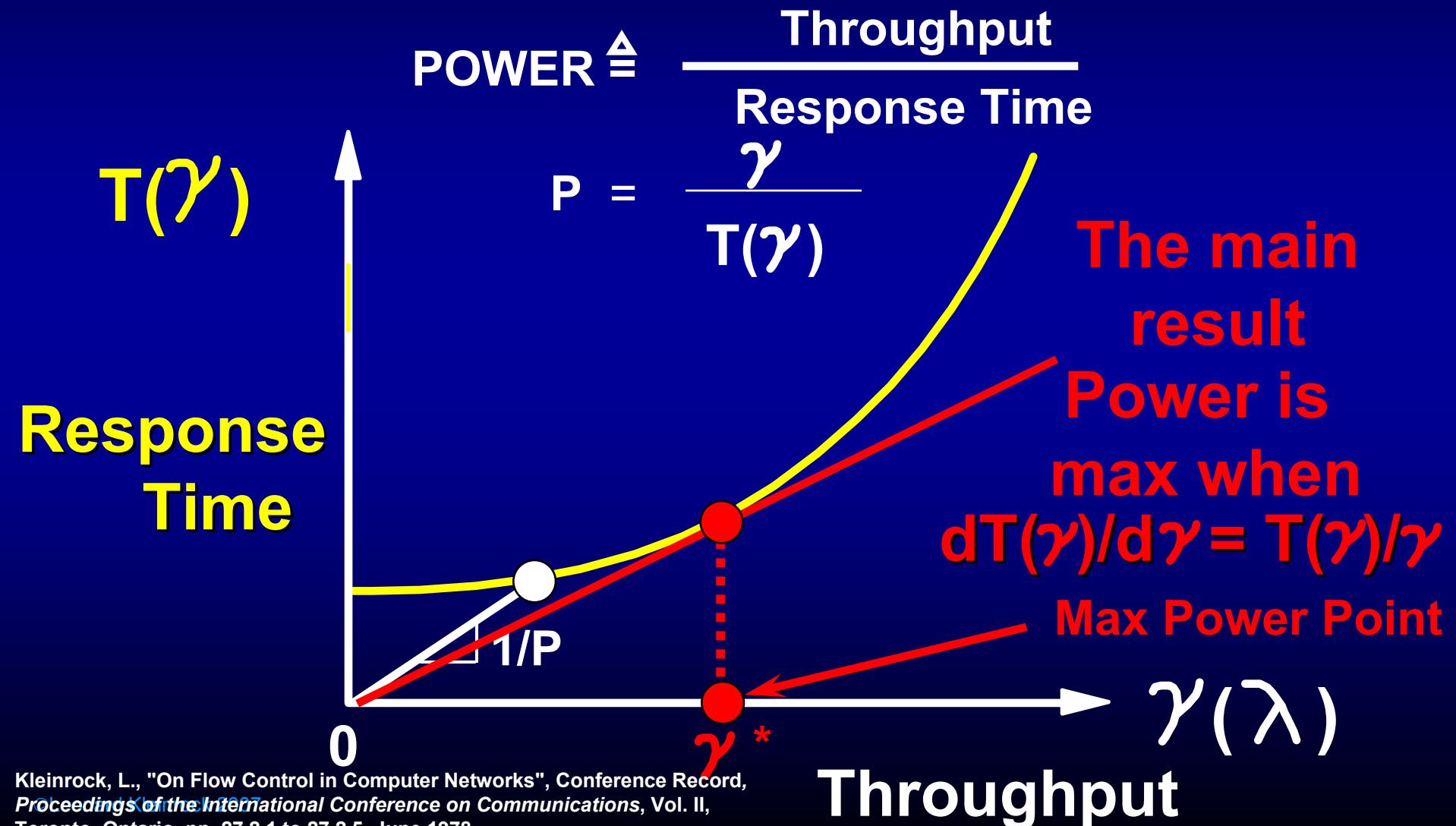
Now let's ask a good question:

Do you want
to operate
here?
Or here?



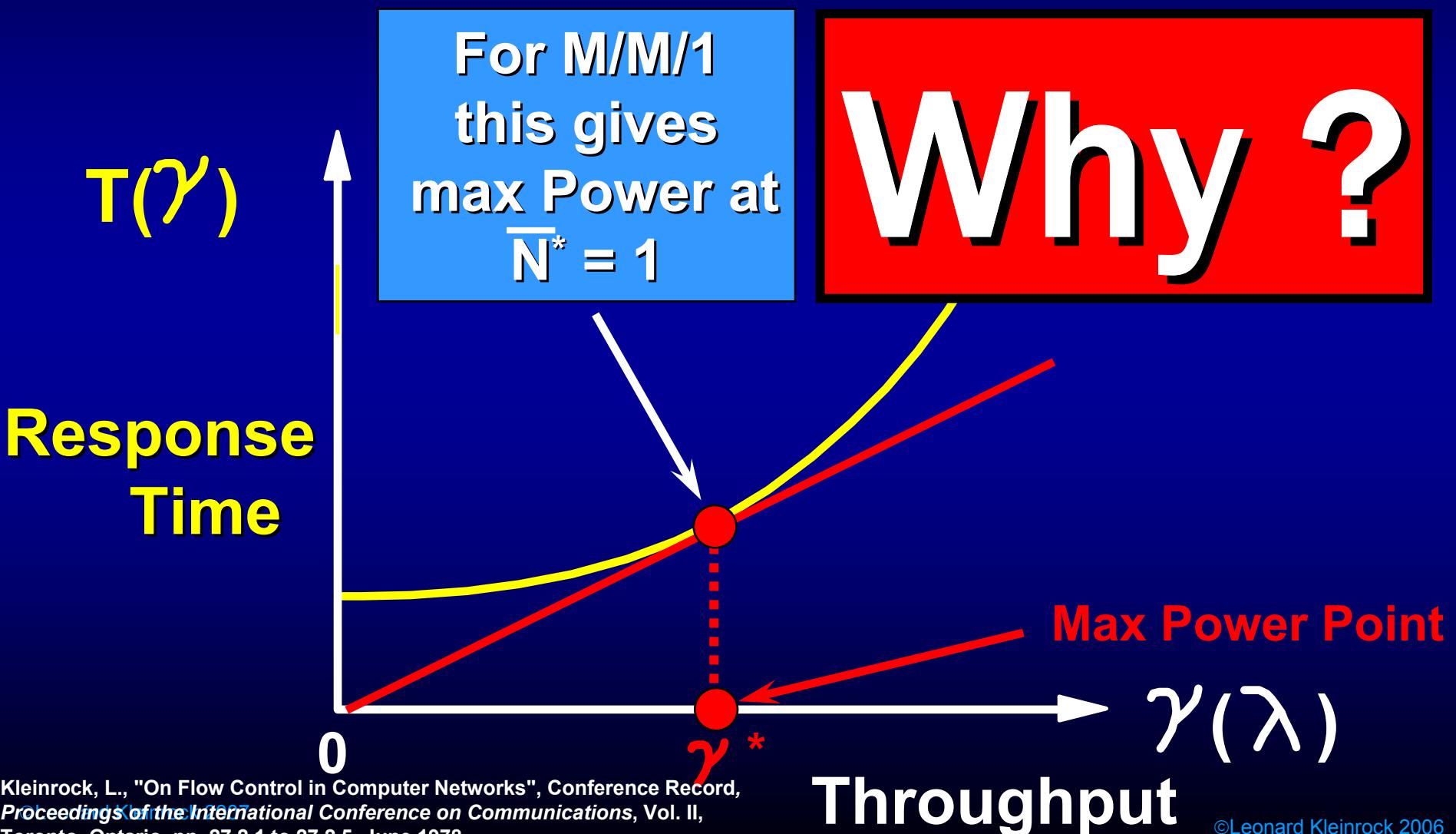
4. Understand Your Own Results

Let me define a new metric of performance:



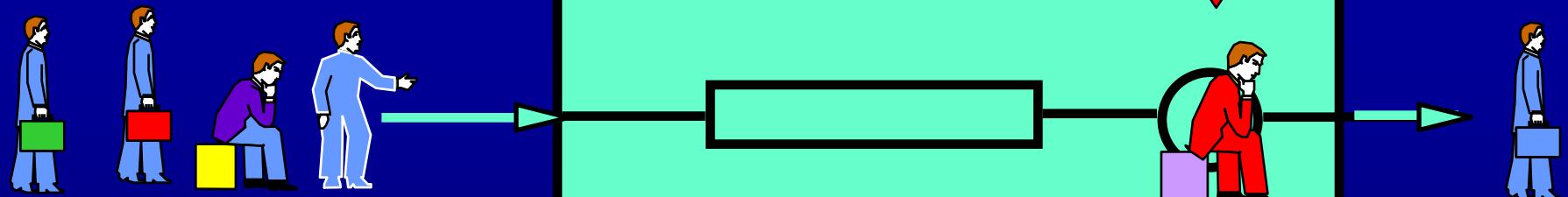
4. Understand Your Own Results

Let's Dig Deeper on Understanding



4. Understand Your Own Results Use Your Intuition

**Only 1 customer
in the system**



**Insight:
Just keep the
pipe full!**

T
 $T = \text{Min}$
 $\text{Eff} = \text{Max}$

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.,

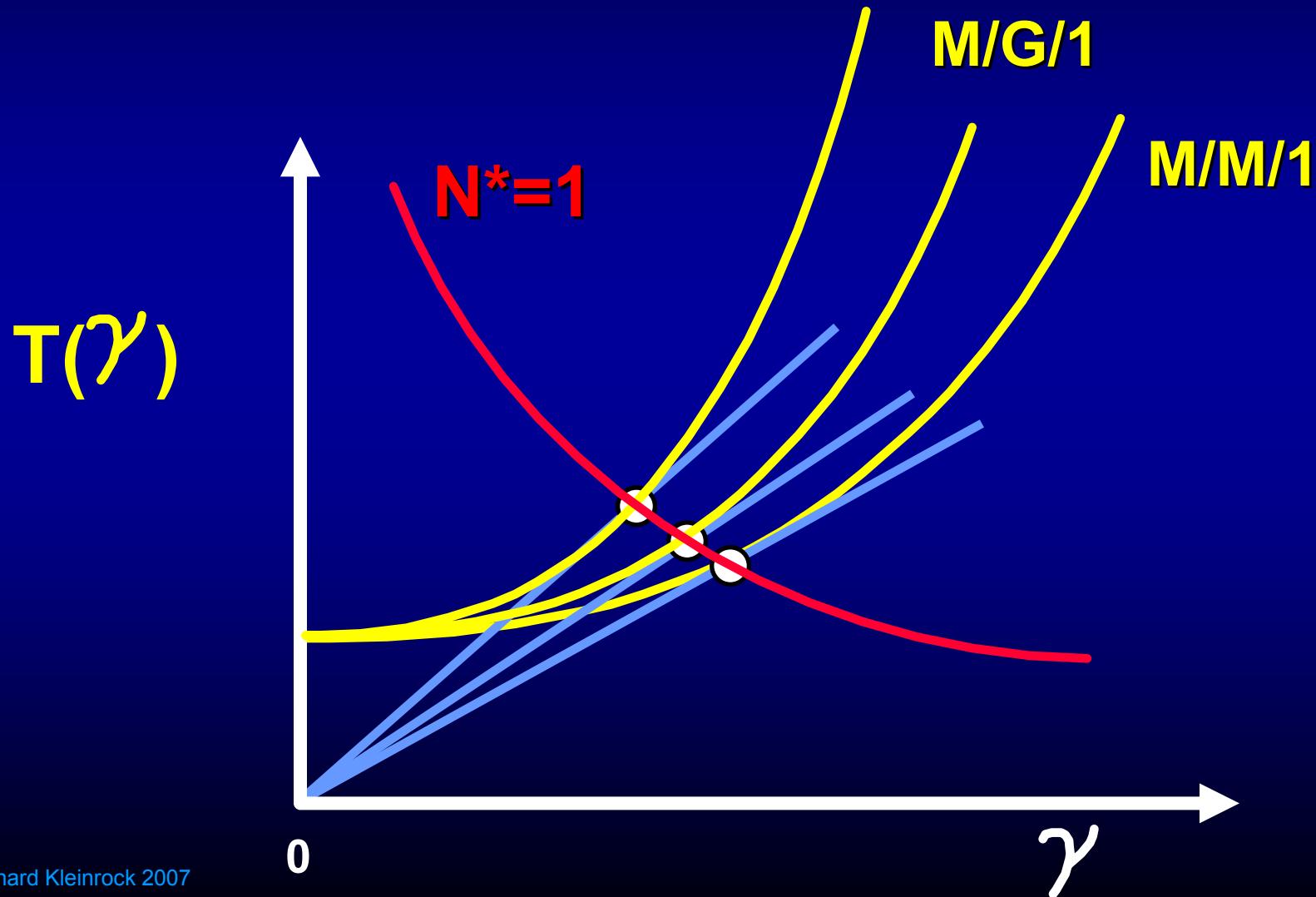
At Max Power
 $\bar{N}^* = 1$
for M/M/1

Gee, that's funny!

5. Gee, that's funny!

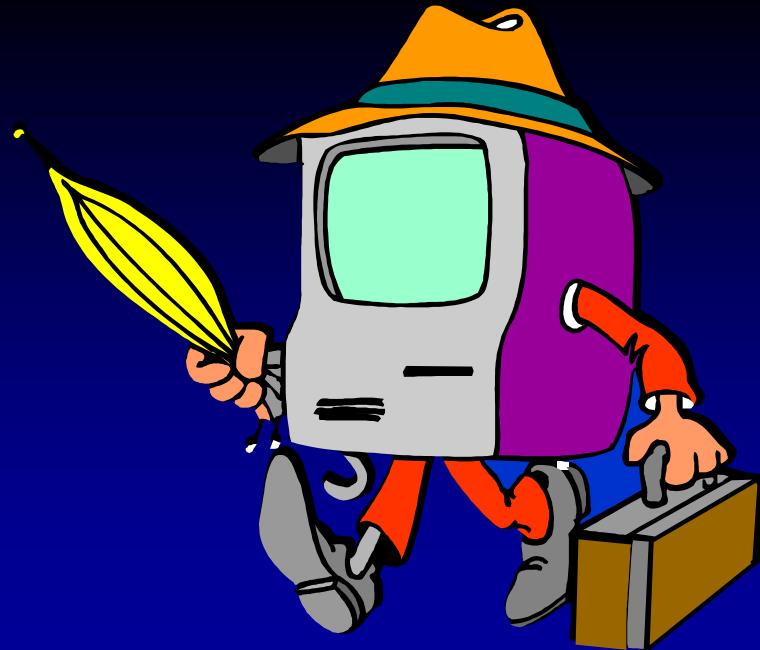
5. Gee, that's funny!

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