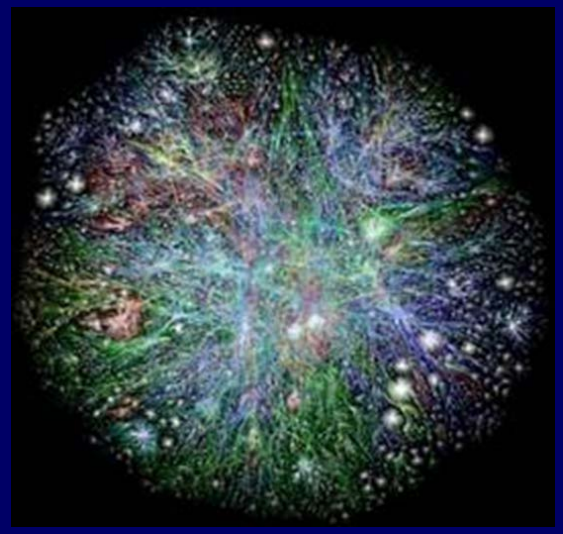
Center for Research in Knowledge Communications

VISION 2005 to 2030

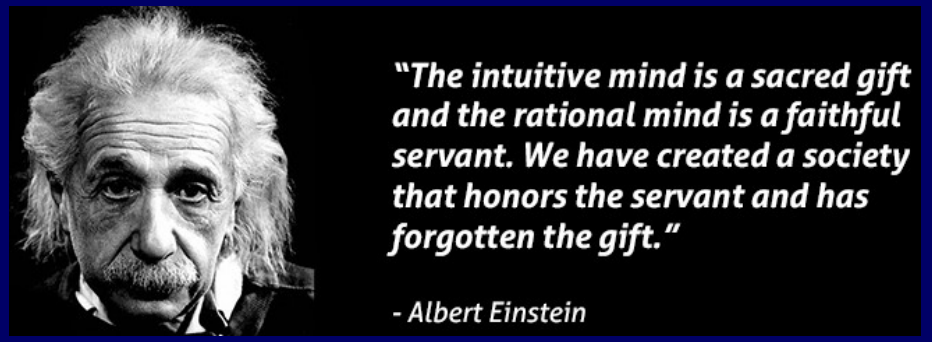


Dr. Mohsen Kavehrad (IEEE Life Fellow)

Director: Center for Research in Knowledge Communications (CRKC)

E-MAIL: mkavehrad1000@gmail.com

Vision for Future of Knowledge Communications



- The author Jay Harman [1] interviewed Dr. Kavehrad on a paper he had published that was funded through a DARPA/AFRL project [2].
- He had discovered that dolphin chirps look like a wavelet waveform and he used this observation to transmit ultrashort optical pulses through clouds with promising results.
- He now believes the next revolution in networking will take a similar course.

1. Jay Harman, "The Shark's Paintbrush: Biomimicry and How Nature is Inspiring Innovation," White Cloud Press, ISBN: 978-1-935952-84-8, 2013.
2. M. Kavehrad, "Mitigation Approaches for Optical Imaging Through Clouds and Fog," DARPA/AFRL Final Report: AFRL-RY-WP-TR-2009-1331, Released on December

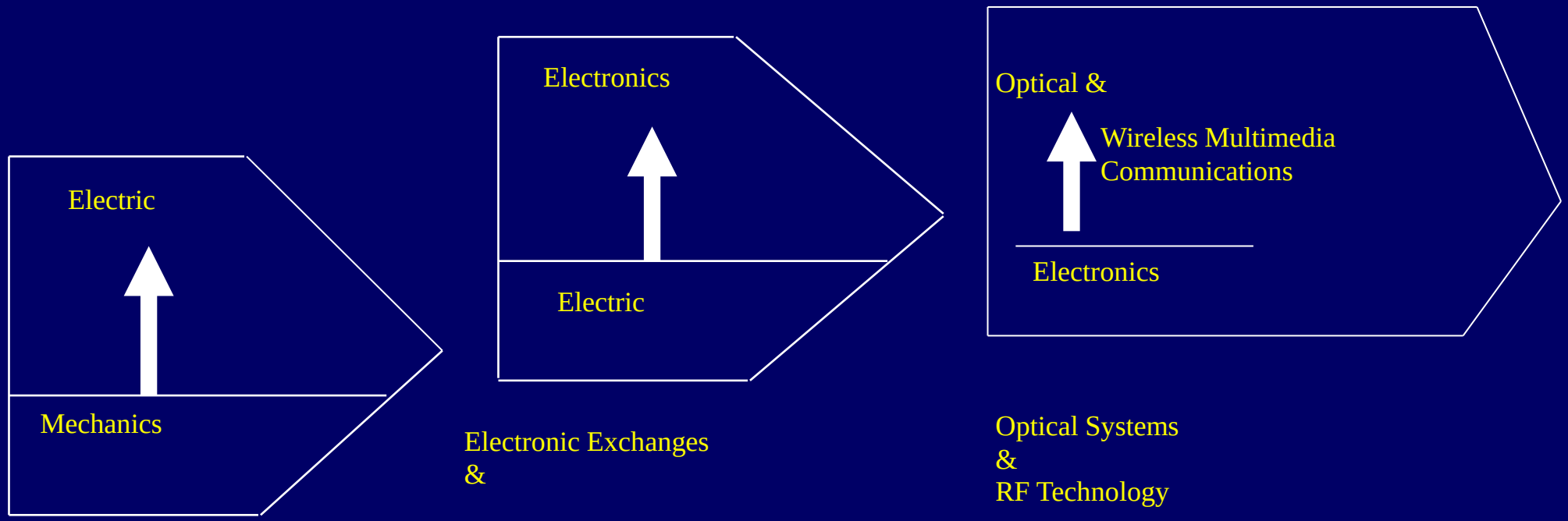
VISION 2005 to 2030

• Normally, start of a new century brings with it dramatic changes. The 21st century is no different …

• The biggest technological and social change - - will be the

"Convergence of Computers and Communications".

The Evolution of Communications and Computing



Morse Code Telegraph

Electronic Exchanges
&

Computers

Optical Systems
&
RF Technology

Knowledge Communications Age

Next five years will mark the start of a Multimedia Age, freeing people from; *constraints* of *time and place* and from *limits* on the *form of the information* they send and receive.

“I think there is a world market for may be 5 computers”

Thomas Watson,
Chairman of IBM,
1943

"There is no reason anyone would want a computer in their home"

Ken Olson,
Founder of Digital Equipment Corp.,
1977

“640K ought to be enough for anybody”

Bill Gates,
1981

Knowledge Communications Age

Homes will be wired and equipped for ‘Tele-work’, ‘distance-learning’ and an unimaginable range of ‘entertainment’ options.

Knowledge Communications Age

- People will work for "virtual corporations" made up of "virtual workgroups" including *consultants*, *suppliers* and *customers* who operate globally using “virtual travel” for most face-to-face meetings.

- In sum, we will become a "virtual society”.

Knowledge Communications Age

•*What will make this possible ?*
One network of many choices ... a vast and comprehensive multimedia ... based on broadband transmission and switching of voice, data and video.

•Separate private voice and data networks replaced by a single multimedia network with seamless connectivity.

Knowledge Communications Age

- The new network will deliver voice, "video dial-tone" and advanced data services as cost-effectively and *as easily as* telephone service is delivered today.

- It will fundamentally alter how we live and work in a Global Society.

Knowledge Communications Age

Yet, even as this network enables daring new concepts to take hold, it allows cherished old ones to return:

- Doctors will again make "house-calls".
- More people will work at home than at any time since the end of the Agrarian Age.

A glimpse into the future

Around the year 2005, we'll begin to see:

- The Virtual Corporation
- The Wired Home
- The Virtual Hospital
- The Virtual Campus

A glimpse into the future

The Virtual Corporation

Organizational hierarchies will flatten, workgroups will flourish and the use of contract workers and consultants will accelerate.

"Virtual corporation" will become a reality as "virtual Project teams" composed of corporate employees, suppliers, consultants and even consumers redefine hierarchies in organizations.

A glimpse into the future

The Virtual Corporation -- Cont'd

• People will travel less for business and more for pleasure as TV-quality video conferencing makes "virtual travel" a lower-cost and more productive alternative. Seeing distant colleagues will help people create more personal business relationships, improving productivity.

• Consumer service will make or break the relationship between buyer and seller as savvy consumers demand Service when and how they want it..

A glimpse into the future

The Wired Home

•Access to 500+ cable television channels and thousands of Internet sites and a warehouse of on-demand videos will make the home a multimedia theater.

•The work-at-home movement will create new flexibility and opportunities. Employers will be open to new arrangements to save on real estate costs and attract talented workers. Furthermore, studies will show "tele-workers" are as productive as their counterparts in a central office.

The Wired Home -- Cont'd

Computer-assisted learning and training in the home will supplement the role played by traditional educational institutions.

Families and telecommuters will increasingly use communications technology to overcome a lost sense of community. Videoconference "chat lines" will become an alternative to e-mail.

A glimpse into the future

The Virtual Hospital

Health-care providers will re-engineer to deliver services more effectively, lower-administrative-costs and optimize laboratory and hospital resources.

Patient registration will be done remotely and the processing of bills and insurance forms will be done faster using standardized electronic forms.

A glimpse into the future

The Virtual Hospital -- Cont'd

- Rural hospitals will use videoconferencing and high-resolution visual communications technology for remote consulting and for training health care professionals.

- Remote diagnosis and videoconferencing will enable "house-calls" for some basic health services and follow-up visits or to reach areas without decent health care.

The Virtual Campus

Traditional public and private educational institutions will use information technology to "re-engineer" themselves in even more dramatic fashion than the major corporations that reinvented themselves in the 1990s.

"Lifetime learning" will be enabled by new technologies, including video training and access to the Internet and on-line services from the home or office. Universities will form alliances based on distance learning to offer specialized joint degrees, drawing on the strengths of their faculties.

A glimpse into the future

Electrical and Computer Engineering (ECE)

- Wireless communications technologies promise to dramatically alter the telecommunications landscape over the next decade. In so doing, they may significantly change the makeup of what we consider to be Electrical and Computer Engineering (ECE).

- We have conventionally considered Analog and Digital Circuits to be "center" or "core" topics of ECE, the present trends in telecommunications may shift the center of ECE more toward Digital Communications and Signal Processing.

- The changes in technology will be no less dramatic. In a decade, we will be amused at how many things we used to connect with wires.

Networks

• Today's voice and data networks are marvels of efficiency and productivity. Yet, they are different in fundamental Ways.

• Voice networks are based on end-to-end connections of Circuit switching, while data networks are based on hop-by-hop datagram packet switching.

• Through the end of the decade, multimedia solutions will be delivered that effectively bridge the worlds of voice and data. The large required bandwidth will be provided through an optical backbone and broadband local access.

Networks Seamless Communications

Recent Past:

Integrated, low-rate voice, data, and video; independent wideband voice and data services.

Current:

Low-rate interactive applications over internet, extensive TCP/IP and connection-oriented traffic in the backbone.

Long Term:

Collaborative, wideband data-intensive knowledge communications, several gigabits to a user, connectionless and connection-oriented packet-switching straight through the backbone. A more heterogeneous traffic necessitates re-visiting circuit switches.

As Easy as the Telephone

As easy to use as the ‘telephone’ is today's standard for user friendly products. In a Knowledge Communications Age, that standard may even be surpassed, as, a revolution in human interface technologies makes interaction with multimedia systems almost as intuitive and comfortable as talking to another person.

As Easy as the Telephone

The mouse, keyboard and traditional telephone will be gone, or used as supplements to a system that interacts with the individual in a more natural way.

Today's automated voice response systems, voice recognition systems, handwriting recognition systems and real-time interactive video systems will advance, delivering human-like responsiveness.

Other technologies such as Artificial Intelligence (AI) and “Expert Systems" software will rapidly mature into systems that can ‘learn as they go’.

As Easy as the Telephone

Publishing will be transformed because people will have all the convenience of today's portable newspapers, magazines and books in the form of wireless computing display screens, capable of downloading virtually any newspaper or magazine in the world.

Tele-presence

Travel will be transformed as today's ‘infant’ video conferencing systems grow into wall-size *3-D Displays* that can meld a conference room in Boston with another room in San Francisco, creating a virtual conference center where teams of people can spend a day or a week together as if they were in the same room.

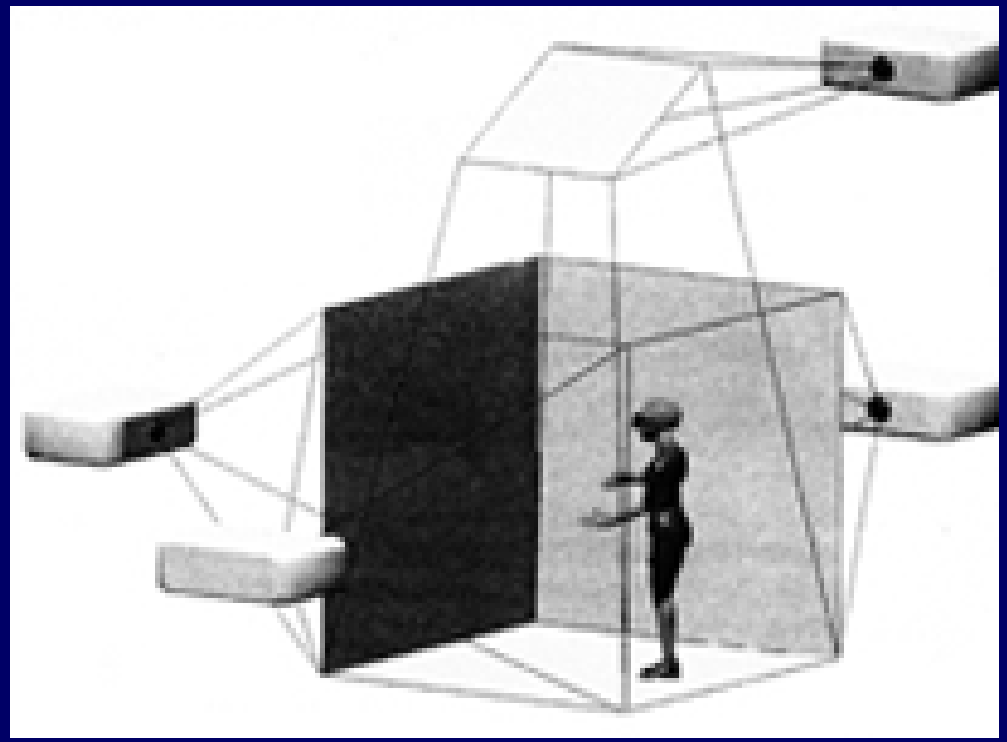
Tele-presence

Breakthroughs in *'holographic'* and *'virtual reality'* technologies will bring complete integration of individuals from multiple locations around the world into single virtual meeting rooms.

In such a meeting, only the firmness of a person's handshake will make it possible to know whether the individual is really in the same room or not.

Virtual Reality

- As cost of ‘Virtual Reality’ technology falls, this will have a huge impact.
- Linked to high-speed networks, will allow entire new collaborative possibilities.



The Web is the Computer

- Expect people in future to have persistent access to the web ... - Peta-bytes of storage.
- Information is growing exponentially, we no longer throw away information, thus the birth of Big Data …
- Finding, sorting, distributing this information is the next big challenge.
- Networks to serve this data will be very important. Copper, fiber, satellites, microwave, mm-wave, free-space optical…
- The role and importance of the operating system will fade.
- Microprocessors will not just be in computers.

Storage & Networking

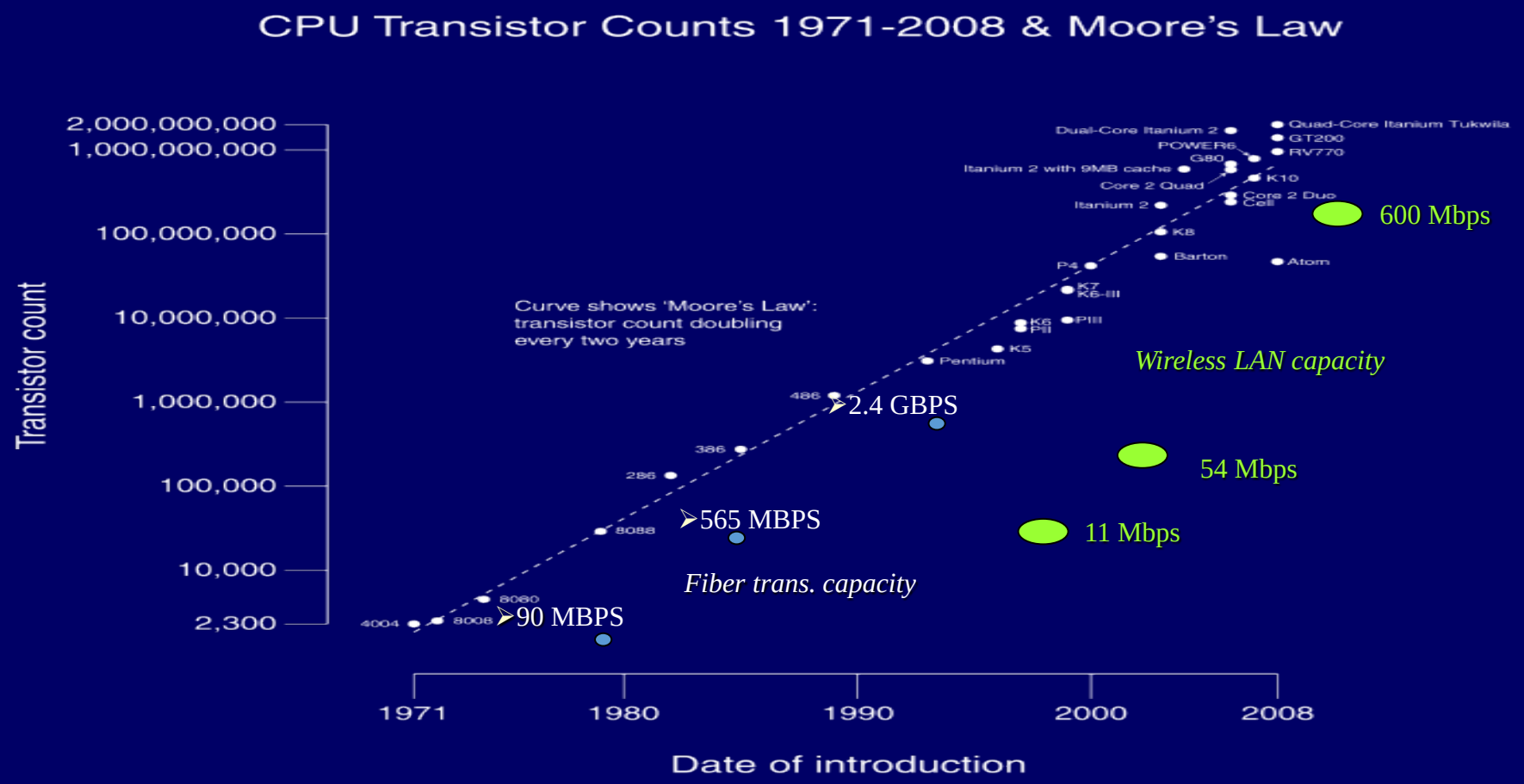
What if a palmtop could store a terabyte of data?

- The Encyclopedia Britannica is only about 1 Gigabyte
- A Terabyte would hold photos of 10% of the U.S. population (30 million photos each 30KB)

What if a palmtop smart-phone is capable of OC-48 (2.5 Gigabits per second) ?

- Could send encyclopedia in 3 seconds
- Could send photos of 10% of U.S. population in one hour
- Full motion video to a palmtop smart-phone ?

Moore's - Law: Computer power doubles every 24 months with cost remaining constant



- Fiber communications capacity doubled every 12 months up to 1995. Since then, it has been more than doubling, with use of WDM and D-WDM.
- RF wireless communications capacity increased by a factor 1.5 every 12 months in 2000's and the growth is slowing down due to power/Band/Performance/Mobility limits.

Optics Technology

Devices

- Broadband Tunable Lasers
- Broadband Tunable Detectors
- Wavelength Converter

→ WDMA,
Dense -WDM (D-WDM)
FE – CDMA, OFDMA, …

- Ultra-fast Switching Devices
- Low-Cost Mode-Locked Lasers

→ TDMA, CDMA, OFDMA, …

- 2-D arrays of Switching Devices
- High Power Lasers
- Ultra-fast Spatial Light Modulators
- Optical Interconnects

→ Free-Space
Networks & Switches

Optics Technology

Networks and Systems

Inexpensive Wavelength-Selective Interconnects, Optical Memory

WDM Switching ,

Optical Switch / Optical Cross-Connect

Applications :

- Intelligent Multimedia Networks
- All-optical Backbone & Broadband Local Access

Why D-WDM ?

- Local exchange carriers are increasingly faced with problems associated with fiber exhaust.
- An open system architecture facilitates the integration of different data protocols, e.g., MPLS, IP, SONET, SDH.
- SONET hierarchy has already reached the transmission speed of the fiber.
- Installing more fiber is only cost-effective in limited cases.
- Less number of Amplifiers.
- Spatial Division Multiplexing (SDM) and Multicore Fibers can remedy the limited-capacity problems for now.

Novel Optical Device Invention made D-WDM possible

- Add-Drop Multiplexers
- Wide-Band Optical Amplifiers
- Optical Cross Connects
- Optical Switches
- Narrow Band, High-Isolation Optical Filters

Flexibility in Ultimate Solution

- D-WDM and SDM Can be Used as Unifying Layers.
- D-WDM and SDM are Data-Rate and Data-Format Transparent.
- D-WDM and SDM can be Seamlessly Integrated into the Current Network Structure.
- No other wired or Wireless Technology is capable of delivering such a capacity.
- Current research in the 2000 nm, 1600nm and 1400nm regions promise colossal bandwidth available in future. Although, non-linearity of fibers may limit the transmission rate, thus SDM is a remedy.

D-WDM and SDM in Network

- Circuit Switched: Using Cross Connects
- Wavelength switched: Using Add-Drop Multiplexers
- Packet Switching using MPLS over SONET

Optical Transmission / Electrical Switching

i) RAINBOW (I, II, and III)
ii) MONET
iii) ONTC
iv) STARNE

All-Optical

i) ATMOS
ii) CORD
iii) LEARN

Wireless Communication

- *"We're just getting started. The market is going to be huge.*
- *People talk about the window of opportunity; the window is the next 20 or 30 years"*

Wireless Communication

Wireless communications technologies are currently experiencing explosive growth and promise to dramatically alter the telecommunications landscape over the next decade.

Digital Signal Processing

SILICON PERFORMANCE IMPROVEMENT FOR MIPS, RAM, FPGAs ~ 20% PER YEAR

- **VIDEO COMPRESSION:** ANALOG (NTSC) - 6 MHZ, 50 dB SNR
  DIGITAL - 100 Mb/s, 20 dB SNR
  MPEG-2 - 3-5 Mb/s, 20dB SNR
  MPEG-x …….

- **CELLULAR/PCS** AMPS HANDSET
  HANDSETS: PHS/PACS TDMA, CDMA, OFDMA – LTE

- **MODEM TECHNOLOGY:** 56.0 Kbps DATA MODEM , 10 Mbps DSL MODEM, 200 Mbps CABLE MODEM, 40 Gbps ETHERNET MODEM, ….

- **COUNTERMEASURE TECHNIQUES:** ERROR CORRECTION CODES, ADAPTIVE EQUALIZATION, SMART/ADAPTIVE ANTENNA PROCESSING, MIMO PROCESSING …

Wireless Communication

As the term "wireless" enters its second century, it is experiencing a renaissance of rare proportions.

Some projections show the number of wireless subscribers as high as billions in the first decade of new millennium.

Wireless Communication

Trends in Wireless Communications point to the merger of multiple services into integrated multimedia and knowledge communications technologies.

Wireless Communication

The most widely used wireless service was mobile voice. The first U.S. standard, AMPS (Advanced Mobile Phone Service), was based on analog technologies.

At the end of 1995, there were in excess of 30 million cell phone subscribers. This number has increased, substantially.
However, the quality of this service (both sound quality and reliability) is not as good as wire-line standards.

Wireless Communication

Advantages of digital technology:

- More efficient use of spectrum via compression.
- Increased reliability using error correction coding.
- Superior encryption to ensure privacy.
- Digitized information are well suited for the integration of multiple services.

Progress in Wireless Technologies

- Advances in displays, battery technology and processing power have made it affordable to carry around laptops, notebooks and smart palmtop phones.

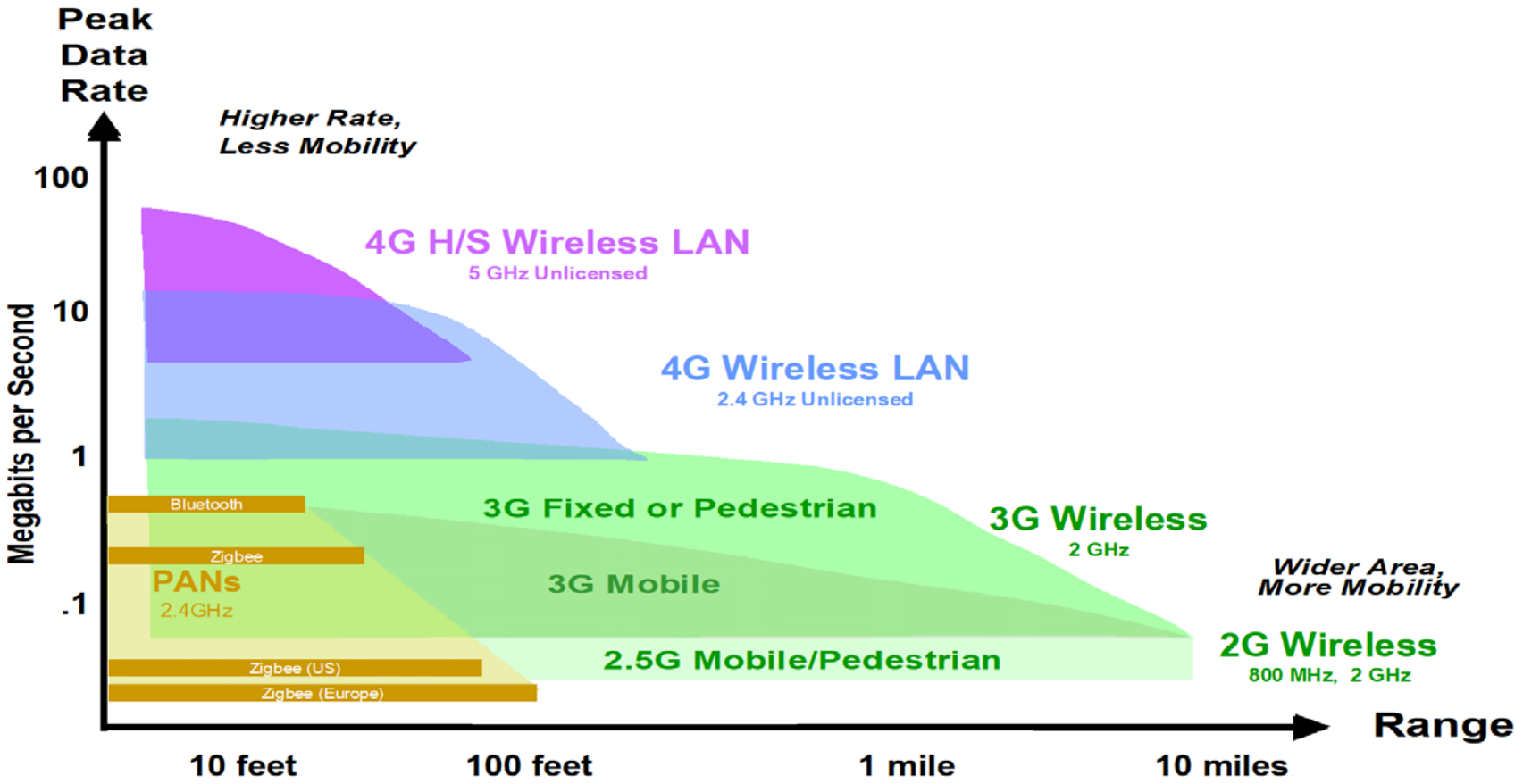
- Bit rate limitation of current cellular phone systems can be addressed by the concept of Adaptive Rate delivery of future Wireless Multimedia services.

- Services are provided by a combination of delivery technologies giving:
  - Low bit rates (~ 100 Mbits/s) with universal coverage;
  - Medium bit rates (~1 Gbits/s) over campus-like areas;
  - Very high bit rates (> 1 Gbits/s) services in localized areas (cellular systems).

Examples : GSM, New HIPERLAN radio standard, WiMax and Optical Wireless for high bandwidth islands, e.g., classroom, hotel lobby, shopping mall, train stations, etc.

Wireless Communication

Next-Generation Wireless Systems



Wireless Communication

Market Needs

Market needs to consolidate the data into one single handset

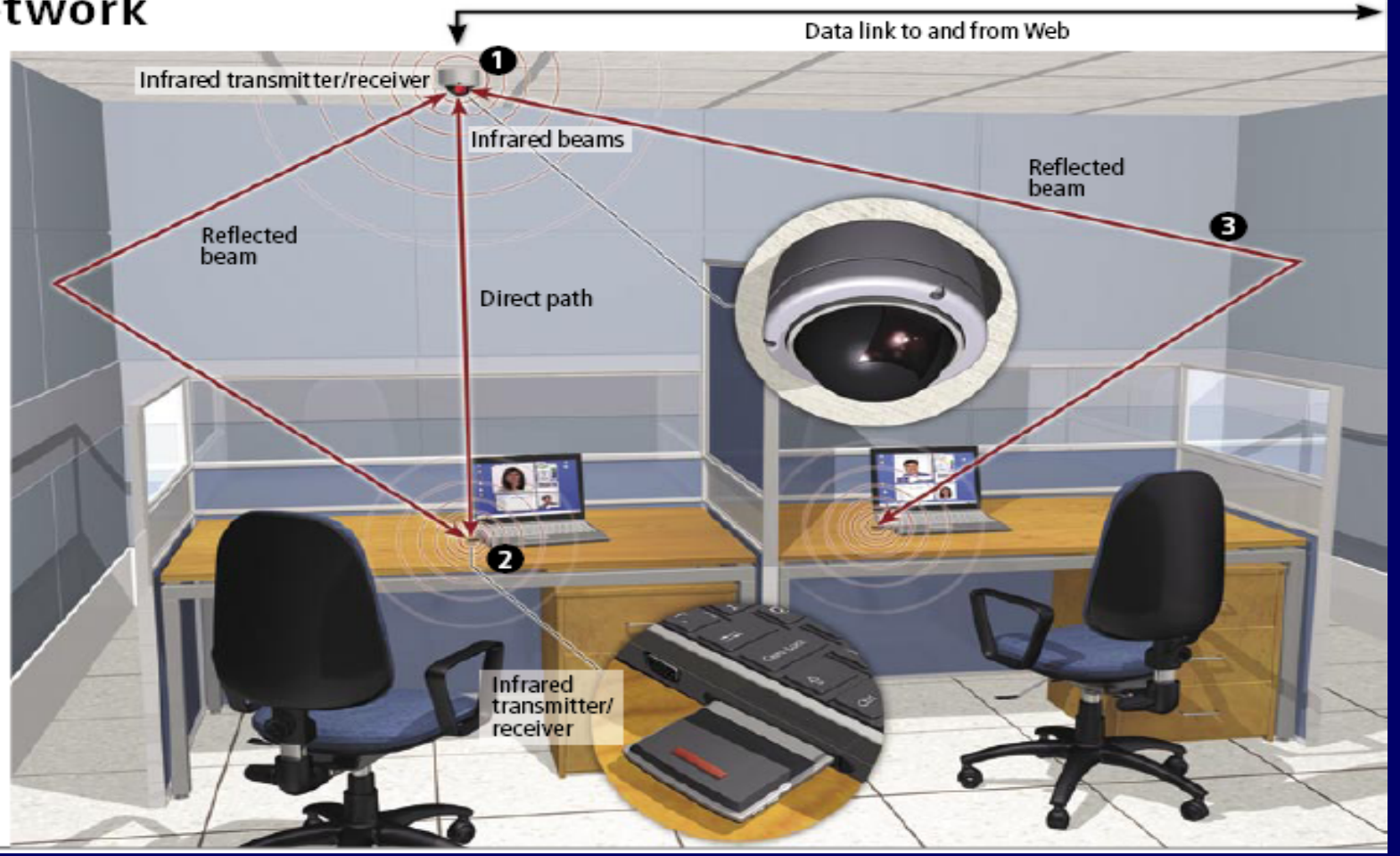
Demands for fast speed data transfer

Optical Wireless Communications

[HOW IT WORKS]

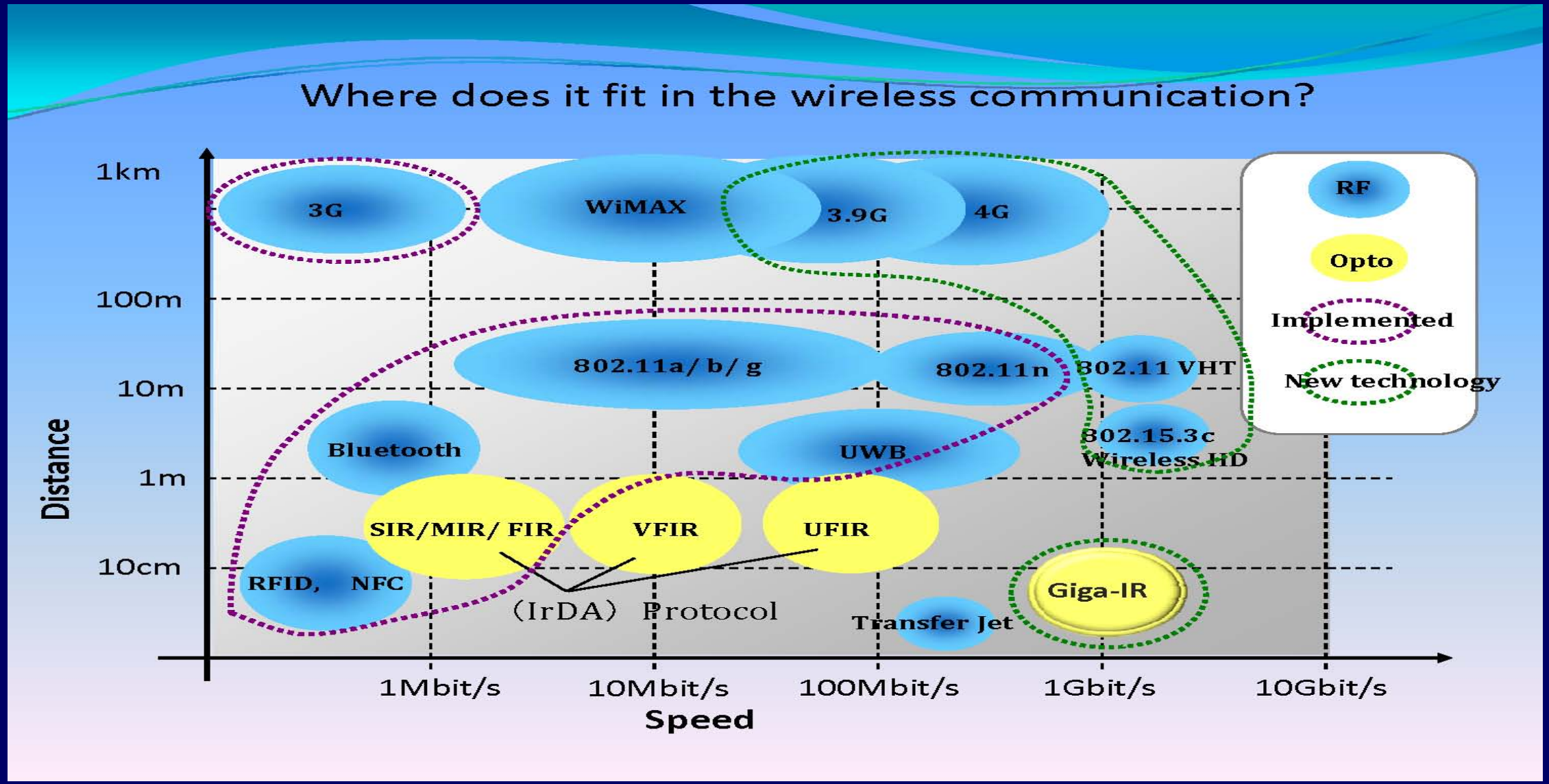
Optical Wireless Network

In contrast to radio-wave-based technology, such as Wi-Fi or the new WiMAX systems, optical wireless networks can connect multiple indoor portable devices to the Internet at broadband speeds using infrared light. Inexpensive infrared transmitters/receivers beam signals into a room ❶ to link with devices fitted with plug-in cards that can both receive and transmit the coded infrared light ❷. Because light signals do not interfere with one another—as radio signals can—and offer greater bandwidth, many more devices can share the optical network. Barriers such as partitions do not halt reception because beams reflect off room surfaces ❸. Engineers are working on similar systems that use white LED lamps, flickering in code faster than the human eye can detect.



M. Kavehrad, "Broadband Room Service by Light," Scientific American Journal, pp. 82-87, July 2007.

Optical Wireless Communications



What can one do with an LED Light Bulb that has its own IP Address?

"The IPv6-Addressable Light Bulbs Go On Sale"

Add a Node, thus more (Interference-Free) Bandwidth to Global Network via Internet

"The most compelling story of how Internet-of-Light will transform our world is the one still being written: the future of lighting, communications, sensing and the birth of a new enterprise lighting network."

Internet-of-Light in Manufacturing

Knowledge Age

"Survival of the fastest"; global economy will dictate the use of the most advanced information technology to develop and manufacture products and provide service support.

Knowledge Age

Broadband information services will transform global communications into "Have's" & "Have not's" for information age; or as it is known, the "Digital Divide".

The "Digital Divide" is the gap between those who are able to benefit from the digital age and those who are not. The absence of connectivity is not merely a technological barrier, but one that affects access to healthcare, education, social services, work, and participation in the global and local economies. A similar problem exists with local infrastructure. Internet providers may not be focused on deploying the infrastructure necessary to bring services to all rural homes and villages.

Knowledge Age

The "Have's"

- Leapfrogging technology
- Developing economy
- Productivity increasing 4 - 6% each year
- Significant advances in learning theory

The "Have not's"

- Falling behind
- Growing political and social discontent
- Decreasing productivity
- High uses of energy sources
- Overall reduction in quality of life

Knowledge Age

Broadband delivery of Internet over any available medium holds the great promise for closing a gaping “broadband gap” throughout the Globe.