Where have we come from? Where are we going?

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Presentation Outline

- Setting the stage
- Disruptive technologies
- Hardware evolution and economics
- Software evolution and economics
- Communications evolution and economics
- Computer networking
- Current Internet issues
- Artificial Intelligence

Setting the stage

- “History begins with me”
- “Those who do not understand the past are condemned to repeat it” – Santayana

- History provides a context in which to view current issues
- The era of electronic computing is almost 75 years old
- Characterized by multiple rapidly evolving complementary industries and disruptive technologies
- Understanding their evolution and nature helps to understand futures

Disruptive technologies

- All new technologies have the potential to be disruptive
  - New technologies can be used for good or bad purposes
  - Schumpeter's concept: capitalism's entrepreneurial creative destruction
  - Gunpowder, steam engine, railroads, automobiles, atomic fission, computers, robotics, gene manipulation
- Disruption useful but stresses the social fabric
- Role of entrepreneurs important in technical progress
  - Ability to discern both existing and (especially) latent needs
  - Essential in creating the Internet's commercial ecosystem

Hardware evolution and economics

- Generations of computer technology
  - Defined by underlying electronics generation
  - Markets competitive, linked to big players, some new to data processing
  - Difficult to use, limited software base, operating systems only emerging
  - Rapid technical progress caused short economic lifetime
  - Initial strategy to differentiate products by applications market segment
    - Some product differentiation to retain customers: a long term failure
    - Experimentation with architectures before partially coming together
  - Current: Two major mass marketing models, other specialized sectors
    - Elasticity of demand has exploded market, enabled further progress
  - New major customer, AI, likely to drive innovation in computing

Software evolution and economics

- Software a new concept; automated processes or algorithms
- Evolution of software methodologies
  - Machine language, assembly language, high-level languages, operating systems, general and special purpose
- Starting at nothing, lots of experimentation, many languages
  - Special position of Fortran and Cobol
  - Programs as economic assets, can have long lived value
- New languages being introduced due to exploding scope of application

Communications revolution and economics

- Before 1840, information could not travel faster than a railroad train
- Use of analog communication evolved into digital transmission
  - Digital came first: Telegraphy, Morse code, Baudot codes, telex/teletype
  - Analog: Telephony, modems, digital, copper wire, wireless voice, satellite
  - Reliable digital electronics needed to ensure digital transmission
- Wired land line transmission favored natural monopolies
  - New media of communication led to a more competitive industry
    - Microwave, satellite, fixed mobile, and full mobile
  - Breaking the historic tie between now exploiting infrastructure and services allows PTT-independent services to use it with no capital communication investment (1968 in US)
- Optical fiber is gradually making existing wire plant obsolete
- Changes in all three technologies are happening at high speed!

Computer networking

- Need for real time machine communication always present
  - Early time-sharing systems
  - Store and forward networks: FidoNet, UUCP, Bitnet/Earn
  - SneakerNet : One of the motivations for the early AFPANet
  - Dedicated static point to point links for special purposes: ARPANet, military
- Wide area network (WAN) developments not useful for local networking
- In 1980s, diverse approaches to LANs
  - ATT Starlan, Datapoint ARCNet, IBM Token ring, AppleTalk, Novell Netware
- WAN protocol wars: ISO/OSI, TCP/IP, SNA, ATM
  - Rough consensus and running code eventually won for TCP/IP
  - Growth of microcomputers, TC/IP stacks migrated and became global standard
- Emergence of distributed computing models: Client-server, remote computing, precursors of ”the cloud”

Communications industry

- Telephony started with local telephone companies
  - In US, consolidated into larger companies, primarily ATT
  - In many countries, PTT was par t of or attached to governments
  - Locality imposed by capital investment in physical connections
- International interconnections: ITU treaty organization
  - Billing for national circuit switched usage possible by various means
  - International balance of connections by settlements regime
- Packet switched services have major measurement problems
  - Internet model of communication a revolution in communications management

Comparing PSTN and Internet (1 of 2)

	Internet Characteristics	*Public Switched Telephone Network (PSTN) Characteristics*
Roots	Support for research and academic computing and exploration of network technologies	Consumer service in a technological age where communication systems were a natural monopoly
Pricing	Initial culture of free good to end user; more generally pricing by maximum bandwidth available to customer. Distance independent.	By unit of service, with price very dependent upon distance and length of call.
Attitudes toward use	Information is free, explore and search what exists and find what you need.	Pay for your communication needs according to an existing tariff.
Organization	Bottom up. Decentralized both with respect to control and choice of services offered.	Top down. Centrally administered and controlled. Available services decided and offered centrally.
Standards	Initially *de facto*, but standardized through IETF, a meritocracy with no legal status. Criteria for adoption are rough consensus and running code.	Formal, through national and international standards bodies such as ITU and IOS. Criteria for adoption are unanimous agreement by member governments.

Comparing PSTN and Internet (2 of 2)

	Internet Characteristics	*Public Switched Telephone Network (PSTN) Characteristics*
Scope of communication	Multiple possibilities, with 1-to-1, 1-to many, many-to-many modes of communication all possible in a variety of ways	Generally 1-to-1 communication, although few-to-few and few-to-many broadcasts possible with additional equipment.
Style	Experimental, flexible, very innovative	Businesslike and structured, formal agreements among participants
Rate of change	Rapid obsolescence, little respect for prior investment, major changes are in software and protocols, malleable media.	Long time horizons, major investments are in hardware, a very physical and durable medium.
Ownership	No one owns the Internet. Pieces of the infrastructure that makes it possible are owned by multiple players of various types.	Initially almost completely governmentally owned; recently evolving to more private sector ownership.
Administration	Highly decentralized	Government and private sector, with governments still having control through ownership and/or regulation in many developing countries.
Control	At the edge of the network	At the center of the network
Innovation	At the edge of the network	At the center of the network

Effects of shift to packet switching

- Management model of telecommunications of Internet is opposite of classical PTTs
- Initial charging algorithm used bandwidth at local loop
- Peering model initially set for charging between ISPs
  - Peering cost calculations depend on traffic flow that change over time
  - ISPs differentiated selves by tiers
- Growth of content providers leads to private networks
  - Peering model breaks when traffic only flows in one direction
- This is a transportation economics question

Transportation economics

- Manufacture goods here, deliver to customers elsewhere
  - Use warehouse(s) to store inventory?
  - Decentralize operations substantially or maintain central control?
  - Pay existing transport companies or create your own?
- Answers depend on sever al factors that are dynamic
  - Cost of warehousing and shipping goods to warehouse
  - Use existing shipping services to warehouse or create your own
  - Cost of local distribution, and how to distribute
- Simplified model but applies to Internet content shipments
  - May be incompatible with Internet assumption regarding packet deliveries and evolving peering issues

Current Internet issues

- “The Internet was an experiment that escaped from the lab,” Vint Cerf
  - Private sector governance, private sector voluntary standards
  - Demonstrated interoperability (INTEROP) drove market interest and acceptance
  - But insufficient attention in design to security
- Fragmentation: Physical and political
- Degradation of content: disinformation and misinformation
  - Loss of trust in Internet as a reliable source: ”Internet slop”
- Intermediary liability: ISPs at legal risk
- Inadequate support for “free software”
- Cybercrime: enabled by software bugs, inadequate security measures
  - Almost all of human behavior has migrated to the Internet

Governments and the Internet

- Early Internet development supported by governments
  - But ”under the radar” of being a universal communication network
- Since UN World Sumit on the Information Society (1998 and 2003), Internet governance has been a major topic
  - Definition: Does this mean governance of the Internet or on the Internet?
- Three major areas of intersection and concern
  - Internationally: Multilateral or multistakeholder governance
  - National: Industrial policy with regard to the IT industry
  - Both: Content control
- Difficulty in decision making in a multicultural world

Artificial Intelligence

- **"Any sufficiently advanced technology is indistinguishable from magic." — Arthur C. Clarke**
  - A payroll program on a digital computer would have been magic in 1900
- Currently AI means large language models (LLMs)
  - Nutrition: Like humans, AI models become what they “eat”
- AI appears to have a lot of promise, but also has problems
  - AI responses are statistical constructs, can easily generate hallucinations
  - AI has capacity to destroy the advertising model underlying the Web
  - AI’s energy needs impossible to meet without significant climate damage?
  - AI can become hostile to people and recommend aggressive action
  - AI can design toxic organic compounds
  - AI may be ungovernable and maybe even undetectable
- Agentic AI offers great promise, also significant threats
  - Alan Kay’s DynaBook (1970) predicted an agentic wireless networked laptop

Existential threats

- Existential threats more powerful using advanced technology
  - Before 1940, impossible to cause world to become uninhabitable
- Nuclear weapons and rapid delivery mechanisms change that
  - Rational choice stops their use, but accidents happen
  - Several near-catastrophies have been documented
- Spectacular increases in biology permit creation/modification of life
- **“The real problem of humanity … we have Paleolithic emotions; medieval institutions; and godlike technology.” —EO Wilson**
- AI, and especially Agentic AI, may offer the capability to determine whether we continue to exist as a species

Conclusion

- Computing and networking tech continue to evolve rapidly
- Communication is advanced (but what about quantum networking?)
- Internet is in its adolescence
  - Services well established but significant exploration and service innovation
- Large language models: AI is in its infancy
  - Exploring by major innovation in multiple directions: what works?
  - Connection with robotics gives “legs” to its ability to act
  - Agentic AI both promises spectacular possibilities and serious threats
- What could go wrong?
  - We will find out, hopefully not too late .....

Thank you