THE INTERNET'S COMING OF AGE

President's Information Technology Advisory Council

May 11, 20001

Computer Science and Telecommunications Board

National Research Council

The National Academies

The Internet in its Adolescence

- research network → vital infrastructure
- "Internet illusion" hides complexity of underlying network
  - everyone talks about the Internet, but few really understand how it does and doesn't work
- how to sustain, grow Internet
- early in a "revolution" a hard time to gauge outcomes, make decisions, set public policy
  - distinguishing transient from persistent phenomena
  - chaotic, fertile time: many experiments, losers as well as winners

Study Committee

ERIC SCHMIDT, Novell/Google, *Chair*
TERRENCE McGARTY, Telmarc Group, *Vice-chair*
ANTHONY S. ACAMPORA, UCSD
WALTER S. BAER, RAND Corporation
FRED BAKER, Cisco Systems
ANDREW BLAU, Flanerie Works
DEBORAH ESTRIN, UCLA
CHRISTIAN HUITEMA, Microsoft
EDWARD JUNG, Intellectual Ventures
DAVID A. KETTLER, H.I.G. Ventures
JOHN C. KLENSIN, AT&T
MILO MEDIN, Excite@Home
CRAIG PARTRIDGE, BBN Technologies
DANIEL SCHUTZER, Citigroup
DAVID D. CLARK, MIT, *Special Advisor*

Staff

JON EISENBERG, *Study Director*
MARJORY S. BLUMENTHAL, *CSTB Director*
SUZANNE OSSA, *Senior Project Asst*
DAVID PADGHAM, *Project Asst*

Topics

1. The Internet's basic design/architecture
2. Scalability, reliability, and robustness
3. Keeping the Internet the Internet (interconnection, transparency, openness)
4. Key Conclusions Relating to Research, Government Policy Responses

1. Success by Design

Key Design Ideas

Hourglass architecture. The Internet is layered, operates over different underlying communications technologies, and supports multiple, evolving applications and services.

End-to-end. Network provides basic data transport service with intelligence located at or close to edge of network (caching and other support elements change this somewhat).

Robustness principle. Sender takes the narrowest interpretation and receiver is prepared for the broadest possible interpretation.

Distributed design & decentralized control. No single entity controls the Internet in its entirety. Only 2 key functions are centralized: address allocation and DNS (ICANN + regional registrars)

+ Basic design values. Community favors openness/connectivity, simplicity, ...

Design→Marketplace

- Multiple and evolving pricing models.
- Low barriers to entry for innovation
- Tippy markets

2. Sustaining Growth

(scaling, addresses, robustness, QoS)

Scaling Issues

- Coping with growth in the
  - # of users, # of attached devices
  - volume of communications/device and in total
- Novel applications and uses
- Scalability of protocols
- Scalability of the systems put in place to implement a particular service

Coping with Scaling

- key lesson: scaling must be considered in every decision
  - pressures driving deployments of innovations that may not scale well or at all
- shorter-term: sustained effort required
  - basic design has proven durable
  - ongoing attention to designing/fixing application protocols (e.g., HTTP, DNS)
- longer-term: new approaches required
  - e.g., distribute topological information for routing

Address Space

- problem: “only” 4.3 bil addresses in today’s IPv4
  - current allocations are very low density
  - today, impacts unevenly distributed
- growing use→long-term risk
  - potential for explosive growth in # of devices (e.g., 3G wireless)
  - difficult to project when “long term” will come
- two paths: IPv6 solution vs. NAT response
  - IPv6 deployment is complex
  - NAT is undesirable for some apps and may further deteriorate long-term
- transition going slowly but important in long-term

- Recommendation: Investment in deployment and promotion of benefits of IPv6 should be continued.

Robustness and Reliability

- Internet has become a critical resource
- not a new observation...but growing use, dependence demand continued attention
- good news: some challenges understood
- but...
  - typical/average practice lags best practice
  - not enough known about primary causes of Internet failures

- Recommendation: ISPs should develop an approach for reporting outages and make the info available for studying the root causes of failure & identifying actions and technologies that would improve the Internet's robustness
  - voluntary program as alternative to future mandates
  - not all info need be reported publicly (operators and research community best placed to use detailed information)

Quality of Service

- Origins in multimedia support → broader range of applications
- uncertainty about
  - limitations of best-effort service
  - effectiveness of various QoS measures
  - investment priorities between QoS and greater capacity
  - end-to-end vs. localized use of QoS
- better understanding, more operational experience required

3. Keeping the Internet Interconnected and Open

Interconnection

- physical, logical, financial dimensions
- two models predominate: peering, transit
- risks:
  - peering dominance by tier-1 player
  - insufficient competition in transit market
  - neither of these are evident today
- future of interconnection
  - New business models: InterNAP, Akamai, ...
  - ISPs increasingly diverse, differentiated→new models?

Openness

- power of open standards: entire industries built on Internet's open standards
  - common standard, multiple implementations
- growing stakes in standards process
  - network effects: small advantage can snowball → concentrated markets
  - tippy market opens doors to upstarts→ attempts to differentiate, extend, or close
- today, standards are being developed in an active, diverse, and dynamic market space
  - evolution of traditional forums
  - consortium alternatives

Transparency

- principle: networks do not tamper with or restrict data in across the network
- tradeoffs between transparency and security, control of network resources, etc.
- potential for escalating filtering battles
- openness best preserved when users are aware of tradeoffs and strike their own balance

Recommendation

- ISPs should make public their policies for filtering/prioritizing customer IP traffic

4. Conclusions

- Technology Base
- Government Policy Responses

Underlying Conclusion

The Internet is fundamentally healthy…

Most of the problems and issues discussed here can be addressed and solved by evolutionary changes within the Internet's current architectural framework and associated processes.

Technology Base

- continue industry and gov't support for R&D on scaling, reliability, and robustness

  not a new point, but underscored here because

  - *use and dependence are both growing*
  - *the job is far from done*
  - *new problems/surprises are sure to emerge*
- find opportunities for research in realistic, operational settings
- conduct R&D and experiment with business models & technology for interconnection
- continue support for developing open standards

Government Policy Responses

- present policy of nonregulation should be accompanied by close monitoring (watchful waiting)
  - Areas to watch include:
    - interconnection
    - activities and operations of Internet organizations
    - IP/Internet telephony
- monitoring should be accompanied by broad-based research effort & efforts to understand what would be potential triggers for possible future intervention

Significant points of interaction between the Internet and broader society

As Internet penetration grows, every issue is an Internet issue…

The committee examined:

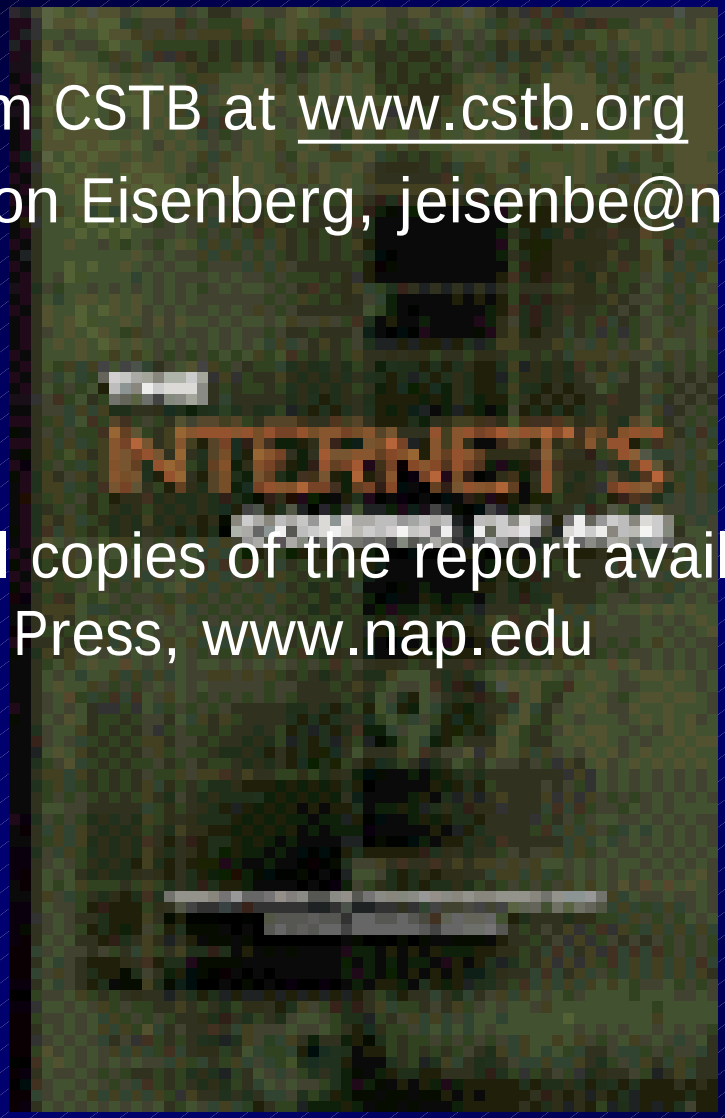
- collisions with existing industries (telephony)
- privacy, identity, anonymity, authentication
- taxation of Internet commerce
- universal service

Guiding Principles for Regulation

1. Focus laws and regulations on the activities and behaviors of concern rather than on the network architecture or its constituent networks. Use existing laws and regulations first, provided they are consistent with the capabilities and design of the relevant technologies.
2. Where Internet-specific intervention is required, laws and regulations should establish the framework and overall parameters while industry and other non-governmental stakeholders should devise appropriate implementations.
3. Keep a broad geographical perspective when thinking about Internet issues.

For more information

- more from CSTB at www.cstb.org
- contact Jon Eisenberg, jeisenbe@nas.edu, 202-334-2605



- additional copies of the report available from National Academy Press, www.nap.edu