The Long Arc Behind Internet Economics: Five Rules of Thumb

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For GENI meeting, March 3, 2008

Prologue

- Thanks for giving me the opportunity to speak with you.
- Happy to hear feedback. All comments welcome

Motivating question

- If a set of very talented researchers had the opportunity – and funding – to redesign the Internet (or the infrastructure under an advanced data network), using recent past as a guide, what should they do and why?
- Scholarly interest:
- emergence of new commercial communications network governed by a new (?) set of principles.
- What long run economic factors shaped value creation during development of commercial Internet?
- Raise questions. Bring a different perspective.

Explaining talk's title

- Organize the talk around "rules of thumb", not economic "principles". Why?
  - I will summarize a lot of economic thinking.
  - Not a precise science. One big example (and several small ones) from which to infer generalities.
  - *Eternal truths > Rules of thumb > Yogi Berra*
- Also cognizant of Spenser Silver's warning:
  - *"If I had thought about it, I wouldn't have done the experiment. The literature was full of examples that said you can't do this."*
  - If you believe you can change the world with your research, just go for it and please ignore me.

Five rules of thumb

- Limits to the breadth of Moore's law motivates much invention.
- New functionality diffuses quickly when it gets the platform economics right.
- Capital deepening differs from investment to encourage participation.
- Working prototypes catalyze commercial response.
- Market-oriented experimentation shapes and reshapes priorities.

Outline

- **Limits to the breadth of Moore's law motivate much invention.**
- Platform economics
- Capital deepening/participation
- Working prototypes
- Market oriented experimentation

Moore's law as a basic and familiar place to start
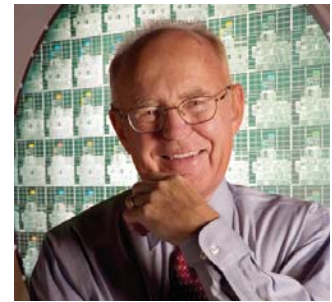
- What is Moore's Law? Observation about technical improvement in past *and* a forecast for coordinating actions in near future.
- Enables new valuable opportunities.
  - For same cost… performance increase at exponential rate → cost of achieving prior performance declines at exponential rate
  - Range of capabilities by affordable device continues → "new range" = "new mass market capability."
  - Moore meant it *only* for ICs. What does it have to do w/networks?

Historical experience suggests a broad construction of metaphor

- Range of hardware experiences similar trend
  - Memory devices, display screens, data switches, data transmission lines, sensors, etc. and so on.
  - Can reasonably expect it to continue.
- But *does not* hold for *all* complementary inputs into frontier networking.
  - New opportunities, but not uniformly for all inputs.
  - Human ability to learn new software languages.
  - Software coding for new applications taking advantage of new hardware capabilities.
 - Last mile delivery/sensor devices.

Response: Clever inventive activity.

- Economize on expensive input (e.g., humans).
  - By "automating" as much as (cheaply) possible.
- Specialize expensive device to high value use.
  - E.g., Distinct access technologies for distinct uses, including multiple wire-line & wireless modes.
- Redeploy existing capital to new purposes.
  - E.g., Instead of building delivery mechanism from scratch, invent the phone modem – a cheap way to repurpose existing telephone system for new use – and design TCP/IP to run over it.
  - In general, "compromise" on an ideal, but make progress in some way.

More responses (continued)

- Share inventions among costly inputs.
  - Reduce costs of imitation or multi-site deployment of inventive software (e.g., shareware).
  - Develop means to aid disclosure of new discovery while still crediting inventors (e.g., the RFC).
  - Mandate compatibility across components (e.g., DOD TCP/IP compatibility requirements), reducing need to reinvent building blocks.
- Expect similar inventiveness w/GENI...
  - Leave open question of how that will be done institutionally...
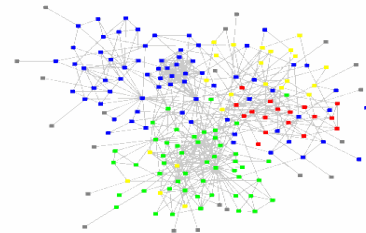
Open questions as Moore's Law continues

- GENI research rethinks the compromises of prior eras and address scarcity of new era?
- One idea: Introduce pricing for scarce goods.
  - Accessing network expensive (e.g., for video or for multi-sensor networks)... make users reveal urgency of their send/receive. Let packets "bid" for priority.
  - If transient scarcity in transit capacity... rethink protocols for real-time identification and resolution of scarcity through prices localized to place/time.
- In networks operator's attention is scarce...
  - Rethink protocols that bring info to operator's attention...

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Diffusion of new invention and platform economics
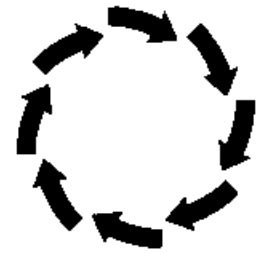
- Success at GENI will encounter platforms…
- Platform = standard bundle of components that users employ together for services.
  - Is the Internet a platform? (Yes. No. Probably.)
  - VERY short answer: Internet has standard bundle… but…also an unprecedented governance structure.
- Platform economics focuses on emergence (or not) of fragmentation & governance:
  - Fragmentation: large or small set of bundles which users have in common, around which build services.
  - Governance (aka platform leadership): Predictable rules/processes for changing standard bundle.

Fragmentation tends not to occur in use of network infrastructure

- Because scale has advantages.
  - Scale allows users/developers to *share* in scarce resources, inventive tools, fixed costs.
  - Scale aggregates capabilities. Easier to *add-on* new capability to existing platform (to expand scope & suit new niche demand) than start from scratch.
  - More participation enables more potential communication, which is more valuable for users.
- Commercial computing platforms tend to be identified with firm taking leadership.
  - IBM 360/370, DEC VAX, Wintel, dial-up AOL.

Platforms can fragment b/c…

- Why not one dominant platform? Somebody always unhappy w/dominant platform.
    - Once dominant platform starts can be hard to stop, but range of scope leaves some niches unfulfilled.
    - Some users want to employ the technology for different purposes and they are willing to pay for it (e.g., very high end computing boxes)
    - User/developers have strong opinions about design choices & options (e.g., Unix design wars).
- Commercial sponsors have strong strategic incentives to differentiate from others.
    - E.g., Commercial Unix in the 1980s.

The Internet/WWW experienced curse of success
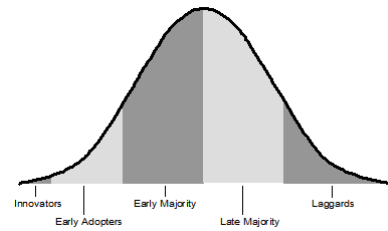
- First-gen Internet designed to make progress for users in face of long odds (Historical note: wow, it did), & scaled by accumulating uses...
  - Designed for ftp, e-mail, etc., not to prevent spam...
  - Not for the instantaneous (?!) apps my kids use it for.
  - Presumed known participants, similar research goals, absence of malevolence, lack of commerce, etc....
- WWW made possible hyper-linked commerce.
  - Designed so researchers could send graphics, etc.
  - Not payments, massive search, identity/privacy, etc.
- Gives GENI research plenty to improve.

If new platform in GENI does not respect backward compatibility...

– Opportunity to rethink the assumptions made in the effort to deploy into an installed base.
  – If every developer/user starts from scratch.
– Expect the opportunity directed at high-risk "compelling" new stuff or future "killer app".
  – Historically… new platforms succeed more often when they attract new users /w new uses… so…
  – Respecting b.c. interferes w/deploying frontier designs at peak performance. Chance to rethink.
  – Sacrifice widespread participation on same platform in short run, raise costs to new adoption of "new" device or serving new niche user.

The other part of platforms: governance.

I E T F

- Commercial platforms tend to have core/periphery structure (e.g., MS & Windows).
  - What does core do? Typically (1) sets rules for determining standards, (2) operates processes to alter standards, (3) establishes targets/roadmaps to coordinate developers.
  - Sometimes (4) provides tools to build apps.
  - Leadership: controls pervasive standards on which others build.
- GENI not assuming particular governance form.
  - Focus on building tools, developing new standards…
  - If something starts to succeed, this topic will arise.

GENI platform organizational model? Unlikely to be traditional.

- Traditional research: "Teams" of lone wolves.
  - ◦ Confederation of academics on same budget.
- Commercial model: "Teams" in a hierarchy.
  - ◦ Core defines layer, invents on one side, enables peripheral developments at another layer.
  - ◦ Each periphery "team" aimed at niche use.
  - ◦ Core retains control, withholds information from "unfriendly" others, provides tools to periphery.
- Likely: Mixed developer & user model.
  - ◦ Give individual credit, but accumulate advance.
  - ◦ Restricted access to code (Apache, Mozilla) or loosely mediated interaction (Wikipedia).

If GENI follows the norms for self-organizing platforms...

- Lacks commercial core, but has a hierarchy.
  - Distribution of effort tends to self-define hierarchy. 1% who do most work, as in 1/9/90 distribution of contribution. (see. E.g., Apache, Mozilla, Wikipedia).
  - Cooperation at 1% level, but rivalry within, and mediated etiquette at, other contributor levels.
- Initially core makes (1) rules for determining standards, (2) processes to alter.
  - Initially loose about (3) roadmaps/targets, and (4) about making tools for others. The latter emerge over time if there is success.

Open questions for GENI about platforms

- Rethink infrastructure platform code to support commerce w/o strict end-to-end.
  - Micropayment infrastructure w/ & w/o full identity. Opt-in/out choices about privacy/identity. Who owns what about the user? Who decides? When?
  - Opt-in/out for location/nexus of sales for taxation purposes/economic measurement. Who decides?
- Experiment: ways to get emergent networks from new sets of tools/processes.
  - If the core allows to opt-in/out deeper layers?
  - Which infrastructures enable designs for large scale user-suggested improvements?

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Capital deepening distinct from investment to grow participation

- If anything succeeds, soon will face this…
- Capital deepening: Increase performance of existing processes already in use.
  - Usually with the intent/goal of enabling scale.
  - E.g., Investment that increases bandwidth of high-capacity backbone or large scale routing.
- Investment to grow participation.
  - Develop new processes or products, usually with goal/intent of motivating new users to join, or migrate activity from one niche use to the network.
  - E.g., The windows-based browser (Mosaic) made hyperlink computing accessible to general user.

Why are these distinct?

- Deepening/participation often involve different actors and distinct specializations.
  - Expertise needed for invention/investment differ.
- Need each other to be prosperous.
  - Incentives to invest in one (e.g., backbone services) depends on how parties are compensated in other (e.g., access services).
  - Some scale will emerge if there will be success.
- Inherent tensions for network at boundaries.
  - What is neglected due to lack of coordination?
  - Unbalanced growth b/w parts?
  - Boundary & discretion. Who is responsible for what?

More inherent tensions: Scale and variety trade-offs

- Deepening for scale helps & hurts variety
  - Capital deepening → refine processes → become basis for accumulating "add-ons" → scale can become basis for a variety of new developments to address groups of specific niches.
  - Interconnected refined process impose constraints on systemic invention → suppress variety.
- Parties w/distinct views over best use of expensive asset → conflict over refinement.
  - Example: Contemporary "neutrality" fights b/w broadband carriers & content providers over control to routing/delivery.

Questions for GENI about deepening/participation.

- Question: Prior Internet grew participation through deployment of TCP/IP to wide variety of installations.
  - Many proposals for rethinking price or non-price mechanisms for routing or access have implications for governance at boundary b/w different actors.
  - Cloud computing, similar boundary issues.
  - Researchers makes choices about enabled variety.
- Even more out there: Third world user base.
  - Thin networks to grow participation in resource-poor regions distinct from capital deepening? How do these complement?

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Working prototypes

- Any success will generate a working prototype…
- Working prototype: a tangible demonstration of a frontier process or design.
  - Show theoretical concept in workable solution.
  - E.g., "running code" beats "prospective solution."
- Why important to complex technologies?
  - Identify solutions to bottleneck issues.
  - Reduce uncertainty about viability of proposal.
  - Sharpen estimates about design trade-offs.
  - Satisfy impatient user/vendor who wants *workable* now instead of promise about *better* tomorrow.
  - Aids forecasting.

A broad understanding of design/value of a prototype

- More than merely technical prototypes.
  - Also value in illustrating a workable new process or institution for enabling new activity (e.g., CIX).
  - Building bandwagons of use/improvement around technology or standards (e.g., SMTP, WWW).
- Prototypes can be especially catalytic for non-research participants.
  - Regulatory actors hesitate in absence of illustration (e.g., FCC has little incentive to take risks).
  - VCs hesitate (e.g., due to short time horizons).
  - Skeptical commercial managers may not "perceive the user value" (e.g., Gates and the browser).

How prototyping research shapes goals at GENI
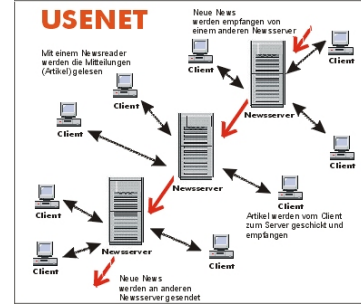
- If some value cannot be learned until it involves regulatory actors, VCs, and skeptical commercial managers, why is GENI valuable?
  - Other actors have distinct milestones for measuring progress, distinct visions of value of opportunity, distinct capabilities for aspects of frontier.
  - They will interpret prototypes in a variety of ways…
- Inherently unpredictable response: Widely dispersed technical leadership (e.g., many orgs employ technical skilled personnel).
  - No single vision captures technical conversation.
  - (e.g., BBSs first commercial firms to deploy WWW).

Open Questions for GENI about working prototypes

- If rethinking traffic management thru time/place auctions or prioritizing & aggregating massive inform in real time...raise questions.
  - How to prototype results to show a non-technical observer? To demonstrate value?
  - How to prototype to test its macro-system properties, e.g., consequences of partially applied micro-pricing rules. (e.g., does saving cost in one place raises in another? And so on.).
- How to prototype the value from increased participation, when GENI limits participation?
  - Building communities around student participation.
  - Experiments with emergent social networks... among user/developers...

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Post-GENI: Mkt-oriented deployment & experimentation

- Actions to learn about value that cannot otherwise be learned in lab or w/user survey.
  - Full mkt value uncertain until this type of action.
- Different learning (illustration from 1997-98)
  - Technical features of new equipment (e.g., features of a 56K modem bank).
  - Operations for new equipment (e.g., to learn about regular peak load time/use patterns).
  - Market position (e.g., how much to charge and bundle with other services?)
  - Business organization logic (e.g., charge for complementary services or let others provide it?).

GENI is valuable for market-oriented experimentation

- Why frontier research computer science valuable. It finds its way into myriad uses.
  - Accelerates development in private R&D.
  - Fosters substitutes (e.g., 802.11 v 2G/3G).
  - Fosters complements that work together or build on one another (e.g., Mosaic browser/Apache server).
  - Fosters systems where whole greater than sum of parts (e.g., broad based electronic commerce).
- Letting a thousand flowers bloom inevitably leads to a mess.
  - After solution becomes known, exploratory investment looks like waste of resources.

Open questions for GENI about experimentation

- Can pioneering work be positioned in advance of *inevitable* experimentation by commercial actors?
- First gen Internet was not sure the research would leave their small community.
  ◦ Stuff makes its way into commercial use w/big benefits (e.g., imagine the benefit if TCP/IP had made it into private use a decade earlier).
- GENI not market oriented, by design, but that does not mean not valuable for mkt actors.
  ◦ It can have a huge value by helping commercial actors rethink their own designs.

Time to cool down

Summary: Five rules of thumb

- What economic principles shape creation of value during commercialization of internet?
  - Limits to the breadth of Moore's law motivate much invention.
  - New functionality diffuses quickly when it gets the platform economics right.
  - Capital deepening differs from investment to encourage participation.
  - Working prototypes catalyze commercial response.
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Thank you

- Thank you for your attention.