CSC 595 - Research Skills

A Case Study in Great Ideas
Or: From Avoiding Nuclear War to Distributed Networks and Packets

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*For the overall structure and some content, heavy credit goes to Nick Feamster and Alex Gray: https://noise-lab.net/research-course/

Paul Baran

- Born: 1926
- Undergraduate at Drexel Institute of Technology (now Drexel University), in Philadelphia
- Masters at UCLA
- Worked at RAND
- Claim to fame: inventor of packet-switched networks

- Baran interview
- An Evening with Paul Baran (video)
- On Distributed Communications Networks

The Problem

- Survivable network - a network that can still function even after a nuclear attack
- Danger of not having survivable networks?
  - US and USSR distrusted each other and wanted to defend against surprise nuclear attacks
  - Default policy: if attack detected, immediately launch counter-attack (before attack hits)
    - Why? Once attack hits, communications are compromised. Too late to launch counter-attack or send “surrender” message
  - Danger: attack detection can be erroneous (prone to machine error, human error)

The Problem

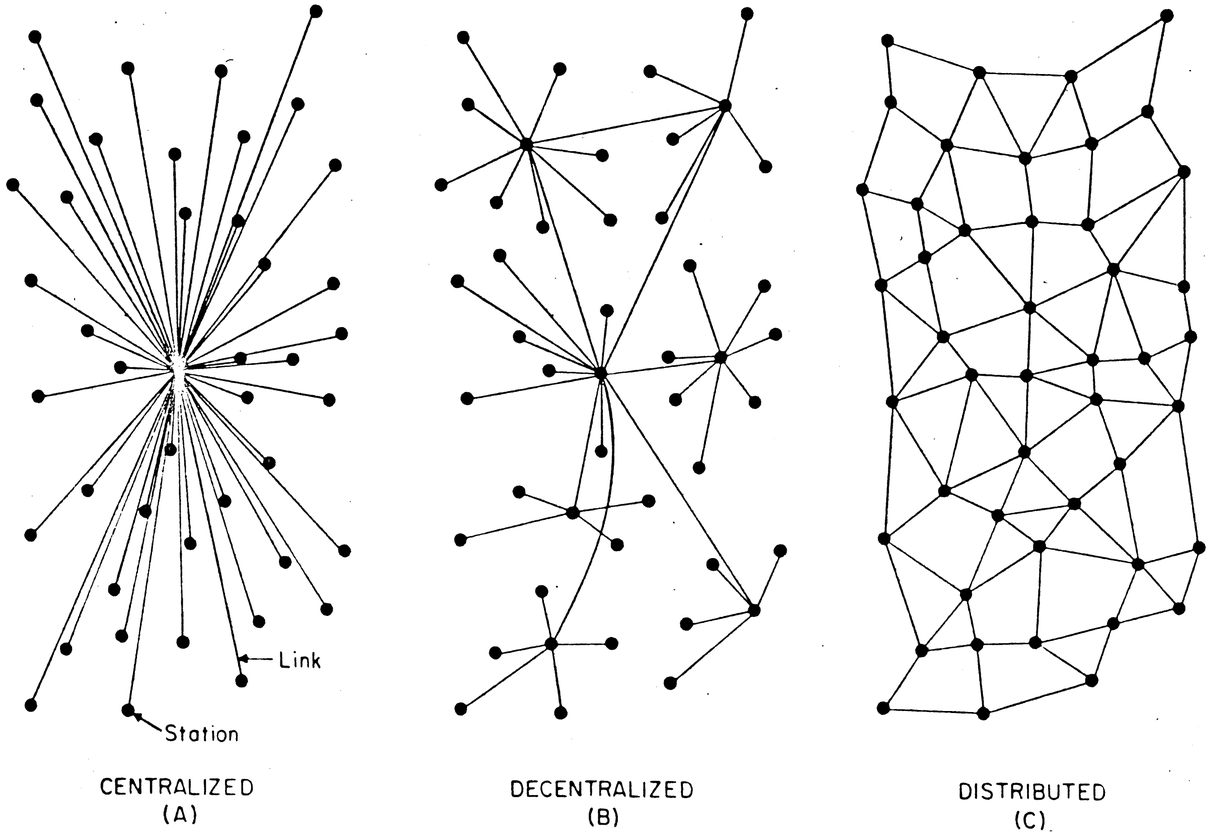
- Benefit of having survivable network:
  - With survivable network, can launch counter-attack (if needed) or surrender *after* attack hits
  - Sidesteps issue with erroneous attack detection
  - Increased deterrent: one who launches first strike will know opponent will detect it (since waits for strike to hit) and return the “favor”

The Problem

- Survivable networks - already a well-known problem (not a novel one)
- Baran was convinced it was solvable either prior to coming to RAND or shortly after arriving
- Why did Baran work on problem?
  - Was ***not*** tasked by RAND to work on it
  - Wasn't interested in papers or satisfying intellectual curiosity
  - Key personal interest: avoiding nuclear war
- It helps that RAND often had government projects and also wished to avoid nuclear war

Centralized vs Distributed Networks

- Centralized networks are not survivable
  - Destroying small number of nodes easily compromises communication
- Solution: distributed networks



A small amount of redundancy goes a long way

- Baseline: number of links needed for connectivity
- Network with redundancy level about 3 times the minimum links enjoys high survivability
  - Make this the goal; how to make it work?

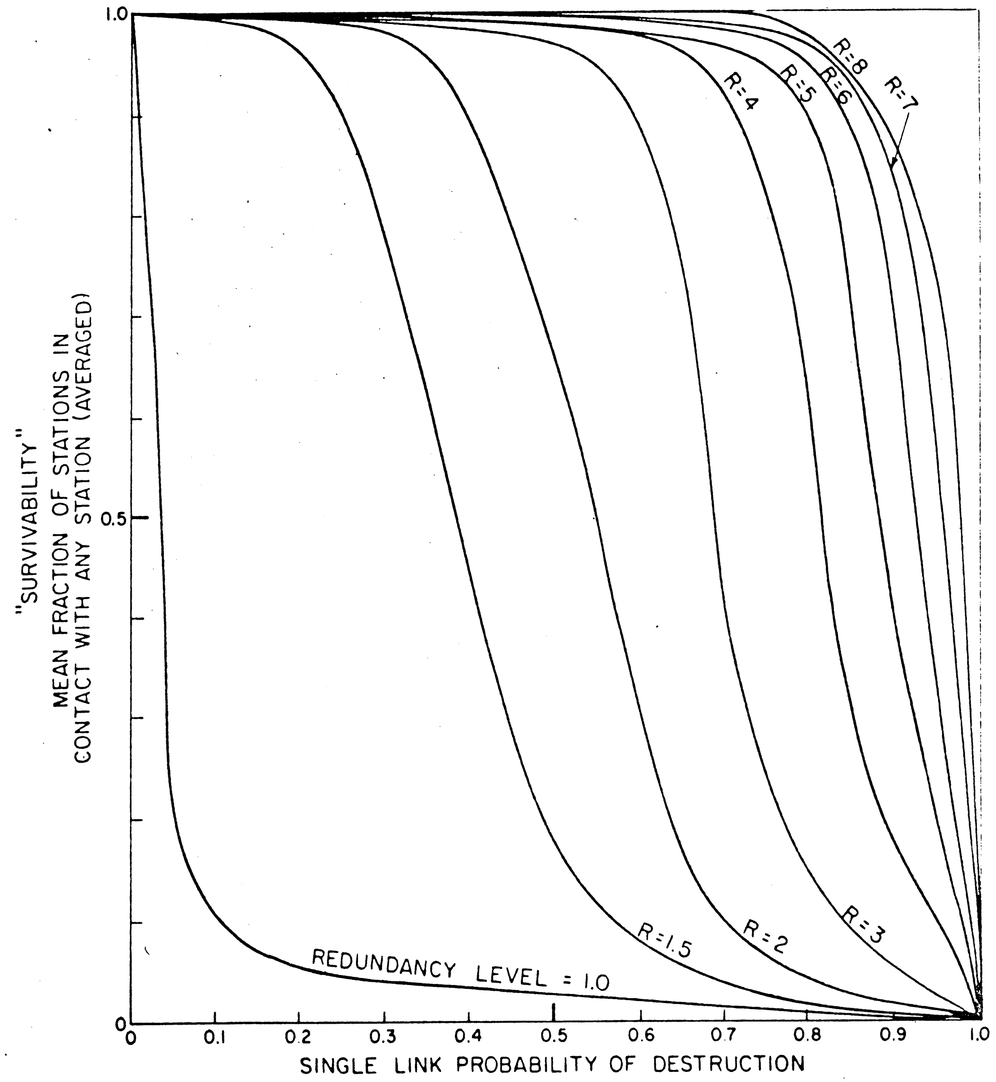


FIG. 5 — Perfect Switching in a Distributed Network — Sensitivity to Link Destruction, 100% of Nodes Operative.

Diversity of Assignment vs Perfect Switching

- Diversity of Assignment: for each pair of nodes, consider a small number of paths
- Perfect Switching: if there is a path, it will be used! (data will find its way, somehow…)
- Perfect Switching gives “reliability from unreliability”: reliable system from unreliable parts

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Revolutionary: if you could chop up network and it would still work well, you don’t need expensive parts (don’t need gold-plated stuff that AT&T was using)

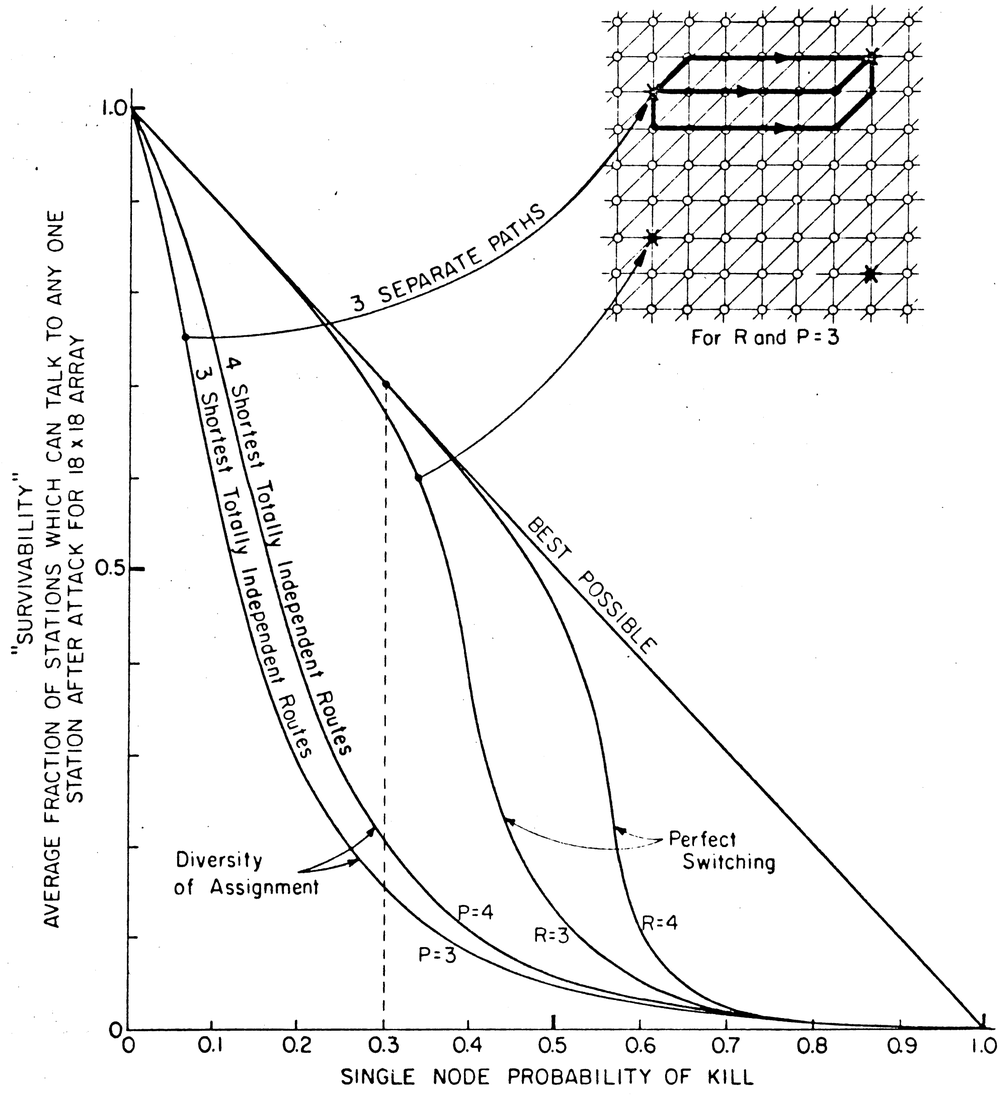


FIG. 8 — Diversity of Assignment vs. Perfect Switching in a Distributed Network.

Initial solution

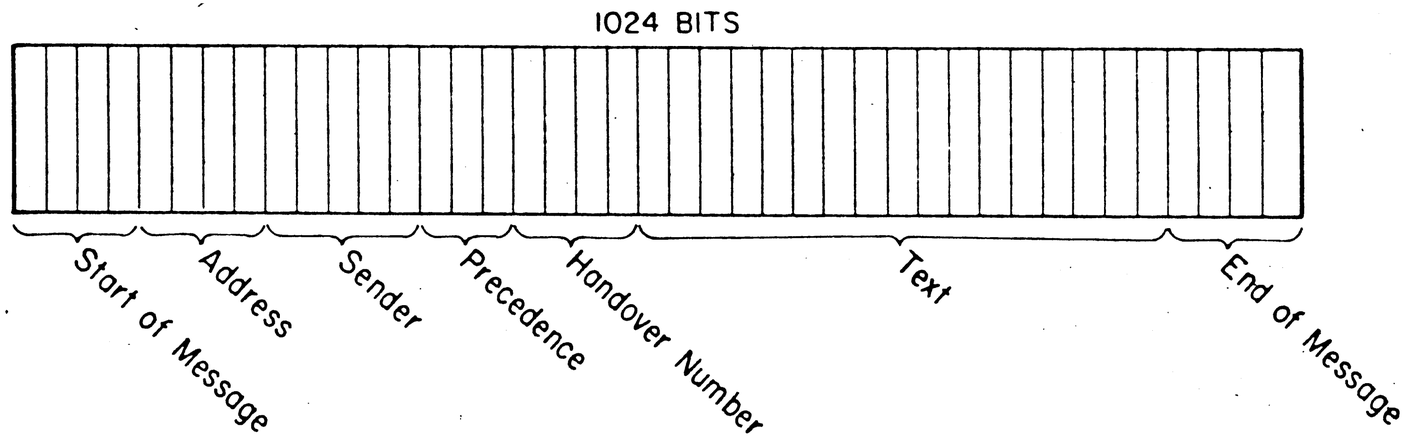
- Found solution using ground-wave radio, but wasn’t good enough because people wanted more bandwidth
- So decided to “design system with so much communication you wouldn’t know what to do with it!”
- Result was packet switching (revolutionary idea)

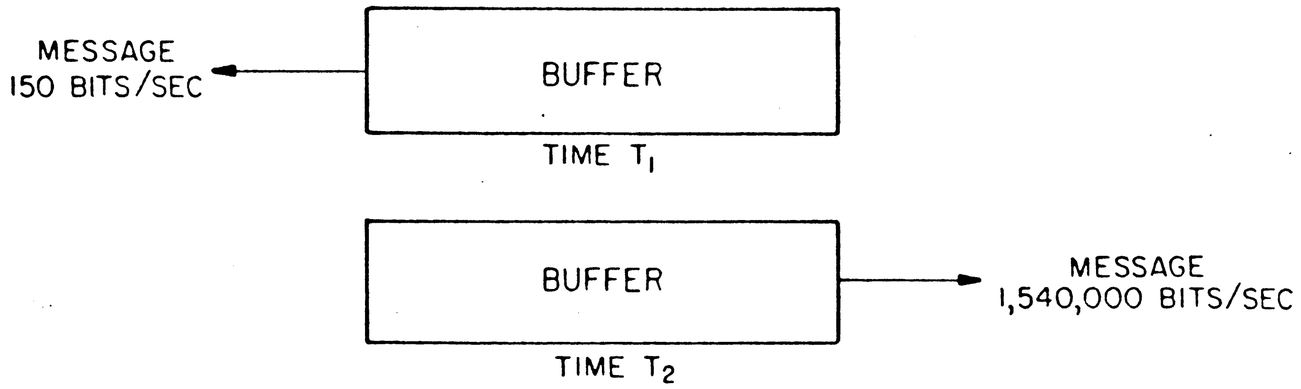
Problems in making this all work (toward packet switching)

- In conventional systems, need to match transmission bandits for each link
- Switching time exceeds transmission time
- Different users/nodes have different send rates (which may also vary over time)

The birth of packets

- “Message Block” → Later called “packets” by Donald Davies (way better name…)





“Where do you get your ideas from?”

- Progenitor of idea may be AM broadcasting (a type of radio broadcasting)
- President of of RAND proposed using AM broadcast stations to relay messages, repeating messages from station to station
  - Baran came up with prototype (using digital, not analogue) and demonstrated it could work
  - Didn’t yet consider intelligent routing; instead, just flood the network

Paradigm shift

- Distributed networks with cheap unreliable links
- Reliance on digital instead of analog
- standard message block - now called a “packet”

Struggle with the establishment

- AT&T engineers: opposed ideas, were patronizing
  - telephone people couldn’t visualize anything that wouldn’t go through the system instantaneously: “you can’t open a switch in the middle of a conversation”
  - couldn’t understand a paradigm shift - blocks of information going from one end to the other
  - people thought it was a telephone system… but with digital it could be for anything (just sending bits)
- (but… Bell Labs engineers “got it”)

Baran’s response

- Just implement the thing and show people it works

- “And then you had to tell them that each packet will find its own route on a statistical basis to get where it wants to go. After I heard the melodic refrain of "bullshit" often enough **I was motivated to go away and write papers to show that algorithms were possible that did in fact allow a short message to contain all the information it needs to know where to go**.”

Environment at RAND

- “It takes 30 briefings to sell one idea”, but questions/objections were good

- “RAND was already funded… RAND received its money once a year and **it was allowed pretty much to do what it wanted to do**.”

- “There are a few projects that they would be informally obligated to do. These are readily manned because while everybody likes to think that they are able to come up with their own projects in their own field of interests, as a practical matter most people in research send the message, ‘Gee, what am I supposed to be doing?’ Those who made the mistake of asking got the project work to do.”

- “Very quickly at RAND I received what would now be an amazing amount of freedom. **I could do whatever I wanted to do.** The only thing that RAND management did require was that my underlying assumptions be realistic and the logic consistent.”

- “**RAND was by far the most effective research organization I have ever encountered in my life, in part because of that freedom.** It trusted the people, and the trust was honored. I might mention that **this degree of freedom was not a result of management laziness. Rather it was the result of management wisdom, dedication to intellectual honesty, trust in individuals, and a true understanding of the research process.**”

Closing on the report that introduced packets

Although it is premature at this time to know all the problems involved in such a network and understand all costs, there are reasons to suspect that we may not wish to build future digital communication networks exactly the same way the nation has built its analog telephone plant.

Is it time to consider the detailed format of a standard message block as a possible new data standard of the future?

Baran’s advisor quote

- Quote from Baran about his advisor Jerry Estrin (UCLA)
  - “He kept me continually challenged. He has a wonderful way of finding out what you knew and what you didn't. He would gently, but firmly, focus you into your weakest areas.”