Logistics:
http://web.mit.edu/6.033

• Schedule has all assignments
• Every class meeting has preparation/assignment
• First deliverable is due Tuesday 2/12.
• To help you: read the Therac paper before Friday’s writing recitation.
• Fill out sign up sheet and return at the end of lecture (if you didn’t do so yesterday)
• We will post sections assignment tonight

Emergent Property Example: Ethernet

• All computers share single cable
• Goal is reasonably reliable delivery
• Listen before send to avoid collisions
• Will listen-while-send detect collisions?
  ➢ Minimum packet size!
  ➢ Maximum cable length!

Propagation of Effects Example (L. Cole 1969)

• WHO attempted to control malaria in North Borneo
• Sprayed villages with DDT
• Wiped out mosquitos, but …
  ➢ Roaches collected DDT in tissue
  ➢ Lizards ate roaches and became slower
  ➢ Easy target for cats
  ➢ Cats didn’t deal with DDT well and died
  ➢ Forest rats moved into villages
• Rats carried the bacillus for the plague
  ➢ WHO replaced malaria with the plague

Galileo in 1638

“To illustrate briefly, I have sketched a bone whose natural length has been increased three times and whose thickness has been multiplied until, for a correspondingly large animal, it would perform the same function which the small bone performs for its small animal. From the figures here shown you can see how out of proportion the enlarged bone appears. Clearly then if one wishes to maintain in a great giant the same proportion of limb as that found in an ordinary man he must either find a harder and stronger material for making the bones, or he must admit a diminution of strength in comparison with men of medium stature; for if his height be increased inordinately he will fall and be crushed under his own weight. Whereas, if the size of a body be diminished, the strength of that body is not diminished in the same proportion; indeed the smaller the body the greater its relative strength. Thus a small dog could probably carry on his back two or three dogs of his own size; but I believe that a horse could not carry even one of his own size.”

Incommensurate scaling

• Scaling mouse to elephant size (Haldane 1928)
  ➢ Volume ~ O(x³) where x is a linear measure
  ➢ Bone strength – cross section ~ O(x²)

• Scaling the Internet
  ➢ 39 sites in 1973
  ➢ Total size of tables (for shortest paths): O(n²)

• Scaling Ethernet’s bit-rate
  ➢ 10 mbit/s: min packet 64 bytes, max diameter 2.5 km
  ➢ 1000 mbit/s: min packet 512 bytes, max diameter 0.25 km
  ➢ Switched architecture: don’t share cable
Incommensurate scaling

• Scaling mouse to elephant size (Haldane 1928)
  • Volume $\sim O(x^3)$ where $x$ is a linear measure
  • Bone strength $\sim$ cross section $\sim O(x^2)$

Scaling the Internet

• 39 sites in 1973
  • Total size of tables (for shortest paths): $O(n^2)$

Scaling Ethernet

• $10$ mbit/s: min packet 64 bytes, max diameter 2.5 km
• $1000$ mbit/s: min packet 512 bytes, max diameter 0.25 km
• Switched architecture: don’t share cable

Example: more goals, more complexity

• 1975 Unix kernel: 10,500 lines of code
• 2008 Linux 2.6.24 line counts:
  85,000 processes
  430,000 sound drivers
  490,000 network protocols
  710,000 file systems
  1,000,000 different CPU architectures
  4,000,000 drivers
  7,800,000 Total

Example: interacting features, more complexity

• Call forwarding
• Call Number Delivery blocking
• Automatic callback
• Itemized billing

Example: ACB + IB:

A calls B, B is busy
Once B is done, B calls A
A’s number on appears on B’s bill

Principles

• Expect surprises
• There is no small change
• Every 10x increase $\Rightarrow$ major re-design
• Just one more feature!
• Complexity is super-linear
• Performance causes complexity

Class plan

• Next lecture: computer systems are different
• Naming: gluing modules together
• Client/server: enforced modularity
• Networks: hard boundaries between modules
• Reliability and transactions: handing failures
• Security: handling malicious failures