oueees-201506 Part 1: Sustainable computer systems and networks

Kenji Rikitake

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School of Engineering Science
Osaka University
Toyonaka, Osaka, Japan
@jj1bdx

Lecture notes on GitHub

- https://github.com/jj1bdx/oueees-201505-public/
- Don't forget to *check out the issues*!

Sustainable computer systems

Trends in mobile computer devices

- Physically small
- Less physical constraints
- Less power
- Also applicable to *all* computers (from the supercomputers to cloud computing clusters)

Pursuing better mobility

- Smaller parts
- Higher available energy density
- Less wires or cables
- Less energy consumption
- Details on energy issues will be explained in another talk of this lecture series

Computer needs *millions* of discrete devices

- DRAM: 1 transistor = 1 bit
- 4 Gigabytes = 32G transistors (or more)
- 4GB DDR3 SDRAM: ~7W (0.2nW/transistor)
- Intel 18-core CPU: 5.6B transistors [1]
- CPU consumes power: ~26nW/transistor [2]

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[1] Intel Xeon E5-2699 v3, 18 Cores

[2] Intel's pdf brochure says: 145W TDP

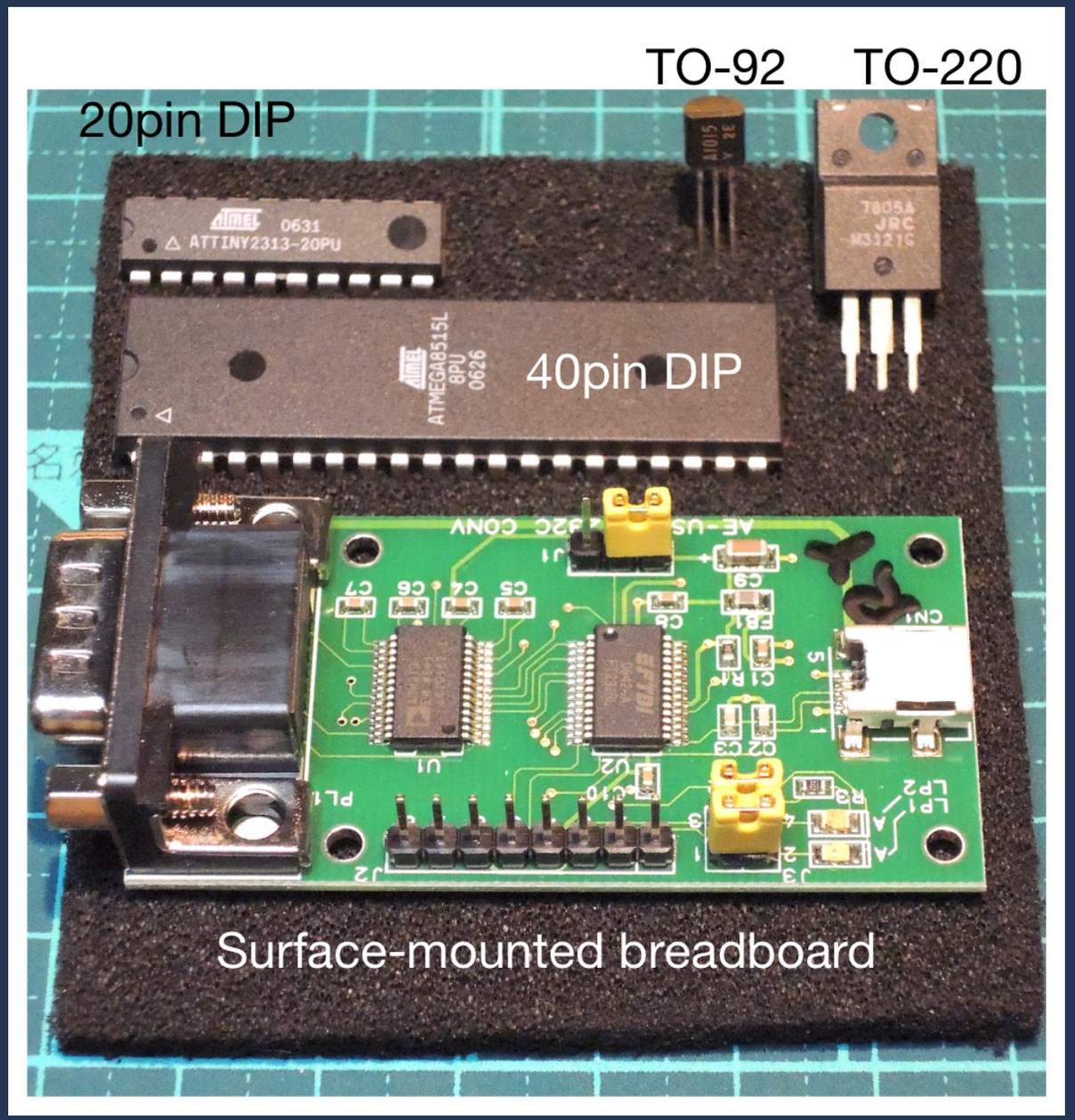
Smaller discrete devices

- Vacuum tubes: ~W/tube
- Discrete Transistors: ~mW/transistor
- Integrated circuits (ICs): nW/transistor, millions of transistors/chip
- Atom transistors: pW/chip or less
- Using less energy per device

Smaller electronic packages

- Hand mounting: TO-92, TO-220
- Hand mounting ICs: SIP, DIP
- Surface mounting: SOIC, BGA, PGA
- *Higher density*: the *same or even more energy per system*, ironically
- More *heat* for each module

Electronic parts



Moore's law

"[...] over the history of computing hardware, the number of transistors in a dense integrated circuit has doubled approximately every two years. " [3]

An important issue

- Can we proceed forever with this law?

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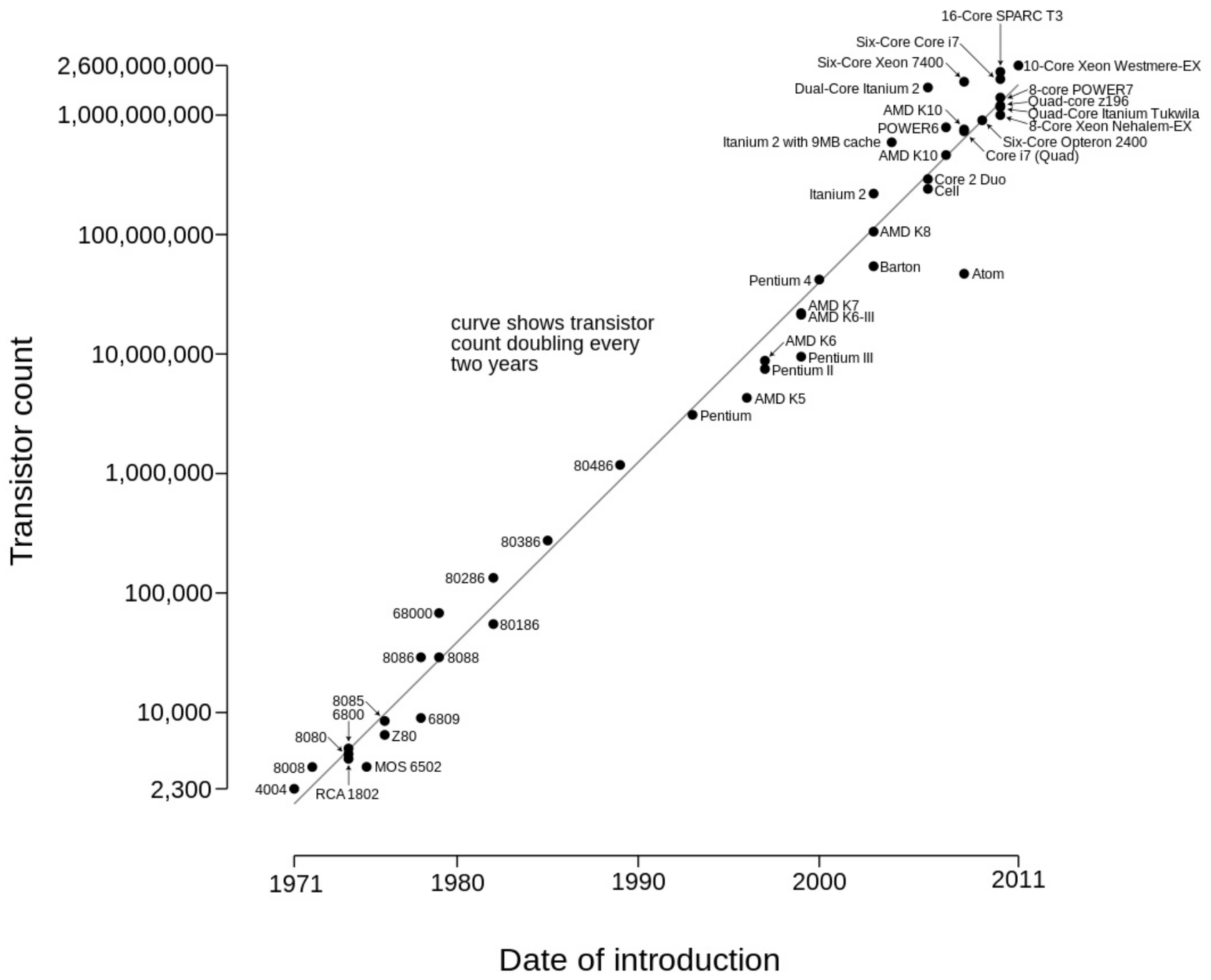
[3] http://en.wikipedia.org/wiki/Moore%27s_law

Microprocessor Transistor Counts 1971-2011 & Moore's Law



Issues on mobility: physics

- Power consumption
- Radio bandwidth limitation
- Latency (= speed of light)

Question

- How can we solve these issues?

Sustainable computer networks

We all live in the Internet

"The network is the computer" [4]

[4] By John Gage, also popular as the Sun Microsystems' Slogan, presumably coined in 1982

Wired and wireless networks

- Wired networks: optic fibers and metal/ coaxial cables, smaller error rates
- Wireless networks: mostly on radiowaves (some on lightwaves), more error prone
- Speed of wired networks is ~*1000 times faster than wireless networks*

Wired communications

- Consumer: 1000BASE-T, 1Gbps
- Higher speed: 10G/40G/100Gbps Ethernets
- Interconnects: InfiniBand, SATA, PCIe
- I/O: HDMI, USB, Thunderbolt
- ... and many other standards

Wireless communications

- Wifi: 20MHz for max 54Mbps (IEEE 802.11b)
- LTE: 20MHz for 150Mbps
- Endpoint protocols: Bluetooth (BLE), Zigbee

- ~1000 times *slower* than *wired* networks
- ~1 *million more times of error rates*

Issues on networks

- Physics: speed of light
- Addressing objects
- Routing between nodes/networks

Speed of light:
299 792 458
[m/s]

Refractive indices

- Air: 1.000293 (0C, 1atm, 598nm) [5]
- Water: 1.333 (20C, 598nm)
- Optic fiber (pure silica): 1.444 at 1500nm [6]
- Signal speed in optic fiber: ~200000 [km/s]
- Tokyo-Osaka (500km) Optic Fiber Round Trip Time (RTT) = 5 milliseconds

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[5] http://en.wikipedia.org/wiki/Refractive_index

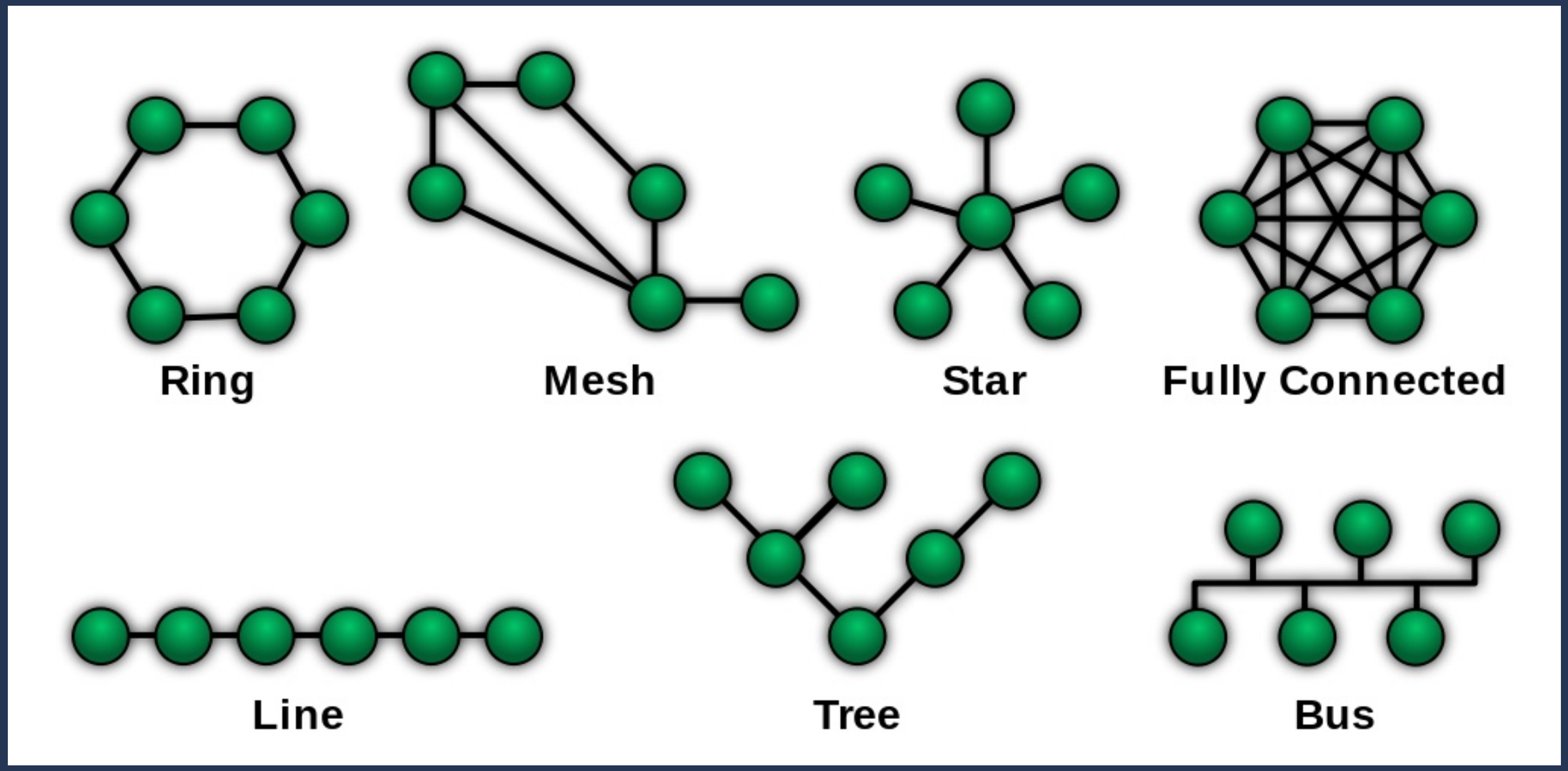
[6] http://en.wikipedia.org/wiki/Optical_fiber

How latency affects the error handling

- RTT of Osaka - San Francisco, CA, USA (9000km) in optic fiber = 18ms
- 18ms in 10Gbps = 180Mbits = 22.5Mbytes
- An error between KIX-SFO may cause retransmission of 22.5Mbytes (or even more)!

Routing: where and how to deliver the information

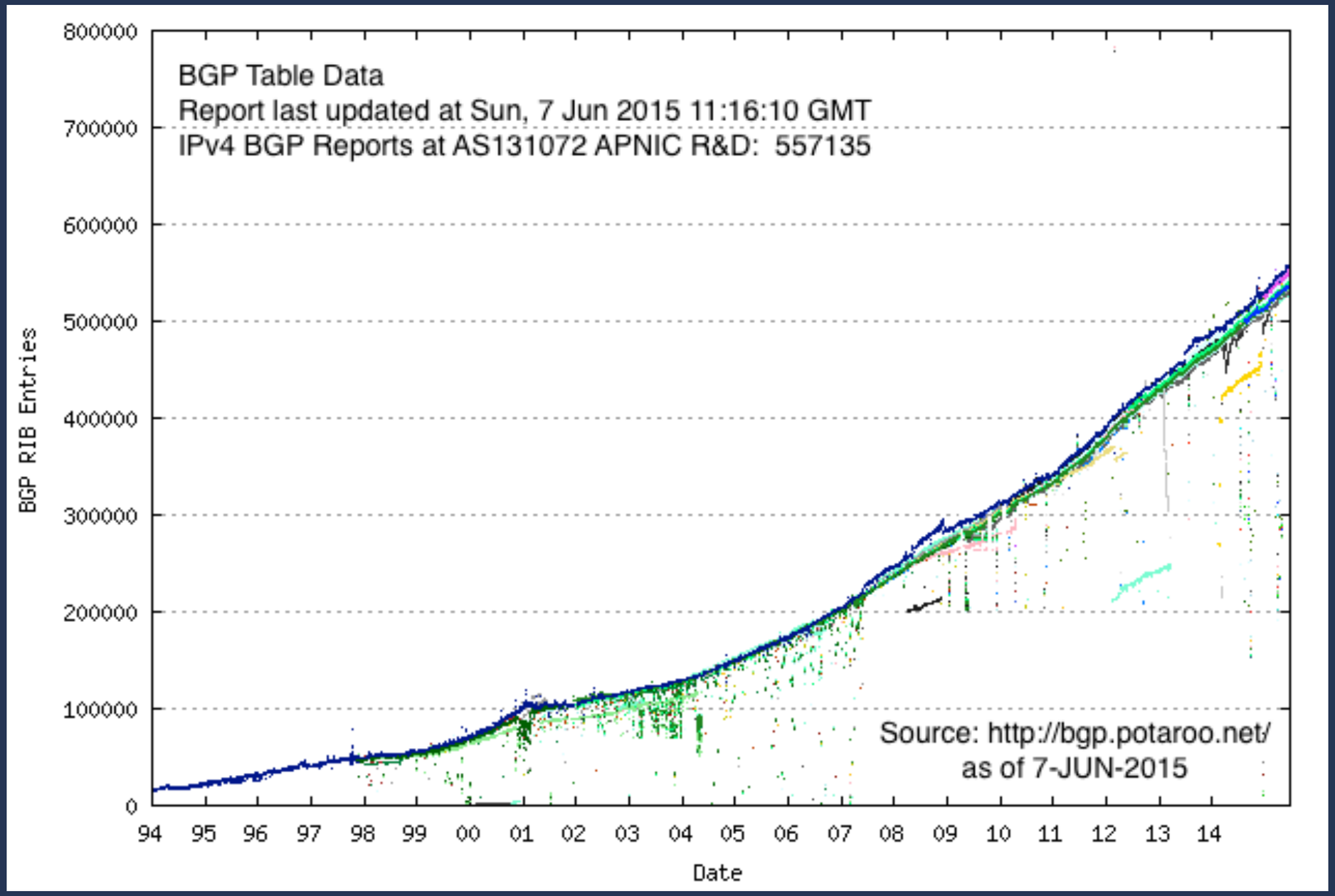
Different types of routes and network topologies



Routing issues

- The optimal route always changes as the availability of forwarding nodes changes
- Recalculation of routes: O(N^2) for N nodes
- Each and every forwarding nodes or *routers* have to compute all the necessary routes simultaneously
- Routes always increase (exponentially)

IPv4 Internet: ~560k routes



Another problem: We're using up the IPv4 address space

IPv4 address space: only 32 bits = ~4 billions

No new space available since 2011

IPv4 address space issues

- Internet service providers (ISPs) are now selling and buying the address spaces
- The unassigned address spaces are getting smaller every day
- Emerging economies and companies have difficulties on obtaining globally-reachable IPv4 addresses

Transition to IPv6 still fails to happen

- IPv6 allows 128bit address space, and is similar to IPv4, but a *completely different* protocol: new ISP investment needed
- BGP prefixes: only 22705 (IPv4: 557135)
- Still not available in most regions of the world without extra payment to ISPs; reachability is severely limited

Lots of efforts are needed to keep Internet sustainable

Question: What should be done?