Lessons from Two Decades of Networking

Andy Gospodarek
Software Architect/Engineer/Open Sourcerer at Broadcom
NC State Class of 2001

Who is Andy Gospodarek?

- NC State class of 2001 (Computer Engineering)
- Open Source Expert/Enthusiast/Advocate/True Believer
- Spent entire career in computer networking:
  - Two Co-op terms at Cisco and one summer internship at SAS
  - Worked at 2 startups (LVL7 Systems and Cumulus Networks), one high-growth company (Red Hat), and one large company (Broadcom)
- Enjoy mountain biking, running, and Oxford commas
- Married to a NC State graduate (Class of 2001 in EE and Applied Math) and have 3 kids

What was happening in 2001?

2001:

Google was just starting to take off (Search was the only service)

2021:
It's hard to imagine life without Google's services…

2021:
...but many people wonder if that's a good thing?

2001:
Smartphones were *rare*

2021:
Everyone has a smartphone including [sadly] many kids in elementary school...

2021:
...but more and more adults claim they are taking a break from their phones

2001:
Wireless networking hardware was extremely expensive

2021:
Wireless networking hardware is cheap...

2021:
...and service is so cheap that it is either free or practically free

2001:
Kevin Systrom, Yiming Zhang, and Mark Zuckerberg were all still living with their parents

2021:
Systrom, Zhang, and Zuckerberg can all buy their parents new houses

2001:
Internet was used for [illegally] sharing copyrighted images and music

2021:
Internet is used for *everything*

2000:
NC State beat UNC-CH in football 38-20 in Chapel Hill

2021:
NC State beat UNC-CH in football 34-30 in Raleigh

I thought this was a talk about networking?

What enabled these changes to occur?

2001:
Networking was hard

2001:
Proprietary software dominated networking infrastructure

2001:
Networking vendors were extremely powerful and valuable

2021:
Networking and compute infrastructure has been commoditized

2021:
Open-source and standards-based software now dominate the networking industry

2021:
Data centers operators now extremely powerful and valuable

What software enabled this shift in power?

2001:
Linux Kernel contains ~4M LoC

2021:
Linux Kernel contains >30M LoC

Linux has more features and runs on more hardware than ever

2001:
Version control software was terrible

2005:
`git` was created

2008:
GitHub was founded

2021:
`git` is used by default for version control

2001:
High-speed network applications were custom to hardware running them

2021:
Packet processing frameworks like DPDK (userspace) or XDP (kernel) enable rapid, high-performance application development

What about protocol changes over the years?

When was TCP first proposed as a standard?

1974: TCP described by Vint Cerf and Bob Khan

2001: New TCP congestion algorithms begin to be developed to deal with growing scale of the Internet

2008: Cubic TCP released based on research done at NC State

2010: Data Center TCP (DCTCP) research begins and continues today to boost network utilization

2011: TCP Fast Open introduced by Google to cut down on number of RTTs per session

2012: Google develops SPDY that serves as the basis for HTTP/2

2013: Google develops QUIC that will serve as the basis for HTTP/3, but will now be over UDP instead of TCP

2021: Google, YouTube, Facebook, and more all use QUIC/UDP by default instead of HTTPS/TCP

Apply a display filter ... <⌘/>   Expression...

No.	Time	Source	Destination	Protocol	Length	Info
88	1.064078	10.0.100.119	iad30s36-in-f3.1e100.net	UDP	1392	58717 → https(
91	1.080063	10.0.100.119	iad30s36-in-f3.1e100.net	UDP	75	58717 → https(
320	4.048142	10.0.100.119	lax17s44-in-f3.1e100.net	UDP	135	56997 → https(
324	4.141923	10.0.100.119	lax17s44-in-f3.1e100.net	UDP	75	56997 → https(
325	4.419457	10.0.100.119	lax17s44-in-f3.1e100.net	UDP	132	62075 → https(
329	4.527500	10.0.100.119	lax17s44-in-f3.1e100.net	UDP	75	62075 → https(

▷ Frame 88: 1392 bytes on wire (11136 bits), 1392 bytes captured (11136 bits) on interface 0
▷ Ethernet II, Src: RealtekS_68:00:2e (00:e0:4c:68:00:2e), Dst: PcPartne_bc:7c:a0 (00:01:2e:bc:7c:a0)
▷ Internet Protocol Version 4, Src: 10.0.100.119 (10.0.100.119), Dst: iad30s36-in-f3.1e100.net (142.250.73.227)
▽ User Datagram Protocol, Src Port: 58717 (58717), Dst Port: https (443)
　　Source Port: 58717 (58717)
　　Destination Port: https (443)
　　Length: 1358
　　Checksum: 0x3681 [unverified]
　　[Checksum Status: Unverified]
　　[Stream index: 1]
　▷ [Timestamps]
▽ Data (1350 bytes)
　　Data: c65130353008ef00028df4cfa0e000004534743a1d0c5710…
　　[Length: 1350]

```
0020   49 e3 e5 5d 01 bb 05 4e  36 81 c6 51 30 35 30 08   I··]···N 6··Q050·
0030   ef 00 02 8d f4 cf a0 e0  00 00 45 34 74 3a 1d 0c   ········ ··E4t:··
0040   57 10 21 fc 71 1c a7 c1  23 b2 0a cd 1e ba cf 54   W·!·q··· #······T
0050   58 da 28 67 ef d4 44 0f  dd 92 aa 08 85 3d 9f 2f   X·(g··D· ·····=·/
0060   31 3c 2f ed 0b 50 fb 67  a5 ed 0d 59 44 08 89 bf   1</··P·g ···YD···
0070   d6 2a e5 6e 4b 32 da ae  85 15 2e d1 a7 b1 7e 89   ·*·nK2·· ··.···~·
0080   5e 67 9e 44 32 f4 be b4  1a 90 14 6d 40 dc c2 95   ^g·D2··· ···m@···
0090   07 7a 5f 46 e3 ef 63 e4  38 d8 a1 6e 70 e6 af 48   ·z_F··c· 8··np··H
00a0   ac c7 83 30 f4 88 f4 3e  f2 a7 e0 0c a9 5f 43 7c   ···0···> ·····_C|
00b0   48 8d 5b 3e c7 b7 be 9b  30 ab 91 aa fd b8 40 26   H·[>···· 0·····@&
00c0   c5 02 56 32 59 e6 6f df  f8 fc ae 96 c8 63 4f 5e   ··V2Y·o· ·····cO^
00d0   de 2f f6 24 dd ce ab 33  95 44 67 95 f3 f1 b5 1a   ·/·$···3 ·Dg·····
00e0   ac de 7a 92 10 81 26 b1  15 32 e2 8f 18 ac 3d be   ··z···&· ·2·····=·
00f0   fe 01 ea 3a ec b1 10 29  81 aa 45 40 d5 57 0a 05   ···:···) ··E@·W··
0100   09 19 83 ab 14 97 5c 0f  a5 42 87 a5 bd c5 f8 3d   ······\· ·B·····=
0110   55 71 3d e8 d8 31 10 07  10 dc 49 bd d4 2c 27 a9   Uq=··1·· ··I··,'
0120   be 2a 95 2a 56 a9 fc b4  62 3d 5b d9 c9 c6 23 ec   ·*·*V··· b=[···#·
```

Data (data), 1350 bytes   Packets: 467 · Displayed: 467 (100.0%) · Dropped: 0 (0.0%)   Profile: Default

QUIC moves many features of TCP to userspace (client and server) rather than kernel

QUIC's main goal is to reduce latency of connection setup and retransmission

QUIC's secondary goal is to enable rapid protocol enhancement and development

Switch to UDP will impact every firewall product that exists today

Adoption of QUIC by IETF as standard *should* prevent a return to proprietary networking

2020: Everyone was online all the time for everything

2021: In-person work and school are back

Content providers do not want us to put down our devices

Providers and their algorithms know what we like...

...sometimes better than we know ourselves

Where do we go from here?

Humans still have the power to impact change

Value is created by people

Playing well with others is critical for success

"First I learned to read and write and then I conquered the world"

"First I learned to read and write *code* and then I conquered the world"

```
exit(0);
```

Commoditize?

To make the difference in quality between the most expensive and cheapest version of products in the same category virtually indistinguishable