Disk|Crypt|Net

High performance video streaming

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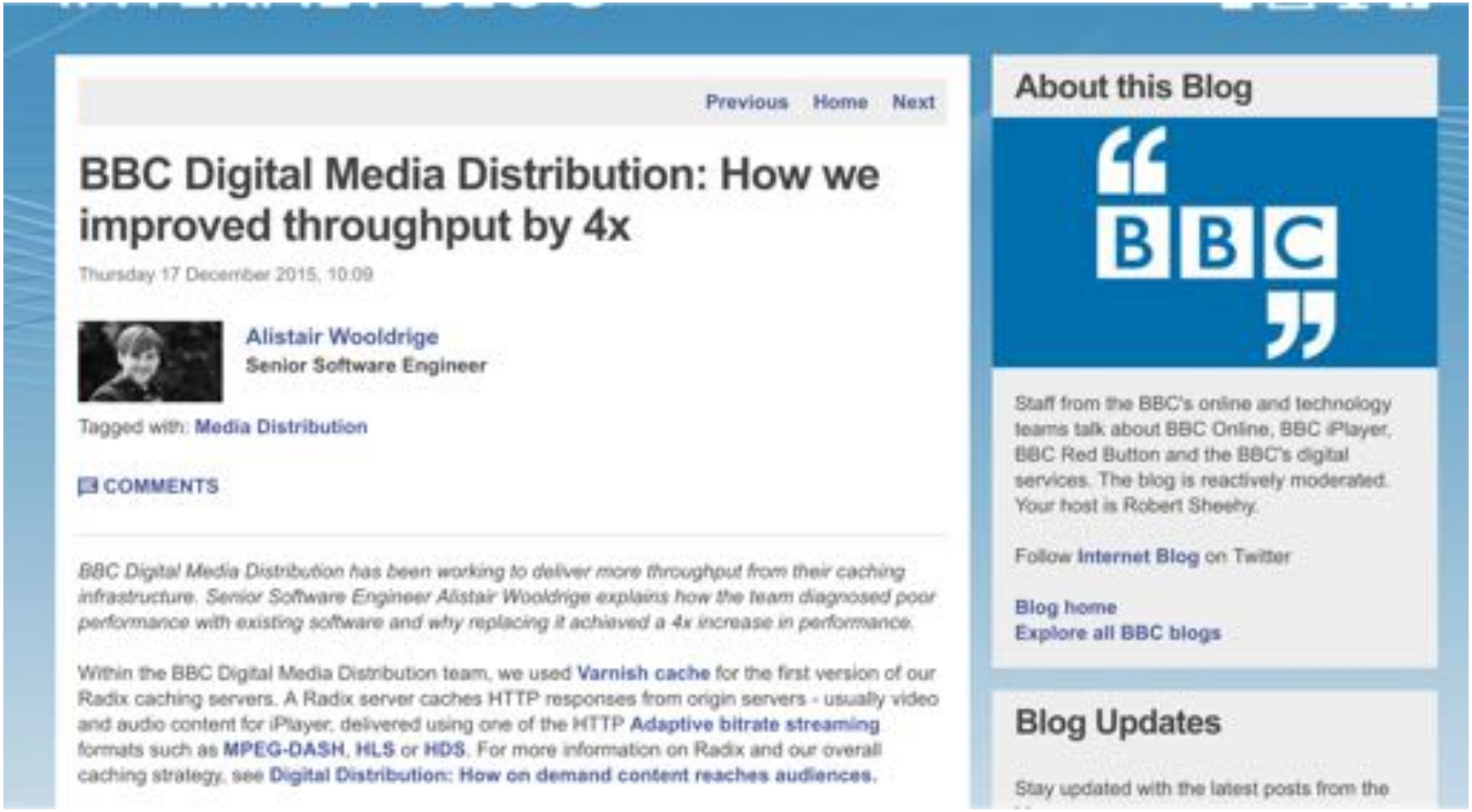
Modern Video Streaming

- Just lots of HTTP requests for video chunks.
- Client picks chunks, so as to adapt rate.
- Server is pretty dumb – just has to go fast.
- HTTP/1.1 persistent connections.
- TLS has become important (YouTube is 95% TLS).

- More than 50% of Internet traffic.
- Important to make good use of expensive hardware. How fast can you go?



New iPlayer setup, Dec 2015:

- nginx on Linux, 24 cores on two Intel Xeon E5-2680v3 processors, 512 GB DDR4 RAM, 8.6TB RAID array of SSDs.
- 20Gb/s per server. ←Not so impressive!

NETFLIX

- FreeBSD, but tweaked.
  - Asynchronous sendfile()
    - Non-blocking zero copy from disk buffer cache to Net.
  - VM scaling
    - Fake NUMA domains to avoid lock contention
    - Proactive clearup of disk buffer cache.

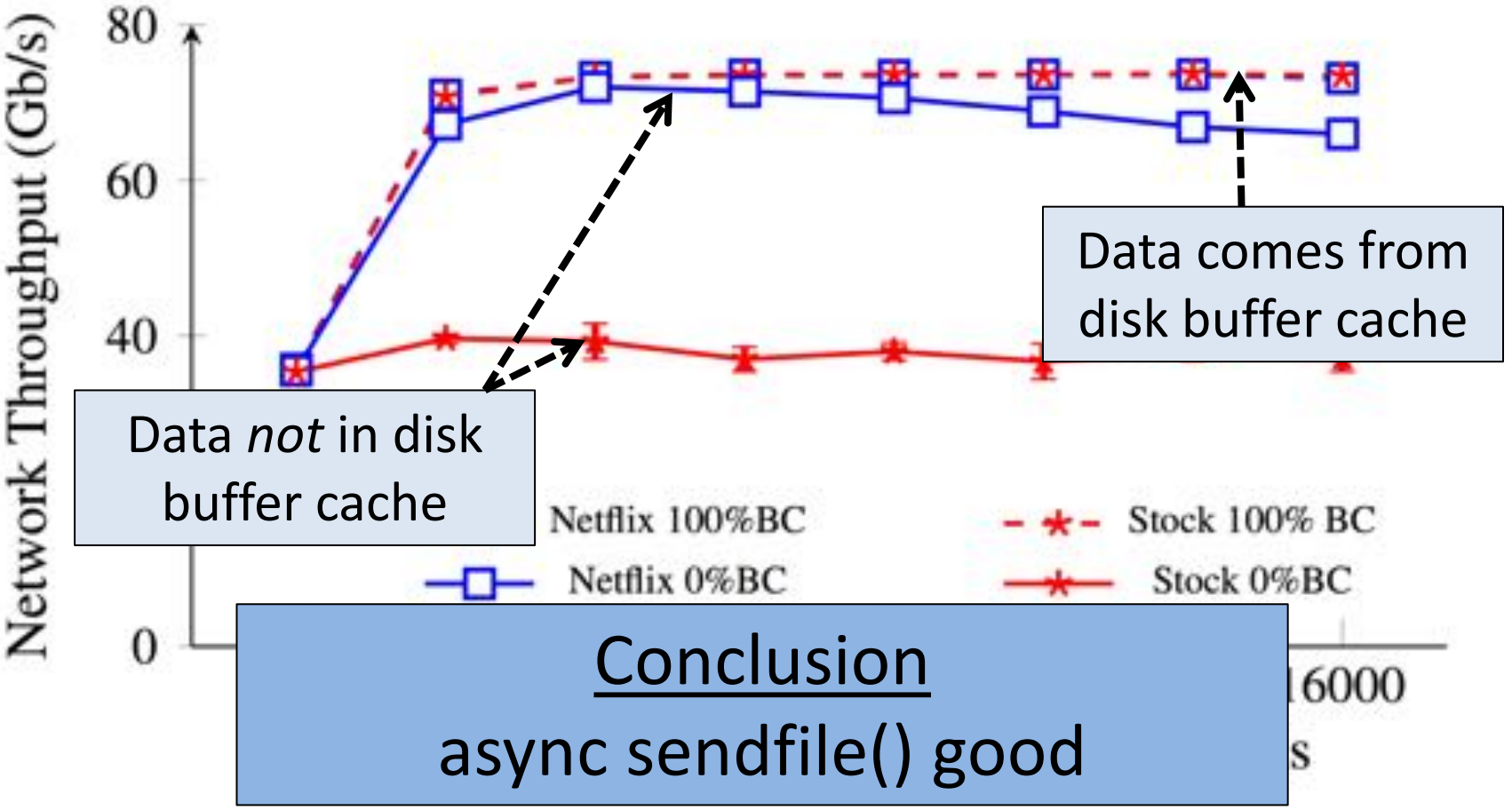
Lets Do Some Experiments

- 8 core server, 2x 40Gb/s NICs, 4x NVMe SSDs
- Synthetic workload, middlebox adds delay to reverse path to make RTT realistic.
- Theoretical limits: about 73Gb/s

Compare:

- Stock FreeBSD/nginx
- Netflix version of FreeBSD/nginx
  - production codebase in autumn 2016

Unencrypted video streaming workload



Conclusion

async sendfile() good

Encryption Problem

sendfile():

- Zero copy from disk buffer cache

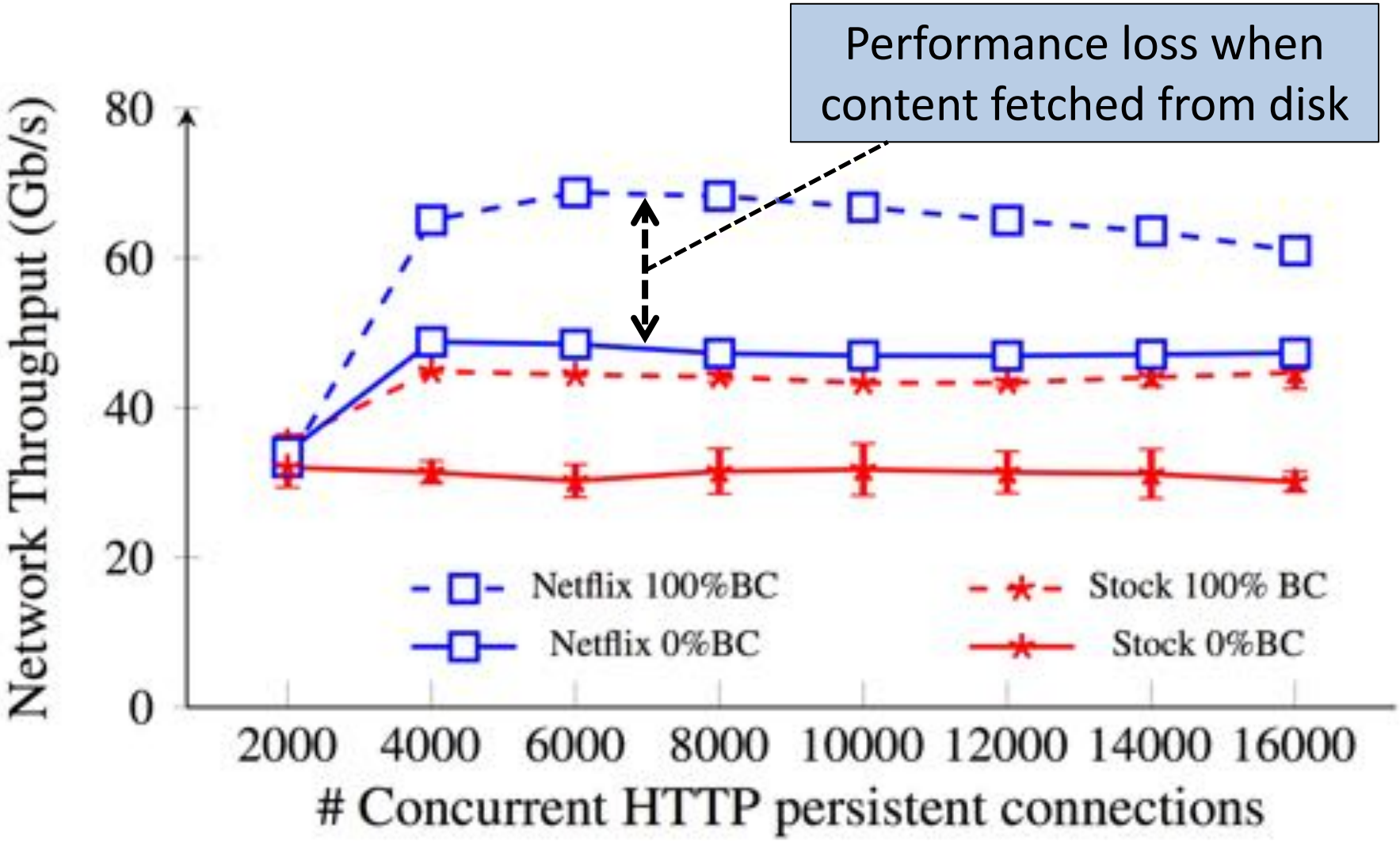
TLS:

- Different encrypted stream per user.

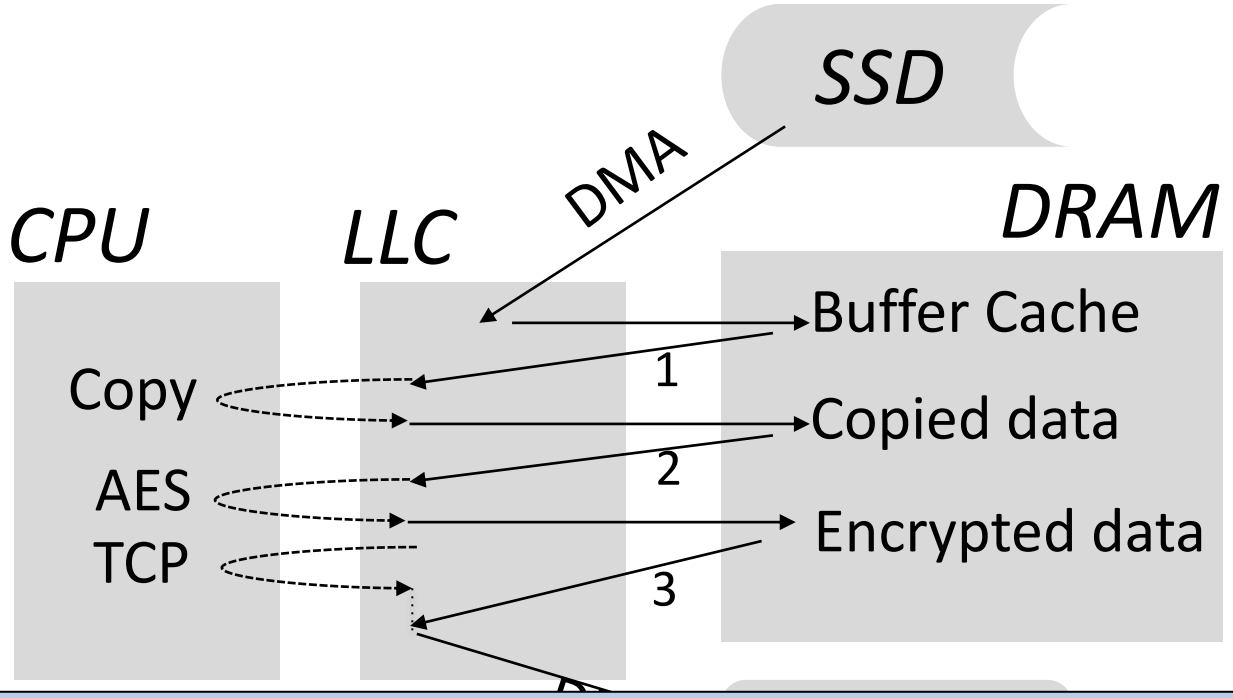
Sendfile() and TLS are incompatible!

- Conventional TLS stack gave Netflix 8.5Gb/s
- Netflix implemented kernel stream encryption for encrypted sendfile.
  - But can't be zero copy anymore.

Encrypted video streaming workload



What's happening?



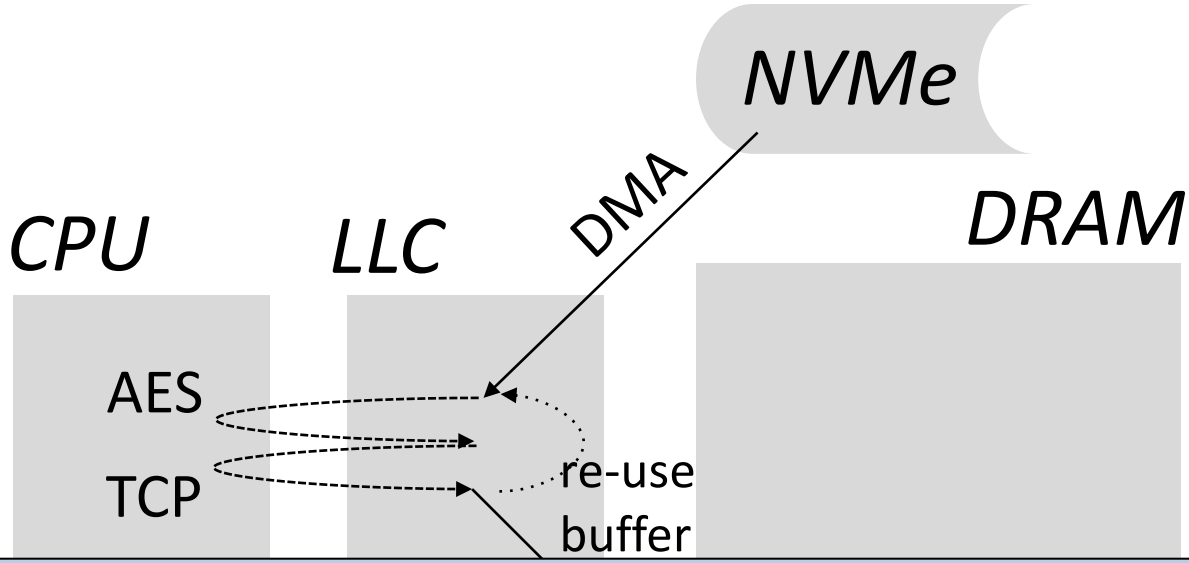
The stack is too asynchronous.
Data keeps getting flushed from the LLC, and re-loaded.
System is bottlenecked on memory.

Production Netflix workload

- 192GB of RAM as disk buffer cache.
- Only gets a 10% hit ratio.

- Modern NVMe SSDs have low latency.
- Modern Intel CPUs DMA directly to the L3 cache.
- Can we eliminate the disk buffer cache completely, and fetch everything from SSD on demand?

Ideal Stack



To achieve this, we must:

- Fetch on demand from the SSD when TCP needs data.
- As soon as the SSD returns data, process it to completion and DMA it to the NIC.

Solution Outline

1. A TCP ACK arrives, freeing up congestion window.
2. Trigger storage stack to request more data from SSDs to fill that congestion window.

***Atlas*: a complete user-space stack:**

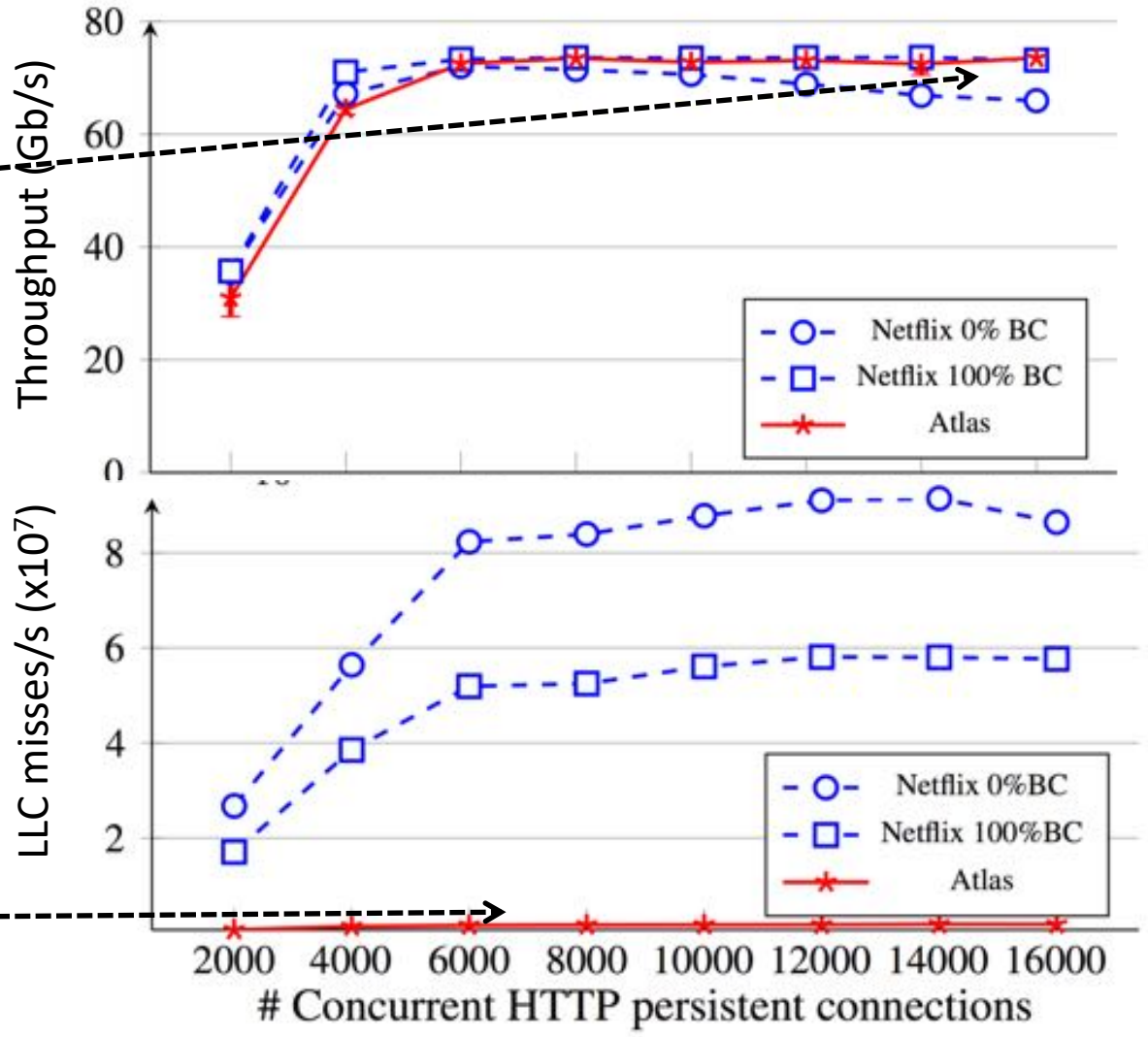
- *Netmap* to handle the network
- User-space TCP.
- Implemented *diskmap*, storage equivalent of netmap
  - Maps NVMe buffer rings to userspace and manages submission and completion queues.

Atlas vs Netflix, unencrypted content

15% better throughput than Netflix when cache hit ratio is low.

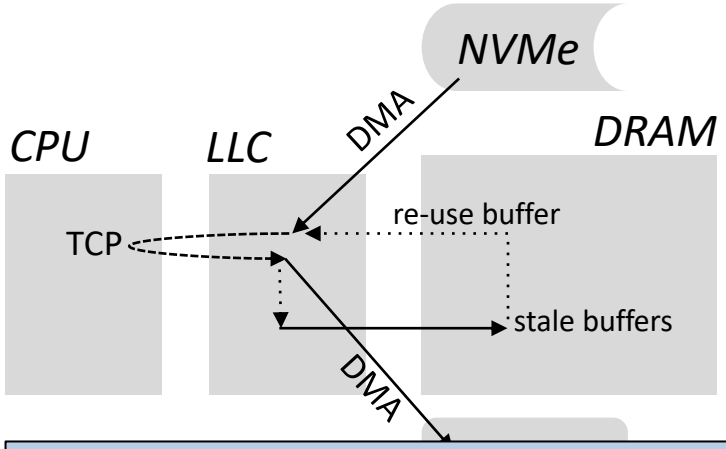
Netflix needs 8 cores, Atlas only needs 4

Almost no LLC misses. Data in LLC when we want it.

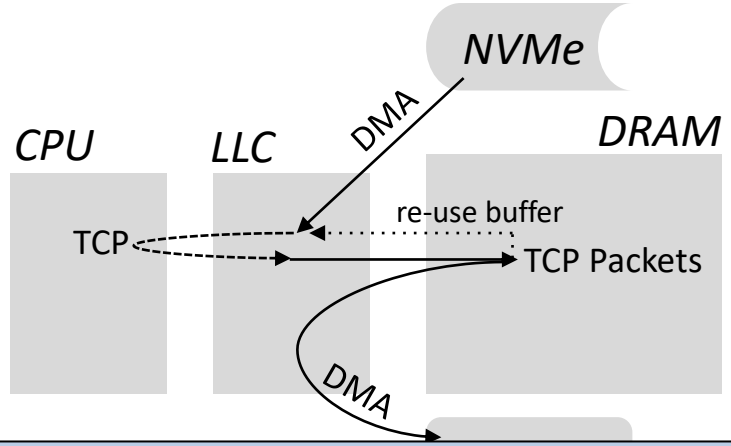


Still some memory traffic though

If we're lucky:



If we're unlucky:

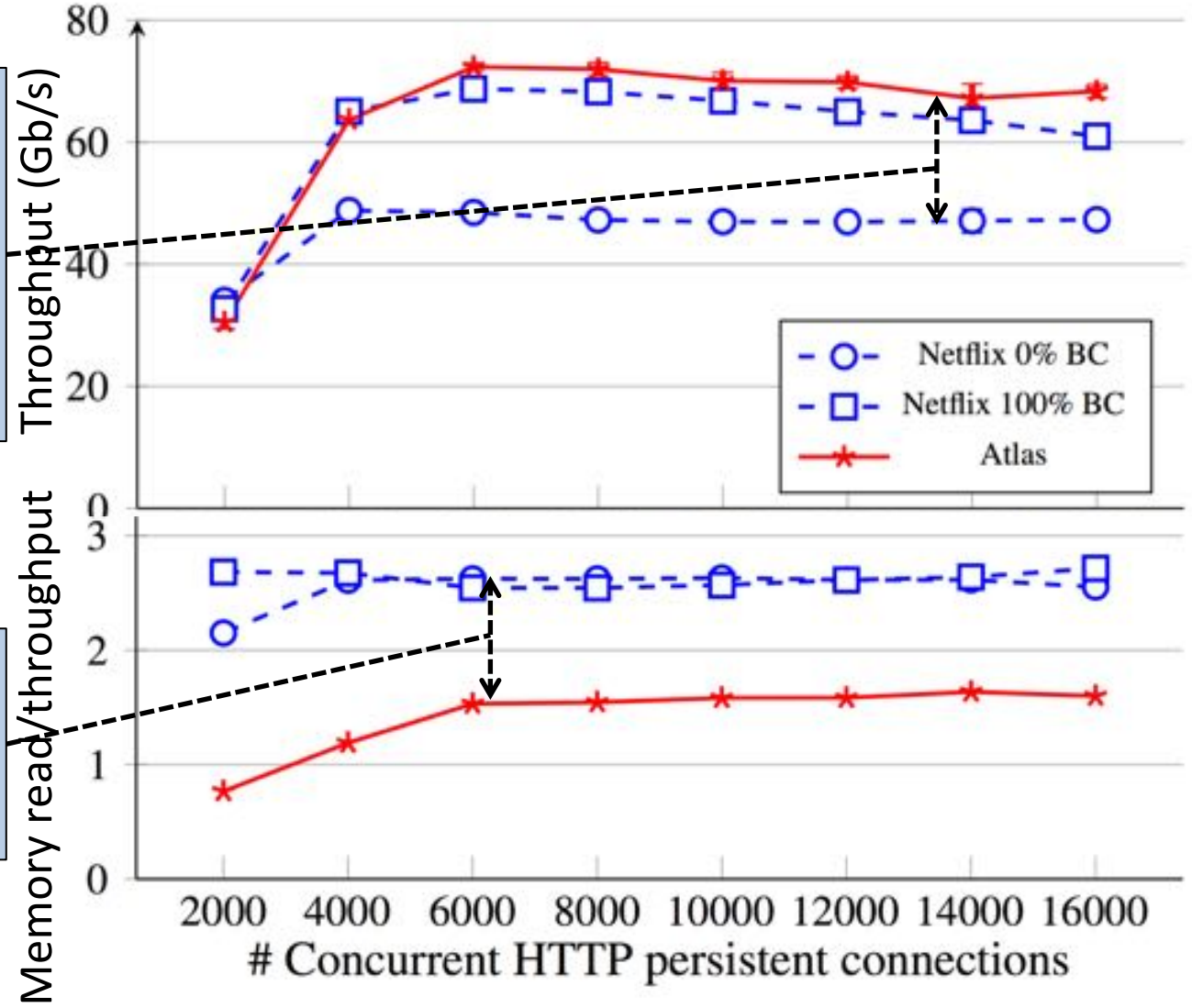


Netmap doesn't provide a good low-delay fine-grained way to handle DMA completions.
Can't reuse buffers fast enough, and this adds some cache pressure.

Atlas vs Netflix, Encrypted Content

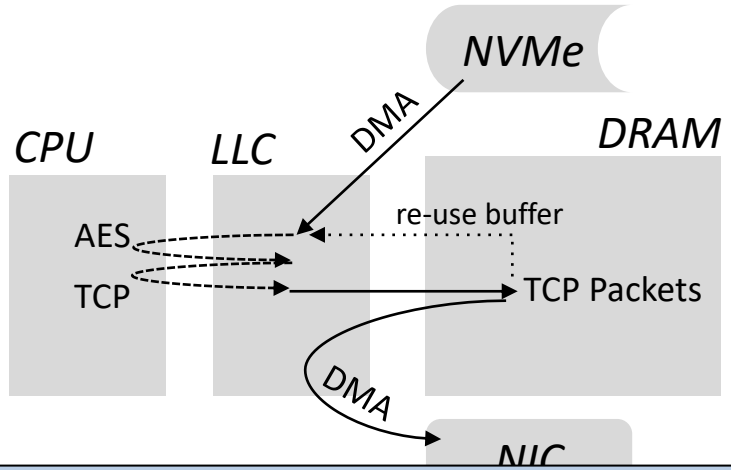
When cache hit ratio is low, 50% more throughput using half the cores.

Almost half the memory reads for each packet sent.

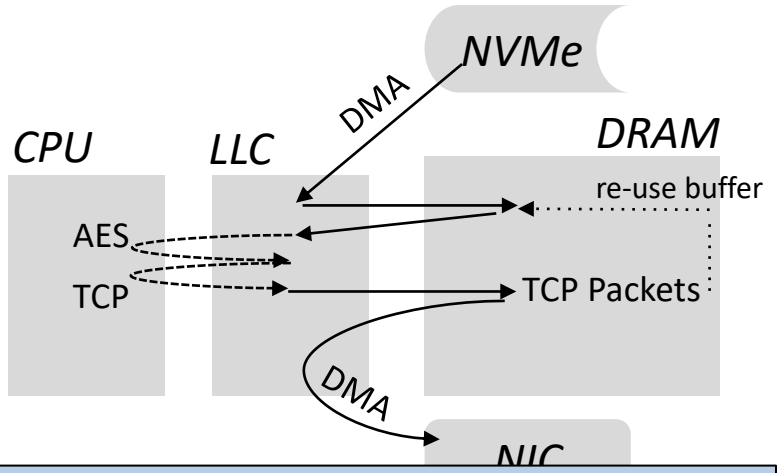


Atlas TLS memory usage

With no premature cache eviction:



When some other DMA causes cache eviction



DDIO can only DMA to 10% of the LLC

To operate entirely from the LLC, we'd need to recycle netmap buffers faster, using a LIFO stack for free buffers. We'd need more control over DDIO policy (newer CPU!)

Summary

- Netflix addressed all the low-hanging fruit
  - Very fast, but now bottlenecked on memory
- Atlas is a specialized stack
  - Puts SSD in TCP control loop
  - Immediately processes disk reads to completion and transmits.
  - 50% throughput improvement with encrypted content, close to 50% reduction in memory reads
- Netflix inspired by Atlas
  - Now experimenting with how to directly trigger encryption off of disk DMA completions in their FreeBSD stack.