eBPF-Assisted Relays for Multimedia Streaming

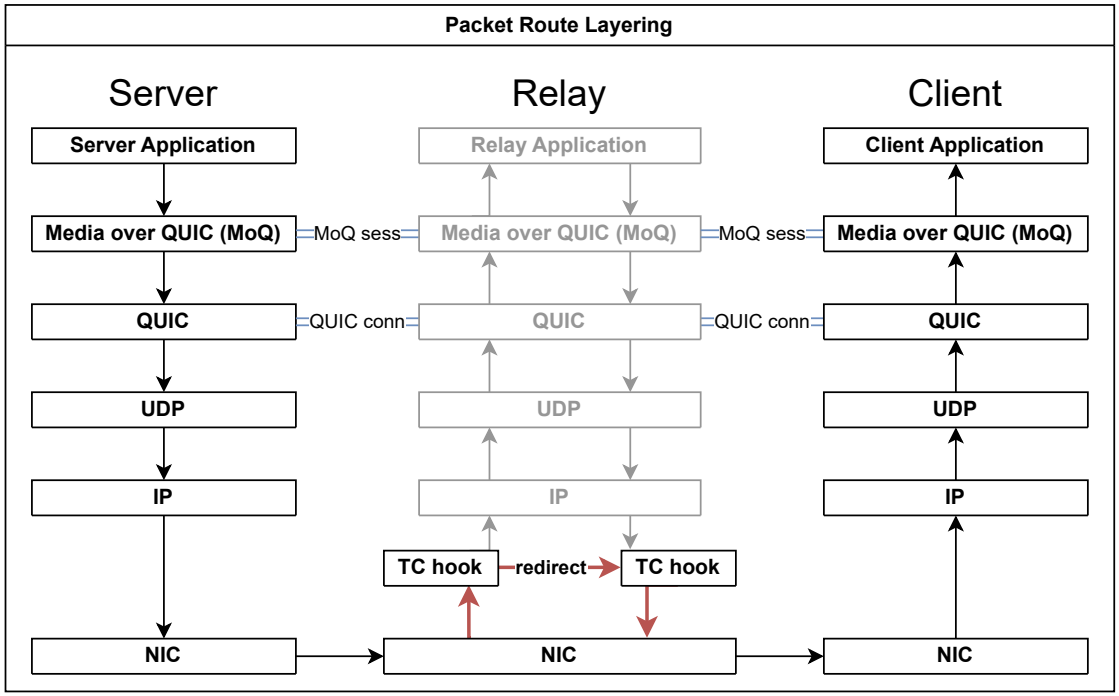
Daniel Alexander Antonius Pfeifer

Technical University of Munich

August 12, 2024

Motivation

- Shorten Critical Path
- Avoid Network Stack Traversal
- Reduce Forwarding Delay

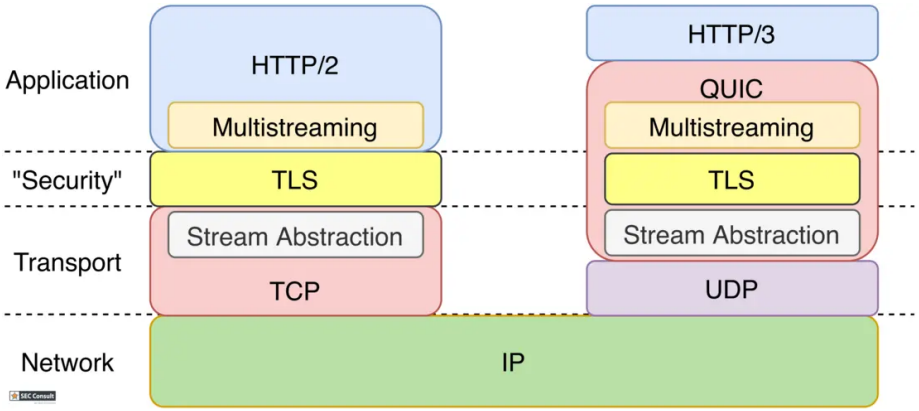


Research Question

- *Improve relay performance by using eBPF technology?*
  - *Remove userspace packet-processing from critical path?*
  - *Handle packet en- and decryption?*
  - *Communication between userspace and the eBPF program?*
  - *Generalize to support other protocols?*

QUIC

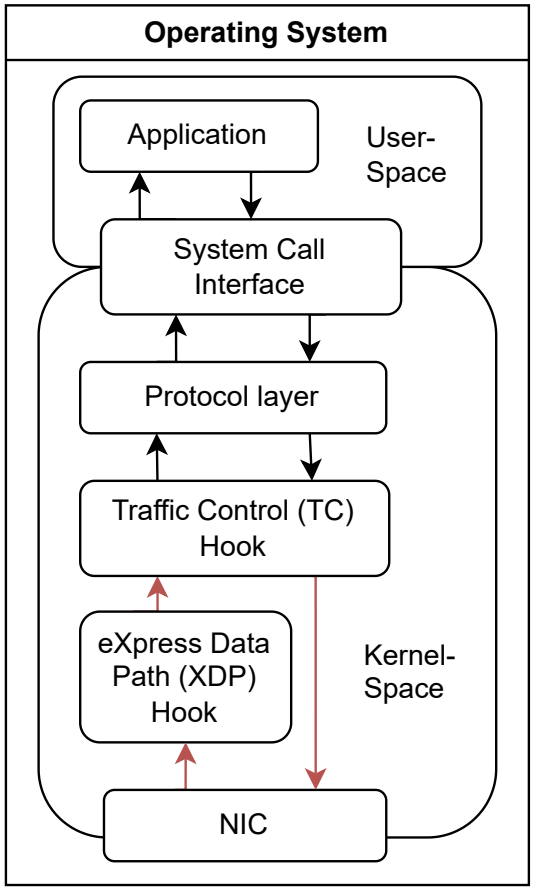
- Started by Google as *Quick UDP Internet Connections*
- Standardized by IETF
- Fast Development Cycle since Userspace Implementation
- Gets rid of Issues like Head-of-Line Blocking



Source: https://sec-consult.com/blog/detail/better-dont-be-too-quick/

eBPF

- Kernel-Internal Virtual Machine
- Used for Packet Filtering and Tracing
- Multiple Hook-Points in the Kernel (e.g. XDP and TC)
- Userspace Communication via Maps



QUIC Adaptations

- Turn off en- and decryption
- Public endpoint for packet registration
- Function pointer additions for eBPF state handling
  - Relay developer defines functions for eBPF map access
  - Called within quic-go if defined

Function Pointer Additions

```
1 /* Function pointer call within actual quic-go code */
2 if packet_setting.ConnectionIdUpdateBPFHandler != nil /* &&
      potentially other conditions */ {
3     packet_setting.ConnectionIdUpdateBPFHandler(connId.Bytes(),
          uint8(connId.Len()), p.connection)
4 }
```

Listing 1: Function-pointer addition to the quic-go library.

```
1 /* Function pointer signature definition within additional
      config file */
2 ConnectionIdUpdateBPFHandler func(id []byte, l uint8, conn
      QuicConnection) = nil
```

Listing 2: The signature will be defined within the library itself.

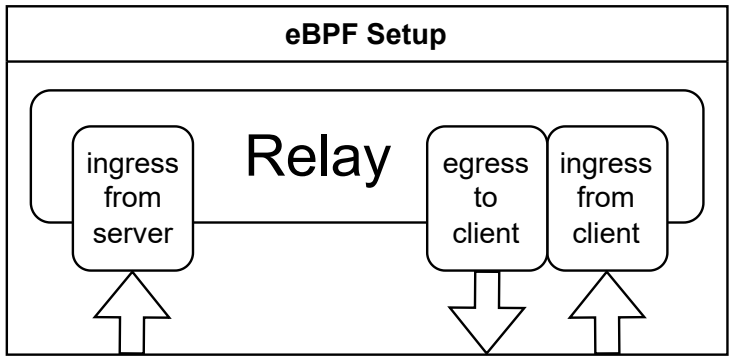
Function Pointer Additions

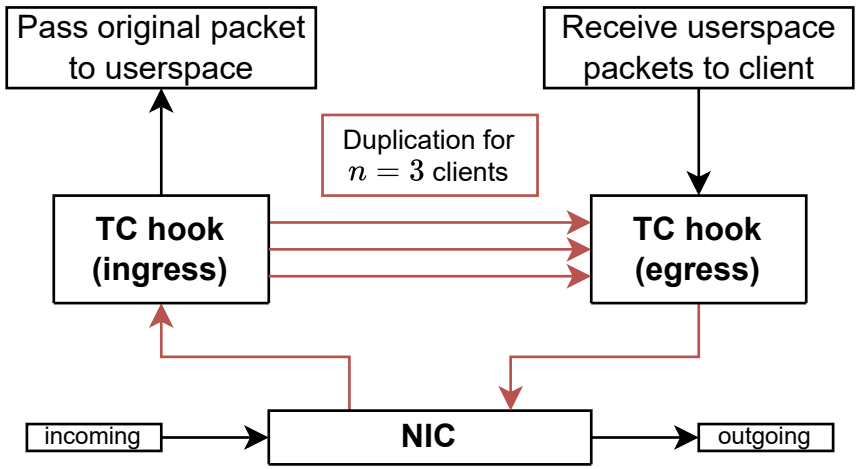
```
1  /* Definition of the function within the local relay code */
2  func localUpdateConnectionId(id []byte, l uint8, conn
       packet_setting.QuicConnection) {
3      /* handle the connection update by interacting with the eBPF
           program */
4  }
5
6  /* Providing the function to the quic-go library */
7  func main() {
8      /* ... */
9      packet_setting.ConnectionIdUpdateBPFHandler =
           localUpdateConnectionId
10     /* ... */
11 }
```

Listing 3: An example of how the addition looks on the relay side.

eBPF Setup

- Three eBPF Programs
  - Client ingress (client registration)
  - Server ingress (packet duplication and forwarding)
  - Client egress (state management)



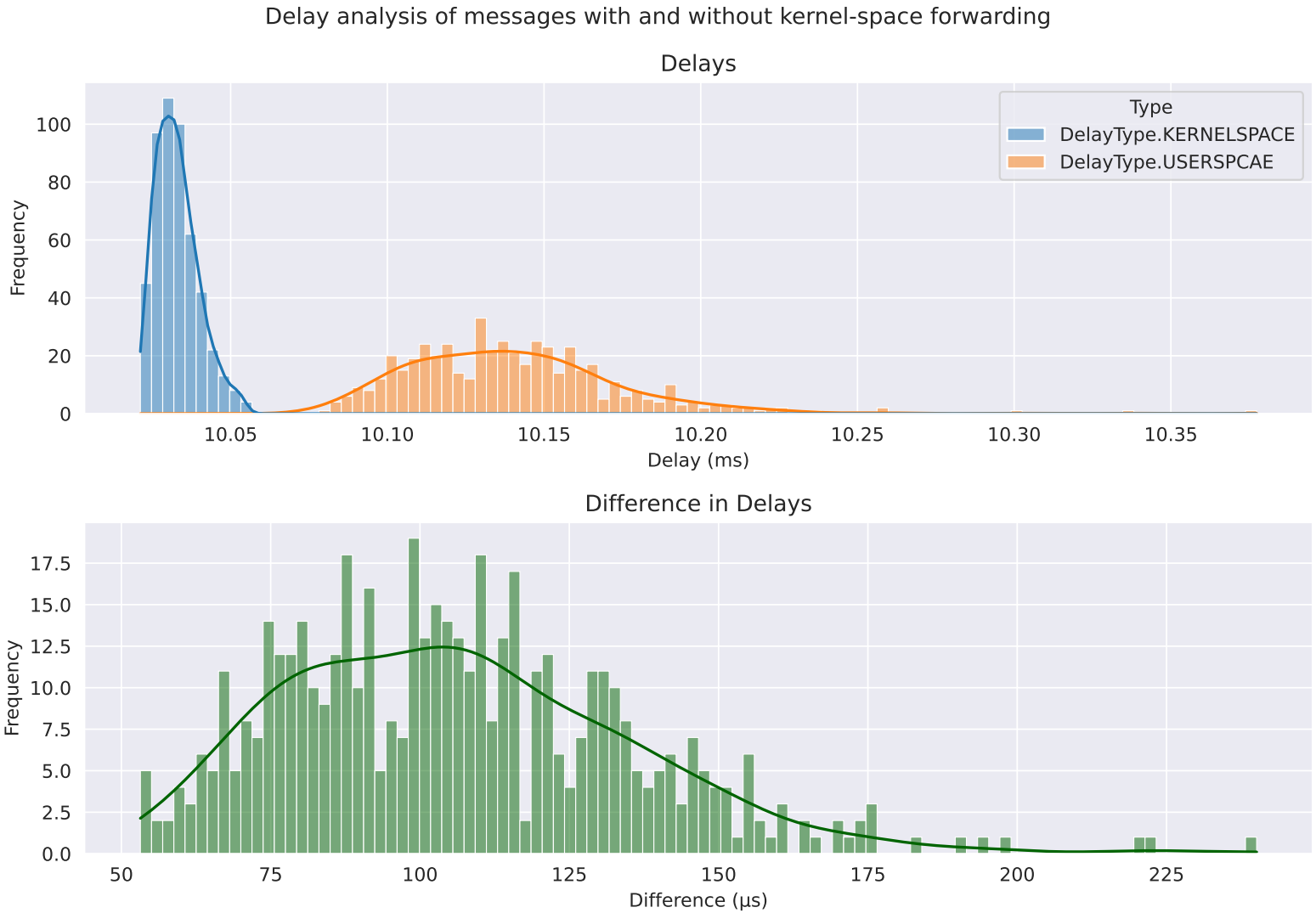


Userspace Synchonization

Congestion Considerations

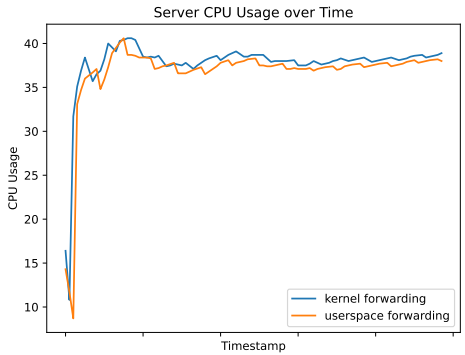
Test Setup

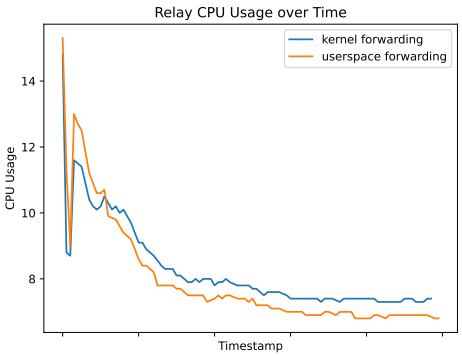
Test Results Delay Reduction

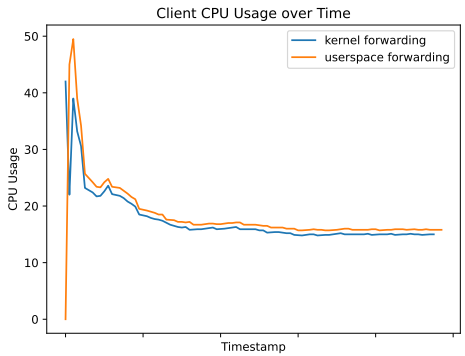


Test Results CPU Usage

- No Impact on CPU Usage
- Fewer System Calls
  - Mainly due to reduced Userspace Synchronization







System Calls

- Example Stream of 30 Seconds
- Overall System Calls
  - Userspace forwarding: 296132 calls
  - eBPF forwarding: 225674 calls
  - Reduction of 24%
- *futex*
  - Reduction of 34%
  - 21666 calls instead of 32940
- *nanosleep*
  - Reduction of 42%
  - 14293 calls instead of 24716
- *epoll_wait*
  - Reduction of 67%
  - 11289 calls instead of 34149

Conclusion

Future Work