

A Structural Approach to Modeling Encrypted Connections

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Overview

- Sequence of Lengths (SOL) Background
- Zeek Background
- Applications of SOL using Zeek (pictures and graphs)
 - SSH
 - RDP
 - SSL
- Future work

Sequence of Lengths (SOL) Background

- Inspired by
 - SPLT feature in *Deciphering Malware's use of TLS (without Decryption)* [1]
 - Implementation of feature extraction - Joy [2]
- Generalizes across protocols - works on encrypted ones, too
 - Lengths of data
 - Order of data
 - Direction of data
- Combines well with rule based expert systems - maybe ML, too

Zeek Background

Zeek : "a powerful network analysis framework that is much different from the typical IDS you may know." ^[6]

- SDN approach to network security monitoring
 - Event-driven scripting language
- Protocol parsing
 - Analyzers detach once encryption begins to save resources
 - SOL can be used instead of full parsing
- Logging, file extraction, intel matching, and more

Applications of SOL using Zeek

Within Zeek, sequences can be represented as vectors

vector : "An associate array that maps from one set of values to another... its indices are non-negative integers, starting from zero" ^[4]

- Originator message lengths are positive
- Responder message lengths are negative
- Order is preserved using vector indices

Applications of SOL using Zeek

```
v: vector of int = {24, -24, 48, -12, 36, -42, 24, -124, -12, 96, -48, -48, 48}
```

Applications of SOL using Zeek

```
v: vector of int = {24, -24, 48, -12, 36, -42, 24, -124, -12, 96, -48, -48, 48}
```

First message length

First originator message length

Applications of SOL using Zeek

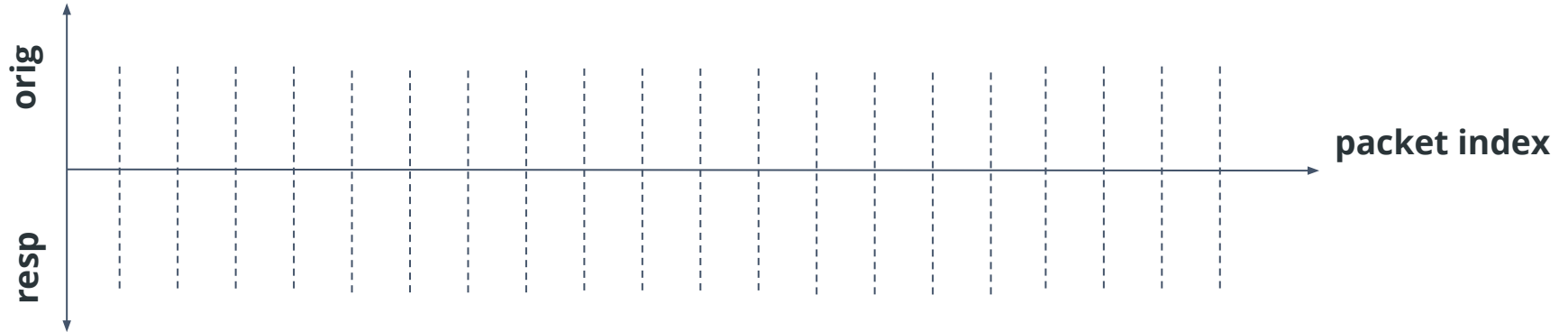
```
v: vector of int = {24, -24, 48, -12, 36, -42, 24, -124, -12, 96, -48, -48, 48}
```

Second message length

First responder message length

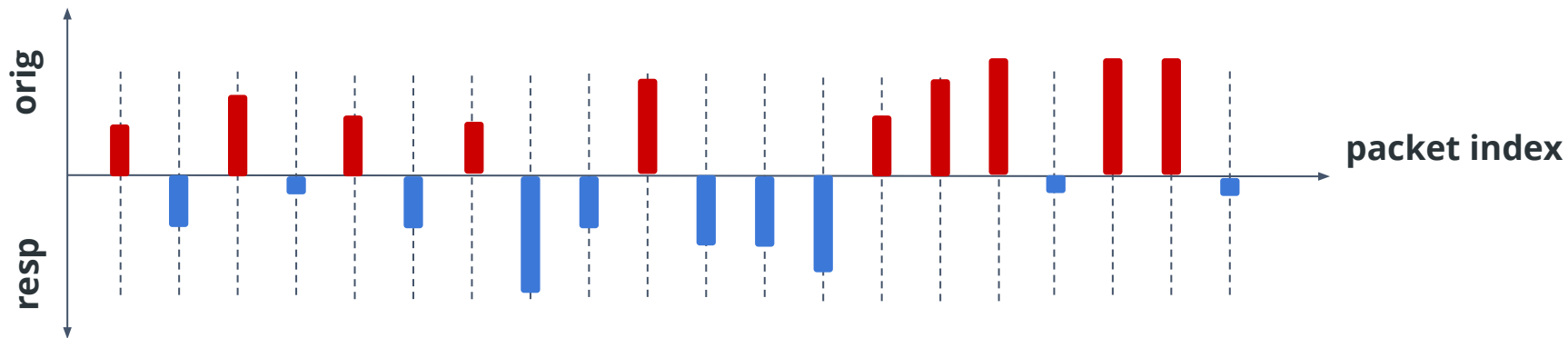
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Applications of SOL using Zeek

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Applications of SOL using Zeek

Useful vector operations for rule building:

- Index slicing (heads and tails)
- Summary statistics (max, min, mean, range, etc)
- "Runs"
 - Increasing
 - Decreasing
 - Repeating
- PCR ^[7]
- Find first, second, third occurrence of...
 - Positive
 - Negative
 - "run"

Applications of SOL using Zeek: SSH

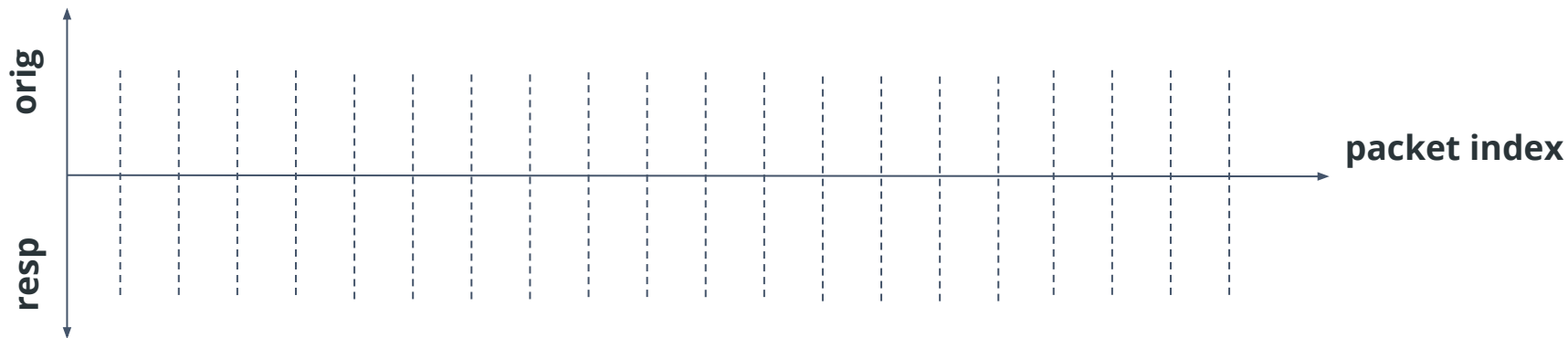
- SSH consists of 3 sub-protocols
 - Transport
 - Authentication
 - Connection
- SSH cleartext handshake/negotiations
- SSH PDUs are called messages
 - One or more messages are formatted in an SSH "packet" struct

[3]

Applications of SOL using Zeek: SSH

Cleartext (negotiations)

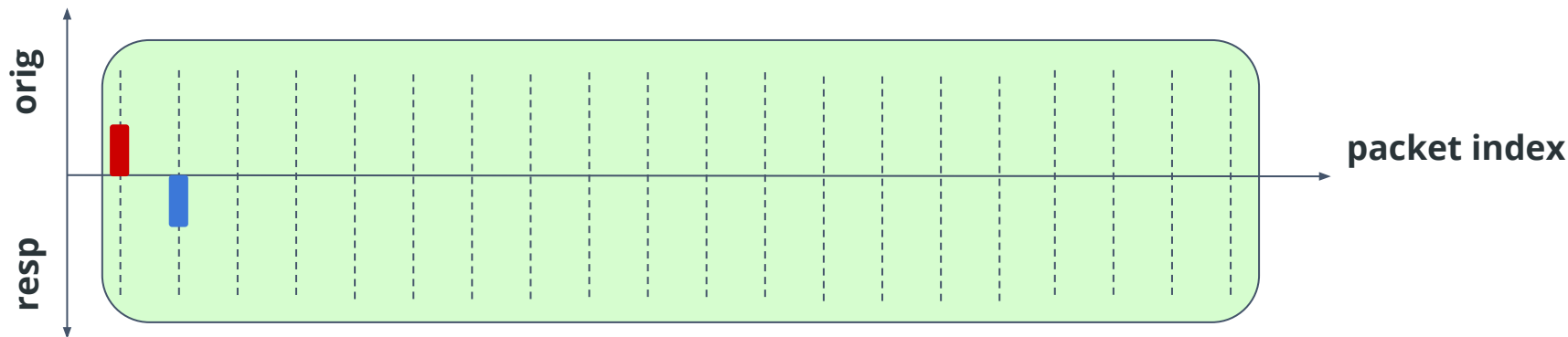
`v: vector of int`



Applications of SOL using Zeek: SSH

Cleartext (negotiations) Transport (encryption)

```
v: vector of int = {24, -24,
```



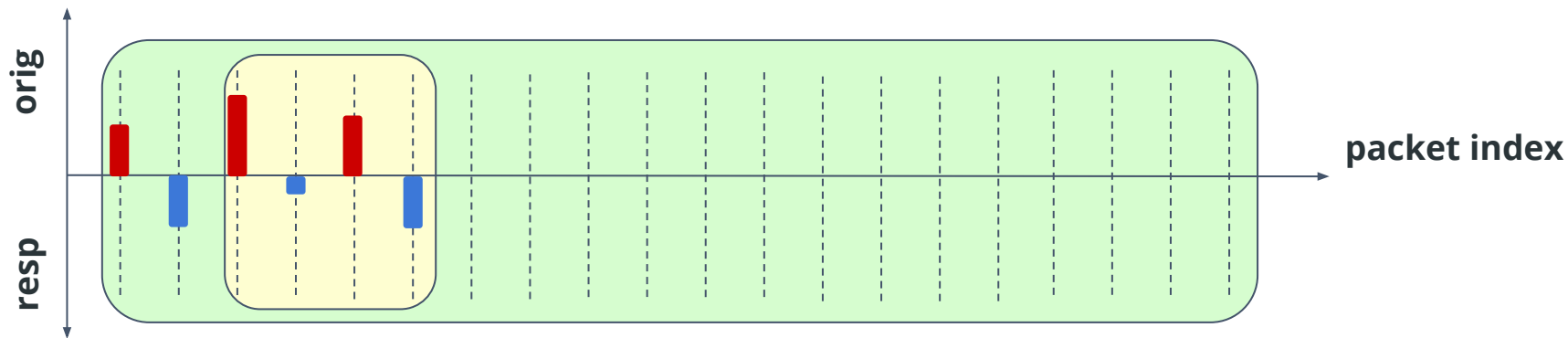
Applications of SOL using Zeek: SSH

Cleartext (negotiations)

Transport (encryption)

Authentication

`v: vector of int = {24, -24, 48, -12, 36, -42,`



Applications of SOL using Zeek: SSH

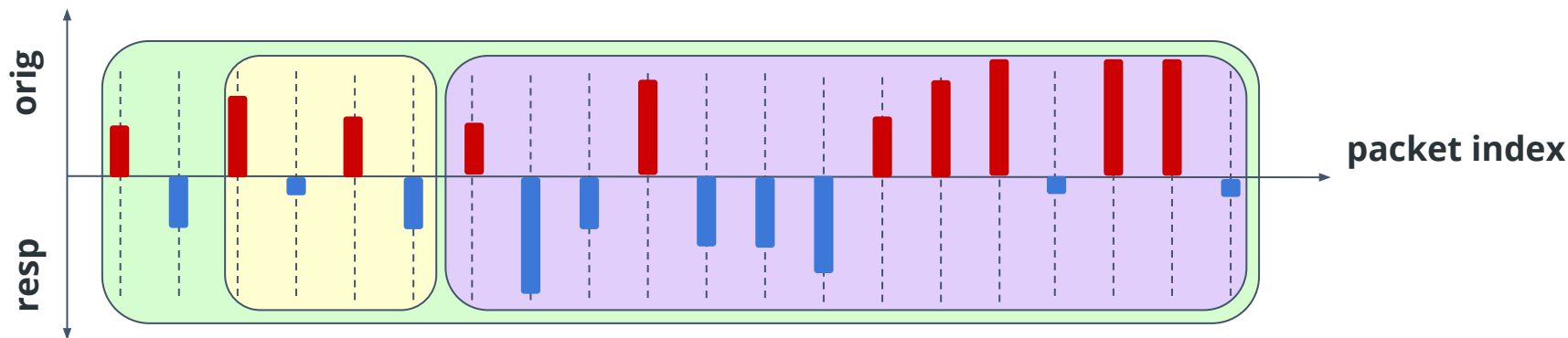
Cleartext (negotiations)

Transport (encryption)

Authentication

Connection

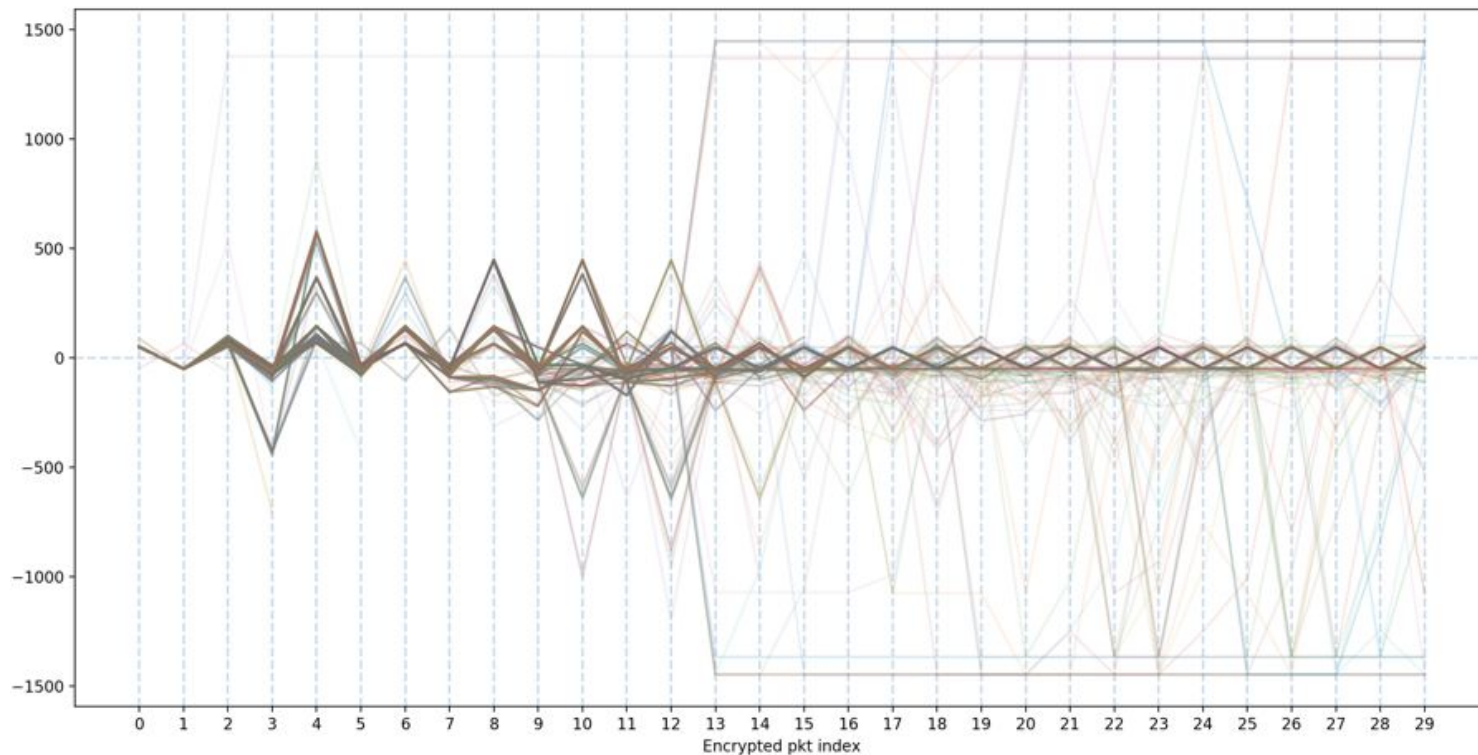
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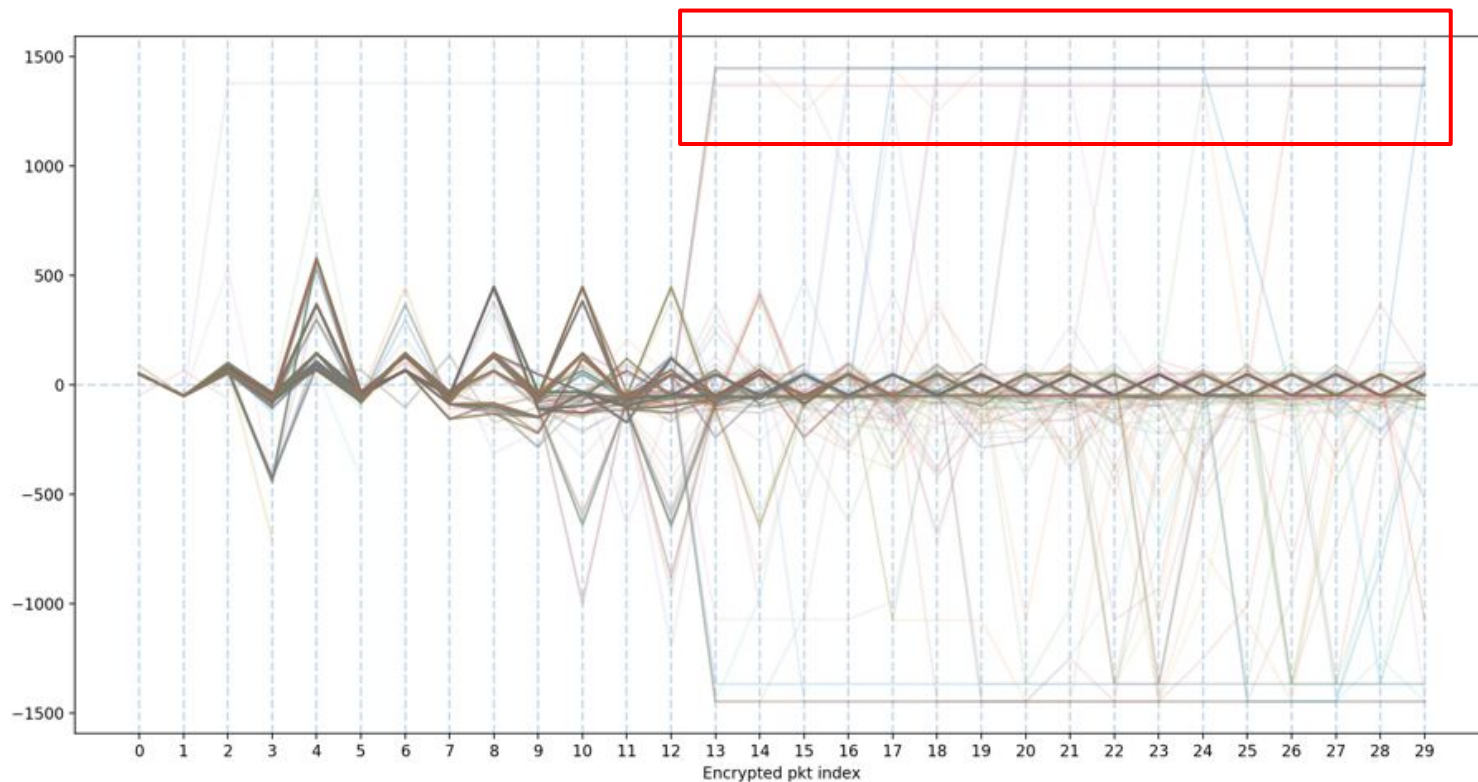
Applications of SOL using Zeek: SSH

- Authentication
 - Bruteforce guessing
 - Interactive vs automated authentication
 - Password vs pubkey
- Mode of use
 - File transfers vs keystrokes
 - Timing profiles
 - Counting keystrokes
 - Root password lengths, oh my!
- State machine transitions
 - Authentication bypass exploits
 - *do not pass authentication, do not collect \$200*
 - Protocol is SSH in the clear and something different once encrypted

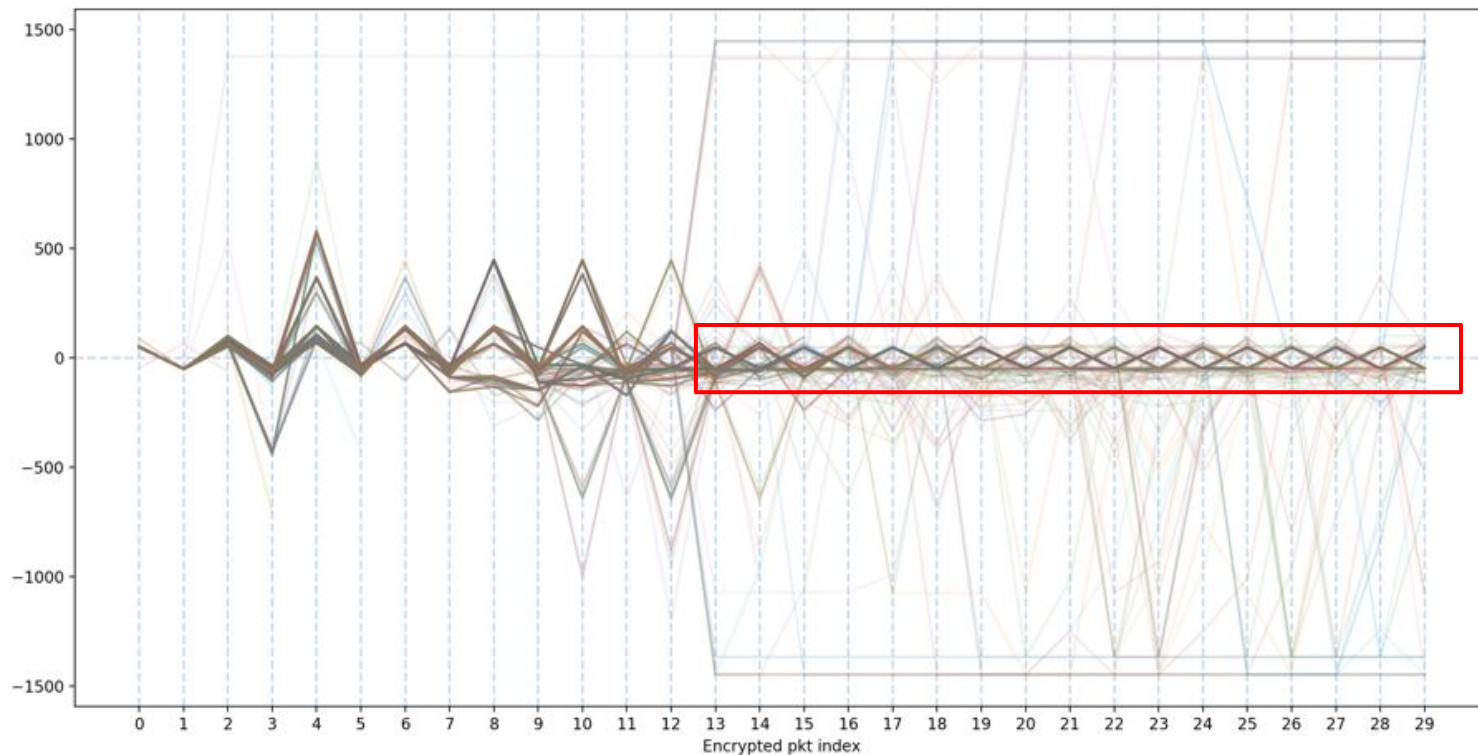
Applications of SOL using Zeek: SSH



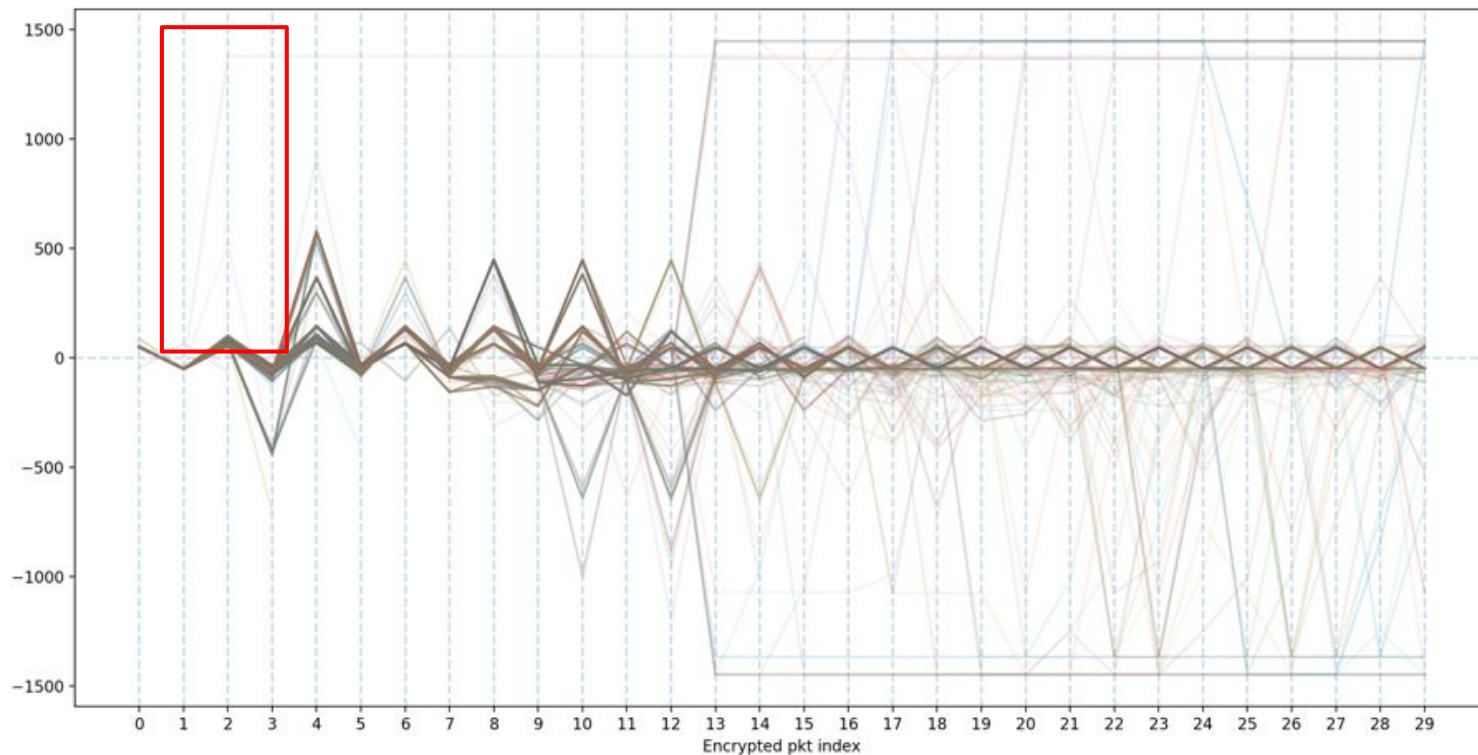
Applications of SOL using Zeek: SSH



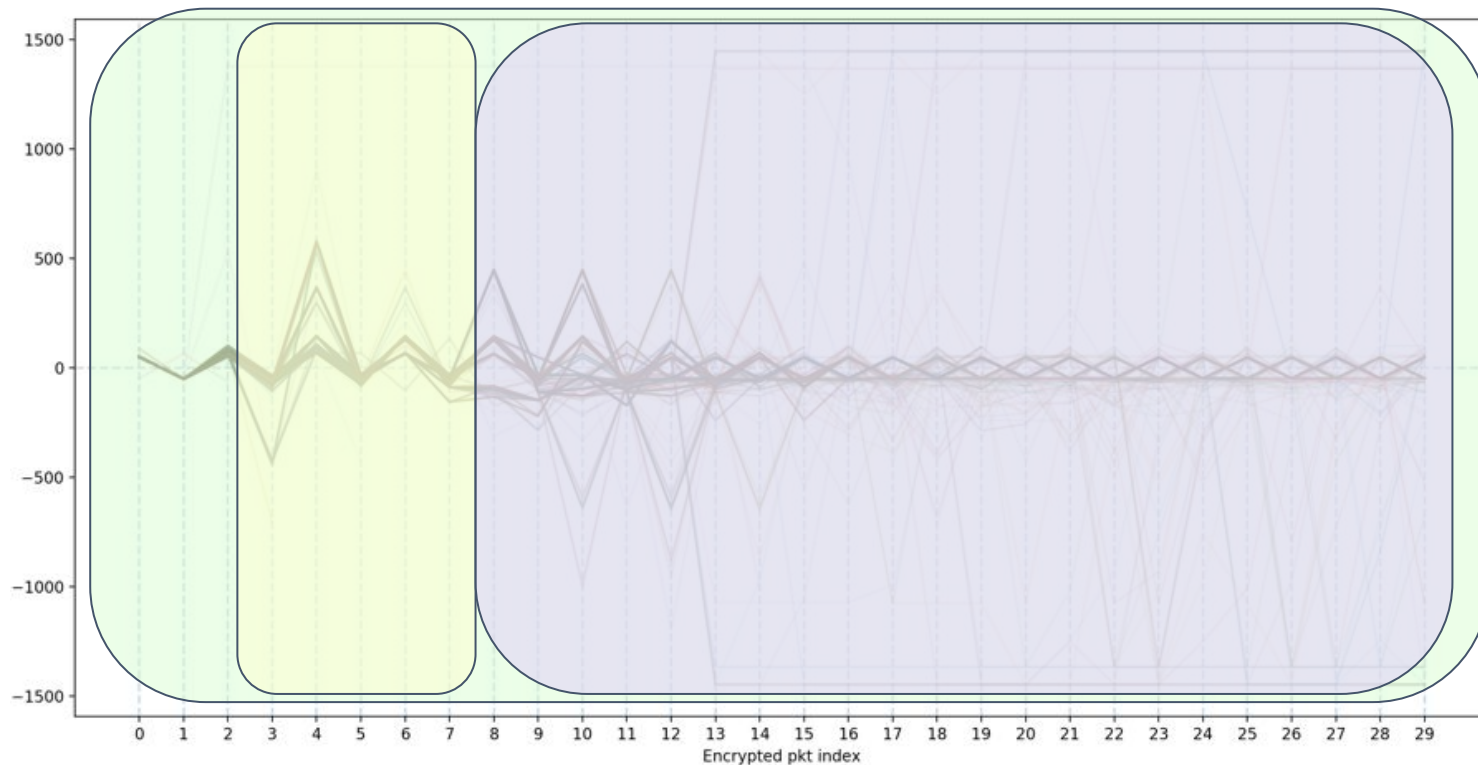
Applications of SOL using Zeek: SSH



Applications of SOL using Zeek: SSH



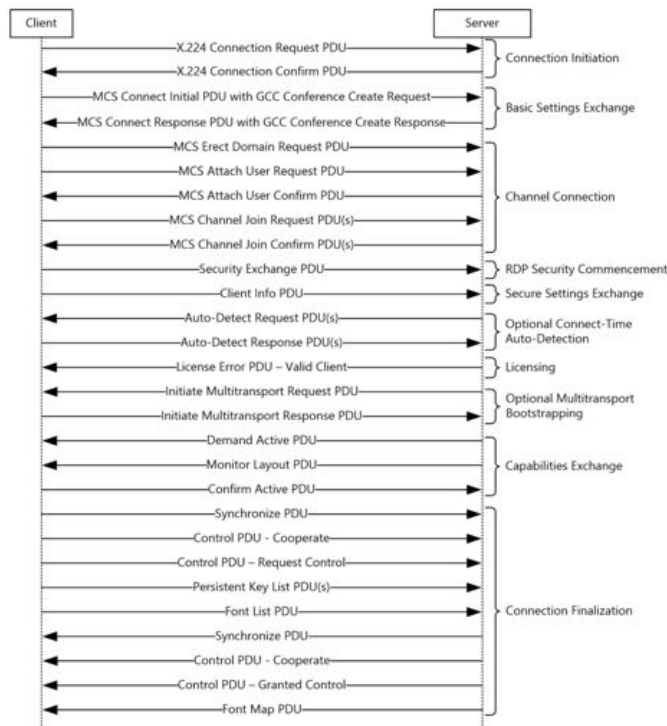
Applications of SOL using Zeek: SSH



Applications of SOL using Zeek: RDP

- non-NLA
 - native crypto
 - Unauthenticated clients can do things
 - Channels opened before authentication + encryption
 - Can monitor for `MS_T120` (Bluekeep) channel opens
- NLA
 - TLS
 - Authenticate client before anything else
 - Channels opened after authentication + encryption
 - Bluekeep exploits
 - Requires valid creds
 - Occurs after encryption begins

Applications of SOL using Zeek: RDP Connection Sequence



[5]

Figure 1: Remote Desktop Protocol (RDP) connection sequence

Applications of SOL using Zeek: RDP Connection Sequence

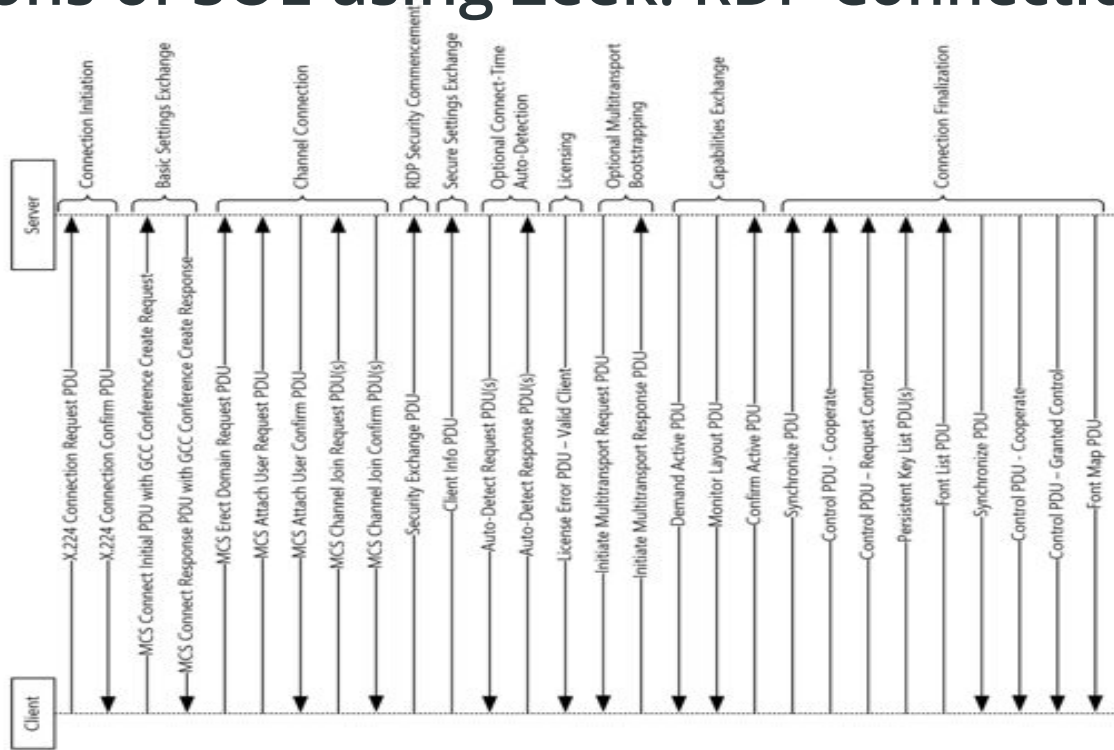


Figure 1: Remote Desktop Protocol (RDP) connection sequence

Applications of SOL using Zeek: RDP Connection Sequence

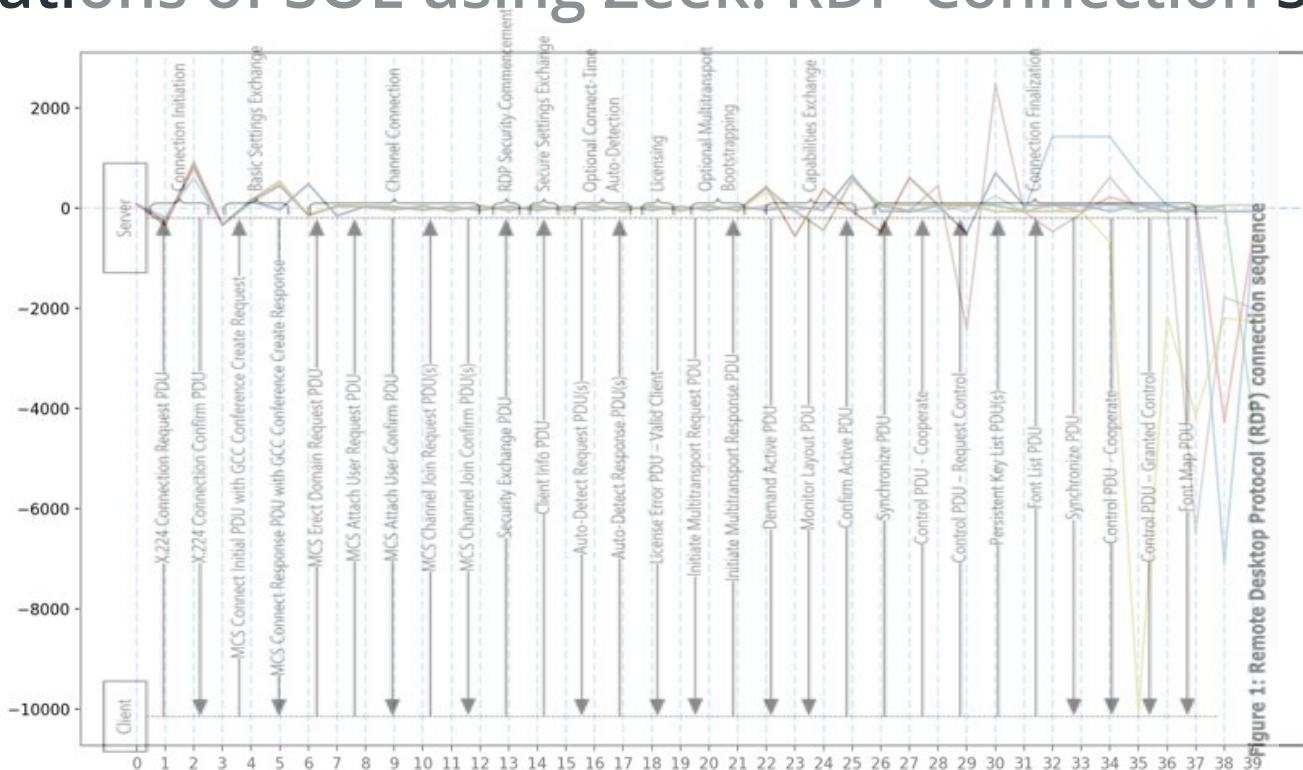
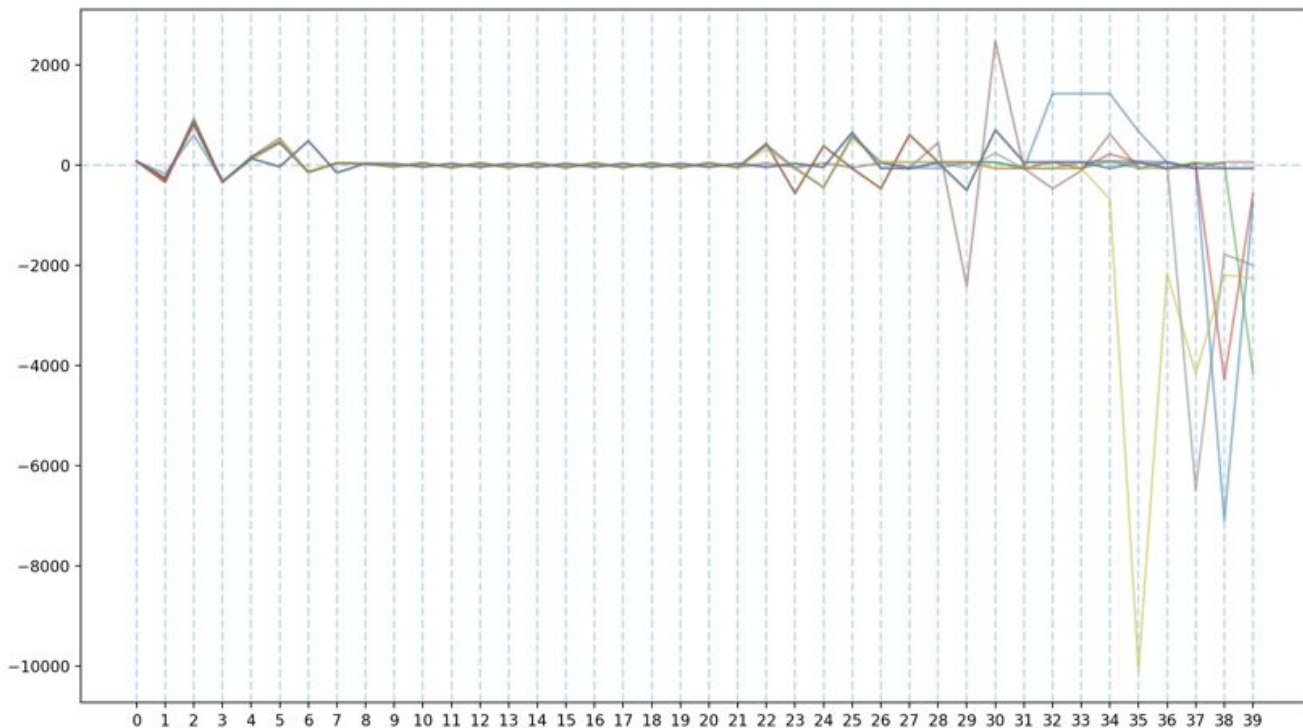
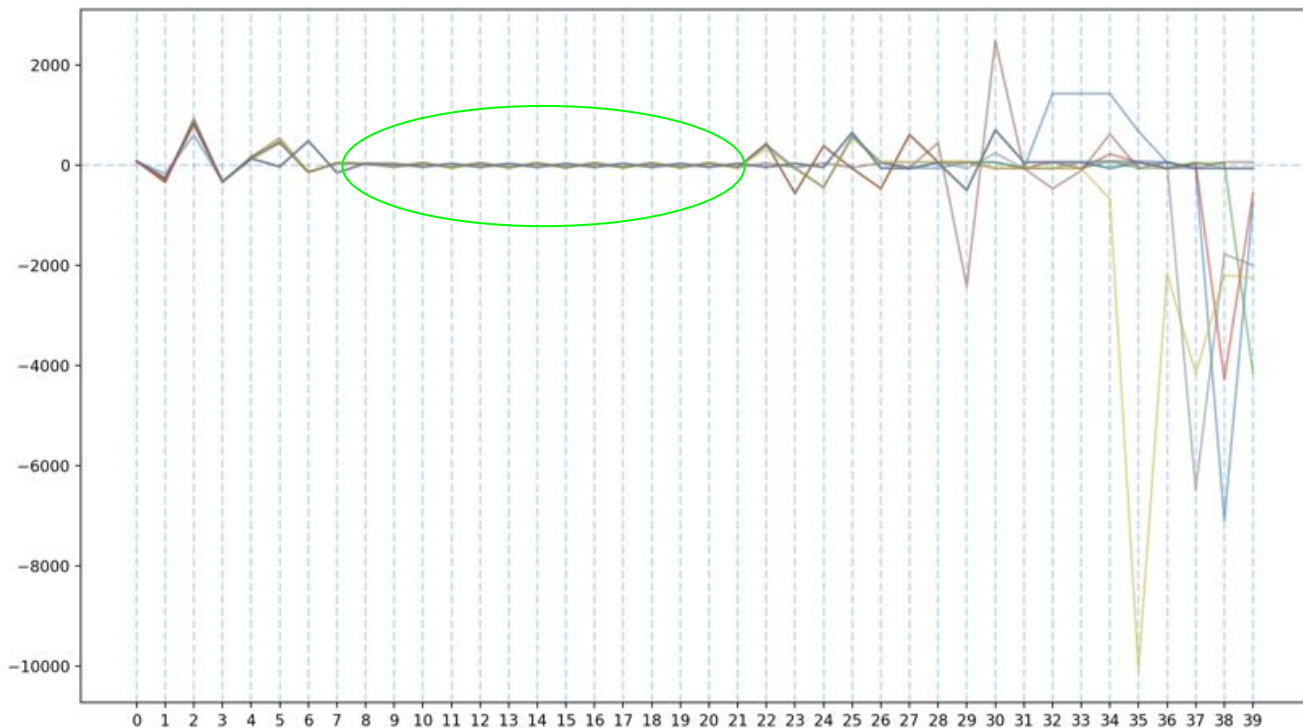


Figure 1: Remote Desktop Protocol (RDP) connection sequence

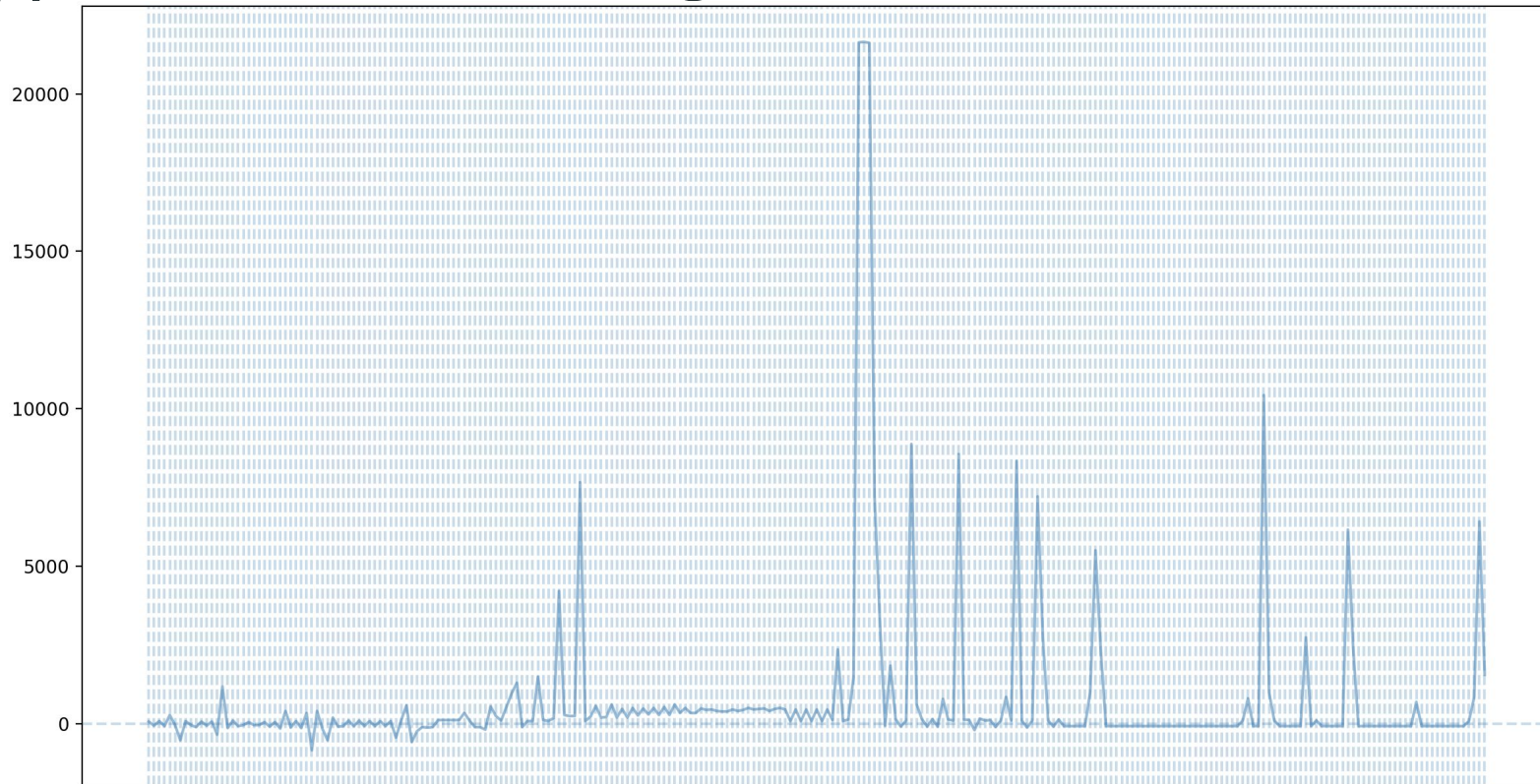
Applications of SOL using Zeek: RDP (NLA - TLS, ~10)



Applications of SOL using Zeek: RDP (NLA - TLS, ~10)



Applications of SOL using Zeek: RDP over SSH (NLA - TLS, 1)

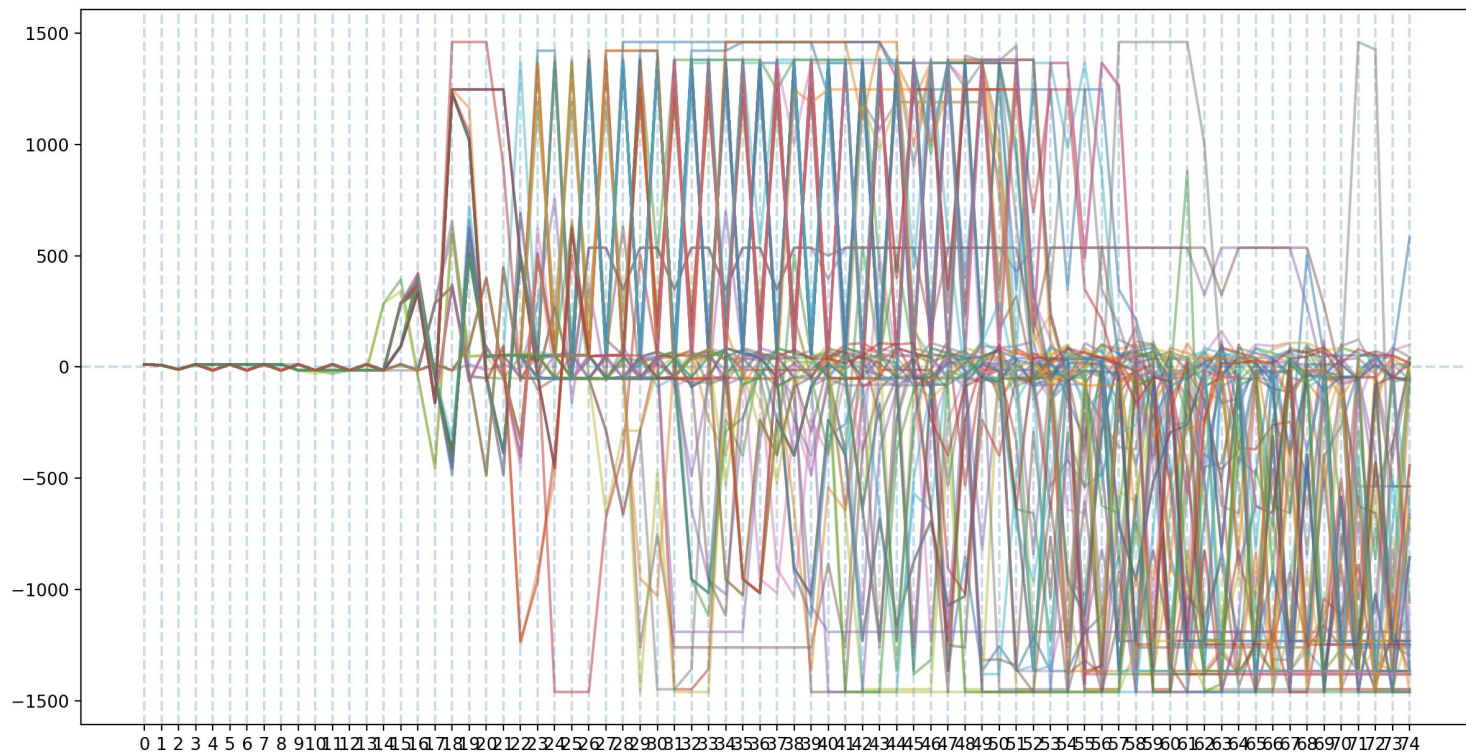


See also: [8]

Applications of SOL using Zeek: RDP (NLA - TLS, ~2300)



Applications of SOL using Zeek: RDP (non-NLA - native, ~70)



Applications of SOL using Zeek: TLS

SPLT can be used to identify malware communications over TLS.

Can it conceptually be applied to identify other application layer protocols?

Applications of SOL using Zeek: TLS

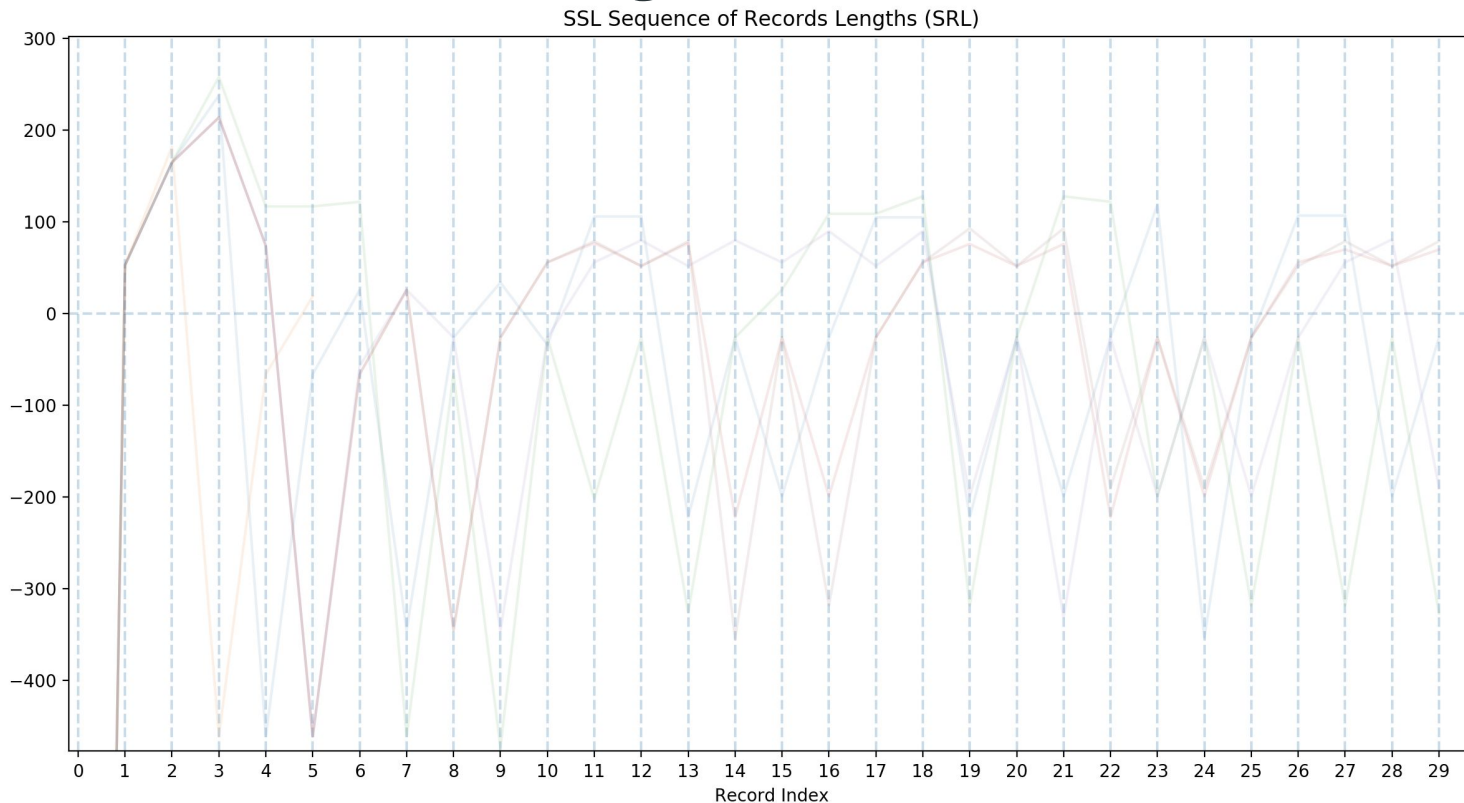
SPLT can be used to identify malware communications over TLS.

Can it conceptually be applied to identify other application layer protocols?

I think so.

DNS has intrinsic size ceilings/floors and expected PCRs [7]

Applications of SOL using Zeek: TLS (DoH POSTs and GETs)



[9]

Future Work

- Apply LSTM RNNs to investigate application layer protocols' SOLs
- Incorporate timing deltas (sequence of times/deltas)
 - Timing of specific pkts or states of a protocol can be insightful
- Generically identifying TCP proxies:
 - Align sequences of two connections (within a time window)
 - If one sequence is a multiple of the other, it may be a tunnel

References and Resources

1. <https://arxiv.org/pdf/1607.01639.pdf>
2. <https://github.com/cisco/joy>
3. <https://corelight.blog/2019/05/07/how-zeek-can-provide-insights-despite-encrypted-communications/>
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