UNIVERSITY OF SAN FRANCISCO

Simulating Network Link Compression in Loss-less Wireless Sensor Networks (WSNs) Environment

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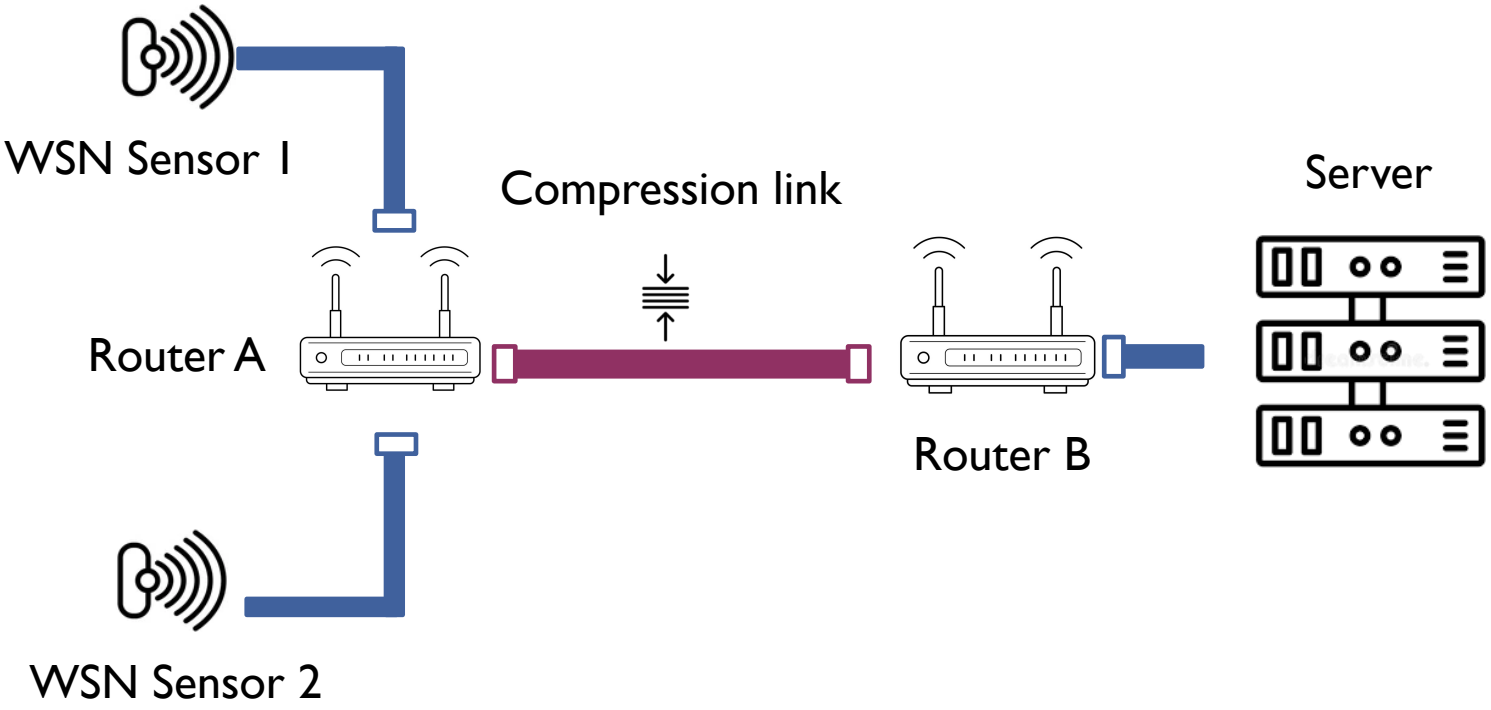
Motivation

More and more industries adapt to WSNs and generate WSN node in the network. Loss-less data compression is essential solution to handle the high data traffic produced by WSNs. Hence, simulating loss-less compression link in open-source Network Simulator 3 (NS3) and validate the simulated environment motivate us to implement this research project.

Objective

- To simulate network link compression in Loss-less Wireless Sensor Networks (WSNs)
- To compress network link using zLib library
- To validate the simulated environment

Overview


WSN Sensor 1
Compression link
Server
Router A
Router B
WSN Sensor 2

Terms:

High Entropy:

High Entropy traffics is a wide verity of values between 0x00 and 0xFF.
It may consist of uniform distribution and dump data.

Low Entropy:

Low Entropy traffics is a limited range of values and
very skewed distribution of data and limited ASCII characters.

LZS Compression

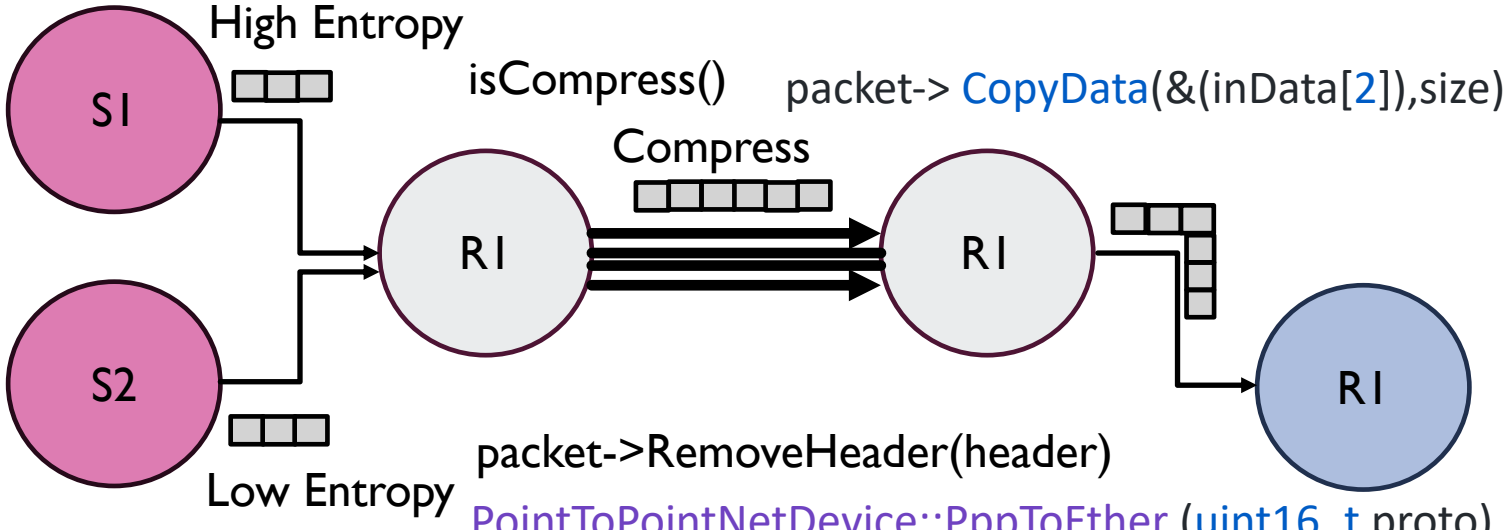
- Lempel–Ziv–Stac is a lossless data compression algorithm
- Combination of the LZ77 sliding-window compression and fixed Huffman coding.

Length	Bit encoding
2	00
3	01
4	10
5	1100
6	1101
7	1110
8 to 22	1111 xxxx, where xxxx is length − 8
23 to 37	1111 1111 xxxx, where xxxx is length − 23
length > 37	(1111 repeated N times) xxxx, where N is integer result of (length + 7) / 15, and xxxx is length - (N*15 − 7)

Ref. Cisco

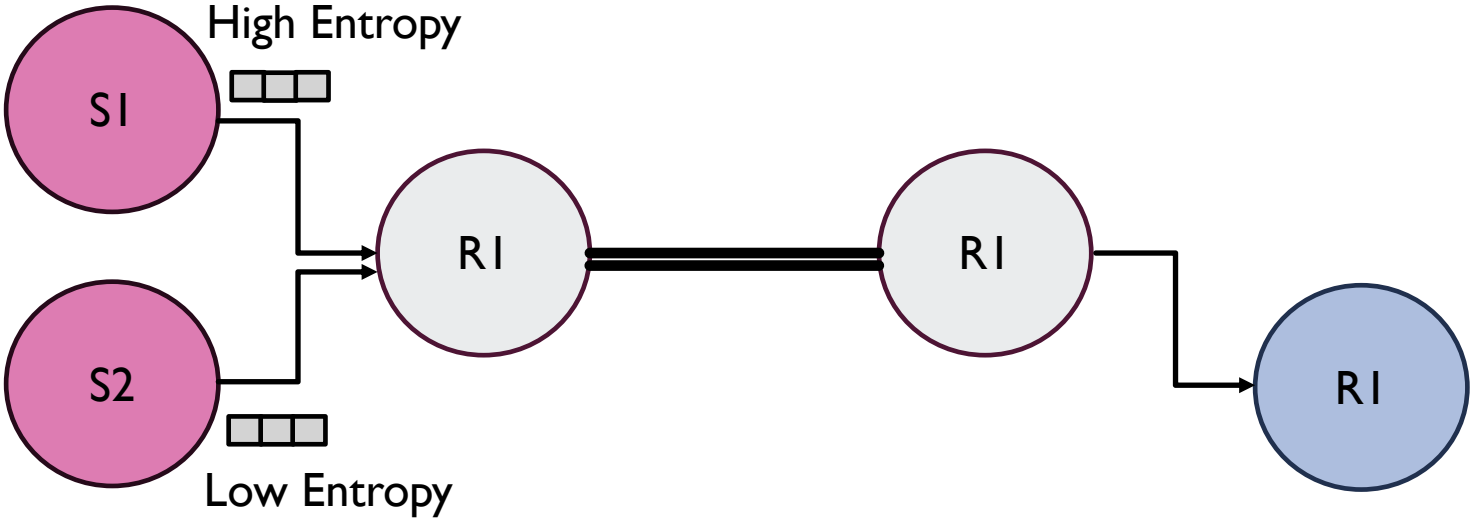
System Architecture

PointToPointNetDevice::Send()

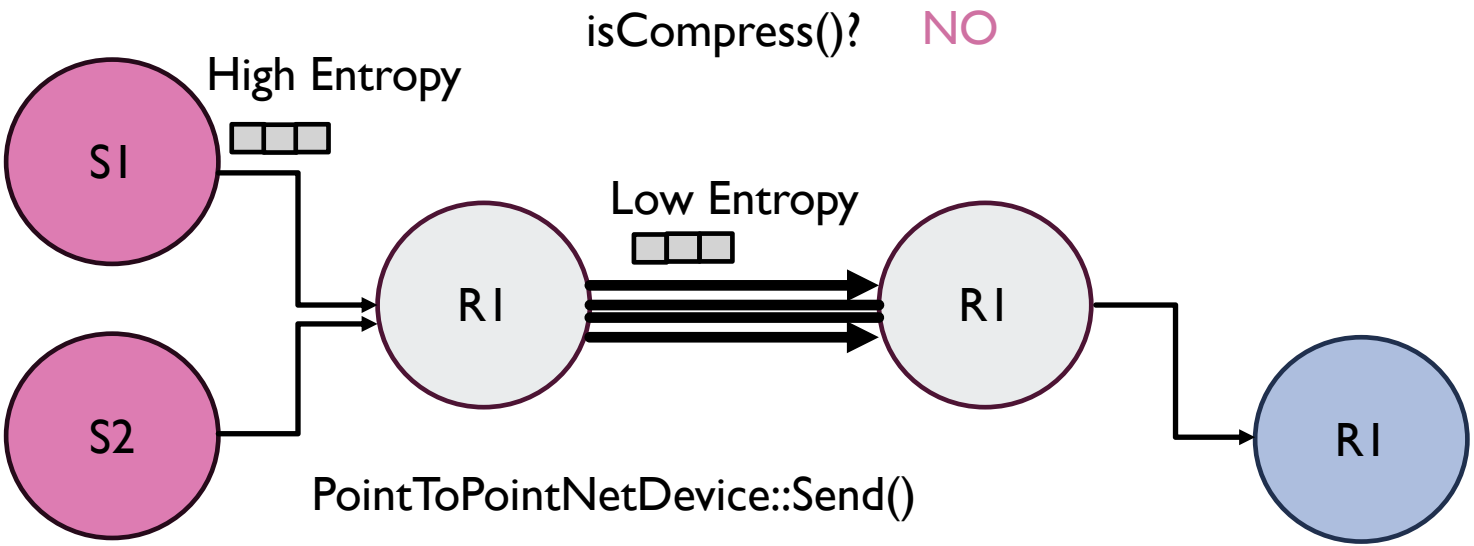


PointToPointNetDevice::Send()

System Architecture



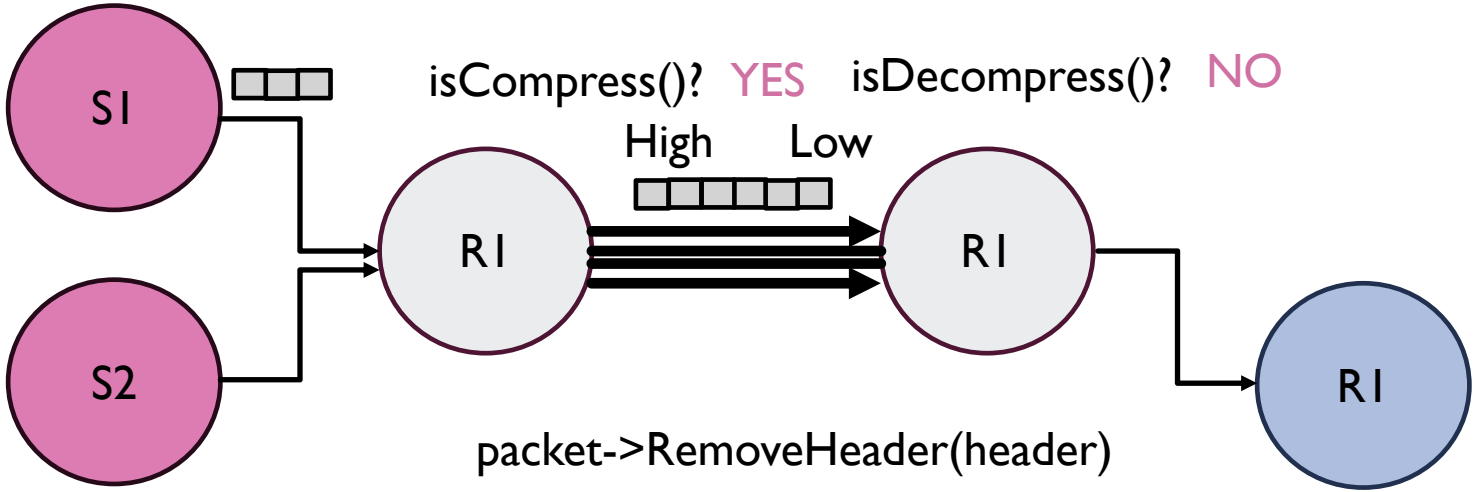
System Architecture



System Architecture

PointToPointNetDevice::Send()

packet-> CopyData(&(inData[2]),size)

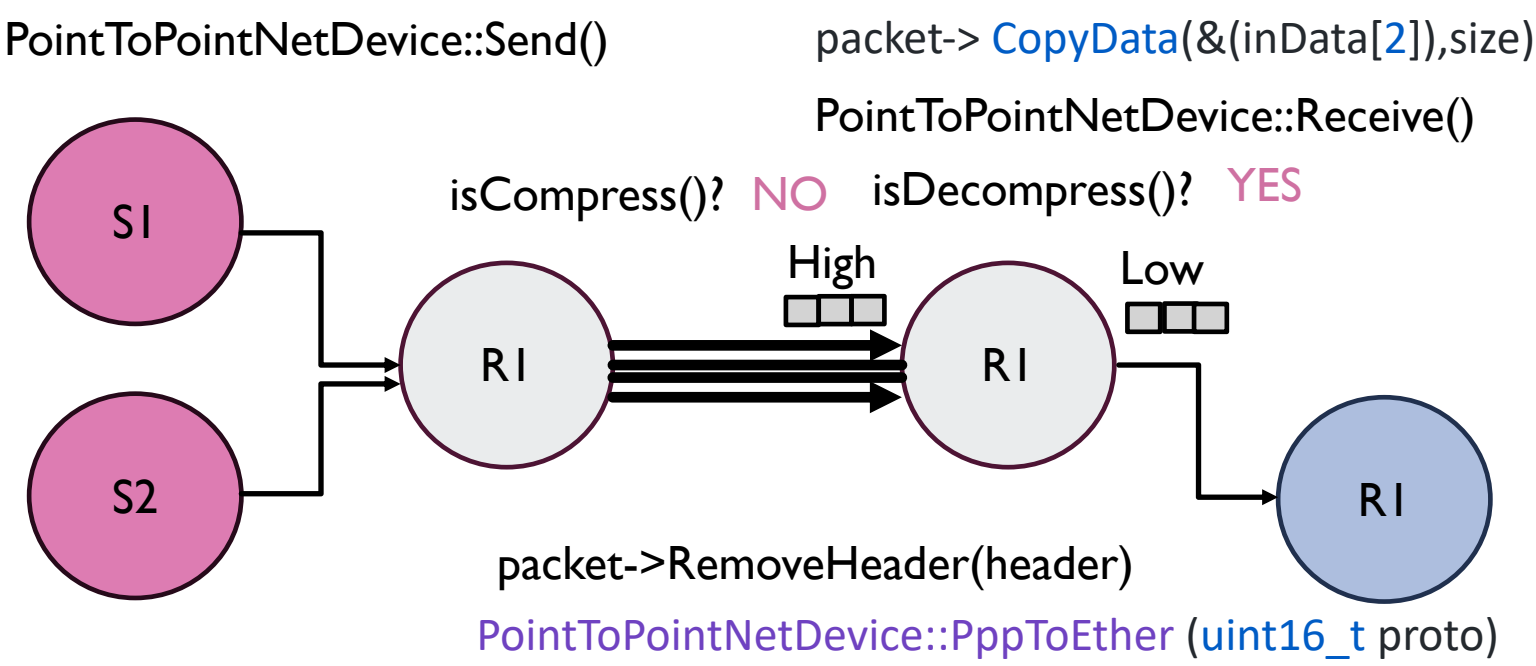


packet->RemoveHeader(header)

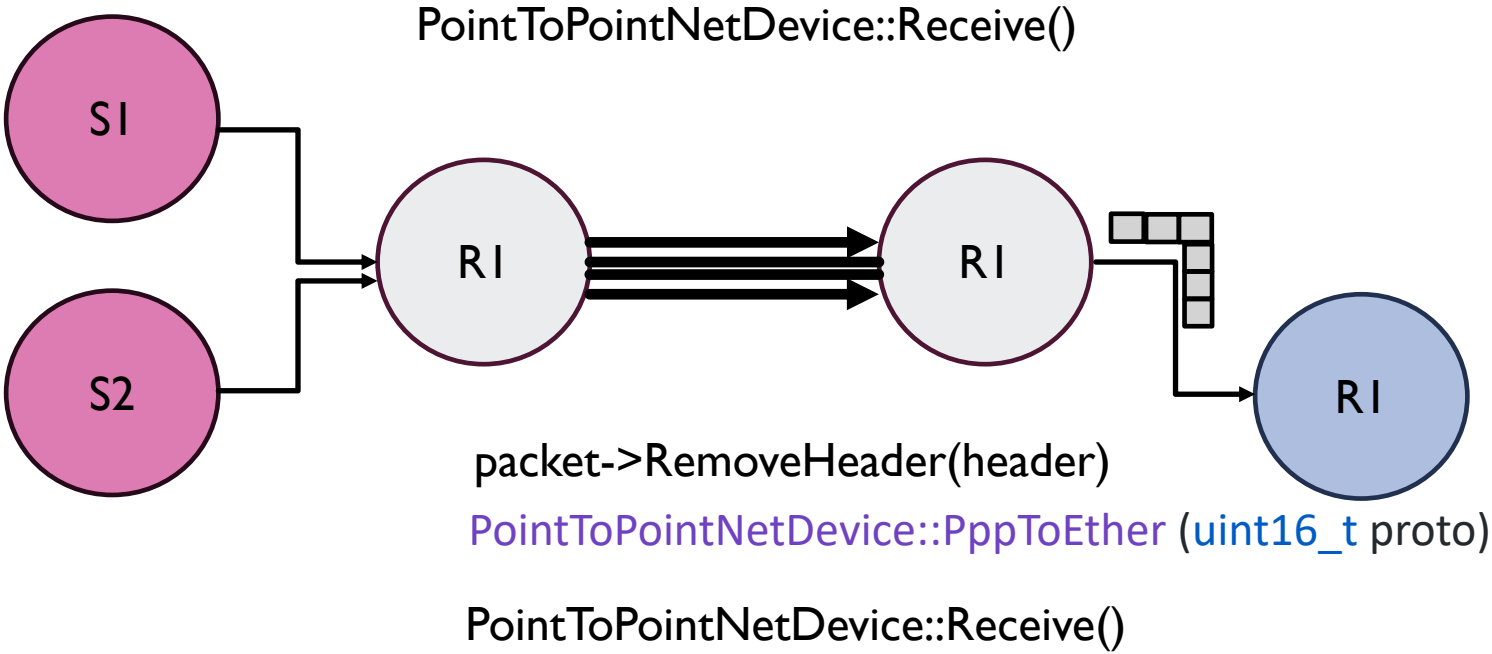
PointToPointNetDevice::PppToEther (uint16_t proto)

PointToPointNetDevice::Send()

System Architecture

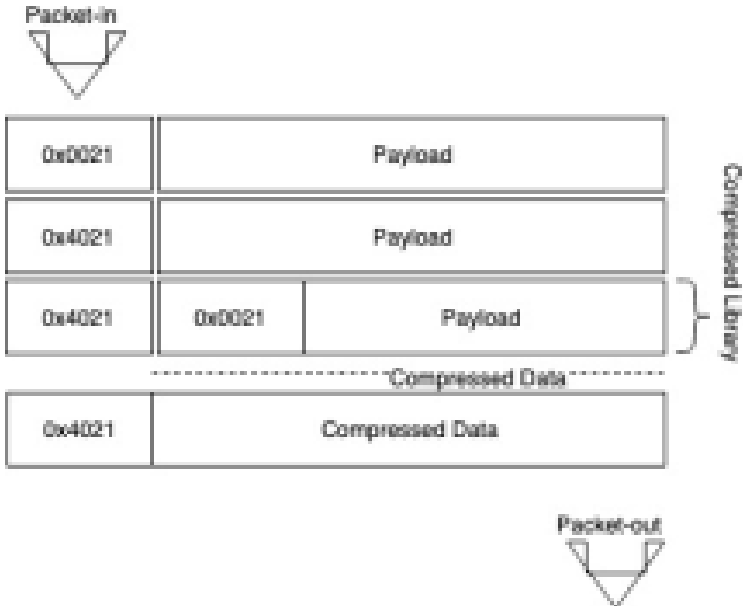


System Architecture



System Architecture

Packet arrival



Packet Departure

System Design

NS3:

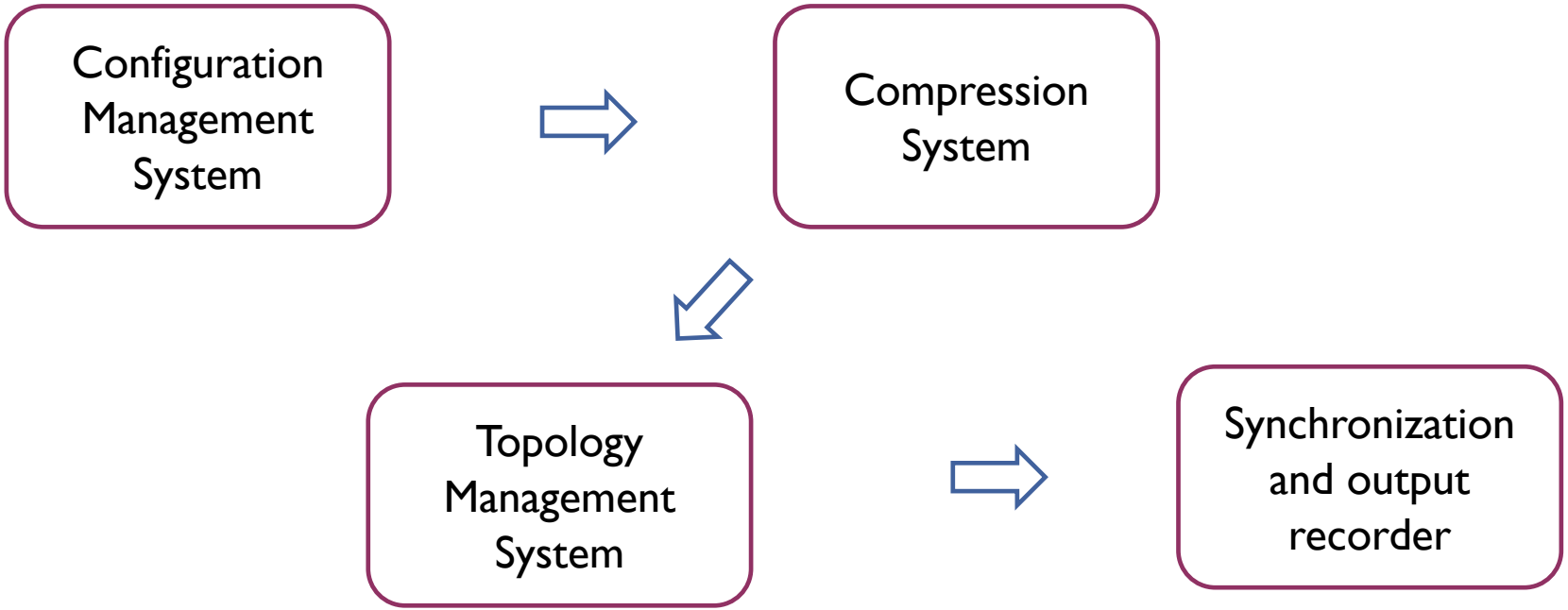
.udp-client.cc
.udp-server.cc
.point-to-point-net-device.cc
.point-to-point.cc (application)

```
.AddAttribute ("Entropy","Boolean Value", BooleanValue(true),
MakeBooleanAccessor(&UdpClient::m_entropy),
MakeBooleanChecker());
```

```
bool isHighEntropy; /* entropy flag */

bool doCompress = false; /* Compress flag */
```

System Design

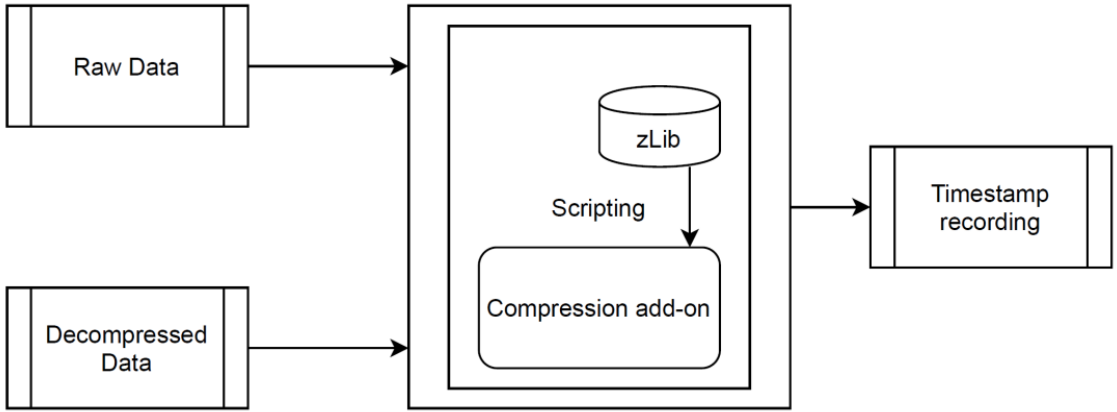


Detection Tool

$$\Delta tH_{HighEntropy} = T_{FirstP\ ktArrival} - T_{LastPktArrival}$$

$$\Delta tL_{LowEntropy} = T_{FirstP\ ktArrival} - T_{LastPktArrival}$$

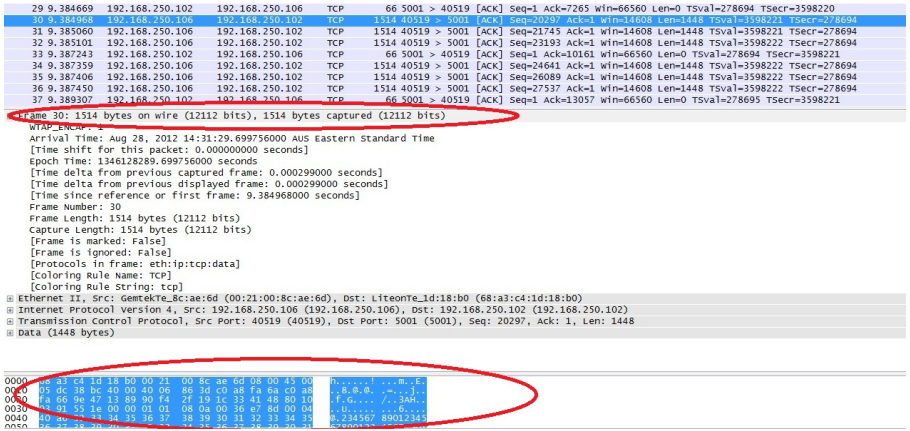
Detection Factor = $\Delta tH - \Delta tL$



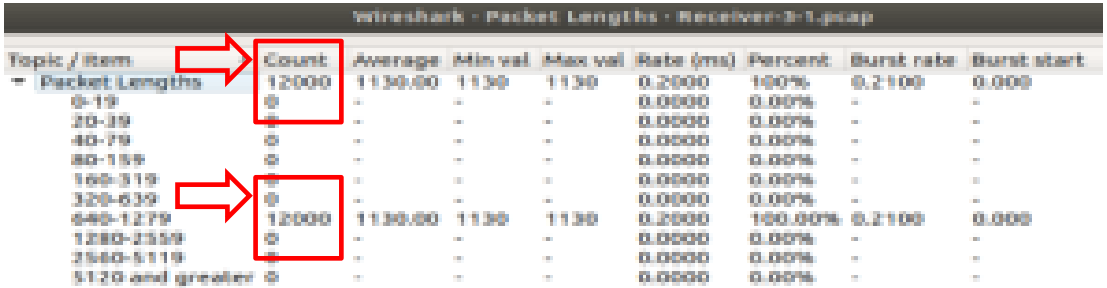
Build the Feature

```
/*
* To compile and build the project
*/
$ cd workspace/Transport-Layer-Security
/ns-3-allinone/ns-3-dev
$ ./waf configure
$ ./waf build
$ ./waf --run "scratch/point2point
--IsHighEntropy=1
--IsCompress=1
--MaxPacketCount=2"
```

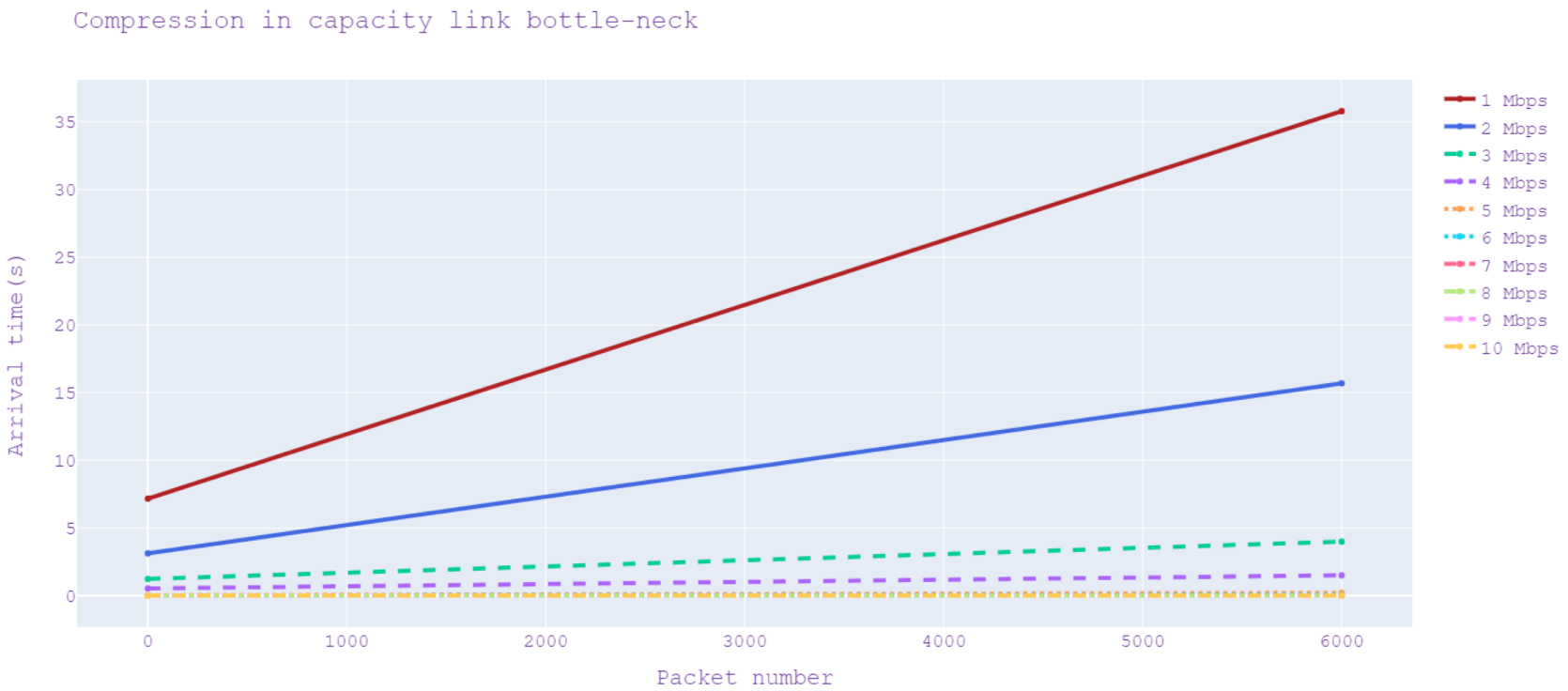
Validation



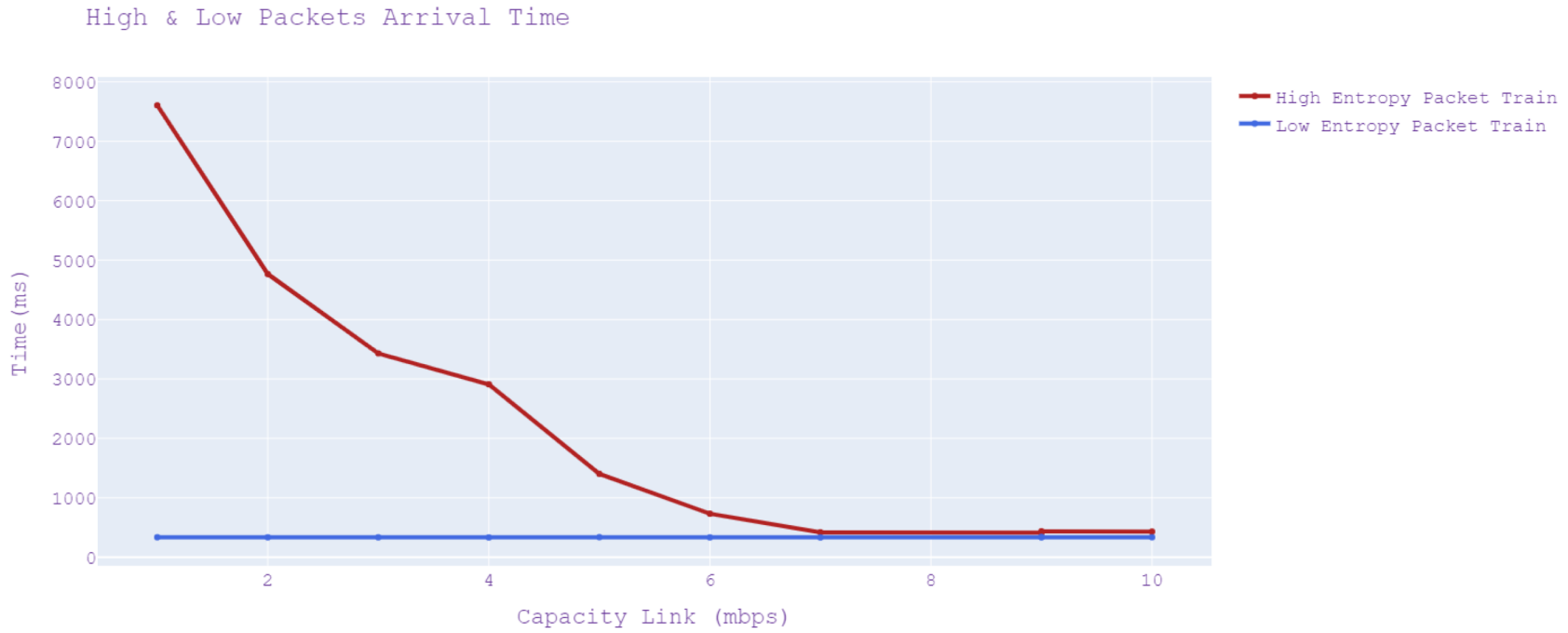
Wireshark Packet Analyzer



Validation


Compression in capacity link bottle-neck
Arrival time(s)
0
5
10
15
20
25
30
35
0
1000
2000
3000
4000
5000
6000
Packet number
1 Mbps
2 Mbps
3 Mbps
4 Mbps
5 Mbps
6 Mbps
7 Mbps
8 Mbps
9 Mbps
10 Mbps

Validation


High & Low Packets Arrival Time
Time (ms)
8000
7000
6000
5000
4000
3000
2000
1000
0
2
4
6
8
10
Capacity Link (mbps)
High Entropy Packet Train
Low Entropy Packet Train

Conclusion

- Enriched open-source NS-3 simulation environment with compression feature
- Simulated packet compression algorithm when the network faced with high traffic .
- Testing and validation of compression and decompression embedded model.
- Result shows Compression has no effect on the data transmission speed if there is no bottle-neck exists in the capacity compression link.

Reference

- U.S. National Science Foundation (NSF), “A discrete-event network simulator for internet systems, NS-3 Network Simulator”, https://www.nsnam.org/, 2011-2021.

- V. Pournaghshband, A. Afanasyev, P. Reiher, “End-to-end detection of compression of traffic flows by intermediaries”, 2014 IEEE Network Operations and Management Symposium (NOMS), May 2014, DOI: 10.1109/NOMS.2014.6838247 , pp.1–8.

- J. Azar, A. AMakhoul, R. Couturier, J. Demerjian, “Robust IoT time series classification with data compression and deep learning”, Neurocomputing,
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