Simplemux Readme file

About Simplemux

There are some situations in which multiplexing a number of small packets into a bigger one is desirable. For example, a number of small packets can be sent together between a pair of machines if they share a common network path. Thus, the traffic profile can be shifted from small to larger packets, reducing the network overhead and the number of packets per second to be managed by intermediate routers.

Simplemux is a generic multiplexing protocol, described in draft-saldana-tsvwg-simplemux. It is able to encapsulate a number of packets belonging to different protocols into a single packet. It includes the "Protocol" field on each multiplexing header, thus allowing the inclusion of a number of packets belonging to different protocols in a packet of another protocol (Fig. 1). The size of the multiplexing headers is kept very low (it may be a single byte when multiplexing small packets) in order to reduce the overhead.

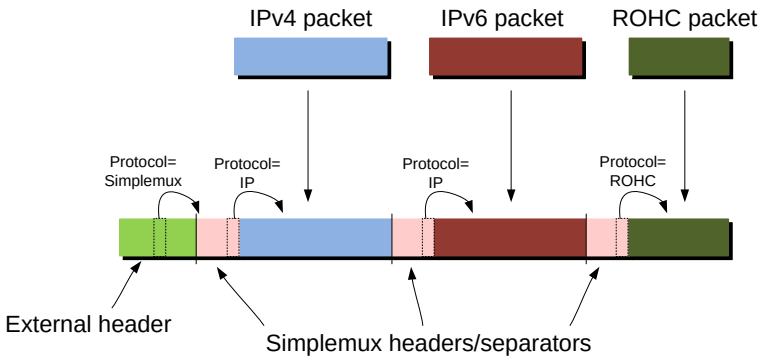


Fig. 1. Example of a Simplemux packet including packets of different protocols

Simplemux is designed to optimize together a number of flows sharing a common network path or segment (Fig. 2). Optimization in the end host is (in principle) not useful, since a number of small-packet flows departing from the same host are unusual. The multiplexing is performed between a pair of machines called ingress-optimizer and egress-optimizer.

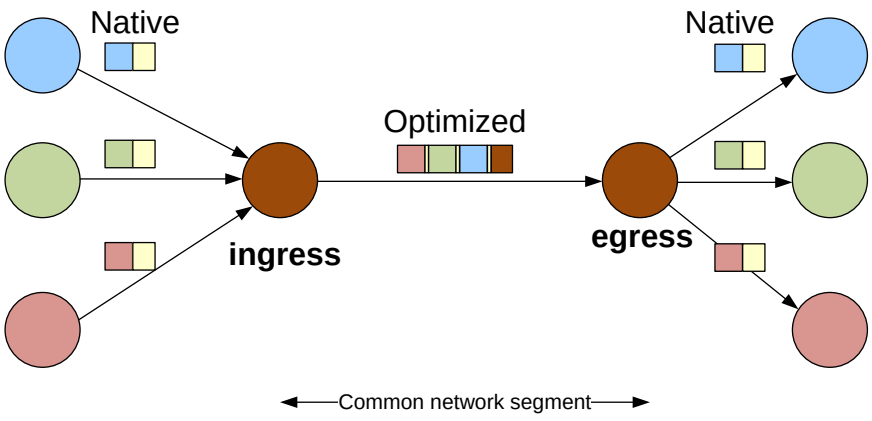


Fig. 2. Scheme of the optimization

The present code is an implementation of **Simplemux**, using IP/UDP as the *multiplexing protocol*, and IP or ROHC (RFC 3095) as the *multiplexed protocol*, as illustrated in Fig. 3. Thus, it is able to perform traffic optimization, combining multiplexing with header compression. This may result on significant bandwidth savings and pps reductions for small-packet flows (e.g. VoIP, online games).

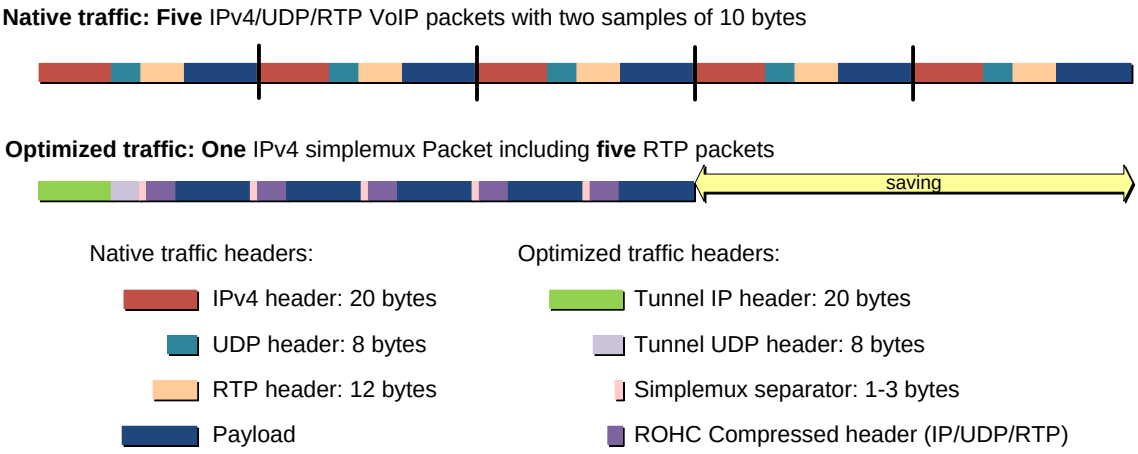


Fig. 3. Optimization of five RTP packets of VoIP

Simplemux can be used as an option at the multiplexing layer of TCM[1], a protocol combining **T**unneling, **C**ompressing and **M**ultiplexing for the optimization of small-packet flows. TCM may use of a number of different standard algorithms for header compression, multiplexing and tunneling, combined in a similar way to RFC 4170, as proposed in draft-saldana-tsvwg-tcmtf.

The implementation is written in C for Linux. It compresses headers using an implementation of ROHC by Didier Barvaux (https://rohc-lib.org/).

Simplemux uses Linux TUN virtual interface.

Header compression

Simplemux uses an implementation of ROHC by Didier Barvaux (https://rohc-lib.org/).

Multiplexing

The **Mux separator** (see Fig. 4) has two different formats: one for the *First header* (the separator before the first packet included in the multiplexed bundle), and another one for *Non-first headers* (the rest of the separators).

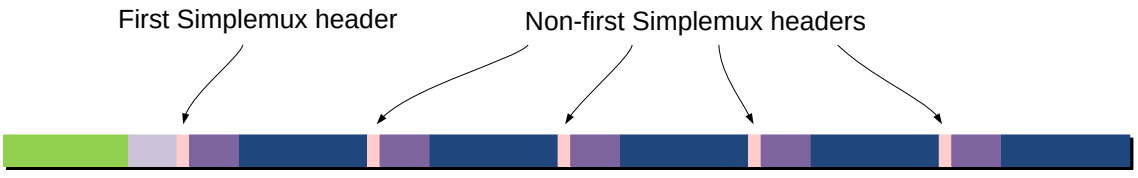


Fig. 4. First and Non-first Simplemux headers (also known as separators)

[1] Jose Saldana *et al, "Emerging Real-time Services: Optimizing Traffic by Smart Cooperation in the Network,"* IEEE Communications Magazine, Vol. 51, n. 11, pp 127-136, Nov. 2013. doi 10.1109/MCOM.2013.6658664

Format of the First Simplemux header/separator

The format of the First Simplemux separator is illustrated in Fig. 5:

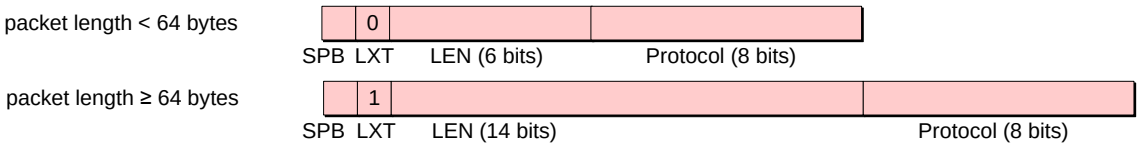


Fig. 5. Fields of the First Simplemux header/separator

- **Single Protocol Bit (SPB, one bit)** only appears in the first Simplemux header. It is set to 1 if all the multiplexed packets belong to the same protocol (in this case, the "protocol" field will only appear in the first Simplemux header). It is set to 0 when each packet MAY belong to a different protocol.

- **Length Extension (LXT, one bit)** is 0 if the length of the first packet can be expressed in 6 bits, and 1 in other case.

- **Length (LEN, 6 or 14 bits)**: This is the length of the multiplexed packet in bytes not including the length field. If the length of the multiplexed packet is less than 64 bytes (less than or equal to 63 bytes), LXT is set to 0 and the 6 bits of the length field are the length of the multiplexed packet. If the length of the multiplexed packet is greater than 63 bytes, LXT is set to 1 and the 14 bits of the length field are the length of the multiplexed packet. The maximum length of a multiplexed packet is 16,383 bytes. Packets larger than 16,383 bytes will need to be sent in their native form. A Simplemux ingress is not required to multiplex all packets smaller than 16,383 bytes. It may choose to only multiplex packets smaller than a configurable size into a Simplemux multiplexed packet.

- **Protocol (8 bits)** is the Protocol field of the multiplexed packet, according to IANA "Assigned Internet Protocol Numbers".

Format of the Non-first Simplemux header/separator

If the SPB (Single Protocol Bit) of the First Simplemux header is set to 1, it means that all the multiplexed packets belong to the same protocol. In this case, the format is the one presented in Fig. 6:

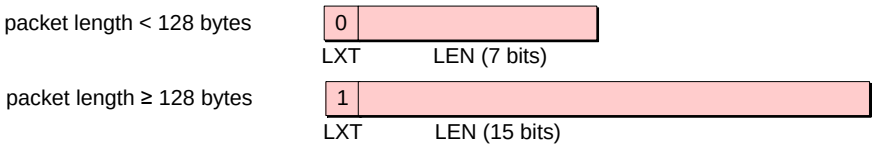


Fig. 6. Fields of the Non-first Simplemux header/separator, when the SPB bit of the First header is 1

If the SPB of the First Simplemux header is set to 0, then each packet may belong to a different protocol, so the "Protocol" field is also included, as shown in Fig. 7:

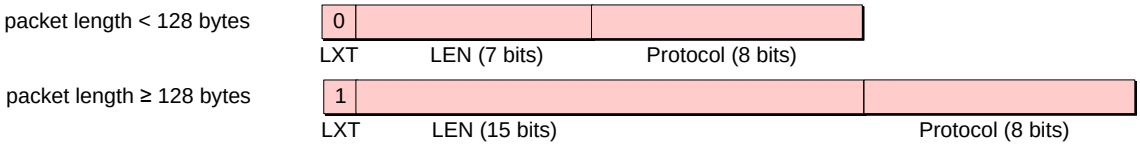


Fig. 7. Fields of the Non-first Simplemux header/separator, when the SPB bit of the First header is 0

These are the fields:

- **Length Extension (LXT, one bit)** is 0 if the length of the first packet can be expressed in 7 bits, and 1 in other case.

- **Length (LEN, 7 or 15 bits)**: This is the length of the multiplexed packet in bytes not including the length field. If the length of the multiplexed packet is less than 128 bytes (less than or equal to 127 bytes), LXT is set to 0 and the 7 bits of the length field represent the length of the multiplexed packet. If the length of the multiplexed packet is greater than 127 bytes, LXT is set to 1 and the 15 bits of the length field are the length of the multiplexed packet. The maximum length of a multiplexed packet is 32,768 bytes. Packets larger than 32,768 bytes will need to be sent in their native form. However, this will have to be reduced to 16,383 bytes taking into account that the maximum size of the First header is 14 bits. A Simplemux ingress is not required to multiplex all packets smaller than 32,768 bytes. It may choose to only multiplex packets smaller than a configurable size into a Simplemux multiplexed packet.

- **Protocol (8 bits)** is the Protocol field of the multiplexed packet, according to IANA "Assigned Internet Protocol Numbers". It is only included when the SPB of the First Multiplexing header is 0.

Tunneling

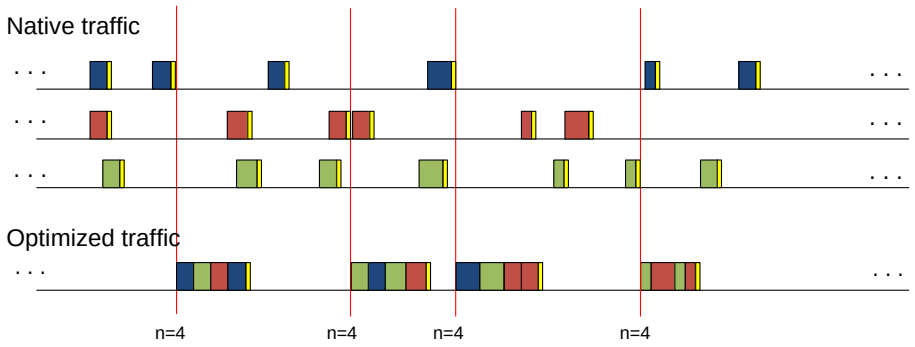
In this **Simplemux** implementation, tunneling is included in a very simple way: an IP/UDP header is added before the first **Mux separator.** By default, the destination UDP port is 55555.

ROHC feedback information (when using ROHC Bidirectional modes) is sent in UDP packets using port 55556 by default.

Multiplexing policies

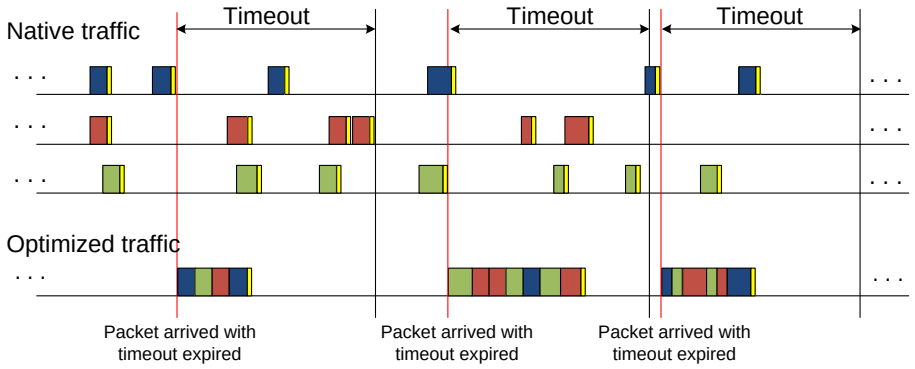
Four different conditions can be used and combined for triggering the sending of a multiplexed packet (in the figures, the triggering moment is expressed by red lines):

- **number of packets**: a number of packets have arrived to the multiplexer.

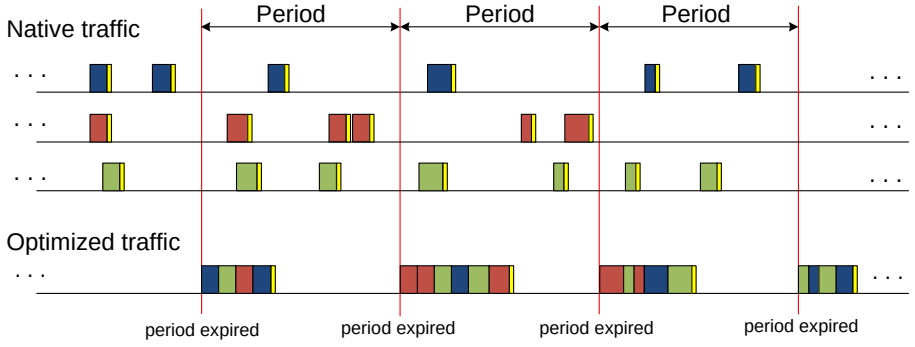


- **size**: the size of the multiplexed packet has reached a threshold.

- **timeout**: a packet arrives, and a timeout since the last sending has expired.



- **period**: an active waiting is performed, and a multiplexed packet including all the packets arrived during a period is sent.



More than one condition can be set at the same time. Please note that if (timeout < period), then the timeout has no effect.

Simplemux is symmetric, i.e. both machines may act as ingress and egress simultaneously. However, different policies can be established at each of the optimizers, e.g. in one side you can send a multiplexed packet every two native ones, and in the other side you can set a timeout.

ROHC cannot be enabled in one of the peers and disabled in the other.

What will you find in this package

You will find two different source files:

Simplemux_vX.Y.c	The complete version of **Simplemux**
simplemux-no-compress.c	A *light* version which does not compress headers

Required tools

ROHC (not required for simplemux-no-compress.c)

First, you have to install rohc 1.7.0 from https://rohc-lib.org/. Download and uncompress the ROHC package.

```
cd rohc-1.7.0
./configure --prefix=/usr
make all
make check
make install
```

Compiling simplemux

```
gcc -o simplemux -g -Wall $(pkg-config rohc --cflags) simplemux_vX.Y.c
$(pkg-config rohc --libs )
```

Usage of simplemux

```
./simplemux -i <ifacename> [-c <peerIP>] [-p <port>] [-d
<debug_level>] [-r <ROHC_option>] [-n <num_mux_tun>] [-b
<num_bytes_threshold>] [-t <timeout (microsec)>] [-P <period
(microsec)>] [-l <log file name>] [-L]

./simplemux -h

-i <ifacename>: Name of tun interface to use (mandatory)
-e <ifacename>: Name of local interface to use (mandatory)
-c <peerIP>: specify peer destination address (-d <peerIP>)
(mandatory)
-p <port>: port to listen on, and to connect to (default 55555)
-d: outputs debug information while running. 0:no debug; 1:minimum
debug; 2:medium debug; 3:maximum debug (incl. ROHC)
-r: 0:no ROHC; 1:Unidirectional; 2: Bidirectional Optimistic; 3:
Bidirectional Reliable (not available yet)
-n: number of packets received, to be sent to the network at the same
time, default 1, max 100
-b: size threshold (bytes) to trigger the departure of packets,
default 1472 (1500 - 28)
-t: timeout (in usec) to trigger the departure of packets
-P: period (in usec) to trigger the departure of packets. If ( timeout
< period ) then the timeout has no effect
-l: log file name
-L: use default log file name (day and hour Y-m-d_H.M.S)
-h: prints this help text
```

Format of the Simplemux traces

Using the options `-l log file name` or `-L` you can obtain a text file with traces. This is the format of these traces:

timestamp	event	type	size	sequence number	from/to	IP	port	number of packets	triggering event(s)
%"PRIu64"	text	text	%i	%lu	text	%s	%d	%i	text
microseconds	rec	native	packet size in bytes	sequence number	-	-	-	-	-
		muxed			from	ingress IP address	port		
		ROHC_feedback							
	sent	muxed			to	egress IP address	port	number	numpacket_limit size_limit timeout period MTU
		demuxed			-	-	-	-	-
	forward	native			from	ingress IP address	port	-	-
	error	bad_separator			-	-	-	-	-
		demux_bad_length			-	-	-	-	-
		decomp_failed			-	-	-	-	-
		comp_failed			-	-	-	-	-

- `timestamp`: it is in microseconds. It is obtained with the function `GetTimeStamp()`.

- `event` and `type`:

    - `rec`: a packet has been received:

        - `native`: a native packet has arrived to the ingress optimizer.

        - `muxed`: a multiplexed packet has arrived to the egress optimizer.

        - `ROHC_feedback`: a ROHC feedback-only packet has been received from the decompressor. It only contains ROHC feedback information, so there is nothing to decompress

    - `sent`: a packet has been sent

        - `muxed`: the ingress optimizer has sent a multiplexed packet.

- `demuxed`: the egress optimizer has demuxed a native packet and sent it to its destination.

- `forward`: when a packet arrives to the egress with a port different to the one where the optimization is being deployed, it is just forwarded to the network.

- `error`:

- `bad_separator`: the Simplemux header before the packet is not well constructed.

- `demux_bad_length`: the length of the packet expressed in the Simplemux header is excessive (the multiplexed packet would finish after the end of the global packet).

- `decomp_failed`: ROHC decompression failed.

- `comp_failed`: ROHC compression failed.

- `size`: it expresses (in bytes) the size of the packet. If it is a muxed one, it is the global size of the packet (including IP header). If It is a `native` or `demuxed` one, it is the size of the original (native) packet.

- `sequence number`: it is a sequence number generated internally by the program. Two different sequences are generated: one for received packets and other one for sent packets.

- `IP`: it is the IP address of the peer Simplemux optimizer.

- `port`: it is the destination port of the packet.

- `number of packets`: it is the number of packets included in a multiplexed bundle.

- `triggering event(s)`: it is the cause (more than one may appear) of the triggering of the multiplexed bundle:

- `numpacket_limit`: the limit of the number of packets has been reached.

- `size_limit`: the maximum size has been reached.

- `timeout`: a packet has arrived once the timeout had expired.

- `period`: the period has expired.

- `MTU`: the MTU has been reached.

Trace examples

In the ingress optimizer you may obtain:

```
1417693720928101  rec   native   63   1505
1417693720931540  rec   native   65   1506
1417693720931643  rec   native   52   1507
1417693720936101  rec   native   48   1508
1417693720936210  rec   native   53   1509
1417693720936286  rec   native   67   1510
1417693720937162  rec   native   57   1511
1417693720938081  sent  muxed    237  1511  to    192.168.137.4  55555 7  period
```

This means that 7 native packets (length 63, 65, … 57, and sequence numbers 1505 to 1511) have been received, and finally the period has expired, so they have been sent together to the egress Simplemux optimizer at 192.168.137.4, port 55555.

In the egress optimizer you may obtain:

```
1417693720922848  rec   muxed    237  210   from  192.168.0.5   55555
1417693720922983  sent  demuxed  63   210
1417693720923108  sent  demuxed  65   210
1417693720923186  sent  demuxed  52   210
1417693720923254  sent  demuxed  48   210
1417693720923330  sent  demuxed  53   210
1417693720923425  sent  demuxed  67   210
1417693720923545  sent  demuxed  57   210
```

This means that a multiplexed packet (sequence number 210) has been received from the ingress optimizer 192.168.0.5 with port 55555, and it has been demuxed, resulting into 7 different packets of lengths 63, 65, … 57.

Scripts for calculating some statistics

This package includes the next Perl scripts:

Calculate throughput and packets per second

`simplemux_throughput_pps.pl`

It is able to calculate the throughput and the packet-per-second rate, from a Simplemux output trace. The result is in three columns:

```
tick_end_time(us)    throughput(bps)   packets_per_second
1000000              488144            763
2000000              490504            759
3000000              475576            749
4000000              483672            760
5000000              481784            758
6000000              487112            762
7000000              486824            760
8000000              488792            765
9000000              483528            761
10000000             486360            760
```

Usage:

```
$perl simplemux_throughput_pps.pl <trace file> <tick(us)> <event> <type> <peer IP>
<port>
```

Examples:

```
# $ perl simplemux_throughput_pps.pl tracefile.txt 1000000 rec native all all
# $ perl simplemux_throughput_pps.pl log_simplemux 1000000 rec muxed all all
# $ perl simplemux_throughput_pps.pl log_simplemux 1000000 rec muxed 192.168.0.5 55555
# $ perl simplemux_throughput_pps.pl log_simplemux 1000000 sent demuxed
```

Calculate the multiplexing delay of each packet

`simplemux_multiplexing_delay.pl`

It is able to calculate the multiplexing delay of each packet, from a Simplemux output trace. The result is an output file in two columns:

```
packet_id multiplexing_delay(us)
1         5279
2         1693
3         1202
4         507
5         10036
6         8471
7         6974
8         5588
9         1143
10        10435
11        8935
12        7522
13        5981
14        4520
15        3011
...
```

And other results are shown in stdout:

```
total native packets: 6661
Average multiplexing delay:   5222.47680528449 us
stdev of the multiplexing delay:     3425.575192789 us
```

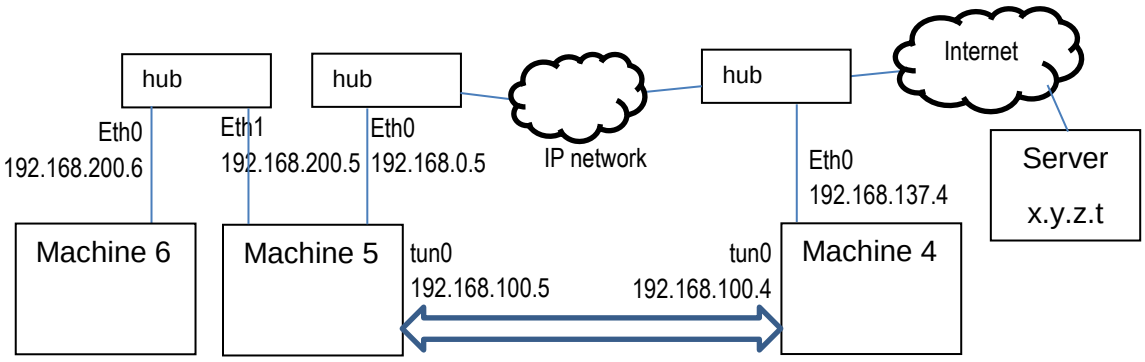
Usage:

```
$ perl simplemux_multiplexing_delay.pl <trace file> <output file>
```

Usage example with three machines

This is the setup:

Machine 6 is the source. Machine 5 and Machine 4 are the two optimizers. Server x.y.z.t is the destination.



Create a tun interface in machine 4

`ip tuntap add dev tun0 mode tun user root`[2]
(`openvpn --mktun --dev tun0 --user root` will also work[3]).

`ip link set tun0 up` (or `ifconfig tun0 up` for e.g. OpenWRT)

If you want to add an IP address to the tun0 interface, use:

```
ip addr add 192.168.100.4/24 dev tun0
```

If you do not need an IP address, you can omit the previous command.

Create a tun interface in machine 5

```
ip tuntap add dev tun0 mode tun user root
```
(`openvpn --mktun --dev tun0 --user root` will also work)

```
ip link set tun0 up
```

```
ip addr add 192.168.100.5/24 dev tun0
```

Establish the simplemux tunnel between machine 4 and machine 5

In machine4:

```
# ./simplemux -i tun0 -e eth0 -c 192.168.0.5
```

In machine5:

```
# ./simplemux -i tun0 -e eth0 -c 192.168.137.4
```

Now you can ping from machine6 to machine 4:

```
$ ping 192.168.100.4
```

---

[2] For removing the interface use `ip tuntap del dev tun0 mode tun`
[3] Openvpn is used to create and destroy tun/tap devices. In Debian you can install it this way: `#apt-get install openvpn`
In OpenWRT you will not be able to run `ip tuntap`, so you should install openvpn with `#opkg install openvpn`.

The ping arrives to the `tun0` interface of machine 5, goes to machine 4 through the tunnel and is returned to machine 6 through the tunnel.

How to steer traffic from Machine 6 to server x.y.z.t through the tunnel

The idea of **simplemux** is that it does not run on endpoints, but on some "optimizing" machines in the network. Soy you have to define policies in order to steer the flows of interest, in order to make them go through the TUN interface of the ingress (machine 5). This can be done with `iprules` and `iptables`.

Following with the example:

In Machine 5, add a rule that makes the kernel route packets marked with "2" through `table 3`:

```
# ip rule add fwmark 2 table 3
```

In Machine 5, add a new route for `table 3`:

```
# ip route add default dev tun0 table 3 [4]
# ip route flush cache
```

If you show the routes of table 3, you should see this:

```
# ip route show table 3
default via 192.168.100.5 dev tun0
```

And now you can use `iptables` in order to mark certain packets as "2" if they have a certain destination IP, or a port number.

Examples:

All packets with destination IP address x.y.z.t

```
iptables -t mangle -A PREROUTING -p udp -d x.y.z.t -j MARK --set-mark 2
```

All packets with destination UDP port 8999

```
iptables -t mangle -A PREROUTING -p udp --dport 8999 -j MARK --set-mark 2
```

All packets with destination TCP port 44172

```
iptables -t mangle -A PREROUTING -p tcp --dport 44172 -j MARK --set-mark 2
```

Other examples implementing different policies

Set a period of 50 ms

```
./simplemux -i tun0 -e eth0 -c 192.168.0.5 -P 50000
```

Send a multiplexed packet every 2 packets, use ROHC Bidirectional Optimistic

```
./simplemux -i tun0 -e eth0 -c 192.168.0.5-n 2 -r 2
```

Send a multiplexed packet if the size of the multiplexed bundle is 400 bytes

```
./simplemux -i tun0 -e eth0 -c 192.168.0.5 -b 400
```

[4] If you have set an IP address in the tun0 interface, this command should also work:
`# ip route add default via 192.168.100.5 table 3`

Send a timeout of 50ms, and a period of 100 ms (to set an upper bound on the added delay), use ROHC Unidirectional

```
./simplemux -i tun0 -e eth0 -c 192.168.0.5 –t 50000 –P 100000 –r 1
```

Credits

The author of **simplemux** is Jose Saldana (jsaldana at unizar.es). **Simplemux** has been written for research purposes, so if you find it useful, I would appreciate that you send a message sharing your experiences, and your improvement suggestions.

The software is released under the **GNU General Public License**, Version 3, 29 June 2007.

Thanks to Didier Barvaux for his ROHC implementation.

Thanks to Davide Brini for his simpletun program.

If you have some improvement suggestions, do not hesitate to contact me.

http://diec.unizar.es/~jsaldana/