Linux SCTP is catching up and going above

Red Hat, Inc.

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Outline

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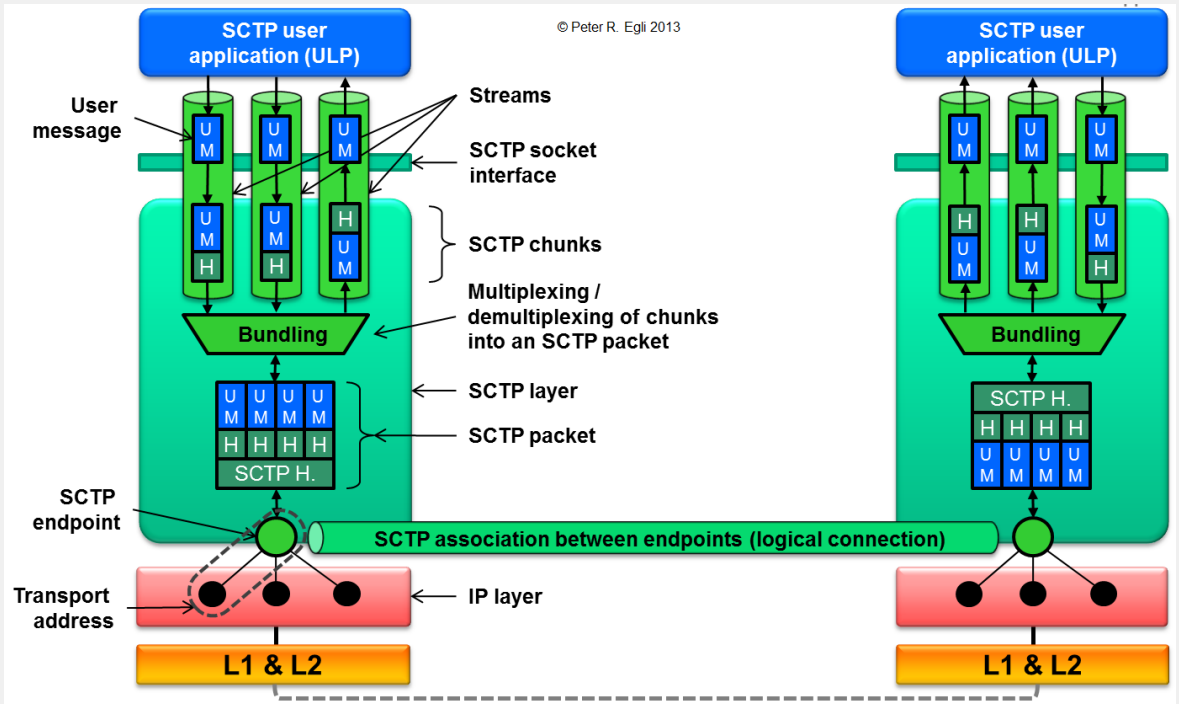
Structures

1. Endpoint
2. Association
3. Transport
4. Stream
5. Msg
6. Packet
7. Chunk

overview



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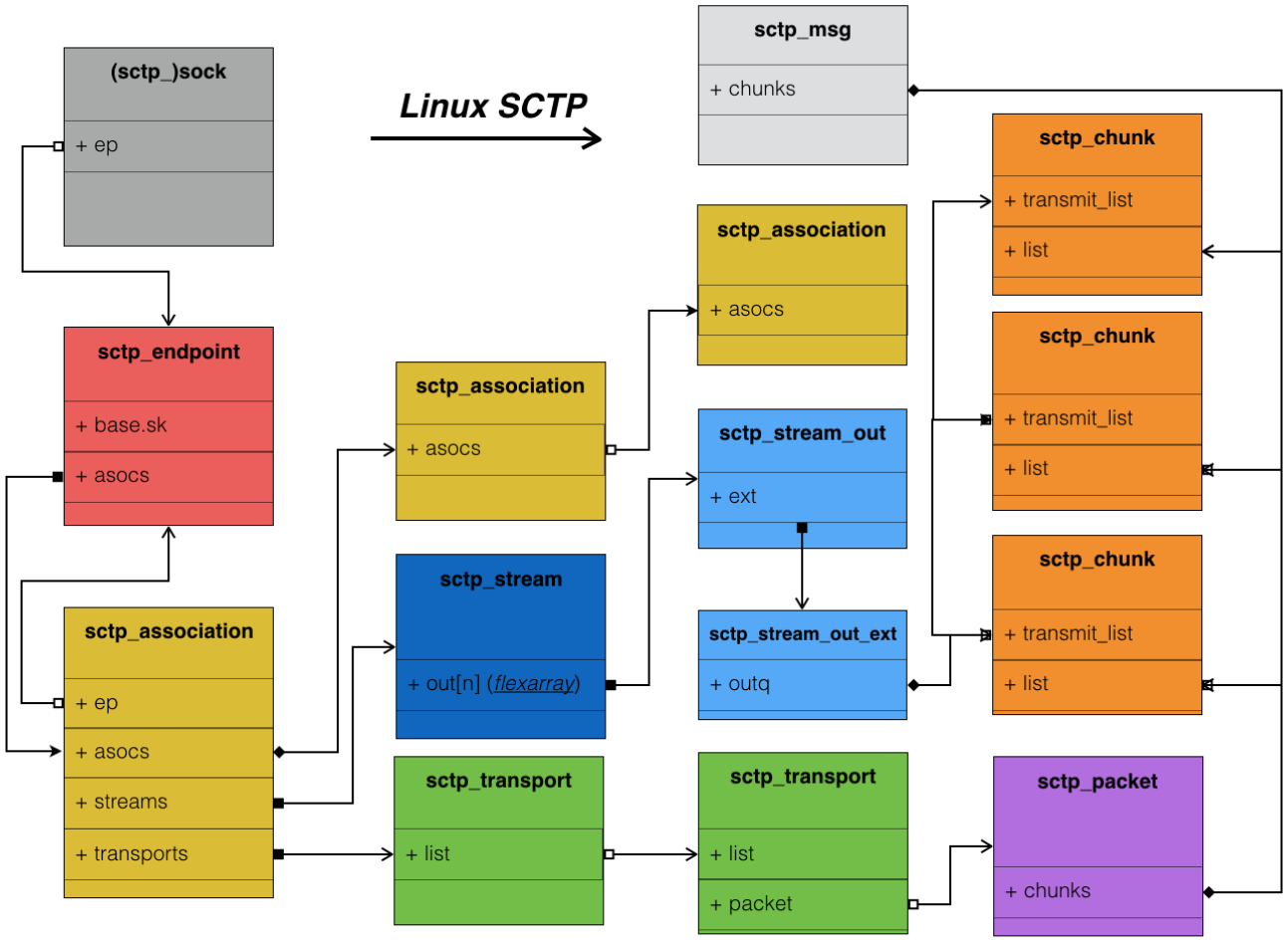
SCTP Structures in Linux



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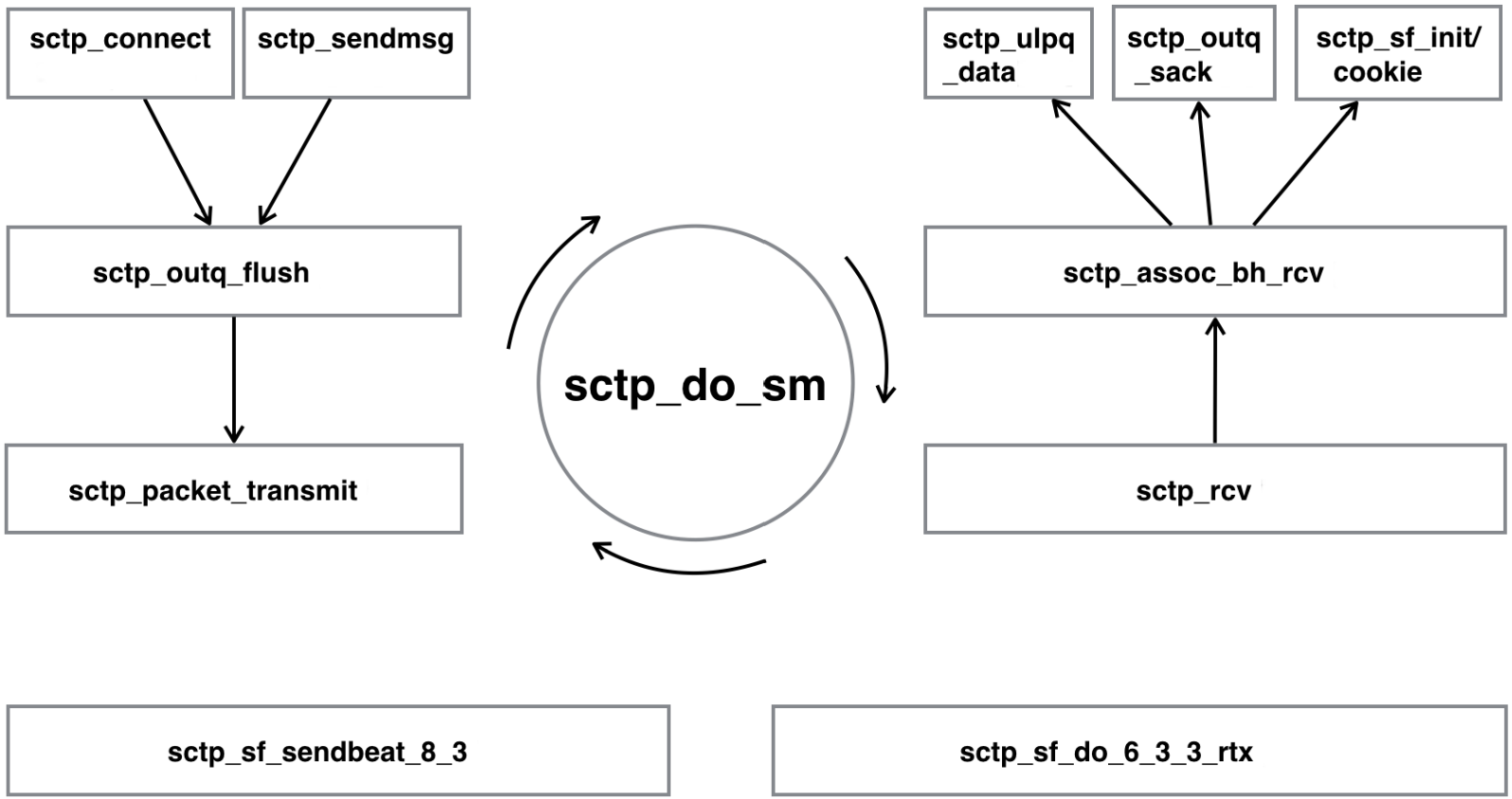
SCTP Procedures in Linux



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SCTP vs TCP/UDP on Feature

	SCTP	TCP	UDP
• Full-duplex	yes	yes	yes
• Connection oriented	yes	yes	no
• Reliable data transmission	yes	yes	no
• Unreliable data transmission	yes	no	yes
• Partially reliable data transmission	yes	no	no
• In order delivery	yes	yes	no
• Out of order delivery	yes	no	yes
• Flow- and Congestion Control	yes	yes	no
• ECN support	yes	yes	no
• Selective ACKs	yes	yes	no
• Protection of message boundaries	yes	no	yes
• Fragmentations	yes	yes	no
• Multistreaming	yes	no	no
• Multihoming	yes	no	no
• Protection against SYN flooding	yes	no	n/a
• Half-closed connection	no	yes	n/a

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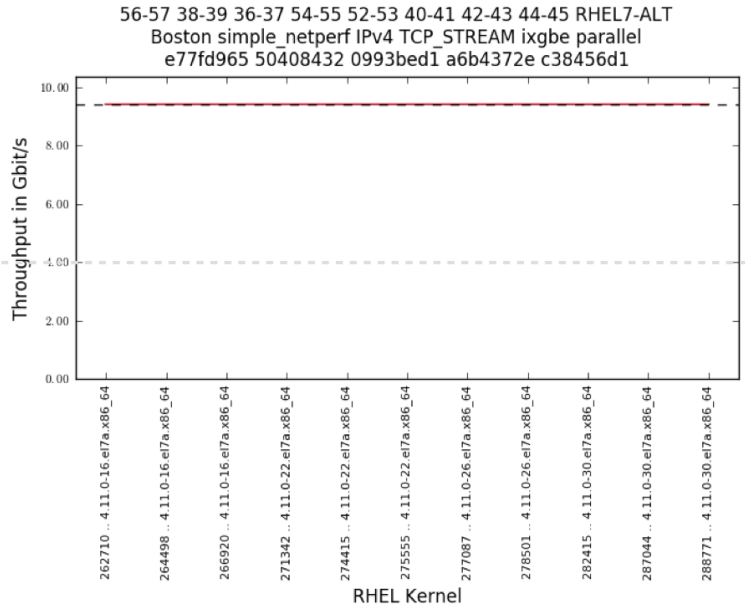
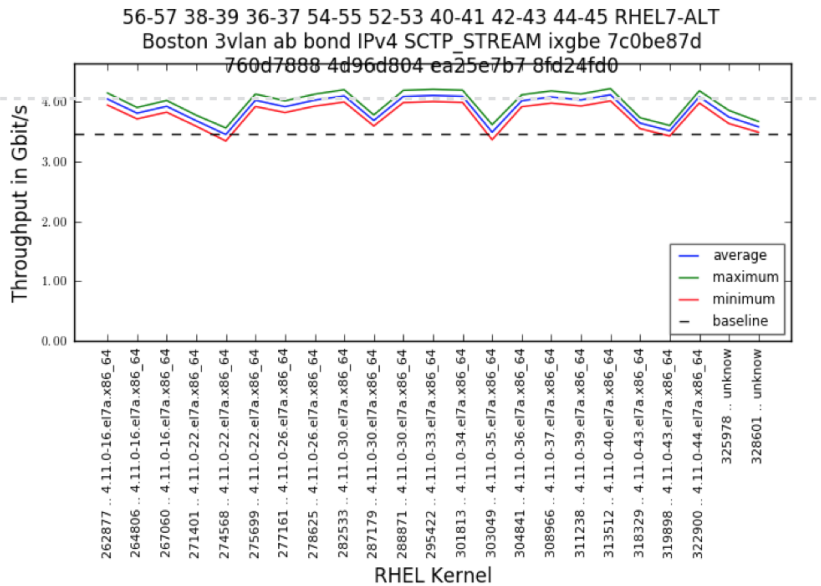
SCTP vs TCP on Performance

Performance ?





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lksctp-tools (lib and unit test)

MANIFEST ———

.

|– bin

|– doc

|– man

|– src

... |– **apps**

... |– **func_tests**

... |– include

... |... '– netinet

... |– **lib**

... |– testlib

... '– withsctp

- sctp_darn, sctp_test
- sctp_status, sctp_xconnect
- peel_client, peel_server
- bindx_test, myftp, nagle_rcv, nagle_snd

"""

Unit Test: Look in src/func_tests and in lksctp-tests package for examples of of tests. Please do not submit code that fails its own tests or any of the unit tests. If it fails a functional test, please document that with the submission.

"""

- sctp_send, sctp_sendmsg, sctp_recvmsg
- sctp_connectx_orig, sctp_connectx2, sctp_connectx3
- sctp_bindx, sctp_opt_info
- sctp_peeloff, sctp_peeloff_flags

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sctp-tests (regression test): 27 test cases so far

```
.
├── libst
│   ├── bin
│   ├── keys
│   ├── logging.sh
│   ├── network.sh
│   └── system.sh
├── st.cfg
├── sctp-tests
├── testcase
│   ├── misc
│   │   └── demo
│   ├── conformance
│   │   ├── streamreconf
│   │   ├── streamndata
│   │   ├── interleave
│   │   └── prsctp
│   ├── performance
│   │   ├── repeatability
│   │   └── sctphashtable
│   ├── regression
│   │   ├── extoverflow
│   │   ├── gsomtuchange
│   │   │   ├── issue
│   │   │   └── test.sh
│   │   └── peeloffbusy
│   ├── stress
│   │   ├── procdumps
│   │   └── sctpdiag
│   └── testsuit
│       └── lksctptools
├── testplan
│   ├── phostcase.list
│   └── upstream.list
└── topos
    ├── netns.sh
    ├── netns_cs.sh
    ├── netns_crs.sh
    ├── netns_sit_cs.sh
    ├── netns_ipsec_cs.sh
    ├── netns_vlan_cs.sh
    ├── netns_team_cs.sh
    ├── netns_bridge_cs.sh
    ├── ph.cfg
    ├── phost.sh
    ├── phost_cs.sh
```

```
# ./sctp-tests help
sctp-tests v1.0

usage: sctp-tests [ OPTIONS ] COMMAND
where  OPTIONS:= { -e {TestCase | TestPlan}    |
                   -o  Prefix    | -l LogLevel |
                   -O  Outfile   | -l LogFile  |
                   -T  TOPOOPT   | -f Confile }
       COMMAND:= { init | run | shell }

       TOPOOPT:= { st_team_opt=xxx  | st_ipsec_opt=xxx }
```

```
# cat upstream.list
testcase/testsuit/lksctptools/test.sh
testcase/performance/repeatability/sctp_rr.sh
testcase/performance/repeatability/sctp_stream.sh
testcase/performance/repeatability/sctp_rr~on_ipsec.sh
testcase/performance/repeatability/sctp_stream~on_ipsec.sh
testcase/performance/repeatability/sctp_stream~on_sit.sh
testcase/stress/procdumps/test.sh
testcase/stress/sctpdiag/test.sh
testcase/regression/gsomtuchange/test.sh
testcase/regression/peeloffbusy/test.sh
testcase/regression/extoverflow/test.sh
testcase/performance/sctphashtable/test~on_netns.sh
testcase/performance/sctphashtable/test~on_team.sh
```

```
# cat netns_ipsec_cs.sh
source "$ROOTDIR/topos/netns.sh"

st_topo_setup()
{
        local def_opt="proto esp spi 0x1000 mode transport enc blowfish i
                       proto esp spi 0x2000 mode transport enc blowfish :
        local ipsec_opt=${Topo_opt:-"$st_ipsec_opt"}

        ipsec_opt=${ipsec:-"$def_opt"}

        st_c_eth=(eth1 eth2)
        st_s_eth=(eth1 eth2)

        st_c_ip6=(2000::1 1000::1)
        st_s_ip6=(2000::2 1000::2)
        st_c_ip4=(192.0.0.1 172.0.0.1)
        st_s_ip4=(192.0.0.2 172.0.0.2)

        st_netns_ns_create c s
        st_netns_veth_create c "${st_c_eth[*]}" s "${st_s_eth[*]}"

        st_netns_addr_assign c "${st_c_eth[*]}" "${st_c_ip4[*]}" "24 16"
        st_netns_addr_assign s "${st_s_eth[*]}" "${st_s_ip4[*]}" "24 16"
        st_netns_addr_assign c "${st_c_eth[*]}" "${st_c_ip6[*]}" "64 128"
        st_netns_addr_assign s "${st_s_eth[*]}" "${st_s_ip6[*]}" "64 128"

        st_netns_ipsec_create c "${st_c_ip4[*]}" "${st_s_ip4[*]}" \
                "$ipsec_opt" "${st_c_ip4[*]}" "${st_s_ip4[*]}" "out"
        st_netns_ipsec_create c "${st_c_ip6[*]}" "${st_s_ip6[*]}" \
                "$ipsec_opt" "${st_c_ip6[*]}" "${st_s_ip6[*]}" "out"
        st_netns_ipsec_create s "${st_c_ip4[*]}" "${st_s_ip4[*]}" \
                "$ipsec_opt" "${st_c_ip4[*]}" "${st_s_ip4[*]}" "in"
        st_netns_ipsec_create s "${st_c_ip6[*]}" "${st_s_ip6[*]}" \
                "$ipsec_opt" "${st_c_ip6[*]}" "${st_s_ip6[*]}" "in"
}

st_topo_clean()
{
        st_netns_ipsec_destroy c
        st_netns_ipsec_destroy s
        st_netns_ns_destroy c s
}
```

```
# cat test.sh
Name="gsomtuchange"
Topo="netns_crs"

do_setup()
{
        st_s_run sctp_test -H :: -P 33331 -l -T > /dev/null 2>&1 &
}

do_clean()
{
        pkill sctp_test
        rm -rf *.log
}

do_test()
{
        local mtus="1490 1480 1470 1460 1450 1440 1430 1420 1410 1400"
        local logf="$(st_o)_send.log"
        local pids=""
        local i=0

        st_log DBG "sctp_test start"
        for mtu in $mtus; do
                st_c_run sctp_test -H ${st_c_ip4[0]} -P 3333$i \
                                   -h ${st_s_ip4[0]} -p 33331 -s -c 5 \
                                   -x 1000 -T 2>&1 >> $logf &
                pids="$pids $!"
                st_c_run sctp_test -H ${st_c_ip6[0]} -P 3333$i \
                                   -h ${st_s_ip6[0]} -p 33331 -s -c 5 \
                                   -x 1000 -T 2>&1 >> $logf &
                pids="$pids $!"
                sleep 2
                st_r_run ip link set dev ${st_r_eth[0]} mtu $mtu
                st_r_run ip link set dev ${st_r_eth[2]} mtu $mtu
                let i++
        done

        st_log DBG "wait for children $pids"
        wait $pids

        st_log INFO " - PASS - No Panic"
}
```

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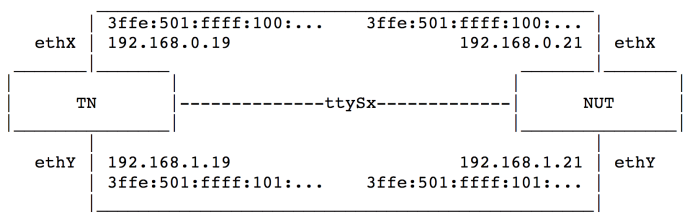
tahi-sctp (conformance test)



RFC4960: Association Initialization
RFC4960: Association Termination
RFC4960: Fault Management
RFC4960: Error Cause
RFC4960: Chunk Bundling
RFC4960: User Data Transfer
RFC4960: Retransmission Timer
RFC4960: Congestion Control
RFC4960: Path MTU Discovery
RFC4960: Multi-Homed Endpoints
RFC4960: Explicit Congestion Notification
RFC4960: Packet Format
RFC4960: Miscellaneous Test
RFC4895: Authentication Chunks
RFC5061: Dynamic Address Reconfiguration
RFC3758: Partial Reliability Extension
RFC3554: Internet Protocol Security

SCTP Conformance Test For Dynamic Address Reconfiguration

Tool Version : REL_3_3_2
Test Program Version : REL_1_0_3

Start: 2017/05/12 13:00:44
End : 2017/05/12 13:32:18

No.	Title	Result	Log	Script	Packet	Dump (bin)
	Initialize					
1	Initialization Test Environment	-	X	X	-	Link0 Link1
	ASCONF Chunk Procedures					
	Sequence Number					
2	ASCONF chunk is received with duplicate Peer Sequence Number and cached ASCONF-ACK response exists	PASS	X	X	X	Link0 Link1
3	ASCONF chunk is received with duplicate Peer Sequence Number but no cached ASCONF-ACK is outstanding	PASS	X	X	X	Link0 Link1
4	ASCONF chunk is received with Sequence Number greater than next expected Sequence Number	PASS	X	X	X	Link0 Link1
	Parameter Type					
5	ASCONF chunk is received with unrecognized parameter which does not understand	FAIL, Why	X	X	X	Link0 Link1
	Add IP Address					
6	ASCONF chunk is received with Add IP Address Parameter which contain a broadcast or multicast address	PASS	X	X	X	Link0 Link1
7	ASCONF chunk is received with Add IP Address Parameter which contain a unspecified address	FAIL, Why	X	X	X	Link0 Link1
8	ASCONF chunk is received with Add IP Address Parameter which contain a different type address	PASS	X	X	X	Link0 Link1
9	ASCONF chunk is received with Add IP Address Parameter which contain a valid address	PASS	X	X	X	Link0 Link1
	Delete IP Address					
10	ASCONF chunk is received with Delete IP Address Parameter which contain a broadcast or multicast address	PASS	X	X	X	Link0 Link1
11	ASCONF chunk is received with Delete IP Address Parameter which contain a unspecified address	PASS	X	X	X	Link0 Link1
12	ASCONF chunk is received with Delete IP Address to delete last remaining IP address from an association	PASS	X	X	X	Link0 Link1
13	ASCONF chunk is received with Delete IP Address to delete an IP address that is also the source address	PASS	X	X	X	Link0 Link1
14	ASCONF chunk is received with Delete IP Address Parameter which contain a address not part of the association	PASS	X	X	X	Link0 Link1

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Others

- Syzkaller (fuzz test)
- Codenomicon (fuzz test)
- Packetdrill (conformance test)
- Scapy (packet generating)
- More ?

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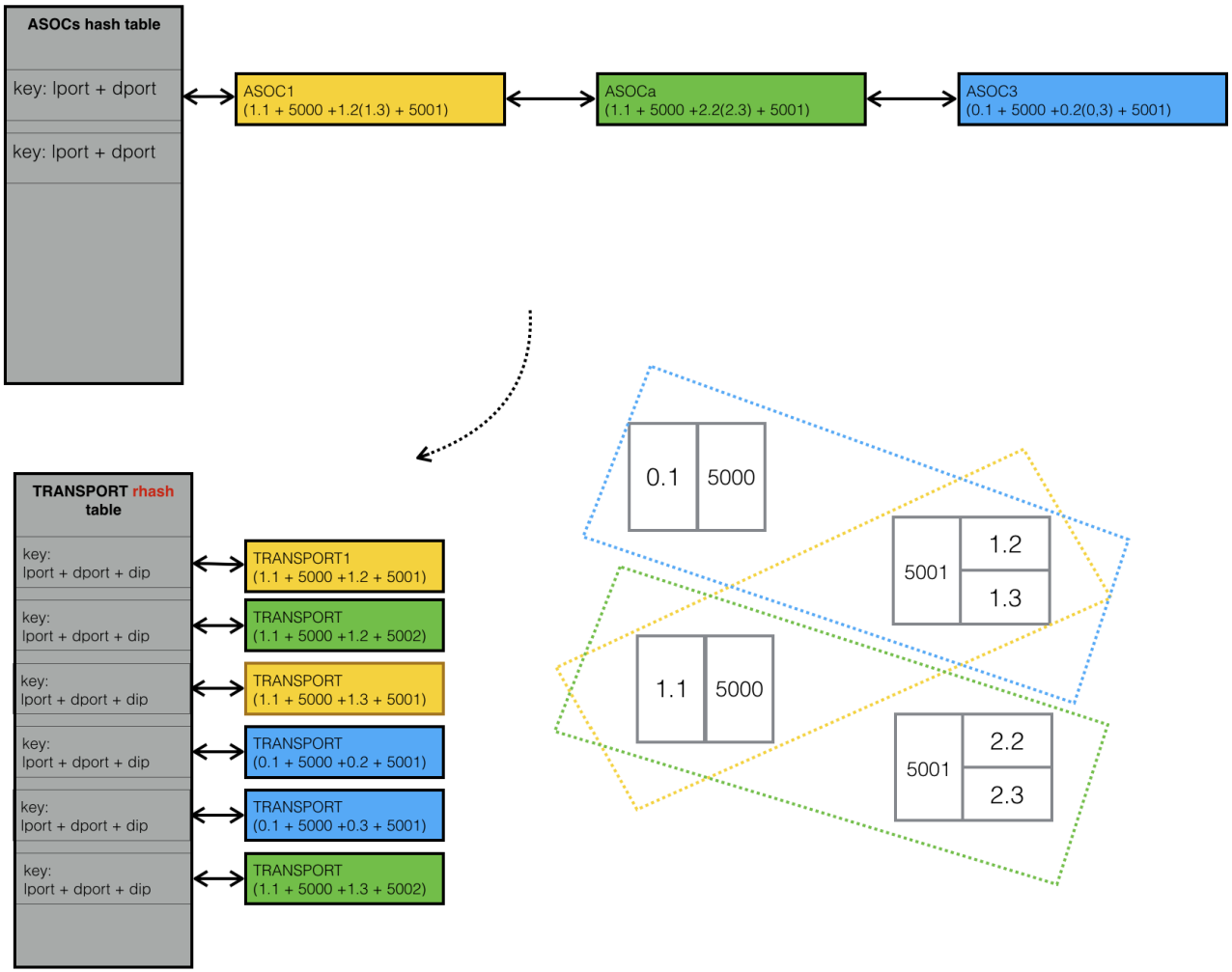
Transport Rhashtable 1



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Transport Rhashtable 2

1. 1-to-many(with "the same dport and different dip" lookup fast
2. 1-step to find both transport and asoc
3. Rhashtable (rhlist) features: rcu_lock and resize memory
4. Why not use the key with hash(dport, lport, dip, lip) ?
5. Why not make rhashtable per endpoint/socket ?

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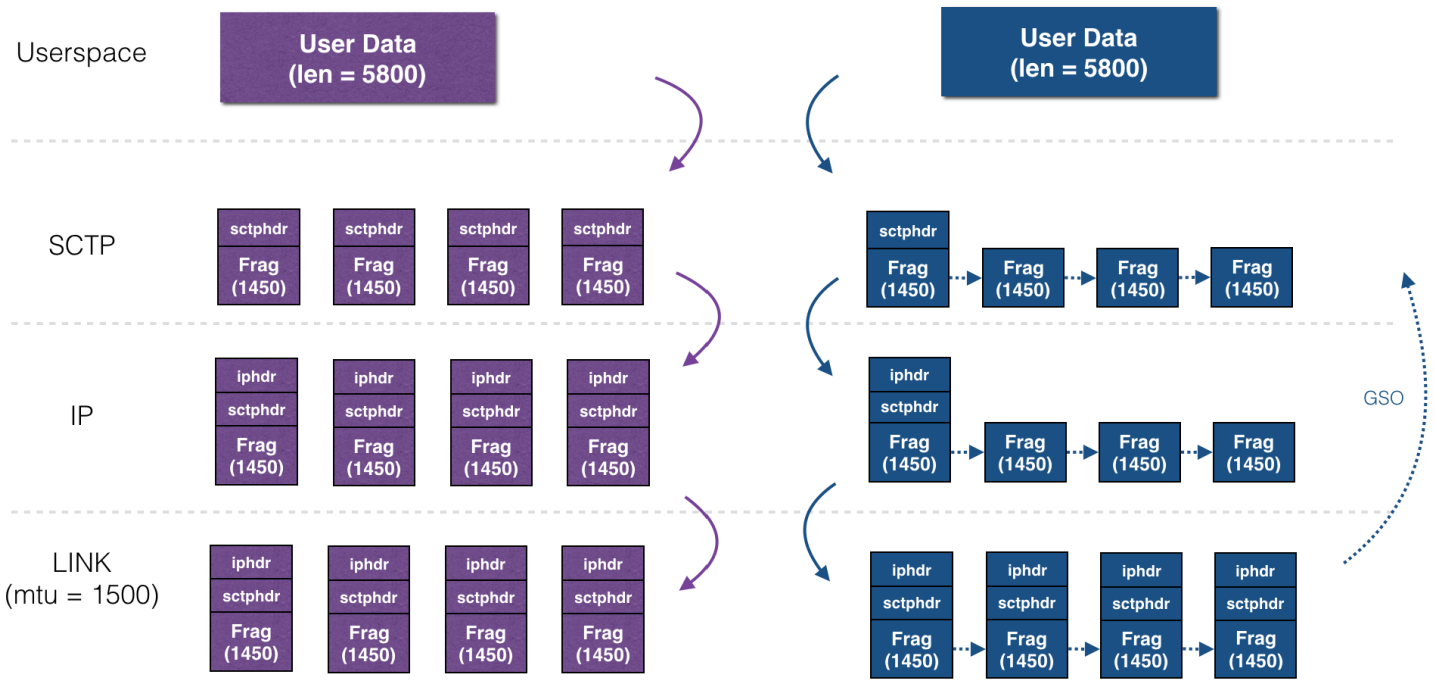
SCTP Offload 1



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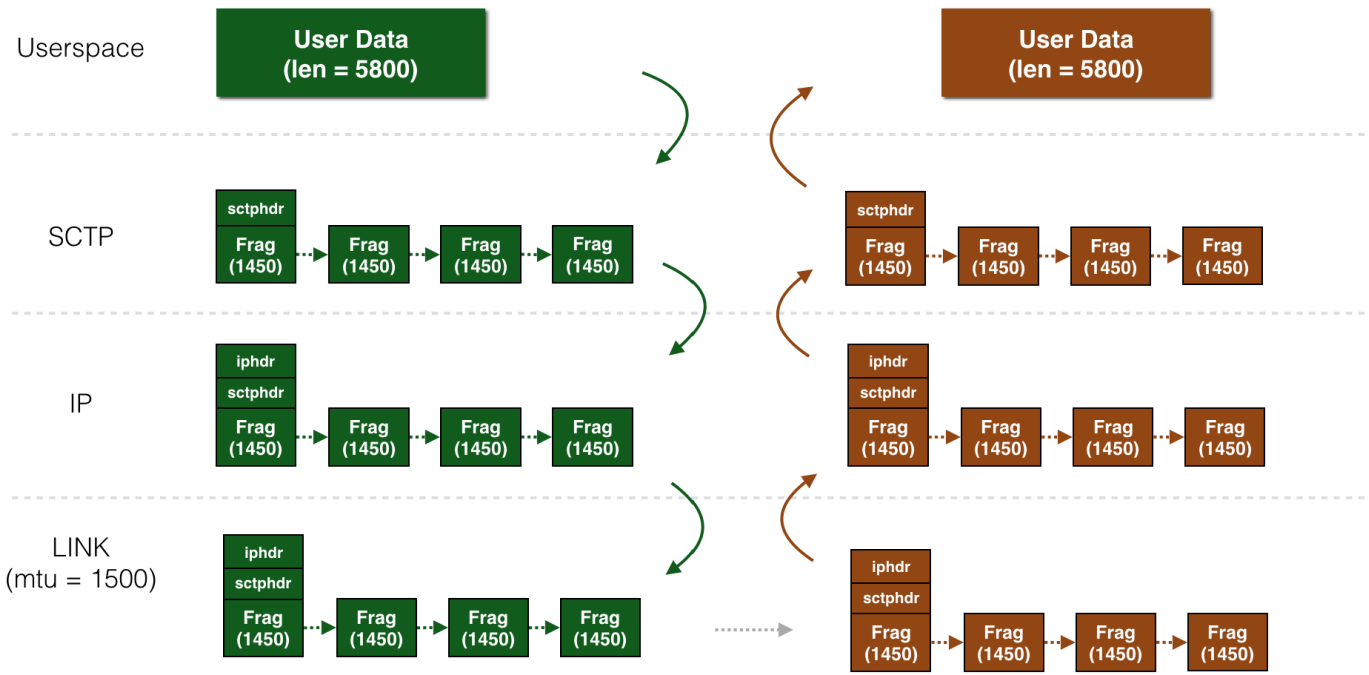
SCTP Offload 2



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SCTP Diag 1

```
[iproute2]# ss --sctp  -n -l
State      Recv-Q Send-Q   Local Address:Port       Peer Address:Port
LISTEN     0      128      172.16.254.254:8888      *:*
LISTEN     0      5        127.0.0.1:1234           *:*
LISTEN     0      5        127.0.0.1:1234           *:*
  - ESTAB  0      0        127.0.0.1%lo:1234        127.0.0.1:4321
LISTEN     0      128      172.16.254.254:8888      *:*
  - ESTAB  0      0        172.16.254.254%eth1:8888 172.16.253.253:8888
  - ESTAB  0      0        172.16.254.254%eth1:8888 172.16.1.1:8888
  - ESTAB  0      0        172.16.254.254%eth1:8888 172.16.1.2:8888
  - ESTAB  0      0        172.16.254.254%eth1:8888 172.16.2.1:8888
  - ESTAB  0      0        172.16.254.254%eth1:8888 172.16.2.2:8888
  - ESTAB  0      0        172.16.254.254%eth1:8888 172.16.3.1:8888
  - ESTAB  0      0        172.16.254.254%eth1:8888 172.16.3.2:8888
LISTEN     0      0        127.0.0.1:4321           *:*
  - ESTAB  0      0        127.0.0.1%lo:4321        127.0.0.1:1234
```

```
[iproute2]# ss -Snai
State       Recv-Q Send-Q  Local Address:Port     Peer Address:Port
LISTEN      0      1           127.0.0.1:27375               *:*
locals:127.0.0.1,192.168.42.2, v4mapped:1
ESTAB       0      0           127.0.0.1:37636       127.0.0.1:27375
locals:0.0.0.0, v4mapped:1
```

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SCTP Diag 2

```
# cat /proc/net/sctp/assocs
 ASSOC     SOCK   STY SST ST HBKT ASSOC-ID TX_QUEUE RX_QUEUE UID INODE LPORT RPORT
LADDRS <-> RADDRS HBINT INS OUTS MAXRT T1X T2X RTXC wmema wmemq sndbuf rcvbuf
```


```
struct sctp_info {
        __u32   sctpi_tag;
        __u32   sctpi_state;
        __u32   sctpi_rwnd;
        __u16   sctpi_unackdata;
        __u16   sctpi_penddata;
        __u16   sctpi_instrms;
        __u16   sctpi_outstrms;
        __u32   sctpi_fragmentation_point;
        __u32   sctpi_inqueue;
        __u32   sctpi_outqueue;
        __u32   sctpi_overall_error;
        __u32   sctpi_max_burst;
        __u32   sctpi_maxseg;
        __u32   sctpi_peer_rwnd;
        __u32   sctpi_peer_tag;
        __u8    sctpi_peer_capable;
        __u8    sctpi_peer_sack;
        __u16   __reserved1;

        /* assoc status info */
        __u64   sctpi_isacks;
        __u64   sctpi_osacks;
        __u64   sctpi_opackets;
        __u64   sctpi_ipackets;
        __u64   sctpi_rtxchunks;
        __u64   sctpi_outofseqtsns;
        __u64   sctpi_idupchunks;
        __u64   sctpi_gapcnt;
        __u64   sctpi_ouodchunks;
        __u64   sctpi_iuodchunks;
        __u64   sctpi_oodchunks;
        __u64   sctpi_iodchunks;
        __u64   sctpi_octrlchunks;
        __u64   sctpi_ictrlchunks;

        /* primary transport info */
        struct sockaddr_storage sctpi_p_address;
        __s32   sctpi_p_state;
        __u32   sctpi_p_cwnd;
        __u32   sctpi_p_srtt;
        __u32   sctpi_p_rto;
        __u32   sctpi_p_hbinterval;
        __u32   sctpi_p_pathmaxrxt;
        __u32   sctpi_p_sackdelay;
        __u32   sctpi_p_sackfreq;
        __u32   sctpi_p_ssthresh;
        __u32   sctpi_p_partial_bytes_acked;
        __u32   sctpi_p_flight_size;
        __u16   sctpi_p_error;
        __u16   __reserved2;

        /* sctp sock info */
        __u32   sctpi_s_autoclose;
        __u32   sctpi_s_adaptation_ind;
        __u32   sctpi_s_pd_point;
        __u8    sctpi_s_nodelay;
        __u8    sctpi_s_disable_fragments;
        __u8    sctpi_s_v4mapped;
        __u8    sctpi_s_frag_interleave;
        __u32   sctpi_s_type;
        __u32   __reserved3;
};
```

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Others

- Dst source addr selection
- Rwnd improvements
- Partial reliability fixes
- MTU handling refactor
- PMTU discovery (critical) fixes
- CRC32c offloading on virtual interfaces
- Some codes cleaning up
- More ...

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Overview

- Stream Schedulers and User Message Interleaving for the Stream Control Transmission Protocol [RFC8260]
- Additional Policies for the Partially Reliable Stream Control Transmission Protocol Extension [RFC7496]
- Stream Control Transmission Protocol (SCTP) Stream Reconfiguration [RFC6525]
- Sockets API Extensions for the Stream Control Transmission Protocol (SCTP) [RFC6458]
- Full SELinux support
- More ...

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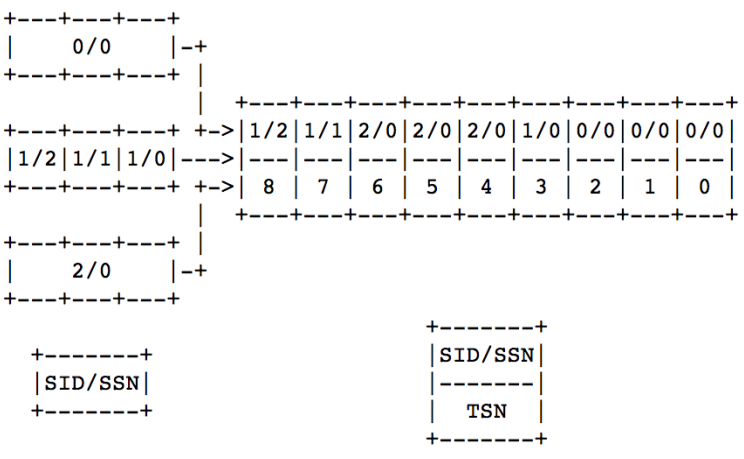
Stream Schedulers




```
struct sctp_sched_ops {
        /* Property handling for a given stream */
        int (*set)(struct sctp_stream *stream, __u16 sid, __u16 value,
                   gfp_t gfp);
        int (*get)(struct sctp_stream *stream, __u16 sid, __u16 *value);

        /* Init the specific scheduler */
        int (*init)(struct sctp_stream *stream);
        /* Init a stream */
        int (*init_sid)(struct sctp_stream *stream, __u16 sid, gfp_t gfp);
        /* Frees the entire thing */
        void (*free)(struct sctp_stream *stream);

        /* Enqueue a chunk */
        void (*enqueue)(struct sctp_outq *q, struct sctp_datamsg *msg);
        /* Dequeue a chunk */
        struct sctp_chunk *(*dequeue)(struct sctp_outq *q);
        /* Called only if the chunk fit the packet */
        void (*dequeue_done)(struct sctp_outq *q, struct sctp_chunk *chunk);
        /* Sched all chunks already enqueued */
        void (*sched_all)(struct sctp_stream *steam);
        /* Unched all chunks already enqueued */
        void (*unsched_all)(struct sctp_stream *steam);
};
```

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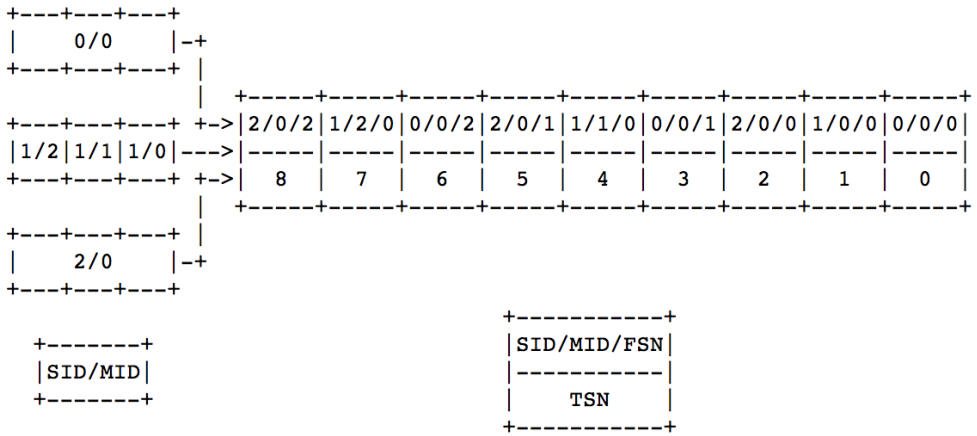
Message Interleaving




```
struct sctp_stream_interleave {
        __u16   data_chunk_len;
        __u16   ftsn_chunk_len;
        /* (I-)DATA process */
        struct sctp_chunk *(*make_datafrag)(const struct sctp_association *asoc,
                                            const struct sctp_sndrcvinfo *sinfo,
                                            int len, __u8 flags, gfp_t gfp);
        void    (*assign_number)(struct sctp_chunk *chunk);
        bool    (*validate_data)(struct sctp_chunk *chunk);
        int     (*ulpevent_data)(struct sctp_ulpq *ulpq,
                                 struct sctp_chunk *chunk, gfp_t gfp);
        int     (*enqueue_event)(struct sctp_ulpq *ulpq,
                                 struct sctp_ulpevent *event);
        void    (*renege_events)(struct sctp_ulpq *ulpq,
                                 struct sctp_chunk *chunk, gfp_t gfp);
        void    (*start_pd)(struct sctp_ulpq *ulpq, gfp_t gfp);
        void    (*abort_pd)(struct sctp_ulpq *ulpq, gfp_t gfp);
        /* (I-)FORWARD-TSN process */
        void    (*generate_ftsn)(struct sctp_outq *q, __u32 ctsn);
        bool    (*validate_ftsn)(struct sctp_chunk *chunk);
        void    (*report_ftsn)(struct sctp_ulpq *ulpq, __u32 ftsn);
        void    (*handle_ftsn)(struct sctp_ulpq *ulpq,
                               struct sctp_chunk *chunk);
};
```

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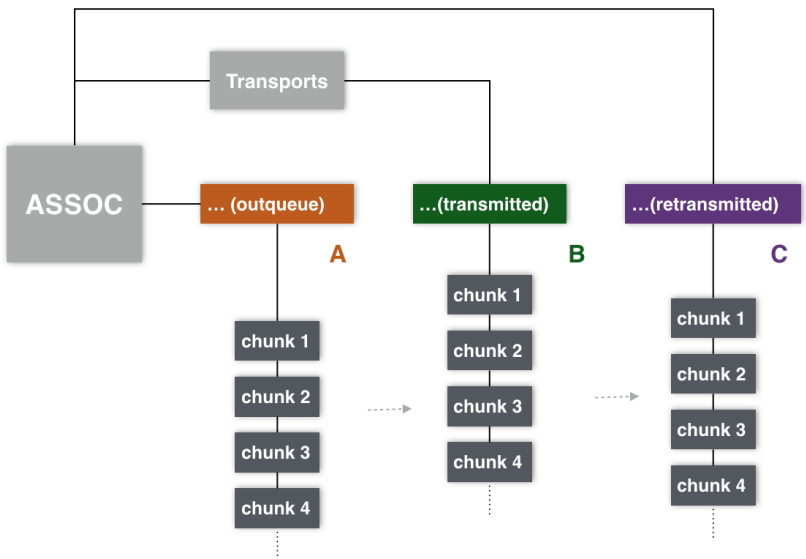
PR_SCTP policies

1. Timed Reliability
   SCTP_PR_SCTP_TTL
2. Limited Retransmissions Policy
   SCTP_PR_SCTP_RTX
   - When dequeuing chunks from A
   - When dequeuing chunks from C
   - When moving chunks from B to C
   - After receiving a SACK, check B and C
3. Priority Policy
   SCTP_PR_SCTP_PRIO
   - Before enqueuing chunk into A
   - And No Enough TX Buffer
   - Then try to drop C -> B -> A.



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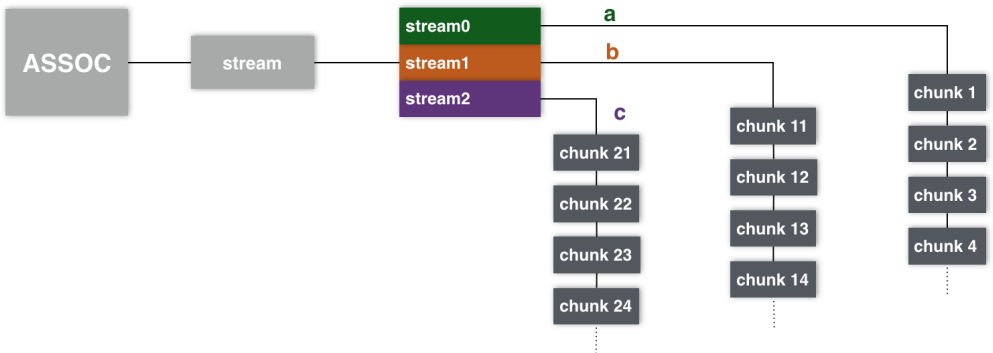
Stream Reconfig



1. Add Outgoing Streams:
   No restrictions
2. Add Incoming Streams:
   No restrictions
3. Reset Outgoing Streams:
   Reset stream 1, b have to be empty
4. Reset Incoming Streams:
   Peer will send Outgoing Stream request for which it has to follow the above rule
5. Reset SSN/TSN:
   All queues have to be empty: A, B, C, a, b, c

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Socket APIs

1. User APIs
   - sctp_sendv
   - sctp_recvv
2. Snd Info Flags
   - SENDALL
   - MSG_MORE
3. Cmsgs
   - PR_INFO
   - AUTH_INFO
   - DSTv4
   - DSTv6

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Linux vs BSD on Features

Chunks

```
LINUX:
 ongoing

BSD:
 SCTP_NR_SELECTIVE_ACK (draft)
 SCTP_PACKET_DROPPED (draft)
 SCTP_PAD_CHUNK
```

Others

```
LINUX:
 sctp_do_sm()
 transport rhashtable
 offload
 diag

BSD:
 sctp_cc_functions
```

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Outline

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Features Development

- Support more Chunks, Apis, Sockopts, Notifications.
- Other features from Draft RFC, like SCTP NAT and CMT.
- SCTP Performance Improvement (including sndbuf auto-tuning)
- Add more test cases in sctp-tests.

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Code Refactor

- Some huge and messy functions.
- Congestion framework.
- Refactor lksctp-tools.

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Hardware Support

- GSO x frag_list x frags.
- Checksum.
- Offload.

The end.

Thanks for listening.