SCTP Tail Loss Recovery

Advances of SCTP Fast Recovery

Tsvwg, IETF 90, Toronto

Karen E E Nielsen, Ericsson, <karen.nielsen@tieto.com>

Goals

- To amend deficiencies of SCTP Fast Recovery (SCTP FR) in situations where SCTP FR is not able to repair losses due to little traffic or drop in tails (bursty traffic patterns).
- Have losses be repaired by timely proactive FR as opposed to lengthy, and throughput degrading, T3 Recovery.
- SIDE NOTE: T3 in SCTP MH results in path changes. Could possibly be addressed by other venues.

Advances of SCTP FR

A. RFC6675 equivalent enhancements of RFC4960 SCTP FR:
   - LOST counts based on SACK scoreboard enhanced with SCTP packet boundary information (DupThress applied to packet counting).
   - "Tail Loss" features of RFC6675 FR. Nextseg() 3) and 4)

B. SCTP TLP: Probe Timer driven entering of SCTP FR – Aka Google TCP TLP ([1], [2]):
   - PTO timer driven entering of Loss Recovery when network has been responsive. Tail Loss Probe Packet used to probe network responsiveness, when necessary.
   - T3 timeout only when network remains unresponsive.

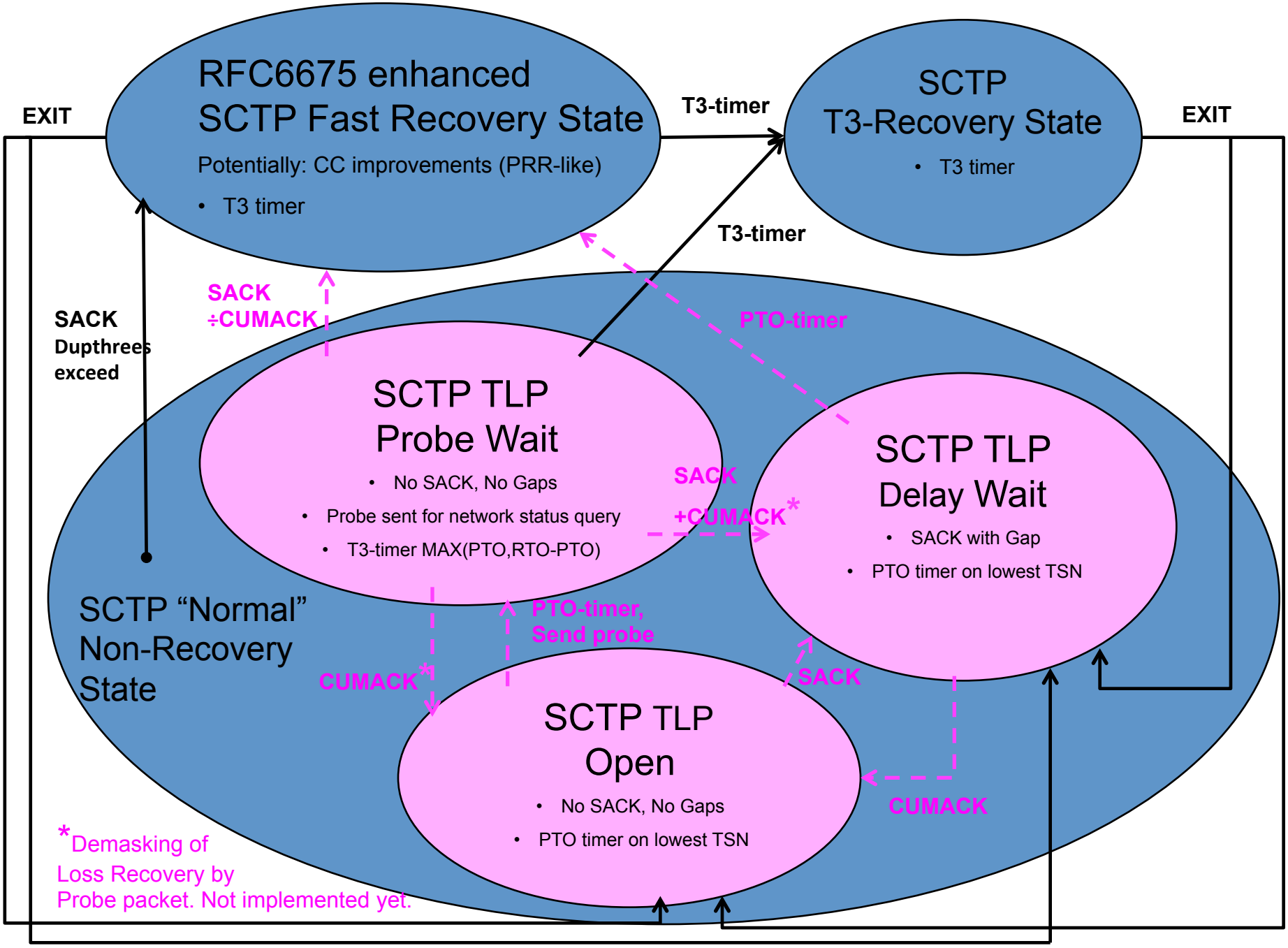
- SCTP TLP Implemented as a supplement to RFC4960 FR.

SCTP TLP State Machine

- Implemented as a new function – similarities with, but no direct dependency to, SCTP/TCP Early FR, RFC5827 or TCP FACK, [5].
- When NOT in Loss Recovery:
  - Proactive Probe Timer (PTO) running on lowest outstanding TSN. Right now: PTO = MIN(RTO, MAX(2*SRTT, 1,5*SRTT+delay_ack))
  - Supplement to DupThress driven entering of FR:
- Tick of PTO + Network responsiveness indication (SACK of TSN higher than lowest TSN has arrived) → Enter FR
  - Probing for network responsiveness test:
- Tick of PTO + no SACK indication → send Tail Loss Probe Packet (TLPP) to determine network responsiveness (at max one TLPP sent per TSN).
- PTO timer delay gives some basic robustness towards re-ordering effects (to be qualified – OUTSTANDING. Prior work on delayed Early FR for TCP – [3]).

Resulting SCTP STM

- Simplified view → (see next slide)
  - PINK States are new SCTP TLP States
  - Dotted PINK lines are new state transitions
  - Not all SACK event types shown (all state transitions shown)
  - Tail Probe Timer - PTO:
    - PTO = MIN(RTO, MAX(2*SRTT, 1,5*SRTT+delay_ack))


RFC6675 enhanced
SCTP Fast Recovery State
Potentially: CC improvements (PRR-like)
• T3 timer
SCTP
T3-Recovery State
• T3 timer
EXIT
EXIT
T3-timer
T3-timer
SACK
÷CUMACK
SACK
Dupthrees
exceed
PTO-timer
SCTP TLP
Probe Wait
• No SACK, No Gaps
• Probe sent for network status query
• T3-timer MAX(PTO,RTO-PTO)
SACK
+CUMACK*
SCTP TLP
Delay Wait
• SACK with Gap
• PTO timer on lowest TSN
SCTP "Normal"
Non-Recovery
State
PTO-timer,
Send probe
CUMACK*
SACK
SCTP TLP
Open
• No SACK, No Gaps
• PTO timer on lowest TSN
CUMACK
*Demasking of
Loss Recovery by
Probe packet. Not implemented yet.

Preliminary Results (1)

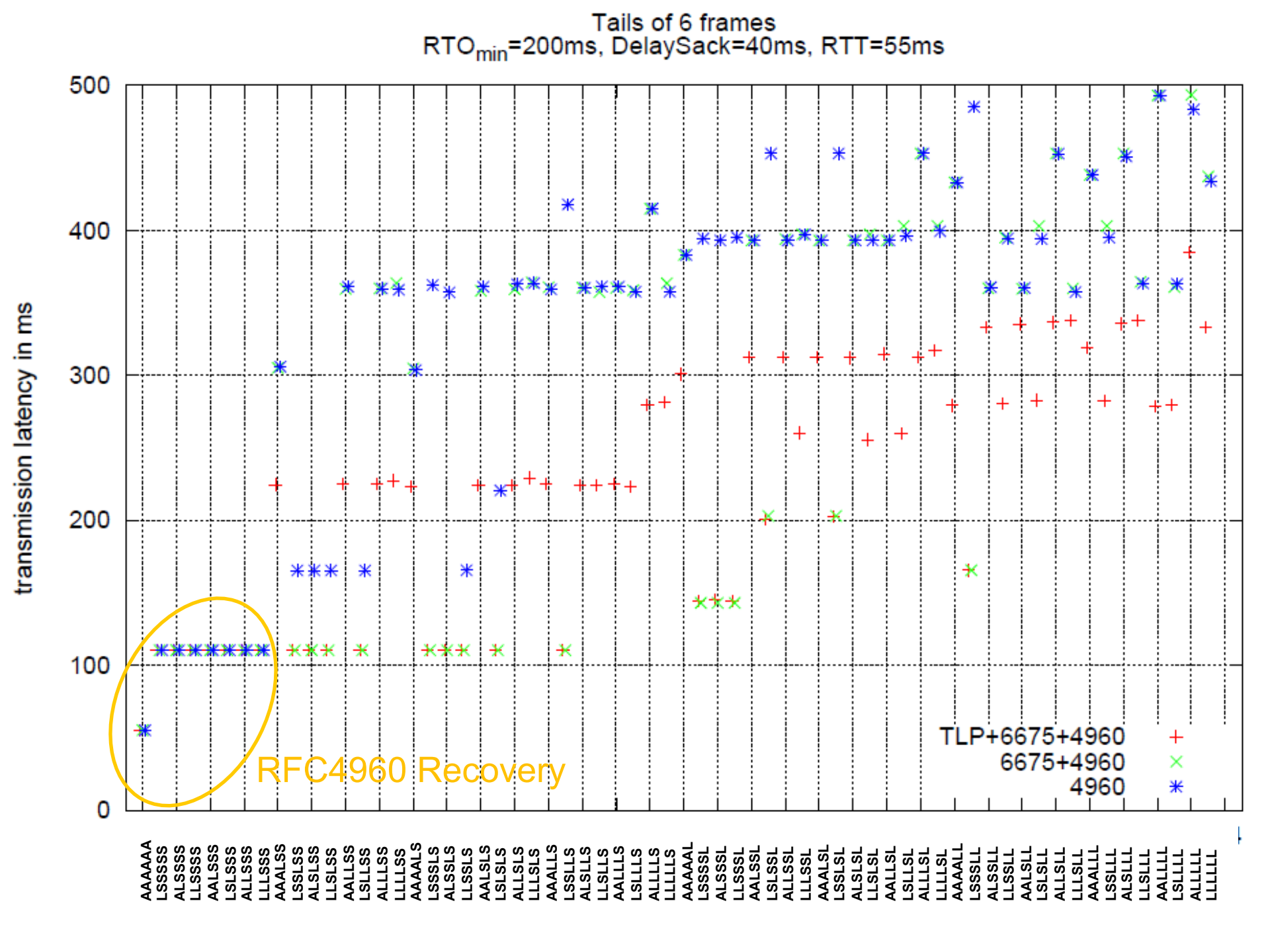
Functional tests:

- Latency of Loss Recovery over a tail loss pattern over 6 SCTP packets transmitted instantly (IW of 4MTU)
- Latency = time from transmit (write) of packets to CUMACK all
- All combinations of tail loss patterns tested (drop filter in ETH egress).
- Results shows median value obtained over a number of tests. Variation only from timer-resolution issues. RTT, RTO_MIN, DELAY_ACK set to prevent algorithmic race conditions.
- No SACK loss, no RTT variation, no retransmission losses.

Preliminary Results (2)

DISCLAIMERS:

- Functional results show logical effect of function
  - Functional tests are limited by Tail size of 6 →Tail loss recovery is not prevented by CWND constrains of present FR logic.
  - Functional result reflects latency gains during FR only - CC operation after FR thus not exposed. Lack of demasking of loss recovery by TLPP not exposed.
  - Relative effect depends crucially on RTO_MIN versus RTT, DELAY_ACK settings.
- Traffic tests are required to evaluate:
  - True significance of function – Overall latency and throughput perspective – This is OUTSTANDING !!

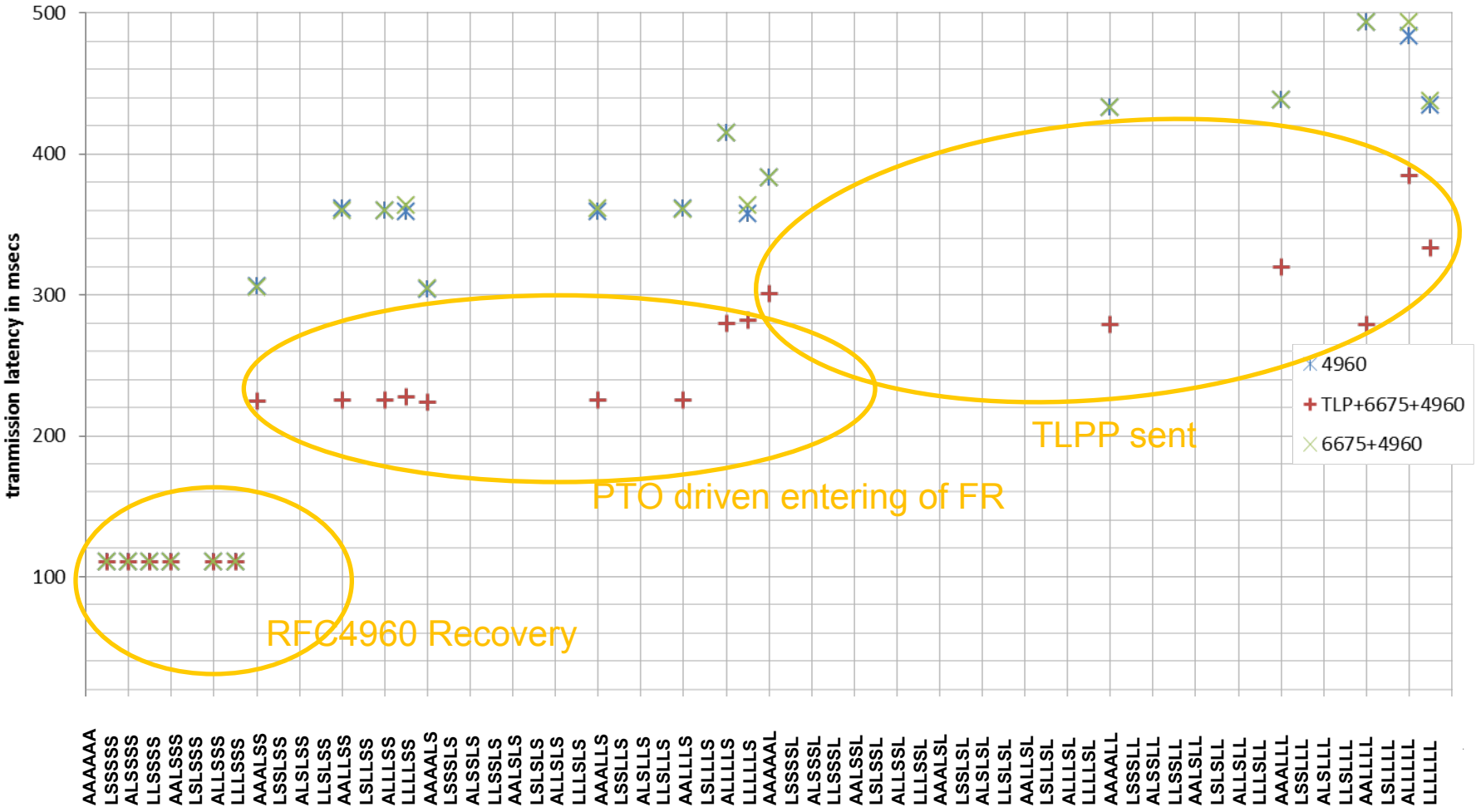

Tails of 6 frames
RTO$_{min}$=200ms, DelaySack=40ms, RTT=55ms
transmission latency in ms
500
400
300
200
100
0
RFC4960 Recovery
TLP+6675+4960
6675+4960
4960
AAAAA
LSSSSS
ALSSSS
LLSSSS
AALSSS
LSLSSS
ALLSSS
LLLSSS
AAALSS
LSSLSS
ALSLSS
LLSLSS
AALLSS
LSLLSS
ALLLSS
LLLLSS
AAAALS
LSSSLS
ALSSLS
LLSSLS
AALSLS
LSLSLS
ALLSLS
LLLSLS
AAALLS
LSSLLS
ALSLLS
LLSLLS
AALLLS
LSLLLS
ALLLLS
LLLLLS
AAAAAL
LSSSSL
ALSSSL
LLSSSL
AALSSL
LSLSSL
ALLSSL
LLLSSL
AAALSL
LSSLSL
ALSLSL
LLSLSL
AALLSL
LSLLSL
ALLLSL
LLLLSL
AAAALL
LSSSLL
ALSSLL
LLSSLL
AALSLL
LSLSLL
ALLSLL
LLLSLL
AAALLL
LSSLLL
ALSLLL
LLSLLL
AALLLL
LSLLLL
ALLLLL
LLLLLL

Evaluation of Results (1)

- T3 prevented for all 63 loss patterns
- No benefits compared with RFC4960 for 7 loss scenarios
- RFC4960 yields T3 for 50 of the loss patterns
- In all 15 “pure” tail loss scenarios - one loss of consecutive LLL’s – SCTP TLP kicks in and SCTP TLP + RFC6775 nextseg() 3) is required to prevent T3.
- In scenarios were RFC6675 improvements alone kick in (SCTP TLP does not), RFC4960 would give T3 in 9 out of the 15. All multiple event loss scenarios.
- SCTP TLP kicks in for 41 of the 63 loss scenarios

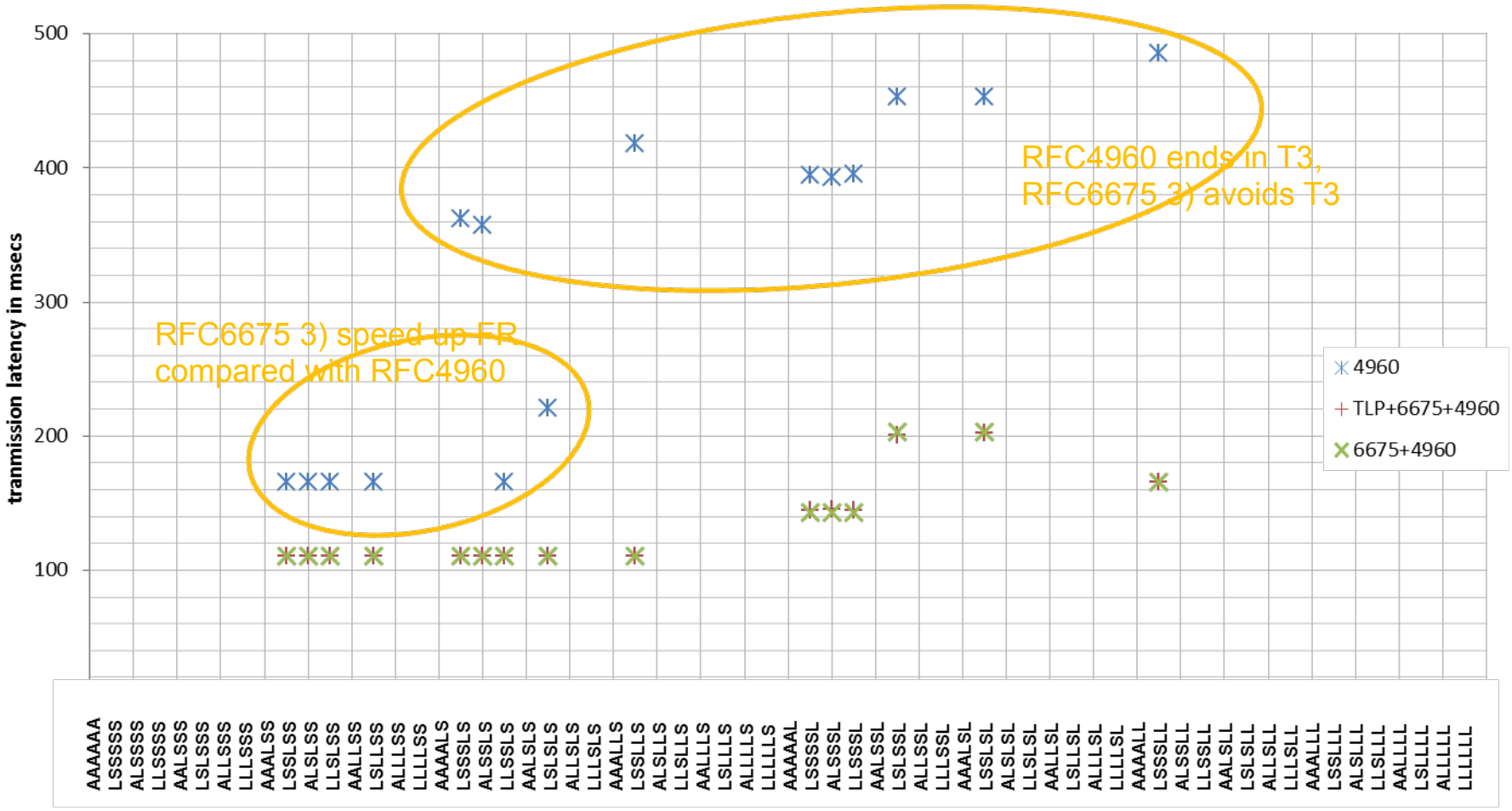
Evaluation of Results (2)

TLP effects for One Tail Loss Event types



Evaluation of Results (3)

RFC6675 Effects (TLP does not (need to) Kick In)



Future work

- Traffic Profile tests: Signaling traffic profiles, Other SCTP user traffic, RTCWEB traffic profiles
- Tail Loss Probe Loss Recovery demasking (aka TCP TLP approach [1])
- CC: CC during FR (RFC6937, TCP-PPR like approach ?) and evaluation of effects of CC after exit of FR.
- SCTP PTO initial: Initial RTT & Initial DATA
- SCTP MH issues, SCTP Max burst pacing during FR
- Potentially: RTO restart considerations aka [4]
- Collect results & Write draft

Next

- Questions and Comments are kindly solicited !
- Very open for help and collaboration, SCTP only, SCTP with close attention to TCP advances or SCTP/TCP jointly
- Would be looking for implementation in other SCTP stacks, e.g., FreeBSD.
- PLEASE comment on tsvwg list

THANK YOU

Miscellaneous

- Running code. Ericsson In-house SCTP/IP SW.
- Product level code – New Logic implementation scales for high performance.
- RFC6675 improvements (A) in product SW in deployment.
- SCTP TLP (B) pt. implemented for investigation and future work only.

References

[1] Dukkipati et al., Tail Loss Probe (TLP): An Algorithm for Fast Recovery of Tail Losses, Expired work.
http://tools.ietf.org/html/draft-dukkipati-tcpm-tcp-loss-probe-01

[2] http://www.ietf.org/mail-archive/web/tcpm/current/msg08627.html

[3] Dukkipati et al, "Proportional Rate Reduction for TCP", Proceedings of the 11th ACM SIGCOMM Conference on Internet Measurement 2011, Berlin, Germany, November 2011.

[4] Hurtig et al, TCP and SCTP RTO Restart, draft-ietf-tcpm-rtorestart-03, Work In Progress

[5] M. Mathis and J. Mahdavi, Forward Acknowledgment, Refining TCP Congestion Control, ACM SIGCOMM Computer Communication Review, vol. 26, 4, 1996.

Appendix

Details of implementation and Discussion

RFC6675-SCTP FR impl. (1)

- Mis-Indication counting:
  - SCTP TSN chunk control and SACK scoreboard information enhanced with SCTP packet boundary information.
  - Mis-indication counting based on *number of packets of higher TSN numbers that have been SACK'ed by the receiver*.
  - DupThress threshold applied to number of packets of higher TSN numbers instead of to number of SACKs arrived.
  - Add robustness towards loss of SACKs.
  - Compare RFC6675/RFC3517 Islost() more than (DupThresh-1)*SMSS bytes above has been SACK'ed. Byte approach not valid for many SCTP applications not sending full sized packets.

RFC6675-SCTP FR impl. (2)

- Fast Recovery Enhancement – nextseg() 3):
  - If there is no data with DupThresh or more mis-indications available and no new data available to send, then outstanding TSNs less than highest SACK'ed TSN are eligible for retransmission.
  - Such TSN must fit within CWND (counted twice in in-flight).

Note: Compared with TCP RFC6675, SCTP RFC4960 does special additional mis-indication counting:

```
(RFC4960 section 7.2.4): If an endpoint is in Fast
 Recovery and a SACK arrives that advances the Cumulative TSN Ack
 Point, the miss indications are incremented for all TSNs reported
 missing in the SACK.
```

But RFC6675 nextseg() 3) still relevant to prevent stop of Fast Recovery for many Tail Loss Patterns.

SCTP – PRR ?

- In present implementation CWND halving may prevent progress of Fast Recovery.
- Improvements are to be investigated. Possibly following approach taken by RFC6937.
- Issue is general relevant for RFC4960 as well as for the RFC6675 and TP improvements considered here.
- Relation to SCTP max burst pacing. Not investigated yet.

RFC6675-SCTP FR impl. (3)

- Fast Recovery Enhancement – nextseg() 4):
  - Single Rescue of tail losses: No TSN eligible for retransmission due to mis-indication count >= DupThresh or due to nextseg() 3), and no new data is available, then one packet of highest outstanding TSNs may be send.
  - At most one Rescue operation per Fast Recovery period. Rescue TSN counts twice in in-flight.

Discussion:

- Should Rescue packet be limited by CWND. Present implementation only sends RESCUE if CWND allows.
- Should Rescue TSNs be limited by (<=) Recovery Point TSN. Present implementation apply this limit. Not sure about TCP impl.

SCTP TLP impl (1)

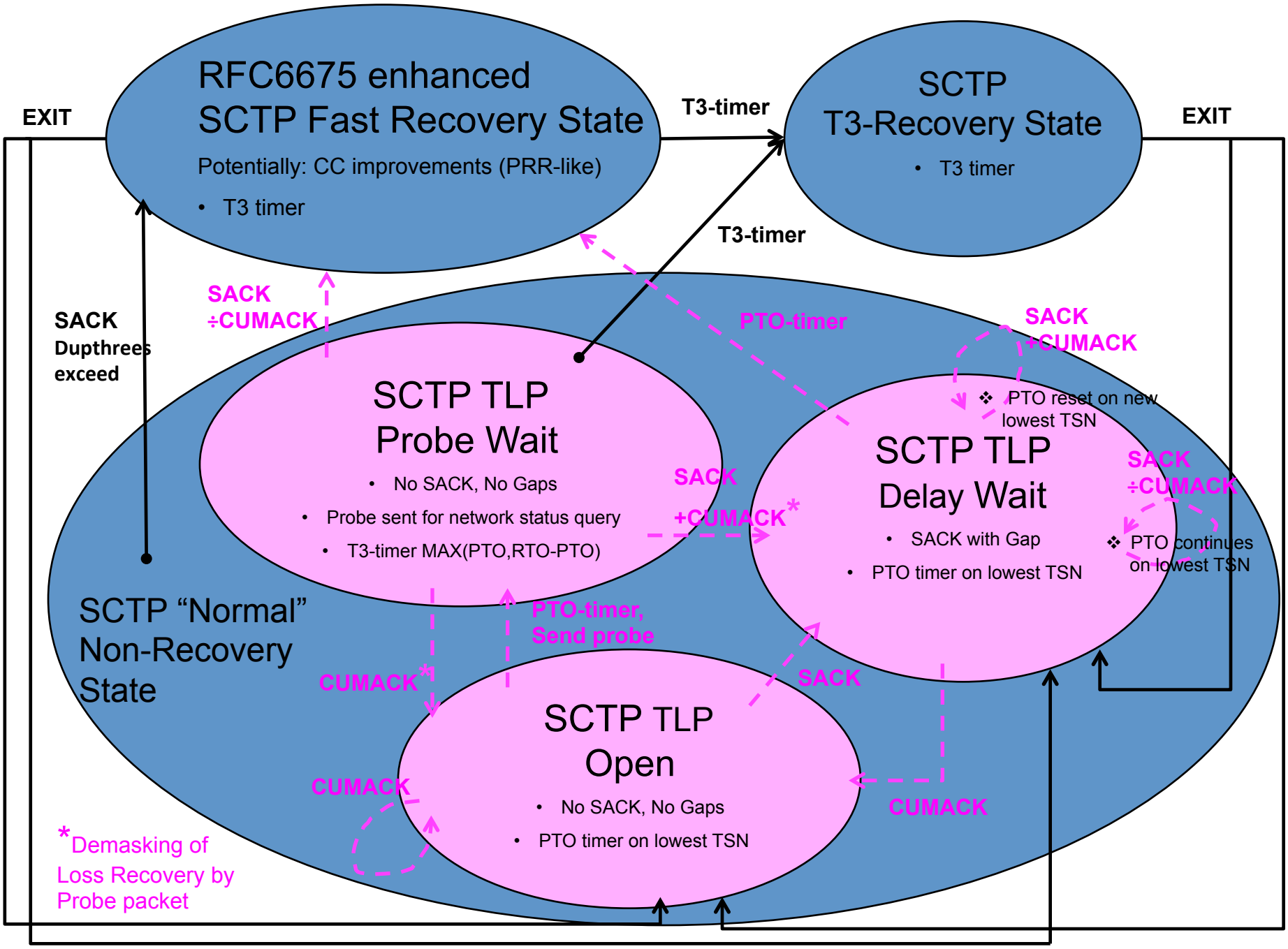
- Tail Loss Probe Packet (TLPP) Transmission details:
  - TLPP as new data is full-sized packet
  - TLPP of Rxt data is one TSN chunk. TLPP of Rtx data counts twice in in-flight.
  - TLPP of new data is always preferred if available.
- TLPP Transmission conditions
  - If no TLPP is outstanding, a probe is sent unconditionally of CWND,
  - If a TLPP is outstanding, a probe is sent conditionally to flightsize < CWND + 1PMTU, otherwise no TLPP is sent.
    - New data is always preferred.
    - If no new data exists, a probe of RTX data is sent conditional to whether a TLPP is already outstanding.
      - If no TLPP is outstanding, send TLPP consisting of highest outstanding TSN
      - If a TLPP is outstanding, then if and only if the probe is highest outstanding TSN may it be resent. Otherwise no TLPP is sent.

SCTP TLP impl (2)

- At TLP driven entering of Fast Recovery, RFC6675enhanced RFC4960 Fast Recovery actions are taken.
  - CWND is halved (conditional to future PRR ?)
  - First Lowest TSN full sized packet is retransmitted unconditional to CWND
  - Additional TSNs are retransmitted conditional to CWND and RFC6675enhanced RFC4960 FR procedures.
- Discussion:
  - Should first unconditional retransmission be counted twice in in-flight
  - General CC considerations (PRR ?) during Fast Recovery

SCTP TLP impl (3)

- Demasking of Loss Recovery achieved by virtue of Tail Loss Probe packet is not implemented yet. Logic of TCP TLP, [1], is believed to apply (founded on TLPP transmission conditions).
  - Demasking entails CWND halving as if Fast Recovery had been entered.
- No PTO timer running in Persist State (Zero Window probing). Implemented.


RFC6675 enhanced
SCTP Fast Recovery State
Potentially: CC improvements (PRR-like)
• T3 timer
SCTP
T3-Recovery State
• T3 timer
EXIT
T3-timer
T3-timer
EXIT
SACK
Dupthrees
exceed
SACK
÷CUMACK
PTO-timer
SACK
+CUMACK
SCTP TLP
Probe Wait
• No SACK, No Gaps
• Probe sent for network status query
• T3-timer MAX(PTO,RTO-PTO)
SACK
+CUMACK*
❖ PTO reset on new lowest TSN
SCTP TLP
Delay Wait
• SACK with Gap
• PTO timer on lowest TSN
SACK
÷CUMACK
❖ PTO continues on lowest TSN
SCTP "Normal"
Non-Recovery
State
PTO-timer,
Send probe
CUMACK*
SACK
SCTP TLP
Open
• No SACK, No Gaps
• PTO timer on lowest TSN
CUMACK
CUMACK
*Demasking of
Loss Recovery by
Probe packet

CC handling

- Benefits of TLP (versus entering RFC4960/ RFC6675 T3-recovery) likely to depend on CC operation after exit of Fast Recovery.
- SCTP RFC4960 CC is standard, not CUBIC. TCP TLP results (Google) presumably based on CUBIC.
- Issue to be evaluated in future tests.

RTO/PTO Restart

- TSN timer running on lowest outstanding TSN presently. RT0/PTO restart not implemented.
- PTO restart is observed to decrease Loss Recovery latency in some Loss Patterns (6-packets).
- Issue may be considered in future activity.

Functional Test Results

- Environment:
  - RTT = 55 msecs (not varied)
  - RTO_MIN = 200 msecs
  - DELAY_ACK = 40 msecs
  - PTO =MIN(RTO , MAX(2*SRTT, 1,5*SRTT+delay_ack)) ~ 125 msecs
  - No Packet loss except for controlled packet loss at ETH egress
- Legend in the following:

LEGEND	
Effects	
RFC4960	No effect of RFC6675 improvements nor TLP
RFC6675	Effect of RFC6675 improvements, TLP does not kick in
TLP	Effect of TLP and RFC6675 improvements, Kick in of TLP is significant.
Effect Comments	
RFC6675 3)speed	Recovery progresses faster due to RFC6675 nextseg() 3)
RFC6675 3)no stop	Fast Recovery would terminate in T3 if RFC6675 nextseg() 3) was not active
RFC6675 4)	Fast Recovery would terminate in T3 if RFC6675 nextseg() 4) was not active
RFC6675 3)no stop + 4)	Fast Recovery would terminate in T3 if RFC6675 nextseg() 4) or 3) was not active
RFC4960 recover high L's	RFC4960, sec 7.2.4, mis-indication counting at Cumack serves to approriately increase mis-indications for highest outstanding TSNs even if there are no higher SACK'ed TSNs. This feature makes RFC6675 4) unnecessary

Results 0-31

Pattern	TLP + RFC6675 + RFC4960 msec	RFC6675 + RFC4960 msec	RFC4960 msec	RFC4960 T3	RFC6675 T3	Probe sent	Effects	Effect comments	Comments	Loss Pattern	SACK at FR start	#Loss Events
0	55	55	55							AAAAAA	=	0
1	110	110	110				RFC4960			LSSSSS	=	1
2	110	110	110				RFC4960			ALSSSS	=	1
3	111	111	110				RFC4960			LLSSSS	=	1
4	110	110	110				RFC4960			AALSSS	=	1
5	110	110	110				RFC4960			LSLSSS	=	2
6	110	110	110				RFC4960			ALLSSS	=	1
7	111	111	111				RFC4960			LLLSSS	=	1
8	225	305	306	1	1		TLP		Compare Delayed Early FR	AAALSS	=	1
9	110	110	166				RFC6675	RFC6675 3)speed		LSSLSS	=	2
10	110	110	166				RFC6675	RFC6675 3)speed		ALSLSS	=	2
11	110	110	166				RFC6675	RFC6675 3)speed		LLSLSS	=	2
12	225	360	361	1	1		TLP	RFC6675 3)speed		AALLSS	=	1
13	110	110	166				RFC6675	RFC6675 3)speed		LSLLSS	=	2
14	225	360	360	1	1		TLP	RFC6675 3)speed		ALLLSS	=	1
15	227	364	359	1	1		TLP	RFC6675 3)speed		LLLLSS	=	1
16	223	305	304	1	1		TLP		Compare Delayed Early FR	AAAALS	=	1
17	110	110	362	1			RFC6675	RFC6675 3)no stop		LSSSLS	=	2
18	110	110	357	1			RFC6675	RFC6675 3)no stop		ALSSLS	=	2
19	110	111	166				RFC6675	RFC6675 3)speed		LLSSLS	=	2
20	224	358	361	1	1		TLP	RFC6675 3)no stop		AALSLS	=	2
21	110	110	221				RFC6675	RFC6675 3)speed		LSLSLS	=	2
22	225	359	363	1	1		TLP	RFC6675 3)speed		ALLSLS	=	2
23	229	364	364	1	1		TLP	RFC6675 3)speed		LLLSLS	=	2
24	225	361	359	1	1		TLP	RFC6675 3)no stop		AAALLS	=	1
25	110	110	418	1			RFC6675	RFC6675 3)no stop		LSSLLS	=	2
26	224	361	360	1	1		TLP	RFC6675 3)no stop		ALSLLS	=	2
27	224	357	361	1	1		TLP	RFC6675 3)speed		LLSLLS	=	2
28	225	360	361	1	1		TLP	RFC6675 3)no stop		AALLLS	=	1
29	224	359	358	1	1		TLP	RFC6675 3)no stop		LSLLLS	=	2
30	280	415	415	1	1		TLP	RFC6675 3)no stop		ALLLLS	=	1
31	282	363	358	1	1		TLP	RFC6675 3)no stop		LLLLLS	=	1

Results 32-63

Pattern	TLP + RFC6675 + RFC4960 msec	RFC6675 + RFC4960 msec	RFC4960 msec	RFC4960 T3	RFC6675 T3	Probe sent	Effects	Effect comments	Comments	Loss Pattern	SACK at FR start	#Loss Events
32	301	383	383	1	1y		TLP			AAAAAL	AAAAAA	1
33	145	143	394	1			RFC6675	RFC6675 4)		LSSSSL	=	2
34	146	143	393	1			RFC6675	RFC6675 4)		ALSSSL	=	2
35	145	143	395	1			RFC6675	RFC6675 4)		LLSSSL	=	2
36	312	393	393	1	1		TLP	RFC6675 4)		AALSSL	=	2
37	201	203	453	1			RFC6675	RFC6675 3)speed + 4)		LSLSSL	=	3
38	313	394	393	1	1		TLP	RFC6675 3)speed + 4)		ALLSSL	=	2
39	260	397	397	1	1		TLP	RFC6675 3)speed	RFC4960 recover high L	LLLSSL	=	2
40	313	393	393	1	1		TLP	RFC6675 4)		AAALSL	=	2
41	203	203	453	1			RFC6675	RFC6675 3)no stop + 4)		LSSLSL	=	3
42	312	393	393	1	1		TLP	RFC6675 3)no stop + 4)		ALSLSL	=	3
43	256	397	393	1	1		TLP	RFC6675 3)speed	RFC4960 recover high L	LLSLSL	=	3
44	315	393	393	1	1		TLP	RFC6675 3)no stop + 4)		AALLSL	=	2
45	260	403	397	1	1		TLP	RFC6675 3)no stop	RFC4960 recover high L	LSLLSL	=	2
46	313	453	453	1	1		TLP	RFC6675 3)no stop	RFC4960 recover high L	ALLLSL	=	2
47	318	403	400	1	1		TLP	RFC6675 3)no stop	RFC4960 recover high L	LLLLSL	=	2
48	279	433	433	1	1y		TLP			AAAALL	AAAALS	1
49	166	166	485	1			RFC6675	RFC6675 3)no stop + 4)		LSSSLL	=	2
50	333	360	361	1	1		TLP	RFC6675 3)no stop + 4)		ALSSLL	=	2
51	281	395	394	1	1		TLP	RFC6675 4)		LLSSLL	=	2
52	336	360	360	1	1		TLP	RFC6675 3)no stop + 4)		AALSLL	=	2
53	283	403	394	1	1		TLP	RFC6675 3)no stop + 4)		LSLSLL	=	2
54	337	453	453	1	1		TLP	RFC6675 3)no stop + 4)		ALLSLL	=	2
55	338	360	358	1	1		TLP	RFC6675 3)no stop	RFC4960 recover high L's	LLLSLL	=	2
56	319	438	438	1	1y		TLP	RFC6675 3)no stop		AAALLL	AAALLS	1
57	283	403	395	1	1		TLP	RFC6675 3)no stop + 4)		LSSLLL	=	2
58	336	453	451	1	1		TLP	RFC6675 3)no stop + 4)		ALSLLL	=	2
59	338	365	364	1	1		TLP	RFC6675 3)no stop + 4)		LLSLLL	=	2
60	279	493	493	1	1y		TLP	RFC6675 3)no stop		AALLLL	AALLLS	1
61	280	361	363	1	1		TLP	RFC6675 3)no stop + 4)		LSLLLL	=	2
62	385	493	483	1	1y		TLP	RFC6675 3)no stop		ALLLLL	ALLLLS	1
63	333	437	434	1	1y		TLP	RFC6675 3)no stop		LLLLLL	LLLLLS	1

Results – One Loss Event

Pattern	TLP + RFC6675 + + RFC4960 msec	RFC6675 + RFC4960 msec	RFC4960 msec	RFC4960 T3	RFC6675 T3	Probe sent	Effects	Effect comments	Comments	Loss Pattern	SACK at FR start	#Loss Events
1	110	110	110				RFC4960			LSSSSS	=	1
2	110	110	110				RFC4960			ALSSSS	=	1
3	111	111	110				RFC4960			LLSSSS	=	1
4	110	110	110				RFC4960			AALSSS	=	1
6	110	110	110				RFC4960			ALLSSS	=	1
7	111	111	111				RFC4960			LLLSSS	=	1
8	225	305	306	1	1		TLP		Compare Delayed Early FR	AAALSS	=	1
12	225	360	361	1	1		TLP	RFC6675 3)speed		AALLSS	=	1
14	225	360	360	1	1		TLP	RFC6675 3)speed		ALLLSS	=	1
15	227	364	359	1	1		TLP	RFC6675 3)speed		LLLLSS	=	1
16	223	305	304	1	1		TLP		Compare Delayed Early FR	AAAALS	=	1
24	225	361	359	1	1		TLP	RFC6675 3)no stop		AAALLS	=	1
28	225	360	361	1	1		TLP	RFC6675 3)no stop		AALLLS	=	1
30	280	415	415	1	1		TLP	RFC6675 3)no stop		ALLLLS	=	1
31	282	363	358	1	1		TLP	RFC6675 3)no stop		LLLLLS	=	1
32	301	383	383	1	1	y	TLP			AAAAAL	AAAAAA	1
48	279	433	433	1	1	y	TLP			AAAALL	AAAALS	1
56	319	438	438	1	1	y	TLP	RFC6675 3)no stop		AAALLL	AAALLS	1
60	279	493	493	1	1	y	TLP	RFC6675 3)no stop		AALLLL	AALLLS	1
62	385	493	483	1	1	y	TLP	RFC6675 3)no stop		ALLLLL	ALLLLS	1
63	333	437	434	1	1	y	TLP	RFC6675 3)no stop		LLLLLL	LLLLLS	1

Notes:

- TLP function required for all loss patterns not handled by RFC4960. RFC6675 improvements does not suffice to avoid T3
- RFC6675 4) improvement not significant

Results – RFC6675 effects

Pattern	TLP + RFC6675 + RFC4960 msec	RFC6675 + RFC4960 msec	RFC4960 msec	RFC4960 T3	RFC6675 T3	Probe sent	Effects	Effect comments	Comments	Loss Pattern	SACK at FR start	#Loss Events
9	110	110	166				RFC6675	RFC6675 3)speed		LSSLSS	=	2
10	110	110	166				RFC6675	RFC6675 3)speed		ALSLSS	=	2
11	110	110	166				RFC6675	RFC6675 3)speed		LLSLSS	=	2
13	110	110	166				RFC6675	RFC6675 3)speed		LSLLSS	=	2
17	110	110	362	1			RFC6675	RFC6675 3)no stop		LSSSLS	=	2
18	110	110	357	1			RFC6675	RFC6675 3)no stop		ALSSLS	=	2
19	110	111	166				RFC6675	RFC6675 3)speed		LLSSLS	=	2
21	110	110	221				RFC6675	RFC6675 3)speed		LSLSLS	=	2
25	110	110	418	1			RFC6675	RFC6675 3)no stop		LSSLLS	=	2
33	145	143	394	1			RFC6675	RFC6675 4)		LSSSSL	=	2
34	146	143	393	1			RFC6675	RFC6675 4)		ALSSSL	=	2
35	145	143	395	1			RFC6675	RFC6675 4)		LLSSSL	=	2
37	201	203	453	1			RFC6675	RFC6675 3)speed + 4)		LSLSSL	=	3
41	203	203	453	1			RFC6675	RFC6675 3)no stop + 4)		LSSLSL	=	3
49	166	166	485	1			RFC6675	RFC6675 3)no stop + 4)		LSSSLL	=	2

Results – TLP

Pattern	TLP + RFC6675 + RFC4960 msec	RFC6675 + RFC4960 msec	RFC4960 msec	RFC4960 T3	RFC6675 T3	Probe sent	Effects	Effect comments	Comments	Loss Pattern	SACK at FR start	#Loss Events
8	225	305	306	1	1		TLP		Compare Delayed Early FR	AAALSS	=	1
12	225	360	361	1	1		TLP	RFC6675 3)speed		AALLSS	=	1
14	225	360	360	1	1		TLP	RFC6675 3)speed		ALLLSS	=	1
15	227	364	359	1	1		TLP	RFC6675 3)speed		LLLLSS	=	1
16	223	305	304	1	1		TLP		Compare Delayed Early FR	AAAALS	=	1
20	224	358	361	1	1		TLP	RFC6675 3)no stop		AALSLS	=	2
22	225	359	363	1	1		TLP	RFC6675 3)speed		ALLSLS	=	2
23	229	364	364	1	1		TLP	RFC6675 3)speed		LLLSLS	=	2
24	225	361	359	1	1		TLP	RFC6675 3)no stop		AAALLS	=	1
26	224	361	360	1	1		TLP	RFC6675 3)no stop		ALSLLS	=	2
27	224	357	361	1	1		TLP	RFC6675 3)speed		LLSLLS	=	2
28	225	360	361	1	1		TLP	RFC6675 3)no stop		AALLLS	=	1
29	224	359	358	1	1		TLP	RFC6675 3)no stop		LSLLLS	=	2
30	280	415	415	1	1		TLP	RFC6675 3)no stop		ALLLLS	=	1
31	282	363	358	1	1		TLP	RFC6675 3)no stop		LLLLLS	=	1
32	301	383	383	1	1	y	TLP			AAAAAL	AAAAAA	1
36	312	393	393	1	1		TLP	RFC6675 4)		AALSSL	=	2
38	313	394	393	1	1		TLP	RFC6675 3)speed + 4)		ALLSSL	=	2
39	260	397	397	1	1		TLP	RFC6675 3)speed	RFC4960 recover high L	LLLSSL	=	2
40	313	393	393	1	1		TLP	RFC6675 4)		AAALSL	=	2
42	312	393	393	1	1		TLP	RFC6675 3)no stop + 4)		ALSLSL	=	3
43	256	397	393	1	1		TLP	RFC6675 3)speed	RFC4960 recover high L	LLSLSL	=	3
44	315	393	393	1	1		TLP	RFC6675 3)no stop + 4)		AALLSL	=	2
45	260	403	397	1	1		TLP	RFC6675 3)no stop	RFC4960 recover high L	LSLLSL	=	2
46	313	453	453	1	1		TLP	RFC6675 3)no stop	RFC4960 recover high L	ALLLSL	=	2
47	318	403	400	1	1		TLP	RFC6675 3)no stop	RFC4960 recover high L	LLLLSL	=	2
48	279	433	433	1	1	y	TLP			AAAALL	AAAALS	1
50	333	360	361	1	1		TLP	RFC6675 3)no stop + 4)		ALSSLL	=	2
51	281	395	394	1	1		TLP	RFC6675 4)		LLSSLL	=	2
52	336	360	360	1	1		TLP	RFC6675 3)no stop + 4)		AALSLL	=	2
53	283	403	394	1	1		TLP	RFC6675 3)no stop + 4)		LSLSLL	=	2
54	337	453	453	1	1		TLP	RFC6675 3)no stop + 4)		ALLSLL	=	2
55	338	360	358	1	1		TLP	RFC6675 3)no stop	RFC4960 recover high L's	LLLSLL	=	2
56	319	438	438	1	1	y	TLP	RFC6675 3)no stop		AAALLL	AAALLS	1
57	283	403	395	1	1		TLP	RFC6675 3)no stop + 4)		LSSLLL	=	2
58	336	453	451	1	1		TLP	RFC6675 3)no stop + 4)		ALSLLL	=	2
59	338	365	364	1	1		TLP	RFC6675 3)no stop + 4)		LLSLLL	=	2
60	279	493	493	1	1	y	TLP	RFC6675 3)no stop		AALLLL	AALLLS	1
61	280	361	363	1	1		TLP	RFC6675 3)no stop + 4)		LSLLLL	=	2
62	385	493	483	1	1	y	TLP	RFC6675 3)no stop		ALLLLL	ALLLLS	1
63	333	437	434	1	1	y	TLP	RFC6675 3)no stop		LLLLLL	LLLLLS	1