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Y. Nishida  
GE Global Research  
P. Natarajan  
Cisco Systems  
A. Caro  
BBN Technologies  
P. Amer  
University of Delaware  
K. Nielsen  
Ericsson  
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**SCTP-PF: Quick Failover Algorithm in SCTP**  
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Abstract

SCTP supports multi-homing. However, when the failover operation specified in [RFC4960](#) is followed, there can be significant delay and performance degradation in the data transfer path failover. To overcome this problem this document specifies a quick failover algorithm (SCTP-PF) based on the introduction of a Potentially Failed (PF) state in SCTP Path Management.

The document also specifies a dormant state operation of SCTP. This dormant state operation is required to be followed by an SCTP-PF implementation, but it may equally well be applied by a standard [RFC4960](#) SCTP implementation.

Additionally, the document introduces an alternative switchback operation mode called Primary Path Switchover that will be beneficial in certain situations. This mode of operation applies to both a standard [RFC4960](#) SCTP implementation as well as to a SCTP-PF implementation.

The procedures defined in the document require only minimal modifications to the [RFC4960](#) specification. The procedures are sender-side only and do not impact the SCTP receiver.

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## [1.](#) Introduction

The Stream Control Transmission Protocol (SCTP) specified in [\[RFC4960\]](#) supports multi-homing at the transport layer. SCTP's multi-homing features include failure detection and failover procedures to provide network interface redundancy and improved end-to-end fault tolerance. In SCTP's current failure detection procedure, the sender must experience Path.Max.Retrans (PMR) number of consecutive failed timer-based retransmissions on a destination address before detecting a path failure. Until detecting the path failure, the sender continues to transmit data on the failed path. The prolonged time in which [\[RFC4960\]](#) SCTP continues to use a failed path severely degrades the performance of the protocol. To address this problem, this document specifies a quick failover algorithm (SCTP-PF) based on the introduction of a new Potentially Failed (PF) path state in SCTP path management. The performance deficiencies of the [\[RFC4960\]](#) failover operation, and the improvements obtainable from the introduction of a Potentially Failed state in SCTP, were proposed and documented in [\[NATARAJAN09\]](#) for Concurrent Multipath Transfer SCTP [\[IYENGAR06\]](#).

While SCTP-PF can accelerate failover process and improve performance, the risks that an SCTP endpoint enters in dormant state where all destination addresses are inactive can be increased. [\[RFC4960\]](#) leaves the protocol operation during dormant state to implementations and encourages to avoid entering the state as much as possible by careful tuning of the Path.Max.Retrans (PMR) and Association.Max.Retrans (AMR) parameters. We specify a dormant state operation for SCTP-PF which makes SCTP-PF provide the same disruption tolerance as [\[RFC4960\]](#) despite that the dormant state may be entered more quickly. The dormant state operation may equally well be applied by an [\[RFC4960\]](#) implementation and will here serve to provide added fault tolerance for situations where the tuning of the Path.Max.Retrans (PMR) and Association.Max.Retrans (AMR) parameters fail to provide adequate prevention of the entering of the dormant state.

The operation after the recovery of a failed path equally well impacts the performance of the protocol. With the procedures specified in [\[RFC4960\]](#) SCTP will, after a failover from the primary



path, switch back to use the primary path for data transfer as soon as this path becomes available again. From a performance perspective such a forced switchback of the data transmission path can be suboptimal as the CWND towards the original primary destination address has to be rebuilt once data transfer resumes, [CAR002]. As an optional alternative to the switchback operation of [RFC4960], this document specifies an alternative Primary Path Switchover procedure which avoid such forced switchbacks of the data transfer path. The Primary Path Switchover operation was originally proposed in [CAR002].

While SCTP-PF primarily is motivated by a desire to improve the multi-homed operation, the feature applies also to SCTP single-homed operation. Here the algorithm serves to provide increased failure detection on idle associations, whereas the failover or switchback aspects of the algorithm will not be activated. This is discussed in more detail in [Appendix C](#).

A brief description of the motivation for the introduction of the Potentially Failed state including a discussion of alternative approaches to mitigate the deficiencies of the [RFC4960] failover operation are given in the Appendices. Discussion of path bouncing effects that might be caused by frequent switchover, are also provided there.

## **[2. Conventions and Terminology](#)**

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in [RFC2119].

## **[3. SCTP with Potentially Failed Destination State \(SCTP-PF\)](#)**

### **[3.1. Overview](#)**

To minimize the performance impact during failover, the sender should avoid transmitting data to a failed destination address as early as possible. In the [RFC4960] SCTP path management scheme, the sender stops transmitting data to a destination address only after the destination address is marked inactive. This process takes a significant amount of time as it requires the error counter of the destination address to exceed the Path.Max.Retrans (PMR) threshold. The issue cannot simply be mitigated by lowering of the PMR threshold because this may result in spurious failure detection and unnecessary prevention of the usage of a preferred primary path as well as it, due to the coupled tuning of the Path.Max.Retrans (PMR) and the Association.Max.Retrans (AMR) parameter values in [RFC4960], may result in compromisation of the fault tolerance of SCTP.



The solution provided in this document is to extend the SCTP path management scheme of [RFC4960] by the addition of the Potentially Failed (PF) state as an intermediate state in between the active and inactive state of a destination address in the [RFC4960] path management scheme, and let the failover of data transfer away from a destination address be driven by the entering of the PF state instead of by the entering of the inactive state. Thereby SCTP may perform quick failover without compromising the overall fault tolerance of [RFC4960] SCTP. At the same time, RT0-based HEARTBEAT probing is initiated towards a destination address once it enters PF state. Thereby SCTP may quickly ascertain whether network connectivity towards the destination address is broken or whether the failover was spurious. In the case where the failover was spurious data transfer may quickly resume towards the original destination address.

The new failure detection algorithm assumes that loss detected by a timeout implies either severe congestion or network connectivity failure and it assumes that by default a destination address is classified as PF already at the occurrence of one first timeout.

### **3.2. Specification of the SCTP-PF Procedures**

The SCTP-PF operation is specified as follows:

1. The sender maintains a new tunable SCTP Protocol Parameter called PotentiallyFailed.Max.Retrans (PFMR). The PFMR defines the new intermediate PF threshold on the destination address error counter at exceed of which the destination address is classified as PF. The RECOMMENDED value of PFMR is 0, but other values MAY be used. Setting PFMR larger to or equal to Path.Max.Retrans (PMR) does not result in definition of a PF threshold for the destination address. I.e., the destination address will not be classified as PF prior to reaching inactive state.
2. The error counter of an active destination address is incremented as specified in [RFC4960]. This means that the error counter of the destination address will be incremented each time the T3-rtx timer expires, or each time a HEARTBEAT chunk is sent when idle and not acknowledged within an RT0. When the value in the destination address error counter exceeds PFMR, the endpoint MUST mark the destination address as in the PF state.
3. The PFMR threshold defines the point the destination address no longer is considered a good candidate for data transmission and a SCTP-PF sender SHOULD NOT send data to destination addresses



in PF state when alternative destination addresses in active state are available. Specifically this means that:

- i When there is outbound data to send and the destination address presently used for data transmission is in PF state, the sender SHOULD choose a destination address in active state, if one exists, and failover to deploy this destination address for data transmission.
- ii When retransmitting data that has timed out and the sender thus by [\[RFC4960\], section 6.4.1](#), should attempt to pick a new destination address for data retransmission, the sender SHOULD choose an alternate destination transport address in active state if one exists.
- iii When there is outbound data to send and the SCTP user explicitly requests to send data to a destination address in PF state, the sender SHOULD send the data to an alternate destination address in active state if one exists.

When choosing among multiple destination addresses in active state the following considerations are given:

- A. An SCTP sender should comply with [\[RFC4960\], section 6.4.1](#), principles of choosing most divergent source-destination pairs compared with, for i.: the destination address in PF state that it performs a failover from, and for ii.: the destination address towards which the data timed out. Rules for picking the most divergent source-destination pair are an implementation decision and are not specified within this document.
- B. A SCTP-PF sender MAY choose to send data to a destination address in PF state, even if destination addresses in active state exist, have the SCTP-PF sender other means of information available that disqualifies the destination address in active state from being preferred. However, the discussion of such mechanisms is outside of the scope of the SCTP-PF operation specified in this document.

In all cases, the sender MUST NOT change the state of chosen destination address, whether this state be active or PF, and it MUST NOT clear the error counter of the destination address as a result of choosing the destination address for data transmission.

- 4. When the destination addresses are all in PF state or some in PF state and some in inactive state, the sender MUST choose one



destination address in PF state and transmit or retransmit data to this destination address using the following rules:

- A. The sender SHOULD choose the destination in PF state with the lowest error count (fewest consecutive timeouts) for data transmission and transmit or retransmit data to this destination.
- B. When there are multiple destination addresses in PF state with same error count, the sender should let the choice among the multiple destination addresses in PF state with equal error count be based on the [\[RFC4960\], section 6.4.1](#), principles of choosing most divergent source-destination pairs when executing (potentially consecutive) retransmission. Rules for picking the most divergent source-destination pair are an implementation decision and are not specified within this document.
- C. A sender MAY choose to deploy other strategies than the above when choosing among multiple destinations in PF state have the SCTP-PF sender other means of information available that qualifies a particular destination address for being used. The SCTP-PF protocol operation specified in this document makes no assumption of the existence of such other means of information and specifies for the above as the default operation of an SCTP-PF sender.

The sender MUST NOT change the state and the error counter of any destination address regardless of whether it has been chosen for transmission or not.

5. The HB.interval of the Path Heartbeat function of [\[RFC4960\]](#) MUST be ignored for destination addresses in PF state. Instead HEARTBEAT chunks are sent to destination addresses in PF state once per RT0. HEARTBEAT chunks SHOULD be sent to destination addresses in PF state, but the sending of HEARTBEATS MUST honor whether the Path Heartbeat function ([Section 8.3 of \[RFC4960\]](#)) is enabled for the destination address or not. I.e., if the Path Heartbeat function is disabled for the destination address in question, HEARTBEATS MUST NOT be sent. Note that when Heartbeat function is disabled, it may take longer to transition a destination address in PF state back to active state.
6. HEARTBEATS are sent when a destination address reaches the PF state. When a HEARTBEAT chunk is not acknowledged within the RT0, the sender increments the error counter and exponentially backs off the RT0 value. If the error counter is less than PMR, the sender transmits another packet containing the HEARTBEAT



chunk immediately after timeout expiration on the previous HEARTBEAT. When data is being transmitted to a destination address in the PF state, the transmission of a HEARTBEAT chunk MAY be omitted in case receipt of a SACK or a T3-rtx timer expiration on the outstanding data can provide equivalent information, such as a case where the data chunk has transmitted to a single destination. Likewise, the timeout of a HEARTBEAT chunk MAY be ignored if data is outstanding towards the destination address.

7. When the sender receives a HEARTBEAT ACK from a HEARTBEAT sent to a destination address in PF state, the sender SHOULD clear the error counter of the destination address and transition the destination address back to active state. When the sender resumes data transmission on a destination address after a transition of the destination address from PF to active state, it MUST do this following the prescriptions of [Section 7.2 of \[RFC4960\]](#). In a situation where a HEARTBEAT ACK arrives while there is data outstanding towards the destination address to which the HEARTBEAT was sent, then an implementation MAY choose to not have the HEARTBEAT ACK reset the error counter, but have the error counter reset await the fate of the outstanding data transmission. This situation can happen when data is sent to a destination address in PF state.
8. Additional (PMR - PFMR) consecutive timeouts on a destination address in PF state confirm the path failure, upon which the destination address transitions to the inactive state. As described in [\[RFC4960\]](#), the sender (i) SHOULD notify the ULP about this state transition, and (ii) transmit HEARTBEAT chunks to the inactive destination address at a lower HB.interval frequency as described in [Section 8.3 of \[RFC4960\]](#) (when the Path Heartbeat function is enabled for the destination address).
9. Acknowledgments for chunks that have been transmitted to multiple destinations (i.e., a chunk which has been retransmitted to a different destination address than the destination address to which the chunk was first transmitted) SHOULD NOT clear the error count for an inactive destination address and SHOULD NOT transition a destination address in PF state back to active state, since a sender cannot disambiguate whether the ACK was for the original transmission or the retransmission(s). A SCTP sender MAY apply a different approach for the error count handling based on unequivocally information on which destination (including multiple destination addresses) the chunk reached. This document makes no reference to what such unequivocally information could consist of, neither how



such unequivocally information could be obtained. The design of such an alternative approach is left to implementations.

10. Acknowledgments for data chunks that has been transmitted to one destination address only MUST clear the error counter for the destination address and MUST transition a destination address in PF state back to active state. This situation can happen when new data is sent to a destination address in the PF state. It can also happen in situations where the destination address is in the PF state due to the occurrence of a spurious T3-rtx timer and acknowledgments start to arrive for data sent prior to occurrence of the spurious T3-rtx and data has not yet been retransmitted towards other destinations. This document does not specify special handling for detection of or reaction to spurious T3-rtx timeouts, e.g., for special operation Vis-avis the congestion control handling or data retransmission operation towards a destination address which undergoes a transition from active to PF to active state due to a spurious T3-rtx timeout. But it is noted that this is an area which would benefit from additional attention, experimentation and specification for single-homed SCTP as well as for multi-homed SCTP protocol operation.
11. When all destination addresses are in inactive state, and SCTP protocol operation thus is said to be in dormant state, the prescriptions given in [Section 4](#) shall be followed.
12. The SCTP stack SHOULD provide the ULP with the means to expose the PF state of its destinations as well as the means to notify of state transitions from active to PF, and vice-versa. However it is recommended that an SCTP stack implementing SCTP-PF also allows for that the ULP is kept ignorant of the PF state of its destinations and the associated state transition. For this reason it is recommended that an SCTP stack implementing SCTP-PF also should provide the ULP with the means to suppress exposure of PF state and the associated state transitions.

#### **4. Dormant State Operation**

In a situation with complete disruption of the communication in between the SCTP Endpoints, the aggressive HEARTBEAT transmissions of SCTP-PF on destination addresses in PF state may make the association enter dormant state faster than a standard [\[RFC4960\]](#) SCTP implementation given the same setting of Path.Max.Retrans (PMR) and Association.Max.Retrans (AMR). For example, an SCTP association with two destination addresses typically would reach dormant state in half the time of an [\[RFC4960\]](#) SCTP implementation in such situations. This is because a SCTP PF sender will send HEARTBEATS and data



retransmissions in parallel with RTO intervals when there are multiple destinations addresses in PF state. This argument presumes that  $RTO \ll HB.interval$  of [RFC4960]. With the design goal that SCTP-PF shall provide the same level of disruption tolerance as an [RFC4960] SCTP implementation with the same Path.Max.Retrans (PMR) and Association.Max.Retrans (AMR) setting, we prescribe for that an SCTP-PF implementation SHOULD operate as described below in [Section 4.1](#) during dormant state.

An SCTP-PF implementation MAY choose a different dormant state operation than the one described below in [Section 4.1](#) provided that the solution chosen does not compromise the fault tolerance of the SCTP-PF operation.

The below prescription for SCTP-PF dormant state handling SHOULD NOT be coupled to the value of the PFMR, but solely to the activation of SCTP-PF logic in an SCTP implementation.

It is noted that the below dormant state operation is considered to provide added disruption tolerance also for an [RFC4960] SCTP implementation, and that it can be sensible for an [RFC4960] SCTP implementation to follow this mode of operation. For an [RFC4960] SCTP implementation the continuation of data transmission during dormant state makes the fault tolerance of SCTP be more robust towards situations where some, or all, alternative paths of an SCTP association approach, or reach, inactive state prior to that the primary path used for data transmission observes trouble.

#### **[4.1](#). SCTP Dormant State Procedure**

- a. When the destination addresses are all in inactive state and data is available for transfer, the sender MUST choose one destination and transmit data to this destination address.
- b. The sender MUST NOT change the state of the chosen destination address (it remains in inactive state) and it MUST NOT clear the error counter of the destination address as a result of choosing the destination address for data transmission.
- c. The sender SHOULD choose the destination in inactive state with the lowest error count (fewest consecutive timeouts) for data transmission. When there are multiple destinations with same error count in inactive state, the sender SHOULD attempt to pick the most divergent source - destination pair from the last source - destination pair where failure was observed. Rules for picking the most divergent source-destination pair are an implementation decision and are not specified within this document. To support differentiation of inactive destination addresses based on their



error count SCTP will need to allow for increment of the destination address error counters up to some reasonable limit above PMR+1, thus changing the prescriptions of [\[RFC4960\]](#), [section 8.3](#), in this respect. The exact limit to apply is not specified in this document but it is considered reasonable to require for such to be an order of magnitude higher than the PMR value. A sender MAY choose to deploy other strategies than the strategy defined by here. The strategy to prioritize the last active destination address, i.e., the destination address with the fewest error counts is optimal when some paths are permanently inactive, but suboptimal when a path instability is transient.

## 5. Primary Path Switchover

The objective of the Primary Path Switchover operation is to allow the SCTP sender to continue data transmission on a new working path even when the old primary destination address becomes active again. This is achieved by having SCTP perform a switch over of the primary path to the new working path if the error counter of the primary path exceeds a certain threshold. This mode of operation can be applied not only to SCTP-PF implementations, but also to [\[RFC4960\]](#) implementations.

The Primary Path Switchover operation requires only sender side changes. The details are:

1. The sender maintains a new tunable parameter, called Primary.Switchover.Max.Retrans (PMR). For SCTP-PF implementations, the PMR MUST be set greater or equal to the PFMR value. For [\[RFC4960\]](#) implementations the PMR MUST be set greater or equal to the PMR value. Implementations MUST reject any other values of PMR.
2. When the path error counter on a set primary path exceeds PMR, the SCTP implementation MUST autonomously select and set a new primary path.
3. The primary path selected by the SCTP implementation MUST be the path which at the given time would be chosen for data transfer. A previously failed primary path can be used as data transfer path as per normal path selection when the present data transfer path fails.
4. For SCTP-PF, the recommended value of PMR is PFMR when Primary Path Switchover operation mode is used. This means that no forced switchback to a previously failed primary path is performed. An SCTP-PF implementation of Primary Path Switchover



MUST support the setting of  $PMR = PFMR$ . A SCTP-PF implementation of Primary Path Switchover MAY support setting of  $PMR > PFMR$ .

5. For [RFC4960] SCTP, the recommended value of PMR is PMR when Primary Path Switchover is used. This means that no forced switchback to a previously failed primary path is performed. A [RFC4960] SCTP implementation of Primary Path Switchover MUST support the setting of  $PMR = PMR$ . An [RFC4960] SCTP implementation of Primary Path Switchover MAY support larger settings of  $PMR > PMR$ .
6. It MUST be possible to disable the Primary Path Switchover operation and obtain the standard switchback operation of [RFC4960].

The manner of switch over operation that is most optimal in a given scenario depends on the relative quality of a set primary path versus the quality of alternative paths available as well as it depends on the extent to which it is desired for the mode of operation to enforce traffic distribution over a number of network paths. I.e., load distribution of traffic from multiple SCTP associations may be sought to be enforced by distribution of the set primary paths with [RFC4960] switchback operation. However as [RFC4960] switchback behavior is suboptimal in certain situations, especially in scenarios where a number of equally good paths are available, an SCTP implementation MAY support also, as alternative behavior, the Primary Path Switchover mode of operation and MAY enable it based on users' requests.

For an SCTP implementation that implements the Primary Path Switchover operation, this specification RECOMMENDS that the standard [RFC4960] switchback operation is retained as the default operation.

## 6. Suggested SCTP Protocol Parameter Values

This document does not alter the [RFC4960] value RECOMMENDATIONS for the SCTP Protocol Parameters defined in [RFC4960].

The following protocol parameter is RECOMMENDED:

PotentiallyFailed.Max.Retrans (PFMR) - 0

## 7. Socket API Considerations

This section describes how the socket API defined in [RFC6458] is extended to provide a way for the application to control and observe the SCTP-PF behavior as well as the Primary Path Switchover function.



Please note that this section is informational only.

A socket API implementation based on [RFC6458] is, by means of the existing SCTP\_PEER\_ADDR\_CHANGE event, extended to provide the event notification when a peer address enters or leaves the potentially failed state as well as the socket API implementation is extended to expose the potentially failed state of a peer address in the existing SCTP\_GET\_PEER\_ADDR\_INFO structure.

Furthermore, two new read/write socket options for the level IPPROTO\_SCTP and the name SCTP\_PEER\_ADDR\_THLDS and SCTP\_EXPOSE\_POTENTIALLY\_FAILED\_STATE are defined as described below. The first socket option is used to control the values of the PFMR and PMR parameters described in Section 3 and in Section 5. The second one controls the exposition of the potentially failed path state.

Support for the SCTP\_PEER\_ADDR\_THLDS and SCTP\_EXPOSE\_POTENTIALLY\_FAILED\_STATE socket options need also to be added to the function sctp\_opt\_info().

### **7.1. Support for the Potentially Failed Path State**

As defined in [RFC6458], the SCTP\_PEER\_ADDR\_CHANGE event is provided if the status of a peer address changes. In addition to the state changes described in [RFC6458], this event is also provided, if a peer address enters or leaves the potentially failed state. The notification as defined in [RFC6458] uses the following structure:

```
strict sctp_paddr_change {
    uint16_t spc_type;
    uint16_t spc_flags;
    uint32_t spc_length;
    struct sockaddr_storage spc_aaddr;
    uint32_t spc_state;
    uint32_t spc_error;
    sctp_assoc_t spc_assoc_id;
}
```

[RFC6458] defines the constants SCTP\_ADDR\_AVAILABLE, SCTP\_ADDR\_UNREACHABLE, SCTP\_ADDR\_REMOVED, SCTP\_ADDR\_ADDED, and SCTP\_ADDR\_MADE\_PRIM to be provided in the spc\_state field. This document defines in addition to that the new constant SCTP\_ADDR\_POTENTIALLY\_FAILED, which is reported if the affected address becomes potentially failed.

The SCTP\_GET\_PEER\_ADDR\_INFO socket option defined in [RFC6458] can be used to query the state of a peer address. It uses the following structure:



```
strict sctp_paddrinfo {
    sctp_assoc_t spinfo_assoc_id;
    strict sockaddr_storage spinfo_address;
    int32_t spinfo_state;
    uint32_t spinfo_cwnd;
    uint32_t spinfo_srtt;
    uint32_t spinfo_rto;
    uint32_t spinfo_mtu;
};
```

[RFC6458] defines the constants SCTP\_UNCONFIRMED, SCTP\_ACTIVE, and SCTP\_INACTIVE to be provided in the spinfo\_state field. This document defines in addition to that the new constant SCTP\_POTENTIALLY\_FAILED, which is reported if the peer address is potentially failed.

## **7.2. Peer Address Thresholds (SCTP\_PEER\_ADDR\_THLDS) Socket Option**

Applications can control the SCTP-PF behavior by getting or setting the number of consecutive timeouts before a peer address is considered potentially failed or unreachable. The same socket option is used by applications to set and get the number of timeouts before the primary path is changed automatically by the Primary Path Switchover function. This socket option uses the level IPPROTO\_SCTP and the name SCTP\_PEER\_ADDR\_THLDS.

The following structure is used to access and modify the thresholds:

```
strict sctp_paddrthlds {
    sctp_assoc_t spt_assoc_id;
    strict sockaddr_storage spt_address;
    uint16_t spt_pathmaxrxt;
    uint16_t spt_pathpfthld;
    uint16_t spt_pathcpthld;
};
```

**spt\_assoc\_id:** This parameter is ignored for one-to-one style sockets. For One-romany style sockets the application may fill in an association identifier or SCTP\_FUTURE\_ASSOC. It is an error to use SCTP\_{CURRENT|ALL}\_ASSOC in spt\_assoc\_id.

**spt\_address:** This specifies which peer address is of interest. If a wild card address is provided, this socket option applies to all current and future peer addresses.

**spt\_pathmaxrxt:** Each peer address of interest is considered unreachable, if its path error counter exceeds spt\_pathmaxrxt.



spt\_pathpfthld: Each peer address of interest is considered Potentially Failed, if its path error counter exceeds spt\_pathpfthld.

spt\_pathcpthld: Each peer address of interest is not considered the primary remote address anymore, if its path error counter exceeds spt\_pathcpthld. Using a value of 0off disables the selection of a new primary peer address. If an implementation does not support the automatically selection of a new primary address, it should indicate an error with Erna set to RIVAL if a value different from 0off is used in spt\_pathcpthld. For SCTP-PF, the setting of spt\_pathcpthld < spt\_pathpfthld should be rejected with Erna set to RIVAL. For [RFC4960] SCTP, the setting of spt\_pathcpthld < spt\_pathmaxrxt should be rejected with Erna set to RIVAL. A SCTP-PF implementation MAY support only setting of spt\_pathcpthld = spt\_pathpfthld and spt\_pathcpthld = 0off and a [RFC4960] SCTP implementation MAY support only setting of spt\_pathcpthld = spt\_pathmaxrxt and spt\_pathcpthld = 0off. In these cases SCTP shall reject setting of other values with Erna set to RIVAL.

### **7.3. Exposing the Potentially Failed Path State**

(SCTP\_EXPOSE\_POTENTIALLY\_FAILED\_STATE) Socket Option

Applications can control the exposure of the potentially failed path state in the SCTP\_PEER\_ADDR\_CHANGE event and the SCTP\_GET\_PEER\_ADDR\_INFO as described in [Section 7.1](#). The default value is implementation specific.

This socket option uses the level IPPROTO\_SCTP and the name SCTP\_EXPOSE\_POTENTIALLY\_FAILED\_STATE.

The following structure is used to control the exposition of the potentially failed path state:

```
strict sctp_assoc_value {
    sctp_assoc_t assoc_id;
    uint32_t assoc_value;
};
```

assoc\_id: This parameter is ignored for one-to-one style sockets. For One-to-many style sockets the application may fill in an association identifier or SCTP\_FUTURE\_ASSOC. It is an error to use SCTP\_{CURRENT|ALL}\_ASSOC in assoc\_id.

assoc\_value: The potentially failed path state is exposed if and only if this parameter is non-zero.



## **8. Security Considerations**

Security considerations for the use of SCTP and its APIs are discussed in [[RFC4960](#)] and [[RFC6458](#)].

The logic introduced by this document does not impact existing On-anthe-wire SCTP messages. Also, this document does not introduce any new On-anthe-wire SCTP messages that require new security considerations.

SCTP-PF makes SCTP not only more robust during primary path failure/congestion but also more vulnerable to network connectivity/congestion attacks on the primary path. SCTP-PF makes it easier for an attacker to trick SCTP to change data transfer path, since the duration of time that an attacker needs to compromise the network connectivity is much shorter than [[RFC4960](#)]. However, SCTP-PF does not constitute a significant change in the duration of time and effort an attacker needs to keep SCTP away from the primary path. With the standard switchback operation [[RFC4960](#)] SCTP resumes data transfer on its primary path as soon as the next HEARTBEAT succeeds.

On the other hand, usage of the Primary Path Switchover mechanism, does change the threat analysis. This is because attackers can force a permanent change of the data transfer path by blocking the primary path until the switchover of the primary path is triggered by the Primary Path Switchover algorithm. This especially will be the case when the Primary Path Switchover is used together with SCTP-PF with the particular setting of  $PMR = PFMR = 0$ , as Primary Path Switchover here happens already at the first RTO timeout experienced. Users of the Primary Path Switchover mechanism should be aware of this fact.

The event notification of path state transfer from active to potentially failed state and vice versa gives attackers an increased possibility to generate more local events. However, it is assumed that event notifications are rate-limited in the implementation to address this threat.

## **9. IANA Considerations**

This document does not create any new registries or modify the rules for any existing registries managed by IANA.

## **10. Acknowledgements**

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## **11. Proposed Change of Status (to be Deleted before Publication)**

Initially this work looked to entail some changes of the Congestion Control (CC) operation of SCTP and for this reason the work was proposed as Experimental. These intended changes of the CC operation have since been judged to be irrelevant and are no longer part of the specification. As the specification entails no other potential harmful features, consensus exists in the G to bring the work forward as PS.

Initially concerns have been expressed about the possibility for the mechanism to introduce path bouncing with potential harmful network impacts. These concerns are believed to be unfounded. This issue is addressed in [Appendix B](#).

It is noted that the feature specified by this document is implemented by multiple SCTP SW implementations and furthermore that various variants of the solution have been deployed in Tel co signaling environments for several years with good results.

## **12. References**

### **12.1. Normative References**

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- [RFC4960] Stewart, R., Ed., "Stream Control Transmission Protocol", [RFC 4960](#), DOI 10.17487/RFC4960, September 2007, <<http://www.rfc-editor.org/info/rfc4960>>.

### **12.2. Informative References**

- [CAR002] Caro Jr., A., Iyengar, J., Amer, P., Heinz, G., and R. Stewart, "A Two-level Threshold Recovery Mechanism for SCTP", Tech report, CIS Dept, University of Delaware , 7 2002.
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Iyengar, J., Amer, P., and R. Stewart, "Concurrent Multipath Transfer using SCTP Multi homing over Independent End-to-end Paths.", IEEE/ACM Trans on Networking 14(5), 10 2006.

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[RFC6458] Stewart, R., Tuexen, M., Poon, K., Lei, P., and V. Yasevich, "Sockets API Extensions for the Stream Control Transmission Protocol (SCTP)", [RFC 6458](#), DOI 10.17487/RFC6458, December 2011, <<http://www.rfc-editor.org/info/rfc6458>>.

## **Appendix A. Discussions of Alternative Approaches**

This section lists alternative approaches for the issues described in this document. Although these approaches do not require to update [RFC4960](#), we do not recommend them from the reasons described below.

### **A.1. Reduce Path.Max.Retrans (PMR)**

Smaller values for Path.Max.Retrans shorten the failover duration and in fact this is recommended in some research results [[JUNGMAIER02](#)] [[GRINNEMO04](#)] [[FALLON08](#)]. However to significantly reduce the failover time it is required to go down (as with PFMR) to Path.Max.Retrans=0 and with this setting SCTP switches to another destination address already on a single timeout which may result in spurious failover. Spurious failover is a problem in [RFC4960](#) SCTP as the transmission of HEARTBEATS on the left primary path, unlike in



SCTP-PF, is governed by 'HB.interval' also during the failover process. 'HB.interval' is usually set in the order of seconds (recommended value is 30 seconds) and when the primary path becomes inactive, the next HEARTBEAT may be transmitted only many seconds later. Indeed as recommended, only 30 secs later. Meanwhile, the primary path may since long have recovered, if it needed recovery at all (indeed the failover could be truly spurious). In such situations, post failover, an endpoint is forced to wait in the order of many seconds before the endpoint can resume transmission on the primary path and furthermore once it returns on the primary path the CWND needs to be rebuild anew - a process which the throughput already have had to suffer from on the alternate path. Using a smaller value for 'HB.interval' might help this situation, but it would result in a general waste of bandwidth as such more frequent HEARTBEATING would take place also when there are no observed troubles. The bandwidth overhead may be diminished by having the ULP use a smaller 'HB.interval' only on the path which at any given time is set to be the primary path, but this adds complication in the ULP.

In addition, smaller Path.Max.Retrans values also affect the 'Association.Max.Retrans' value. When the SCTP association's error count exceeds Association.Max.Retrans threshold, the SCTP sender considers the peer endpoint unreachable and terminates the association. [Section 8.2 in \[RFC4960\]](#) recommends that Association.Max.Retrans value should not be larger than the summation of the Path.Max.Retrans of each of the destination addresses. Else the SCTP sender considers its peer reachable even when all destinations are INACTIVE and to avoid this dormant state operation, [\[RFC4960\]](#) SCTP implementation SHOULD reduce Association.Max.Retrans accordingly whenever it reduces Path.Max.Retrans. However, smaller Association.Max.Retrans value compromises the fault tolerance of SCTP as it increases the chances of association termination during minor congestion events.

## **[A.2.](#) Adjust RTO related parameters**

As several research results indicate, we can also shorten the duration of failover process by adjusting RTO related parameters [\[JUNGMAIER02\]](#) [\[FALLON08\]](#). During failover process, RTO keeps being doubled. However, if we can choose smaller value for RTO.max, we can stop the exponential growth of RTO at some point. Also, choosing smaller values for RTO.initial or RTO.min can contribute to keep the RTO value small.

Similar to reducing Path.Max.Retrans, the advantage of this approach is that it requires no modification to the current specification, although it needs to ignore several recommendations described in the [Section 15 of \[RFC4960\]](#). However, this approach requires to have



enough knowledge about the network characteristics between end points. Otherwise, it can introduce adverse side-effects such as spurious timeouts.

The significant issue with this approach, however, is that even if the `RT0.max` is lowered to an optimal low value, then as long as the `Path.Max.Retrans` is kept at the [\[RFC4960\]](#) recommended value, the reduction of the `RT0.max` doesn't reduce the failover time sufficiently enough to prevent severe performance degradation during failover.

## **[Appendix B](#). Discussions for Path Bouncing Effect**

The methods described in the document can accelerate the failover process. Hence, they might introduce the path bouncing effect where the sender keeps changing the data transmission path frequently. This sounds harmful to the data transfer, however several research results indicate that there is no serious problem with SCTP in terms of path bouncing effect [\[CAR004\]](#) [\[CAR005\]](#).

There are two main reasons for this. First, SCTP is basically designed for multipath communication, which means SCTP maintains all path related parameters (`CWND`, `ssthresh`, `RTT`, error count, etc) per each destination address. These parameters cannot be affected by path bouncing. In addition, when SCTP migrates the data transfer to another path, it starts with the minimal or the initial `CWND`. Hence, there is little chance for packet reordering or duplicating.

Second, even if all communication paths between the end-nodes share the same bottleneck, the SCTP-PF results in a behavior already allowed by [\[RFC4960\]](#).

## **[Appendix C](#). SCTP-PF for SCTP Single-homed Operation**

For a single-homed SCTP association the only tangible effect of the activation of SCTP-PF operation is enhanced failure detection in terms of potential notification of the PF state of the sole destination address as well as, for idle associations, more rapid entering, and notification, of inactive state of the destination address and more rapid end-point failure detection. It is believed that neither of these effects are harmful, provided adequate dormant state operation is implemented, and furthermore that they may be particularly useful for applications that deploys multiple SCTP associations for load balancing purposes. The early notification of the PF state may be used for preventive measures as the entering of the PF state can be used as a warning of potential congestion. Depending on the `PMR` value, the aggressive HEARTBEAT transmission in PF state may speed up the end-point failure detection (exceed of `AMR`



threshold on the sole path error counter) on idle associations in case where relatively large HB.interval value compared to RT0 (e.g. 30secs) is used.

#### Authors' Addresses

Yoshifumi Nishida  
GE Global Research  
2623 Camino Ramon  
San Ramon, CA 94583  
USA

Email: nishida@wide.ad.jp

Preethi Natarajan  
Cisco Systems  
510 McCarthy Blvd  
Milpitas, CA 95035  
USA

Email: prenatar@cisco.com

Armando Caro  
BBN Technologies  
10 Moulton St.  
Cambridge, MA 02138  
USA

Email: acar@bbn.com

Paul D. Amer  
University of Delaware  
Computer Science Department - 434 Smith Hall  
Newark, DE 19716-2586  
USA

Email: amer@udel.edu



Karen E. E. Nielsen  
Ericsson  
Kistavaegen 25  
Stockholm 164 80  
Sweden

Email: karen.nielsen@tieto.com