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Reliability Models of SRP Rings

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Abstract

In this paper the all-terminal reliability and the two-terminal reliability models of rings using the Spatial Reuse Protocol (SRP) are developed. Moreover the interconnection of SRP-rings is considered.

1 Introduction

The Spatial Reuse Protocol (SRP) has recently been introduced as a MAC layer protocol for ring based media [1, 2]. The protocol carries both IP and ATM client traffic and supports ring network redundancy similar to bidirectional self-healing rings (BSHRs) of SDH/SONET standards.
Since each network element is subject to failures or disruptions, the network reliability is an important parameter for the employment of such a ring. This also emerges for today's IP networks [3], which may run over SRP.
It should be noted that the major concern of reliability considerations is not motivated by the discard of packets at the SRP-buffers caused by network congestion, which are momentary effects (partly used for flow-control as in TCP) and should be negligible in a well dimensioned network.
The overall network reliability can be used for the comparison of different design alternatives, e.g. between SRP-rings and rings operated with other protocols, or the dimensioning alternatives of rings in multiple-rings networks (e.g. size of ring-nodes).
The reliability for an end-to-end connection also comes to front as a Quality of Service (QoS) parameter, which can be offered to customers (SRP-clients) or can be used for the QoS-routing in traffic engineered networks.
The reliability models of SONET/SDH BSHRs have been determined in [4, 5]. The reliability models of SRP-rings differ from these, since SRP-rings interconnect hosts and allow for bypassing the hosts (e.g. during a host's software failure) in the "pass-thru mode" [1]. Thus the SRP nodes are organized differently in contrast to SONET/SDH nodes.
In this paper we develop the reliability models of SRP-rings and moreover consider the interconnection of SRP-rings. It should be noted that the models are applicable both on repairable and non-repairable systems, where strictly speaking in former ones we deal with "reliabilities" and in latter ones with "availabilities."

2 Network Model

We describe a SRP-ring with n nodes by the network model in figure 1. A symmetric network model is used, where each element (e.g. each host) has the same reliability.

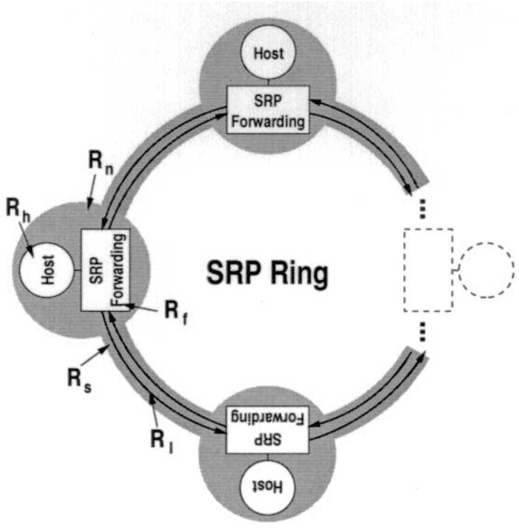

Figure 1: Generic model of a SRP-ring.

The nodes (with reliability R_n) comprise both a host (R_h) and the SRP forwarding device (R_f). The SRP forwarding device is responsible for terminating the links, interfacing the host and performing all SRP-protocol processing (framing, buffering, etc.), see [1]. The host may be bypassed in the "pass-thru mode" [1] by the forwarding device.
Two adjacent SRP-nodes are interconnected by a bidirectional point-to-point link (e.g. SONET/SDH or fiber link), which is modeled by two unidirectional links (R_l) for each direction both guided through a segment (R_s).
The SRP-ring uses the Intelligent Protection Switching (IPS) protocol in combination with an automated topology discovery mechanism. For instance refer to the four-node ring with an end-to-end connection in figure 2 (a). A link failure as in (b) causes a (bidirectional) protection switching and the ring reaches the so-called "wrap state." A subsequent topology discovery as in (c) may reroute connections according to the novel topology.

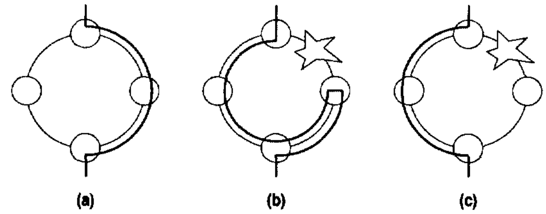

Figure 2: (a) four-node SRP-ring with an end-to-end connection. Protection switching (b) and topology discovery (c) after a failure.

In this paper we consider single failures at a time only, even if the IPS protocol can handle multiple failures. We should also note that in the states (b) and (c) new routes and thus new bandwidth demands are present in the ring.
Therefore the ring has to be dimensioned to cope with these states. This can be done somewhat similar to SONET/SDH BSHRs, where half of the capacity bandwidth is used for working traffic and the other half is used for protection (spare capacity). A more advanced approach would calculate the routes and dimensioning requirements by evaluating a set of likely failure scenarios. As the SRP-ring does not provide synchronous multiplexing of working and protection traffic, a further margin may be introduced for possible packet discards in SRP-buffers (e.g. due to the packet clumping effect).

3 Reliability Models of the SRP-Ring

For the SRP-ring reliability model we employ the all-terminal reliability and the two-terminal reliability (which are defined similar to [4]).

3.1 All-Terminal Reliability

The all-terminal reliability (R_{all}) is defined as the reliability that all hosts on the ring are operating and can communicate with

each other (network operator's viewpoint).
Two mutually exclusive events contribute to the all-terminal reliability.
(1) All parts of the network are operational.

$$r_1 = (R_n R_h R_f R_s R_l^2)^n \qquad (1)$$

(2) At least one (unidirectional) link in a segment or the segment itself failed, while all other elements of the ring are operating. Thus the ring wrap function is performed.

$$r_2 = n(R_n R_f R_h)^n (R_s R_l^2)^{n-1} \times [R_s(1 - R_l^2) + (1 - R_s)] \qquad (2)$$

The all-terminal reliability is the sum of equations (1) and (2):

$$R_{all} = r_1 + r_2 \qquad (3)$$

3.2 Two-Terminal Reliability

The two-terminal reliability ($R_{s\text{-}t,ring}$) is defined as the reliability that two given hosts on the ring can communicate with each other, independent of the states of the other parts of the network (user's viewpoint).
Three mutually exclusive events contribute to the two-terminal reliability, where the first two are contained in section 3.1 excluding all non-terminal hosts (i.e. divide the all-terminal reliability by R_h^{n-2}). The third event is described here.
(3) At one node (which is not one of the terminal nodes) the ring is disconnected since the node's forwarding part failed or the node itself failed, all forwarding devices, all segments and links except for the failed node's adjacent segments and links and the terminal hosts are operating. Thus the ring wrap is performed.

$$r_3 = (n-2)(R_n R_f)^{n-1} R_h^2 (R_s R_l^2)^{n-2} \times [R_n(1 - R_f) + (1 - R_n)] \qquad (4)$$

The two-terminal reliability is obtained via equations (1), (2), and (4) and independent of the considered terminal nodes:

$$R_{s\text{-}t,ring} = \frac{r_1 + r_2}{R_h^{n-2}} + r_3 \qquad (5)$$

4 Ring Interconnection

In networks with multiple rings, SRP client data traffic (e.g. IP traffic) may be guided through a segment more than once, if some links of both rings are guided through one segment (i.e. ring overlap). In this case the failure events of the rings are not mutually exclusive anymore, however, the above reliability models provide an approximation.
Assuming a ring interconnection as in figure 3, the failure events for the node reliability are also not mutually exclusive, since both rings share the node.
Concerning the all-terminal reliability, again the reliability models provide an approximation. But for the two-terminal reliability an exact calculation scheme can be determined.

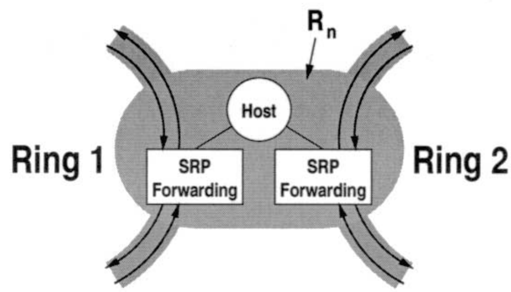

Figure 3: Single interconnection between rings.

We assume that there is only one possible path between rings. In this case we can calculate the two-terminal reliability of nodes residing on different rings via the product of the sub-paths' reliabilities corresponding to each ring.
Denote m as the number of rings the path of the two terminals is routed. Then the two-terminal reliability $R_{s\text{-}t}$ can be

calculated as:

$$R_{s\text{-}t} = R_h R_n \prod_{i=1}^{m} \frac{R_{s\text{-}t,ring_i}}{R_h R_n} \tag{6}$$

Example: Consider the two-terminal reliability when deciding between one 16 node ring and two interconnected 8 node rings (single homing at one node) to realize a 16 node network. We neglect that by these decision options the 16 node ring would have at least one node in common. Assume that each reliability is equal $R_n = R_h = R_f = R_l = 0.99999$ (equivalent to 5 minutes outage per year), except for the segments' reliability which is $R_s = 0.9993$ (equivalent to 6 hours outage per year). This could represent a metropolitan area network example.

Then by (5) the 16 node ring with $R_{s\text{-}t}(n = 16) = 0.9998753918$ (equivalent to 66 minutes outage per year) is slightly more reliable than the 8 node rings for interring connectivities which have via (6) $R_{s\text{-}t}(n = 8, m = 2) = 0.9998700213$ (equivalent to 68 minutes outage per year) but is considerably less reliable for intraring connectivities which have by (5) $R_{s\text{-}t}(n = 8, m = 1) = 0.9999250092$ (equivalent to 40 minutes outage per year). Thus it may be desirable to partition the network in two rings while trying to minimize the interring traffic.

If two rings are interconnected more than once, we obtain a higher reliability than above, e.g. like in the dual homing case in figure 4. The SRP's client layer can reroute the traffic upon a node failure. The node failure events in equation (4) then become mutually dependent and are for future research.

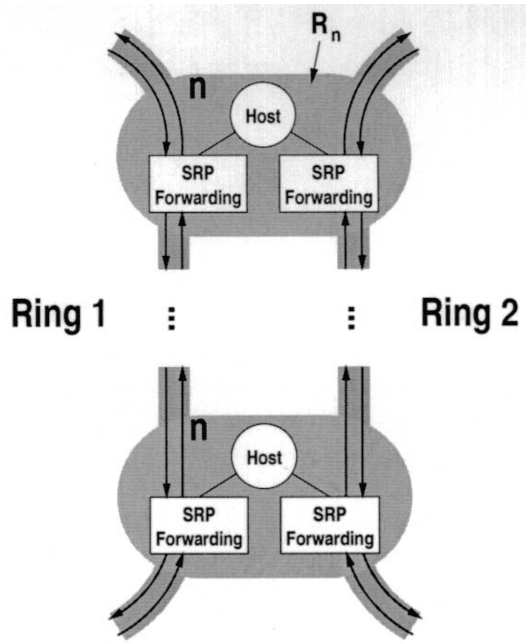

Figure 4: Double interconnection between rings.

5 Conclusions

In this paper we determined the reliability models for a SRP-ring and considered the case of the single interconnection of multiple SRP-rings. The models are the basis for a further reliability analysis.

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