Implementing the Availability Model of a Software-Defined Backbone Network in Möbius

(Technical Report)

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Abstract—Software-defined networking (SDN) promises to improve the programmability and flexibility of networks, but it may bring also new challenges that need to be explored. One open issue is the quantitative assessment of the properties of SDN backbone networks to determine whether they can provide similar availability to the traditional IP backbone networks. To achieve this goal, a two-level availability model that is able to capture the global network connectivity without neglecting the essential details and which includes a failure correlation assessment should be considered. The two-level availability model is composed by a structural model and the dynamic models of the principal minimal-cut sets of the network. The purpose of this technical report is to extensively present the implementation on Möbius of the Stochastic Activity Network (SAN) availability model of the network elements and the principal minimal-cut sets of a SDN backbone network and the corresponding traditional backbone network.

I. INTRODUCTION

During the recent years, the SDN has emerged as a new network paradigm, which mainly consists of a programmable network approach where the forwarding plane is decoupled from the control plane [1], [2]. Despite programmable networks having been studied for decades, SDN is experiencing a growing success because it is expected that the ease of changing protocols and provide support for adding new services and applications will foster future network innovation, which is limited and expensive in todays legacy systems.

A simplified sketch of the SDN architecture from IRFT RFC 7426 [1] without the management plane is depicted in Figure 1. The control plane and data plane are separated. Here the control plane is logically centralised in a software-based controller (“network brain”), while the data plane is composed of the network devices (“network arms”) that conduct the packet forwarding.

The control plane has a northbound and a southbound interface. The northbound interface provides an network abstraction to the network applications (e.g. routing protocol, firewall, load balancer, anomaly detection, etc...), while the southbound interface (e.g. OpenFlow) standardises the information exchange between control and data planes.

In [3], the following set of potential advantages of SDN were pointed out:

- commoditising network hardware;
- eliminating middle-boxes;
- enabling the design and deployment of third-party applications.

However, from a dependability perspective, the SDN poses a set of new vulnerabilities and challenges compared with traditional networking, as discussed in [4]:

- consistency of network information (user plane state information) and controller decisions;
- consistency between the distributed SDN controllers in the control plane;
- increased failure intensities of (commodity) network elements;
- compatibility and interoperability between general purpose, non-standard network elements
- interdependency between path setup in network elements and monitoring of the data plane in the control plane;
- load sharing (to avoid performance bottleneck) and fault tolerance in the control plane have conflicting requirements;

In [5], a two-level availability model has been proposed in order to capture the global network connectivity without neglecting the essential details and which includes a failure correlation assessment. The two-level availability model is...
composed by a structural model and the dynamic models of the principal minimal-cut sets of both the SDN backbone network and the corresponding traditional backbone network.

The purpose of this technical report is the detailed presentation of the implementation on Möbius [14] of the Stochastic Activity Network (SAN) availability model of both the network elements and the principal minimal-cut sets. These models have been used in [5].

In Section II, we introduce the nation-wide backbone network that has been used for computing the principal minimal-cut sets. The SAN models of the network elements and the principal minimal-cut sets are presented in Section III and Section IV, respectively. Finally, the conclusions are summarized in Section V.

II. Model Case Study

In this technical report and in [5], we consider a nation-wide backbone network that consists of 10 nodes across 4 cities, and two dual-homed SDN controllers. See Figure 2 for an illustration of the topology. The nodes are located in the four major cities in Norway, Bergen (BRG), Trondheim (TRD), Stavanger (STV), and Oslo (OSL). Each town has duplicated nodes, except Oslo which has four nodes (OSL1 and OSL2). The duplicated nodes are labelled, $X_1$ and $X_2$, where $X$=OSL1, OSL2, BRG, STV, and TRD. In addition to the forwarding nodes, there are two dual-homed SDN controllers ($SC_1$ and $SC_2$), which are connected to TRD and OSL1.

![Fig. 2: Nation-wide backbone network](image)

Given this network, for computing and comparing the network availability of SDN with a traditional IP network we need to calculate the availability of the single network elements [12] or of the principal minimal-cut sets [5].

III. SAN Model of the Network Elements

In the following, we present the SAN models of the network elements: links (which are the same in both SDN and traditional network), traditional IP routers, SDN switches, and SDN controllers.

A. Link

The model of a link is assumed to be dominated by physical link failures. Therefore, a simple two-state Markov model is used. Figure 3 shows the SAN representation. The links are either up or down due to hardware failure. We use the same model for both traditional network and SDN. Given failure rate $\lambda_L$ and repair rate $\mu_L$, the availability of a link is $A_L = \frac{\mu_L}{\lambda_L + \mu_L}$. This model is assumed for each of the link components in the structural model. We don’t know the geographical location of the nodes and therefore the distance between them either, which implies that the length of the links connecting the nodes in the network can’t be determined. Hence, in our case studies we have to assume that the link failure rate is not dependent on the link length. Note that in general the failure rate is expected to be proportional to the length of the link.

B. Traditional IP router

The SAN model of a traditional router is depicted in Figure 4. In the model we focus on the router functionalities and the related failure sources, each component of the router has not been considered because it would be dependent on a particular router architecture. In any case, we assume 1+1 redundancy of the controller hardware, which is a common best practice in any architecture. Multiple failures are not included in the model since they are assumed to be less frequent and will probably not have significant impact on the expected accuracy of the approach.

The SAN model of the traditional router is composed of eight places:

- **Working** represents the state when the system is fully working and it is initialized with one token;
- **failed_MAN** is equal to 1 when there is a failure of the Operation and Management (O&M), 0 otherwise;
- **spare_CHW** represents the state when one of the two redundant control hardware is failed but the other one is correctly working;
- **sys_down** is a coverage state and is equal to 1 if there is an unsuccessful activation of the stand-by hardware after a failure (manual recovery).
- **failed_CHW** represents the state when both controllers has an hardware failure;
The router is failed when the token is not in Working or spare_CHW.

The places are connected by mean of the following timed activities with exponential time distribution:

- failed_SW represents the state when there is a software failure, 0 otherwise;
- failed_FHW represents the state when there is a permanent hardware failure in forwarding plane;
- failed_FHWt represents the presence of a transient hardware failure in forwarding plane;

The states related to the control hardware failures are not contained in this model, since all the control logic is located in the controller. O&M associated with the SDN switch has been also omitted because we assume that the complexity of the O&M operations done on a single switch is likely to be small relative to a router and globally in the controller. The software is still present but its failure rate will be very low otherwise (with probability $1 - C_{dc}$) the system is not able to manage the control hardware failure and the system goes down;

- CHW_F represents the failure event of the control hardware with a rate of $\lambda_{dc}$ and there are two cases, with probability $C_{dc}$ a token is put into spare_CHW, otherwise (with probability $1 - C_{dc}$) the system is not able to manage the control hardware failure and the system goes down;
- CHW_F2 represents the failure event of the spare control with a rate of $\lambda_{dc}$;
- CHW_R and CHW_R2 represent the recovery of the control hardware with a rate of $\mu_{dc}$;
- UCHW_R represents the recovery after an unsuccessful activation of the stand-by hardware with a rate of $\mu_{dUC}$;
- SW_F and SW_R represent the failure and the recovery events of the software with a rate of $\lambda_{ds}$ and $\mu_{ds}$, respectively;
- FHW_F and FHW_R represent the permanent failure and the recovery events of the forwarding hardware with a rate of $\lambda_{df}$ and $\mu_{df}$, respectively;
- $FHWt_F$ and $FHWt_R$ represent the transient failure and the recovery events of the forwarding hardware with a rate of $\lambda_{dft}$ and $\mu_{dft}$, respectively;

**TABLE I: Model parameters for the IP network with numerical values used in the case studies**

<table>
<thead>
<tr>
<th>intensity description</th>
<th>intensity symbol</th>
<th>intensity time symbol</th>
<th>intensity symbol description</th>
</tr>
</thead>
<tbody>
<tr>
<td>expected time to link repair</td>
<td>$\lambda_{dC}$</td>
<td>months</td>
<td>expected time to next link failure</td>
</tr>
<tr>
<td>expected time to software repair</td>
<td>$\mu_{dC}$</td>
<td>months</td>
<td>expected time to recover from uncovered control hardware failure</td>
</tr>
<tr>
<td>expected time to control hardware failure</td>
<td>$\lambda_{dc}$</td>
<td>hours</td>
<td>expected time to next permanent forwarding hardware failure</td>
</tr>
<tr>
<td>expected time to transient forwarding hardware failure</td>
<td>$\lambda_{dft}$</td>
<td>weeks</td>
<td>expected time to next transient forwarding hardware failure</td>
</tr>
<tr>
<td>expected time to repair control hardware</td>
<td>$\mu_{dft}$</td>
<td>hours</td>
<td>expected time to repair permanent forwarding hardware failure</td>
</tr>
<tr>
<td>expected time to repair control hardware</td>
<td>$\mu_{dC}$</td>
<td>months</td>
<td>expected time to repair control hardware</td>
</tr>
<tr>
<td>expected time to repair control hardware</td>
<td>$\mu_{dS}$</td>
<td>hours</td>
<td>expected time to repair transient forwarding hardware</td>
</tr>
<tr>
<td>expected time to cover from uncovered control hardware failure</td>
<td>$1 - C_{dc}$</td>
<td>minutes</td>
<td>expected time to repair software repair</td>
</tr>
<tr>
<td>expected time to O&amp;M repair</td>
<td>$\mu_{dS}$</td>
<td>months</td>
<td>expected time to next O&amp;M failure</td>
</tr>
<tr>
<td>expected time to repair transient forwarding hardware</td>
<td>$\mu_{dS}$</td>
<td>weeks</td>
<td>expected time to cover from uncovered control hardware failure</td>
</tr>
<tr>
<td>coverage factor</td>
<td>$C_{dc}$</td>
<td>minutes</td>
<td>expected time to recover from uncovered control hardware failure</td>
</tr>
</tbody>
</table>

**TABLE II: Model parameters for the SDN switch**

<table>
<thead>
<tr>
<th>intensity description</th>
<th>intensity symbol</th>
<th>intensity time symbol</th>
<th>intensity symbol description</th>
</tr>
</thead>
<tbody>
<tr>
<td>intensity of permanent hardware failures</td>
<td>$\lambda_{df}$</td>
<td>months</td>
<td>expected time to next link failure</td>
</tr>
<tr>
<td>repair intensity of permanent hardware failures</td>
<td>$\mu_{df}$</td>
<td>months</td>
<td>expected time to link repair</td>
</tr>
<tr>
<td>intensity of transient hardware failures</td>
<td>$\lambda_{dft}$</td>
<td>weeks</td>
<td>expected time to next transient forwarding hardware failure</td>
</tr>
<tr>
<td>restoration intensity after transient hardware failures</td>
<td>$\mu_{dft}$</td>
<td>hours</td>
<td>expected time to repair transient forwarding hardware failure</td>
</tr>
<tr>
<td>intensity of software failure</td>
<td>$\lambda_{dS}$</td>
<td>months</td>
<td>expected time to next permanent forwarding hardware failure</td>
</tr>
<tr>
<td>expected time to software repair</td>
<td>$\mu_{dS}$</td>
<td>hours</td>
<td>expected time to recover from uncovered control hardware failure</td>
</tr>
</tbody>
</table>

- $FHWt_F$ and $FHWt_R$ represent the transient failure and the recovery events of the forwarding hardware with a rate of $\lambda_{dft}$ and $\mu_{dft}$, respectively.

All the model parameters are defined in Table I. Note that for sake of simplicity we have assumed homogeneous equipment. The table includes the numerical values used in the case studies and that are inspired by and taken from several studies [9], [10], [11].

C. SDN switch

Figure 5 shows the model of the switch in an SDN, which is significantly simpler than the router in a traditional network. The states related to the control hardware failures are not contained in this model, since all the control logic is located in the controller. O&M associated with the SDN switch has been also omitted because we assume that the complexity of the O&M operations done on a single switch is likely to be small relative to a router and globally in the controller. The software is still present but its failure rate will be very low since the functionality is much simpler.

Table II describes the parameters for modelling the SDN switch.

All SDN parameters are expressed relative to the parameters for the traditional network (Table I). In an SDN switch, the failure/repair intensities of (permanent/transient) hardware failures are the same because failures with the same cause,
have the same intensities in both models. However, we assume that the software on an SDN switch will be much less complicated than on a traditional IP router because the control logic has been moved to the controllers, and we have set the failure rate to zero, for the sake of simplicity.

D. SDN controller

The SDN controller has been modelled with the SAN model depicted in Figure 6. We have assumed that the SDN controller is a cluster of $M$ processors and the system is working, i.e., possesses sufficient capacity if $K$ out of the $M$ processors are active, which means that both software and hardware are working. The other main assumptions of the model are:

- single repairman for a hardware failure;
- load dependency of software failure when the system is working, $\lambda_S(N_a) = \lambda_S/N_a$, where $N_a$ is the number of active processors;
- when the entire system fails, only processors failed due to hardware failures will be down until the system recovers;
- load independence of software failure when the system has failed, $\lambda_S(N_a) = \lambda_S$, since the remaining unfailed processors are working at the full capacity.

The SAN model of the SDN controller is composed of six places:

- $Active\_proc$ represents the number of active processors and it is initialized to the total number of processors;
- $failed\_MAN$ is equal to 1 when there is a failure of the O&M, 0 otherwise;
- $failed\_SW$ represents the number of processors where the software has failed;
- $failed\_HW$ represents the number of processors where the hardware has failed;
- $sys\_down$ is a coverage state and is equal to 1 if the hardware failure in one processor forces all the system to be down;
- $sw\_sys\_down$ is a coverage state and is equal to 1 if the software failure in one processor causes the crash of all the processors.

The places are connected by mean of the following timed activities with exponential time distribution:

- $MAN\_F$ and $MAN\_R$ represent the failure and the recovery of the O&M with a rate of $\lambda_O$ and $\mu_O$, respectively;
- $SW\_F$ represents the failure of the software with a rate of $\lambda_S$, if the number of active processors is at least $K$, or $N_a \lambda_S$, otherwise; there are two cases, with probability $C_S$ a token is put into $failed\_SW$ (if there are enough working processors, the system is still working), otherwise (with probability $1 - C_S$) the system is not able to manage the software failure and the system goes down;
- $SW\_R$ represents the recovery of the software with a rate of $\mu_S$;
- $USW\_R$ represents the recovery after an unsuccessful activation of the stand-by hardware with a rate of $\mu_{US}$;
- $HW\_F1$ represents the failure of the hardware of the active processors with a rate of $N_a \lambda_H$ and there are two cases, with probability $C_C$ a token is put into $failed\_HW$ (the hardware is failed but if there are enough working processors, the system is working), otherwise (with probability $1 - C_C$) the system is not able to manage the hardware failure and the system goes down (note that if there is already a token in $failed\_MAN$ or $sys\_down$, the token is forced to be put in $failed\_HW$);
- $HW\_F2$ represents the failure of the hardware of the processors with a failed software with a rate of $N_s \lambda_H$, where $N_s$ is the number of token in $failed\_SW$;
- $HW\_R$ represents the recovery of the hardware with a rate of $\mu_H$;
- $UHW\_R$ represent the recovery after an unsuccessful activation of the stand-by hardware with a rate of $\mu_{UH}$;
### Table III: Model parameters for the SDN controller

<table>
<thead>
<tr>
<th>parameter</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\lambda_H = 0.5\lambda_{dC}$, $N/K$</td>
<td>intensity of hardware failures</td>
</tr>
<tr>
<td>$\lambda_S = 0.5\lambda_{dS}$, $N$</td>
<td>intensity of software failures</td>
</tr>
<tr>
<td>$\lambda_O = 0.5\lambda_{dO}$, $N$</td>
<td>intensity of O&amp;M failures</td>
</tr>
<tr>
<td>$\mu_H = 0.9\mu_{fH}$, $0.5h$</td>
<td>hardware repair intensity</td>
</tr>
<tr>
<td>$\mu_S = 0.5\mu_{fS}$, $0.5h$</td>
<td>restoration intensity after software failure</td>
</tr>
<tr>
<td>$\mu_O = 0.5\mu_{fO}$, $0.5h$</td>
<td>rectification intensity after O&amp;M failures</td>
</tr>
<tr>
<td>$C_H = 0.9$</td>
<td>hardware failure coverage factor</td>
</tr>
<tr>
<td>$C_S = 0.9$</td>
<td>software failure coverage factor</td>
</tr>
</tbody>
</table>

Furthermore, the following input and output gates are included:

- **IG_MAN** enables the O&M failure activity only if there are no tokens in failed_MAN, sys_down, and sw_sys_down;
- **IG_SW** enables the software failure activity only if there are no tokens in failed_MAN, sys_down, sw_sys_down, and there are active processors and implies the decrease of the number of active processors;
- **OG_MAN** and **OG_SSD** resets the number of software failures and sets the number of active processors to the total number of processors minus the number of failures and sets the number of active processors to the total number of processors minus the number of active processors;
- **OG_SD** increases the number of failed hardware, resets the number of software failure, and sets the number of active processors to the total number of processors minus the number of processors with failed hardware.

In the proposed model the system is down where the number of tokens in Active_proc is lower than $K$ or there is a token in failed_MAN, in sys_down, or in sw_sys_down.

The parameters the SDN controller model are listed in Table III.

In an SDN controller, all failure rates are $N$-times larger than in the traditional network, where $N$ is the number of network nodes (10 in the addressed nation-wide backbone network). This is because we assume that the SDN needs roughly the same processing capacity and amount of hardware than in the traditional network. Therefore, the failure intensity is assumed to be proportional to $N$, and of the same order of magnitude as the total failure intensity of the traditional distributed IP router system. For the hardware failures the total failure intensity is divided by the number of needed processors $K = \lceil 0.8 \cdot M \rceil$, where $M = N$ is the total number of processors. Moreover, we set the proportionality factors $\alpha_H$, $\alpha_S$, and $\alpha_O$ as follows by basing on previous work [12]: $\alpha_H = 1$, $\alpha_S = 1$, $\alpha_O = 0.2$, and $\alpha_C = 1$.

### IV. SAN MODEL OF THE PRINCIPAL MINIMAL-CUT SETS

In [5], we have determined the minimal-cut sets for the different networks (TN: traditional network, F-SDN: forwarding part of SDN, C-SDN: control part of SDN), then we have identifies the principal minimal-cut sets, i.e. the ones with lower cardinality, (see Table IV).

Successively, we have evaluated which are the the failure correlation sources among the elements composing the principal minimal-cut set. Table V maps the failure correlation sources to the elements composing the 12 kinds of minimal-cut sets (4 for the traditional network, 8 for the SDN). The considered failure correlation sources are the following: Geographical Proximity (GEO), Physical Proximity (PHY), Common O&M (COM), Misconfiguration (MIS), Compatibility Issue (CIS), Homogeneous Equipment (HEQ), Traffic Migration (TMI).

### Table V: Type of minimal-cut sets for the different networks vs failure correlation source

<table>
<thead>
<tr>
<th>type</th>
<th>network</th>
<th>GEO</th>
<th>PHY</th>
<th>COM</th>
<th>MIS</th>
<th>CIS</th>
<th>TMI</th>
<th>HEQ</th>
</tr>
</thead>
<tbody>
<tr>
<td>n,n</td>
<td>TN</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>n,n,n</td>
<td>F-SDN</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>n,n</td>
<td>C-SDN</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>n,n,l</td>
<td>TN</td>
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<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>n,n,l</td>
<td>F-SDN</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
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<td>✓</td>
</tr>
<tr>
<td>n,n,l</td>
<td>C-SDN</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
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<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>n,l</td>
<td>F-SDN</td>
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<td>✓</td>
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<tr>
<td>n,l</td>
<td>C-SDN</td>
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<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

For modelling the availability of the minimal-cuts sets, in [5] we have used a modular and systematic approach to compose the SAN model of the network elements. In the composition, for considering the failure correlation among the network elements we have "added", "modified", or "merged" dependency models. In particular, we have added for GEO, PHY, MIS, and CIS, modified for TMI and HEQ, and merged for COM.

Table VI shows the parameters related to the failure correlation. In [13], the authors discovered that around of the 10% failures are actually multiple simultaneous failures. Based on this consideration we have consider an intensity of the correlated failures that is ten times lower than the "original" one. In particular, the "original" intensity of the GEO, PHY, MIS, and CIS are related to the permanent forwarding hardware or link (depending on the correlated elements), link, O&M, and SDN controller software, respectively. Since the COM failure is a merge failure correlation, we have considered a failure intensity equal to the intensity of distributed O&M failure. For the GEO and CIS recovery, we have considered a rate three times lower than the "original" rate since they need more time for restoring from the failure source (e.g. blackout) or to discover the origin of the failure. Instead, for the PHY, MIS and COM recovery, the rate for restoring the single element as been considered. Moreover, for conducting our sensitivity analysis we use the multiplicative.
TABLE IV: Principal minimal-cut sets (2 and 3 cardinality) for the different networks

<table>
<thead>
<tr>
<th>cardinality</th>
<th>type</th>
<th>TN &amp; F-SDN</th>
<th>C-SDN</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>{n,n}</td>
<td>{n_{BRG_1},n_{BRG_2}}</td>
<td>{n_{SC_1},n_{SC_2}}</td>
</tr>
<tr>
<td></td>
<td></td>
<td>{n_{STV_1},n_{STV_2}}</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>{n_{TRD_1},n_{TRD_2}}</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>{n,n,n}</td>
<td>{n_{BRG_1},n_{STV_1},n_{TRD_1}}</td>
<td>{n_{OSL_1},n_{OSL_2},n_{SC_1}}</td>
</tr>
<tr>
<td></td>
<td>{n,n}</td>
<td>{n_{BRG_1},n_{STV_2},n_{TRD_2}}</td>
<td>{n_{OSL_1},n_{SC_1},n_{OSL_2},n_{SC_2}}</td>
</tr>
<tr>
<td></td>
<td>{n}</td>
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<td>{n_{OSL_1},n_{OSL_2},n_{SC_1}}</td>
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<tr>
<td></td>
<td>{n}</td>
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<td>{n_{OSL_1},n_{SC_1},n_{OSL_1},n_{SC_2}}</td>
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<tr>
<td></td>
<td>{}</td>
<td>{n_{BRG_1},n_{STV_1},n_{TRD_1}}</td>
<td>{n_{SC_1},n_{TRD_1},n_{TRD_2}}</td>
</tr>
<tr>
<td></td>
<td>{}</td>
<td>{n_{BRG_1},n_{STV_2},n_{TRD_2}}</td>
<td>{n_{SC_1},n_{TRD_1},n_{TRD_2}}</td>
</tr>
</tbody>
</table>

TABLE VI: Model parameters for failure correlation sources

<table>
<thead>
<tr>
<th>intensity</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\lambda_{GEO}$ = $\alpha_{GEO} \lambda_{FW}$</td>
<td>intensity of geographical-spread failure</td>
</tr>
<tr>
<td>$\mu_{GEO}$ = $\beta_{FW}$</td>
<td>repair rate after a geographical-spread failure</td>
</tr>
<tr>
<td>$\lambda_{PHY}$ = $\alpha_{PHY} \lambda_{L}$</td>
<td>intensity of physical-spread failure</td>
</tr>
<tr>
<td>$\mu_{PHY}$ = $\mu_{L}$</td>
<td>repair rate after a physical-spread failure</td>
</tr>
<tr>
<td>$\lambda_{COM}$ = $\alpha_{COM} \lambda_{O}$</td>
<td>failure intensity caused by a shared O&amp;M</td>
</tr>
<tr>
<td>$\mu_{COM}$ = $\mu_{O}$</td>
<td>recovery rate from a shared-O&amp;M failure</td>
</tr>
<tr>
<td>$\lambda_{MIS}$ = $\alpha_{MIS} \lambda_{O}/10$</td>
<td>misconfiguration failure intensity</td>
</tr>
<tr>
<td>$\mu_{MIS}$ = $\mu_{O}$</td>
<td>intensity to recover from a misconfiguration failure</td>
</tr>
<tr>
<td>$\lambda_{CIS}$ = $\alpha_{CIS} \lambda_{S}/10$</td>
<td>failure intensity caused by a compatibility issue among different elements</td>
</tr>
<tr>
<td>$\mu_{CIS}$ = $\mu_{S}/3$</td>
<td>recovery rate from a incompatibility failure</td>
</tr>
<tr>
<td>$C_{TMI}$ = 0.95 + $\beta_{TMI}$</td>
<td>coverage factor for considering failures induced by traffic migration</td>
</tr>
<tr>
<td>$C_{HEQ}$ = 0.99 + $\beta_{HEQ}$</td>
<td>coverage factor for taking into account failures due to homogeneous equipment</td>
</tr>
</tbody>
</table>

factors $\alpha_{GEO}$, $\alpha_{PHY}$, $\alpha_{MIS}$, $\alpha_{COM}$, and $\alpha_{CIS}$ and the addends $\beta_{TMI}$ and $\beta_{HEQ}$. In particular we have considered $\alpha_{GEO,PHY,MIS,COM,CIS} \in \{10^i\} i = 0, \pm 1, \pm 2, \beta_{TMI} \in \{\pm 0.5, \pm 0.02, 0\}$, and $\beta_{HEQ} \in \{\pm 0.01, 0\}$.

In the remainder of the section, we briefly describe the SAN model of the principal minimal-cut sets, for further details the reader can find the Möbius documentation in the appendix.

A. \{n,n\} in TN

Figure 7 depicts the SAN model of \{n,n\} in TN, where the two routers are in the same city (GEO), share the O&M (COM), and if one fails all the traffic is managed by the other one (TMI). The SAN model is composed of the SAN of the two routers (*_S1 and *_S2), where the single O&M failure places have been deleted and the following places are added:

- **GEO** is equal to 1 when there is a GEO failure, 0 otherwise;
- **failed_MAN** is equal to 1 when there is a COM failure, 0 otherwise.

The places are connected by mean of the following timed activities with exponential time distribution:

- **MAN_F** and **MAN_R** represent the failure and the recovery of the common O&M with a rate of $\lambda_{COM}$ and $\mu_{COM}$, respectively;
- **GEO_F** and **GEO_R** represent the failure and the recovery from GEO failure with a rate of $\lambda_{GEO}$ and $\mu_{GEO}$, respectively.

For considering the TMI failure, the SW_F, FHW_F, FHw1_F, CHW_F time activities of the two routers are modified by creating two cases: if both routers are working, with probability $C_{TMI}$ only one router is failing and instead with probability $1 - C_{TMI}$ both the routers are failing, otherwise only one router is failing.

Furthermore, the following input and output gates are included:

- **IG_GF** and **IG_MF** enable the GEO and COM failure activities only if there in a token in both *Working_S1 and Working_S2*, i.e. both routers are working, and reset the token in both *Working_S1 and Working_S2*;
- **OG_GF** and **OG_MF** set the token in both *Working_S1 and Working_S2* again;
- **OG_SW**, **OG_FHW**, **OG_FHw1**, and **OG_CHW** reset the token in both *Working_S1 and Working_S2* and set failed_SW, failed_FHW, failed_FHw1, and failed_CHW, respectively, of both routers.

The minimal-cut set is unavailable when there are not tokens in *Working_S1*, *Working_S2*, spare_CHW_S1, and spare_CHW_S2.

Further details on the implementation in Möbius of the SAN model and the related simulation can be found in the Appendix A6 and B8, respectively.

B. \{n,n\} in F-SDN

Figure 8 shows the SAN model of \{n,n\} in F-SDN, where the two SDN switches (*_S1 and *_S2) are in the same city (GEO), if one fails all the traffic is managed by the other one (TMI), and share a common configuration (MIS). The SAN model is similar to the one for the two routers (see Figure 7): there is not the part related to the control hardware and there is the MIS failure instead of the COM failure.

The minimal-cut set is unavailable when there are not tokens in *Working_S1 and Working_S2*.

Further details on the implementation in Möbius of the SAN model and the related simulation can be found in the Appendix A10 and B12, respectively.
Fig. 7: SAN model of \( \{n,n\} \) in TN

Fig. 8: SAN model of \( \{n,n\} \) in F-SDN
C. \{n, n\} in C-SDN

Figure 9 depicts the SAN model of \{n, n\} in C-SDN, where the two SDN controllers share a common configuration (MIS) and if one fails the other one takes over the control (TMI). The SAN model is composed of the SAN of the two SDN controllers (*C1 and *C2), where the MIS place has been added and it is by mean of MIS_F and MIS_R timed activities, which represent the failure and the recovery of the common O&M with a rate of $\lambda_{MIS}$ and $\mu_{MIS}$, respectively.

Moreover, similarly to the two routers and two switches cases, several time activities of the two controllers are modified for considering the TMI failure. In particular, the MAN_F, HW_F1, FHw1_F, CHW_F2 time activities of the two controllers are modified by adding one case: if sys_down, sw_sys_down, and failed_MAN of the other router have zero token and if Active_proc of the addressed router is equal to $K$, i.e. the addressed router is not able to fulfil the demand and the other router is working, then with probability $C_{TMI}$ only one router is failing and instead with probability $1 - C_{TMI}$ both the routers are failing.

Furthermore, the following output gates are included:

- OG_TM sets failed_MAN of both controllers;
- OG_TH_C1 (and OG_TH_C2) sets sys_down_C1 (or sys_down_C2), decreases the tokens in Active_proc_C2 (or Active_proc_C1) and increases the tokens in failed_SW_C1 (or failed_SW_C2).
- OG_TS_C1 (and OG_TS_C2) similarly sets sys_down_C1 (or sys_down_C2), decreases the tokens in Active_proc_C2 (or Active_proc_C1) and increases the tokens in failed_HW_C1 (or failed_HW_C2);

The minimal-cut set is unavailable when both the SDN controllers are "singularly" failed or there is a token in MIS place. A SDN controller is "singularly" failed when Active_proc < $K$ or there is a token in one of these places: failed_MAN, sys_down, sw_sys_down.

Further details on the implementation in Möbius of the SAN model and the related simulation can be found in the Appendix A1 and B1, respectively.

D. \{n, n, n\} in TN

Figure 10 shows the SAN model of \{n, n, n\} in TN, where the three routers have both HW and SW homogeneous equipment (HEQ). Similarly as for the TMI in the two routers case, time activities are modified and output gates are added for considering the HEQ failure.

The minimal-cut set is unavailable when there are not token in Working_S1, Working_S2, Working_S3, spare_CHW_S1, spare_CHW_S2, and spare_CHW_S3.

Further details on the implementation in Möbius of the SAN model and the related simulation can be found in the Appendix A8 and B7, respectively.

E. \{n, n, n\} in F-SDN

Figure 11 depicts the SAN model of \{n, n, n\} in F-SDN where the three SDN switches have mainly HW homogeneous equipment (HEQ). The SAN model is similar to the one for the three routers (see Figure 10): there is not the part related
Fig. 10: SAN model of \( \{n, n, n\} \) in TN

Fig. 11: SAN model of \( \{n, n, n\} \) in F-SDN
to the control hardware and there is the MIS failure instead of the O&M failure.

The minimal-cut set is unavailable when there are not token in Working_S1, Working_S2, and Working_S3.

Further details on the implementation in Möbius of the SAN model and the related simulation can be found in the Appendix A12 and B11, respectively.

**F. \{n, n, n\} in C-SDN**

Figure 12 depicts the SAN model of \{n, n, n\} in C-SDN, where the SDN switches are in the same city (GEO), instead the controller and the switches can have compatibility issues (CIS). The GEO failure is included as in the two router case (see Figure 8). For the CIS failure, the following places (with the related timed activities and output gates) are added:

- **CIS** that assesses the CIS between the SDN controller and both the switches;
- **CIS_S1 and CIS_S2** consider the CIS between the SDN controller and the single switch (S1 and S2, respectively).

The minimal-cut set is unavailable when both SDN switches are failed and the SDN controller is "singularly" failed or there is a token the the CIS places.

Further details on the implementation in Möbius of the SAN model and the related simulation can be found in the Appendix A3 and B3, respectively.

**G. \{n, n, l\} in TN**

Figure 13 shows the SAN model of SAN model of \{n, n, l\} in TN, where one router and the link are in the same city (GEO) and the two routers have homogeneous equipment (HEQ). The HEQ failure is added as in the case of only two routers (see Figure 7), but note that in this case there is the O&M failure places are not merged because there is not COM failure here. The GEO place (with the related timed activities and output gates) is added between the working places of the link and one of the SDN switches.

The minimal-cut set is unavailable when there are not token in Working_S1, Working_S2, Working_L, spare_CHW_S1, and spare_CHW_S2.

Further details on the implementation in Möbius of the SAN model and the related simulation can be found in the Appendix A7 and B6, respectively.

**H. \{n, n, l\} in F-SDN**

Figure 14 depicts the SAN model of \{n, n, l\} in F-SDN, where one SDN switch and the link are in the same city (GEO) and the two SDN switches have homogeneous equipment (HEQ). The SAN model is similar to the one for the three routers: there is not the part related to the control hardware and the O&M failures.

The minimal-cut set is unavailable when there are not token in Working_S1, Working_S2, and Working_L.

Further details on the implementation in Möbius of the SAN model and the related simulation can be found in the Appendix A11 and B10, respectively.

**I. \{n, n, l\} in C-SDN**

Figure 15 depicts the SAN model of \{n, n, l\} in C-SDN, where the SDN switch and the link are in the same city (GEO), instead the controller and the switch can have compatibility issues (CIS). The GEO failure is similar to the one of the two switches and the link (see Figure 14). The CIS failure is similar to the one of the two switches and the controller (see Figure 12).

The minimal-cut set is unavailable when both SDN switch and link are failed and the SDN controller is "singularly" failed or there is a token the the CIS place.

Further details on the implementation in Möbius of the SAN model and the related simulation can be found in the Appendix A2 and B2, respectively.

**J. \{n, l, l\} in TN**

Figure 16 shows the SAN model of \{n, l, l\} in TN, where the two links are connected to the same router (PHY) and the router and the two links are in the same city (GEO). The PHY place (with the related timed activities and output gates) is added between the working place of the links. Instead, the GEO place is connected to the working places of each network element, i.e. the links and the SDN switch.

The minimal-cut set is unavailable when there are not token in Working_L1, Working_L2, Working_R, and spare_CHW.

Further details on the implementation in Möbius of the SAN model and the related simulation can be found in the Appendix A5 and B5, respectively.

**K. \{l, l, l\} in F-SDN**

Figure 17 shows the SAN model of \{l, l, l\} in F-SDN, where the two links are connected to the same SDN switch (PHY) and the SDN switch and the two links are in the same city (GEO). As in the previous cases, the SAN model is similar to the one for the router and the two links: there is not the part related to the control hardware and the O&M failures.

The minimal-cut set is unavailable when there are not token in Working_L1, Working_L2, and Working_S.

Further details on the implementation in Möbius of the SAN model and the related simulation can be found in the Appendix A9 and B9, respectively.

**L. \{l, l\} in C-SDN**

Figure 18 shows the SAN model of \{l, l\} in C-SDN, where the two links are connected to the same SDN switch (GEO, PHY). The SDN controller is independent.

The two links are unavailable when there are not token in Working_L1 and Working_L2. The unavailability of the minimal-cut set is the multiplication of the unavailability of the two links and the unavailability of the SDN controller.

Further details on the implementation in Möbius of the SAN models and the related simulations can be found in the Appendix A4 and B4, respectively.
Fig. 12: SAN model of \{n, n, n\} in C-SDN

V. CONCLUSION

The technical report has detailed presented of the implementation on Möbius of the SAN availability model of both the network elements and the principal minimal-cut sets. The models of principal minimal-cut sets have been have been used in [5].

APPENDIX

MÖBIUS DOCUMENTATION

In the following appendix, the Möbius documentation of the SAN model and the simulation for the principal minimal-cut sets is introduced by indicating the pages of the attached document.

A. Documentation on SAN models

Firstly, we introduce the documentation on the implementation in Möbius of the SAN model of the principal minimal-cut sets.

1) \{n, n\} in C-SDN: Form page A-1 to page A-5.
2) \{n, n, l\} in C-SDN: Form page A-5 to page A-9.
3) \{n, n, n\} in C-SDN: Form page A-9 to page A-13.
4) \{n, l, l\} in C-SDN: Form page A-13 to page A-14 the model of the two links and form page A-55 to page A-57 the model of the SDN controller.
5) \{n, l, l\} in TN: Form page A-52 to page A-53.
6) \{n, n, l\} in TN: In page A-53.
7) \{n, n, n\} in TN: In page A-54.
8) \{n, n\} in TN: Form page A-54 to page A-55.
9) \{n, n, l\} in F-SDN: Form page A-57 to page A-58.
10) \{n, n, l\} in F-SDN: Form page A-58 to page A-59.
11) \{n, n\} in F-SDN: In page A-59.
12) \{n, n\} in F-SDN: Form page A-59 to page A-60.

B. Documentation on simulations

Secondly, we introduce the documentation on the simulation (reward and study) in Möbius of the SAN model of the principal minimal-cut sets.

1) \{n, n\} in C-SDN: In page A-48.
2) \{n, n, l\} in C-SDN: Form page A-48 to page A-49.
3) \{n, n, n\} in C-SDN: Form page A-49 to page A-50.
4) \{n, l, l\} in C-SDN: Form page A-50 to page A-51 the model of the SDN controller and form page A-51 to page A-52 the model of the two links.
5) \{n, l, l\} in TN: Form page A-52 to page A-53.
6) \{n, n, l\} in TN: In page A-53.
7) \{n, n, n\} in TN: In page A-54.
8) \{n, n\} in TN: Form page A-54 to page A-55.
9) \{n, n, l\} in F-SDN: Form page A-57 to page A-58.
10) \{n, n, l\} in F-SDN: Form page A-58 to page A-59.
11) \{n, n\} in F-SDN: In page A-59.
12) \{n, n\} in F-SDN: Form page A-59 to page A-60.

REFERENCES

Fig. 13: SAN model of \{n,n,l\} in TN


Fig. 14: SAN model of \{n, n, l\} in F-SDN

Fig. 15: SAN model of \{n, n, l\} in C-SDN
Fig. 16: SAN model of \( \{n, l, l\} \) in TN

Fig. 17: SAN model of \( \{n, l, l\} \) in F-SDN

Fig. 18: SAN model of \( \{l, l\} \) in C-SDN
Model: cc

<table>
<thead>
<tr>
<th>Place Names</th>
<th>Initial Markings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Active_proc_C1</td>
<td>N_proc</td>
</tr>
<tr>
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</tr>
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</tr>
<tr>
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</tr>
<tr>
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</tr>
<tr>
<td>failed_MAN_C1</td>
<td>0</td>
</tr>
<tr>
<td>failed_MAN_C2</td>
<td>0</td>
</tr>
<tr>
<td>failed_SW_C1</td>
<td>0</td>
</tr>
<tr>
<td>failed_SW_C2</td>
<td>0</td>
</tr>
<tr>
<td>sw_sys_down_C1</td>
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</tr>
<tr>
<td>sw_sys_down_C2</td>
<td>0</td>
</tr>
<tr>
<td>sys_down_C1</td>
<td>0</td>
</tr>
<tr>
<td>sys_down_C2</td>
<td>0</td>
</tr>
</tbody>
</table>

**Timed Activity: HW_F1_C1**

- **Distribution Parameters**
  - Rate: Active_proc_C1->Mark() * hw_fail_rate
- **Activation Predicate**: (none)
- **Reactivation Predicate**: (none)

**Case Distributions**

1. if (MIS->Mark() == 0 && sys_down_C1->Mark() == 0 && sw_sys_down_C1->Mark() == 0 && sw_sys_down_C2->Mark() == 0 && failed_MAN_C1->Mark() == 0)
   
2. else
   
3. return(1-hw_cvg);

4. else
   
5. return(0);

6. case 2

7. if (MIS->Mark() == 0 && sys_down_C1->Mark() == 0 && sw_sys_down_C1->Mark() == 0 && sw_sys_down_C2->Mark() == 0 && failed_MAN_C1->Mark() == 0)
   
8. { if (sys_down_C2->Mark()==0 && sw_sys_down_C2->Mark()==0 && failed_MAN_C2->Mark()==0 && Active_proc_C1->Mark()==K_th)
   
9. return(hw_cvg*tmi_cvg);
   
10. else
   
11. return(hw_cvg);

12. else
   
13. return(1);

14. else
   
15. return(0);

16. case 3

17. if (MIS->Mark() == 0 && sys_down_C1->Mark() == 0 && sw_sys_down_C1->Mark() == 0 && sw_sys_down_C2->Mark() == 0 && failed_MAN_C1->Mark() == 0)
   
18. { if (sys_down_C2->Mark()==0 && sw_sys_down_C2->Mark()==0 && failed_MAN_C2->Mark()==0 && Active_proc_C1->Mark()==K_th)
   
19. return(hw_cvg*(1-tmi_cvg));
   
20. else
   
21. return(0);

22. else
   
23. return(0);

**Timed Activity: HW_F1_C2**

- **Distribution Parameters**
  - Rate: Active_proc_C2->Mark() * hw_fail_rate
- **Activation Predicate**: (none)
- **Reactivation Predicate**: (none)

**Case Distributions**

1. case 1

2. if (MIS->Mark() == 0 && sys_down_C2->Mark() == 0 && sw_sys_down_C2->Mark() == 0 && sw_sys_down_C1->Mark() == 0 && failed_MAN_C2->Mark() == 0)
   
3. return(0);

4. else
   
5. return(1-hw_cvg);

6. case 2

7. if (MIS->Mark() == 0 && sys_down_C2->Mark() == 0 && sw_sys_down_C2->Mark() == 0 && sw_sys_down_C1->Mark() == 0 && failed_MAN_C2->Mark() == 0)
   
8. { if (sys_down_C1->Mark()==0 && sw_sys_down_C1->Mark()==0 && failed_MAN_C1->Mark()==0 && Active_proc_C2->Mark()==K_th)
   
9. return(hw_cvg*tmi_cvg);
   
10. else
   
11. return(hw_cvg);

12. else
   
13. return(1);

14. else
   
15. return(0);
if (MIS->Mark() == 0 && sys_down_C2->Mark() == 0 && sw_sys_down_C2->Mark() == 0 && failed_MAN_C2->Mark() == 0) {
  if (sys_down_C1->Mark()==0 && sw_sys_down_C1->Mark()==0 && failed_MAN_C1->Mark()==0 && Active_proc_C2->Mark()==K_th)
    return(hw_cvg*(1-tmi_cvg));
  else
    return(0);
} else
  return(0);

Timed Activity: HW_F2_C1
Distribution Parameters
Rate
hw_fail_rate * failed_SW_C1->Mark()
Activation Predicate
(none)
Reactivation Predicate
(none)

Timed Activity: HW_F2_C2
Distribution Parameters
Rate
hw_fail_rate * failed_SW_C2->Mark()
Activation Predicate
(none)
Reactivation Predicate
(none)

Timed Activity: HW_R_C1
Distribution Parameters
Rate
hw_rcv_rate
Activation Predicate
(none)
Reactivation Predicate
(none)

Timed Activity: HW_R_C2
Distribution Parameters
Rate
hw_rcv_rate
Activation Predicate
(none)
Reactivation Predicate
(none)

Timed Activity: MAN_F_C1
Distribution Parameters
Rate
man_fail_rate
Activation Predicate
(none)
Reactivation Predicate
(none)

Case Distributions

<table>
<thead>
<tr>
<th>Case</th>
<th>Condition</th>
<th>Action</th>
</tr>
</thead>
<tbody>
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<td>failed_MAN_C2-&gt;Mark() == 0 &amp;&amp; sys_down_C2-&gt;Mark() == 0 &amp;&amp; sw_sys_down_C2-&gt;Mark() == 0</td>
<td>return(tmi_cvg);</td>
</tr>
<tr>
<td>2</td>
<td>failed_MAN_C2-&gt;Mark() == 0 &amp;&amp; sys_down_C2-&gt;Mark() == 0 &amp;&amp; sw_sys_down_C2-&gt;Mark() == 0</td>
<td>return(1);</td>
</tr>
</tbody>
</table>

Timed Activity: MAN_F_C2
Distribution Parameters
Rate
man_fail_rate
Activation Predicate
(none)
Reactivation Predicate
(none)

Case Distributions

<table>
<thead>
<tr>
<th>Case</th>
<th>Condition</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>failed_MAN_C1-&gt;Mark() == 0 &amp;&amp; sys_down_C1-&gt;Mark() == 0 &amp;&amp; sw_sys_down_C1-&gt;Mark() == 0</td>
<td>return(tmi_cvg);</td>
</tr>
<tr>
<td>2</td>
<td>failed_MAN_C1-&gt;Mark() == 0 &amp;&amp; sys_down_C1-&gt;Mark() == 0 &amp;&amp; sw_sys_down_C1-&gt;Mark() == 0</td>
<td>return(1);</td>
</tr>
<tr>
<td>Timed Activity</td>
<td>Distribution Parameters</td>
<td>Rate</td>
</tr>
<tr>
<td>---------------</td>
<td>--------------------------</td>
<td>------</td>
</tr>
<tr>
<td>MAN_R_C1</td>
<td></td>
<td>man_rcv_rate</td>
</tr>
<tr>
<td>MAN_R_C2</td>
<td></td>
<td>man_rcv_rate</td>
</tr>
<tr>
<td>MIS_F</td>
<td></td>
<td>mis_fail_rate</td>
</tr>
<tr>
<td>MIS_R</td>
<td></td>
<td>mis_rcv_rate</td>
</tr>
<tr>
<td>SW_F_C1</td>
<td></td>
<td>if(Active_proc_C1-&gt;Mark() &gt;= K_th) return(sw_fail_rate); else return(sw_fail_rate * Active_proc_C1-&gt;Mark());</td>
</tr>
<tr>
<td>SW_F_C2</td>
<td></td>
<td>if(Active_proc_C2-&gt;Mark() &gt;= K_th) return(sw_fail_rate); else return(sw_fail_rate * Active_proc_C2-&gt;Mark());</td>
</tr>
</tbody>
</table>

Case Distributions:

### SW_F_C1

- **Case 1**: 1-sw_cvg
- **Case 2**
  - if (sys_down_C2->Mark()==0 & sw_sys_down_C2->Mark()==0 & failed_MAN_C2->Mark()==0 & Active_proc_C1->Mark()==K_th)
    - return(sw_cvg*tmi_cvg);
  - else return(sw_cvg);
- **Case 3**
  - if (sys_down_C2->Mark()==0 & sw_sys_down_C2->Mark()==0 & failed_MAN_C2->Mark()==0 & Active_proc_C1->Mark()==K_th)
    - return(sw_cvg*(1-tmi_cvg));
  - else return(0);

### SW_F_C2

- **Case 1**: 1-sw_cvg
- **Case 2**
  - if (sys_down_C1->Mark()==0 & sw_sys_down_C1->Mark()==0 & failed_MAN_C1->Mark()==0 & Active_proc_C2->Mark()==K_th)
    - return(sw_cvg*tmi_cvg);
  - else return(sw_cvg);
- **Case 3**
  - if (sys_down_C1->Mark()==0 & sw_sys_down_C1->Mark()==0 & failed_MAN_C1->Mark()==0 & Active_proc_C2->Mark()==K_th)
    - return(sw_cvg*(1-tmi_cvg));
  - else return(0);
<table>
<thead>
<tr>
<th>Timed Activity:</th>
<th>SW_R_C1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distribution Parameters</td>
<td>Rate: <code>sw_rcv_rate</code></td>
</tr>
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### Input Gate: IG_MAN_C1

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<tr>
<th>Predicate</th>
<th>(MIS-&gt;Mark() == 0 &amp; &amp; failed_MAN_C1-&gt;Mark() == 0 &amp; &amp; sys_down_C1-&gt;Mark() == 0 &amp; &amp; sw_sys_down_C1-&gt;Mark() == 0)</th>
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### Input Gate: IG_MAN_C2

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### Input Gate: IG_MF

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### Input Gate: IG_SW_C1

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<tr>
<td>Function</td>
<td>Active_proc_C1-&gt;Mark()--;</td>
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### Input Gate: IG_SW_C2

<table>
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<th>(failed_MAN_C2-&gt;Mark()==0 &amp; &amp; sys_down_C2-&gt;Mark() == 0 &amp; &amp; sw_sys_down_C2-&gt;Mark() == 0 &amp; &amp; Active_proc_C2-&gt;Mark() &gt; 0)</th>
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</thead>
<tbody>
<tr>
<td>Function</td>
<td>;</td>
</tr>
</tbody>
</table>
Function
Active_proc_C2->Mark()--;  

Output Gate: OG_MAN_C1
Function
Active_proc_C1->Mark() = N_proc - failed_HW_C1->Mark();
failed_SW_C1->Mark()=0;

Function
Active_proc_C2->Mark() = N_proc - failed_HW_C2->Mark();
failed_SW_C2->Mark()=0;

Output Gate: OG_MAN_C2
Function
Active_proc_C1->Mark() = N_proc - failed_HW_C1->Mark();
failed_SW_C1->Mark()=0;

Output Gate: OG_MR
Function
;

Output Gate: OG_SD_C1
Function
failed_HW_C1->Mark()++;  
Active_proc_C1->Mark() = N_proc - failed_HW_C1->Mark();
failed_SW_C1->Mark()=0;

Function
failed_HW_C2->Mark()++;  
Active_proc_C2->Mark() = N_proc - failed_HW_C2->Mark();
failed_SW_C2->Mark()=0;

Output Gate: OG_SD_C2
Function
failed_HW_C1->Mark()++;  
Active_proc_C1->Mark() = N_proc - failed_HW_C1->Mark();
failed_SW_C1->Mark()=0;

Function
failed_HW_C2->Mark()++;  
Active_proc_C2->Mark() = N_proc - failed_HW_C2->Mark();
failed_SW_C2->Mark()=0;

Output Gate: OG_SSD_C1
Function
failed_HW_C1->Mark()++;  
Active_proc_C1->Mark() = N_proc - failed_HW_C1->Mark();
failed_SW_C1->Mark()=0;

Function
failed_HW_C2->Mark()++;  
Active_proc_C2->Mark() = N_proc - failed_HW_C2->Mark();
failed_SW_C2->Mark()=0;

Output Gate: OG_SSD_C2
Function
failed_HW_C1->Mark()++;  
Active_proc_C1->Mark() = N_proc - failed_HW_C1->Mark();
failed_SW_C1->Mark()=0;

Function
failed_HW_C2->Mark()++;  
Active_proc_C2->Mark() = N_proc - failed_HW_C2->Mark();
failed_SW_C2->Mark()=0;

Output Gate: OG_TH_C1
Function
sys_down_C2->Mark()=1;
Active_proc_C2->Mark()--;  
failed_HW_C1->Mark()++;  

Function
sys_down_C1->Mark()=1;
Active_proc_C1->Mark()--;  
failed_HW_C2->Mark()++;  

Output Gate: OG_TH_C2
Function
sys_down_C2->Mark()=1;
Active_proc_C2->Mark()--;  
failed_HW_C1->Mark()++;  

Function
sys_down_C1->Mark()=1;
Active_proc_C1->Mark()--;  
failed_HW_C2->Mark()++;  

Output Gate: OG_TM
Function
failed_MAN_C1->Mark()=1;
failed_MAN_C2->Mark()=1;

Output Gate: OG_TS_C1
Function
sw_sys_down_C2->Mark()=1;
Active_proc_C2->Mark()--;  
failed_SW_C1->Mark()++;  

Function
sw_sys_down_C1->Mark()=1;
Active_proc_C1->Mark()--;  
failed_SW_C2->Mark()++;  

Output Gate: OG_TS_C2
Function
sw_sys_down_C2->Mark()=1;
Active_proc_C2->Mark()--;  
failed_SW_C1->Mark()++;  

Function
sw_sys_down_C1->Mark()=1;
Active_proc_C1->Mark()--;  
failed_SW_C2->Mark()++;  

Model: csl
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<tr>
<td>Failed_L</td>
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</tr>
<tr>
<td>GEO</td>
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<tr>
<td>Working_S</td>
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<tr>
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**Timed Activity:** CIS_F

- **Activation Predicate:** (none)
- **Reactivation Predicate:** (none)

**Distribution Parameters**
- **Rate:** cis fail rate

**Timed Activity:** CIS_R

- **Activation Predicate:** (none)
- **Reactivation Predicate:** (none)

**Distribution Parameters**
- **Rate:** cis rcv rate

**Timed Activity:** FHW_F_S

- **Activation Predicate:** (none)
- **Reactivation Predicate:** (none)

**Distribution Parameters**
- **Rate:** fhw fail rate

**Timed Activity:** FHW_R_S

- **Activation Predicate:** (none)
- **Reactivation Predicate:** (none)

**Distribution Parameters**
- **Rate:** fhw rcv rate

**Timed Activity:** FHWt_F_S

- **Activation Predicate:** (none)
- **Reactivation Predicate:** (none)

**Distribution Parameters**
- **Rate:** fhwt fail rate

**Timed Activity:** FHWt_R_S

- **Activation Predicate:** (none)
- **Reactivation Predicate:** (none)

**Distribution Parameters**
- **Rate:** fhwt rcv rate

**Timed Activity:** GEO_F

- **Activation Predicate:** (none)
- **Reactivation Predicate:** (none)

**Distribution Parameters**
- **Rate:** geo fail rate

**Timed Activity:** GEO_R

- **Activation Predicate:** (none)
- **Reactivation Predicate:** (none)

**Distribution Parameters**
- **Rate:** geo rcv rate

**Timed Activity:** HW_F1

- **Activation Predicate:** (none)
- **Reactivation Predicate:** (none)

**Distribution Parameters**
- **Rate:** Active proc->Mark() * hw fail rate

**Case Distributions**
- Case 1
if (sys_down->Mark() == 0 && sw_sys_down->Mark() == 0 && failed_MAN->Mark() == 0)
    return(1-hw_cvg);
else
    return(0);

case 2
if (sys_down->Mark() == 0 && sw_sys_down->Mark() == 0 && failed_MAN->Mark() == 0)
    return(hw_cvg);
else
    return(1);

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<tbody>
<tr>
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<td>hw_fail_rate * failed_SW-&gt;Mark()</td>
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<td></td>
<td>if(Active_proc-&gt;Mark() &gt;= K_th)</td>
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<tr>
<td></td>
<td></td>
<td>return(csw_fail_rate);</td>
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<tr>
<td></td>
<td></td>
<td>else return(csw_fail_rate * Active_proc-&gt;Mark());</td>
</tr>
<tr>
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| Case Distributions: | Rate | |
|                    | case 1 | 1-sw_cvg |
|                    | case 2 | sw_cvg |

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### Activation Predicate
- (none)

### Reactivation Predicate
- (none)

### Timed Activity: SW_R

**Distribution Parameters**
- Rate: csw_rcv_rate

**Activation Predicate**
- (none)

**Reactivation Predicate**
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### Timed Activity: SW_R_S

**Distribution Parameters**
- Rate: sw_rcv_rate

**Activation Predicate**
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**Reactivation Predicate**
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### Timed Activity: UHW_R

**Distribution Parameters**
- Rate: uhw_rcv_rate

**Activation Predicate**
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**Reactivation Predicate**
- (none)

### Timed Activity: USW_R

**Distribution Parameters**
- Rate: usw_rcv_rate

**Activation Predicate**
- (none)

**Reactivation Predicate**
- (none)

### Input Gate: IG_CF

**Predicate**
- (CIS->Mark() == 0 && Working_S->Mark()==1 && failed_MAN->Mark() == 0 && sys_down->Mark() == 0 && sw_sys_down->Mark() == 0)

**Function**
- Working_S->Mark()=0;

### Input Gate: IG_GF

**Predicate**
- (Working_L->Mark()==1 && Working_S->Mark()==1)

**Function**
- Working_L->Mark()==0;
  Working_S->Mark()==0;

### Input Gate: IG_MAN

**Predicate**
- (failed_MAN->Mark() == 0 && sys_down->Mark() == 0 && sw_sys_down->Mark() == 0)

**Function**
- ;

### Input Gate: IG_SW

**Predicate**
- (failed_MAN->Mark() == 0 && sys_down->Mark() == 0 && sw_sys_down->Mark() == 0 && Active_proc->Mark() > 0)

**Function**
- Active_proc->Mark()--;

### Output Gate: OG_CR

**Function**
- Working_S->Mark()==1;

### Output Gate: OG_GR

**Function**
- Working_L->Mark()==1;
  Working_S->Mark()==1;

### Output Gate: OG_MAN

**Function**
- \( \text{Active_proc->Mark()} = \text{N_proc} - \text{failed_HW->Mark()}; \)
  \( \text{failed_SW->Mark()==0}; \)

### Output Gate: OG_SD

**Function**
- \( \text{failed_HW->Mark()++}; \)
  \( \text{Active_proc->Mark()} = \text{N_proc} - \text{failed_HW->Mark()}; \)
  \( \text{failed_SW->Mark()==0}; \)
Output Gate: OG_SSD

Function

\[
\text{Active}_\text{proc}\text{->Mark()} = \text{N}_\text{proc} - \text{failed}_\text{HW}\text{->Mark();}
\]

\[
\text{failed}_\text{SW}\text{->Mark()} = 0;
\]

Model: css

### Place Attributes:

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### Timed Activity: CIS_F_S1

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### Timed Activity: CIS_R

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### Timed Activity: CIS_R_S1

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### Timed Activity: CIS_R_S2

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<td>Timed Activity:</td>
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</tr>
<tr>
<td>Distribution Parameters</td>
<td>Rate</td>
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<tr>
<td></td>
<td>Active_proc-&gt;Mark() * hw_fail_rate</td>
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<tr>
<td>Reactivation Predicate</td>
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</table>

**Case Distributions**

- **case 1**
  ```
  if (sys_down->Mark() == 0 && sw_sys_down->Mark() == 0 && failed_MAN->Mark() == 0)
  return(1-hw_cvg);
  else
  return(0);
  ```

- **case 2**
  ```
  if (sys_down->Mark() == 0 && sw_sys_down->Mark() == 0 && failed_MAN->Mark() == 0)
  return(hw_cvg);
  else
  return(1);
  ```

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<tbody>
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<tbody>
<tr>
<td>Distribution Parameters</td>
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<tr>
<td></td>
<td>if(Active_proc-&gt;Mark() == K_th) return(csw_fail_rate); else return(csw_fail_rate * Active_proc-&gt;Mark());</td>
</tr>
<tr>
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**Case Distributions**

- **case 1**
  ```
  1-sw_cvg
  ```

- **case 2**
  ```
  sw_cvg
  ```

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<tr>
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<th>SW_F_S1</th>
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<td>Reactivation Predicate</td>
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<table>
<thead>
<tr>
<th>Input Gate:</th>
<th>IG_CF</th>
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<tbody>
<tr>
<td>Predicate</td>
<td>(Working_S1-&gt;Mark() == 1 &amp;&amp; Working_S2-&gt;Mark() == 1 &amp;&amp; failed_MAN-&gt;Mark() == 0 &amp;&amp; sys_down-&gt;Mark() == 0 &amp;&amp; sw_sys_down-&gt;Mark() == 0)</td>
</tr>
<tr>
<td>Function</td>
<td>Working_S1-&gt;Mark()=0; Working_S2-&gt;Mark()=0;</td>
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<thead>
<tr>
<th>Input Gate:</th>
<th>IG_CF_S1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Predicate</td>
<td>(CIS_S2-&gt;Mark() == 0 &amp;&amp; Working_S1-&gt;Mark() == 1 &amp;&amp; failed_MAN-&gt;Mark() == 0 &amp;&amp; sys_down-&gt;Mark() == 0 &amp;&amp; sw_sys_down-&gt;Mark() == 0)</td>
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<tr>
<td>Function</td>
<td>Working_S1-&gt;Mark()=0;</td>
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<thead>
<tr>
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<td>Predicate</td>
<td>(CIS_S1-&gt;Mark() == 0 &amp;&amp; Working_S2-&gt;Mark() == 1 &amp;&amp; failed_MAN-&gt;Mark() == 0 &amp;&amp; sys_down-&gt;Mark() == 0 &amp;&amp; sw_sys_down-&gt;Mark() == 0)</td>
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<tr>
<td>Function</td>
<td>Working_S2-&gt;Mark()=0;</td>
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<td>Working_S1-&gt;Mark()=0; Working_S2-&gt;Mark()=0;</td>
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<tr>
<th>Input Gate:</th>
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<tbody>
<tr>
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<tr>
<td>Function</td>
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<tr>
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<tr>
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<tr>
<td>Function</td>
<td>Active_proc-&gt;Mark()--;</td>
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<td>Output Gate:</td>
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<td>Function</td>
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<td>Output Gate:</td>
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<tr>
<td>Function</td>
<td>Working_S1-&gt;Mark() = 1;</td>
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<td>OG_CR_S2</td>
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<tr>
<td>Function</td>
<td>Working_S2-&gt;Mark() = 1;</td>
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<td>Function</td>
<td>Working_S1-&gt;Mark() = 1; Working_S2-&gt;Mark() = 1;</td>
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<td>OG_MAN</td>
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<tr>
<td>Function</td>
<td>Active_proc-&gt;Mark() = N_proc - failed_HW-&gt;Mark(); failed_SW-&gt;Mark() = 0;</td>
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<td>Output Gate:</td>
<td>OG_SD</td>
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<td>Function</td>
<td>failed_HW-&gt;Mark()++; Active_proc-&gt;Mark() = N_proc - failed_HW-&gt;Mark(); failed_SW-&gt;Mark() = 0;</td>
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<tr>
<td>Function</td>
<td>Active_proc-&gt;Mark() = N_proc - failed_HW-&gt;Mark(); failed_SW-&gt;Mark() = 0;</td>
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**Model: ll**

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<tr>
<th>Place Names</th>
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<td>Failed_L2</td>
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**Timed Activity: GEO_F**

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**Timed Activity: GEO_R**

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**Timed Activity: L_F1**

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**Timed Activity: L_F2**
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| Timed Activity:         |              |                      |                        |
| L_R1                    |              |                      |                        |
| Distribution Parameters |              |                      |                        |
| Rate                    | link_rcv_rate |                      |                        |
| Activation Predicate    | (none)       |                      |                        |
| Reactivation Predicate  | (none)       |                      |                        |

| Timed Activity:         |              |                      |                        |
| L_R2                    |              |                      |                        |
| Distribution Parameters |              |                      |                        |
| Rate                    | link_rcv_rate |                      |                        |
| Activation Predicate    | (none)       |                      |                        |
| Reactivation Predicate  | (none)       |                      |                        |

| Timed Activity:         |              |                      |                        |
| PHY_F                   |              |                      |                        |
| Distribution Parameters |              |                      |                        |
| Rate                    | phy_fail_rate |                      |                        |
| Activation Predicate    | (none)       |                      |                        |
| Reactivation Predicate  | (none)       |                      |                        |

| Timed Activity:         |              |                      |                        |
| PHY_R                   |              |                      |                        |
| Distribution Parameters |              |                      |                        |
| Rate                    | phy_rcv_rate  |                      |                        |
| Activation Predicate    | (none)       |                      |                        |
| Reactivation Predicate  | (none)       |                      |                        |

| Input Gate:             |              |                      |                        |
| IG_GF                   |              |                      |                        |
| Predicate               | (Working_L1->Mark()==1 && Working_L2->Mark()==1) | | |
| Function                | Working_L1->Mark()==0; Working_L2->Mark()==0; | | |

| Input Gate:             |              |                      |                        |
| IG_PF                   |              |                      |                        |
| Predicate               | (Working_L1->Mark()==1 && Working_L2->Mark()==1) | | |
| Function                | Working_L1->Mark()==0; Working_L2->Mark()==0; | | |

| Output Gate:            |              |                      |                        |
| OG_GR                   |              |                      |                        |
| Function                | Working_L1->Mark()==1; Working_L2->Mark()==1; | | |

| Output Gate:            |              |                      |                        |
| OG_PR                   |              |                      |                        |
| Function                | Working_L1->Mark()==1; Working_L2->Mark()==1; | | |

Model: rl

<p>| Place Attributes:       |                      |                        |
| Place Names             | Initial Markings     |                        |
| Failed_L1              | 0                     |                        |
| Failed_L2              | 0                     |                        |
| GEO                    | 0                     |                        |
| PHY                    | 0                     |                        |
| Working_L1             | 1                     |                        |
| Working_L2             | 1                     |                        |
| Working_R              | 1                     |                        |
| failed_CHW             | 0                     |                        |
| failed_FHW             | 0                     |                        |
| failed_FHWt            | 0                     |                        |</p>
<table>
<thead>
<tr>
<th>Activity</th>
<th>Distribution Parameters</th>
<th>Rate</th>
<th>Activation Predicate</th>
<th>Reactivation Predicate</th>
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<tr>
<td>GEO_F</td>
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<tr>
<td>Timed Activity</td>
<td>Distribution Parameters</td>
<td>Rate</td>
<td>Activation Predicate</td>
<td>Reactivation Predicate</td>
</tr>
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<tr>
<td>Distribution Parameters</td>
<td>Rate</td>
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<tr>
<td>Activation Predicate</td>
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<tr>
<td>Reactivation Predicate</td>
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<table>
<thead>
<tr>
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<th>SW_R</th>
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<tbody>
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<td>Rate</td>
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<tr>
<td>Activation Predicate</td>
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<tr>
<td>Reactivation Predicate</td>
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<table>
<thead>
<tr>
<th>Timed Activity:</th>
<th>UCHW_R</th>
</tr>
</thead>
<tbody>
<tr>
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<td>Rate</td>
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<tr>
<td>Activation Predicate</td>
<td>(none)</td>
</tr>
<tr>
<td>Reactivation Predicate</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Input Gate:</th>
<th>IG_GF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Predicate</td>
<td>(Working_L1-&gt;Mark()==1 &amp;&amp; Working_L2-&gt;Mark()==1 &amp;&amp; Working_R-&gt;Mark()==1)</td>
</tr>
<tr>
<td>Function</td>
<td>Working_L1-&gt;Mark()=0; Working_L2-&gt;Mark()=0; Working_R-&gt;Mark()=0;</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Input Gate:</th>
<th>IG_PF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Predicate</td>
<td>(Working_L1-&gt;Mark()==1 &amp;&amp; Working_L2-&gt;Mark()==1)</td>
</tr>
<tr>
<td>Function</td>
<td>Working_L1-&gt;Mark()=0; Working_L2-&gt;Mark()=0;</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Output Gate:</th>
<th>OG_GR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Function</td>
<td>Working_L1-&gt;Mark()=1; Working_L2-&gt;Mark()=1; Working_R-&gt;Mark()=1;</td>
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</table>

<table>
<thead>
<tr>
<th>Output Gate:</th>
<th>OG_PR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Function</td>
<td>Working_L1-&gt;Mark()=1; Working_L2-&gt;Mark()=1;</td>
</tr>
</tbody>
</table>

Model: rr

<table>
<thead>
<tr>
<th>Place Names</th>
<th>Initial Markings</th>
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<tbody>
<tr>
<td>Failed_MAN</td>
<td>0</td>
</tr>
<tr>
<td>GEO</td>
<td>0</td>
</tr>
<tr>
<td>Working_S1</td>
<td>1</td>
</tr>
<tr>
<td>Working_S2</td>
<td>1</td>
</tr>
<tr>
<td>failed_CHW_S1</td>
<td>0</td>
</tr>
<tr>
<td>failed_CHW_S2</td>
<td>0</td>
</tr>
<tr>
<td>failed_FHW_S1</td>
<td>0</td>
</tr>
<tr>
<td>failed_FHW_S2</td>
<td>0</td>
</tr>
<tr>
<td>failed_FHWt_S1</td>
<td>0</td>
</tr>
<tr>
<td>failed_FHWt_S2</td>
<td>0</td>
</tr>
<tr>
<td>failed_SW_S1</td>
<td>0</td>
</tr>
<tr>
<td>failed_SW_S2</td>
<td>0</td>
</tr>
<tr>
<td>spare_CHW_S1</td>
<td>0</td>
</tr>
<tr>
<td>spare_CHW_S2</td>
<td>0</td>
</tr>
<tr>
<td>sys_down_S1</td>
<td>0</td>
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<tr>
<td>sys_down_S2</td>
<td>0</td>
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</table>

<table>
<thead>
<tr>
<th>Timed Activity:</th>
<th>CHW_F2_S1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distribution Parameters</td>
<td>Rate</td>
</tr>
<tr>
<td>Activation Predicate</td>
<td>(none)</td>
</tr>
</tbody>
</table>
### Case Distributions

#### CHW_F2_S2

**Activation Predicate:** (none)

**Reactivation Predicate:** (none)

<table>
<thead>
<tr>
<th>Case</th>
<th>Distribution</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>if (Working_S2-&gt;Mark() == 1) return(tmi_cvg); else return(1);</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>if (Working_S2-&gt;Mark() == 1) return(1-tmi_cvg); else return(0);</td>
<td></td>
</tr>
</tbody>
</table>

**Timed Activity:** CHW_F2_S2

**Distribution Parameters**
- Rate: chw_fail_rate

### Case Distributions

#### CHW_F_S1

**Activation Predicate:** (none)

**Reactivation Predicate:** (none)

<table>
<thead>
<tr>
<th>Case</th>
<th>Distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1-chw_cvg</td>
</tr>
<tr>
<td>2</td>
<td>chw_cvg</td>
</tr>
</tbody>
</table>

**Timed Activity:** CHW_F_S1

**Distribution Parameters**
- Rate: 2 * chw_fail_rate

### Case Distributions

#### CHW_F_S2

**Activation Predicate:** (none)

**Reactivation Predicate:** (none)

<table>
<thead>
<tr>
<th>Case</th>
<th>Distribution</th>
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<tbody>
<tr>
<td>1</td>
<td>1-chw_cvg</td>
</tr>
<tr>
<td>2</td>
<td>chw_cvg</td>
</tr>
</tbody>
</table>

**Timed Activity:** CHW_F_S2

**Distribution Parameters**
- Rate: 2 * chw_fail_rate

### Case Distributions

#### CHW_R2_S1

**Activation Predicate:** (none)

**Reactivation Predicate:** (none)

<table>
<thead>
<tr>
<th>Case</th>
<th>Distribution</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>1-chw_cvg</td>
</tr>
<tr>
<td>2</td>
<td>chw_cvg</td>
</tr>
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</table>

**Timed Activity:** CHW_R2_S1

**Distribution Parameters**
- Rate: chw_rcv_rate

### Case Distributions

#### CHW_R2_S2

**Activation Predicate:** (none)

**Reactivation Predicate:** (none)

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<tr>
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<th>Distribution</th>
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<tbody>
<tr>
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<td>1-chw_cvg</td>
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<tr>
<td>2</td>
<td>chw_cvg</td>
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</tbody>
</table>

**Timed Activity:** CHW_R2_S2

**Distribution Parameters**
- Rate: chw_rcv_rate
## Timed Activity: CHW_R_S1

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<th>Distribution Parameters</th>
<th>Rate</th>
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</tr>
<tr>
<td>Reactivation Predicate</td>
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## Timed Activity: CHW_R_S2

<table>
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</tr>
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<tr>
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<td></td>
</tr>
<tr>
<td>Reactivation Predicate</td>
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</tbody>
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## Timed Activity: FHW_F_S1

<table>
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<th>Distribution Parameters</th>
<th>Rate</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Activation Predicate</td>
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<td></td>
</tr>
<tr>
<td>Reactivation Predicate</td>
<td>(none)</td>
<td></td>
</tr>
</tbody>
</table>

### Case Distributions

**Case 1**

```c
if(Working_S1->Mark()==1 && Working_S2->Mark()==1)
    return(1-tmi_cvg);
else
    return(0);
```

**Case 2**

```c
if(Working_S1->Mark()==1 && Working_S2->Mark()==1)
    return(tmi_cvg);
else
    return(1);
```

## Timed Activity: FHW_F_S2

<table>
<thead>
<tr>
<th>Distribution Parameters</th>
<th>Rate</th>
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<tr>
<td>Reactivation Predicate</td>
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</tr>
</tbody>
</table>

### Case Distributions

**Case 1**

```c
if(Working_S1->Mark()==1 && Working_S2->Mark()==1)
    return(1-tmi_cvg);
else
    return(0);
```

## Timed Activity: FHW_R_S1

<table>
<thead>
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<th>Distribution Parameters</th>
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<td></td>
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## Timed Activity: FHW_R_S2

<table>
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<tr>
<td>Reactivation Predicate</td>
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## Timed Activity: FHWT_F_S1

<table>
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<td></td>
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<tr>
<td>Reactivation Predicate</td>
<td>(none)</td>
<td></td>
</tr>
</tbody>
</table>

### Case Distributions

**Case 1**

```c
if(Working_S1->Mark()==1 && Working_S2->Mark()==1)
    return(1-tmi_cvg);
else
    return(tmi_cvg);
```
if(Working_S1->Mark()==1 && Working_S2->Mark()==1)
    return(1-tmi_cvg);
else
    return(0);

case 2
if(Working_S1->Mark()==1 && Working_S2->Mark()==1)
    return(tmi_cvg);
else
    return(1);

Timed Activity: **FHWt_F_S2**

<table>
<thead>
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<th>Rate</th>
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<tbody>
<tr>
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<td>fhwt_fail_rate</td>
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</tbody>
</table>

| Activation Predicate | (none) |
| Reactivation Predicate | (none) |

**Case Distributions**

**case 1**
if(Working_S1->Mark()==1 && Working_S2->Mark()==1)
    return(1-tmi_cvg);
else
    return(0);

**case 2**
if(Working_S1->Mark()==1 && Working_S2->Mark()==1)
    return(tmi_cvg);
else
    return(1);

Timed Activity: **FHWt_R_S1**

<table>
<thead>
<tr>
<th>Distribution Parameters</th>
<th>Rate</th>
</tr>
</thead>
<tbody>
<tr>
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<td>fhwt_rcv_rate</td>
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| Activation Predicate | (none) |
| Reactivation Predicate | (none) |

Timed Activity: **FHWt_R_S2**

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<tr>
<th>Distribution Parameters</th>
<th>Rate</th>
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<tbody>
<tr>
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| Activation Predicate | (none) |
| Reactivation Predicate | (none) |

Timed Activity: **GEO_F**

<table>
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<tr>
<th>Distribution Parameters</th>
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<tbody>
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<td>geo_fail_rate</td>
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| Activation Predicate | (none) |
| Reactivation Predicate | (none) |

Timed Activity: **GEO_R**

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<th>Distribution Parameters</th>
<th>Rate</th>
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<tbody>
<tr>
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</table>

| Activation Predicate | (none) |
| Reactivation Predicate | (none) |

Timed Activity: **MAN_F**

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<tbody>
<tr>
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<td>man_fail_rate</td>
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</table>

| Activation Predicate | (none) |
| Reactivation Predicate | (none) |

Timed Activity: **MAN_R**

<table>
<thead>
<tr>
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<th>Rate</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>man_rcv_rate</td>
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</tbody>
</table>

| Activation Predicate | (none) |
| Reactivation Predicate | (none) |

Timed Activity: **SW_F_S1**
Distribution Parameters

<table>
<thead>
<tr>
<th>Case Distributions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>else</strong></td>
</tr>
<tr>
<td><strong>return</strong>(1);</td>
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Timed Activity: **SW_F_S2**

<table>
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</thead>
<tbody>
<tr>
<td><strong>Rate</strong></td>
</tr>
<tr>
<td><strong>sw_fail_rate</strong></td>
</tr>
</tbody>
</table>

Activation Predicate

| **(none)** |

Reactivation Predicate

| **(none)** |

Case Distributions

<table>
<thead>
<tr>
<th><strong>case 1</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>if(Working_S1-&gt;Mark()==1 &amp;&amp; Working_S2-&gt;Mark()==1)</td>
</tr>
<tr>
<td><strong>return</strong>(1-tmi_cvg);</td>
</tr>
<tr>
<td><strong>else</strong></td>
</tr>
<tr>
<td><strong>return</strong>();</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>case 2</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>if(Working_S1-&gt;Mark()==1 &amp;&amp; Working_S2-&gt;Mark()==1)</td>
</tr>
<tr>
<td><strong>return</strong>();</td>
</tr>
<tr>
<td><strong>else</strong></td>
</tr>
<tr>
<td><strong>return</strong>();</td>
</tr>
</tbody>
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Timed Activity: **SW_R_S1**

<table>
<thead>
<tr>
<th>Distribution Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Rate</strong></td>
</tr>
<tr>
<td><strong>sw_rcv_rate</strong></td>
</tr>
</tbody>
</table>

Activation Predicate

| **(none)** |

Reactivation Predicate

| **(none)** |

Timed Activity: **SW_R_S2**

<table>
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<th>Distribution Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Rate</strong></td>
</tr>
<tr>
<td><strong>sw_rcv_rate</strong></td>
</tr>
</tbody>
</table>

Activation Predicate

| **(none)** |

Reactivation Predicate

| **(none)** |

Timed Activity: **UCHW_R_S1**

<table>
<thead>
<tr>
<th>Distribution Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Rate</strong></td>
</tr>
<tr>
<td><strong>uchw_rcv_rate</strong></td>
</tr>
</tbody>
</table>

Activation Predicate

| **(none)** |

Reactivation Predicate

| **(none)** |

Timed Activity: **UCHW_R_S2**

<table>
<thead>
<tr>
<th>Distribution Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Rate</strong></td>
</tr>
<tr>
<td><strong>uchw_rcv_rate</strong></td>
</tr>
</tbody>
</table>

Activation Predicate

| **(none)** |

Reactivation Predicate

| **(none)** |

Input Gate: **IG_GF**

Predicate

| (Working_S1->Mark()==1 && Working_S2->Mark()==1) |

Function

| Working_S1->Mark()==0; |
| Working_S2->Mark()==0; |

Input Gate: **IG_MF**

Predicate

| **(none)** |
\[
(\text{Working}_S1->\text{Mark}()==1 \&\& \text{Working}_S2->\text{Mark}()==1)
\]

**Function**

- **OG_CHW**
  - Working_S1->Mark() = 0;
  - Working_S2->Mark() = 0;

- **OG_FHW**
  - Working_S1->Mark() = 0;
  - Working_S2->Mark() = 0;
  - failed_CHW_S1->Mark() = 1;
  - failed_CHW_S2->Mark() = 1;

- **OG_FHWt**
  - Working_S1->Mark() = 0;
  - Working_S2->Mark() = 0;
  - failed_FHW_S1->Mark() = 1;
  - failed_FHW_S2->Mark() = 1;

- **OG_GR**
  - Working_S1->Mark() = 0;
  - Working_S2->Mark() = 0;

- **OG_SW**
  - Working_S1->Mark() = 0;
  - Working_S2->Mark() = 0;
  - failed_SW_S1->Mark() = 1;
  - failed_SW_S2->Mark() = 1;

**Model: rrl**

**Place Attributes:**

<table>
<thead>
<tr>
<th>Place Names</th>
<th>Initial Markings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Failed_L</td>
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</tr>
<tr>
<td>GEO</td>
<td>0</td>
</tr>
<tr>
<td>Working_L</td>
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</tr>
<tr>
<td>Working_S1</td>
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</tr>
<tr>
<td>Working_S2</td>
<td>1</td>
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<tr>
<td>failed_CHW_S2</td>
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<tr>
<td>failed_FHW_S1</td>
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<tr>
<td>failed_FHW_S2</td>
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<tr>
<td>failed_FHWt_S1</td>
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<tr>
<td>failed_FHWt_S2</td>
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<tr>
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<tr>
<td>failed_SW_S1</td>
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<tr>
<td>failed_SW_S2</td>
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<tr>
<td>spare_CHW_S1</td>
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<tr>
<td>spare_CHW_S2</td>
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<tr>
<td>sys_down_S1</td>
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<tr>
<td>sys_down_S2</td>
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</table>

**Timed Activity: CHW_F2_S1**

<table>
<thead>
<tr>
<th>Distribution Parameters</th>
<th>Rate</th>
</tr>
</thead>
<tbody>
<tr>
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</table>

<table>
<thead>
<tr>
<th>Activation Predicate</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Reactivation Predicate</td>
<td>(none)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Case Distributions</th>
<th>Case 1</th>
</tr>
</thead>
</table>
| if (Working_S2->Mark() == 1)
  return(heq_cvg); |
else
  return(1);

case 2
if (Working_S2->Mark() == 1)
  return(1-heq_cvg);
else
  return(0);

Timed Activity: CHW_F2_S2
Distribution Parameters
Rate
chw_fail_rate
Activation Predicate
(none)
Reactivation Predicate
(none)

Case Distributions
  case 1
  if (Working_S1->Mark() == 1)
    return(heq_cvg);
  else
    return(1);
  case 2
  if (Working_S1->Mark() == 1)
    return(1-heq_cvg);
  else
    return(0);

Timed Activity: CHW_F_S1
Distribution Parameters
Rate
2 * chw_fail_rate
Activation Predicate
(none)
Reactivation Predicate
(none)

Case Distributions
  case 1
  1-chw_cvg
  case 2
  chw_cvg

Timed Activity: CHW_F_S2
Distribution Parameters
Rate
2 * chw_fail_rate
Activation Predicate
(none)
Reactivation Predicate
(none)

Case Distributions
  case 1
  1-chw_cvg
  case 2
  chw_cvg

Timed Activity: CHW_R2_S1
Distribution Parameters
Rate
chw_rcv_rate
Activation Predicate
(chw_rcv_rate)
Reactivation Predicate
(none)

Timed Activity: CHW_R2_S2
Distribution Parameters
Rate
chw_rcv_rate
Activation Predicate
(chw_rcv_rate)
Reactivation Predicate
(none)

Timed Activity: CHW_R_S1
Distribution Parameters
Rate
chw_fail_rate
Activation Predicate
(none)
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<thead>
<tr>
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**Timed Activity:** CHW_R_S2  
**Distribution Parameters**  
Rate  
chw_fail_rate  
**Activation Predicate**  
(none)  
**Reactivation Predicate**  
(none)

**Timed Activity:** FHW_F_S1  
**Distribution Parameters**  
Rate  
fhw_fail_rate  
**Activation Predicate**  
(none)  
**Reactivation Predicate**  
(none)

**Case Distributions**  
**case 1**  
if(Working_S1->Mark()==1 \&\& Working_S2->Mark()==1)  
return(1-heq_cvg);  
else  
return(0);

**case 2**  
if(Working_S1->Mark()==1 \&\& Working_S2->Mark()==1)  
return(heq_cvg);  
else  
return(1);

**Timed Activity:** FHW_F_S2  
**Distribution Parameters**  
Rate  
fhw_fail_rate  
**Activation Predicate**  
(none)  
**Reactivation Predicate**  
(none)

**Case Distributions**  
**case 1**  
if(Working_S1->Mark()==1 \&\& Working_S2->Mark()==1)  
return(1-heq_cvg);  
else  
return(0);

**case 2**  
if(Working_S1->Mark()==1 \&\& Working_S2->Mark()==1)  
return(heq_cvg);  
else  
return(1);

**Timed Activity:** FHW_R_S1  
**Distribution Parameters**  
Rate  
fhw_rcv_rate  
**Activation Predicate**  
(none)  
**Reactivation Predicate**  
(none)

**Timed Activity:** FHW_R_S2  
**Distribution Parameters**  
Rate  
fhw_rcv_rate  
**Activation Predicate**  
(none)  
**Reactivation Predicate**  
(none)

**Timed Activity:** FHWT_F_S1  
**Distribution Parameters**  
Rate  
fhwt_fail_rate  
**Activation Predicate**  
(none)  
**Reactivation Predicate**  
(none)

**Case Distributions**  
**case 1**  
if(Working_S1->Mark()==1 \&\& Working_S2->Mark()==1)  
return(1-heq_cvg);  
else  
return(0);

**case 2**
if(Working_S1->Mark()==1 && Working_S2->Mark()==1)
    return(heq_cvg);
else
    return(1);

<table>
<thead>
<tr>
<th>Timed Activity:</th>
<th>FHWt_F_S2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distribution Parameters</td>
<td>Rate</td>
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<tr>
<td>Activation Predicate</td>
<td>fhwt_fail_rate</td>
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<tr>
<td>Reactivation Predicate</td>
<td>(none)</td>
</tr>
<tr>
<td>Case Distributions</td>
<td>case 1</td>
</tr>
</tbody>
</table>
| | if(Working_S1->Mark()==1 && Working_S2->Mark()==1)
| |    return(1-heq_cvg);
| | else
| |    return(0);
| | case 2 |
| | if(Working_S1->Mark()==1 && Working_S2->Mark()==1)
| |    return(heq_cvg);
| | else
| |    return(1);

<table>
<thead>
<tr>
<th>Timed Activity:</th>
<th>FHWt_R_S1</th>
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</thead>
<tbody>
<tr>
<td>Distribution Parameters</td>
<td>Rate</td>
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<tr>
<td>Activation Predicate</td>
<td>fhwt_rcv_rate</td>
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<tr>
<td>Reactivation Predicate</td>
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<td>Rate</td>
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<tr>
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<td>fhwt_rcv_rate</td>
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<tr>
<td>Reactivation Predicate</td>
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<table>
<thead>
<tr>
<th>Timed Activity:</th>
<th>GEO_F</th>
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<tbody>
<tr>
<td>Distribution Parameters</td>
<td>Rate</td>
</tr>
<tr>
<td>Activation Predicate</td>
<td>geo_fail_rate</td>
</tr>
<tr>
<td>Reactivation Predicate</td>
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</table>

<table>
<thead>
<tr>
<th>Timed Activity:</th>
<th>GEO_R</th>
</tr>
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<tbody>
<tr>
<td>Distribution Parameters</td>
<td>Rate</td>
</tr>
<tr>
<td>Activation Predicate</td>
<td>geo_rcv_rate</td>
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<tr>
<td>Reactivation Predicate</td>
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</table>

<table>
<thead>
<tr>
<th>Timed Activity:</th>
<th>L_F</th>
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<tbody>
<tr>
<td>Distribution Parameters</td>
<td>Rate</td>
</tr>
<tr>
<td>Activation Predicate</td>
<td>link_fail_rate</td>
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<tr>
<td>Reactivation Predicate</td>
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</table>

<table>
<thead>
<tr>
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<th>L_R</th>
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<tbody>
<tr>
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<td>Rate</td>
</tr>
<tr>
<td>Activation Predicate</td>
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<tr>
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<table>
<thead>
<tr>
<th>Timed Activity:</th>
<th>MAN_F_S1</th>
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<tbody>
<tr>
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<td>Rate</td>
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<tr>
<td>Activation Predicate</td>
<td>man_fail_rate</td>
</tr>
<tr>
<td>Reactivation Predicate</td>
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</tbody>
</table>
Case Distributions

### Case 1

```c
if(Working_S1->Mark()==1 && Working_S2->Mark()==1)
    return(1-heq_cvg);
else
    return(0);
```

### Case 2

```c
if(Working_S1->Mark()==1 && Working_S2->Mark()==1)
    return(heq_cvg);
else
    return(1);
```

---

**Timed Activity: MAN_F_S2**

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<tbody>
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</tbody>
</table>

**Activation Predicate**: (none)

**Reactivation Predicate**: (none)

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**Timed Activity: MAN_R_S1**

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<tbody>
<tr>
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<td>man_rcv_rate</td>
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</table>

**Activation Predicate**: (none)

**Reactivation Predicate**: (none)

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**Timed Activity: MAN_R_S2**

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</thead>
<tbody>
<tr>
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<td>man_rcv_rate</td>
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</tbody>
</table>

**Activation Predicate**: (none)

**Reactivation Predicate**: (none)

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**Timed Activity: SW_F_S1**

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<tr>
<th>Distribution Parameters</th>
<th>Rate</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>sw_fail_rate</td>
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</tbody>
</table>

**Activation Predicate**: (none)

**Reactivation Predicate**: (none)

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**Timed Activity: SW_F_S2**

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<th>Distribution Parameters</th>
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<tbody>
<tr>
<td></td>
<td>sw_fail_rate</td>
</tr>
</tbody>
</table>

**Activation Predicate**: (none)

**Reactivation Predicate**: (none)

---

Case Distributions

### Case 1

```c
if(Working_S1->Mark()==1 && Working_S2->Mark()==1)
    return(1-heq_cvg);
else
    return(0);
```

### Case 2

```c
if(Working_S1->Mark()==1 && Working_S2->Mark()==1)
    return(heq_cvg);
else
    return(1);
```
```plaintext
else
    return(0);

case 2
    if(Working_S1->Mark()==1 && Working_S2->Mark()==1)
        return(heq_cvg);
    else
        return(1);

Timed Activity:  SW_R_S1
Distribution Parameters
    Rate
        sw_rcv_rate
Activation Predicate
    (none)
Reactivation Predicate
    (none)

Timed Activity:  SW_R_S2
Distribution Parameters
    Rate
        sw_rcv_rate
Activation Predicate
    (none)
Reactivation Predicate
    (none)

Timed Activity:  UCHW_R_S1
Distribution Parameters
    Rate
        uchw_rcv_rate
Activation Predicate
    (none)
Reactivation Predicate
    (none)

Timed Activity:  UCHW_R_S2
Distribution Parameters
    Rate
        uchw_rcv_rate
Activation Predicate
    (none)
Reactivation Predicate
    (none)

Input Gate:  IG_GF
Predicate
    (Working_L->Mark()==1 && Working_S2->Mark()==1)
Function
    Working_L->Mark()=0;
    Working_S2->Mark()=0;

Output Gate:  OG_CHW
Function
    Working_S1->Mark()=0;
    Working_S2->Mark()=0;
    failed_CHW_S1->Mark()=1;
    failed_CHW_S2->Mark()=1;

Output Gate:  OG_FHW
Function
    Working_S1->Mark()=0;
    Working_S2->Mark()=0;
    failed_FHW_S1->Mark()=1;
    failed_FHW_S2->Mark()=1;

Output Gate:  OG_FHWt
Function
    Working_S1->Mark()=0;
    Working_S2->Mark()=0;
    failed_FHWt_S1->Mark()=1;
    failed_FHWt_S2->Mark()=1;

Output Gate:  OG_GR
Function
    Working_L->Mark()=1;
    Working_S2->Mark()=1;

Output Gate:  OG_MAN
Function
    Working_S1->Mark()=0;
    Working_S2->Mark()=0;
    failed_SW_S1->Mark()=1;
    failed_SW_S2->Mark()=1;

Output Gate:  OG_SW
Function
    Working_S1->Mark()=0;
```
Model: rrr

Place Attributes:

<table>
<thead>
<tr>
<th>Place Names</th>
<th>Initial Markings</th>
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<tbody>
<tr>
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<td>1</td>
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<tr>
<td>Working_S2</td>
<td>1</td>
</tr>
<tr>
<td>Working_S3</td>
<td>1</td>
</tr>
<tr>
<td>failed_CHW_S1</td>
<td>0</td>
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<tr>
<td>failed_CHW_S2</td>
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<tr>
<td>failed_CHW_S3</td>
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<tr>
<td>failed_FHW_S1</td>
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<tr>
<td>failed_FHW_S2</td>
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<tr>
<td>failed_FHW_S3</td>
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</tr>
<tr>
<td>failed_FHWt_S1</td>
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<tr>
<td>failed_FHWt_S2</td>
<td>0</td>
</tr>
<tr>
<td>failed_FHWt_S3</td>
<td>0</td>
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<tr>
<td>failed_MAN_S1</td>
<td>0</td>
</tr>
<tr>
<td>failed_MAN_S2</td>
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<tr>
<td>failed_MAN_S3</td>
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<tr>
<td>failed_SW_S1</td>
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</tr>
<tr>
<td>failed_SW_S2</td>
<td>0</td>
</tr>
<tr>
<td>failed_SW_S3</td>
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<tr>
<td>spare_CHW_S1</td>
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<tr>
<td>spare_CHW_S2</td>
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<tr>
<td>spare_CHW_S3</td>
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</tr>
<tr>
<td>sys_down_S1</td>
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<tr>
<td>sys_down_S2</td>
<td>0</td>
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<tr>
<td>sys_down_S3</td>
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</table>

Timed Activity: CHW_F2_S1

Distribution Parameters:

<table>
<thead>
<tr>
<th>Rate</th>
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</thead>
</table>

Activation Predicate:

(none)

Reactivation Predicate:

(none)

Case Distributions:

<table>
<thead>
<tr>
<th>Case</th>
<th>Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>if (Working_S2-&gt;Mark()==1 &amp;&amp; Working_S3-&gt;Mark()==1)</td>
</tr>
<tr>
<td>2</td>
<td>if (Working_S1-&gt;Mark()==1 &amp;&amp; Working_S3-&gt;Mark()==1)</td>
</tr>
</tbody>
</table>

Timed Activity: CHW_F2_S2

Distribution Parameters:

<table>
<thead>
<tr>
<th>Rate</th>
<th>chw_fail_rate</th>
</tr>
</thead>
</table>

Activation Predicate:

(none)

Reactivation Predicate:

(none)

Case Distributions:

<table>
<thead>
<tr>
<th>Case</th>
<th>Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>if (Working_S1-&gt;Mark()==1 &amp;&amp; Working_S3-&gt;Mark()==1)</td>
</tr>
<tr>
<td>2</td>
<td>if (Working_S1-&gt;Mark()==1 &amp;&amp; Working_S3-&gt;Mark()==1)</td>
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</table>

Timed Activity: CHW_F2_S3

Distribution Parameters:

<table>
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<tr>
<th>Rate</th>
<th>chw_fail_rate</th>
</tr>
</thead>
</table>

Activation Predicate:

(none)

Reactivation Predicate:

(none)

Case Distributions:

<table>
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<tr>
<th>Case</th>
<th>Condition</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>if (Working_S1-&gt;Mark()==1 &amp;&amp; Working_S3-&gt;Mark()==1)</td>
</tr>
<tr>
<td>2</td>
<td>if (Working_S1-&gt;Mark()==1 &amp;&amp; Working_S3-&gt;Mark()==1)</td>
</tr>
<tr>
<td>Distribution Parameters</td>
<td>chw_fail_rate</td>
</tr>
<tr>
<td>-------------------------</td>
<td>--------------</td>
</tr>
<tr>
<td>Activation Predicate</td>
<td>(none)</td>
</tr>
<tr>
<td>Reactivation Predicate</td>
<td>(none)</td>
</tr>
</tbody>
</table>

**Case Distributions**

- **case 1**
  - if (Working_S1->Mark()==1 && Working_S2->Mark() == 1)
    - return(heq_cvg);
  - else
    - return(1);

- **case 2**
  - if (Working_S1->Mark()==1 && Working_S2->Mark() == 1)
    - return(1-heq_cvg);
  - else
    - return(0);

### Timed Activity: CHW_F_S1

<table>
<thead>
<tr>
<th>Distribution Parameters</th>
<th>Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<tr>
<td>Activation Predicate</td>
<td>(none)</td>
</tr>
<tr>
<td>Reactivation Predicate</td>
<td>(none)</td>
</tr>
</tbody>
</table>

**Case Distributions**

- **case 1**
  - 1-chw_cvg
- **case 2**
  - chw_cvg

### Timed Activity: CHW_F_S2

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</tr>
</thead>
<tbody>
<tr>
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<tr>
<td>Reactivation Predicate</td>
<td>(none)</td>
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</tbody>
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**Case Distributions**

- **case 1**
  - 1-chw_cvg
- **case 2**
  - chw_cvg

### Timed Activity: CHW_F_S3

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<tr>
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</thead>
<tbody>
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<tr>
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<td>(none)</td>
</tr>
<tr>
<td>Reactivation Predicate</td>
<td>(none)</td>
</tr>
</tbody>
</table>

**Case Distributions**

- **case 1**
  - 1-chw_cvg
- **case 2**
  - chw_cvg

### Timed Activity: CHW_R2_S1

<table>
<thead>
<tr>
<th>Distribution Parameters</th>
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</thead>
<tbody>
<tr>
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<td>Reactivation Predicate</td>
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### Timed Activity: CHW_R2_S2

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<tr>
<th>Distribution Parameters</th>
<th>chw_rcv_rate</th>
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<tbody>
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<td>(none)</td>
</tr>
<tr>
<td>Reactivation Predicate</td>
<td>(none)</td>
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</tbody>
</table>

### Timed Activity: CHW_R2_S3
Case Distributions

**Case 1**
```c
if(Working_S1->Mark()==1 && Working_S2->Mark()==1 && Working_S3->Mark()==1)
    return(1-heq_cvg);
else
    return(0);
```

**Case 2**
```c
if(Working_S1->Mark()==1 && Working_S2->Mark()==1 && Working_S3->Mark()==1)
    return(heq_cvg);
else
    return(1);
```
```plaintext

Timed Activity: FHW_R_S1
Distribution Parameters
Rate
fhw_rcv_rate
Activation Predicate
(none)
Reactivation Predicate
(none)

Timed Activity: FHW_R_S2
Distribution Parameters
Rate
fhw_rcv_rate
Activation Predicate
(none)
Reactivation Predicate
(none)

Timed Activity: FHW_R_S3
Distribution Parameters
Rate
fhw_rcv_rate
Activation Predicate
(none)
Reactivation Predicate
(none)

Timed Activity: FHWt_F_S1
Distribution Parameters
Rate
fhwt_fail_rate
Activation Predicate
(none)
Reactivation Predicate
(none)

Case Distributions

<table>
<thead>
<tr>
<th>Case</th>
<th>Conditions</th>
<th>Return Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>case 1</td>
<td>Working_S1-&gt;Mark()==1 &amp; Working_S2-&gt;Mark()==1 &amp; Working_S3-&gt;Mark()==1</td>
<td>1-heq_cvg</td>
</tr>
<tr>
<td>case 2</td>
<td>Working_S1-&gt;Mark()==1 &amp; Working_S2-&gt;Mark()==1 &amp; Working_S3-&gt;Mark()==1</td>
<td>0</td>
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</tbody>
</table>

Timed Activity: FHWt_F_S2
Distribution Parameters
Rate
fhwt_fail_rate
Activation Predicate
(none)
Reactivation Predicate
(none)

Case Distributions

<table>
<thead>
<tr>
<th>Case</th>
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<tbody>
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<td>case 1</td>
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<td>1-heq_cvg</td>
</tr>
<tr>
<td>case 2</td>
<td>Working_S1-&gt;Mark()==1 &amp; Working_S2-&gt;Mark()==1 &amp; Working_S3-&gt;Mark()==1</td>
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Timed Activity: FHWt_F_S3
Distribution Parameters
Rate
fhwt_fail_rate
Activation Predicate
(none)
Reactivation Predicate
(none)

Case Distributions

<table>
<thead>
<tr>
<th>Case</th>
<th>Conditions</th>
<th>Return Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>case 1</td>
<td>Working_S1-&gt;Mark()==1 &amp; Working_S2-&gt;Mark()==1 &amp; Working_S3-&gt;Mark()==1</td>
<td>1-heq_cvg</td>
</tr>
<tr>
<td>case 2</td>
<td>Working_S1-&gt;Mark()==1 &amp; Working_S2-&gt;Mark()==1 &amp; Working_S3-&gt;Mark()==1</td>
<td>0</td>
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</table>
```

### Case Distributions

**Case 1**

```c
if(Working_S1->Mark()==1 && Working_S2->Mark()==1 && Working_S3->Mark()==1)
    return(1-heq_cvg);
else
    return(0);
```

**Case 2**

```c
if(Working_S1->Mark()==1 && Working_S2->Mark()==1 && Working_S3->Mark()==1)
    return(heq_cvg);
else
    return(1);
```

---

### Timed Activity: `FHWt_R_S1`

**Distribution Parameters**

- **Rate**: `fhwt_rcv_rate`
- **Activation Predicate**: (none)
- **Reactivation Predicate**: (none)

---

### Timed Activity: `FHWt_R_S2`

**Distribution Parameters**

- **Rate**: `fhwt_rcv_rate`
- **Activation Predicate**: (none)
- **Reactivation Predicate**: (none)

---

### Timed Activity: `FHWt_R_S3`

**Distribution Parameters**

- **Rate**: `fhwt_rcv_rate`
- **Activation Predicate**: (none)
- **Reactivation Predicate**: (none)

---

### Timed Activity: `MAN_F_S1`

**Distribution Parameters**

- **Rate**: `man_fail_rate`
- **Activation Predicate**: (none)
- **Reactivation Predicate**: (none)

---

### Case Distributions

**Case 1**

```c
if(Working_S1->Mark()==1 && Working_S2->Mark()==1&& Working_S3->Mark()==1)
    return(1-heq_cvg);
else
    return(0);
```

**Case 2**

```c
if(Working_S1->Mark()==1 && Working_S2->Mark()==1&& Working_S3->Mark()==1)
    return(heq_cvg);
else
    return(1);
```

---

### Timed Activity: `MAN_F_S2`

**Distribution Parameters**

- **Rate**: `man_fail_rate`
- **Activation Predicate**: (none)
- **Reactivation Predicate**: (none)

---

### Timed Activity: `MAN_F_S3`

**Distribution Parameters**

- **Rate**: `man_fail_rate`
- **Activation Predicate**: (none)
- **Reactivation Predicate**: (none)
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<thead>
<tr>
<th>Case Distributions</th>
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<tbody>
<tr>
<td>case 1</td>
<td>if(Working_S1-&gt;Mark()==1 &amp;&amp; Working_S2-&gt;Mark()==1 &amp;&amp; Working_S3-&gt;Mark()==1) return(1-heq_cvg); else return(0);</td>
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</tr>
<tr>
<td>case 2</td>
<td>if(Working_S1-&gt;Mark()==1 &amp;&amp; Working_S2-&gt;Mark()==1 &amp;&amp; Working_S3-&gt;Mark()==1) return(heq_cvg); else return(1);</td>
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<th>MAN_R_S1</th>
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<td>man_rcv_rate</td>
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<tr>
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<th>SW_F_S1</th>
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<td>sw_fail_rate</td>
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<td>Activation Predicate</td>
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<td>if(Working_S1-&gt;Mark()==1 &amp;&amp; Working_S2-&gt;Mark()==1 &amp;&amp; Working_S3-&gt;Mark()==1) return(heq_cvg); else return(1);</td>
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<td>if(Working_S1-&gt;Mark()==1 &amp;&amp; Working_S2-&gt;Mark()==1 &amp;&amp; Working_S3-&gt;Mark()==1) return(heq_cvg); else return(1);</td>
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<tr>
<td>Activation Predicate</td>
<td></td>
</tr>
<tr>
<td>Reactivation Predicate</td>
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</table>

**Case Distributions**

**case 1**

```plaintext
if(Working_S1->Mark()==1 && Working_S2->Mark()==1 && Working_S3->Mark()==1)
  return(1-heq_cvg);
else
  return(0);
```

**case 2**

```plaintext
if(Working_S1->Mark()==1 && Working_S2->Mark()==1 && Working_S3->Mark()==1)
  return(heq_cvg);
else
  return(1);
```

<table>
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<tr>
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<th>SW_R_S1</th>
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<tbody>
<tr>
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<td>Rate</td>
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<td>Reactivation Predicate</td>
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<td>Reactivation Predicate</td>
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<tr>
<th>Timed Activity:</th>
<th>UCHW_R_S1</th>
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<td>Activation Predicate</td>
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</tr>
<tr>
<td>Reactivation Predicate</td>
<td></td>
</tr>
</tbody>
</table>

**Output Gate: OG_CHW**

```plaintext
Working_S1->Mark()==0;
Working_S2->Mark()==0;
Working_S3->Mark()==0;
fail_CHW_S1->Mark()==1;
fail_CHW_S2->Mark()==1;
fail_CHW_S3->Mark()==1;
```

**Output Gate: OG_FHW**

```plaintext
Working_S1->Mark()==0;
Working_S2->Mark()==0;
Working_S3->Mark()==0;
fail_FHW_S1->Mark()==1;
```
failed_FHW_S2->Mark()=1;
failed_FHW_S3->Mark()=1;

Output Gate: OG_FHWt

Function
Working_S1->Mark()=0;
Working_S2->Mark()=0;
Working_S3->Mark()=0;
failed_FHWt_S1->Mark()=1;
failed_FHWt_S2->Mark()=1;
failed_FHWt_S3->Mark()=1;

Output Gate: OG_MAN

Function
Working_S1->Mark()=0;
Working_S2->Mark()=0;
Working_S3->Mark()=0;

Output Gate: OG_SW

Function
Working_S1->Mark()=0;
Working_S2->Mark()=0;
Working_S3->Mark()=0;
failed_SW_S1->Mark()=1;
failed_SW_S2->Mark()=1;
failed_SW_S3->Mark()=1;

Model: sll

Place Attributes:

<table>
<thead>
<tr>
<th>Place Names</th>
<th>Initial Markings</th>
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<tbody>
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<tr>
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<tr>
<td>PHY</td>
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<tr>
<td>Working_L2</td>
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<td>Working_S</td>
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<tr>
<td>Working_S2</td>
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<td>Working_S3</td>
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<td>failed_SW</td>
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</table>

Timed Activity: FHW_F

Distribution Parameters
Rate
fhw_fail_rate

Activation Predicate (none)
Reactivation Predicate (none)

Timed Activity: FHW_R

Distribution Parameters
Rate
fhw_rcv_rate

Activation Predicate (none)
Reactivation Predicate (none)

Timed Activity: FHWt_F

Distribution Parameters
Rate
fhwt_fail_rate

Activation Predicate (none)
Reactivation Predicate (none)

Timed Activity: FHWt_R

Distribution Parameters
Rate
fhwt_rcv_rate

Activation Predicate (none)
Reactivation Predicate (none)

Timed Activity: GEO_F

Distribution Parameters
Rate

A – 35
<table>
<thead>
<tr>
<th>Timed Activity:</th>
<th>Distribution Parameters</th>
<th>Rate</th>
<th>Activation Predicate</th>
<th>Reactivation Predicate</th>
</tr>
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<tbody>
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<td>geo_r_r_c_rate</td>
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<td>link_f_d_rate</td>
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<td>L_F2</td>
<td>link_f_d_rate</td>
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<td>sw_r_d_rate</td>
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</table>
Input Gate: IG_GF
Predicate: (Working_L1->Mark()==1 && Working_L2->Mark()==1 && Working_S->Mark()==1)
Function:
- Working_L1->Mark()=0;
- Working_L2->Mark()=0;
- Working_S->Mark()=0;

Input Gate: IG_PF
Predicate: (Working_L1->Mark()==1 && Working_L2->Mark()==1)
Function:
- Working_L1->Mark()=0;
- Working_L2->Mark()=0;

Output Gate: OG_GR
Function:
- Working_L1->Mark()==1;
- Working_L2->Mark()==1;
- Working_S->Mark()==1;

Output Gate: OG_PR
Function:
- Working_L1->Mark()==1;
- Working_L2->Mark()==1;

Model: ss

Place Attributes:

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<th>Place Names</th>
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Timed Activity: FHW_F_S1
Distribution Parameters:
- Rate: fhw_fail_rate
- Activation Predicate: (none)
- Reactivation Predicate: (none)

Case Distributions:

- case 1
  - if(Working_S1->Mark()==1 && Working_S2->Mark()==1)
    - return(1-tmi_cvg);
  - else
    - return(0);

- case 2
  - if(Working_S1->Mark()==1 && Working_S2->Mark()==1)
    - return(tmi_cvg);
  - else
    - return(1);

Timed Activity: FHW_F_S2
Distribution Parameters:
- Rate: fhw_fail_rate
- Activation Predicate: (none)
- Reactivation Predicate: (none)

Case Distributions:

- case 1
  - if(Working_S1->Mark()==1 && Working_S2->Mark()==1)
    - return(1-tmi_cvg);
  - else
    - return(0);

- case 2
  - if(Working_S1->Mark()==1 && Working_S2->Mark()==1)
    - return(tmi_cvg);
  - else
    - return(1);
Timed Activity: FHW_R_S1
Distribution Parameters
Rate
fhw_rcv_rate
Activation Predicate
(none)
Reactivation Predicate
(none)

Timed Activity: FHW_R_S2
Distribution Parameters
Rate
fhw_rcv_rate
Activation Predicate
(none)
Reactivation Predicate
(none)

Timed Activity: FHWt_F_S1
Distribution Parameters
Rate
fhwt_fail_rate
Activation Predicate
(none)
Reactivation Predicate
(none)

Case Distributions

```c
case 1
if(Working_S1->Mark()==1 && Working_S2->Mark()==1)
  return(1-tmi_cvg);
else
  return(0);
```

```c
case 2
if(Working_S1->Mark()==1 && Working_S2->Mark()==1)
  return(tmi_cvg);
else
  return(1);
```

Timed Activity: FHWt_F_S2
Distribution Parameters
Rate
fhwt_fail_rate
Activation Predicate
(none)
Reactivation Predicate
(none)

Case Distributions

```c
case 1
if(Working_S1->Mark()==1 && Working_S2->Mark()==1)
  return(1-tmi_cvg);
else
  return(0);
```

```c
case 2
if(Working_S1->Mark()==1 && Working_S2->Mark()==1)
  return(tmi_cvg);
else
  return(1);
```

Timed Activity: FHWt_R_S1
Distribution Parameters
Rate
fhwt_rcv_rate
Activation Predicate
(none)
Reactivation Predicate
(none)

Timed Activity: FHWt_R_S2
Distribution Parameters
Rate
fhwt_rcv_rate
Activation Predicate
(none)
Reactivation Predicate
(none)

Timed Activity: GEO_F
Distribution Parameters
Rate
geo_fail_rate
Activation Predicate
(none)
Reactivation Predicate
(none)
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</tbody>
</table>

**Case Distributions**

- **Case 1**
  ```
  if(Working_S1->Mark()==1 && Working_S2->Mark()==1)
  return(1-tmi_cvg);
  else
  return(0);
  ```

- **Case 2**
  ```
  if(Working_S1->Mark()==1 && Working_S2->Mark()==1)
  return(tmi_cvg);
  else
  return(1);
  ```

<table>
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<th>Rate</th>
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<td></td>
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</table>

**Case Distributions**

- **Case 1**
  ```
  if(Working_S1->Mark()==1 && Working_S2->Mark()==1)
  return(1-tmi_cvg);
  else
  return(0);
  ```

- **Case 2**
  ```
  if(Working_S1->Mark()==1 && Working_S2->Mark()==1)
  return(tmi_cvg);
  else
  return(1);
  ```

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<th>Timed Activity: SW_R_S1</th>
<th>Rate</th>
<th>Distribution Parameters: sw_rcv</th>
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<tr>
<td><strong>Input Gate:</strong></td>
<td>IG_GF</td>
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<tr>
<td>-----------------</td>
<td>-------</td>
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</tr>
<tr>
<td><strong>Predicate</strong></td>
<td>(Working_S1-&gt;Mark()==1 &amp;&amp; Working_S2-&gt;Mark()==1)</td>
<td></td>
</tr>
<tr>
<td><strong>Function</strong></td>
<td>Working_S1-&gt;Mark()=0; Working_S2-&gt;Mark()=0;</td>
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<table>
<thead>
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<th><strong>Input Gate:</strong></th>
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<tr>
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</tr>
<tr>
<td><strong>Function</strong></td>
<td>Working_S1-&gt;Mark()=0; Working_S2-&gt;Mark()=0;</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Output Gate:</strong></th>
<th>OG_FHW</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Function</strong></td>
<td>Working_S1-&gt;Mark()=0; Working_S2-&gt;Mark()=0; failed_FHW_S1-&gt;Mark()=1; failed_FHW_S2-&gt;Mark()=1;</td>
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</table>

<table>
<thead>
<tr>
<th><strong>Output Gate:</strong></th>
<th>OG_FHWt</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Function</strong></td>
<td>Working_S1-&gt;Mark()=0; Working_S2-&gt;Mark()=0; failed_FHWt_S1-&gt;Mark()=1; failed_FHWt_S2-&gt;Mark()=1;</td>
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</table>

<table>
<thead>
<tr>
<th><strong>Output Gate:</strong></th>
<th>OG_GR</th>
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</thead>
<tbody>
<tr>
<td><strong>Function</strong></td>
<td>Working_S1-&gt;Mark()=1; Working_S2-&gt;Mark()=1;</td>
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<thead>
<tr>
<th><strong>Output Gate:</strong></th>
<th>OG_MR</th>
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</thead>
<tbody>
<tr>
<td><strong>Function</strong></td>
<td>Working_S1-&gt;Mark()=1; Working_S2-&gt;Mark()=1;</td>
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<thead>
<tr>
<th><strong>Output Gate:</strong></th>
<th>OG_SW</th>
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</thead>
<tbody>
<tr>
<td><strong>Function</strong></td>
<td>Working_S1-&gt;Mark()=0; Working_S2-&gt;Mark()=0; failed_SW_S1-&gt;Mark()=1; failed_SW_S2-&gt;Mark()=1;</td>
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**Model: ssl**

**Place Attributes:**

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<td>failed_FHW_S2</td>
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<tr>
<td>failed_FHWt_S1</td>
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<tr>
<td>failed_FHWt_S2</td>
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<td>failed_SW_S2</td>
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**Timed Activity:**

**FHW_F_S1**

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| **Activation Predicate** | (none) |
| **Reactivation Predicate** | (none) |

**Case Distributions**

- **Case 1**
  
  if(Working_S1->Mark()==1 && Working_S2->Mark()==1)
  
  return(1-heq_cvg);

  else
  
  return(0);

- **Case 2**
  
  if(Working_S1->Mark()==1 && Working_S2->Mark()==1)
  
  return(heq_cvg);

  else
  
  return(1);
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<tr>
<td>Case Distributions</td>
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</tr>
<tr>
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<tr>
<td>if(Working_S1-&gt;Mark()==1 &amp; Working_S2-&gt;Mark()==1)</td>
<td>return(1-heq_cvg);</td>
<td></td>
</tr>
<tr>
<td>else</td>
<td></td>
<td>return(0);</td>
</tr>
<tr>
<td>case 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>if(Working_S1-&gt;Mark()==1 &amp; Working_S2-&gt;Mark()==1)</td>
<td>return(heq_cvg);</td>
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<tr>
<td>else</td>
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<td>return(1);</td>
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<td>if(Working_S1-&gt;Mark()==1 &amp; Working_S2-&gt;Mark()==1)</td>
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<tr>
<td>else</td>
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<td>return(0);</td>
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<tr>
<td>case 2</td>
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<tr>
<td>if(Working_S1-&gt;Mark()==1 &amp; Working_S2-&gt;Mark()==1)</td>
<td>return(heq_cvg);</td>
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<tr>
<td>else</td>
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<td>return(1);</td>
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<td>if(Working_S1-&gt;Mark()==1 &amp; Working_S2-&gt;Mark()==1)</td>
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<tr>
<td>if(Working_S1-&gt;Mark()==1 &amp; Working_S2-&gt;Mark()==1)</td>
<td>return(heq_cvg);</td>
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<td>Reactivation Predicate</td>
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<td>Activation Predicate</td>
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<td>Timed Activity</td>
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<td>Activation Predicate</td>
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<td>L_R</td>
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<td>Timed Activity</td>
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<td>Case Distributions</td>
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<td>case 1</td>
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<td></td>
</tr>
<tr>
<td>if(Working_S1-&gt;Mark()==1 &amp; Working_S2-&gt;Mark()==1)</td>
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</tr>
<tr>
<td>else</td>
<td></td>
<td></td>
</tr>
<tr>
<td>return(1-heq_cvg);</td>
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</tr>
<tr>
<td>case 2</td>
<td></td>
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</tr>
<tr>
<td>if(Working_S1-&gt;Mark()==1 &amp; Working_S2-&gt;Mark()==1)</td>
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<tr>
<td>return(heq_cvg);</td>
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<tr>
<td>return(1);</td>
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<td>Timed Activity</td>
<td>Rate</td>
<td>Activation Predicate</td>
</tr>
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<td>case 1</td>
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<tr>
<td>if(Working_S1-&gt;Mark()==1 &amp; Working_S2-&gt;Mark()==1)</td>
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</tr>
<tr>
<td>else</td>
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<td></td>
</tr>
<tr>
<td>return(1-heq_cvg);</td>
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</tr>
<tr>
<td>case 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>if(Working_S1-&gt;Mark()==1 &amp; Working_S2-&gt;Mark()==1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>else</td>
<td></td>
<td></td>
</tr>
<tr>
<td>return(0);</td>
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</table>
```plaintext
return(heq_cvg);
else
return(1);

Timed Activity: SW_R_S1
Distribution Parameters
Rate
sw_rcv_rate
Activation Predicate
(none)
Reactivation Predicate
(none)

Timed Activity: SW_R_S2
Distribution Parameters
Rate
sw_rcv_rate
Activation Predicate
(none)
Reactivation Predicate
(none)

Input Gate: IG_GF
Predicate
(Working_L->Mark()==1 && Working_S2->Mark()==1)
Function
Working_L->Mark()=0;
Working_S2->Mark()=0;

Output Gate: OG_FHW
Function
Working_S1->Mark()=0;
Working_S2->Mark()=0;
Failed_FHW_S1->Mark()=1;
Failed_FHW_S2->Mark()=1;

Output Gate: OG_FHWt
Function
Working_S1->Mark()=0;
Working_S2->Mark()=0;
Failed_FHWt_S1->Mark()=1;
Failed_FHWt_S2->Mark()=1;

Output Gate: OG_GR
Function
Working_L->Mark()==1;
Working_S2->Mark()==1;

Output Gate: OG_SW
Function
Working_S1->Mark()==0;
Working_S2->Mark()==0;
Failed_SW_S1->Mark()==1;
Failed_SW_S2->Mark()==1;

Model: sss
Place Attributes:
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<thead>
<tr>
<th>Place Names</th>
<th>Initial Markings</th>
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<tr>
<td>Working_S3</td>
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<tr>
<td>failed_FHW_S2</td>
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<td>failed_FHW_S3</td>
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Timed Activity: FHW_F_S1
Distribution Parameters
Rate
fhw_fail_rate
Activation Predicate
(none)
Reactivation Predicate
(none)
Case Distributions
<table>
<thead>
<tr>
<th>case 1</th>
</tr>
</thead>
</table>
if (Working_S1->Mark()==1 && Working_S2->Mark()==1 && Working_S3->Mark()==1) |
```


return(1-heq_cvg);  
else  
  return(0);  

case 2  
if (Working_S1->Mark() == 1 && Working_S2->Mark() == 1 && Working_S3->Mark() ==1)  
  return(heq_cvg);  
else  
  return(1);  

Timed Activity: FHW_F_S2  

Distribution Parameters  
Rate  
fhw_fail_rate  

Activation Predicate  
(none)  

Reactivation Predicate  
(none)  

Case Distributions  
  case 1  
  if (Working_S1->Mark() == 1 && Working_S2->Mark() == 1 && Working_S3->Mark() ==1)  
    return(1-heq_cvg);  
  else  
    return(0);  
  case 2  
  if (Working_S1->Mark() == 1 && Working_S2->Mark() == 1 && Working_S3->Mark() ==1)  
    return(heq_cvg);  
  else  
    return(1);  

Timed Activity: FHW_F_S3  

Distribution Parameters  
Rate  
fhw_fail_rate  

Activation Predicate  
(none)  

Reactivation Predicate  
(none)  

Case Distributions  
  case 1  
  if (Working_S1->Mark() == 1 && Working_S2->Mark() == 1 && Working_S3->Mark() ==1)  
    return(1-heq_cvg);  
  else  
    return(0);  
  case 2  
  if (Working_S1->Mark() == 1 && Working_S2->Mark() == 1 && Working_S3->Mark() ==1)  
    return(heq_cvg);  
  else  
    return(1);  

Timed Activity: FHW_R_S1  

Distribution Parameters  
Rate  
fhwr_rcv_rate  

Activation Predicate  
(none)  

Reactivation Predicate  
(none)  

Timed Activity: FHW_R_S2  

Distribution Parameters  
Rate  
fhwr_rcv_rate  

Activation Predicate  
(none)  

Reactivation Predicate  
(none)  

Timed Activity: FHW_R_S3  

Distribution Parameters  
Rate  
fhwr_rcv_rate  

Activation Predicate  
(none)  

Reactivation Predicate  
(none)  

Timed Activity: FHWt_F_S1  

Distribution Parameters  
Rate  
fhwt_fail_rate  

Activation Predicate  
(none)  

Reactivation Predicate  
(none)
case 1
if (Working_S1->Mark() == 1 && Working_S2->Mark() == 1 && Working_S3->Mark() == 1)
    return(1-heq_cvg);
else
    return(0);

case 2
if (Working_S1->Mark() == 1 && Working_S2->Mark() == 1 && Working_S3->Mark() == 1)
    return(heq_cvg);
else
    return(1);

Timed Activity: FHWt_F_S2
Distribution Parameters
Rate
fhwt_fail_rate
Activation Predicate
(none)
Reactivation Predicate
(none)

Timed Activity: FHWt_F_S3
Distribution Parameters
Rate
fhwt_fail_rate
Activation Predicate
(none)
Reactivation Predicate
(none)

Timed Activity: FHWt_R_S1
Distribution Parameters
Rate
fhwt_rcv_rate
Activation Predicate
(none)
Reactivation Predicate
(none)

Timed Activity: FHWt_R_S2
Distribution Parameters
Rate
fhwt_rcv_rate
Activation Predicate
(none)
Reactivation Predicate
(none)

Timed Activity: FHWt_R_S3
Distribution Parameters
Rate
fhwt_rcv_rate
Activation Predicate
(none)
Reactivation Predicate
(none)

Timed Activity: SW_F_S1
Distribution Parameters
Rate
sw_fail_rate
### Activation Predicate

<table>
<thead>
<tr>
<th>Case Distributions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Case 1</strong></td>
</tr>
<tr>
<td>if (Working_S1-&gt;Mark() == 1 &amp;&amp; Working_S2-&gt;Mark() == 1 &amp;&amp; Working_S3-&gt;Mark() ==1)</td>
</tr>
<tr>
<td>return(1-heq_cvg);</td>
</tr>
<tr>
<td>else</td>
</tr>
<tr>
<td>return(0);</td>
</tr>
<tr>
<td><strong>Case 2</strong></td>
</tr>
<tr>
<td>if (Working_S1-&gt;Mark() == 1 &amp;&amp; Working_S2-&gt;Mark() == 1 &amp;&amp; Working_S3-&gt;Mark() ==1)</td>
</tr>
<tr>
<td>return(heq_cvg);</td>
</tr>
<tr>
<td>else</td>
</tr>
<tr>
<td>return(1);</td>
</tr>
</tbody>
</table>

### Reactivation Predicate

A – 46

### Timed Activity: SW_F_S2

**Distribution Parameters**
- **Rate**
  - sw_fail_rate

**Activation Predicate** (none)

**Reactivation Predicate** (none)

### Timed Activity: SW_F_S3

**Distribution Parameters**
- **Rate**
  - sw_fail_rate

**Activation Predicate** (none)

**Reactivation Predicate** (none)

### Timed Activity: SW_R_S1

**Distribution Parameters**
- **Rate**
  - sw_rcv_rate

**Activation Predicate** (none)

**Reactivation Predicate** (none)

### Timed Activity: SW_R_S2

**Distribution Parameters**
- **Rate**
  - sw_rcv_rate

**Activation Predicate** (none)

**Reactivation Predicate** (none)

### Timed Activity: SW_R_S3

**Distribution Parameters**
- **Rate**
  - sw_rcv_rate

**Activation Predicate** (none)

**Reactivation Predicate** (none)
<table>
<thead>
<tr>
<th>Output Gate:</th>
<th>OG_FHW</th>
</tr>
</thead>
</table>
| **Function** | Working S1->Mark[]=0;  
                Working S2->Mark[]=0;  
                Working S3->Mark[]=0;  
                failed_FHW S1->Mark[]=1;  
                failed_FHW S2->Mark[]=1;  
                failed_FHW S3->Mark[]=1; |

<table>
<thead>
<tr>
<th>Output Gate:</th>
<th>OG_FHWt</th>
</tr>
</thead>
</table>
| **Function** | Working S1->Mark[]=0;  
                Working S2->Mark[]=0;  
                Working S3->Mark[]=0;  
                failed_FHWt S1->Mark[]=1;  
                failed_FHWt S2->Mark[]=1;  
                failed_FHWt S3->Mark[]=1; |

<table>
<thead>
<tr>
<th>Output Gate:</th>
<th>OG_SW</th>
</tr>
</thead>
</table>
| **Function** | Working S1->Mark[]=0;  
                Working S2->Mark[]=0;  
                Working S3->Mark[]=0;  
                failed SW S1->Mark[]=1;  
                failed SW S2->Mark[]=1;  
                failed SW S3->Mark[]=1; |
### Range Study Variable Assignments for Study CC_study in Project SDNbackbone:

<table>
<thead>
<tr>
<th>Variable</th>
<th>Type</th>
<th>Range Type</th>
<th>Range</th>
<th>Increment</th>
<th>Increment Type</th>
<th>Function</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>K_th</td>
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<tr>
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<td>-</td>
</tr>
<tr>
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<td>-</td>
<td>-</td>
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<tr>
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<td>Fixed</td>
<td>9.0E-5</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<tr>
<td>mis_fail_rate</td>
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<td>Manual</td>
<td>[5.0E-6, 5.0E-7, 5.0E-8, 5.0E-9, 5.0E-10]</td>
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<tr>
<td>mis_rcv_rate</td>
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<td>Fixed</td>
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<tr>
<td>uhw_rcv_rate</td>
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<td>Fixed</td>
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<tr>
<td>usw_rcv_rate</td>
<td>double</td>
<td>Fixed</td>
<td>6.0E-4</td>
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<td>-</td>
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</tbody>
</table>

### Performance Variable Model: CC_unavailability

**Top Level Model Information**
- Child Model Name: cc
- Model Type: SAN Model

**Performance Variable: U_cc**

**Reward Function**

(Reward is over all Available Models)

```c
if (((cc->Active_proc_C1->Mark()<K_th || cc->failed_MAN_C1->Mark()==1 || cc->sys_down_C1->Mark()==1 || cc->sw_sys_down_C1->Mark()==1)
    && (cc->Active_proc_C2->Mark()<K_th || cc->failed_MAN_C2->Mark()==1 || cc->sys_down_C2->Mark()==1 || cc->sw_sys_down_C2->Mark()==1)
    || cc->MIS->Mark()==1){
    return(1);
}
else{
    return(0);
}
```

**Simulator Statistics**

- **Type**: Time Averaged Interval of Time
- **Options**: Estimate Mean, Include Lower Bound on Interval Estimate, Include Upper Bound on Interval Estimate, Estimate out of Range Probabilities, Confidence Level is Relative
- **Parameters**
  - Start Time: 0.0
  - Stop Time: 10000000
- **Confidence**
  - Confidence Level: 0.95
  - Confidence Interval: 0.1

### Range Study Variable Assignments for Study CSL_study in Project SDNbackbone:

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<th>Variable</th>
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<th>Range</th>
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<th>Increment Type</th>
<th>Function</th>
<th>n</th>
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<tbody>
<tr>
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<td>-</td>
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<tr>
<td>N_proc</td>
<td>int</td>
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<tr>
<td>cis_fail_rate</td>
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<td>Manual</td>
<td>[2.0E-4, 2.0E-5, 2.0E-6, 2.0E-7, 2.0E-8]</td>
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<td>-</td>
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<td>Variable</td>
<td>Type</td>
<td>Range Type</td>
<td>Range</td>
<td>Increment</td>
<td>Increment Type</td>
<td>Function</td>
<td>n</td>
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<tr>
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<td>-----------</td>
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</tr>
<tr>
<td>K_th</td>
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<td>Fixed</td>
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<td>-</td>
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<td>-</td>
</tr>
<tr>
<td>N_proc</td>
<td>int</td>
<td>Fixed</td>
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<tr>
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<td>Manual</td>
<td>[2.0E-4, 2.0E-5, 2.0E-6, 2.0E-7, 2.0E-8]</td>
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<td>-</td>
</tr>
</tbody>
</table>
### PERFORMANCE VARIABLE MODEL: CSS_unavailability

#### Top Level Model Information
- **Model Name**: css
- **Model Type**: SAN Model

#### Performance Variable: U_css

<table>
<thead>
<tr>
<th>Affecting Models</th>
<th>css</th>
</tr>
</thead>
<tbody>
<tr>
<td>Impulse Functions</td>
<td>(Reward is over all Available Models)</td>
</tr>
</tbody>
</table>
| Reward Function | if (css->Working_S1->Mark()==0 && css->Working_S2->Mark()==0 && 
 (css->Active_proc->Mark()==K_th || css->failed_MAN->Mark()==1 || css->sys_down->Mark()==1 || css->sw_sys_down->Mark()==1) 
 | return(1); 
 | } else{ 
 | return(0); 
 | } |

#### Simulator Statistics
- **Type**: Time Averaged Interval of Time
- **Options**:
  - Estimate Mean
  - Include Lower Bound on Interval Estimate
  - Include Upper Bound on Interval Estimate
  - Estimate out of Range Probabilities
  - Confidence Level is Relative
- **Parameters**:
  - Start Time: 0.0, Stop Time: 10000000
- **Confidence**:
  - Confidence Level: 0.95
  - Confidence Interval: 0.1

#### Range Study Variable Assignments for Study C_study in Project SDNbackbone

<table>
<thead>
<tr>
<th>Variable</th>
<th>Type</th>
<th>Range Type</th>
<th>Range</th>
<th>Increment</th>
<th>Increment Type</th>
<th>Function</th>
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</tr>
</thead>
<tbody>
<tr>
<td>K_th</td>
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<td>Fixed</td>
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<td>-</td>
<td></td>
</tr>
<tr>
<td>N_proc</td>
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<td>Fixed</td>
<td>10</td>
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<td>-</td>
<td></td>
</tr>
<tr>
<td>hw_cvg</td>
<td>double</td>
<td>Fixed</td>
<td>0.97</td>
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<tr>
<td>hw_fail_rate</td>
<td>double</td>
<td>Fixed</td>
<td>1.0E-8</td>
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</tbody>
</table>
**Performance Variable Model: C_unavailability**

<table>
<thead>
<tr>
<th>Top Level Model Information</th>
<th>Child Model Name</th>
<th>SDNcontroller</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model Type</td>
<td>SAN Model</td>
<td></td>
</tr>
</tbody>
</table>

**Performance Variable: U_c**

Affecting Models: SDNcontroller

Impulse Functions:

**Reward Function**

```c
if (SDNcontroller->Active_proc->Mark()<K_th || SDNcontroller->failed_MAN->Mark()==1 || SDNcontroller->sys_down->Mark()==1 || SDNcontroller->sw_sys_down->Mark()==1){
    return(1);
} else{
    return(0);
}
```

**Simulator Statistics**

<table>
<thead>
<tr>
<th>Type</th>
<th>Time Averaged Interval of Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Options</td>
<td>Estimate Mean</td>
</tr>
<tr>
<td></td>
<td>Include Lower Bound on Interval Estimate</td>
</tr>
<tr>
<td></td>
<td>Include Upper Bound on Interval Estimate</td>
</tr>
<tr>
<td></td>
<td>Estimate out of Range Probabilities</td>
</tr>
<tr>
<td>Confidence Level is Relative</td>
<td>Confidence Level 0.95</td>
</tr>
<tr>
<td></td>
<td>Confidence Interval 0.1</td>
</tr>
</tbody>
</table>

**Range Study Variable Assignments for Study LL_study in Project SDNbackbone:**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Type</th>
<th>Range Type</th>
<th>Range</th>
<th>Increment</th>
<th>Increment Type</th>
<th>Function</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>geo_fail_rate</td>
<td>double</td>
<td>Manual</td>
<td>[1.0E-5, 1.0E-6, 1.0E-7, 1.0E-8, 1.0E-9]</td>
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</tr>
<tr>
<td>geo_rcv_rate</td>
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</tr>
<tr>
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<td>[1.0E-5, 1.0E-6, 1.0E-7, 1.0E-8, 1.0E-9]</td>
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</table>

**Performance Variable Model: LL_unavailability**

<table>
<thead>
<tr>
<th>Top Level Model Information</th>
<th>Child Model Name</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Model Type</td>
<td>SAN Model</td>
<td></td>
</tr>
</tbody>
</table>

**Performance Variable: U_ll**

Affecting Models: ll

Impulse Functions: ll

**Reward Function**

*(Reward is over all Available Models)*
if (ll->Working_L1->Mark()==0 && ll->Working_L2->Mark()==0){
    return(1);
} else{
    return(0);
}

Simulator Statistics

<table>
<thead>
<tr>
<th>Type</th>
<th>Time Averaged Interval of Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Options</td>
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<tr>
<td>Parameters</td>
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</tr>
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Range Study Variable Assignments for Study RLL\_study in Project SDN\_backbone:

<table>
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<th>Range</th>
<th>Increment</th>
<th>Increment Type</th>
<th>Function</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>chw_cvg</td>
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</tr>
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</tr>
<tr>
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Performance Variable Model: RLL\_unavailability

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<th>Top Level Model Information</th>
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<tbody>
<tr>
<td>Model Type</td>
<td>SAN Model</td>
<td></td>
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</tbody>
</table>

Performance Variable : U\_rll

Affecting Models  
| rll |

Impulse Functions

Reward Function

(Reward is over all Available Models)

if (rll->Working_L1->Mark()==0 && rll->Working_L2->Mark()==0 && rll->Working_R->Mark()==0 && rll->spare_CHW->Mark()==0){
    return(1);
} else{
    return(0);
}

Simulator Statistics

<table>
<thead>
<tr>
<th>Type</th>
<th>Time Averaged Interval of Time</th>
</tr>
</thead>
<tbody>
<tr>
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Range Study Variable Assignments for Study RRL_study in Project SDNbackbone:

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<th>Increment Type</th>
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Performance Variable Model: RRL_unavailability

Top Level Model Information

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<th>Model Type</th>
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<tbody>
<tr>
<td>rrl</td>
<td>SAN Model</td>
</tr>
</tbody>
</table>

Performance Variable: U_rrl

Affecting Models

| rrl |

Impulse Functions

(Reward is over all Available Models)

```cpp
if ((rrl->Working_S1->Mark()==0 && rrl->Working_S2->Mark()==0) 
    && rrl->Working_L->Mark()==0) 
    && rrl->spare_CHW_S1->Mark()==0 && rrl->spare_CHW_S2->Mark()==0) {
    return(1);
} 
else{
    return(0);
}
```

Simulator Statistics

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<thead>
<tr>
<th>Type</th>
<th>Time Averaged Interval of Time</th>
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<tbody>
<tr>
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<tr>
<td>Estimate out of Range Probabilities</td>
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<tr>
<td>Confidence Level is Relative</td>
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### Range Study Variable Assignments for Study RRR study in Project SDNbackbone:

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<th>Increment Type</th>
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</table>

### Performance Variable Model: RRR_unavailability

**Top Level Model Information**
- Child Model Name: rrr
- Model Type: SAN Model

### Performance Variable: U_rrr

- **Impulse Functions**
- **Reward Function**

```c
if (rrr->Working_S1->Mark()==0 && rrr->Working_S2->Mark()==0 && rrr->Working_S3->Mark()==0 &&
    rrr->spare_CHW_S1->Mark()==0 && rrr->spare_CHW_S2->Mark()==0 && rrr->spare_CHW_S3->Mark()==0){
    return(1);
}
else{
    return(0);
}
```

### Simulator Statistics

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<thead>
<tr>
<th>Type</th>
<th>Time Averaged Interval of Time</th>
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<tbody>
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<tr>
<td>Confidence Level is Relative</td>
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- **Parameters**
  - Start Time: 0.0
  - Stop Time: 10000000
- **Confidence**
  - Confidence Level: 0.95
  - Confidence Interval: 0.1

### Range Study Variable Assignments for Study RR study in Project SDNbackbone:

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<th>Type</th>
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<th>Range</th>
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<th>Increment Type</th>
<th>Function</th>
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<tr>
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</table>
Performance Variable Model: RR_unavailability

Top Level Model Information
Child Model Name: rr
Model Type: SAN Model

Performance Variable: U_rr
Affecting Models: rr

Impulse Functions
(Reward is over all Available Models)
if (rr->Working_S1->Mark()==0 && rr->Working_S2->Mark()==0 &&
    rr->spare_CHW_S1->Mark()==0 && rr->spare_CHW_S2->Mark()==0){
    return(1);
} else{
    return(0);
}

Reward Function

Type: Time Averaged Interval of Time
Options: Estimate Mean
Include Lower Bound on Interval Estimate
Include Upper Bound on Interval Estimate
Estimate out of Range Probabilities
Confidence Level is Relative

Simulator Statistics
Parameters:
Start Time: 0.0,
Stop Time: 10000000,
Confidence Level: 0.95
Confidence Interval: 0.1

Model: SDNcontroller

Place Attributes:
Place Names | Initial Markings
--- | ---
Active_proc | N_proc
failed_HW | 0
failed_MAN | 0
failed_SW | 0
sw_sys_down | 0
sys_down | 0

Timed Activity: HW_F1

Distribution Parameters
Rate
Active_proc->Mark() * hw_fail_rate
Activation Predicate
none
Reactivation Predicate
none

Case Distributions
case 1
if (sys_down->Mark()==0 && sw_sys_down->Mark()==0 && failed_MAN->Mark()==0)
    return(1-hw_cvg);
else
    return(0);
case 2
if (sys_down->Mark() == 0 && sw_sys_down->Mark() == 0 && failed_MAN->Mark() == 0)
    return(hw_cvg);
else
    return(1);

<table>
<thead>
<tr>
<th>Timed Activity:</th>
<th>Rate</th>
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<tbody>
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<td>hw_fail_rate * failed_SW-&gt;Mark()</td>
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<td>Reactivation Predicate</td>
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<thead>
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<tbody>
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<tbody>
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<td>Activation Predicate</td>
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</tr>
<tr>
<td>Reactivation Predicate</td>
<td>(none)</td>
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<table>
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<th>Rate</th>
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</thead>
<tbody>
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<td>Distribution Parameters</td>
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<tr>
<td>Activation Predicate</td>
<td>(none)</td>
</tr>
<tr>
<td>Reactivation Predicate</td>
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<table>
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<tbody>
<tr>
<td><strong>SW_F</strong></td>
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</tr>
<tr>
<td>Distribution Parameters</td>
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</table>
| if(Active_proc->Mark() >= K_th)
    return(sw_fail_rate);
else
    return(sw_fail_rate * Active_proc->Mark()); |
| Activation Predicate | (none) |
| Reactivation Predicate | (none) |

<table>
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<th>Case Distributions</th>
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<td>case 2</td>
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</tr>
<tr>
<td>Reactivation Predicate</td>
<td>(none)</td>
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<table>
<thead>
<tr>
<th>Timed Activity:</th>
<th>Rate</th>
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<tbody>
<tr>
<td><strong>UHW_R</strong></td>
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</table>
**Distribution Parameters**

<table>
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<th>Value</th>
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<tr>
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<tr>
<td>Reactivation Predicate</td>
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**Timed Activity:**

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<th>Rate Parameter</th>
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<td>usw_rcv_rate</td>
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<tr>
<td>Reactivation Predicate</td>
<td>(none)</td>
</tr>
<tr>
<td>Activation Predicate</td>
<td>(none)</td>
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**Input Gate:**

<table>
<thead>
<tr>
<th>Gate</th>
<th>Predicate</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>IG_MAN</td>
<td>(failed_MAN-&gt;Mark() == 0 &amp;&amp; sys_down-&gt;Mark() == 0 &amp;&amp; sw_sys_down-&gt;Mark() == 0)</td>
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</tr>
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**Input Gate:**

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<th>Predicate</th>
<th>Function</th>
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</thead>
<tbody>
<tr>
<td>IG_SW</td>
<td>(failed_MAN-&gt;Mark() == 0 &amp;&amp; sys_down-&gt;Mark() == 0 &amp;&amp; sw_sys_down-&gt;Mark() == 0 &amp;&amp; Active_proc-&gt;Mark() &gt; 0)</td>
<td>Active_proc-&gt;Mark()--;</td>
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**Output Gate:**

<table>
<thead>
<tr>
<th>Gate</th>
<th>Predicate</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>OG_MAN</td>
<td>Active_proc-&gt;Mark() = N_proc - failed_HW-&gt;Mark(); failed_SW-&gt;Mark()=0;</td>
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</tbody>
</table>

**Output Gate:**

<table>
<thead>
<tr>
<th>Gate</th>
<th>Predicate</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>OG_SD</td>
<td>failed_HW-&gt;Mark()++; Active_proc-&gt;Mark() = N_proc - failed_HW-&gt;Mark(); failed_SW-&gt;Mark()=0;</td>
<td></td>
</tr>
</tbody>
</table>

**Output Gate:**

<table>
<thead>
<tr>
<th>Gate</th>
<th>Predicate</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>OG_SSD</td>
<td>Active_proc-&gt;Mark() = N_proc - failed_HW-&gt;Mark(); failed_SW-&gt;Mark()=0;</td>
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**Range Study Variable Assignments for Study SLL_study in Project SDNbackbone:**

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<th>Range</th>
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<th>Increment Type</th>
<th>Function</th>
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<td>-</td>
<td>-</td>
</tr>
<tr>
<td>geo_rcv_rate</td>
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<td>-</td>
<td>-</td>
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<tr>
<td>link_fail_rate</td>
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**Performance Variable Model:**

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<th>Value</th>
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</tr>
<tr>
<td></td>
<td>Model Type: SAN Model</td>
</tr>
</tbody>
</table>
Performance Variable: U_sll

Affecting Models
- sll

Impulse Functions

Reward Function

\( (\text{Reward is over all Available Models}) \)

\[
\begin{array}{l}
\text{if } (\text{sll->Working_L1->Mark()==0 } \&\& \text{sll->Working_L2->Mark()==0 } \&\& \text{sll->Working_S->Mark()==0}) \{ \\
\text{ return(1); } \\
\text{ else } \{ \\
\text{ return(0); } \\
\}
\end{array}
\]

Simulator Statistics

<table>
<thead>
<tr>
<th>Type</th>
<th>Time Averaged Interval of Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Options</td>
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</tr>
<tr>
<td>Estimate Mean</td>
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</tr>
<tr>
<td>Include Lower Bound on Interval Estimate</td>
<td></td>
</tr>
<tr>
<td>Include Upper Bound on Interval Estimate</td>
<td></td>
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<tr>
<td>Estimate out of Range Probabilities</td>
<td></td>
</tr>
<tr>
<td>Confidence Level is Relative</td>
<td></td>
</tr>
</tbody>
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Parameters
- Start Time: 0.0
- Stop Time: 10000000
- Confidence Level: 0.95
- Confidence Interval: 0.1

Range Study Variable Assignments for Study SSL_study in Project SDNbackbone:

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<thead>
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<th>Range</th>
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<th>Increment Type</th>
<th>Function</th>
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<tbody>
<tr>
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<td>Fixed</td>
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<tr>
<td>geo_fail_rate</td>
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<tr>
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<tr>
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<tr>
<td>sw_rcv_rate</td>
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Performance Variable Model: SSL_unavailability

Top Level Model Information
- Child Model Name: sll
- Model Type: SAN Model

Performance Variable: U_ssl

Affecting Models
- sll

Impulse Functions

Reward Function

\( (\text{Reward is over all Available Models}) \)

\[
\begin{array}{l}
\text{if } (\text{sll->Working_S1->Mark()==0 } \&\& \text{sll->Working_S2->Mark()==0 } \&\& \text{sll->Working_L->Mark()==0}) \{ \\
\text{ return(1); } \\
\text{ else } \{ \\
\text{ return(0); } \\
\}
\end{array}
\]

Simulator Statistics

<table>
<thead>
<tr>
<th>Type</th>
<th>Time Averaged Interval of Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Options</td>
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<tr>
<td>Estimate Mean</td>
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<tr>
<td>Include Lower Bound on Interval Estimate</td>
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<tr>
<td>Include Upper Bound on Interval Estimate</td>
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</tr>
<tr>
<td>Estimate out of Range Probabilities</td>
<td></td>
</tr>
<tr>
<td>Confidence Level is Relative</td>
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</tr>
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Parameters
- Start Time: 0.0
Range Study Variable Assignments for Study SSS_study in Project SDNbackbone:

<table>
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<th>Type</th>
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<th>Range</th>
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<th>Increment Type</th>
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</table>

Performance Variable Model: SSS_unavailability

Top Level Model Information
Child Model Name: sss
Model Type: SAN Model

Performance Variable: U_sss

Affecting Models: sss
Impulse Functions:

Reward Function:

```c
if (sss->Working_S1->Mark()==0 && sss->Working_S2->Mark()==0 && sss->Working_S3->Mark()==0){
    return(1);
} else{
    return(0);
}
```

Simulator Statistics

<table>
<thead>
<tr>
<th>Options</th>
<th>Value</th>
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<tbody>
<tr>
<td>Time Averaged Interval of Time</td>
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Parameters

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Range Study Variable Assignments for Study SS_study in Project SDNbackbone:

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<th>Range</th>
<th>Increment</th>
<th>Increment Type</th>
<th>Function</th>
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<tbody>
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### Performance Variable Model: SS_unavailability

<table>
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<tbody>
<tr>
<td>Model Type</td>
<td>SAN Model</td>
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</table>

#### Affecting Models
- ss

#### Impulse Functions

**(Reward is over all Available Models)**

```c
if (ss->Working_S1->Mark()==0 && ss->Working_S2->Mark()==0){
    return(1);
} else{
    return(0);
}
```

#### Simulator Statistics

<table>
<thead>
<tr>
<th>Options</th>
<th>Type</th>
<th>Time Averaged Interval of Time</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Estimate Mean</td>
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<td></td>
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<td>Stop Time</td>
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<tr>
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