

# Dependable Network Analyzer Tutorial:

Dependable Network Analyzer  
Version 2.2, August 2008

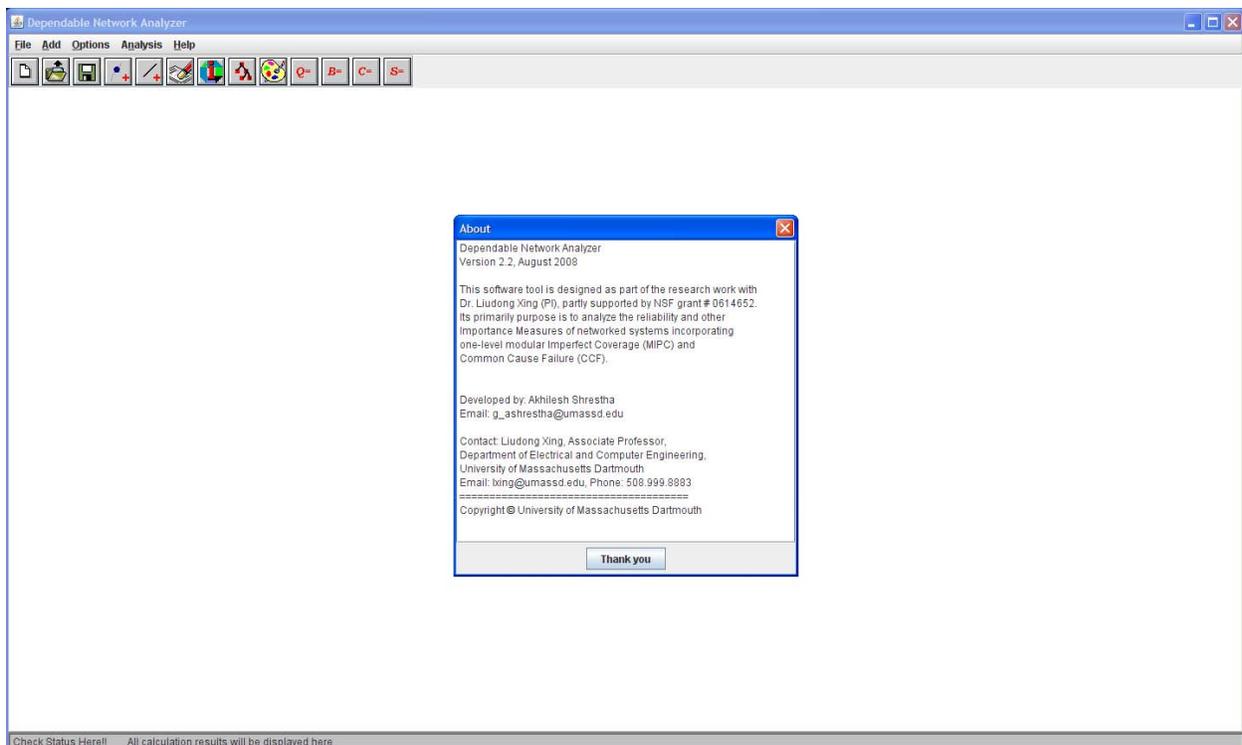
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This software tool is designed as part of the research work with Dr. Liudong Xing (PI), partly supported by NSF grant # 0614652. Its primary purpose is to analyze the reliability and other Importance Measures of networked systems incorporating one-level modular Imperfect Coverage (MIPC) and Common Cause Failure (CCF).

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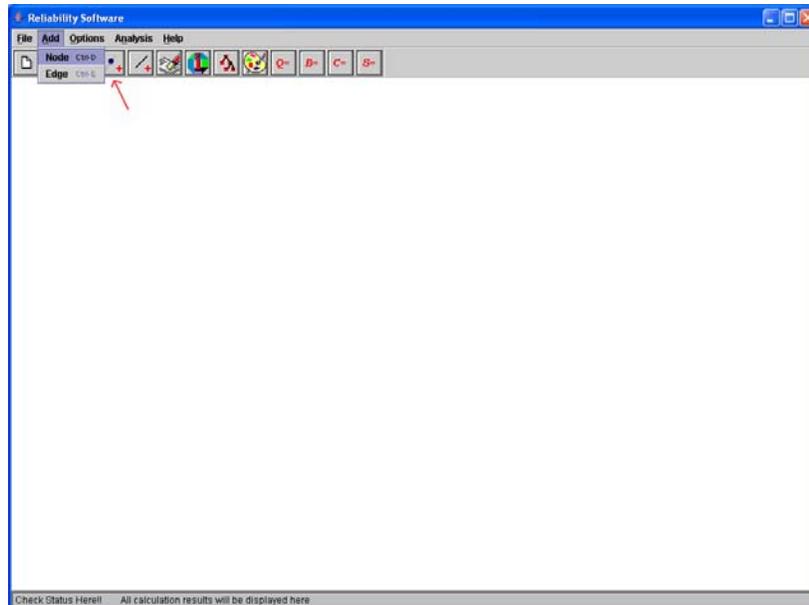
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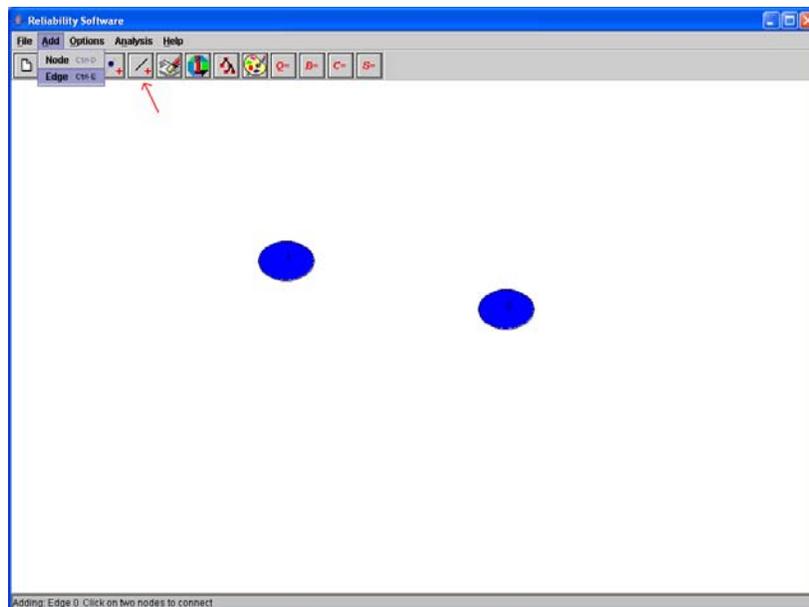


To draw a network topology use “Add->Node” and “Add->Edge”.

“Add->Node” adds a node at the top-left portion of the screen. Click and drag the node to the required position on the screen.



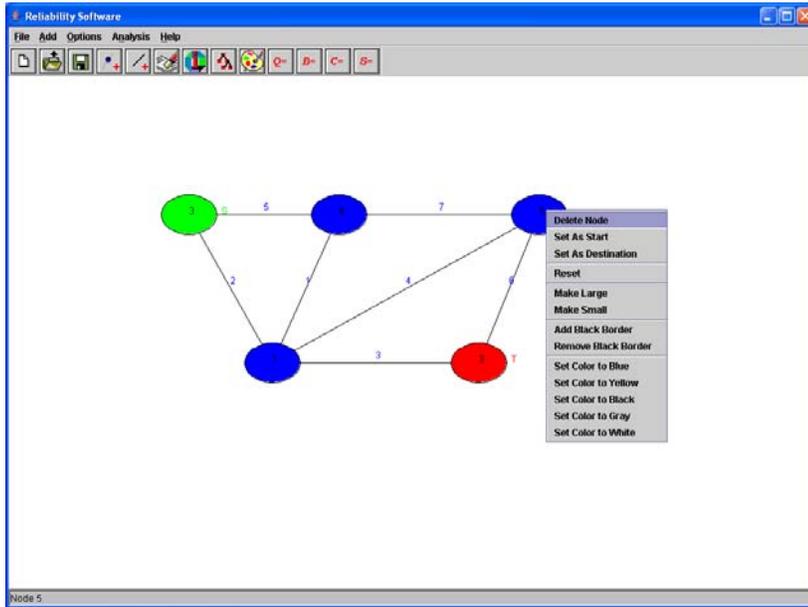
First add the required number of nodes. To connect them, click “Add->Edge” and then click on the two nodes to be connected.



*Currently, only undirected edges are considered. Also the nodes are considered to be perfect nodes and node failure is not considered. Future work will incorporate imperfect nodes and directional edges.*

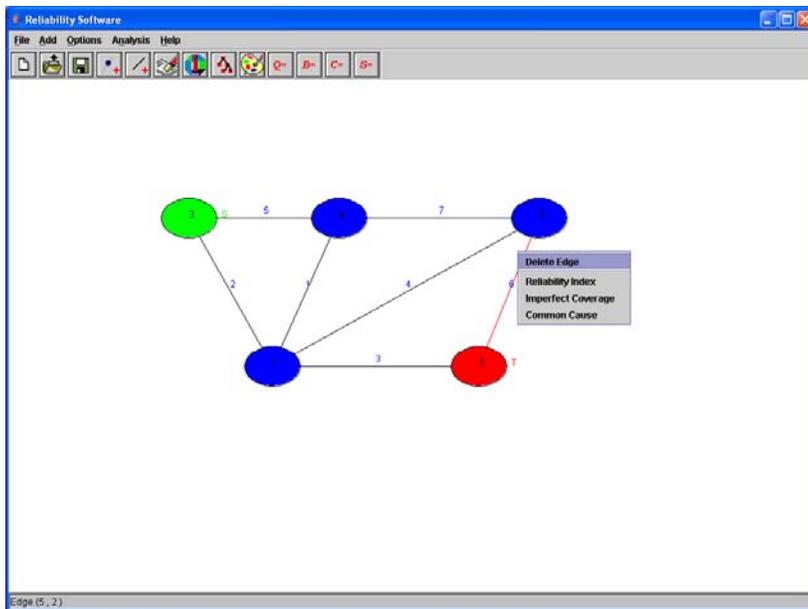
To change Node properties: Right Click on the relevant node, you will get a pop-up menu.

- “Delete Node” deletes the node and all associated edges.
- “Set as Start” sets the start node. Color changes to GREEN.
- “Set as Destination” sets the destination node. Color changes to RED.
- “Reset” resets start/destination node to normal node. Color resets to default color, which is BLUE.



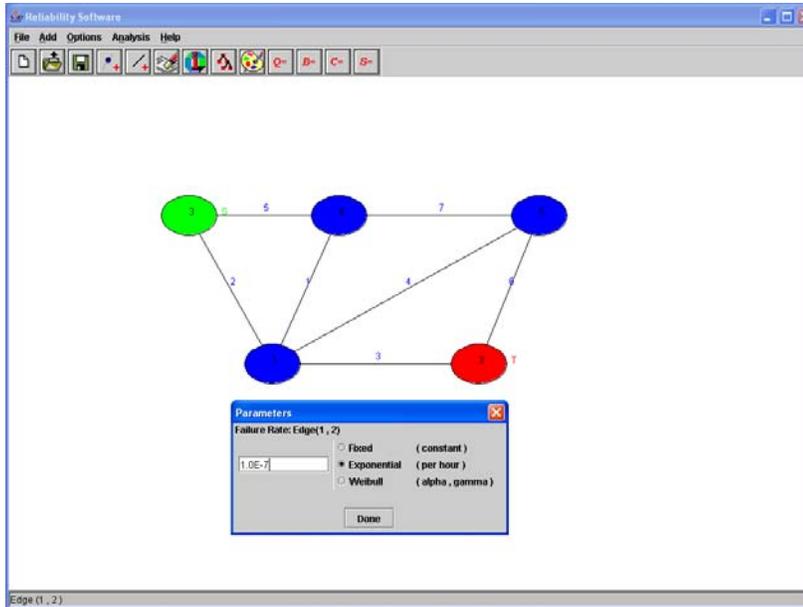
To change Edge properties: Right Click on the relevant edge, you will get a pop-up menu.

- “Delete Edge” deletes the edge.



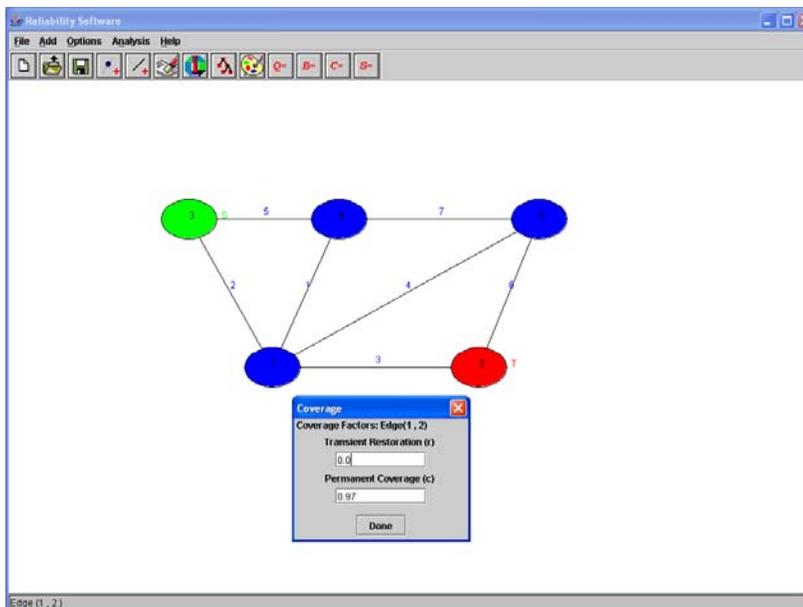
- “Reliability Index” sets the edge failure distribution and the associated parameters.

For our example, all the edges’ failure distribution have been set to exponential failure with failure rate ( $\alpha$ ) =  $1.0E-7$  hr<sup>-1</sup>.



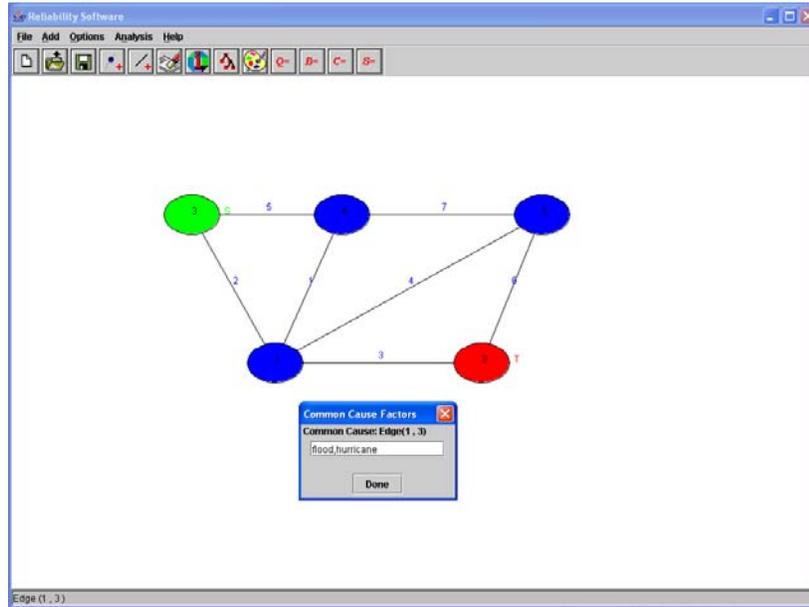
- “Imperfect Coverage” sets the imperfect coverage parameters: transient restoration (r) and permanent coverage (c).

For our example, all the edges’ coverage parameters has been set to r=0, c=0.97.

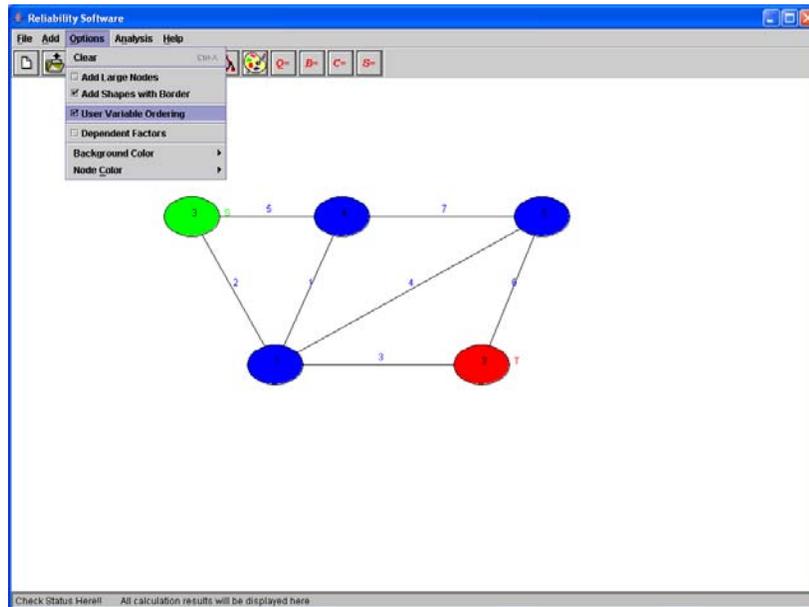


- “Common Cause” sets the common cause factors associated with the edge. To add common causes, use the free text box; separating the factors by ‘comma’. For example to set common cause factors as rain and hurricane, type “rain, hurricane”.

For our example: Common Cause  $\{e_2(1,3)\} = \{\text{flood, hurricane}\}$ , Common Cause  $\{e_1(1,4)\} = \{\text{flood}\}$ , Common Cause  $\{e_3(1,2)\} = \{\text{hurricane}\}$ .

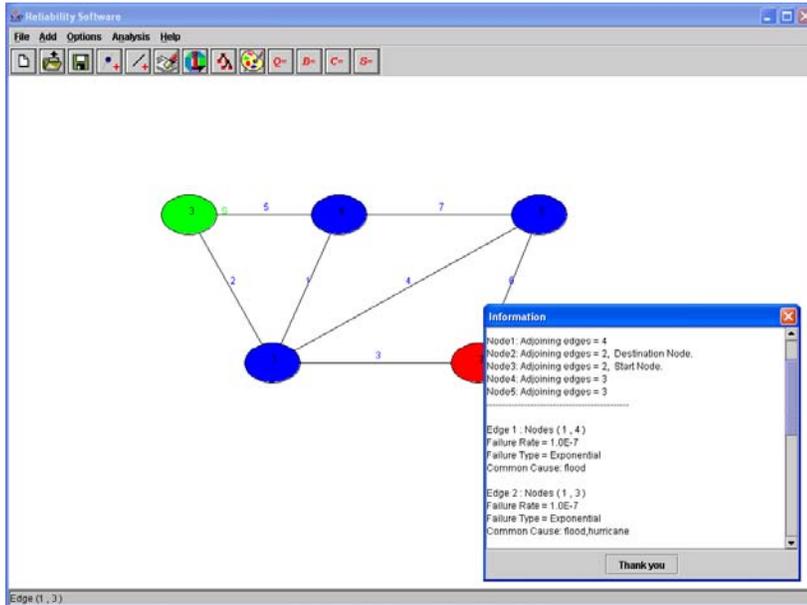


- “Options->User Variable Ordering” allows user to enter the variable ordering.



- “Options->Dependent Factors” check box allows the user to specify if the common cause factors are dependent or independent. For our example, this check box is checked.

- “Analysis->Information” gives the list of network components with their properties.



- “Analysis->Generate BDD”. This step must be done prior to all the analysis routines (except Information). It generates the BDD structure of the given network topology. It asks the user for the “Mission Time” and Common Cause Factor Probabilities (if any) and the variable ordering if the “Options->User Variable Ordering” check box is ticked. For our example:

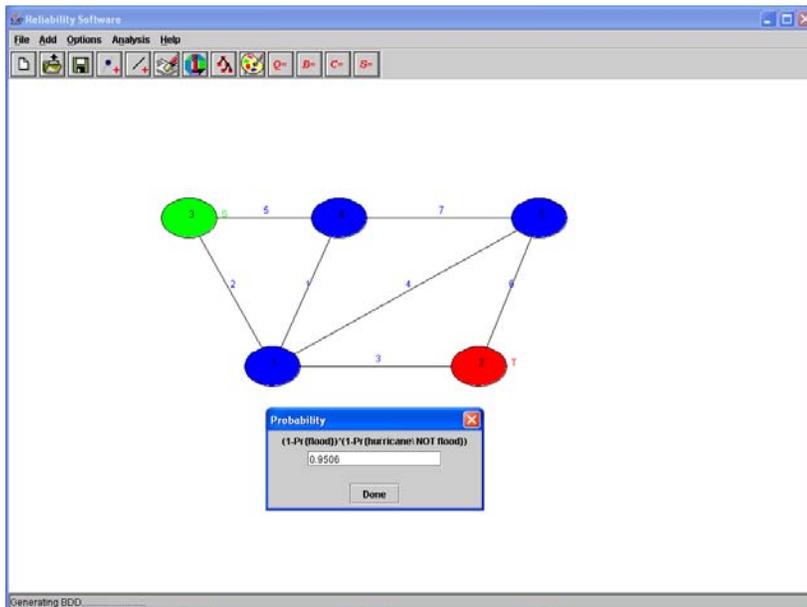
Mission Time = 1000 hrs

$$\Pr\{\text{flood}\} * (1 - \Pr\{\text{hurricane} \setminus \text{flood}\}) = 0.008$$

$$(1 - \Pr\{\text{flood}\}) * \Pr\{\text{hurricane} \setminus \text{NOT flood}\} = 0.0294$$

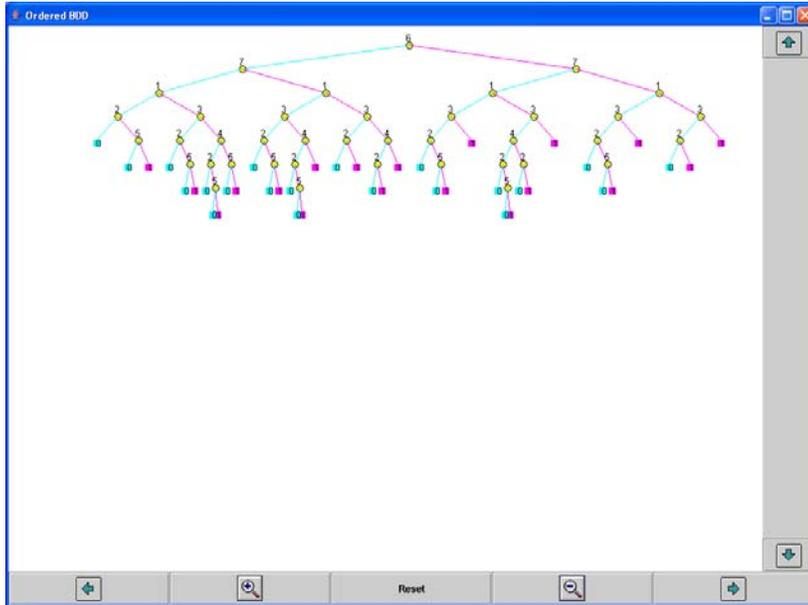
$$\Pr\{\text{flood}\} * \Pr\{\text{hurricane} \setminus \text{flood}\} = 0.012$$

$$(1 - \Pr\{\text{flood}\}) * (1 - \Pr\{\text{hurricane} \setminus \text{NOT flood}\}) = 0.9506$$

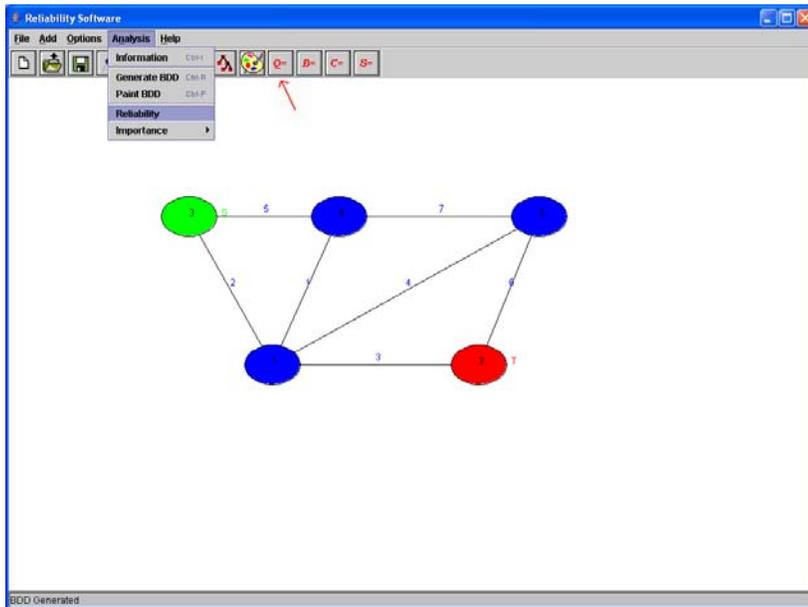


- “Analysis->Paint BDD” shows graphically the structure of the OBDD and ROBDD.

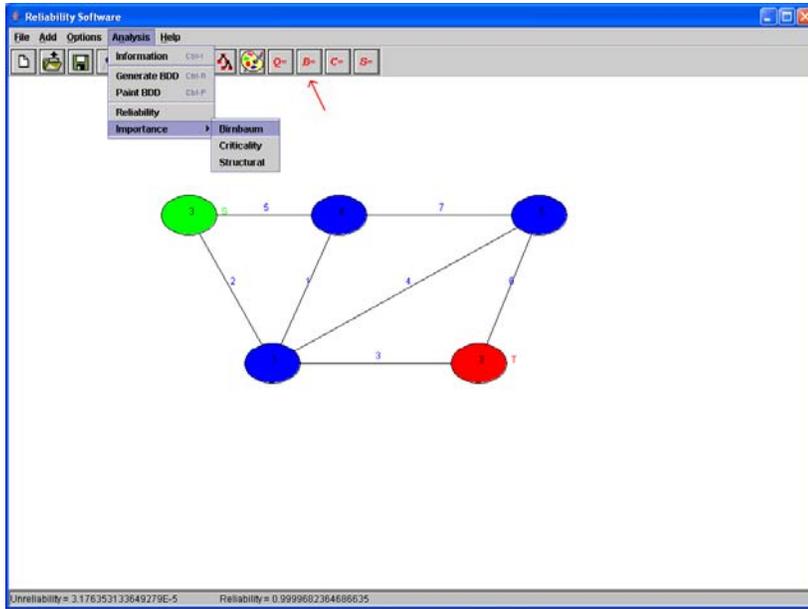
You can use the Zoom In, Zoom Out, Left Arrow, Right Arrow, Up Arrow and Down Arrow to custom view the OBDD and ROBDD. Use Reset to reset to the original default view.



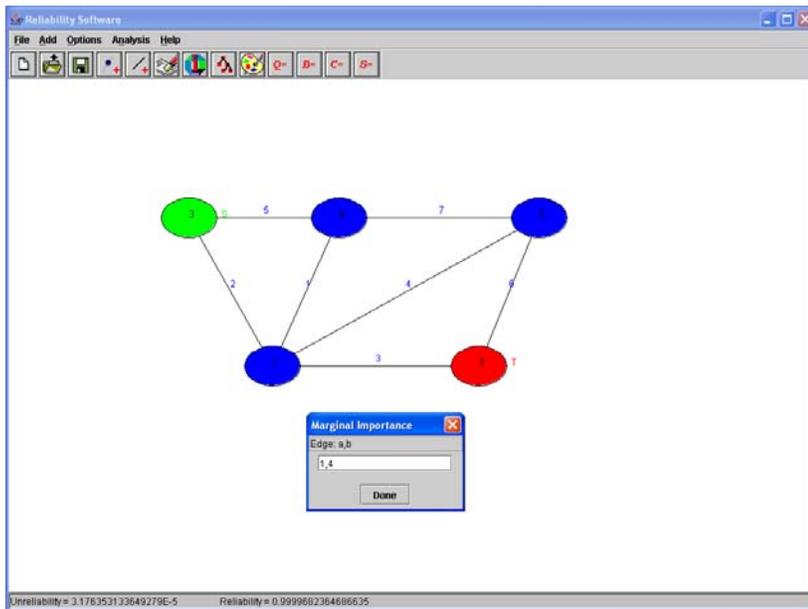
- “Analysis->Reliability” finds the reliability of the Network for the given mission time with given coverage parameters and common cause factors.



- “Analysis->Importance” has three importance measures; namely, Birnbaum’s, Criticality and Structural that finds the importance values of the relevant edge.



- “Analysis->Importance->Birnbbaum’s” finds the Birnbbaum’s marginal importance value of the edge.



- “Analysis->Importance->Criticality” finds the Criticality value of the edge.
- “Analysis->Importance->Structural” finds the Structural Importance value of the edge.

### Summary of the Example Network:

- Probability of Event 1 (flood  $\cap$  NOT hurricane) =  $\Pr\{\text{flood}\} \cdot (1 - \Pr\{\text{hurricane} \mid \text{flood}\}) = 0.0080$   
Intermediate value ( $Q_1$ ) =  $1.9400028582011012E-4$
- Probability of Event 2 (NOT flood  $\cap$  hurricane) =  $(1 - \Pr\{\text{flood}\}) \cdot \Pr\{\text{hurricane} \mid \text{NOT flood}\} = 0.0294$   
Intermediate value ( $Q_2$ ) =  $1.9400028582011012E-4$
- Probability of Event 3 (flood  $\cap$  hurricane) =  $\Pr\{\text{flood}\} \cdot \Pr\{\text{hurricane} \mid \text{flood}\} = 0.012$   
Intermediate value ( $Q_3$ ) =  $2.9095809996605785E-4$
- Probability of Event 4 (NOT flood  $\cap$  NOT hurricane) =  $(1 - \Pr\{\text{flood}\}) \cdot (1 - \Pr\{\text{hurricane} \mid \text{NOT flood}\}) = 0.9506$   
Intermediate value ( $Q_4$ ) =  $1.881805620139661E-8$

Mission Time = 1000 hrs

$P_u = \Pr\{\text{No links in the network experiences an uncovered failure}\} = 0.9999790012389453$

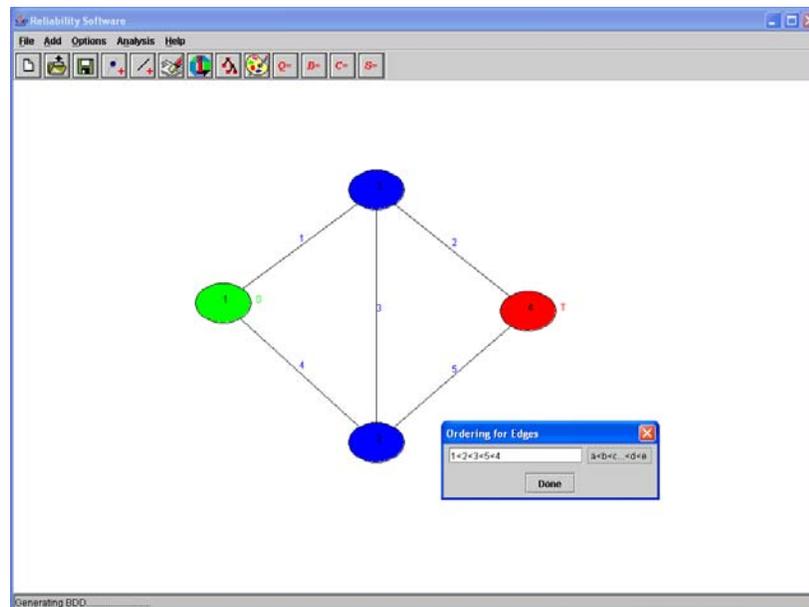
Unreliability of the network =  $3.176353133649279E-5$

Reliability of the network =  $0.9999682364686635$

Edge	Birnbaum's Importance	Criticality Importance	Structural Importance
$e_1 (1,4)$	$3.000353351E-02$	$9.162098311E-02$	$1.1357442467E-01$
$e_2 (1,3)$	$3.008658370E-02$	$9.187459125E-02$	$3.7262206323E-01$
$e_3 (1,2)$	$3.008503026E-02$	$9.186984756E-02$	$3.8040730135E-01$
$e_4 (1,5)$	$3.000227525E-02$	$9.161714081E-02$	$1.0625161522E-01$
$e_5 (3,4)$	$7.167989534E-02$	$2.1888696806E-01$	$2.4029489559E-01$
$e_6 (2,5)$	$7.024246057E-02$	$2.1449751218E-01$	$2.7555809680E-01$
$e_7 (4,5)$	$4.881943847E-02$	$1.4907860592E-01$	$1.5167313011E-01$

### Some more Examples:

An Example from "A BDD-Based Algorithm for Reliability Graph Analysis." Xinyu Xang, Hairong Sun, Kishor S. Trivedi.



Edge	Failure Prob.	Birnbaum's Importance	Criticality Importance	Structural Importance
$e_1$	0.010	$1.02873400E-02$	$3.10956980E-01$	$3.75000000E-01$
$e_2$	0.015	$1.51905600E-02$	$6.88751026E-01$	$3.75000000E-01$
$e_3$	0.020	$2.92545000E-04$	$1.76856038E-02$	$1.25000000E-01$
$e_4$	0.010	$1.02873400E-02$	$3.10956980E-01$	$3.75000000E-01$
$e_5$	0.015	$1.51905600E-02$	$6.88751026E-01$	$3.75000000E-01$

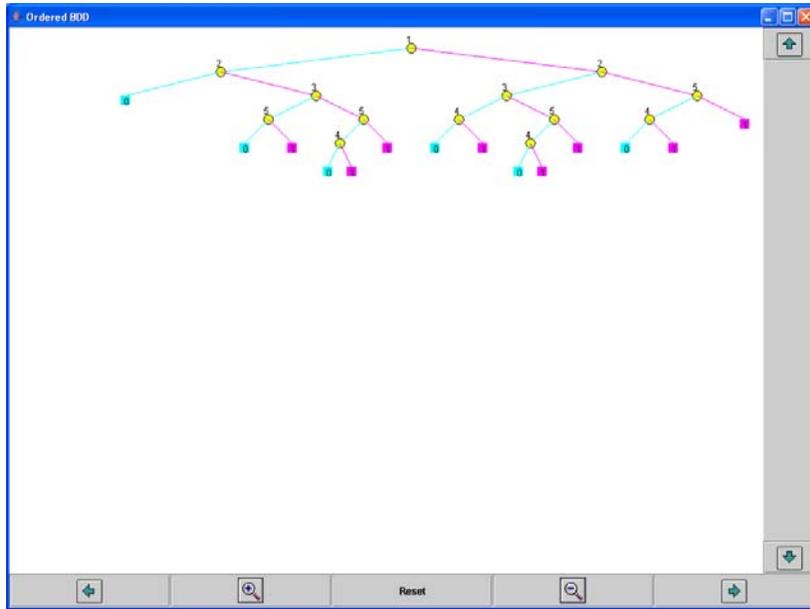


Fig. Ordered BDD with variable ordering:  $1 < 2 < 3 < 5 < 4$

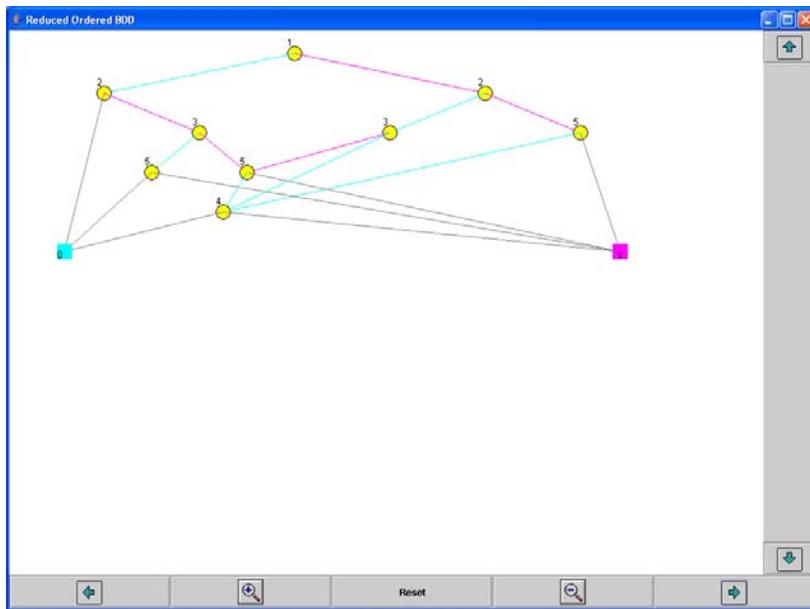
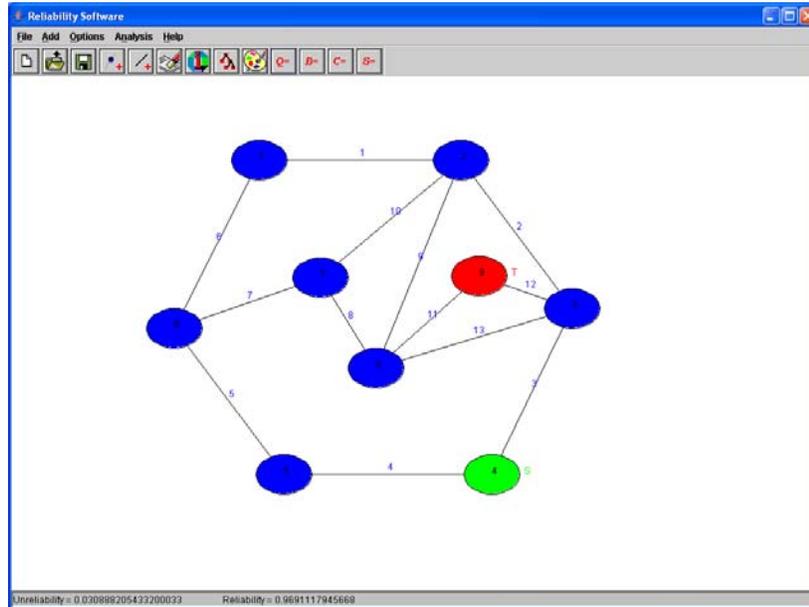


Fig. Reduced Ordered BDD with variable ordering:  $1 < 2 < 3 < 5 < 4$

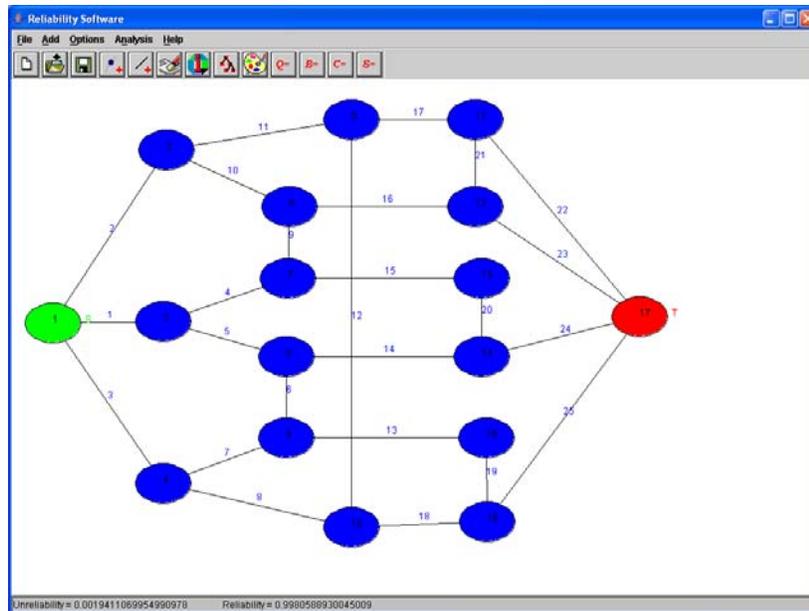
Examples from “A Practical Implementation of the Factoring Theorem for Network Reliability.” Lavon B. Page, Jo Ellen Perry

- Network 1:



All failure probabilities of links are 0.1.  
 Unreliability = 0.030888205433200033. Reliability = 0.9691117945668.

- Network 2:



All failure probabilities of links are 0.1.  
 Unreliability = 0.0019411069954990978. Reliability = 0.9980588930045009.

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Thank you for using Dependable Network Analyzer

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