King Fahd University of Petroleum and Minerals
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COE 444 – Internetwork Design and Management

Problem # 1: A network has three backbone switches B_1, B_2, and B_3 that are interconnected with full duplex links according to a tree topology with B_1 as the root of the tree, and B_2 and B_3 as the children of B_1. Suppose that there are 6 workgroup switches, labelled S_1 to S_6, that are assigned as follows: S_1 and S_2 to B_1, S_3 and S_4 to B_2, and S_5 and S_6 to B_3. Assume that the MTBF and MTTR of any link are respectively 8 years and 1 day, and the MTBF and MTTR of any switch are respectively 12 years and 3 days. (1 year = 365.25 days)

a. Find P_l and P_s, the links and switches reliabilities (use precision at 10^{-5})

$$P_l = 1 - \frac{MTTR_l}{MTBF_l} = 1 - \frac{1\ day}{8 \times 365.25\ days} = 0.99966$$
$$P_s = 1 - \frac{MTTR_s}{MTBF_s} = 1 - \frac{3\ day}{12 \times 365.25\ days} = 0.99932$$

b. Find the overall network reliability, that is, the probability that the network is connected.

$$P_c(T) = (P_s)^9 (P_l)^8 = 0.99114$$

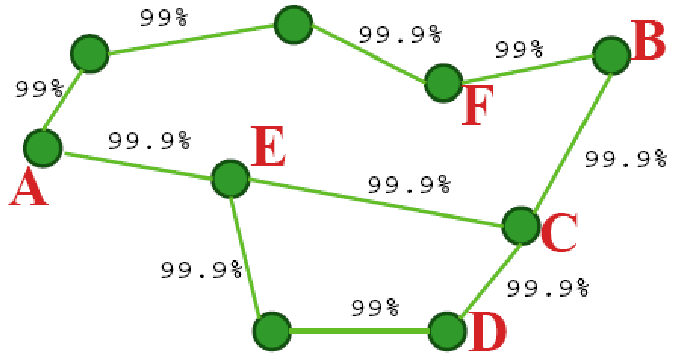
c. Find $E(B_1)$, the expected number of nodes communicating with the root node B_1.

$$E(B_1) = \sum_{i=1}^{9} P_c(i)$$
$P_c(B_1)$ =0.99932
$$P_c(B_2) = P_{B_2} P_{B_1} P_{l_{B_2 B_1}} = (0.99932)^2 (0.99966) = 0.99829 = P_c(B_3) = P_c(S_1) = P_c(S_2)$$
$$P_c(S_3) = P_{S_3} P_{l_{S_3 B_2}} P_c(B_2) = (0.99932)(0.99966)(0.99829) = 0.99727 = P_c(S_4) = P_c(S_5) = P_c(S_6)$$
$$E(B_1) = 8.98153$$

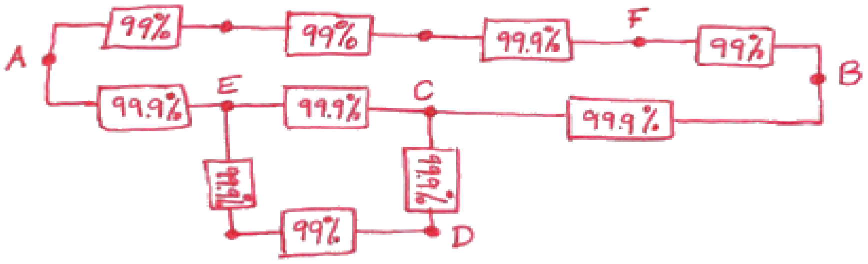
d. Find $EPR(B_1)$, the expected number of node pairs communicating through the root node B_1.

$E(S_1) = E(S_2) = E(S_3) = E(S_4) = E(S_5) = E(S_6) = 0.99932$
$$E(B_2) = P_{B_2} + P_{B_2}(P_l E(S_3) + P_l E(S_4)) = (0.99932)[1 + [0.99966(2 \times 0.99932)]] = 2.99590 = E(B_3)$$
$$EPR(B_1) = P_{B_1}[P_l E(S_1) + P_l E(S_2) + P_l E(B_2) + P_l E(B_3)] + P_{B_1}[P_l E(S_1) P_l E(B_2) + P_l E(S_1) P_l E(B_3) + P_l E(S_1) P_l E(S_2) + P_l E(B_2) P_l E(S_2) + P_l E(B_2) P_l E(B_3) + P_l E(B_3) P_l E(S_2)] = 29.9016$$

Problem # 2: Calculate the reliability of the path from router **A** to router **F** of the following network given the associated links reliabilities. Assume that the reliability of each router is 100%. (***Note: Show all steps of your calculation***)

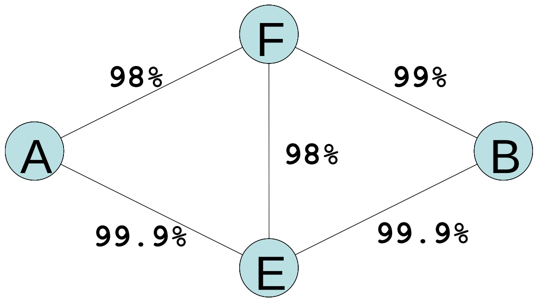


Convert the network above into the following reliability graph.



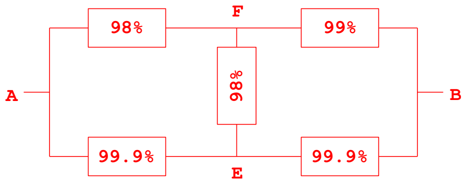
$Upper\ AF\ path\ P_{AF} = (0.99)(0.99)(0.999) = 0.9791199$
$P_{EDC} = (0.999)(0.99)(0.999) = 0.98802099$
$P_{EC} = 1 - (1 - 0.999)(1 - P_{EDC}) = 0.99998802099$
$P_{AECBF} = (0.999)(P_{EC})(0.999)(0.99) = 0.98800915448668058\underline{0}1$
$Total\ P_{AF} = 1 - (1 - P_{AF})(1 - P_{AECBF}) = 0.99974962994659733918054601$

<u>Problem # 3:</u> Consider the following simplified computer network along with the associated links' reliabilities.



By showing all the steps, calculate the reliability of the path from router ***A*** to router ***B*** by assuming that the link ***EB*** is working/not working.

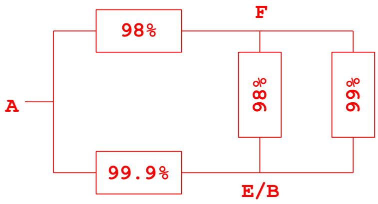
Convert the network above into the following reliability graph.



Considering that link ***EB*** is working/not working we get:

$$P_{AB} = P_{EB} \times P(path\ AB\ working|EB\ is\ working) + (1 - P_{EB}) \times P(path\ AB\ working|EB\ is\ NOT\ working) \quad \ldots (1)$$

When ***EB*** is working we get:

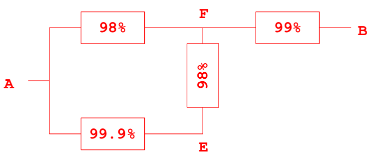


$$P(path\ AB\ working|EB\ is\ working) = 1 - (1 - P_{AF(E/B)})(1 - P_{A(E/B)})$$

$$P_{AF(E/B)} = (98\%)\big(1 - (1 - 98\%)(1 - 99\%)\big) = 0.979804$$

$$P(path\ AB\ working|EB\ is\ working) = 1 - (1 - 0.979804)(1 - 99.9\%) = 0.999979804$$

When ***EB*** is NOT working we get:



$$P(path\ AB\ working|EB\ is\ NOT\ working) = (P_{AF})(P_{FB})$$

$$P_{AF} = 1 - (1 - 98\%)(1 - (99.9\%)(98\%)) = 0.9995804$$

$$P(path\ AB\ working|EB\ is\ NOT\ working) = (0.9995804)(99\%) = 0.989584596$$

From (1): $P_{AB} = (99.9\%)(0.999979804) + (1 - 99.9\%)(0.989584596) =$ 0.999969408792