Example

Our black hole attack model is with a single malicious node. Then we evaluated the network performance while preventing attacks is established to approve our approach.

The 4 shortest paths between a source node 22 and the destination node 47, with minimal weight according to the paths taken as indicated below:

ω_1 = Weight1 = 12 hop counts of path1(v_1) = { 22,7,8,37,5,17,18,36,34,32,28,49,47}
ω_2 = Weight2 = 12 hop counts of path2(v_2) = { 22,7,8,37,5,17,4,27,33,28,46,49,47}
ω_3 = Weight3 = 12 hop counts of path3(v_3) = { 22,7,6,14,15,3,25,26,27,33,28,49,47}
ω_4 = Weight4 = 11 hop counts of path4(v_4) = { 22,7,8,37,5,17,4,27,33,28,49,47}

$S = \Omega = \{\omega_1 ; \omega_2 , \omega_3 , \omega_4 \}$,

$V = \{v_1; v_2, v_3, v_4\}$

Than we launched observation sequence steps O randomly, for the time T = 10, and each entity in the sequences of observation sequences represents the random path decision made at that time.

The transition matrix is:

$$A = [a_{ij}]_{1 \le i,j \le 4}, \text{with } a_{ij} = \mathbf{P}(X_t = \omega_j / X_{t-1} = \omega_i, \lambda)$$

a_{ij}: is elementary transition probability of ω_i to ω_j

$$A = \begin{bmatrix} a_{11} & a_{12} & a_{13} & a_{14} \\ a_{21} & a_{22} & a_{23} & a_{24} \\ a_{31} & a_{32} & a_{33} & a_{34} \\ a_{41} & a_{42} & a_{43} & a_{44} \end{bmatrix} = \begin{bmatrix} 0.3 & 0.2 & 0.2 & 0.3 \\ 0.2 & 0.3 & 0.2 & 0.3 \\ 0.2 & 0.2 & 0.3 & 0.3 \\ 0.2 & 0.2 & 0.2 & 0.4 \end{bmatrix}$$

The emission matrix is:

$$B = \{b_j(v_t)\} \text{ with } b_j(k) = \mathbf{P}(Y_t = v_k / X_t = \omega_j) ;\ 1 \le j \le 4;\ 1 \le k \le 4$$

$$\mathbf{B} = \begin{bmatrix} \mathbf{b}_{\omega_1}(\mathbf{Y_t}) & \mathbf{b}_{\omega_1}(\mathbf{Y_t}) & \mathbf{b}_{\omega_1}(\mathbf{Y_t}) & \mathbf{b}_{\omega_1}(\mathbf{Y_t}) \\ \mathbf{b}_{\omega_2}(\mathbf{Y_t}) & \mathbf{b}_{\omega_2}(\mathbf{Y_t}) & \mathbf{b}_{\omega_2}(\mathbf{Y_t}) & \mathbf{b}_{\omega_2}(\mathbf{Y_t}) \\ \mathbf{b}_{\omega_3}(\mathbf{Y_t}) & \mathbf{b}_{\omega_3}(\mathbf{Y_t}) & \mathbf{b}_{\omega_3}(\mathbf{Y_t}) & \mathbf{b}_{\omega_3}(\mathbf{Y_t}) \\ \mathbf{b}_{\omega_4}(\mathbf{Y_t}) & \mathbf{b}_{\omega_4}(\mathbf{Y_t}) & \mathbf{b}_{\omega_4}(\mathbf{Y_t}) & \mathbf{b}_{\omega_4}(\mathbf{Y_t}) \end{bmatrix} = \begin{bmatrix} \mathbf{0.3} & \mathbf{0.3} & \mathbf{0.3} & \mathbf{0.1} \\ \mathbf{0.3} & \mathbf{0.3} & \mathbf{0.3} & \mathbf{0.1} \\ \mathbf{0.3} & \mathbf{0.3} & \mathbf{0.3} & \mathbf{0.1} \\ \mathbf{0.1} & \mathbf{0.1} & \mathbf{0.1} & \mathbf{0.7} \end{bmatrix}$$

The initial probability matrix:

$$\boldsymbol{\Pi} = \begin{bmatrix} \boldsymbol{\Pi_1} \\ \boldsymbol{\Pi_2} \\ \boldsymbol{\Pi_3} \\ \boldsymbol{\Pi_4} \end{bmatrix} = \begin{bmatrix} \mathbf{0.2} \\ \mathbf{0.2} \\ \mathbf{0.2} \\ \mathbf{0.4} \end{bmatrix}$$

The Forward Algorithm $\alpha_{t+1}(j) = \mathrm{b}_{\omega_j}(\mathrm{Y}_{t+1}) \sum_{i=1}^{4} \alpha_t(i)\, a_{ij}$

The Forward Variables and Numerical Values

Initialization

$$\alpha_1(i) = \mathbf{P}(\mathrm{X}_1 = \omega_i / \lambda).\mathbf{P}(\mathrm{Y}_1/\mathrm{X}_1 = \omega_i, \lambda) = \Pi_{\omega_i}.\mathrm{b}_{\omega_i}(\mathrm{Y}_1)$$

$$\alpha_1(\omega_1) = \Pi_{\omega_1}.\mathrm{b}_{\omega_1}(\mathrm{Y}_1) - \quad \alpha_1(\omega_1) = 0.2 \times 0.1 = 0.02$$

$$\alpha_1(\omega_1) = \alpha_1(\omega_2) = \alpha_1(\omega_3) = \mathbf{0,02} \qquad \text{et} \;\; \alpha_1(\omega_4) = \mathbf{0,28}$$

Induction

$$\alpha_{t+1}(j) = \mathrm{b}_{\omega_j}(\mathrm{Y}_{t+1}) \sum_{i=1}^{4} \alpha_t(i)\, a_{ij}$$

$$\alpha_2(\omega_1) = \mathrm{b}_{\omega_1}(\mathrm{Y}_1)[\alpha_1(\omega_1)a_{11} + \alpha_1(\omega_2)a_{21} + \alpha_1(\omega_3)a_{31} + \alpha_1(\omega_4)a_{41}]$$

$$\alpha_2(\omega_1) = 0.1 \times [0.02 \times 0.3 + 0.02 \times 0.2 + 0.02 \times 0.2 + 0.28 \times 0.2]$$

$$\alpha_2(\omega_1) = \alpha_2(\omega_2) = \alpha_2(\omega_3) = \mathbf{0,007} \qquad et\; \alpha_2(\omega_4) = \mathbf{0,091}$$

L'algorithme X.X : **Algorithme Forward**

Pour i=1 à N Faire

| $\alpha_1 = \Pi_i \mathrm{b}_i(\mathrm{Y}_1)$

Fin Pour

Pour t=1 à T-1 Faire

| Pour j=1 à N Faire

| | $\alpha_{t+1}(j) = \left(\sum_{i=1}^{N} \alpha_t(i)\, a_{ij}\right)\mathrm{b}_j(\mathrm{Y}_{t+1})$

| Fin Pour

Fin Pour

$$\mathbf{P}(\mathrm{Y}/\lambda) = \sum_{i=1}^{N} \alpha_T(i)$$