A Quantitative Approach Towards Detection of an Optimal Attack Path in Wireless Network using Modified PSO Technique

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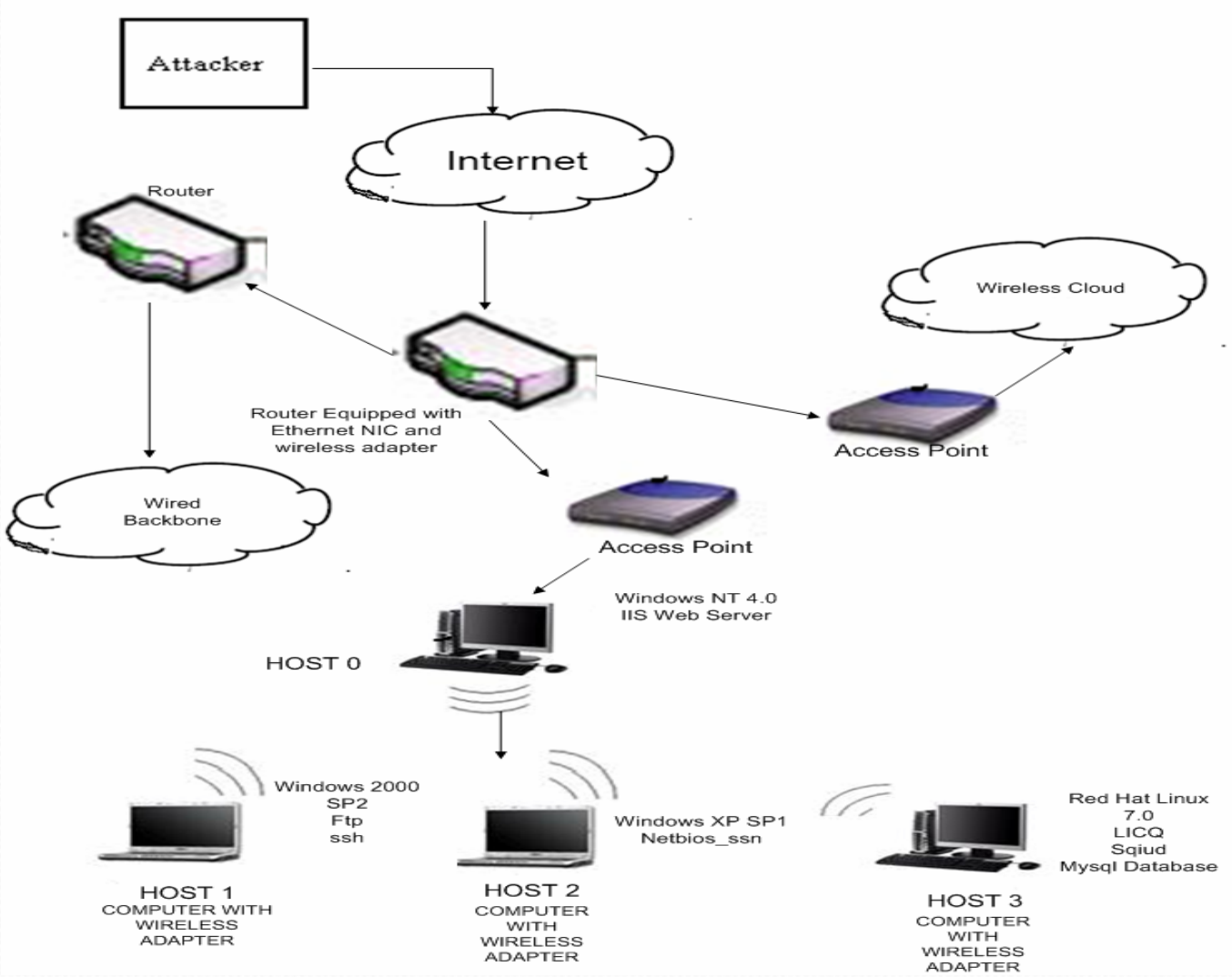
Introduction

- Immense proliferation of wireless networks.
- Becoming increasingly vulnerable to attacks.
- Network Security assumes great importance.

Backbone Network



Motivation

- Networks are becoming vulnerable to attacks.
- Attack Graph: a tool that provides all possible attack scenarios that jeopardize the network.
- Attack Path: a series of *exploits* where each exploit in the chain lays the groundwork for subsequent exploits.
- Complete attack graphs have the following problems:-
  - Scalability
  - Exponential time complexity
  - Contains redundant nodes and edges
  - Difficulty in understanding
- *Minimal* attack graph: consists of *minimal* attack paths.

Contd..

- Finding out an optimal attack path from a given set of *minimal* attack paths.
- Optimality of an attack path is given by the *effort* required on path of the attacker to reach the *goal* following that path.
- Not much work related to wireless network security using attack path has been reported till date.

Problem Definition

- To determine near optimal attack path in WLAN based on the Risk Values associated with the hosts of the WLAN using Soft-Computing Technique, Particle Swarm Optimization (PSO).
- Problem decomposed as
  - Simulation of a Wireless scenario
  - Assignment of risk values to the Wireless Hosts
  - Attack Path Identification using PSO

Particle Swarm Optimization (PSO)

- PSO model consists of a swarm of particles[18], which are initiated with a population of random candidate solutions.

$$\overrightarrow{v_i}(t) = w * \overrightarrow{v_i}(t-1) + c_1 * \phi_1 * (\overrightarrow{pi} - \overrightarrow{x_i}(t-1)) + c_2 * \phi_2 * (\overrightarrow{p_g} - \overrightarrow{x_i}(t-1))$$

$$\overrightarrow{x_i}(t) = \overrightarrow{x_i}(t-1) + \overrightarrow{v_i}(t)$$

Where, w [23]is an inertia weight which is employed to control the impact of the previous velocity on the current velocity.

The *c1 & c2 are the social/cognitive coefficients and Ø1 & Ø2 [23] are the two uniform* random numbers in the range [0,1].

Detection Of Optimal Attack Path In A Wireless Network Using Modified PSO Techniques

Severity Measurement

- Classical formula of risk by *Y. Chen, B. Boehm, L. Sheppard* [13]:

  $$Risk = P_{success} \times SizeOfLoss$$

- $P_{success}$ *is the probability that such an attack will be successful*
- ***SizeOfLoss*** characterizes how much the loss will be if such an attack happens.

Relevance	Attributes	Sub – attributes
$P_{success}$	Access (Acc)	Access Vector(AV)
		Authentication(Auth)
		Attack Complexity(AC)
	Vulnerability (Vul)	Availability(Avail)
		Popularity
		Remediation Level(RL)
		Report Confidence(RC)
SizeOfLoss	Vulnerability	Damage Potential(DP)
	Target Asset	Asset Value Impact Association(AVIA)
	Affected Value	Value Importance(VI)

Ref: [14][13][15][16][17]

$P_{success}$ & *SizeOfLoss* Relevant Attribute Ratings

CVE – ID	AV	Auth	AC
CVE-2002-0364	Network Access(0.646)	Not Required(0.704)	Low(0.71)
CVE-2008-1396	Network Access(0.646)	Not Required(0.704)	Low(0.71)
CVE-1999-1455	Network Access(0.646)	Not Required(0.704)	Low(0.71)
CVE-1999-0180	Network Access(0.646)	Not Required(0.704)	Low (0.71)
CVE-2003-0661	Network Access(0.646)	Not Required(0.704)	Low (0.71)
CVE-2001-0439	Network Access(0.646)	Not Required(0.704)	Low(0.71)
CVE-2001-1030	Network Access(0.646)	Not Required(0.704)	Low(0.71)
CVE-2006-3368	Network Access(0.646)	Not Required(0.704)	Low(0.71)

$P_{success}$ Relevant Base metrics for CVE-IDs

CVE – ID	Avail	Popularity	RL	RC
CVE-2002-0364	Proof-of-concept(0.9)	High(1.0)	Official-fix(0.87)	Confirmed(1.0)
CVE-2008-1396	Functional(0.85)	High(1.0)	Workaround(0.95)	Confirmed(1.0)
CVE-1999-1455	Unproven(0.85)	High(1.0)	Unavailable (1.0)	Unconfirmed(1.0)
CVE-1999-0180	Not defined(1.0)	High(1.0)	Not defined(1.0)	Not defined(1.0)
CVE-2003-0661	Functional(0.95)	Medium(0.7)	Workaround(0.95)	Uncorroborated(0.95)
CVE-2001-0439	Not defined(1.0)	High(1.0)	Workaround(0.95)	Confirmed(1.0)
CVE-2001-1030	Functional(0.95)	High(1.0)	Official-fix(0.87)	Uncorroborated(0.95)
CVE-2006-3368	Functional(0.95)	Medium(0.7)	Unavailable(1.0)	Confirmed(1.0)

$P_{success}$ Relevant Temporal Metrics for CVE-IDs

CVE – ID	DP	AVIA	VI
CVE-2002-0364	Low(0.1)	Medium(0.62)	Medium(0.6)
CVE-2008-1396	Low(0.1)	Complete(0.96)	Medium(0.6)
CVE-1999-1455	Low(0.1)	Medium(0.62)	Medium(0.6)
CVE-1999-0180	High(0.5)	Medium(0.62)	Medium(0.6)
CVE-2003-0661	Medium-high(0.4)	Medium (0.62)	Medium(0.6)
CVE-2001-0439	Medium-high(0.4)	Complete(0.96)	Medium(0.6)
CVE-2001-1030	Low(0.1)	Medium(0.62)	Medium(0.6)
CVE-2006-1030	Medium-high(0.4)	Low(0.275)	Medium(0.6)

SizeOfLoss Attribute Ratings

Ref : [14][15][16][17]

Computation of CVE-ID Risk

- $P_{success}$ attribute is the sum of the Acc and Vul and is given as:

$$P_{success} = Acc + Vul$$

- Acc and Vul depends on different sub-attributes viz. Access Vector(AV), Authentication(Auth), Attack Complexity (AC) and Availability(Avail), Popularity, Remediation Level(RL), and Report Confidence(RC) respectively.

$$Acc = AV \times Auth \times AC$$

$$Vul = Avail \times Popularity \times RL \times RC$$

$$P_{success} = (AV \times Auth \times AC) + (Avail \times Popularity \times RL \times RC)$$

Attack Index (AI) & Size of Loss Index (SI)

- The contribution of *Acc and Vul towards the calculation of* $P_{success}$ *will vary as per the* security requirements of the organization.

$$AI = W1 \times Acc + W2 \times Vul$$

$$AI = 0.6 \times Acc + 0.4 \times Vul$$

- Sub-attributes that constitute *SizeOfLoss are Damage Potential(DP), Asset Value Impact Association(AVIA), Value Importance(VI).*

$$SizeOfLoss = DP + AVIA + VI$$

- Considering *equal contributions of DP, AVIA, VI towards the calculation* of *SizeOfLoss*

$$SI = 0.33 \times (DP + AVIA + VI)$$

Severity Measure

- Finally, the classic risk calculation formula is:

$$\boldsymbol{Risk = AI \times SI}$$

- If a particular host has *n number of vulnerabilities each with corresponding CVE-ID, then* using the above formulae the risk associated with each such CVE-IDs may be computed as:

$$Severitymeasure(host_i) = \sum_{j=1}^{j=n} Risk(CVE - ID_j)$$

Algorithm: Severity Calculation

Input: Set of Vulnerabilities in terms of CVE-IDs
Output: severity measures and the Connectivity among the nodes
foreach *Host i* **do**
  Find vulnerabilities associted with *i*
  foreach *Vulnerability j in host i* **do**
    Calculate *Risk*(*j*)
    severity measure(*i*)=$\sum$(Risk$_j$)
  end
end
Call **Connectivity**
Print *OptimalAttackPath*

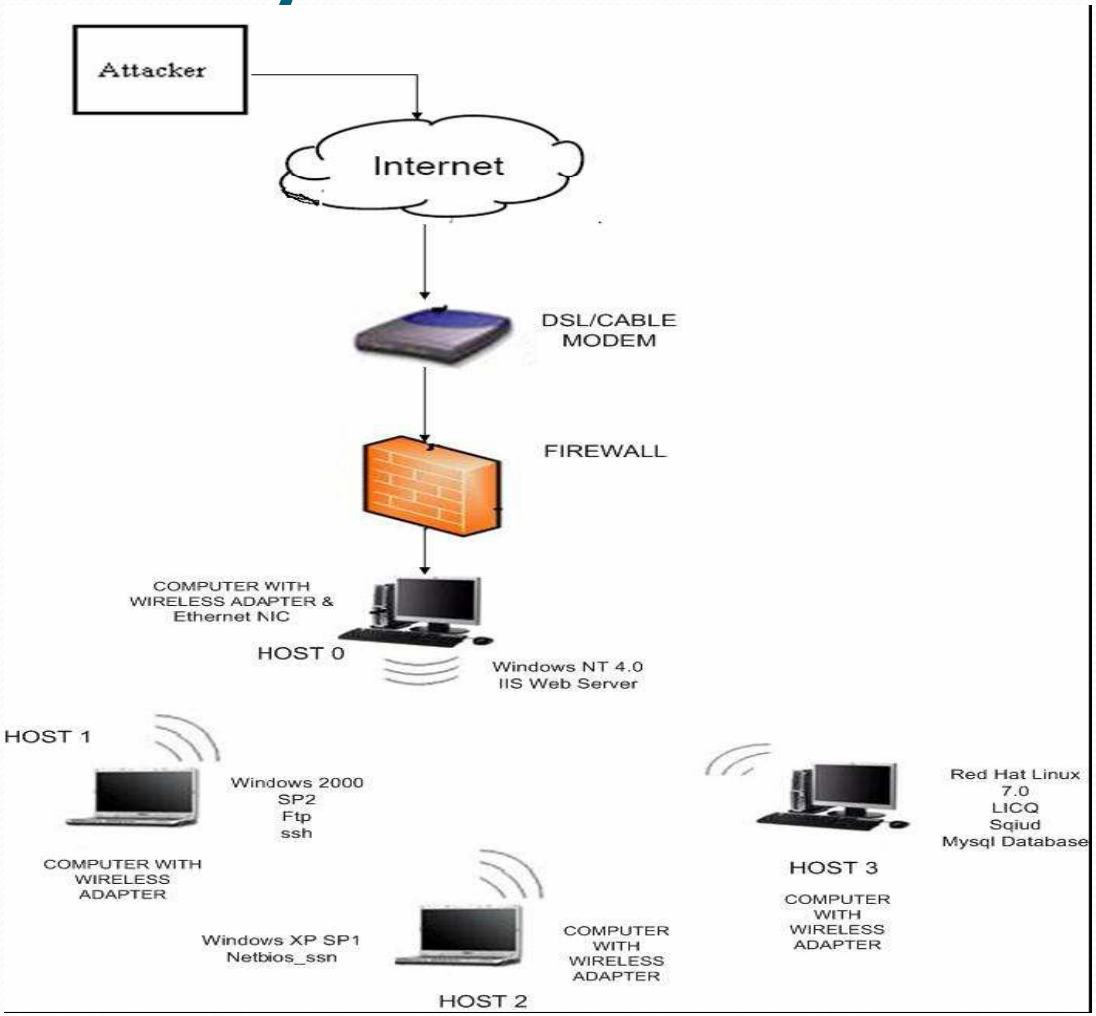
Algorithm: Connectivity

Input: Network Region,Threshold Range
Output: Connectivity relationship among wireless nodes
while *true* **do**
  if $CheckTimer(T_{max}) = 1$ **then**
    foreach *Host i* **do**
      Initialize the position
      Calculate the $Range(Host_i)$
    end
    foreach *Host i* **do**
      if $Range(Host_i) < Threshold$ **then**
        Print *ConnectivityRelationship*
      end
    end
    Read *Source*
    Read *Destination*
    Call **PSOfitness**(*Source*, *Destination*)
  end
end

Algorithm: PSOfitness

Input: Source node and Destination node
Output: An optimized attack path
if *source* = *destination* **then**
  return
end
Mark *Source* →Visited
foreach *Host j* **do**
  if *connection exits between source and Host j && Host j is not visited* **then**
    Set flag → 1
    arr[*i* + +]← *host*j
  end
end
foreach *Host i* **do**
  Calculate max(*risk*(*arr*[*i*]))
  next←arr[i]
end
if *risk*[*next*] > pbest **then**
  gbest=*risk*[*next*]
end
else
  gbest = *pbest*
end
Mark *next* →Visited
Call **ComputeAttackVector**(*gbest*, *pbest*)
Call **PSOfitness**(*next*, *destination*)

Case Study


Attacker
Internet
DSL/CABLE MODEM
FIREWALL
COMPUTER WITH WIRELESS ADAPTER & Ethernet NIC
HOST 0
Windows NT 4.0 IIS Web Server
HOST 1
Windows 2000 SP2 Ftp ssh
COMPUTER WITH WIRELESS ADAPTER
Red Hat Linux 7.0 LICQ Sqiud Mysql Database
HOST 3
COMPUTER WITH WIRELESS ADAPTER
Windows XP SP1 Netbios_ssn
COMPUTER WITH WIRELESS ADAPTER
HOST 2

System Characteristics

Host	Services	Ports	Vulnerabilities	CVE – IDs	OperatingSystem
H0	IIS Web Service	80	IIS buffer overflow	CVE-2002-0364	Windows NT 4.0
H1	ftp	21	ftp rhost overwrite	CVE-2008-1396	
	ssh	22	ssh buffer overflow	CVE-1999-1455	Windows 2000 SP1
	rsh	514	rsh login	CVE-1999-0180	
H2	Netbios-ssn	139	Netbios-ssn nullsession	CVE-2003-0661	Windows XP SP2
	rsh	514	rsh login	CVE-1999-0180	
H3	LICQ	5190	LICQ-remote-to-user	CVE-2001-0439	
	Squid Proxy	80	squid-port-scan	CVE-2001-1030	Red Hat Linux 7.0
	Mysql DB	3306	local-setuid-bof	CVE-2006-3368	

Host – ID	CVE – ID
H0	CVE-2002-0364
H1	CVE-2008-1396
	CVE-1999-1455
	CVE-1999-0180
H2	CVE-2001-0439
	CVE-1999-0180
H3	CVE-2001-0439
	CVE-2001-0103
	CVE-2006-3368

Ref : [19][20]

Calculations

$$AI = 0.6 \times (0.646 \times 0.704 \times 0.71) + 0.4 \times (0.9 \times 1.0 \times 0.87 \times 1.0)$$
$$= (0.6 \times 0.322) + (0.4 \times 0.783) = 0.193 + 0.313 = 0.506$$

$$SI = 0.33 \times (0.1 + 0.62 + 0.6) = 0.33 \times 1.32 = 0.436$$

$$Risk = 0.506 \times 0.436 = 0.220$$

$$Severity(Host0) = 0.220$$

Contd…

CVE – ID	Risk
CVE-2008-1396	0.304
CVE-1999-1455	0.232
CVE-1999-0180	0.337
CVE-2003-0661	0.232
CVE-2001-0439	0.307
CVE-2001-1030	0.221
CVE-2006-3368	0.193

Risk Values of the Vulnerabilities

Host – ID	severitymeasure
H1	0.873
H2	0.644
H3	0.721

severity measures of each Host

Calculation of *gbest* & Attack Vector Scenario 1

$$\begin{bmatrix} 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 1 \\ 0 & 0 & 1 & 0 \end{bmatrix}$$

Connectivity matrix

Host – ID	gbest	AttackVector
H2	0.644	0.219972
H3	0.721	0.162986

Attack Vectors of the visited hosts

Optimal attack path with this connectivity matrix is :

$H_0 \rightarrow H_2 \rightarrow H_3$

Scenario 2

$$\begin{bmatrix} 0 & 0 & 1 & 0 \\ 1 & 0 & 1 & 1 \\ 1 & 1 & 0 & 1 \\ 1 & 1 & 1 & 0 \end{bmatrix}$$

Connectivity matrix

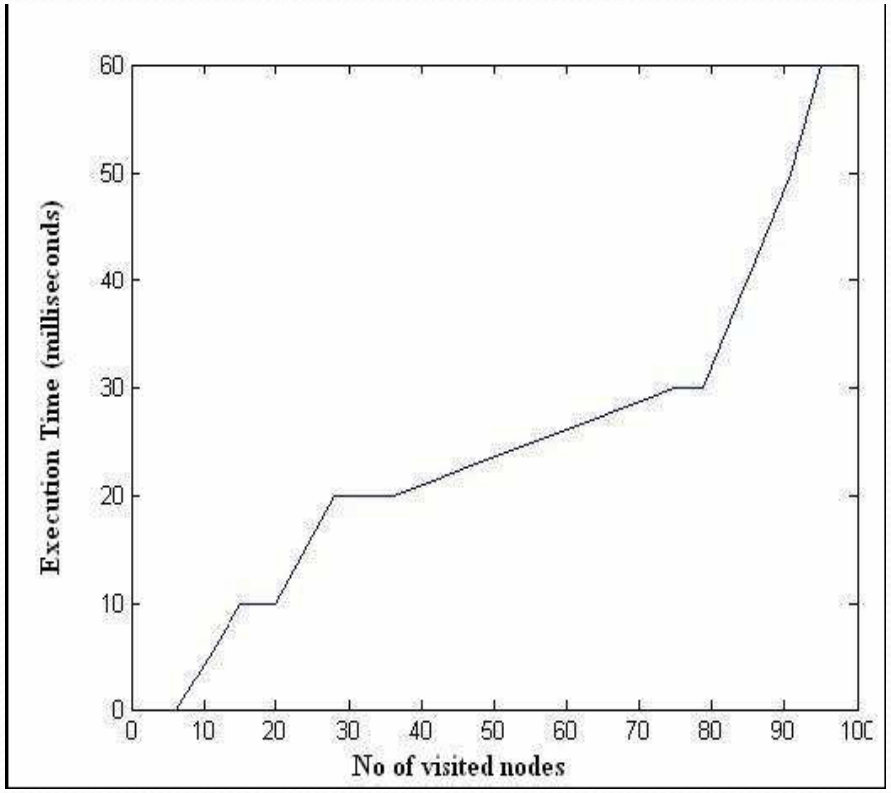
Host – ID	*gbest*	AttackVector
H2	0.644	0.149176
H1	0.873	0.024638
H3	0.873	0.021534

Attack Vectors of the visited hosts

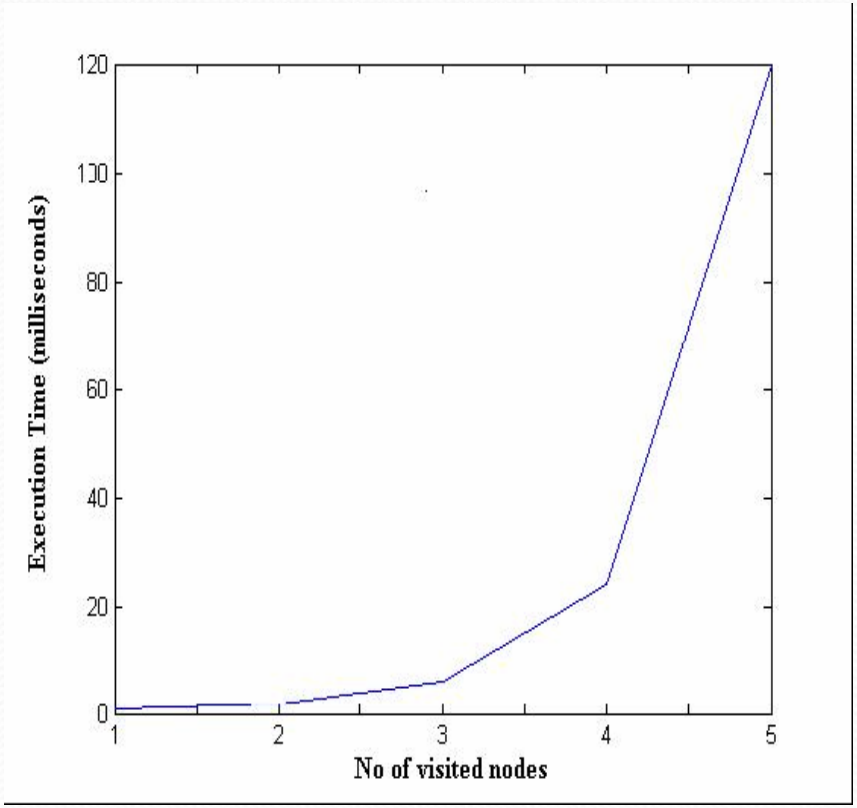
Optimal attack path with this connectivity matrix is :

$$H0 \rightarrow H2 \rightarrow H1 \rightarrow H3$$

Proposed Methodology *vs* Brute Force Technique (in terms of Execution Time)



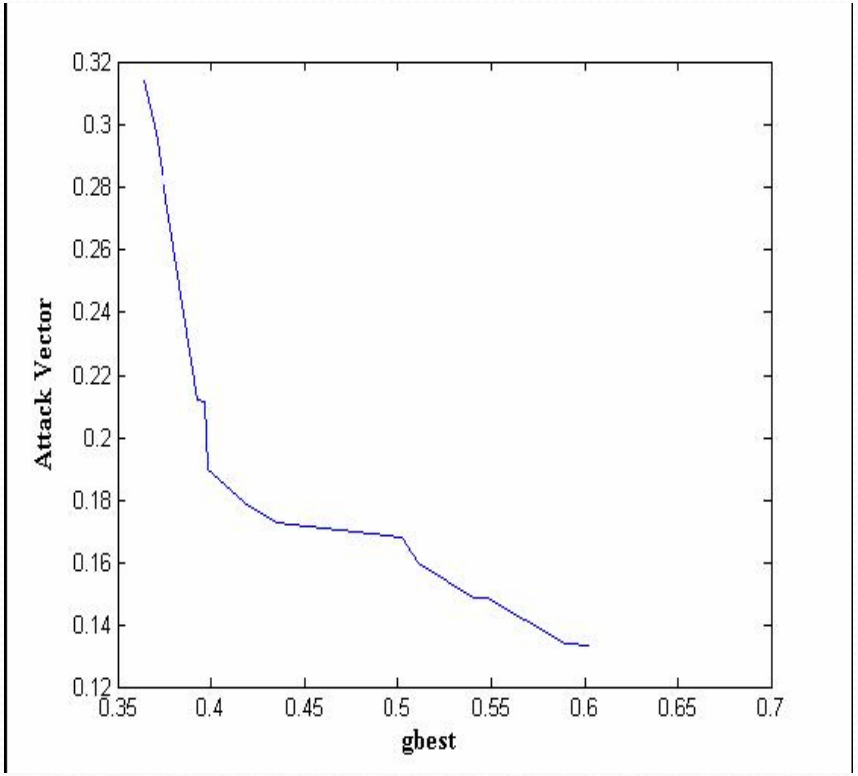
Proposed model



Brute force method

Result

- *Attack Vector values are inversely proportional* gbest.
- The gbest is the global maximum *severity measure and as it increases, the Effort* required to compromise the host *reduces*.



gbest vs Attack Vector (effort)

Conclusion

- An optimal attack path in a wireless network using modified PSO technique is detected.
- The wireless hosts in the test network are assigned some weightages in terms of risk parameters obtained from well known public sites.
- These weightages are computed by customized risk formulae.
- Finally, these *severity measures are input to PSO* based proposed algorithms to find out the optimal attack path in the wireless network.
- The output of the proposed model is compared with existing brute force technique to exhibit efficiency.

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THANK YOU!!