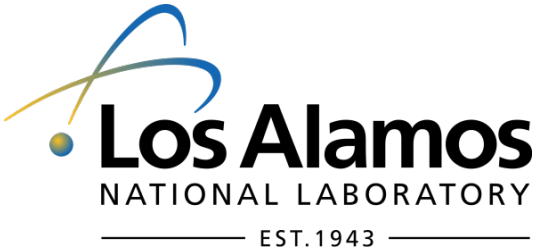

Towards Sound Analysis of Computer Evidence

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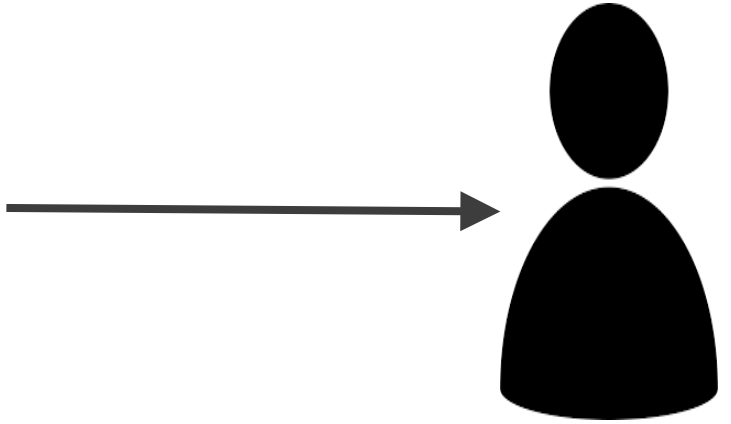
Acquisition

Analysis

Reporting

GUILTY

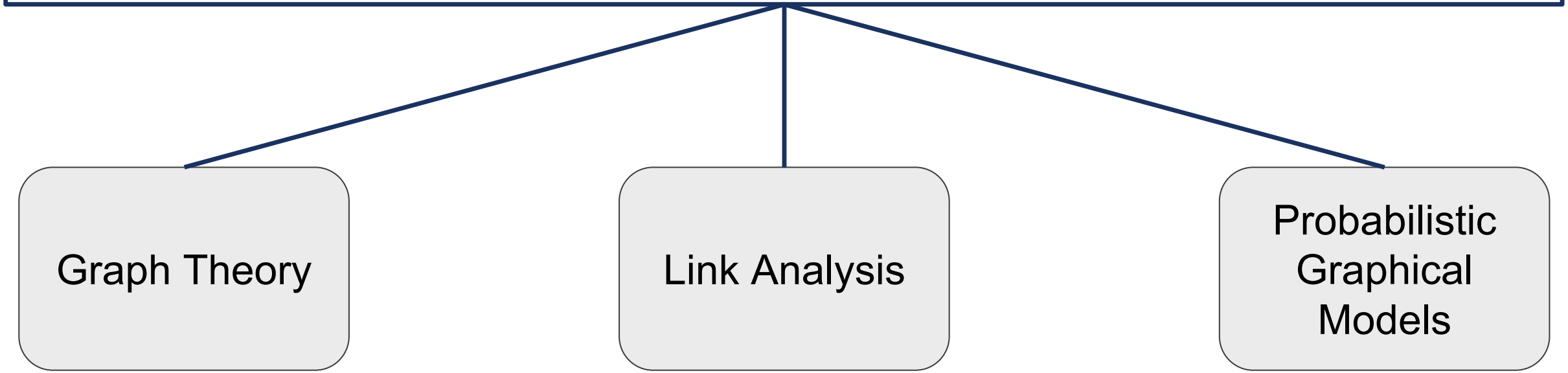
- Chat Logs
- Emails
- Photos
- System Logs
- Metadata
- Programs



Undefined Knowledge Base

Report

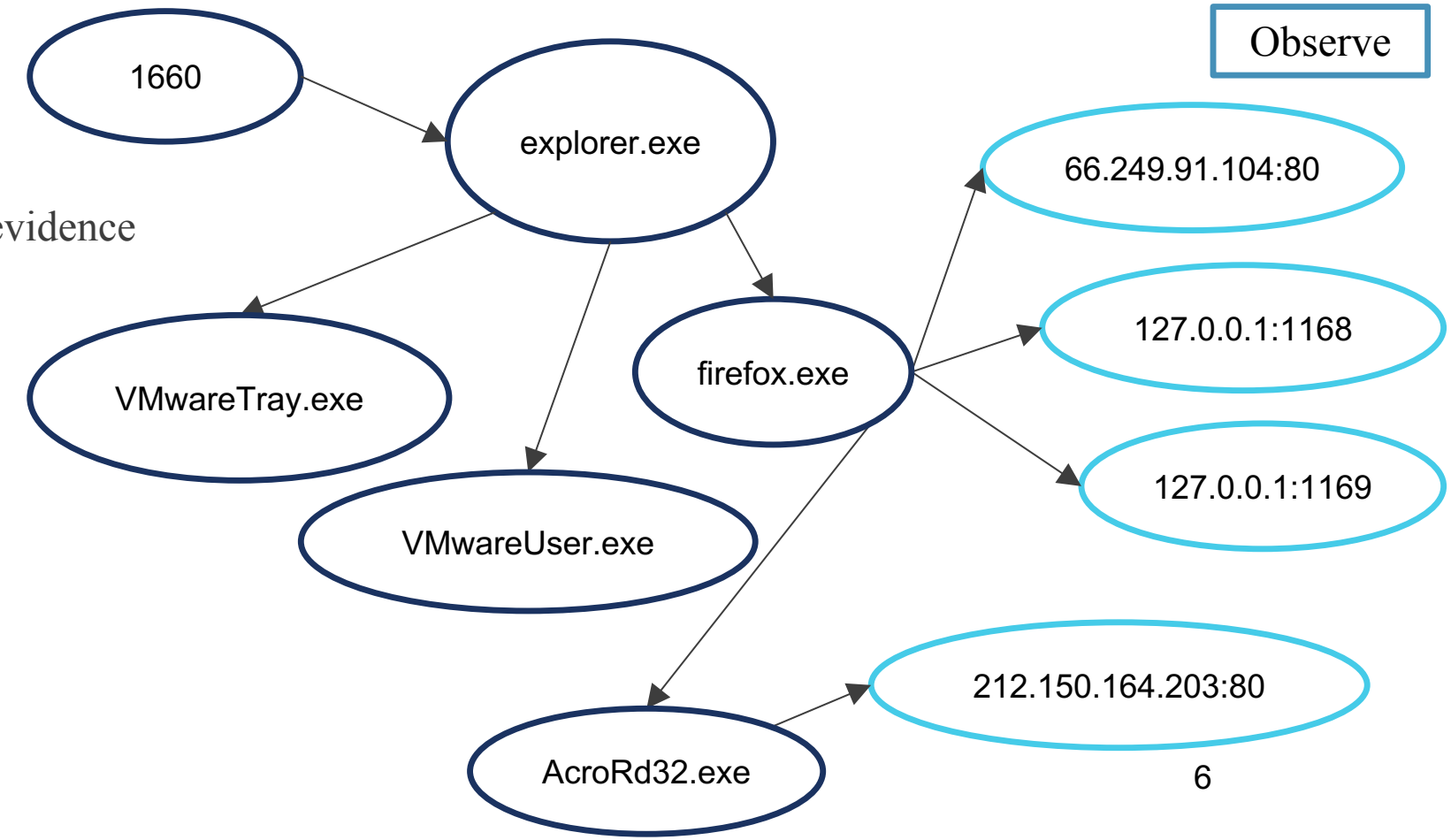
The application of computer science methodologies can aid the digital forensic analysis process.



Case Study

Observe Evidence

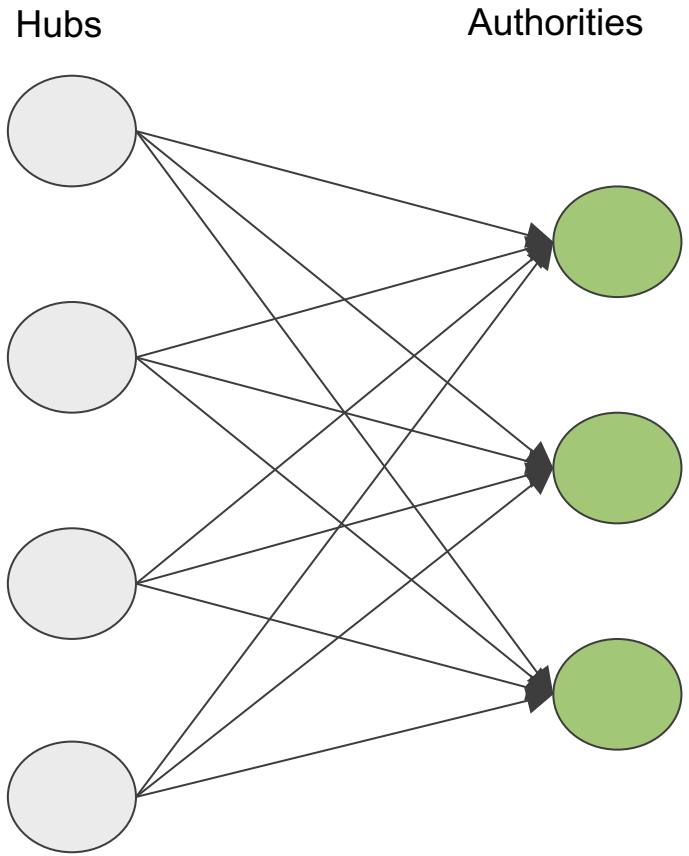
- Graph-based representation of the evidence
  - Nodes
    - Processes and sockets
  - Edges
    - Parent process -> Child Process
    - Process -> Socket



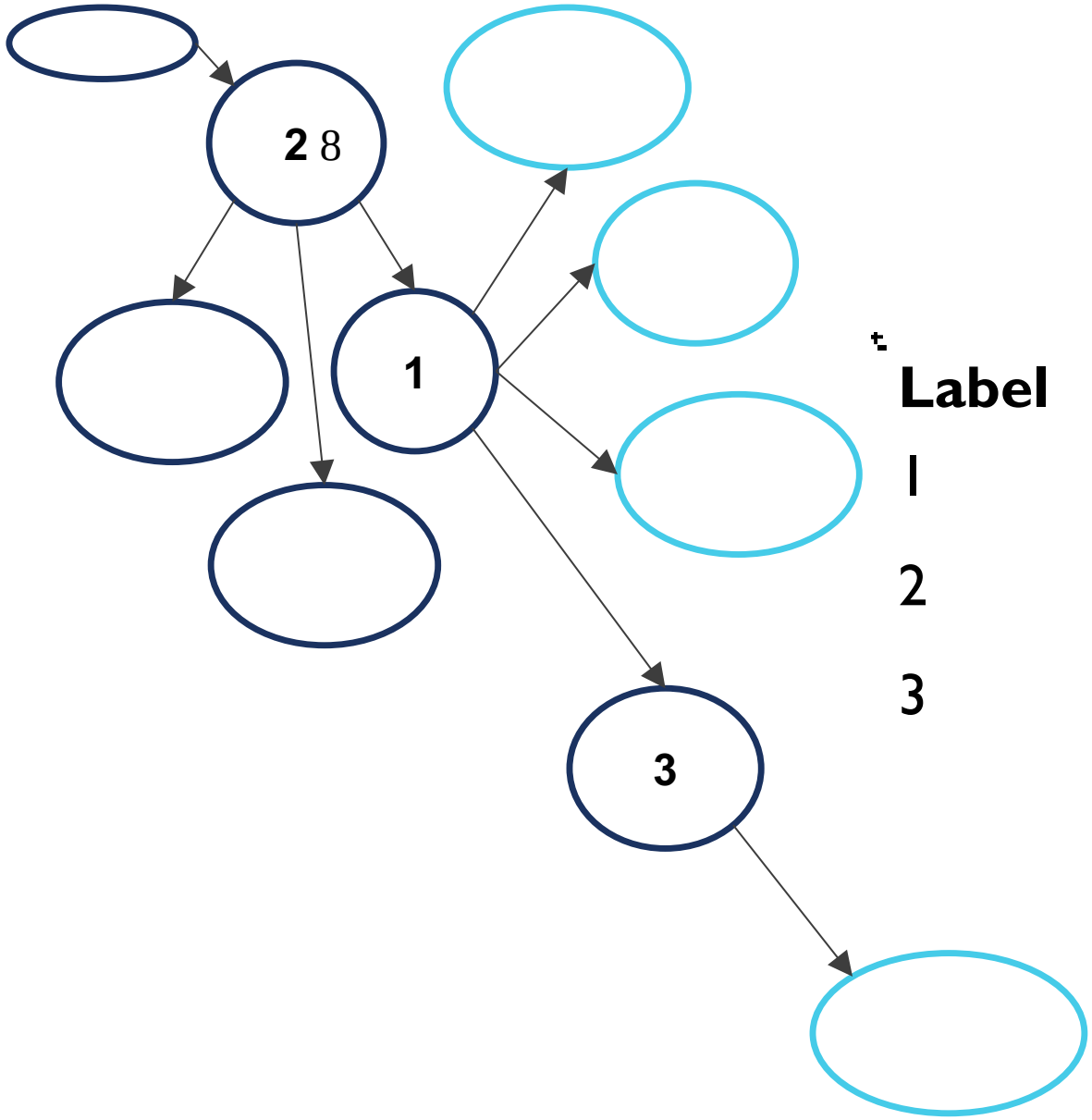
Hyperlink-Induced Topic Search (HITS)

Observe

- **Authority:** a node that hubs link to
- **Hub::** a node that links to many authorities



Observe

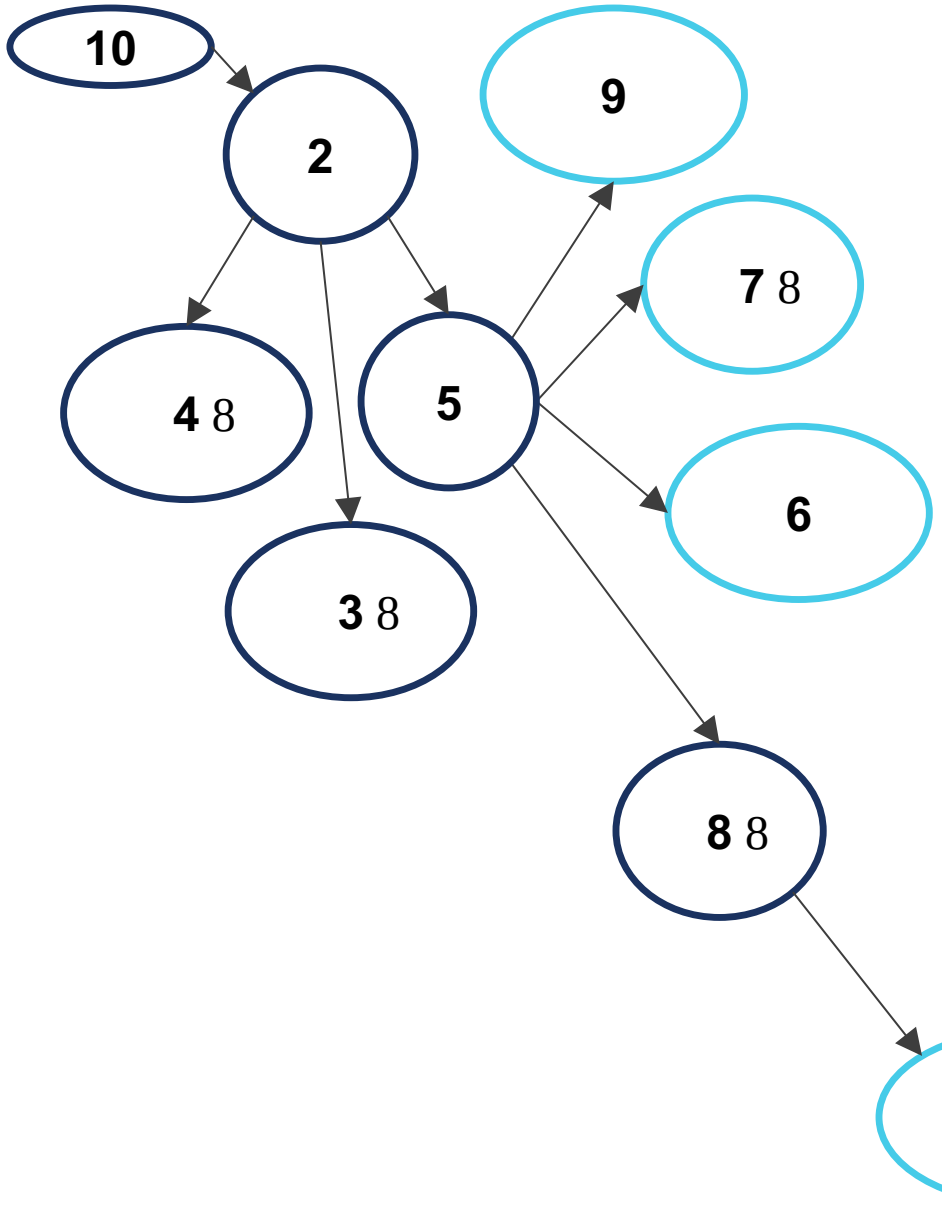


Label	Node	Hub	Authority
1	firefox.exe	0.9999	7.9728e-09
2	explorer.exe	2.3918e-08	1.8807-e37
3	AcroRd32.exe	1.8807e-37	0.2499

PageRank

Observe

- Relationship from **Node A** to **Node B** is a vote for **Node B** cast by **Node A**
- Votes cast by nodes that are important weigh more heavily
- Numeric value that represents the importance of a node present on a graph

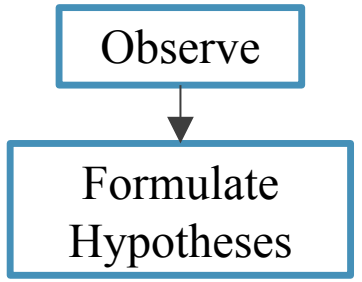


Label	Node	PageRank
1	212.150.164.203:80	0.1431
2	explorer.exe	0.1246
3	VMwareUser.exe	0.1026
4	VMwareTray.exe	0.1026
5	firefox.exe	0.1026
6	127.0.0.1:1169	0.0891
7	127.0.0.1:1168	0.0891
8	AcroRd32.exe	0.0891
9	66.249.91.104:80	0.0891 *
10	1660	0.0673 *

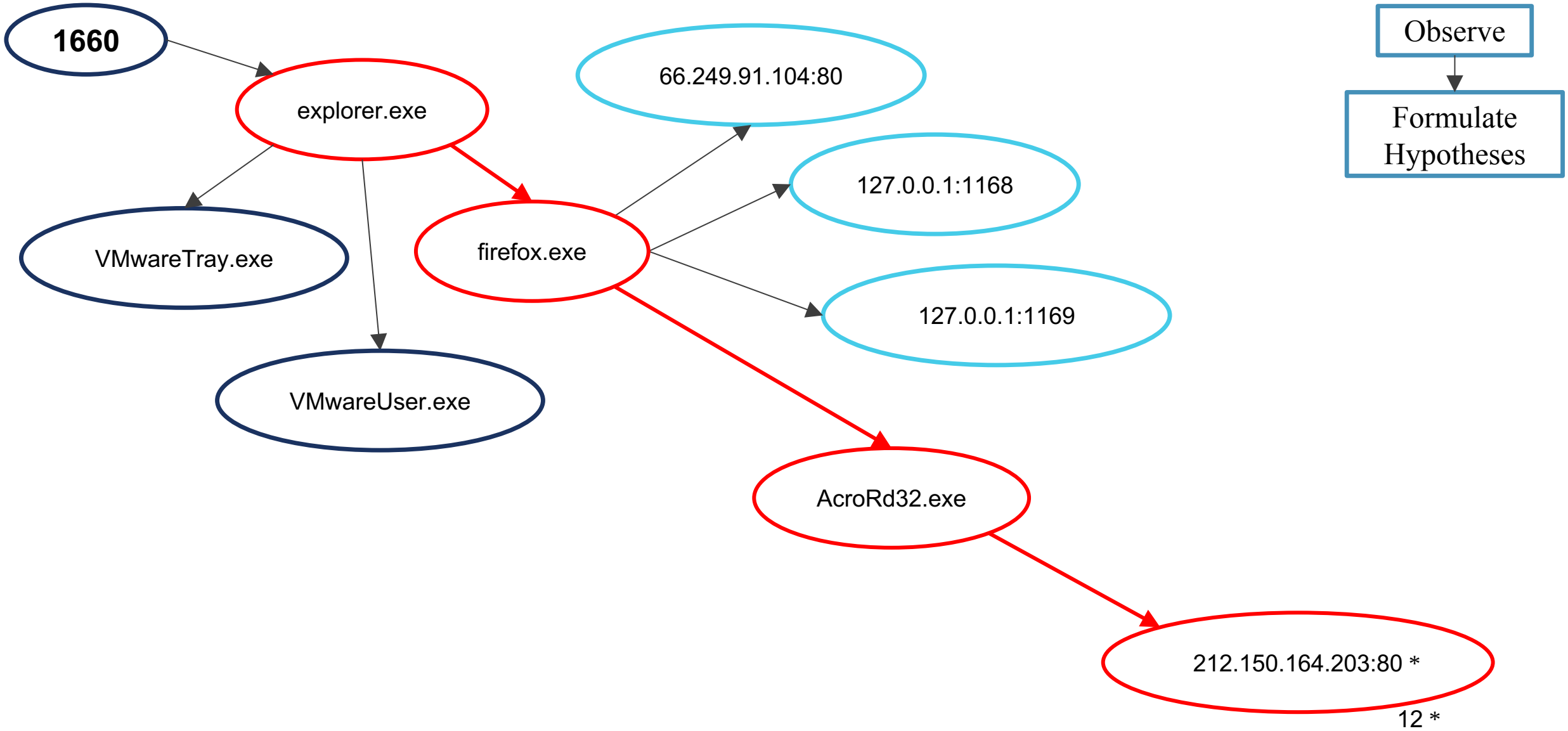
Observe

10 *

Formulate Hypotheses

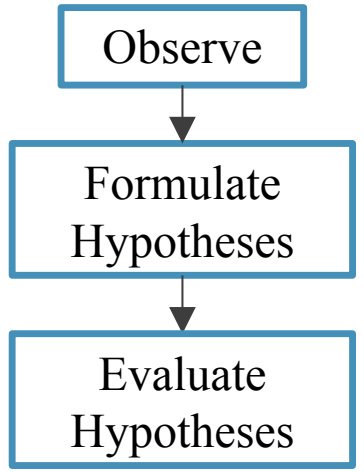


- Determine that hypothesis ***H*** is supported by a chain of evidence
- Graph traversal
- **Hypothesis**: X downloaded a file that made a network connection

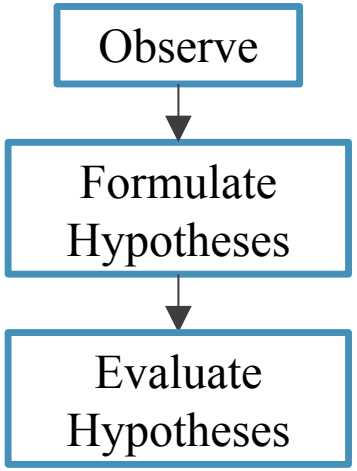

1660
explorer.exe
66.249.91.104:80
Observe
Formulate Hypotheses
VMwareTray.exe
firefox.exe
127.0.0.1:1168
127.0.0.1:1169
VMwareUser.exe
AcroRd32.exe
212.150.164.203:80 *
12 *

Evaluate Hypotheses

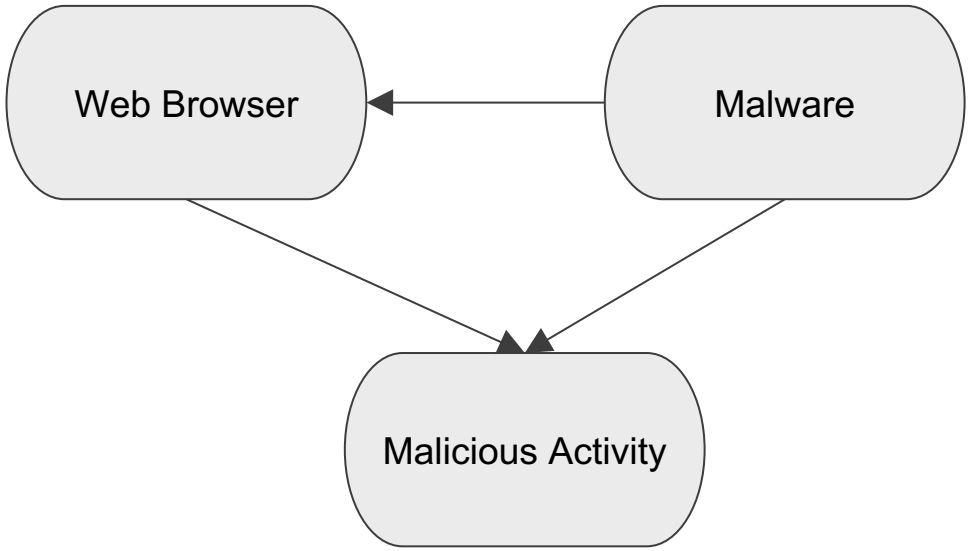
- Test abductive reasoning
- Reason about hypotheses
- Uncertainty
- Probabilistic approaches



Bayesian Network

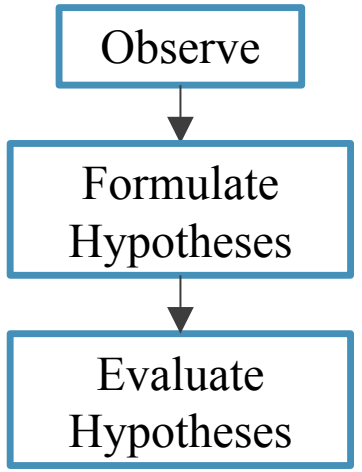


- Probabilistic graphical model
- Represent evidence & conditional dependencies via a DAG
- Compute probabilities



Bayes' Theorem

- A method to calculate the probability of a hypothesis



$$P(H|E) = P(H)\,P(E|H) / P(E)$$

likelihood ratio = **posterior probability** x **normalizing constant**

hypothesis prior probability

P(H): prior probability of hypothesis *H*

P(E): prior probability of evidence *E*

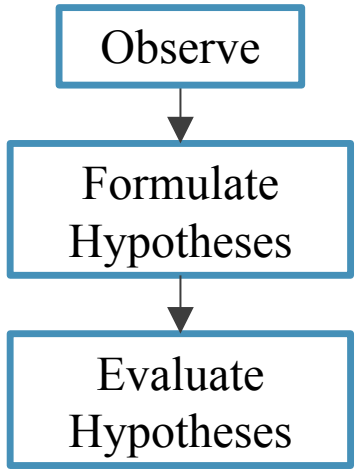
P(*H*|*E*): probability of *H* given *E*

P(*E*|*H*): probability of *E* given *H*

Building the Model

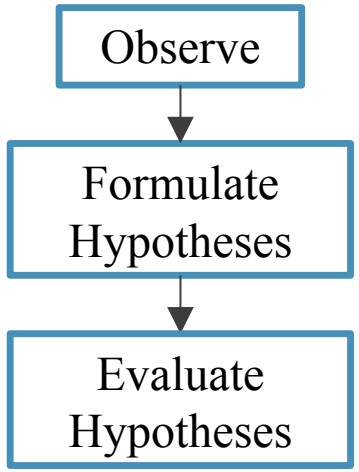
- H: User X downloaded a malicious file onto their computer

Node	State	P(H)
H	Yes	0.333
	No	0.333
	Uncertain	0.333



Determine Informative Prior Probabilities

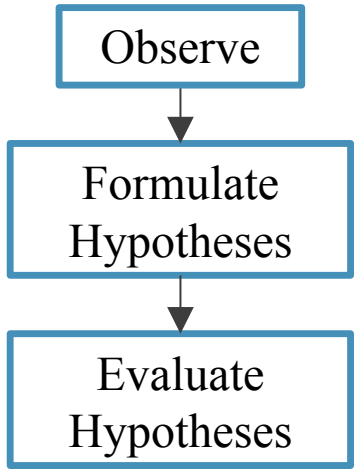
- Previous approaches have relied on uninformative priors
  - An investigator can determine priors
- Informative prior
  - Survey investigators to inform the priors
  - Probability mass function

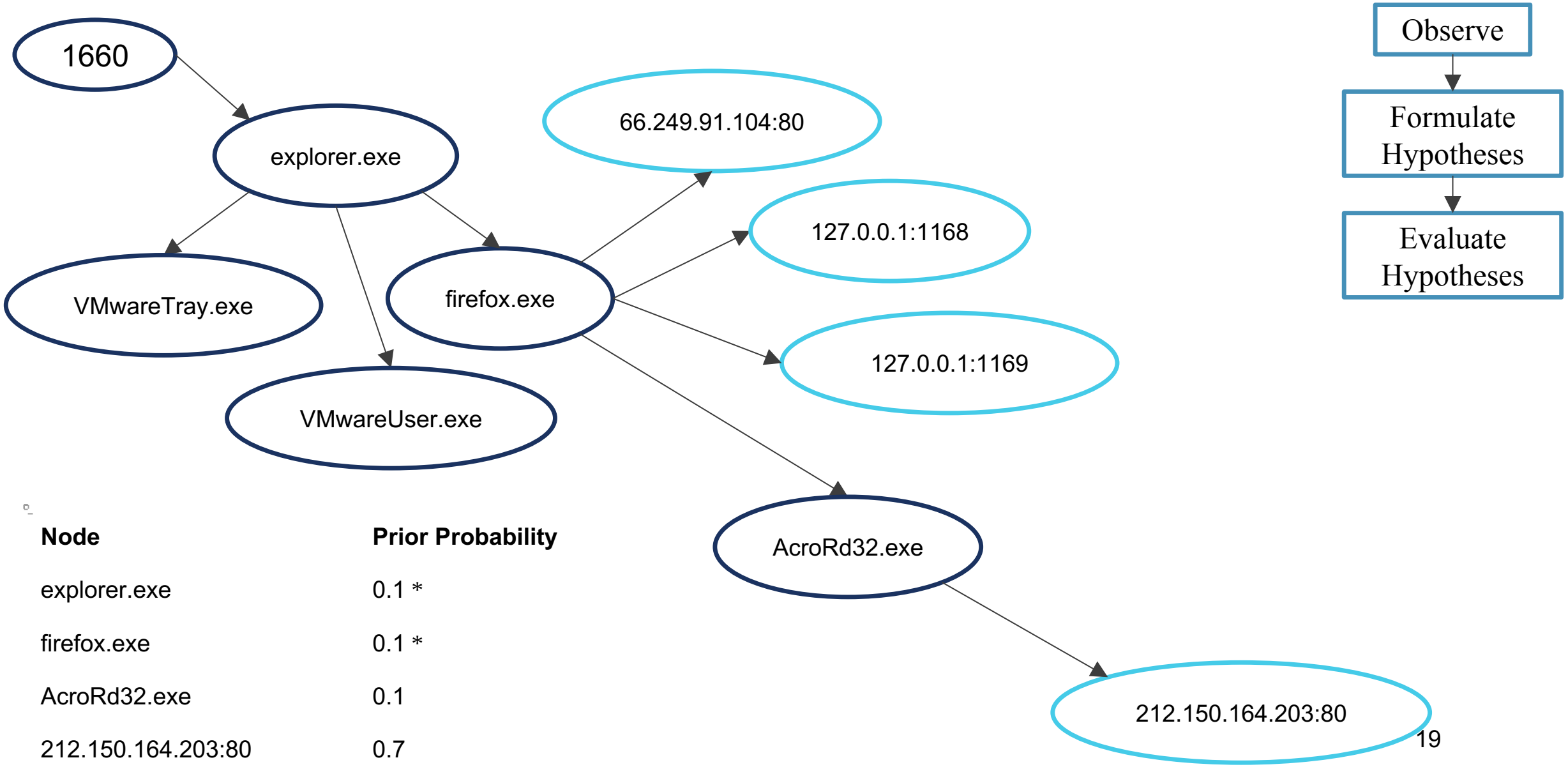


Informative Priors

- Degree distribution
- Probability mass function

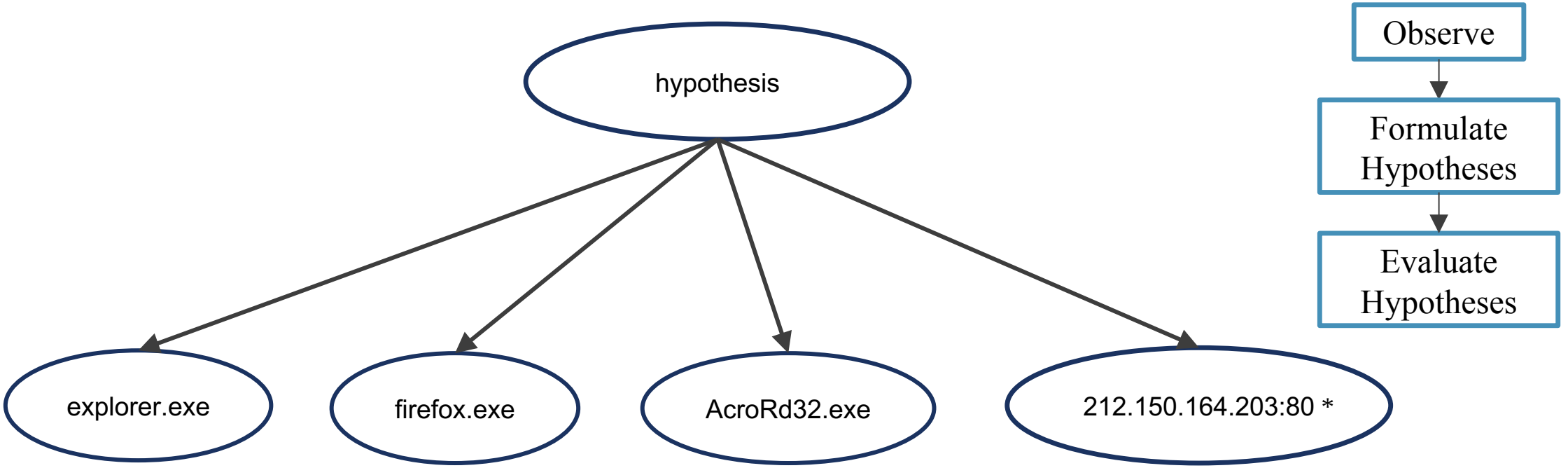
Degree	Degree Distribution	Probability
1	7	0.7
2	1	0.1
4	1	0.1
5	1	0.1



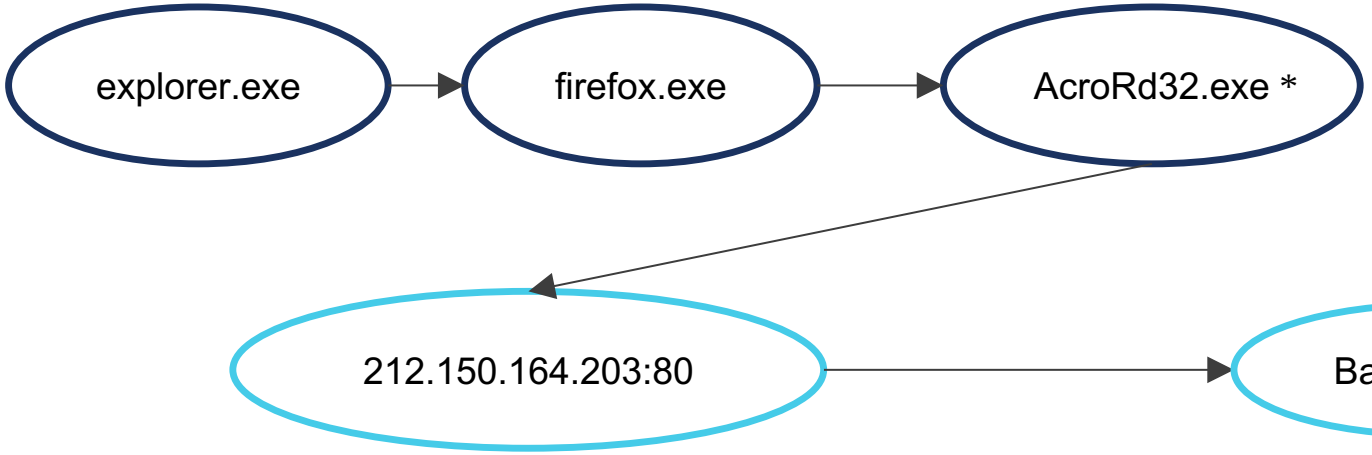


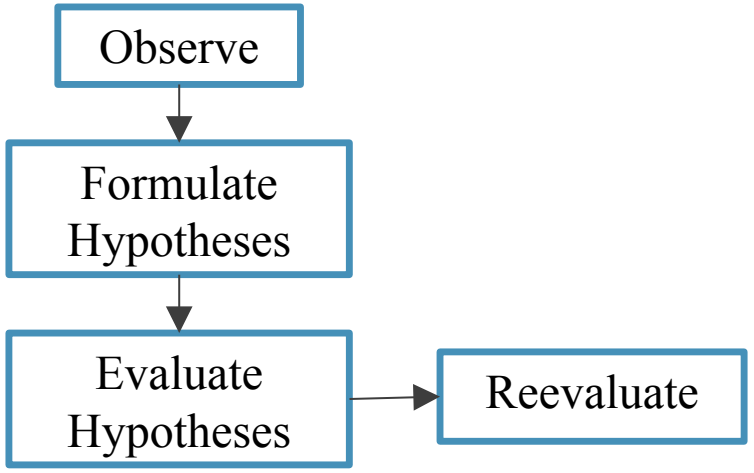
Node	Prior Probability
explorer.exe	0.1 *
firefox.exe	0.1 *
AcroRd32.exe	0.1
212.150.164.203:80	0.7

Evaluate Hypotheses



Yes	No	Uncertain
0.33050901	0.48902865	0.84046234

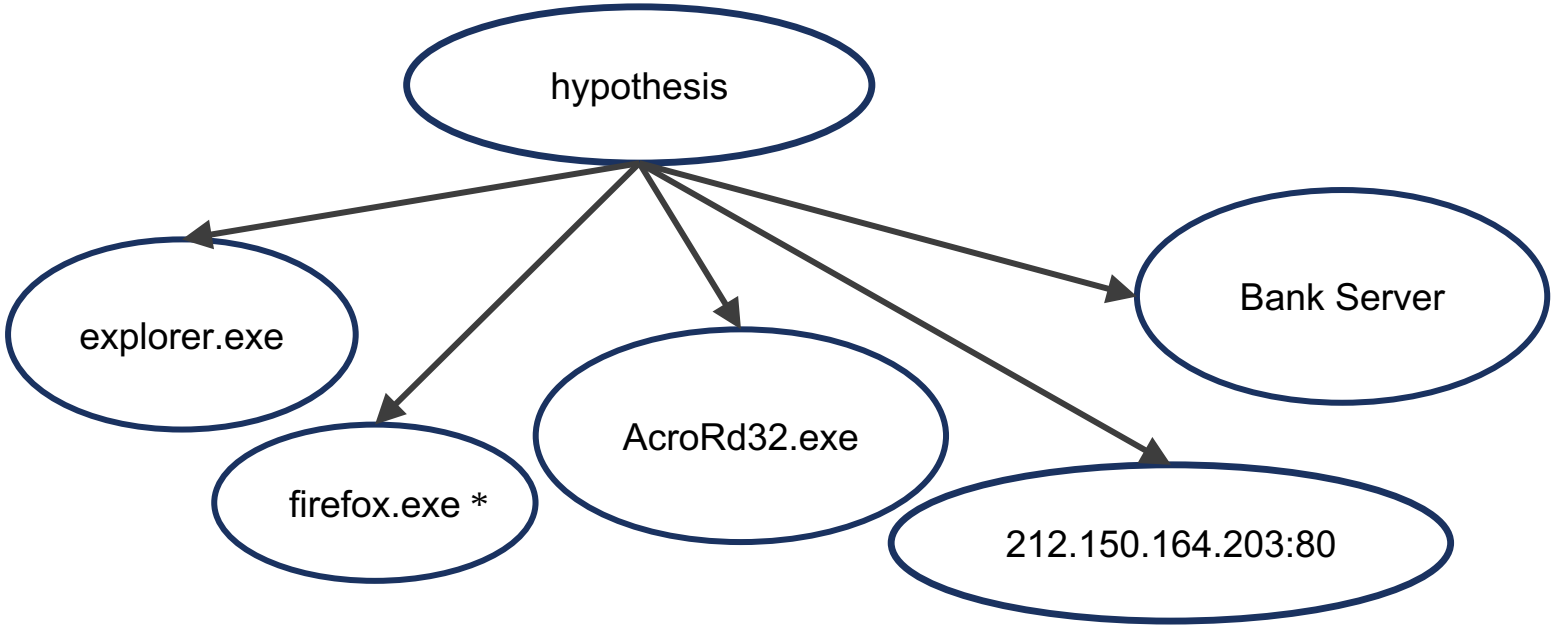


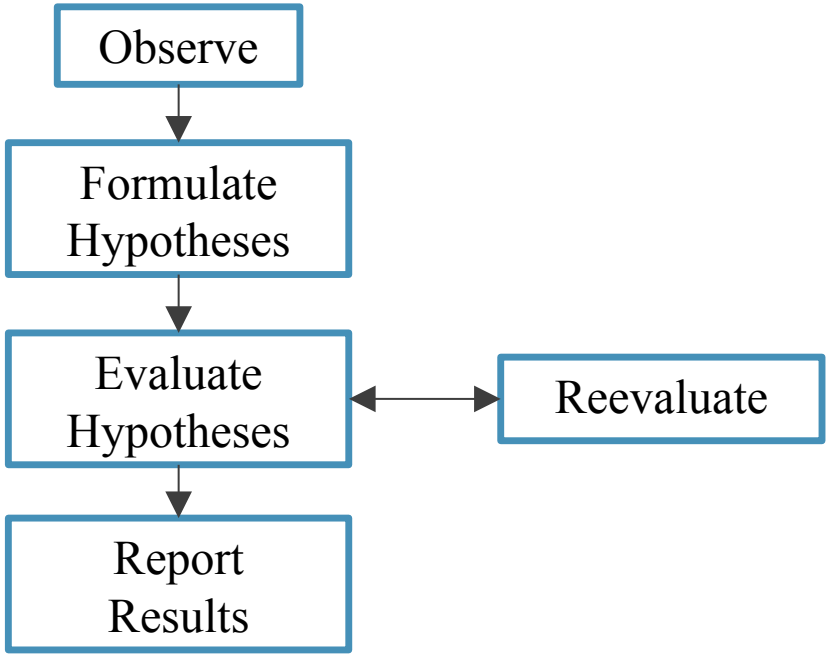


Degree	Degree Distribution	Probability
1	2	0.4
2	3	0.6

Node	Probability
explorer.exe	0.4
firefox.exe	0.6
AcroRd32.exe	0.6
212.150.164.203:80	0.6
Bank Server	0.6

Report Results





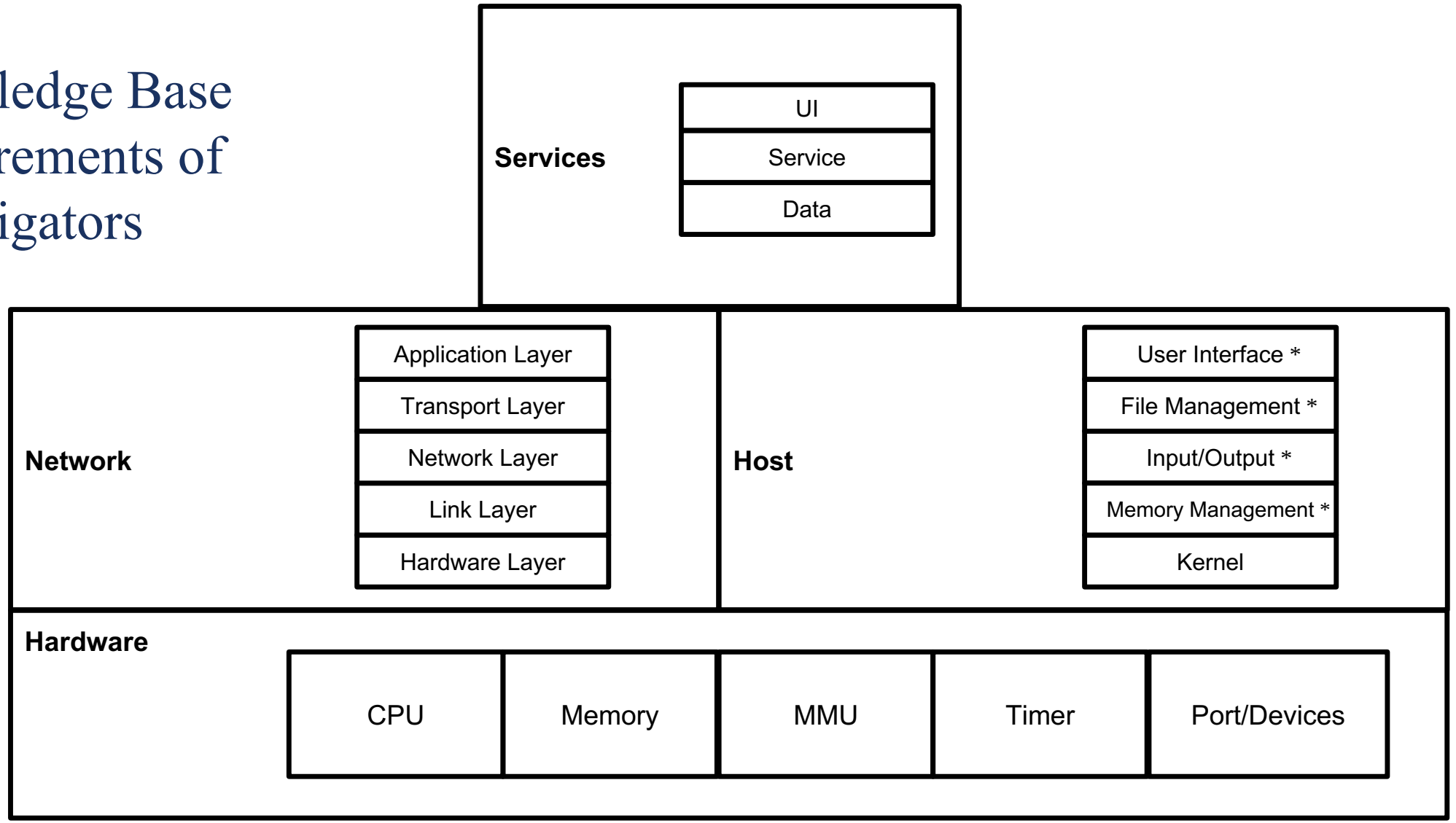
Yes	**No**	**Maybe** 8
0.63661017	0.46627119	0.55711864

Conclusion

- Digital forensic analysis is need of a reliable method
- Benefit from structure of mathematics, statistics & probability
  - Computer science research can assist the digital forensics community

Backup Slides

Knowledge Base Requirements of Investigators



Degree Distribution

- Degree of a node in a graph is the number of connections it has to other nodes
- Degree distribution is the probability distribution of these degrees over the graph
- Degree distribution P(k) of a graph is then defined to be the fraction of nodes in the graph with degree k
- If there are n nodes in total in a graph and n_k of them have degree k, we have $P(k)=n_k/n$

Probabilistic Mass Function

- A function that gives the probability that a discrete random variable is exactly equal to some value
- Primary means of defining a discrete distribution

Bayesian Network

- Probabilistic graphical model that represents a set of random variables and their conditional dependencies via a directed acyclic graph
- Edges represent conditional dependencies
- Nodes that are not connected represent variables that are conditionally independent of each other
- Each node is associated with a probability function that takes a set of values for the node's parent variables and gives the probability of variables represented by the node
- Attempt to alleviate the subjectivity in assigning prior probabilities through the probabilistic mass function

Normalizing Constant

- Reduce any probability function to a probability density function with total probability of one
- A constant by which an everywhere non-negative function must be multiplied so the area under its graph is 1