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Runtime Intrusion Diagnosis Under Uncertainty

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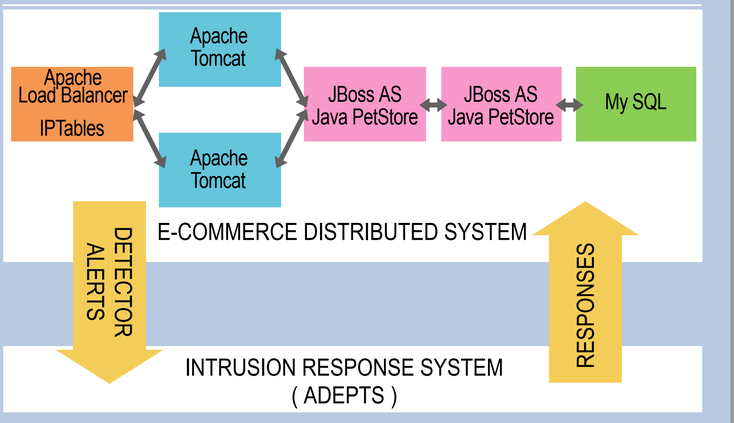
Problem Definition

- **What is diagnosis?**
  - To identify (in runtime) the services that have been affected by an attack
- **Complexity in distributed computing systems and imperfect knowledge of attacks**
- **Necessary to provide runtime diagnosis mechanisms to effectively build robust distributed systems**
- **Based on indeterministic and imperfect properties of systems**

Solution Approach

- **Use the bayesian network model to deal with imperfect detectors and incomplete knowledge base**
- **Organically grow the knowledge representation based on observed attacks**

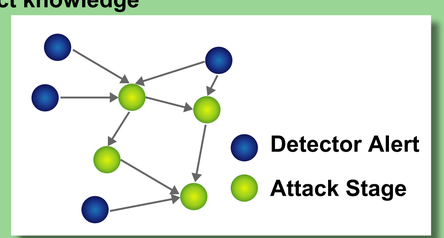
Sample Payload System



- **Web-based e-commerce three-tier server structure**
- **Attacks are performed against the e-commerce system**
- **An intrusion response system, called ADEPTS, provides diagnosis and response mechanism to thwart attacks**

Solution based on Bayesian Networks

- **Bayesian Networks are probabilistic directed acyclical graphs (DAGs) in which:**
  - Nodes represent random variables and
  - Edges represent conditional independence assumptions
- **Application to intrusion diagnosis (and consequential response) with imperfect knowledge**
- **Types of nodes:**
  - Detector Alerts (observed)
  - Attack stages (unobserved)

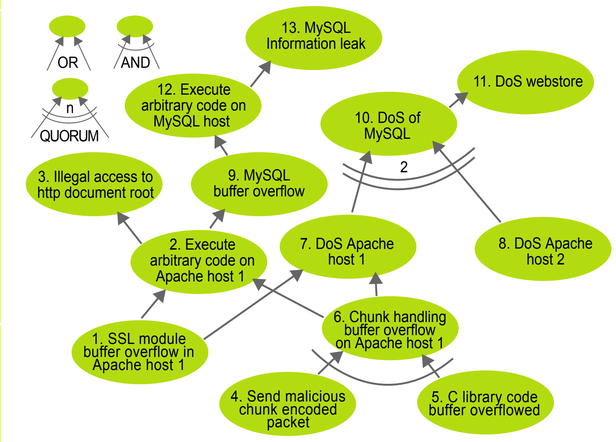


Testbed

- **Bayesian networks are created from**
  - dynamic multi-stage attack scenarios
  - related system detectors
- **Bayesian networks are simulated by using Matlab-based BNT toolkit**

I-Graph

- **Knowledge modeling of multi-stage attacks in the payload system for diagnosis purposes**
- **Each intrusion goal is represented by one node in the graph**
- **Intrusion goals have dependency relationships between one another**
- **Three types of edges**
  - Quorum, defines a minimum number of child nodes to be achieve in order to achieve its parent
  - OR, at least one child node
  - AND, all child nodes

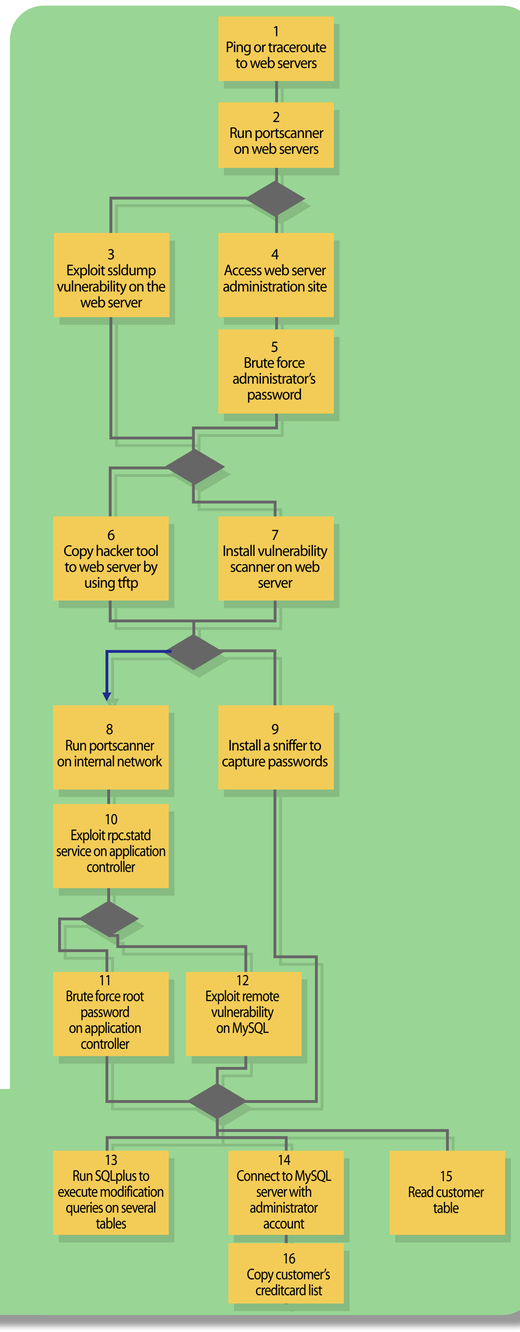


Solution based on I-Graph

- ***Compromised Confidence Index (CCI)***
  - A computation algorithm developed to determine probability of which I-Graph nodes have been achieved
  - Each detector has a confidence value for its alerts
  - A candidate mathematical formulation for the CCI of a node is

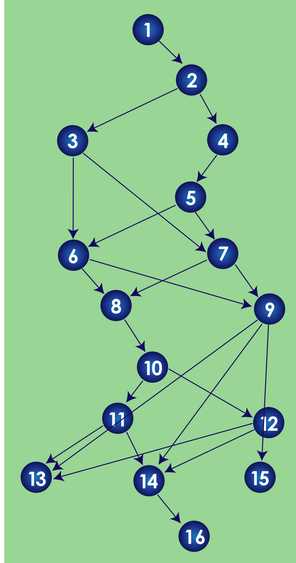
$$CCI = \begin{cases} alertconfidence & \text{,no child} \\ f'(CCI_i) & \text{,no detector } f' = \\ f(f'(CCI_i, alertconf.) & \text{,otherwise} \end{cases} \begin{cases} \max(CCI_i) & \text{,OR edge} \\ \min(CCI_i) & \text{,AND edge} \\ mean(CCI_i) \mid (CCI_i > \tau) & \text{, Quorum edge and quorum met} \\ o & \text{, Quorum edge and quorum not met} \end{cases}$$

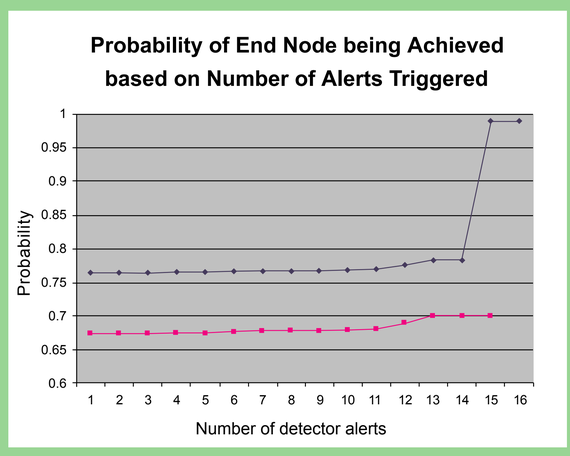
where CCI_i corresponds to the CCI of the i^{th} child and is a per node threshold



Sample Results for Scenario 1

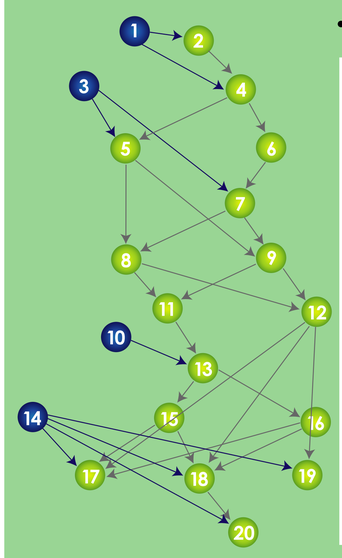
- **All attack nodes have (perfect) detectors**

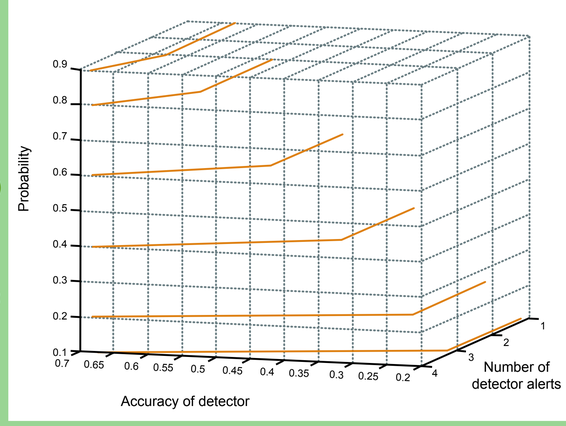




Sample Results for Scenario 2

- **Some attack nodes have (imperfect) detectors**





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