Attacks

ECS 153 Spring Quarter 2021

Module 6

Attacks

- *Attack*: a sequence of actions creating a violation of a security policy
  - *Multistage attack*: attack requiring several steps to achieve its goal
- *Goal of the attack*: what the attacker hopes to achieve
- *Target of the attack*: entity that the attacker wishes to affect
- Example: burglar stealing someone's jewelry
  - *Attack*: what she does to steal the jewelry; probably *multistage* (break window, find jewelry box, break it open, take jewelry, get out of house)
  - *Goal of the attack*: steal the jewelry
  - *Target of the attack*: the jewelry, also the owner of the jewelry

Representing Attacks

- Can be done at many levels of abstraction
- As you go deeper, some steps become more detailed and break down into multiple steps themselves
- *Subgoal*: the goal of each step to move the attacker closer to the goal of the attack

Example: Penetration of Corporate Computer System

- Goal: gain access to corporate computer system
- Procedure was to try to get people to reveal account information, change passwords to something the attackers knew
  - Target: newly-hired employees who hadn’t had computer security awareness briefing
  - Subgoal 1: find those people
  - Subgoal 2: get them to reveal account info, change passwords

Focus on Subgoal 1

- For subgoal 1, needed to find list of these people
  - Subgoal 1-1: learn about company's organization
- Procedure was to get annual report (public), telephone directory (not public)
  - Subgoal 1-2: acquire the telephone directory (this required 2 numbers)
  - Subgoal 1-3: get the two numbers (only available to employees)
  - Subgoal 1-4: impersonate employees
- Had corporate controls blocked attackers from achieving subgoal, they would need to find other ways of doing it

Attack Trees

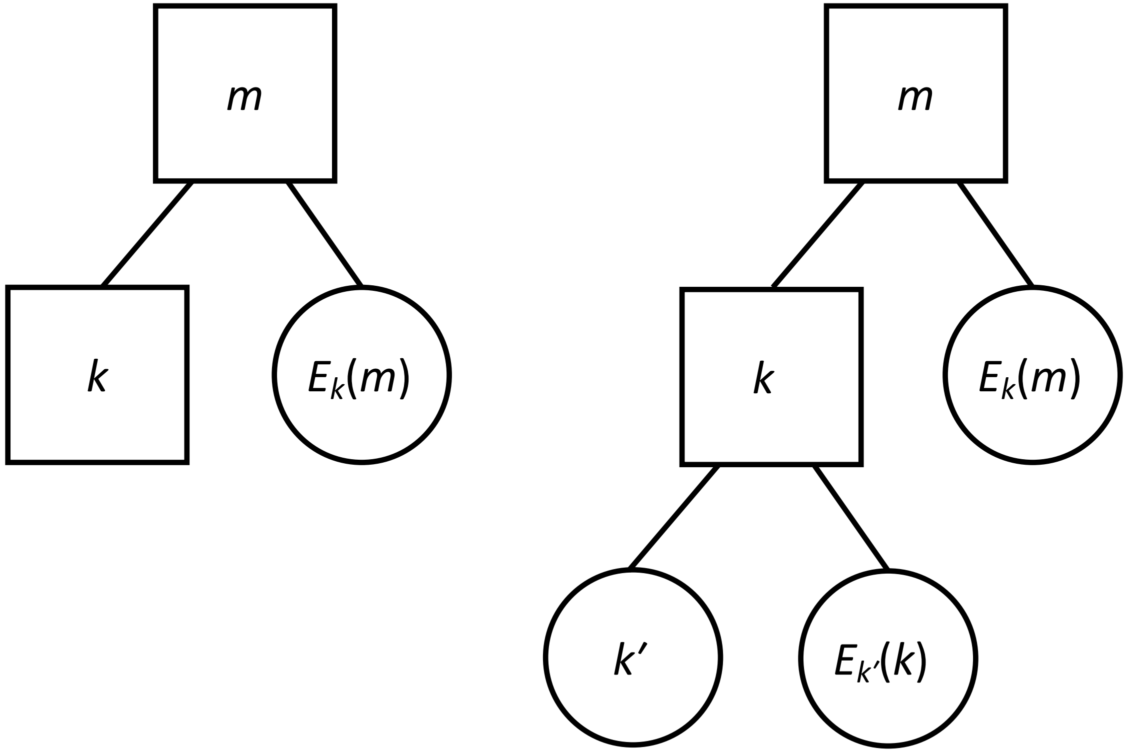
- Represent the goals and subgoals as a sequence of hierarchical nodes in a tree
  - Goal is the root

Security Flaws in Cryptographic Key Management Schemes

- Goal: develop package to allow attackers to ask what data is needed to determine encryption key
- System has only 2 functions, $E_k(m)$ and $D_k(c)$
- Attack ("search") tree has the required information represented as root node, other nodes represent subgoals
- 2 types of nodes
  - Required: represents information necessary for parent; *satisfied* when that information becomes available
  - Available: represents known information
- As tree constructed, find leaf nodes that are required (using breadth-first search), construct additional layer

Example

- Assume Sage knows $E_k(m)$, $E_{k'}(k)$, k'
  - Nodes for these are available nodes
- Goal: determine m
  - Node representing m is required node
- Tree construction:
  - To get m, use k to decrypt $E_k(m)$ (left tree)
  - To get k, determine if it is encrypted and if so, try to decrypt it (right tree)
- Now all leaves are available nodes



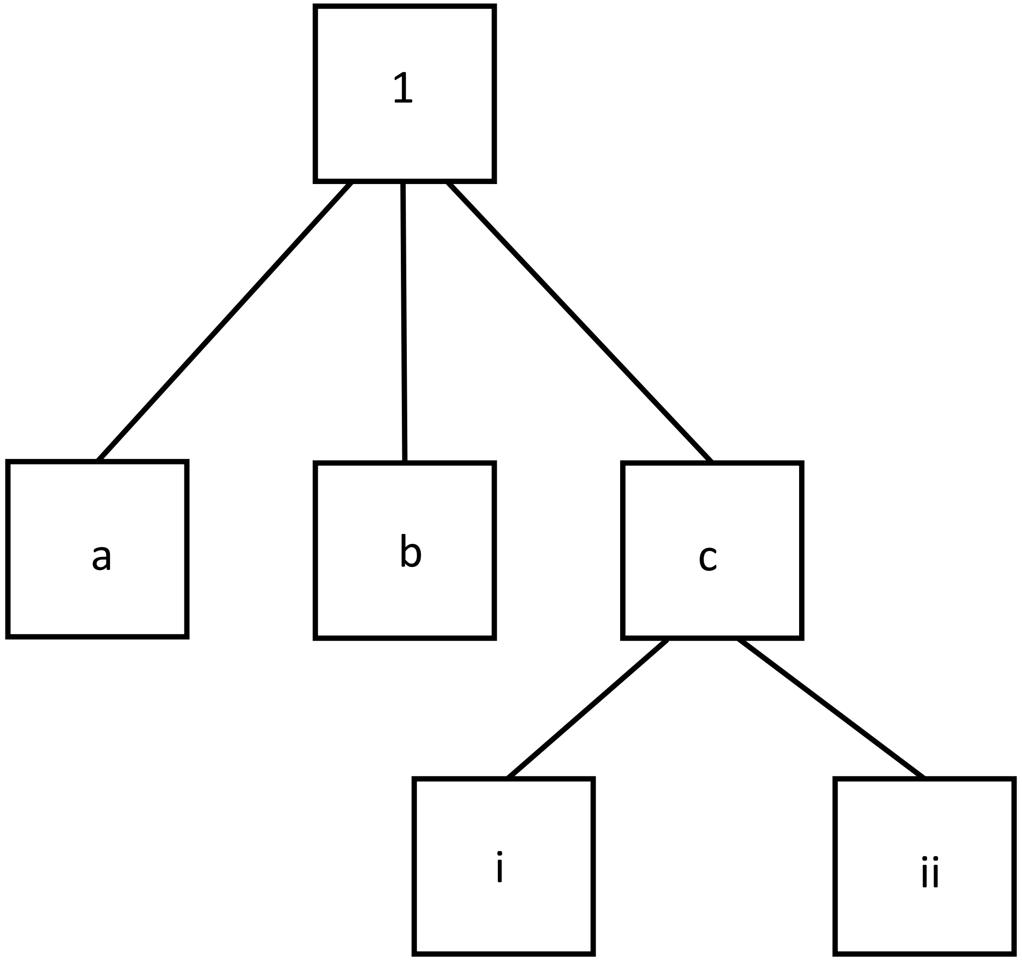
Schneier's Attack Trees

- Two types of nodes
  - *And* nodes require all children to be satisfied before it is satisfied
  - *Or* nodes require at least 1 of its children to be satisfied before it is satisfied
  - *Weight* of node indicates some relevant characteristic, like difficulty of satisfying node
    - Weights of interior nodes depend upon weights of child nodes
    - Weights of leaf nodes assigned externally
- Goal represented as root node of set of tree
- Determine the steps needed to satisfy the goal
  - These become children of the root
- Repeat that step for each child
  - Stop when leaf nodes are at appropriate level of abstraction

Example: Reading PGP-Encrypted Message

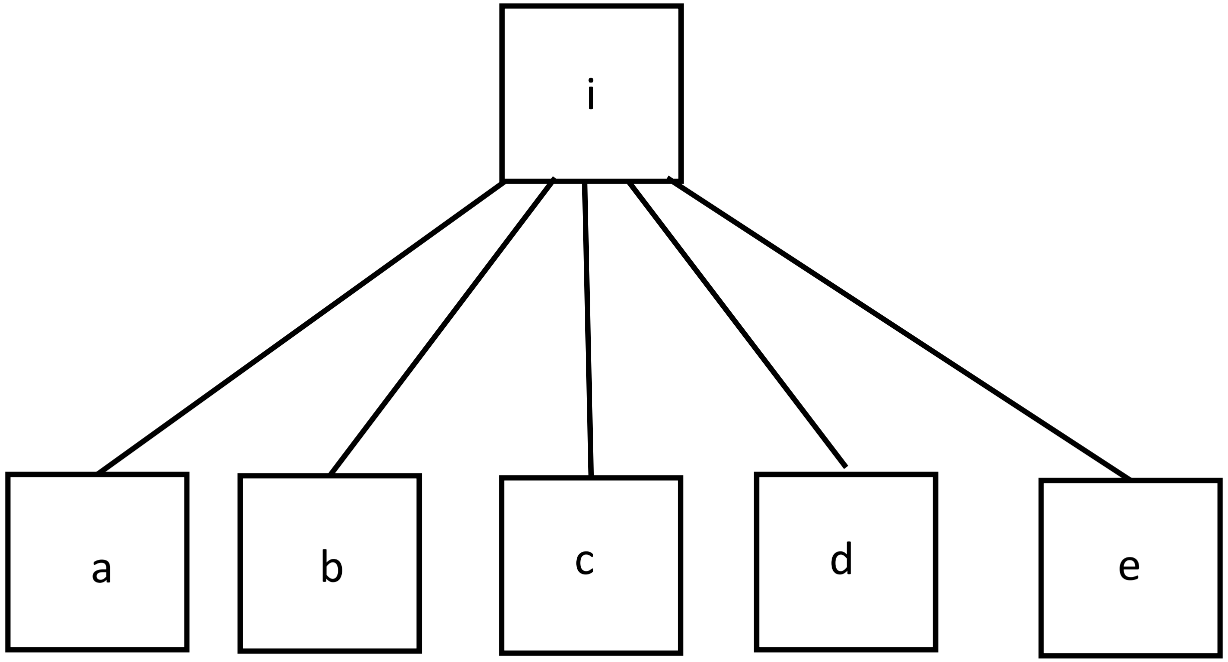
- Sage wants to read message Skyler sends to Caroline
- Five ways:
  1. Read message before Skyler encrypts it
  2. Read message after Caroline decrypts it
  3. Break encryption used to encrypt message
  4. Determine symmetric key used to encrypt message
  5. Obtain Caroline’s private key
- Focus on 2, read message after Caroline decrypts it

Beginning the Tree



1. Read message after Caroline decrypts it
   a. Monitor Caroline's outgoing mail; or
   b. Add a "Reply-To:" header (or change an existing one); or
   c. Compromise Caroline's computer and read the decrypted message
      i. Compromise Caroline's computer; and
      ii. Read the decrypted message

Next Layer



i. Read message after Caroline decrypts it
   a. Copy decrypted message from memory; or
   b. Copy decrypted message from secondary storage; or
   c. Copy decrypted message from backup; or
   d. Monitor network to observe Caroline sending the plaintext message; or
   e. Use a Van Eyk device to monitor the display of the message on Caroline's screen as it is displayed there

Textual Representation

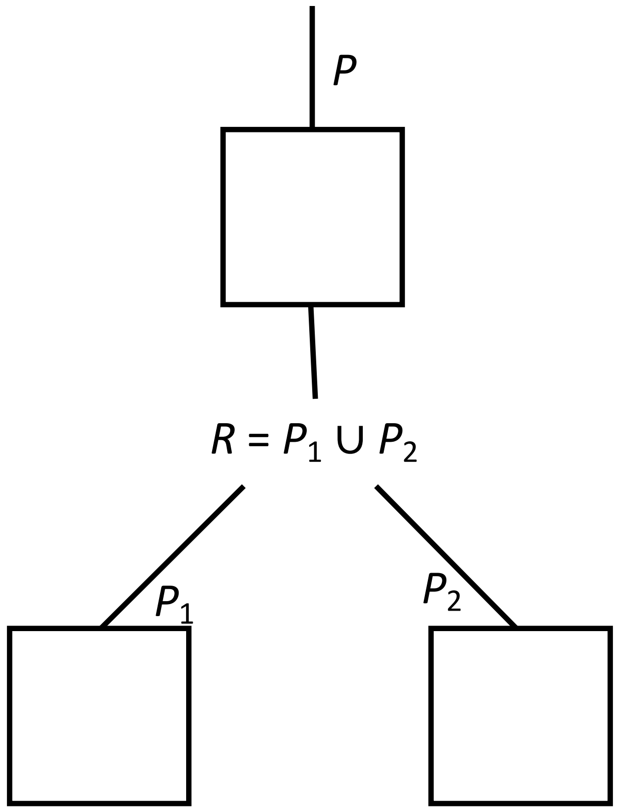
1. Read a message that Skyler is sending to Caroline. (OR)
    1.1. Read the message before Skyler encrypts it.
    1.2. Read the message after Caroline decrypts it. (OR)
        1.2.1. Monitor Caroline's outgoing mail.
        1.2.2. Add a "Reply-To" field to the header (or change the address in the existing "Reply-To" field).
        1.2.3. Compromise Caroline's computer and read the decrypted message. (AND)
            1.2.3.1. Compromise Caroline's computer. (OR)
                1.2.3.1.1. Copy decrypted message from memory.
                1.2.3.1.2. Copy decrypted message from secondary storage.
                1.2.3.1.3. Copy decrypted message from backup.
                1.2.3.1.4. Monitor network to observe Caroline sending the cleartext message.
                1.2.3.1.5. Use a Van Eck device to monitor the display of the message on Caroline's monitor as it is displayed.
            1.2.3.2. Read the decrypted message.
    1.3. Break the encryption used to encrypt the message.
    1.4. Determine the symmetric key used to encrypt the message.
    1.5. Obtain Caroline's private key.

Requires/Provides Model

- Generalization of attack trees
- Based on *capabilities*, semantic objects encapsulating semantically typed attributes
  - Represent information or a situation to advance an attack
- *Concept* is a set C of capabilities and a mapping from C to another set of capabilities that are provided
  - Description of subgoal of attack
  - Attacker has a set of *required* capabilities R to reach subgoal; it then acquires a set P of provided capabilities

Concept

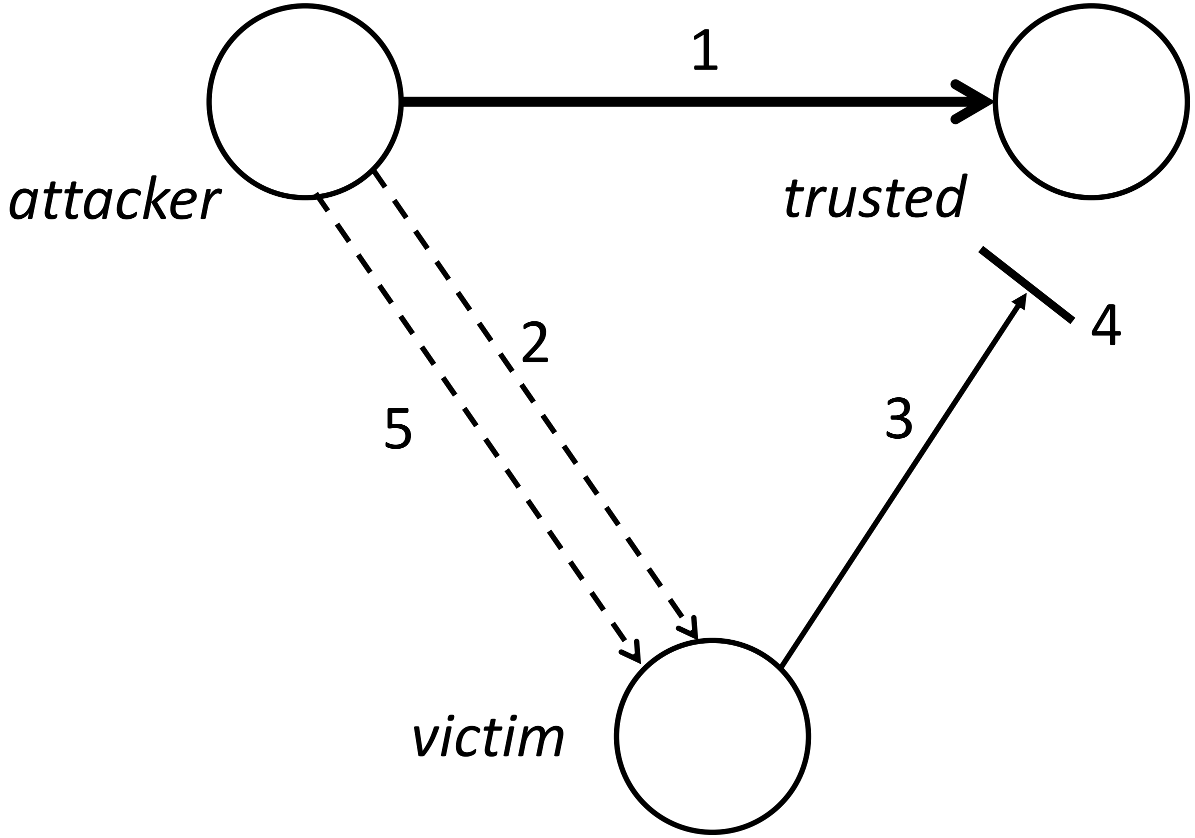
- *Concept* is a set *R* of capabilities and a mapping from *R* to another set *P* of capabilities that are provided
  - Description of subgoal of attack
- Interpretation: attacker has a set of *required* capabilities *R* to reach subgoal; it then acquires a set *P* of *provided* capabilities



Concept

- Captures *effect* of attack
  - How the attack works (ie, how capabilities are required) irrelevant to concept; that attacker has them is what matters
- Moves away from having to know every method of attack to get to a step
  - Concept embodies the step, so all model needs is required capabilities
- Can compose attacks based solely on effects and not methods of attack

Example: *rsh* Attack



1. *attacker* launches a DoS against *trusted*
2. *attacker* sends *victim* forged SYN, apparently from *trusted*
3. *victim* sends SYN/ACK to *trusted*
4. It never gets there due to DoS
5. *attacker* sends forged SYN/ACK to *trusted*, with command in data segment of packet
   - Need to know right sequence number
   - If so, causes command to be executed as though *trusted* requested it

Example: *rsh* Attack

- *Requires* capability: blocking of a connection between the *trusted* and *victim* hosts
  - Contains source address, destination address
  - Also time interval indicating when communication is blocked (ie, when the DoS attack is under way, and how long it lasts)
- *Provides* capability: execute command on *victim* host as if command were from *trusted* host
- *Concept*: spoof *trusted* host to *victim* host

JIGSAW Language

- Implements requires/provides model
- Capabilities: sets of typed attributes and values
  - **`extern`** keyword means it is defined elsewhere
- Concepts: two sets of capabilities
  - Required capabilities in **`requires`** block
  - Provided capabilities in **`provides`** block
  - **`action`** block lists actions to take when a concept is active

Example: JIGSAW Representation of *rsh* Attack

```
capability nosend is
      true_src, src, dst: type Host; # attacker, trusted, victim
      using: type Service;           # service to be exploited
end.
```

Structure of a capability:

- *using* is command to be executed, exploiting a service (here, *rsh*)

Example: JIGSAW Representation of *rsh* Attack

```
concept rsh_connection_spoofing is
      requires
            TP: type Trusted_Partner;        #- trusted host
            SA: type Active_Service;         #- service (here, rshd)
            PPS: type Prevent_Packet_Send;
            FPS: type Forged_Packet_Send;
            extern SNP: type SeqNumProbe;
```

PPS: capability for *true_src* to block *src* host receiving packets from *dst*

FPS: capability for *true_src* to send forget packet to *dst*

SNP: capability for *true_src* to determine next sequence number of *dst*

Example: JIGSAW Representation of *rsh* Attack

```
with          #- These instantiate the capabilities
      TP.service is RSH,        #- service is RSH
      PPS.host is TP.trusted,         #- blocked host = trusted host
      FPD.dst.host is TP.trustor,     #- spoofed packets go to host
                                      #-  trusting TP
      FPS.src is [PPS.host, PPS.port], #- apparent source of forged
                                      #-  packets is blocked
      SNP.dst is [SA.host, SA.port],  #- probed host must be
      SA.port is TCP/RSH,             #-  running RSH on usual port
      SA.service is RSH,
      SNP.dst is FPS.dst              #- forged packets go to probed
      active(FPS) during active(PPS)  #-  host while DoS of trusted
                                      #-  host is active
```

Example: JIGSAW Representation of *rsh* Attack

To meet **`requires`** conditions, relationships in **`with`** block must hold:

- Trusted host must be running *rsh* servicve
- Attacker must be able to block trusted host from sending packets to victim
- Attacker must be able to send spoofed packets ostensibly from trusted host to victim
- Attacker must know sequence number of packet victim sends to trusted host
- When attack on victim is being carried out, attack on trusted host must also be active

Example: JIGSAW Representation of *rsh* Attack

```
requires
      PSC: type push_channel;
      REX: type remote_execution;
```

PSC: capability to send code, commands to *dst*

REX: capability to execute that code, commands on *dst*

Example: JIGSAW Representation of *rsh* Attack

```
with         #- These set the new capabilities
      PSC.src <- FPS.true_src,          #- capability to move code from
      PSC.dst <- FPS.dst,               #-  attacker to rsh server
      PSC.true_src <- FPS.true_src,     #-  (victim)
      PSC.using <- rsh;
      REX.src <- FPS.true_src,          #- capability to execute code,
      REX.dst <- FPS.dst,               #-  commands on rsh server
      REX.true_src <- FPS.true_src,     #-  (victim)
      REX.using <- rsh;
end;
action
      true -> report("rsh connection spoofing: " + TP.hostname)
end;
```

Example: JIGSAW Representation of *rsh* Attack

- When all conditions in **`requires`** block satisfied, concept *rsh_connection_spoofing* is realized
- Attacker gets capabilities defined in **`provides`** section
  - Here, *PSC* and *REX* capabilities
- Events in **`action`** block executed
  - Here, message is printed to alert observer an *rsh* spoofing attack under way

Attack Graphs

- Describe attacks in terms of a general graph
  - Generalization of attack trees
- Used to represent attacks, detect attacks, guide penetration testing

Attack Graph and Penetration Testing

Here attack graph is a Petri net

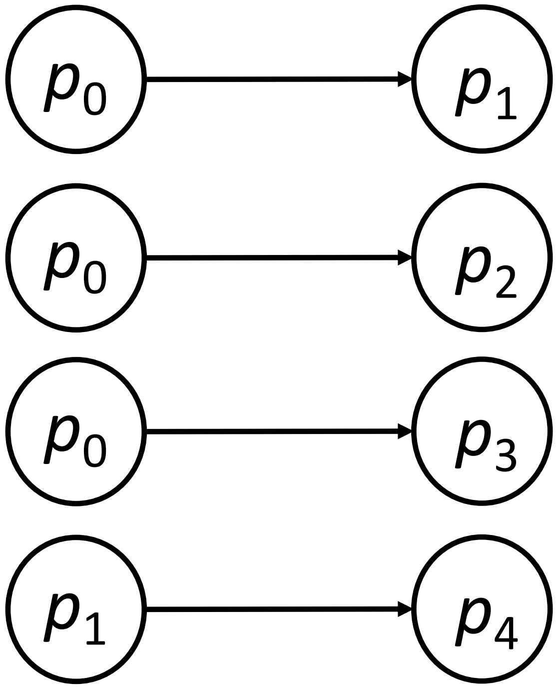
- Nodes $P = \{ p_1, ..., p_n \}$ states of entities relevant to system under attack
- Edges $T = \{ t_1, ..., t_m \}$ transitions between states
- Token on a node means attacker has appropriate control of that entity
- Tokens move to indicate progress of attack
- If node p_i precedes node p_j, attacker must get control of p_i before it can get control of p_j

Attack Graph and Penetration Testing

- McDermott: hypothesize individual flaws as 2 nodes connected by transition; then examine nodes for relationships that allow them to be linked

Attack Graph and *rsh* Attack

- First steps in attack:



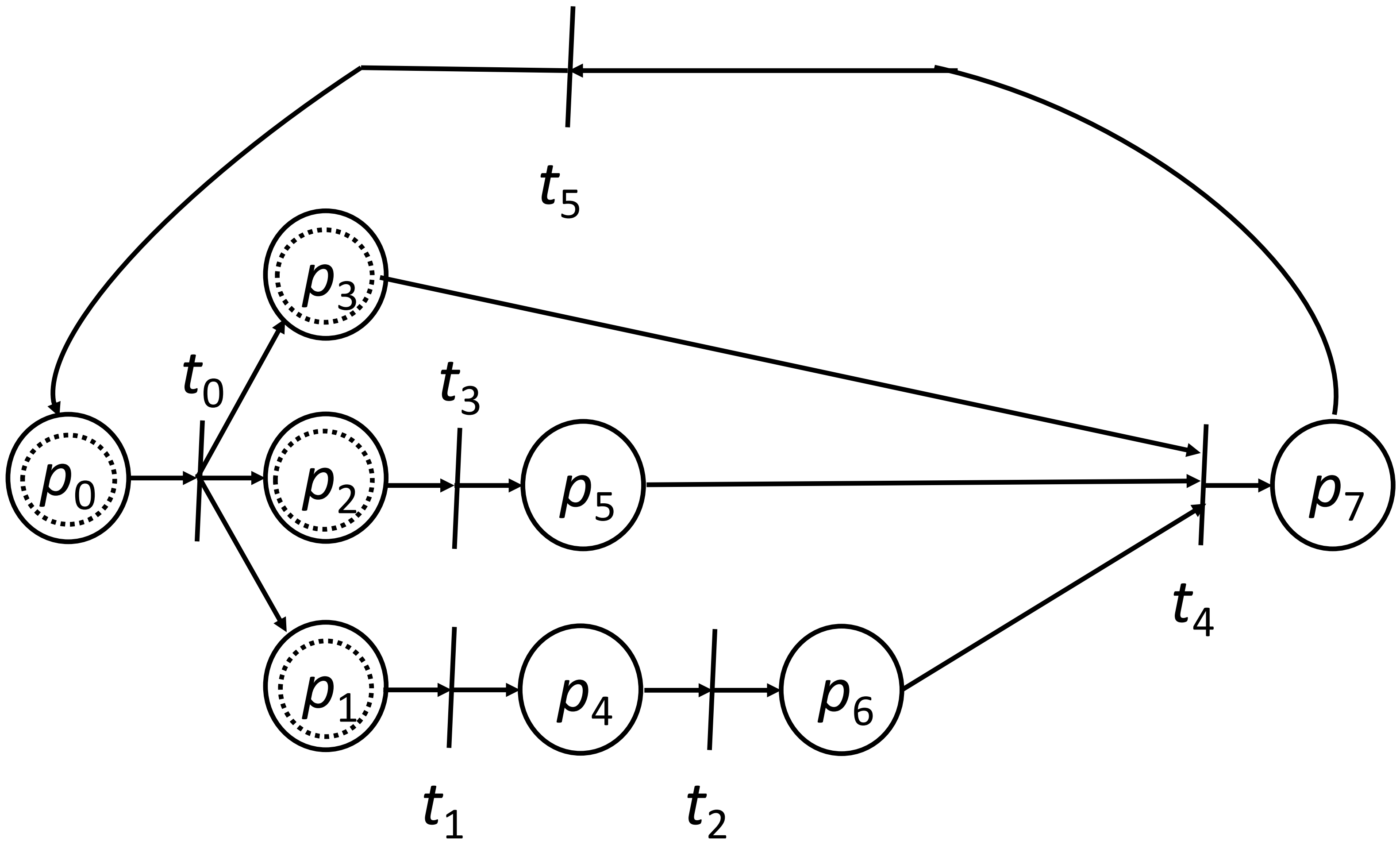
Initial scan of target

Identify an unused address

Establish that target trusts another host

Forge SYN packet

Attack Graph and *rsh* Attack



Petri net represents *rsh* attack

1. Before attack
2. After attack

Attack Graph and *rsh* Attack

States

- p_0: starting state
- p_1: found unused address on target network
- p_2: found trusted host
- p_3: found target that trusts the trusted host
- p_4: forged SYN packet created
- p_5: able to predict TCP sequence numbers of target host
- p_6: saturated state of network connections of trusted host
- p_7: final (compromised) state

Transitions

- t_0: attacker scanning system (splits into 3 transitions)
- t_1: attacker creating forged SYN packet
- t_2: attacker launching SYN flood against trusted host
- t_3: attacker figuring out how to predict victim's TCP sequence numbers
- t_4: forged SYN packet created
- t_5: attacker modifying trusted host file on victim
  - Attacker can now get *root* access on victim

Attack Graph and *rsh* Attack

- Attack starts at p_0
- t_0 splits into 3 transitions, as on success, 3 states of interest
- Need to instantiate all 3 states:
  - p_1: find unused address on target
  - p_2: find trusted host
  - p_3: find target that trusts trusted host
- t_1 is creating forged SYN packet
  - Transition from p_1 to p_4
- t_2 is attacker launching SYN flood (DoS) against trusted host
  - Transition from p_4 to p_6

Attack Graph and *rsh* Attack

- t_3: attacker figuring out how to predict victim's TCP sequence numbers
  - Transition from p_2 to p_4
- t_4: attacker launches attack using entities above
  - Transition from p_3, p_5, and p_6 to p_7
- t_5: attacker executes command
  - Example: modifying trusted hosts file to be able to get *root*