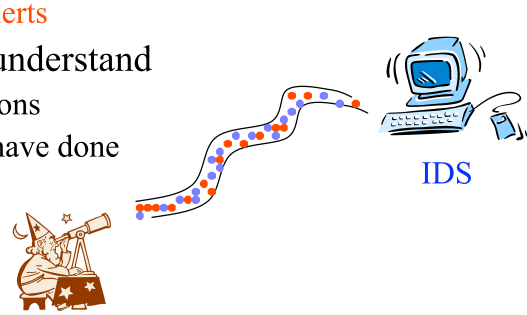
NC STATE UNIVERSITY Computer Science

CSC 774 Network Security

Topic 5.2 Hypothesizing and Reasoning About Attacks Missed by IDSs

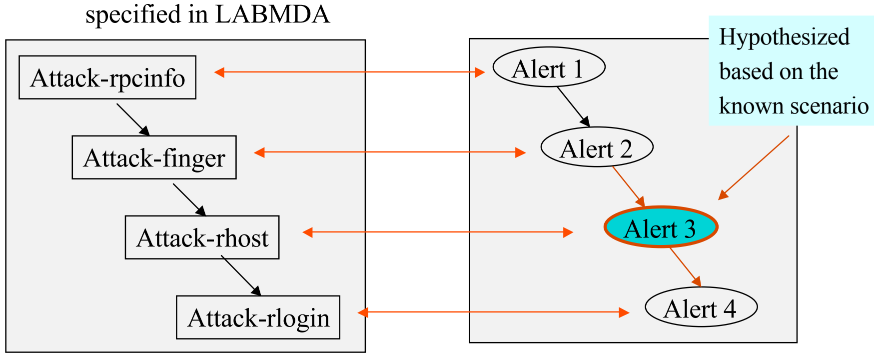
Background

- Intrusion detection forms the second line of defense
- But current Intrusion Detection Systems (IDSs) are still not perfect
  - False negatives (missed attacks)
  - False positives (false alerts)
  - Large numbers of alerts
- It is challenging to understand
  - What are the intrusions
  - What the intruders have done



Background (Cont'd)

- A common problem of most existing alert correlation methods
  - Cannot handle missed attacks.
- Abductive correlation [Cuppens and Miege 2002]
  - Hypothesis of missed attacks are guided by known attack scenarios specified in LABMDA



Known scenario

Correlated alerts

Our Contributions

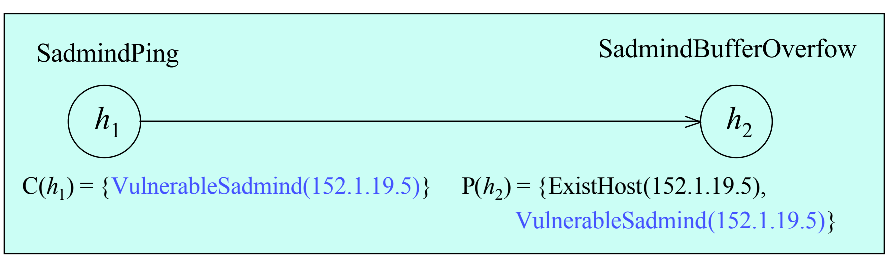
- A framework to automatically hypothesize and reason about missed attacks based on knowledge about individual attacks
  - Hypotheses of missed attacks
  - Inference of attack attributes
  - Validation of hypothesized attacks
  - Consolidation of hypothesized attacks
- Prototype implementation and initial experimental evaluation of this approach

Outline

- A series of techniques to hypothesize and reason about attacks missed by IDSs
  - A naïve approach
  - Type graph guided hypothesis
  - Inferring the attribute values of hypothesized attacks
  - Validation/pruning through raw audit data
  - Consolidation of hypothesized attacks
- Experimental results
- Conclusion and future work

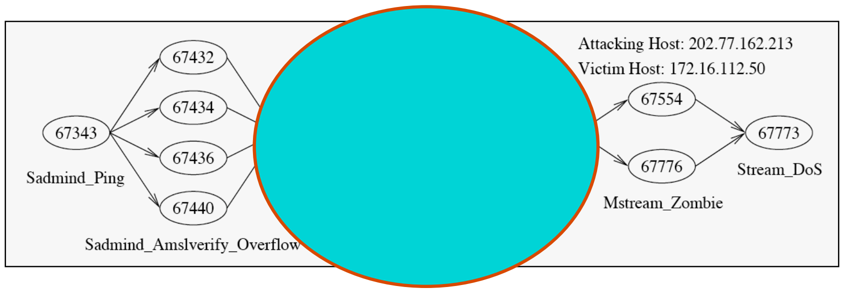
Previous Work: Correlation Based on Prerequisites and Consequences of Attacks

- Model
  - Hyper-alert type: represent our knowledge as prerequisites and consequences of attacks
  - Hyper-alert: an instance of a hyper-alert type; instantiated from IDS alerts
  - An earlier hyper-alert *prepares for* a later one if the former makes the later easier to be successful



Previous Work (Cont'd)

- An example hyper-alert correlation graph
  - Would be split into multiple graphs if critical attacks are missed by the IDSs

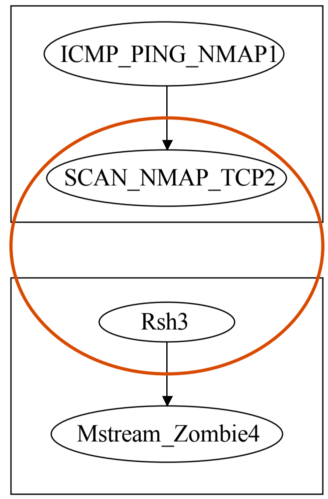


Naïve Approach

- Integrate complementary correlation methods
  - Clustering correlation methods
    - Based on the similarity between alert attribute values
    - May still cluster related alerts even if critical attacks are missed
    - Unable to discover the causal relationships between alerts
  - Causal correlation methods
    - Based on prerequisites and consequences of attacks
    - May discover the causal relationships between alerts
    - Don't work if critical attack steps are missed

Naïve Approach (Cont'd)

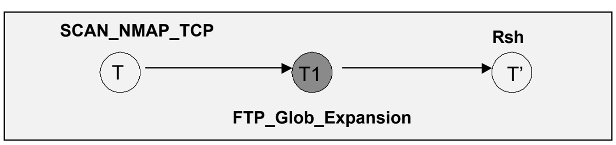
- Put multiple attack scenarios together if the clustering correlation method says they are similar
- But …
  - How about the possible causal relationships between these alerts?



Naïve Approach (Cont'd)

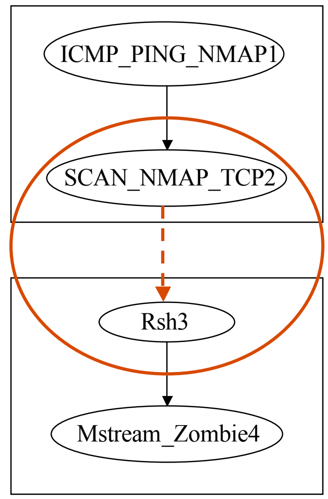
- Given attack types T and T', T *may prepare for* T' if
  - Informally, a type T attack may contribute to a type T' attack

- T *may indirectly prepare for* T' if
  - Informally, a type T attack may indirectly contribute to a type T' attack through other intermediate attacks



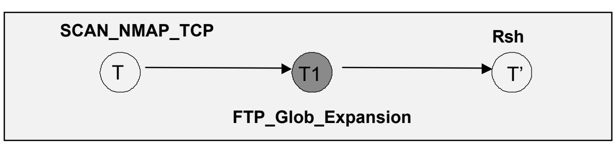
Naïve Approach (Cont'd)

- *May-indirectly-prepare-for* relations can help hypothesize missed attacks
  - More complete attack scenarios



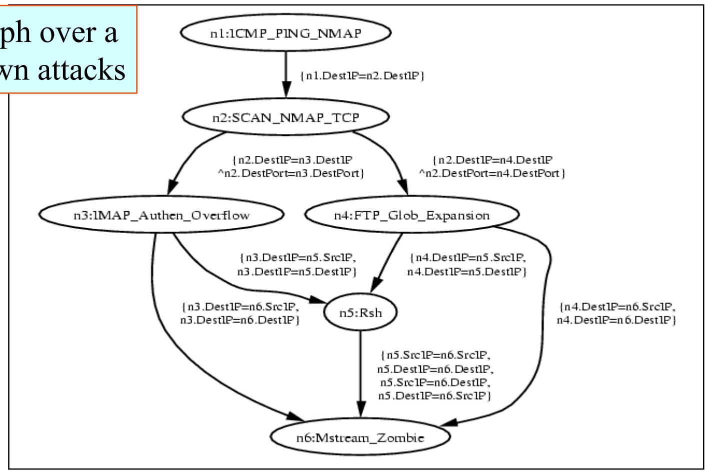
Type Graph Guided Approach

- *May-prepare-for* and *may-indirectly-prepare-for* relations give us more opportunities
  - We may use them to hypothesize about what have been missed by the IDSs



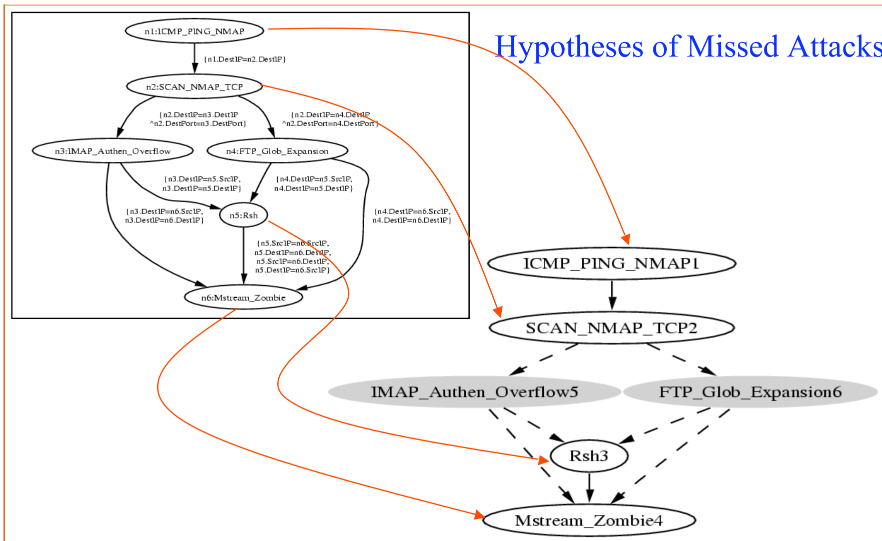
Type Graph Guided Approach (Cont'd)

A type graph over a set of known attacks



- Note: A type graph is computed automatically over a given set of attack types

A Type Graph Guided Approach (Cont'd)



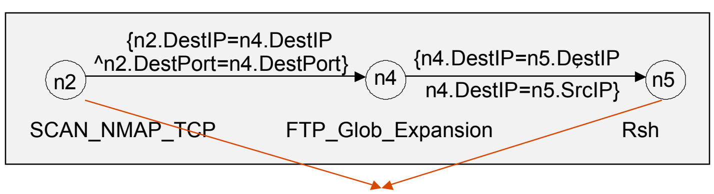
Reasoning about the Hypotheses

- How do we know these are good hypotheses?
- Equality constraint
  - *Represent dependency between adjacent attack steps*
  - An *equality constraint* for two hyper-alert types (or attack types) T_1 and T_2 is a conjunction of equalities $u_1 = v_1 \wedge \ldots \wedge u_n = v_n$,
  - where $u_1, \ldots, u_n$ are attributes of T_1, and $v_1, \ldots, v_n$ are attributes of T_2,
  - such that if a type T_1 hyper-alert h_1 and a type T_2 hyper-alert h_2 satisfy this condition, then h_1 prepares for h_2
- h_1 prepares for h_2 if and only if they satisfy at least one equality constraint

T.DestIP=T'.DestIP ^ T.DestPort=T'.DestPort

Reasoning about The Hypotheses (Cont'd)

- Indirect equality constraint



n2.DestIP=n5.DestIP or n2.DestIP=n5.SrcIP

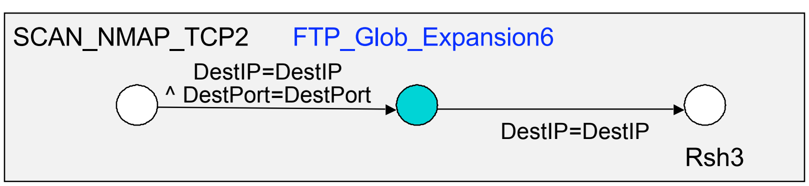
- Use indirect equality constraints to verify the hypothesized indirect causal relationships

Reasoning about Missed Attacks (Cont'd)

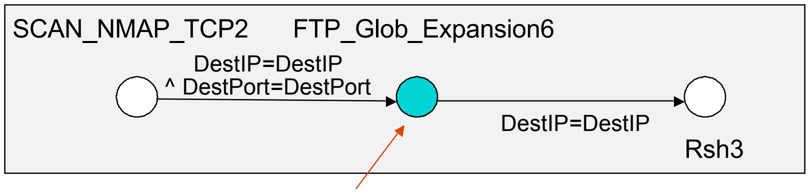
- Pre-computation of the indirect equality constraints
  - For each pair of attack types
    - For each path between these two attack types
      - For each combination of (direct) equality constraints between adjacent attack types in the path
        - » Derive the equality conditions
  - Store the indirect equality constraint in a constraint matrix
- Check against the pre-computed indirect constraints when hypothesizing missed attacks

Infer Attribute Values of Hypothesized Attacks

- SCAN_NMAP_TCP2
  - DestIP = 10.10.10.2; DestPort = 21
- Rsh3
  - DestIP = 10.10.10.2
- FTP_Glob_Expansion6
  - DestIP = 10.10.10.2; DestPort = 21
  - Timestamp in [SCAN_NMAP_TCP2.end_time, Rsh3.begin_time]



Validating and Pruning via Raw Audit Data

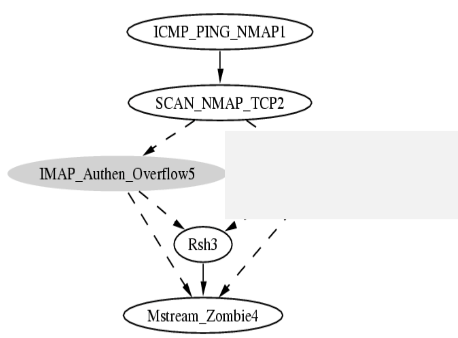


Again. Have we hypothesized the right attacks?

- Filtering conditions for hypothesized attacks
  - Prior knowledge
    - protocol = ftp (FTP_Glob_Expansion)
  - Inferred attribute values
    - protocol = ftp ^ DestIP = 10.10.10.2
  - Possible range of Timestamp
    - protocol = ftp ^ DestIP = 10.10.10.2 ^ TS in [11:00AM, 11:10AM]

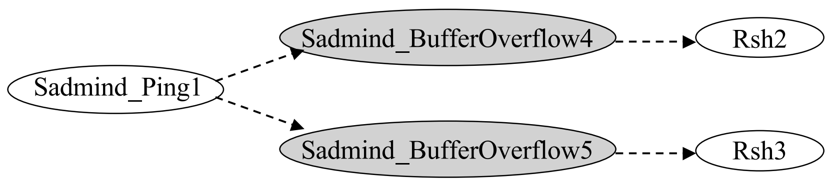
An Example

- There doesn't exist ftp traffic between SCAN_NMAP_TCP2 and Rsh3.



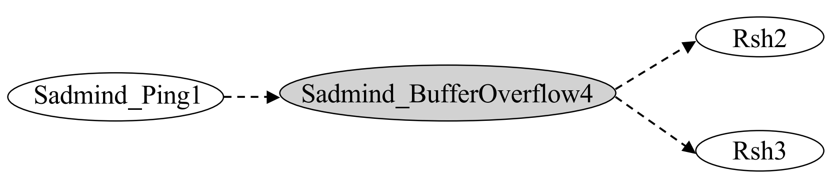
Consolidate Hypothesized Attacks

- One missed attack may be hypothesized multiple times through different related alerts
- There may have been multiple instances of the missed attack, but
  - Introduce complexity into analysis



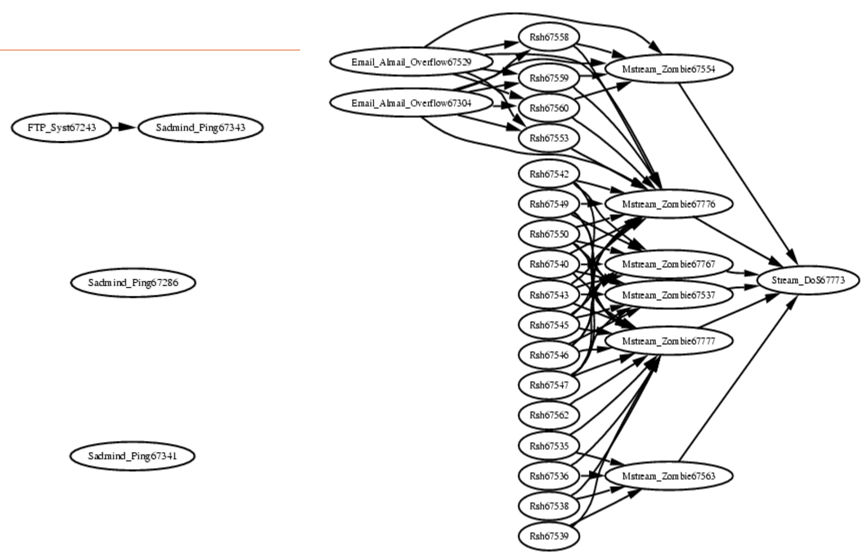
Consolidate Hypothesized Attacks (Cont'd)

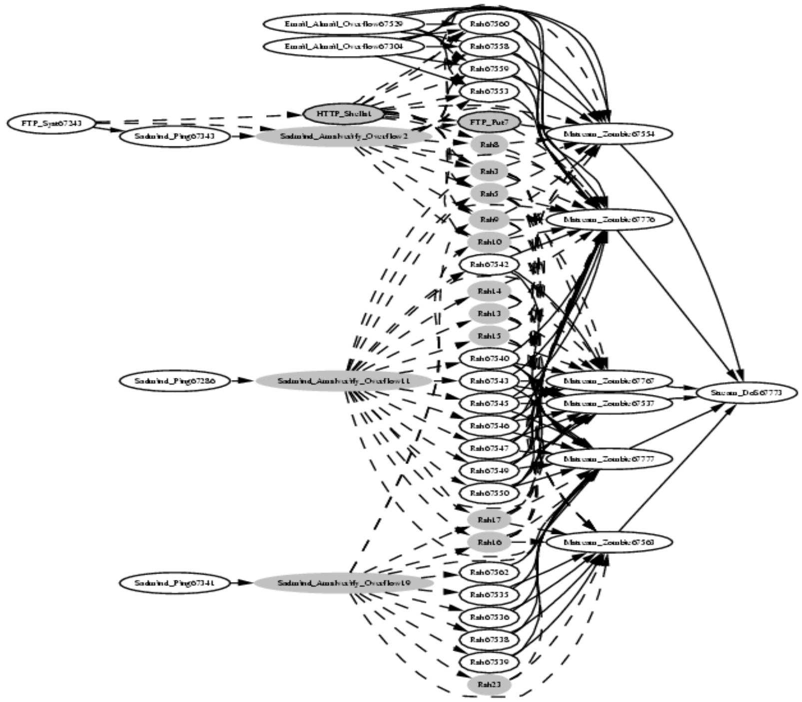
- Consolidate two hypothesized attacks, if they possibly refer to the same attack
  - They have the same type
  - Their inferred attribute values do not conflict
  - The ranges of their timestamps overlap



Experiments

- Data Set
  - 2000 DARPA ID evaluation dataset: LLDOS 1.0
- IDS
  - ISS RealSecure Network Sensor 6.0
- Clustering
  - Same destination IP address
- Causal correlation
  - NCSU Intrusion Alert Correlator (Version 0.2)
- Network audit data process
  - Ethereal 0.9.14
- Type graph
  - All attacks detected by the IDS
- Drop all Sadmind_Amslverify_Overflow alerts





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Conclusion and Future Work

- Integrates two complementary intrusion alert correlation methods
- Build attack scenarios based on type graphs and (indirect) equality constraints:
  - Hypothesize and reason about missed attacks
  - Infer about attack attribute values
  - Validate and consolidate hypothesized attacks
- Future Work
  - Additional techniques to validate and reason about hypothesized attacks
  - Large scale experiments
  - Quantitative evaluation