Detecting Attacks, Part 2

CS 161: Computer Security

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Announcements

- Talk of possible interest next Monday: *Tor and the Censorship Arms Race: Lessons Learned*
  - Roger Dingledine, head of the Tor project
  - 4-5:30PM, 110 South Hall
- HKN reviews next Thursday (April 21)
- Project #2 out soon
  - Due RRR week

Goals For Today

- General approaches ("styles") to detecting attacks
- The fundamental problem of evasion
- Analyzing successful attacks: forensics

Styles of Detection: Signature-Based

- Idea: look for activity that matches the structure of a known attack
- Example (from the freeware *Snort* NIDS):

```
alert tcp $EXTERNAL_NET any -> $HOME_NET
  139 flow:to_server,established
content:"|eb2f 5feb 4a5e 89fb 893e 89f2|"
msg:"EXPLOIT x86 linux samba overflow"
reference:bugtraq,1816
reference:cve,CVE-1999-0811
classtype:attempted-admin
```

- Can be at different semantic layers,
  e.g.: IP/TCP header fields; packet payload; URLs

Signature-Based Detection, con’t

- E.g. for FooCorp, search for “../../” or “/etc/passwd”

- What’s nice about this approach?
  - Conceptually simple
  - Takes care of known attacks (of which there are zillions)
  - Easy to share signatures, build up libraries
- What’s problematic about this approach?
  - Blind to novel attacks
  - Might even miss *variants* of known attacks (“..///.//../”)
    - Of which there are zillions
  - Simpler versions look at low-level syntax, not semantics
    - Can lead to weak power (either misses variants, or generates lots of false positives)

Vulnerability Signatures

- Idea: don't match on known attacks, match on known problems
- Example (also from *Snort*):

```
alert tcp $EXTERNAL_NET any -> $HTTP_SERVERS 80
uricontent: ".ida?"; nocase; dsize: > 239; flags:A+
msg:"Web-IIS ISAPI .ida attempt"
reference:bugtraq,1816
reference:cve,CAN-2000-0071
classtype:attempted-admin
```

- That is, match URIs that invoke *.ida?*, have more than 239 bytes of payload, and have ACK set (maybe others too)
- This example detects any* attempt to exploit a particular buffer overflow in IIS web servers
  - Used by the "Code Red" worm
  - * (Note, signature is not quite complete)

Vulnerability Signatures, con't

- What's nice about this approach?
  - Conceptually fairly simple
  - Takes care of known attacks
  - Easy to share signatures, build up libraries
  - Can detect variants of known attacks
  - Much more concise than per-attack signatures

Benefits of attack signatures

- What's problematic?
  - Can't detect novel attacks (new vulnerabilities)
  - Signatures can be hard to write / express
    - Can't just observe an attack that works …
    - … need to delve into how it works

Styles of Detection: Anomaly-Based

- Idea: attacks look peculiar.
- High-level approach: develop a model of normal behavior (say based on analyzing historical logs). Flag activity that deviates from it.
- FooCorp example: maybe look at distribution of characters in URL parameters, learn that some are rare and/or don’t occur repeatedly
  - If we happen to learn that ‘.’s have this property, then could detect the attack *even without knowing it exists*
- Big benefit: potential detection of a wide range of attacks, including novel ones

Anomaly Detection, con't

- What's problematic about this approach?
  - Can fail to detect known attacks
  - Can fail to detect novel attacks, if don't happen to look peculiar along measured dimension
  - What happens if the historical data you train on includes attacks?
  - Base Rate Fallacy particularly acute: if prevalence of attacks is low, then you're more often going to see benign outliers
    - High FP rate
    - OR: require such a stringent deviation from "normal" that most attacks are missed (high FN rate)

Specification-Based Detection

- Idea: don't learn what's normal; specify what's allowed
- FooCorp example: decide that all URL parameters sent to foocorp.com servers **must** have at most one '/' in them
  - Flag any arriving param with > 1 slash as an attack
- What's nice about this approach?
  - Can detect novel attacks
  - Can have low false positives
    - If FooCorp audits its web pages to make sure they comply
- What's problematic about this approach?
  - Expensive: lots of labor to derive specifications
    - And keep them up to date as things change ("churn")

Styles of Detection: Behavioral

- Idea: don't look for attacks, look for evidence of compromise
- FooCorp example: inspect all output web traffic for any lines that match a passwd file
- Example for monitoring user shell keystrokes:

  `unset HISTFILE`

- Example for catching code injection: look at sequences of system calls, flag any that prior analysis of a given program shows it can't generate
  – E.g., observe process executing **`read`**(), **`open`**(), **`write`**(), **`fork`**(), **`exec`**() …
  – … but there's *no code path* in the (original) program that calls those in exactly that order!

Behavioral-Based Detection, con't

- What's nice about this approach?
  - Can detect a wide range of novel attacks
  - Can have low false positives
    - Depending on degree to which behavior is distinctive
    - E.g., for system call profiling: **no false positives**!
  - Can be cheap to implement
    - E.g., system call profiling can be mechanized
- What's problematic about this approach?
  - Post facto detection: discovers that you definitely have a problem, w/ no opportunity to prevent it
  - Brittle: for some behaviors, attacker can maybe avoid it
    - Easy enough to not type "`unset HISTFILE`"
    - How could they evade system call profiling?
      - **Mimicry**: adapt injected code to comply w/ allowed call sequences

Styles of Detection: Honeypots

- Idea: deploy a sacrificial system that has no operational purpose
- Any access is by definition not authorized …
- … and thus an intruder
  - (or some sort of mistake)

- Provides opportunity to:
  - Identify intruders
  - Study what they're up to
  - Divert them from legitimate targets

Honeypots, con’t

- Real-world example: some hospitals enter fake records with celebrity names …
  - … to entrap staff who don't respect confidentiality
- What’s nice about this approach?
  - Can detect all sorts of new threats
- What’s problematic about this approach?
  - Can be difficult to lure the attacker
  - Can be a lot of work to build a convincing environment
  - Note: both of these issues matter less when deploying honeypots for automated attacks
    - Because these have more predictable targeting & env. needs
    - E.g. “spamtraps”: fake email addresses to catching spambots

5 Minute Break

Questions Before We Proceed?

The Problem of Evasion

- For any detection approach, we need to consider how an adversary might (try to) elude it
  - Note: even if the approach is evadable, it can still be useful to operate in practice
  - But if it's very easy to evade, that's especially worrisome (security by obscurity)

- Some evasions reflect incomplete analysis
  - In our FooCorp example, hex escapes or "..////.//../" alias
  - In principle, can deal with these with implementation care (make sure we fully understand the spec)

The Problem of Evasion, con't

- Some evasions exploit *deviation from the spec*
  - E.g., double-escapes for SQL injection:
    %25%32%37 ⇒ %27 ⇒ '
- Some can exploit more fundamental ambiguities:
  - Problem grows as monitoring viewpoint increasingly removed from ultimate endpoints
    - Lack of end-to-end visibility
- Particularly acute for network monitoring
- Consider detecting occurrences of the string "**`root`**" inside a network connection …
  - We get a copy of each packet
  - How hard can it be?

Detecting "`root`": Attempt #1

- Method: scan each packet for 'r', 'o', 'o', 't'
  - Perhaps using Boyer-Moore, Aho-Corasick, Bloom filters …

Packet

1 ....**root**.......................

Are we done?

Oops: TCP *doesn't preserve text boundaries*

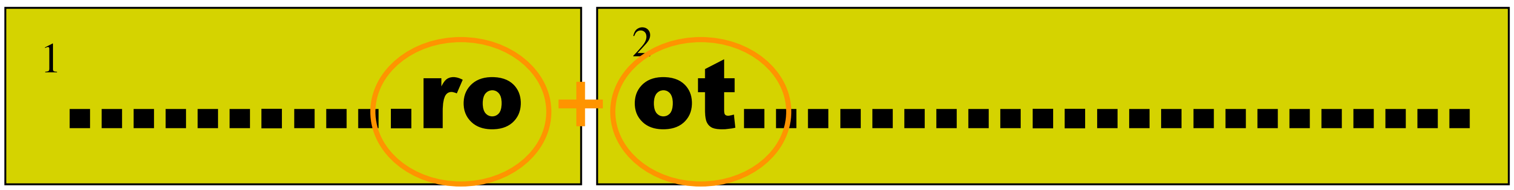
1 ....**ro**	2 **ot**.......................

Packet #1 Packet #2

Fix?

Detecting "`root`": Attempt #2

- Okay: remember match from end of previous packet



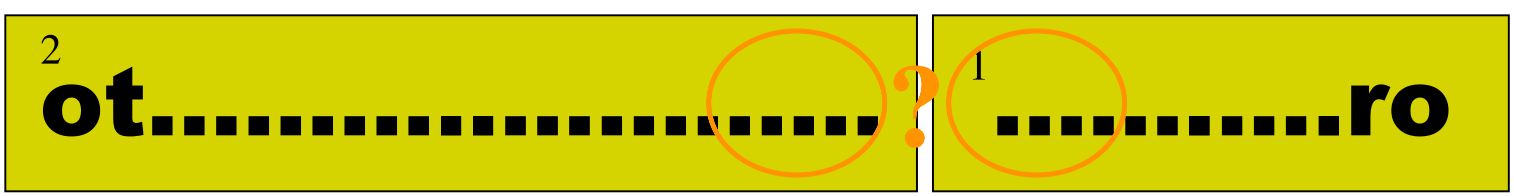
Packet #1 Packet #2

When 2nd packet arrives, continue working on the match

- Now we're managing state :-(

Are we done?

Oops: IP doesn't guarantee in-order arrival



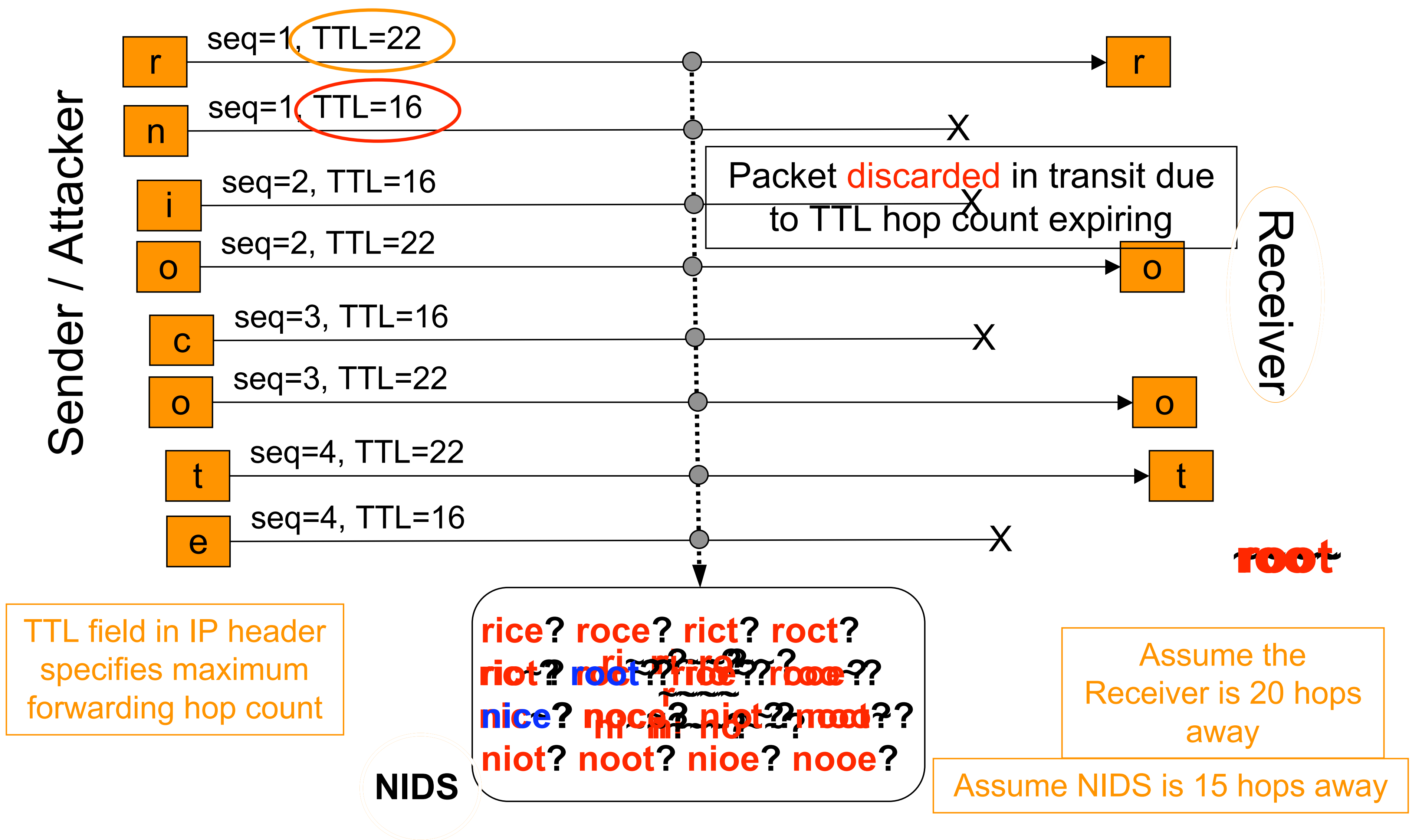
Detecting "`root`": Attempt #3

- Fix?

- We need to reassemble the entire TCP bytestream
  - Match sequence numbers
  - Buffer packets with later data (above a sequence "hole")
- Issues?
  - Potentially requires a lot of state
  - Plus: attacker can cause us to exhaust state by sending lots of data above a sequence hole

- But at least we're done, right?

Full TCP Reassembly is Not Enough



Inconsistent TCP Retransmissions

- Fix?
- Idea: NIDS can alert upon seeing a retransmission inconsistency, as surely it reflects someone up to no good
- This doesn't work: TCP retransmissions broken in this fashion occur in live traffic
  - Rare (a few a day at ICSI)
  - But real evasions much rarer still (Base Rate Fallacy)
  - ⇒ This is a *general problem* with alerting on such ambiguities
- Idea: if NIDS sees such a connection, kill it
  - Works for this case, since benign instance is already fatally broken
  - But for other evasions, such actions have collateral damage
- Idea: rewrite traffic to remove ambiguities
  - Works for network- & transport-layer ambiguities
  - But must operate in-line and at line speed

Forensics

- Vital complement to detecting attacks: figuring out what happened in wake of successful attack
- This entails access to rich/extensive logs
  - Plus tools for analyzing/understanding them
  - (Ala' Project #2!)
- It also entails looking for patterns and understanding the implications of structure seen in activity
- Consider these actual emails from operational security …

Emails omitted from on-line notes