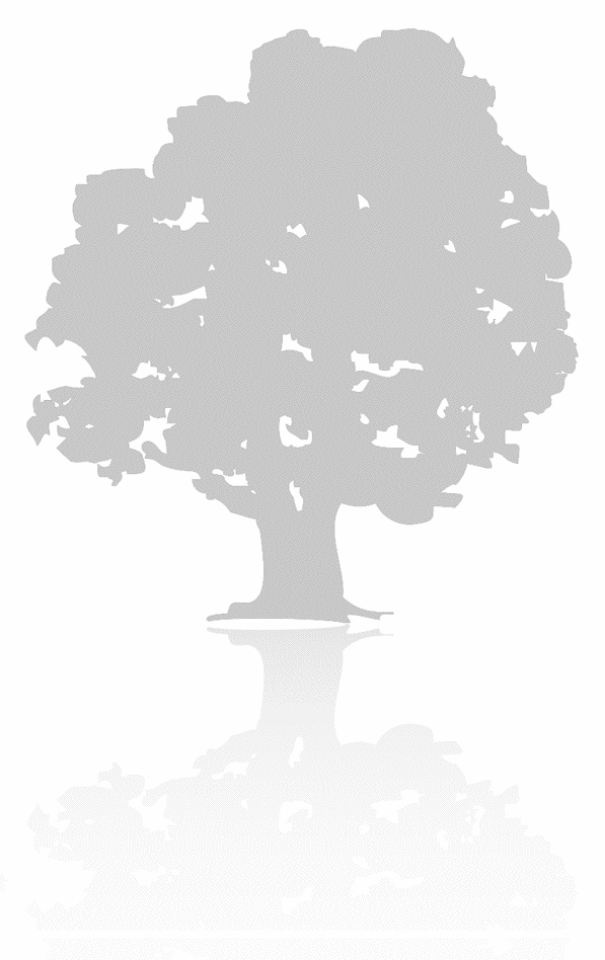


INPUT ATTACK TREES

Death of a thousand leaves

BlackHat Japan 2006
Heikki Kortti, Codenomicon

INPUT ATTACK TREES Why luck does not work

- Great if you have it, takes too long for everyone else
- Does not detect bugs *by the dozen*
- Does not provide details on where the fault is and how likely it is to occur elsewhere

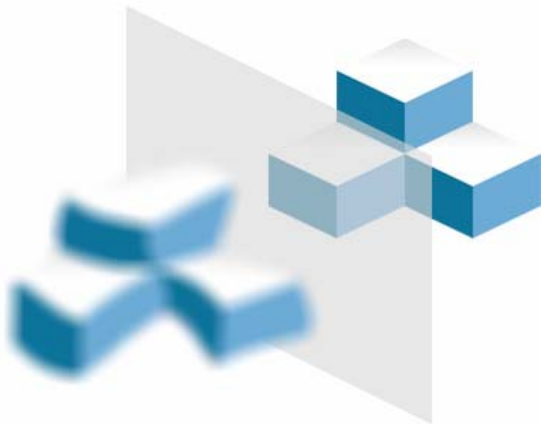
INPUT ATTACK TREES Inspection is slow and error-prone

- Software is complex
- Manual inspection takes ages
- Machine-assisted inspection finds false positives
- Source code may not be available

INPUT ATTACK TREES

Reverse engineering reveals only part of the picture

- Great if you're Halvar Flake, but too hard for everyone else
- Simply a "smoked-glass" view



INPUT ATTACK TREES Observation is tedious

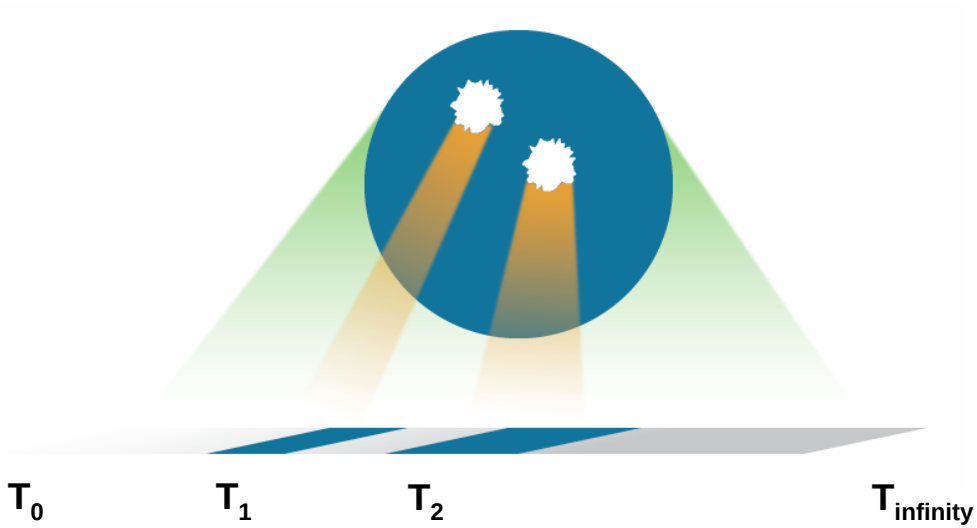
- Trying to assess security by observing how the software functions is like trying to fix a cuckoo clock with an axe
- Observation is very slow
- Creating suitable stimuli to which the software should react is also very slow

INPUT ATTACK TREES Don’t be smart, be evil

- Trying out malicious inputs works well
- Complete coverage = infinite time
- Time can be reduced by generating inputs automatically (fuzzing)
- Fuzzers can be
  - simple (non-structured) or
  - intelligent (structured)

INPUT ATTACK TREES Ways to do input testing

- By hand
- Create a program that tries the inputs for you
- Create a program that creates programs that try the inputs for you



INPUT ATTACK TREES The problem with simple fuzzing

- Fuzzing with random data is not enough for complex protocols like TLS or BGP
- A structural model of the protocol is needed
- “Intelligent fuzzing” or “robustness testing”

INPUT ATTACK TREES What makes a viable fuzzing model?

- At a minimum, a fuzzing model has to capture the following:
  - Field-level structures (8-bit integer, date field)
  - Packet-level structures (header+payload)
  - Context structures (packet sequences)
  - Dynamic behaviour (runtime calculations, crypto functions, nonces, timestamps, lengths)

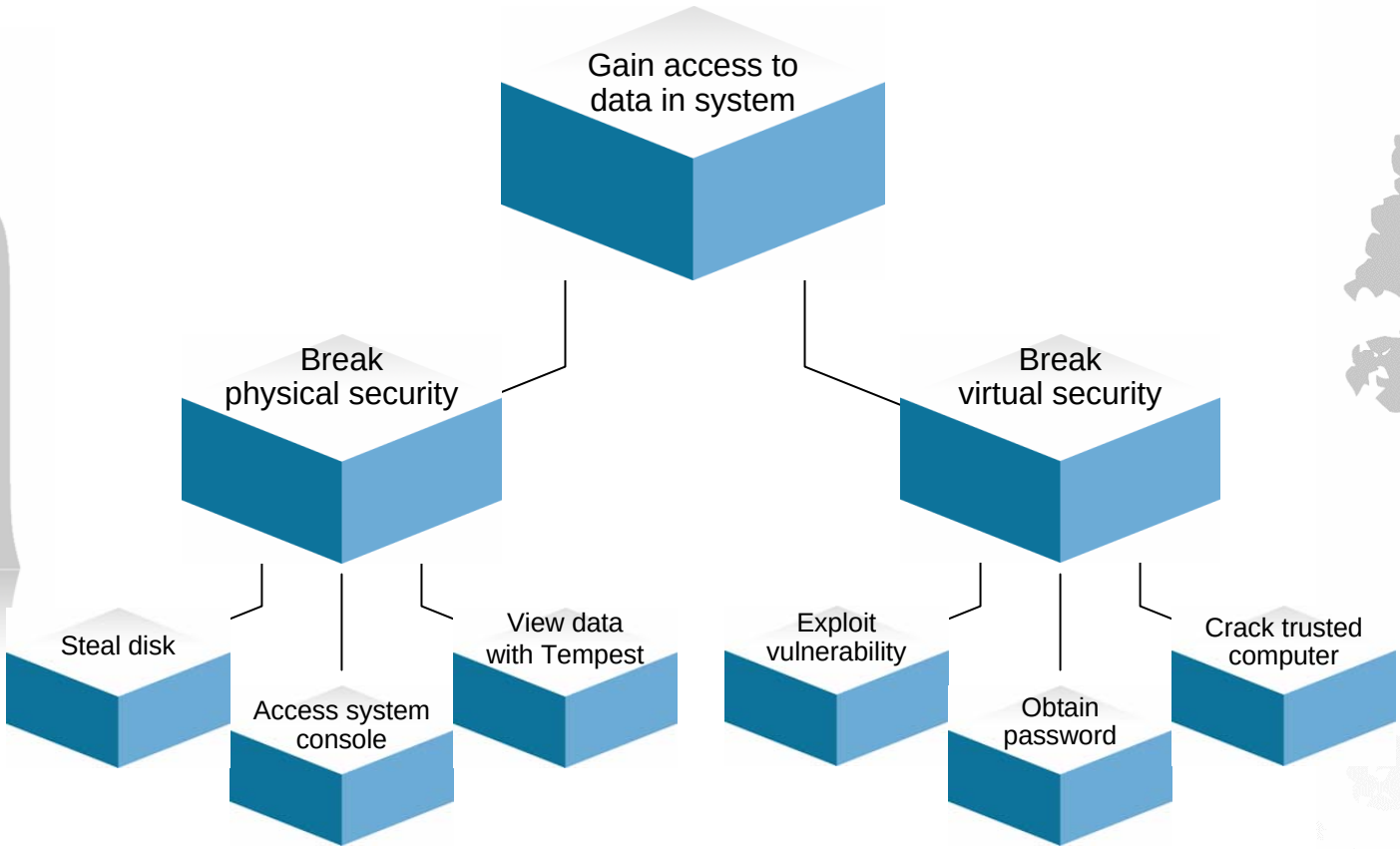
INPUT ATTACK TREES Aiding the design of fuzzing models

- Use existing models
  - ABNF
  - ASN.1
  - XML
- Roll your own
- What makes a good model for designing effective attacks?

INPUT ATTACK TREES Attack trees in general

- Well-known and proven methodology for observing and assessing the security of any system
- Provides a good overall view of the security of a system
- Risks and possible attacks can be viewed at a glance

INPUT ATTACK TREES Sample attack tree



INPUT ATTACK TREES Applying attack trees for input testing

- Input tree: all possible inputs for the defined interface
- Attack tree: a catalogue of all possible attacks against a system
- Input attack tree: an input tree augmented with attacks against all input branches
- Charts all of the possible attacks against an interface

INPUT ATTACK TREES Benefits for attackers

- Easy to see which attacks have been tried
- Easy to see which attacks have not been tried
- Easy to see the vulnerable areas
- Easy to feed into a fuzzer generator for creating tests automatically

INPUT ATTACK TREES Benefits for defenders

- What attacks do we need to protect against?
- What areas of the interface definition are too complex to get right?
- Have we tested all of our input handling code?

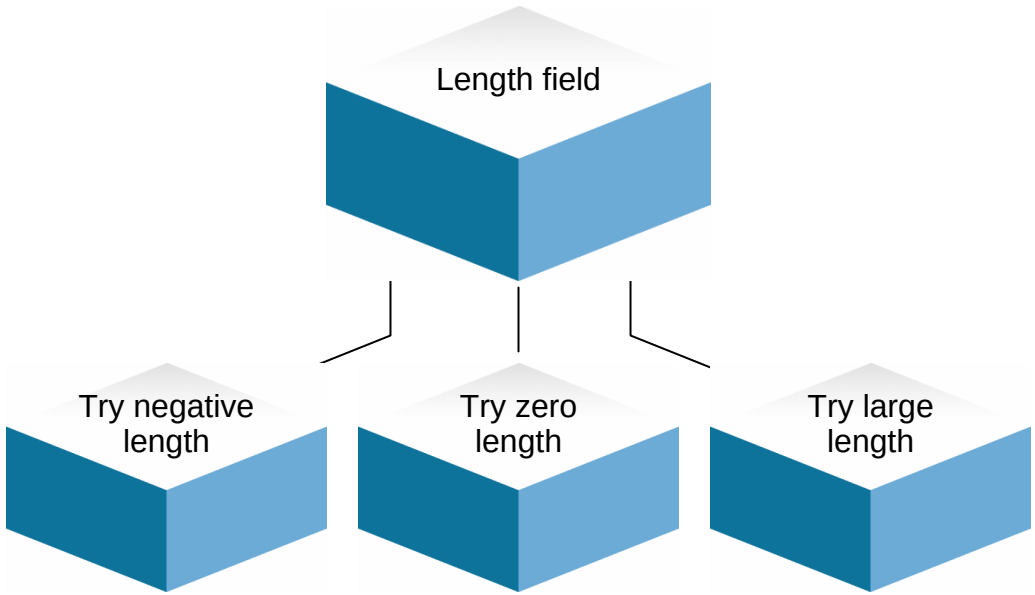
INPUT ATTACK TREES Benefits for designers

- Easy to see which features are likely to be misimplemented
- Easy to see what branches will be attacked and when
- Similar branches can be compared with existing vulnerabilities
- Great feedback for the next release of the interface definition

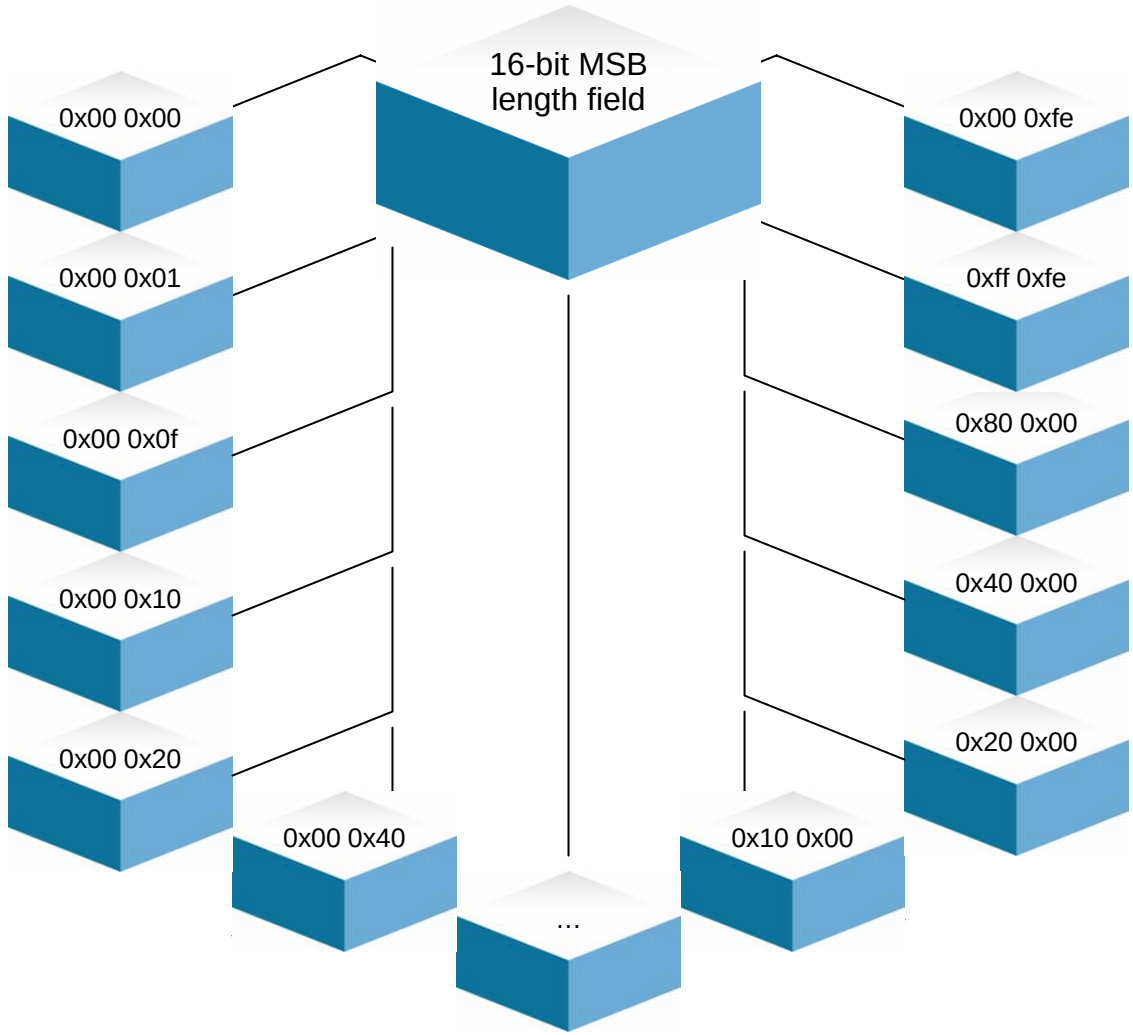
INPUT ATTACK TREES Attack subtrees

- Create an attack once, reuse infinitely
- Attacks against a particular datatype can be used again and again
- Examples: date fields, integers, ASCII and UTF-8 strings, C-style format strings, URIs, IPv4 and IPv6 addresses, regexes

INPUT ATTACK TREES Attaching attack subtrees



INPUT ATTACK TREES Length field attack subtree (detailed)



INPUT ATTACK TREES Using the input attack tree

- Looking at the attack tree already provides good insights
- If tests are created automatically, you may want to create more test cases around the more problematic areas
- More test cases = more problems found
- More test cases = more time for testing

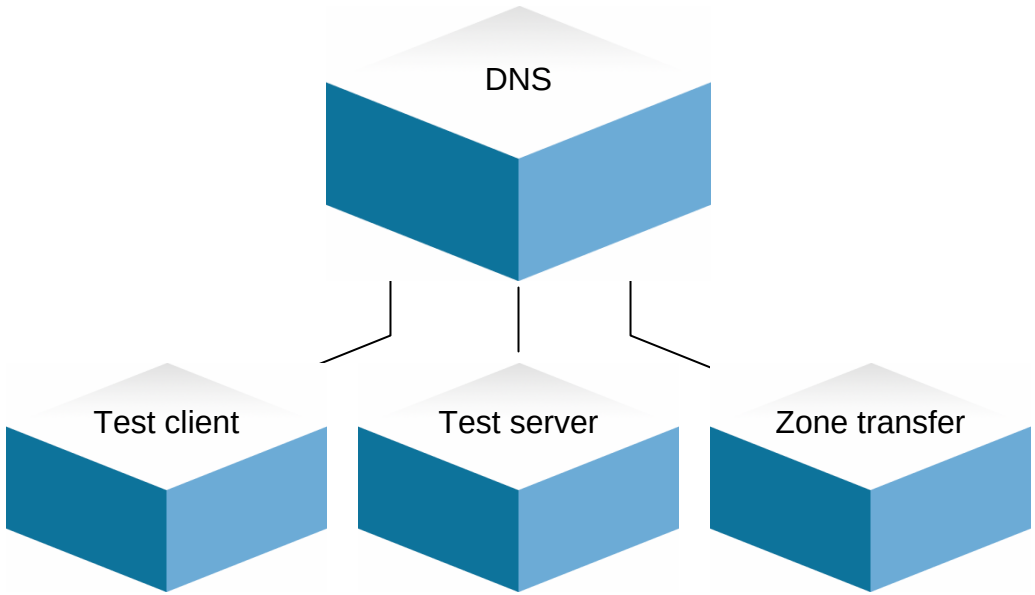
INPUT ATTACK TREES Ways to focus the attacks

- Assign weights to branches
- Complex areas should be heavier
- An automated test generator can steer itself based on branch or leaf weights
- A light branch may merit only a few basic tests
- A very heavy branch needs really thorough coverage

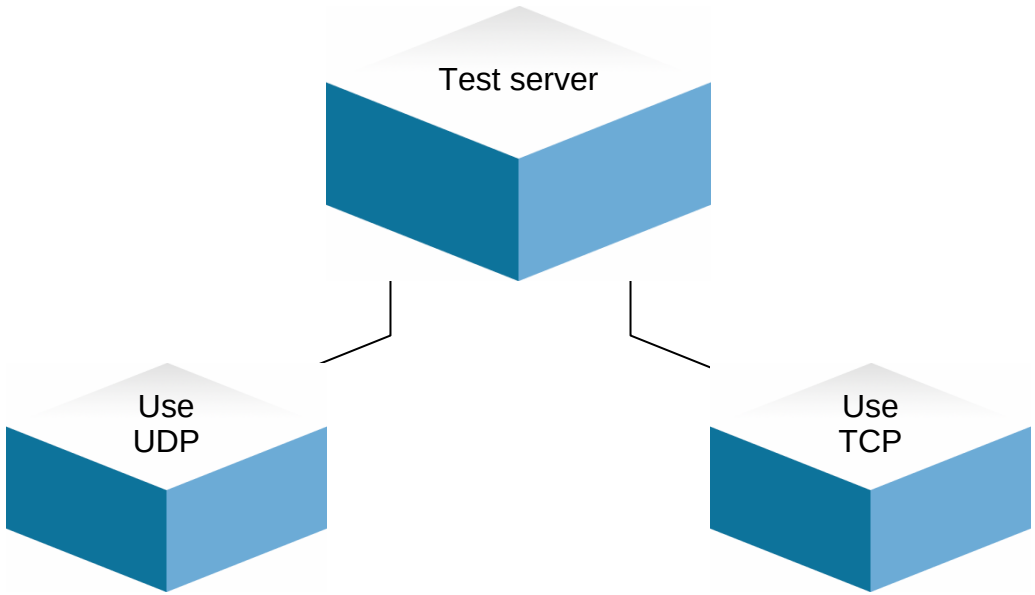
INPUT ATTACK TREES Testing an implementation

- Model the messages and message sequences
- Create the potential malicious inputs for all datatypes, structures and messages
- Attach attack subtrees to the main trunk
- Steer test case selection through weights
- Execute tests and observe the results
- The design and creation of a fuzzing framework and fuzzer have been omitted as trivial

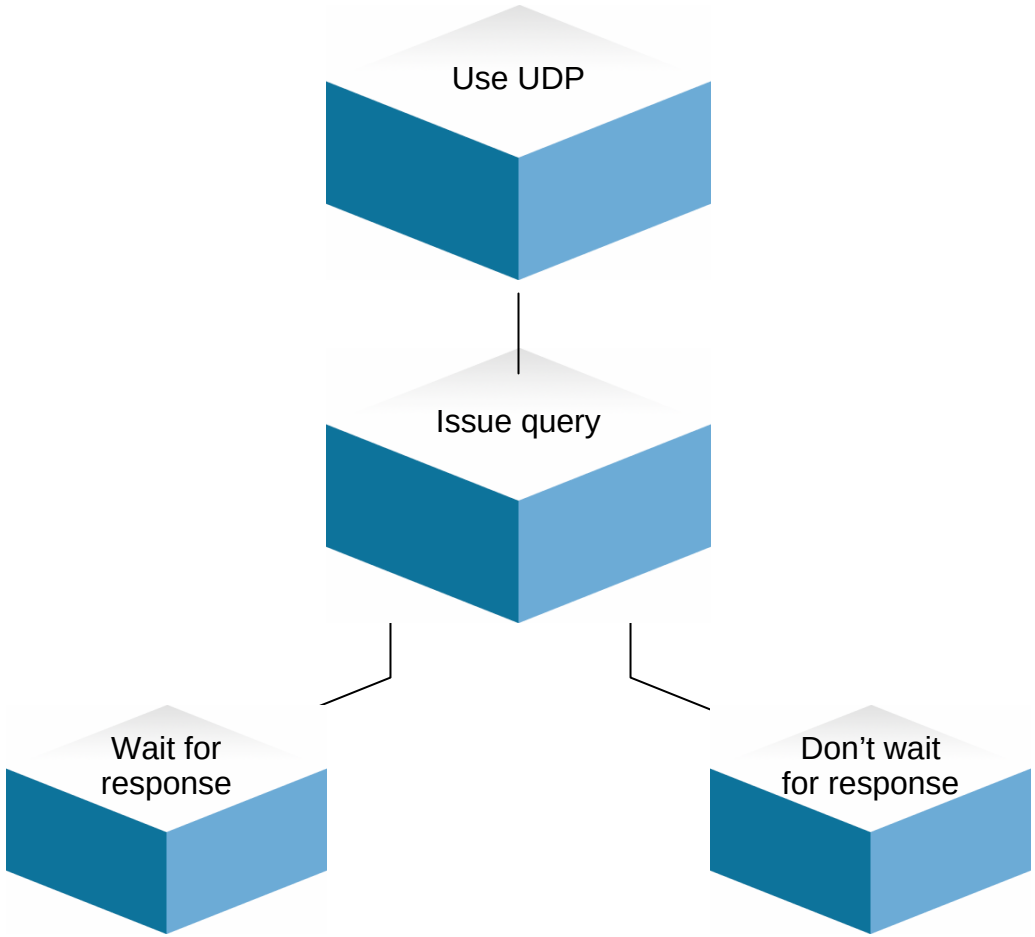
INPUT ATTACK TREES Example: DNS input tree



INPUT ATTACK TREES Testing a DNS server

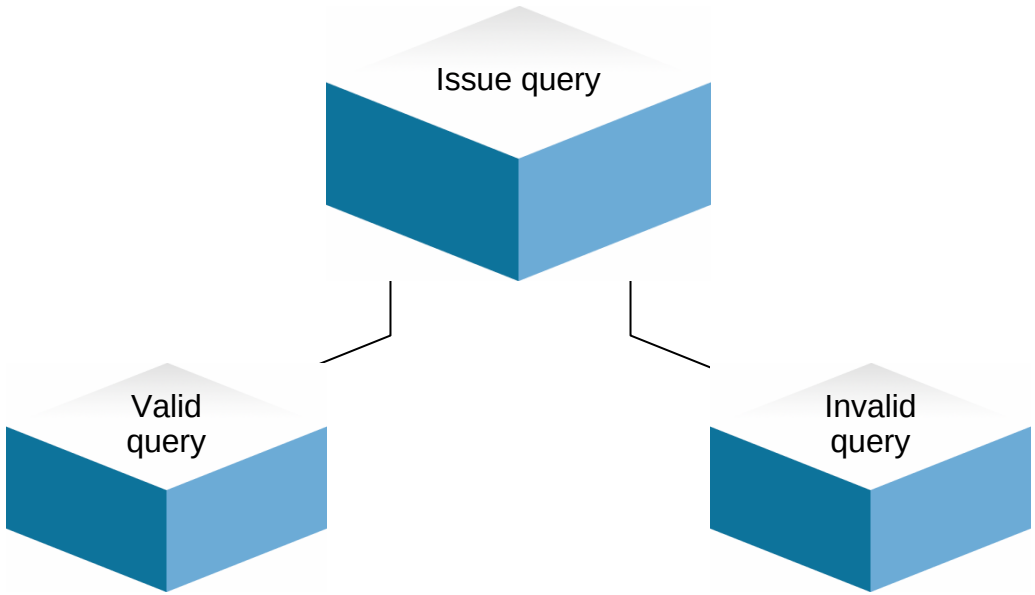


INPUT ATTACK TREES Testing a server over UDP



INPUT ATTACK TREES

Expanding an input tree to an input attack tree



INPUT ATTACK TREES

Sample input attack tree for simple DNS queries

- Issue invalid query
  - Break lower level (UDP/TCP, IP, Ethernet)
  - Break DNS TCP length field (TCP only)
  - Break header
  - Break question section
  - Break answer section
  - Break authority section
  - Break additional section
  - Send response as query
  - Combine

INPUT ATTACK TREES Break lower level

- Surprisingly useful for some protocols
- Think complex, layered abominations like SOAP, RPC, Corba, HTTP
- Practical example: breaking an UDP datagram breaks a SIP implementation

INPUT ATTACK TREES Break DNS TCP length

- All length fields are delicious
- Use zero length
- Use too large lengths
- Use too small lengths
- Use negative lengths

INPUT ATTACK TREES Break header

- Bit-walk through all of the fields in the DNS header
- Interesting branches:
  - Try wrong and non-existing query types
  - Flip the AA, TC, RD, RA fields
  - Break the question/answer/authority/additional counts

INPUT ATTACK TREES Break question section

- Break QNAME
- Break QTYPE
- Break QCLASS
- Add more than one question
- Omit question section
- Underflow

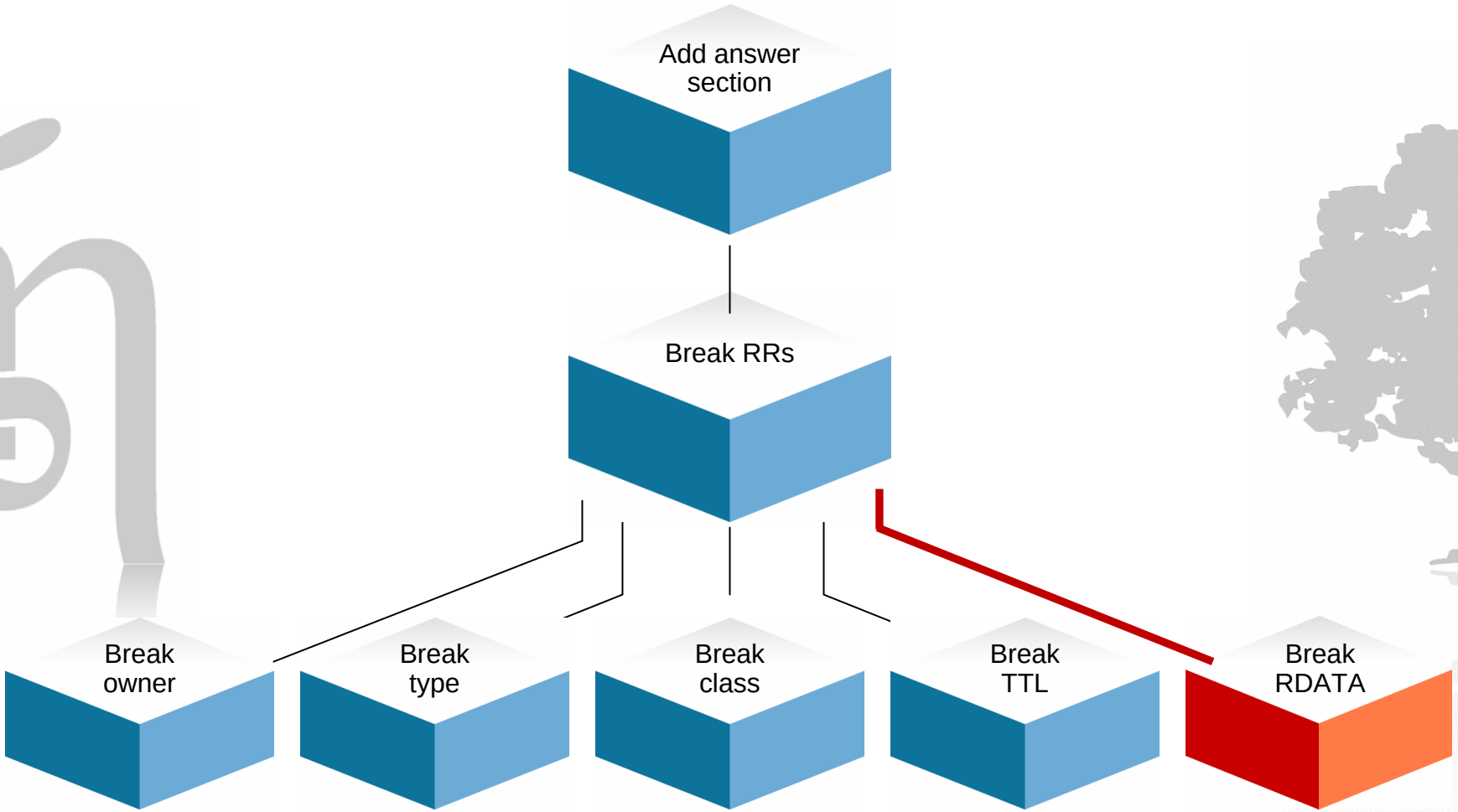
INPUT ATTACK TREES Break answer/authority/additional sections

- Add one
  - Break all possible RRs and their substructures
- Add more than one
- Underflow

INPUT ATTACK TREES Using weights

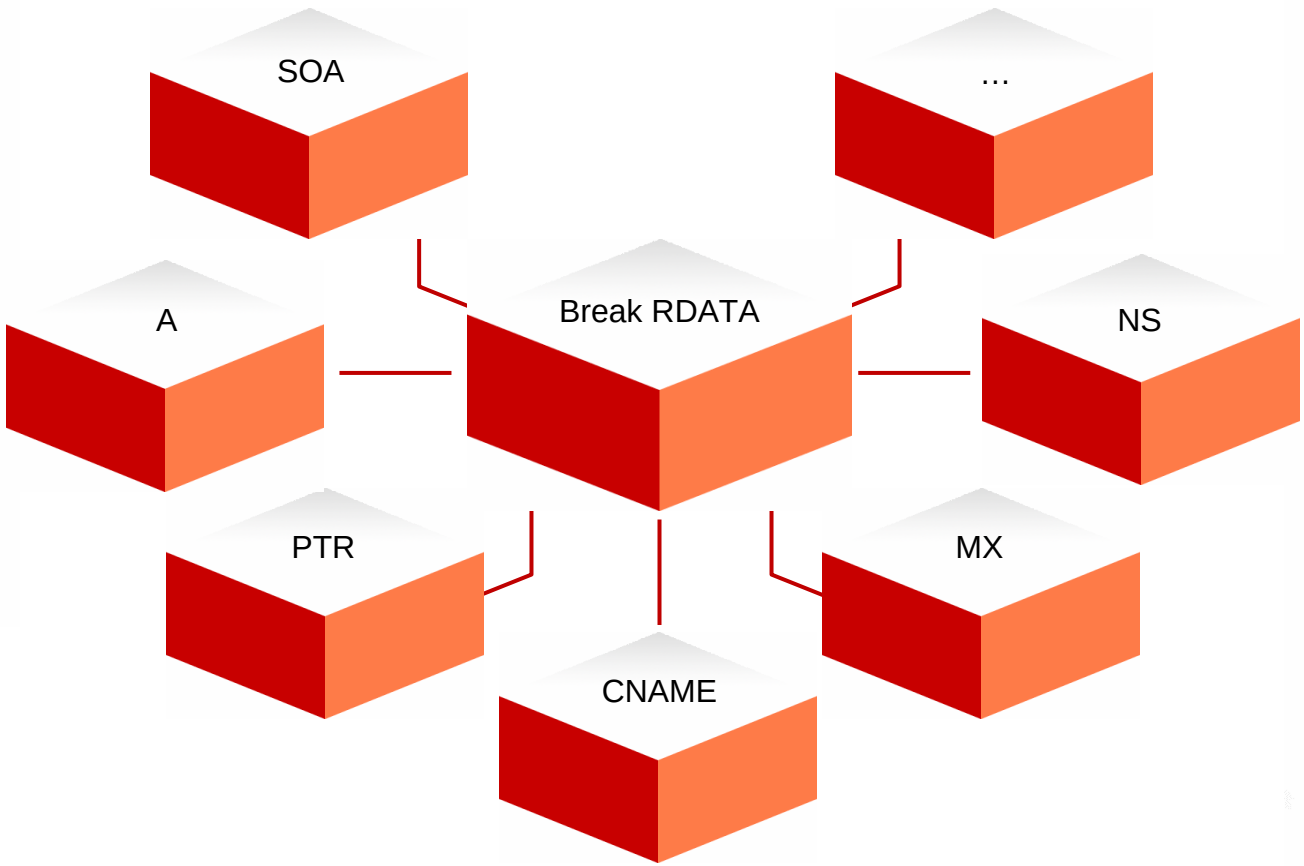
- Answer section can contain any number of RRs (resource records)
- RRs have complex substructures
- A server must parse the answer section also in queries
- Weigh down the branch with answer tests

INPUT ATTACK TREES Weighing down the answer tests



INPUT ATTACK TREES

RDATA substructures are even more interesting



INPUT ATTACK TREES Send response as query

- Out-of-context messages in a sequence can sometimes be very effective

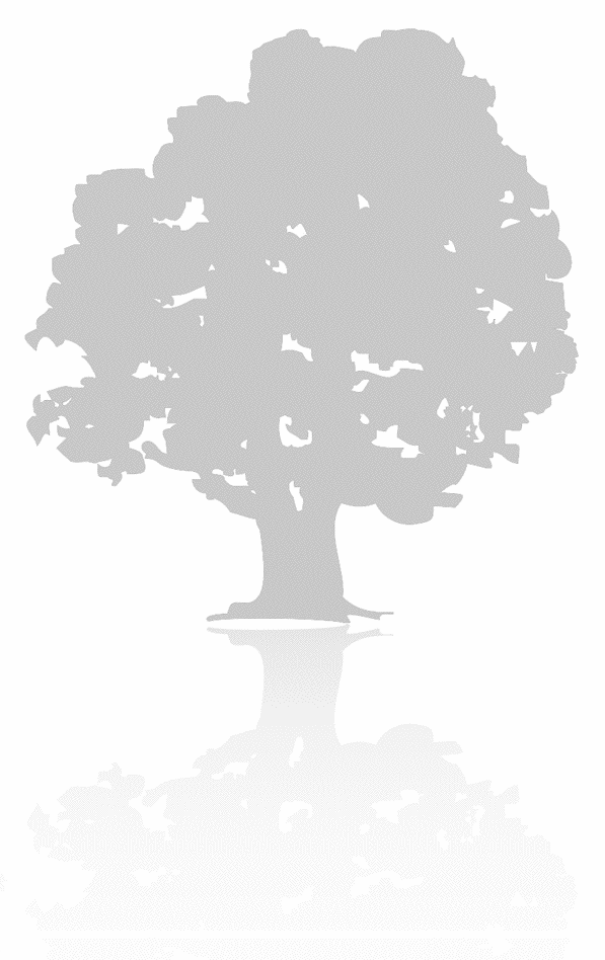
INPUT ATTACK TREES Combine any previous attacks

- Break question count and question section
- Break length and use underflow
- Use wrong length and illegal characters
- Break answer section and send answer as query
- Break length and use invalid offsets

INPUT ATTACK TREES

Read the specification like the devil reads the Bible

- Make labels longer than 63 octets
- Make label sequences longer than 255 octets
- Use a zero-length label in a non-root position
- Try asking for AXFR over UDP
- Use illegal characters
- Try non-specified types
- Try reserved values
- Try invalid combinations (source address = destination address, etc.)



INPUT ATTACK TREES

CONCLUSIONS

INPUT ATTACK TREES Conclusions

- By viewing an interface as an input tree, we can easily see what are its weak points
- Attacks can be attached to the tree easily
- Tests can be created by traversing the tree
- Tests can target complex areas more heavily
- Can be used for attack and defense
- Can be applied to testing any interface

INPUT ATTACK TREES Inspiration

Schneier, Bruce: Attack Trees

http://www.schneier.com/paper-attacktrees-ddj-ft.html

Moore, Andrew; Ellison, Robert; Linger, Richard: Attack Modeling for Information and Survivability

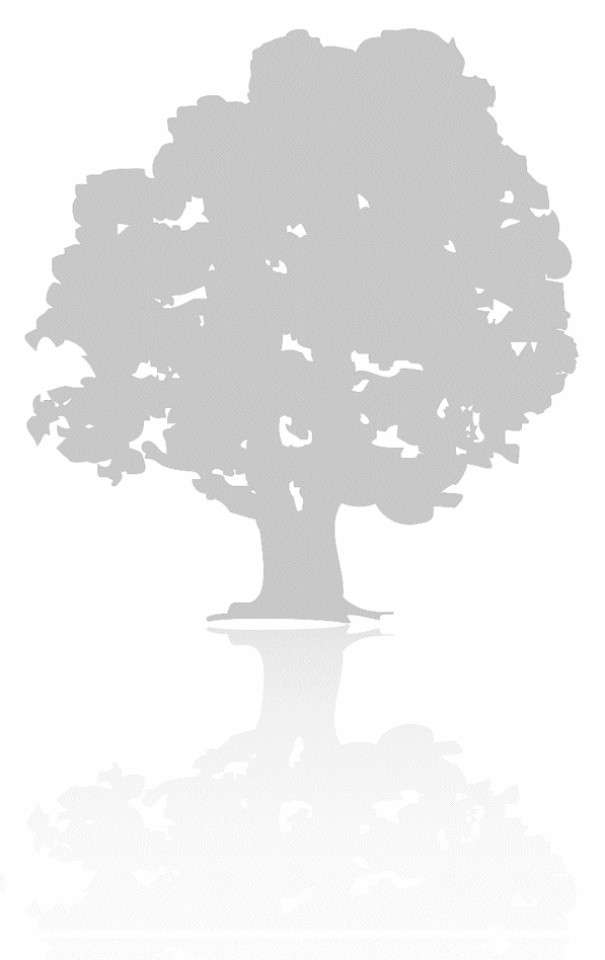
http://www.cert.org/archive/pdf/01tn001.pdf

Convery, Sean; Cook, David; Franz, Matthew: An Attack Tree for the Border Gateway Protocol (obsoleted Internet draft)

http://tools.ietf.org/wg/rpsec/draft-ietf-rpsec-bgpattack/draft-ietf-rpsec-bgpattack-00.txt

Hares, Susan: BGP Attack Trees: Real World Examples

http://www.nanog.org/mtg-0306/pdf/hares.pdf



INPUT ATTACK TREES

ANY QUESTIONS?

THANK YOU!

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