Q1 *DNS over TCP (SU20 Final Q6)* **(20 points)**

Standard DNS uses UDP to send all queries and responses. Consider a modified DNS that instead uses TCP for all queries and responses.

Q1.1 (3 points) Which of the following does DNS over TCP guarantee against a man-in-the-middle attacker? Select all that apply.

☐ (A) Confidentiality ☐ (C) Authenticity ☐ (E) ——

☐ (B) Integrity ■ (D) None of the above ☐ (F) ——

Solution: TCP has no cryptographic guarantees, so a MITM attacker can read and modify any message.

Q1.2 (3 points) Compared to standard DNS, does DNS over TCP defend against more attacks, fewer attacks, or the same amount of attacks against an on-path attacker?

◯ (G) More attacks ◯ (I) Fewer attacks ◯ (K) ——

● (H) Same amount of attacks ◯ (J) —— ◯ (L) ——

Solution: An on-path attacker can see all relevant header fields in TCP and UDP, so they only need to win the race against the legitimate response in both standard DNS and DNS over TCP.

Q1.3 (5 points) What fields does an off-path attacker ***not know*** and need to ***guess*** correctly to spoof a response in DNS over TCP? Assume source port randomization is enabled. Select all that apply.

■ (A) TCP sequence numbers ■ (C) Recursive resolver port ☐ (E) DNS NS records

☐ (B) Name server port ☐ (D) DNS A records ☐ (F) None of the above

Solution: To spoof a TCP packet, the off-path attacker needs to guess the TCP sequence numbers and the randomized resolver port (source port). The name server port (destination port) is public and well-known. The DNS records can be anything the attacker wants, so there is nothing to guess there.

Q1.4 (3 points) Is the Kaminsky attack possible on DNS over TCP? Assume source port randomization is disabled.

◯ (G) Yes, because the attacker only needs to guess the DNS Query ID

● (H) Yes, but we consider it infeasible for modern attackers

◯ (I) No, because the attacker cannot force the victim to generate a lot of DNS over TCP requests

◯ (J) No, because TCP has integrity guarantees

◯ (K) —

◯ (L) —

Solution: The attacker would have to guess at least 32 bits of sequence numbers, which is the same defense as source port randomization in standard DNS.

Q1.5 (3 points) Recall the DoS amplification attack using standard DNS packets. An off-path attacker spoofs many DNS queries with the victim's IP, and the victim is overwhelmed with DNS responses.

Does this attack still work on DNS over TCP?

◯ (A) Yes, the attack causes the victim to consume more bandwidth than the standard DNS attack

◯ (B) Yes, the attack causes the victim to consume less bandwidth than the standard DNS attack

◯ (C) No, because the DNS responses no longer provide enough amplification

● (D) No, because the attacker cannot force the server to send DNS responses to the victim

◯ (E) —

◯ (F) —

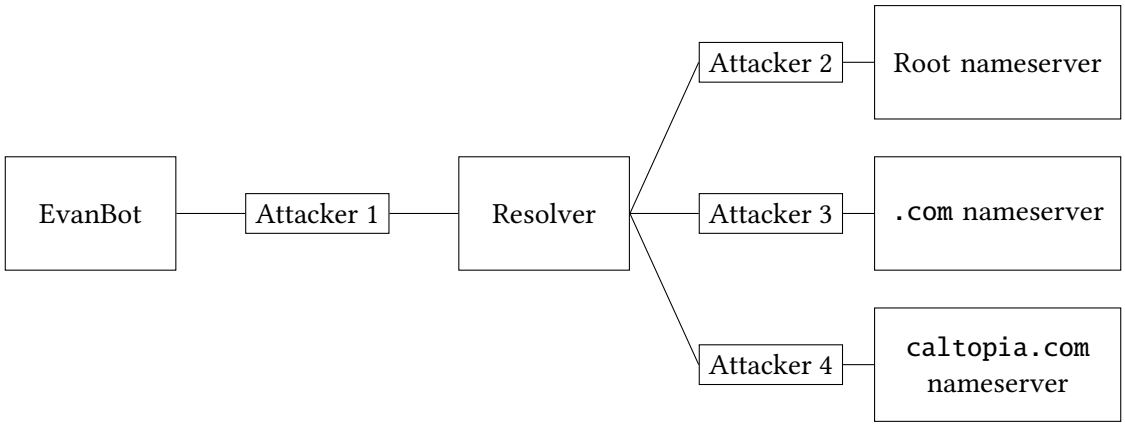
Solution: To force the victim to receive a DNS response, the attacker would need to initiate a TCP connection that looks like it's from the victim. However, an off-path attacker cannot do this, since they cannot see the SYN-ACK response sent to the victim.

Q1.6 (3 points) What type of off-path DoS attack from lecture is DNS over TCP vulnerable to, but standard DNS not vulnerable to? Answer in five words or fewer.

Solution: TCP SYN Flooding

Q2 *Caltopia DNS (SP21 Final Q8)* **(21 points)**

EvanBot is trying to determine the IP address of `caltopia.com` with DNS. However, some attackers on the network want to provide EvanBot with the wrong answer.



Assumptions:

- Each attacker is a man-in-the-middle (MITM) attacker between their two neighbors on the diagram above.
- No attackers can perform a Kaminsky attack.
- Standard DNS (not DNSSEC) is used unless otherwise stated.
- No private keys have been compromised unless otherwise stated.
- In each subpart, both EvanBot's cache and the local resolver's cache start empty.
- Each subpart is independent.

Clarification during exam: Assume that bailiwick checking is in use for this entire question.

In each subpart, EvanBot performs a DNS query for the address of `caltopia.com`.

Q2.1 (4 points) In this subpart only, assume the attackers only passively observe messages.

Which of the attackers would observe an `A` record with the IP address of `caltopia.com` as a result of EvanBot's query? Select all that apply.

- ■ (A) Attacker 1
- ☐ (B) Attacker 2
- ☐ (C) Attacker 3
- ■ (D) Attacker 4
- ☐ (E) None of the above
- ☐ (F) ——

Solution: The `A` type record is sent from the `caltopia.com` name server to the resolver, and then from the resolver to EvanBot.

Q2.2 (3 points) Which of the attackers can poison the local resolver's cached record for `cs161.org` by injecting a record into the additional section of the DNS response? Select all that apply.

Note: Attacker 1 has intentionally been left out as an answer choice.

- ■ (G) Attacker 2
- ☐ (H) Attacker 3
- ☐ (I) Attacker 4
- ☐ (J) None of the above
- ☐ (K) ——
- ☐ (L) ——

Solution: `cs161.org` is in bailiwick for root, so Attacker 2 could add a record for `cs161.org` in the response from root.

However, `cs161.org` is not in bailiwick for `.com` or `caltopia.com`, so attackers 3 and 4 cannot add a record for `cs161.org` in the responses from `.com` or `caltopia.com`.

Q2.3 (4 points) Assume that the resolver and the name servers all validate DNSSEC, but EvanBot does not validate DNSSEC. Which of the attackers can poison EvanBot's cached record for `caltopia.com` by modifying the DNS response? Select all that apply.

- ■ (A) Attacker 1
- ☐ (B) Attacker 2
- ☐ (C) Attacker 3
- ☐ (D) Attacker 4
- ☐ (E) None of the above
- ☐ (F) ——

Solution: Since the resolver and the name servers all validate DNSSEC, any attacker between the resolver and a name server can't do anything to inject malicious records. However, since EvanBot doesn't validate DNSSEC, Attacker 1 can inject a malicious `A` record.

Q2.4 (5 points) In this subpart only, assume the attackers only passively observe messages.

Assume that everyone validates DNSSEC. Which of the following records would Attacker 3 observe as a result of EvanBot's query? Select all that apply.

☐ (G) `DS` record with hash of the `.com` name server's public KSK

■ (H) `DS` record with hash of the `caltopia.com` name server's public KSK

☐ (I) `A` record with the IP address of `caltopia.com`

■ (J) `A` record with the IP address of the `caltopia.com` name server

■ (K) `DNSKEY` record with the `.com` name server's public KSK

☐ (L) None of the above

Solution: The `.com` name server returns:

- A `DNSKEY` record with its public keys (option K)
- An `NS` record with the domain of the next name server (`caltopia.com`)
- An `A` record with the IP of the next name server (`caltopia.com`) (option J)
- A `DS` record with hash of the next name server's public KSK (option H)

Option (G) would be returned by `.com`'s parent (the root), so Attacker 2 would see this record, not Attacker 3.

Option (I) would be returned by the `caltopia.com` name server, so Attacker 4 would see this, not Attacker 3.

Q2.5 (3 points) Assume that everyone validates DNSSEC, and the `caltopia.com` name server's private KSK has been compromised (i.e. all attackers know the `caltopia.com` name server's private KSK). No other private keys have been compromised.

Can EvanBot trust that they received the correct IP address of `caltopia.com`?

◯ (A) Yes, because the ZSK that signs the `A` record has not been compromised

◯ (B) Yes, because the trust anchor (the root's KSK) has not been compromised

◯ (C) No, because the compromised KSK can be used to sign a malicious `A` record

● (D) No, because the compromised KSK can be used to sign a fake ZSK that is used to sign a malicious `A` record

◯ (E) ——

◯ (F) ——

Solution: The chain of trust has been broken, so EvanBot can't trust that they received the correct IP address anymore.

The KSK is only used to sign ZSKs, so the attacker will have to sign a fake ZSK first, and then use the fake ZSK to sign the malicious `A` record.

Q2.6 (2 points) TRUE or FALSE: DNSSEC prevents Attacker 4 from learning the IP address of `caltopia.com`.

◯ (G) True ● (H) False ◯ (I) —— ◯ (J) —— ◯ (K) —— ◯ (L) ——

Solution: DNSSEC provides no confidentiality over the DNSSEC records.

Q3 *Peter Parker in CS161: Training Wheels Protocol* (7 points)

There is an off-path attacker trying to poison Peter's DNS cache. This attacker wishes to trick Peter's recursive resolver into caching their IP address as the address of `cs161.org`. Assume Peter does not use DNSSEC and that Bailiwick checking is implemented.

Q3.1 (2 points) Select all true statements:

- [x] The attacker must send a DNS response before the real nameserver responds to poison the cache
- [ ] The attacker must break symmetric key encryption to poison the cache
- [ ] The attacker must break asymmetric key encryption to poison the cache
- [x] The attacker would not be able to poison the recursive resolver's cache if Peter's recursive resolver and all nameservers used DNSSEC
- [ ] None of the above

Solution: DNS does not use any encryption. An off path attack of this kind (simply off path only) would not work if records were signed by a authorities verified by a chain of trust.

Q3.2 (2½ points) Which of the following domains, when visited by Peter using his browser, would give the attacker a non-negligible chance to poison the cache for `cs161.org`? Select all that apply.

- [x] `https://cs161.org`
- [x] `http://cs161.org`
- [x] `http://nonexistentdomain.cs161.org`
- [x] `http://www.google.com`
- [x] `http://nonexistentdomain.google.com`
- [ ] None of the above

Solution: All of these could query the root name server, for example, and if the off path attacker is able to respond for the root name server, bailiwick checking will enable them to answer for cs161.org. HTTPS vs HTTP does not matter here, since DNS works separately as a domain-ip mapping system.

Q3.3 ($2\frac{1}{2}$ points) Now assume that Peter is a frequent visitor of `cs161.org` and `google.com` and that his recursive resolver has already cached those two domains. Which of the domains below may still give the attacker a non-negligible chance to poison the cache when Peter visits that domain? Select all that apply.

- ☐ `https://cs161.org`
- ☐ `http://cs161.org`
- ☐ `http://nonexistentdomain.cs161.org`
- ☐ `http://www.google.com`
- ☐ `http://nonexistentdomain.google.com`
- ■ None of the above

Solution: The domains which Peter visits are cached, and so would not result in any DNS query being sent to any nameserver. Since Peter has the cs161.org nameserver and the google.com nameserver IPs cached, http://nonexistentdomain.google.com DNS request will go there and the Off-Path attacker injecting malicious cs161.org name records will be ignored due to bailiwick checking.