IPsec ESP Attacks

BİL 448/548

Internet Security Protocols

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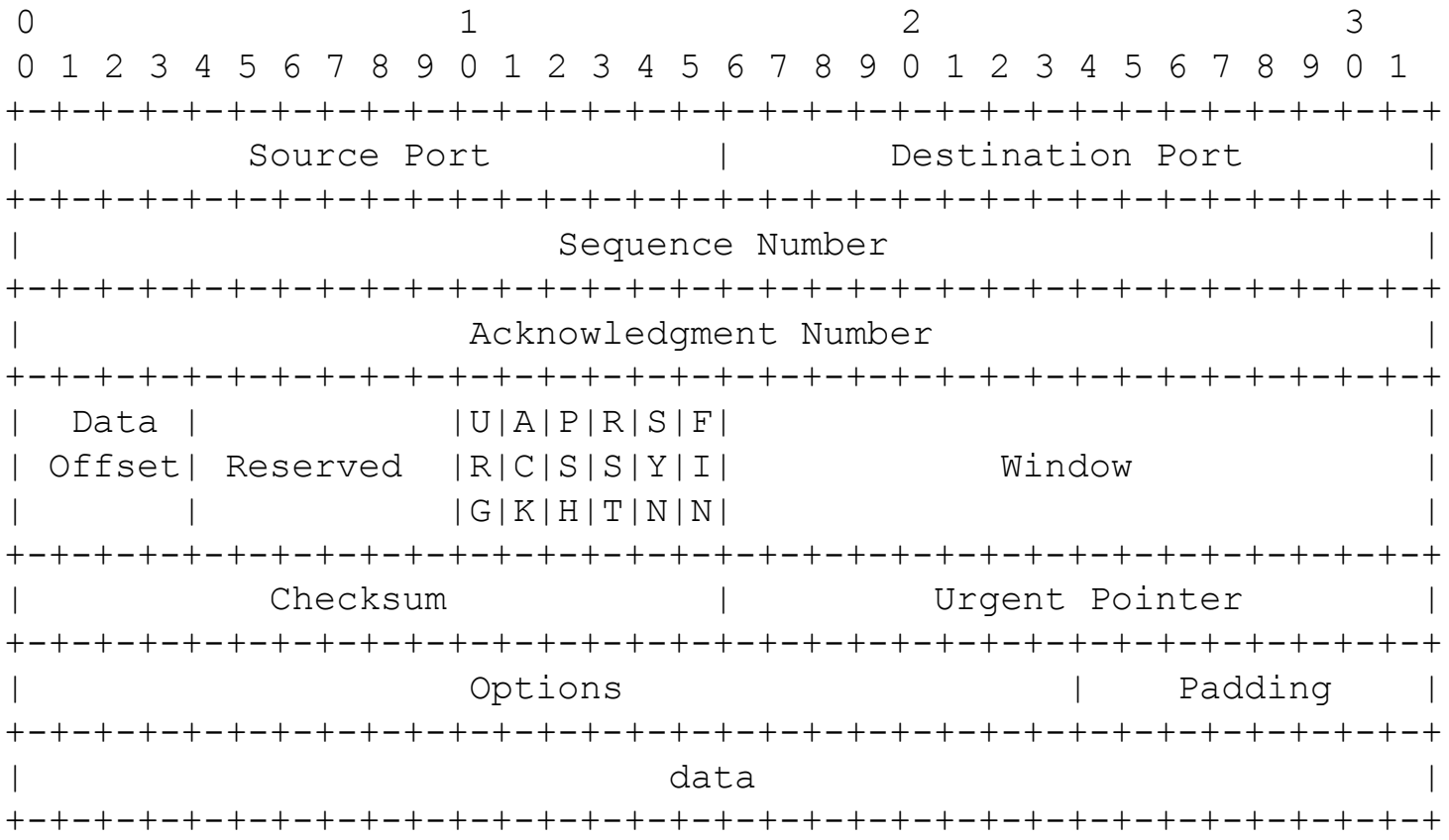
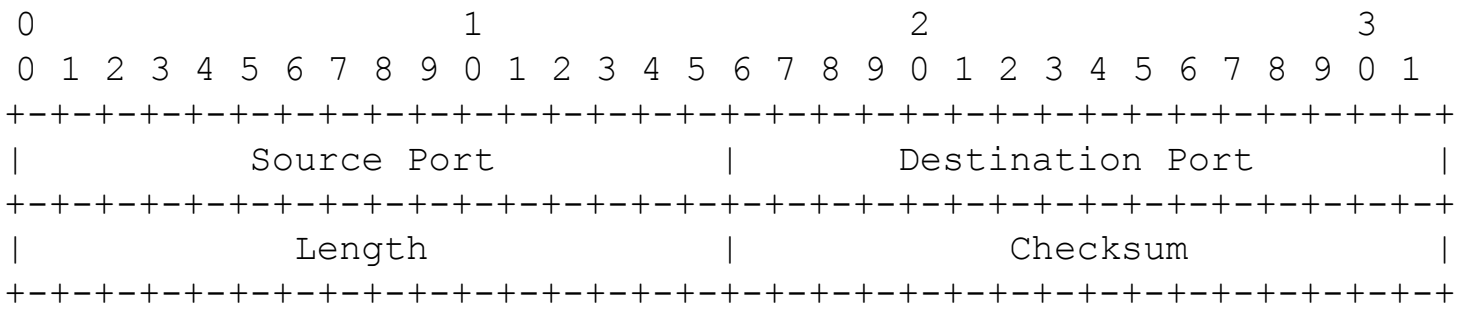
Attacks on ESP Encryption

- S.Bellovin, “Problem areas for the IP security protocols”, *Usenix Security Symposium*, 1996.
- C.McCubbin, A.Selcuk, D.Sidhu, “Initialization Vector Attacks on the IPsec Protocol Suite”, *IEEE Workshop on Enterprise Security*, 2000.
- Attack model:
  - Host-pair keying
  - ESP encryption without authentication
  - CBC mode of encryption

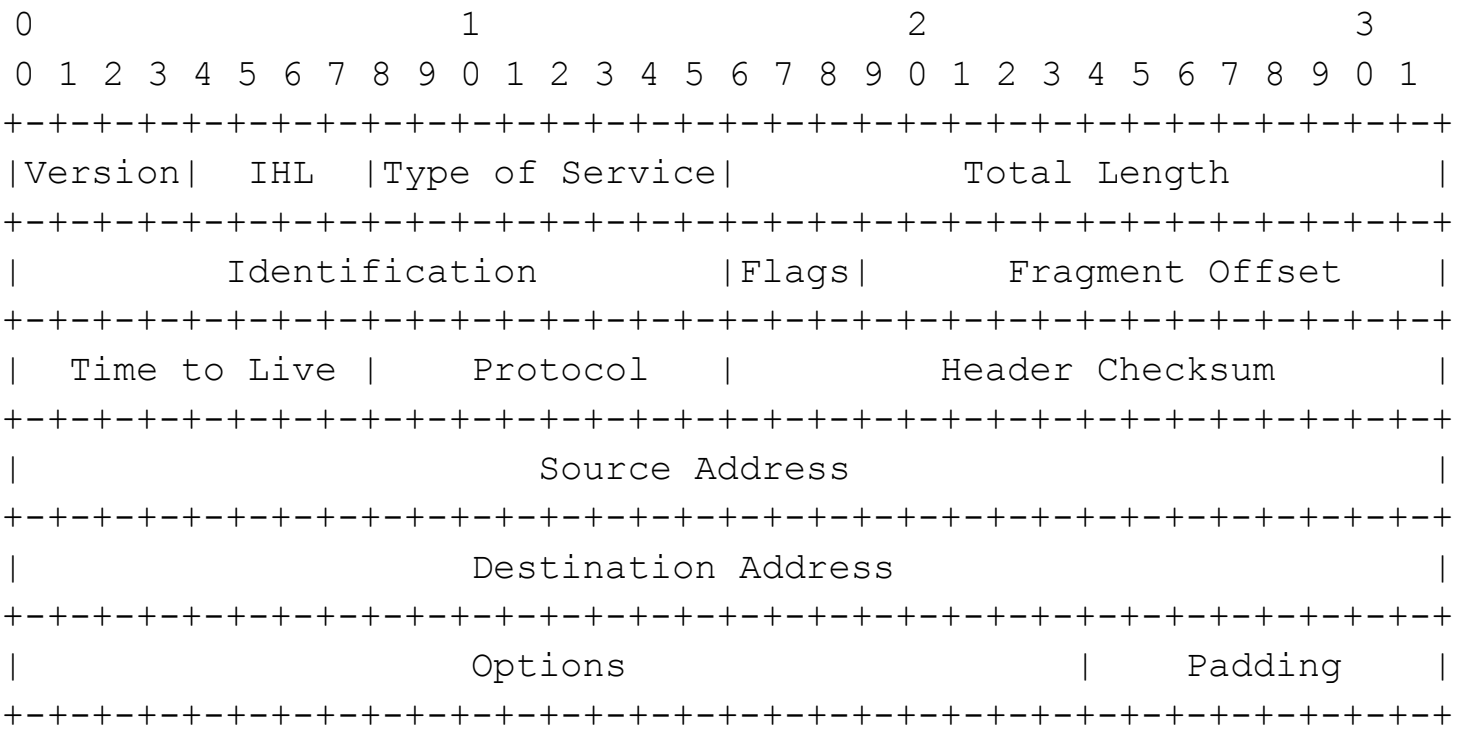
TCP Header


0 1 2 3
0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
Source Port
Destination Port
Sequence Number
Acknowledgment Number
Data Offset
Reserved
U R G
A C K
P S H
R S T
S Y N
F I N
Window
Checksum
Urgent Pointer
Options
Padding
data

UDP Header


0 1 2 3
0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
Source Port
Destination Port
Length
Checksum

IPv4 Header

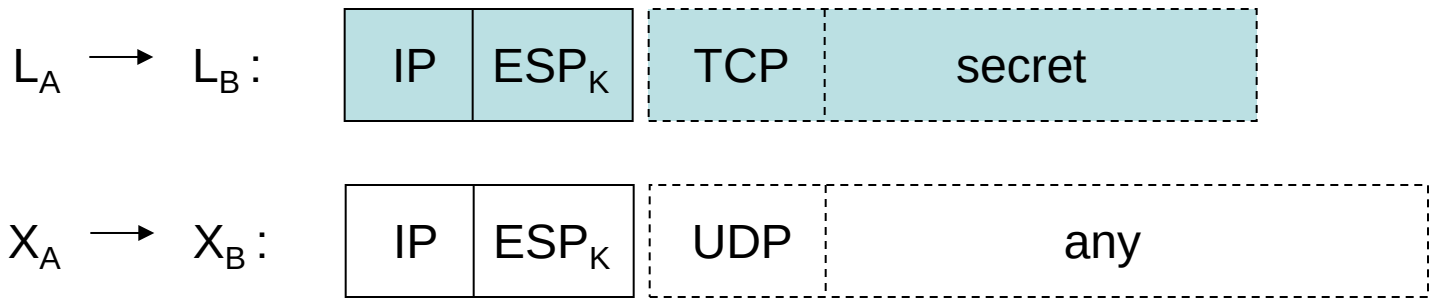

0 1 2 3
0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
Version
IHL
Type of Service
Total Length
Identification
Flags
Fragment Offset
Time to Live
Protocol
Header Checksum
Source Address
Destination Address
Options
Padding

Reading Encrypted Data

L_A, L_B: Legitimate user accounts on hosts A, B

X_A, X_B: Attacker's accounts on A and B

Monitored data:



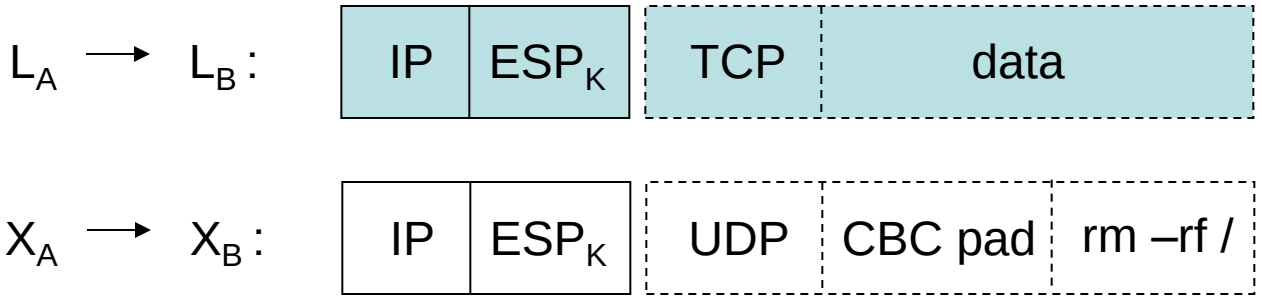
Re-injected data:

Reading Encrypted Data (cont'd)

- Due to CBC, only first block of the pasted packet will be corrupted. (Can be avoided if IV is copied as well)
- Padding may be added to re-injected packet if needed to make lengths match
- If IPv6 in use, UDP checksum mandatory. 2^{16} trials are needed on average to pass validation.
- If L_A, L_B are using UDP, attack is easier:
  - Wait till session ends
  - Allocate L_B's UDP port to X_B
  - Replay all packets

Session Hijacking

Monitored data:



Re-injected data:

Session Hijacking (cont'd)

- Due to CBC, the first pasted block will be corrupted; the "CBC pad".
- Some extra bytes may be needed to restore to a known state (e.g., shell prompt)
- "ckfix" is to fix the checksum; takes on average 2^{16} trials.
- Attack can work without having logins X_A, X_B. (e.g., with SMTP-level source routing)

IV Attacks

- IV is sent in the payload; subject to modification
- By modifying IV, the first plaintext block can be modified in controllable manner:

$$P_1 = D_K(C_1) \oplus IV$$

- Attacks have further impact: First block includes the upper-layer header!!!
- Checksums, if present, may be fixed by modifying insensitive fields in the first block

IV Attacks on TCP

- Fields in first 64 bits: Source Port, Destination Port, Seq.No.
  Fields in bits 65-128: Window Size, Ack.No., Offset, flags
- Attacks on Destination Port: Decrypted packets delivered to X_B.
- Other attacks: Seq.No. (reordering), Window Size (flooding/stalling)
- Checksum fixing: by “reserved” or Ack.No.

IV Attacks on UDP

- Fields in first 64 bits: Source Port, Destination Port, Length, Checksum
  Bits 65-128: Data payload
- Dest. Port: Decrypted packets delivered to X_B.
- Length: Packets can be truncated.
- Checksum can be fixed directly.
- With a 128-bit cipher, the first 64 bits of the payload can be modified.

Conclusion

- Encryption without integrity protection can be all but useless.
- Authentication is better made mandatory in IPsec (and other security protocols).
- Moral of the story: It is safe to always use authentication/integrity protection, even if only confidentiality is the purpose.
(Besides, the extra cost of MAC is marginal.)