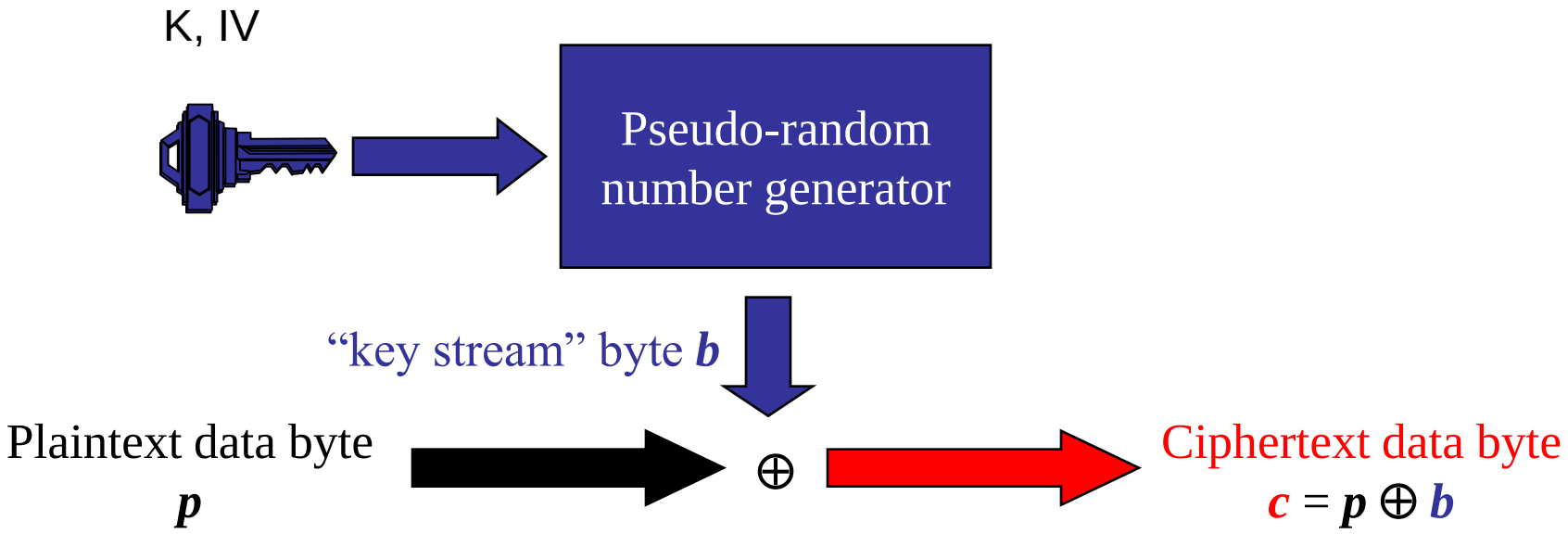
Tutorial 7

Review of the cipher RC4



Decryption works the same way: $p = c \oplus b$

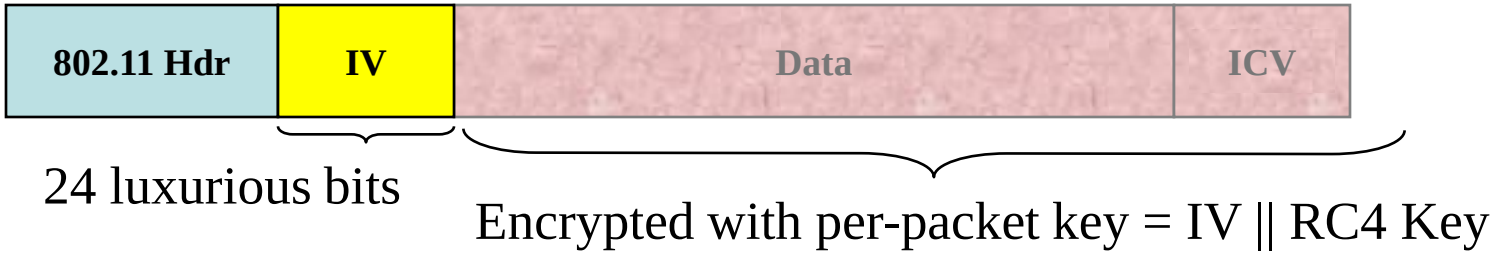
WEP IV Reuse

- Same shared key used in both directions
- Some implementations reset IV to 0 when initialized
  - Low IV values get reused at the beginning of every session
- IV reuse exposes the system to keystream reuse attacks.

WEP IV Reuse

- How about using random IVs?
- IV space – 2^{24} possibilities
- Collision after 5000 packets
  - Birthday Paradox!
- Rough estimate: a busy AP sends 1000 packets/sec
- Collision every 5 sec

Attacks – collision attacks



- WEP expands each RC4 key into 2^{24} per-packet keys

  $\Rightarrow$data can be recovered if IV is ever repeated with same key

  $\Rightarrow$ RC4 key must be changed at least every 2^{24} packets or data is exposed through IV collisions!

A Property of RC4

- Keystream leaks, under known-plaintext attack
  - Suppose we intercept a ciphertext C, and suppose we can guess the corresponding plaintext P
  - Let Z = RC4(K, IV) be the RC4 keystream
  - Since $C = P \oplus Z$, we can derive the RC4 keystream Z by $P \oplus C = P \oplus (P \oplus Z) = Z$
- This is not a problem ... unless keystream is reused!

A Risk of Keystream Reuse

IV, P ⊕ RC4(K, IV)

IV, P′ ⊕ RC4(K, IV)

- If IV's repeat, confidentiality is at risk
  - If we send two ciphertexts (C, C') using the same IV, then the xor of plaintexts leaks (P ⊕ P' = C ⊕ C'), which might reveal both plaintexts

➤ Lesson: If RC4 isn't used carefully, it becomes insecure

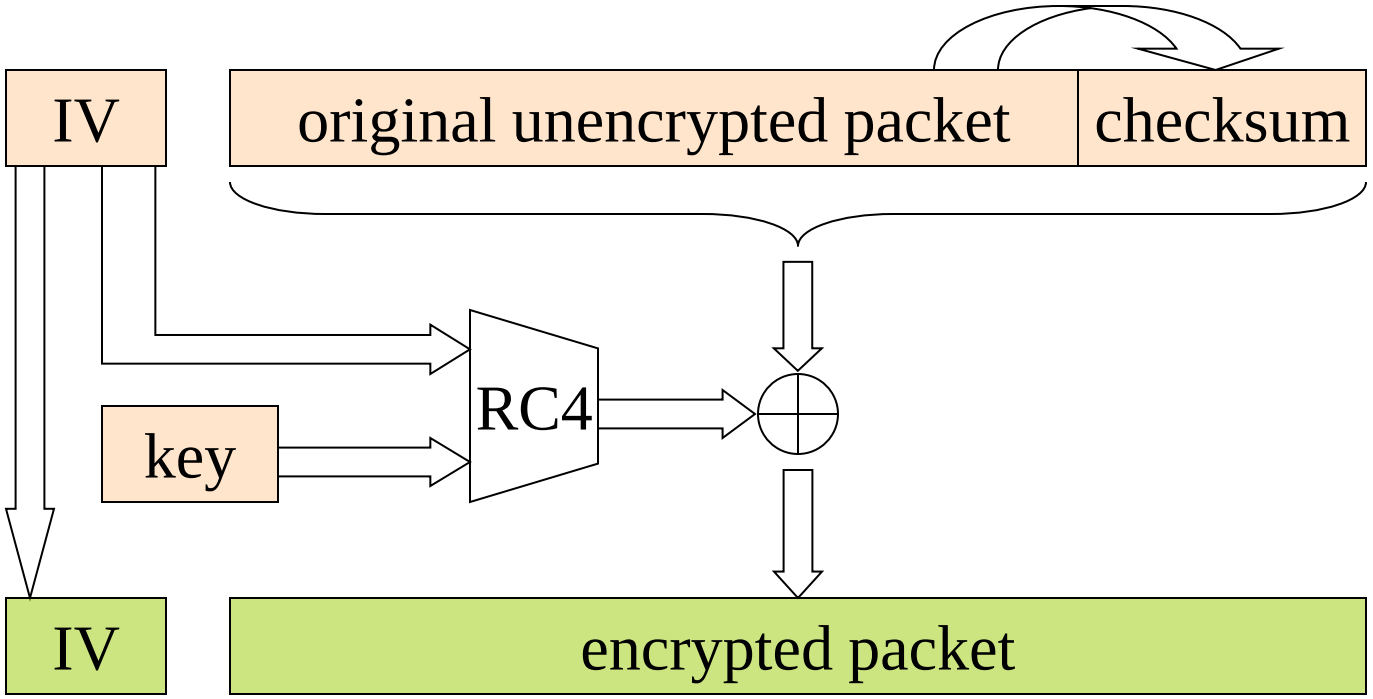
Attack #1: Keystream Reuse

- WEP didn't use RC4 carefully
- The problem: IV's frequently repeat
  - The IV is often a counter that starts at zero
  - Hence, rebooting causes IV reuse
  - Also, there are only 16 million possible IV's, so after intercepting enough packets, there are sure to be repeats

➤ Attackers can eavesdrop on 802.11 traffic

  - An eavesdropper may decrypt intercepted ciphertexts even without knowing the key

WEP -- More Detail



Attack #2: Spoofed Packets

- Attackers can inject forged 802.11 traffic
  - Learn RC4(K, IV) using previous attack
  - Since the checksum is unkeyed, you can then create valid ciphertexts that will be accepted by the receiver

➤ Lesson: checksum must be keyed, preferably using an authentication key different from the encryption key

Attack #3: Modification Attack

$(P||crc(P)) \oplus RC4(K)$

$(P||crc(P)) \oplus RC4(K) \oplus (P'||crc(P'))$

- CRC-32 is linear crc(P XOR P') = crc(P) XOR crc(P')

  $(P||crc(P)) \oplus RC4(K) \oplus (P'||crc(P'))$
  $= (P \oplus P')||((crc(P) \oplus crc(P')) \oplus RC4(K)$
  $= (P \oplus P')||(crc(P \oplus P') \oplus RC4(K)$

- The checksum on received packet is valid, but the message has been modified.

1. Why is WPA more secure than WEP?

(1) TKIP has been adopted for stronger encryption.

- Using 48 bit IV (24 bits in WEP)
- Key mixing: IV and RC4 key are generated with:

  Temporal key (TK) mixed with Transmitter Address (TA) and TKIP Sequence Counter (TSC). TK is derived from Pairwise Master Key (PMK) obtained from 802.1x

  TK ← KeyGen(PMK)
- IV||Key = Mix(Mix(TK, TA, TSC), TSC)

(2) Using MIC (keyed) for integrity (CRC in WEP)

ICV = MIC(TA, DA, TEXT, MIC-key)

Ciphertext = RC4_(IV||Key)[TEXT||ICV]

(3) 802.1x has been adopted for authentication.

2. Does EAP or EAPOL define a fixed authentication scheme?

No.

You can select one of given authentication and key exchange schemes such as TLS, Kerberos, PEAP, IKE, EAP-MD5, etc. EAP-MD5 is generally regarded as insecure, since hashed passwords are sent in clear, which is vulnerable to offline dictionary attack.

3. How are WPA and 802.11i related?

WPA is a subset of 802.11i and provides security service to 802.11i. 802.11i also considers using AES, while WPA is based on TKIP which utilises RC4.

4. Does 802.11 require the mobile IP technology?

No, 802.11 does not require mobile IP.

In 802.11, IP can automatically be assigned. This doesn’t need to be linked with a home identity.

802.11 is for short range high radio frequency (wireless) communications. Mobile IP is for any medium. Mobile IP gives a link to a home identity which isn’t necessary for wireless connections.

5. How are Mobile IP and wireless systems related? Can a connection be wireless and mobile?

- Wireless are kind of short range mobile, they need to have some sort of authorisation to connect locally. Mobile IP relates to establishing a global identity, whether the connection itself is wired or wireless,
- A connection can certainly be wireless and mobile. The wireless relates to not having wires, while the mobile relates to allowing mobility, i.e. not having a fixed entry point.