THE UNIVERSITY OF BRITISH COLUMBIA

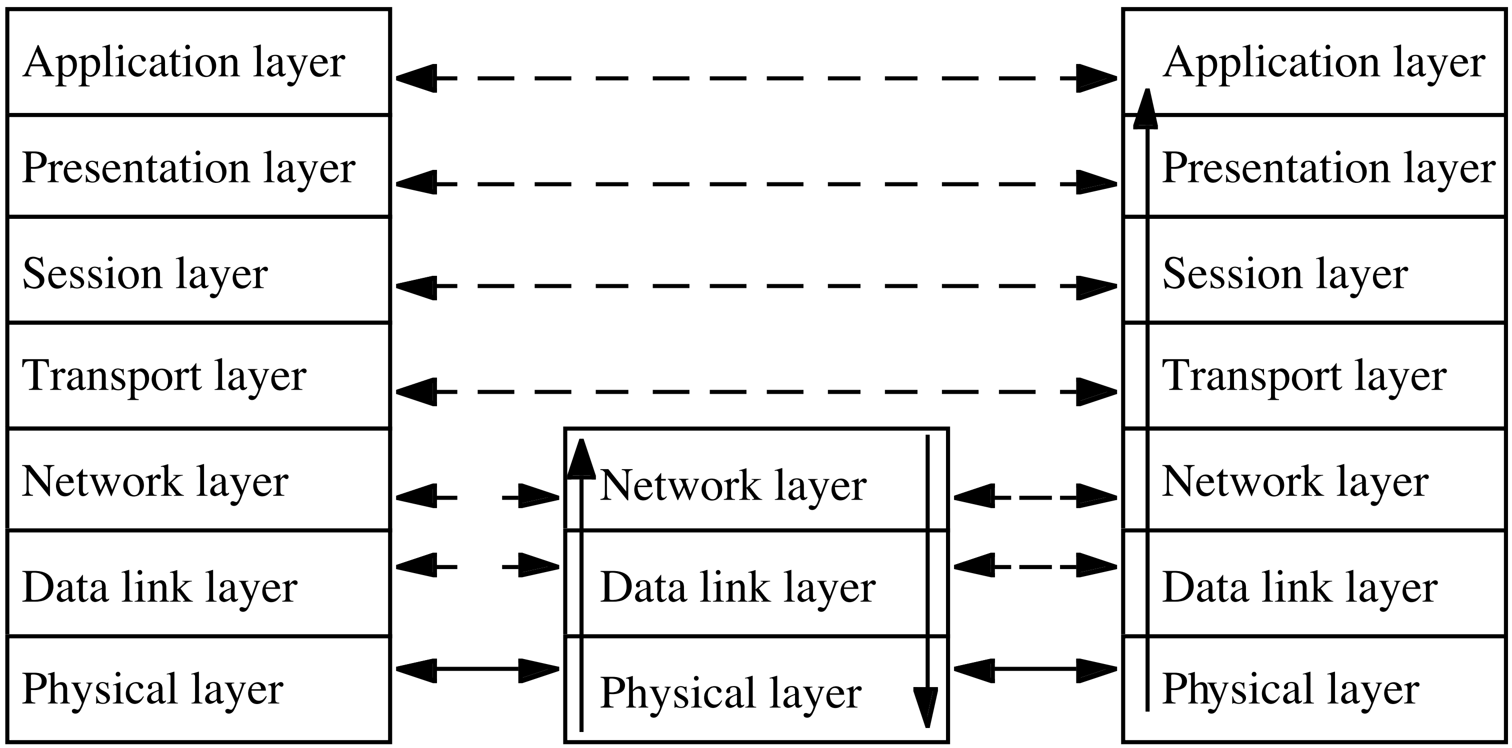
Network Security

EECE 412

Outline

- Link & end-to-end protocols
- SSL/TLS
- WPA

Networks



Application layer
Presentation layer
Session layer
Transport layer
Network layer
Data link layer
Physical layer
Network layer
Data link layer
Physical layer
Application layer
Presentation layer
Session layer
Transport layer
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Physical layer

Link and End-to-End Protocols

Link Protocol

End-to-End (or E2E) Protocol

Examples

- Telnet protocol
  - Messages between client, server enciphered, and
    - encipherment/decipherment occur only at these hosts
  - End-to-end protocol
- PPP Encryption Control Protocol
  - Host gets message, deciphers it
    - Figures out where to forward it
    - Enciphers it in appropriate key and forwards it
  - Link protocol

Link vs. End-to-end protection

Link encryption

- Can protect headers of packets
- Possible to hide source and destination
  - Note: may be able to deduce this from traffic flows

End-to-end encryption

- Cannot hide packet headers
- Attacker can read source, destination

Example Protocols

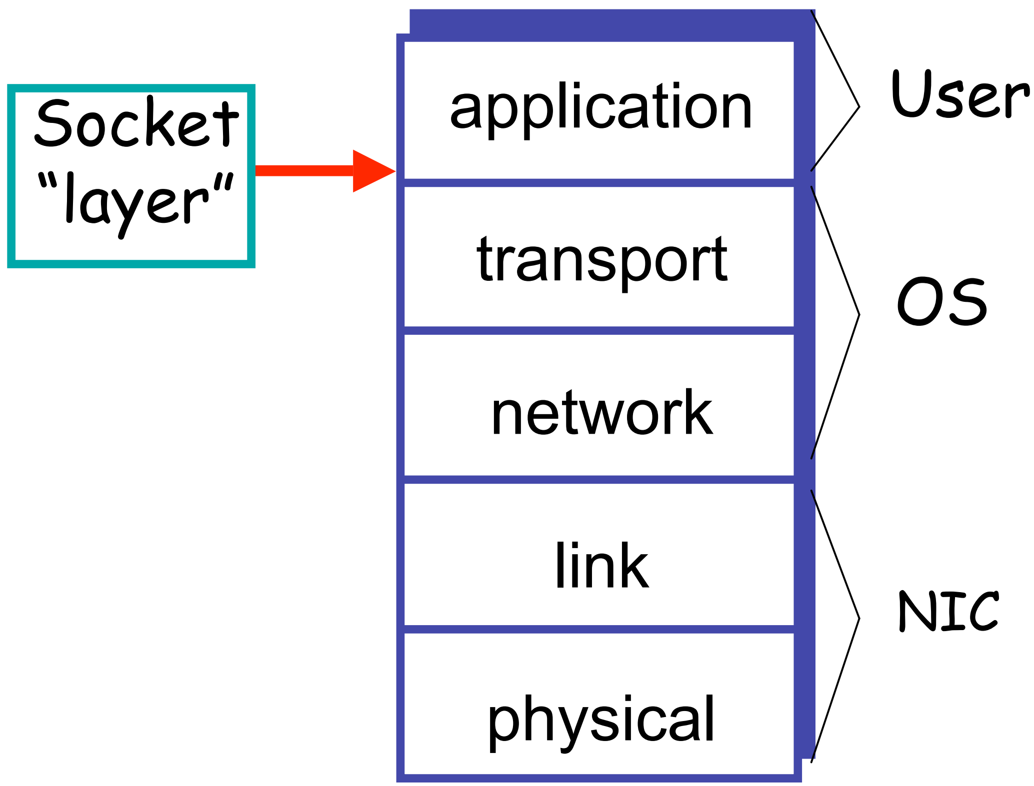
- Privacy-Enhanced Electronic Mail (PEM)
  - Applications layer protocol
  - Bishop
- Secure Socket Layer (SSL)/Transport Layer Security (TLS)
  - Transport layer protocol
- IP Security (IPSec)
  - Network layer protocol
  - Bishop
- Wi-Fi Protected Access (WPA)
  - Data layer protocol
  - Today session

Secure Socket Layer

From “Information Security: Principles and Practice” by Mark Stamp

Socket layer

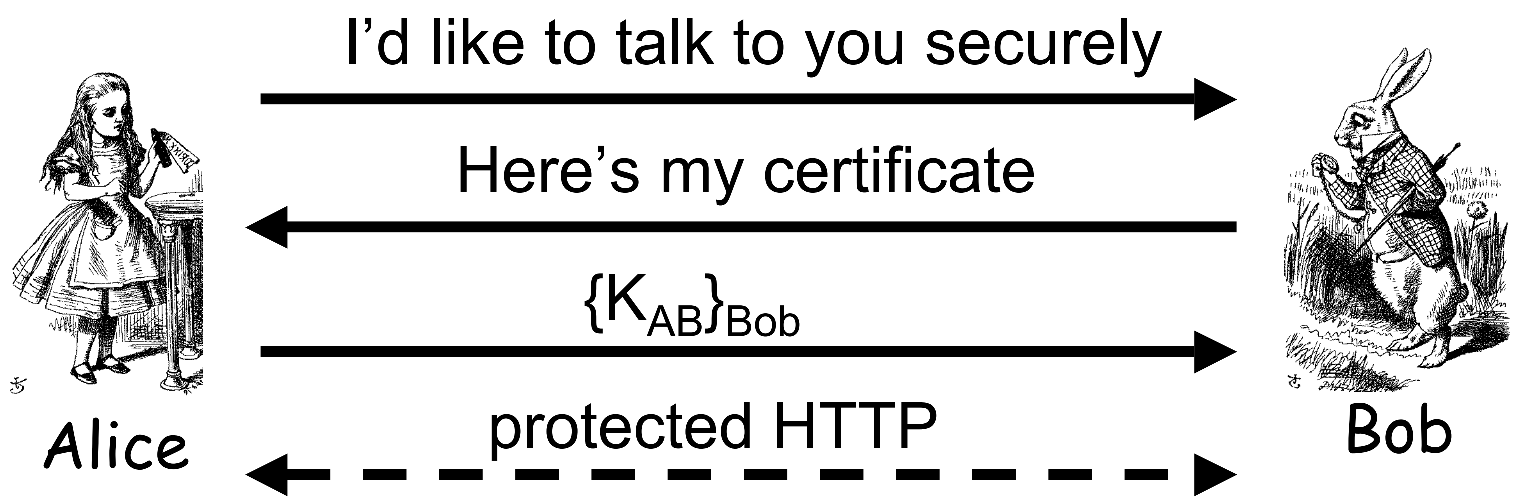
- "Socket layer" lives between application and transport layers
- SSL usually lies between HTTP and TCP



What is SSL?

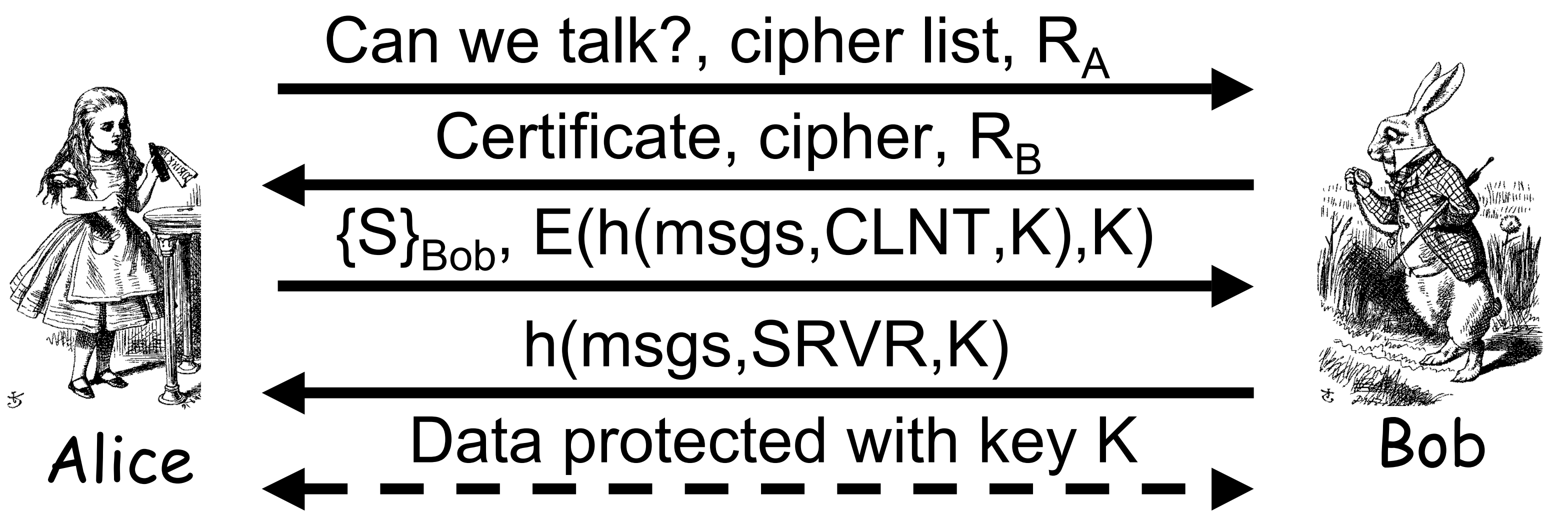
- SSL is the protocol used for most secure transactions over the Internet
- For example, if you want to buy a book at amazon.com…
  - You want to be sure you are dealing with Amazon (**authentication**)
  - Your credit card information must be protected in transit (**confidentiality** and/or **integrity**)
  - As long as you have money, Amazon doesn't care who you are (authentication need not be mutual)

Simple SSL-like Protocol



- Is Alice sure she's talking to Bob?
- Is Bob sure he's talking to Alice?

Simplified SSL Protocol



- S is **pre-master secret**
- $K = h(S,R_A,R_B)$
- msgs = all previous messages
- CLNT and SRVR are constants

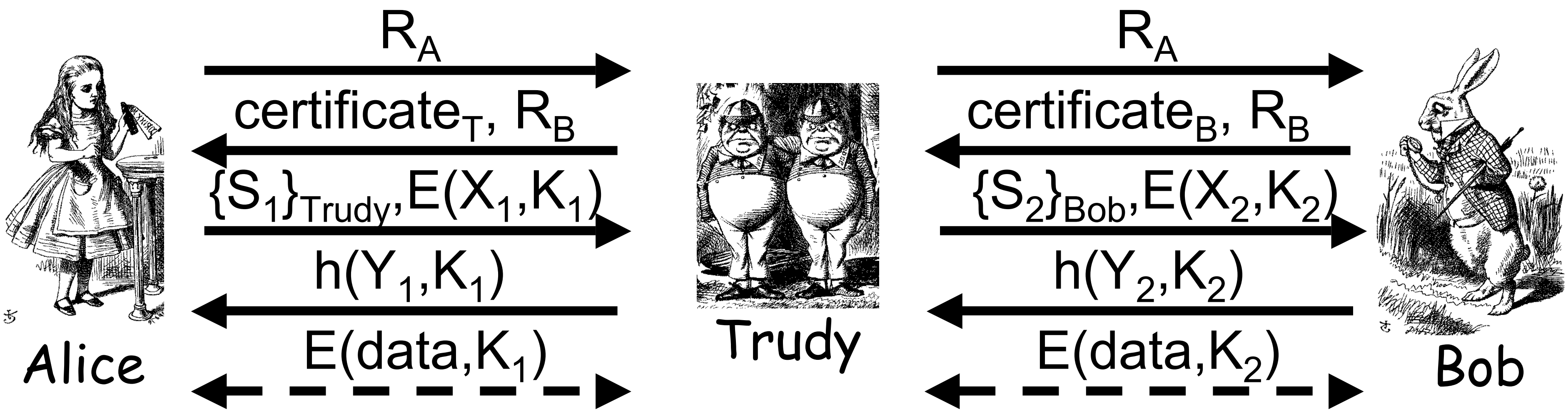
SSL Keys

- 6 "keys" derived from $K = hash(S,R_A,R_B)$
  - 2 encryption keys: send and receive
  - 2 integrity keys: send and receive
  - 2 IVs: send and receive
  - Why different keys in each direction?
- **Q:** Why is h(msgs,CLNT,K) encrypted (and integrity protected)?
- **A:** It adds no security…

SSL Authentication

- Alice authenticates Bob, not vice-versa
  - How does client authenticate server?
  - Why does server not authenticate client?
- Mutual authentication is possible: Bob sends **certificate request** in message 2
  - This requires client to have certificate
  - If server wants to authenticate client, server could instead require (encrypted) password

SSL MiM Attack

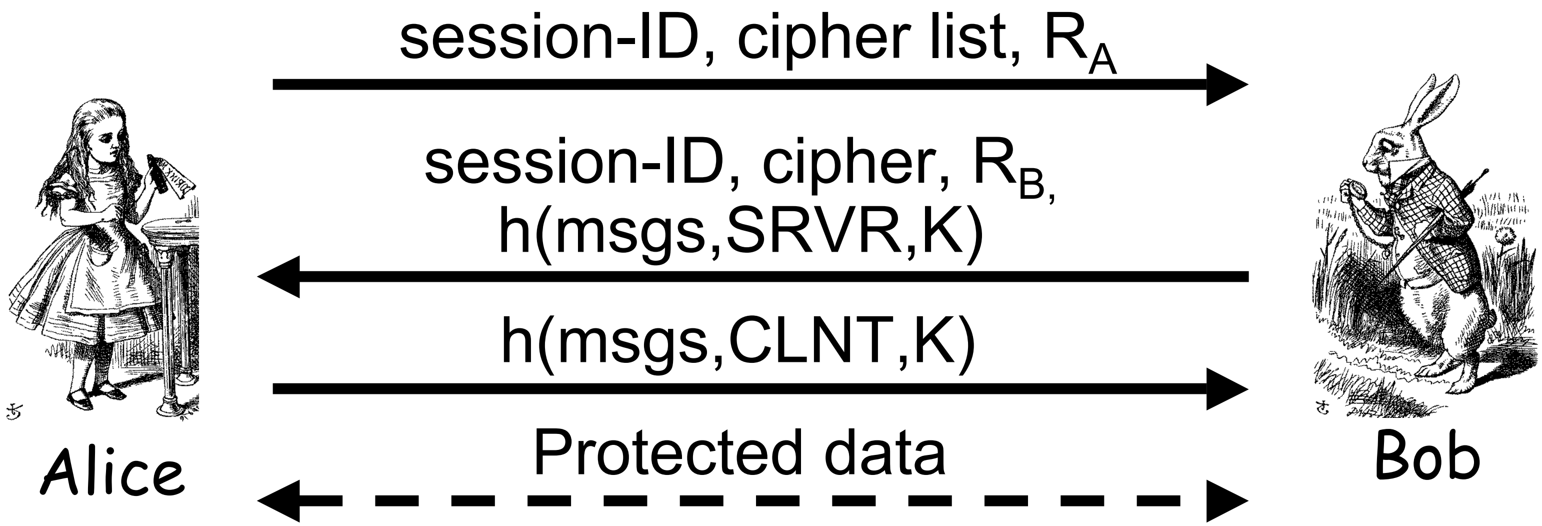


- **Q:** What prevents this MiM attack?
- **A:** Bob's certificate must be signed by a certificate authority (such as Verisign)
- What does Web browser do if sig. not valid?
- What does user do if signature is not valid?

SSL Sessions vs Connections

- SSL **session** is established as shown on previous slides
- SSL designed for use with HTTP 1.0
- HTTP 1.0 usually opens multiple simultaneous (parallel) **connections**
- SSL session establishment is costly
  - Due to public key operations
- SSL has an efficient protocol for opening new connections given an existing session

SSL Connection

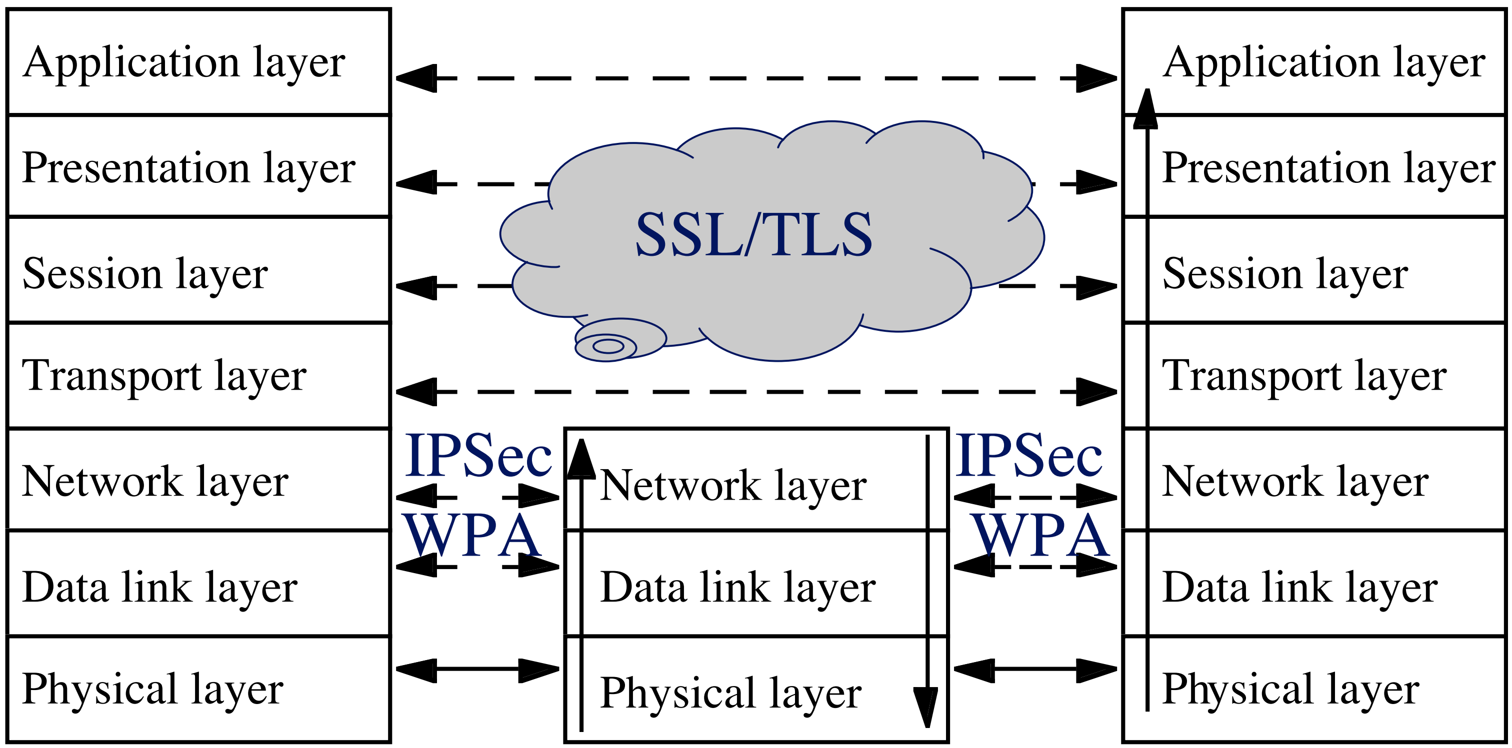


- Assuming SSL **session** exists
- So S is already known to Alice and Bob
- Both sides must remember session-ID
- Again, $K = h(S,R_A,R_B)$

- **No public key operations!** (relies on known S)

Wi-Fi Protected Access (WPA)

Where is WPA?



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IPSec
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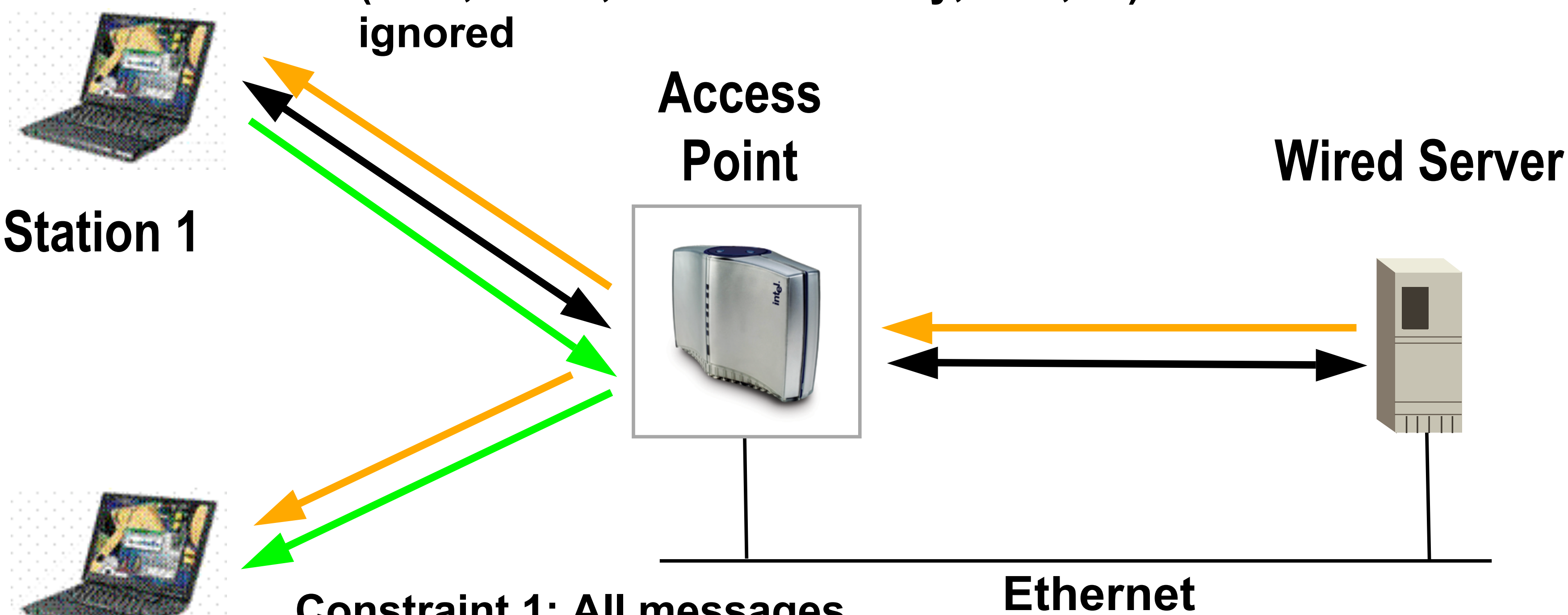
Design Constraints

Constraint 3: Multicast integral to modern networking (ARP, UPnP, Active Directory, SLP, …) and cannot be ignored



Constraint 1: All messages flow through access point; 1st generation AP MIP budget = 4 Million instructions/sec

Constraint 2: WLAN uses short range radios, so APs must be ubiquitous, so lowest cost

Wireless Security Overview

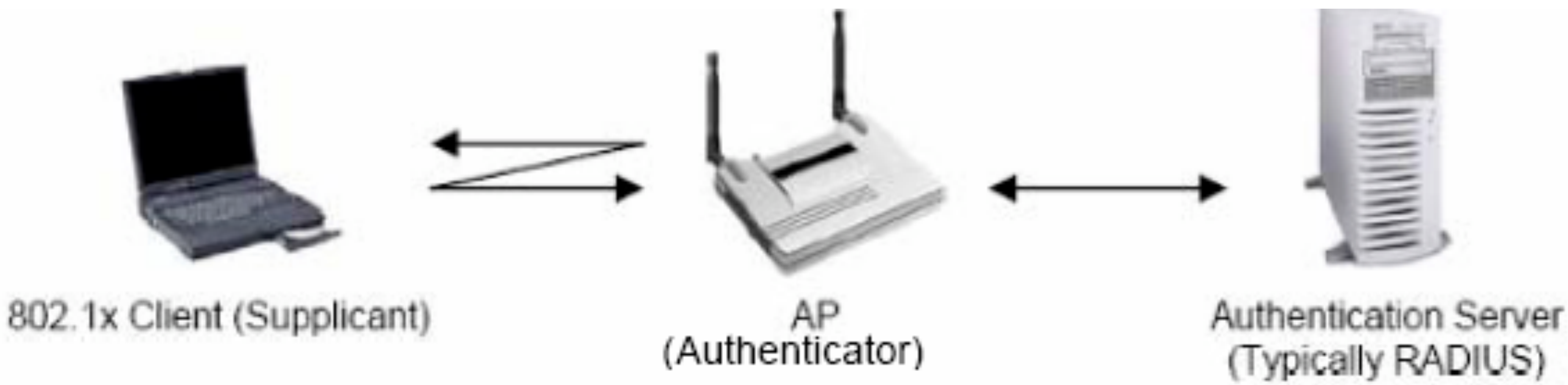
Paul Cychosz

March 2005

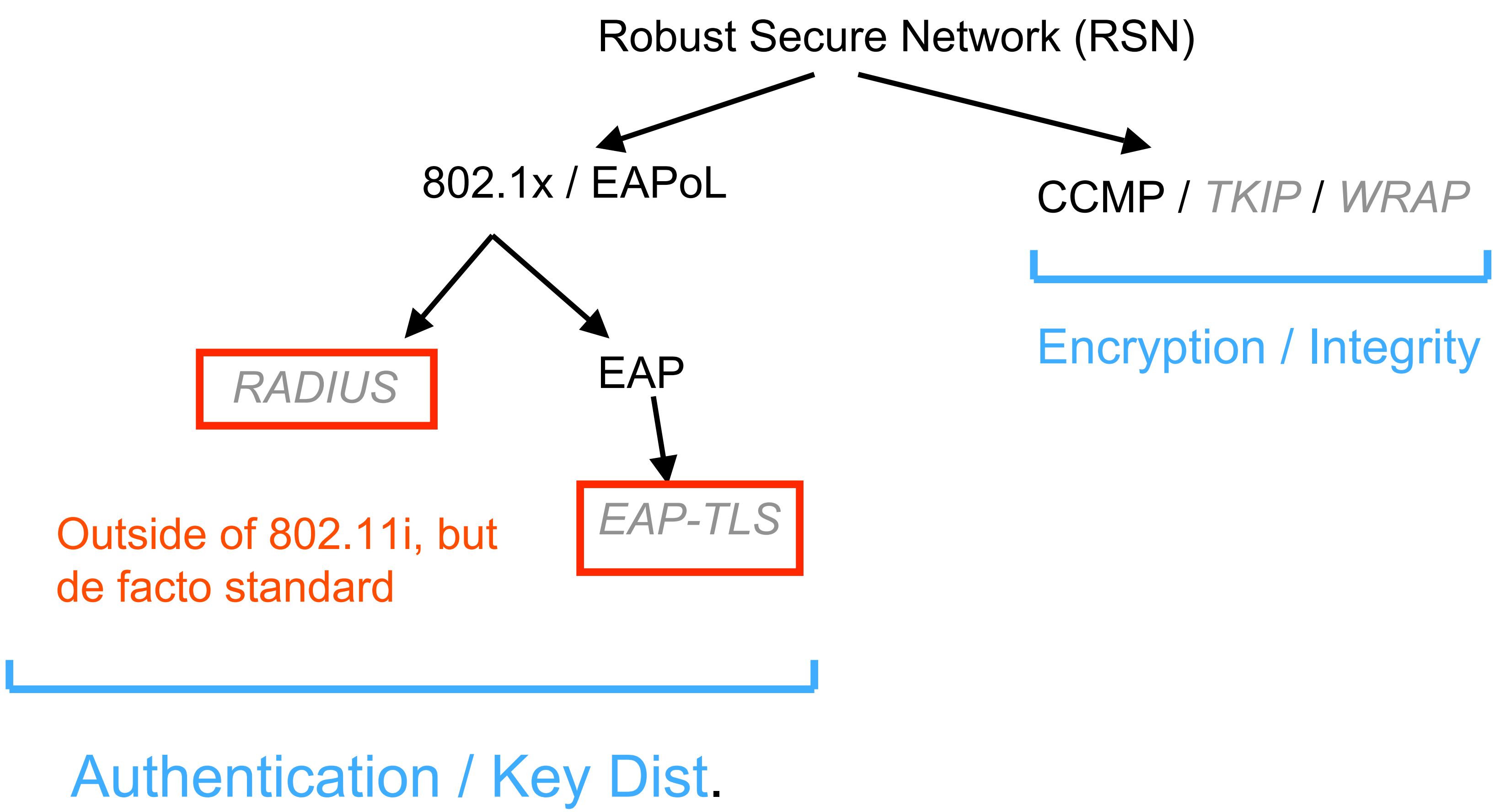
802.11i

Terms:

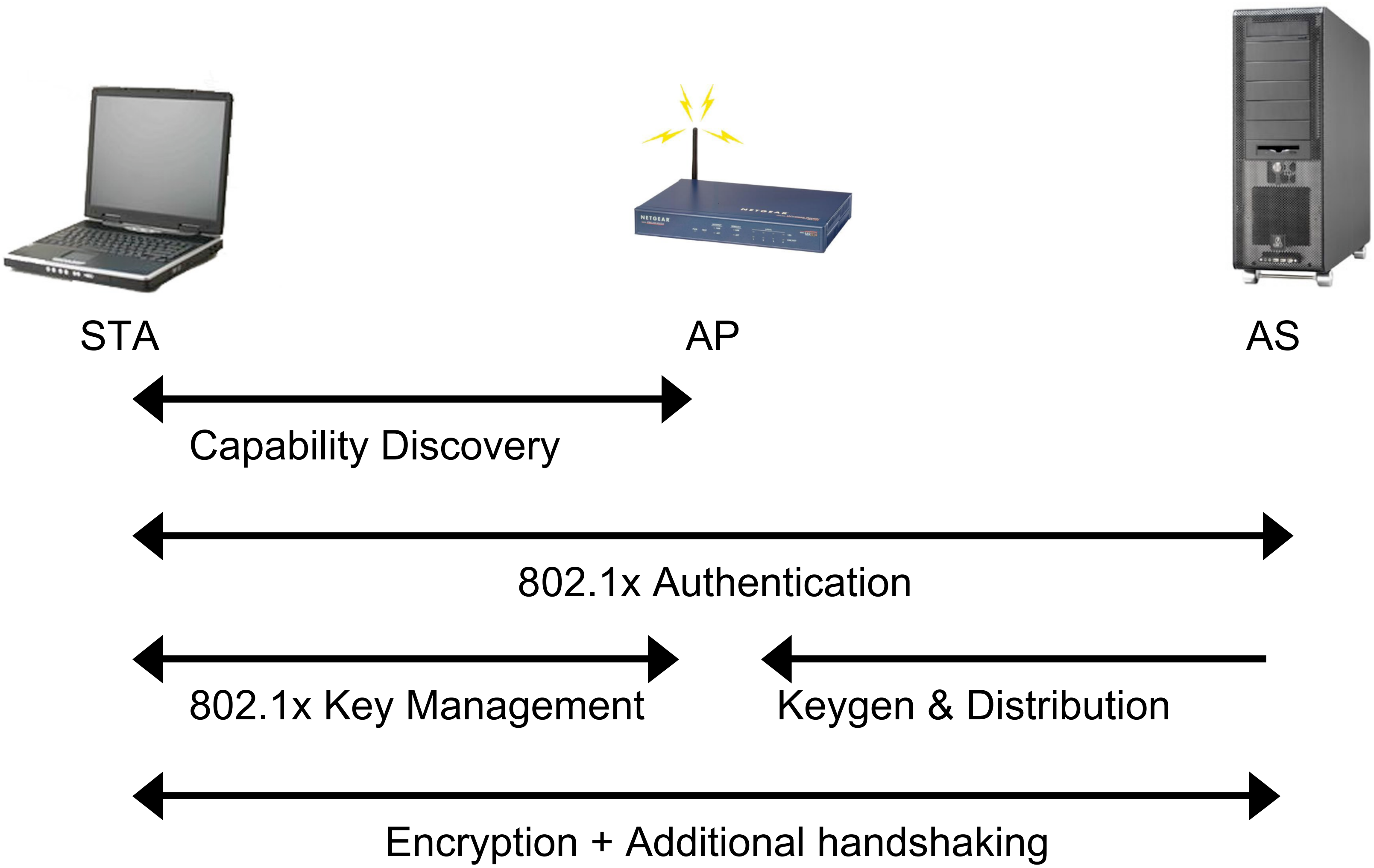
- 802.1x: Authentication standard
- RADIUS: Authentication Server
- EAP: Extensible Authentication Protocol
- CCMP: Encryption based on AES counter mode with CBC-MAC



802.11i Parts



802.11i – First half



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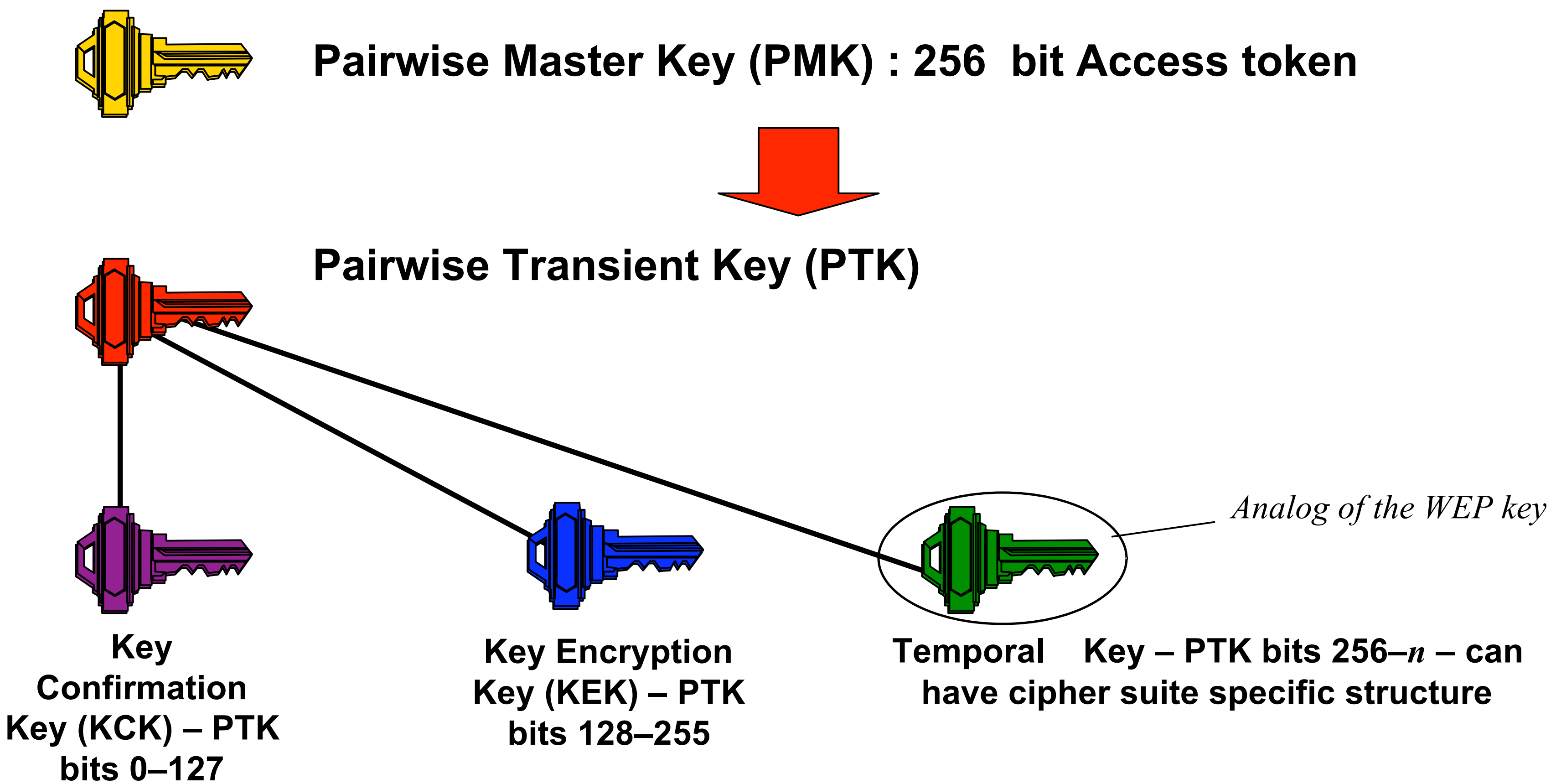
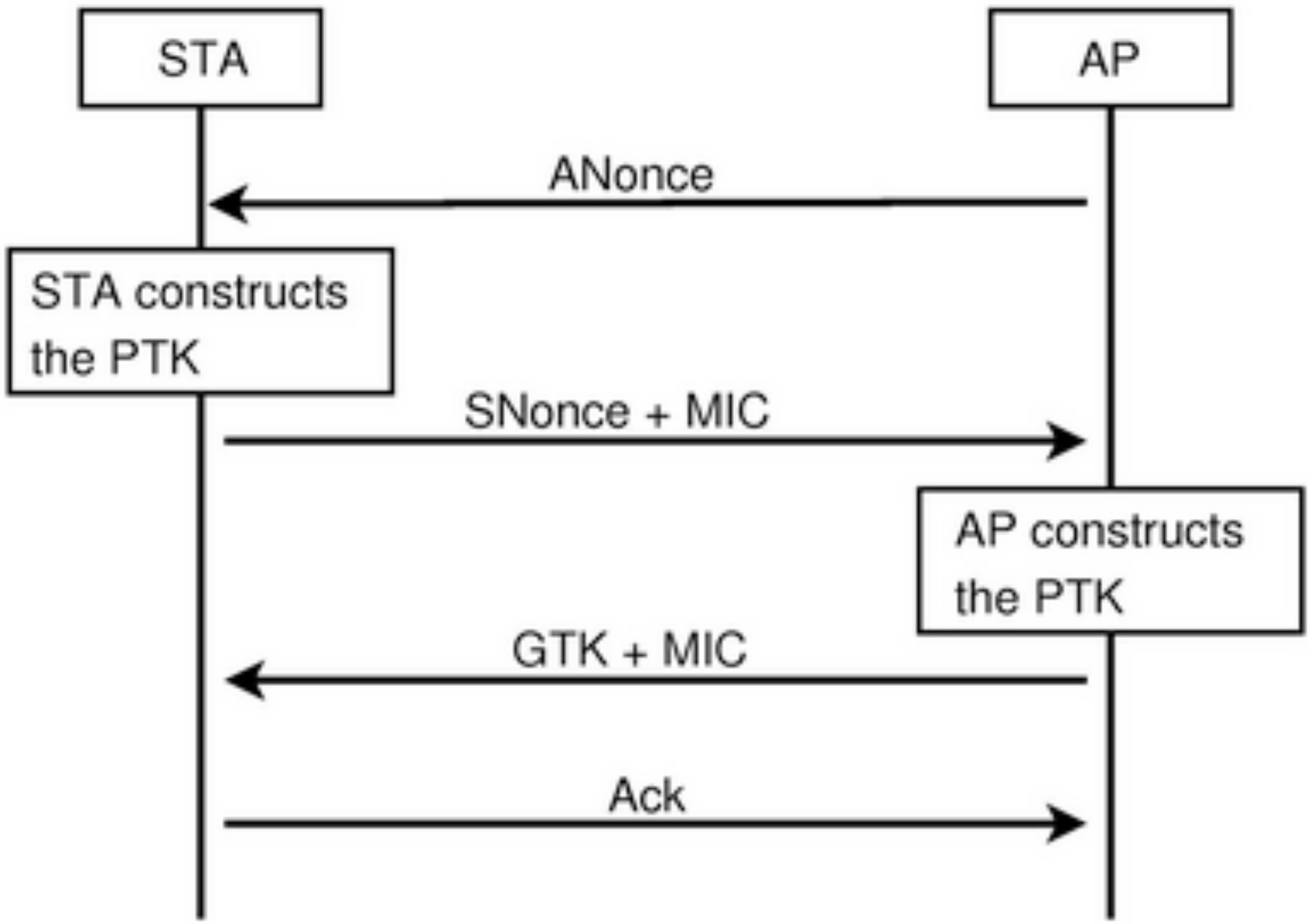
WPA Key Managment

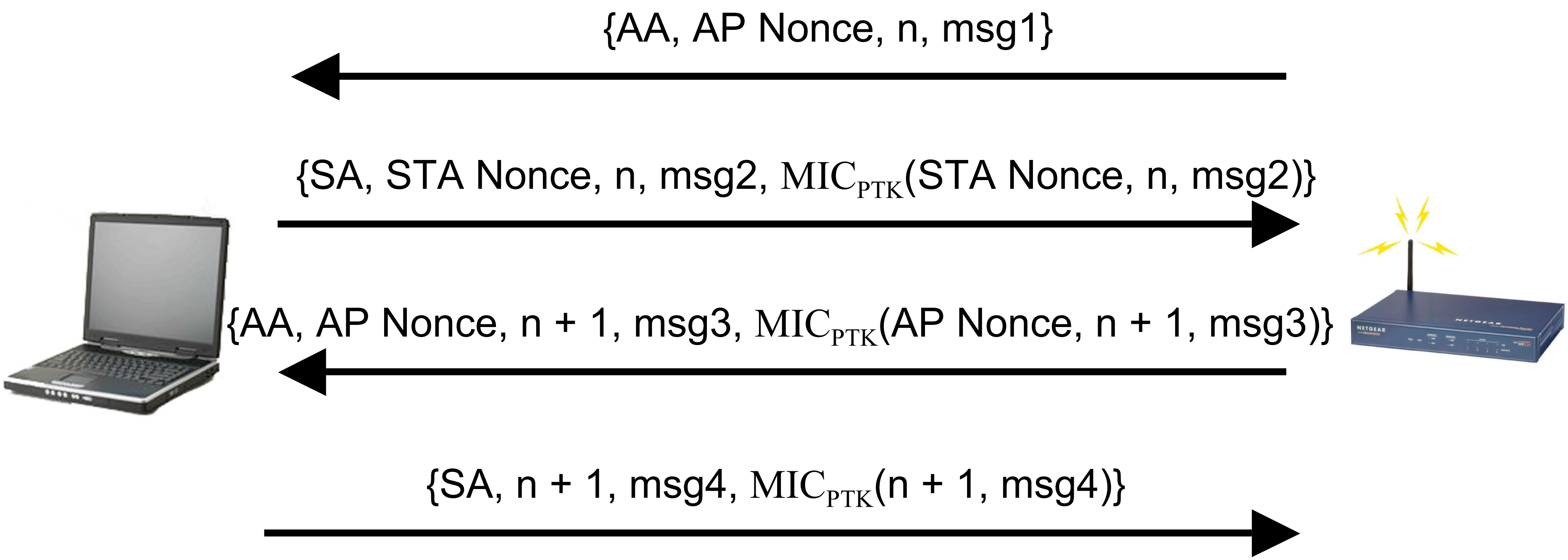
802.11i Pairwise Key Hierarchy



Session Key Establishment



Handshake Details



Message 1

- not protected, doesn't matter though

AP → STA: {AA, AP Nonce, n, msg1}

AA: MAC Address of AP

AP Nonce: random value

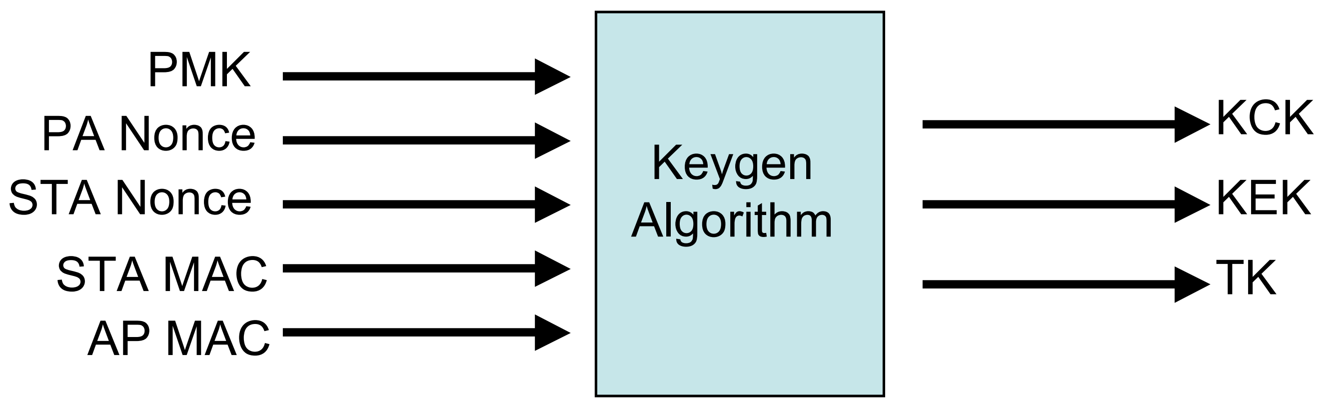
n: sequence identifier

msg1: PMKID = HMAC-SHA1-128(PMK, "PMK Name" || AA || SPA).

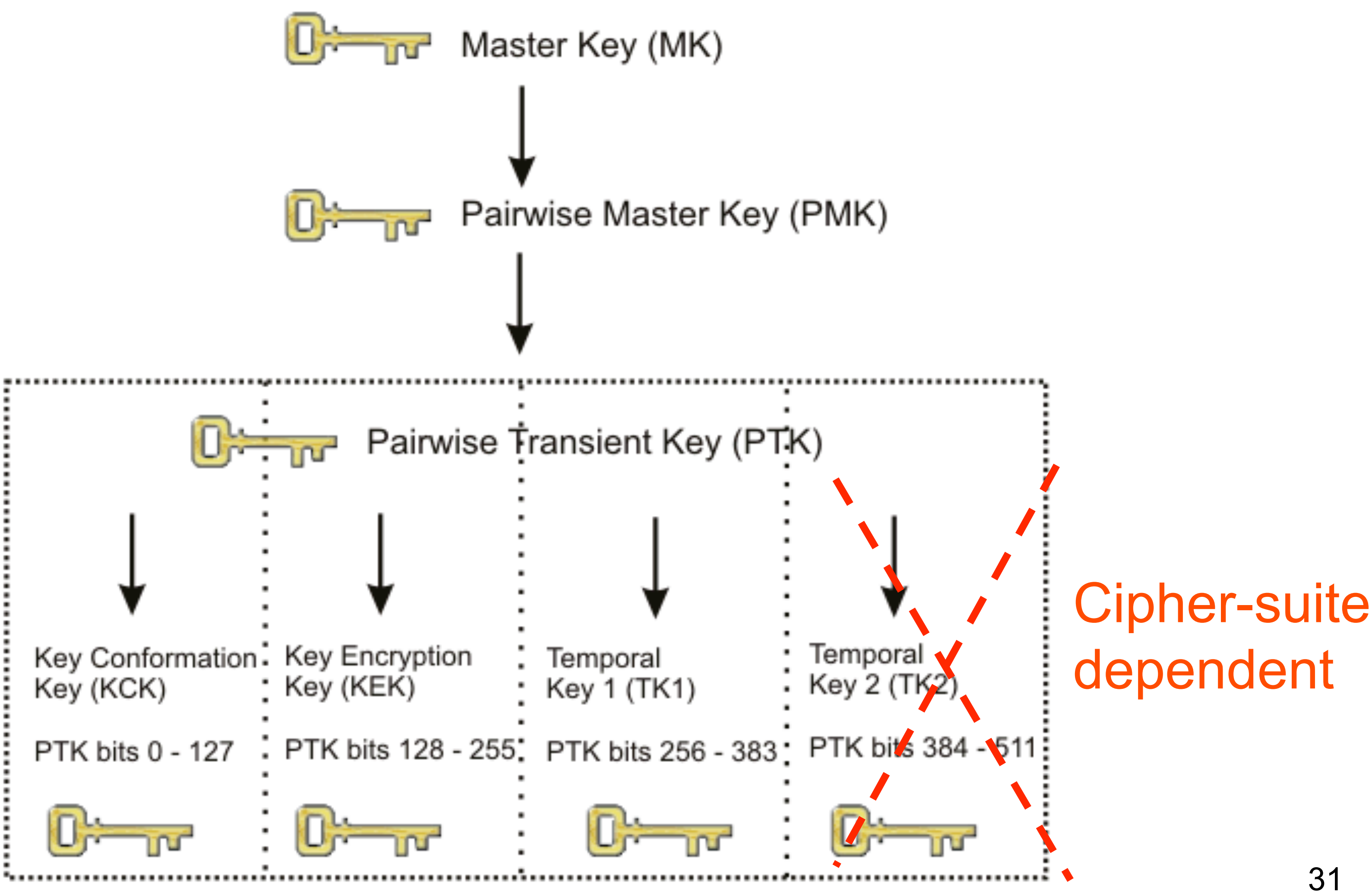
•Client uses AP Nonce and PMK to compute PTK

PTK = 802.11i-PRF(
PMK,
min(AP Nonce, STA Nonce) || max(AP nonce, STA Nonce) ||
min(AP MAC Addr, STA MC Addr) || max(AP MAC Addr, STA MAC Addr))

802.11i – What's PTK?



802.11i – Key Heirarchy



Message 2

STA → AP: {SA, STA Nonce, n, msg2, MIC_{PTK}(STA Nonce, n, msg2)}

SPA: MAC Address of STA

SNonce: random value

n: sequence identifier, matches msg1

msg2: RSN IE of STA

- AP uses STA Nonce and PMK to compute PTK

Message 3

AP → STA: {AA, AP Nonce, n + 1, msg3, MIC_{PTK}(AP Nonce, n + 1, msg3)}

AA: MAC Address of AP

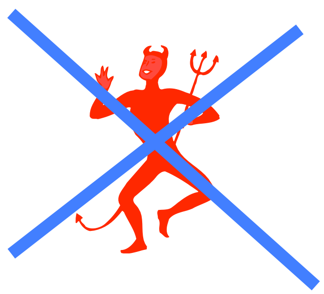
AP Nonce: random value again

n: sequence identifier, to match msg4

msg3: Informs STA that TK ready to use, RSN IE of AP.

MIC: to verify the above. Silently discarded if MIC fails.

Verifies no MITM attack happening



Message 4

STA → AP: {SPA, n + 1, msg4, MIC_{PTK}(n + 1, msg4)}

SPA: MAC Address of STA

n: sequence identifier, to match msg3

MIC: to verify the above. Silently discarded if MIC fails.

- This message dropped in some implementations.
- Only kept for convention

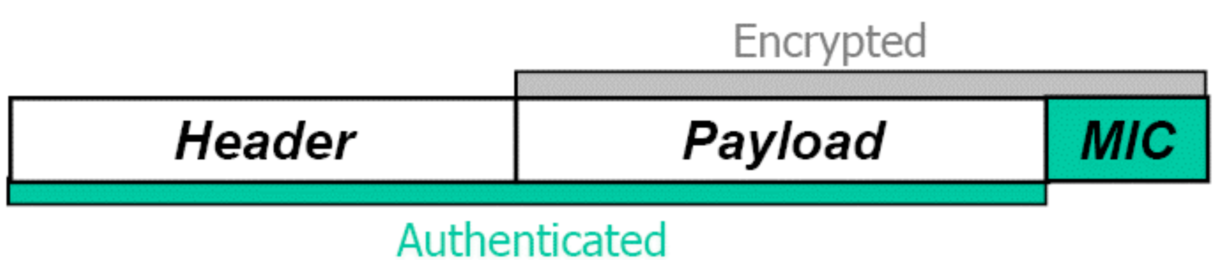
WPA Data Protection

AES-CCMP

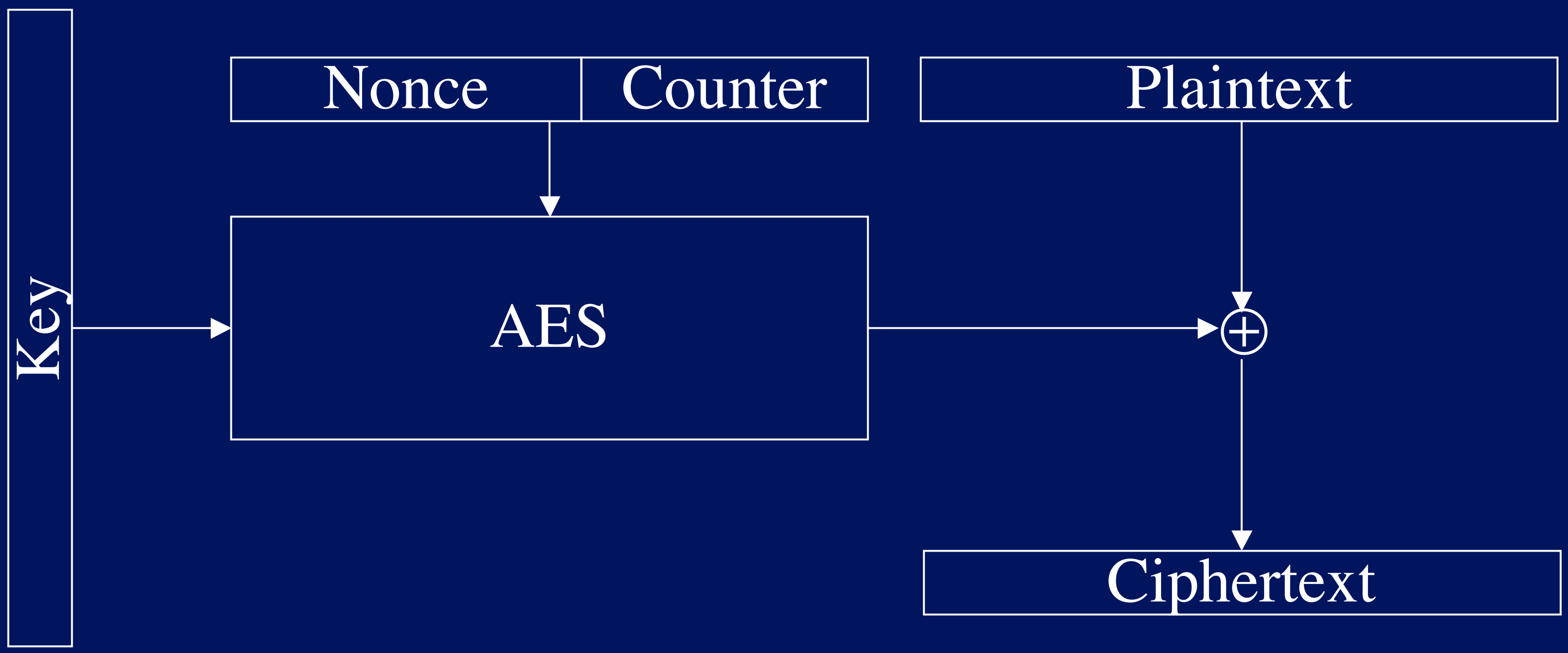
- New encryption based on AES

" NIST estimates that a machine that can break 56-bit DES key in 1 second would take about 149 trillion years to crack a 128-bit AES key (unless someone is very lucky)"

- CCMP: Counter Mode with Cipher Block Chaining Message Authentication Code Protocol
    - Confidentiality protection: counter mode
    - Authenticity and integrity protection: CBC-MAC

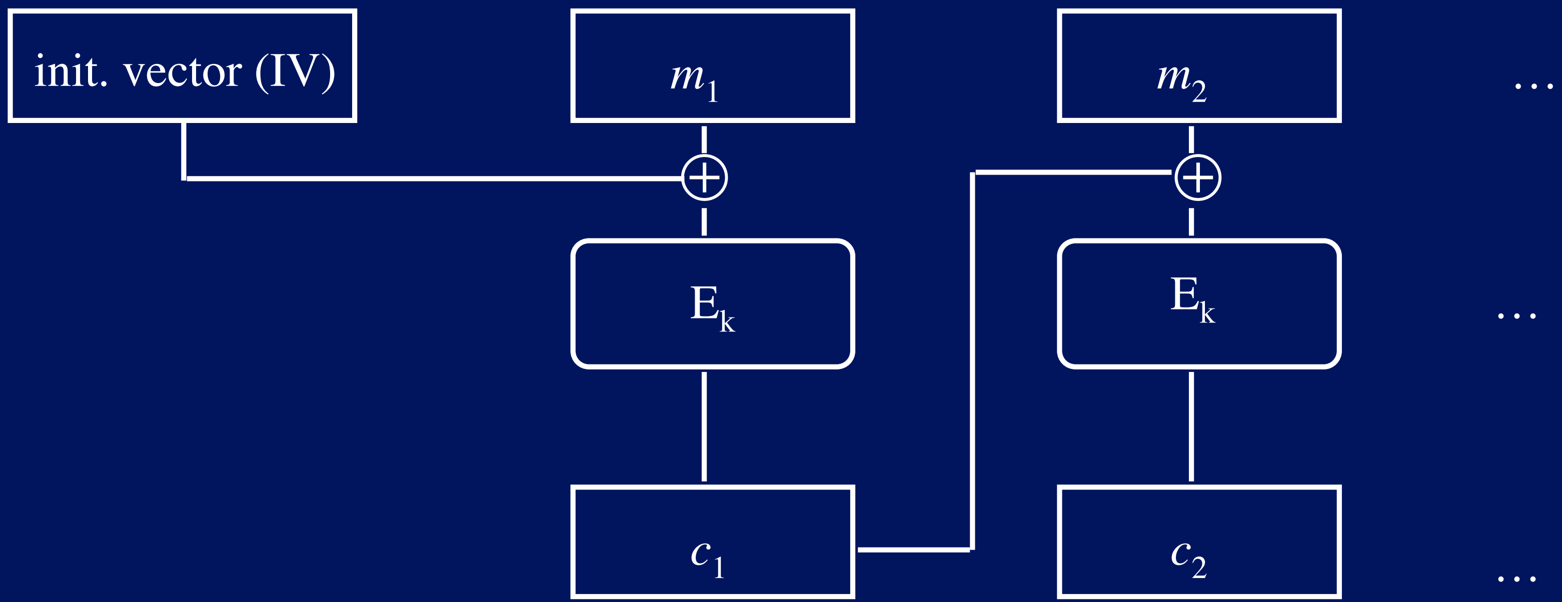


AES-CCMP: Counter Mode Encryption



Cipher Block Chaining (CBC)

$M = m_1 \mid m_2 \mid \ldots \mid m_n$



$C = IV \mid c_1 \mid c_2 \mid \ldots \mid c_n$

Integrity and authenticity Protection

MIC: CBC-MAC / per packet algorithm

- 128-bit generation, but only take first 64-bits
- XOR blocks, hence “block-chaining”
- MIC computed on packet header
- MIC then encrypted (using IV = 0, CTR mode) and appended to payload