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3 Data Link Layer Security

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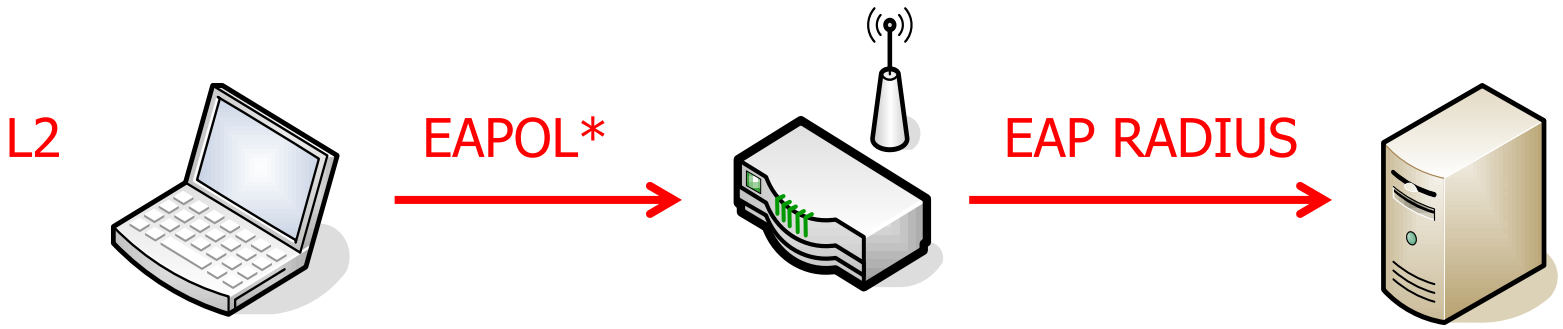
Security Protocols for the OSI Stack

Communication layers	Security protocols
Application layer	Platform Security, Web Application Security, VoIP Security, SW Security
Transport layer	TLS
Network layer	IPsec
Data Link layer	[PPTP, L2TP], IEEE 802.1X, IEEE 802.1AE, IEEE 802.11i (WPA2)
Physical layer	Quantum Cryptography

3.1 Port-Based Network Access Control - IEEE 802.1X

IEEE 802.1X Access Control using EAP Methods



- 802.1X Supplicants and Authenticators are both Port Access Entities (PAEs)

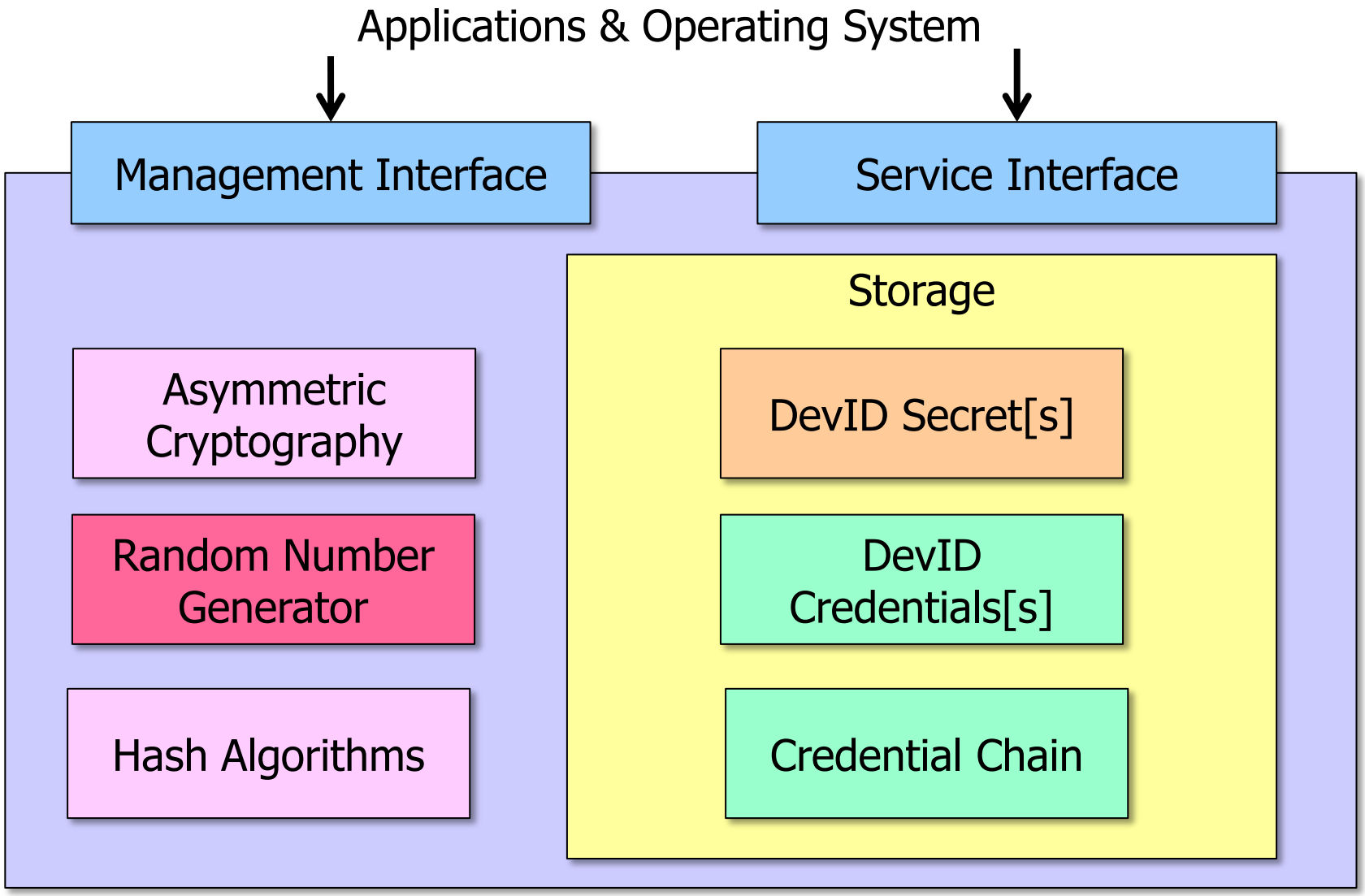
* EAP over LAN (Ethertype 0x888E)

3.2 Secure Device Identity IEEE 802.1AR - DevID

IEEE 802.1AR Secure Device Identifier

- DevID Secure Device Identifier
  - Secure Device Identifier
- IDevID Initial Device Identifier
  - Created during manufacturing and cannot be modified
    Either reaches end of lifetime (certificate) or can be disabled
- LDevID Locally Significant Device Identifier
  - One or several may be created by network administrator
- DevID Module
  - Hardware module which stores the DevID secrets, credentials and the entire credential chain up to the root certificate
  - Contains a strong Random Number Generator (RNG)
  - Implements Asymmetric Algorithms (2048 bit RSA and/or 256 bit ECDSA)
  - Implements SHA-256 Hash Function

IEEE 802.1AR DevID Module

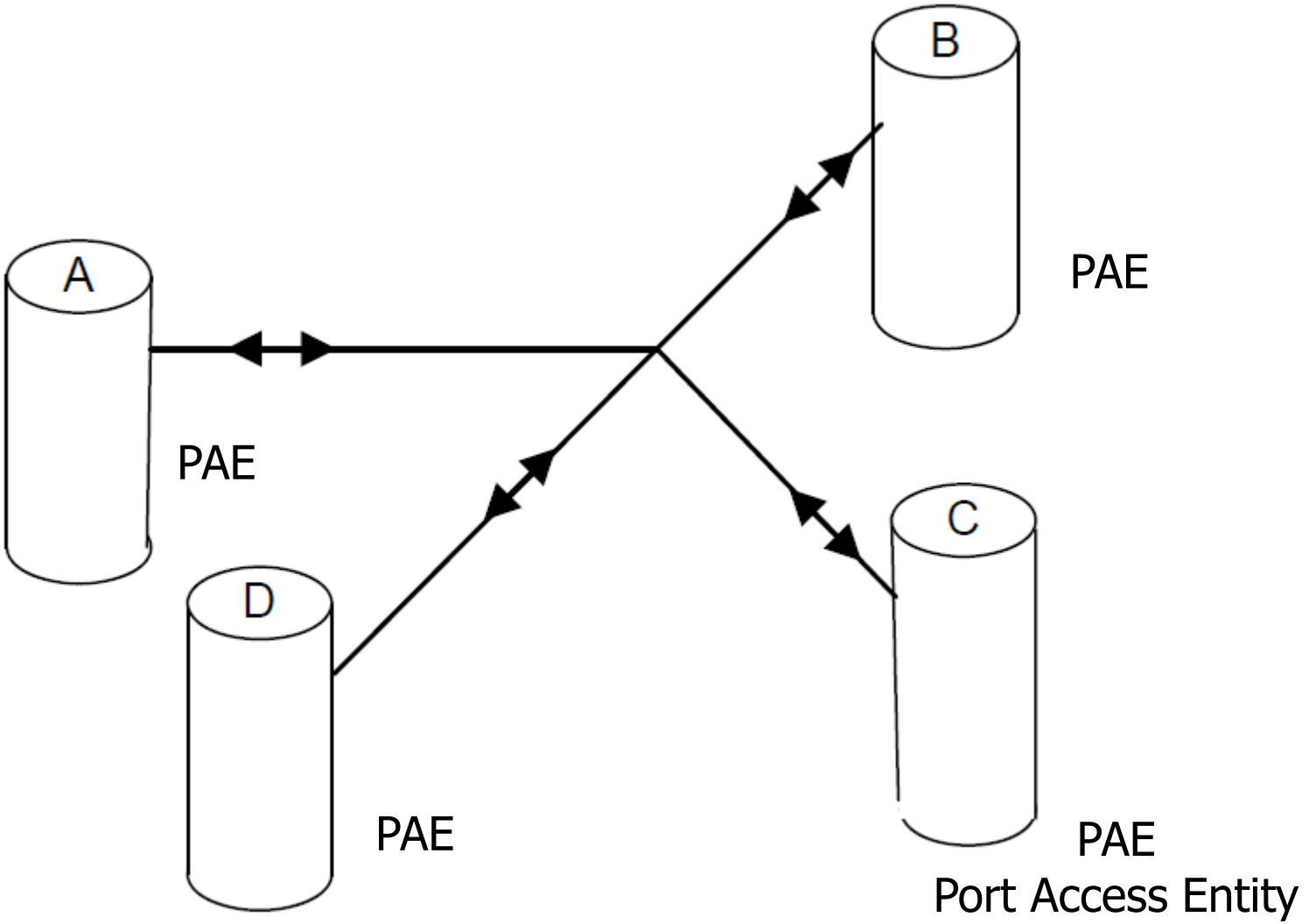


Use of DevIDs

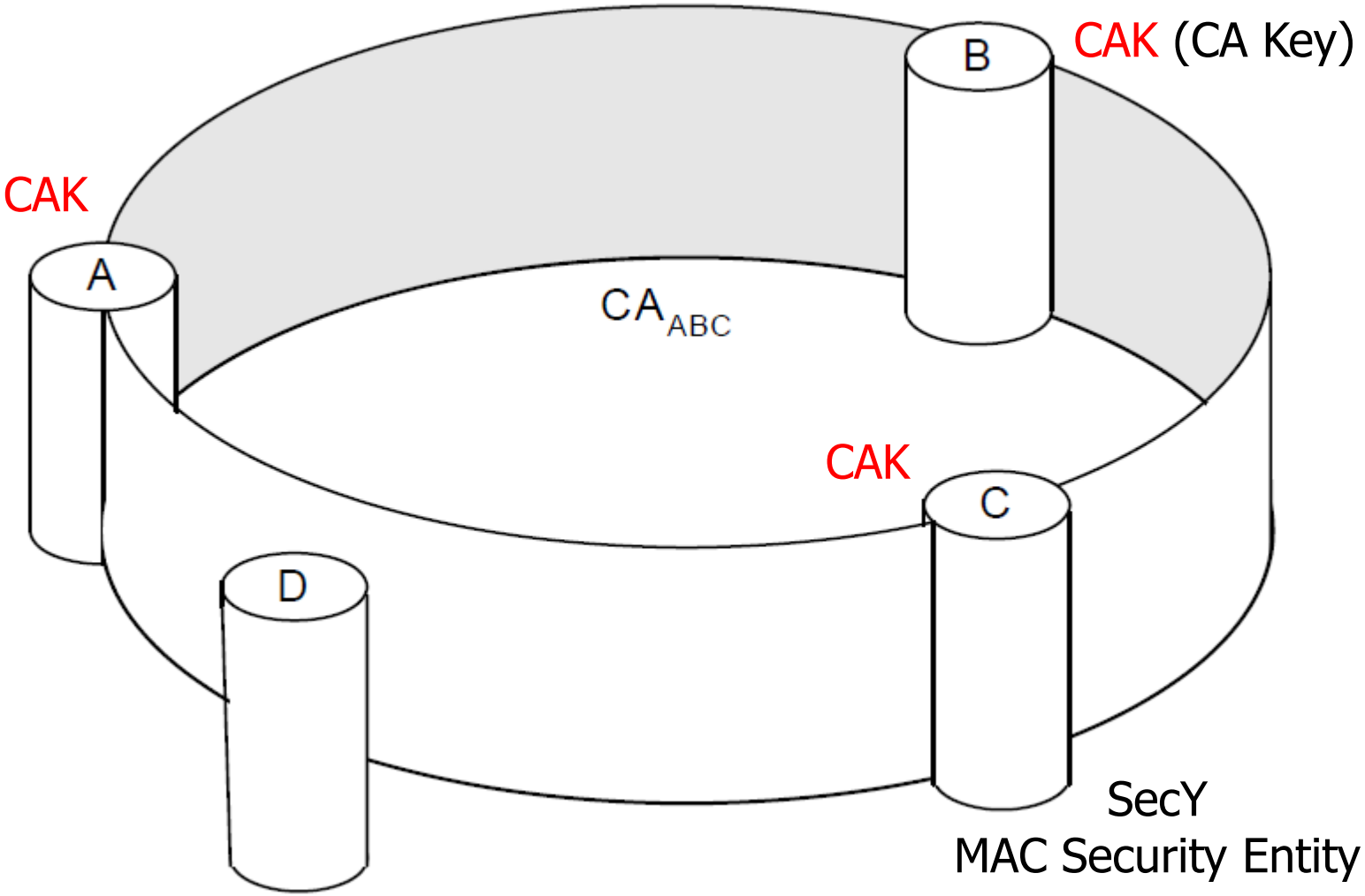
- DevID use EAP-TLS Authentication
  - Device authentication can be based on its DevID certificate.
- DevID use in Consumer Devices
  - Similar but more secure than access control based on a MAC address list which can easily be spoofed, a switch, router or access point can allow access based on a registered commonName (CN), serialNumber (SN) or a subjectAltName contained in the DevID certificate.
- DevID use in Enterprise Devices
  - Similar to the consumer device use case but the DevID is usually registered with a centralAAA server.
- DevID Module based on Trusted Platform Module (TPM)
  - Each TPM has a unique non-erasable Endorsement Key (EK) to which DevID secrets and credentials can be bound.

3.3 Media Access Layer Security IEEE 802.1AE - MACsec

Four Stations Attached to a LAN

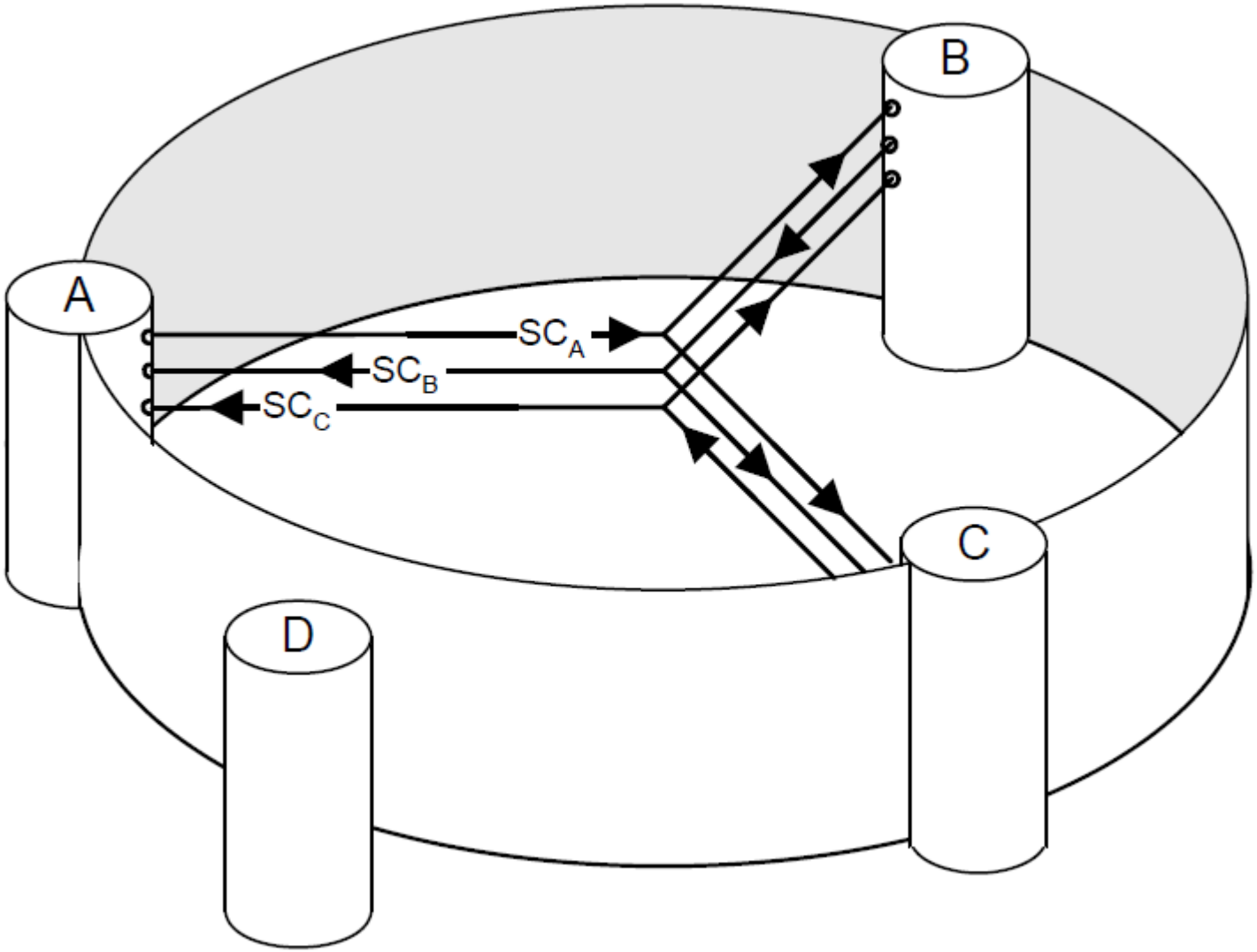


Connectivity Association (CA)



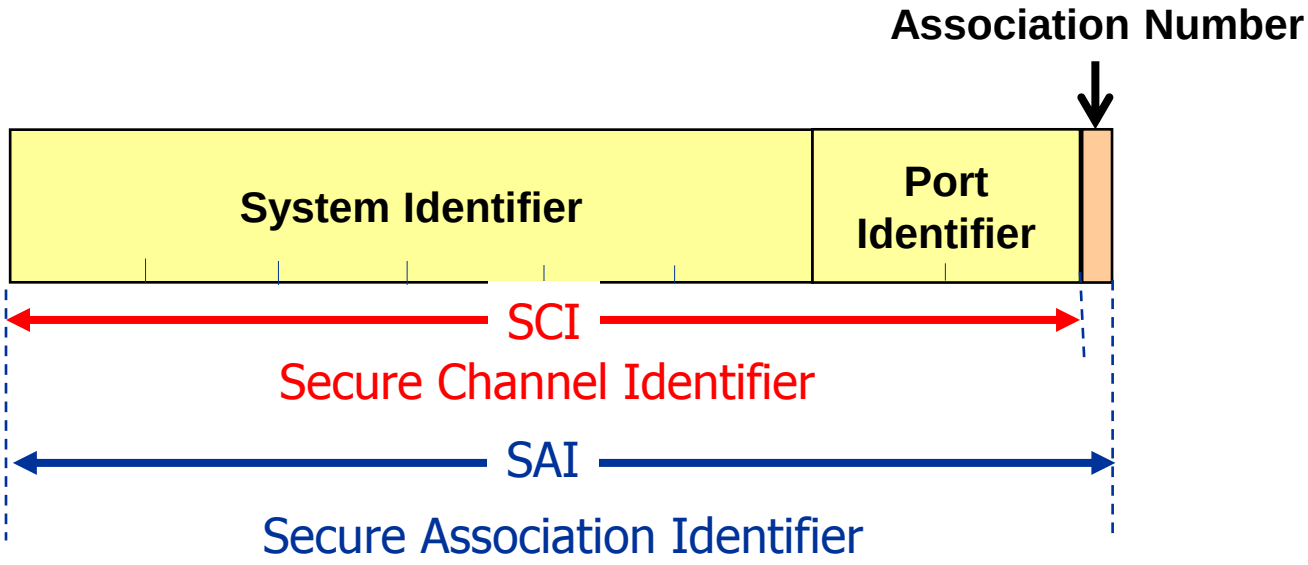
- Station D is not part of the CA

Secure Channel (SC) and Secure Association (SA)



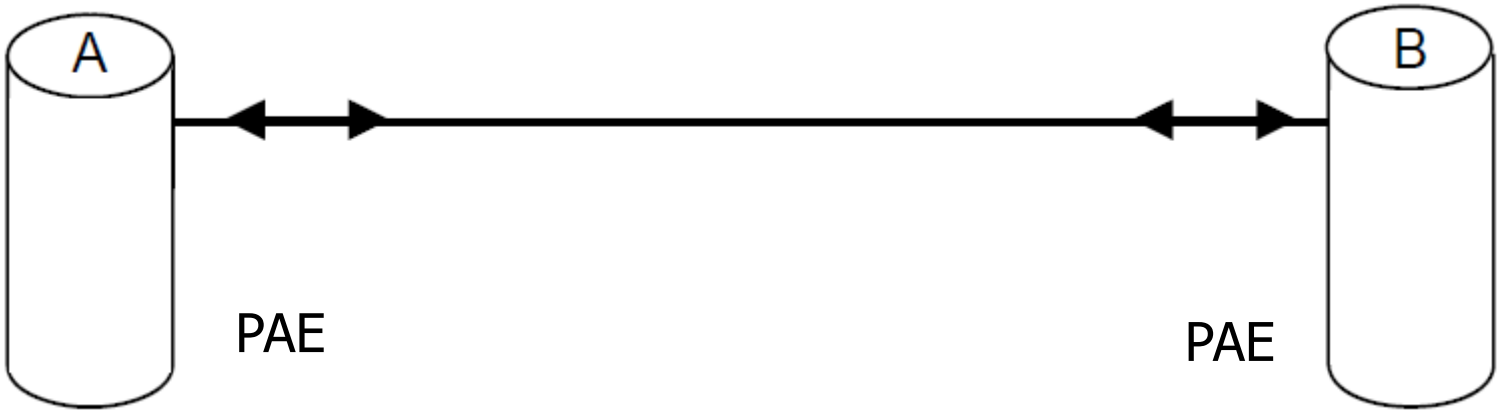
- Each SC comprises a succession of SAs each with a different SAK (SA Key)

Secure Channel and Secure Association Identifiers

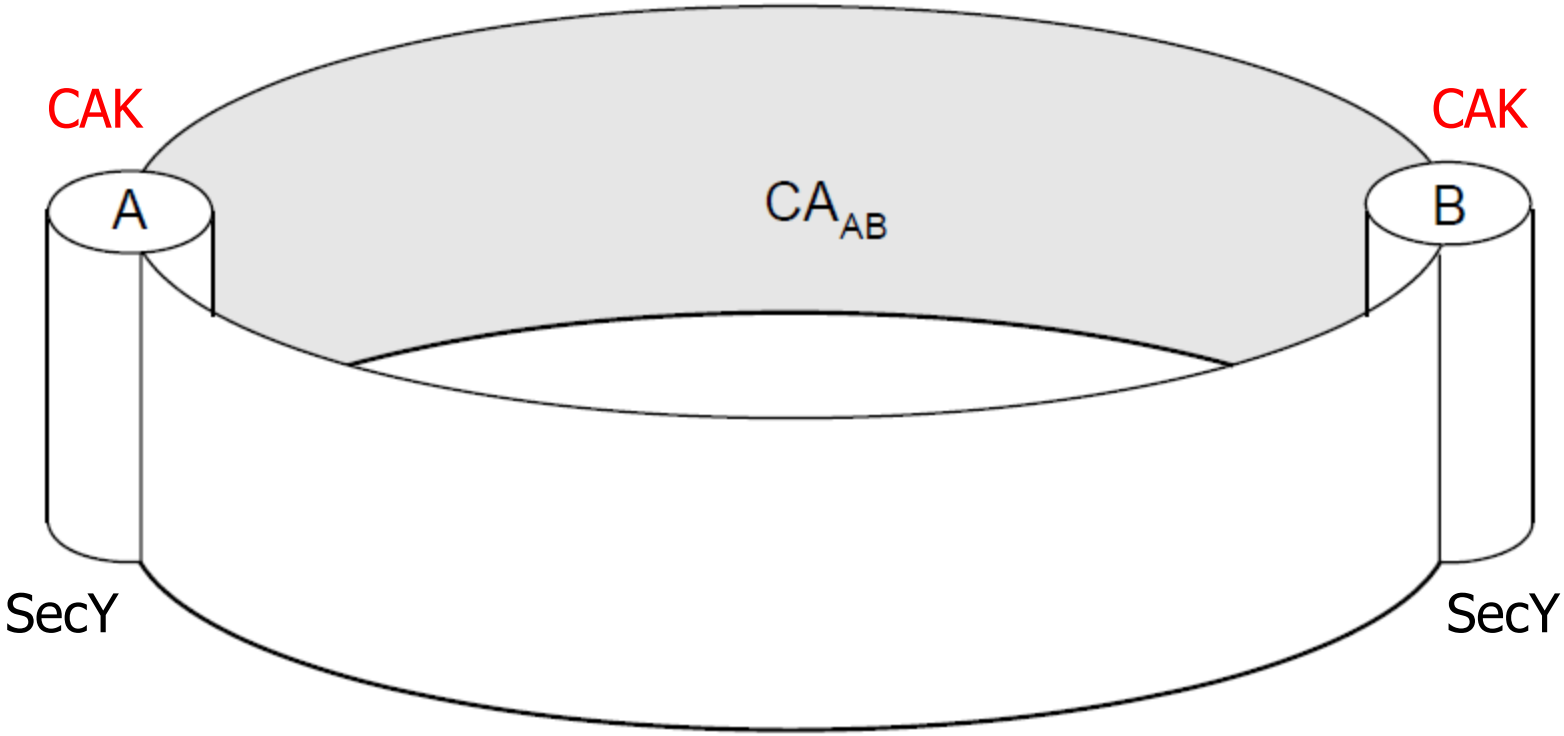


- The Association Number (2 bits) allows the overlapping rekeying of the Secure Association during which two different SAKs co-exist.

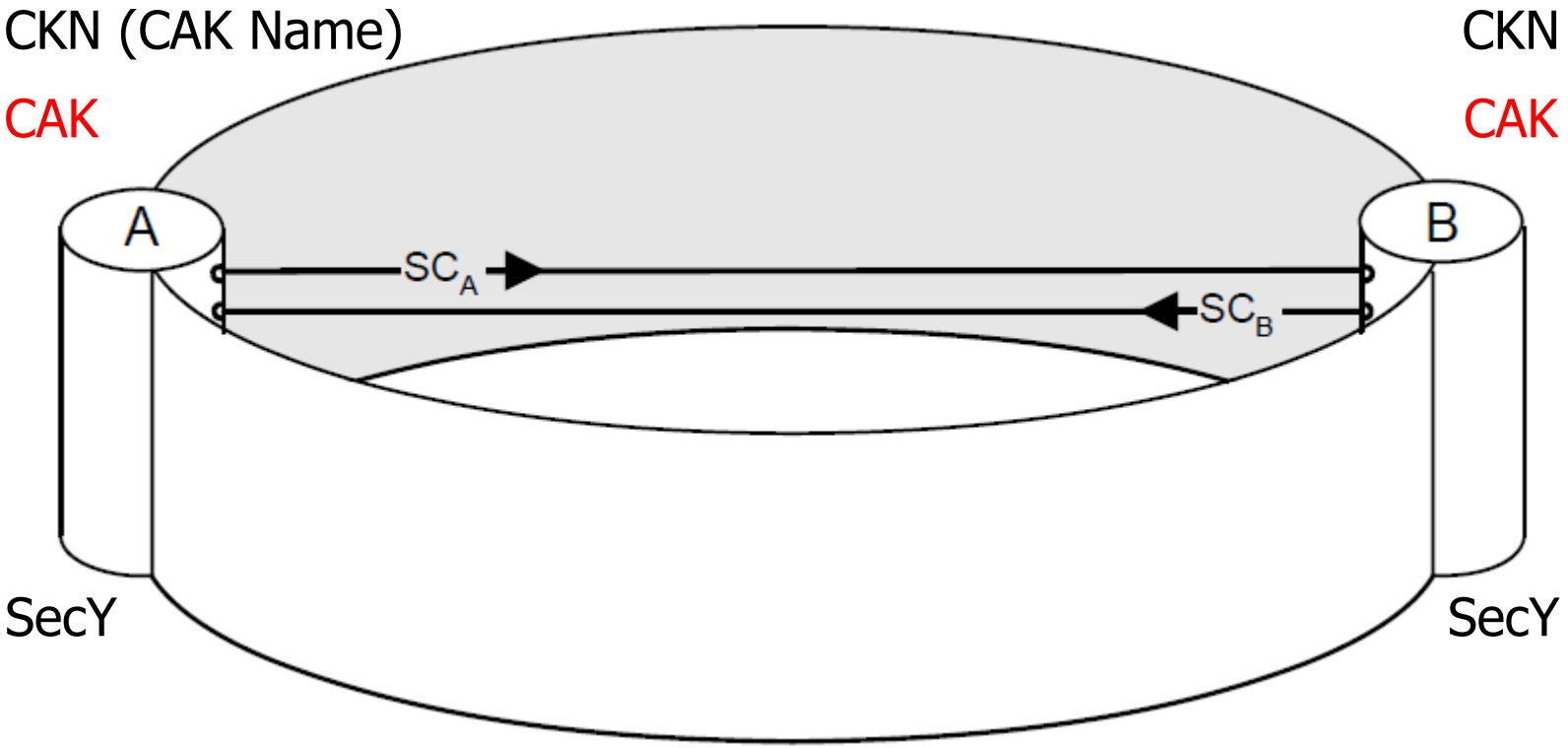
Two Stations in a point-to-point LAN



Connectivity Association (CA)



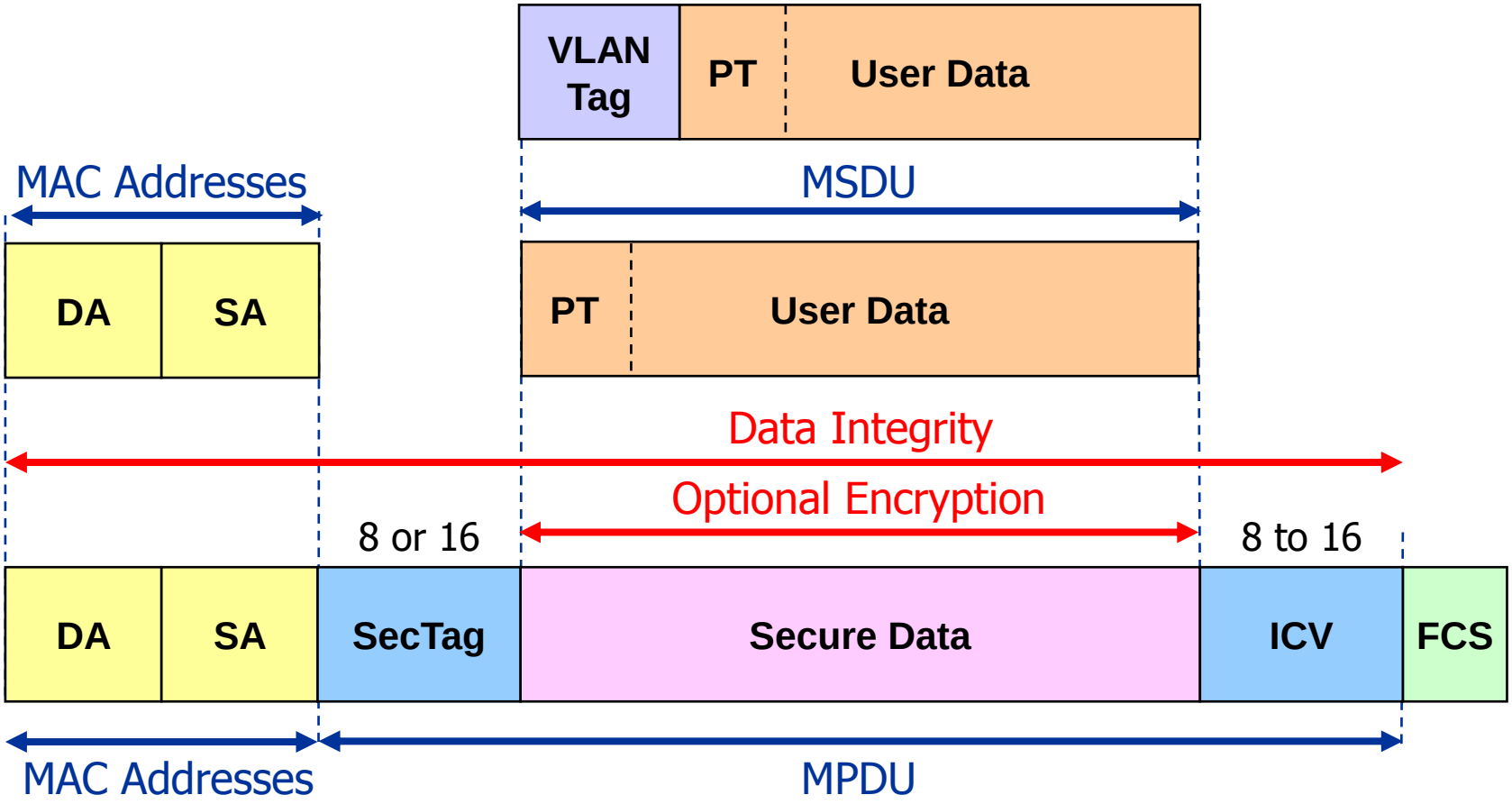
Secure Channel (SC) and Secure Association (SA)



$SA_A \rightarrow SAK_{A0}$, SAK_{A1} , …
$SA_B \rightarrow SAK_{B0}$, SAK_{B1} , …

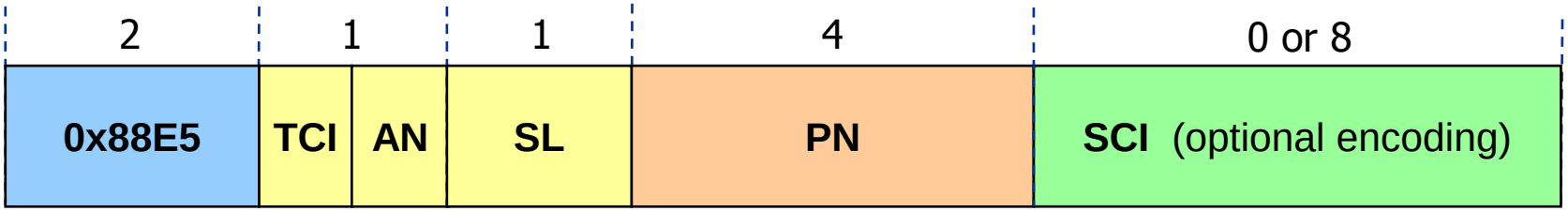
$SA_A \rightarrow SAK_{A0}$, SAK_{A1} , …
$SA_B \rightarrow SAK_{B0}$, SAK_{B1} , …

IEEE 802.1AE MACsec Frame Format



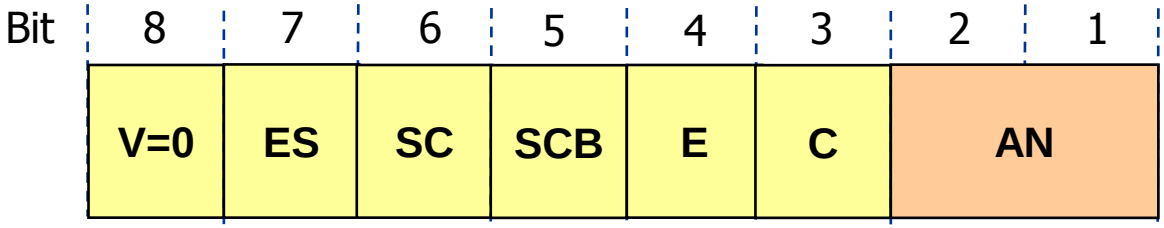
- MSDU – MAC Service Data Unit
- MPDU – MACsec Protocol Data Unit
- ICV – Integrity Check Value

SecTag – Security Tag



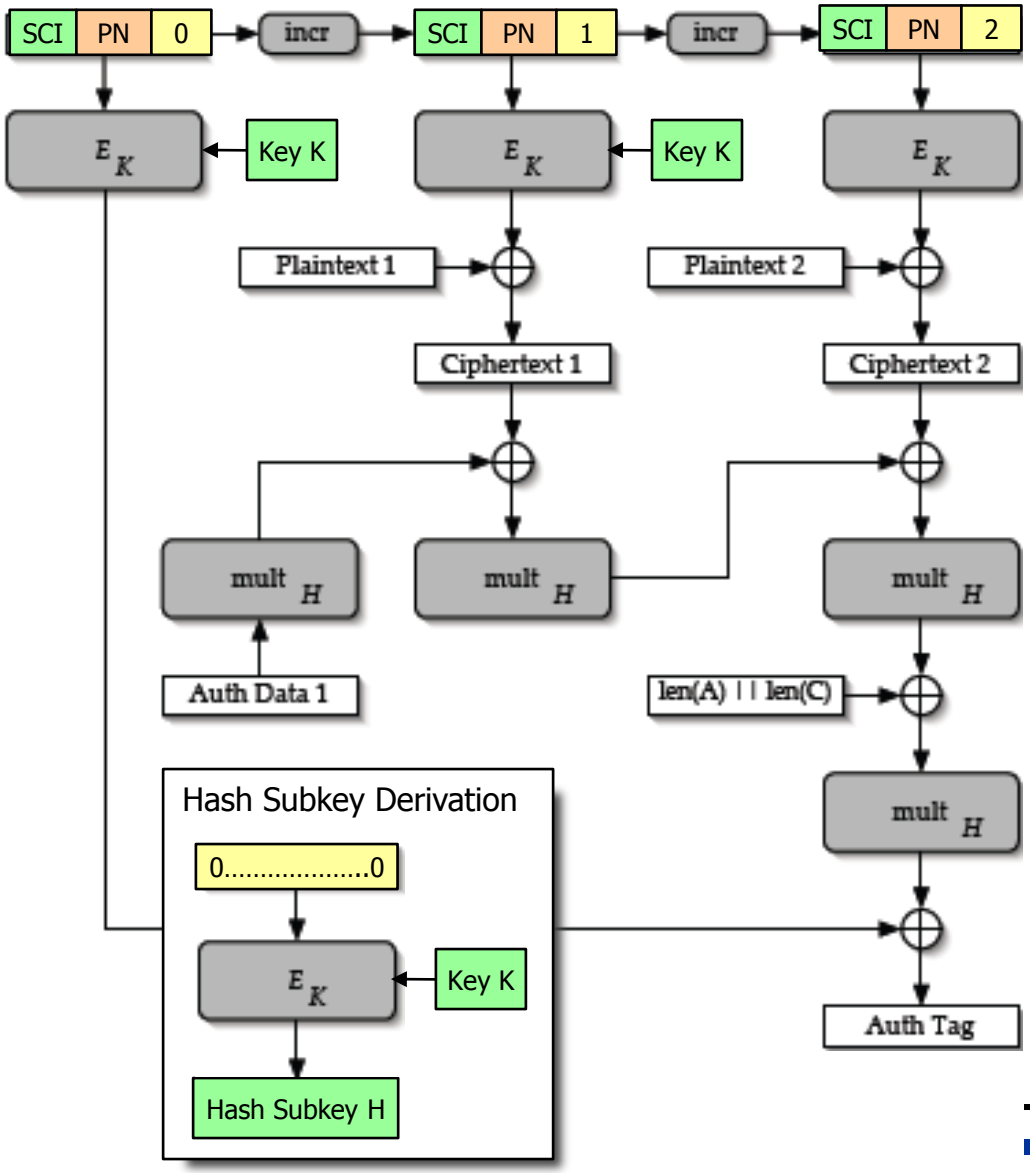
- MACsec Ethertype – is 0x88E5
- TCI – TAG Control Information (6 bits)
- AN – Association Number (2 bits)
- SL – Short Length (6 bits) – length of User Data if < 48 octets, 0 otherwise
- PN – Packet Number – replay protection and IV for encryption
- SCI – Secure Channel Identifier – identifies Secure Association (SA).
  In point-to-point links the SCI consists of the Source MAC Address and the Port Identifier 00-01 and thus the SCI doesn't have to be encoded.

TCI – TAG Control Information Bits



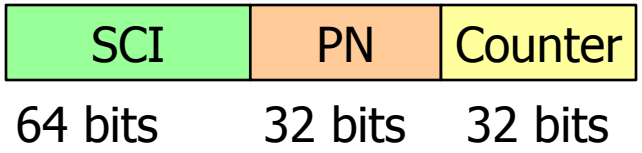
- V – Version (currently 0)
- ES – End Station – if set means that the Source MAC Address is part of the SCI and the SCI shall not be explicitly encoded.
- SC – shall be set only if an explicitly encoded SCI is present
- SCB – Single Copy Broadcast capability – if ES and SCB are set then the implicit SCI comprises a reserved Port Identifier of 00-00.
- E – Encryption – if set encryption is enabled
- C – Changed Text – if clear the Secure Data exactly equals User Data

Authenticated Encryption with Associated Data



ICV

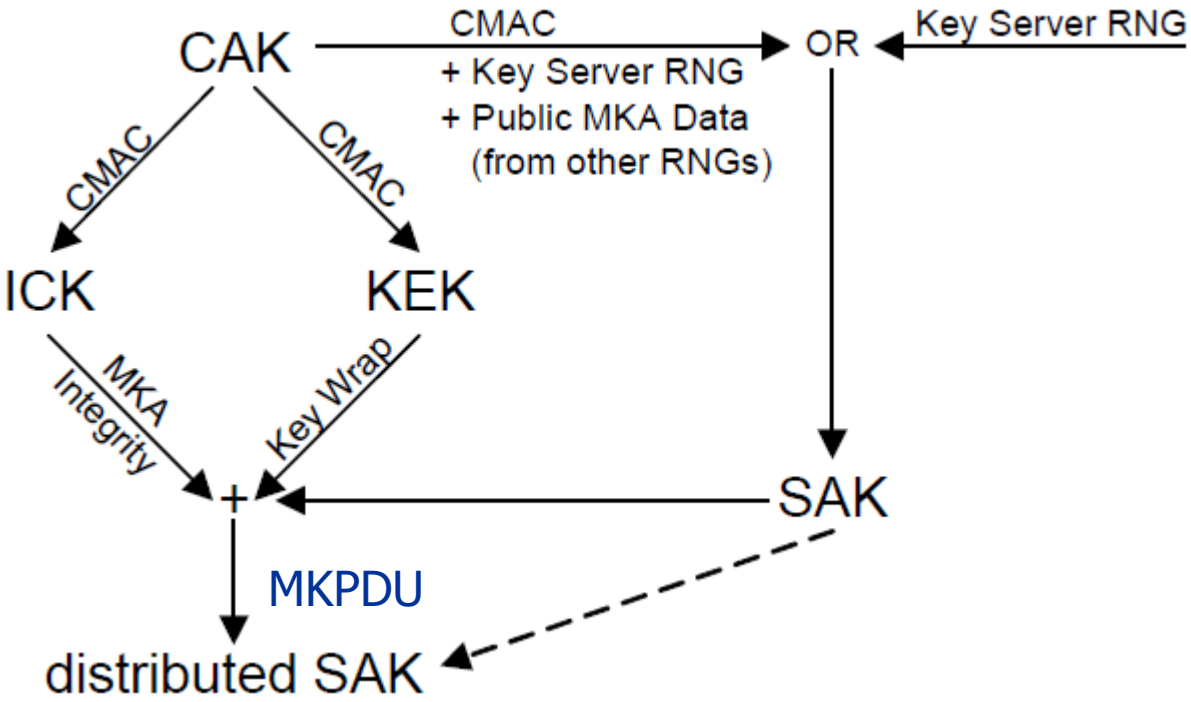
- AEAD is based on special block cipher modes:
- Block size: 128 bits
- Key size: 128/256 bits
- Tag size : 128 bits
- Nonce size: 128 bits



- AES-Galois/Counter Mode AES-GMAC (auth. only)

3.4 MACsec Key Agreement IEEE 802.1X - MKA

MKA distributes random SAK using CAK



- MKPDU – MACsec Key Agreement Protocol Data Unit – carried via EAPOL
- CAK – Connectivity Association Key – pairwise or group root key
- ICK – ICV Key – used for MKPDU Data Integrity
- KEK – Key Encrypting Key – used for AES Key Wrap in MKPDU
- SAK – Secure Association Key

MKA Key Derivation Function - KDF

- The MKA KDF is a Pseudo Random Function (PRF) based on AES-CMAC with a 128 or 256 bit key.

  Output ← KDF(Key, Label, Context, Length)

- KEK ← KDF(CAK, "IEEE8021 KEK", CKN[0..15], 128/256)
- ICK ← KDF(CAK, "IEEE8021 ICK", CKN[0..15], 128/256)
- SAK ← KDF(CAK, "IEEE8021 SAK", KS-nonce | MI-value list | KN, 128/256)
- KS – Key Server – either elected or EAP Authenticator
- MI – Member Identifier – all members of a CA
- KN – Key Number – assigned by Key Server

Connectivity Association Key – CAK

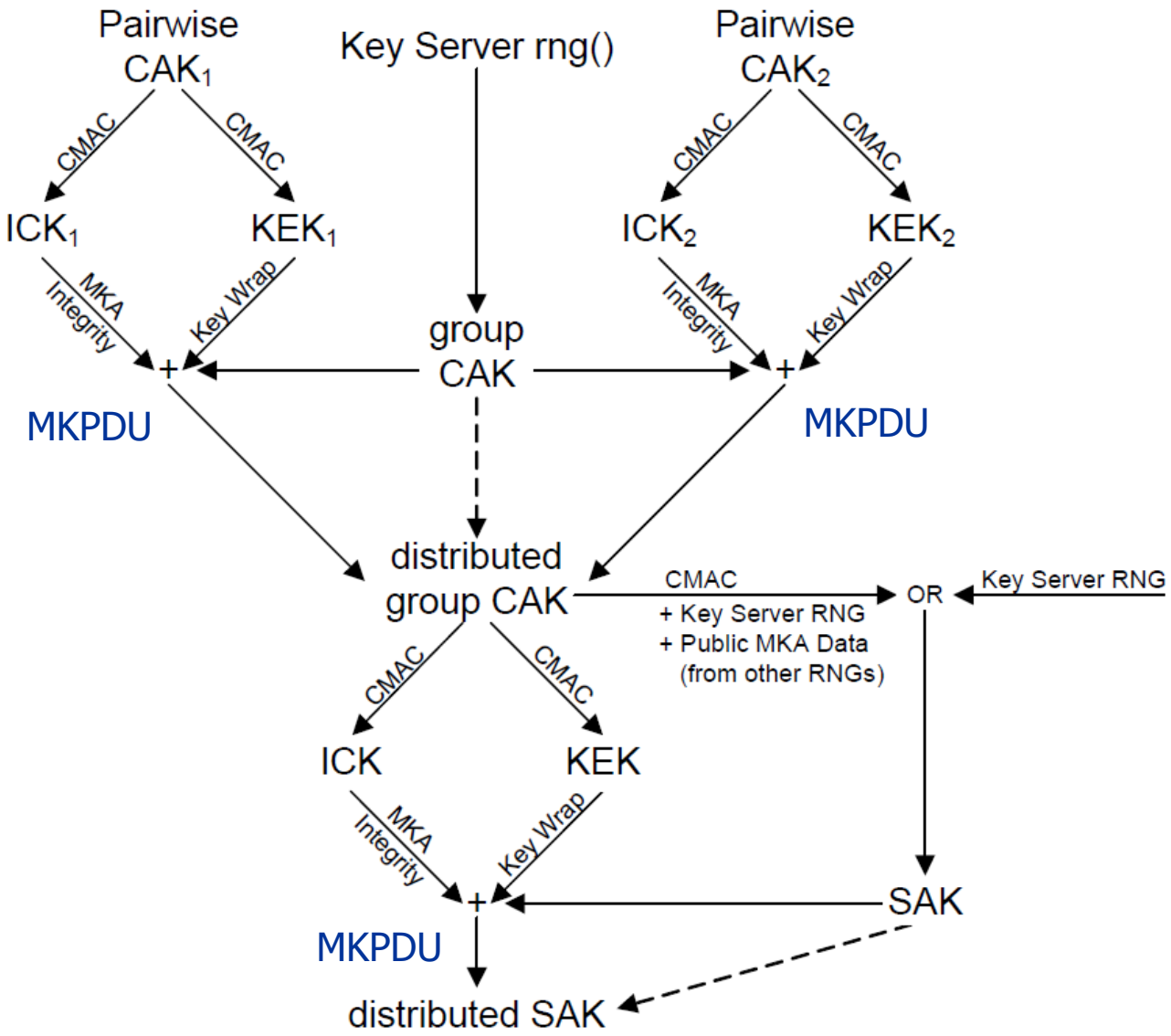
- CAK as a Pre-Shared-Key (PSK)
  - Can be used either as a pairwise CAK or group CAK
  - Statically configured PSK
  - CKN can be chosen arbitrarily with a size of 1..32 octets
- CAK via EAP
  - Can be used as a pairwise CAK.
  - Dynamically derived CAK and CKN between two PAEs via EAP

CAK ← KDF(MSK[0..15]/MSK[0..31], "IEEE8021 EAP CAK",
mac1 | mac2, 128/256)

CKN ← KDF(MSK[0..15]/MSK[0..31], "IEEE8021 EAP CKN" ,
EAP Session-ID | mac1 | mac2, 128/256)

where mac1 < mac2 are the MAC addresses of the PAEs and the Master Session Key (MSK) and Session-ID of the EAP method (EAP-TLS, EAP-PEAP, etc) is included.

Use of Pairwise CAKs to Distribute a Group CAK



IEEE 802.1AE Enabled Products

- Cisco Catalyst 3750-X / 3560-X LAN Access Switch
  - Supports MACsec and MKA on both user/downlink and network/uplink ports

- Juniper EX Series Switches
  - 802.1AE available with the controlled version of Junos OS