Chapter 17

Wireless Network Security

IEEE 802.11

- IEEE 802 committee for LAN standards
- IEEE 802.11 formed in 1990's, to develop a protocol & transmission specifications for wireless LANs (WLANs)
- Demand for WLANs, at different frequencies and data rates, after that list of standards presented.

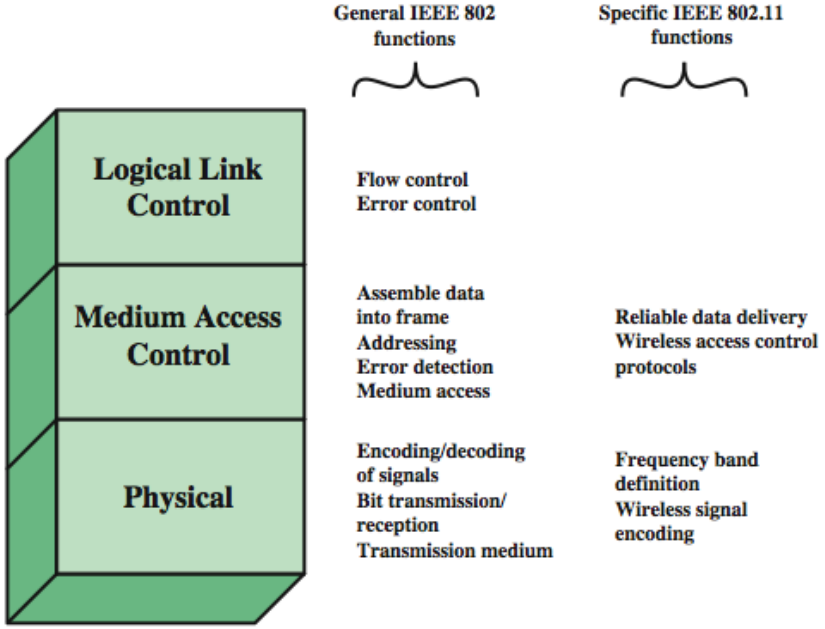
IEEE 802 Terminology

Access point (AP)	Any entity that has station functionality and provides access to the distribution system via the wireless medium for associated stations.
Basic service set (BSS)	A set of stations controlled by a single coordination function.
Coordination function	The logical function that determines when a station operating within a BSS is permitted to transmit and may be able to receive PDUs.
Distribution system (DS)	A system used to interconnect a set of BSSs and integrated LANs to create an ESS.
Extended service set (ESS)	A set of one or more interconnected BSSs and integrated LANs that appear as a single BSS to the LLC layer at any station associated with one of these BSSs.
MAC protocol data unit (MPDU)	The unit of data exchanged between two peer MAC entities using the services of the physical layer.
MAC service data unit (MSDU)	Information that is delivered as a unit between MAC users.
Station	Any device that contains an IEEE 802.11 conformant MAC and physical layer.

Wi-Fi Alliance

- 802.11b first broadly accepted standard
- Wireless Ethernet Compatibility Alliance (WECA) industry association formed 1999
  - To assist interoperability of products
  - Renamed Wi-Fi (Wireless Fidelity) Alliance
  - Created a test suite to certify interoperability
  - Initially for 802.11b, later extended to 802.11g
  - Concerned with a range of WLANs markets, including enterprise, home, and hot spots

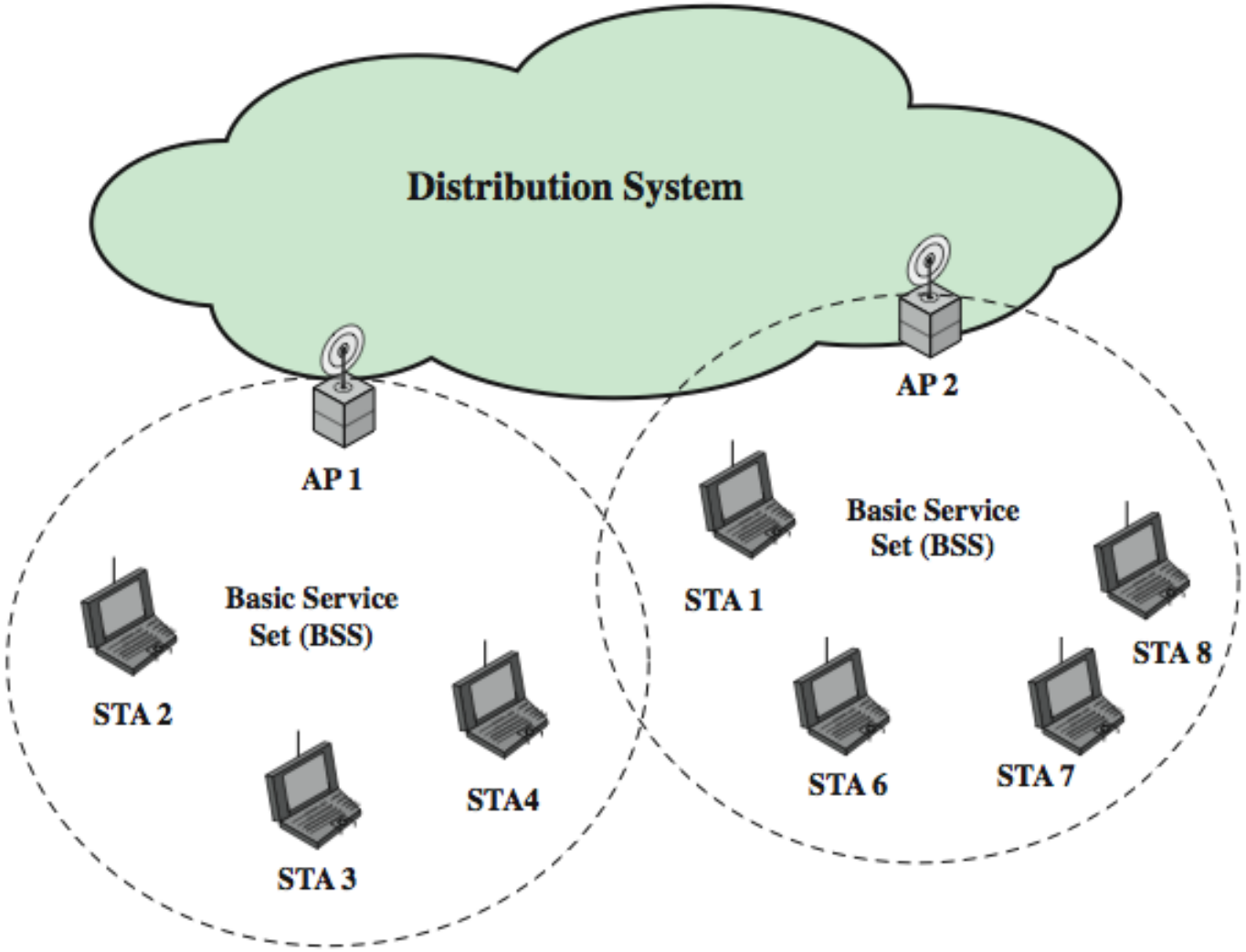
IEEE 802 Protocol Architecture



- **IEEE 802 physical layer includes:**
  - Encoding/decoding of signals
  - Transmission/reception
  - Specification of the transmission medium.
- **IEEE 802.11 physical layer also defines:**
  - Frequency bands
  - Antenna characteristics.
- **Media Access Control (MAC) layer** controls access to the transmission medium:
  - Receives data from a higher-layer protocol (LLC) layer, in the form of a block of data known as **MAC service data unit (MSDU)**
  - Responsible for detecting errors and discarding any frames that contain errors.
- **The Logical Link Control (LLC)layer**

  (optionally) keeps track of which frames have been successfully received and retransmits unsuccessful frames.

Network Components & Architecture



IEEE 802.11 Extended Service Set

IEEE 802.11 Services (9 Services)

Service	Provider	Used to support
Association	Distribution system	MSDU delivery
Authentication	Station	LAN access and security
Deauthentication	Station	LAN access and security
Dissassociation	Distribution system	MSDU delivery
Distribution	Distribution system	MSDU delivery
Integration	Distribution system	MSDU delivery
MSDU delivery	Station	MSDU delivery
Privacy	Station	LAN access and security
Reassociation	Distribution system	MSDU delivery

IEEE 802.11 Services (9 Services)

The service provider can be either the station or the DS:

- **Station services are implemented in every 802.11 station, including AP stations.**
- **Distribution services are provided between BSSs; these may be implemented in an AP or in another special-purpose device attached to the distribution system.**

Three services control IEEE 802.11 LAN access and confidentiality:

- **Authentication, Deauthentication and Privacy**

Six services support delivery of MSDUs between stations: If the MSDU is too large to be transmitted in a single MPDU, it may be fragmented and transmitted in a series of MPDUs.

- **Association, Reassociation, Disassociation, Distribution, Integration and MSDU delivery**

MSDU delivery, basic service, in which the information that is delivered as a unit between MAC users.

Distribution, the primary service used by stations to exchange MPDUs when the MPDUs must traverse the DS to get from a station in one BSS to a station in another BSS.

Integration, enables transfer of data between a station on an IEEE 802.11 LAN and a station on an integrated (wired) IEEE 802.x LAN. To deliver a message within a DS, the distribution service needs to know where the destination station is located.

Association, establishes an initial association between a station and an AP.

Reassociation, enables an established association to be transferred from one AP to another, allowing a mobile station to move from one BSS to another.

Disassociation, a notification from either a station or an AP that an existing association is terminated.

802.11 Wireless LAN Security

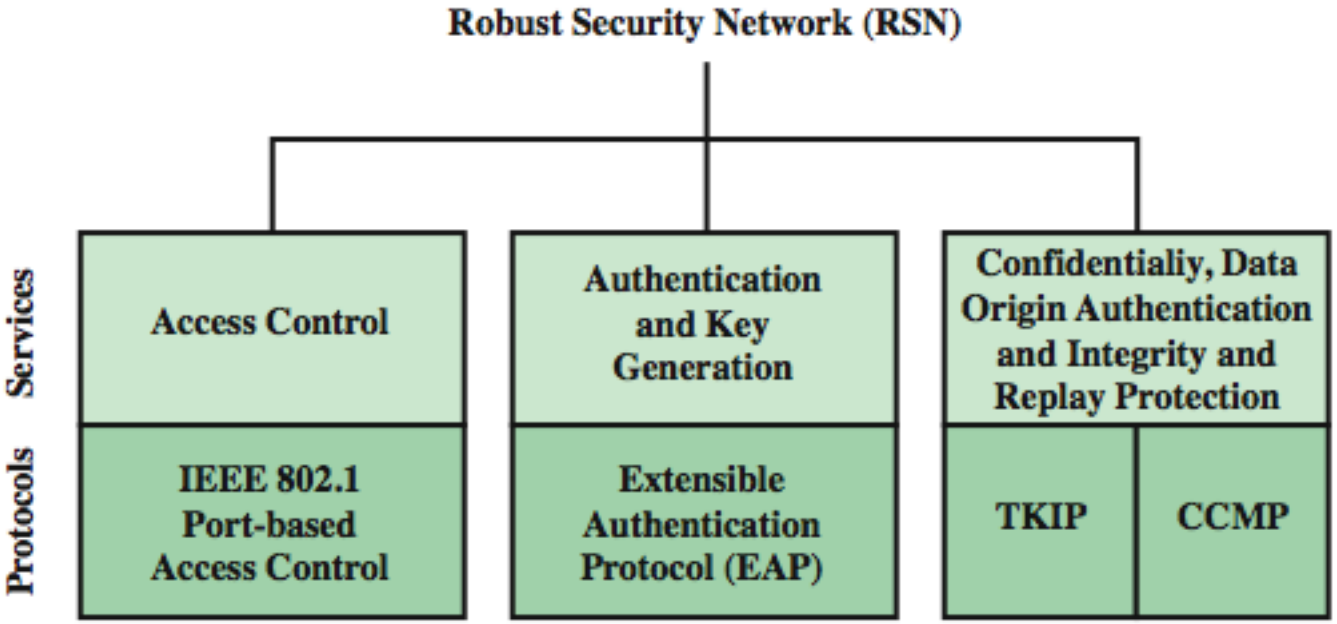
- Wireless LANs traffic can be monitored by any radio in range, not physically connected as in Wired LANs

- Original 802.11 spec had security features for privacy and authentication.
  - **Wired Equivalent Privacy (WEP) algorithm**, but contained major weaknesses

- 802.11i group developed capabilities for WLAN security issues
  - Wi-Fi Alliance **Wi-Fi Protected Access (WPA)**

    WPA is a set of security mechanisms that eliminates most 802.11 security issues and was based on the current state of the 802.11i standard.
  - final 802.11i **Robust Security Network (RSN)**

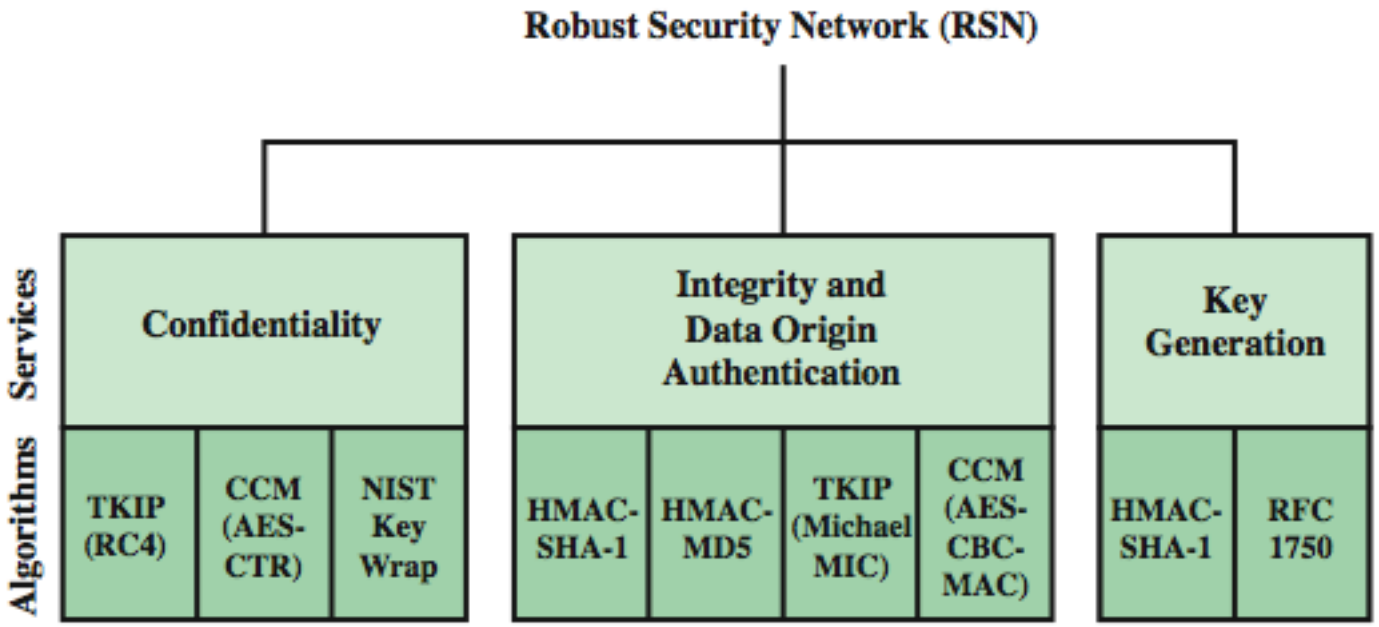
802.11i RSN Services and Protocols



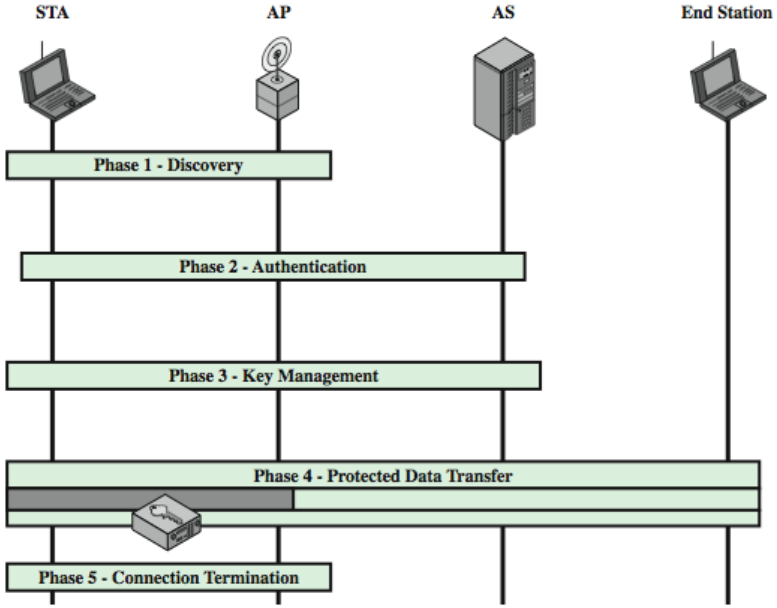
The 802.11i RSN security specification defines the following services:

- **Authentication**: A protocol is used to define an exchange between a user and AS that provides mutual authentication and generates temporary keys to be used between the client and the AP over the wireless link.
- **Access control**: Enforces the use of the authentication function, routes the messages properly, and facilitates key exchange. It can work with a variety of authentication protocols.
- **Privacy with message integrity**: MAC-level data (e.g., an LLC PDU) are encrypted, along with a message integrity code that ensures that the data have not been altered.

802.11i RSN Cryptographic Algorithms



802.11i Phases of Operation



IEEE 802.11i RSN operation can be broken down into five distinct phases of operation

- **Discovery**: AP uses messages called Beacons and Probe Responses to advertise its **IEEE802.11i** security policy. STA uses these to identify AP for a WLAN with which it wishes to communicate. STA associates AP, which it uses to select the cipher suite and authentication mechanism when Beacons and Probe Responses present a choice.
- **Authentication**: STA and AS prove their identities to each other. AP blocks non-authentication traffic between STA and AS until the authentication transaction is successful. AP does not participate in the authentication transaction other than forwarding traffic between STA & AS.
- **Key generation and distribution**: AP and STA perform several operations that cause cryptographic keys to be generated and placed on AP and STA. Frames are exchanged between AP and STA only
- **Protected data transfer**: Frames are exchanged between STA and end station through AP. As denoted by the shading and the encryption module icon, secure data transfer occurs between STA and AP only; security is not provided end-to-end.
- **Connection termination**: AP and STA exchange frames. During this phase, the secure connection is torn down and the connection is restored to the original state.

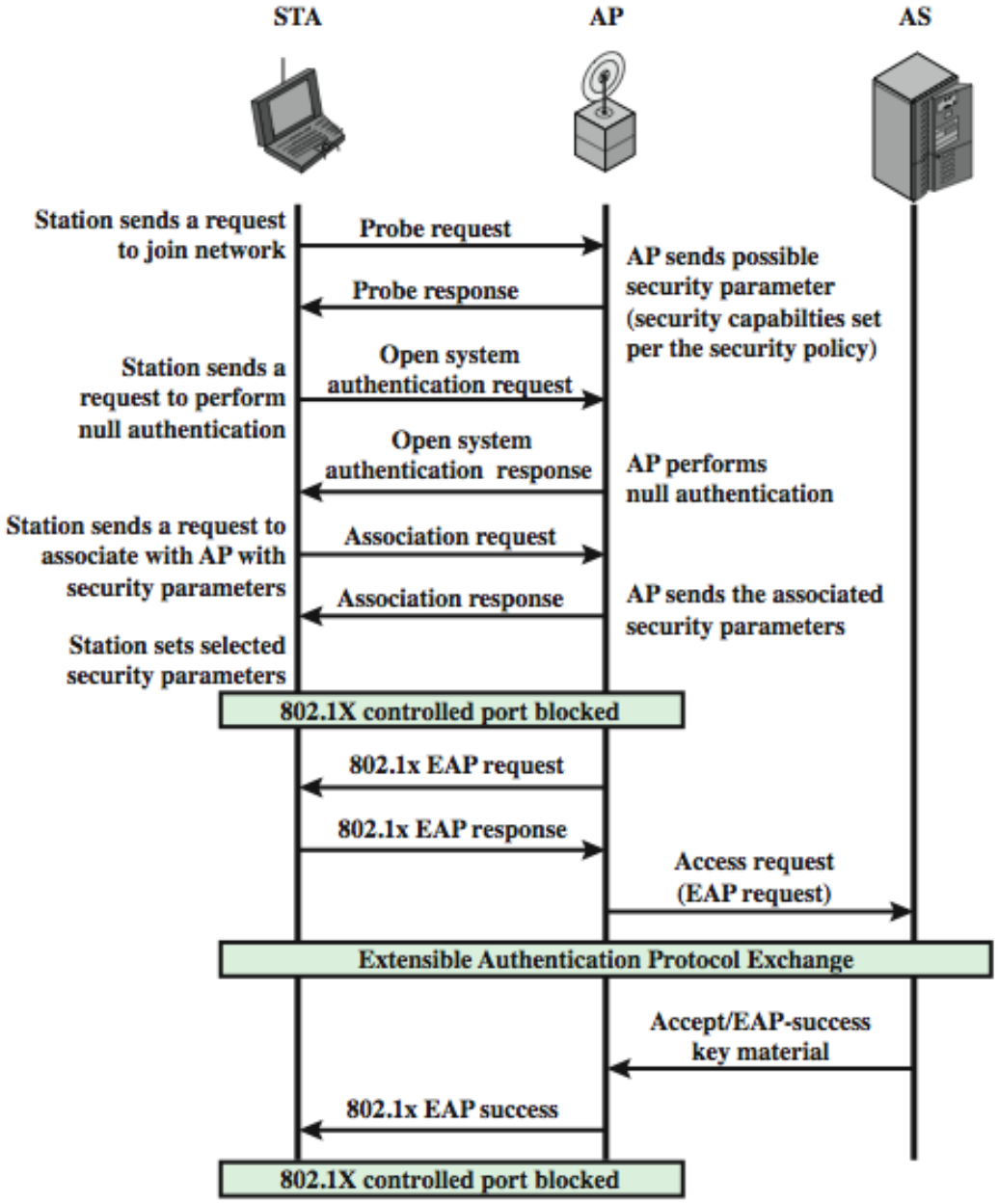
802.11i Discovery and Authentication Phases

The Discovery phase is for an STA and an AP to recognize each other, agree on a set of security capabilities, and establish an association for future communication.

It consists of three exchanges:
Network and security capability discovery, Open system authentication, and Association.

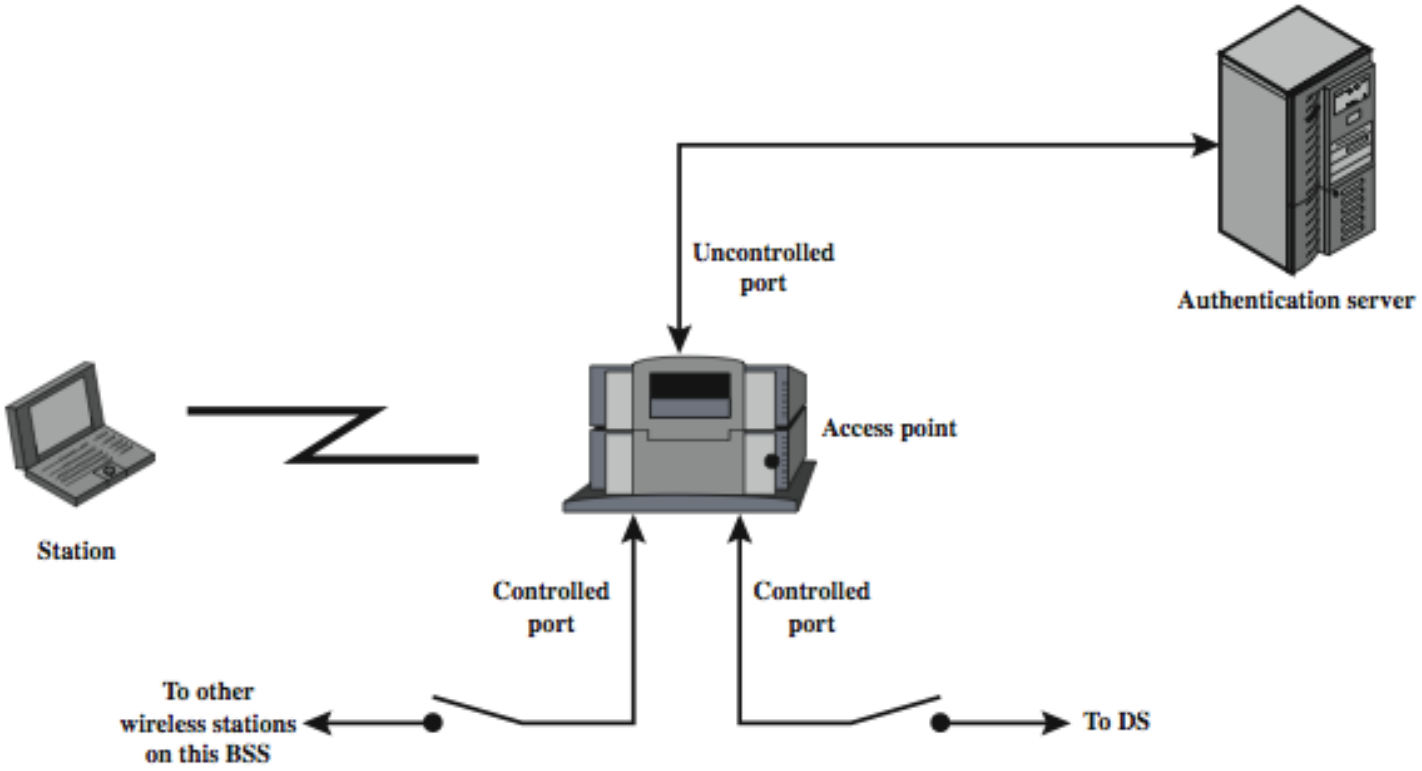
The authentication phase enables mutual authentication between an STA and an authentication server (AS) located in the DS.

Authentication is designed to allow only authorized stations to use the network and to provide the STA with assurance that it is communicating with a legitimate network.



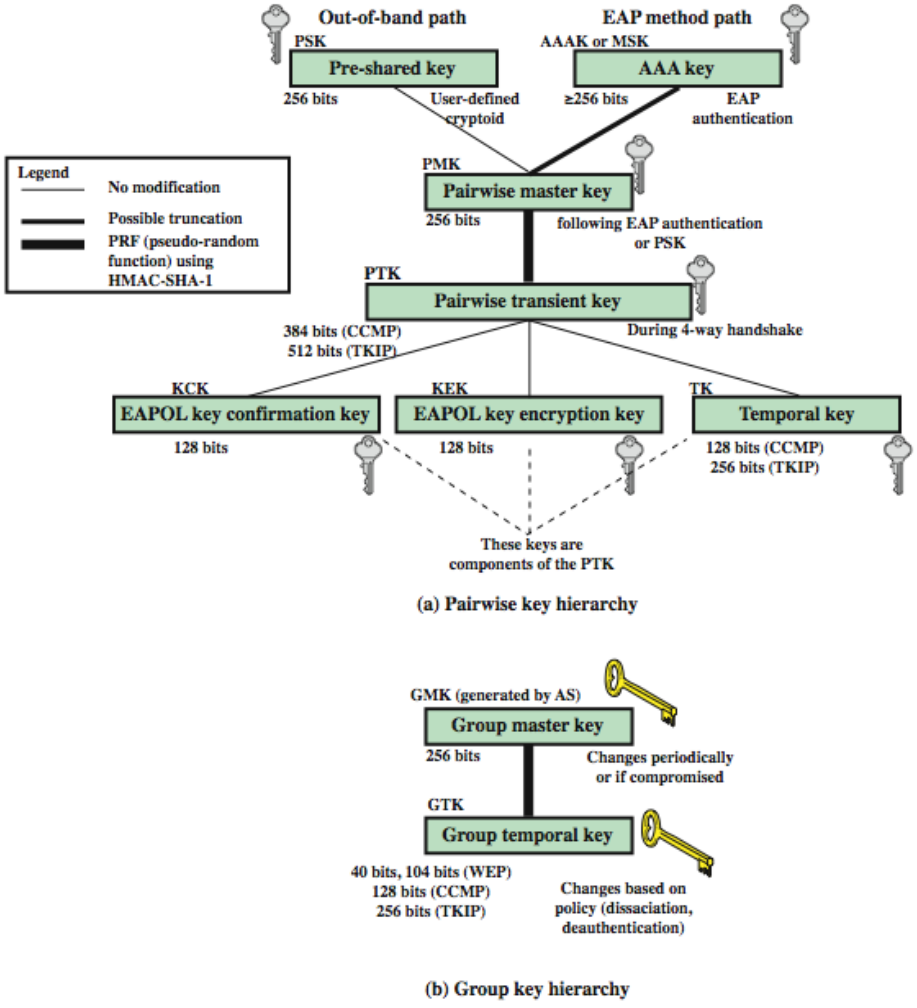
IEEE 802.1X Access Control Approach

- IEEE 802.11i uses the Extensible Authentication Protocol (EAP). Before wireless station (STA) is authenticated by AS, the (AP) only passes control or authentication messages between STA and AS.
- The 802.1X control channel is unblocked but the 802.11 data channel is blocked.
- Once STA is authenticated and keys are provided, the AS can forward data from STA, subject to predefined access control limitations for STA to the network and the data channel is unblocked.



802.11i Key Management Phase

- AP controlled ports remain blocked until the temporal keys are installed in the STA and AP, which occurs during the 4-Way Handshake.
- A variety of cryptographic keys are generated and distributed to STAs.
- There are two types of keys:
  - **Pairwise keys,** used for communication between STA and AP; and
  - **Group keys,** for multicast communication.
- **Pairwise keys** form a hierarchy, beginning with a master key from which other keys are derived dynamically and used for a limited period of time.
- **Pre-shared key (PSK)** A secret key shared by AP and STA
- **Master session key (MSK),** also known **AAAK**, which is generated using the IEEE 802.1X protocol during the authentication phase,
- **Pairwise master key (PMK)** is derived from the master key as follows:
  - If PSK is used, then PSK is used as the PMK;
  - If MSK is used, then PMK is derived from MSK. By the end of the authentication phase both AP and STA have a copy of their shared PMK.
- PMK is used to generate **pairwise transient key (PTK),** which in fact consists of three keys to be used for communication between an STA and AP after they have mutually authenticated.



IEEE 802.11i Keys for Data Confidentiality and Integrity Protocols

Abbrev-iation	Name	Description / Purpose	Size (bits)	Type
AAA Key	Authentication, Accounting, and Authorization Key	Used to derive the PMK. Used with the IEEE 802.1X authentication and key management approach. Same as MMSK.	≥ 256	Key generation key, root key
PSK	Pre-shared Key	Becomes the PMK in pre-shared key environments.	256	Key generation key, root key
PMK	Pairwise Master Key	Used with other inputs to derive the PTK.	256	Key generation key
GMK	Group Master Key	Used with other inputs to derive the GTK.	128	Key generation key
PTK	Pair-wise Transient Key	Derived from the PMK. Comprises the EAPOL-KCK, EAPOL-KEK, and TK and (for TKIP) the MIC key.	512 (TKIP) 384 (CCMP)	Composite key
TK	Temporal Key	Used with TKIP or CCMP to provide confidentiality and integrity protection for unicast user traffic.	256 (TKIP) 128 (CCMP)	Traffic key
GTK	Group Temporal Key	Derived from the GMK. Used to provide confidentiality and integrity protection for multicast/broadcast user traffic.	256 (TKIP) 128 (CCMP) 40, 104 (WEP)	Traffic key
MIC Key	Message Integrity Code Key	Used by TKIP's Michael MIC to provide integrity protection of messages.	64	Message integrity key
EAPOL-KCK	EAPOL-Key Confirmation Key	Used to provide integrity protection for key material distributed during the 4-Way Handshake.	128	Message integrity key
EAPOL-KEK	EAPOL-Key Encryption Key	Used to ensure the confidentiality of the GTK and other key material in the 4-Way Handshake.	128	Traffic key / key encryption key
WEP Key	Wired Equivalent Privacy Key	Used with WEP.	40, 104	Traffic key

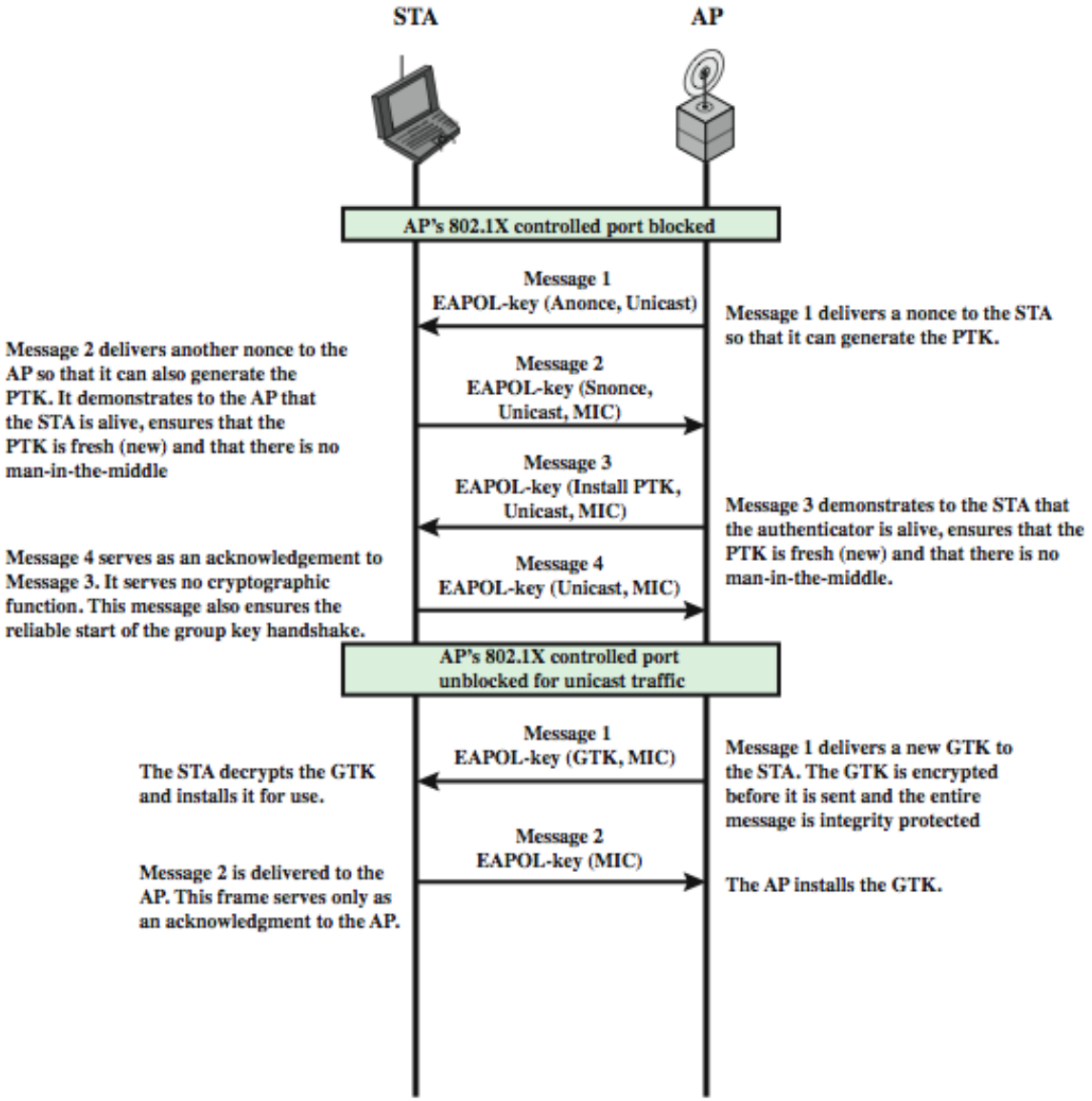
Pairwise Keys

- Pairwise Master Key (PMK)
  - derived from PSK or MSK (AAAK)
  - at end of auth phase, both AP & STA have PMK
- Pairwise Transient Key (PTK)
  - generated by PMK using HMAC-SHA-1
  - consists of three keys
    - EAP Over LAN Key Confirmation Key (EAPOL-KCK)
    - EAPOL Key Encryption Key (EAP-KEK)
    - Temporal Key (TK)

802.11i Key Management Phase

4-way handshake exchange MPDU for distributing pairwise keys. STA and SP confirm the existence of the PMK, verify the selection of the cipher suite, and derive a fresh PTK for the following data session.

For group key distribution, the AP generates a GTK and distributes it to each STA in a multicast group.



802.11i Protected Data Transfer Phase

Two schemes for protecting data :

- Temporal Key Integrity Protocol (TKIP)
  - s/w changes only to older WEP
  - Adds 64-bit Michael message integrity code (MIC)
  - Encrypts MPDU plus MIC value using RC4
- Counter Mode-CBC MAC Protocol (CCMP)
  - Uses the cipher block chaining message authentication code (CBC-MAC) for integrity
  - Uses the CRT block cipher mode of operation

Wireless Application Protocol (WAP)

- (WAP) is a universal, open standard developed by the WAP Forum to provide mobile users of wireless phones and other wireless devices, access to telephony and information services.
- WAP is designed to work with all wireless network technologies (e.g., GSM, CDMA, TDMA).
- WAP is based on existing Internet standards, such as IP, XML, HTML, and HTTP, as much as possible, & also includes security facilities.
- Strongly affecting the use of mobile phones and terminals for data services are the significant limitations of the devices (in processors, memory, and battery life) and the networks (relatively low bandwidth, high latency, and unpredictable availability and stability) that connect them.

- WAP specification includes:
  - A programming model based on the WWW Programming Model
  - A markup language, the Wireless Markup Language, adhering to XML
  - A specification of a small browser suitable for a mobile, wireless terminal
  - A lightweight communications protocol stack
  - A framework for wireless telephony applications (WTAs)

WAP Infrastructure

* HTML content must go through an HTML filter.

*The filter translates the HTML content into WML content.

*The proxy converts the WML into binary WML and delivers it to the mobile user over a wireless network using the WAP protocol stack.

* If the Web server is capable of directly generating WML content, then the WML is delivered using HTTP/TCP/IP to the proxy,