Csci388 Wireless and Mobile Security – Access Control: 802.1X, EAP, and RADIUS

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WEP Weakness

1. **IV is too short and not protected from reuse**
2. **The per packet key is constructed from the IV, making it susceptible to weak key attacks**
3. **No effective detection of message tampering (message integrity)**
4. **Master key is used directly and no built-in provision to update the keys**
5. **There is no protection against message replay**

Wi-Fi and IEEE 802.11

- **Wi-Fi refers to the wireless LAN network**
- **IEEE 802.11 is a standard, specifying the physical characteristics of the 802.11 LAN**
- **Wi-Fi Alliance: formed by a group of major manufactures**
  - Solve the interoperability problem
  - Ambiguous/undefined areas in 802.11 standard
  - Options of 802.11: some are avoid, some are required in Wi-Fi
  - To obtain the Wi-Fi certification, a manufacturer must submit its product for testing against a set of "gold standard" Wi-Fi products.

IEEE 802.11i and WPA

- **IEEE 802.11i is the addendum to the 802.11 standard. 802.11i specifies the new generation of security.**
  - 802.11i defines a new type of network called a robust security network (RSN). RSN-enables device is not compatible with Wi-Fi equipment
  - 802.11i task group developed a security solution base on the current capabilities of the Wi-Fi products: TKIP
- **Wi-Fi Protected Access (WPA): a subset of RSN specifying TKIP**
- **RSN and WPA share a single security architecture that covers procedures such as upper-level authentication, key distribution and renewal.**
  - More complex and scalable compared to WEP

802.11i – Three pieces, Two Layers

- **Lower layer: TKIP and CCMP**
  - By the 802.11i working group
  - Temporal Key Integrity Protocol
  - Counter Mode with CBC-MAC protocol
  - Both provides enhanced data integrity over WEP
  - TKIP being targeted at legacy equipment and CCMP being targeted at future WLAN equipment
- **Upper Layer: 802.1x**
  - 802.1x is a standard for port based access control developed by a different body within the IEEE 802 organization
  - 802.1x provides a framework for robust user authentication and encryption key distribution
    - Original 802.11 has neither of these features.
- **The three pieces discussed above work together to form an overall security system**

Importance of Access Control

- **Separate the world with "good guys" and "bad guys"**
- **How to do it in WPA and RSN?**
  - IEEE 802.1X: Originally designed for authenticating ports on wired LANs
  - EAP: Extensible Authentication Protocol
  - RADIUS: Remote Authentication Dial-In User Service
- **IEEE 802.1X with EAP are mandatory for WPA and RSN**
- **RADIUS is the method of choice by WPA, and is optional in RSN**
- **EAP and RADIUS were both developed for dial-in access**
  - Dial-in access control is organized in a very similar way to IEEE 802.1X

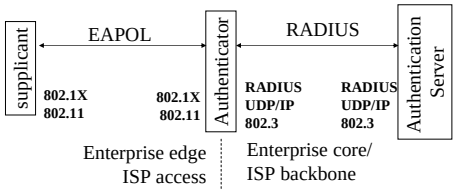
802.1X

- **A standard for port based network access control**
- **It can be applied to both wired and wireless networks and provides a framework for user authentication and encryption key distribution.**
  - It can be used to restrict access to a network until the user has been authenticated by the network.
  - In addition, 802.1x is used in conjunction with one of a number of upper layer authentication protocols to perform verification of credentials and generation of encryption keys.

Entities in 802.1X

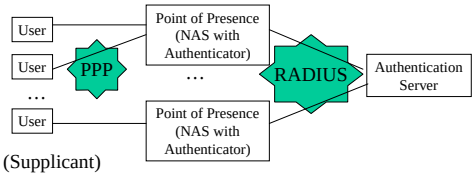
- **Three Components**
  - Supplicant (client): An entity that wants to have access
  - Authenticator (switch, AP, other NAS, preferably RADIUS capable): An entity that controls the access gate
  - Authentication Server (sometimes part of Authenticator, otherwise RADIUS server, the most common type of authentication server): An entity that decides whether the supplicant is to be admitted – authorizer

802.1X Architecture



- **Authenticator acts as a bridge**
- **802.1X is a framework, not a complete specification in and of itself. The actual authentication mechanism is implemented by the authentication server**

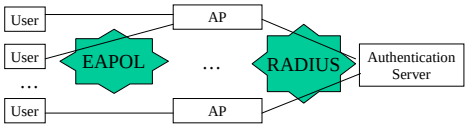
Authentication for Dial-In Users



Database server is centralized

PPP protocol defines two weak authentication methods:
PAP and CHAP -- Users provide UNANE and PWD
PAP: UNAME and PWD are transmitted in clear text
CHAP: a challenge-response scheme is exploited
EAP is proposed for stronger authentication in PPP

Authentication for Wireless LAN Users



Database server is centralized

- **Similar to the dial-in network organization**
- **IEEE 802.1X Utilizes EAP for access control**
  - 802.1X implement access control at the point at which a user joins the network
  - In Wireless LAN, an AP needs to create a logical port in software with an authenticator for each wireless user -- no physical port is available!
  - The number of 802.1X entities in operation is the same as the number of associated mobile devices
  - Port traffic, except for 802.1X, blocked until successful authentication

More on 802.1X

- **802.1X authenticates users, rather than machines**
  - WEP relies on the shared key, stored each machine
- **802.1X is a framework based on EAP; it is an IEEE adaptation of the IETF's EAP**
  - EAP is originally specified in RFC 2284 and updated by RFC 3748
- **EAP is a framework protocol too.**
  - Rather than specifying how to authenticate users, EAP allows protocol designers to build their own EAP methods, subprotocols, that perform the authentication transaction
  - EAP methods can have different goals, and therefore, often use many different methods for authenticating users depending on the requirements of a particular situation

EAP

- **Motivation of EAP**
  - When PPP is first introduced in the early 1990s, there were two protocols available for user authentication: PAP and CHAP
  - Both PAP and CHAP require the use of a PPP protocol number
    - Assigning a PPP protocol number to each authentication method that might be obsolete soon is not favorable
  - EAP uses a single PPP protocol number while supporting a wide variety of authentication mechanisms
    - EAP is a single encapsulation that can run over link layer such as PPP, 802.3, 802l.11
    - It is most widely deployed on PPP links
- **Generic EAP packet format (EAP over PPP & EAP over LAN**

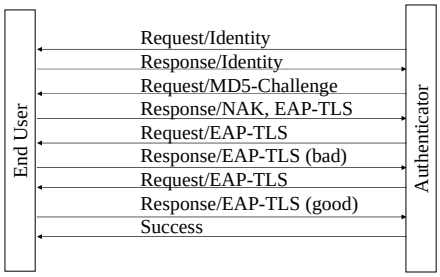
PPP Header	Code	Identifier	Length	Data
	1	1	2	Variable length

LAN Header	Code	Identifier	Length	Data

EAP Packet Format (Four Types)

- **EAP Requests and Responses**
  - Code = 1 for request and 2 for response
  - Extra field called Type-Code in EAP Request/Response message before the Data field
    - Type Code: 1 for identity, 2 for notification, 3 for NAK
    - Notification: for notification message (eg. Pwd is going to expire…), rarely used for 802.1X
    - NAK: Null ACK, used to suggest a new authentication method
  - Type-Code >3 specifying authentication method
    - Type-code = 4: MD5 Challenge
    - Type-code = 13: EAP-TLS
  - Identifier: a number incremented for each message send, data field may contain a prompt (Req/Res) message; used for pairing the request/response – same number for the pair
- **EAP Success and Failure**
  - Code = 3 for success, =4 for failure
  - Short data package containing no data

A Simple EAP Message Exchange



Request/Identity: starting the exchange, telling the end users That the network is likely to drop data traffic before the authentication procedure is complete

EAP Demystified

- **Authentication framework**
  - EAP utilizes authentication-specific messages
  - Authenticators only need to recognize a few well defined messages
    - Request/Response
    - Success/Failure
  - EAP subtypes allow for new types of authentication methods to be added without requiring upgrades to the Authenticators
  - You can write MyMethod over EAP

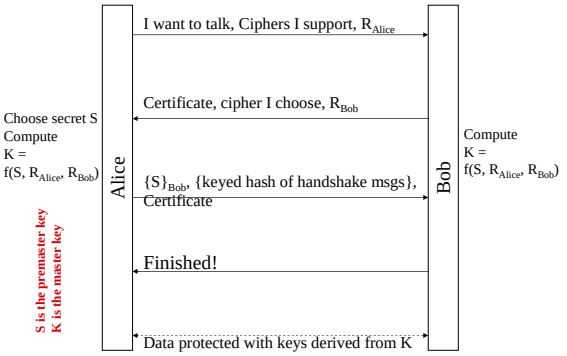
How to Choose an EAP Method?

- **Driven by the back-end authentication system**
- **An EAP method for Wireless LAN should meet the three major goals**
  - Strong cryptographic protection of user credentials
  - Mutual authentication
  - Key derivation

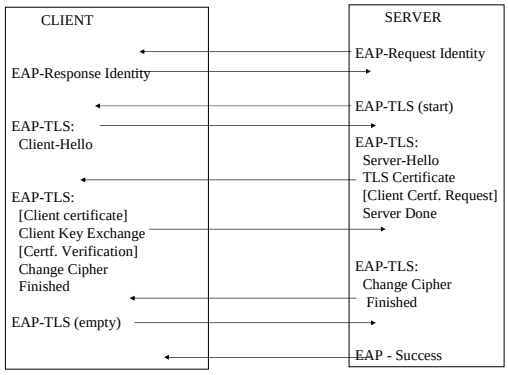
EAP Authentication Methods

- **EAP-MD5**
  - Does NOT provide for dynamic encryption – encryption key can't be generated dynamically
  - User authenticated by password
  - Network NOT authenticated to user (no mutual authentication)
- **EAP-TLS**
  - Provides for dynamic encryption
  - User and network mutually authenticated using certificates
  - Meet the three goals
  - Has limited use due to the requirement of the PKI (digital certificate)
- **EAP-TTLS and PEAP**
  - Provides for dynamic encryption
  - Network authenticated using certificate (outer authentication), the protocol is similar to EAP-TLS
  - Client authentication tunneled inside of EAP-TLS (inner authentication)
    - Significantly decrease the number of digital certificates
    - Non-cryptographic or older EAP methods such as PAP and CHAP can be applied for inner authentication because a secure tunnel has been created
  - Inner and outer authentication can use different user name, even anonymous usernames

TLS Basic Protocol



TLS over EAP



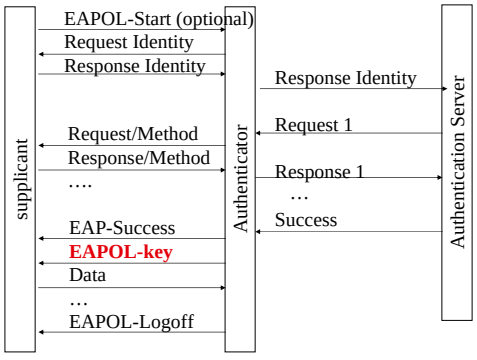
TLS and WPA/RSN

- **TLS handshake process accomplishes three things:**
  - Server authentication (optionally for client)
  - A master key for the session
  - Cipher suites to protect the communication (multiple keys are derived)
- **In WPA**
  - Encryption and integrity protection is provided by WEP or TKIP
- **In RSN**
  - Encryption and integrity protection is provided by TKIP or AES-CCMP
- **For WPA and RSN,**
  - All we need from TLS is the authentication function and the master key generation function

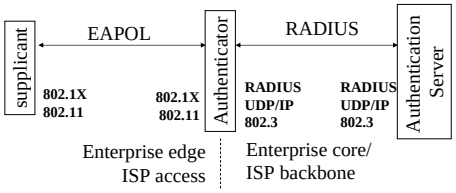
EAP Over LAN

- **EAP RFC does not specify how messages should be passed around**
  - It was originally designed for use with dial-up authentication via a modem
- **EAP messages have to be encapsulated in order to be transmitted in a Wi-Fi network**
  - Prepend the MAC address? – most simple way
- **IEEE 802.1X defines EAPOL: EAP Over LAN**
  - Not just prepend the MAC header. Defines more messages and fields
  - EAPOL-Start message to a special group-multicast address (reserved for 802.1X authenticators) to announce the existence of a supplicant
  - EAPOL-Key from the authenticator to send encryption keys to the suppliant
    - How to encrypt the key? – no definition
  - EAPOL-Packet, for transmitting the original EAP messages
  - EAPOL-Logoff
  - EAPOL-Encapsulated-ASF-Alert (not used by WPA and RSN)

EAPOL Message Flow



802.1X Architecture – Revisited



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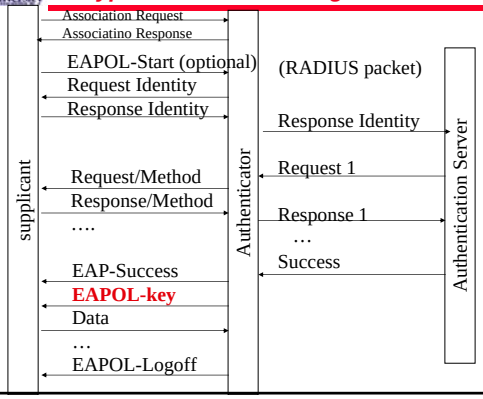
802.1X in AP

- **Wireless devices act as supplicants, applying for access by sending messages to the authenticator.**
- **All done in software**
- **For SOHO, authentication server could be a simple process inside the AP**
  - Eg. Just a list of user names and passwords
  - No need for RADIUS since the authenticator and the authentication server do not need to communicate
  - The number of supported authentication methods would be limited

802.1X over 802.11

- **In Wireless LAN, an AP needs to create a logical port with an authenticator for each supplicant (wireless user)**
  - The number of 802.1X entities in operation is the same as the number of associated mobile devices
- **If authentication server and authenticator both reside in the AP, no RADIUS protocol is needed**
- **In wireless LAN, EAPOL can proceed only after the association is complete since no port exists; Association process allows supplicant and AP to exchange MAC address**

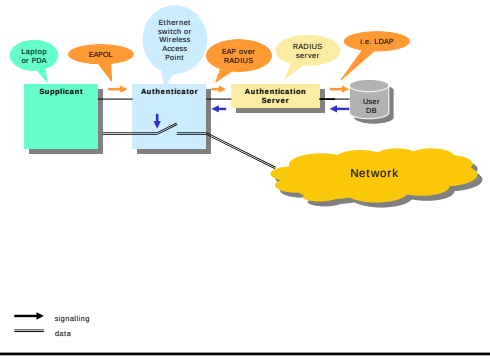
Typical 802.1X Exchange on 802.11



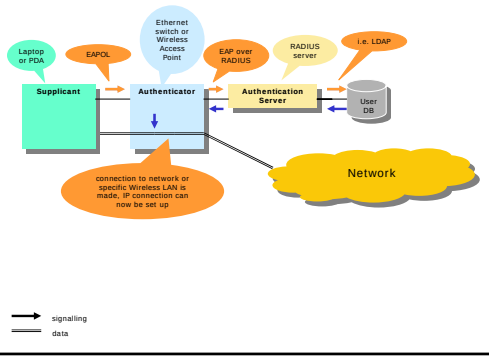
802.1X Message Exchange on 802.11

- **Keys are exchanged only after successful authentication**
  - EAPOL-Key can be used periodically to dynamically update keys
  - Will be further explained latter when discussing TKIP
- **EAPOL starts after the association process is complete**
  - Association process exchanges MAC address first

How 802.1X works



How 802.1X works



802.1X Meets Wireless -- Summary

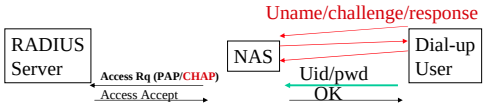
- Associations (wireless clients with access points) become virtual "ports"
- Frequent reauthentications reset key information and insure no session hijacking has occurred
- EAPoL-Key frame used to provide dynamic encryption -- dynamically refresh session keys
- Now used as the basis for enterprise authentication in WPA and WPA2 (802.11i)

RADIUS – Remote Access Dial-In User Service

- Optional in RSN, originally designed for TCP/IP type of networks
- A protocol for the communication between the NAS (network access server) and the AS (authentication server)
  - Dial-up modem pool server (NAS) at Point-of-Presence
  - RADIUS server (AS)
- In Wi-Fi networks
  - NAS is AP
  - AS is the server with the authentication database

How RADIUS Works

- The core protocol contains four messages:
  - Access-Request (NAS→AS)
  - Access-Challenge (NAS←AS)
  - Access-Accept (AS→NAS)
  - Access-Reject (AS→NAS)
- RADIUS is used for dial-in system authentication, with two options:



  - PAP Operation: username/password sent as plaintexts
  - CHAP Operation: based on challenge response

Basic Format of RADIUS Message

Code	Identifier	Length	Authenticator	Attributes…

- Code identifies the four types of RADIUS messages
  - Access-Request: 1
  - Access-Accept: 2
  - Access-Reject: 3
  - Access-Challenge: 11

  } Response messages
- Identifier: a number incremented for each message; used to match up requests and replies
- Authenticator:
  - For Access-Request, a 16B nonce is included.
  - This nonce together with the shared key (between AS and NAS) is used for encrypting the password (together with the shared key) if password value is sent as an attribute
  - For response messages, the nonce with the key will be used for integrity check to counter replay attacks. The integrity check value will be inserted to the Authenticator field. – How to compute?
- Attributes
  - Information carried in RADIUS message is contained within attributes
  - Each attribute contains the fields of Type, Length and Data

EAP over RADIUS

- Defined in RFC 2869
- The EAP message is sent inside one or more special attributes that have a type value of 79

Improvement of 802.1X over WEP

- 802.1x provides support for a centralized security management model for user authentication.
- The primary encryption keys are unique to each station so the traffic on any single key is significantly reduced.
  - Either pre-shared (eg. A password for SOHO) or generated through an upper layer authentication protocol (eg. TLS)
  - When used with an AS, the encryption keys are generated dynamically and don't require a network administrator for configuration or intervention by the user
- It provides support for strong upper layer authentication.