802.1X, EAP and RADIUS

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Security of IT infrastructure (2016/17)

Content

Network access control

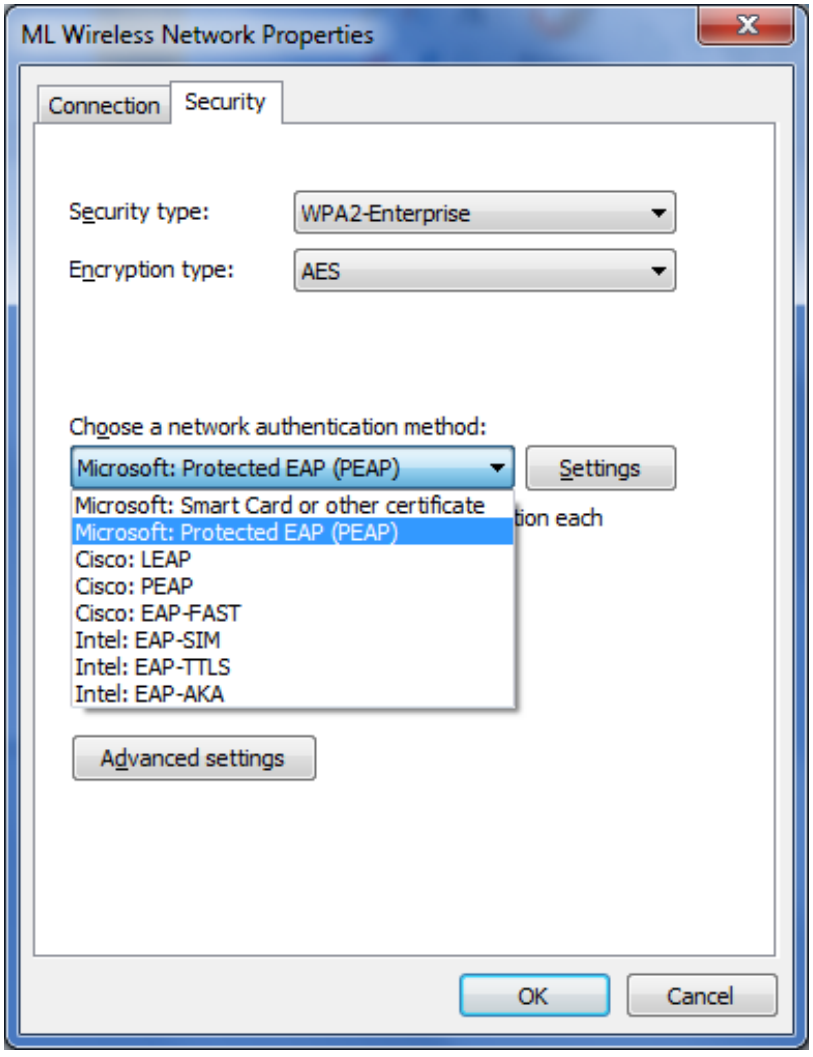
- AAA services ~ authentication, authorization, accounting
- **authentication**: verification (proving) of subject's identity
- authorization: determining whether the subject can perform given action
- accounting: tracking the use (consumption) of network resources
  - session duration, packets and data transferred, ...

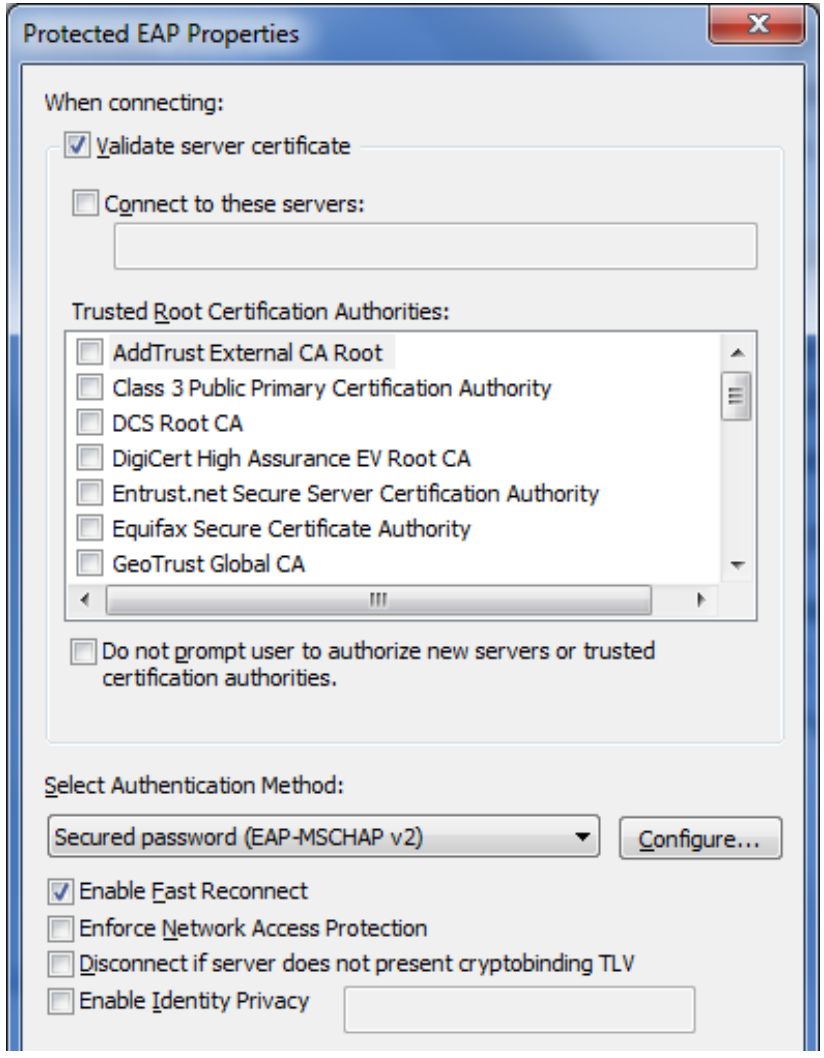
IEEE Std 802.1X

- Port-Based Network Access Control
- IEEE standard (versions 2001, 2004, 2010)
  - http://standards.ieee.org/about/get/802/802.1.html, more than 200 pages
- the standard:
  - specifies a general method for provision of port-based network access control;
  - specifies protocols that establish secure associations for IEEE Std 802.1AE MAC Security;
    (MAC – Media Access Control, part of a link layer in OSI model),
    encryption and integrity for Layer 2 (default AES-128-GCM)
  - facilitates the use of industry standard authentication and authorization protocols.
- example: WPA2 Enterprise (WPA2-802.1X, Wi-Fi Protected Access II)
  - cf. WPA2 Personal (WPA2-PSK, Pre-shared key)

Windows 7

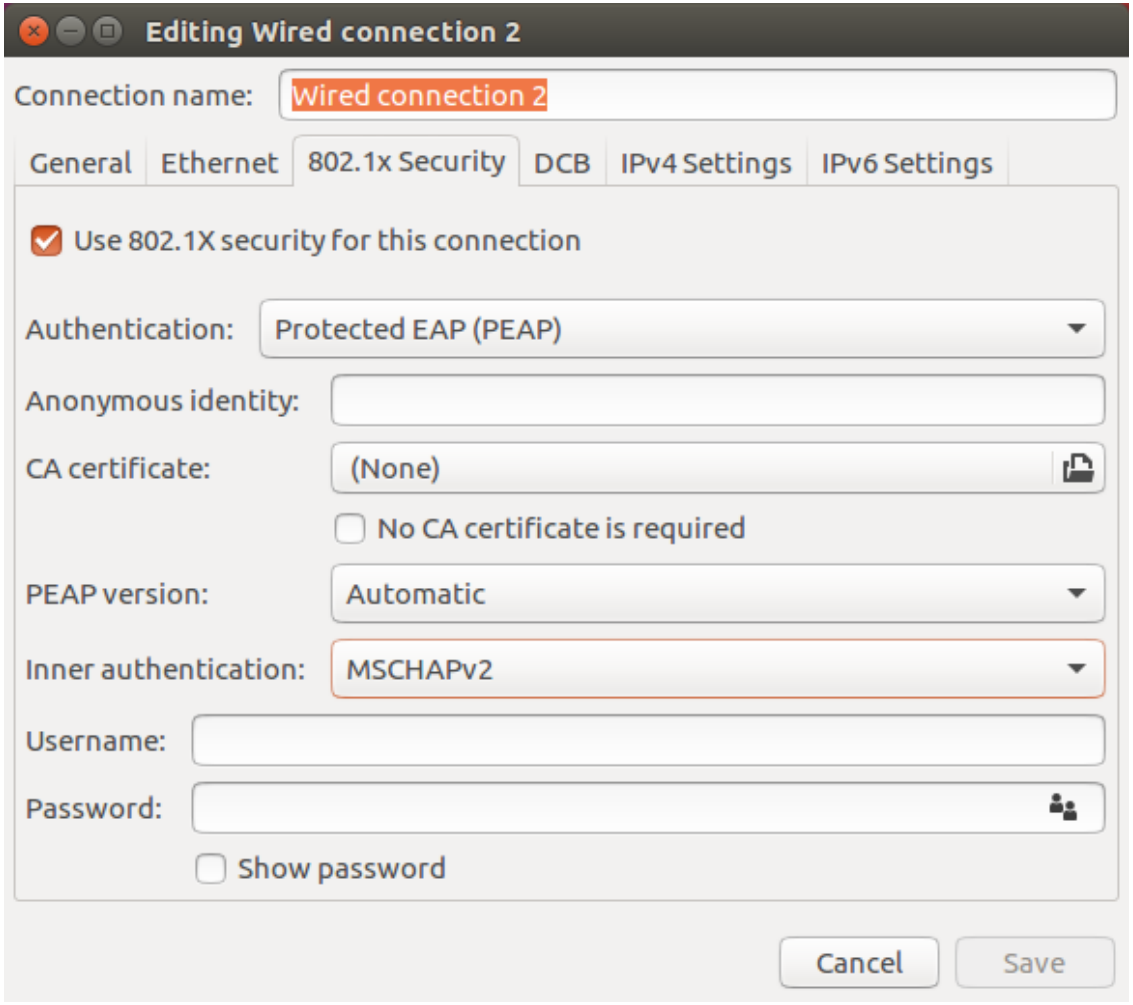
- WiFi; Wired AutoConfig service for 802.1X on wired Ethernet interfaces



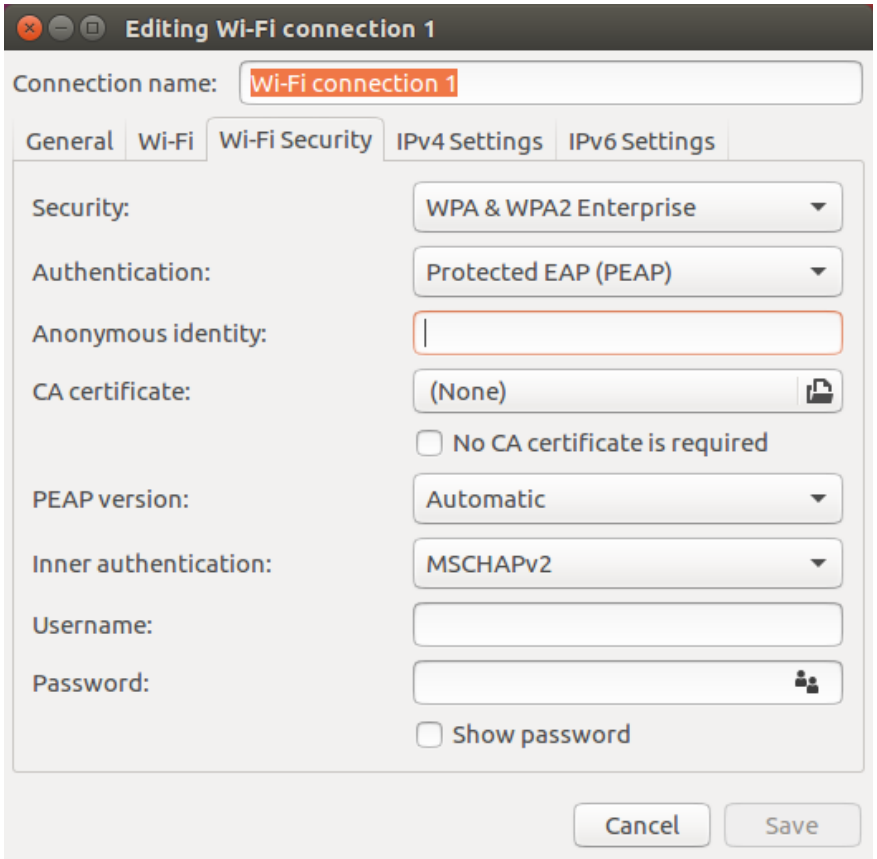


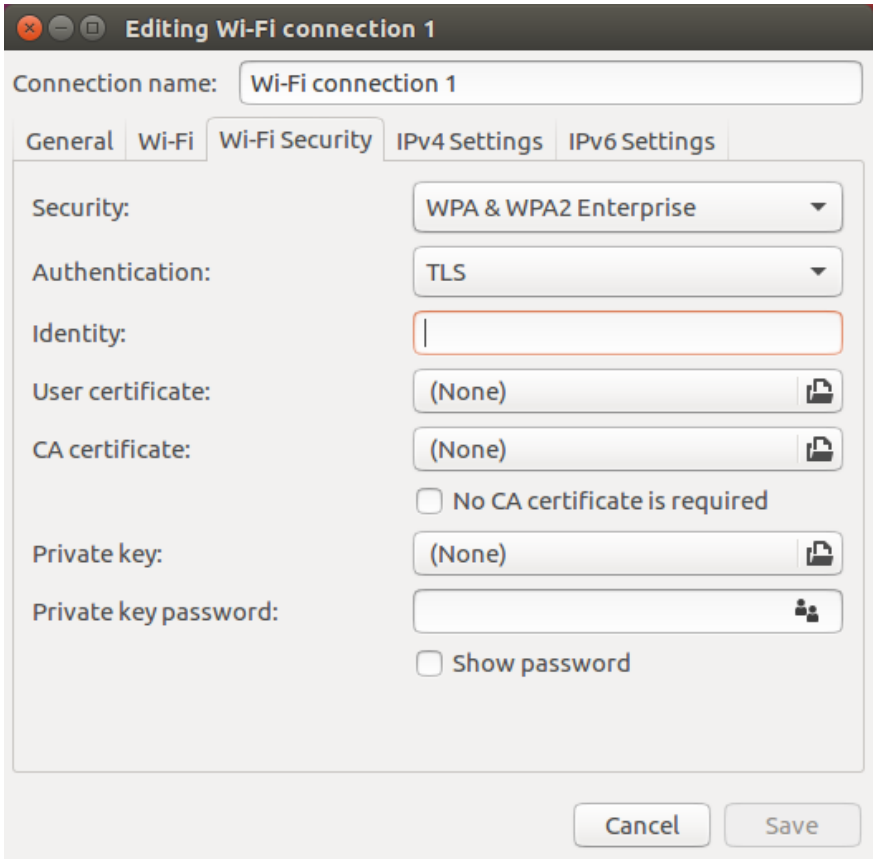
Ubuntu 16.04 (Wired connection)

- NetworkManager

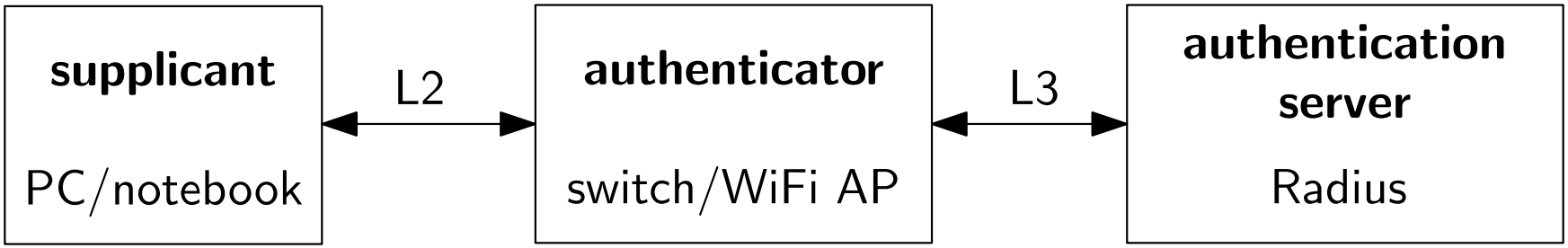


Ubuntu 16.04 (WiFi connection)





Subjects and roles in 802.1X

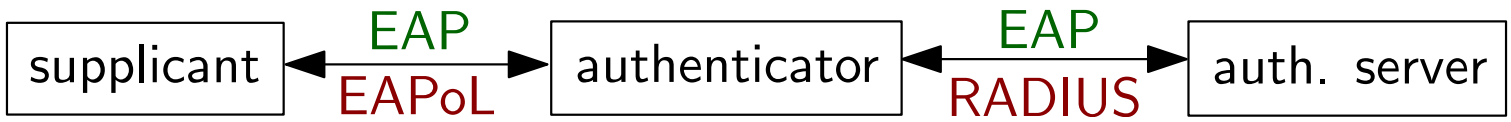


- Supplicant (client)
  - SW, e.g. part of an operating system
  - HW, e.g. Intel AMT (part of Intel vPro platform)
- Authenticator – facilitates authentication of other entities
- Authentication server – provides an authentication service

What's going on in 802.1X

- initial state: port (access point) is closed for any client's communication except EAPoL (EAP over LAN)
- client (supplicant) performs authentication against authentication server (EAP, Extensible Authentication Protocol)
  - success: authenticator opens port, assigns VLAN etc.
  - failure: authenticator keeps port closed / opens port and assigns the client to guest VLAN etc.

Protocols in 802.1X



- EAPoL (EAP over LAN)
  - facilitates communication supplicant ↔ authenticator
  - runs over 802.3 (Ethernet), 802.11 (WLAN), ...
  - packs EAP messages into L2 communication
- RADIUS ... details later
  - communication authenticator ↔ authentication server
  - in this scenario: EAP messages packed into messages of RADIUS protocol

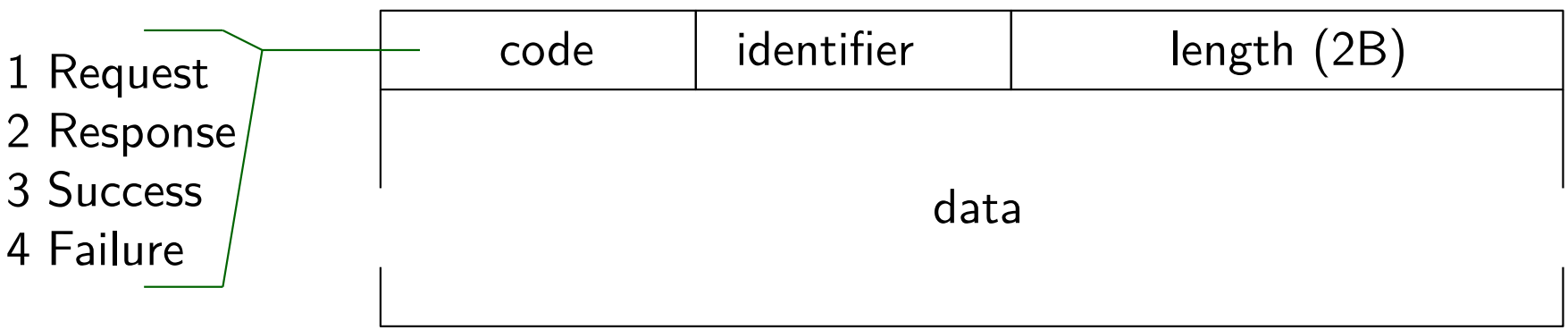
Challenges for deployment

- some EAP methods need certificates – certificate management (provisioning), both server's and supplicant's certificates
- network devices without 802.1X support (e.g. printers)
- Wake on LAN
- multiple devices on single network port (IP phones, hub etc.)
- unavailable authentication server

...etc. ...

EAP (Extensible Authentication Protocol)

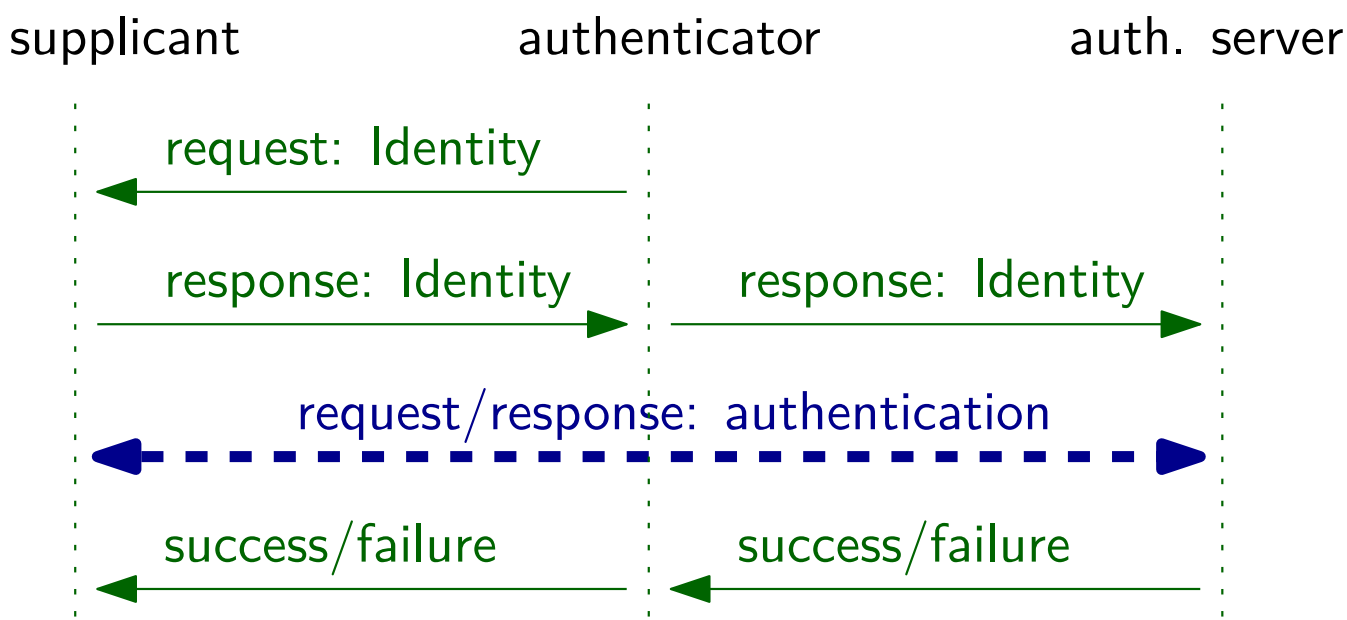
- originally an extension of PPP (Point-to-point protocol), now RFC 3748
- typically over data link layer (e.g. PPP, IEEE 802; i.e. without IP)
- general authentication framework for multiple authentication methods
- packet format:



  - identifier aids in matching responses with corresponding requests
  - RFC 5296: new codes introduced (5 Initiate, 6 Finish)

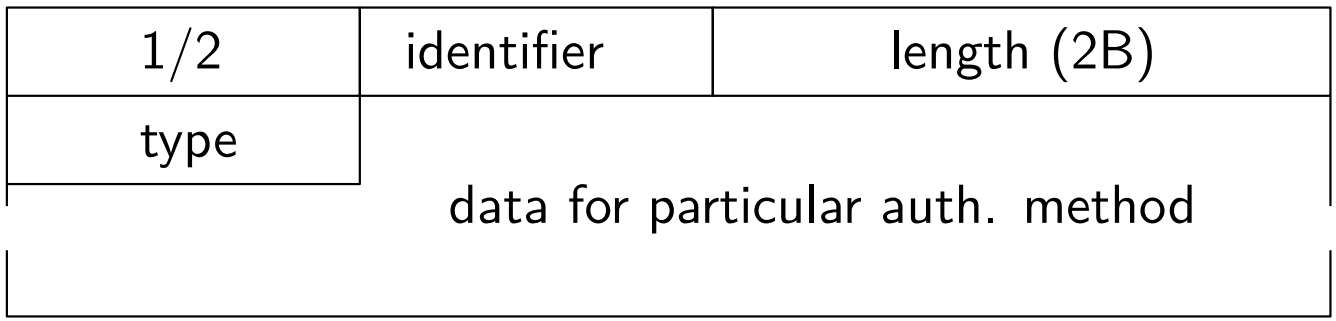
EAP (2)

- very simple protocol
  - (potentially) large number of request/response messages, usually finished with success/failure
- example:



EAP (3)

- complexity in authentication methods



- examples of authentication methods (more than 40, optional custom extensions):

4	MD5	21	PEAP
13	TLS	43	FAST
21	TTLS	49	IKEv2

EAP-MD5

- mandatory method (standard-compliant implementation must support)
- implementation CHAP (Challenge Handshake Authentication Protocol):
  - Request: *challenge*
  - Response: MD5(identifier || *shared secret* || *challenge*)
- avoid this method – security problems:
  - only one-sided (client/supplicant) authentication
  - vulnerable to dictionary and brute-force attacks
  - vulnerable to MITM attack . . . messages in clear-text without any protection of integrity/authenticity
  - identity of client revealed
  - no support for cryptographic key generation – cannot protect further communication
  - . . .

EAP-TLS, EAP-TTLS and EAP-PEAP

Ideas (outer EAP used mostly for solving packet fragmentation):

- EAP-TLS: using TLS authentication
- EAP-TTLS: client authentication (as AVP) tunneled in TLS
- EAP-PEAP: inner EAP instance tunneled in TLS

	EAP-TLS	EAP-TTLS	EAP-PEAP
client certificate	yes	optional	optional
server certificate	yes	yes	yes
mutual authentication	yes	yes	yes
key generation	yes	yes	yes
identity protection of client	no	yes	yes

Some inner authentication methods

- CHAP . . . with MD5 was discussed before
- MS-CHAPv2 . . . CHAP variant (defined in RFC 2759)
  - mutual (two-way) authentication
  - free from LAN Manager history
  - generating cryptographic keys
  - frequently used in practice
  - interesting analysis (standalone MS-CHAPv2):
    Defeating PPTP VPNs and WPA2 Enterprise with MS-CHAPv2
    (DEFCON 20, 2012)

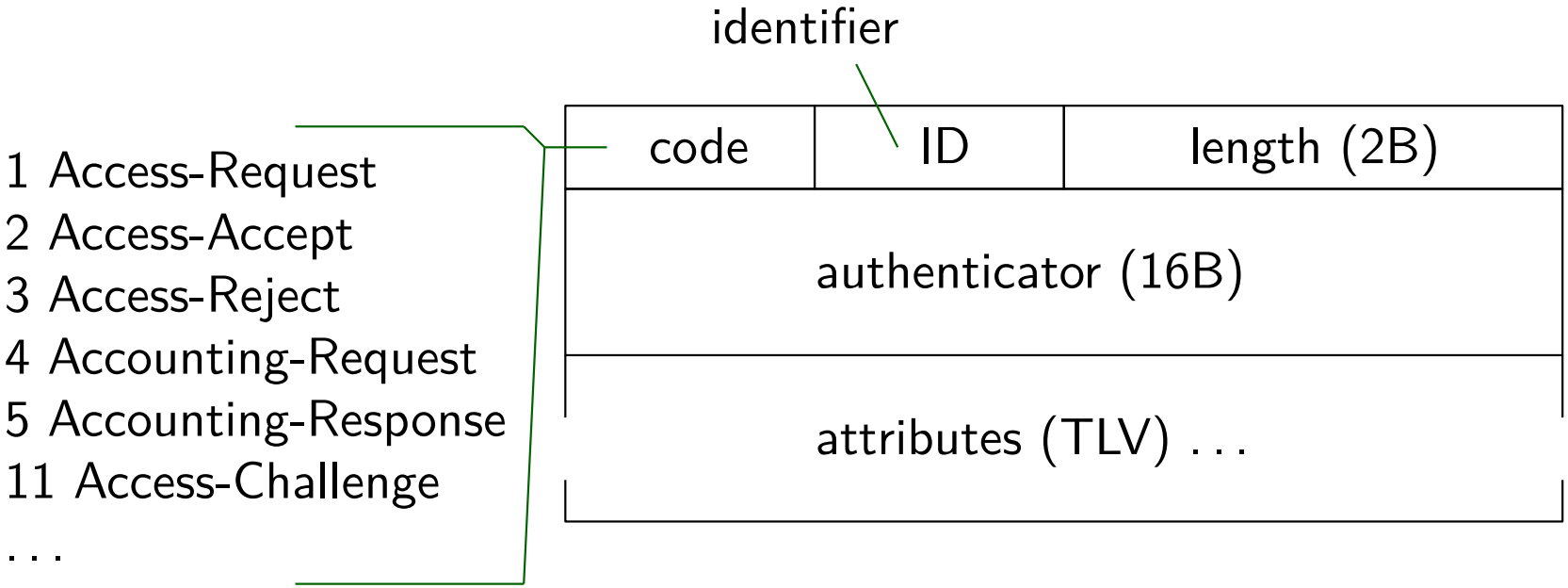
RADIUS

- RADIUS – Remote Authentication Dial In User Service
- RFC 2865, RFC 2866 (Accounting) + other extensions
- centralized authentication of users and systems
- AAA services
- client/server protocol
  - client (NAS – Network Access Server):
    switch, router, access point, VPN server ...
  - server (RADIUS server):
    FreeRADIUS, Network Policy Server (Microsoft), Secure Access Control Server / Identity Services Engine (Cisco)

Basic characteristics

- stateless protocol (UDP)
- database of users: SQL database, LDAP, text files, ...
- communication client $\leftrightarrow$ server (initialized by client)
- proxy RADIUS server (facilitates roaming of users between realms)

Packet



- authenticator:
  - request auth. (in Access-Request packets) – unpredictable and unique over lifetime of a secret
  - response auth. (Access-[Accept, Reject, Challenge] packets) MD5(code || ID || length || request auth. || attributes || secret)
  - secret – password shared by client and server

Security (1)

- user password (P) is transmitted encrypted
  - password padded with 0x00 to multiple of 16 B
  - encryption: $P \oplus MD5(secret \,||\, request\ auth.)$
  - other attributes in clear-text (security?, privacy?)
- value *secret*
  - dictionary attack or brute-force attack (using response auth. or encrypted password)
  - often the same values used in multiple NAS $\Rightarrow$ fake NAS, attacking user passwords

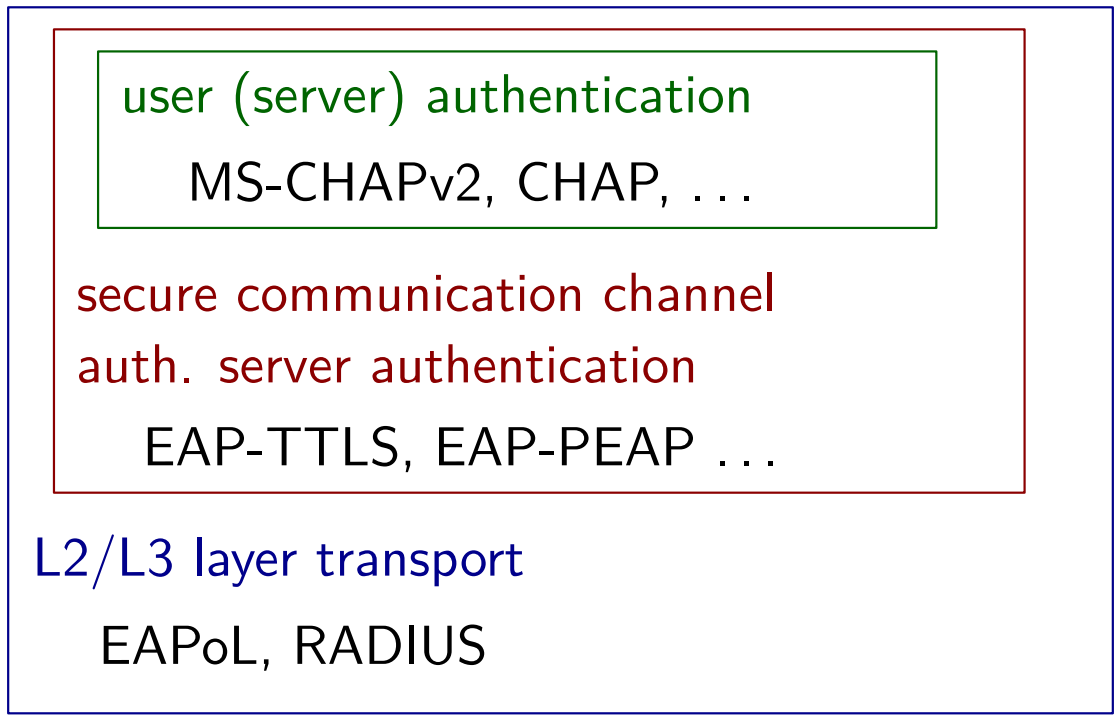
Security (2)

- vulnerability – repeating or predictability of request auth.
  - get server's responses in advance and repeat them later (see also Event-Timestamp attribute)
- Access-Request without integrity protection
  - see Message-Authenticator attribute (HMAC-MD5 for entire packet, key is *secret*)
- some risks are mitigated by employing suitable EAP method
- protection of the protocol – providing secure channel
  - IPSec, RadSec – RADIUS over TLS
- RADIUS support for EAP (RFC 3579)

Alternatives and improvements

- TACACS+ (Terminal Access Controller Access-Control System)
  - proprietary Cisco protocol, primary for access to network components
  - over TCP, separation of authentication and authorization
  - (optional) encrypted body of the packet (without header)
- DIAMETER
  - intended replacement for RADIUS (slow adoption)
  - basics defined in RFC 3588
  - over reliable transport layer (TCP, SCTP)
  - over secure communication channel (IPSec, TLS)
  - both stateful and stateless models
  - easy to extend, ...

Summary – architecture (802.1X example)



Summary – messages (802.1X example)