

Wireless Security - 802.11i



THALES

Securing your future

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Working Group 11 of IEEE 802

'Task Groups' within the WG enhance portions of the standard:

802.11 – 1997: The IEEE standard for wireless networks

- ♦ often called '802.11legacy'
- ♦ transfer using infrared or the 2.4GHz band
- ♦ radio uses frequency-hopping spread spectrum (FHSS) or direct-sequence spread spectrum (DSSS)
- ♦ 1 to 2 Mbps
- ♦ ratified in 1999, resulted in 802.11b
- ♦ today: '802.11 uses three different physical layers (PHY): 802.11a, 802.11b and 802.11g'



802.11a – 1999: Also called 'Wi-Fi5'

- ♦ uses orthogonal frequency division multiplexing (OFDM)
- ♦ not so crowded 5GHz with data rates from 6 to 54Mbps

802.11b – 1999: Also called: '802.11 High Rate' or 'Wi-Fi'

- ♦ most used today
- ♦ ratified version of 802.11 (and the 802.11 groups was born)
- ♦ theoretical 11Mbps speed (average is 4-6Mbps)
- ♦ high rate DSSS in the (crowded) 2.4GHz band
- ♦ uses only DSSS
- ♦ 802.11b+ (non-standard) up to 22Mbps



802.11c – does not exist. Task group C exists however, but has not created their own standard. Instead they have added standard from LAN-bridging (802.1D) to wireless AP operations

802.11d – 2001: New countries

- ♦ modify physical layer to meet regulatory requirements

802.11e – 2002: Enhance MAC layer to improve QoS

802.11f – 2003: Inter Access Point Protocol (IAPP)

802.11g – 2003: Higher rate extension to 2.4GHz band

- ♦ rate up to 54Mbps
- ♦ full backwards compatible with 802.11b (g's slow down to b)
- ♦ Super G = channel bonding up to 108Mbps



802.11h – 2003: Modified 802.11a

- ♦ in Europe, strong potential for 802.11a interfering with satellite communications
- ♦ uses the 5GHz band
- ♦ will become the successor of 802.11a?

802.11i – 2004: new standard for wireless security

802.11j – work in progress: add 4.9 GHz and 5 GHz in Japan

802.11k – work in progress: aims to provide measurement information to make wireless networks more efficient

- ♦ Roaming decisions
- ♦ RF channel knowledge
- ♦ Hidden nodes
- ♦ Client statistics
- ♦ Transmit Power Control (TPC)



802.11l – skipped because it looks like 802.11i

802.11m – work in progress: for maintainance

802.11n – work in progress: new WLAN standard

- ♦ build from ground up (no “turbo-mode” chips)
- ♦ 100Mbps real speed (250Mbps at PHY level)
- ♦ better operating distance
- ♦ standard by the end of 2005?

802.11o – work in progress: Voice over WLAN (faster handoff, prioritize voice traffic over data)

802.11p – work in progress: using 5.9GHz band for ITS (long range)



802.11p – work in progress: using 5.9GHz band for ITS (long range)

802.11q – work in progress: support for VLAN

802.11r – work in progress: r for "roaming", handling "fast handoff" when roaming between AP

802.11s – work in progress: self-healing/self-configuring mesh networks

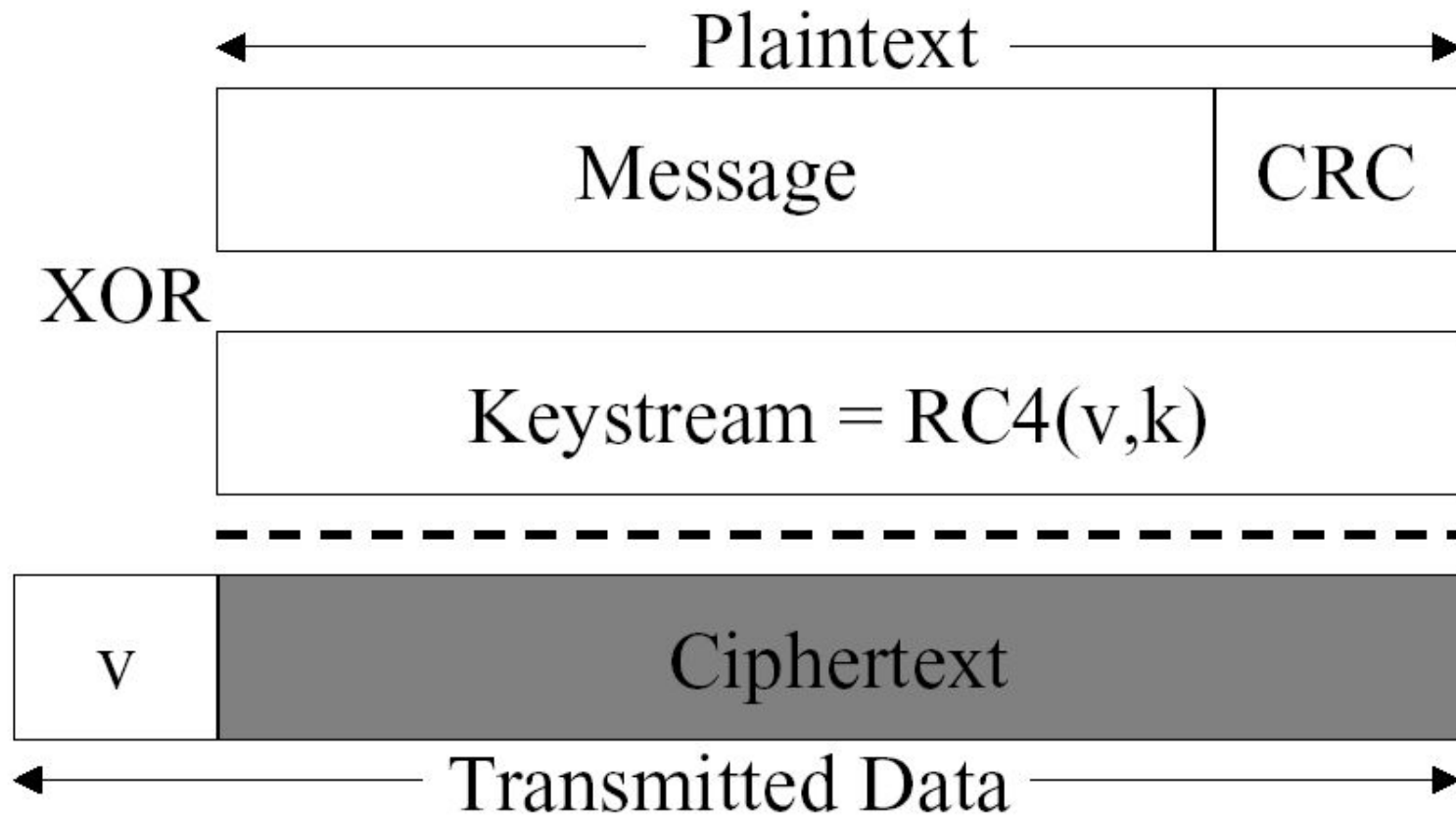
802.11x – is often used to summarize all standards within the Working Group, but it is NOT a standard!



Wired Equivalent Privacy (WEP)

Relies on a secret key k shared between the nodes

- ♦ Checksumming
 - ♦ Integrity checksum $c(M)$ on the message M
 - ♦ called Integrity Check Value (ICV) based on CRC-32
 - ♦ Plaintext $P = \langle M, c(M) \rangle$
- ♦ Encryption
 - ♦ chosen initial vector (IV) v and given secret key k
 - ♦ RC4 produces a keystream as a function of v and k
 - ♦ **XOR the plaintext with the keystream to obtain ciphertext: $C = P \oplus \text{RC4}(v,k)$**





- ◆ WEP key recovery – limited IV range (0 to 16777215). Same IV used over and over again: information to crack WEP key (**data confidentiality, access control**)
- ◆ Violation of data integrity – modify the ciphertext and forward changed message even without knowing the encryption key (**data integrity**)
- ◆ Key management – static manual stored keys
- ◆ No access point authentication (**authentication, access control**)

Crypto experts: "WEP is a broken protocol!"

Conclusion: Wired Equivalent Privacy (WEP) isn't!

Vendor specific "fixes": longer keys, dynamic keys, VPN

Crack-tool: Aircrack-ng



AirSnort

File Edit Settings Help

scan
 channel

Network device Refresh
 Driver type

40 bit crack breadth:
 128 bit crack breadth:

	Name	WEP	Last Seen	Last IV	Chan	Packets	Encrypted	Interesting	PW: Hex	PW: ASCII
94:4C	TSHIACIE2S	Y	Tue Jun 22 13:11:21 2004	44:00:04	1	19675585	19443679	1		
3B:D8	coax	Y	Tue Jun 22 06:41:59 2004	00:00:00	1	23	0	0		
F:FF			Tue Jun 22 12:48:05 2004	00:00:00		2874	0	0		
EE:FC	coax	Y	Tue Jun 22 06:42:03 2004	00:00:00	1	33	0	0		
61:3A	coax	Y	Tue Jun 22 06:42:30 2004	00:00:00	1	23	0	0		
00:59	coax	Y	Tue Jun 22 06:42:41 2004	00:00:00	1	55	0	0		
03:48	coax	Y	Tue Jun 22 06:42:50 2004	00:00:00	1	41	0	0		
066:18	coax	Y	Tue Jun 22 06:43:01 2004	00:00:00	1	51	0	0		
4D:37	coax	Y	Tue Jun 22 06:43:12 2004	00:00:00	1	51	0	0		
10:2A	coax	Y	Tue Jun 22 06:43:22 2004	00:00:00	1	21	0	0		

Start Stop Clear



802.11i to the rescue!

Goal: new standard for wireless security!

Consist of three major parts:

- 1) Temporary Key Integrity Protocol (TKIP)
 - 2) Counter Mode with CBC-MAC Protocol (CCMP)
 - 3) Port-based authentication protocol (802.1X)
- + key management

Other features:

secure IBSS, secure fast handoff, secure deauthentication, disassociation and roaming support

Ratified June 2004



Temporary Key Integrity Protocol (TKIP)

802.11's response to do something – anything – to improve security
Wi-Fi Alliance did not have time to wait for 802.11i --> WPA

- ◆ Enhancement of WEP – fixes all known WEP flaws
- ◆ Software/firmware upgrade 802.11b equipment
- ◆ Will degrade performance: uses more CPU in 802.11b devices!
- ◆ Not ideal design – more 'hacks' to make it work
- ◆ **NB! Not a long term solution!**



1. Michael: Cryptographic Message Integrity Code (MIC)

- ♦ SHA-1/MD5 are too CPU-expensive
- ♦ 64bit MIC designed by Niels Ferguson
- ♦ 'weak' integrity protection (2^{29} attack exists) – limited CPU!
- ♦ TKIP countermeasure: MIC is encrypted + key discarded if attacked (more than 2 failed MIC pr. second)
- ♦ only 'secure' when used with a secure encryption system (RC4 with rapid re-keying and per-packet mixing)
- ♦ **defeating forgeries**

2. IV sequence enforcement

- ♦ IV extended from 24 to 48 bits
- ♦ careful sequencing rules to prevent reuse
- ♦ **defeating replays**

3. Key mixing: per-packet keying – defeating weak keys

* phase 1:

temporary key (TK) 128bit, client's MAC address (TA), IV32
(most significant 32 bits of IV) = P1K 80bits

* phase 2:

P1K, IV16, TK = per-packet key (RC4KEY) 128bit

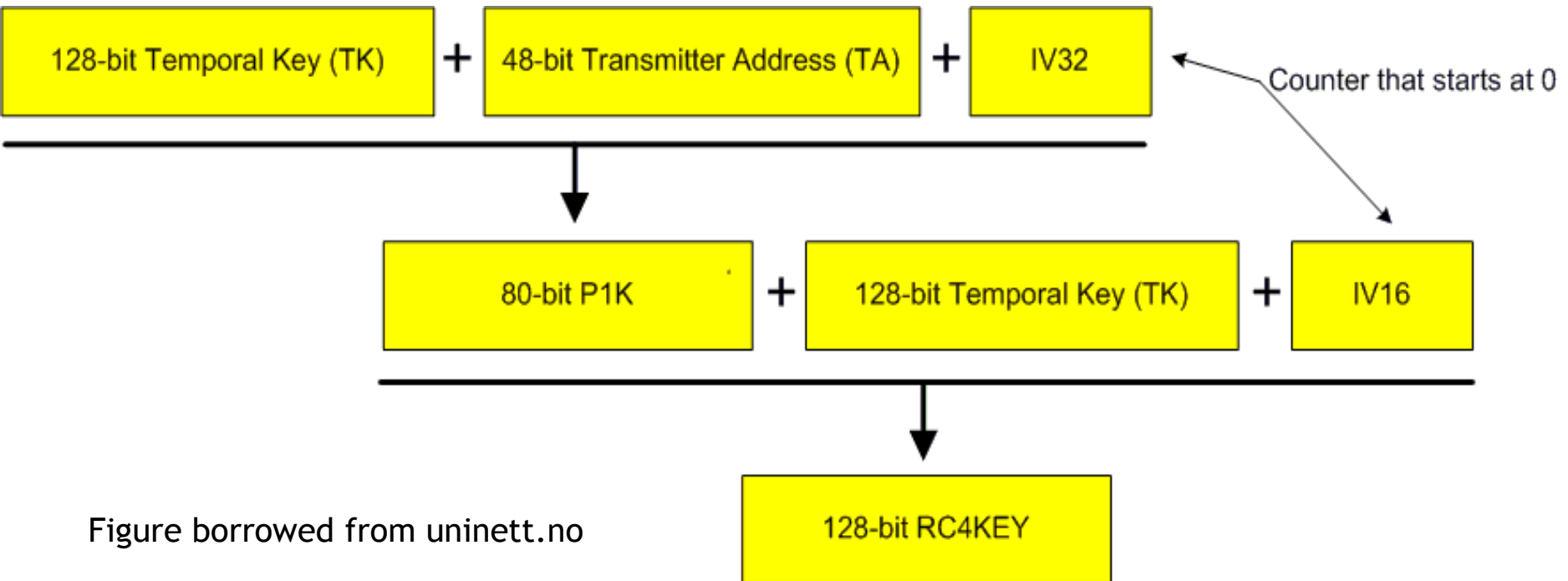
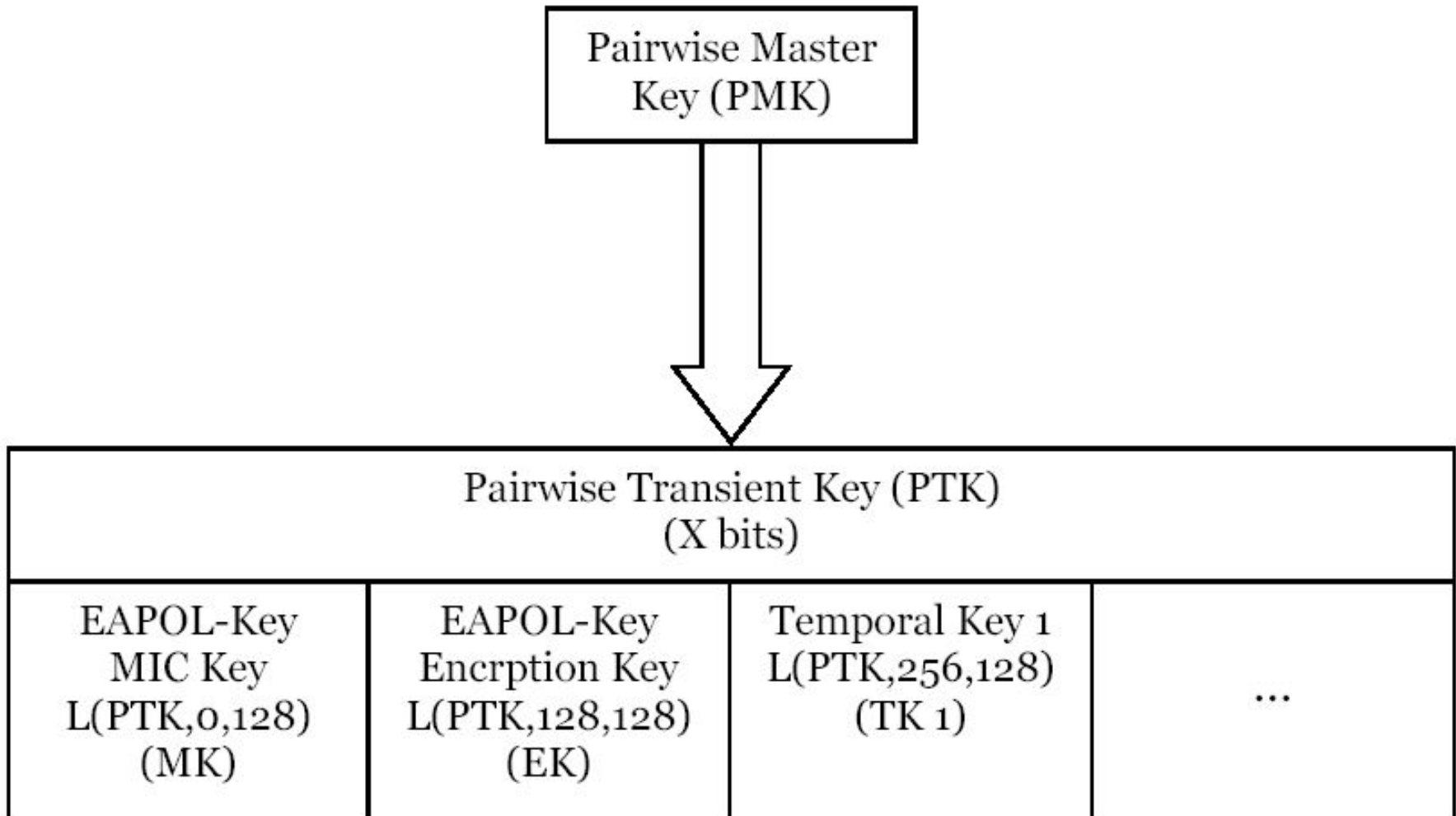


Figure borrowed from uninett.no

4. Rekeying – delivers fresh keys to various TKIP algorithms

- Master Key normally generated by authentication
- PMK is derived from the master key





Counter Mode with Cipher-Block-Chaining Message Authentication Code Protocol (CCMP)

The new flagship of wireless security!

- * designed by N. Ferguson, R. Housley and D. Whiting
- * public domain
- * protocol designed from ground-up
 - not withstood the test of time...
 - but based on well known technology
 - criticized for being too complex



- * block ciphers provides privacy but not authenticy
- * combined modes (authenticated-encryption modes)
 - privacy AND authentication

- * CCMP = combined mode:
 - Counter Mode (CTR) encryption mode = privacy
 - CBC- MAC = integrity and authentication

Uses flashy new AES with 128bit keys, 48bit IV

What about Wireless Robust Authentication Protocol (WRAP)??

- based upon Offset Codebook (OCB) mode of AES
- plagued by intellectual property rights (patents)
- RSN: CCMP is mandatory, WRAPS optional



Port based authentication protocol for Ethernet (802.1X)

Uses Extensible Authentication Protocol (EAP)

June 2004: RFC3748 Extensible Authentication Protocol (EAP)
(Obsoletes RFC2284)

"This document defines the Extensible Authentication Protocol (EAP), **an authentication framework which supports multiple authentication methods.** EAP typically runs directly over data link layers such as Point-to-Point Protocol (PPP) or IEEE 802, without requiring IP."

"EAP is **used to select a specific authentication mechanism,** typically after the authenticator requests more information in order to determine the specific authentication method to be used." --RFC3748, page 3



General EAP authentication with RADIUS as AAA protocol

AAA = Authentication, Authorization, Accounting

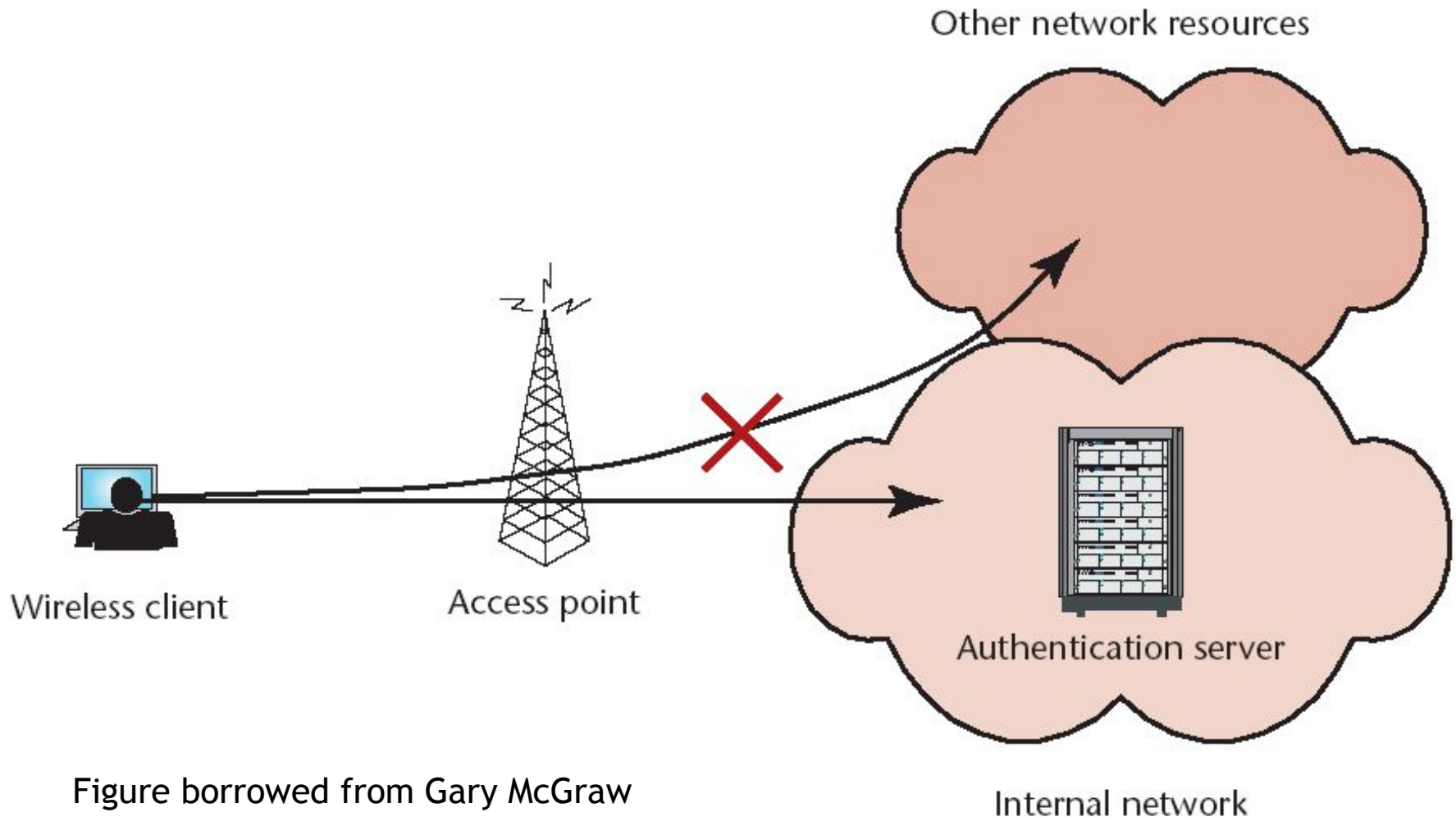


Figure borrowed from Gary McGraw

802.1X- EAP authentication overview



STA



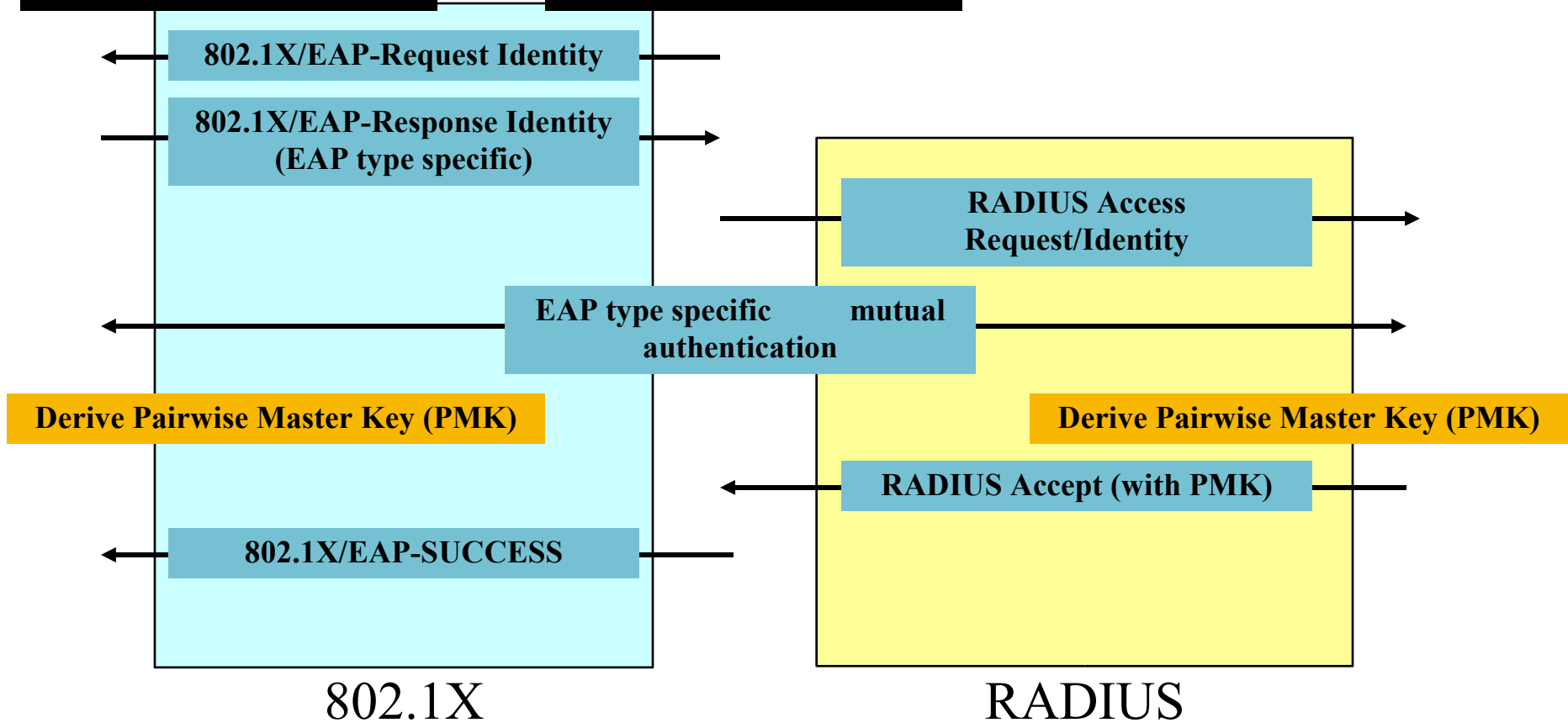
AP



AS

STA 802.1X blocks port for data traffic

AP 802.1X blocks port for data traffic

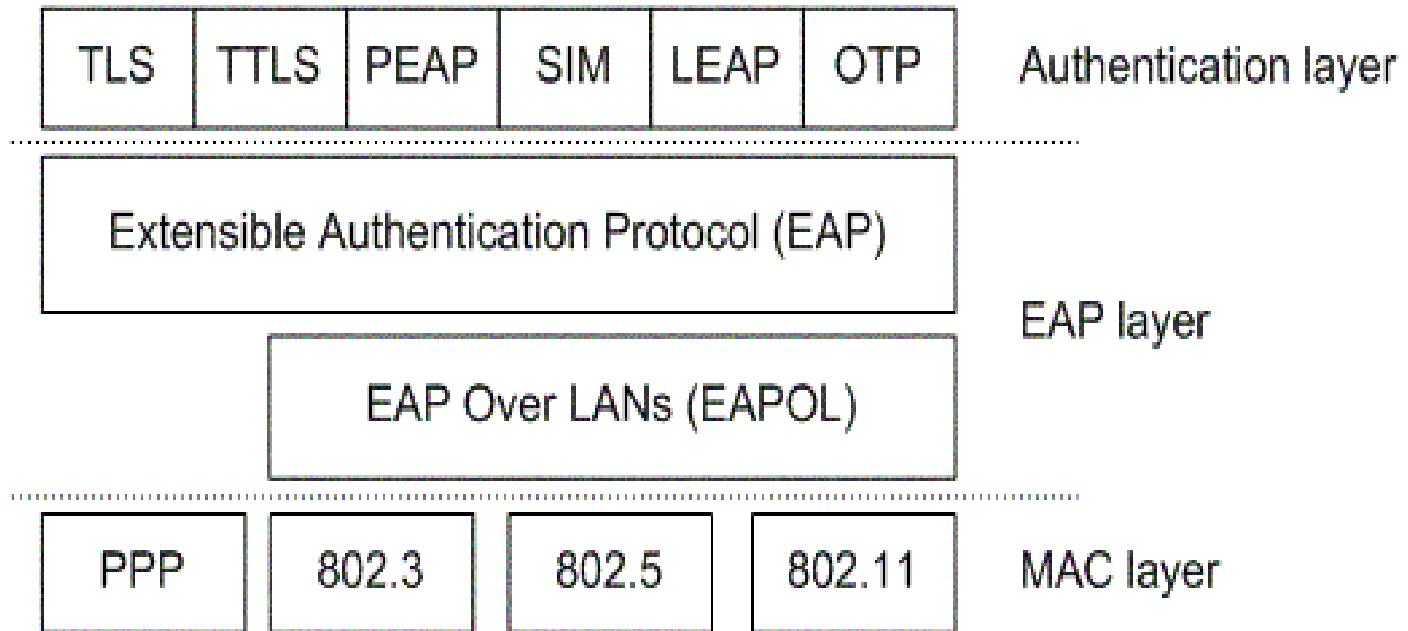


802.1X

RADIUS



Security layers



TLS - Transport Layer Security. Certificate based
TTLS - Tunneled TLS. Hybrid: certificate/password
PEAP - Protected EAP. Hybrid: certificate/password
SIM - SIM card based
LEAP - Cisco EAP variant. Password based
OTP - One Time Password. Password based



RADIUS is **NOT** part of 802.11i, but a 'back-end' protocol! (but is the *de-facto* back-end protocol!)

EAP provides a framework for authentication

May support several different authentication mechanism (not part of 801.11i):

- ♦ EAP-MD5: Username/password (IETF draft)
- ♦ EAP-TLS: Creates a TLS session within the EAP authentication process. Needs certificates and therefore PKI. (RFC2716)
- ♦ LEAP: Cisco proprietary
- ♦ MS-CHAPv2: Microsoft username/password. (RFC2759)
- ♦ EAP-TTLS vs. PEAP: tunnel mode for safe transport of authentication data



802.11i consist of three main part:

1) TKIP

2) CCMP

3) 802.1X

+ key management!

Wi-Fi Protected Access (WPA)

- TKIP + 802.1X

- Wi-Fi Alliance tok 'snapshot' of unfinished 802.11i = WPA

Robust Secure Networks (RSN)

- CCMP + 802.1X

- may also be called WPA2

Transition Security Network (TSN)

- RSN which uses TKIP instead of CCMP



- * how to support roaming between access points?
 - update all other AP?

- * how to make key-architecture support ad-hoc networks?
 - today:
 - i) session oriented to synchronize master key
 - ii) assume 802.1x authentication server
 - > Oakly, Diffie-Hellman, El-Gamal? - must share a secret!

Does NOT exists in ad-hoc networks!

- add these security mechanism
- alter the security architecture
- > else: security not possible



Eurofighter: authenticate and make devices talk
Distributed RADIUS server?

- Group keys: Who issues master keys? Vote for master?
- what if two manet merges? --> issue new master group key?

Existing solution: change to EAP

Two level authentication

