

# The OpenEapSmartcard platform

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**Abstract.** This paper presents the first javacard platform dedicated to IP (Wireless) LAN security issues. We have defined an open architecture that processes Extensible Authentication Protocol (*EAP*) in smartcards, which is the standard defined by IETF<sup>1</sup> and IEEE-802<sup>2</sup> committees for users' authentication in various network environments like *Wi-Fi*, *WiMax*, or *IPSEC*.<sup>3</sup> These tamper resistant devices are generally considered as the most trusted computing platforms. They have been selected by the DoD<sup>4</sup> for military ID cards, by the Belgium government for citizen ID cards, and they will be included in US and European passports. Although secure, javacards are cheap and manufactured by many companies. We present and analyze results obtained with five different smartcards, for two authentication scenari. The first works with an asymmetric algorithm (EAP-TLS, a transparent transport of the well known SSL<sup>5</sup> standard), the second uses a pre-share key scheme (EAP-PSK) based on the AES algorithm and the One-Key CBC MAC function (OMAC), which is under consideration by NIST<sup>6</sup> for standardization. We demonstrate that this open and flexible approach, is working with existing components, although performances enhancement is necessary.

**KEYWORDS:** Security, WLAN, smartcards, javacards

## 1 Introduction

Wireless IP networks, e.g. cheaper 802.11 technologies, follow an exponential growth. Everyday more and more people use wireless IP services at home, at office or in the city. However security issues still remain the Achilles' heel of these emerging ubiquitous networks [10], [11]. Even when Wi-Fi accesses are free, wireless clients need privacy, and organizations providing wireless infrastructures must control and manage network accesses.

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<sup>1</sup> Internet Engineering Task Force.

<sup>2</sup> Institute of Electrical and Electronics Engineers, IEEE 802 LAN/MAN Standards Committee.

<sup>3</sup>IP Security Protocol.

<sup>4</sup> United State Department Of Defense.

<sup>5</sup> Secure Sockets Layer.

<sup>6</sup> National Institute of Standards and Technology.











#### 2.2.4 Method

Each authentication scenario is processed by a specific Method class. Once initialized, it analyses each incoming EAP request and delivers corresponding response. The number of embedded methods is limited by the smartcard non volatile memory (E<sup>2</sup>PROM) size.

### 2.3 Integration to terminals

Some operating systems, like win32, already support the EAP protocol for wired and wireless networks. A given EAP authentication scenario is processed by a particular dynamic library (DLL) named EAP-Provider [17]. A *generic* library that uses PC/SC [2] services (plug and play support for smartcard readers), forwards incoming EAP requests to EAP smartcard that computes corresponding responses.

## 3 EAP-TLS smartcard

The EAP-TLS authentication scenario [6] works with the IETF version of the well known SSL protocol. Additional cryptographic features that are not supported in JC2.x framework are written in java, like HMAC [3], RC4, TLS PRF ([7] *Pseudo Random Function*) and X509 certificate parser.

We have implemented two modes for EAP-TLS. The first is asymmetric and works with a mutual authentication based on RSA keys and X509 certificates. The second called session resume mode [7], is symmetric and is based on Session-ID and Master-Secret parameters computed during a previous (full and asymmetric) session. This last mode may be useful for SIM javacards that don't include RSA crypto-processor.

### 3.1 Experimental results

Tests were performed on four smartcards, equipped with 8 bits processors (8 MHz clock), issued by different manufacturers. Devices A, C and D are general purpose javacards, component B is a SIM module. Two of them that have RTT times less than 30s and may be used for authentication in existing 802.11 wireless infrastructures.

#### 3.1.1 TLS "full mode"

During the authentication scenario about 2,500 bytes are sent and received. The time consumed by this operation ranges between 2 and 5 seconds. This parameter is dependant on three constraints; physical throughput,

performances of embedded JVM, and time required for writing operations in E<sup>2</sup>PROM.

RSA resources, provided by crypto-processor, are used three times. Public key operations need around 200ms, and encryption with private key is rather fast, and consumes less than 500 ms.

According to the TLS specification, three dual digests (MD5 + SHA1) are performed on these exchanged data, e.g. about 7500 bytes (120 blocs of 512 bits). We observe (see table1, Dual Hash column) average computing times (per bloc) ranging between 3,7 ms (900ms/240) and 24 ms (5700ms/240)

Five occurrences of pseudo random function (PRF), imply the calculation of 31 HMAC-MD5 and 31 HMAC-SHA1 procedures [3], which process 140 MD5 blocs and 140 SHA1 blocs. Each HMAC computes 2 digests, whose average size is about 2, 25 blocs. We notice (table 1) an important overhead, induced by our java implementation, excepted for the device D.

RC4 algorithm is fully written in java, observed performances clearly illustrate various behaviors of multiple embedded virtual machines.

Device	RTT MAX	Total Authentica tion Time	Data Transfer 2500 bytes	Dual Hash 2x120 blocs	PRF 2x140 blocs	RC4 2 x 32 bytes	OTHER
A	52,3s	78,1s	2,3s 2,9%	5,7s 7,3%	42,4s 54,2%	14,7s 18,9%	13,0s 16,6%
B	21,0s	34,3s	4,3s 12,5%	4,5s 13,2%	19,7s 57,3%	2,3s 6,7%	3,5s 10,2%
C	22,3s	33,3s	4,9s 14,7%	3,5s 10,4%	13,3s 40,0%	2,8s 8,4%	8,8s 26,5%
D	5,2s	9,3s	1,6s 17,2%	0,9s 9,7%	4,5s 48,4%	0,7s 7,5%	1,6s 17,2%

**Table 1.** Measured authentication time for four smartcards, TLS full mode

Device	RSA 1024 bits Public Key Initialization	RSA 1024 bits Encryption	RSA(Verify Data) 1024 bits Private Key Encryption
A	0,21s	0,16s	0,33s
B	-	-	< 0,80s
C	0,31s	0,38s	0,43s
D	-	0,02s	0,11s

**Table 2.** RSA performances for four smartcards



### 3.2 Resume mode

In this mode around 250 bytes are exchanged, a previously computed master-secret is re-used, and no RSA resources are necessary. Two dual digests (MD5 + SHA1) are performed on about 2x150 bytes (6 blocs of 512 bits)

Four occurrences of the PRF functions imply the calculation of 15 HMAC-MD5 and 15 HMAC-SHA1 procedures which process 108 MD5 blocs and 108 SHA1 blocs. Each HMAC computes 2 digests, whose average size is about 3,6 blocs.

In summary (see table 3) the resume mode is quicker than the normal one, it may be useful for fast user's re-authentication.

Device	Total Authentication Time	Data Transfer 230 bytes	Dual Hash 2x6 blocs	PRF 2x108 blocs	RC4 2x32 bytes	OTHER
A	49,5s	0,9s 1,9%	0,3s 0,6%	32,5s 65,6%	14,7s 29,7%	1,1s 2,2%
B	18,7s	1,0s 5,4%	0,2s 1,0%	15,2s 81,3%	2,3s 12,3%	0,0s 0%
D	5,5s	0,2s 3,6%	0,0s 0%	3,5s 63,7	0,7s 12,7%	1,1s 20,0%

**Table 3.** Measured authentication time for three smartcards, TLS resume mode

### 3.3 Performances limits

	Full Mode					Session Resume Mode			
	Total Time	Data Transfer (2500 bytes)	Dual Hash 2x120 blocs	PRF 2x140 blocs	RSA	Total Time	Data Transfer (250 bytes)	Dual Hash 2x 6 blocs	PRF 2x108 blocs
A	15,6	2,3	5,7	6,7	<0,9	6,4	<1,0	0,3	5,1
B	16,5	4,3	4,5	5,3	<2,4	5,4	<1,0	0,3	4,1
C	14,0	4,9	3,5	4,1	<1,5	4,0	<1,0	0,2	2,8
D	3,7s	1,6	0,9	1,0	<0,2	1,0	<0,2	0,0	0,8

**Table 4.** TLS computing time estimation, obtained by neglecting java overhead, for PRF and RC4 calculation

Table 4 estimates ultimate authentication times for full and resume modes, by neglecting the java overhead. Scenario duration is only dependent on data transfer, number of digest operations, and RSA calculations. It clearly appears that performances are strongly linked to digest computing; although IO throughput can't be neglected for full mode operation.

#### 4 The EAP-PSK smartcard.

The EAP-PSK method [22] is a symmetric authentication scenario, recently proposed at the IETF committee, and based on AES algorithm. We are going to briefly analyze its behavior. Server and client use a (secret) pre share key (PSK, 128 bits), from which are deduced two AES (128 bits) keys: AK (Authentication Key) and KDK (Key-Derivation Key).

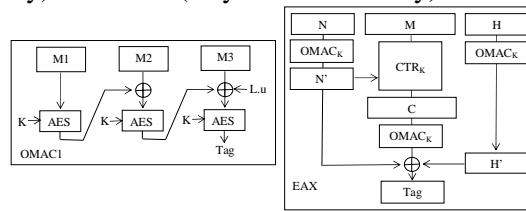


Figure 4: OMAC1 (left part) and EAX (right part) principles; K represents an AES key.

These two entities exchange random values (RAND\_P, RAND\_S) which are associated to MAC (128 bits) values (MAC\_P, MAC\_S) computed according to the OMAC [15] algorithm, which is under consideration by NIST for standardization. This algorithm splits incoming messages in blocs (128 bits) encrypted by AK key and mixed with EXOR operations (see figure 4).

A *Modified Counter Mode* [14] (MCM) algorithm computes from the RAND\_P field and the KDK key, the *Transient EAP Key* (TEK) and the IEEE 802.1x *Pairwise Master Key* (PMK).

EAX [20] is a block-cipher mode of operation, for solving the problem of authenticated encryption with associated header. It works with a nonce N, a message M, and a header H. It is used by EAP-PSK to provide a secure channel (S\_CHANNEL), protected by the TEK key that transports at least, an encrypted and tagged *status byte*. EAX required three OMAC instances (for the nonce, the header and tag, see figure 4) and a counter mode encryption (CTR mode) for message ciphering.

Device	AES SET KEY	AES CIPHER (T <sub>AES</sub> )	OMAC 25 bytes 3xAES T=n <sub>AES</sub> (T <sub>AES</sub> +p)	OMAC 49 bytes 5xAES T=n <sub>AES</sub> (T <sub>AES</sub> +p)	AEX (N=16 bytes, H=5 bytes, M=1 byte) 10xAES
E	0,018s	0,011s	0,114s	0,170s	1,022s
C	2,6s	0,39s	1,30s	2,24s	5,13s

Table 5. Basic parameters for EAP-PSK

Most of today available Javacards implement the JC2.1 standard, which doesn't support the AES algorithm, but hopefully it is included in JC2.2 smartcards. Consequently our tests deal with two kinds of AES instances, full

Java (device C) or native implementation (device E). As illustrated by table 5 the pure software version is rather slow (0,4s per block encryption), specially when it's necessary to initialize a key (1.3s). Additional cryptographic resources (AEX, OMAC, ...) are provided by java classes.

Operation	Number of AES Encrypted blocs (n)	Device E		Device C	
		Computing time CT	Estimated Java overhead CT-n.T <sub>AES</sub>	Computing time CT	Estimated Java overhead CT-n.T <sub>AES</sub>
First Request					
SET_KEY(AK)		0,018		2,60	
OMAC (49 bytes)	5	0,170	0,110	2,24	0,29
Second Request					
OMAC (25 bytes)	3	0,114	0,079	1,30	0,13
SET-KEY(KDK)		0,018		2,60	
MCM	6	0,070		2,34	
SET-KEY(TEK)		0,018		2,60	
AEX(N=16,H=5,M=1)	10	1,022	0,906	5,13	1,23
AEX(N=16,H=5,M=1)	10	1,022	0,906	5,13	1,23
TOTAL	34	2,45s	2,00s	23,90s	2,90s

**Table 6.** EAP-PSK computing time

We (not surprisingly) observe (see table 5) that computing time of OMAC increases proportionally to the number of (AES) blocs. The (Java) penalty per bloc (p, table 5) is about 20ms for device E and 50ms for device C. The EAX procedure is more complex and induces further Java additional computing times whose values are 0,9s for device D and 1,2s for device B. We finally notice for device E, that total computing time (2,45s) is mainly due to Java overhead because the AES penalty (34 x 0,011) is not the predominant factor.

Table 6 details observed computing times, and clearly illustrates that EAP-PSK is faster than EAP-TLS resume mode.

## 5 Conclusion

In this paper we have presented an open, modular and flexible approach for controlling network accesses in WLAN environment. We have demonstrated that this proposal is realistic, even with cheap smartcards that are not specially designed for that purpose. We have published [27] these source codes and we plan to develop an open library that will cover more scenari.

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