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WISTP ’07 – A comparative analysis of common threats, vulnerabilities, attacks and countermeasures within smart card and wireless sensor network node technologies.

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Presentation Structure

- Background to Research
- Objectives of Research
- Technology Definitions
- Security Analysis
- Results
- Conclusion
- Additional Information and Resources

Authors' Backgrounds

- Kevin Eagles:
  - UK MOD Civil Servant in Defence Equipment and Support (DE&S)
  - Security Assurance Manager for Defence Corporate Business Applications IPT
  - Directorate General Information Systems and Services (DGISS) - formerly Defence Communication Services Agency (DCSA)
- Dr. Konstantinos Markantonakis:
  - Smart Card Centre at Royal Holloway University of London
- Dr. Keith Mayes:
  - Director of the Smart Card Centre at Royal Holloway University of London

Background to Paper

- 2004 to 2006 - MSc Information Security at Royal Holloway

- MSc Project was: “A comparative analysis of common threats, vulnerabilities, attacks and countermeasures within smart card and wireless sensor network node technologies.”

- MSc Project is basis for the paper produced for WISTP07

Objectives of this Research

To enable this work, two high level objectives were established:

- OBJECTIVE 1: Determine if there are any security threats, vulnerabilities, attacks and countermeasures that have been established for smart card technologies (both contact and contactless) that can be directly and/or indirectly applied to wireless sensor network node technologies

- OBJECTIVE 2: Determine if there are any existing or emergent security threats, vulnerabilities, attacks and countermeasures that have been established for wireless sensor network node technologies that can be directly and/or indirectly applied to smart card technologies

Technology Definitions

- Smart card
  - integrated circuit (crypto co-processor & tamper resistance a common feature)
  - packaged and embedded within a card carrier
  - not normally a networked device (Java Card 3.0 an exception)
  - normally receives power from a separate source (some exceptions)

  Contact and contactless Smart Cards and also RFID technologies under the unified banner of smart card technologies

- Wireless Sensor Network Node (Mote)
  - integrated circuit (basic micro-controller, no tamper resistance or crypto co-processor)
  - able to function as an element within a network, to send, receive or route
  - onboard battery but low power consumption
  - passing data onto other devices through wireless communications
  - collaborating to form a sensing network

  No focus on specific vendors or operating systems - broad view research

Background to Analysis #1

- Plenty of data on ‘known’ attacks and Security Mechanisms for Smart Cards
- Some data on ‘known’ and theoretical attacks on Motes
- Plenty of Risk Analysis methods around, not many Threat Analysis methods
- Definitions identity crisis – what is a threat?

Background to Analysis #2

- Chose four pillars for the Security Analysis and created own definitions, need to ‘harvest’ as much information as possible:
  - Threat: “an objective a foe might try to realise in order to misuse a target or asset”
  - Vulnerability: “a specific means by which a threat can be executed via an unmitigated attack path”
  - Attacker: “the entity that is exploiting a vulnerability to establish a threat”
  - Countermeasure: “a mitigation measure that prevents, detects or significantly reduces a misdeed associated with a specific threat or group of threats”

This led to the creation of the TVAC Table - four pillars became four blocks

Background to Analysis #3 - TVAC

Technology	Threat Unique ID	(1) THREAT BLOCK			(2) VULNERABILITY BLOCK		
		Target &/or Asset	Threat Class	Threat Summary	Vulnerability Summary	CRIPAL	STRIDE
Contact & Contactless Smart Card	SCA-T6 SCB-T6	Physical – Chip & Logical - Operating System	Physical Static & Dynamic Logical Static & Dynamic Social	**Statement** : Protocol &/or functionality attack.Try to usurp onboard file system and/or execute rogue code - e.g., execute bogus application or bogus update code. **Entry Point**: Various **Impact**: M	**Statement** : Either by randomly trying spurious command sets or some of the attacks already mentioned, it might be possible to gain unauthorised access to the file system and/or run illegal code. **Probability**: L	C I P L	S T I E

(3) ATTACKER BLOCK		(4) COUNTERMEASURE BLOCK	
Attacker Group	Attack Class	Countermeasure Summary Total/Partial/None)	Overhead of Countermeasure on Time, Performance & Cost
C I C II C III	Invasive Active & Passive. Non-Invasive Active & Passive. Semi Invasive.	**Statement** : Memory Management & Firewall for access control to memory areas checking target addresses within limits. No code exec-ution in EEPROM or RAM. EEPROM has write/erase disallowed by setting page to prot-ected state, any bogus access attempt leaves content unaltered. Protection permanent once set, violations lead to prevention of execution and/or erasure of memory contents. Consider Global Platform with Card Manager, signed code, authentication/confirmation for updates. **Effectiveness**: Partial to Total	**Time**: Manufacture time goes up to incorporate these requirements. **Performance**: Possibly a tiny bit slower as these memory protection functions are executed and any signed code verified **Cost**: Cost of manufacture increases to cover this countermeasure

(5) APPLICABILITY TO WIRELESS SENSOR NETWORK NODES (TOTAL/PARTIAL/NONE)

Threat has total applicability to WSN Nodes, the countermeasure may have partial applicability because Global Platform is designed for smart cards

Background to Analysis #4 - TVAC

Technology	Threat Unique ID
Physical – Chip & Logical - Operating System	
Contact & Contactless Smart Card	SCA-T6 SCB-T6

(1) THREAT BLOCK

Target &/or Asset	Threat Class	Threat Summary
Physical – Chip & Logical - Operating System	Physical Static & Dynamic Logical Static & Dynamic Social	**Statement** : Protocol &/or functionality attack.Try to usurp onboard file system and/or execute rogue code - e.g., execute bogus application or bogus update code. **Entry Point**: Various **Impact**: M

(2) VULNERABILITY BLOCK

Vulnerability Summary	CRIPAL	STRIDE
Statement : Either by randomly trying spurious command sets or some of the attacks already mentioned, it might be possible to gain unauthorised access to the file system and/or run illegal code. **Probability**: L	C I P L	S T I E

(3) ATTACKER BLOCK

Attacker Group	Attack Class
C I C II C III	Invasive Active & Passive. Non-Invasive Active & Passive. Semi Invasive.

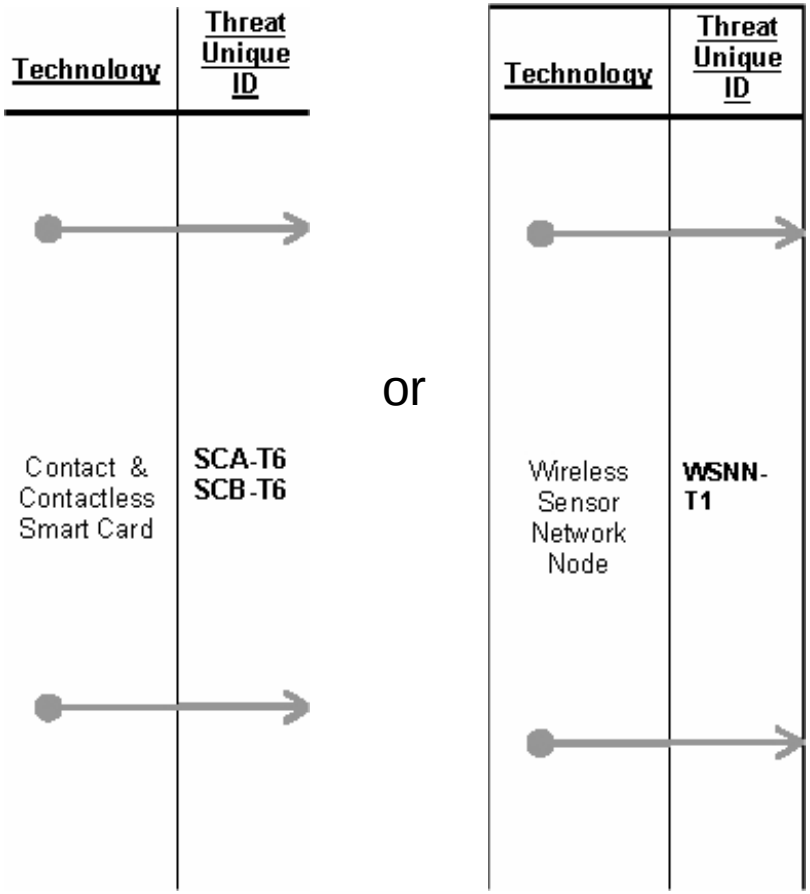
(4) COUNTERMEASURE BLOCK

Countermeasure Summary Total/Partial/None)	Overhead of Countermeasure on Time, Performance & Cost
Statement : Memory Management & Firewall for access control to memory areas checking target addresses within limits. No code exec-ution in EEPROM or RAM. EEPROM has write/erase disallowed by setting page to prot-ected state, any bogus access attempt leaves content unaltered. Protection permanent once set, violations lead to prevention of execution and/or erasure of memory contents. Consider Global Platform with Card Manager, signed code, authentication/confirmation for updates. **Effectiveness**: Partial to Total	**Time**: Manufacture time goes up to incorporate these requirements. **Performance**: Possibly a tiny bit slower as these memory protection functions are executed and any signed code verified **Cost**: Cost of manufacture increases to cover this countermeasure

(5) APPLICABILITY TO WIRELESS SENSOR NETWORK NODES (TOTAL/PARTIAL/NONE)

Threat has total applicability to WSN Nodes, the countermeasure may have partial applicability because Global Platform is designed for smart cards

Background to Analysis #5 - TVAC



The two initial left hand columns categorise the technology type and the threat unique identifier (TUID).

- contact smart card is prefixed SCA
- contactless smart card prefixed SCB
- Wireless Sensor Network Node prefixed WSNN

Background to Analysis #6– TVAC

8 Categories of Threat 'type', indicating what the target or asset is:

- Physical - Chip
- Physical - Other
- Logical - OS
- Logical - Platform
- Logical - Application
- Logical - Other
- Comms Bearer (e.g., Physical Card Reader, RF or RFID);
- Other.

(1) THREAT BLOCK

Target &/or Asset	Threat Class	Threat Summary
Physical – Chip & Logical - Operating System	Physical Static & Dynamic Logical Static & Dynamic Social	**Statement** : Protocol &/or functionality attack.Try to usurp onboard file system and/or execute rogue code - e.g., execute bogus application or bogus update code. **Entry Point**: Various **Impact**: M

Threat Summary:

This includes a 'Statement' of the Threat indicating 'Entry Point' and rating the 'Impact' of the Threat from High, Moderate or Low.

7 Threat Classifications:

- Physical Static (e.g., No Power to Hardware);
- Physical Dynamic (e.g., Power to Hardware);
- Logical Static (e.g., No Power source active, but using glitches e.g., temp)
- Logical Dynamic (e.g., Power to Software);
- Social (e.g., Social Engineering);
- Policy (e.g., Weakness in Governing Policies);
- Other.

Background to Analysis #7 - TVAC

Vulnerability Summary: A 'Statement' of the Vulnerability, with a 'Probability' rating from High, Moderate or Low.

(2) VULNERABILITY BLOCK

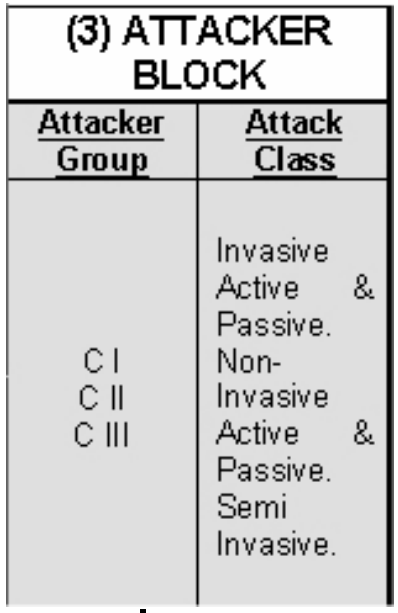
Vulnerability Summary	CRIPAL	STRIDE
Statement : Either by randomly trying spurious command sets or some of the attacks already mentioned, it might be possible to gain unauthorised access to the file system and/or run illegal code. **Probability**: L	C I P L	S T I E

S = Spoofing
T = Tampering
R = Repudiation
I = Information disclosure
D = Denial of Service
E = Elevation of Privilege

Microsoft method to categorise threats during software development. Added granularity to 'CRIPAL'

C = Confidentiality – The restriction of information and/or assets (both physical and logical) to authorised entities/individuals only.
R = Reliability – The ability to access and use information and/or assets (both physical and logical) consistently without disruption
I = Integrity – The maintaining of information and/or assets (both physical and logical) in their complete and intended form.
P = Privacy – The ability for an entity/individual to choose with whom to share their 'Private' information and/or assets (both physical and logical), without concern of impermissible access and/or use.
A = Availability – Constant and timely access to information and/or assets (both physical and logical) for authorised entities/individuals.
L = Legitimate Use – Use of information and/or assets (both physical and logical) is undertaken by authorised entities/individuals who have the legal rights to conduct actions through propriety (DPA '98, CMA '90).

Background to Analysis #8 - TVAC



(3) ATTACKER BLOCK	
Attacker Group	**Attack Class**
C I C II C III	Invasive Active & Passive. Non-Invasive Active & Passive. Semi Invasive.

5 Attack Classes:

Invasive Active (e.g., Cutting new tracks);
Invasive Passive (e.g., Microprobing to observe not to modify);
Non-Invasive Active (e.g., Power Surge or glitch attacks);
Non-Invasive Passive (e.g., DPA and Timing Attacks);
Semi Invasive techniques (e.g., Light attacks).

3 Attacker Groups:

- Class I (clever outsiders) - “Opportunist Attacker”
- Class II (knowledgeable insiders) - “Expert/Professional Attacker
- Class III (funded organisations) - “Sophisticated Attacker”

Background to Analysis #9 - TVAC

Countermeasure Summary:

A ‘Statement’ of the Countermeasure, indicating its ‘Effectiveness’ represented by the following options:

• Total (Complete Effectiveness)

• Partial (Some Effectiveness)

•None

(4) COUNTERMEASURE BLOCK

Countermeasure Summary Total/Partial/None)	Overhead of Countermeasure on Time, Performance & Cost
Statement : Memory Management & Firewall for access control to memory areas checking target addresses within limits. No code exec-ution in EEPROM or RAM. EEPROM has write/erase disallowed by setting page to prot-ected state, any bogus access attempt leaves content unaltered. Protection permanent once set, violations lead to prevention of execution and/or erasure of memory contents. Consider Global Platform with Card Manager, signed code, authentication/confirmation for updates. **Effectiveness**: Partial to Total	**Time**: Manufacture time goes up to incorporate these requirements. **Performance**: Possibly a tiny bit slower as these memory protection functions are executed and any signed code verified **Cost**: Cost of manufacture increases to cover this countermeasure

Overhead of Countermeasure on Time, Performance & Cost:

This looks at any impacts the countermeasure may bring if implemented.

Background to Analysis #10 - TVAC

Short Assessment: “Can the threat and the mitigation to one technology be applied to the other technology”:

- Total
- Partial
- None

Results – 22 TVAC Tables

- Ten threats, SCA-T1 to SCA-T10, have been explored for contact smart cards and these have also been applicable to contactless smart cards too as SCB-T1 to SCB-T10 respectively
- Four additional threats have been applied to contactless smart cards as SCB-T11 to SCB-T14, giving contactless smart cards a count of fourteen
- Eight threats were listed for WSN nodes (WSNN-T1 to WSNN-T8)
- The Comparative Threat Analysis Assessment Matrices (CTAAMs) record any commonality/applicability from one technology to the other

Smart Card Technologies Analysis Assessment

Comparative Threat Analysis Assessment Matrix:

Matrix Key:
SCA/B = Threat and/or Countermeasure is applicable to both Contact and Contactless cards and hence are referenced as so.

Contact Smart Card – has the prefix SCA and the threat reference to follow – e.g., SCA-T1

Contactless Smart Card – has the prefix SCB and the threat reference to follow – e.g., SCB-T1

WSN Node – has the prefix WSNN and the threat reference to follow – e.g., WSNN-T1

✓(T) = Total Match; ✓(P) to (T) = Partial to Total Match; ✓(P) = Partial Match; ×(N) = No Match

Contact & Contactless Smart Card Threats

Smart Card Threat Reference	High Level Threat Description	Threat Applicable to WSN Nodes	Counter-measure Applicable to WSN Nodes
SCA/B-T1	IC Reverse Engineering	✓(T)	✓(P) to (T)
SCA/B-T2	Microprobing	✓(T)	✓(P) to (T)
SCA/B-T3	Side Channel Attacks: SPA, DPA, EM	✓(T)	✓(P) to (T)
SCA/B-T4	DFA	✓(T)	✓(P)
SCA/B-T5	Test Mode Function	✓(T)	✓(T)
SCA/B-T6	Memory Mgt & Firewalling	✓(T)	✓(P)
SCA/B-T7	Data Remanence	✓(T)	✓(P) to (T)
SCA/B-T8	Governing Policies and Acts	✓(T)	✓(P)
SCA/B-T9	Random No. Generation	✓(T)	✓(P) to (T)
SCA/B-T10	Smart Card Mgt &/or Database Mgt System	✓(P)	✓(P)
SCB-T11	Interception of RF Comms	✓(P)	✓(P)
SCB-T12	Malicious Masquerading Reader	✓(P)	✓(P)
SCB-T13	Reach-back to Attack Enterprise Network	✓(P)	✓(P)
SCB-T14	Jamming RF Comms	✓(P)	✓(P)

Threat Totals	Countermeasure Totals
✓(T) = 9	✓(T) = 1
✓(P) to (T) = 0	✓(P) to (T) = 5
✓(P) = 5	✓(P) = 8
×(N) = 0	×(N) = 0

WSN Nodes Analysis Assessment

Comparative Threat Analysis Assessment Matrix:

Matrix Key:
SCA/B = Threat and/or Countermeasure is applicable to both Contact and Contactless cards and hence are referenced as so.

Contact Smart Card – has the prefix SCA and the threat reference to follow – e.g., SCA-T1

Contactless Smart Card – has the prefix SCB and the threat reference to follow – e.g., SCB-T1

WSN Node – has the prefix WSNN and the threat reference to follow – e.g., WSNN-T1

✓(T) = Total Match; ✓(P) to (T) = Partial to Total Match; ✓(P) = Partial Match; ×(N) = No Match

WSN Node Threats

WSN Node Threat Reference	High Level Threat Description	Threat Applicable to Smart Cards (state whether contact or contactless)	Counter-measure Applicable to Smart Cards (state whether contact or contactless)
WSNN-T1	Dos, CoS & DCoS	✓(P) SCB	✓(P) SCB
WSNN -T2	Routing Data	×(N)	×(N)
WSNN -T3	Sybil & Sizzle	✓(P) SCA/B	✓(P) SCA/B
WSNN -T4	Routing Data	×(N)	×(N)
WSNN -T5	Routing Data	×(N)	×(N)
WSNN -T6	Routing Data	×(N)	×(N)
WSNN -T7	Possible 'C' Weaknesses in nesC	✓(P) SCA/B	✓(P) SCA/B
WSNN -T8	IEEE 1149.1 JTAG standard interface	✓(T) SCA/B	✓(T) SCA/B

Threat Totals	Countermeasure Totals
✓(T) = 1	✓(T) = 1
✓(P) to (T) = 0	✓(P) to (T) = 0
✓(P) = 3	✓(P) = 3
×(N) = 4	×(N) = 4

Conclusion

- Novel framework and methodology, for:
  - classifying threats
  - analysing threats
  - assessing threats
- The TVAC Table and the CTAAMs, may have wider applicability to other technologies (e.g., Java Card 3.0 & RFIDs)
- Many attacks against smart card integrated circuits apply to WSN nodes
- Some WSN node RF/Communications attacks may apply to contactless smart cards and RFIDs.
  - High, Medium and Low assurance tamper resistance features within smart cards should be considered for WSN nodes (crypto co-processors too).
  - Many technologies have matured through schemes like Common Criteria and the production of Protection Profiles may help focus the development of security within WSN nodes
- Two new definitions for attacks:
  - Cessation of Service (CoS)
  - Distributed Cessation of Service (DCoS)
- 'Path-finder' research has established the need for thorough scientific testing to prove or disprove assertions

Further Areas of Research?

Suggested further areas of research:

- RF/Communications threats between WSN nodes and Mobile Cell Phones
- A study of WSN nodes and sensor technologies in airports to assist baggage and passenger screening (similar work in US Dept. Homeland Security)
- An assessment of smart card services/functionalities such as Global Platform and Card Manager, Java Card Runtime Environment (JCRE) and smart card APIs to determine applicability to WSN nodes
- Alternative Authentication mechanisms for WSN nodes: (e.g., Attribute Certificates/Kerberos tickets)
- We are interested in investigating an OS/platform independent secure authentication and routing protocol similar to IPSEC, which has a working label of KAFKA (Know Allies & Family, Know Adversaries) to suit the adaptive nature of Wireless Sensor Networks. Also, Sun's SSSL 'sizzle' could lead to work with TLS for secure authentication, confidentiality and Integrity.

More Info & Additional Items

- More information and additional resources (e.g., populated TVAC Tables and CTAAMs) are available at:

  www.sensornets.co.uk

- Thank you & QUESTIONS?