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[Continued on next page]

(54) Title: AN APPARATUS AND METHOD FOR DETERMINING LEVEL OF INTEGRITY IN A VIRTUAL TRUSTED PLATFORM MODULE

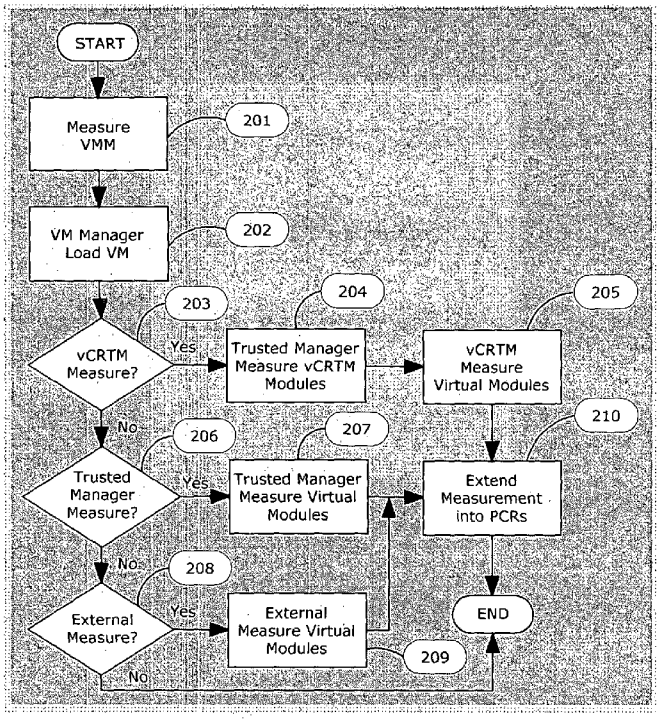

Figure 2

(57) Abstract: A method of determining level of integrity within a plurality of virtual machine monitor (VMM) components in a virtual Trusted Platform Module (vTPM), the method includes the steps of measuring the plurality of VMM components (201), loading all related components to run (202), selecting a virtual core root of trusted measurement (vCRTM) (203), executing vCRTM measuring module (204, 205), measuring all other VMM components and extending measurements into platform configuration register (PCR) (210).

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Declarations under Rule 4.17:

— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*

Published:

— *with international search report (Art. 21(3))*

AN APPARATUS AND METHOD FOR DETERMINING A LEVEL OF INTEGRITY IN A VIRTUAL TRUSTED PLATFORM MODULE

FIELD OF INVENTION

The present invention relates to an apparatus and method of determining level of integrity within a plurality of virtual machine monitor (VMM) components in a virtual Trusted Platform Module (vTPM).

BACKGROUND OF INVENTION

US 20060212939 A1 describes a virtual PCR (VPCR) construct that can be loaded into a resettable hardware PCR to make use of the functionality of a Trusted Platform Module (TPM). The VPCRs may cryptographically reflect their characteristics (resettable or not) in their stored values. Also, since the PCRs are virtualized, they are (effectively) unlimited in number and may be given general names (UUIDs) that are less likely to collide. The VPCRs can be loaded into a physical PCR as needed, but in a way that stops one piece of software from impersonating another piece of software. However, integrity of virtual machine monitors from point to point is not addressed in this document.

US 2007230504 A1 describes a method of generating a chain of trust for a virtual endpoint. The method performs a measurement of the virtual machine monitor and uses the measurement of the virtual machine monitor that is part of the chain of trust. However, this invention is restricted to only hardware TPM. The document is also silent after generation of chain of trust and no information is given on maintaining the chain of trust to endpoint.

Therefore, a more holistic method of ensuring integrity of TPMs is required, which is not restricted to only hardware.

SUMMARY OF INVENTION

Accordingly, there is provided a method of determining level of integrity within a plurality of virtual machine monitor (VMM) components in a virtual Trusted Platform Module (vTPM), the method includes the steps of measuring the plurality of VMM components, loading all related components to run; selecting a virtual core root of trusted measurement (vCRTM), executing vCRTM measuring module, measuring all other VMM components and extending measurements into platform configuration register (PCR).

There is further provided an apparatus for determining level of integrity within a plurality of components in a virtual Trusted Platform Module (vTPM), the apparatus includes a Virtual Machine Monitor (VMM) which further includes a manager, wherein the manager includes a plurality of virtual modules.

The present invention consists of several novel features and a combination of parts hereinafter fully described and illustrated in the accompanying description and drawings, it being understood that various changes in the details may be made without departing from the scope of the invention or sacrificing any of the advantages of the present invention.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will be fully understood from the detailed description given herein below and the accompanying drawings which are given by way of illustration only, and thus are not limitative of the present invention, wherein:

Figure 1 illustrates an architectural block diagram of an apparatus for determining level of integrity within a plurality of components in a virtual Trusted Platform Module (vTPM) in the preferred embodiment of the invention; and

Figure 2 illustrates a flowchart of a method of determining level of integrity within a plurality of components in a virtual Trusted Platform Module (vTPM) in the preferred embodiment of the invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

The present invention relates to an apparatus and method of determining level of integrity within a plurality of virtual machine monitor (VMM) components in a virtual Trusted Platform Module (vTPM). Hereinafter, this specification will describe the present invention according to the preferred embodiment of the present invention. However, it is to be understood that limiting the description to the preferred embodiment of the invention is merely to facilitate discussion of the present invention and it is envisioned that those skilled in the art may devise various modifications and equivalents without departing from the scope of the appended claims.

The following detailed description of the preferred embodiment will now be described in accordance with the attached drawings, either individually or in combination.

Figure 2 illustrates a flow chart showing a method of determining level of integrity within a plurality of virtual machine monitor (VMM) components in a virtual Trusted Platform Module (vTPM). The method includes the steps of measuring the plurality of VMM components (201), loading all related components to run (202), selecting a virtual core root of trusted measurement (vCRTM) (203), executing vCRTM measuring module (204, 205), measuring all other VMM components and extending measurements into platform configuration register (PCR) (210). The step of extending measurements into platform configuration register (PCR) (210) further includes hashing integrity measurement and storing measurements into PCR.

As seen in Figure 2, the method includes the steps of selecting trusted manager measure (206) upon loading components to run (202), executing measuring virtual modules (207), measuring all other VMM components and extending measurements into PCR (210). In

another possibility, the method includes the steps of selecting external measure (208) upon loading components to run (202), executing measuring external measure virtual modules (209), measuring all other VMM components and extending measurements into PCR (210). The step of extending measurements into PCR (210) further includes the steps of hashing integrity measurement and storing measurements into PCR.

Measuring the plurality of VMM (201) is a step to measure all the components in the VMM. A virtual machine Manager loads all related components to run including configurations. If vCRTM measure is selected, Trusted Manager measure vCRTM Modules steps are executed to load vCRTM module, measure vCRTM and pass control to the vCRTM. vCRTM Measure Virtual Modules is a step to initialize the core root of trust measurement (CRTM), measuring the CRTM and then measure other VMM components. If Trusted Manager Measure is selected, Trusted Manager Measure Virtual Modules steps are executed to measure virtual modules and then measure other VMM components. The Trusted Manager is an internal entity that has been subjected with trusted codes which can be verified by other parties such as privacy CA or a producer of source codes. If external measure is selected, external measure virtual modules steps are executed to measure virtual modules and then measure other VMM components.The external measure is a trusted external entity such as third parties or Host OS services that perform integrity measurement. Extending Measurement into PCRs is a step to hash such as SHA1 the integrity measurement and then store (TPM_Extend) these measurements into PCRs. These integrity measurements in the PCRs represent state of the VMM and are used by upper layer services such as OS, application to run at trusted states.

Figure 1 shows architecture of an apparatus for determining level of integrity within a plurality of components in a virtual Trusted Platform Module (vTPM). The apparatus

includes a Virtual Machine Monitor (VMM) (101) which further includes a manager (103), wherein the manager (103) includes a plurality of virtual modules (104). The plurality of virtual modules (104) includes a virtual Trusted Platform Module (vTPM) and virtual core root of trusted measurement (vCRTM).

Figure 1 shows a diagram showing general components of the VMM that can be extracted as integrity measurement. This apparatus uses these measurements as a value (digest) to be stored (TPM_Extend) in PCR. These PCR values represent the integrity of the VMM which is similar to hardware TPM measurement. The VMM (101) is a virtualization tool with the purpose of providing virtual environment to run operating system (OS) and application. The Virtual Machine (VM) (102) executes programs like a real machine and this environment is isolated from other VM or Host OS. The manager (103) includes, but not restricted to, VM, Trusted, Storage and Translator manager modules to manage the VM and VM components. The Virtual Modules (104) components run within VM and provide virtual hardware such as BIOS, Display Card and Sound Card.

PCR Index	PCR Usage
0	VM Measurement, vBIOS, vCRTM, vTBB, virtual Embedded Option ROMs
1	VM Configuration, vCRTM
2	VM Virtual Modules (e.g. vTPM Module, virtual I/O module)
3	VM Virtual Modules Configuration & Data
4	VM Bootstrap Loader, vIPL code (e.g. vMBR)
5	VM Bootstrap Loader, vIPL with configuration and data
6	VM and vTPM State Transition, VM and vTPM Wake Events
7	Reserved for future usage; or Credential Measurement (e.g. vTPM, VM)
8	Guest OS Measurement (e.g. kernel and initial ramdisk images)
17	Virtual Dynamic CRTM (vD-CRTM) and Related Component Measurement

Table 1

Table 1 shows PCR usage for the vTPM in the virtual machine (VM). Usage of the PCR depends on PCR index as specified in TPM specification. These PCR index and usage represent the VM integrity measurement that is similar to the real hardware TPM. In virtualization environment, this method and apparatus provides virtual measurement for

the vTPM by replacing hardware measurement to virtual modules (VM components) measurement. This method and apparatus pursues the TPM specification and deploys that specification to the virtual device. These virtual measurements can be generated via binary hash and properties base measurement of the virtual machine components and modules. Binary hash is a result of hashing process to the source codes, executable files, library files or object files and these result become a static measurement for mapping into PCRs. Properties base measurement is a result of hashing process of logic, semantic and properties of the source codes, executable files, library files or object files and these result become a dynamic measurement for mapping into PCRs. Formulas to generate and extend PCR value are:

Generate Integrity Measurement (IM)

X = VMM Component;

Static_IM = HASH (Virtual Module X);

Dynamic_IM = HASH (PROPERTIES (Virtual Module X));

Extend Integrity Measurement (IM)

PCR Y ← Extend (HASH (IM | PCR Y));

It is to be noted that HASH can be hashing algorithm, PROPERTIES can be logic; semantic; behavior before, during, and after runtime; and properties of VMM Components and Modules, IM can be Static_IM or Dynamic_IM integrity measurement and Y could be PCR Index.

This invention is adapted for use in Virtual Trusted Platform Module (vTPM), virtualization technology and cloud computing to provide secured and trusted services to the client that runs on virtual machine. The disclosed invention is suitable, but not restricted to, for use in measuring integrity and mapping data into PCRs.

CLAIMS

1. A method of determining level of integrity within a plurality of virtual machine monitor (VMM) components in a virtual Trusted Platform Module (vTPM), the method includes the steps of:
   i. measuring the plurality of VMM components (201);
   ii. loading all related components to run (202);
   iii. selecting a virtual core root of trusted measurement (vCRTM) (203);
   iv. executing vCRTM measuring module (204, 205);
   v. measuring all other VMM components; and
   vi. extending measurements into platform configuration register (PCR) (210).

2. The method as claimed in claim 1, wherein extending measurements into platform configuration register (PCR) (210) further includes the steps of:
   i. hashing integrity measurement; and
   ii. storing measurements into PCR.

3. The method as claimed in claim 1, wherein the method includes the steps of:
   i. selecting trusted manager measure (206) upon loading components to run (202);
   ii. executing measuring virtual modules (207);
   iii. measuring all other VMM components; and
   iv. extending measurements into PCR (210).

4. The method as claimed in claim 3, wherein extending measurements into PCR (210) further includes the steps of:
   i. hashing integrity measurement; and
   ii. storing measurements into PCR.

5. The method as claimed in claim 1, wherein the method includes the steps of:
   i. selecting external measure (208) upon loading components to run (202);
   ii. executing measuring external measure virtual modules (209);
   iii. measuring all other VMM components; and
   iv. extending measurements into PCR (210).

6. The method as claimed in claim 5, wherein extending measurements into PCR (210) further includes the steps of:
   i. hashing integrity measurement; and
   ii. storing measurements into PCR.

7. An apparatus for determining level of integrity within a plurality of components in a virtual Trusted Platform Module (vTPM), the apparatus includes:
   a Virtual Machine Monitor (VMM) (101) which further include a manager (103), wherein the manager (103) includes a plurality of virtual modules (104).

8. The apparatus as claimed in claim 7, wherein the plurality of virtual modules (104) include a virtual Trusted Platform Module (vTPM) and virtual core root of trusted measurement (vCRTM).

9. The apparatus as claimed in claim 7, wherein a manager (103) is a Trusted Manager which is an internal entity that has been subjected with trusted codes which can be verified by other parties.

10. The apparatus as claimed in claim 7, wherein a plurality of virtual modules (104) include an external measure module which is a trusted external entity that performs integrity measurement.

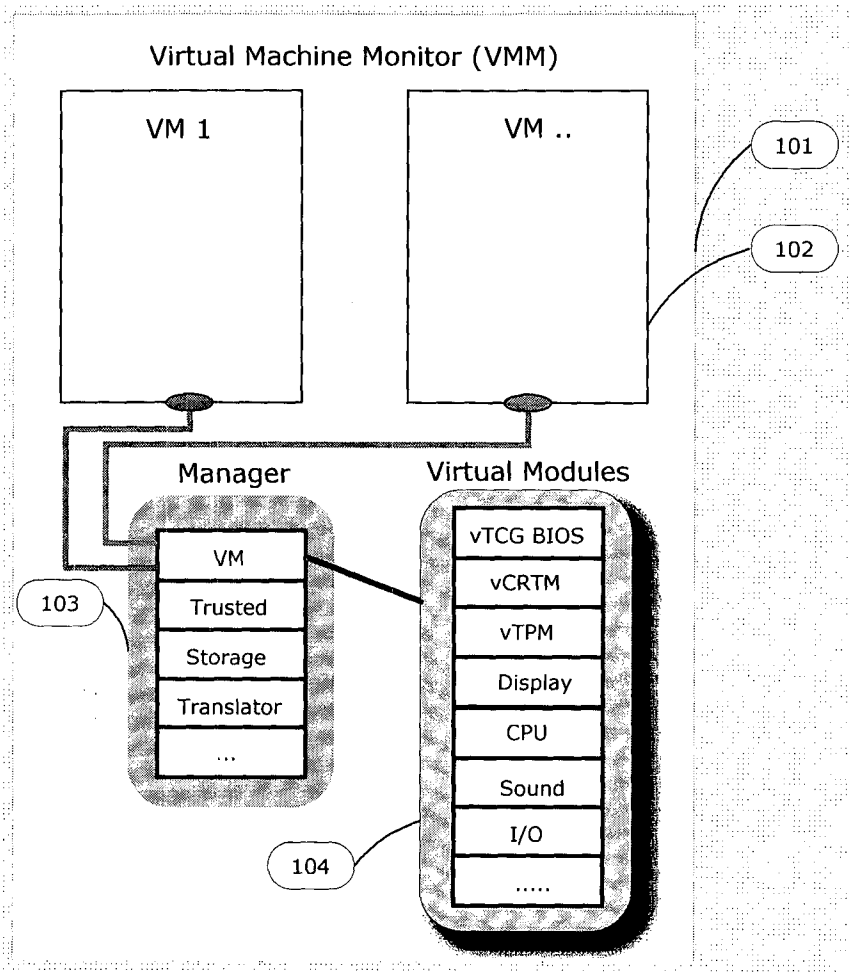
Virtual Machine Monitor (VMM)
VM 1
VM ..
101
102
Manager
Virtual Modules
VM
Trusted
Storage
Translator
...
103
vTCG BIOS
vCRTM
vTPM
Display
CPU
Sound
I/O
.....
104

Figure 1

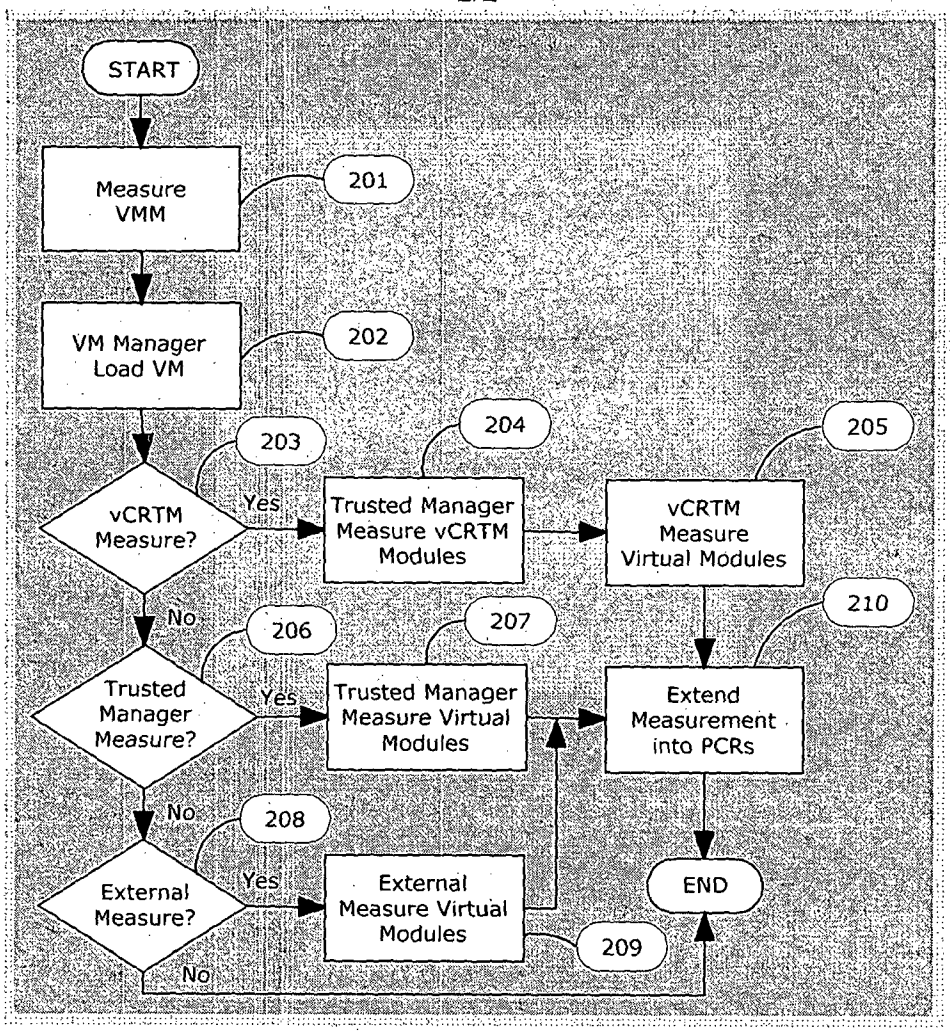
START
Measure VMM
201
VM Manager Load VM
202
203
204
205
vCRTM Measure?
Yes
Trusted Manager Measure vCRTM Modules
vCRTM Measure Virtual Modules
No
206
207
210
Trusted Manager Measure?
Yes
Trusted Manager Measure Virtual Modules
Extend Measurement into PCRs
No
208
External Measure?
Yes
External Measure Virtual Modules
END
209
No

Figure 2

INTERNATIONAL SEARCH REPORT

International application No.
PCT/MY2012/000088

A. CLASSIFICATION OF SUBJECT MATTER

G06F 9/445 (2006.01) G06F 15/177 (2006.01) G06F 12/14 (2006.01)

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPODOC, WPI keywords: Virtual Machine Monitor, VMM, Trusted Platform Module, TPM, Core Root, CRT, Platform Configuration Register, PCR, Measure and similar terms; Google Patents / Google Scholar / FreePatentsOnline keywords: Virtual, Machine, Monitor, VMM, Core, Root, CRT, Platform, Configuration, Register, PCR, Integrity, Measure, Trusted, Platform, Module, TPM, Chain and similar terms

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
	Documents are listed in the continuation of Box C	

[X] Further documents are listed in the continuation of Box C [X] See patent family annex

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
14 August 2012	16 August 2012
Name and mailing address of the ISA/AU AUSTRALIAN PATENT OFFICE PO BOX 200, WODEN ACT 2606, AUSTRALIA Email address: pct@ipaustralia.gov.au Facsimile No.: +61 2 6283 7999	**Authorized officer** Evan Sulcs AUSTRALIAN PATENT OFFICE (ISO 9001 Quality Certified Service) Telephone No. 0399359617

INTERNATIONAL SEARCH REPORT

International application No.
PCT/MY2012/000088

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a)

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

See Supplemental Box for Details

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☒ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		International application No. **PCT/MY2012/000088**
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2011/0040957 A1 (BERGER ET AL) 17 February 2011 page 2, paragraph 0025 - page 3, paragraph 0033; figure 1	7-10
X	EP 2261832 A1 (PANASONIC CORPORATION) 15 December 2010 paragraphs 0011, 0015-0018, 0033-0035, 0046-0066, 0130-0137	7-10
X	US 2009/0169017 A1 (SMITH ET AL) 02 July 2009 page 2, paragraphs 0016-0019; figure 2	7-10
X	BUTLER, K. ET AL: "Firma: Disk-Based Foundations for Trusted Operating Systems", Technical Report NAS-TR-0114-2009, Networking and Security Research Center, Department of Computer Science and Engineering, Pennsylvania State University, University Park, PA, USA, 20 April 2009, pp. 1-11 paragraph 4.2, pages 5-6; paragraph 7.1, pages 8-9	1-6
X	US 2009/0086979 A1 (BRUTCH ET AL) 02 April 2009 page 3, paragraphs 0032-0036; figure 1	7-10
X	US 2007/0230504 A1 (SMITH ET AL) 04 October 2007 page 2, paragraph 0028 - page 3, paragraph 0039; figure 6	7-10
X	US 2006/0256107 A1 (SCARLATA ET AL) 16 November 2006 paragraphs 0057-0071	7-10
A	US 7840801 B2 (BERGER ET AL) 23 November 2010 See the whole document	1-10
A	US 2008/0148064 A1 (CHALLENER ET AL) 19 June 2008 See the whole document	1-10
A	US 2008/0163209 A1 (ROZAS ET AL) 03 July 2008 See the whole document	1-10

Supplemental Box

Continuation of: **Box III**

This International Application does not comply with the requirements of unity of invention because it does not relate to one invention or to a group of inventions so linked as to form a single general inventive concept.

This Authority has found that there are different inventions based on the following features that separate the claims into distinct groups:

- Claims 1-6 are primarily directed to a method of determining a level of integrity within a plurality of virtual machine monitor (VMM) components in a virtual Trusted Platform Module (vTPM), the method including the steps of: measuring the plurality of VMM components; loading all related components to run; selecting a virtual core root of trusted measurement (vCRTM); executing the vCRTM measuring module; measuring all other VMM components; and extending measurements into a platform configuration register (PCR). The feature of measuring the VMM components, loading all related components to run, selecting a vCRTM, executing the vCRTM measuring module, measuring all other VMM components and extending measurements into the PCR is specific to this group of claims.

- Claims 7-10 are primarily directed to an apparatus for determining a level of integrity within a plurality of components in a virtual Trusted Platform Module (vTPM), the apparatus including: a Virtual Machine Monitor (VMM) which further includes a manager, wherein the manager includes a plurality of virtual modules. The feature of the Virtual Machine Monitor (VMM) including a manager, wherein the manager includes a plurality of virtual modules is specific to this group of claims.

PCT Rule 13.2, first sentence, states that unity of invention is only fulfilled when there is a technical relationship among the claimed inventions involving one or more of the same or corresponding special technical features. PCT Rule 13.2, second sentence, defines a special technical feature as a feature which makes a contribution over the prior art.

When there is no special technical feature common to all the claimed inventions there is no unity of invention.

In the above groups of claims, the identified features may have the potential to make a contribution over the prior art but are not common to all the claimed inventions and therefore cannot provide the required technical relationship. The only feature common to all of the claimed inventions and which provides a technical relationship among them is an apparatus for determining a level of integrity within a plurality of components in a virtual Trusted Platform Module (vTPM), the apparatus including a Virtual Machine Monitor (VMM).

However this feature does not make a contribution over the prior art because it is disclosed in:
US 2011/0040957 A1 (BERGER *et al*) 17 February 2011

Therefore in the light of this document this common feature cannot be a special technical feature. Therefore there is no special technical feature common to all the claimed inventions and the requirements for unity of invention are consequently not satisfied *a posteriori*.

INTERNATIONAL SEARCH REPORT Information on patent family members	International application No. **PCT/MY2012/000088**

This Annex lists known patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document/s Cited in Search Report		**Patent Family Member/s**	
Publication Number	**Publication Date**	**Publication Number**	**Publication Date**
US 2011/0040957 A1	17 Feb 2011	US 2011040957 A1	17 Feb 2011
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		EP 2261832 A1	15 Dec 2010
		US 2010325628 A1	23 Dec 2010
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		US 7571312 B2	04 Aug 2009
		US 2006256105 A1	16 Nov 2006
		US 7587595 B2	08 Sep 2009
		US 2006256108 A1	16 Nov 2006
		US 7613921 B2	03 Nov 2009
		US 2006256106 A1	16 Nov 2006
		US 7636442 B2	22 Dec 2009
		US 2010011210 A1	14 Jan 2010
		US 8068613 B2	29 Nov 2011
		US 2007094719 A1	26 Apr 2007
		US 8074262 B2	06 Dec 2011
		US 2012027213 A1	02 Feb 2012
		WO 2006124751 A2	23 Nov 2006
US 7840801 B2	23 Nov 2010	US 2008178176 A1	24 Jul 2008
		US 7840801 B2	23 Nov 2010

Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.

INTERNATIONAL SEARCH REPORT Information on patent family members	International application No. **PCT/MY2012/000088**

This Annex lists known patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document/s Cited in Search Report		Patent Family Member/s	
Publication Number	**Publication Date**	**Publication Number**	**Publication Date**
US 2008/0148064 A1	19 Jun 2008	US 2008148064 A1	19 Jun 2008
US 2008/0163209 A1	03 Jul 2008	US 2008163209 A1	03 Jul 2008

End of Annex

Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.