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Understanding the TC model from a system architecture perspective

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Disclaimer

- This deck of slides has been designed to be used during the ETISS 2009 “understanding the TC model from a system architecture perspective” master class and for that purpose only.
- It will probably be meaningless without the explanation that goes with it.
- In particular, most of the examples presented should not be used in any real world design (can the reader guess why?).

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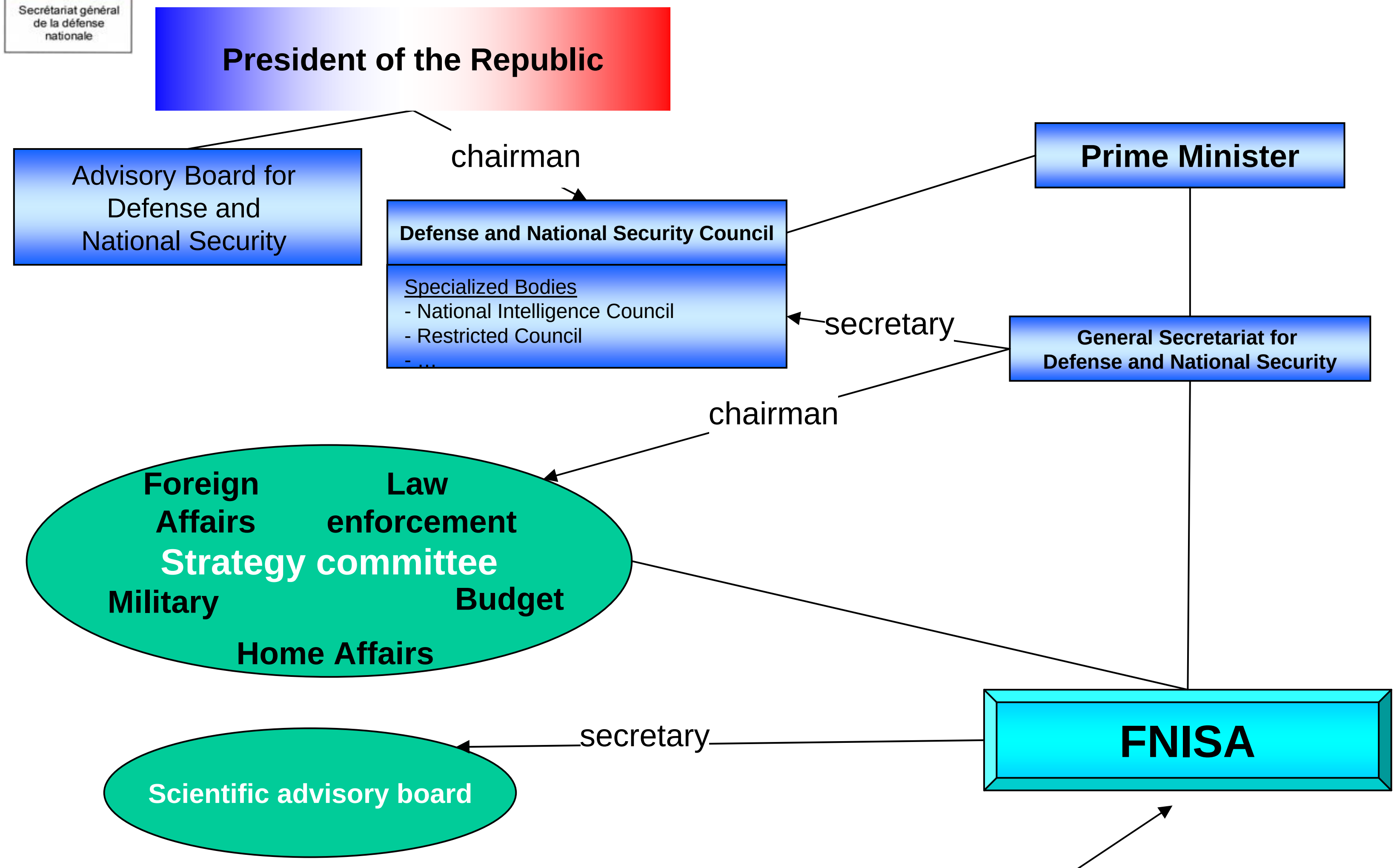
FNISA: who we are


President of the Republic
chairman
Advisory Board for Defense and National Security
Defense and National Security Council
Specialized Bodies
- National Intelligence Council
- Restricted Council
- …
Prime Minister
secretary
General Secretariat for Defense and National Security
chairman
Foreign Affairs
Law enforcement
Strategy committee
Military
Budget
Home Affairs
secretary
Scientific advisory board
FNISA

French Network and Information Security Agency

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Our missions

- Alert warning response:
  - central capacity for **early detection:**
    - of security events, of cyber-attacks.
    - sensors, correlations.
    - monitoring of the governmental gateways.
  - technical assessment.
  - cyber-crisis management.
- High grade security products:
  - To **develop high grade security products** for the protection of the most sensitive networks.
  - To **develop** and **operate** the most sensitive networks.
- “Support” of customers:
  - To **support** the departments and the Critical Infrastructure operators, in increasing their level of security.
  - To **check** the level of protection.
    - in charge of inspections (for the departments).
    - bringing technical support to inspection teams (for CI operators).
  - To spread good practice to other customers (private companies, SMEs, citizens).
- Role of National Communication and Security Agency:
  - Root certification authority.
  - In charge of the policy, certification body.
  - Authority for approvals.

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Introduction

- The goal of this Master Class is to show why system level considerations should be taken into account in any TC design:
    - Focusing on one aspect of TC only (TPMs for instance) is important but is not enough.
        - TC must be looked at from a system architecture perspective.
    - It is important to think "outside the box".
        - Hypothesis and axioms <u>must</u> be verified.
- It is important to focus on the <u>real</u> problems.

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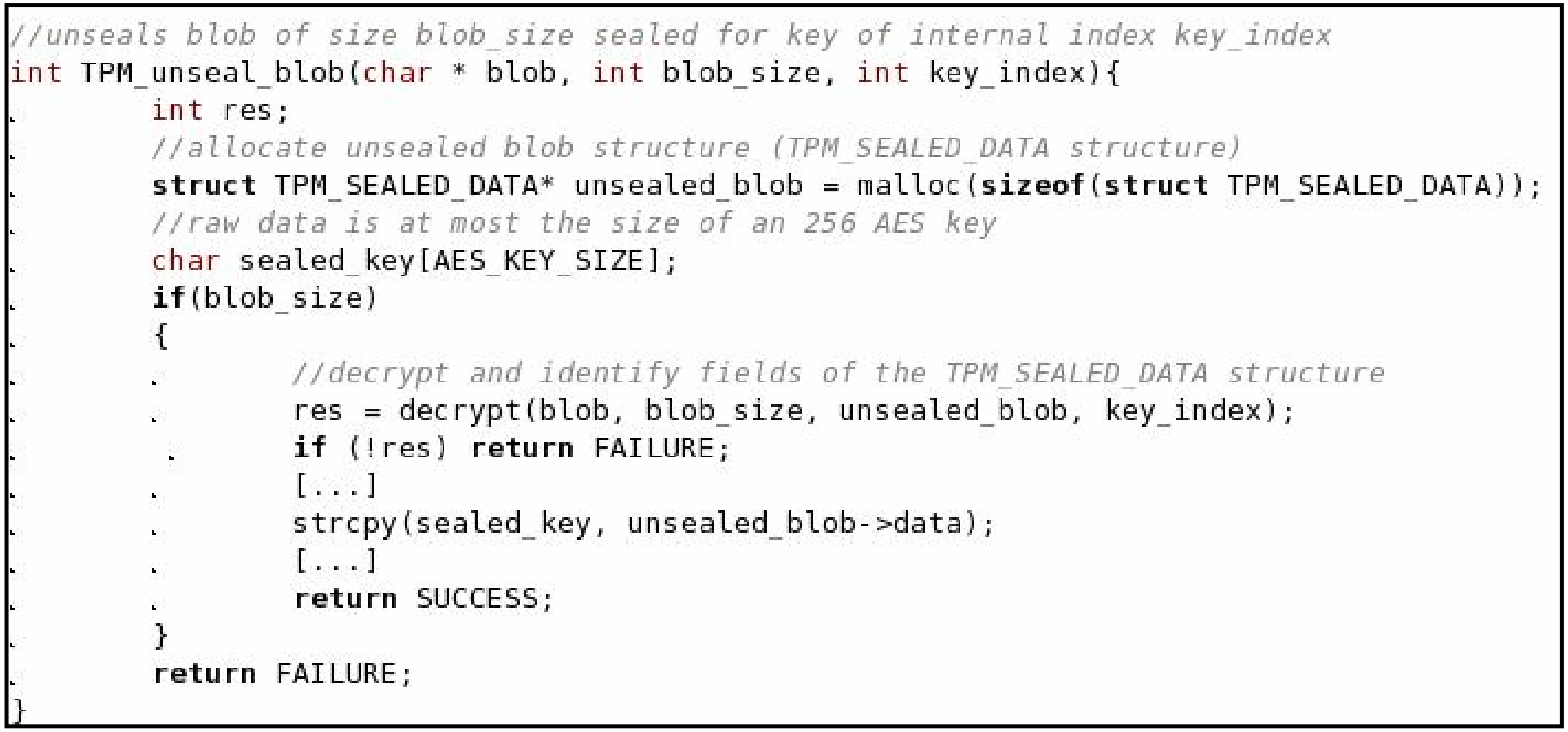
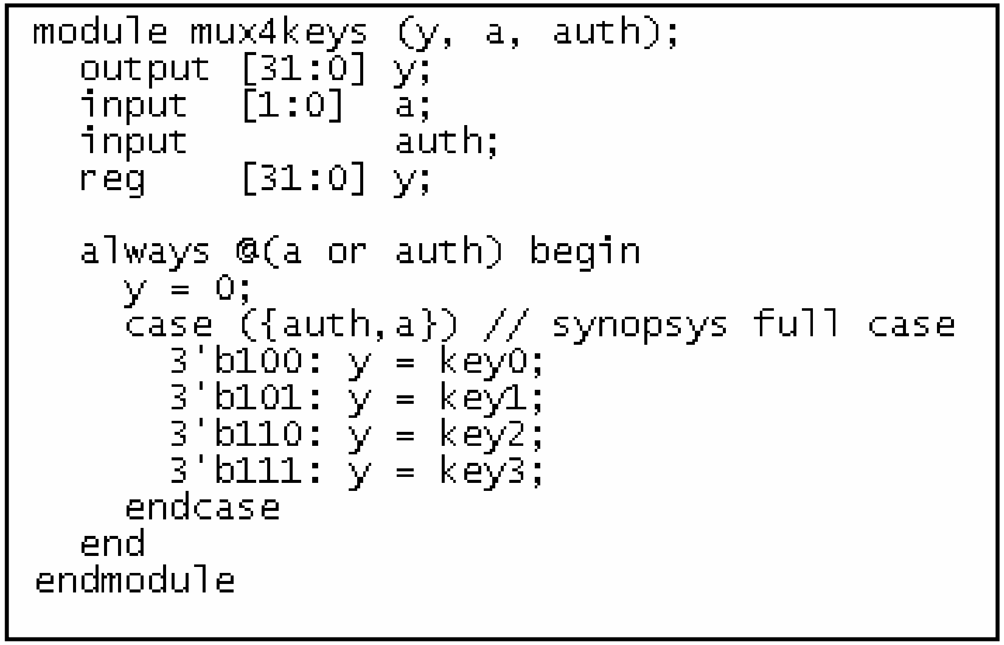
Some well known facts (probably not so true)

What is this?



```c
//unseals blob of size blob_size sealed for key of internal index key_index
int TPM_unseal_blob(char * blob, int blob_size, int key_index){
        int res;
        //allocate unsealed blob structure (TPM_SEALED_DATA structure)
        struct TPM_SEALED_DATA* unsealed_blob = malloc(sizeof(struct TPM_SEALED_DATA));
        //raw data is at most the size of an 256 AES key
        char sealed_key[AES_KEY_SIZE];
        if(blob_size)
        {
                //decrypt and identify fields of the TPM_SEALED_DATA structure
                res = decrypt(blob, blob_size, unsealed_blob, key_index);
                if (!res) return FAILURE;
                [...]
                strcpy(sealed_key, unsealed_blob->data);
                [...]
                return SUCCESS;
        }
        return FAILURE;
}
```

What is this?

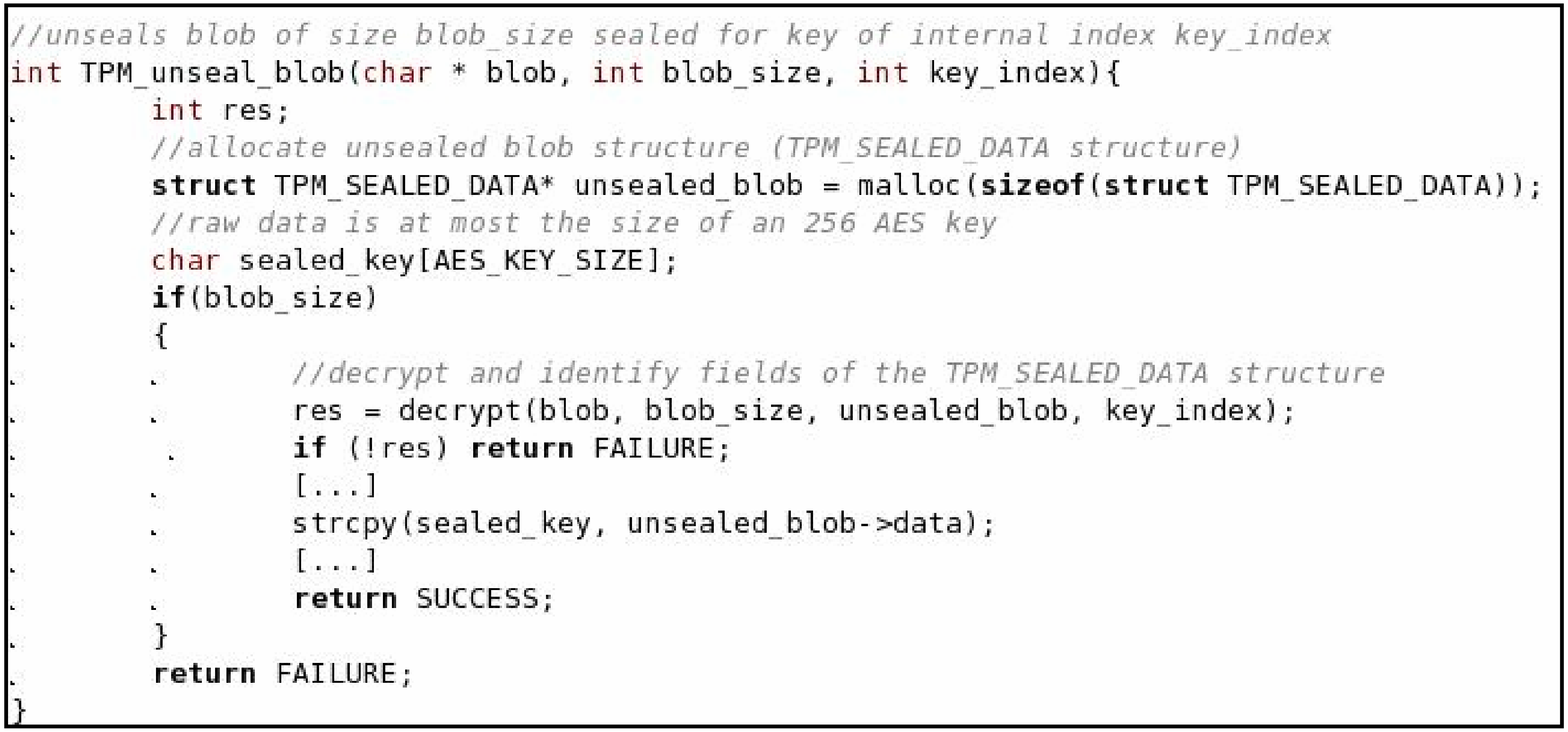


```
module mux4keys (y, a, auth);
  output [31:0] y;
  input  [1:0]  a;
  input         auth;
  reg    [31:0] y;

  always @(a or auth) begin
    y = 0;
    case ({auth,a}) // synopsys full case
      3'b100: y = key0;
      3'b101: y = key1;
      3'b110: y = key2;
      3'b111: y = key3;
    endcase
  end
endmodule
```

Credits: thanks to my colleague K. Khalfallah for digging that up

What is this?



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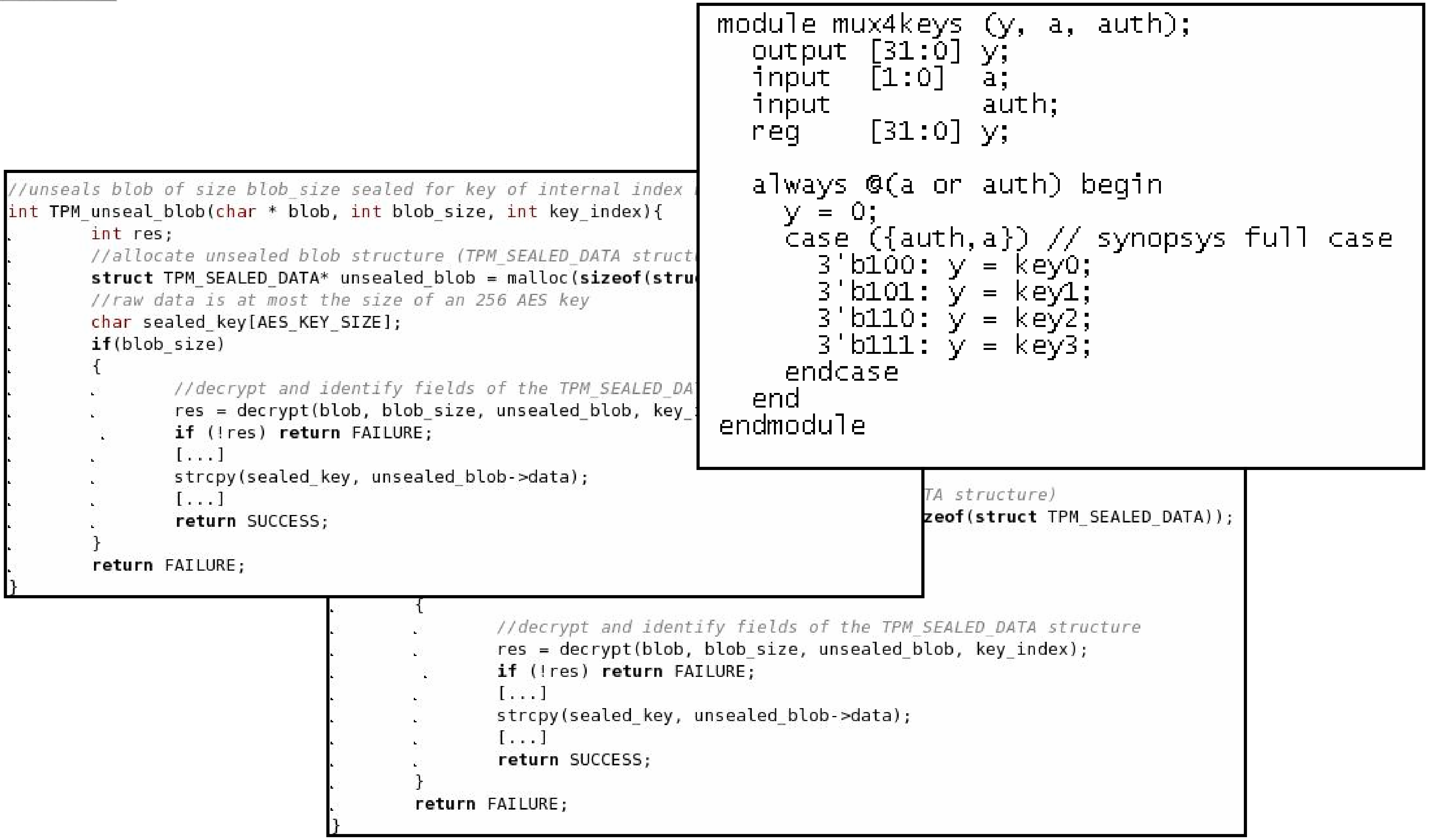
                if (!res) return FAILURE;
                [...]
                strcpy(sealed_key, unsealed_blob->data);
                [...]
                return SUCCESS;
        }
        return FAILURE;
}
```

Which of the three is the more secure?



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  input  [1:0]  a;
  input         auth;
  reg    [31:0] y;

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    y = 0;
    case ({auth,a}) // synopsys full case
      3'b100: y = key0;
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      3'b111: y = key3;
    endcase
  end
endmodule
```

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                [...]
                strcpy(sealed_key, unsealed_blob->data);
                [...]
                return SUCCESS;
        }
        return FAILURE;
}
```

```
TA structure)
zeof(struct TPM_SEALED_DATA));

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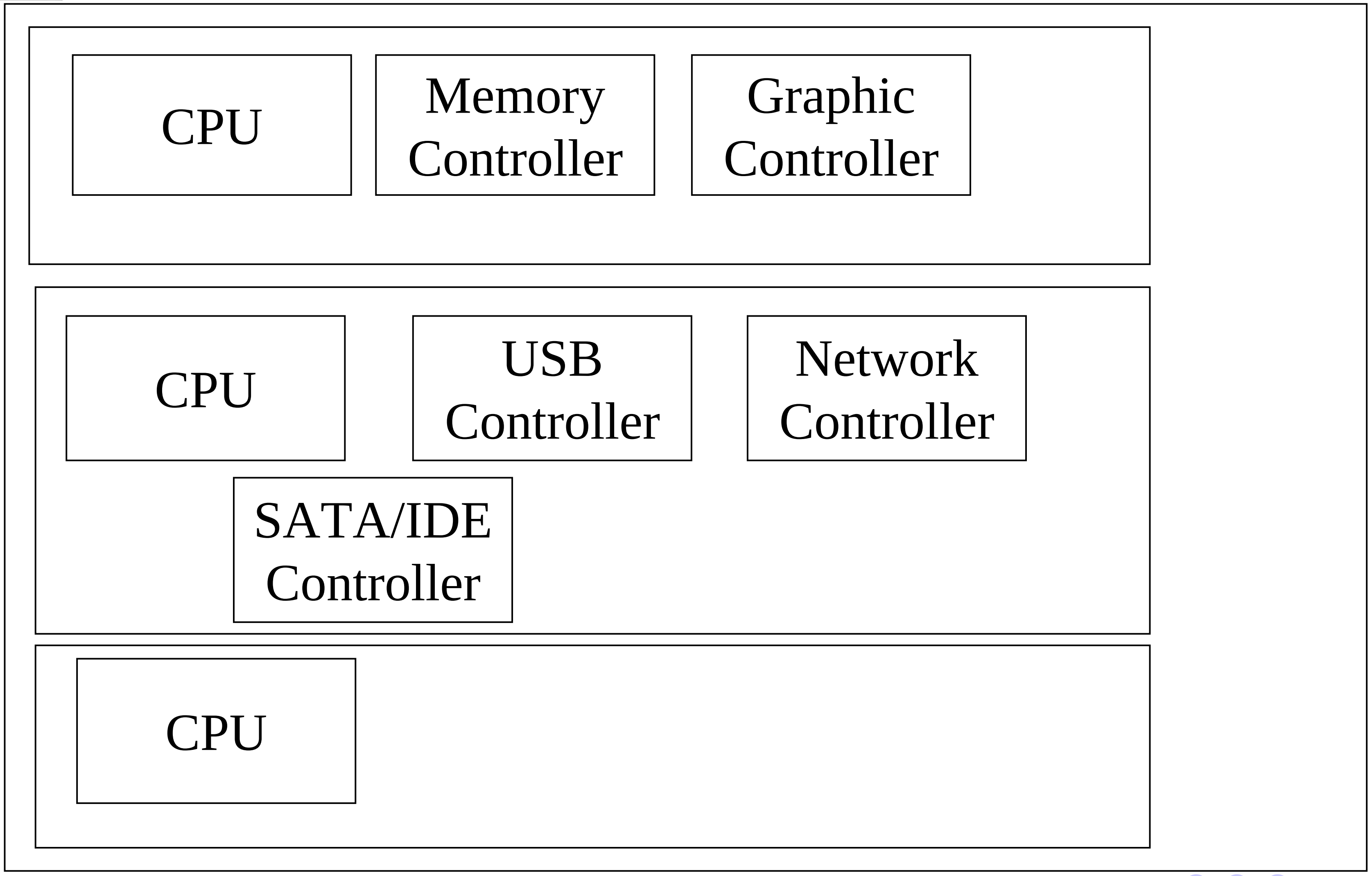
                if (!res) return FAILURE;
                [...]
                strcpy(sealed_key, unsealed_blob->data);
                [...]
                return SUCCESS;
        }
        return FAILURE;
}
```

Well known fact n°1 : hardware is secure

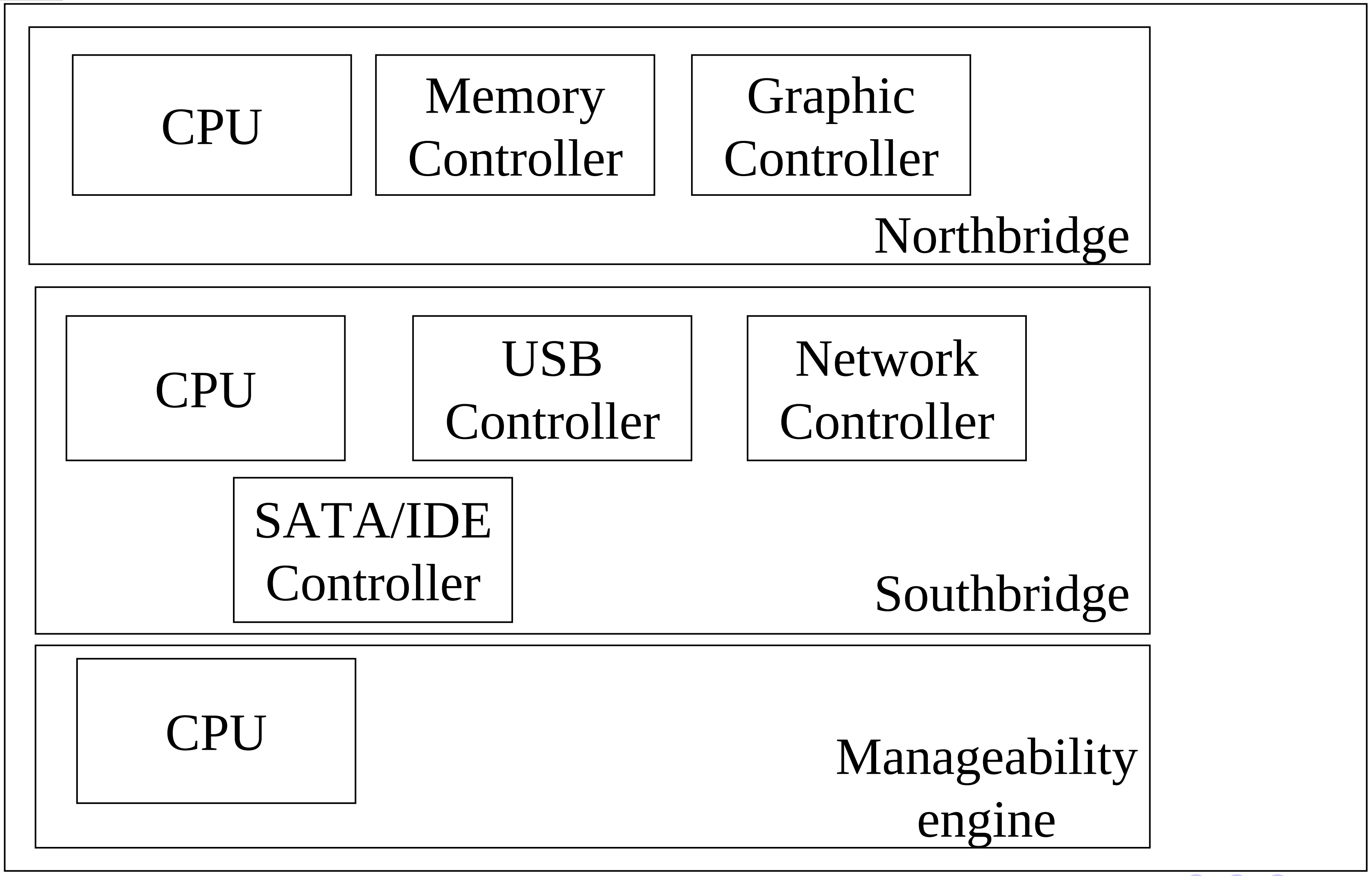
- Hardware conception is similar to software design:
  - Bugs can occur.
- Hardware circuits are really complex:
  - Some circuits are made of billions of transistors.
- Hardware components embed firmware:
  - Firmware is nothing but software.
  - Bugs can occur.

- So, why do we trust hardware?
  - Formal methods use is the design process?
  - In-depth analysis of the netlist or of the Hardware Description Language (HDL) code?
  - Because we have to?

What is this?


CPU
Memory Controller
Graphic Controller
CPU
USB Controller
Network Controller
SATA/IDE Controller
CPU

What is this?

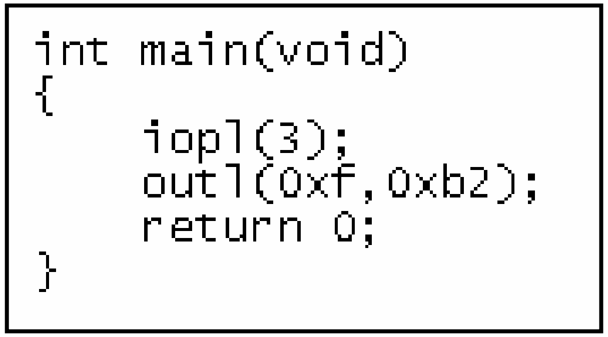


CPU
Memory Controller
Graphic Controller
Northbridge
CPU
USB Controller
Network Controller
SATA/IDE Controller
Southbridge
CPU
Manageability engine

Well known fact n°2: hardware is simple

- Again, integrated circuits today are made of billions of transistors.
- Recent chipsets may encompass:
  - Several CPUs (ARC4 CPUs for instance).
  - A bunch of memory, buses and device controllers and different bridges.
  - Anti-virus/intrusion detection software.
  - A network stack.
  - A HTTP/HTTPS/SOAP server.
  - Remote administration functionalities.

What does this do?



```
int main(void)
{
    iopl(3);
    outl(0xf,0xb2);
    return 0;
}
```

What does this do?

```
int main(void)
{
	iopl(3);
	outl(0xf,0xb2);
	return 0;
}
```

I don’t know

Explanation

- There is **no way** to find out (without exploiting a SMM – see later – vulnerability).
- The consequences of those two lines of code depend on the machine.
    - Feel free to open a tty and run it on your machine (with admin privileges).
    - (Disclaimer) but remember that you do that on your own will (don't blame me afterwards for the effect).
    - The truth is it will probably do exactly nothing.

- Let's find out what it does on my machine…

AMT (Intel vPro) vulnerabilities

- Active Management Technology is a feature that allows an IT department to administrate/configure a platform even when no operating system is running.
- Therefore, some AMT components run in the chipset (the HTTPS/SOAP server I was mentioning before).
- See Alex Tereshkin and Rafal Wojtczuk Blackhat 2009 presentation (Ring -3 rootkits):
    - AMT firmware can be modified by the operating system kernel.
    - This allows rootkits to run code in the chipset.
    - Requires kernel privileges and takes advantage of a « patched » vulnerability.

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SMM

- System Management Mode is a mode of operation of x86 CPU.
- It is used to run power management code (SMI handler).
- SMI handlers are loaded in memory by the BIOS and protected by the chipset.
- When SMM code runs, the operating system is frozen (whole CPU context is saved and stored).

- If an attacker manages to run code in SMM, the attacker owns the machine.

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SMM vulnerabilities

- Security model at the hardware level may be flawed. SMM is a good example.
- In 2006 security features existed but were not used by BIOS vendors.
- Since then (some vendors) issued BIOS updates.
- In 2008 and 2009 various mechanisms were used to bypass those security measures.
    - See CanSecWest 2009 presentation « Getting into the SMRAM, SMM Reloaded » and (independant research) Joanna Rutkowska's blog.
        - We took advantage of a flawed repartition of security features between CPU and chipset.
        - The attack allowed a kernel level rootkit to hide code in the SMI handler supposed to be protected by the chipset.

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ACPI (seen from 10.000 miles)

- ACPI tables are BIOS-provided tables used by the OS Power Management component (OSPM).
- They are written in AML (ACPI Machine Language).
- The ACPI spec says that in order to put the first USB controller in S3 sleep state, the \._SB.PCI0.USB0.S3 function in the DSDT table must be run.
- The function itself is specific to the machine.
- The OS has no way to find out if the function is really doing what it claims it is doing.

- Examples of ACPI rootkits: Trust 2009 paper (O. Levillain, B. Morin and myself).

Well known fact n°3 : low level software/firmware can be trusted

- We never really know what are the exact functions that are embedded on a platform.
- Some low level firmwares cannot be verified but by the BIOS vendor itself.
  - SMM handler code.
- Again, low level software are not free of vulnerabilities:
  - Vulnerability in the BIOS BMP parser allowed an attacker to update Intel BIOS with unsigned code.
  - SMM vulnerabilities.
  - See Wojtczuk and Tereshkin Blackhat 2009 presentations.

Impact on D-RTM based systems

- The SMM, ACPI and AMT attacks are efficient against promising architectures such as Intel TxT.
- By modifying AMT code, ACPI tables or SMM code, an attacker can find ways to leave a backdoor running on the system even after late launches are used.
    - The problem is not easy at all to solve.

Well known fact n°4: hardware specifications are bulletproof

- Gürgens et al. ESORICS 2007 (Security Evaluation of scenarios based on the TCG's TPM specification):
  - They presented several weaknesses on the TPM interface.
- TPMs are vulnerable to offline dictionary attacks
  - Anti-hammering mechanisms exist that prevent (to some extent) an attacker from trying an active dictionary attack on a key authorization value.
  - But the attacker has enough information on the wire to carry out an offline attack.
  - For more details see M. Ryan & L. Chen Offline dictionary attack on TCG TPM weak authorization data and solution. "Future of trust in computing" 2008.
    - Or talk to Mark directly.

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Well known fact n°5 : virtualization improves the level of security

- That is true to some extent, but virtualization allows me to run on the same machines different OS/applications that I would have run on different machines otherwise.
- So even if virtualization isolation were perfect (no flaws, no vulnerabilities), the best I could hope for is the level of security I had in the first place.

Bottom line of all this

- We need to put all those known facts to the question:
    - Is the hardware really that simple?
    - Can it be trusted?
    - Can the BIOS software be trusted?
    - What does virtualization really bring us?
- Only if we are able to answer those questions, will we really be able to trust a platform.

So what do we do?

- We find ways to lower the impact of those axioms not being true:
    - Make it difficult for the attacker to run code on the machine:
        - Deactivate macros.
        - Do not provide compilers and development environment on production machines.
        - Restrict the number of applications allowed to be run on the machine.
        - Enforce such properties as W^X.
- Know the exact risk you are taking if one of your basic hypothesis fails to be true.

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One additional quick question

Is my hard drive encrypted?

- There exists quite a lot of different seamless hard drive encryption products:
  - Microsoft’s « Bitlocker Drive Encryption ».
  - Truecrypt.
  - Native Linux functions dm_crypt.
  - Etc…
- But how can I, as a regular user, make sure that my hard drive is really encrypted?
  - If I could, encryption would not be that seamless.

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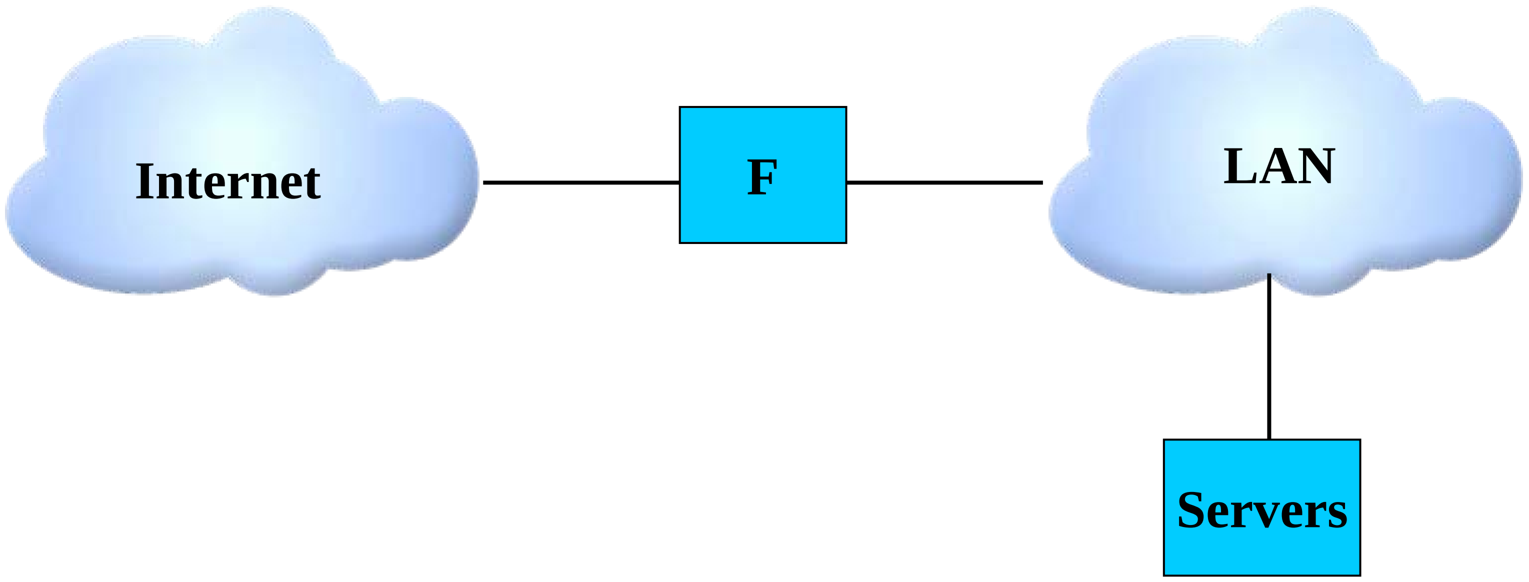
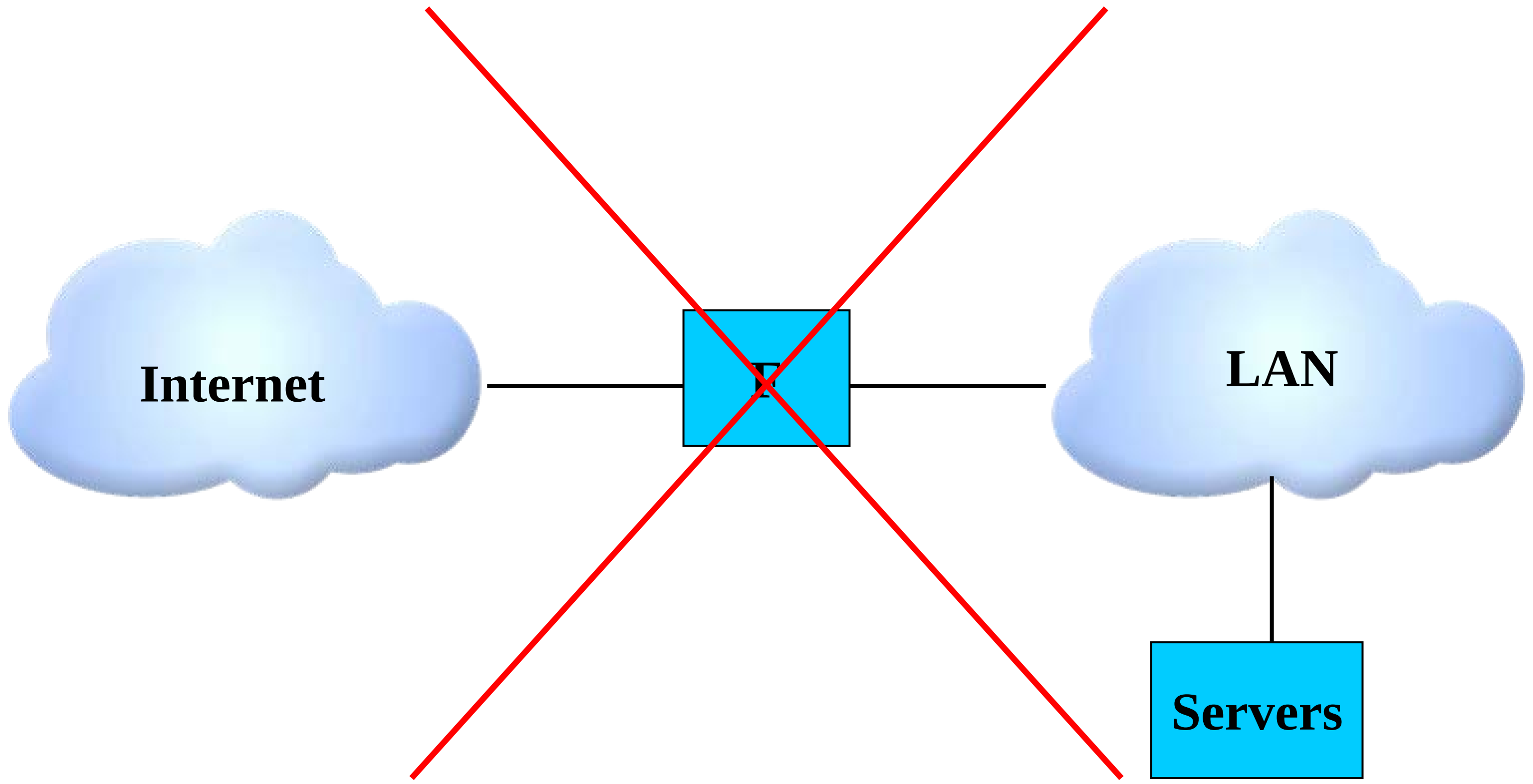
Taking the system aspects into account

Where should I put my IDS?



Where should I put my IDS?



There is no good solution as the network architecture
is a really bad one that should not be used in practice

What is the best password?

- Bonjour
- Bonjour123
- 3!337_Pwd@r00t
- AAAAAAAAAAAAAA

Quoted from/Credits: Nicolas Ruff, SSTIC 2009

Software evaluation challenges

- Security evaluation of cryptographic components (Smart Cards, TPMs) can be done for instance in the Common Criteria scheme.
  - FNISA hosts the French Certification Body.
- Software products can also be evaluated this way.
- But what about PC platforms?
  - How can we evaluate them?
  - What about software updates? Do we have to go through another certification product if we update our BIOS?
  - What kind of assurance level can we get to?

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Conclusions

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