NETWORK INFORMATION HIDING

CH. 3: INTRODUCTION TO GENERIC COUNTERMEASURES

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Introduction

- This chapter introduces heterogenous countermeasures for covert channels.
- In contrast to a later chapter, we will only deal with countermeasures that are **not** network-specific.
- Additional read for those interested:
  - S. Wendzel: *Tunnel und verdeckte Kanäle im Netz*, **Chapter 6**, Springer, 2012.
    - Introduces several of the countermeasures that I present in this chapter but also highlights additional aspects to deepen your knowledge.
    - Not relevant for the exam! (I translated relevant content and put it into slides.)

Shared Resource Matrix (SRM) Methodology [1,2]

General approach to detect covert storage channels

Can be applied at different steps of SDL

Covert channels can be detected within textual specifications of a software

… but also in source code.

The idea was later improved by McHugh, but we will first focus only on the original version introduced by Kemmerer.

General assumption: A system is described by "operations" and "attributes".

[1] Kemmerer, R. A.: Shared resource matrix methodology: An approach to identifying storage and timing channels, ACM Transactions on Computer Systems (TOCS), Vol. 1(3), pp. 256-277, ACM, 1983.
[2] Bishop, M.: Computer Security, Art and Science, Addison-Wesley Professional, 2003, Chapter 17.

Shared Resource Matrix (SRM) Methodology [1,2]

Goal of the SRM is to determine whether an Operation X can modify (M) an attribute A under the condition that an Operation Y (w/ Y≠X) can read (R) attribute A.

Example: Let us assume that:

Attr. / Op.	Read	Write	Delete	Create
Existence of file	R	R	R, M	R, M
File owner	-	-	R	M
File name	R	R	R	M
File size	R	M	M	M

[1] Kemmerer, R. A.: Shared resource matrix methodology: An approach to identifying storage and timing channels, ACM Transactions on Computer Systems (TOCS), Vol. 1(3), pp. 256-277, ACM, 1983.
[2] Bishop, M.: Computer Security, Art and Science, Addison-Wesley Professional, 2003, Chapter 17.

Shared Resource Matrix (SRM) Methodology [1,2]

- Problems:
  - Some „covert channels“ can be false positives (e.g. if two operations could build an (R,M) pair but cannot be called by processes of different security levels).
  - The SRM supports no sequences of operations, but a sequence of *n* operations may lead to an **indirect recognition** of a modified attribute [2].
  - Kemmerer states that all storage and timing channels can be detected using the SRM. However, Bishop stated that this is wrong (see above).

[1] Kemmerer, R. A.: Shared resource matrix methodology: An approach to identifying storage and timing channels, ACM Transactions on Computer Systems (TOCS), Vol. 1(3), pp. 256-277, ACM, 1983.
[2] Bishop, M.: Computer Security, Art and Science, Addison-Wesley Professional, 2003, Chapter 17.

Extended SRM (eSRM)

- McHugh developed an extended SRM by enhancing the original SRM as follows [1,2,3]:

1. **Introduction of „User Flows":** differentiation between input and output for operations through the user. A user can *always* access the input of an operation, but not necessarily the output.
    - E.g., some programming languages would prevent feedback from being sent to the user in case of a failure. McHugh used the *Gypsy* language.
2. **Operation Splitting:** In the original SRM, there is no distinction between *independent* flows within an operation. The matrix is thus further differentiated per each modifiable object (each M gets its separate column).
    - E.g. it could be the case that several attributes are used/referenced in an operation but only subsets are actually related with each other, following fully independent flows. See [2], p. 7 for an example.
3. **Guard Expansion:** For the already separated information flows (2): provide a distinction for different cases, e.g. if A is only set to B if D==1, else A might be set to C. See [2], p. 7 for an example.

[1] J. McHugh, J.: Covert channel analysis. Technical Memo 5540:080A, Naval Research Laboratory, 1995. ||| [2] McHugh, J.: An information flow tool for Gypsy: An extended abstract revisited, in Proc. ACSAC, 2021. ||| [3] S. Wendzel: Tunnel und verdeckte Kanäle im Netz, Ch. 6, Springer, 2012.

Extended SRM (eSRM)

- Drawback of the eSRM in comparison to the SRM is its increased complexity [3].
  - There is at least a tool for the Gypsy language that automatically generates the eSRM [2].

[1] J. McHugh, J.: Covert channel analysis. Technical Memo 5540:080A, Naval Research Laboratory, 1995. ||| [2] McHugh, J.: An information flow tool for Gypsy: An extended abstract revisited, in Proc. ACSAC, 2021. ||| [3] S. Wendzel: Tunnel und verdeckte Kanäle im Netz, Ch. 6, Springer, 2012.

Covert Flow Trees [1]

Code-level Detection for Covert Channels.

(We will only discuss fundamental aspects here.)

Code:

```
Procedure IncreaseTemp()
{
          Heat(cur_temp=internal_temp);
          internal_temp += 1;
}

Procedure CheckTemp()
{
          if (internal_temp < soft_limit)
                    return internal_temp;
          else
                    return 999; # error code
}
```

→

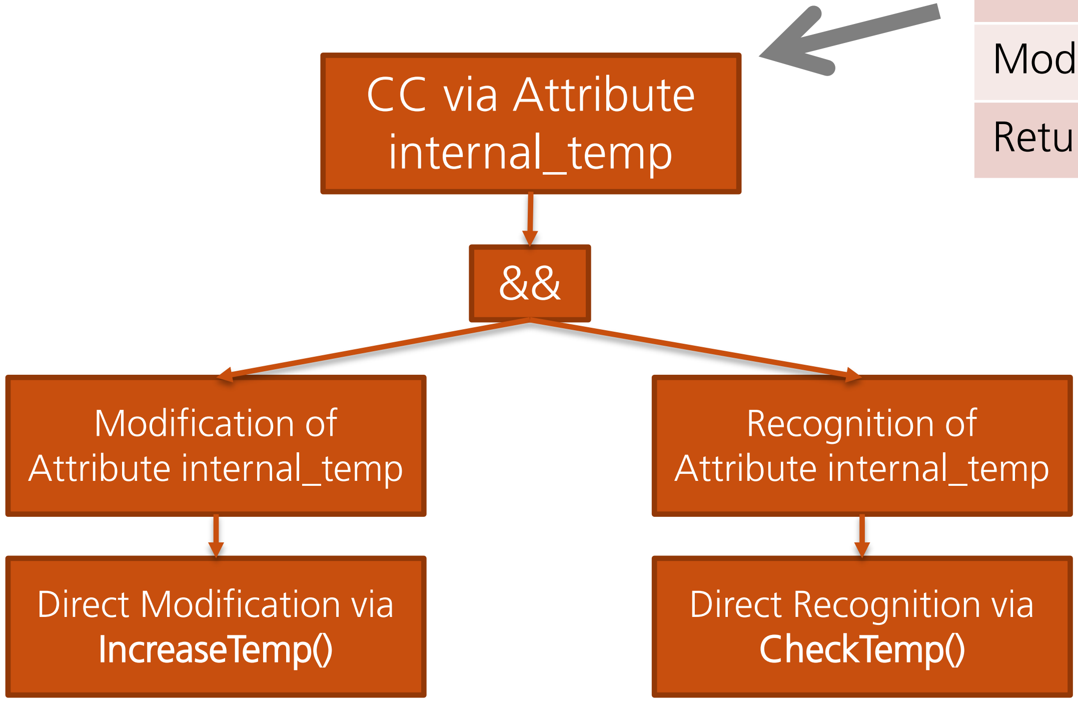
	IncreaseTemp	CheckTemp
Reference	cur_temp, internal_temp	internal_temp soft_limit
Modify	internal_temp	-
Return	-	internal_temp

[1] Kemmerer, R., Porras, P.: Covert Flow Trees: A Visual Approach to Analyzing Covert Storage Channels, Trans. Software Engineering, IEEE, 1991.

Covert Flow Trees [1]

Building a simplified CFT:

	IncreaseTemp	CheckTemp
Reference	cur_temp, internal_temp	internal_temp soft_limit
Modify	internal_temp	-
Return	-	internal_temp



CC via Attribute internal_temp

&&

Modification of Attribute internal_temp

Recognition of Attribute internal_temp

Direct Modification via IncreaseTemp()

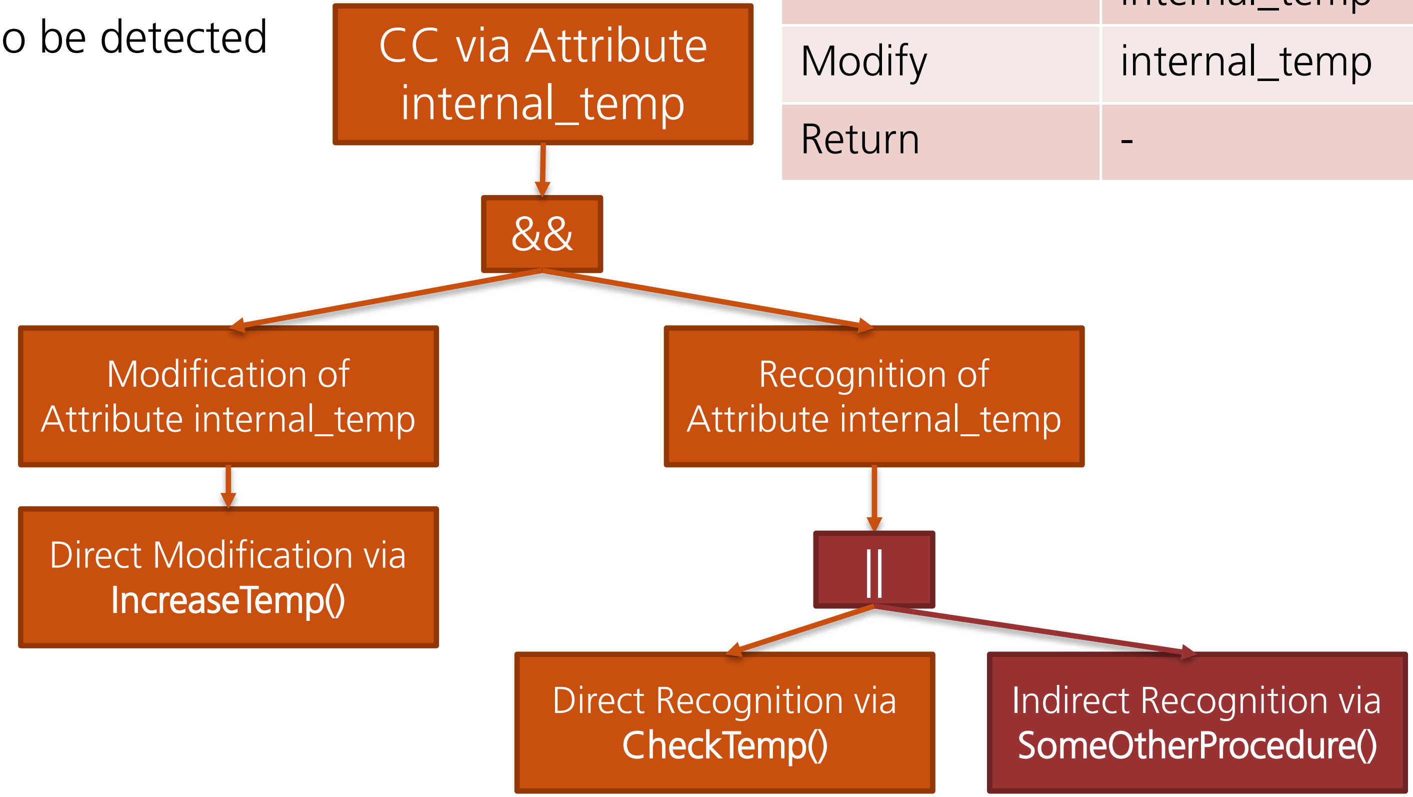
Direct Recognition via CheckTemp()

[1] Kemmerer, R., Porras, P.: Covert Flow Trees: A Visual Approach to Analyzing Covert Storage Channels, Trans. Software Engineering, IEEE, 1991.

Covert Flow Trees [1]

Indirect channels can also be detected

	IncreaseTemp	CheckTemp
Reference	cur_temp, internal_temp	internal_temp soft_limit
Modify	internal_temp	-
Return	-	internal_temp


CC via Attribute internal_temp
&&
Modification of Attribute internal_temp
Recognition of Attribute internal_temp
Direct Modification via IncreaseTemp()
||
Direct Recognition via CheckTemp()
Indirect Recognition via SomeOtherProcedure()

[1] Kemmerer, R., Porras, P.: Covert Flow Trees: A Visual Approach to Analyzing Covert Storage Channels, Trans. Software Engineering, IEEE, 1991.

Covert Flow Trees [1]

Generation of CFT Lists:

They contain sequences of operations that represent a potential covert channel.

List 1: Operations capable of modifying an attribute

List 2: Operations capable of reading an attribute

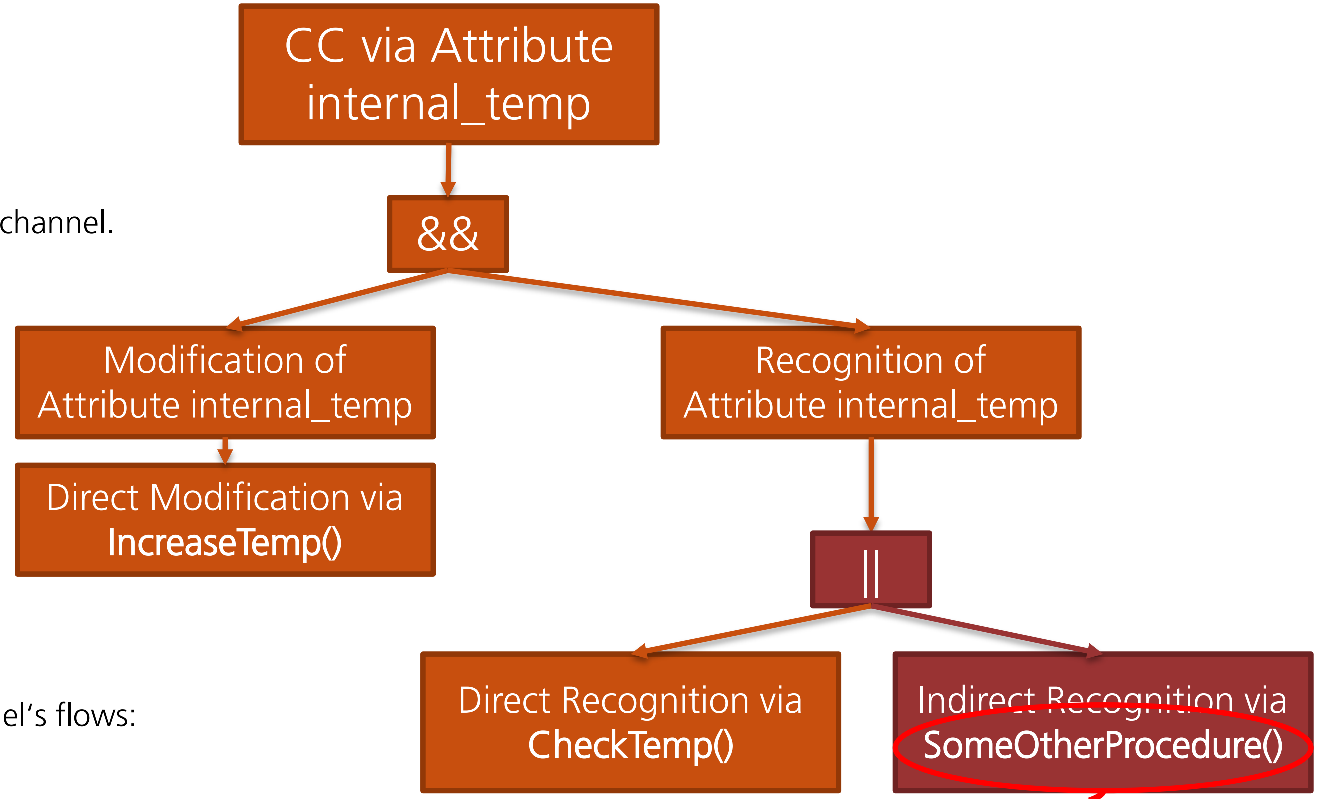
List 1: (`IncreaseTemp()`)

List 2: (`CheckTemp()`, `SomeOtherProcedure()`)

Finally, one combines both lists to determine the potential covert channel's flows:

`IncreaseTemp()` → `CheckTemp()`

`IncreaseTemp()` → `SomeOtherProcedure()`



CC via Attribute internal_temp

&&

Modification of Attribute internal_temp

Direct Modification via IncreaseTemp()

Recognition of Attribute internal_temp

||

Direct Recognition via CheckTemp()

Indirect Recognition via SomeOtherProcedure()

[1] Kemmerer, R., Porras, P.: Covert Flow Trees: A Visual Approach to Analyzing Covert Storage Channels, Trans. Software Engineering, IEEE, 1991.

Covert Flow Trees [1,2]

- Discussion:
  - CFTs can only be applied at the source code level (drawback in comparison to the SRM)
  - Nobody has published work on timing channel detection; so far, CFTs can only be applied to detect storage channels
  - Visual representation of flows and automatic CFT generation supported by tools
  - Support for indirect information flows

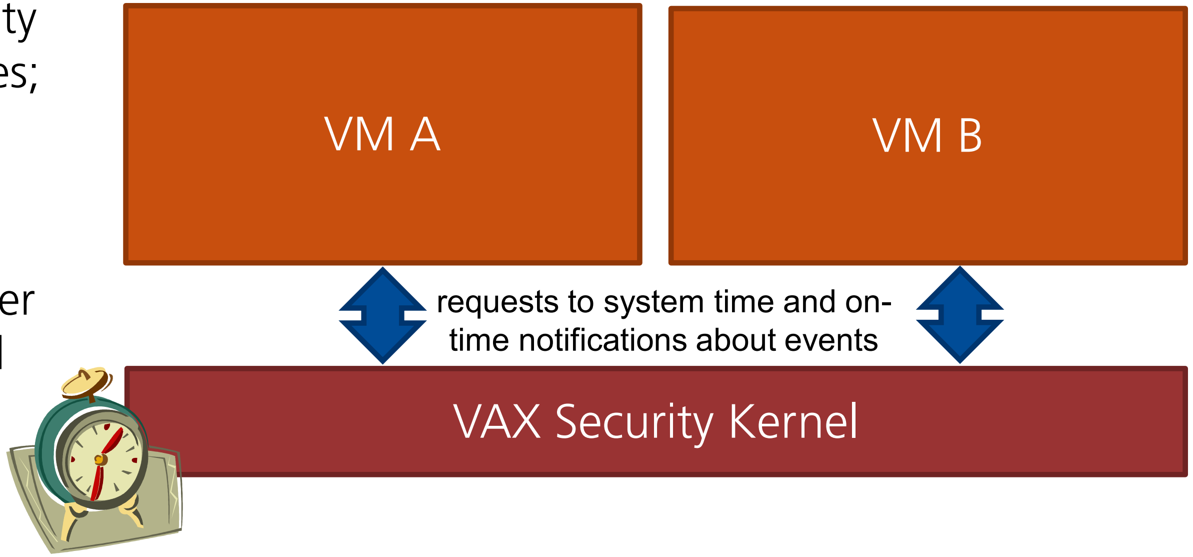
[1] Kemmerer, R., Porras, P.: Covert Flow Trees: A Visual Approach to Analyzing Covert Storage Channels, Trans. Software Engineering, IEEE, 1991.
[2] Bishop, M.: Computer Security, Art and Science, Addison-Wesley Professional, 2003, Chapter 17.

Fuzzy Time [1]

- Approach by W.-M. Hu to limit the channel capacity of covert timing channels between virtual machines; already in 1991 (VAX security kernel).

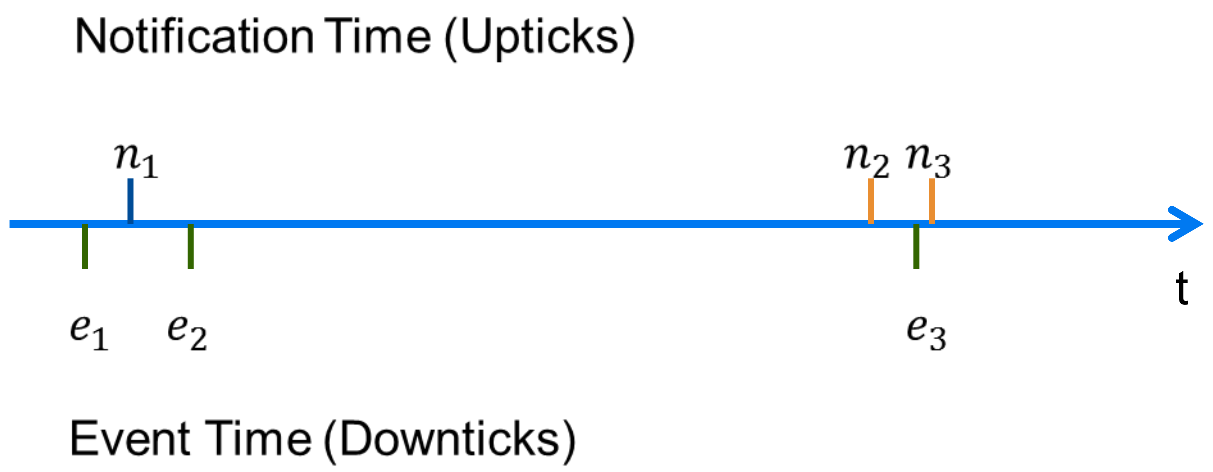
- The more precise a time measurement is, the higher is the channel capacity (finer distinction of elapsed time possible).

- No detection or prevention of timing channels.


VM A
VM B
requests to system time and on-time notifications about events
VAX Security Kernel

[1] Hu, W.-M.: Reducing Timing Channels with Fuzzy Time, Symp. Security and Privacy, IEEE, 1991.

Fuzzy Time [1]



[1] Hu, W.-M.: Reducing Timing Channels with Fuzzy Time, Symp. Security and Privacy, IEEE, 1991.

Spurious Processes Approach [1]

- Originally designed for databases, however, here explained for filesystem-utilizing storage channels

- **Basic idea:** Introduce a „spurious process“ (SP) into all potentially covert communications between two regular processes of an operating environment.
  - limits capacity of covert storage channels
  - SP introduced on context switch if a shared object is accessed by two processes without previous access of SP to the same object. SP has the same permissions as P2.

P1's behavior	P1 creates file		P1 does *not* create file	
SP's behavior	Create()	Create() + Remove()	Create()	Create() + Remove()
Result	File exists	File exists because in write-down, the SP lacks rights	File exists	File does not exist
P2 receives	1 (unsure, whether P1 or SP created file)			0 (sure)

- Example: Two Processes in MLS system; unique filenames; P2 calls Create().

[1] Fadlalla, Y. A. H.: Approaches to Resolving Covert Storage Channels in Multilevel Secure Systems, PhD thesis, University of New Brunswick, 1996.