A Survey on Simulation-Based Fault Injection Tools for Complex Systems

DTIS'14

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Cross-Layer Early Reliability Evaluation for the Computing cOntinuum

Outline

1. Research Project
2. Dependability
3. Fault Tolerance
4. Fault Injection
5. Conclusion and Perspective

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1. **Research Project**
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Motivation

Availability

Security

Reliability

Fault Tolerance

Space Shuttle Columbia, February 1, 2003

CLERECO

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Cross-Layer Early Reliability Evaluation for the Computing cOntinuum

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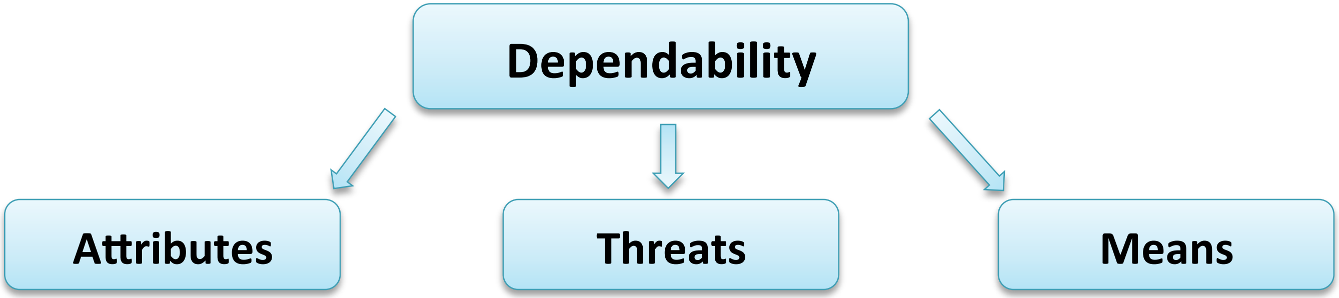
DEPENDABILITY

Dependability

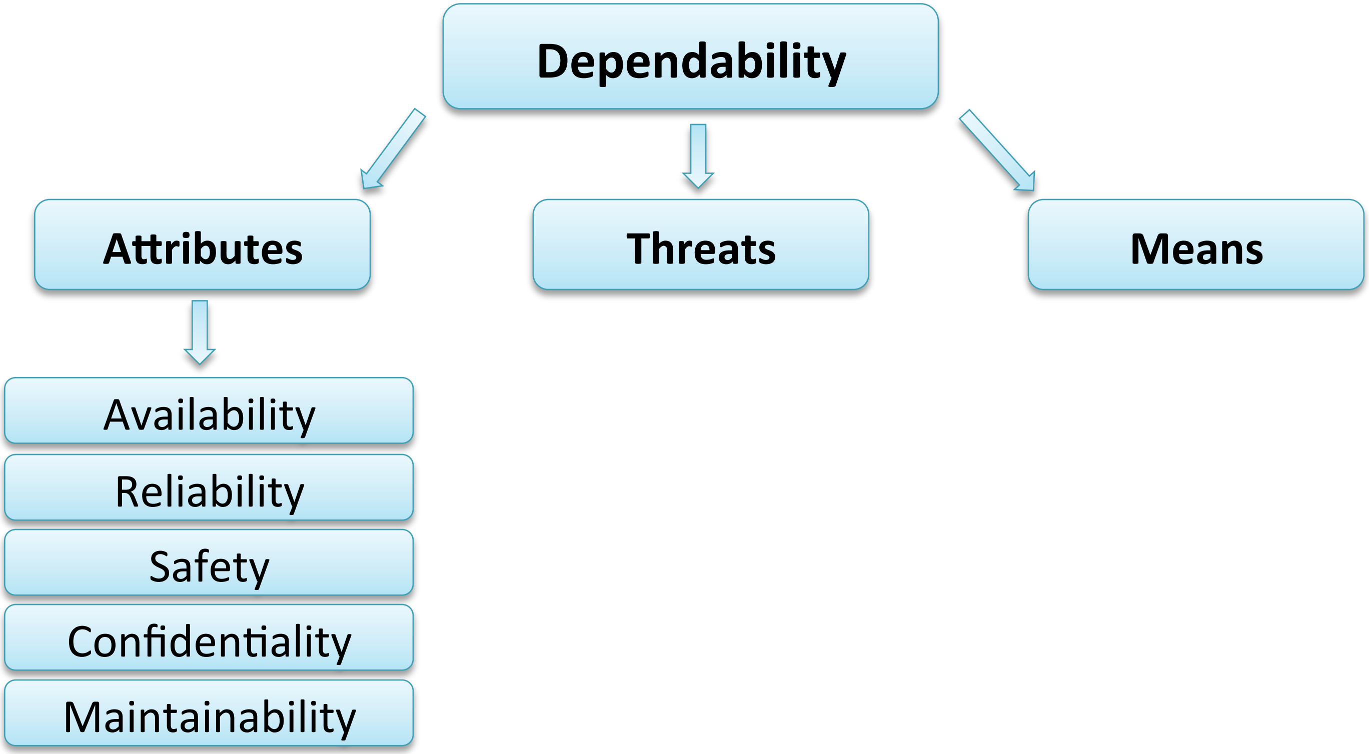
- A global concept that subsumes the usual attributes of reliability, availability, safety, integrity, and maintainability.

- The ability to avoid service failures that can happen to a system frequently and severely than acceptable.

Dependability



DEPENDABILITY



Dependability

Attributes

Threats

Means

Availability

Reliability

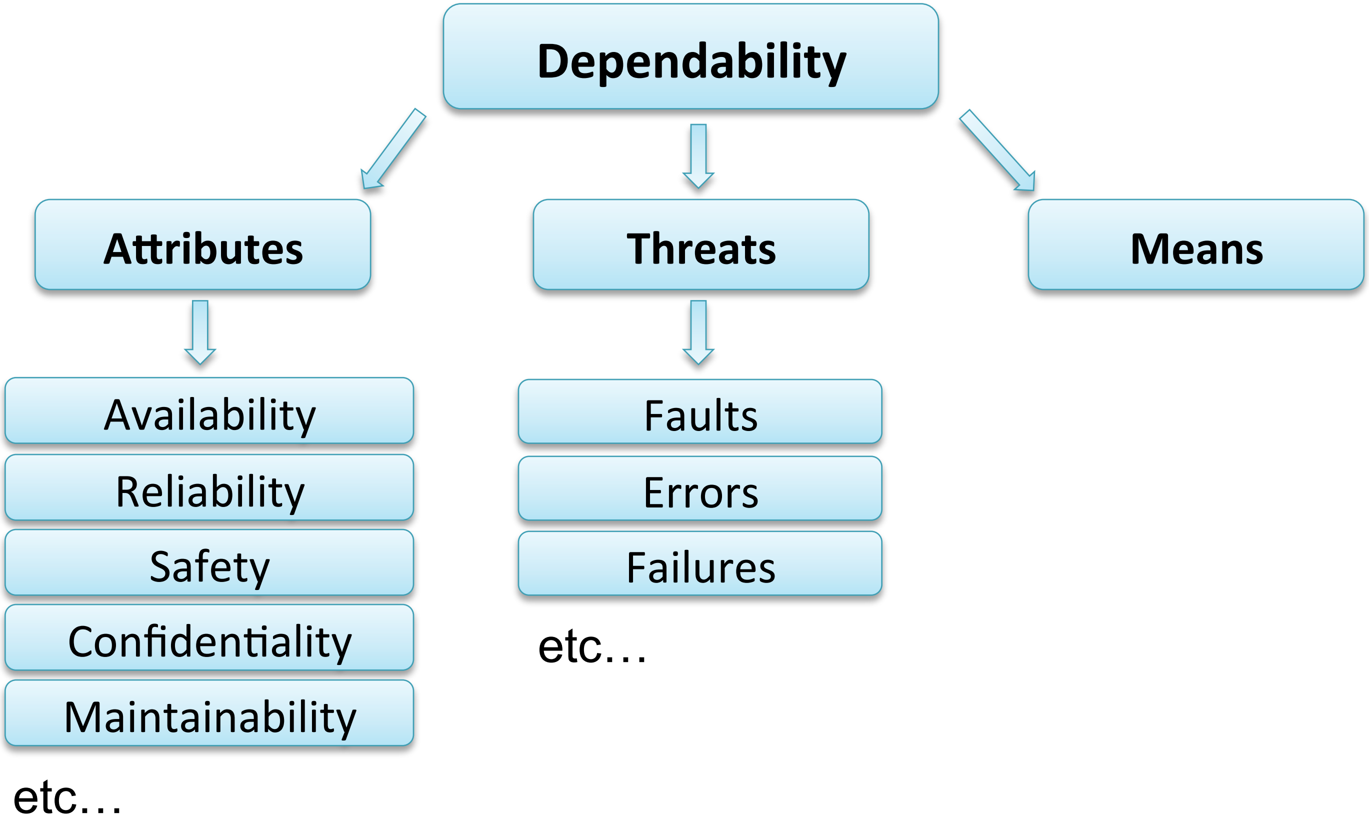
Safety

Confidentiality

Maintainability

etc…

Dependability



Dependability

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etc…

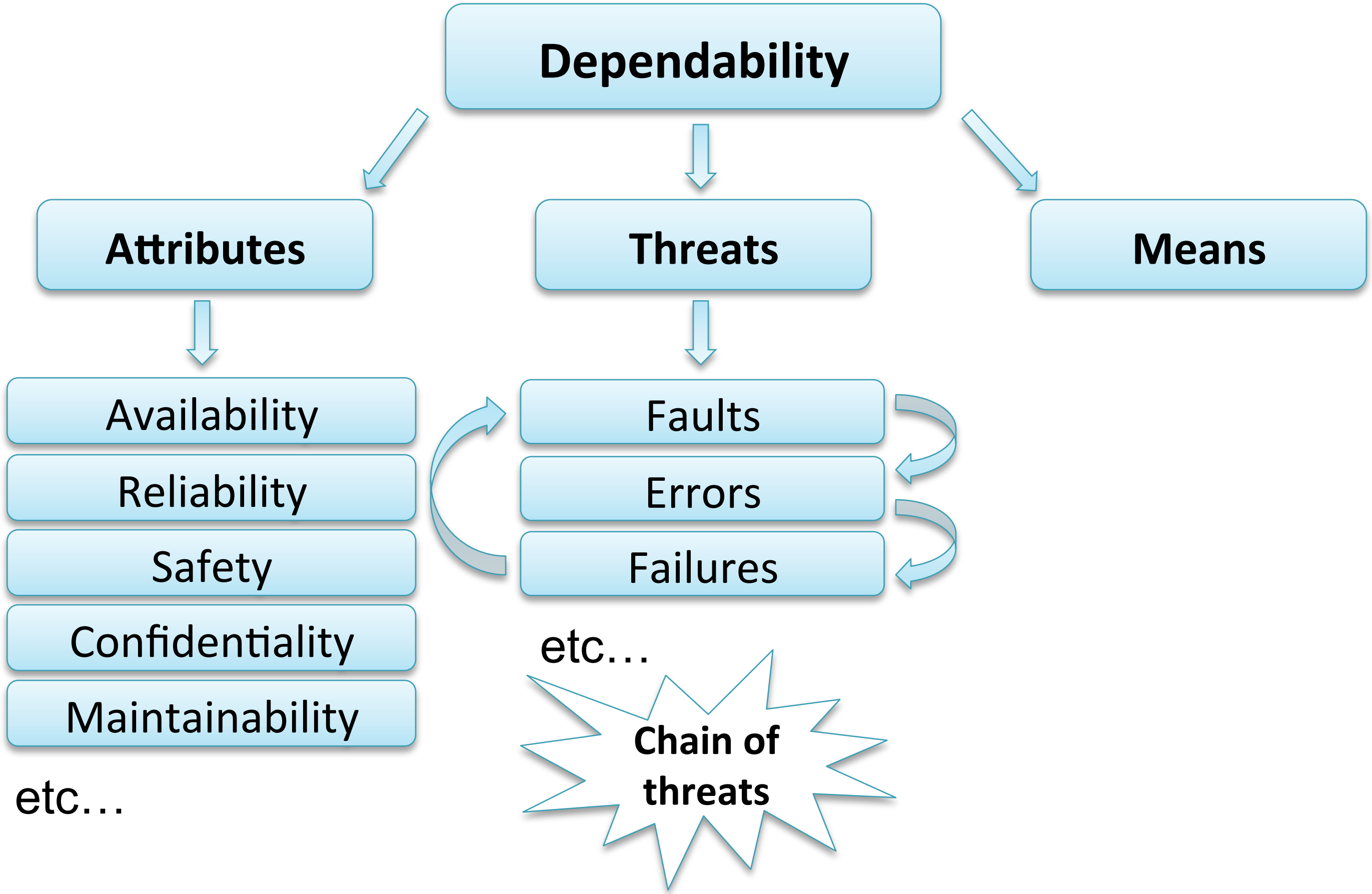
Faults

Errors

Failures

etc…

DEPENDABILITY



Dependability

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etc…

Faults

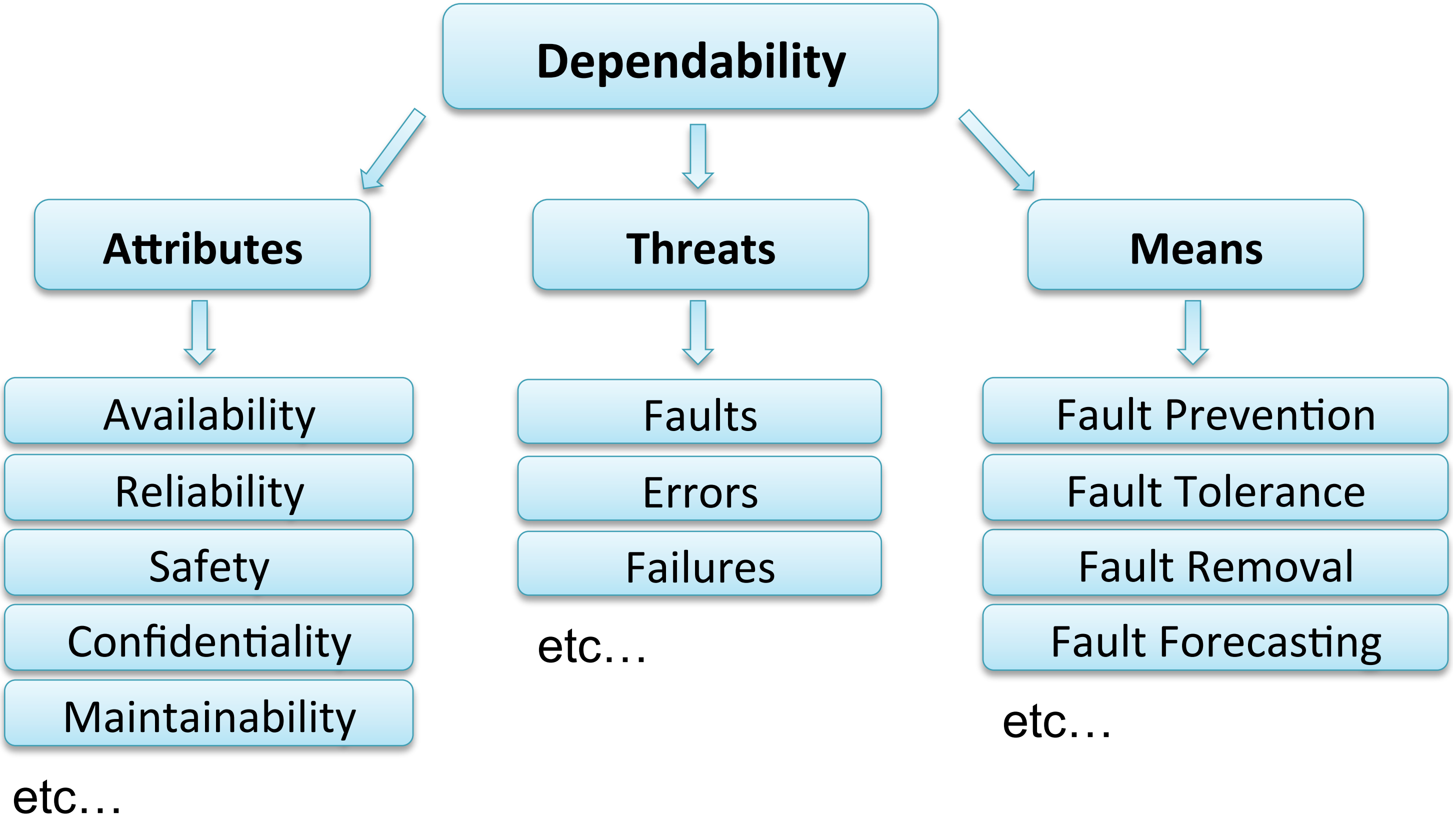
Errors

Failures

etc…

Chain of threats

Dependability



Dependability

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etc…

Threats

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Errors

Failures

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Means

Fault Prevention

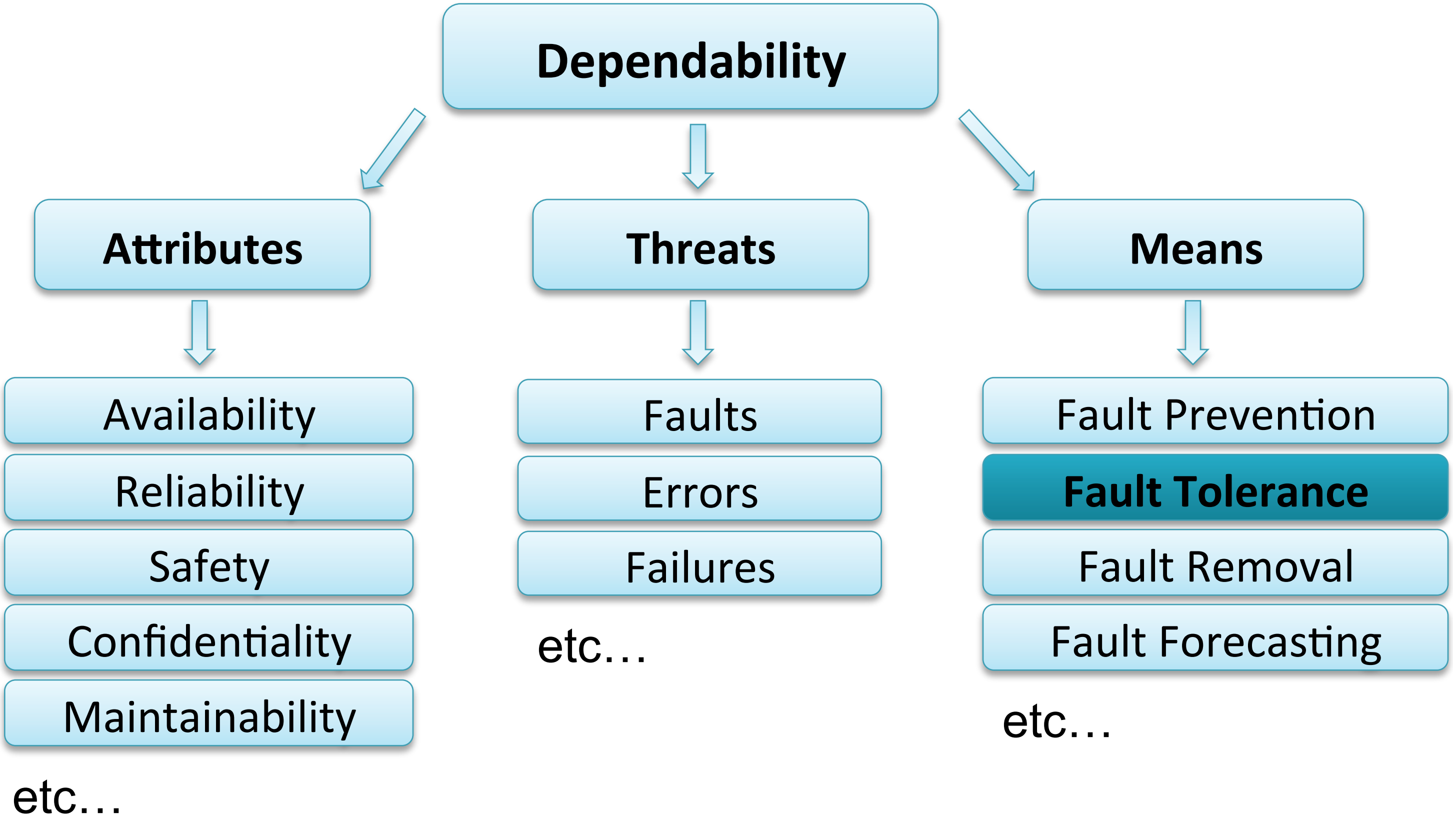
Fault Tolerance

Fault Removal

Fault Forecasting

etc…

Dependability



Dependability

Attributes

- Availability
- Reliability
- Safety
- Confidentiality
- Maintainability

etc…

Threats

- Faults
- Errors
- Failures

etc…

Means

- Fault Prevention
- **Fault Tolerance**
- Fault Removal
- Fault Forecasting

etc…

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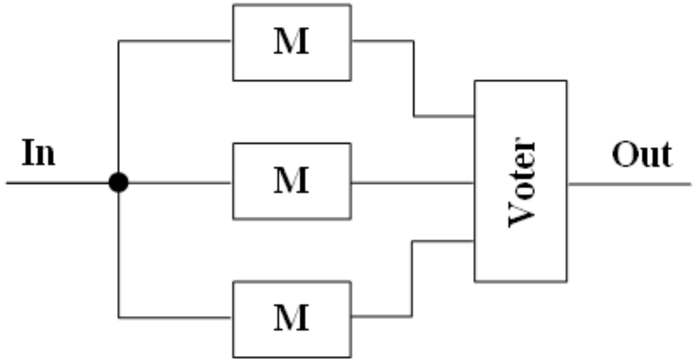
Fault Tolerance

- A method permitting to:
  - Increase the dependability
  - Avoid services failure in the presence of faults

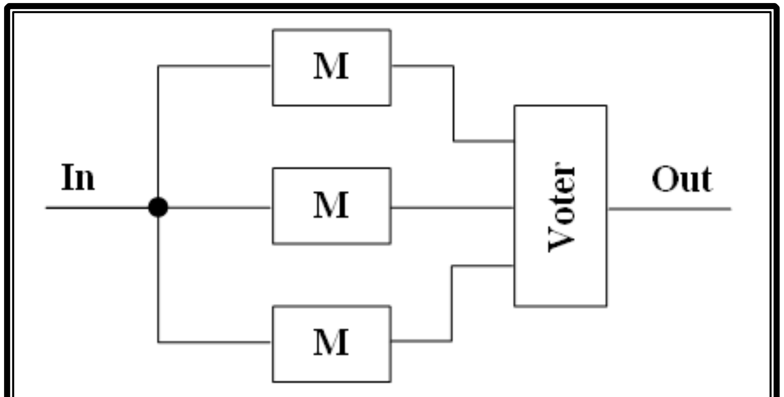
- Several strategies are used to tolerate faults: **Redundancy**

Redundancy



Space Redundancy

Redundancy



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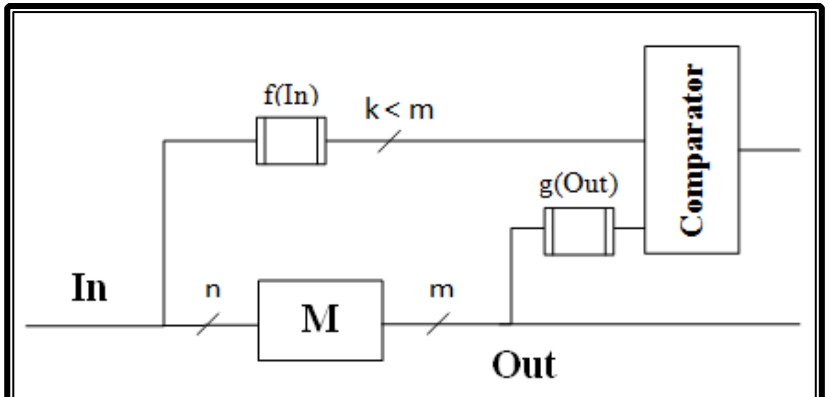
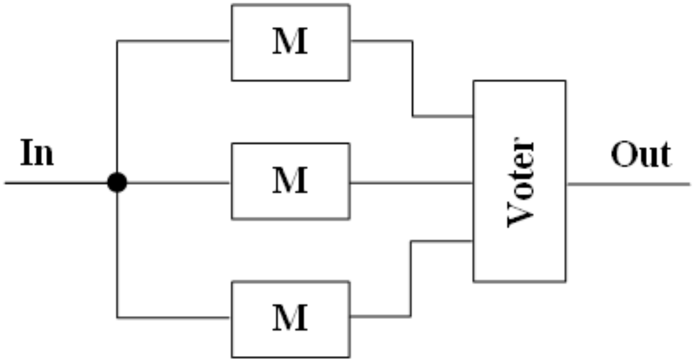


Information Redundancy

Redundancy



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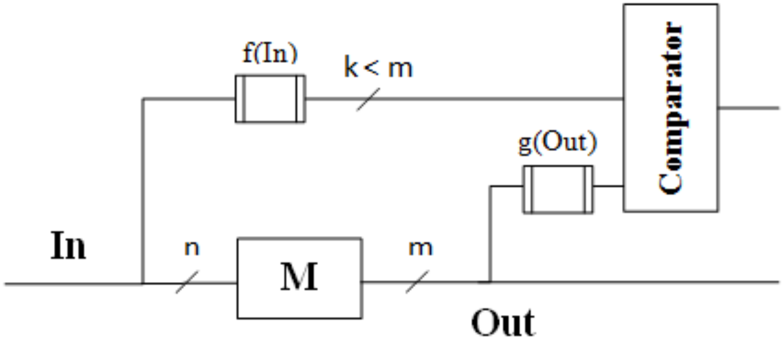

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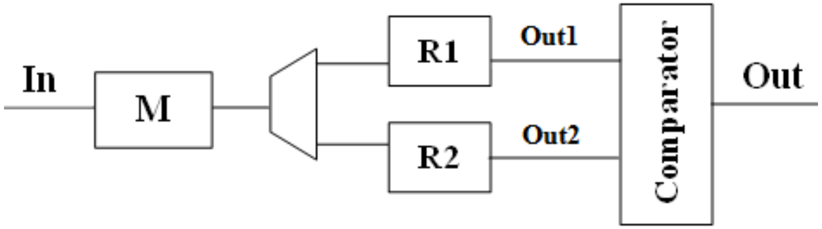

Time Redundancy

Fault Tolerance Techniques

Techniques	Targeted Layer	+/-
Hardware Fault Tolerance	Hardware Layer	- Effective - Costly in term of equipment
Software Implemented Hardware Fault Tolerance (SIHFT)	Operating System Layer	- Requires high skills to modify the OS
	Middleware Layer	- Efficient when the application is not modifiable, and the source code is not available
	Application Software Layer	- Cheap - Better solution when the source code is available

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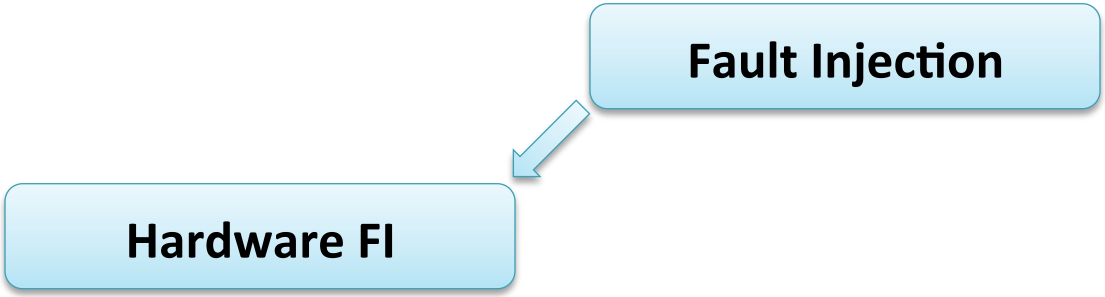
Fault Injection

Fault Injection

- A validation technique of the dependability for fault tolerance systems
- Evaluate the behavior of the system in the presence of faults

Fault Injection

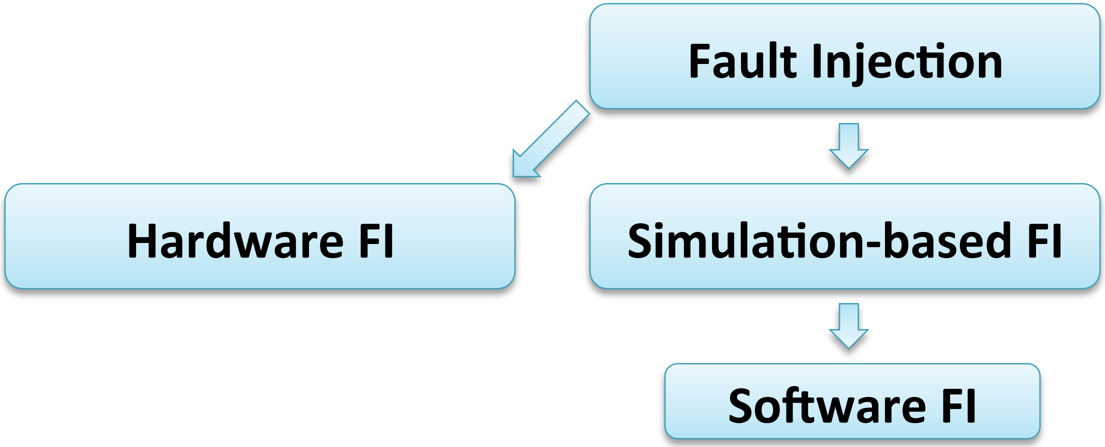


+ High time-resolution.

− Expensive in term of equipment.

− Risk to damage the system.

Fault Injection


Fault Injection

Hardware FI

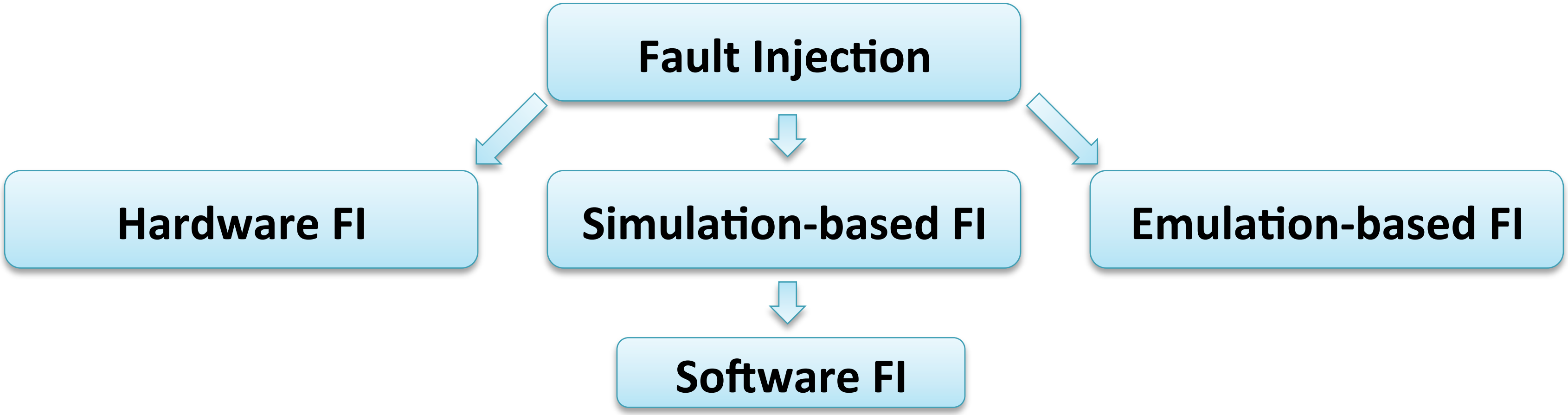
Simulation-based FI

Software FI

- + High time-resolution.
- − Expensive in term of equipment.
- − Risk to damage the system.

- + No risk to damage the system
- + Low-cost
- + Simple to set-up
- − Accuracy of fault model and system model

Fault Injection



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- + It reduces the execution time compared to the simulation-based FI
- − Costly and not flexible

Fault Injection Environments

Tool	Developer	Category	Description
Xception	University of Coimbra, Portugal	Software FI	• Fault are injected in software • It uses advanced debugging features to observe the behavior of the system in detail in presence of faults.

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RIFLE	University of Coimbra, Portugal	Hardware FI	• Faults are injected in pin-level of the modules. • It performs analysis to observe the impact of faults on the processor

Fault Injection Environments

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LLVM-based Fault Injector

- LLVM is a compiler infrastructure, defines an abstraction layer to make the information at software level and the information at hardware level, compatible and easily exchangeable

KULFI & **LLFI**

- Transient and permanent faults injected in the LLVM Intermediate Representation code level

⇨ Target the software layer independently of the architecture of the hardware system

⇨ Observe the effect of hardware faults in the behavior of the application

FAUmachine

- Virtual machine similar to QEMU or Virtual Box, supports Just-In-Time (JIT) compiling
- It supports Linux as OS, and i386 and x86_64 as hardware

- **Memory:** Transient bit flips and Permanent stuck-at and coupling faults
- **Disk/CDROM:** Transient and permanent block and whole disk faults
- **Network:** Transient, Intermittent and Permanent send and receive faults

⇨ Thanks to virtualization, we can observe the fault impacts in the behavior of the whole operating system, without having a real hardware system.

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Conclusion and Perspective

- Define the software fault model:
  - The misbehaviors of the software due to the propagation of a hardware error
  - It should be able to simulate in a software environment that allows injecting faults, without knowing the hardware structure.

- Simulate the fault models at a high level of the system

- Compare the obtained results with the result of the simulation of hardware fault in a real hardware system

Thanks for your attention

Questions?