Computer Architecture
计算机体系结构

Lecture 14. Design for Reliability/Availability
第十四讲、面向可靠性和可用性的设计

Chao Li, PhD.

李超 博士

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Review

- G-States
- S-States
- C-States
- P-States
- TDP, Turbo Boost
- Power management can be challenging

Outlines

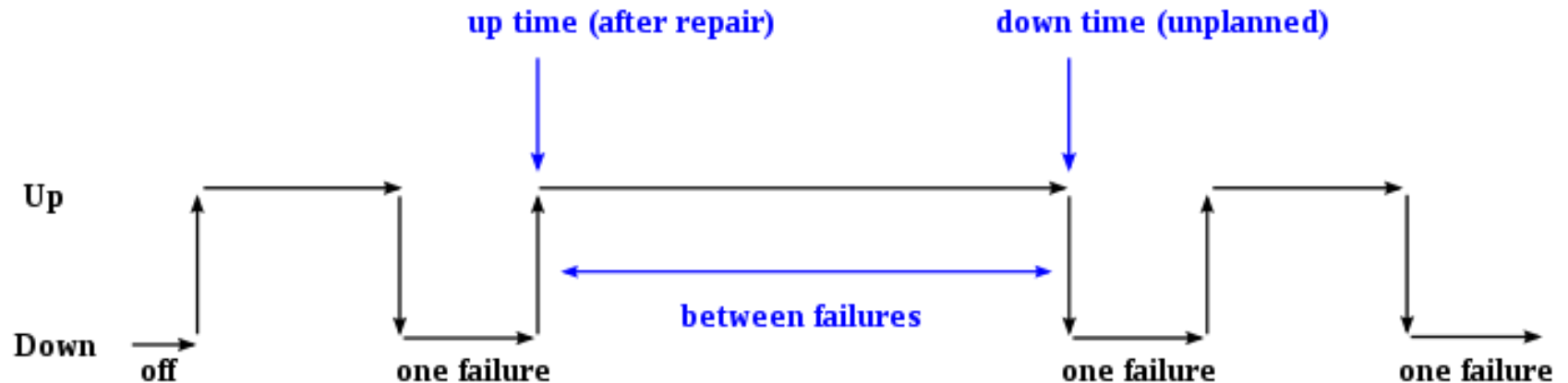- Reliability and Availability

- Discussion and Case Studies

Faults, Errors, and Failures

- A fault is a physical flaw
  - e.g., a broken wire or a wear-out transistor
- A fault can manifest itself as an error
  - e.g. a bit that is a zero instead of a one
  - Fault can be masked and not manifest itself as any error
- An error can be masked or it can result in a failure
  - Failures are user-visible incorrect behavior

> A **transient fault** occurs once and then does not persist
> An error due to a transient fault is known as soft error

MTTF, MTBF, MTTR

- Mean Time to Failure (MTTF)
- Mean Time Between Failures (MTBF)
- Mean Time to Repair (MTTR)


Time Between Failures = { down time - up time}

$$\mathbf{Availability} = \frac{MTTF}{MTBF} = \frac{MTTF}{MTTF+MTTR}$$

Availability and Reliability

- ## The availability of a system at time t
  - is the probability that the system is operating correctly at time t.
  - units for availability are often the "number of nines"

- ## The reliability of a system at time t
  - is the probability that the system has been operating correctly from time zero until time t.

Is it possible for a low-reliability system to have high availability?

Discussion: ACE and AVF
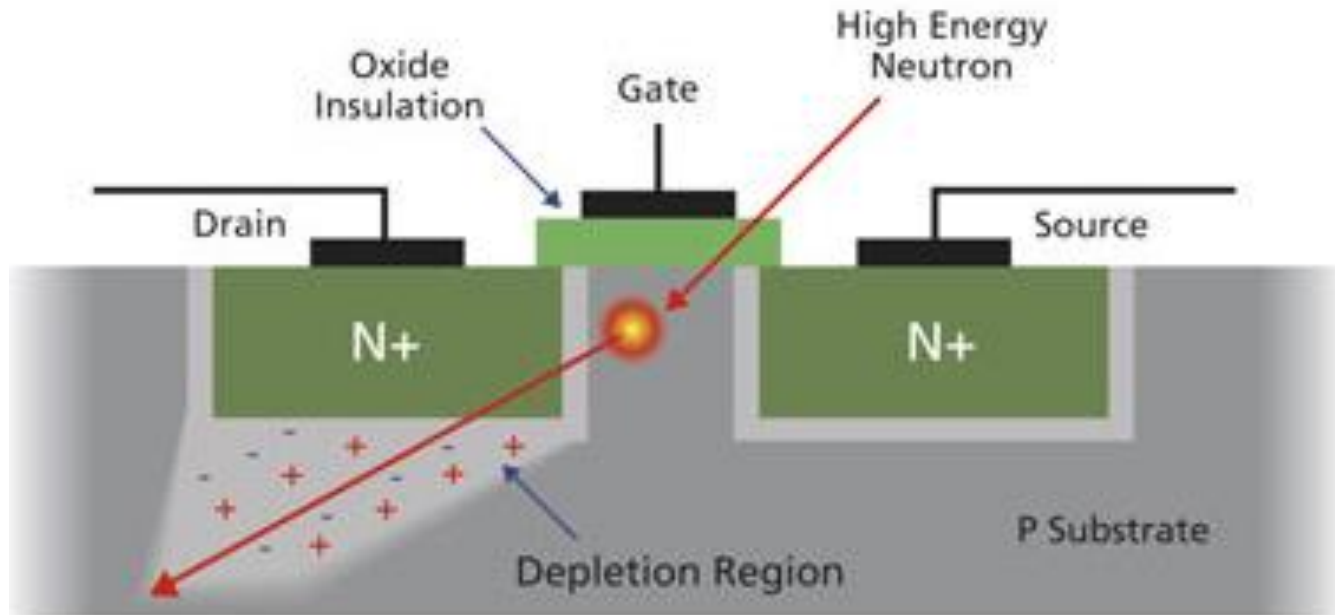
- Architecturally correct execution (ACE) bit
  - Whose correctness is required for the correctness of the program
  - Un-ACE bits: those that are not critical to program correctness

Discussion: ACE and AVF

- Architectural vulnerability factor (AVF)
  - captures the probability that a fault in a structure will manifest as an error in the program output

- The AVF of a hardware structure H containing B bits over a period of N cycles can be expressed as:

$$AVF_{structure} = \frac{1}{N} \sum_{i=0}^{N} \left(\frac{ACE \ bits \ in \ H \ at \ cycle \ i}{B} \right)$$
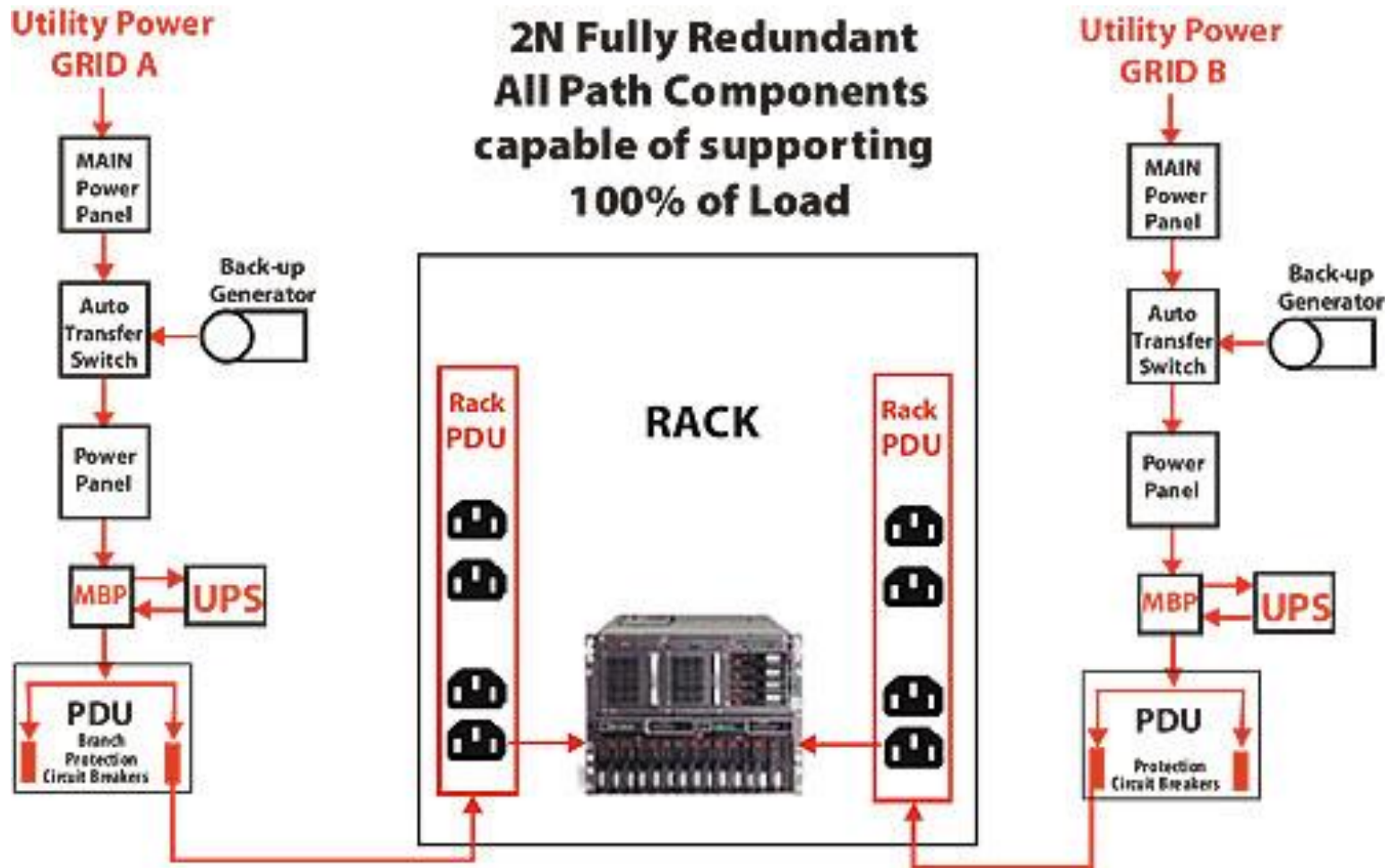
- Design considerations?
  - Appropriate microarchitecture + Application characteristics

Discussion: SMT for Fault Tolerance

- Two independent threads are created for every thread that the application wants to run
  - execute identical code and receive the same inputs
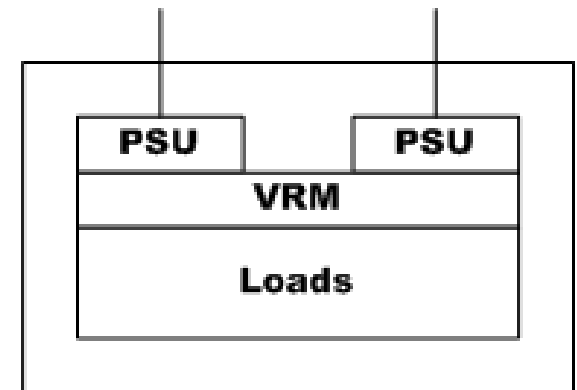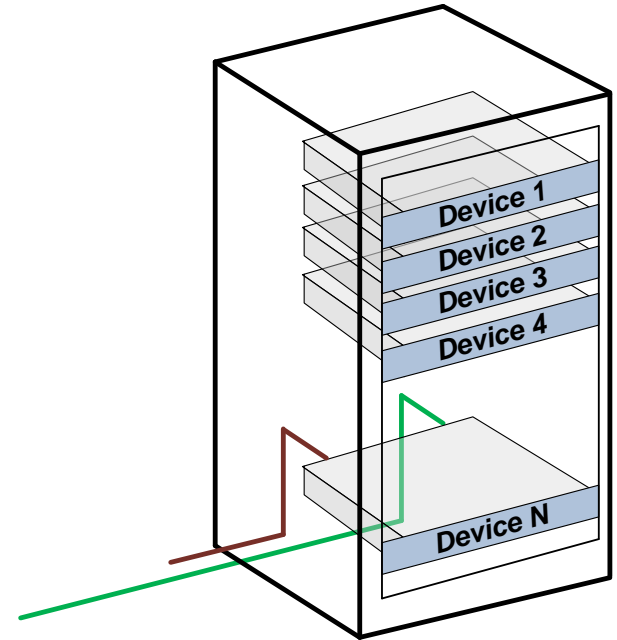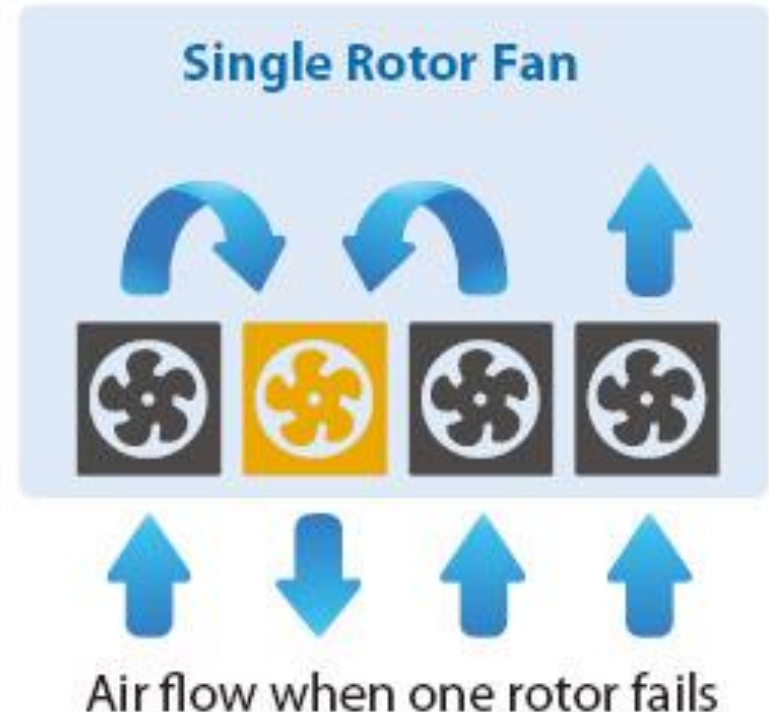 - A divergence in output signals a fault
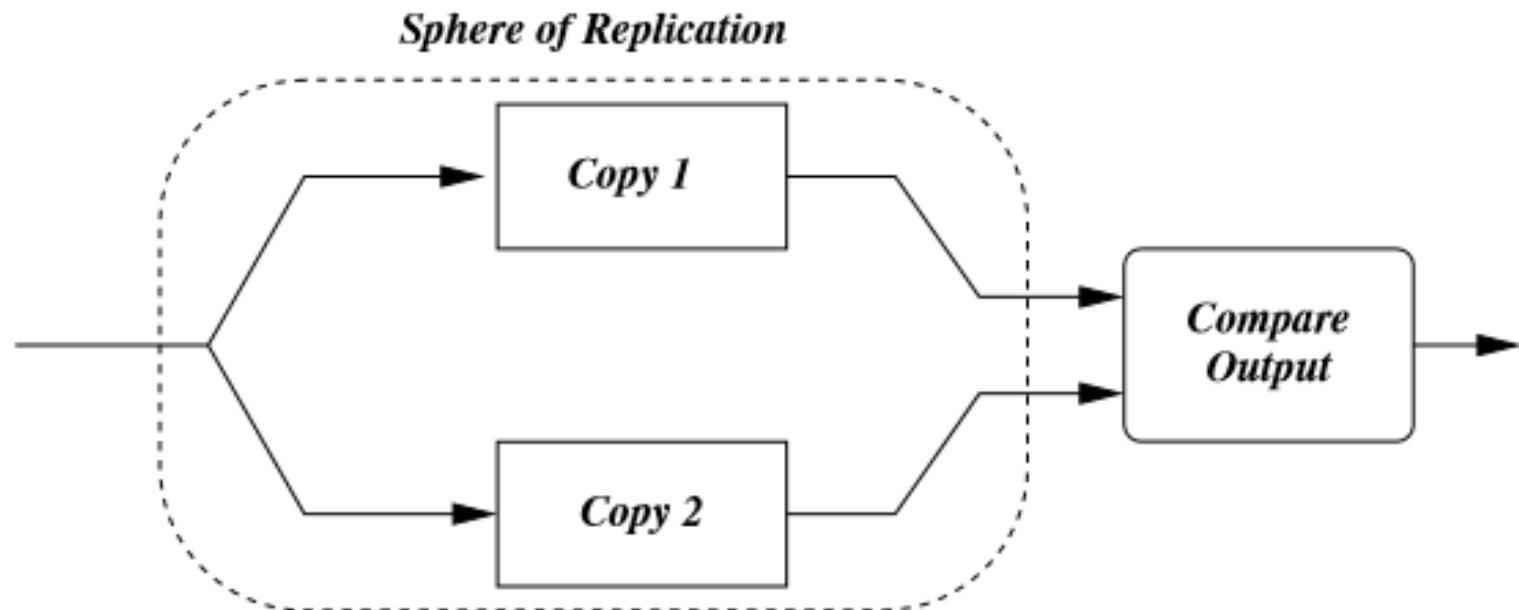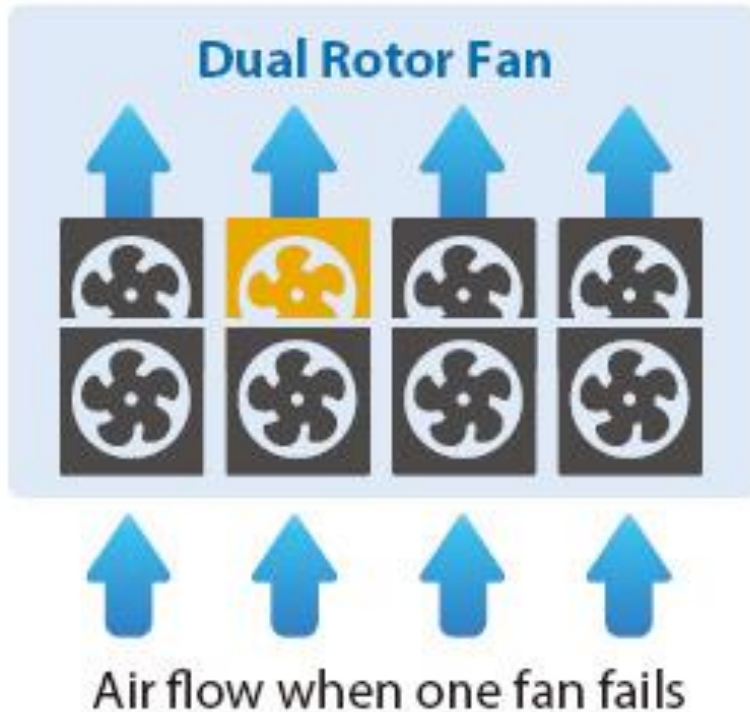
Redundancy: Power Delivery

Dual Power Delivery Path + Dual-Corded Servers

Redundancy: Power Supply

- ## Dual-corded（双电缆）
  - Two PSU is employed for each server!
  - High availability

- ## Single-corded
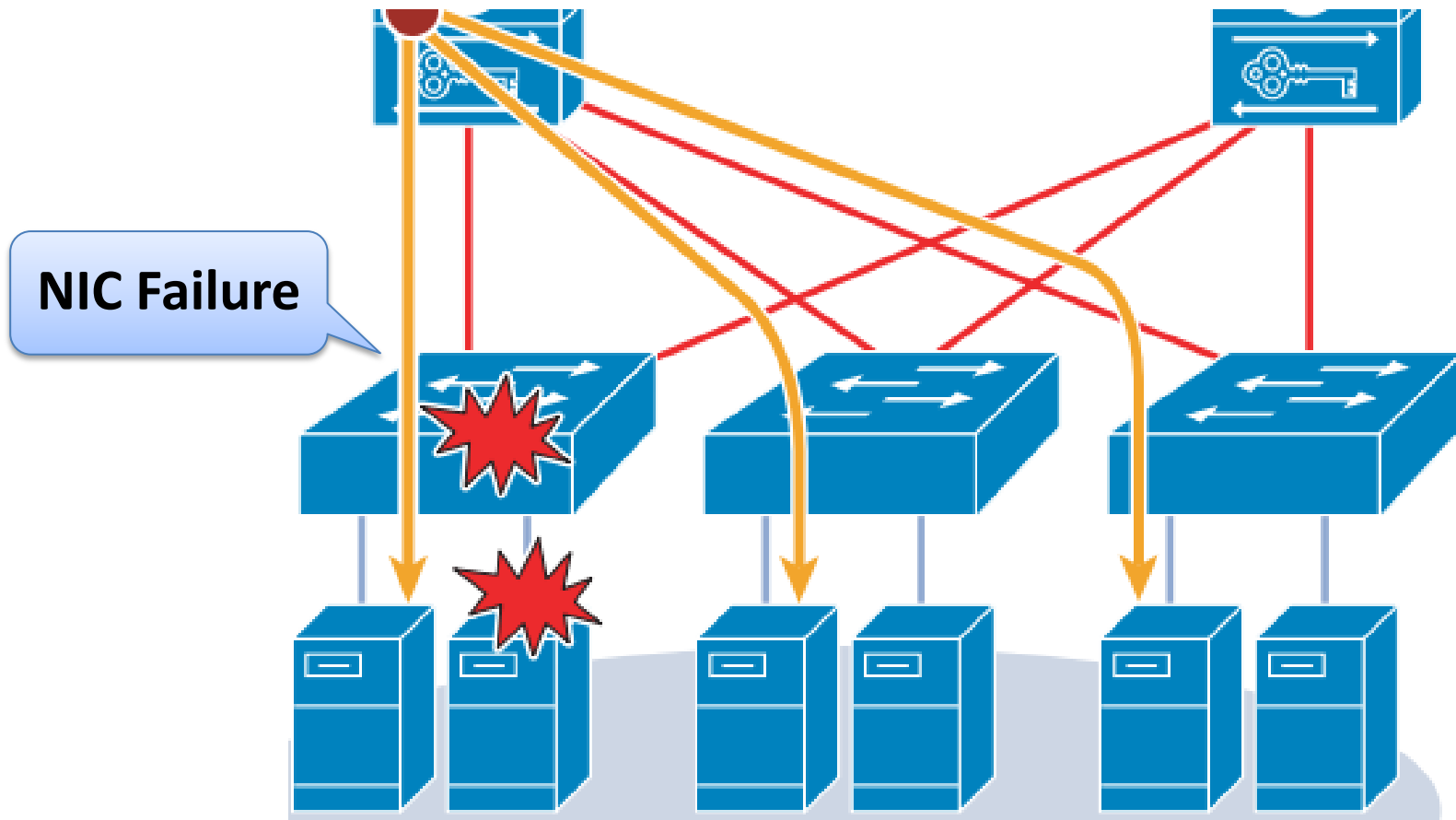 - Single PSU is employed
  - Can be seen in a dual path environment

Redundancy: Cooling System

Dual Rotor Fan vs. Single Rotor Fan

Redundancy: Network System

Fault-Tolerant Load Balancing

Summary

- Faults, error, and failure
- MTTF, MTBF, MTTR
- Availability, reliability
- ACE, AVF
- Redundancy