



# Resilient Computing

Oleh:

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# Agenda

- Introduction
- Resilient Server
- CARS: Cyber Attack-Resilient Server
- RaaS: Resilient as a Service
- Resilient Software-Defined Networking

# Terminator (1991)



HAVE YOU EVER WATCHED THIS MOVIE?



# Transcendence (2014)



AND THIS MOVIE ... ?



#### Introduction

#### Logical and physical failure

```
A problem has been detected and windows has been shut down to prevent damage to your computer.

If this is the first time you've seen this stop error screen, restart your computer. If this screen appears again, follow these steps:

Disable or uninstall any anti-virus, disk defragmentation on backup utilities, check your hard drive configuration, and check for any updated drivers, Run ChROSK / 2 to check for hard drive corruption, and then restart your computer.

Technical information:

*** STOP: 0x00000024 (0x001902FE, 0xF791E948, 0xF791E644, 0xBA6805CC)

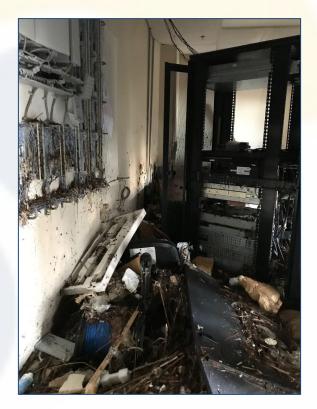
*** Ntfs.sys - Address BA6805CC base at BA645000, Datestamp 41107eea

Beginning dump of physical memory

Physical memory dump complete.

Contact your system administrator or technical support group for further assistance.

**TOSHIBA*
```



#### Introduction: resilience

- "resilience" → Latin verb resilire (re-salire: to jump back)
- ability of a body to recover its normal size and shape after being pushed or pulled out of shape
- Ability to recover to normality after a disturbance.



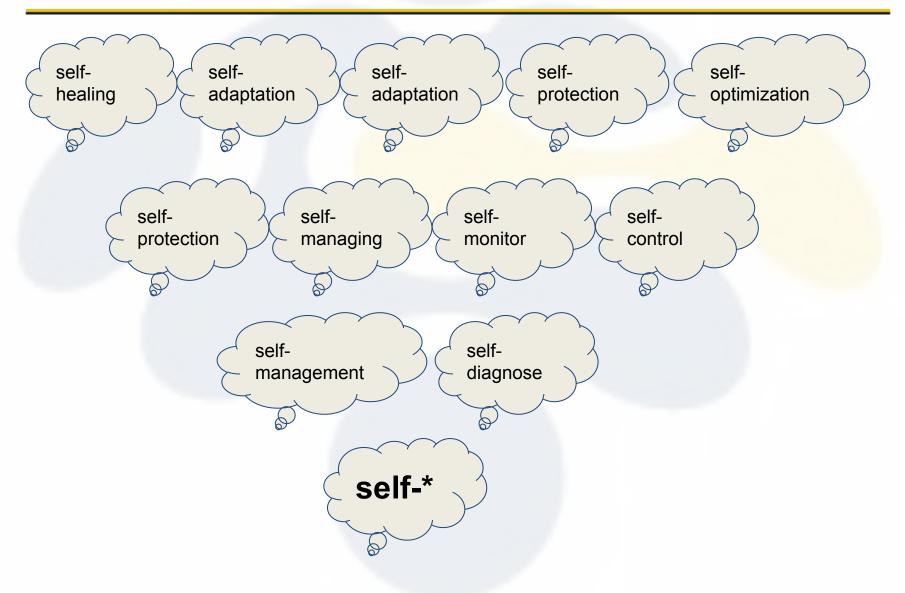
# Introduction: keywords

#### Keywords:

- Diversity
- Auto-recovery
- Human-free

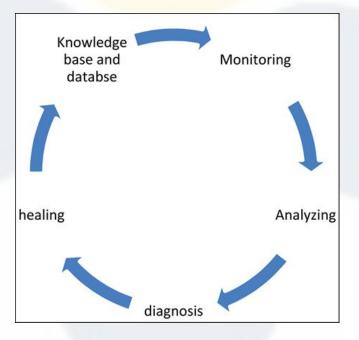


#### Introduction: self-\*



# Self-Healing\*

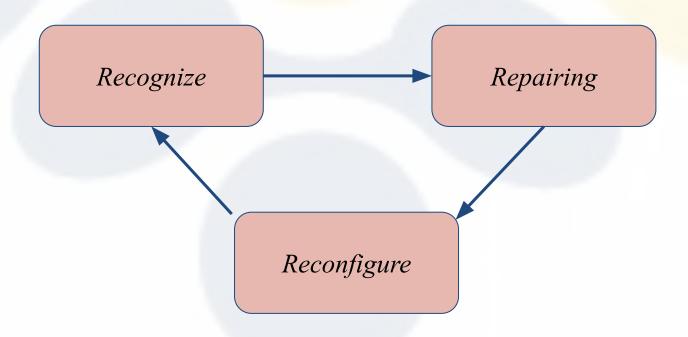
.....is inspired from the biological healing process for human and animals, where the body heals itself by repairing the affected tissue or bone, the process of healing is carried out internally from inside the body, the cells will gather in the place that has been affected (ex. Tissue insured or bold vessel cut) and the heal process retain the affected place to its original health status.



\*Hudaib et al., 2017

#### SR<sup>3</sup>

- Self-Recognition
- Self-Repairing
- Self-Reconfiguration



# Resilient Computing System Area

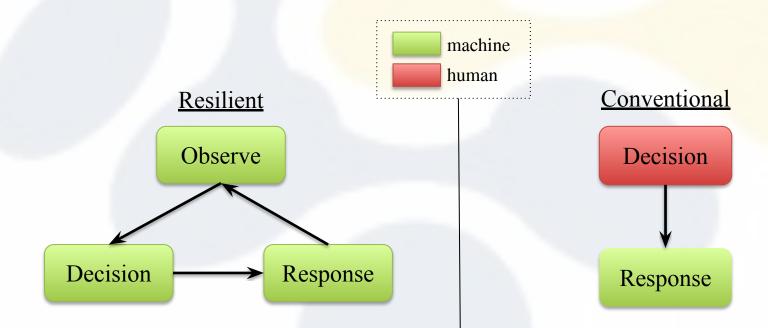
- Fault tolerant computing
- Hardware fault tolerance
- Design fault tolerance
- Reliable communication
- Resilient real-time systems
- Robust distributed programs
- Software Safety
- Software reliability prediction

# (1) Resilient Server



#### Resilient Server: Definition

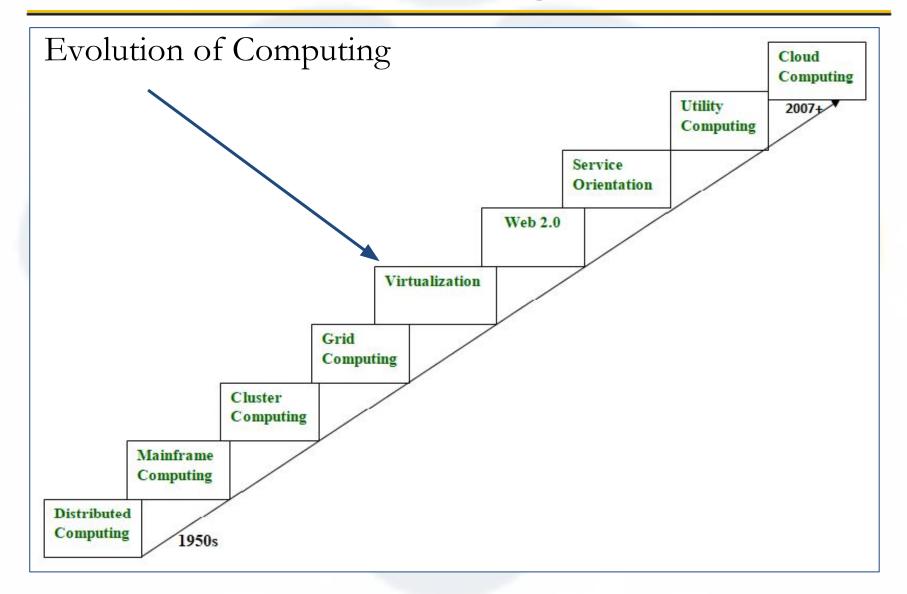
- Able to recover from unhealthy to healthy state
- ☐ Self-observation
- Automatic/human free



- Automatically recover from failure.
- Observing its own behavior.
- No human intervention.

- Manually recover from failure.
- No observation.
- Require human interaction.

# Resilient Server: Background



# Resilient Server: Background

#### Hypervisor (VM Engine)



<sup>\*</sup>image source: infosecinstitute.com

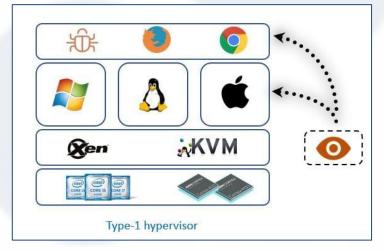
#### Resilient Server: VMI

• Virtual Machine Introspection

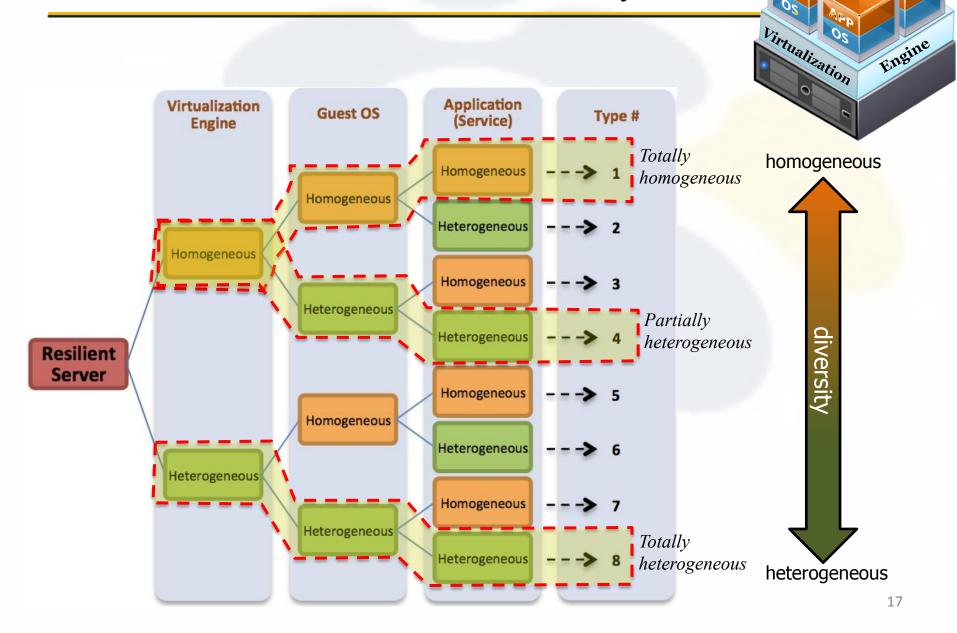
- In-VMI

- Out-VMI

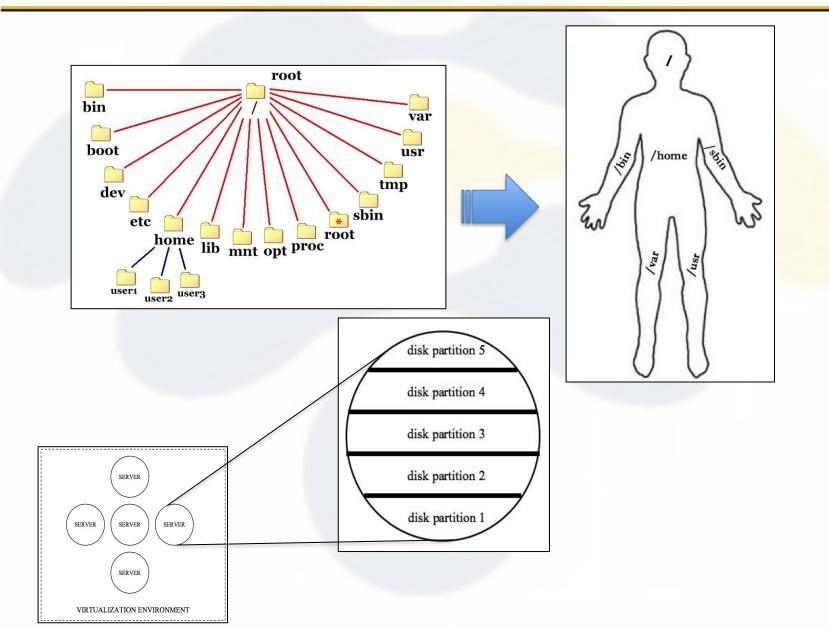




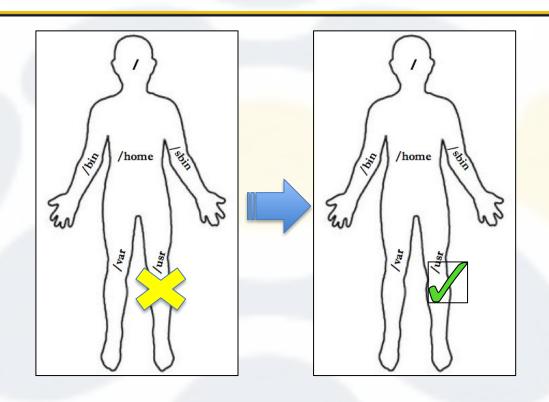
# Resilient Server: Diversity



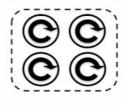
# Resilient Server: Type #1



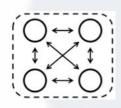
### Resilient Server: Type #1



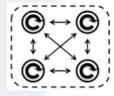
#### \*Self-Repair Network



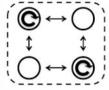
Self-repair



Mutual-repair



Mixed-repair

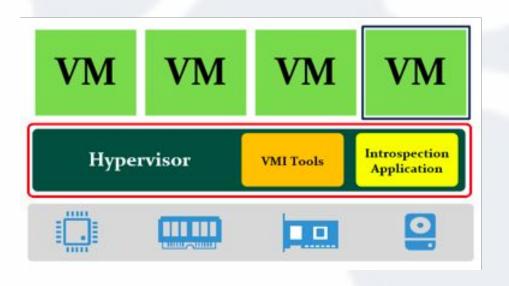


Switch-repair

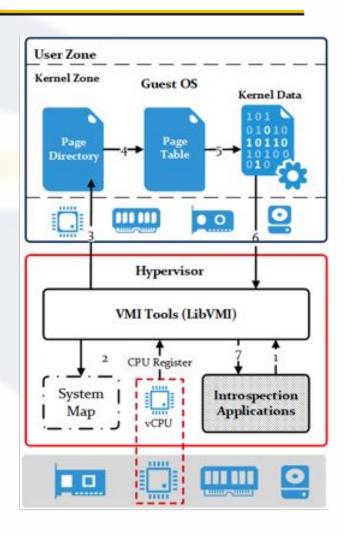
#### Resilient Server: out-VMI

#### System Design

(Hang detection: partial/full)



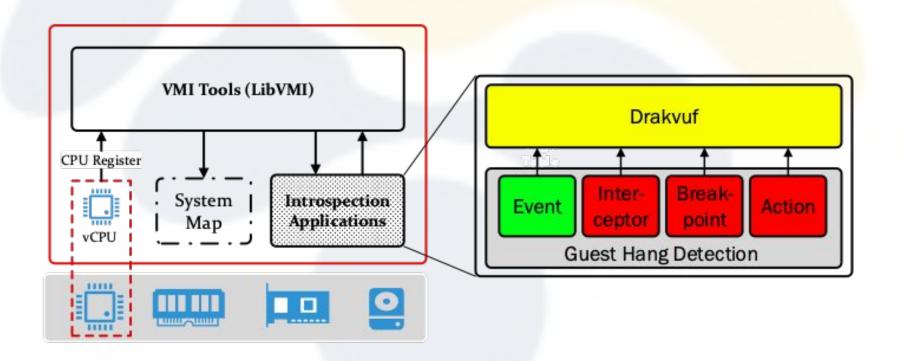




#### Resilient Server: out-VMI

#### System Design

(Hang detection: partial/full)



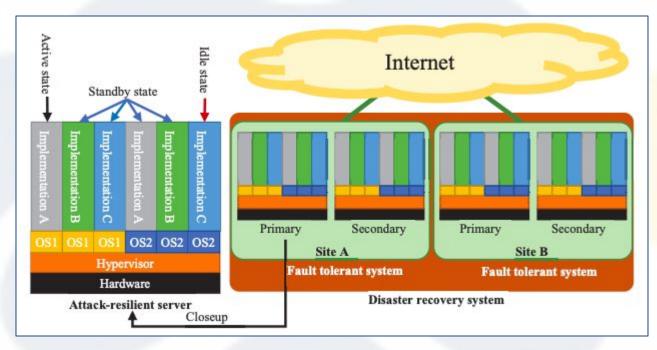
#### Resilient Server: out-VMI

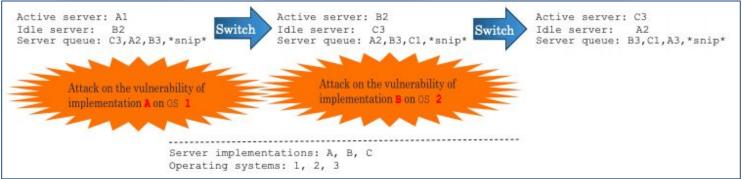
```
SYSCALL] TIME: 1575115346.138021 VCPU: 1 CR3: 0x753da004, "apache2" UID: 33
SYSCALL1 TIME: 1575115346.138244 VCPU: 1 CR3: 0x753da004, "apache2" UID: 33
SYSCALL] TIME: 1575115346.138449 VCPU: 1 CR3: 0x753da004, "apache2" UID: 33
SYSCALL] TIME:1575115346.208964 VCPU:0 CR3:0x77632004, "rtkit-daemon" UI
SYSCALL) TIME: 1575115346.209198 VCPU: 0 CR3: 0x77632004. "rtkit-daemon" U
                             CR3:0x6fc78005, "apache2"
       IN LONG fd: 0x5
      OUT PVOID buf: 0x7f9f0
                             CR3:0x6fc78005, "apache2"
      OUT ULONG count: 0x8
SYSCALL] TIME: 1575115346.2094 CR3: 0x6fc78005, "apache2"
SYSCALL1 TIME: 1575115346.2096
                             CR3:0x6fc78005, "apache2"
       IN LONG fd: 0x5
      IN PVOID buf: 0x7f9f00
                              CR3:0x753da004, "apache2"
       IN ULONG count: 0x8
[SYSCALL] TIME: 1575115346.2099 CR3: 0x753da004, "apache2"
SYSCALL1 TIME: 1575115346.210
SYSCALL] TIME: 1575115346.238126 VCPU: 1 CR3: 0x6fc78005, "apache2" UID: 33
SYSCALL] TIME: 1575115346.238385 VCPU: 1 CR3: 0x6fc78005, "apache2" UID: 33
SYSCALL] TIME:1575115346.238598 VCPU:1 CR3:0x6fc78005, "apache2" UID:33
SYSCALL] TIME: 1575115346.238835 VCPU: 1 CR3: 0x6fc78005, "apache2" UID: 33
SYSCALL] TIME: 1575115346.239059 VCPU: 1 CR3: 0x753da004, "apache2" UID: 33
[SYSCALL] TIME:1575115346.239266 VCPU:1 CR3:0x753da004, "apache2" UID:33
[SYSCALL] TIME: 1575115346.239471 VCPU: 1 CR3: 0x753da004, "apache2" UID: 33
SYSCALL TIME: 1575115346.239675 VCPU: 1 CR3: 0x753da004, "apache2" UID: 33
```

# (2) Cyber Attack-Resilient Server

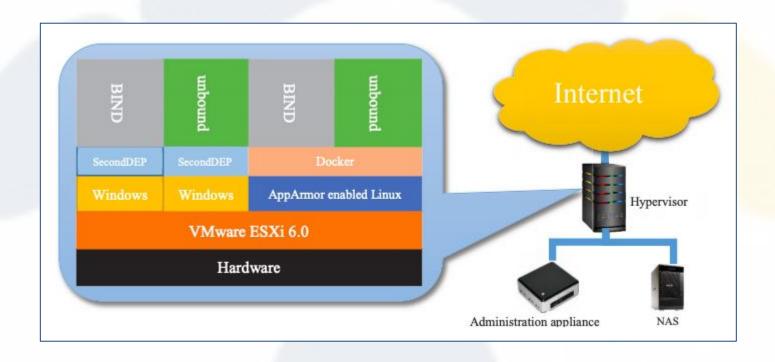


# CARS: System Design

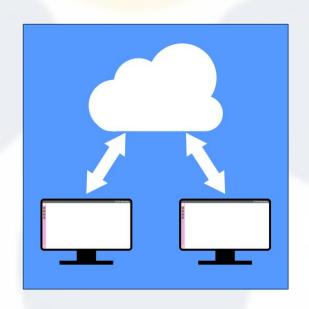




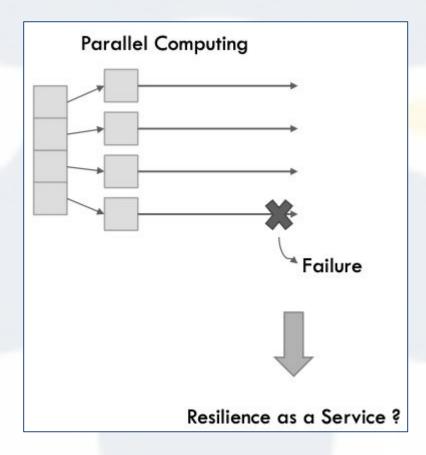
# CASR: Implementation



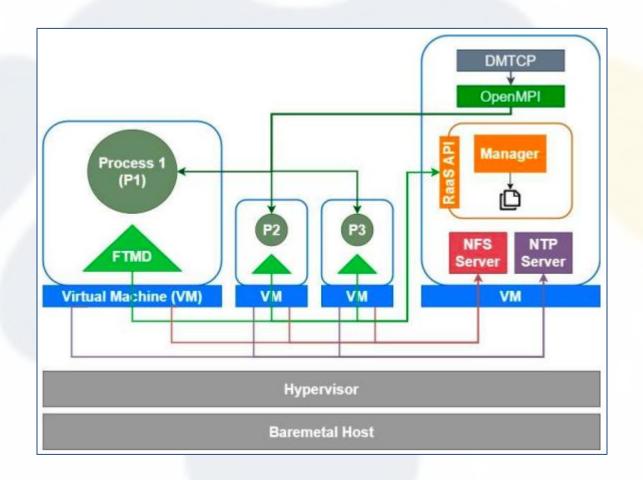
# (3) Resilient as a Service



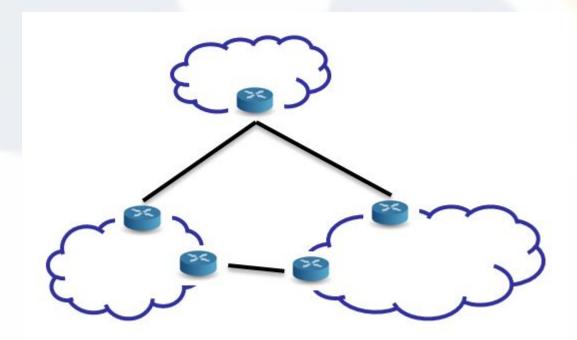
# RaaS: Background



# RaaS: System Design

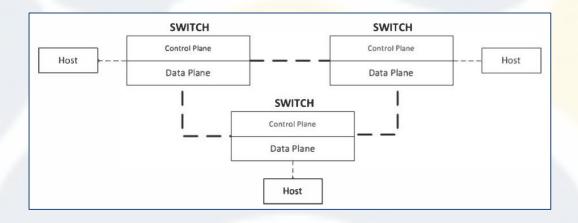


# (4) Resilient Software Defined-Networking

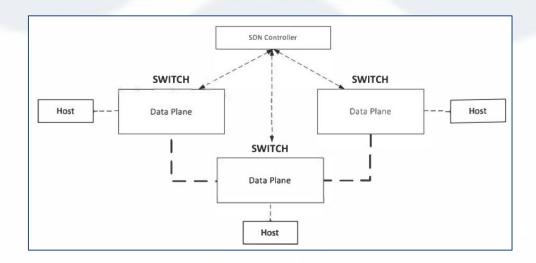


#### Resilient SDN

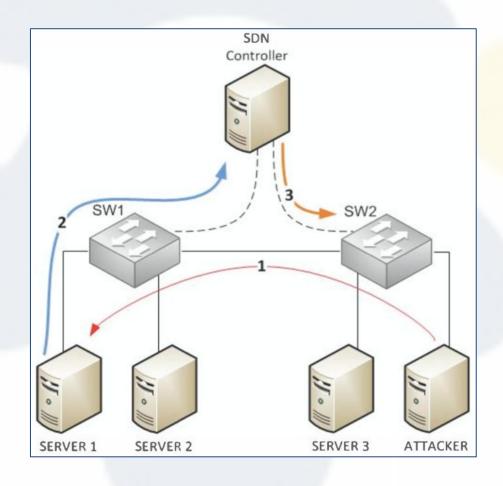
• Traditional network



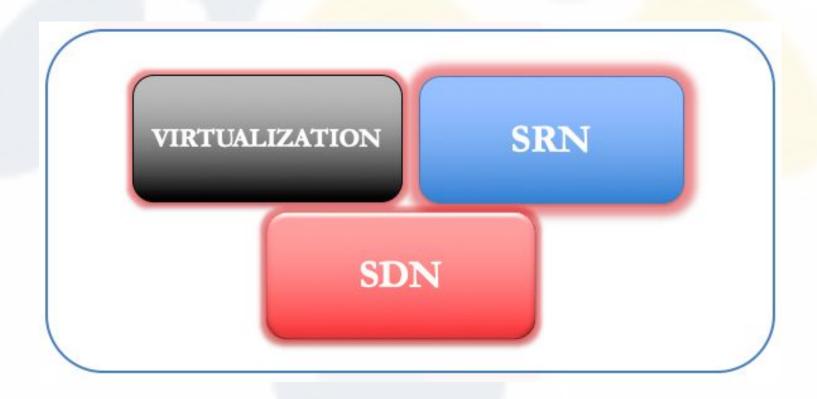
• SDN



#### Resilient SDN



#### Resilient SDN+





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#### **Thanks**