Towards Correct Network Virtualization

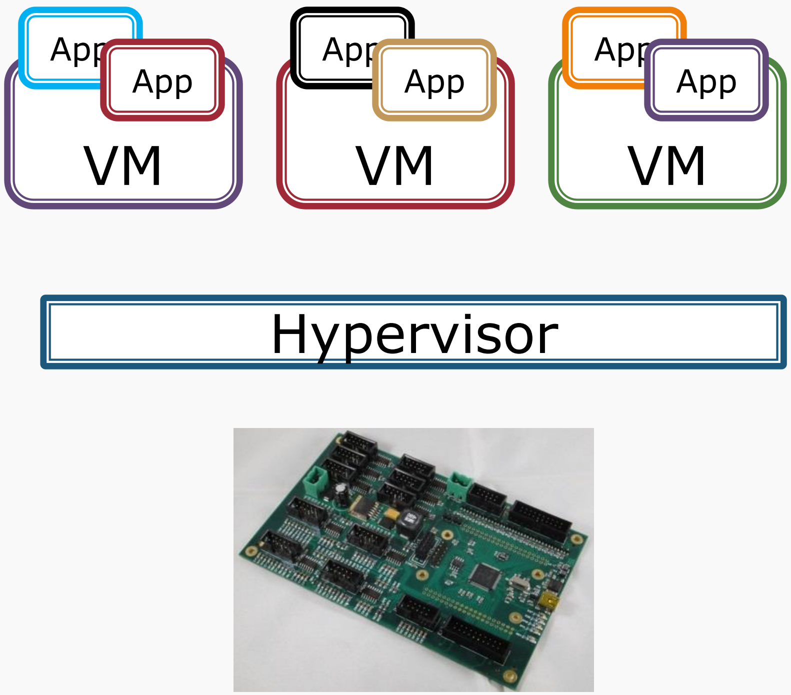
Soudeh Ghorbani

Brighten Godfrey

UIUC

HotSDN 2014

Virtualization



x86

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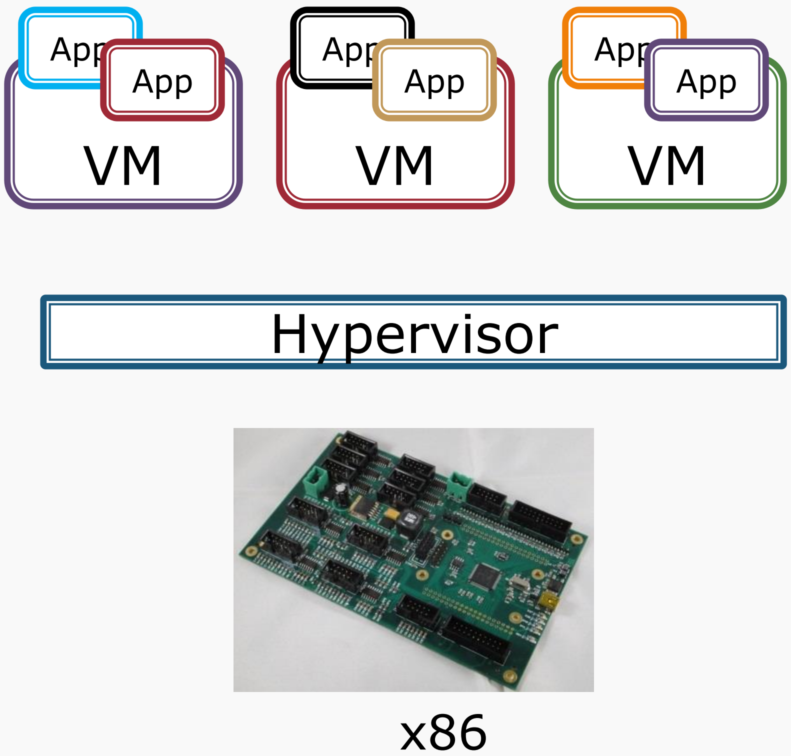

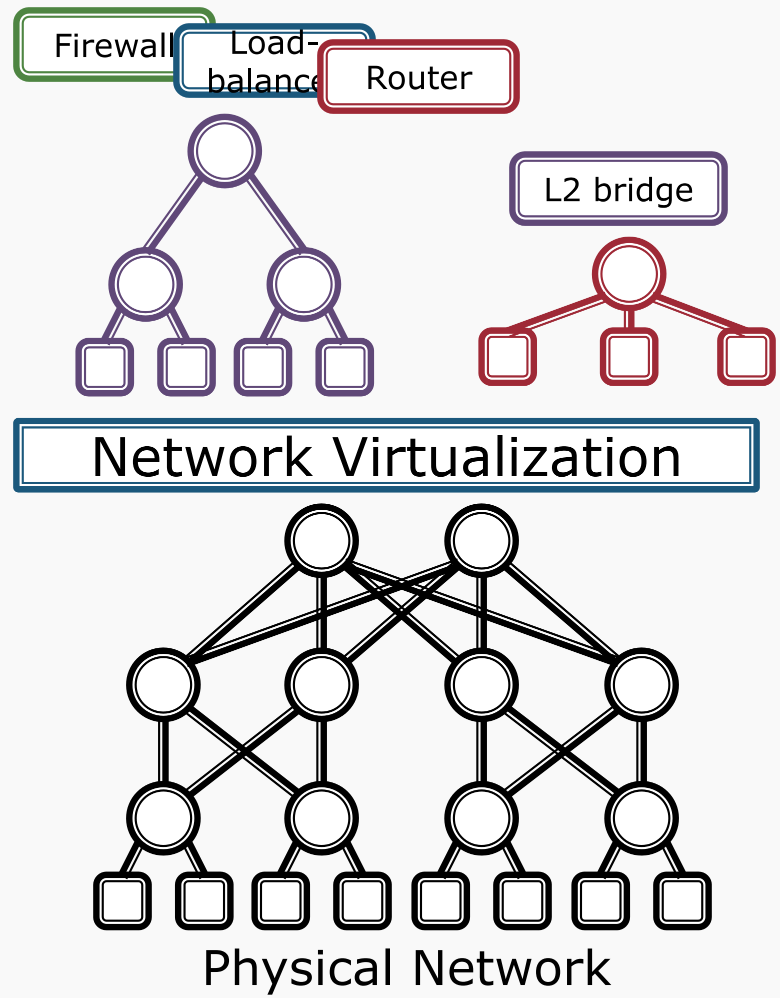

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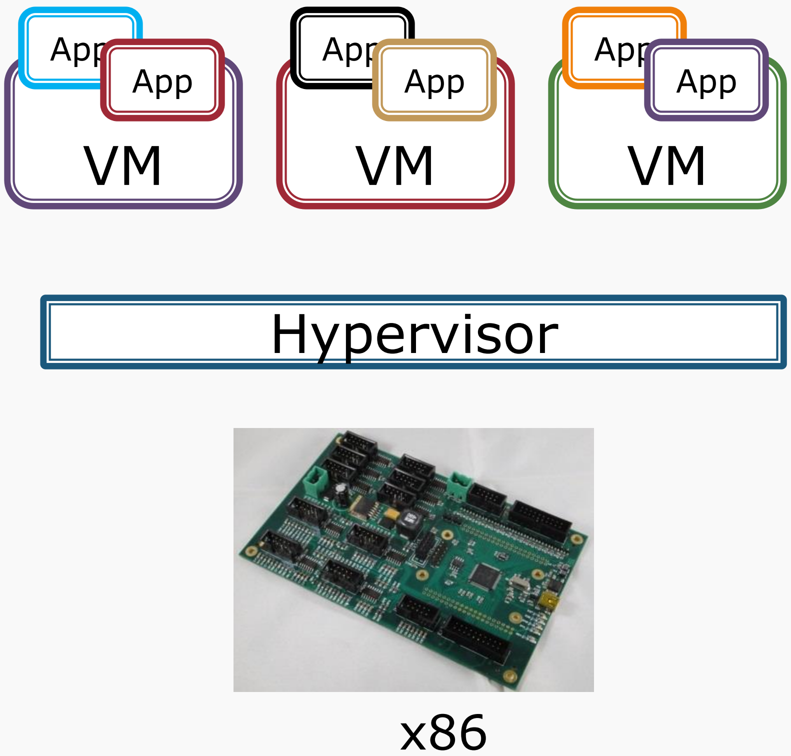


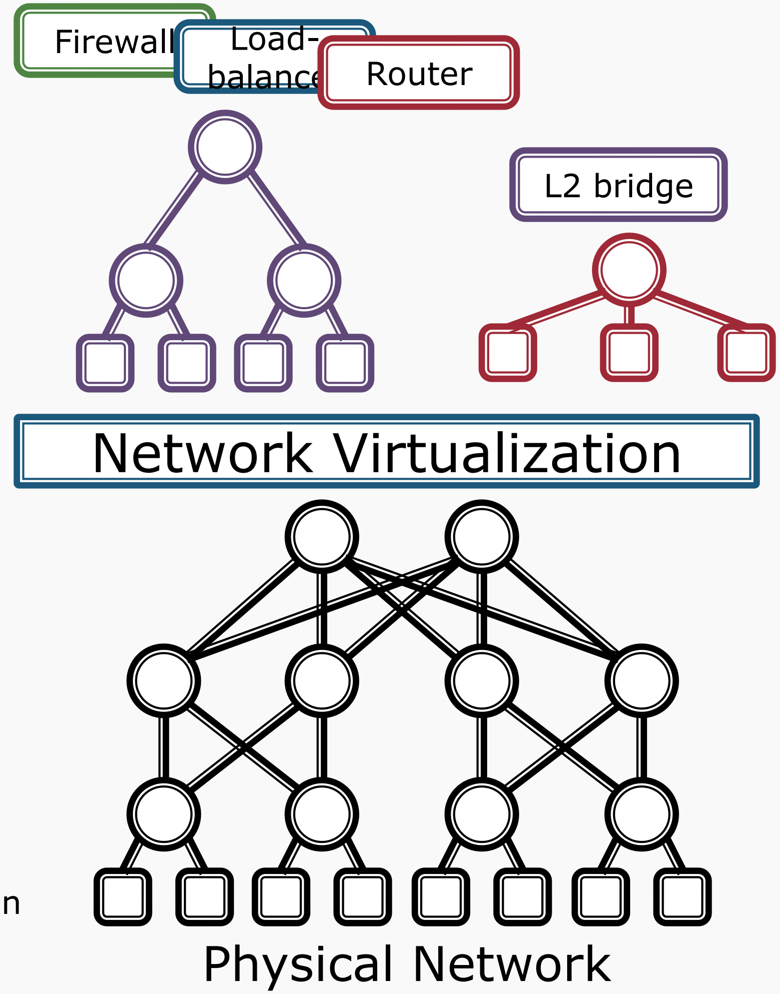
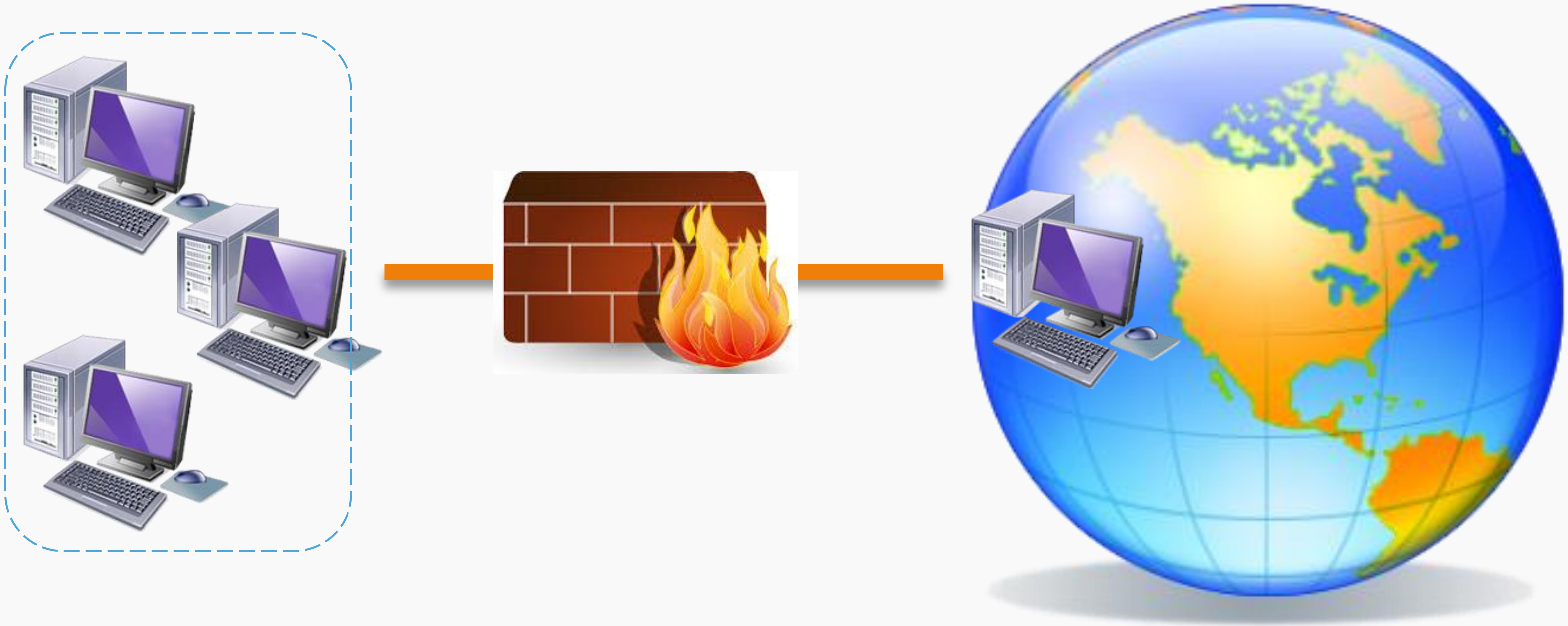


Diagram inspired by Teemu Koponen's NSDI 2014 talk on "*Network Virtualization in Multi-tenant Datacenters*".

Is the physical implementation a faithful reproduction of the virtual network?

Virtual firewall



Policy: permit an external server to talk to an internal client if and only if the client has sent a request to the server.

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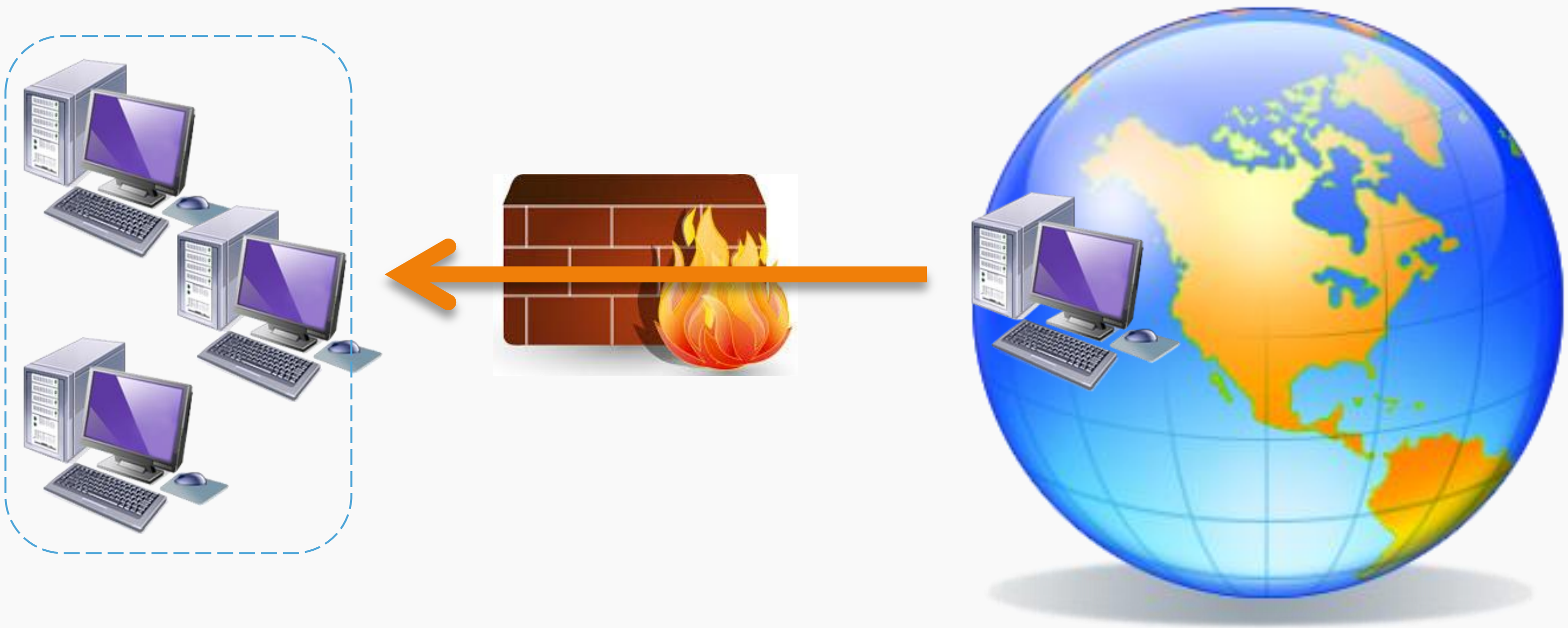

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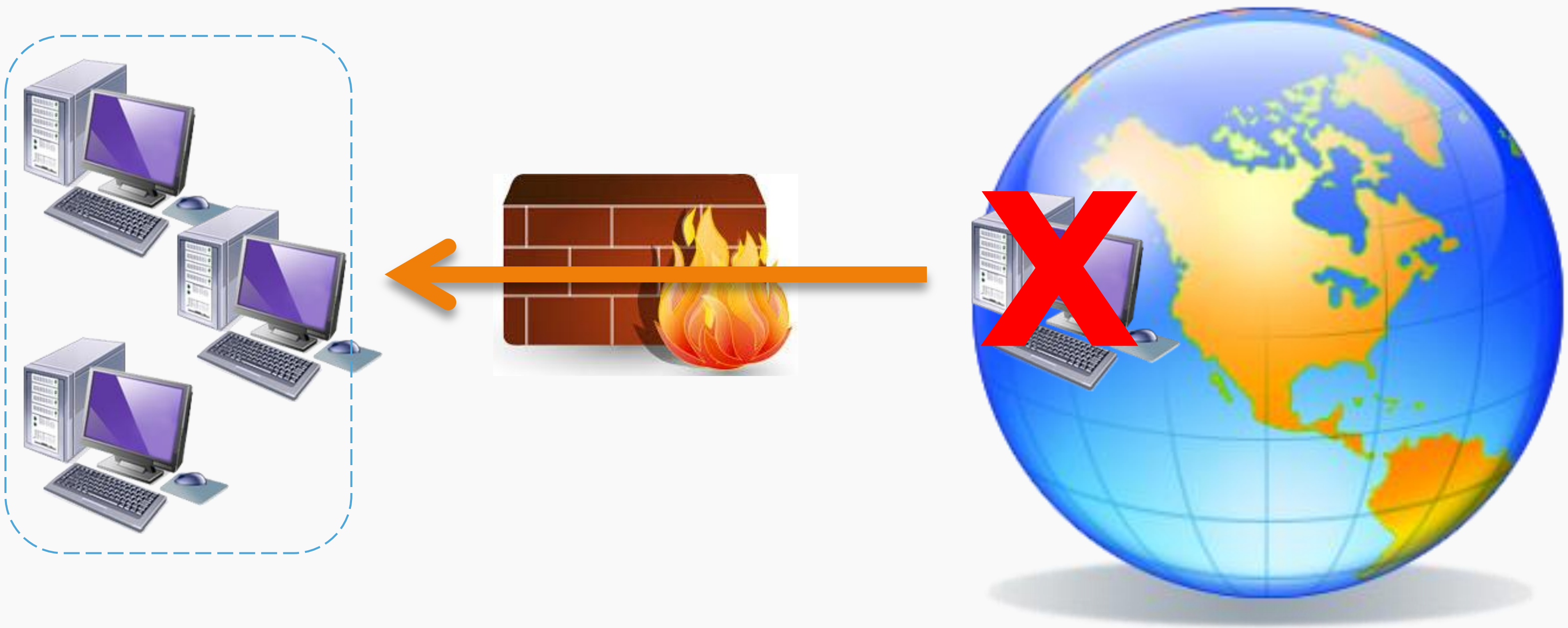

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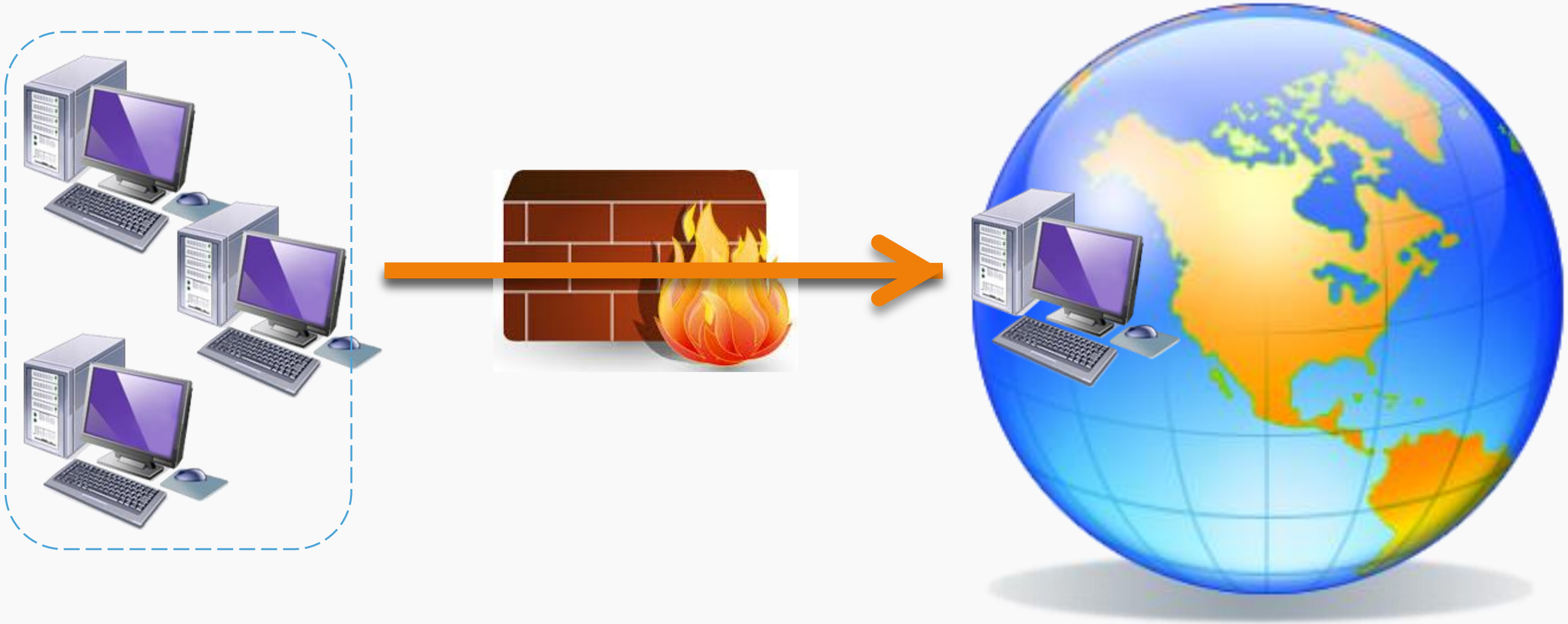

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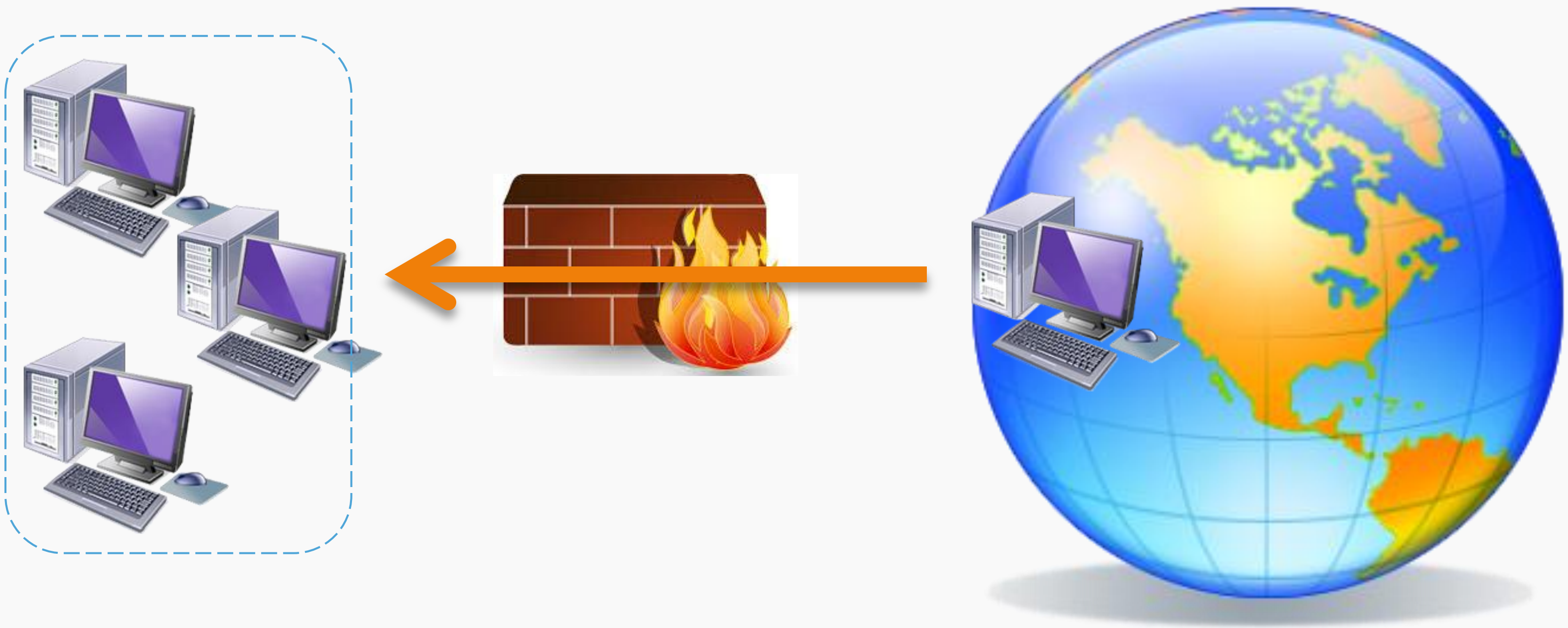

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Virtual firewall app

Firewall Switch

Prio rity	Flow	Action
10	srcip=130.126.*.*	Send to controller, fwd(1)
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(Part of the) Firewall Controller App

```
switch(msg.getType()) {
   case PACKET_IN:
      if ( internal.contains(msg.srcMAC()) ) {
         whitelisted[msg.dstMAC()][msg.srcMACA()] = true;
       }else {
          if (whitelisted[msg.srcMAC()][msg.dstMAC()] ){
             whitelist(sw, msg);
          }else{
              blacklist(sw, msg);
          }
      }
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Virtual firewall app

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Packet-in from an internal client? Save state: dst server is allowed to send back.

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Packet-in from an external server?

- If the server is allowed to send, install rules to allow bidirectional traffic.
- Else, blacklist the external server.

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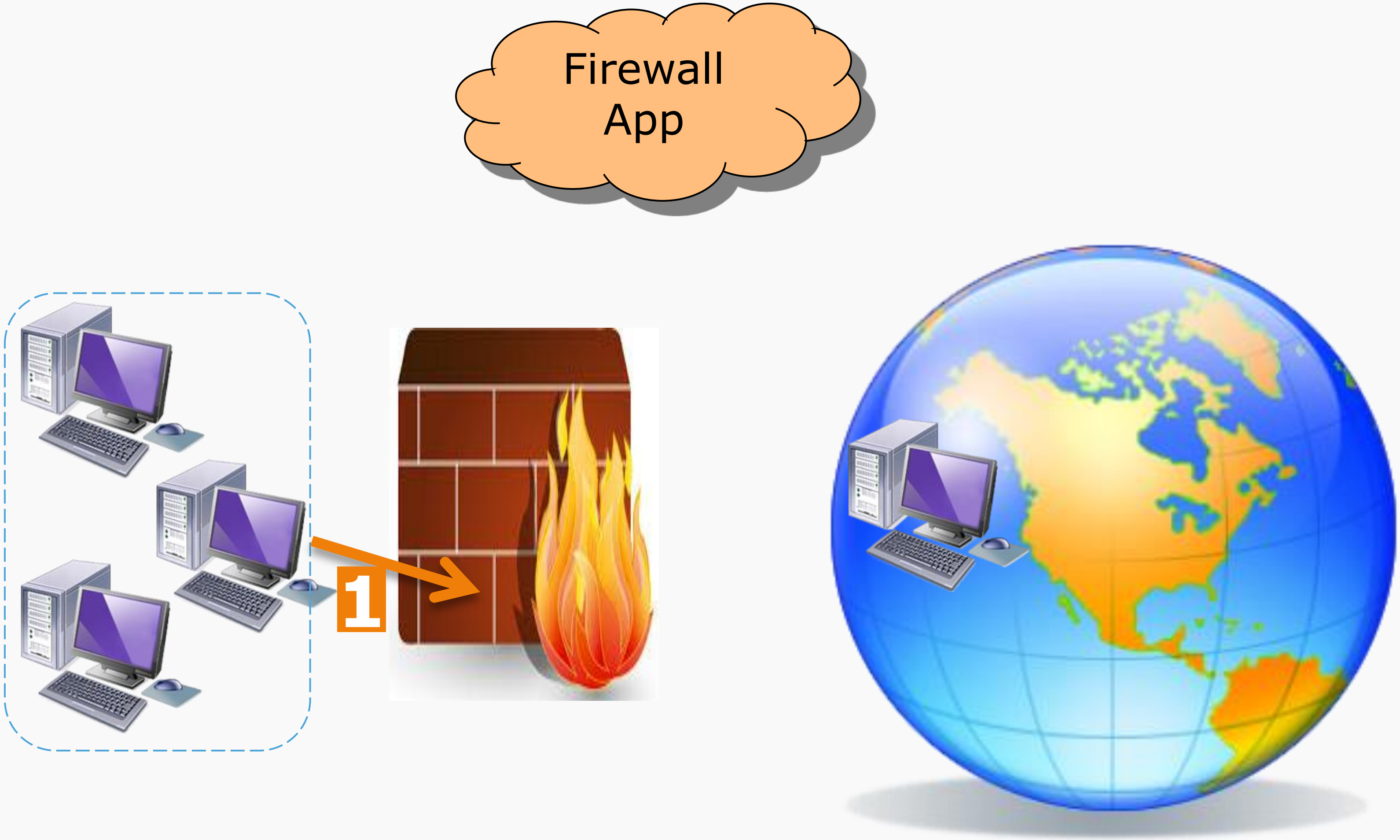

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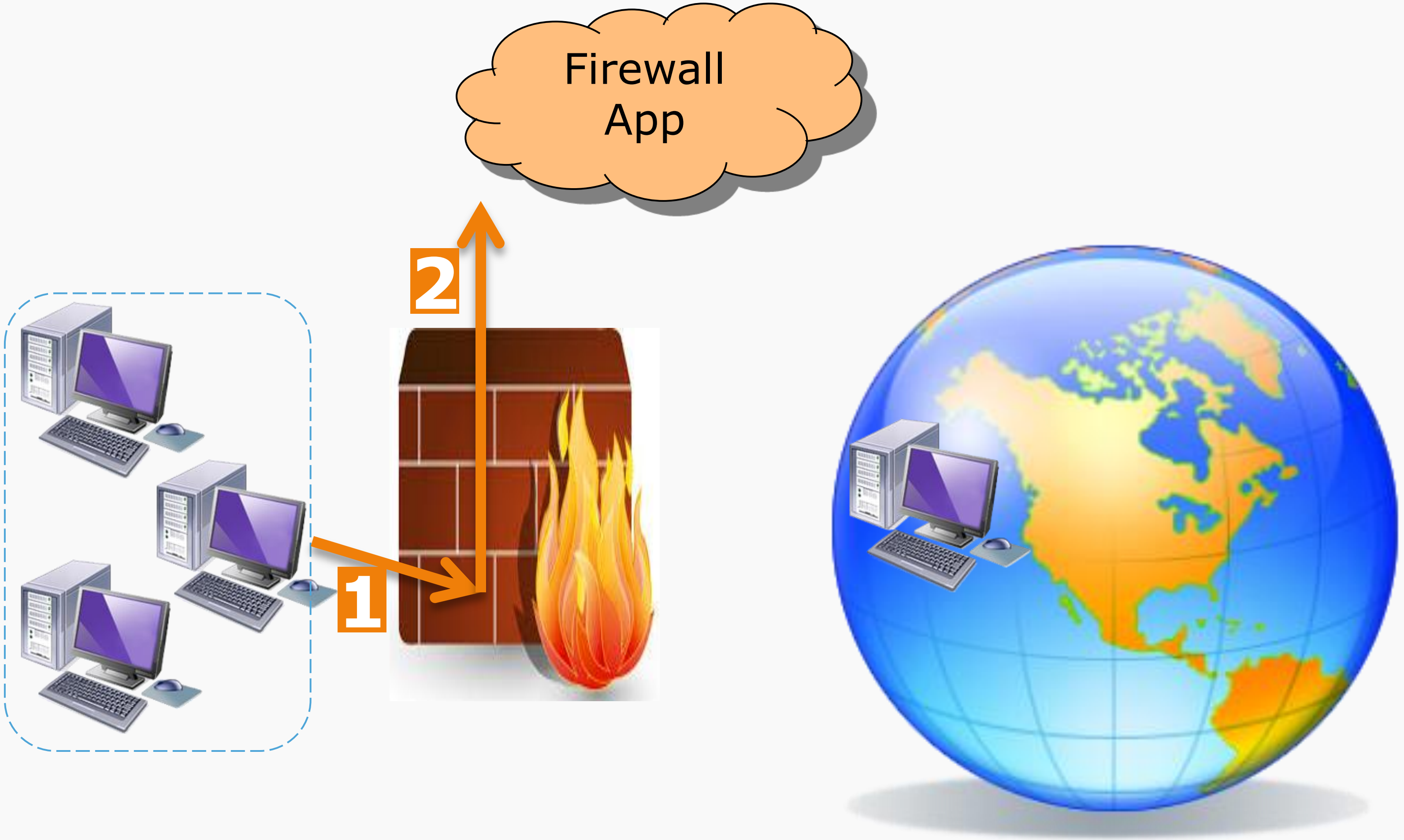

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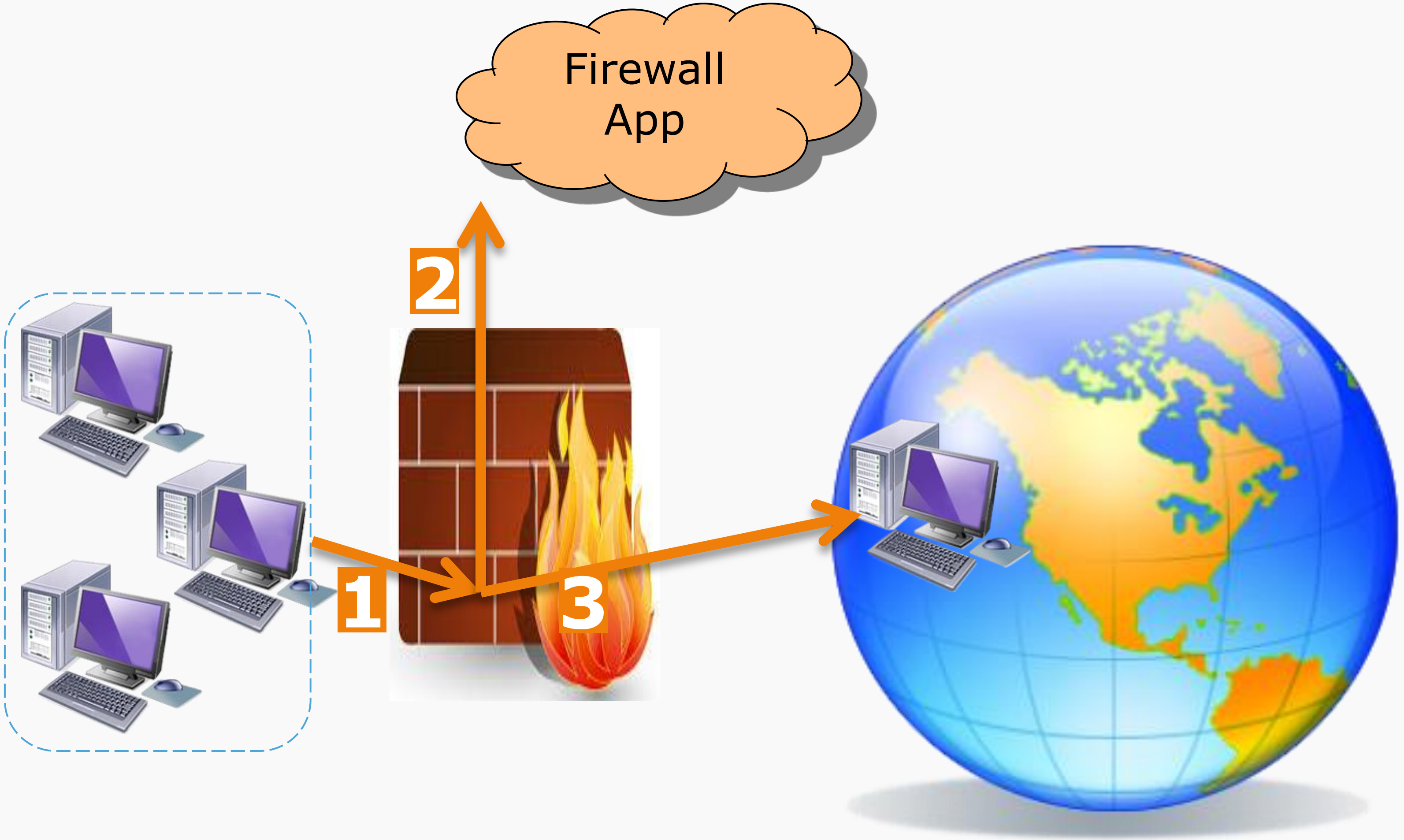

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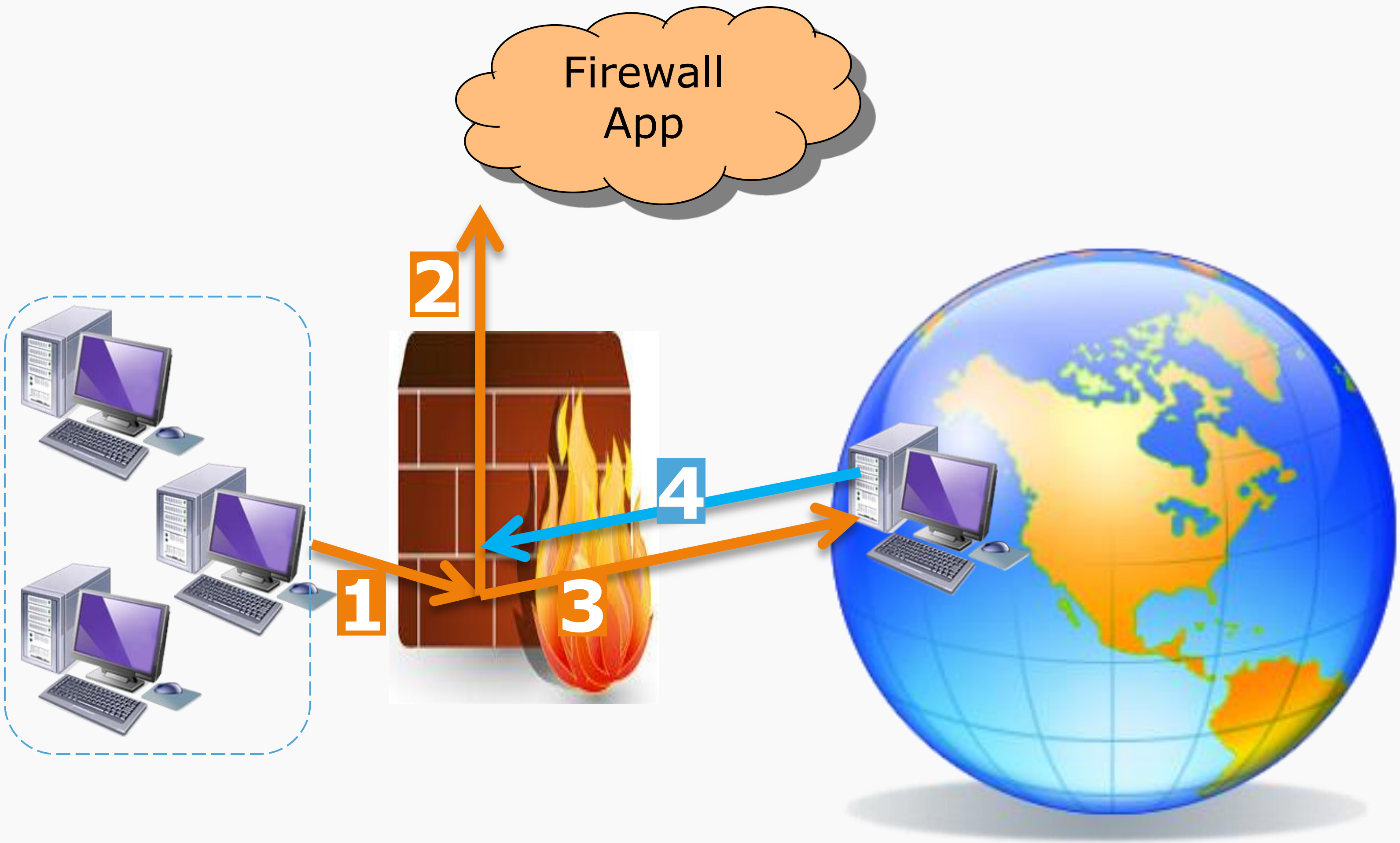

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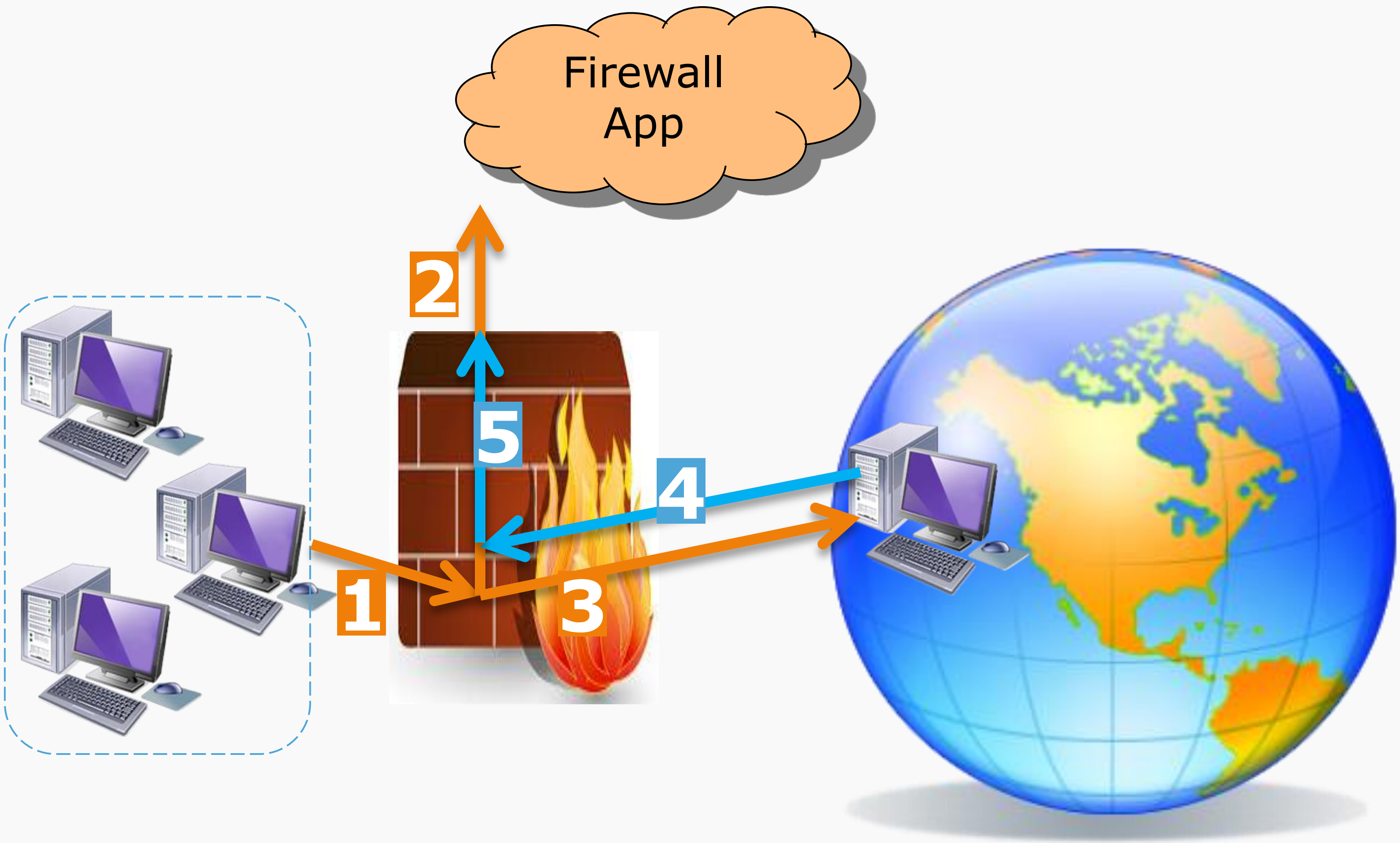
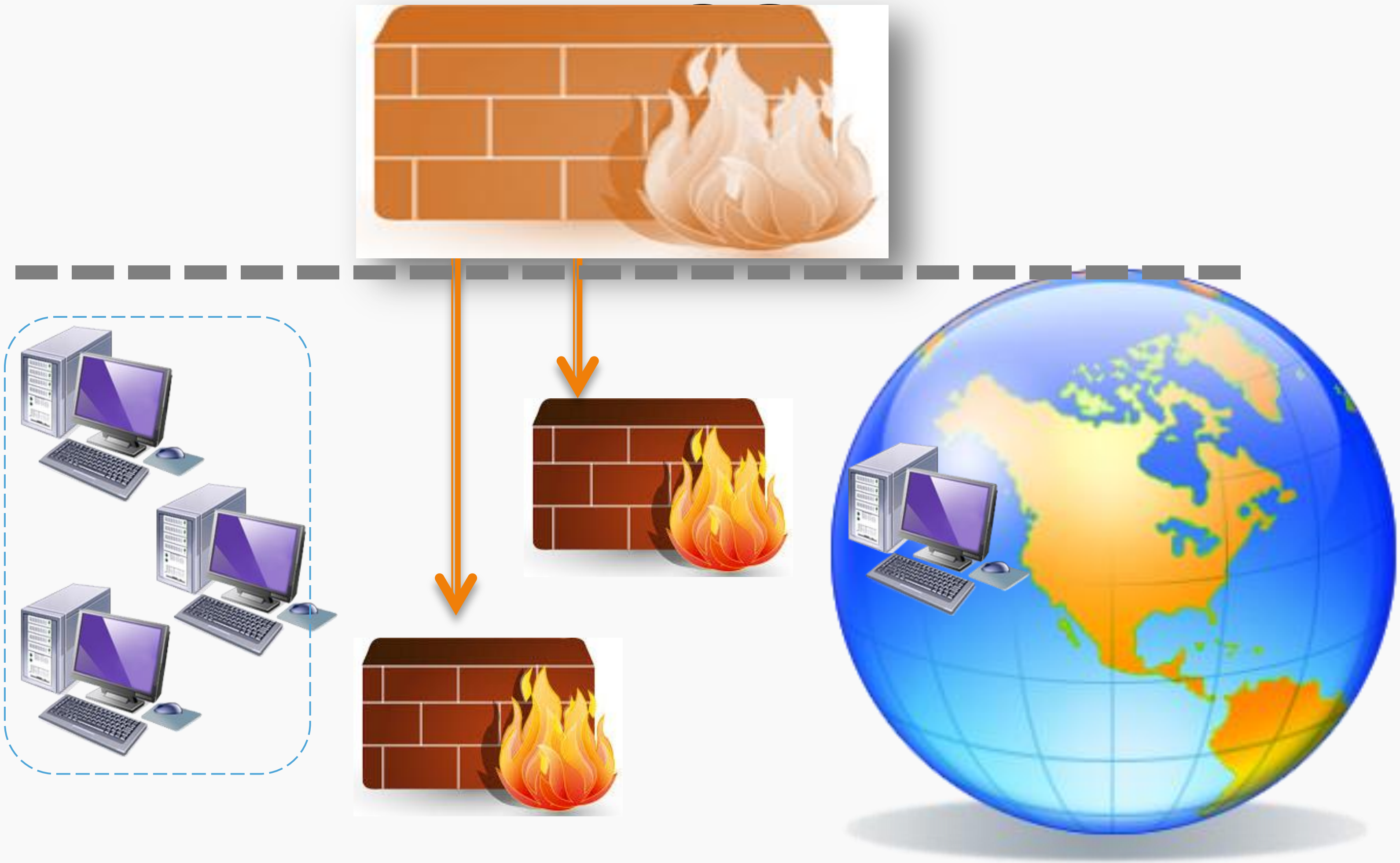


Firewall + virtualization = bug



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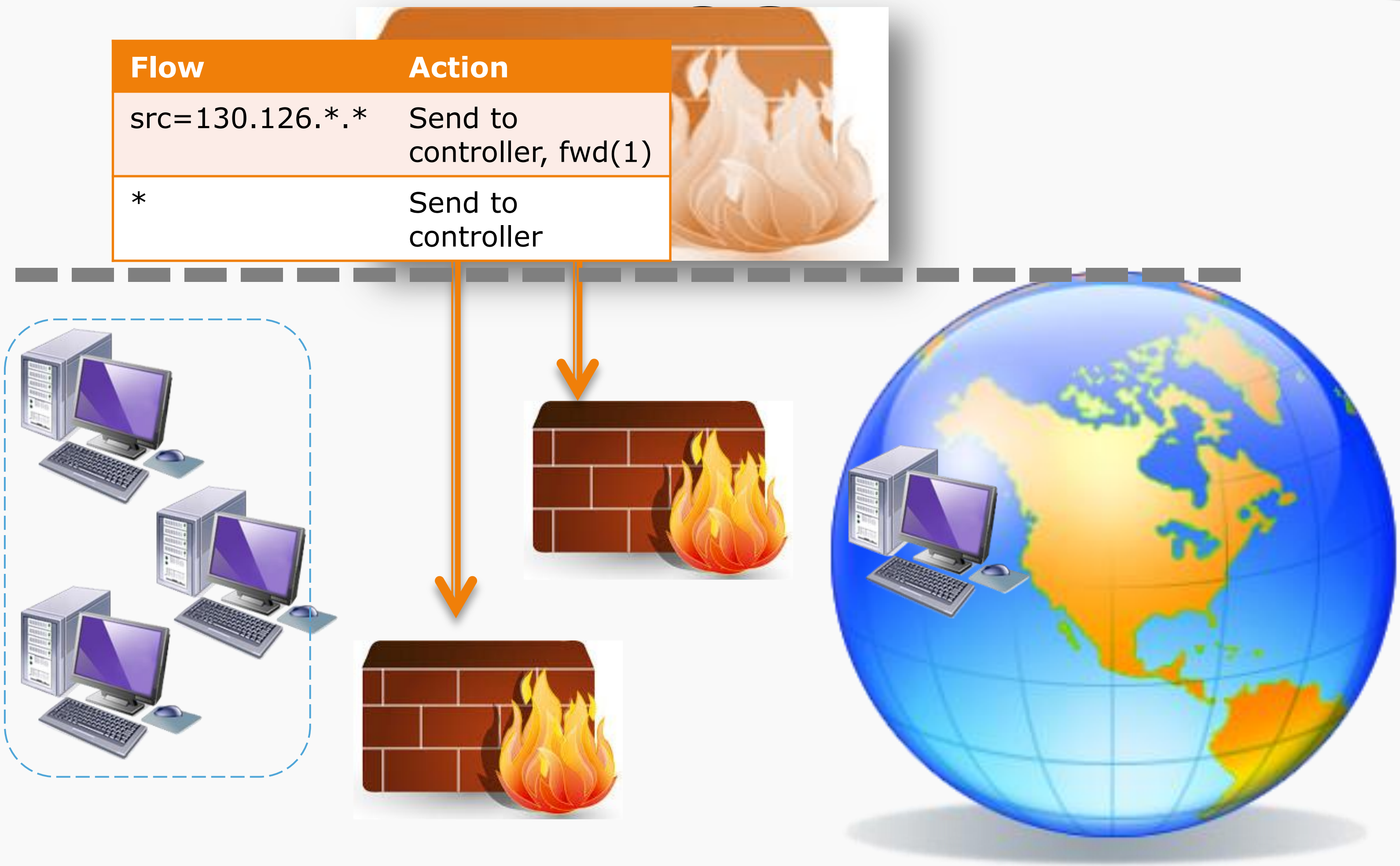

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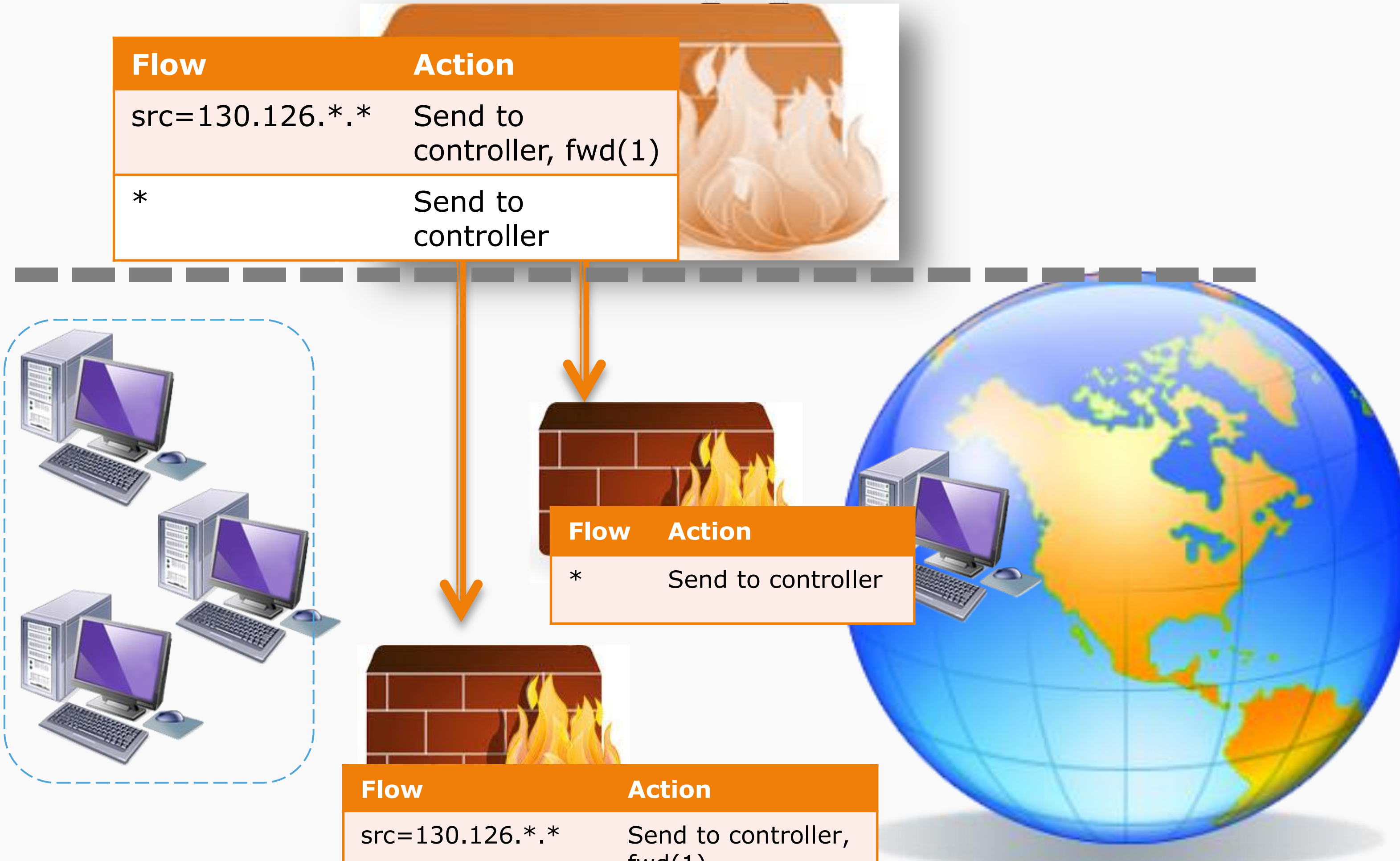

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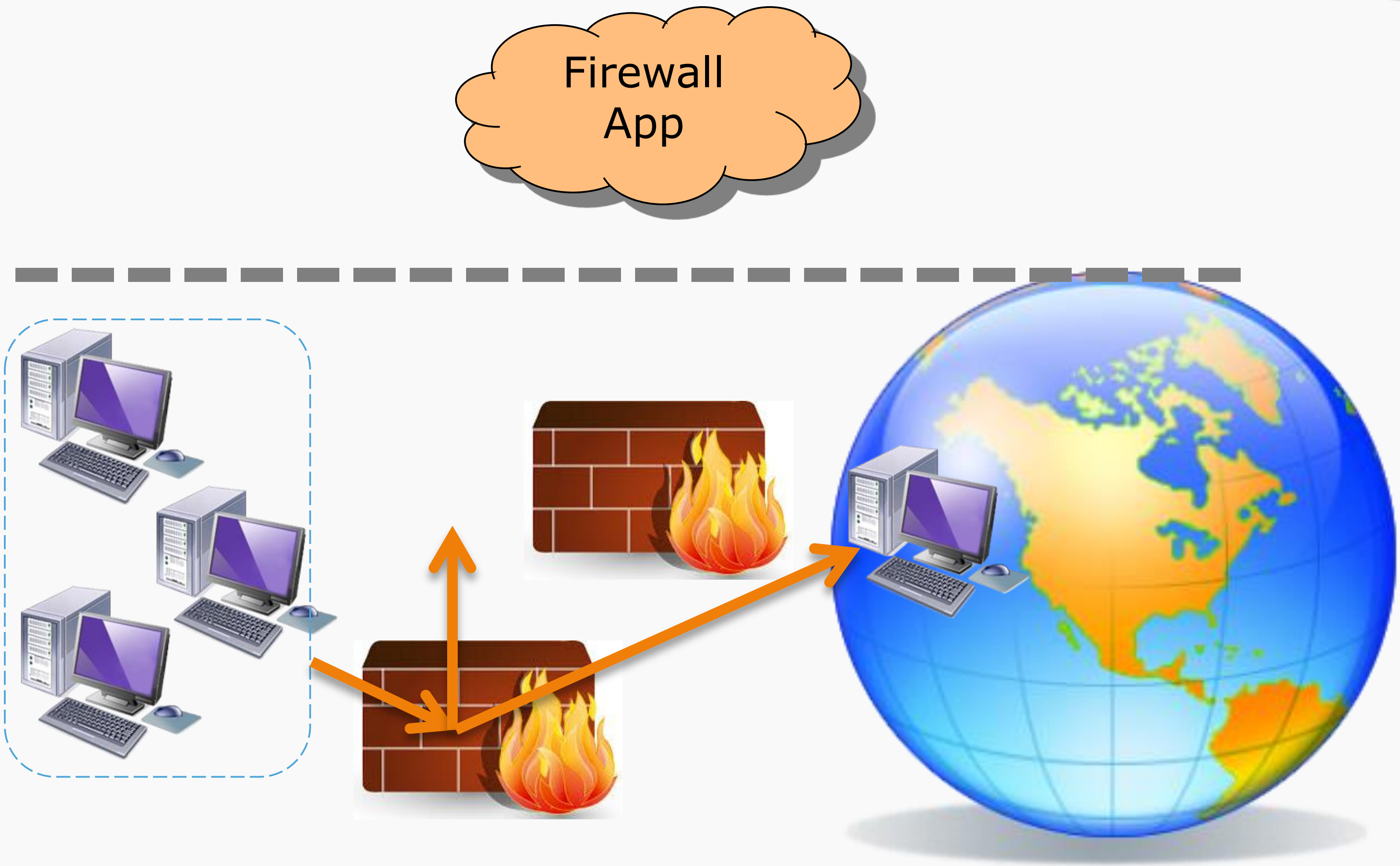

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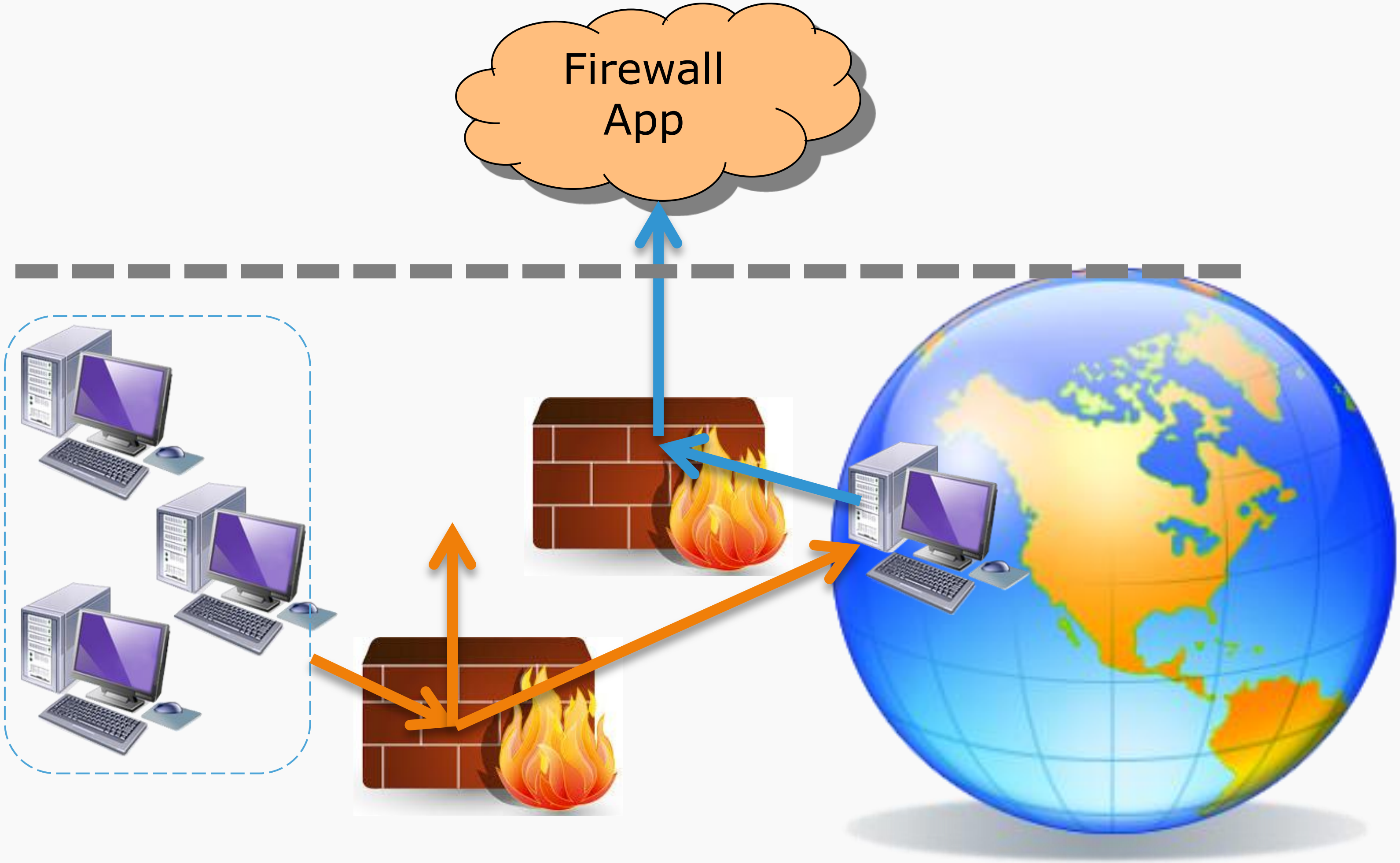

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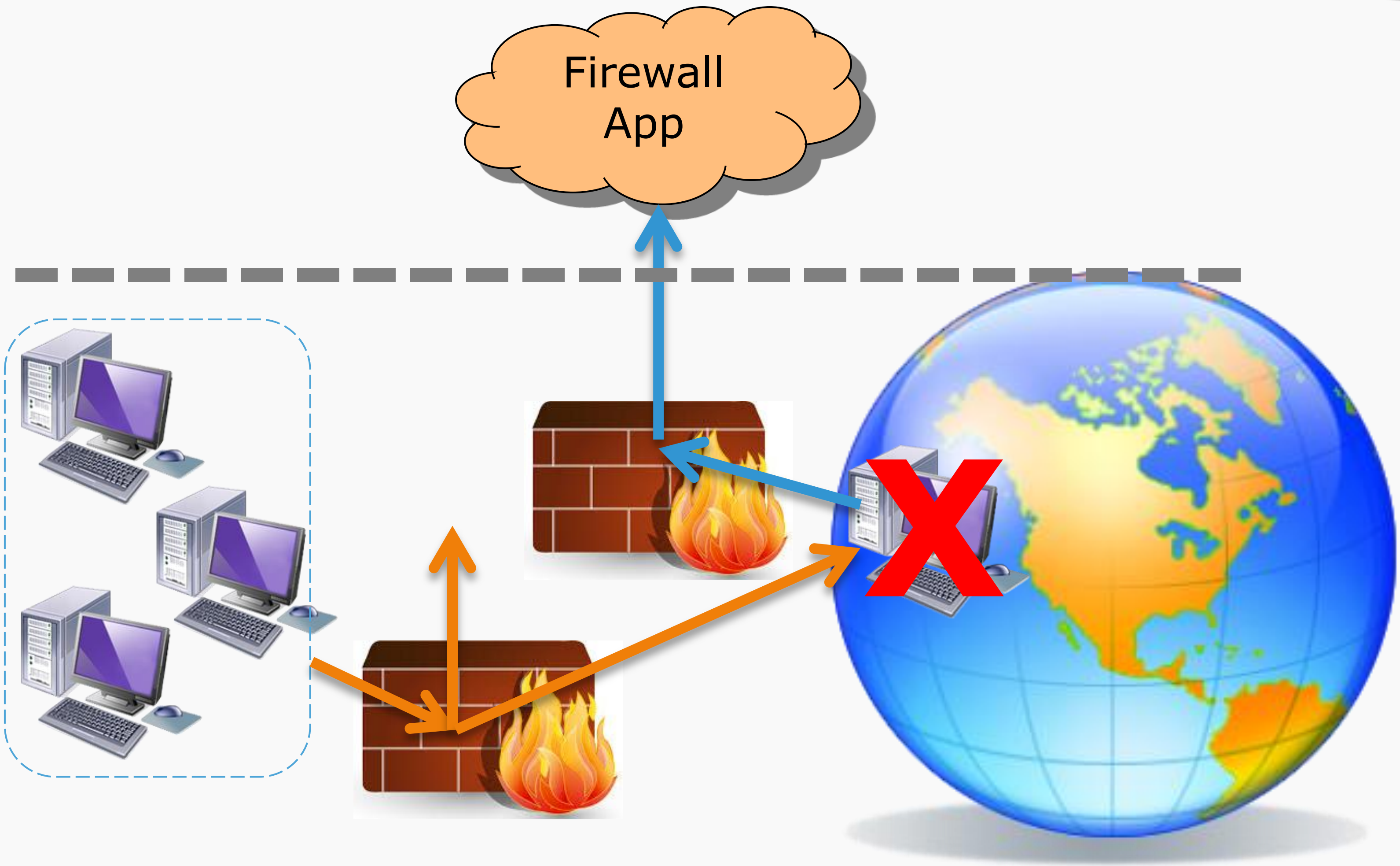

Network virtualization: What could go wrong?

App	Virtualization technique	Incorrect-behavior
Stateful firewall	One-to-many mapping	Blacklisting the legitimate hosts
NAT	One-to-many mapping	Dropping requested packets
Load-balancer	One-to-many mapping	Overloading some servers and leaving some underutilized
Firewall & router	Many-to-one mapping	Blacklisting the legitimate hosts

Related work

- Incorrect behavior caused by moving, observed in:
    1. *"LIME: Transparent, Live Migration of a Software-Defined Network"*, Soudeh Ghorbani, Cole Schlesinger, Matthew Monaco, Eric Keller, Matthew Caesar, Jennifer Rexford, David Walker, under submission.
    2. *"OpenNF: Enabling Innovation in Network Function Control"*, Aaron Gember-Jacobson, Raajay Viswanathan, Chaithan Prakash, Robert Grandl, Junaid Khalid, Sourav Das, Aditya Akella, SIGCOMM 2014.
- These existing solutions are:
    - Only a short-term fix while virtual network is being moved.
    - Infeasible when incorrect behavior is permanent rather than transient.

Root-cause of the incorrect behavior

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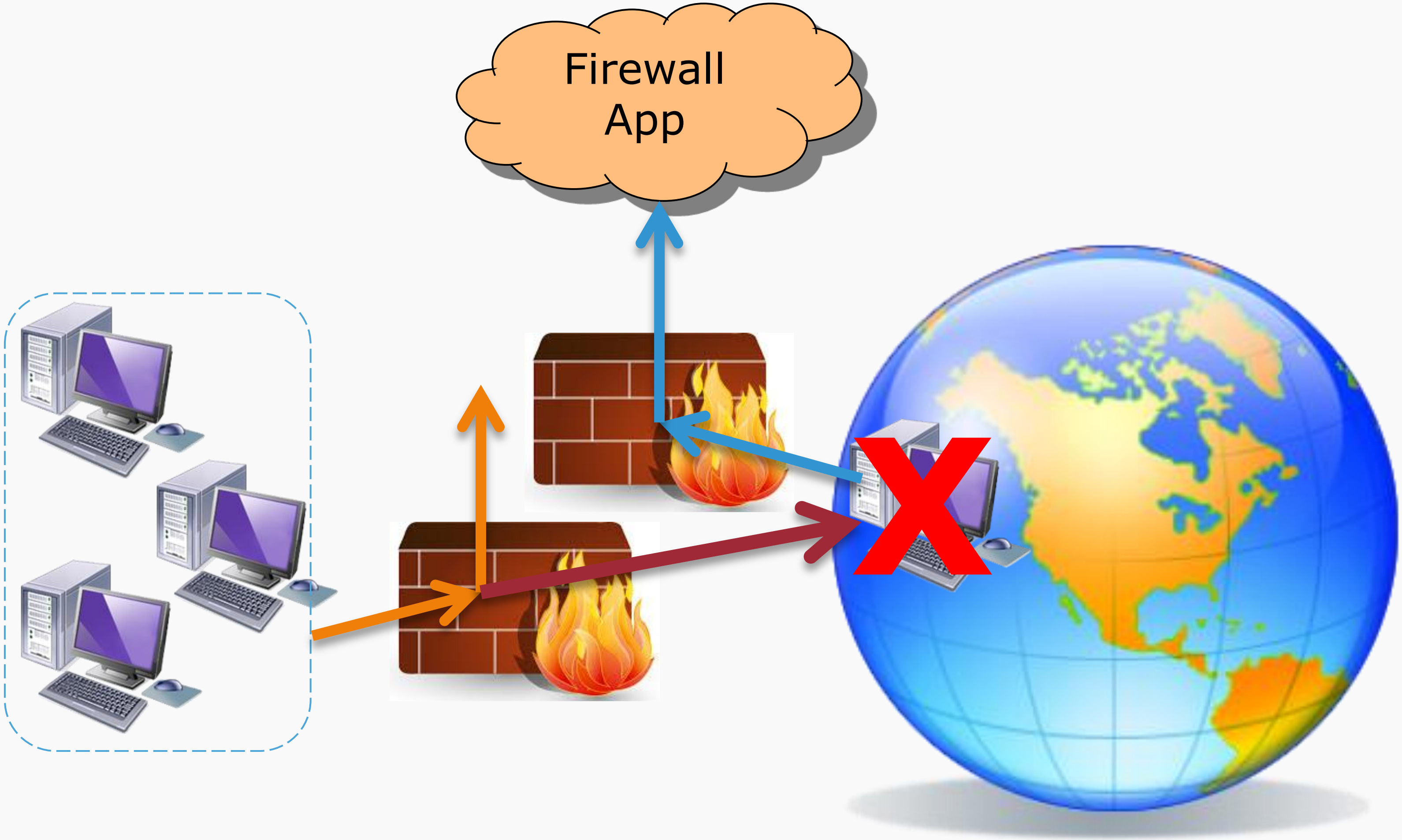

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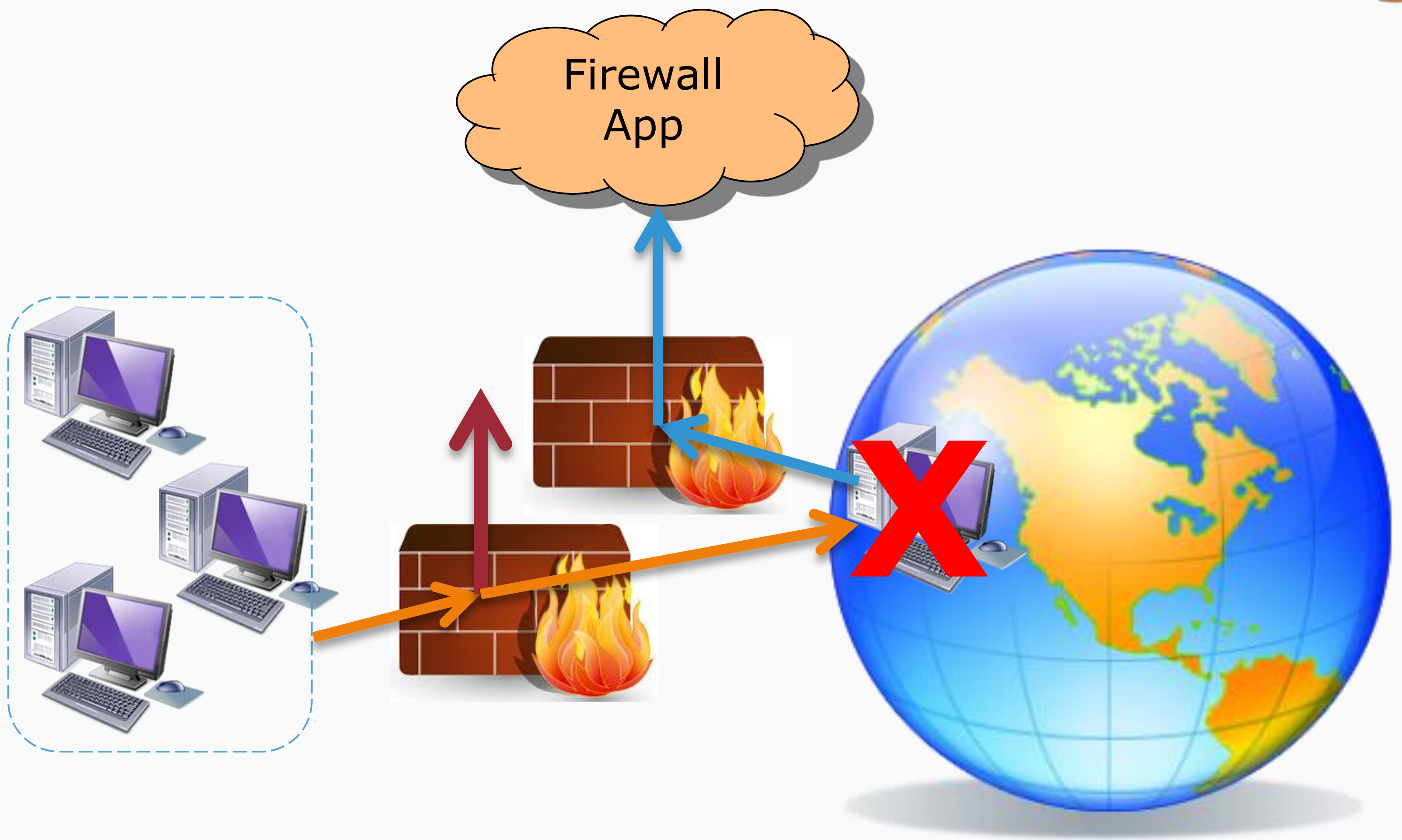

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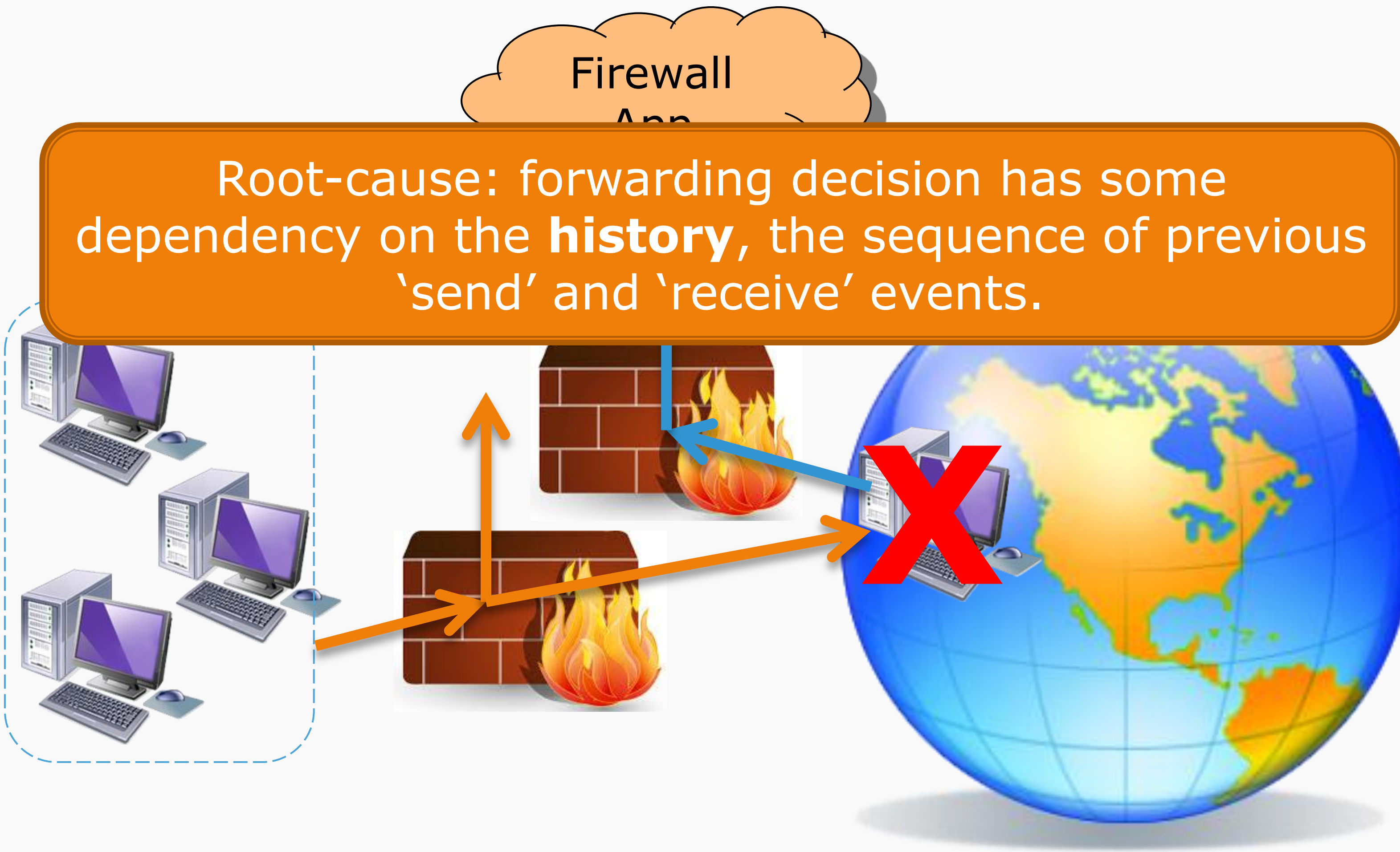

Root-cause: forwarding decision has some dependency on the **history**, the sequence of previous 'send' and 'receive' events.

Who programs the network?

- The entities that can make or influence the forwarding decisions:
  - **Controller**
  - **Switch**: random forwarding like ECMP
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Can existing correctness definitions detect the incorrect behavior?

Correctness conditions:

1. Per-packet/flow consistency: prevents loops, black-holes,…

   Consensus Routing [NSDI'08], Consistent Updates [SIGCOMM'12]

2. Congestion freedom

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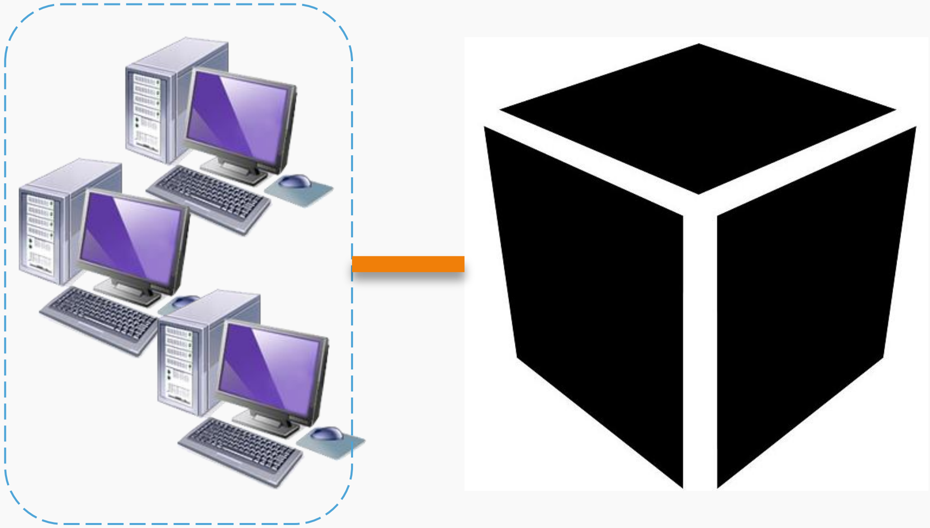
4 We need **new definitions of correctness** and **new techniques** to achieve those.

A new correctness condition: End-to-end correctness



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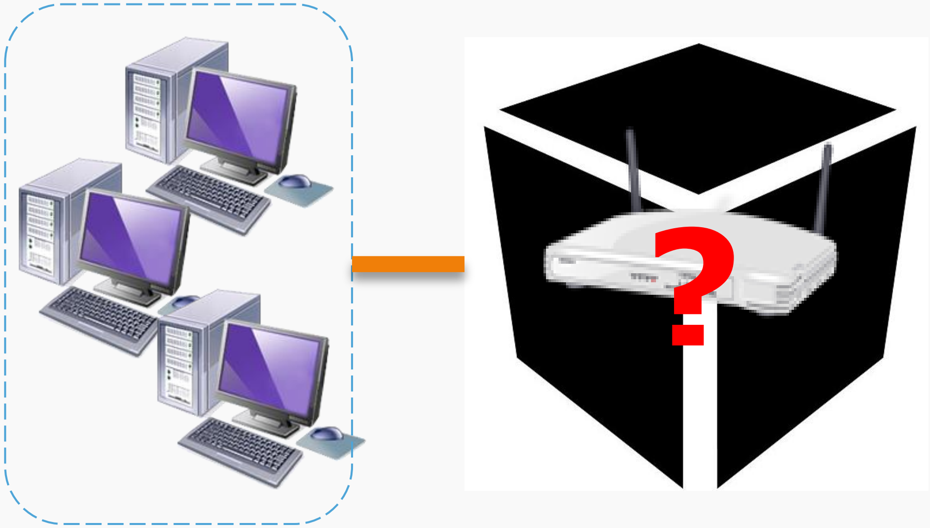

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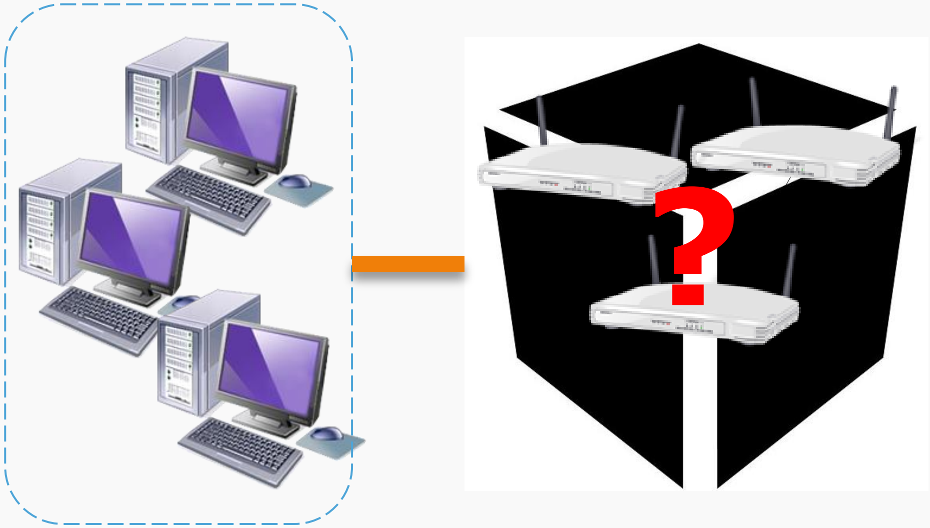

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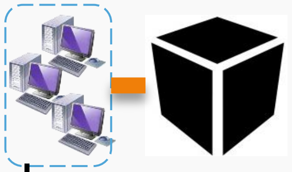

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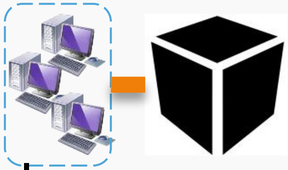

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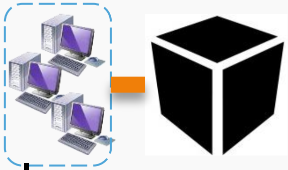

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  - distinguishes between events that happen **always**, **sometimes**, and **never**.
  - permissive of the **differences in packet loss or timing** that do not affect correctness.
  - permissive of the **legitimate differences in orderings** of events.

So far:

1 We identified the **problem:** incorrect application-level behavior under the existing virtualization techniques.

2 We identified its **root-cause:** dependence on the history.

3 We developed an analytical **framework** to reason about the problem.

Research Vision:

Developing a general **algorithm.** 4

Proving its **correctness.** 5

Developing a correct virtualization **System.** 6

Thanks!

Questions?