Fast Transparent Virtual Machine Migration in Distributed Edge Clouds

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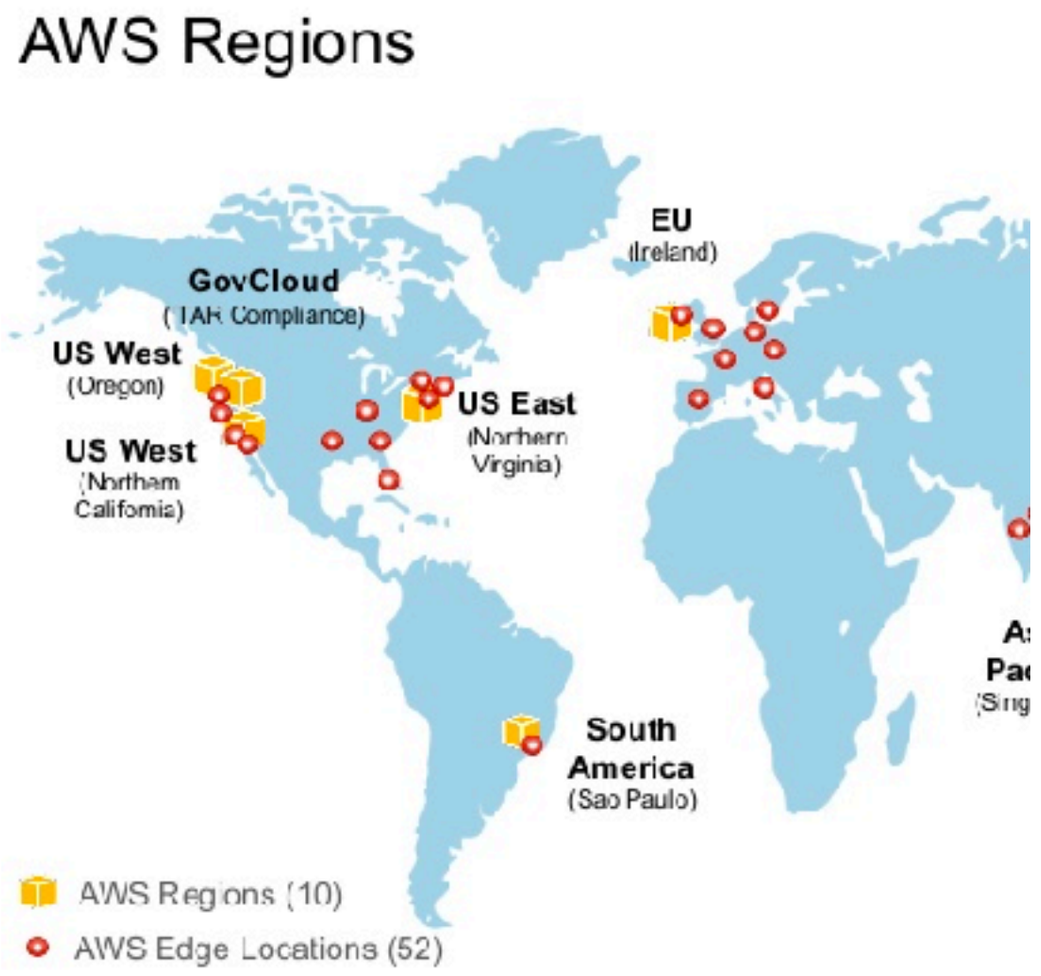
UMASS AMHERST

IBM Research

Cloud Computing

- Modern applications are deployed in centralized data centers.
- Few locations each with lots of servers.
- Benefits:
  - Easy to deploy and scale applications
- Limitations:
  - High Latencies
  - Low WAN Bandwidth

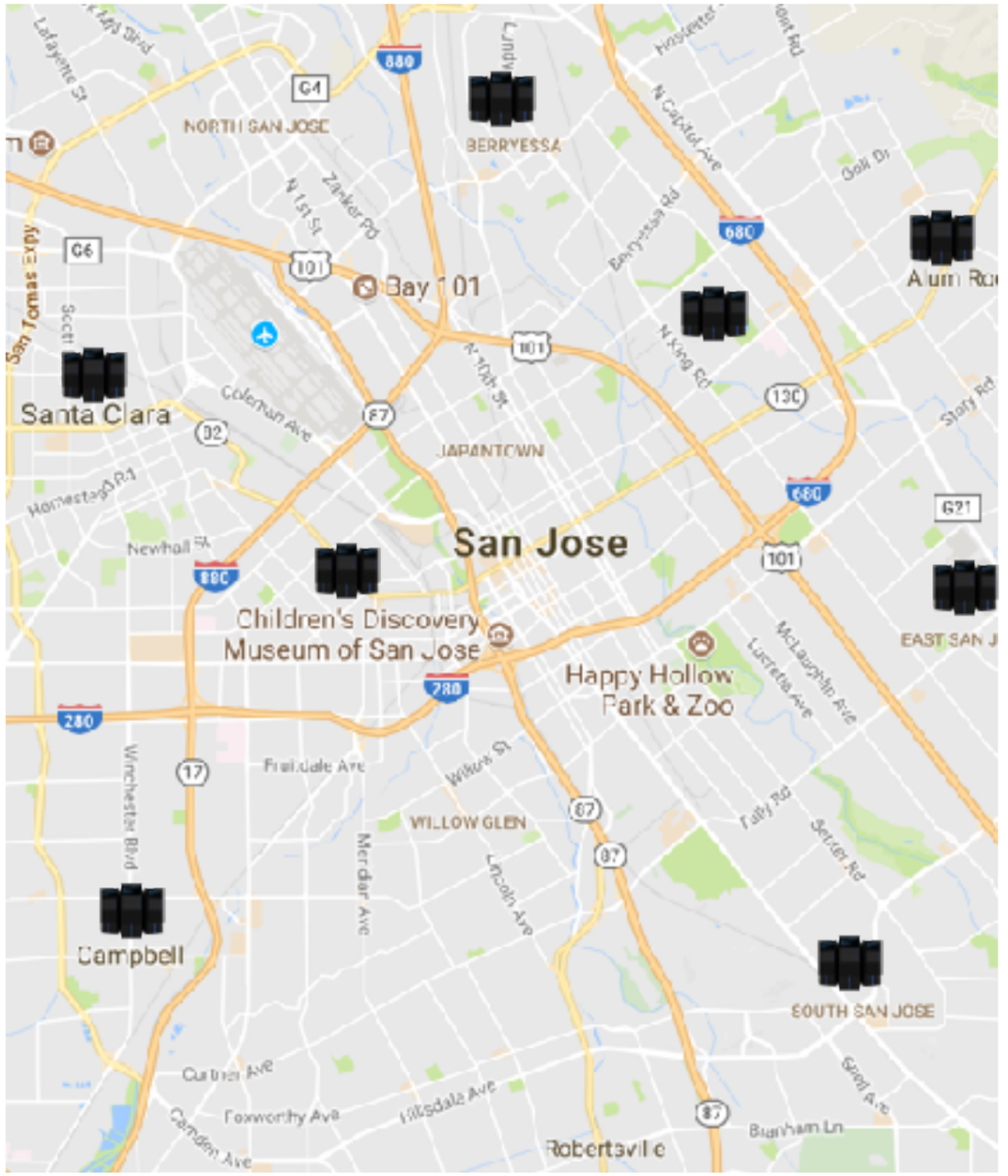


Edge Clouds

- Paradigm where servers are located at the edge rather than remote data centers.

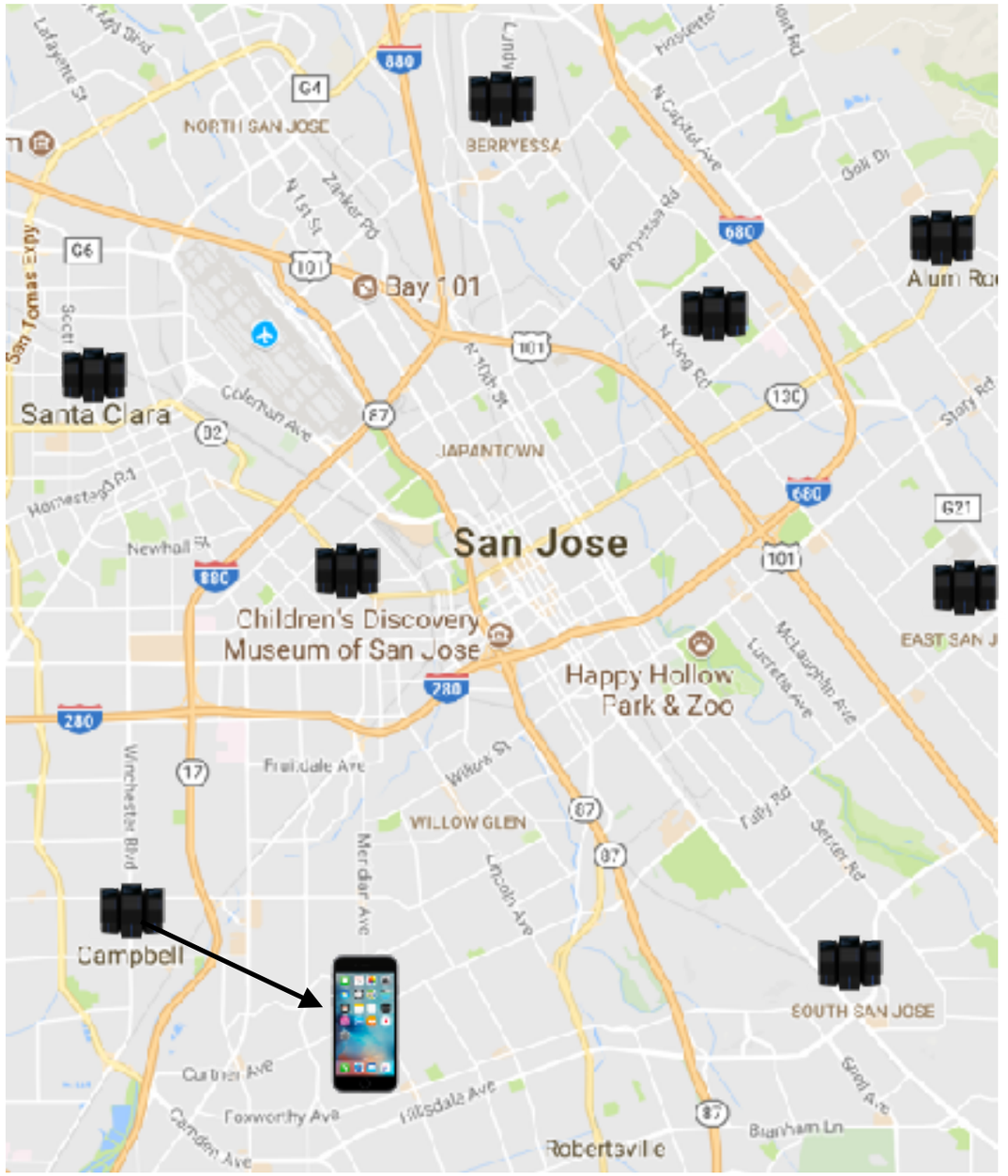
- Lots of locations each with few servers.

- Allows you to host applications closer to users with lower latencies.



Edge Clouds

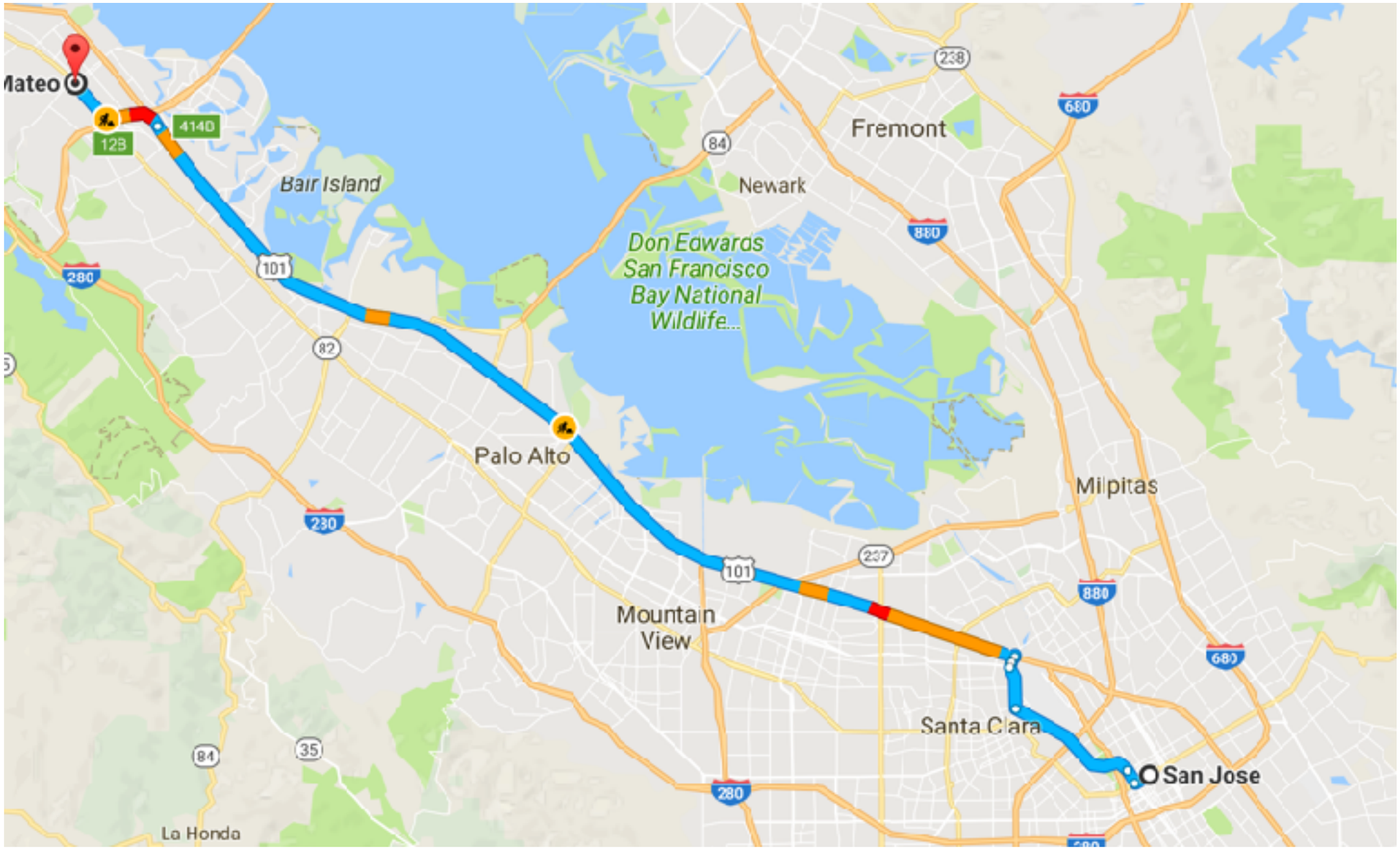
- Users increasingly mobile
- User mobility implies Latency increase
- Potential Solution: Migrating workloads to the closest site.



Meet Alice

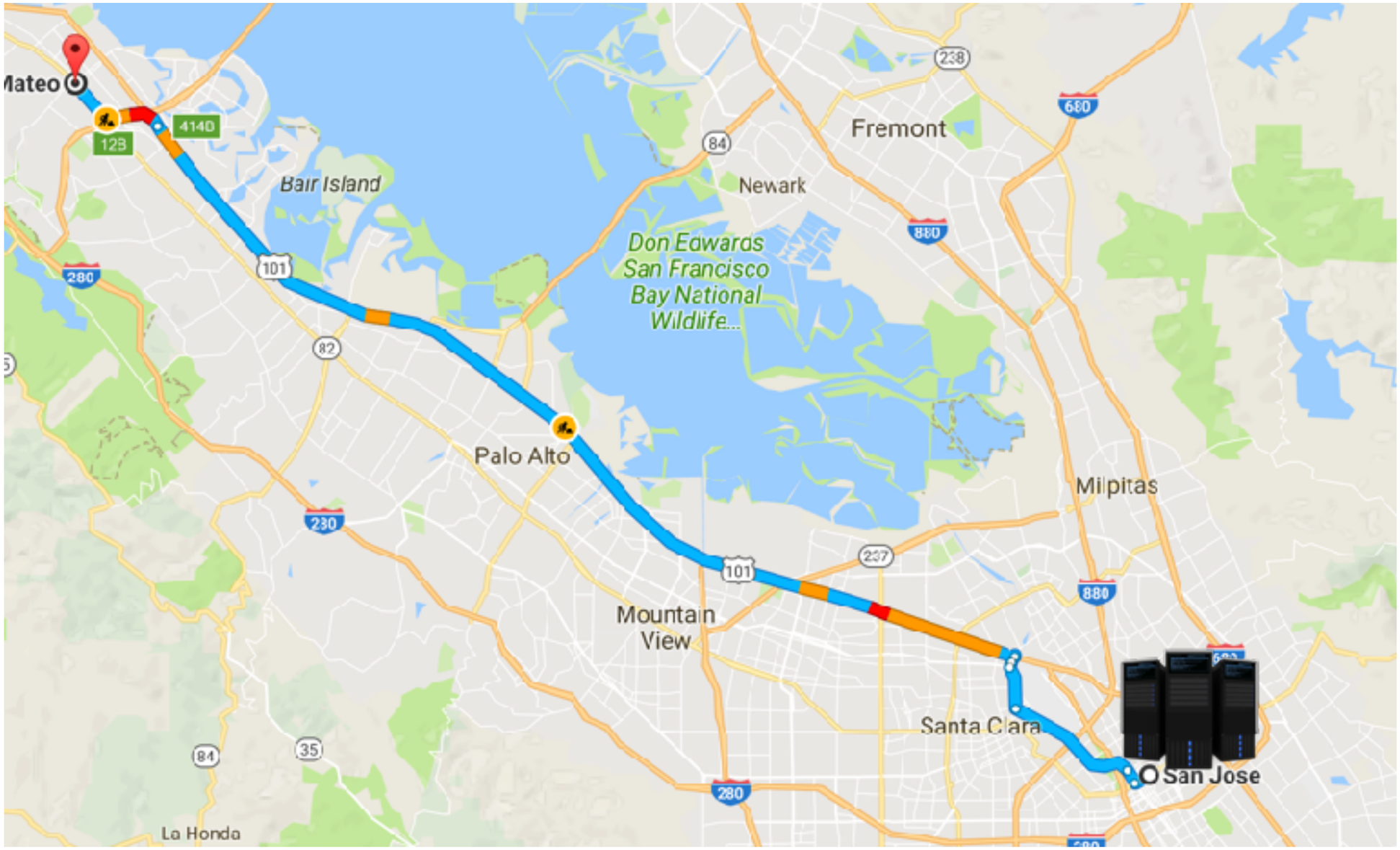
Meet Alice

- A software engineer
- Develops Applications for Augmented Reality(AR)
- Often works from home.
- Tests her AR apps during her commute.



Alice works in San Jose but lives in San Mateo.

An hour long commute by train…

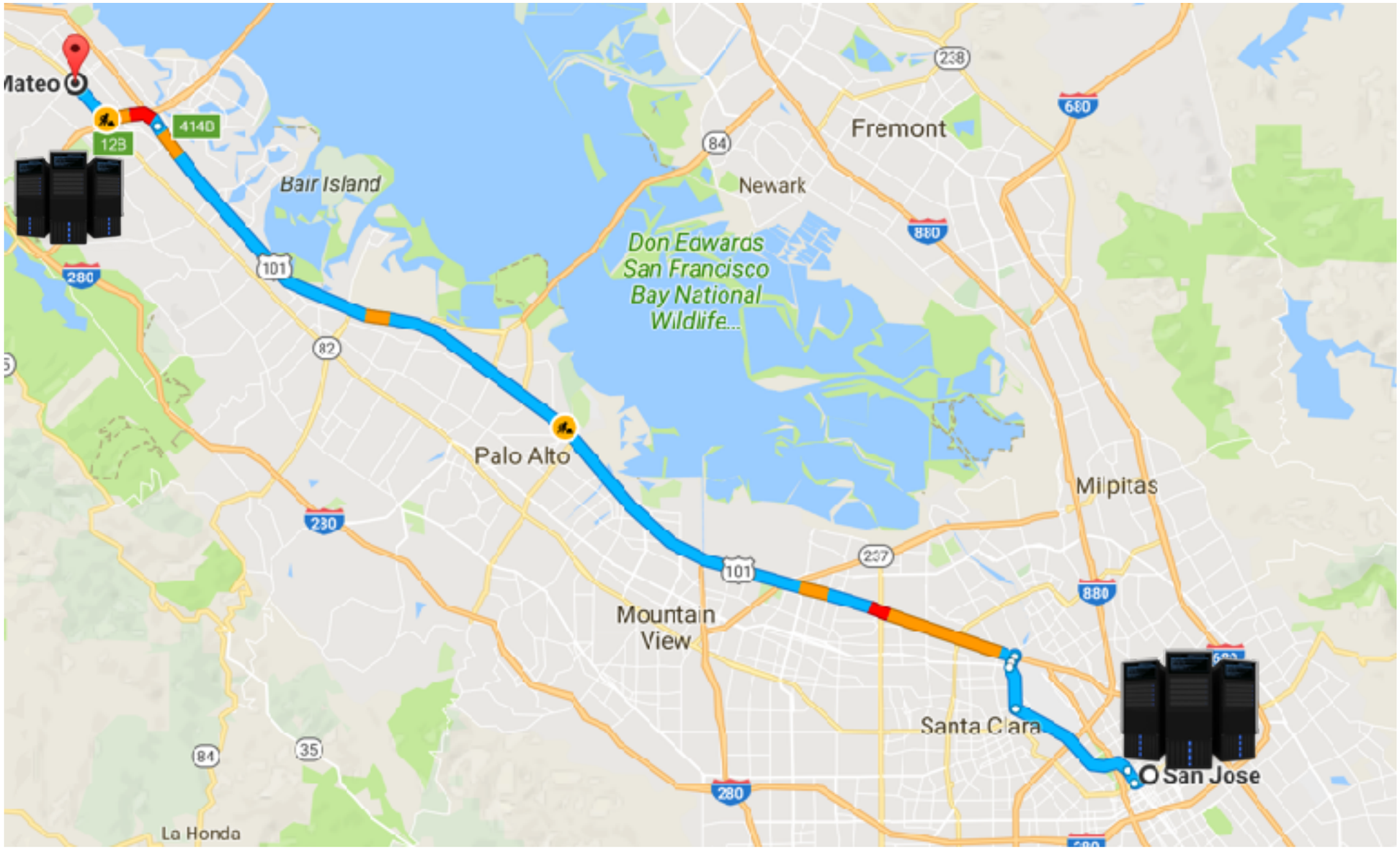


Her company servers are located at a San Jose edge cloud.

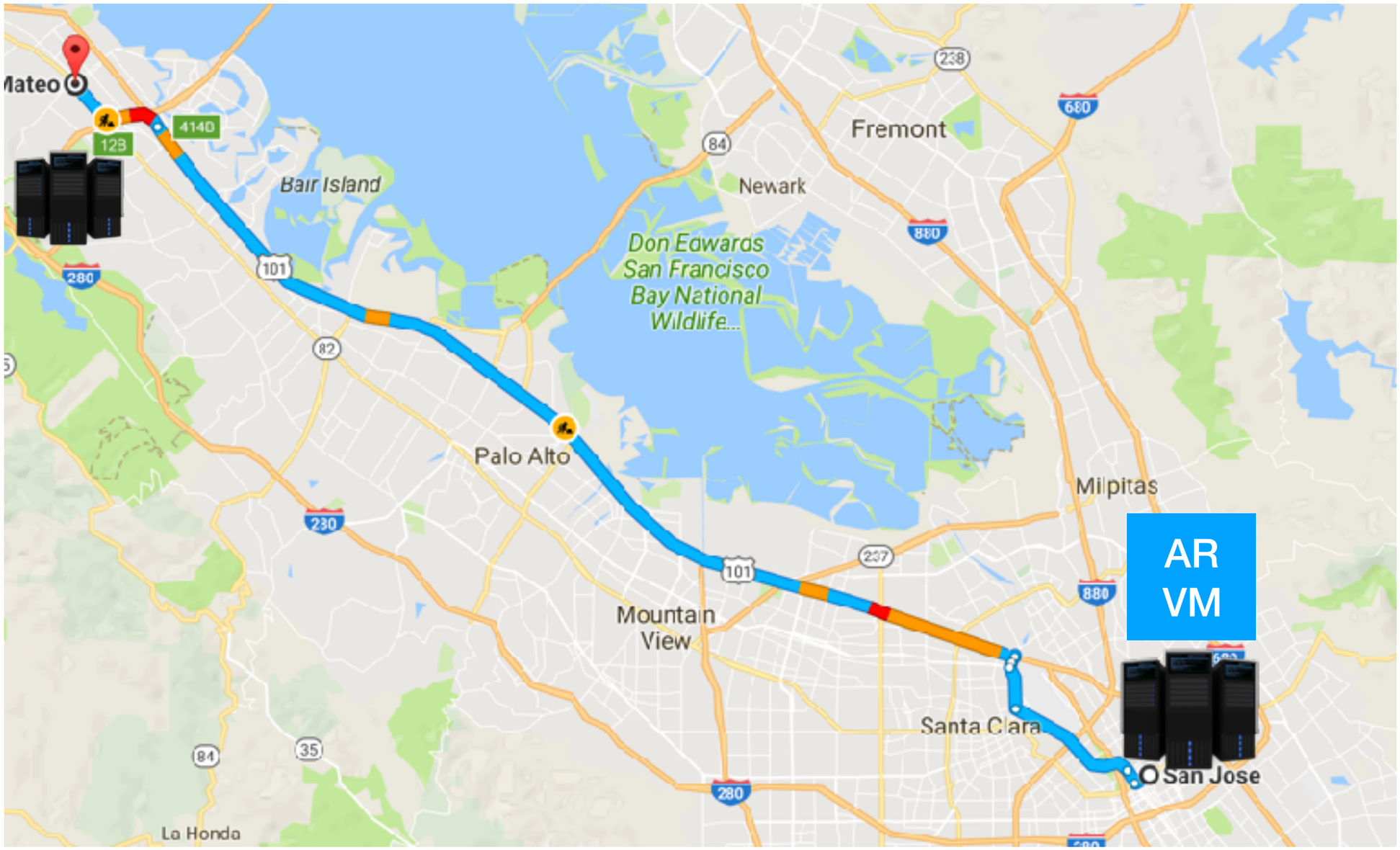
This makes testing her AR apps and working from home a problem…

As Alice gets closer to home, Latencies start to increase.

Higher latencies make it impossible to test her apps.
Working from home means she can’t test her apps.

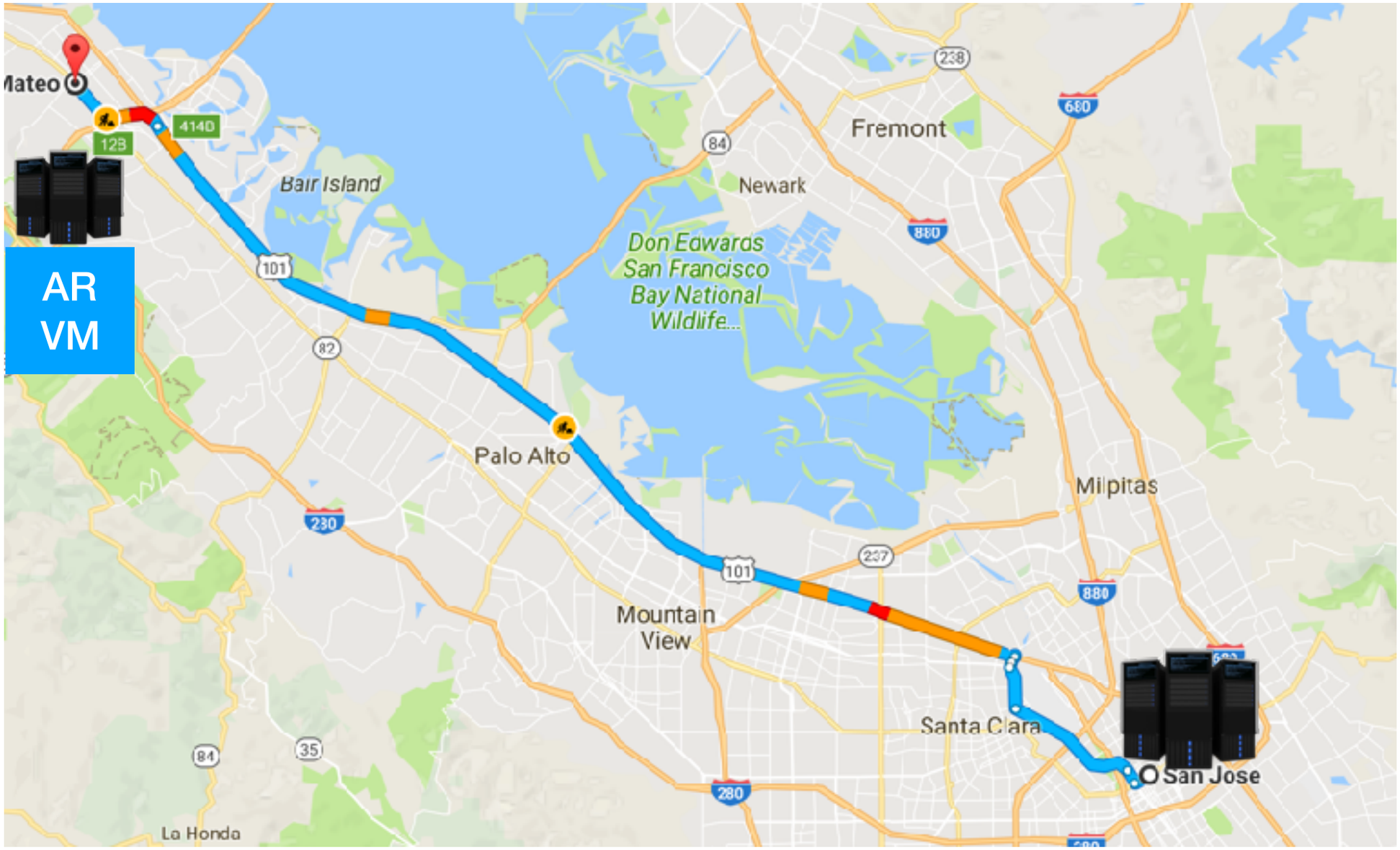


Luckily, there’s an edge cloud location closer to her home.



Luckily, there’s an edge cloud location closer to her home.

Cloud can migrate her AR application to a closer location.



Luckily, there’s an edge cloud location closer to her home.

Cloud can migrate her AR application to a closer location.

Problem Statement

- **Potential Solution**: Live Migrate the VM from one edge cloud location to another.

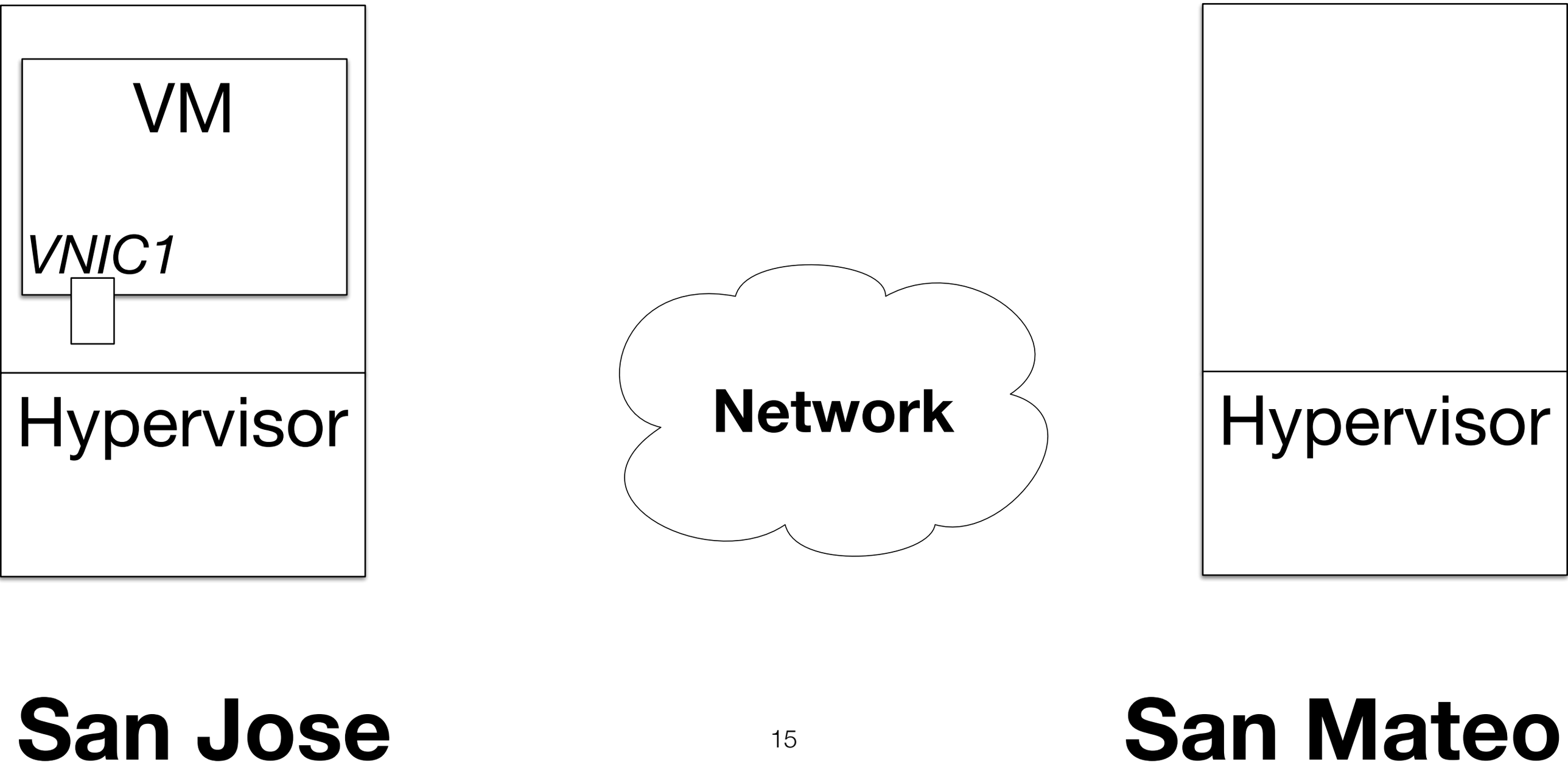
- Two potential problems in VM Migrations in Edge Clouds
  - Low WAN Bandwidth slows down transfers.
  - IP address changes between locations hurts application latencies.

Technique for Transparent Live VM Migrations in Edge Clouds.

Outline

- Motivation and problem statement
- Migration & MPTCP Background
- Implementation
- Results
- Conclusion

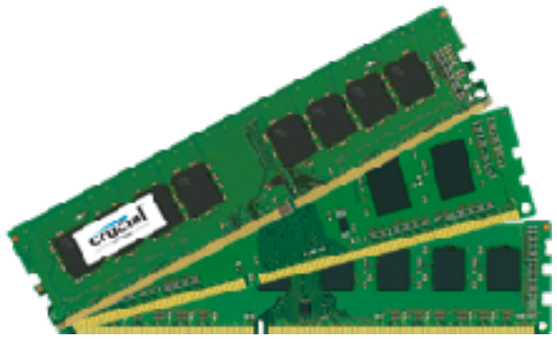
Anatomy of VM Migration



San Jose

San Mateo

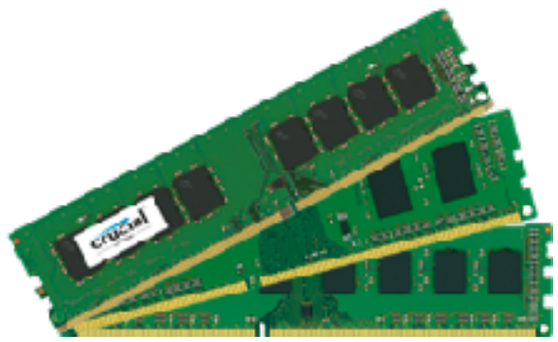
Migration: Three States



Memory

State

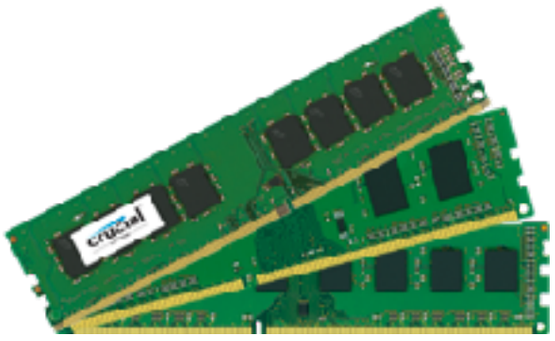
Migration: Three States



Memory State

Disk State

Migration: Three States



Memory State

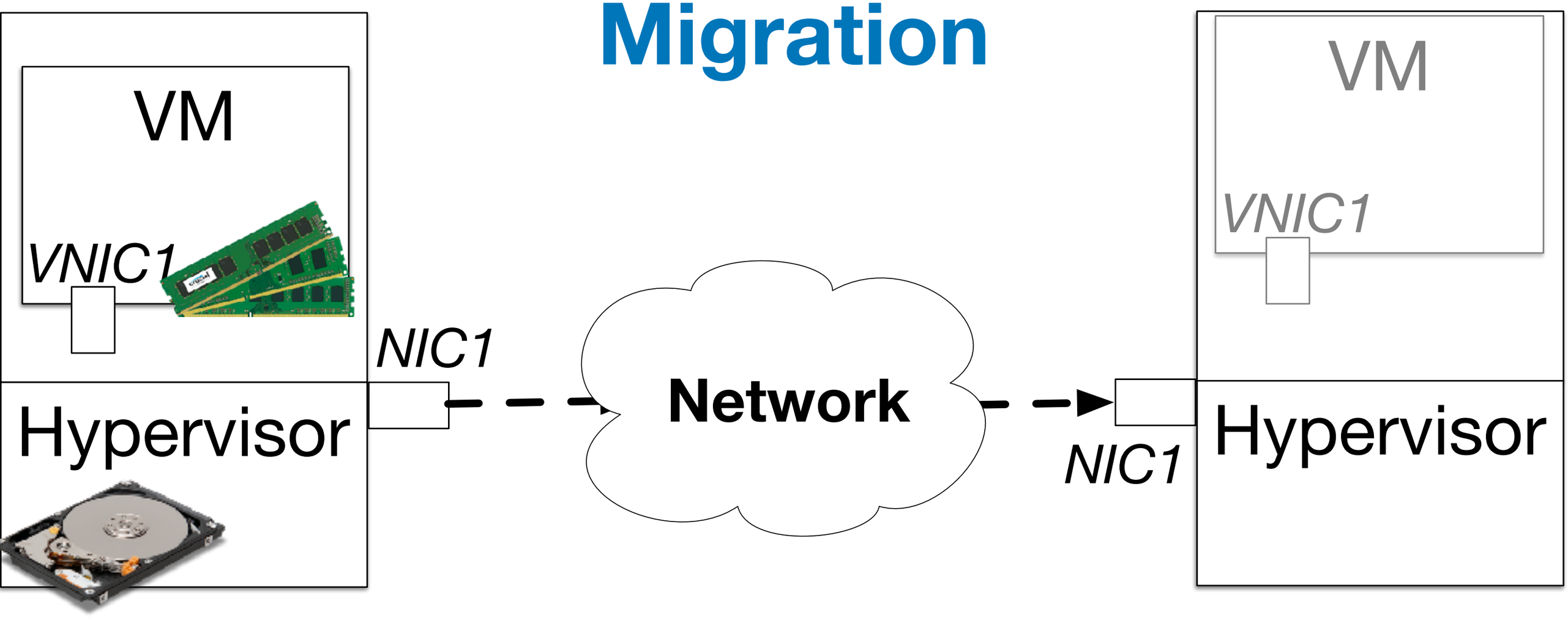
Disk State

192.168.1.1

Network State

Anatomy of VM Migration

Begin Migration



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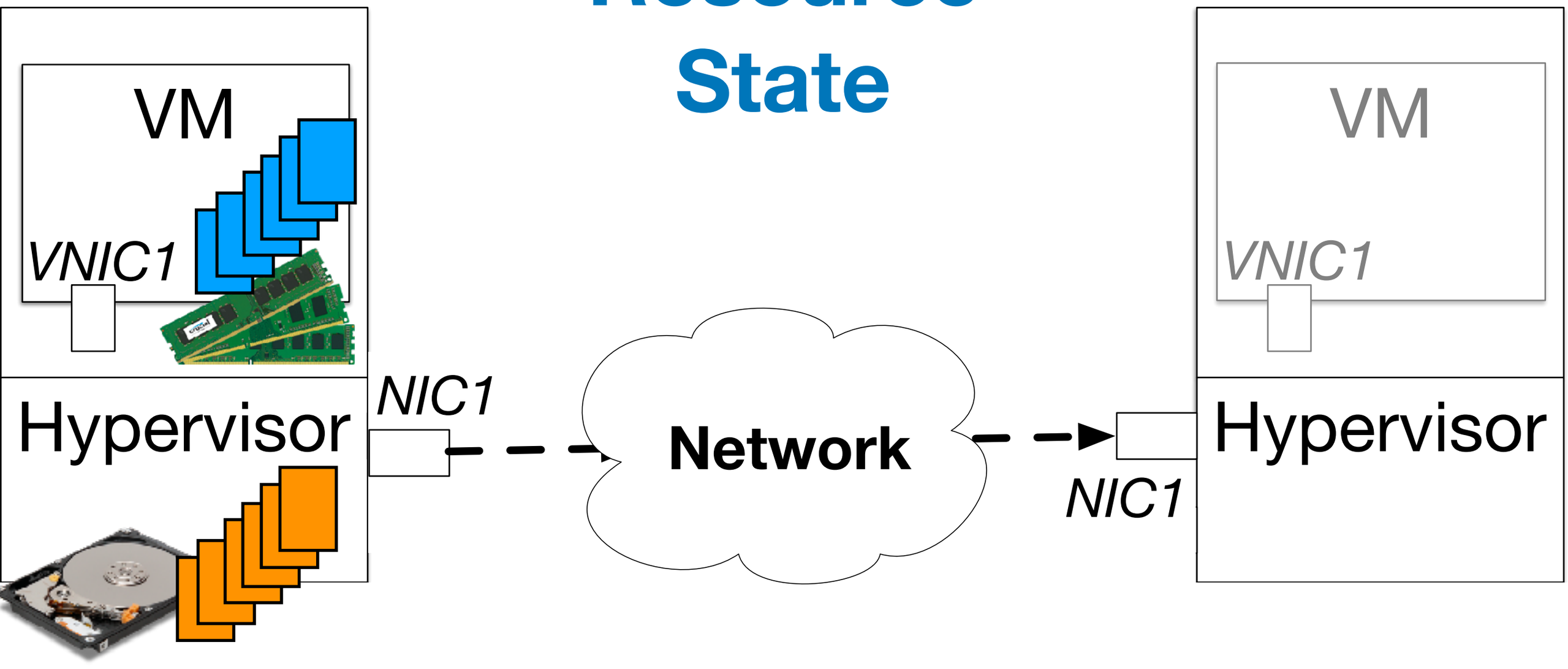
Anatomy of VM Migration

Resource

State



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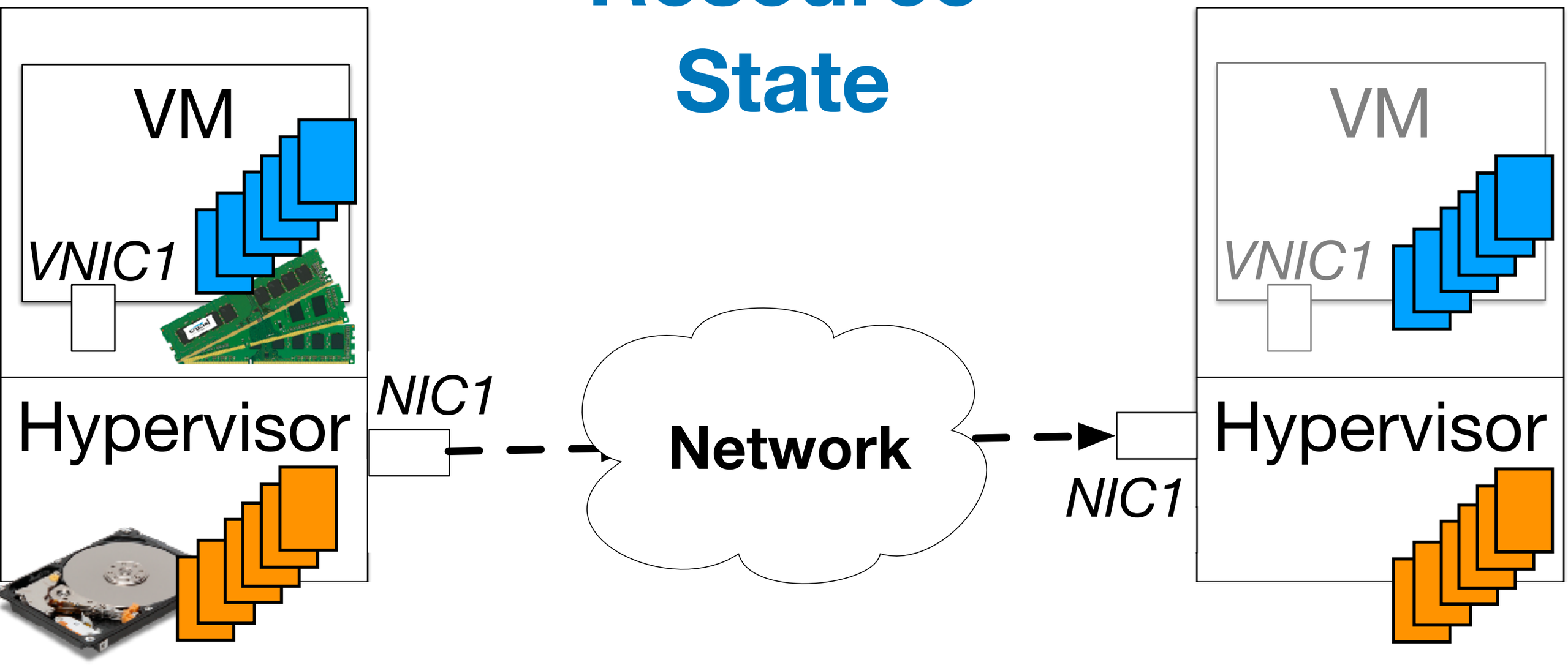
Anatomy of VM Migration

Resource
State



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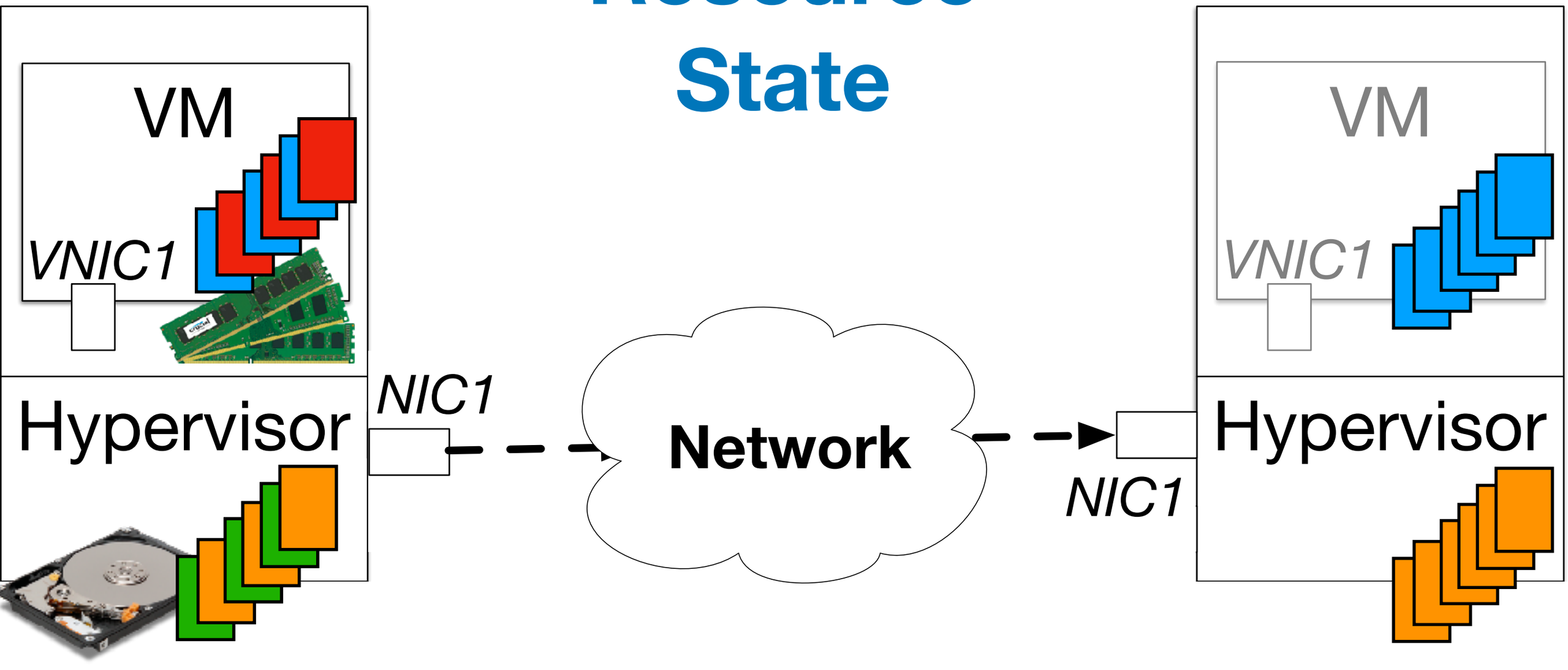
Anatomy of VM Migration

Resource State



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Resource

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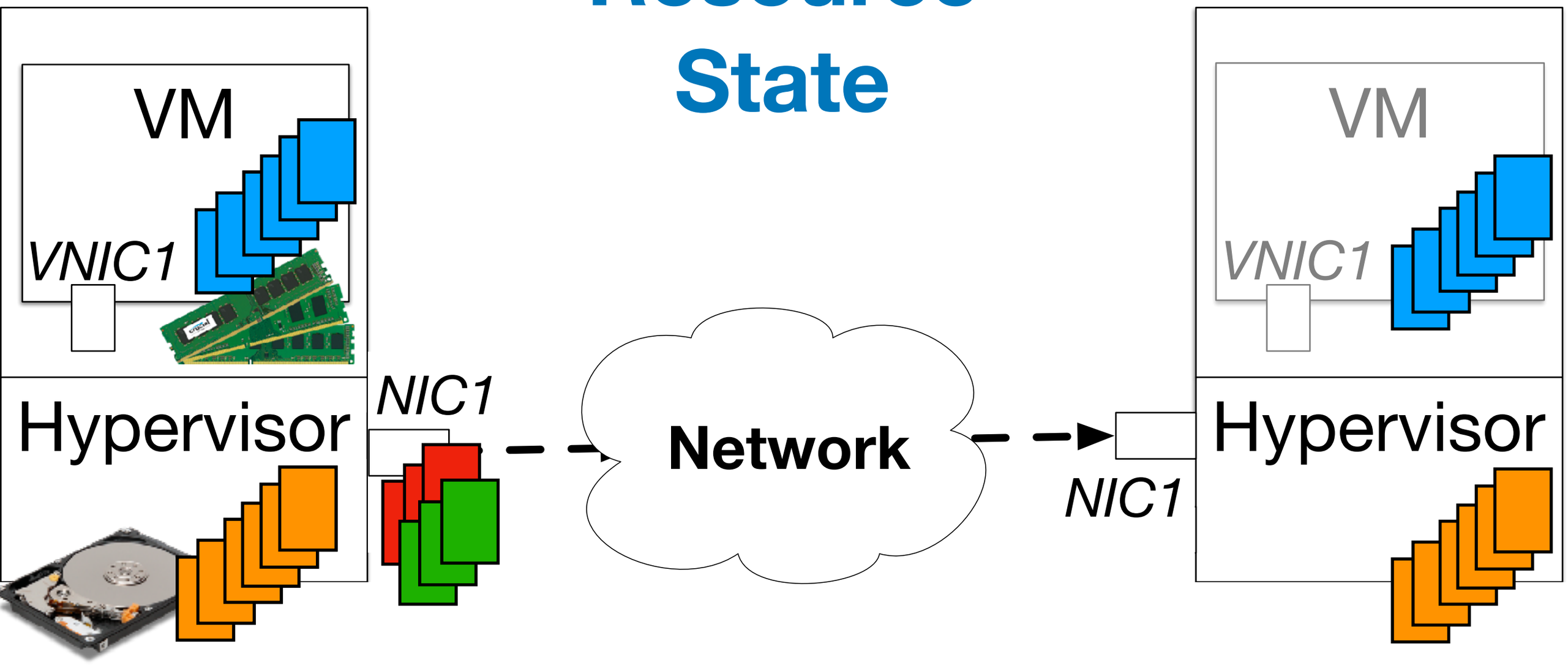

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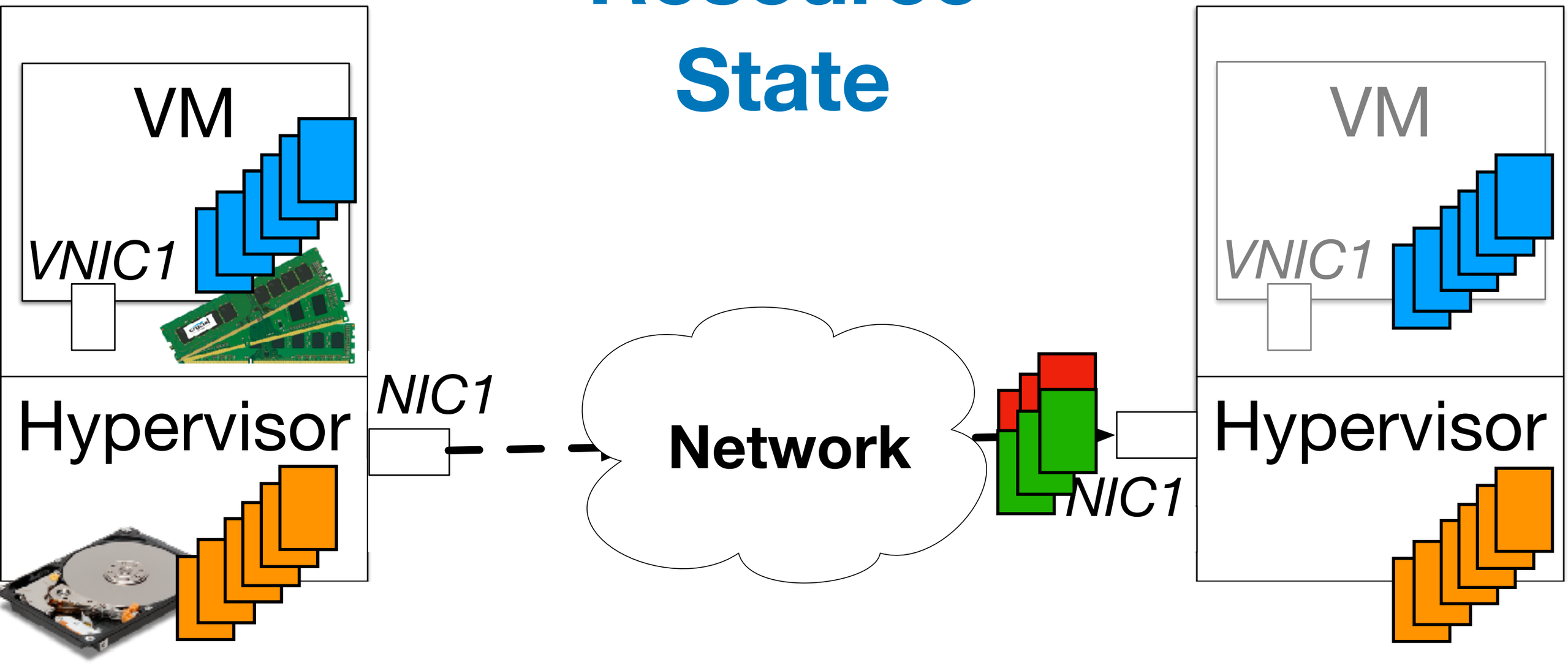
Resource State



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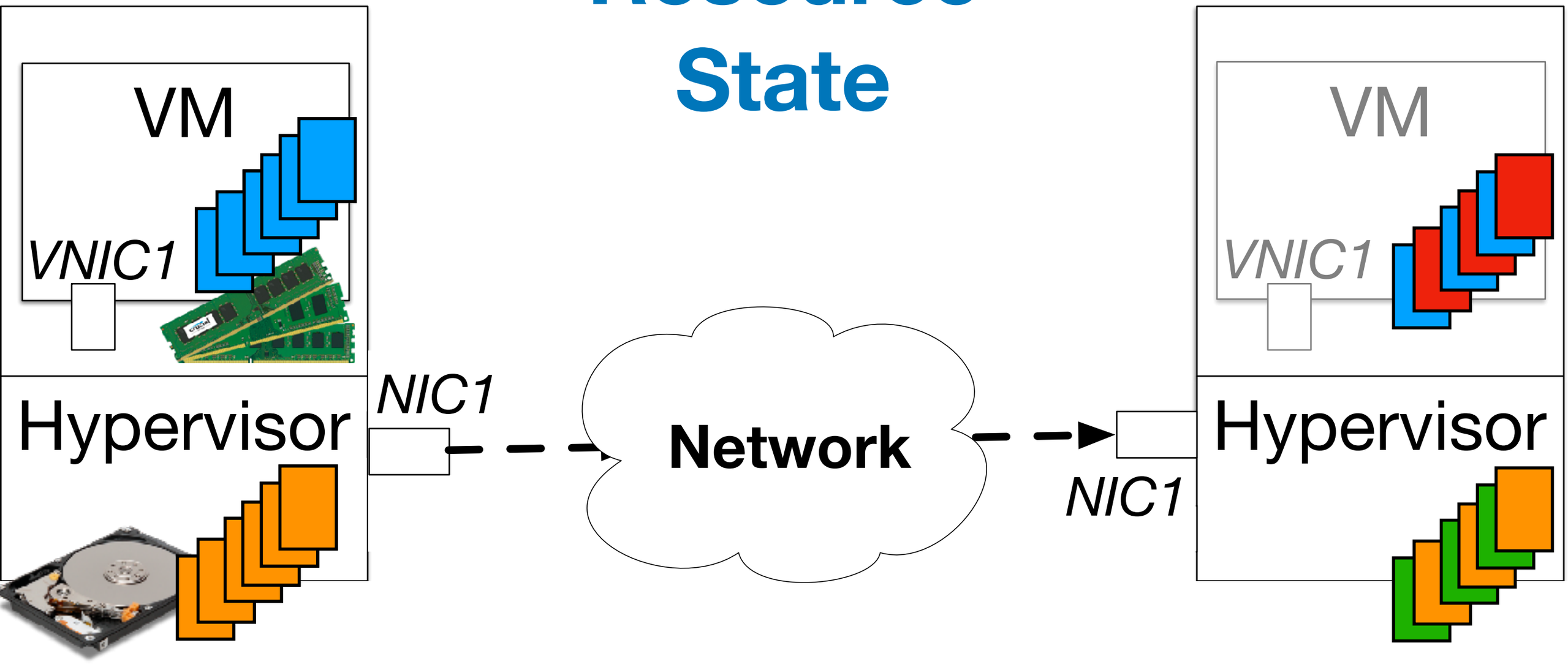

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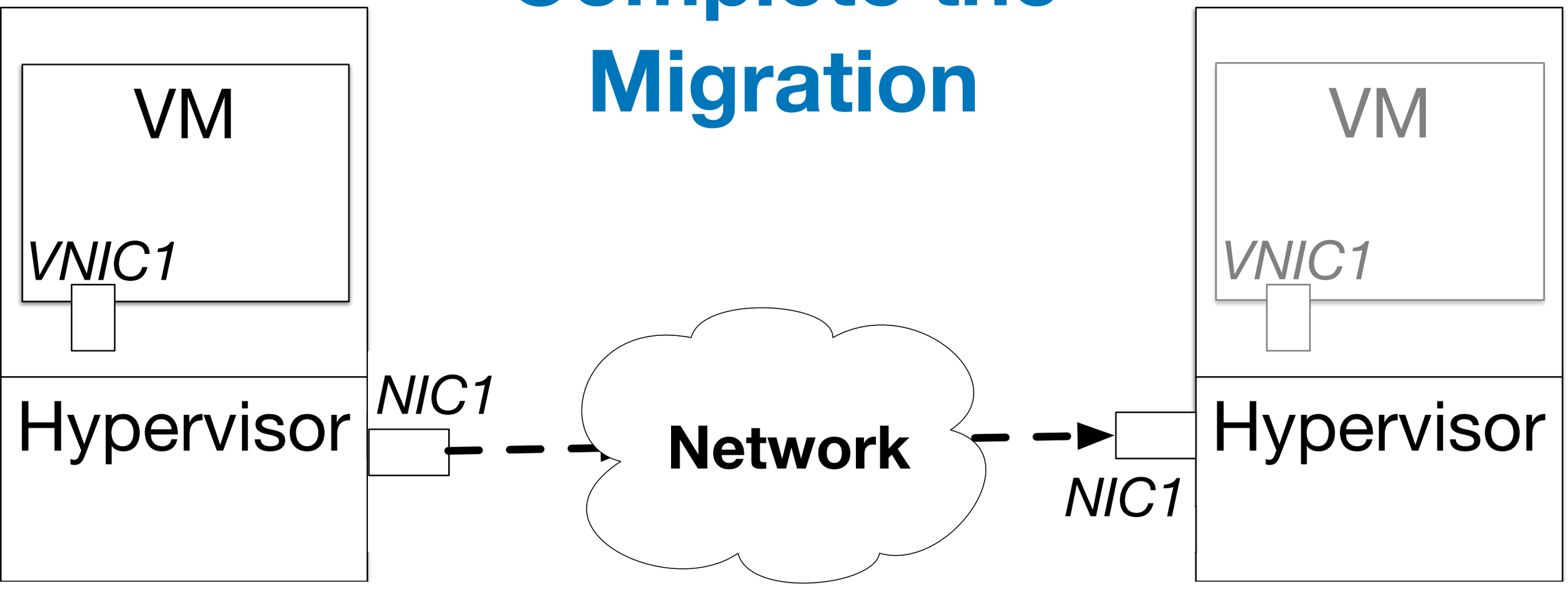
Anatomy of VM Migration

Complete the Migration



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Anatomy of VM Migration

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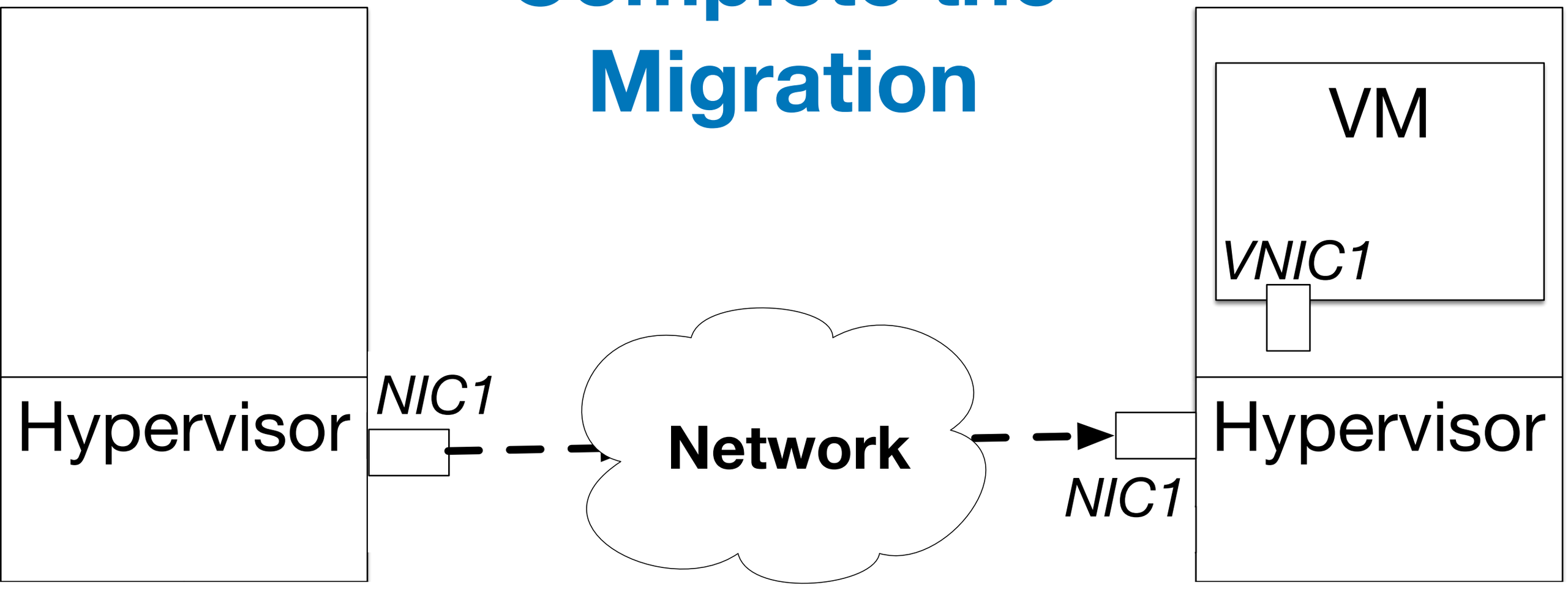

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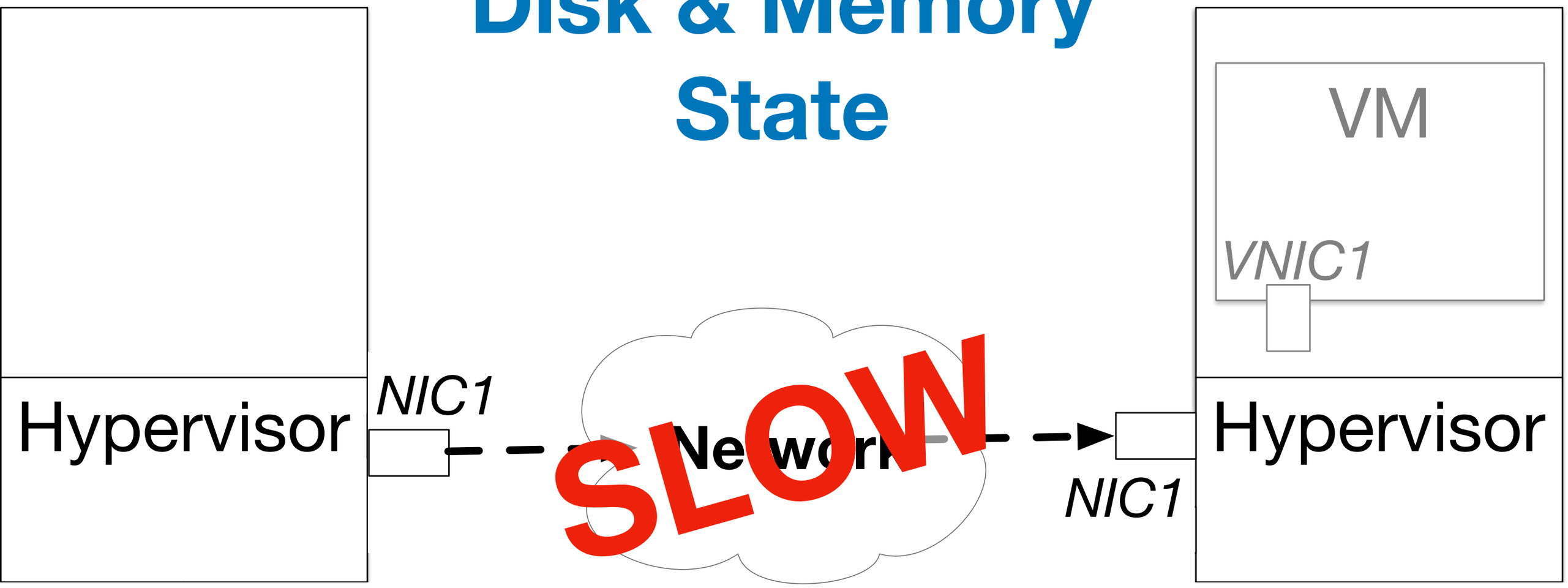
Anatomy of VM Migration

Disk & Memory State



Low Bandwidth Speeds Mean Long Transfer Times.

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Migration over Slow Networks

- **Problem**: Low Bandwidth Speeds Mean Long Transfer Times.

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- **Observation**: Most commodity servers have multiple interfaces and multiple paths are common between edge cloud locations

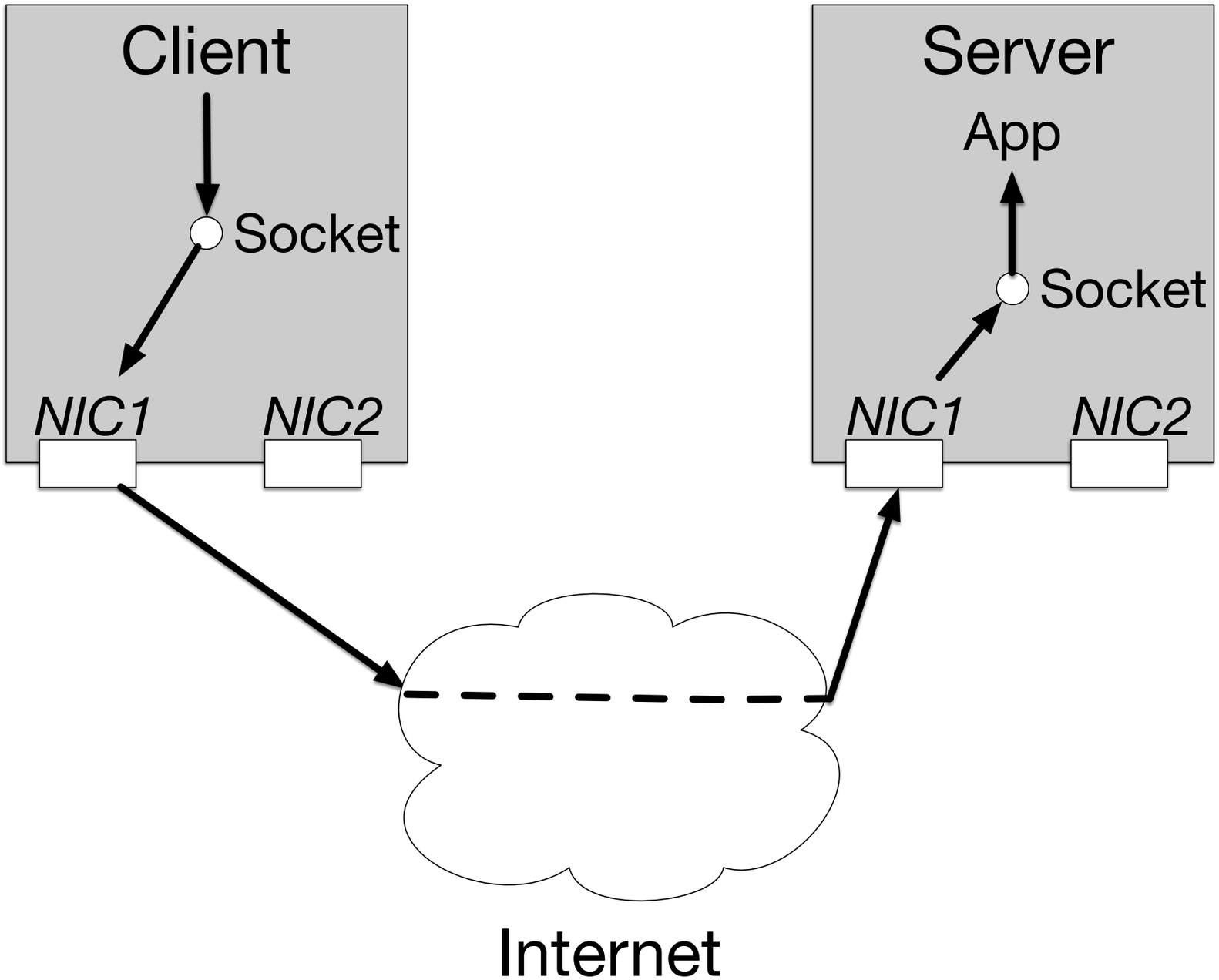
Migration over Slow Networks

- **Problem**: Low Bandwidth Speeds Mean Long Transfer Times.

- **Observation**: Most commodity servers have multiple interfaces and multiple paths are common between edge cloud locations

- **Solution**: Take advantage of multiple network paths to aggregate bandwidth.

A Typical TCP Connection



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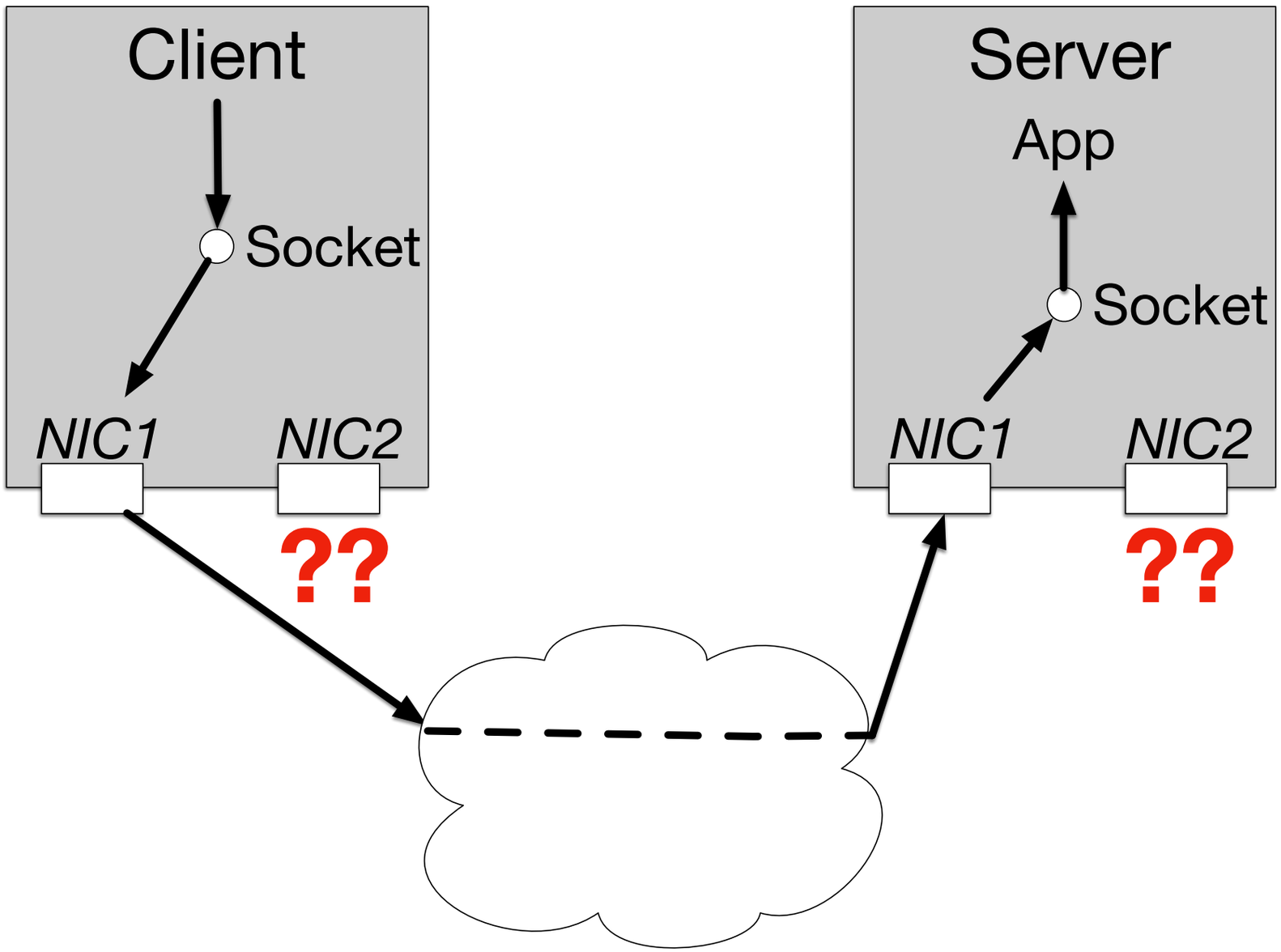
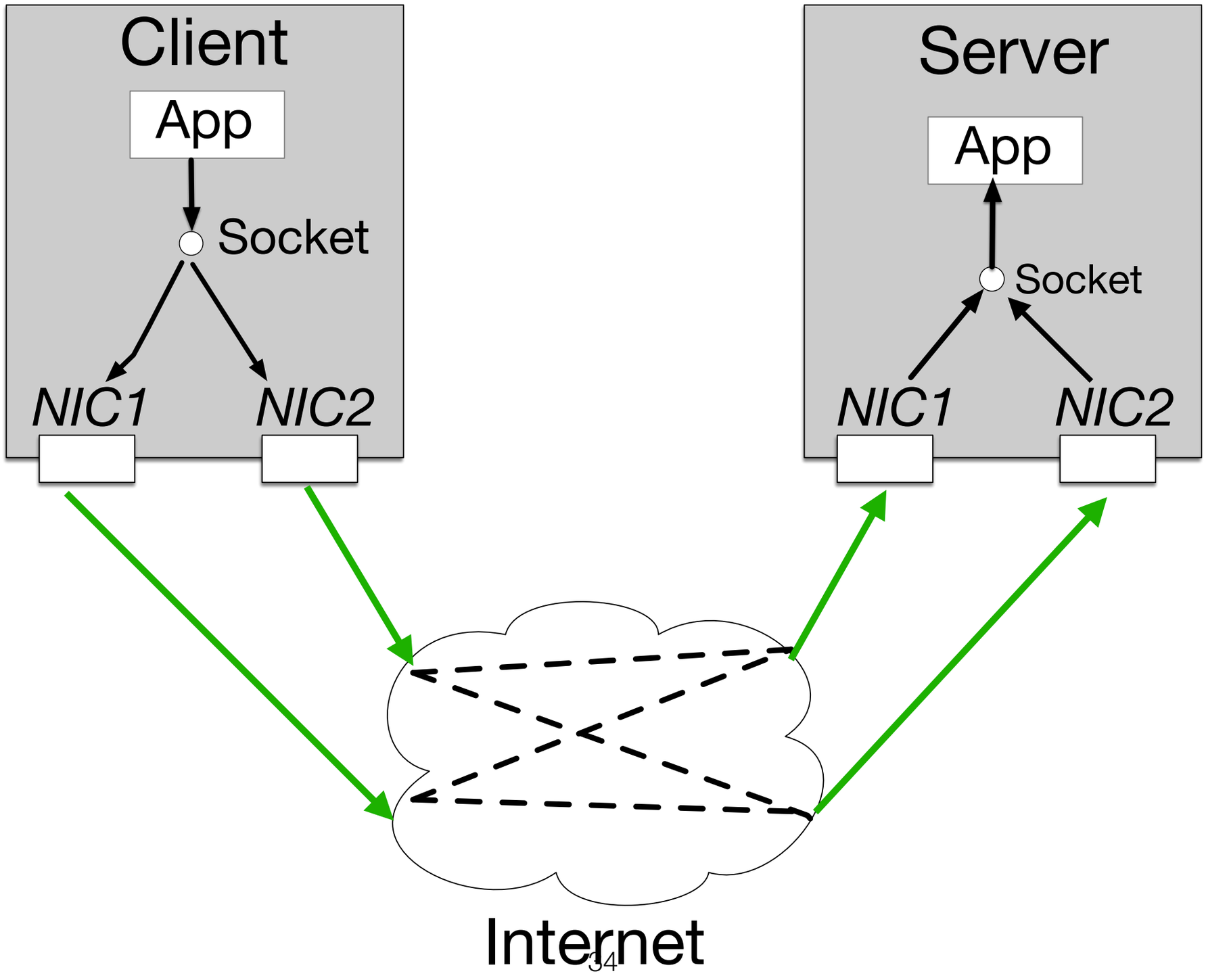


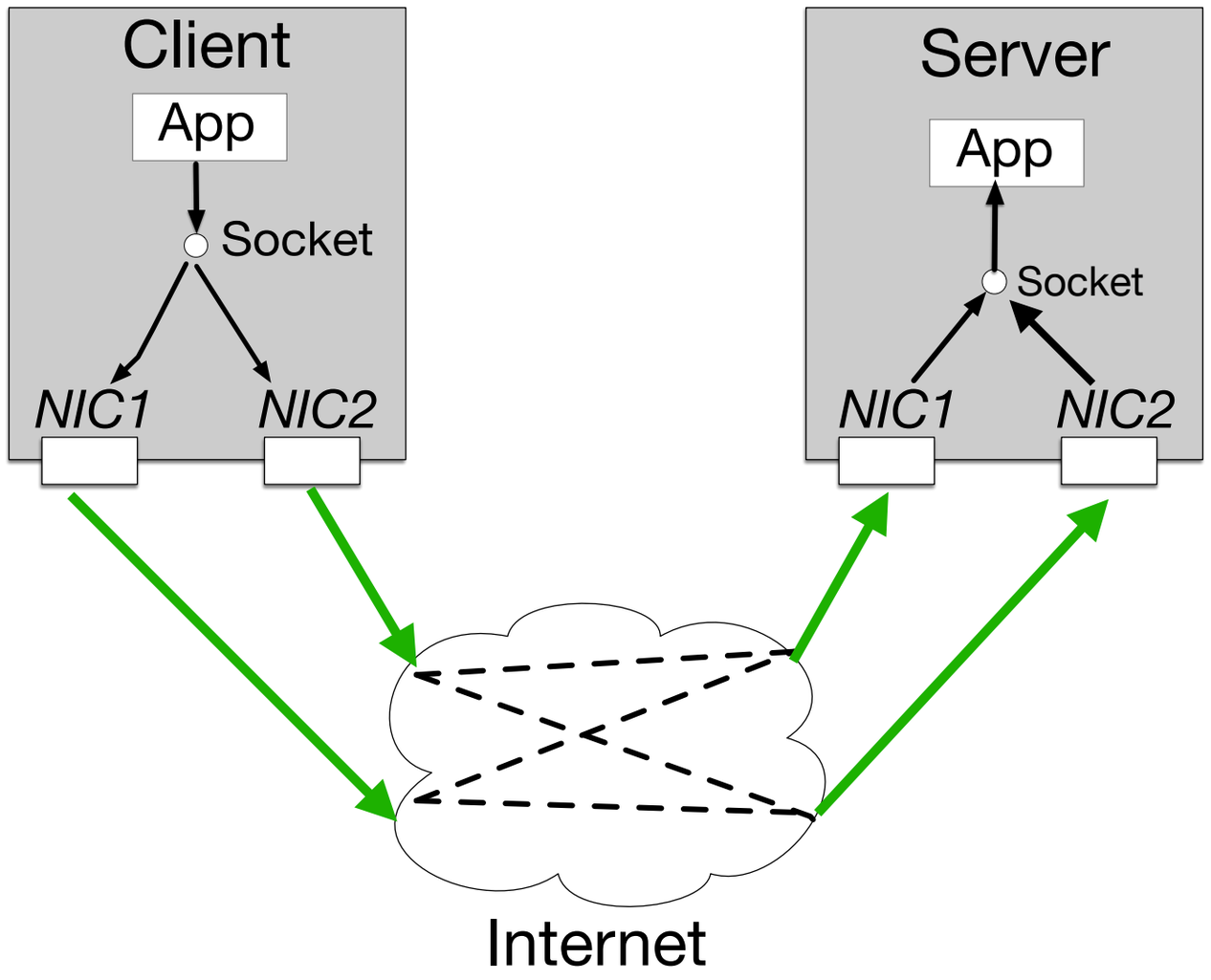
What if we could take advantage of our second interface?

An MPTCP Socket

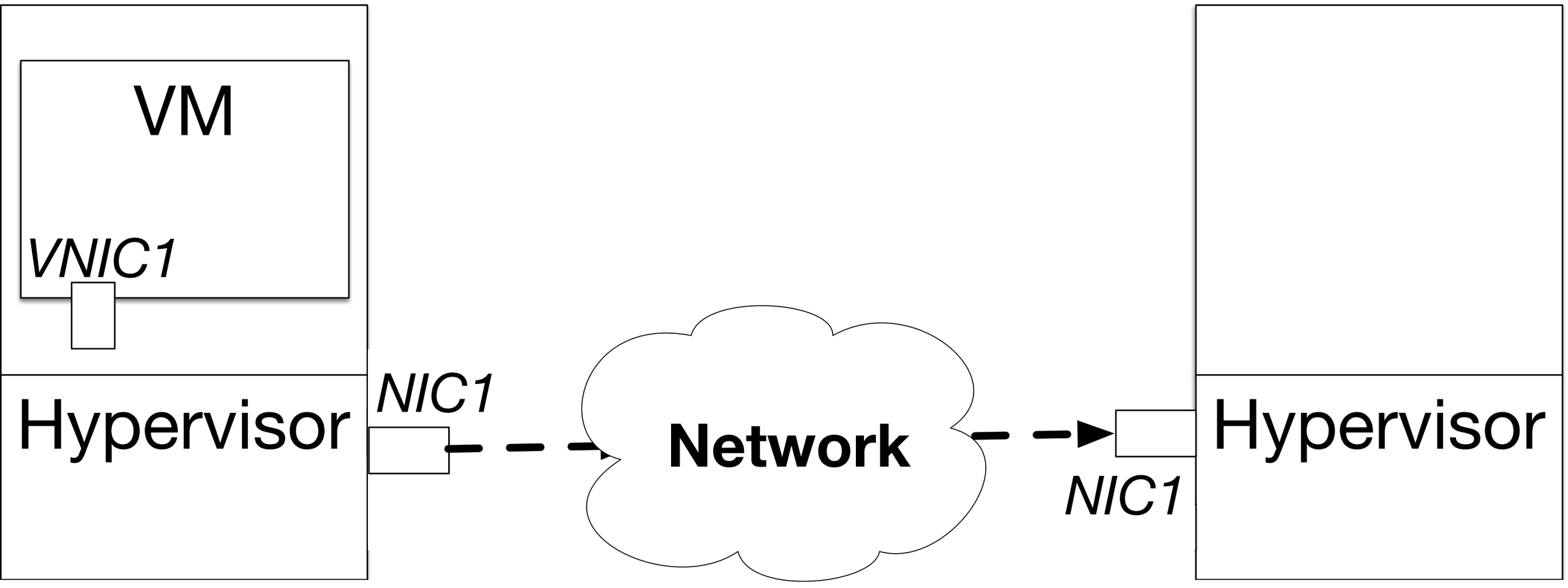


Migrating over MPTCP

- Parallel Paths allow us to aggregate bandwidth
- A net effect of providing faster transfer times for VM state.



Migration



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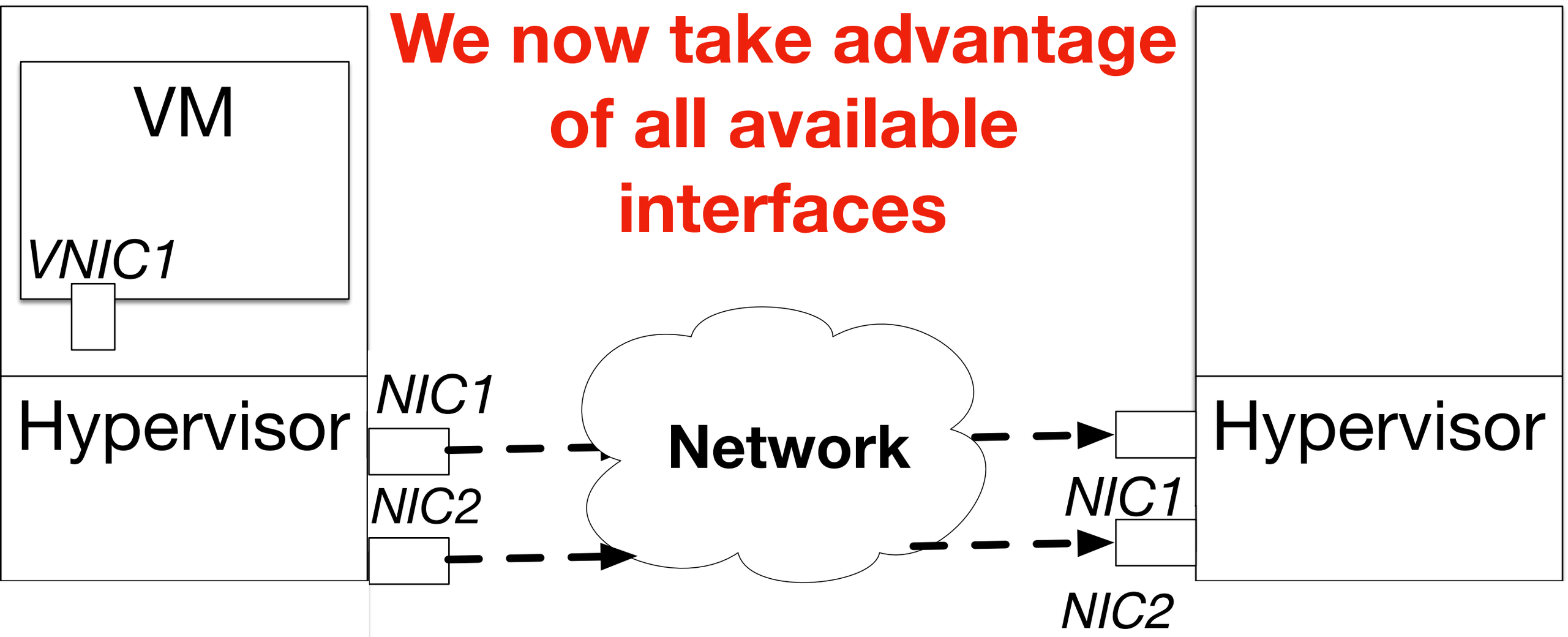
Migration

We now take advantage of all available interfaces



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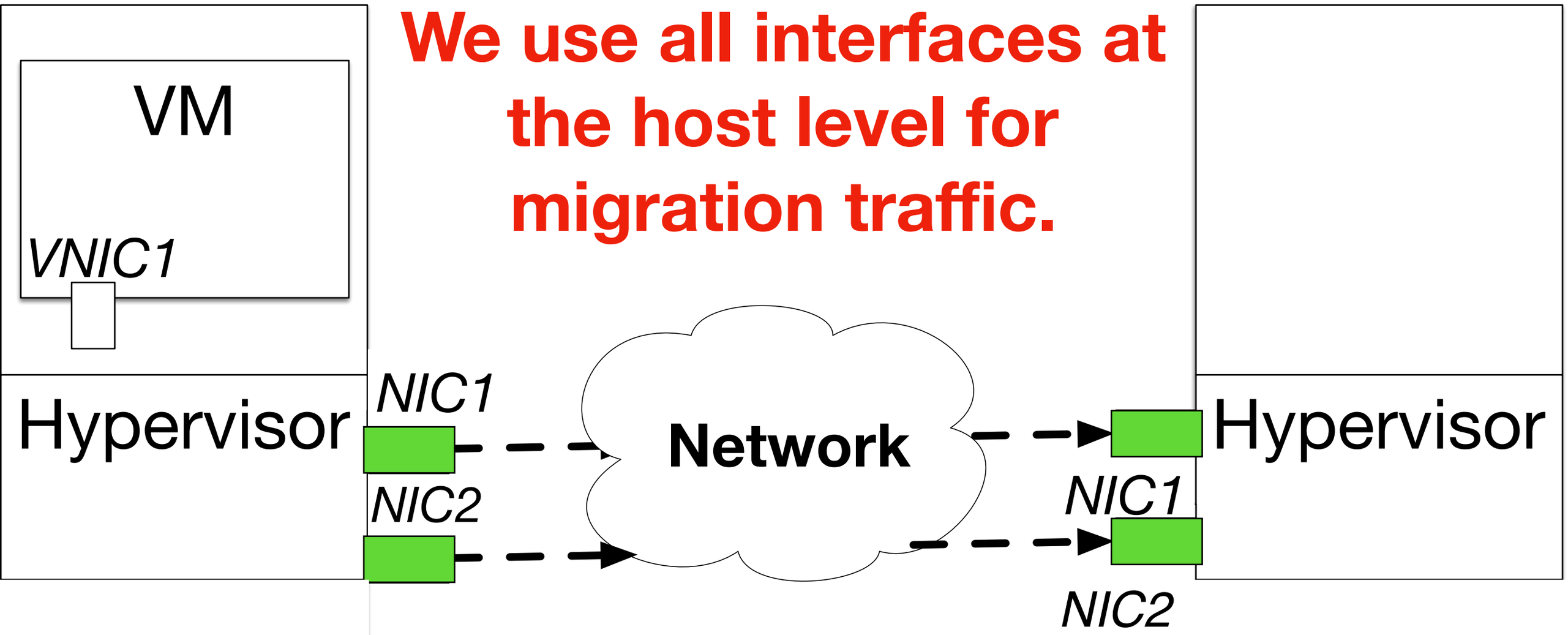
Migration

We use all interfaces at the host level for migration traffic.



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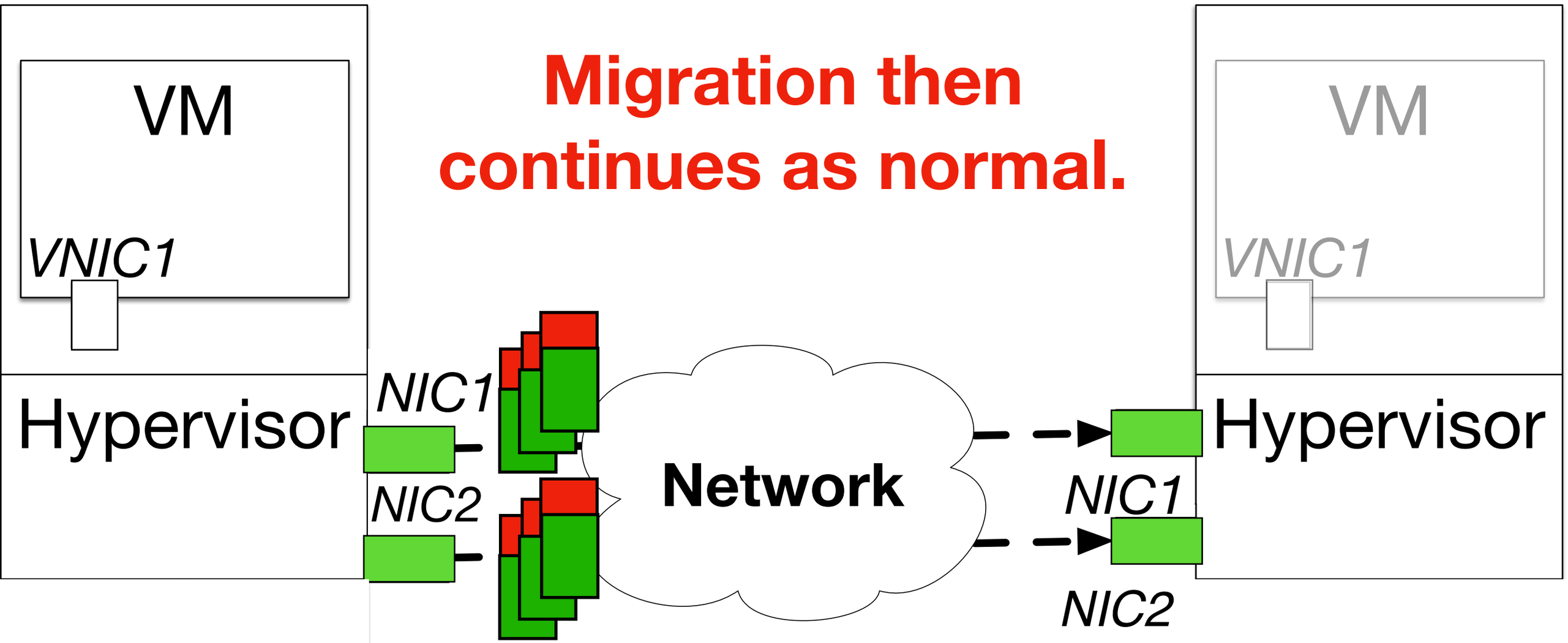
Migration

Migration then continues as normal.



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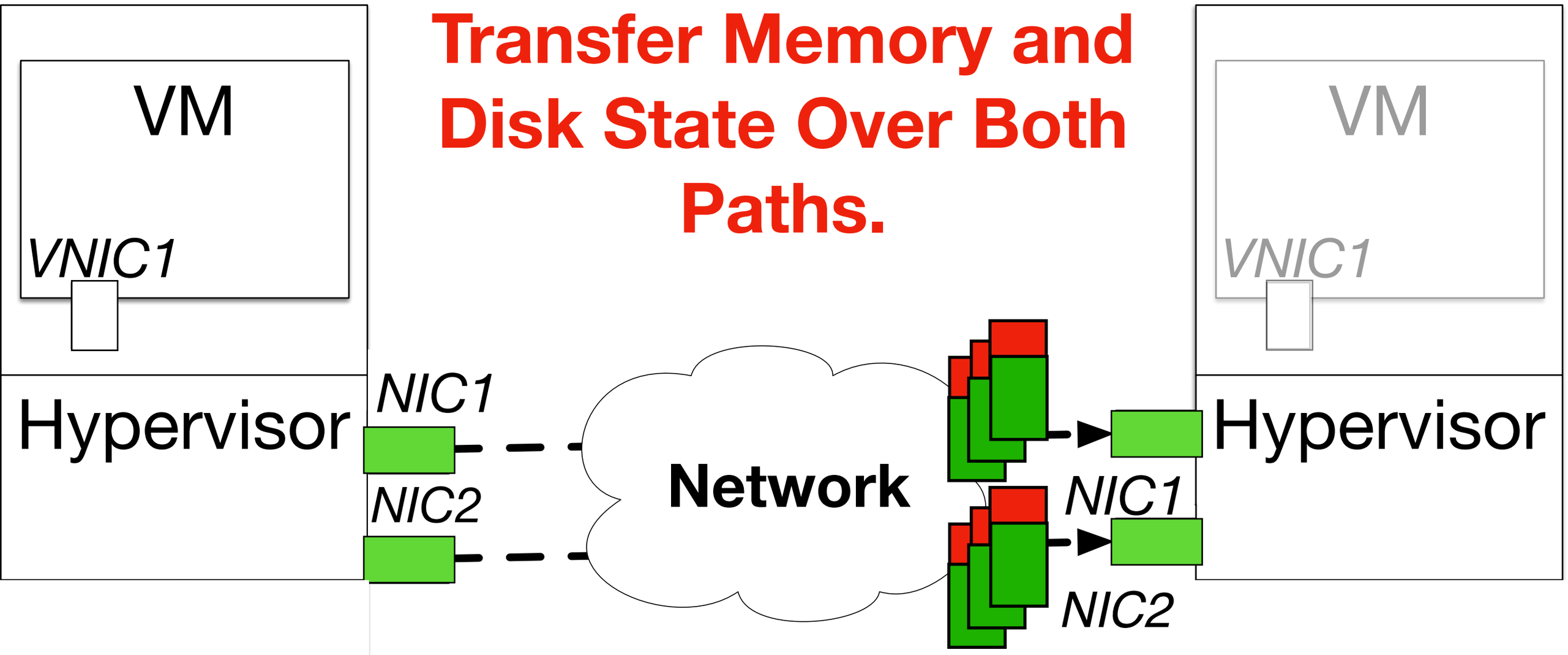
Migration

Transfer Memory and Disk State Over Both Paths.



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Migration

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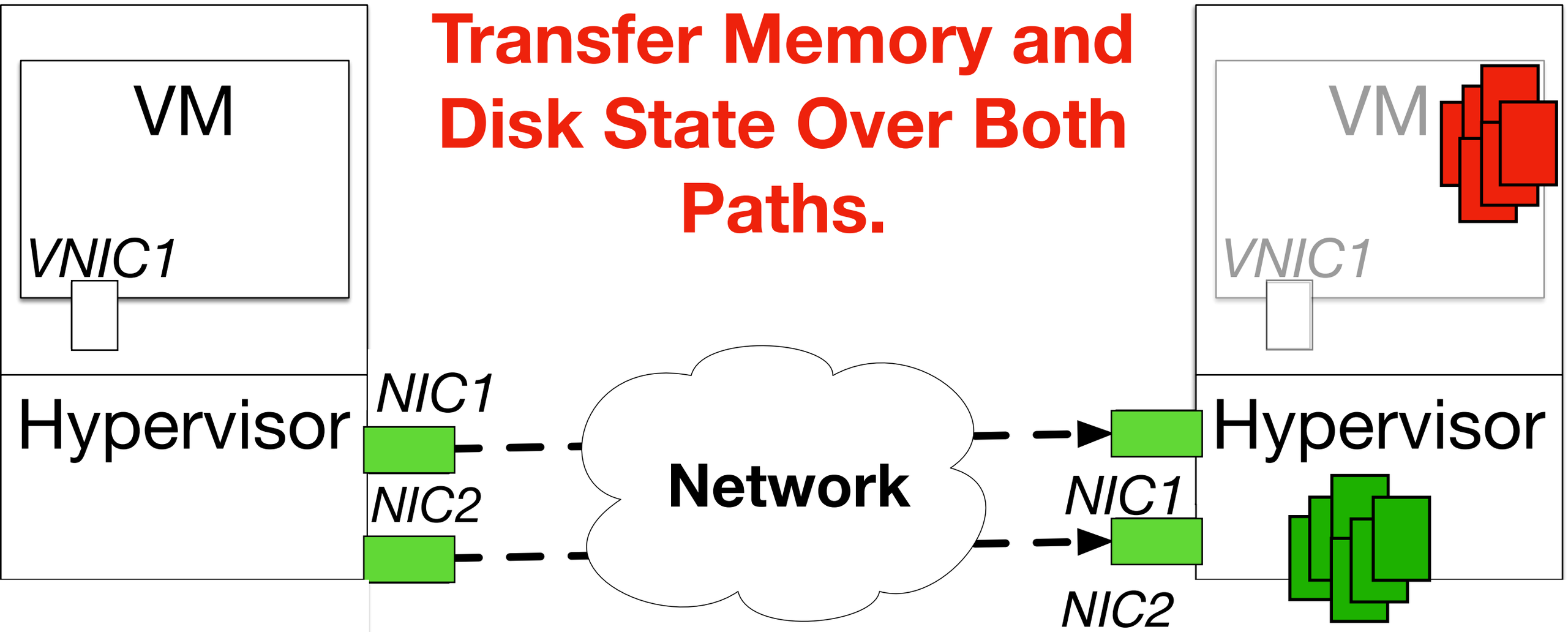

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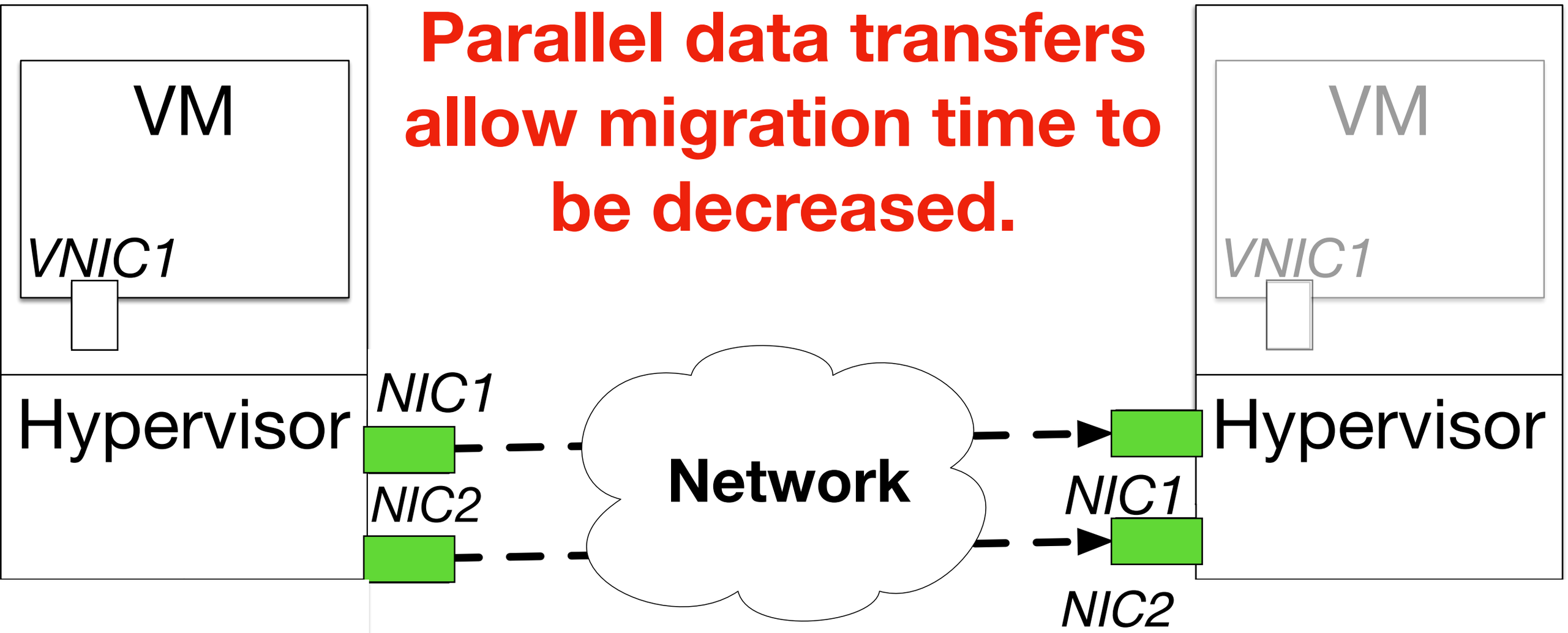
Migration

Parallel data transfers allow migration time to be decreased.



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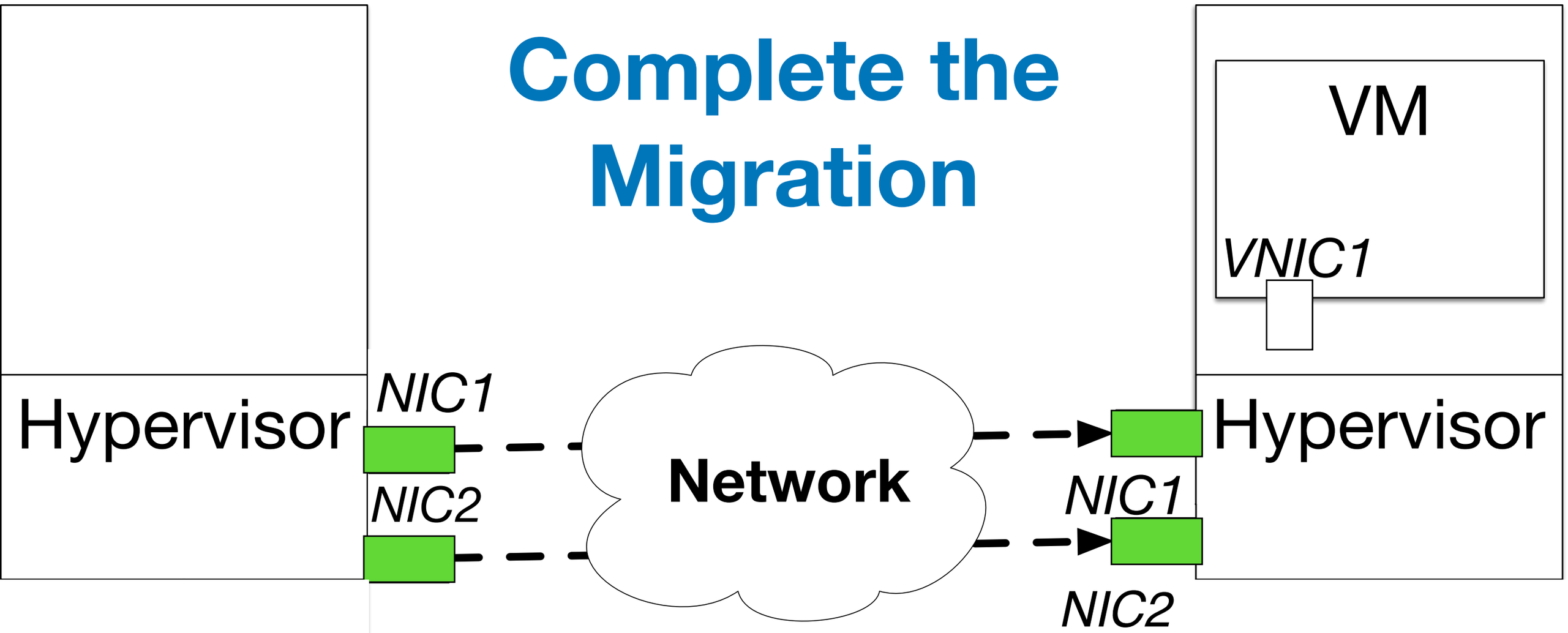
Migration

Complete the Migration



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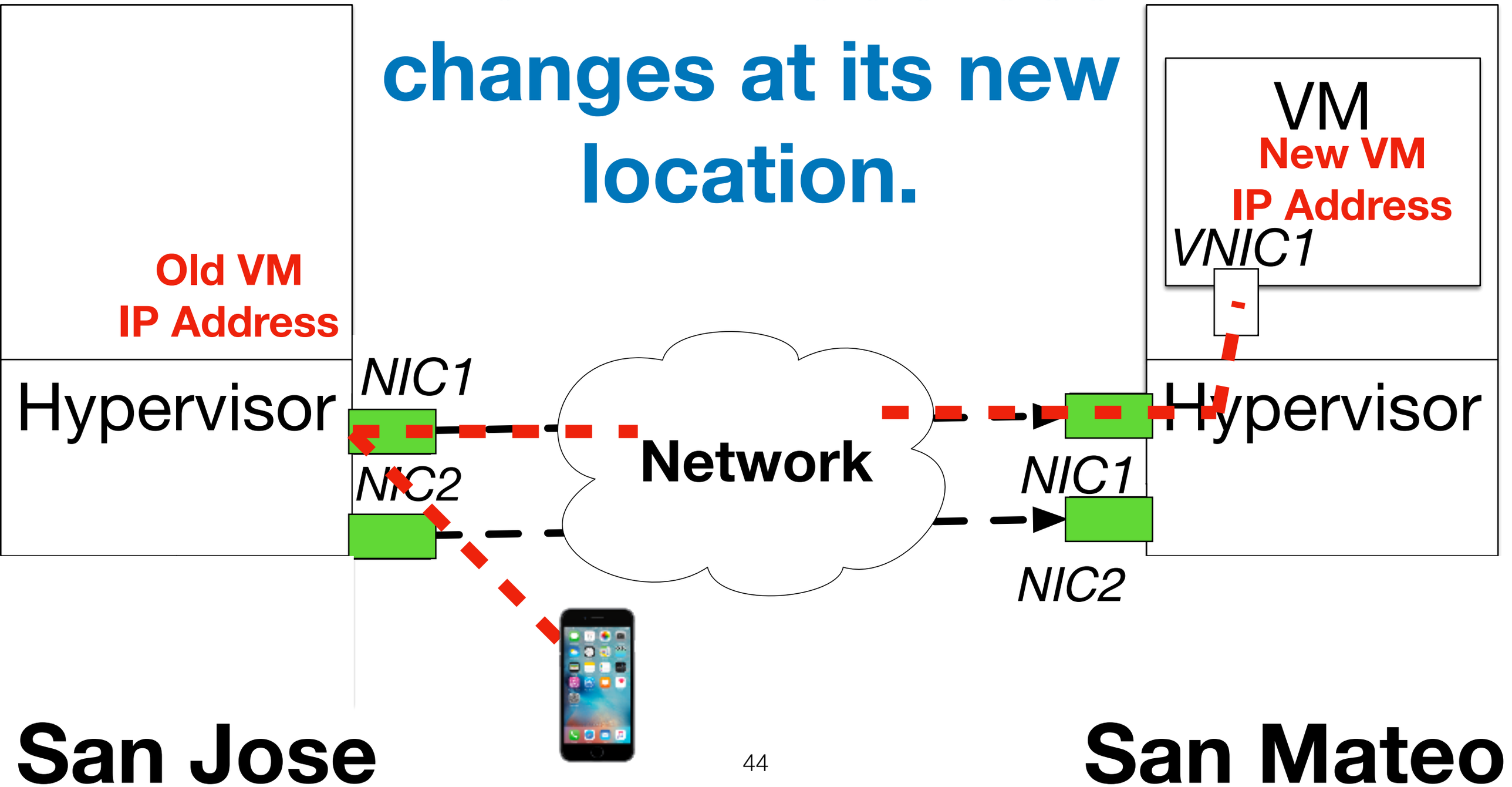
Migration

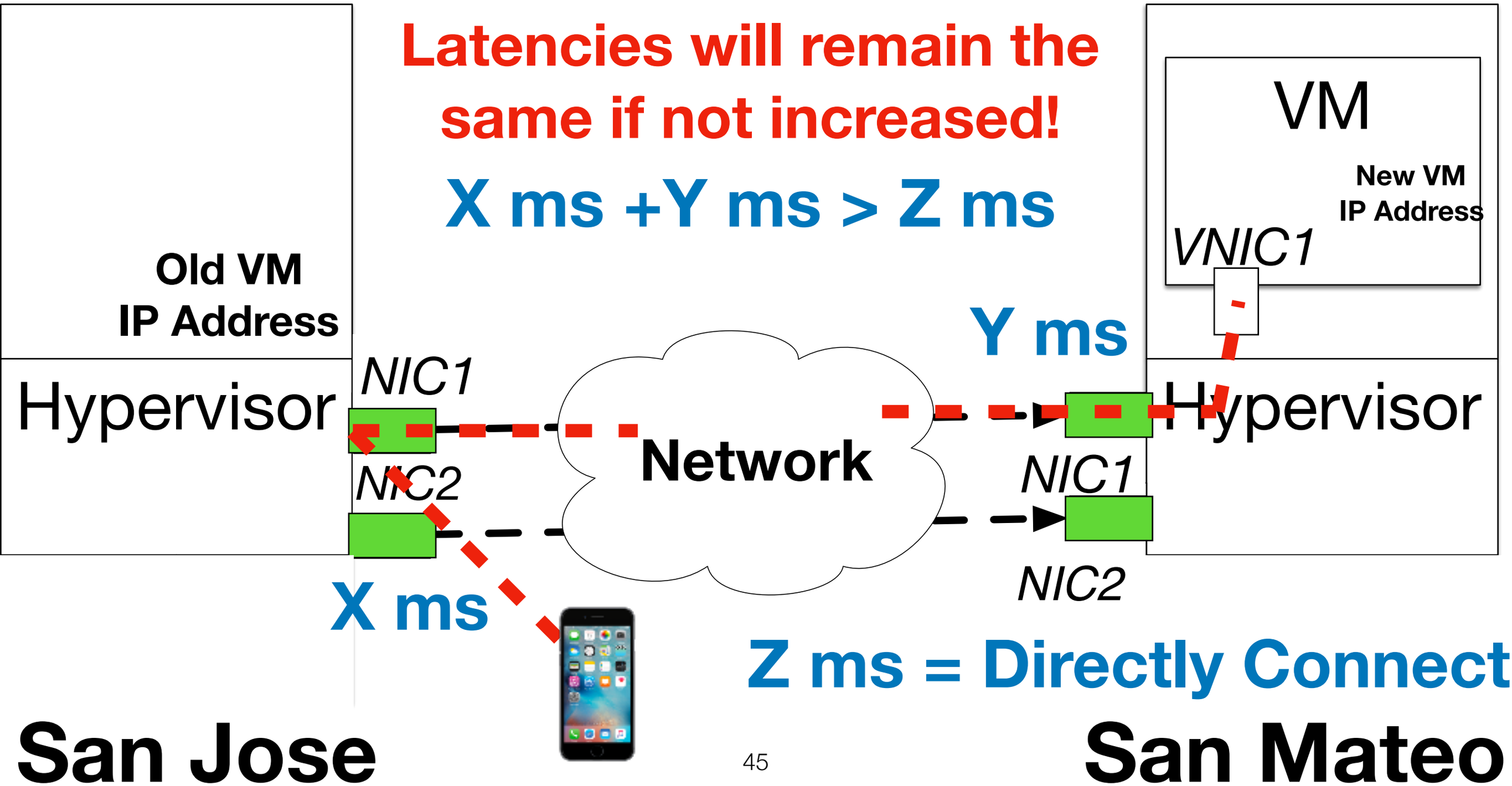
The VM IP address changes at its new location.



Migration

Latencies will remain the same if not increased!

X ms +Y ms > Z ms



Z ms = Directly Connect

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Maintaining Active Network Connections

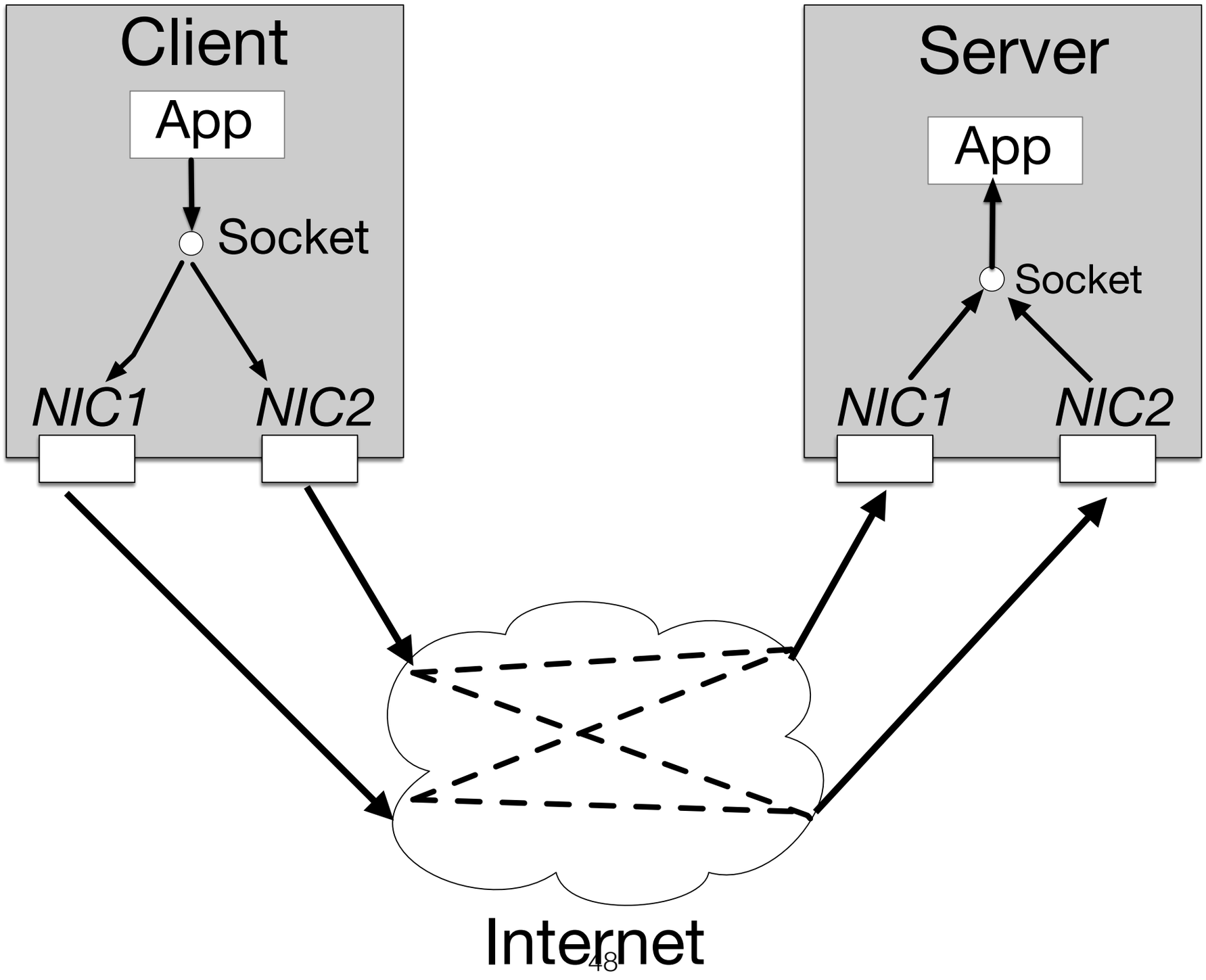
- **Problem**: Current VM Migration approaches can cause latencies to increase for active network connections.

Maintaining Active Network Connections

- **Problem**: Current VM Migration approaches can cause latencies to increase for active network connections.

- **Solution**: MPTCP's seamless address handoff enables transparency in the network.

An MPTCP Socket



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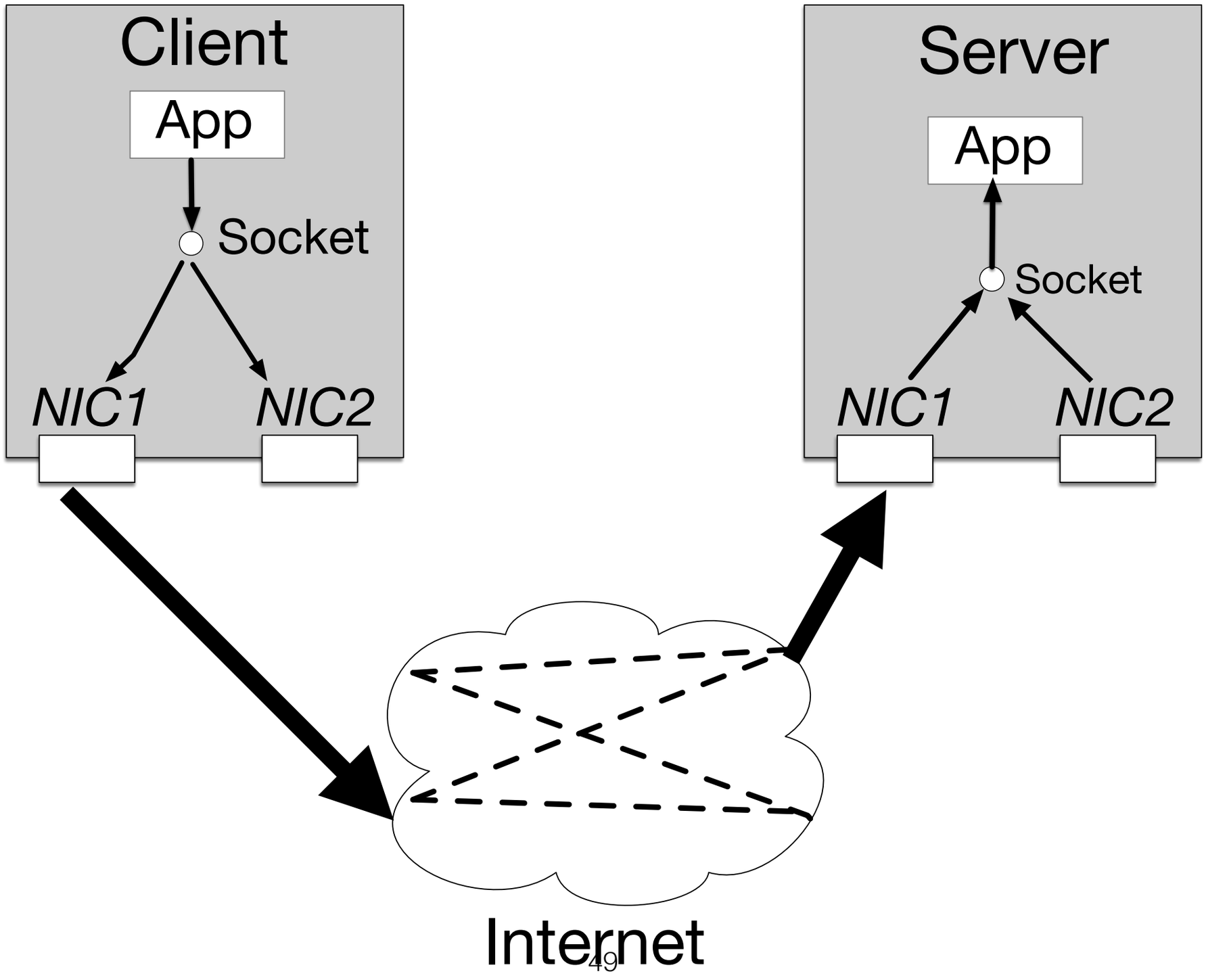

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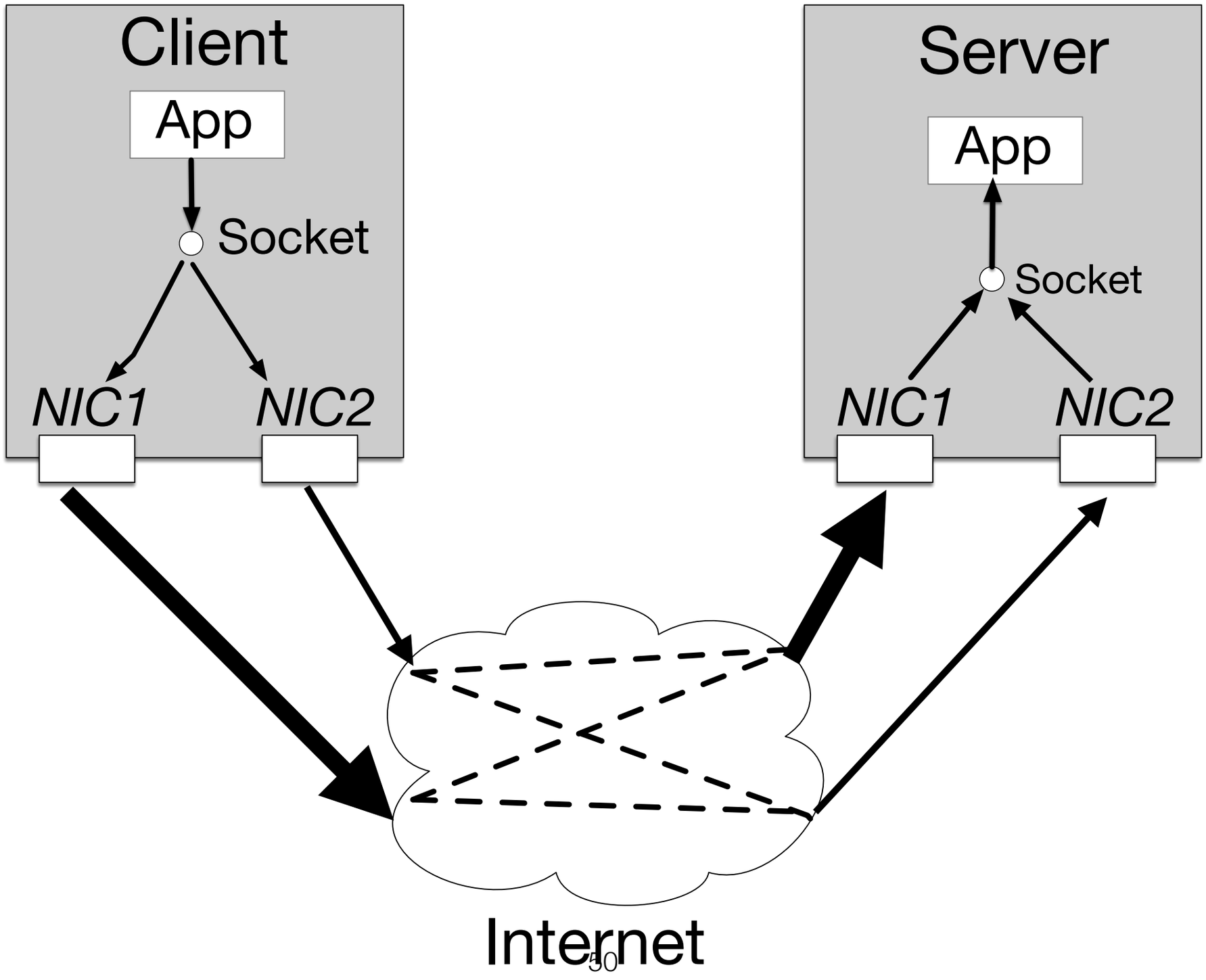

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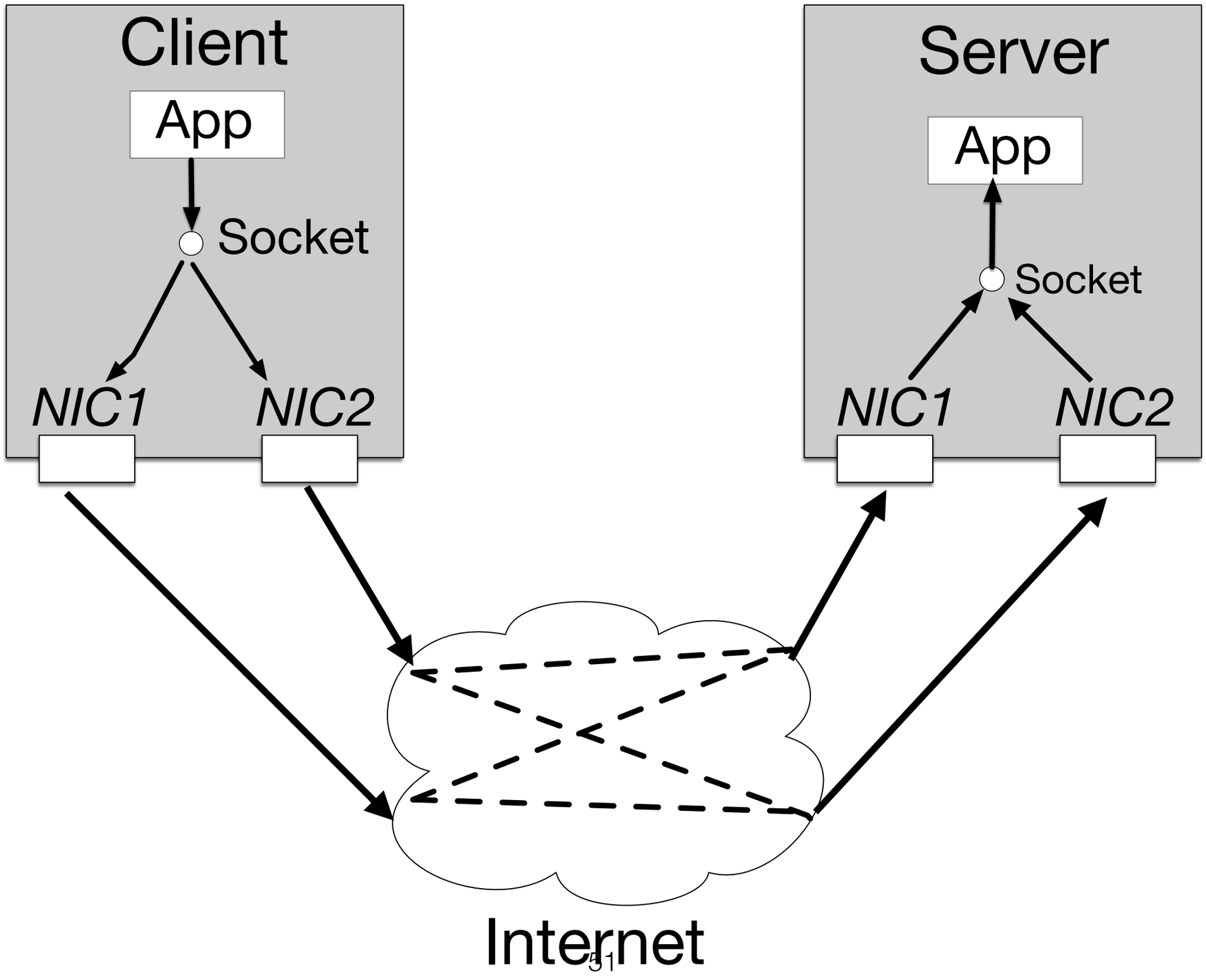
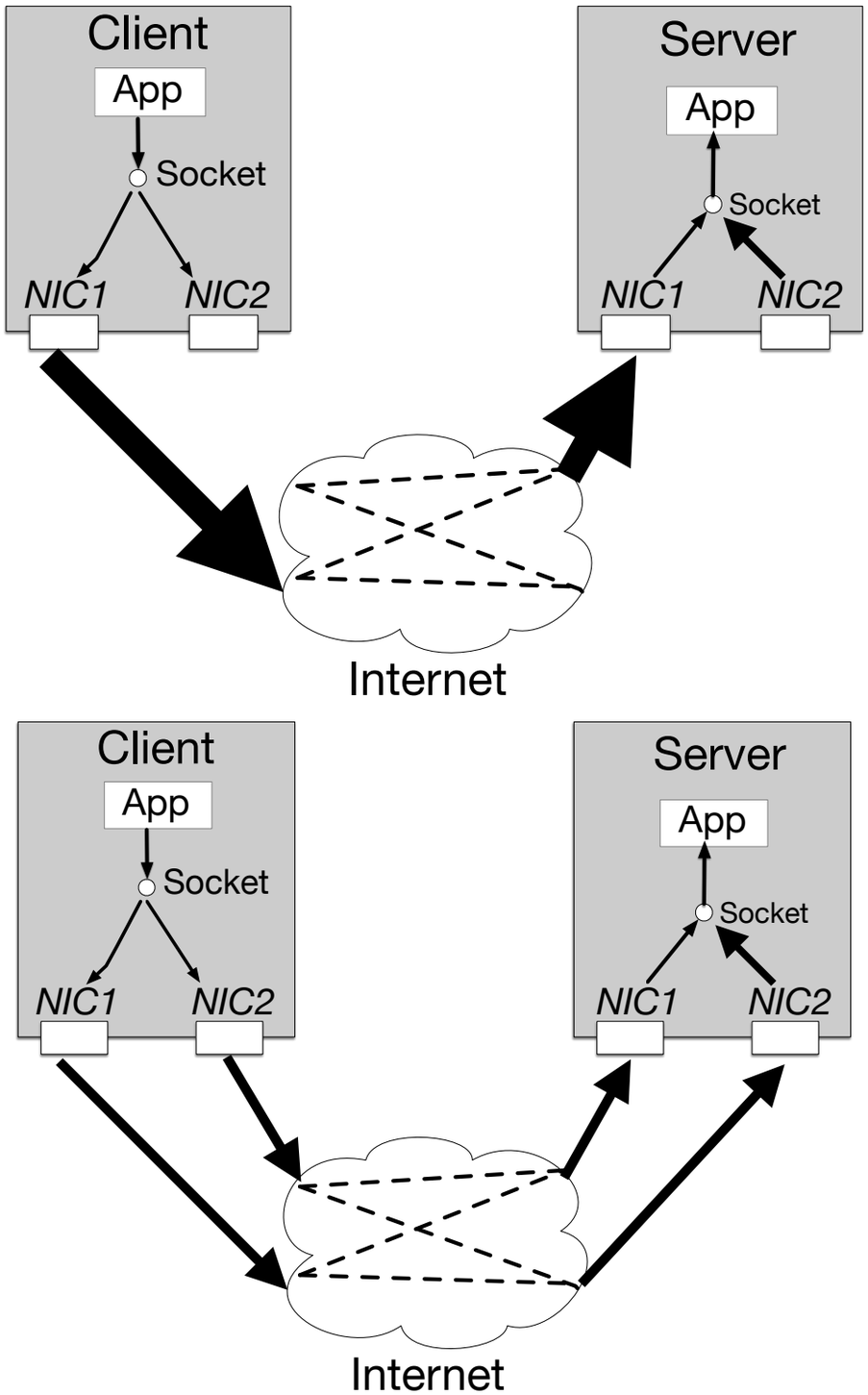


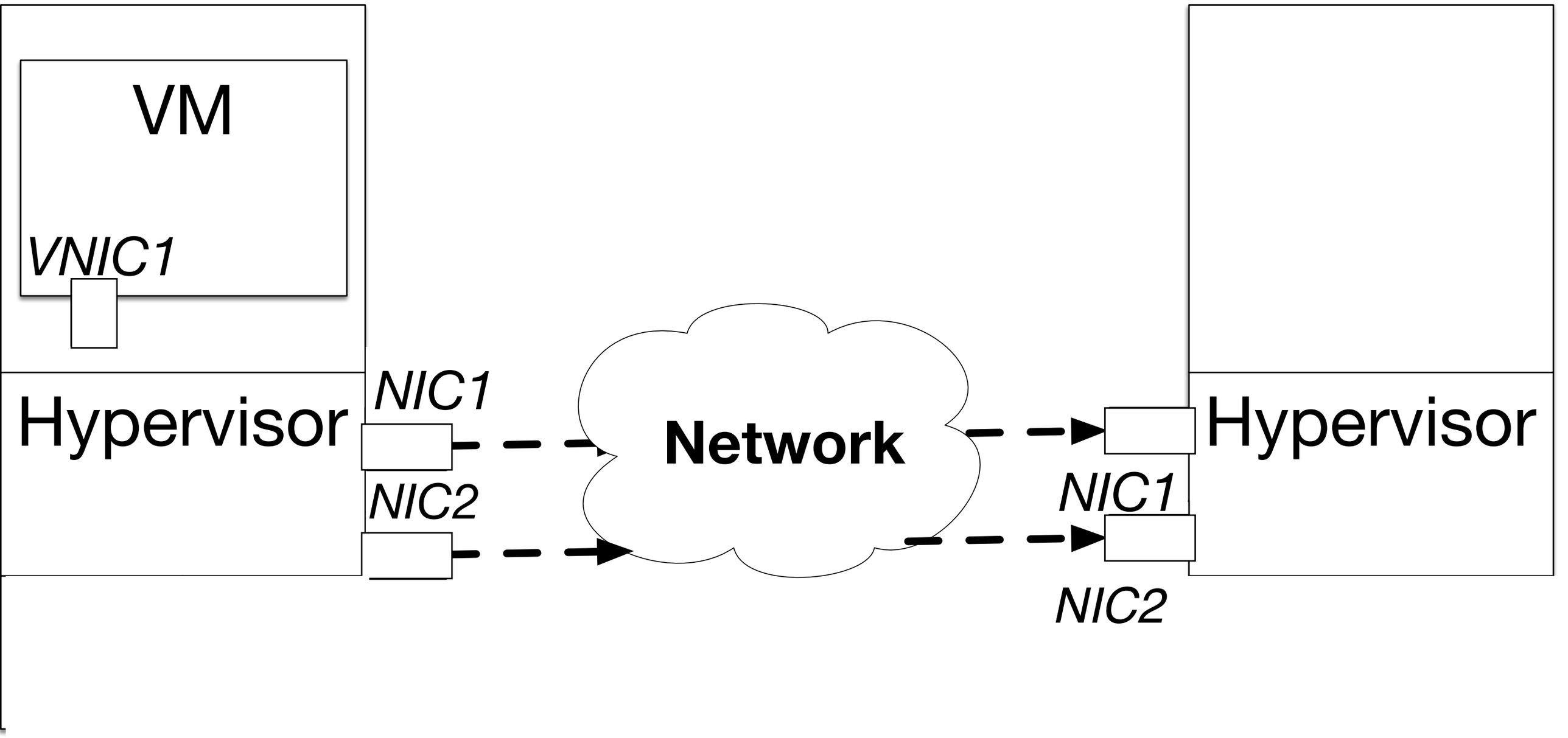
An MPTCP Socket

- MPTCP's ability to add and remove addresses enables transparency in networks.

- We can take advantage of MPTCP's adaptability to notify clients of new addresses.



Migration



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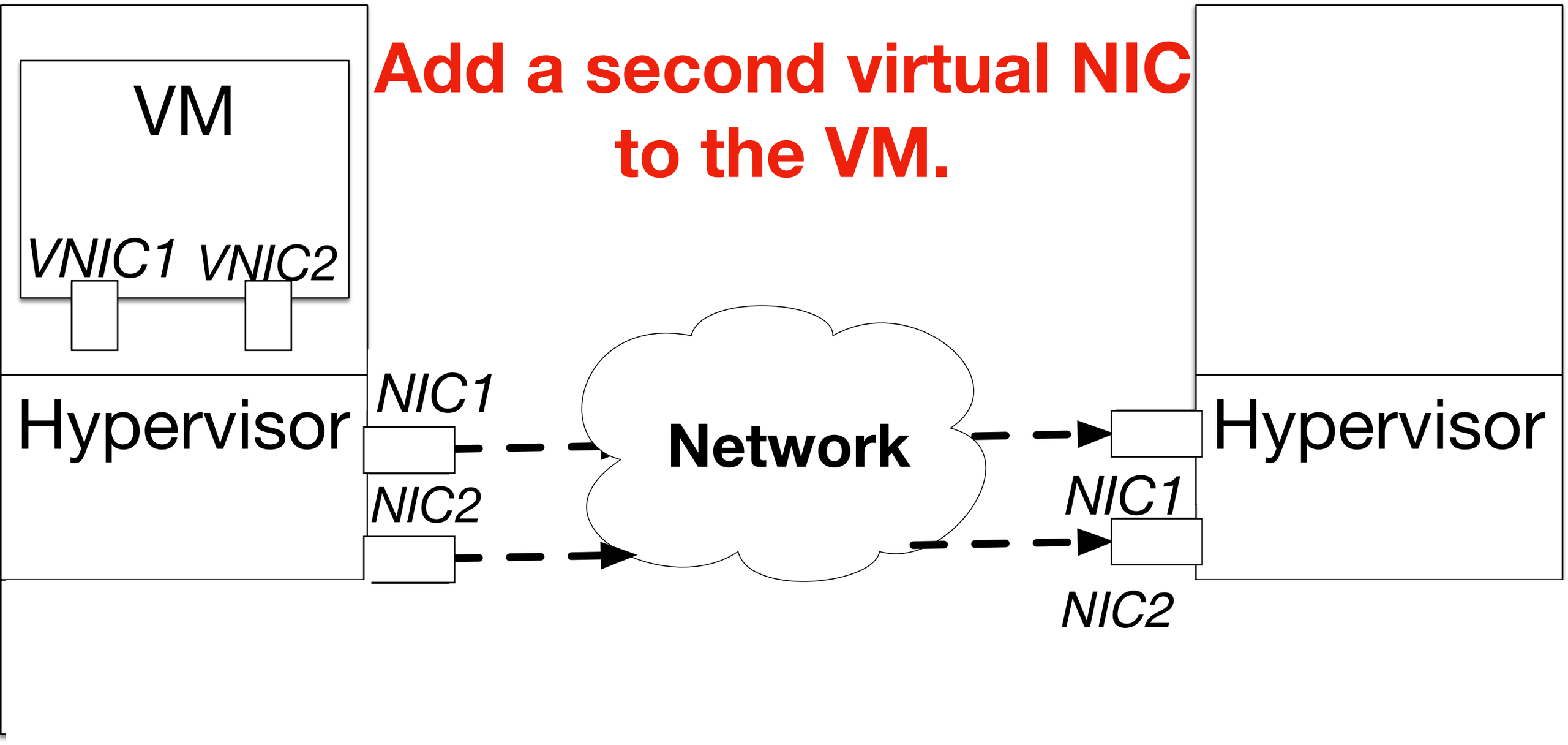
Migration

Add a second virtual NIC to the VM.



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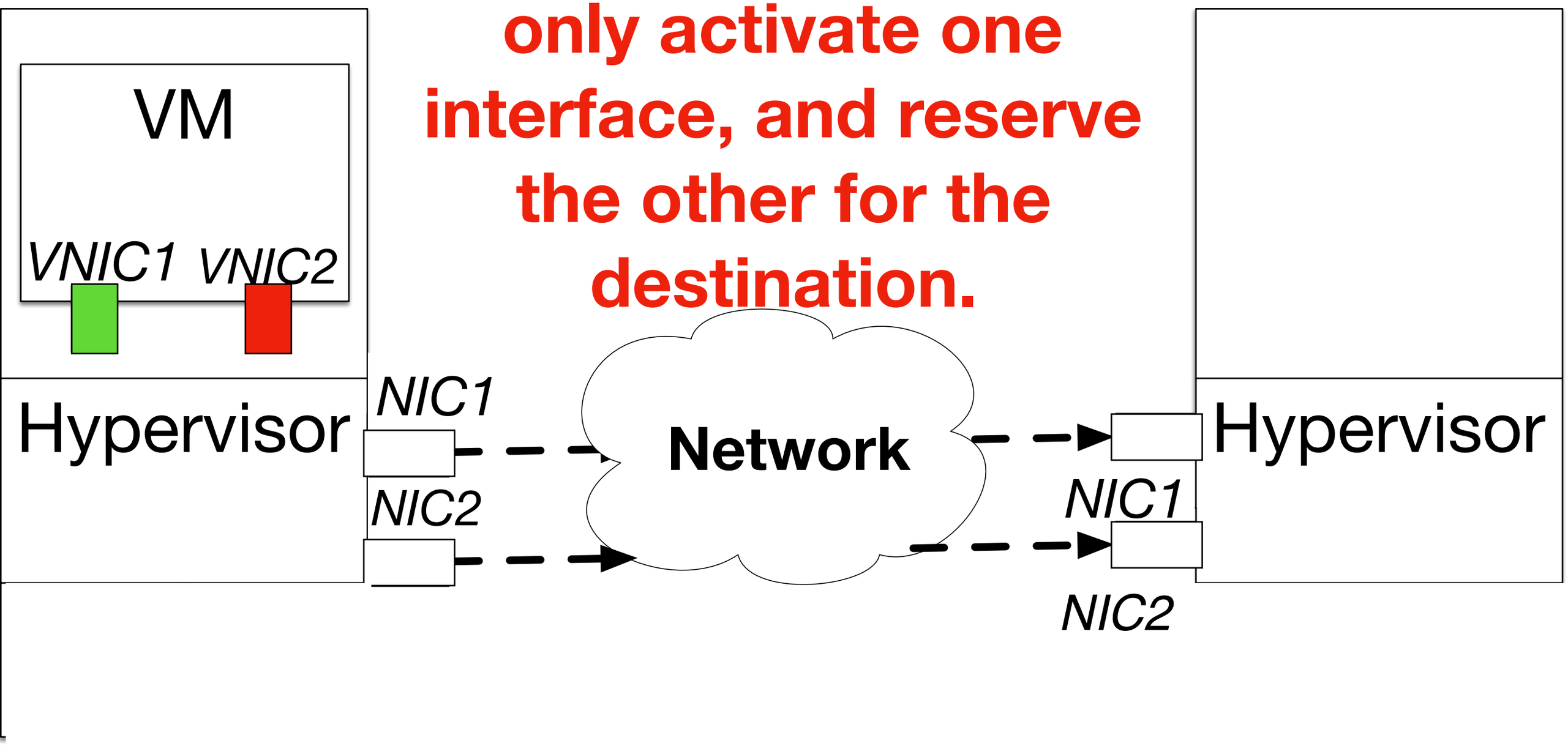
Migration

At the guest level we only activate one interface, and reserve the other for the destination.



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Migration

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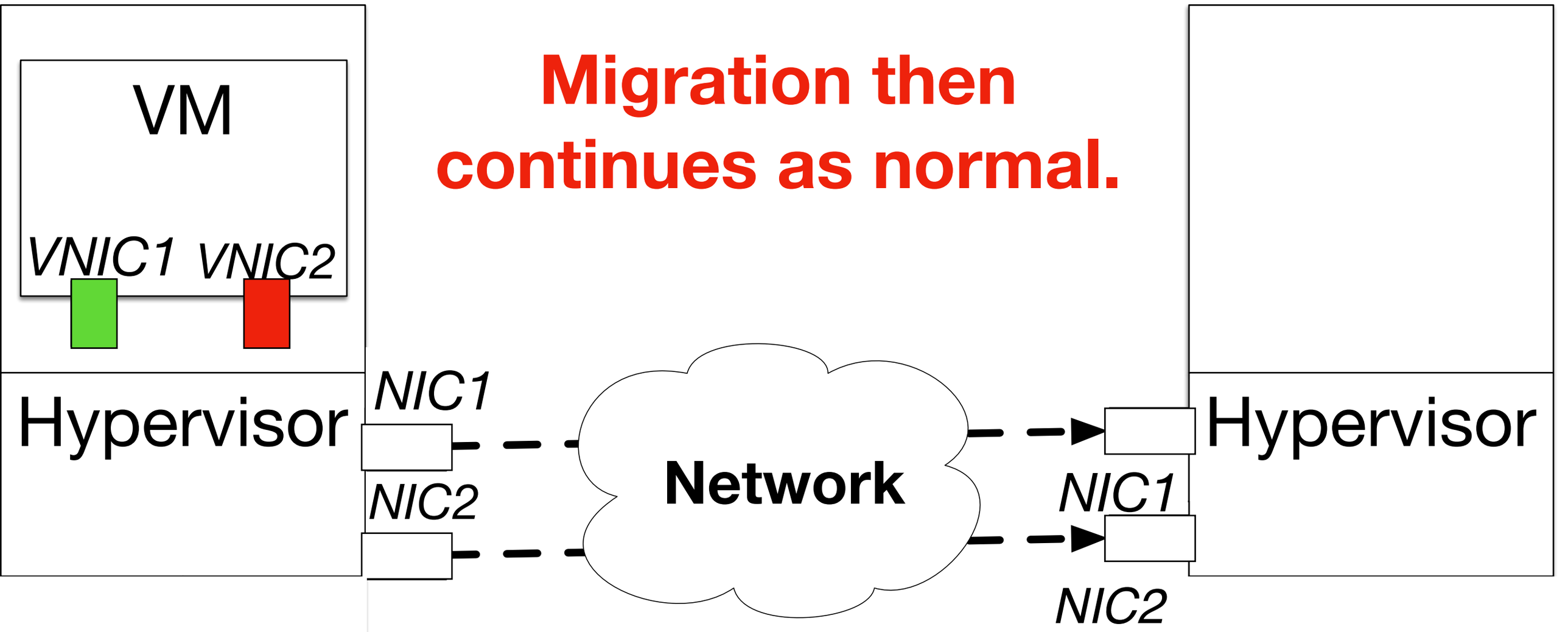

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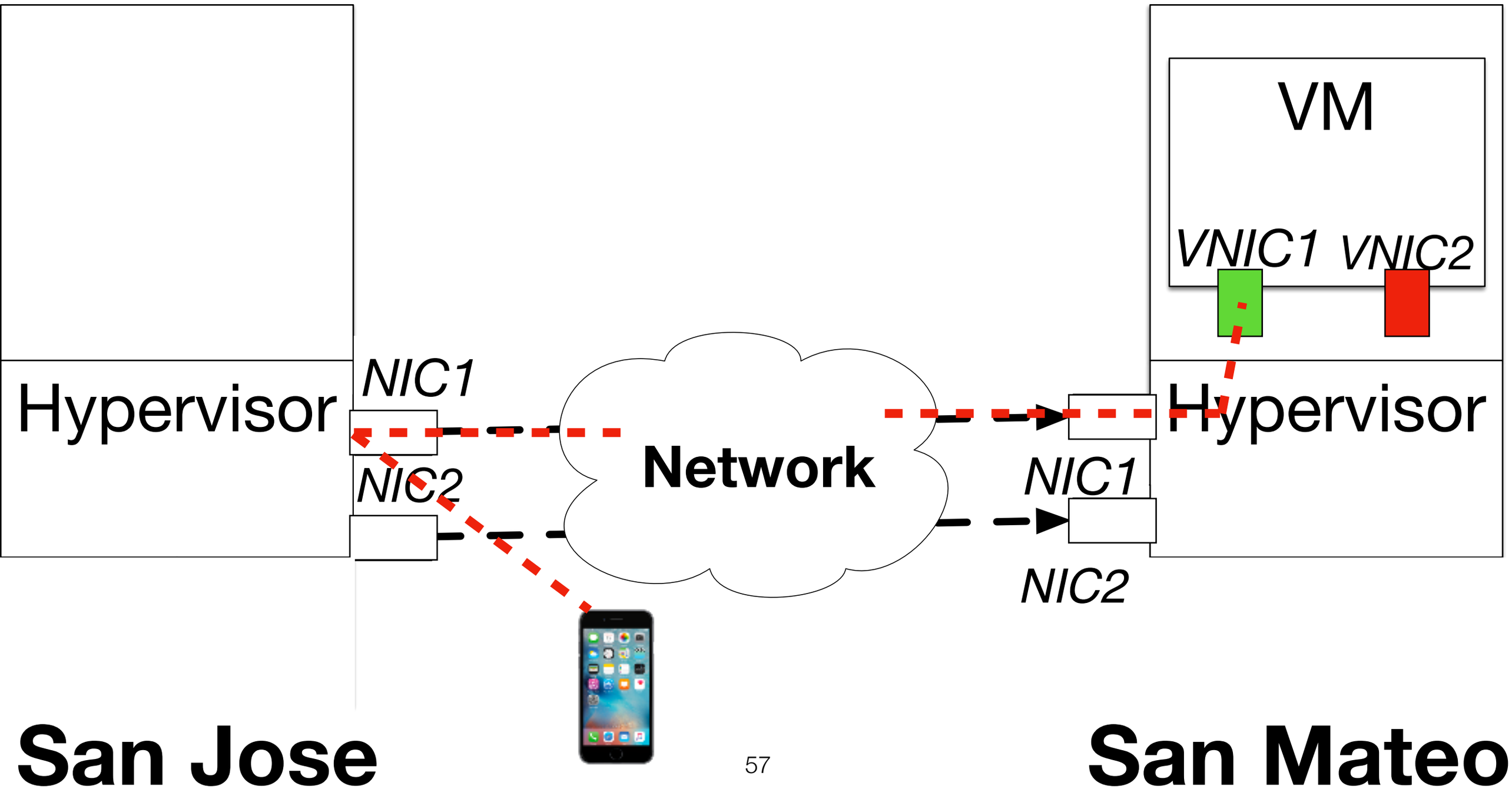
Migration



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Migration

MPTCP notifies existing connections to the new address

Add Address VNIC2

VM

VNIC1 *VNIC2*

Hypervisor

NIC1

NIC2

Network

NIC1

NIC2

Hypervisor

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Migration

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Add Address VNIC2

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VNIC1 *VNIC2*

Hypervisor

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NIC2

Network

NIC1

NIC2

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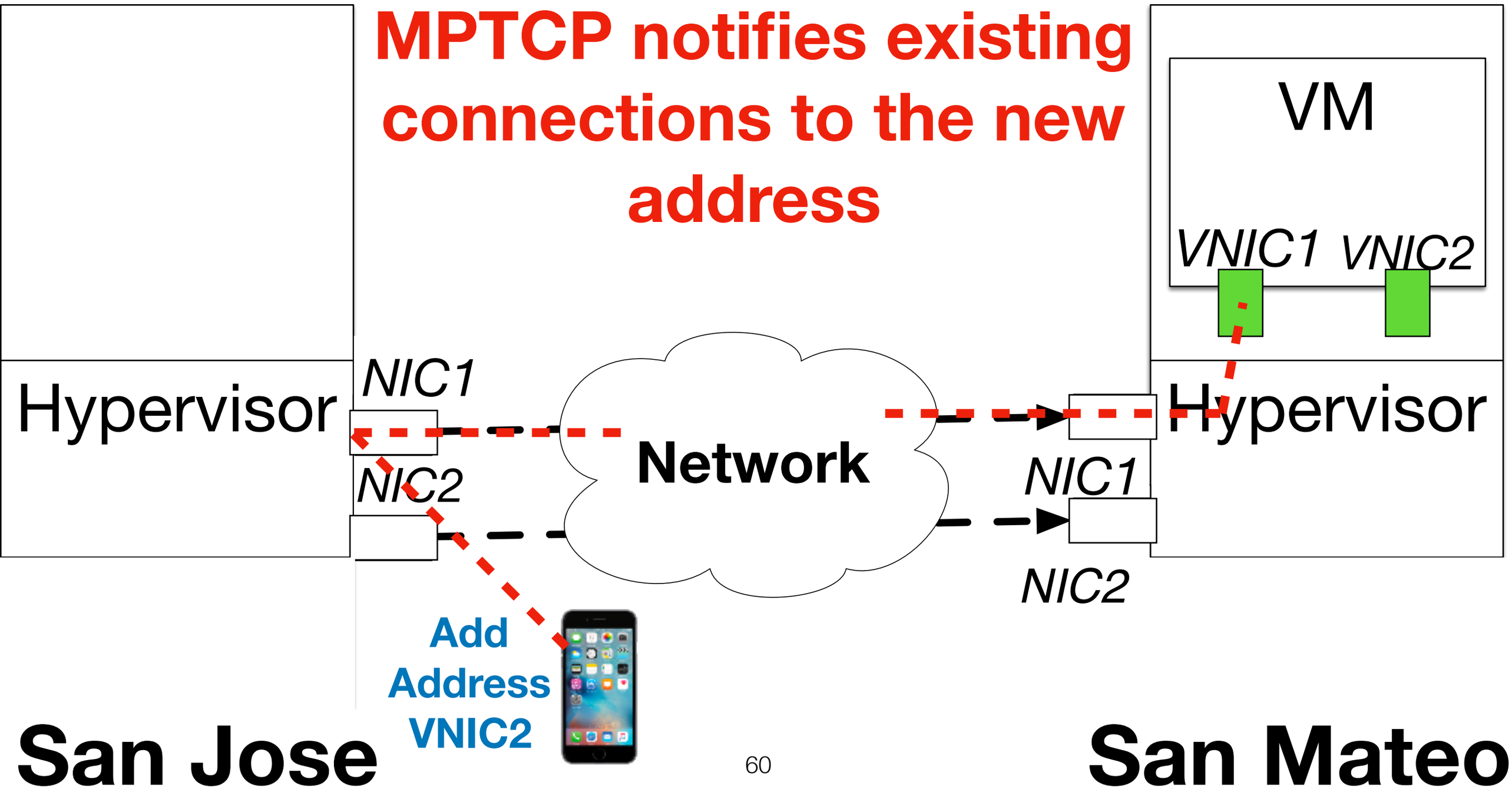
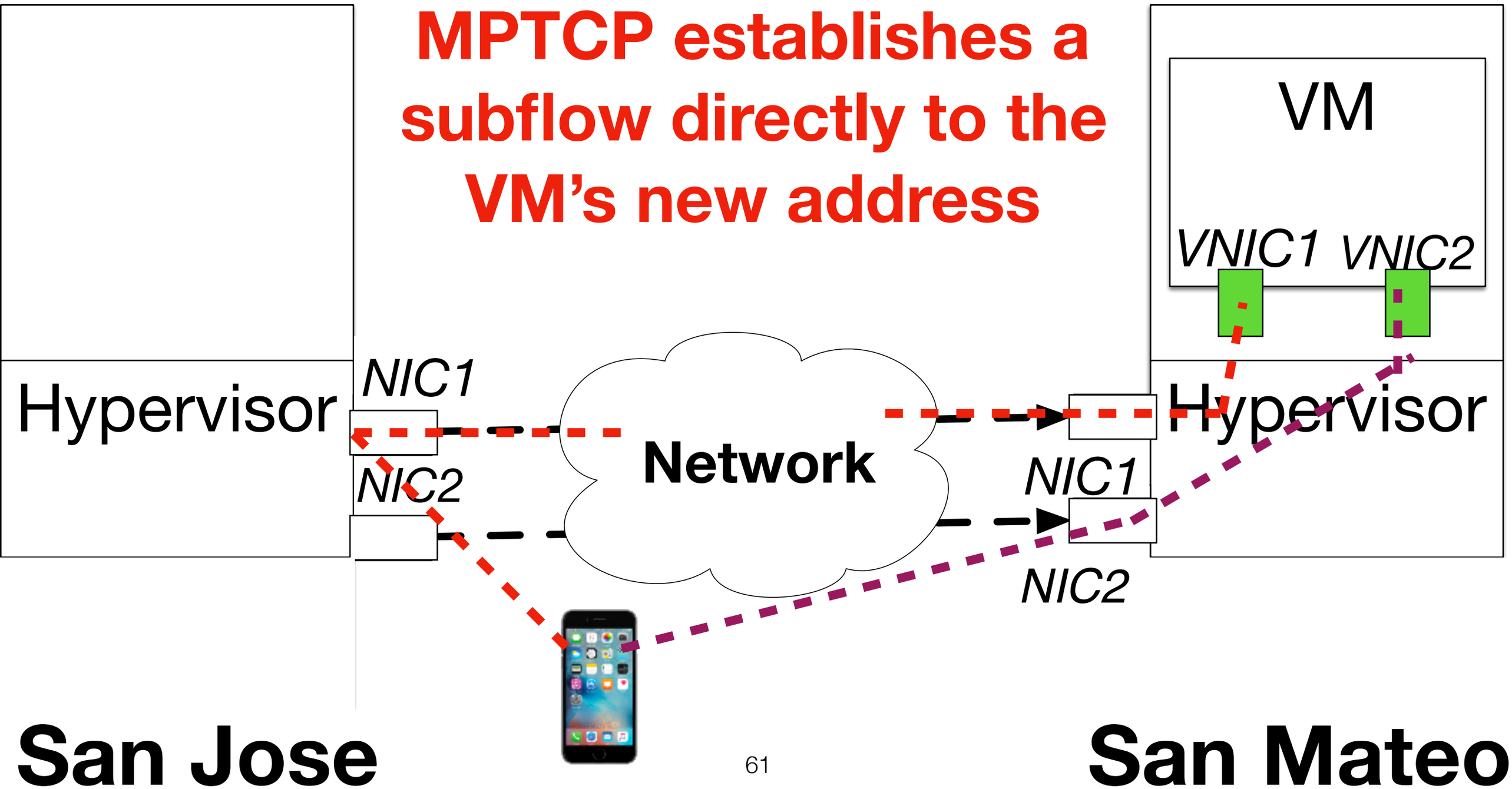
Migration

MPTCP notifies existing connections to the new address



Migration

MPTCP establishes a subflow directly to the VM's new address

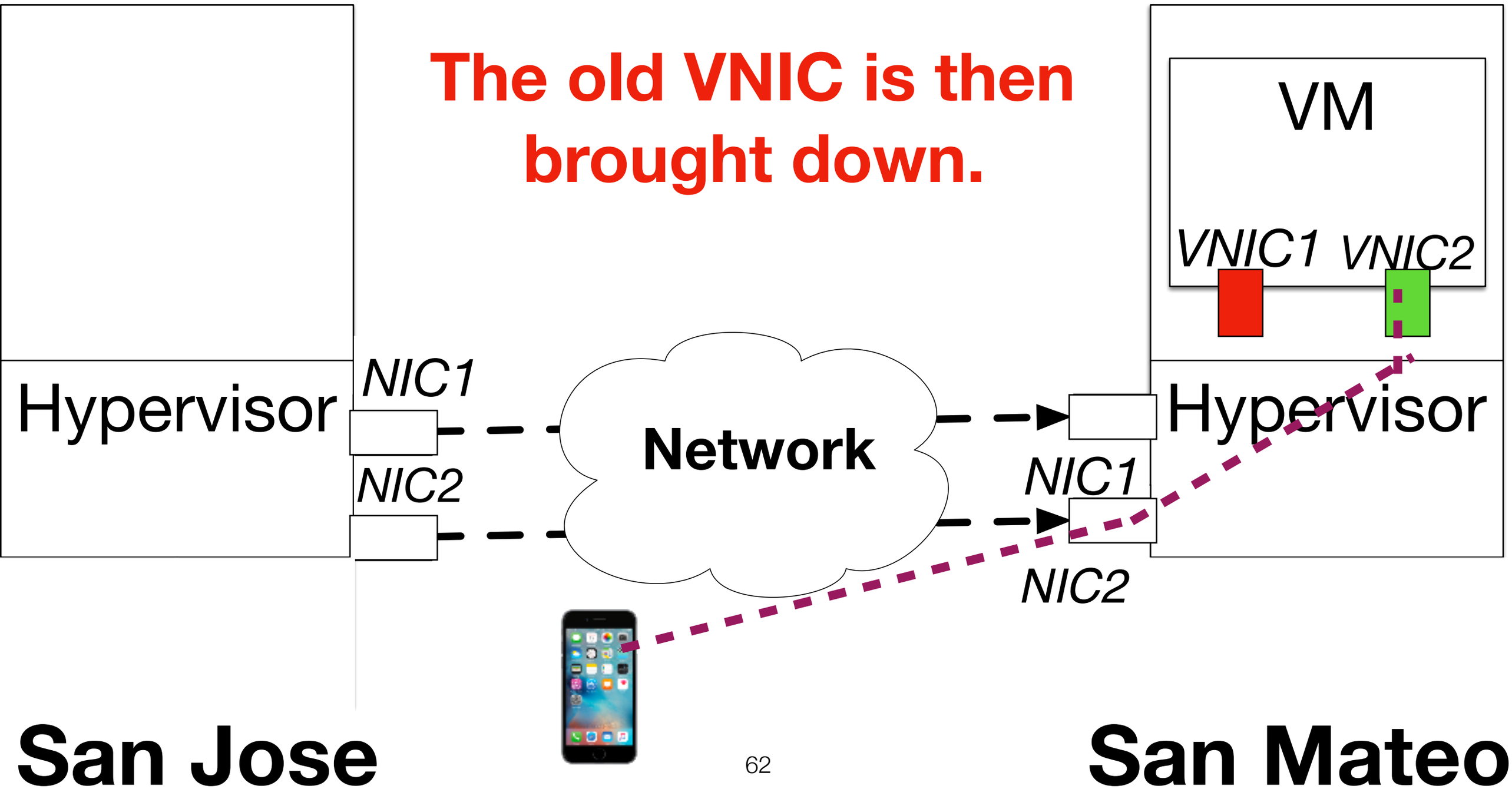


San Jose

San Mateo

Migration

The old VNIC is then brought down.



San Jose

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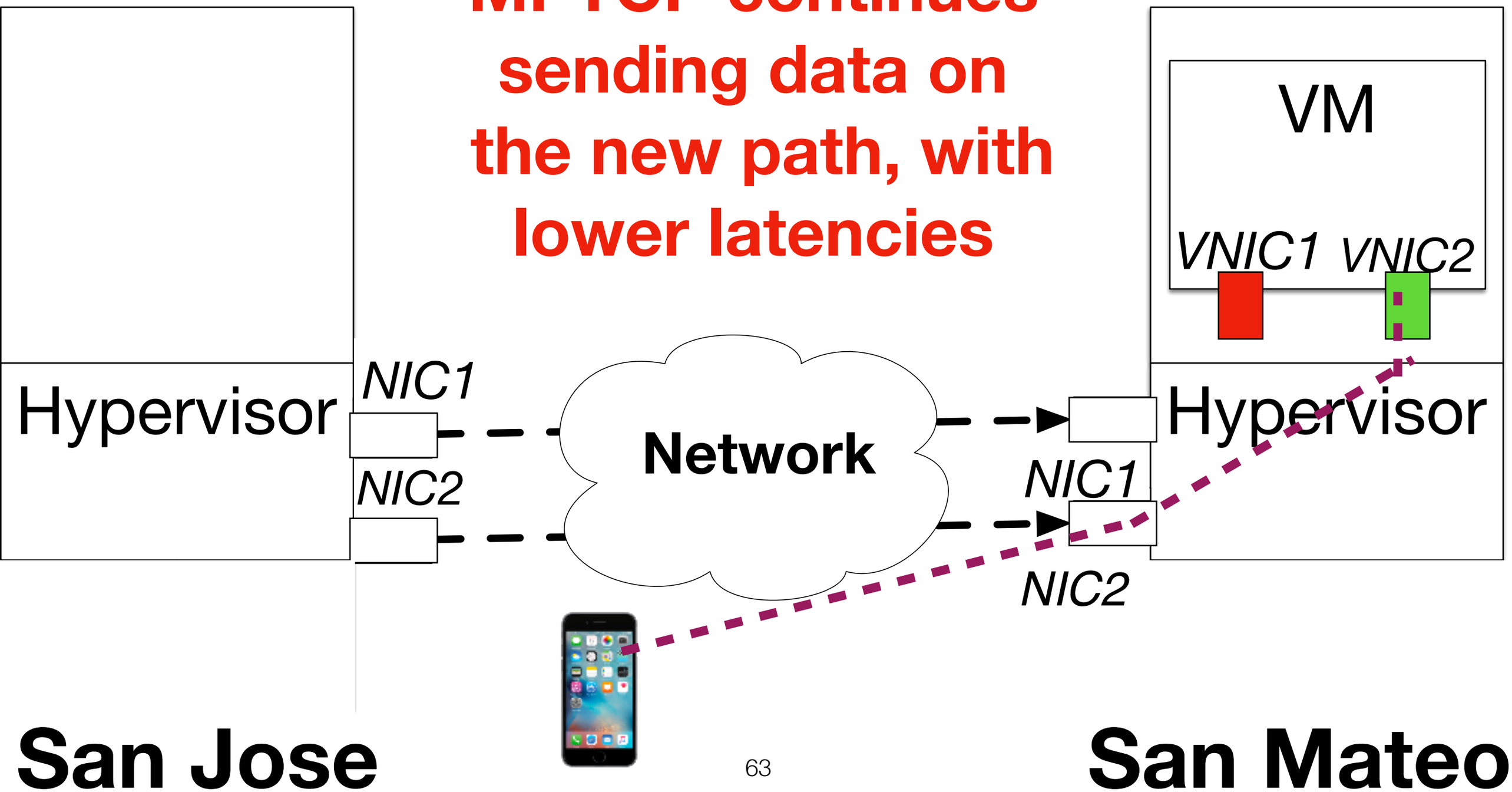
Migration

MPTCP continues sending data on the new path, with lower latencies



San Jose

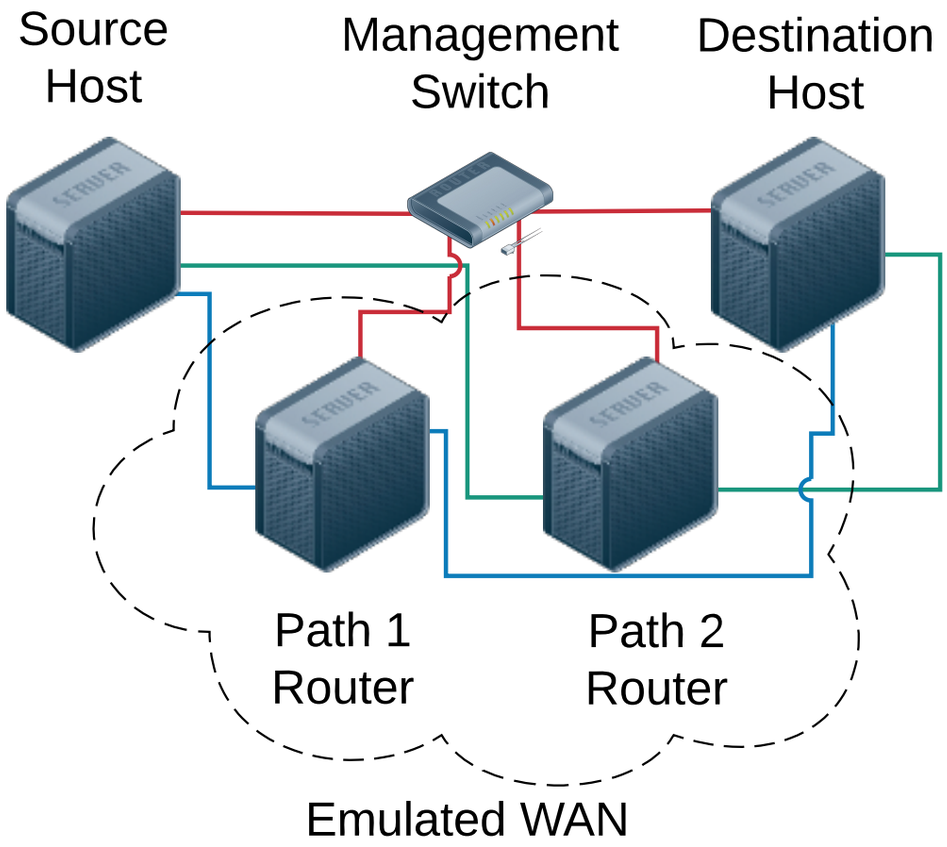
San Mateo

Outline

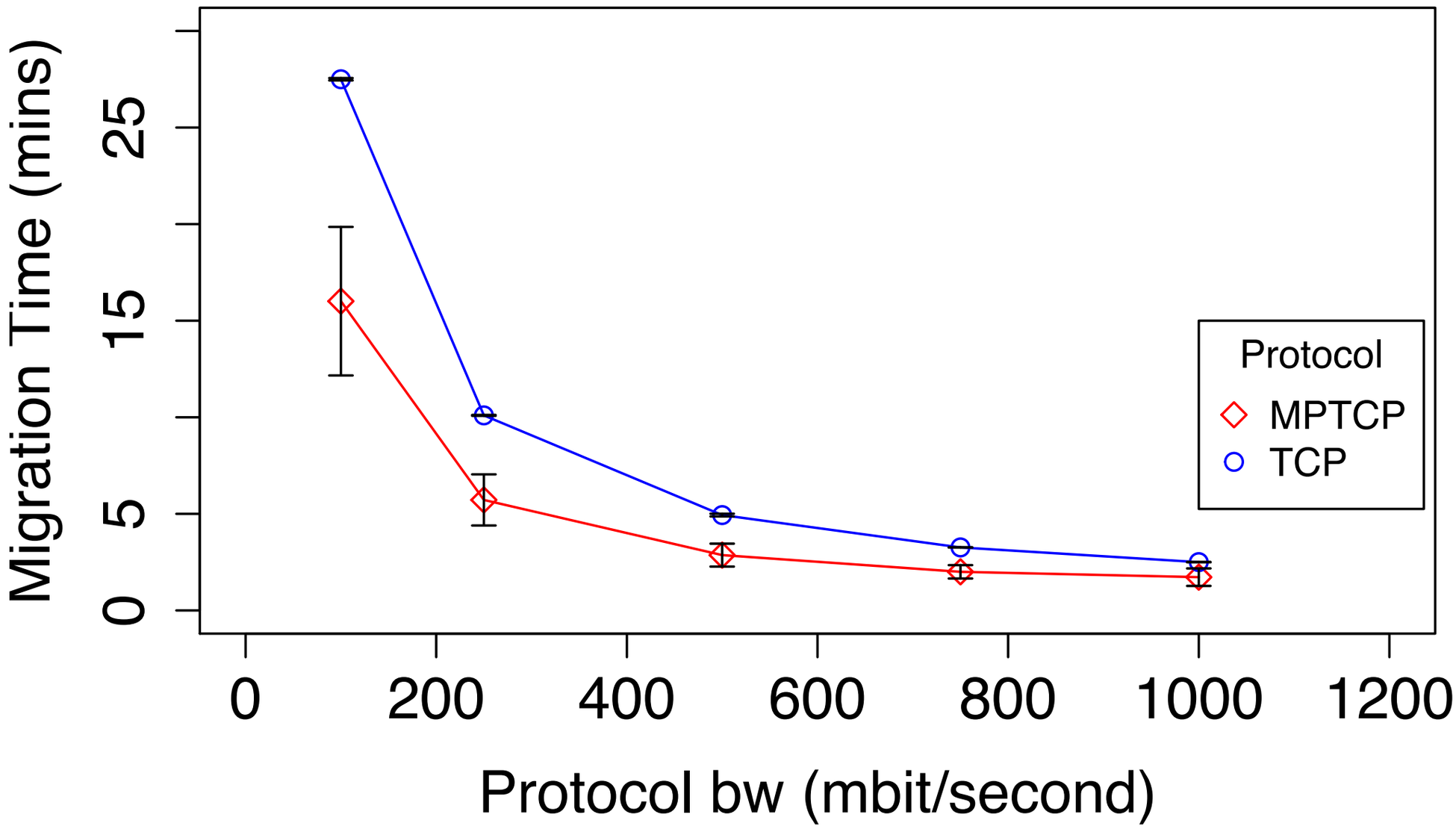
- Motivation and problem statement
- Migration & MPTCP Background
- Implementation
- Results
- Conclusion

Implementation & Evaluation Setup

- Tested our system on IBM's Softlayer Network along with a lab based edge cloud test bed (Dummynet).
- Use latest versions of MPTCP and KVM software.
- VM's run a workloads include dirtying VM memory and IPerf network benchmark.

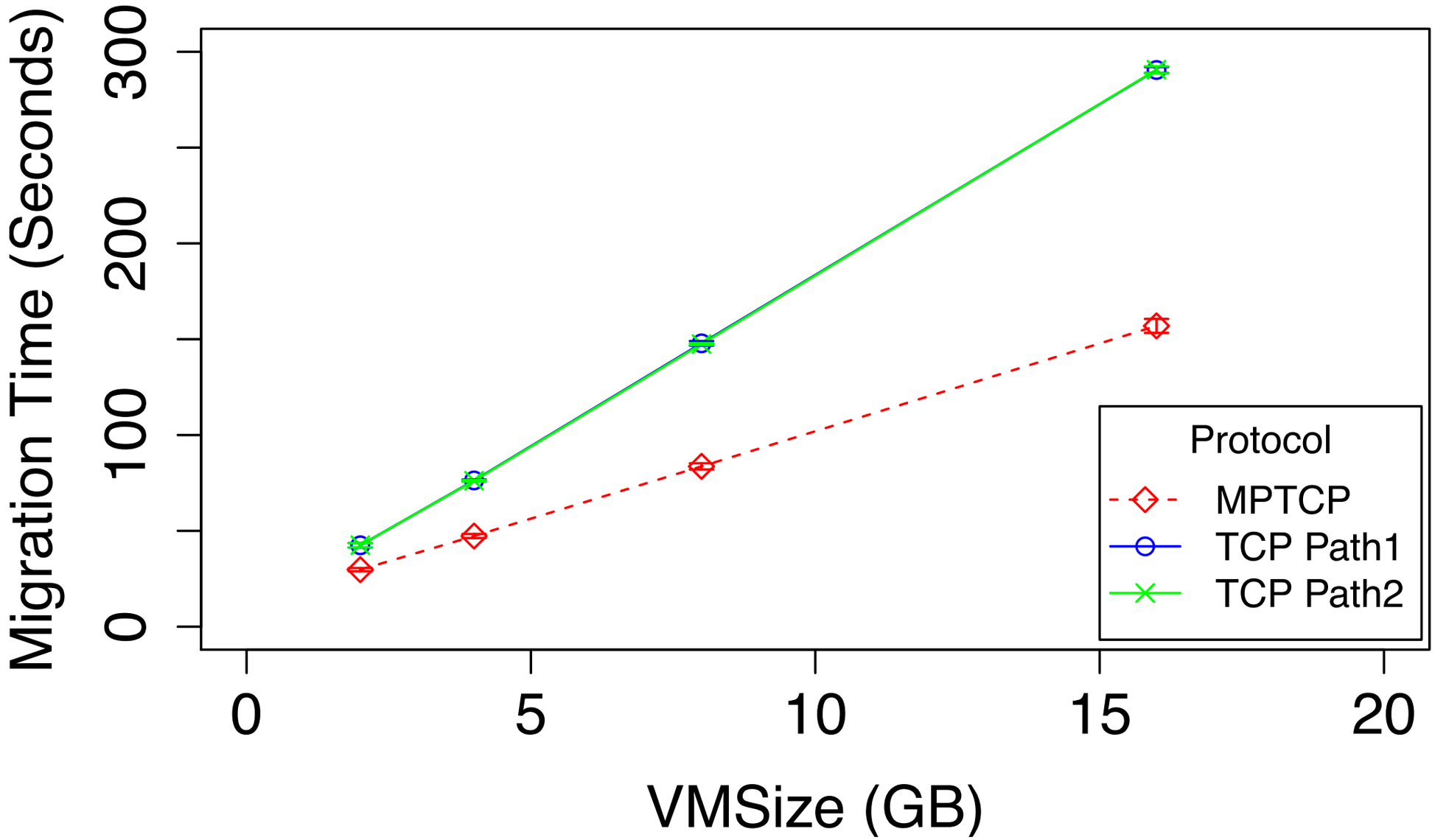


Impact of Network Bandwidth



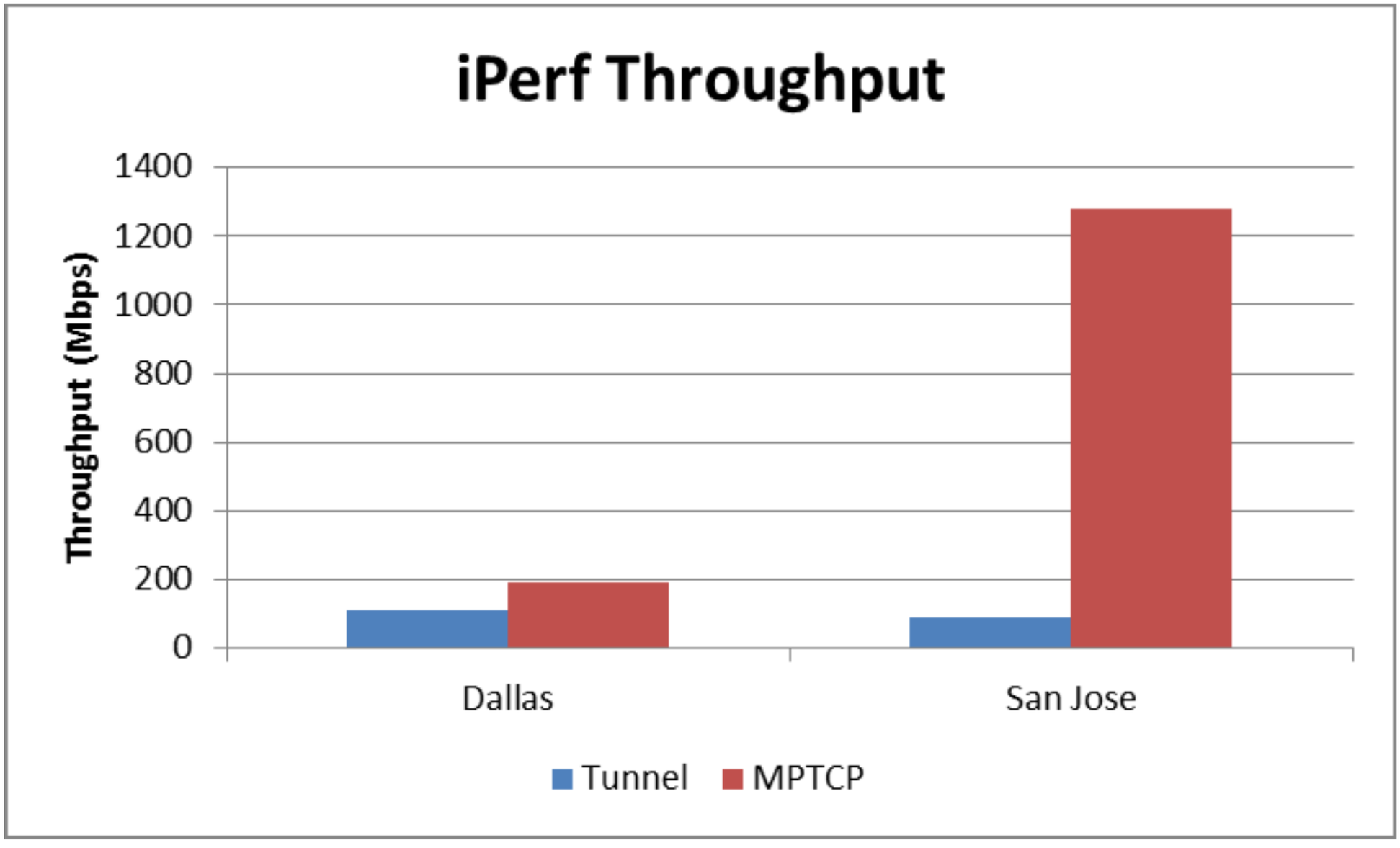
As bandwidths get lower MPTCP's value increases by almost almost 2x.

Impact of VM Application State



As VM memory size grow, MPTCP's performance increases. Allowing 2x faster migrations

Network Transparency & Guest Performance



13x increase in after migration throughput by with MPTCP.

Related Work

- Barham et. al. — Xen and the art of virtualization
- Clark et. al. — Introduced Live Migration
- Wood et. al. — VM Migrations over WAN
- Shen et. al. — WAN migrations between cloud locations
- Nasim et. al. — MPTCP migrations with SDNs in LAN’s
- Ha et. al. — VM Migrations in Edge Clouds

Conclusion

- VM Migrations in edge clouds is challenging.
- Our approach: Exploit MPTCP for Edge Migrations
  - Parallelizes data transfer
  - Provides Network Transparency
- 2x reduction in VM migration time while being network transparent
- Future Work: Edge Cloud Migration Policies

Thank You!
Questions?

https://cs.umass.edu/~lucasch