Fast Transparent Virtual Machine Migration in Distributed Edge Clouds

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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

AWS Regions

- GovCloud (IAP Compliance)
- US West (Oregon)
- US West (Northern California)
- US East (Northern Virginia)
- South America (Sao Paulo)
- EU (Ireland)

- AWS Regions (10)
- AWS Edge Locations (52)
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.
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Cloud can migrate her AR application to a closer location.
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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

Network State

192.168.1.1
Anatomy of VM Migration

Begin Migration

San Jose  

San Mateo
Anatomy of VM Migration

Resource State

San Jose

San Mateo
Anatomy of VM Migration

Resource State

San Jose

San Mateo
Anatomy of VM Migration

Resource State

San Jose

San Mateo
Anatomy of VM Migration

San Jose  

San Mateo
Anatomy of VM Migration

Resource State

San Jose

San Mateo
Anatomy of VM Migration

Resource State

San Jose  San Mateo
Anatomy of VM Migration

Complete the Migration

San Jose

San Mateo
Anatomy of VM Migration

Complete the Migration

San Jose

San Mateo
Anatomy of VM Migration

Low Bandwidth Speeds
Mean Long Transfer Times.
Migration over Slow Networks

• **Problem**: Low Bandwidth Speeds Mean Long Transfer Times.
Migration over Slow Networks

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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
A Typical TCP Connection

What if we could take advantage of our second interface?
An MPTCP Socket

Client
  App
    Socket
  NIC1 → NIC2

Server
  App
    Socket
  NIC1 ← NIC2

Internet
Migrating over MPTCP

• Parallel Paths allow us to aggregate bandwidth

• A net effect of providing faster transfer times for VM state.
Migration

San Jose  

San Mateo
Migration

We now take advantage of all available interfaces
Migration

We use all interfaces at the host level for migration traffic.
Migration then continues as normal.
Migration

Transfer Memory and Disk State Over Both Paths.
Migration

Transfer Memory and Disk State Over Both Paths.
Parallel data transfers allow migration time to be decreased.
Migration

Complete the Migration

San Jose

San Mateo
Migration

The VM IP address changes at its new location.

Old VM IP Address

New VM IP Address

San Jose

San Mateo
Migration

Latencies will remain the same if not increased!

\[ X \text{ ms} + Y \text{ ms} > Z \text{ ms} \]

\[ Z \text{ ms} = \text{Directly Connect} \]
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

Client

App

Socket

NIC1

NIC2

Server

App

Socket

NIC1

NIC2

Internet
An MPTCP Socket

Client

App

Socket

NIC1

NIC2

Server

App

Socket

NIC1

NIC2

Internet
An MPTCP Socket

Client

App

Socket

NIC1

NIC2

Server

App

Socket

NIC1

NIC2

Internet
An MPTCP Socket

Client

App

Socket

NIC1

NIC2

Server

App

Socket

NIC1

NIC2

Internet
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.
Add a second virtual NIC to the VM.
Migration

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

Migration then continues as normal.
Migration
MPTCP notifies existing connections to the new address
Migration

MPTCP notifies existing connections to the new address
MPTCP notifies existing connections to the new address

Add Address VNIC2
MPTCP establishes a subflow directly to the VM’s new address.

San Jose  

San Mateo
The old VNIC is then brought down.
Migration

MPTCP continues sending data on the new path, with lower latencies
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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.
As bandwidths get lower MPTCP’s value increases by almost almost 2x.
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?

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