From Cloud to Edge: A First Look at Public Edge Platforms

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Current Edge Platforms

Cloud Providers
- AWS
- Microsoft Azure
- Google Cloud

Edge Platforms
- AWS Local Zones
- Azure Edge Zone

Edge Applications
- Autonomous driving
- AR/VR
- Smart city
Overview of NEP

• What is NEP?
  • Alibaba ENS\(^1\)
  • A leading edge platform in China, providing IaaS, PaaS, FaaS, etc.

• What consists of NEP physical servers?
  • Built atop Alibaba CDN.
  • Cooperative third-party IDCs and network operators.
  • Mainly based on micro datacenters rather than sinking into cellular core networks.

\(^1\) Extending the Boundaries of the Cloud with Edge Computing
https://www.alibabacloud.com/blog/extending-the-boundaries-of-the-cloud-with-edge-computing_594214
The deployment scale of NEP is larger than current edge/cloud platforms!

| Platform                        | Regions / Coverage | Density ($10^6 \text{mi}^2$) | Platform       | Regions / Coverage | Density ($10^6 \text{mi}^2$) |
|--------------------------------|--------------------|--------------------------------|----------------|--------------------|--------------------------------|
| AWS EC2                         | 24 Global          | 0.13                           | MS Azure       | 33 Global          | 0.17                           |
| Google Cloud                    | 24 Global          | 0.13                           | Alibaba Cloud  | 23 Global          | 0.12                           |
| Azure Edge Zones                | 5 U.S.             | 1.32                           | Huawei Cloud   | 5 China            | 1.35                           |
| AWS Wave-length + Local Zones   | 14 U.S.            | 3.70                           | NEP (our study)| >500 China         | >135                           |
Benefits of NEP-like Edge Platforms

- Latency reduction, application performance improvement.
- Resource saving (e.g., bandwidth).

But all parties are still wondering:

- End users: How much latency and QoE are improved?
- Cloud providers: How much bandwidth and other resources are saved?

We need quantitative characteristics of NEP-like edge platforms.
Measurements over NEP

Nodes: small DCs at different locations
- Beijing-1
- Beijing-2
- Shanghai
- Shenzhen

IaaS VMs

Edge Apps

Wi-Fi / LTE / 5G / Wired

traceroute
iPerf3

Player actions & Game display

videos

Live Streaming

Cloud Gaming

UEs

complete VM traces

Edge performance

Edge workloads characterization
Measurements over NEP

Nodes: small DCs at different locations

Servers

Beijing-1
Beijing-2
Shanghai
Shenzhen

IaaS VMs

Edge Apps

Wi-Fi / LTE / 5G / Wired

• Crowd-sourcing experiments from 158 participants in 41 cities across China.

• Edge performance metrics:
  • Network latency
  • Network throughput
Measurements over NEP

Nodes: small DCs at different locations
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IaaS VMs

Edge Apps

Servers

Wi-Fi / LTE / 5G / Wired

- traceroute
- iPerf3

Player actions & Game display

- videos

Live Streaming

Cloud Gaming

UEs

- Controlled experiments by authors.
- Application-level QoE:
  - Cloud gaming
  - Live streaming
Measurements over NEP

**Nodes:** small DCs at different locations

- Beijing-1
- Beijing-2
- Shanghai
- Shenzhen

**IaaS VMs**

**Edge Apps**

- Offline analysis of Edge workloads.
- Edge workloads metrics:
  - VM subscription
  - Resource usage
  - Application on NEP, Monetary cost, etc.
Experiment Settings

- **Edge and cloud servers**
  - Network latency: one VM on each edge site\(^1\) of NEP and each cloud region of AliCloud.
  - Network throughput: 20 NEP VMs at different sites.

- **Crowd-sourcing participants**
  - Network latency: 158 users from 20 provinces, 41 cities in China, 59%/34%/7% of the results under Wi-Fi/LTE/5G.
  - Network throughput: 25 volunteers which is a subset from above 158 users.

- **Software**
  - Use traceroute (ICMP) and iPerf3 (TCP) to obtain the network latency and throughput.

\(^1\) A site refers to a datacenter at some location, which consists of many servers, and each server hosts many VMs.
Edge Performance: **Latency**

Median RTT across users

1.9X/3.4X faster than the nearest cloud/all clouds!
Edge Performance: Latency

Median RTT across users

RTT coefficient of variation (CV) across users

1.9X/3.4X faster than the nearest cloud/all clouds!

The nearest cloud has 5.8X/3.9X/5.7X higher median RTT CV under Wi-Fi/LTE/5G!
• Edge VMs deliver lower and more stable network latency compared to Cloud VMs.
• The best RTT remains 10.4ms to the nearest edge VM under 5G.
Edge Performance: **Hop number**

![Diagram showing hop number distribution for different categories: nearest edge, 3rd-nearest edge, nearest cloud, all clouds. The 5-12 hops category has a box plot with a lower quartile at 8 and an upper quartile at 14. The 10-16 hops category has a box plot with a lower quartile at 10 and an upper quartile at 16.](image-url)
Edge Performance: Hop number

- The reduced hop number leads to lower network latency and jitter.
- The first 3 hops dominate more than 70 percent of the total latency for the nearest edge site.

| Hop Num | Nearest edge site | Nearest cloud site |
|---------|-------------------|--------------------|
|         | 1st-2nd-3rd hop   | Rest               |
| WiFi    | 44.2%-10.3%-15.1% | 30.2%              |
| LTE     | 10.2%-70.1%-9.4%  | 10.3%              |
| 5G      | 97.9% in total    | 2.1%               |

**Implication:** To reached the envisioned prospects of edge computing, NEP needs to deploy denser sites and collaborate with operators to sink the edge resources into ISP’s core networks or even cellular base stations.
Edge Performance: Throughput

- **Downlink throughput**
  - Phone-VM (LTE): Mean: 42; corr: 0.01
  - Phone-VM (WiFi): Mean: 41; corr: -0.02
  - Phone-VM (5G): Mean: 497; corr: -0.80
  - VM-VM (wired): Mean: 480; corr: -0.73

- **Uplink throughput**
  - Phone-VM (LTE): Mean: 14; corr: -0.01
  - Phone-VM (WiFi): Mean: 26; corr: -0.06
  - Phone-VM (5G): Mean: 76; corr: 0.11

- TCP-based throughput testing.
- Running iPerf3 for 15 seconds each test.
- Corr is calculated by Pearson correlation coefficient.
**Edge Performance: Throughput**

**Implication:** Bringing resources closer to users improves network throughput on NEP only with high bandwidth capacity at the last mile. Throughput improvement will benefit more emerging, bandwidth-hungry edge applications in the future.

- **TCP-based throughput testing.**
- **Running iPerf3 for 15 seconds each test.**
- **Corr is calculated by Pearson correlation coefficient.**
Experiment Settings: Application QoE

• Deploy one nearest edge and three cloud servers
  (670KM/1300M/2000KM away from experiment performed!)

• Software deployment:
  
  ➢ GamingAnywhere\(^1\) for cloud gaming.
  ➢ End-to-end streaming app using RTMP protocol.

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\(^1\) GamingAnywhere – An Open Source Cloud Gaming System [https://gaminganywhere.org/](https://gaminganywhere.org/)
Implication: Placing gaming backend on nearby NEP edges help achieve less than 100ms response delay. To further enhance the experience, we need to improve the server-side gaming execution.
Edge Workloads: **Total Analytics**

Compare with Azure cloud dataset[1]

- VM subscription
- CPU usage
- Application of NEP (e.g., Application type, VM numbers per application)
- Bandwidth usage
- Resource load balance
- Monetary of NEP

[1] Resource Central: Understanding and Predicting Workloads for Improved Resource Management in Large Cloud Platforms. (SOSP '17).
Edge Workloads: VM subscription

Number of vCPUs per VM

| Azure Cloud | Our Edge |
|-------------|----------|
| small       | median   |
| large       |          |

Memory size per VM

| Azure Cloud | Our Edge |
|-------------|----------|
| small       | median   |
| large       |          |

Small / median / large represents ≤4 / 5-16 / >16 CPU cores or GBs memory.

Implication: The large VM size on NEP-like edge platforms may cause severe resource fragmentation. Dynamic VM migration and resource disaggregation may help to solve this problem.
Implication: The relatively low but highly skewed CPU usage challenges the NEP’s VM management. To better utilize the CPU resources, NEP may need smart VM placement algorithms or employ more elastic computing forms, e.g., containers together with IaaS VMs on the same server.
Conclusions

• The first comprehensive measurement on a commercial, multi-tenant edge platform.

• Lead to insightful implications for designing future edge platforms and edge-based applications.

• Edge workloads traces are open-sourced at: https://github.com/xumengwei/EdgeWorkloadsTraces
Thanks for your listening!

Edge workloads:

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