TCSS 562: SOFTWARE ENGINEERING FOR CLOUD COMPUTING

Serverless Computing

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OBJECTIVES

- Questions on:
  - Tutorial #2
  - Tutorial #3
- Presentations Schedule
- Presentations Format
- Group Project Check-in – Sunday May 6
- Midterm Wednesday 5/9
- Serverless Computing

PRESENTATIONS SCHEDULE

- WEEK 8

May 14 – Web Architecture
- Team 1 – Amazon Well Architected Framework (Paper)
- Team 2 – AWS Elastic Beanstalk (Technology)

May 16 – Serverless Computing I
- Team 3 – The Serverless Trilemma (Paper)
- Team 4 – Azure Functions
- Team 5 – Code Transformations to AWS Lambda (Paper)

PRESENTATIONS SCHEDULE - 2

- WEEK 9

May 21 – NoSQL DBs
- Team 6 – Choosing the right NoSQL DB (paper)
- Team 7 – DynamoDB

May 23 – Serverless Computing II – Open Source Frameworks
- Team 8 – Open Lambda (paper)
- Team 9 – Oracle Fn
- Team 10 – Apache OpenWhisk

PRESENTATIONS FORMAT

- Cloud Technology Sharing Presentation:
- http://faculty.washington.edu/wlloyd/courses/tcss562/assignments/TCSS562_s2018_A1A.pdf

- Cloud Research Paper Presentation:
- http://faculty.washington.edu/wlloyd/courses/tcss562/assignments/TCSS562_s2018_A1B.pdf

GROUP PROJECT CHECK IN: MAY 6

- Each group should submit a PDF file to Canvas
- Provides written status-update of group project

Please include on the "Project Checkin":
- 1. Names of the group members
- 2. Project Title/Topic
- 3. Answer the following questions:

- Q1 - How has the group decided to divide the project work? What technologies and/or aspects is each group member responsible for? What aspects of the project have a shared responsibility?

GROUP PROJECT CHECK IN: MAY 6 - 2

- Q2 - Describe progress to date:

CODE:
- What code has been developed or located to support the cloud services evaluation?
- What languages are being used?
- What is the size of the code found/developed (lines of code, size KB)?
- Is there a shared GitHub repository? If so, please share a URL.

DATA:
- If the project involves testing a database, what data sources have been found or developed?
- How large are the data sets?
- What type of information do they describe?

GROUP PROJECT CHECK IN: MAY 6 - 3

PLATFORMS/SERVICES:
- What technologies/services have been tested thus far?
- What initial results do you have?
- Performance data?
- Cost data?

- Q3 - Describe any road blocks or questions you may have.

- The instructor will review road blocks and questions.
- ***It is the team's responsibility to follow-up with the instructor regarding any ongoing road blocks.***

FEEDBACK

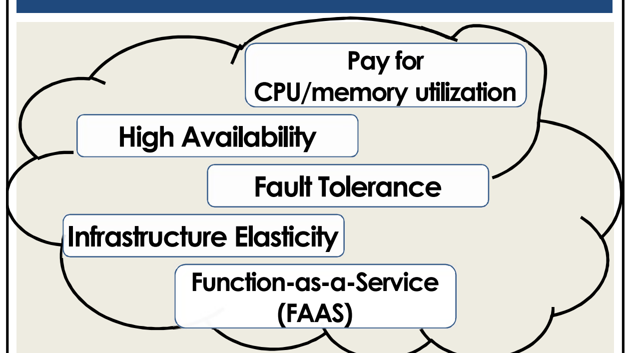
- ...

OUTLINE

- Background
- AWS Lambda Demo
- **Serverless Computing: An Investigation of Factors Influencing Microservice Performance**
  - Research Questions
  - Experimental Workloads
  - Experiments/Evaluation
  - Conclusions

SERVERLESS COMPUTING

ADVANTAGES OF SERVERLESS COMPUTING



SERVERLESS COMPUTING

Why Serverless Computing?

Many features of distributed systems, that are challenging to deliver, are provided automatically

…they are built into the platform

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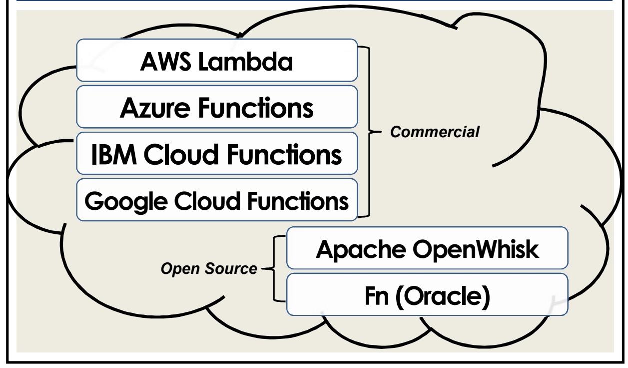
SERVERLESS PLATFORMS



Research Challenges

Image from: https://mobisoftinfotech.com/resources/blog/serverless-computing-deploy-applications-without-fiddling-with-servers/

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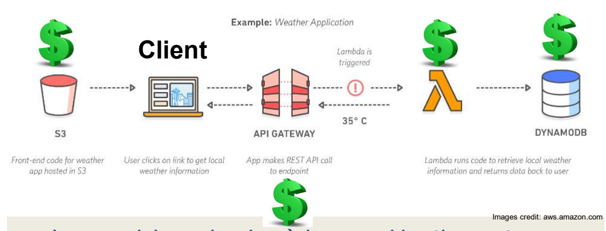
VENDOR ARCHITECTURAL LOCK-IN

- Serverless software architecture requires external services/components



Images credit: aws.amazon.com

- Increased dependencies → increased hosting costs

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SERVERLESS PRICING MODEL

- **EXAMPLE:** AWS Lambda Pricing
- **FREE TIER:** first 1,000,000 function calls/month → FREE
  first 400,000 GB-sec/month → FREE
- ***Obfuscated pricing:***
  $0.0000002 per request
  $0.000000208 to rent 128MB / 100-ms

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WEBSERVICE HOSTING EXAMPLE

- Each service call: 100% of 1 CPU-core
  100% of 4GB of memory
- Workload: 2 continuous client threads
- Duration: 1 month (30 days)
- VM: Amazon EC2 m4.large 2-vCPU VM
- Hosting cost: m4.large: $72/month
  10¢/hour, 24 hrs/day x 30 days
- **How much would hosting this workload cost on AWS Lambda?**

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PRICING OBFUSCATION

- Workload: 20,736,000 GB-sec
- FREE: - 400,000 GB-sec
- C... c
- M... 39
- I...
- F...
- C...
- Calls: $.84
- **Total:** **$339.23**

Worst-case scenario = ~4.7x !
AWS EC2: $72.00
AWS Lambda: $339.23

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PERFORMANCE IMPLICATIONS OF SERVERLESS COMPUTING PLATFORMS

- Infrastructure elasticity
- Load balancing
- Provisioning variation
- Infrastructure retention: COLD vs. WARM
- Memory reservation

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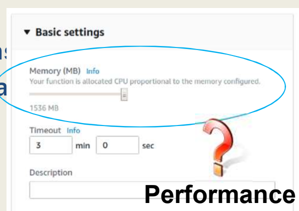
SERVERLESS COMPUTING
MEMORY RESERVATION QUESTION…

- Lambda memory reserved for functions
- UI provides “slider bar” to set function’s memory allocation
- CPU power coupled to slider bar: *“every **doubling** of memory, **doubles** CPU…”*
  - But how much memory does code require?



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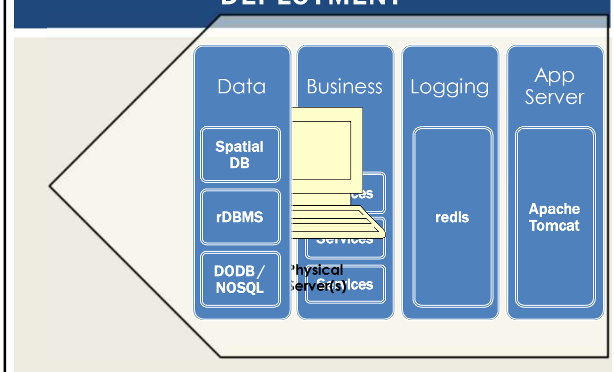
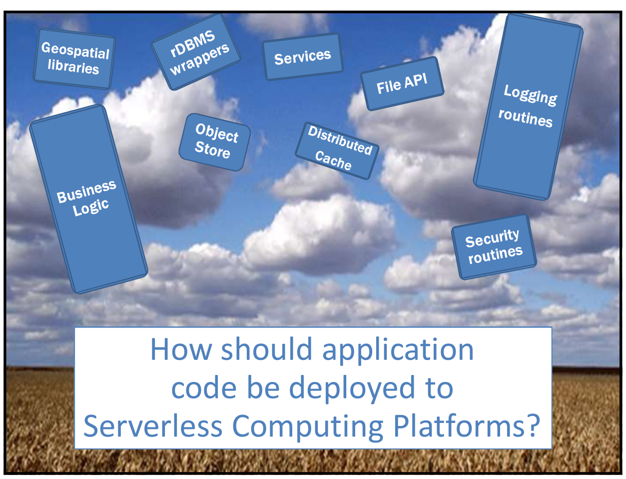
TRADITIONAL APPLICATION DEPLOYMENT





CODE DISAGGREGATION

- How should legacy application code be decomposed into microservices?
- Lambda function limits:
- All source files and libraries must fit into:
- AWS Lambda: 64MB compressed, 256MB uncompressed
- What are the cost implications based on how we disaggregate code into individual functions?
- How does this impact # of invocations and memory utilization?

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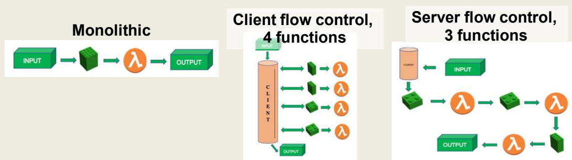
SERVICE COMPOSITION



- Recommended practice: Decompose code into many microservices
- Platform limits: code + libraries ~256MB
- **How does composition impact number of invocations, and memory utilization?**

Performance

FREEZE/THAW CYCLE

- Unused infrastructure is deprecated
  - ***But after how long?***
- Infrastructure: VMs, "containers"
- **Provider-COLD / VM-COLD**
  - "Container" images - built/transferred to VMs
- **Container-COLD**
  - Image cached on VM
- **Container-WARM**
  - "Container" running on VM

Performance

Image from: Denver7 – The Denver Channel News

SERVERLESS COMPUTING RESEARCH CHALLENGES

- Vendor architectural lock-in
- Pricing obfuscation
- Memory reservation
- Service composition
- Infrastructure freeze/thaw cycle

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USING AWS LAMBDA

- Supports many popular languages
  - Node.js, Java, Python, C#
  - Can include libraries (native & custom)
- Simple resource model
  - Memory reservation to 3GB
  - CPU scaled accordingly
- Flexible use
  - Synchronous or asynchronous
  - Integration with other AWS services
- Flexible authorization
  - Access to resources, VPCs
  - Fine-grained access control

Based on AWS Lambda slide set – slides removed for copyright

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USING AWS LAMBDA - 2

- Authoring functions
  - Edit code in GUI, or upload code (jar, zip)
  - Third-party plugin support: Eclipse, Visual Studio
- Monitoring and logging
  - Amazon cloud watch logs
  - Metrics for requests, errors, throttles
- Programming model
  - Language specific: processes, threads, sockets
  - Access to 500MB /tmp space
- Stateless
  - Persist data using external storage
  - No affinity or access to underlying infrastructure

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AWS LAMBDA TRIGGERS

- Data stores
  - S3
  - Dynamo DB
  - Kinesis
  - Cognito
- End points
  - API Gateway
  - AWS IoT
  - AWS Step Functions
  - Amazon Alexa
- Configuration repositories
  - AWS Cloud Formation
  - AWS Cloud Front
  - AWS Code Commit
  - AWS CloudWatch
- Event/message services
  - Simple email service (SES)
  - Simple notification service (SNS)
  - Cron Events

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AWS LAMBDA USE CASES

- Common/suggested use cases
  - Web applications
  - Backends
  - Data processing
  - Chatbots
  - Amazon Alexa
  - IT Automation

Based on AWS Lambda slide set – slides removed for copyright

AWS LAMBDA DEMO

SERVERLESS COMPUTING: AN INVESTIGATION OF FACTORS INFLUENCING MICROSERVICE PERFORMANCE

Wes Lloyd, Shruti Ramesh, Swetha Chinthalapati, Lan Ly, Shrideep Pallickara

April 20, 2018

Institute of Technology, University of Washington, Tacoma, Washington USA

IC2E 2018: IEEE International Conference on Cloud Engineering

OUTLINE

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RESEARCH QUESTIONS

RQ1: What are the performance implications of infrastructure ***elasticity*** for serverless computing? *(e.g. COLD vs. WARM performance)*

RQ2: How does ***load balancing*** vary in serverless computing? How do computational requests impact load balancing, and ultimately performance?

RESEARCH QUESTIONS - 2

RQ3: What performance implications result from ***provisioning variation*** of container infrastructure?

RQ4: What are the impacts on ***infrastructure retention*** based on microservice/function utilization?

RQ5: What performance implications result from microservice ***memory reservation*** size? How does memory reservation size impact container placement?

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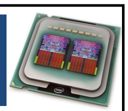
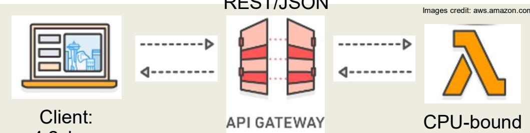
AWS LAMBDA COMPUTE BOUND TEST SERVICE



- Increasing stress levels 1 (none) → 9 (high) *(non-linear)*
- Parameters:

  - Operand array size and number of calculation loops (0, 20, 100, 1,000, 10,000, 25,000, 100,000)
    → Operands stored in random array locations
    → Induces page faults when seeking random locations
  - Number of function calls per loop (0, 20, 1,000, 100,000, 300,000)
- Control CPU time of function as input parameter
- **Goal: observe impact of CPU time on infrastructure scaling, provisioning variation, retention, and service performance**

AWS LAMBDA TESTING



Client: c4.2xlarge

BASH: GNU Parallel Multi-thread client **"partest"**

Up to 100 concurrent synchronous requests

Results of each thread traced individually

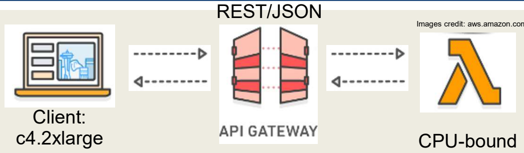
Fixed-availability zone:
EC2 client / Lambda server us-east-1e

CPU-bound Test Function

Max service duration: < 30 seconds

Memory: 128 to 1536MB

AWS LAMBDA TESTING



Client: c4.2xlarge

Automatic Metrics Collection:

New vs. Recycled Containers/VMs

# of requests per container/VM

Avg. performance per container/VM

Avg. performance workload

Standard deviation of requests per container/VM

CPU-bound Test Function

Container Identification UUID → /tmp file

VM Identification btime → /proc/stat

Linux CPU metrics

AZURE FUNCTIONS TESTING

- Http-triggered function app, written in C#
- Logs to Azure Table storage (*similar to Dynamo DB*)
  - Unique app service instance IDs
  - Current worker process ID
- Consumption plan → auto-scaled infrastructure
  - vs. app service plan (*deployment to dedicated VMs*)
- Performance testing: Visual Studio Team System (VSTS)

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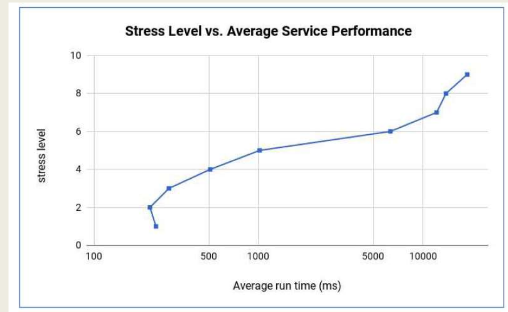
CPU-BOUND LAMBDA TEST SERVICE WARM PERFORMANCE



RQ-1: ELASTICITY

- What are the performance implications of infrastructure ***elasticity*** for serverless computing?

  (e.g. COLD vs. WARM performance)

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RQ-1: AWS LAMBDA LATENCY EVALUATION

- **AWS Lambda Simulation**
- Harness c4.8xlarge 36 vCPU VM instance
  - Intel Xeon E5-2666v3 CPU – *same as Lambda*
- Lambda JAR file deployed Docker container(s)
  - **Set memory**: docker run "-m <ram in MB>"
  - **Set CPUs**: docker run "–cpus <VCPUs>
- Compare: 1 and 12 concurrent runs
  - Avg VM tenancy ~12.3 of all tests
- **How does Lambda scale CPU power?**

Literal Estimates:

Memory (MB)	Expected CPU%
128	16.6%
256	33.3%
384	50.0%
512	66.6%
640	83.3%
768	100.0%
896	116.7%
1024	133.3%
1152	150.0%
1280	166.60%
1408	183.30%
1536	200.00%

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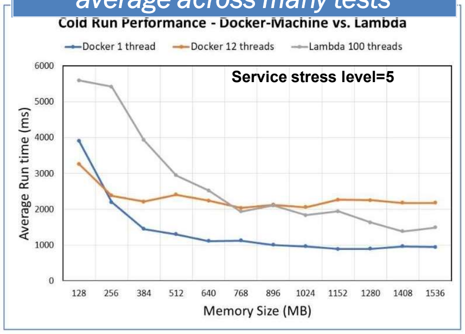
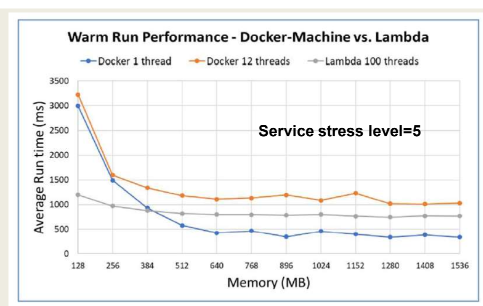
RQ-1 … CE

Assumed tenancy of ~12 service requests per container for Lambda: *average across many tests*



RQ-1: EC2/DOCKER VS. LAMBDA PERFORMANCE INTEL XEON E5-2666 V3 - WARM



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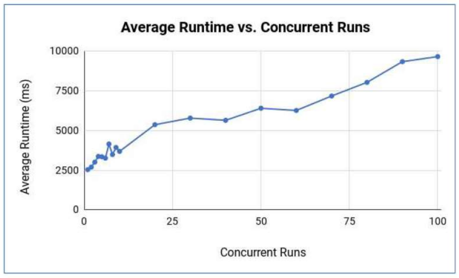
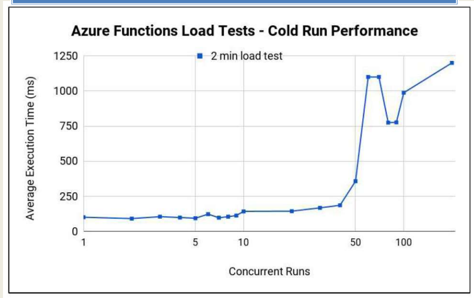
RQ-1: AWS LAMBDA SCALE UP PERFORMANCE



Service stress level=4

RQ-1: AZURE FUNCTIONS COLD

VMs are allocated as opposed to individual container instances. Supports better initial performance.

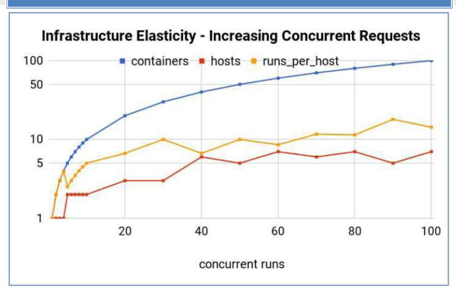


Up to 4 VMs automatically created

RQ-2: LOAD BALANCING

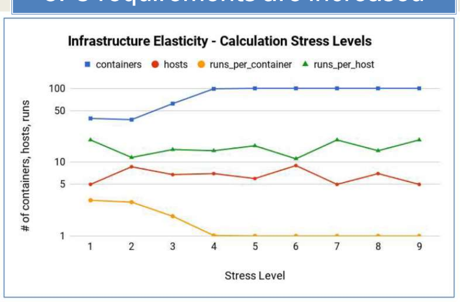
- How does ***load balancing*** vary in serverless computing?
- How do computational requests impact load balancing, and ultimately performance?

COLD service requests receive separate container instances to amortize startup overhead



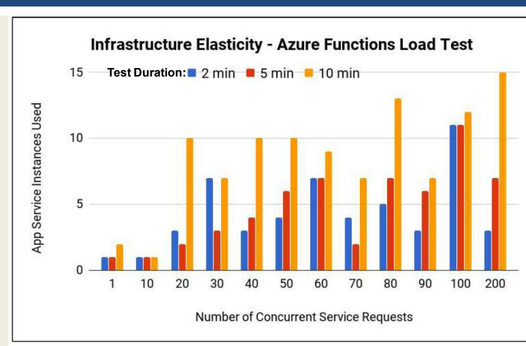
Service stress level=4

WARM service requests share container instances unless CPU requirements are increased



Average for 100 runs

RQ-2: COLD AZURE FUNCTIONS INFRASTRUCTURE FOR SCALING



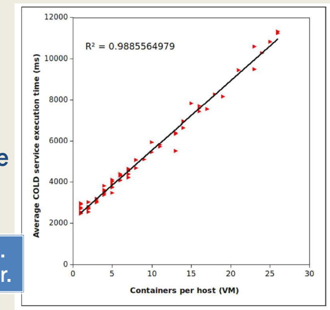
RQ-3: PROVISIONING VARIATION

- What performance implications result from ***provisioning variation*** of container infrastructure?

RQ-3: COLD LAMBDA SERVICE PERFORMANCE VS. CONTAINER PLACEMENT

When more containers were placed on the same VMs for COLD service requests, Lambda Performance suffered up to 5x !

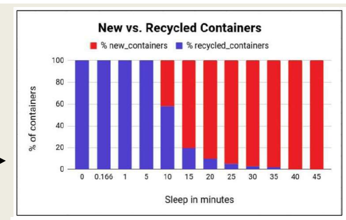
The impact of tenancy vs. performance is quite clear.



RQ-4: INFRASTRUCTURE RETENTION

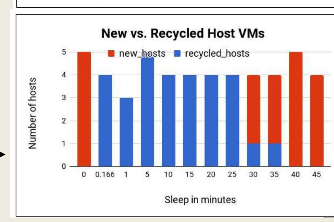
- What are the impacts on ***infrastructure retention*** based on microservice/function utilization?

Lambda Container Recycling



Service stress level=4

Lambda Virtual Machine Recycling

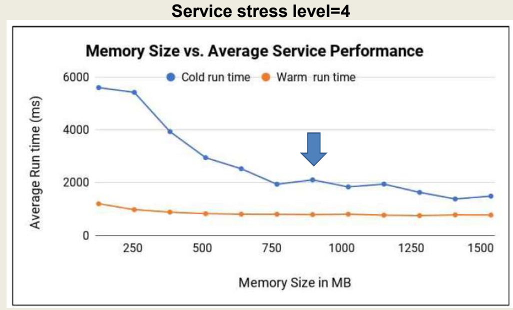


RQ-5: MEMORY RESERVATION

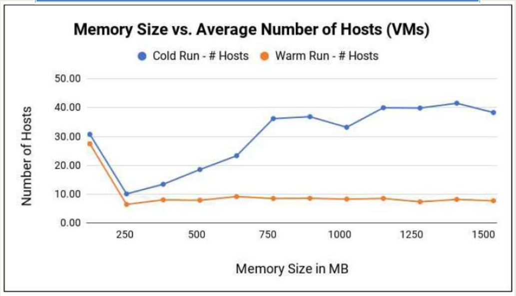
- What performance implications result from microservice ***memory reservation*** size?
- How does memory reservation size impact container placement?

RQ-5: SLIDER BAR TEST: MEMORY VS. CPU POWER

Service stress level=4



Increasing the memory reservation size results in more hosting infrastructure



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CONCLUSIONS

- **RQ-1 Elasticity**: Extra infrastructure is provisioned to compensate for initialization overhead of "container" startup
  - VM COLD: up to ~20x slower than WARM
  - Container COLD: ~5x slower than WARM
- **RQ-2 Load Balancing**: Better when COLD. WARM runs only use all original infrastructure when CPU-bound execution time is similar to container initialization execution time
  - Must increase stress level to harness available infrastructure

CONCLUSIONS - 2

- **RQ-3 Provisioning Variation**: Bad placement can lead to ~4.6x degradation in COLD service performance
- **RQ-4 Infrastructure Retention**: 3 distinct performance states: ***VM COLD***, ***Container COLD***, ***WARM***
  - Containers begin to disappear after 10 minutes
  - VM hosts deprecated after ~40 minutes
- **RQ-5 Memory Reservation**:
- For non memory-bound service, performance improves up to ~512-640MB

QUESTIONS