Tracking Causal Order in AWS Lambda Applications

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IC2E 2018

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AWS Lambda

- Serverless computing platform
- No resource provisioning needed, hence simplifies cloud applications deployment
- Stateless functions interacting with other cloud services
- Billed by runtime duration and memory use, enables scalable distributed applications at low cost

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Challenges

- Difficult to debug, analyze, reason about
- Tooling for serverless applications is nascent with only simple logging services available
  - **CloudWatch**
  - **X-Ray**

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Tools and limitations

- CloudWatch
  - + Runtime duration, memory usage, customized information
  - – No causality information
  - – Difficult to distinguish concurrent invocations
- X-Ray
  - + Presents dependency trees as service graph
  - – Doesn’t track implicit relationship
  - – Doesn’t track dependency across regions
  - – Statistical sampling leads to record loss

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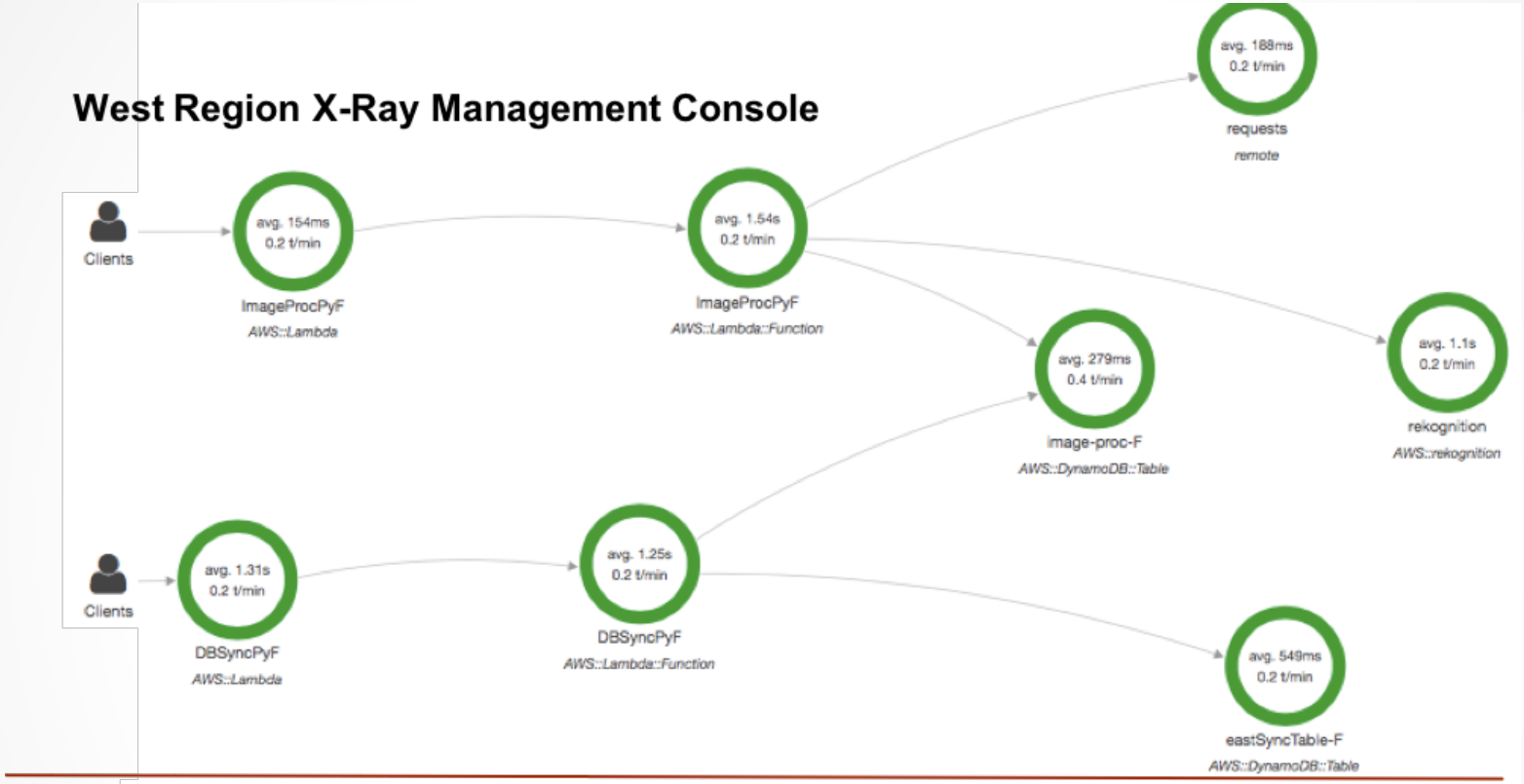
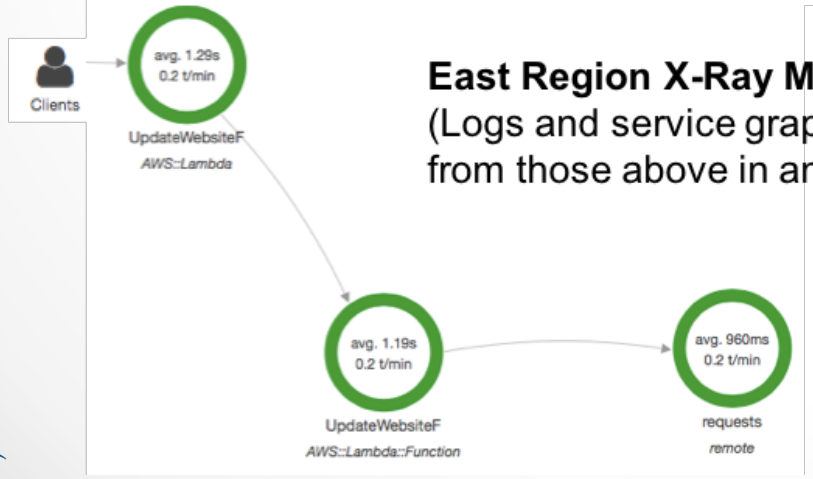
X-Ray service graph





East Region X-Ray Management Console
(Logs and service graphs are separate and disconnected from those above in another AWS region)

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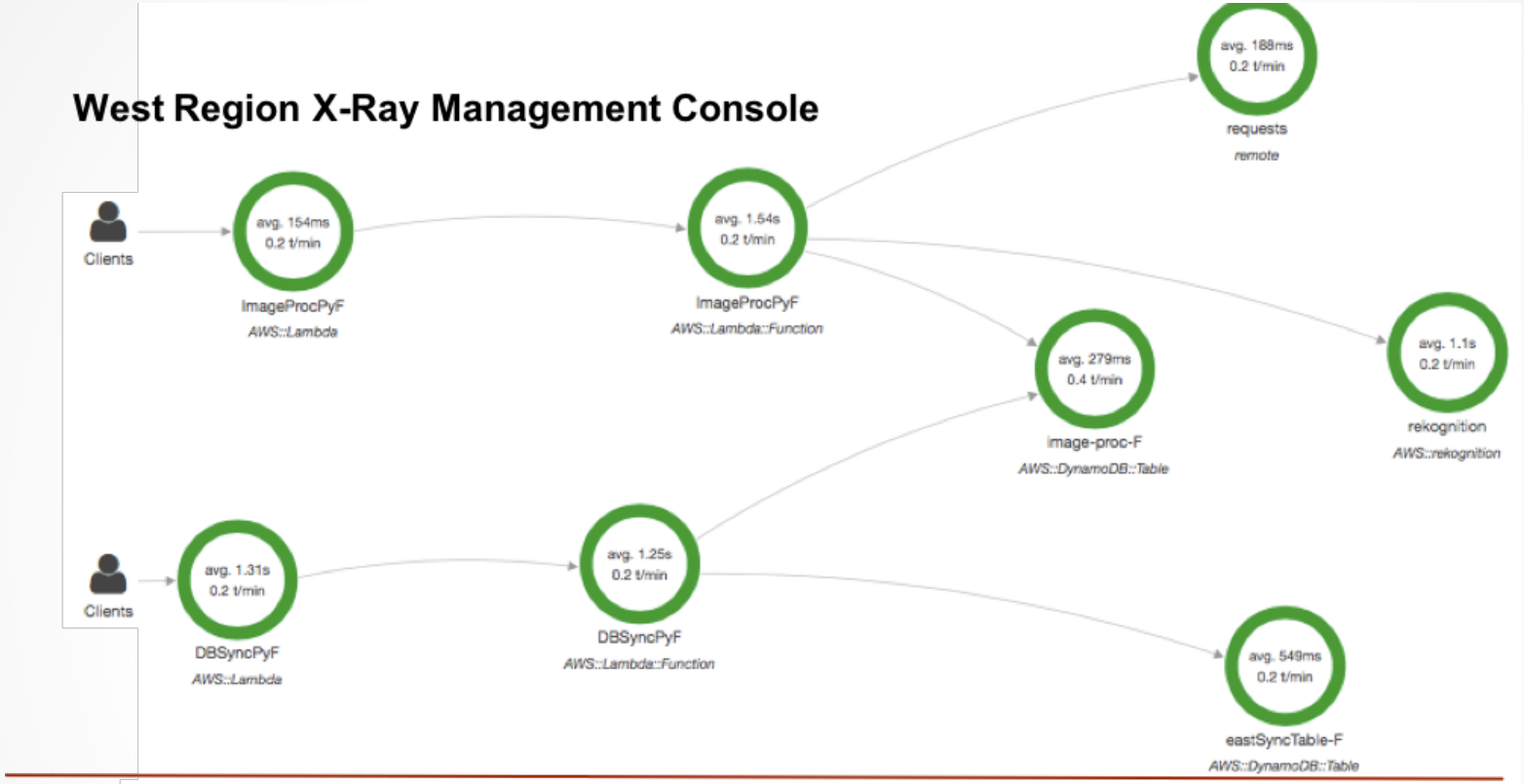

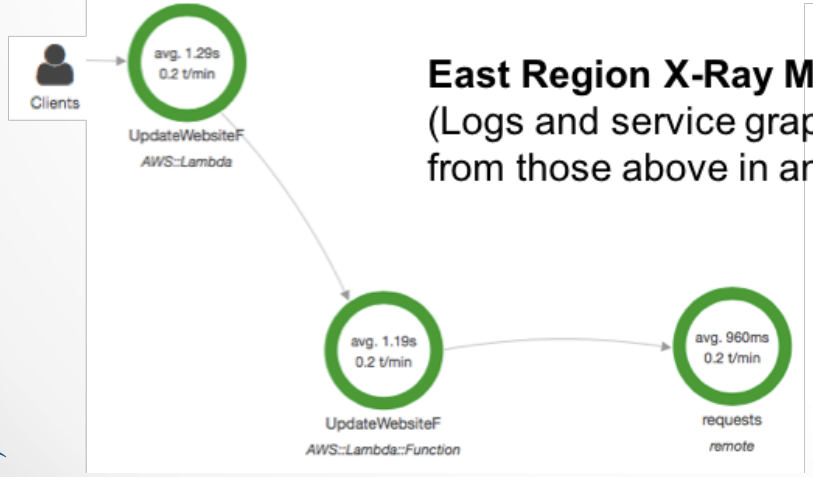

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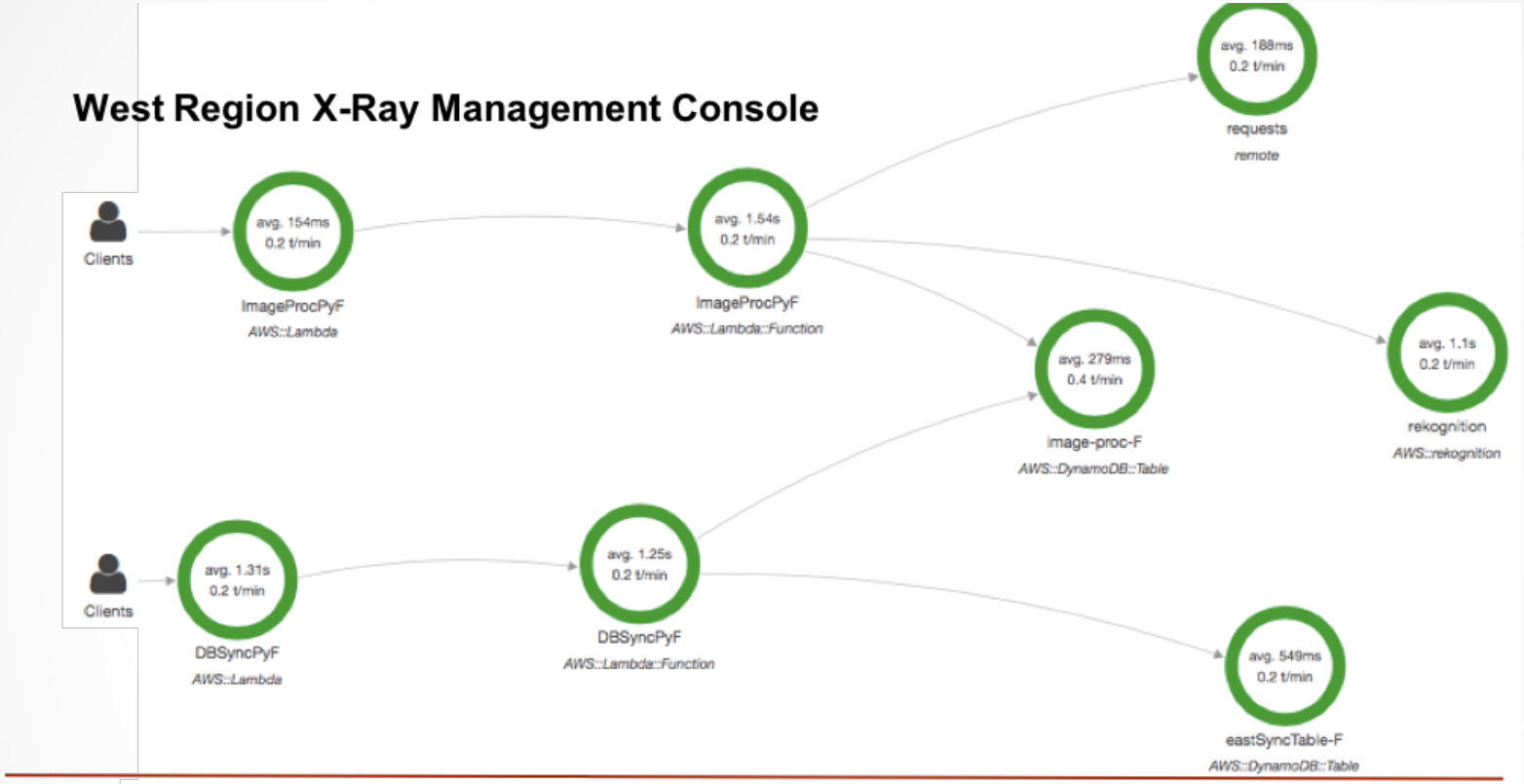

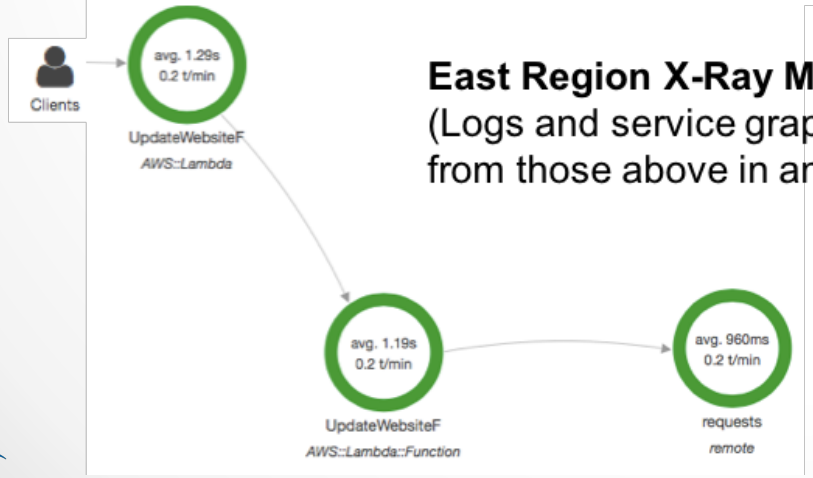

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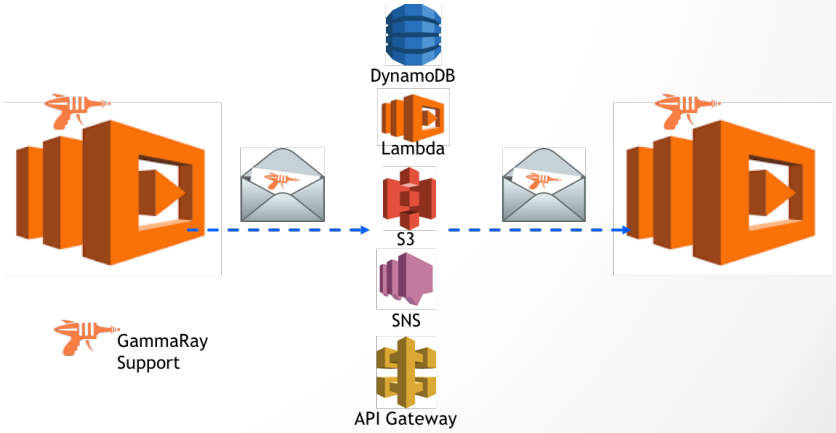
Alternative: GammaRay

- Tracking causal order across all services and regions
- Automatically instrument Lambda functions and AWS SDK
- Compute performance statistics and construct service graph offline
- No record loss



GammaRay components

- **Lambda Deployment tool**
  - Injects GammaRay instrumentation to capture and report events
  - Packs source codes, needed libraries, and runtime support as a zip file
- Runtime support
  - Replace the function entry point with a function wrapper
  - Assume control when Lambda handler or AWS SDK is invoked
  - Assign an unique ID to root event and pass it to all downstream events
  - Capture events and send them to shared DynamoDB table synchronously
- Event processing engine
  - Construct a service graph using DynamoDB stream offline

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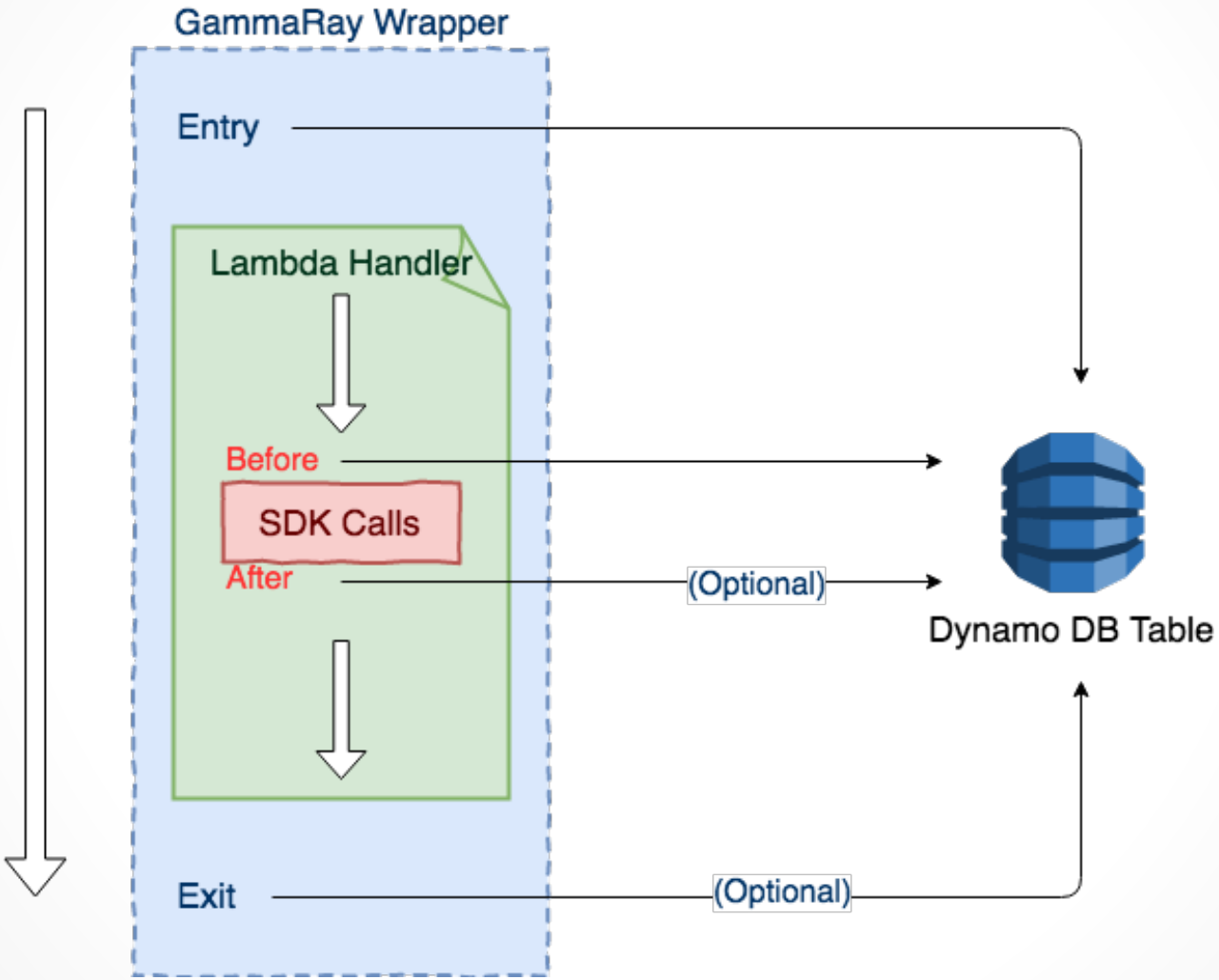
How it works


GammaRay Wrapper
Entry
Lambda Handler
Before
SDK Calls
After
(Optional)
Dynamo DB Table
Exit
(Optional)

Instrumentation injection

- Dynamic
  - “Monkey patches” AWS SDK calls made by the function to invoke the GammaRay runtime before and after the call
  - https://github.com/racker/fleece
- Static
  - Replacing SDK to be imported with modified version
  - Increase memory footprint
- Hybrid
  - Lighter version of dynamic patching
  - Only SDK calls that can trigger other events are captured
  - Relies on X-Ray for performance data gathering

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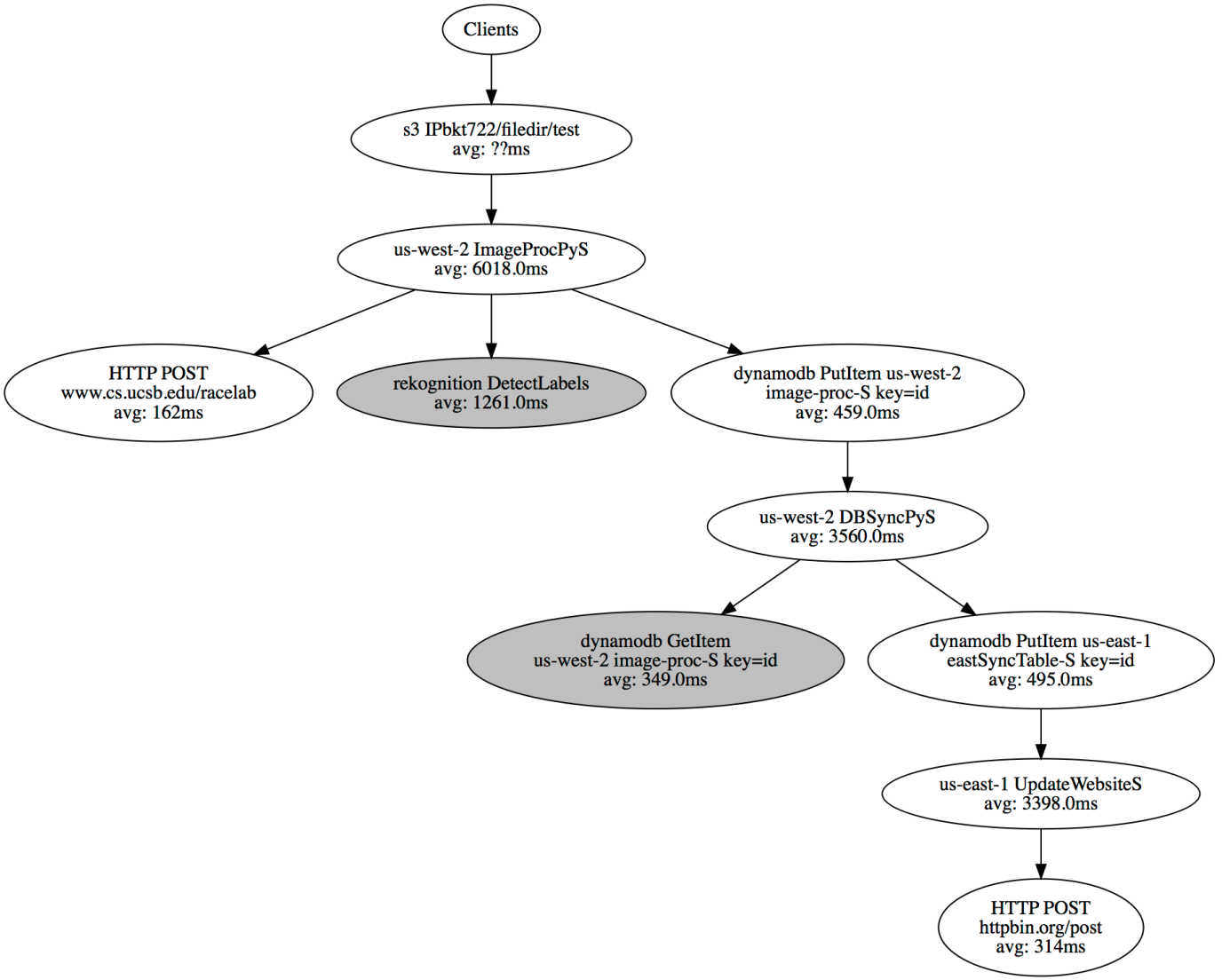

Evaluation

- Applications
  - Map-Reduce
  - ImgProc
- Micro-benchmarks
  - Empty function
  - DynamoDB read/write
  - S3 read/write
  - SNS posting
- Compared to X-Ray with Python SDK logging turned on*

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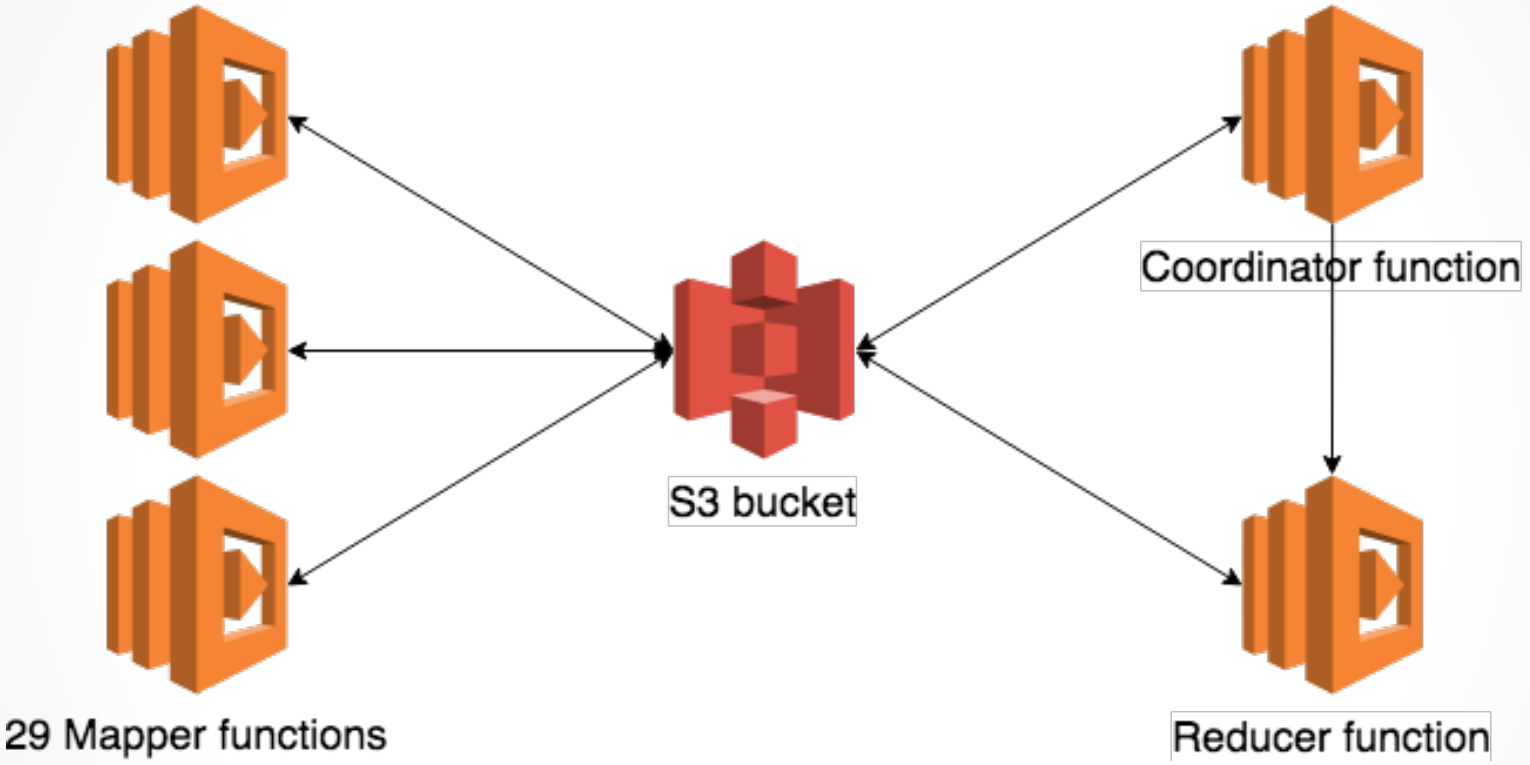
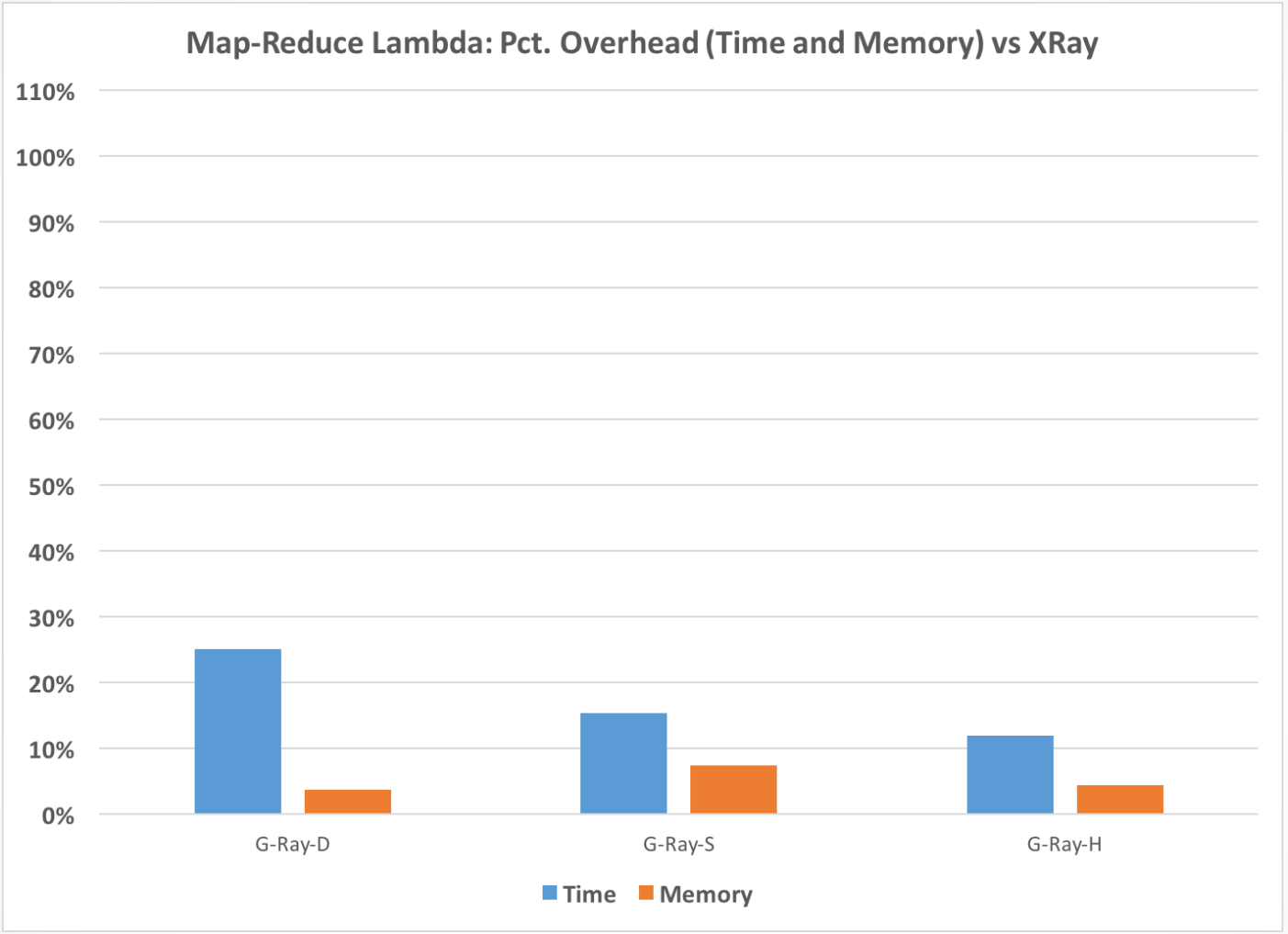
*Fleece: https://github.com/racker/fleece

Application: Map-Reduce



- Dynamic & static: 840 records
- Hybrid: 125 records

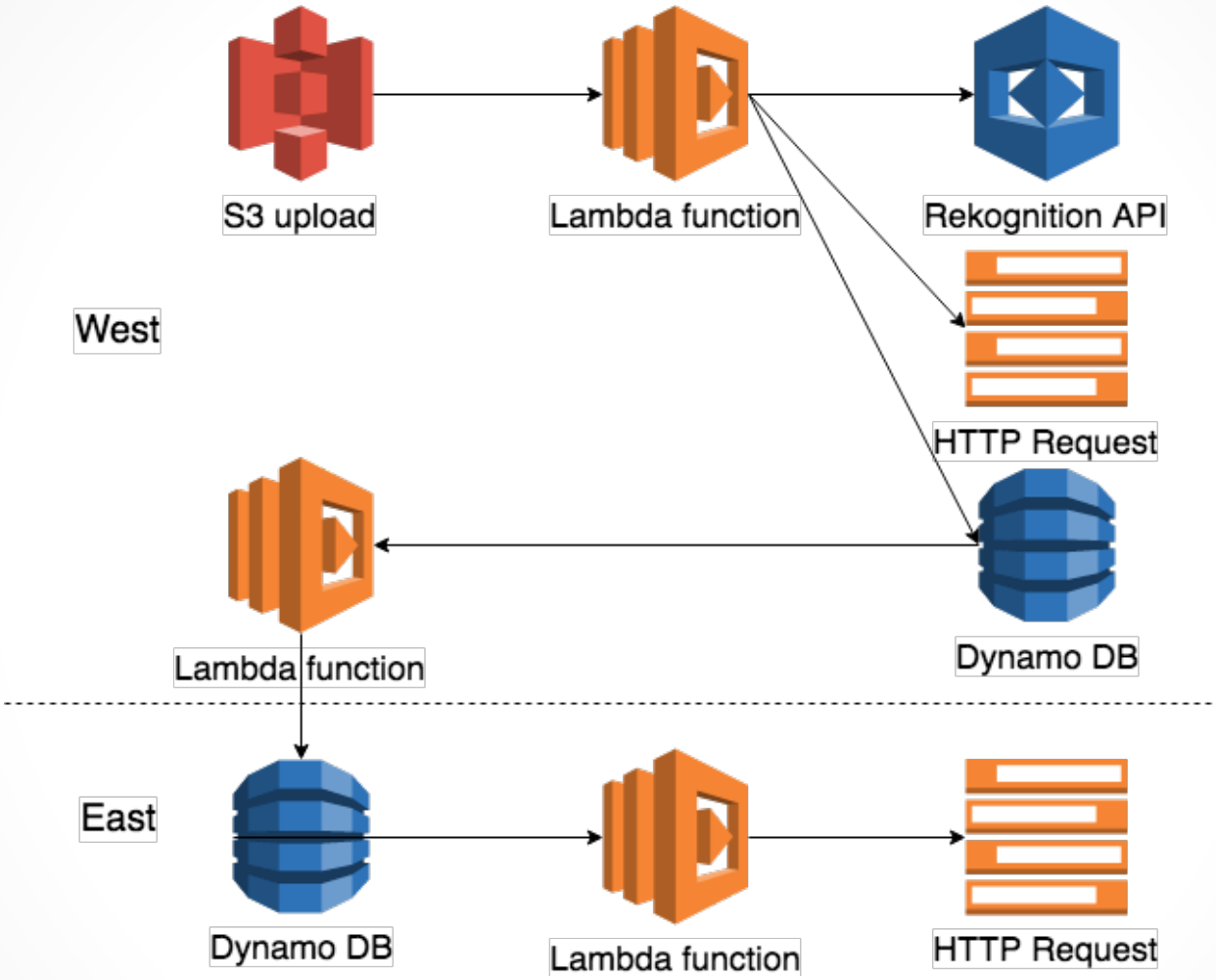
Application: Map-Reduce



Baseline performance (X-Ray)

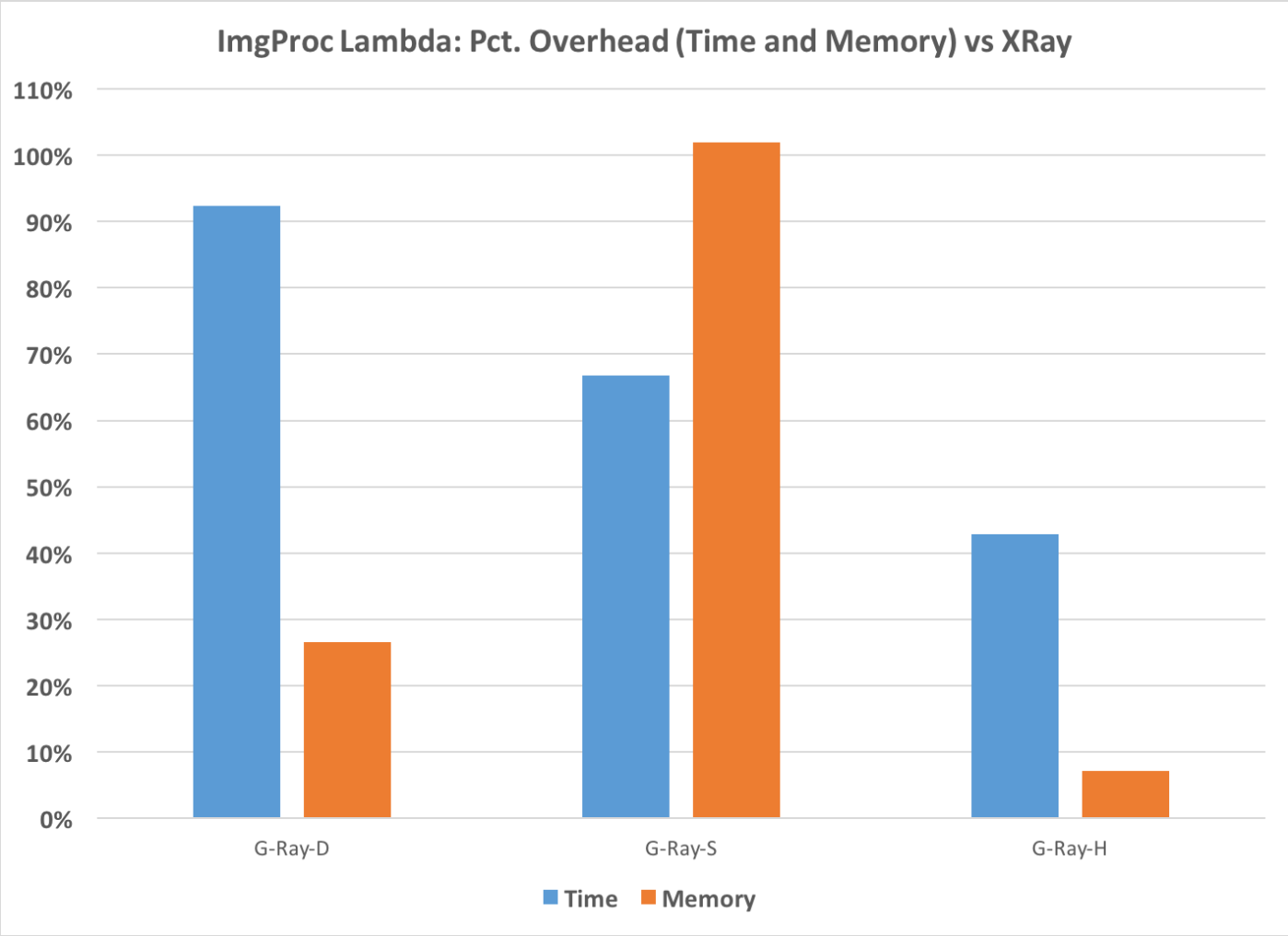
- Total runtime duration: 114 seconds
- Total memory use: 1231 MB

Application: ImgProc



- Dynamic & static: 18 records
- Hybrid: 5 records

Application: ImgProc



Baseline performance (X-Ray)

- Total runtime duration: 3.1 seconds
- Total memory use: 114 MB

Micro-benchmarks

Overhead (ms)	Startup	DDB Read	DDB Write	S3 Read	S3 Write	SNS	Avg
X-Ray	6.0	47.3	47.4	52.0	87.1	64.2	59.6
G-Ray-H	418.9	1.5	29.5	2.7	19.3	33.8	17.3

- Average of 200 runs, each run contains 100 operations
- Row X-Ray shows the overheads over clean application deployment
- Row G-Ray-H shows the overhead of Hybrid GammaRay over X-Ray
- Obtaining DynamoDB handler takes 126ms in average

Summary

- A tool for debugging and reasoning about AWS Lambda application
- Captured causality across regions and services
- No instrumentation needed for developers

Future works

- Optimizing wrapper startup overhead
- Porting to other clouds
- Asynchronous event reporting

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Acknowledgements

- National Science Foundation
- Huawei Technologies Co.

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Thank you!

- https://github.com/MAYHEM-Lab/UCSBFaaS-Wrappers
- http://www.cs.ucsb.edu/~ckrintz/racelab.html
- weitsung@cs.ucsb.edu

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