Georgia Institute of Technology

Fast, Flexible and Secure Onloading of Edge Functions using AirBox

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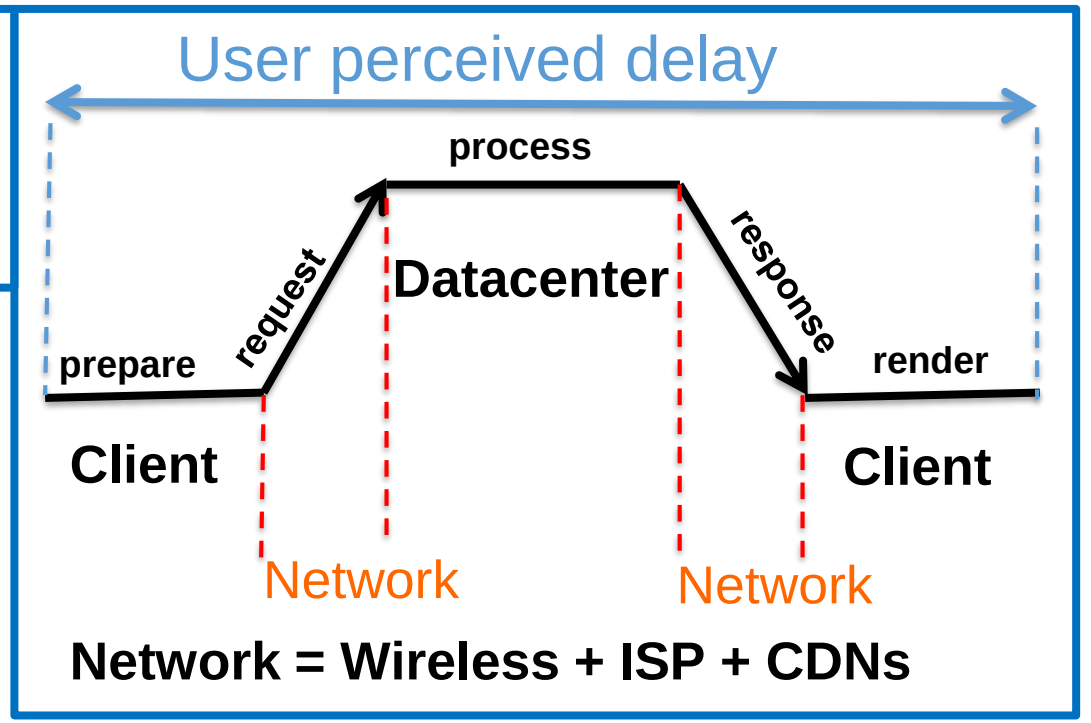
Edge Computing Drivers

Latency matters: Better user experience, revenue



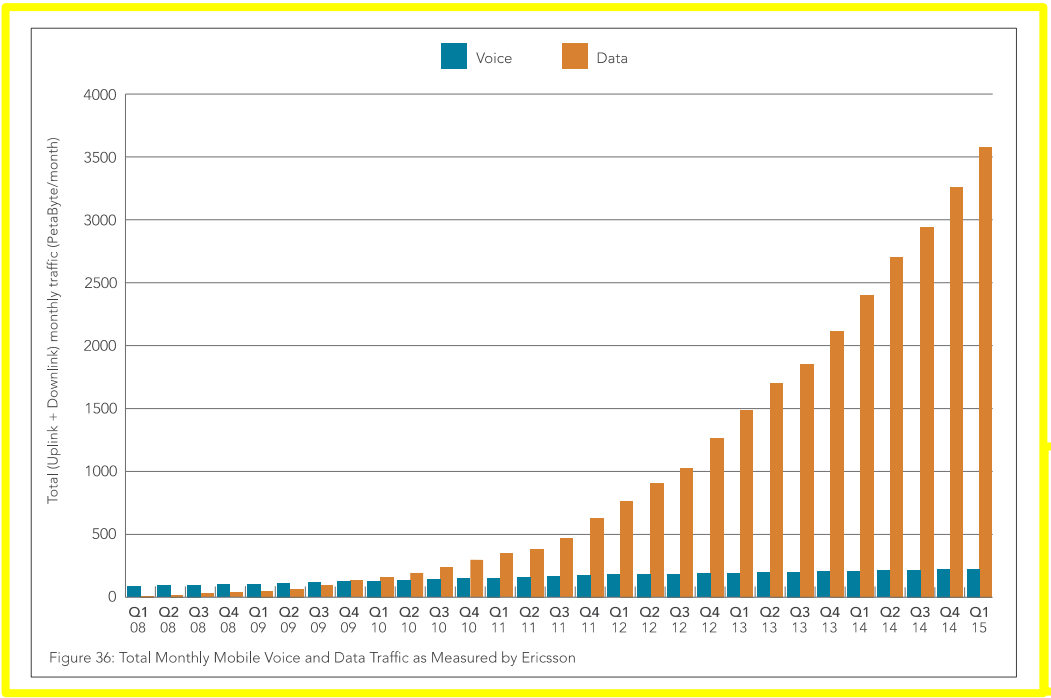


Figure 36: Total Monthly Mobile Voice and Data Traffic as Measured by Ericsson

Bandwidth Costs: For end users and service providers

Source: Akamai state of Internet report Q1'2015

Alternative: Build more, bigger data centers

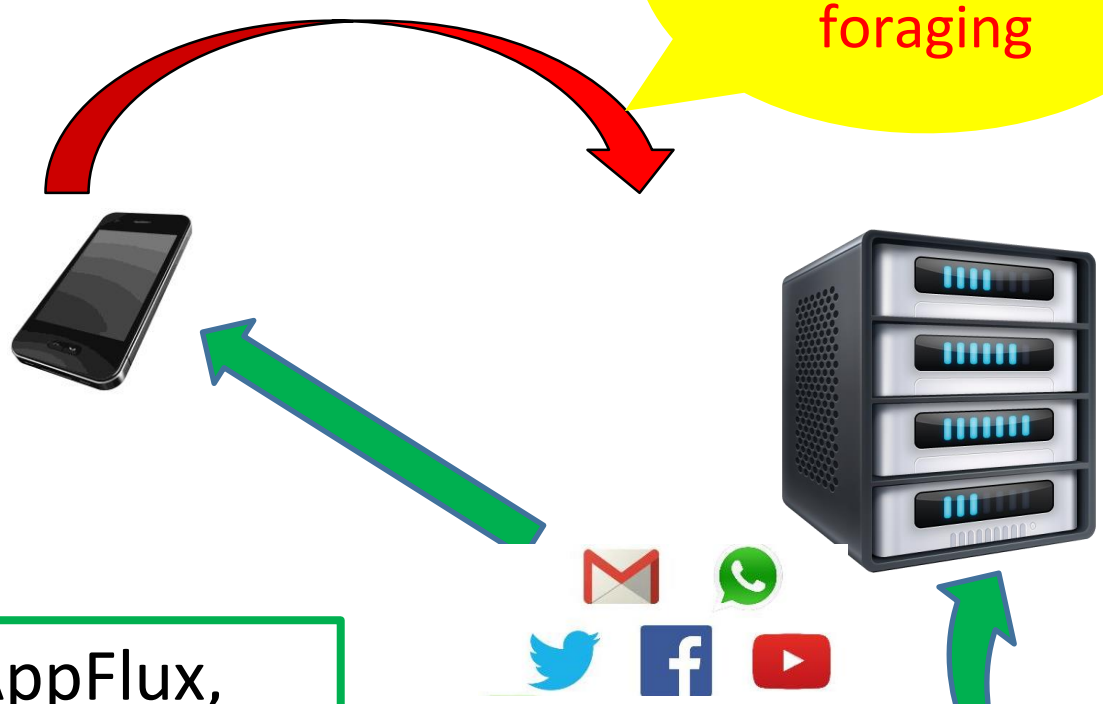
- Capital intensive to build.
- Expensive to operate.

- To achieve 1 ms latency a data center every 300 KM

- Sheer number of bytes that need to travel over Internet
- No control over network

- 3.5 ZB per year by 2019 (Cisco)
- Would take 8 years on 800 Gbps connection

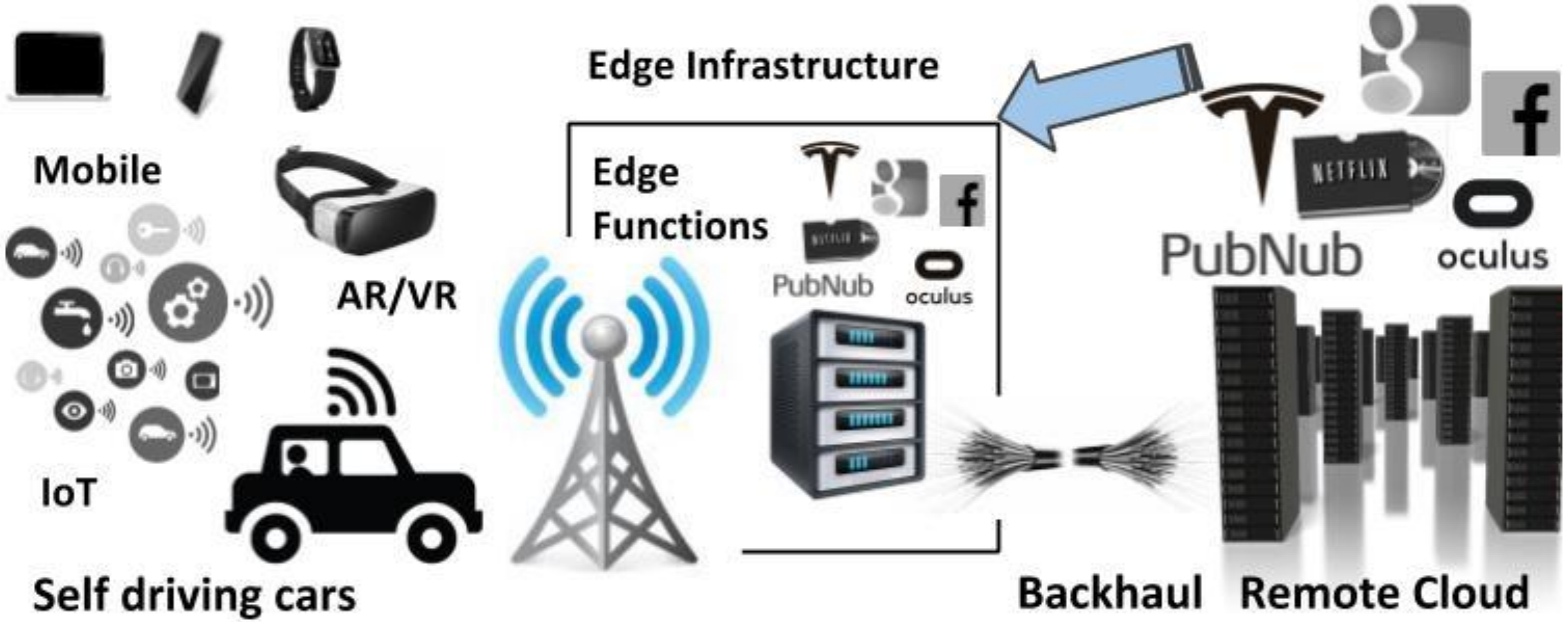
Approaches



Offloading: MAUI, CloneCloud, Comet, PCloud, ECC, COSMOS, …

Onloading: AppFlux, AppSachet, Cloudlet, FlyWheel, CDNs, micro-data centers, …

Onloading: Backend driven Edge Computing



Lets speak the same language …

- Beyond which users only have wireless access - ***Edge***
- Infrastructure – ***Edge cloud, Cloudlet, Fog server, …***
- Services running on edge infrastructure – ***Edge Functions***

Edge Function (EF)

- **Definition:** Any third party service deployed on edge infrastructure that interacts with end client requests on behalf of a backend service deployed in remote clouds.
  - *Typically implemented above layer 3*
  - *Employs application specific knowledge*

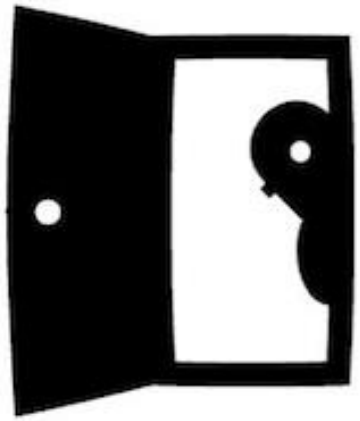
- **Edge function platform (EFP):** Software platform that enables Edge functions to be deployed at the edge

High Level Intuitive Choices

- Leverage cloud model for the edge computing
  - Use of virtualization to enable arbitrary edge functions
- Dynamic just-in-time deployment model
- Secure Edge nodes, Edge functions and their stored state

Challenges for an Edge function Platform

Developer Flexibility



Questions raised in this paper

- What type of virtualization to use for EFs?
  - *OS agnostic hypervisor – Virtual machines*
  - *OS level virtualization – OS Containers*
  - *Application level virtualization – Sandboxes*

- How to handle security concerns of edge functions?
  - Are they different from cloud security concerns?

Technology Space Exploration: Provisioning

- Chosen Technologies
  - Virtual machines - **Cloudlet**
  - Containers - **Docker**
  - Sandboxes - **Embassies**
- Constraints on developers
  - Cloudlet – None
  - Docker – OS
  - Embassies – Porting

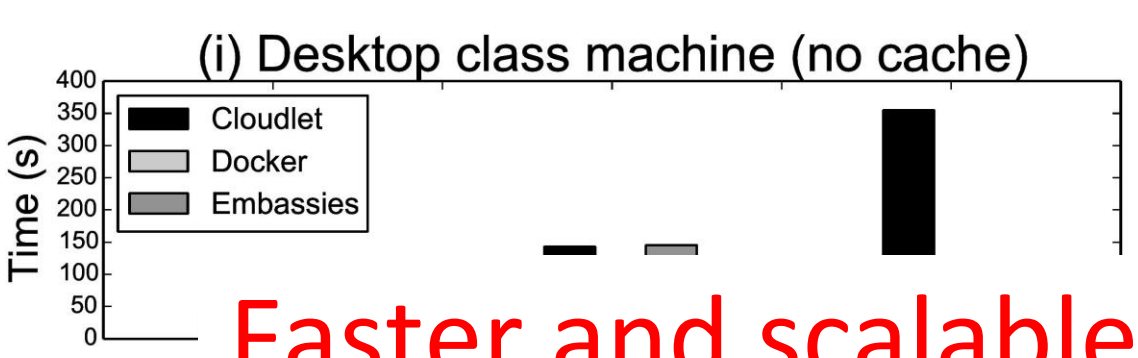
- Other Technologies
  - Java virtual machines
  - Native Sandboxes e.g., Chrome's NaCl
  - Runtimes: node.js
  - Unikernels: Jitsu
- Constraints on developers
  - Specific Toolchains
  - Lack of optimized libraries
  - Deployment packaging

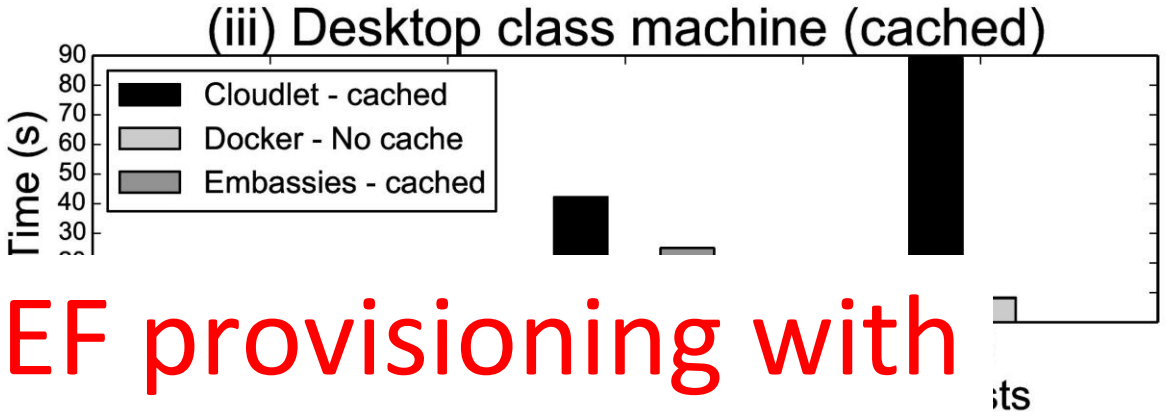
Experimental Setup

Type	Deployment scenario	Hardware configuration
Mini edge	Strategic placed server racks by mobile networks operators or enterprises - Server class machine	Intel x86-64, 24 CPUs, 1.6 GHz, 50 GB RAM, 4 NUMA nodes, 2 sockets, 6 cores per socket, 2 threads per core, VT-x, L1 (i+d): 64 KB, L2: 256 KB, L3: 12 MB
Micro edge	Randomly placed standalone servers by businesses or individuals - Desktop class machine.	Intel x86-64, 4 CPUs, 1.6 GHz, 4 GB RAM, VT-x, L1 (i+d): 64 KB, L2: 4096 KB

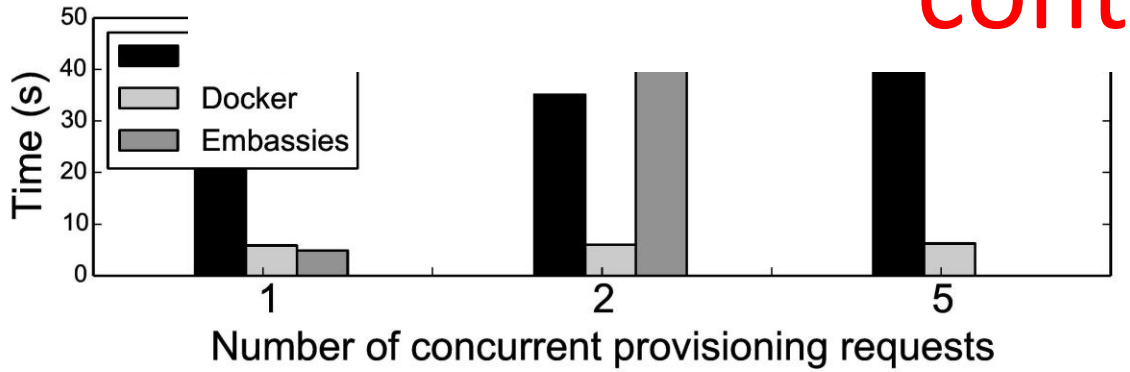
OS: Ubuntu 14.04 LTS, Ported all chosen solutions to it.
Edge function: Image processing using exactimage library, Think Instagram filters.

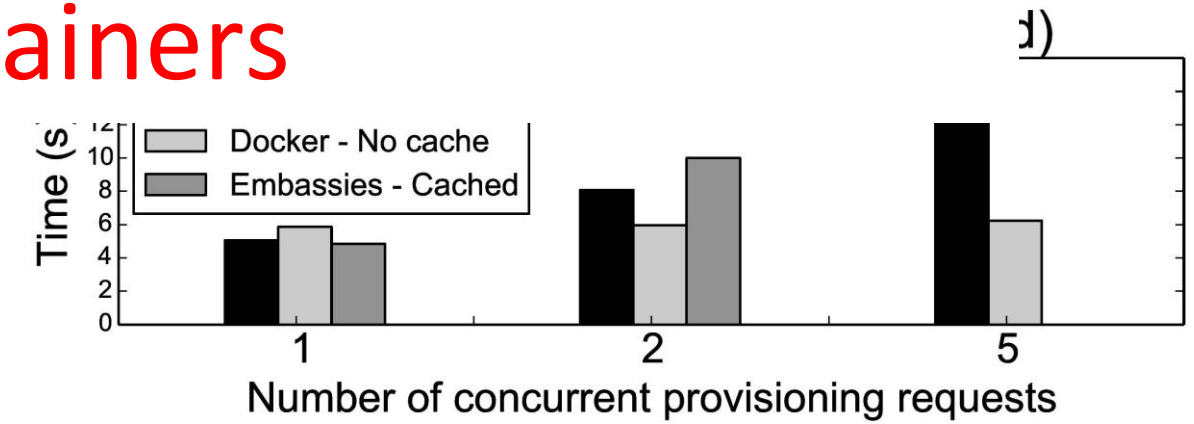
Provisioning Speed and Scalability



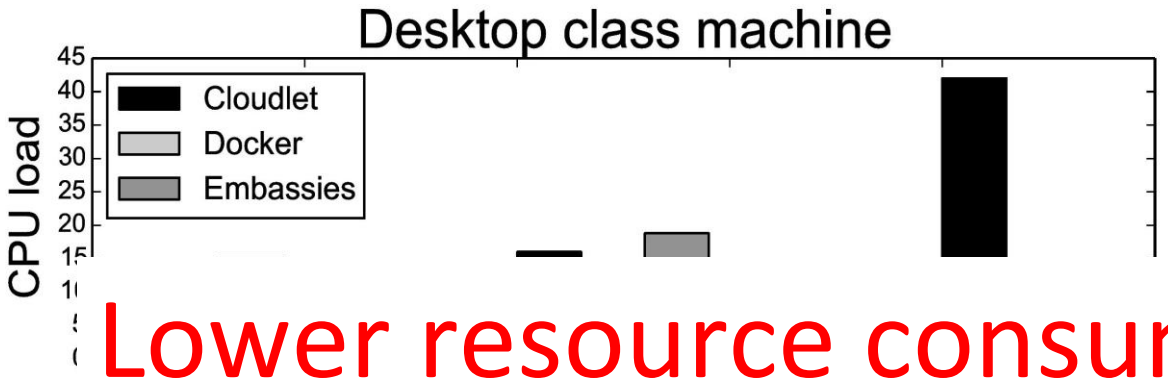


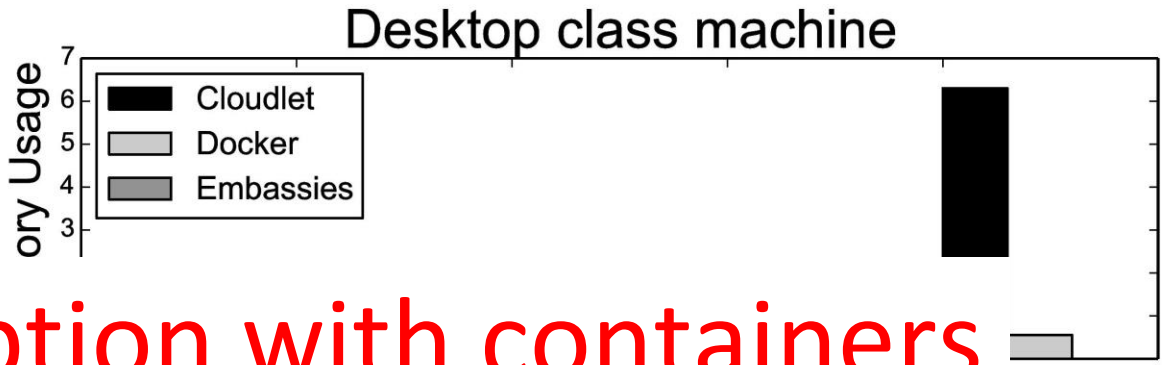
Faster and scalable EF provisioning with containers



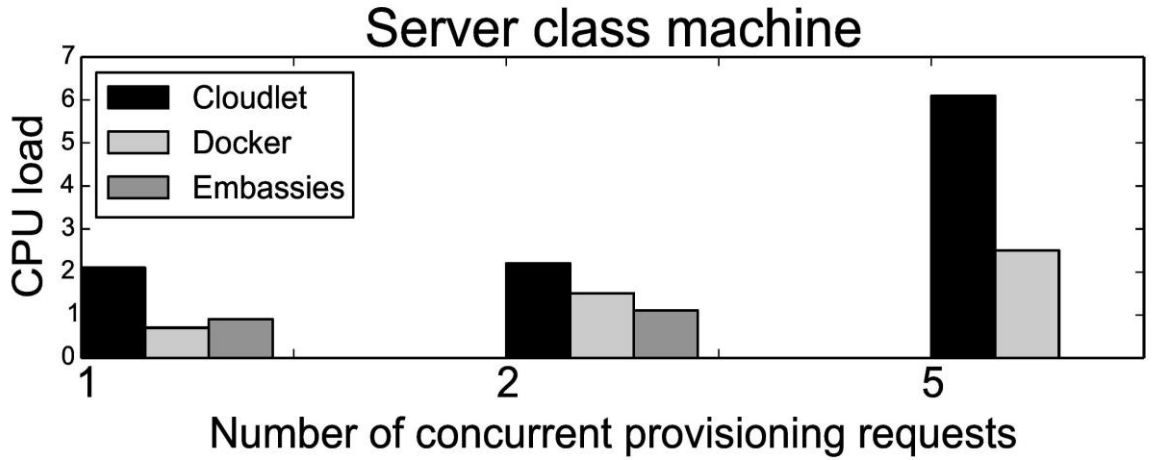


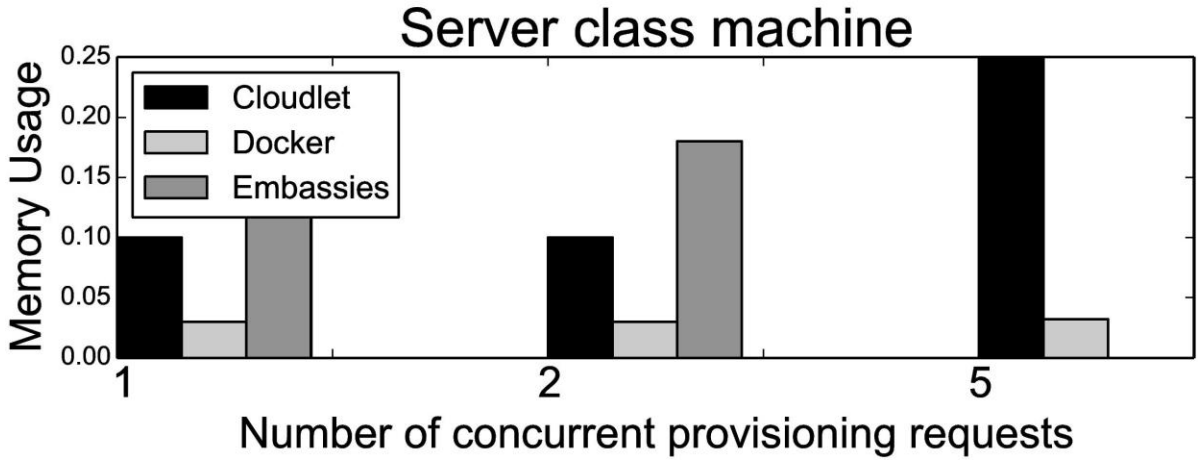
Provisioning Resource Consumption





Lower resource consumption with containers





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EF Security Concerns

1. Integrity verifica cation of d EF code
2. Execution security: g EF execution
3. State confidentiality: ed by EF on edge cloud
4. End user priva hat e ests remain private

Approaches to Security

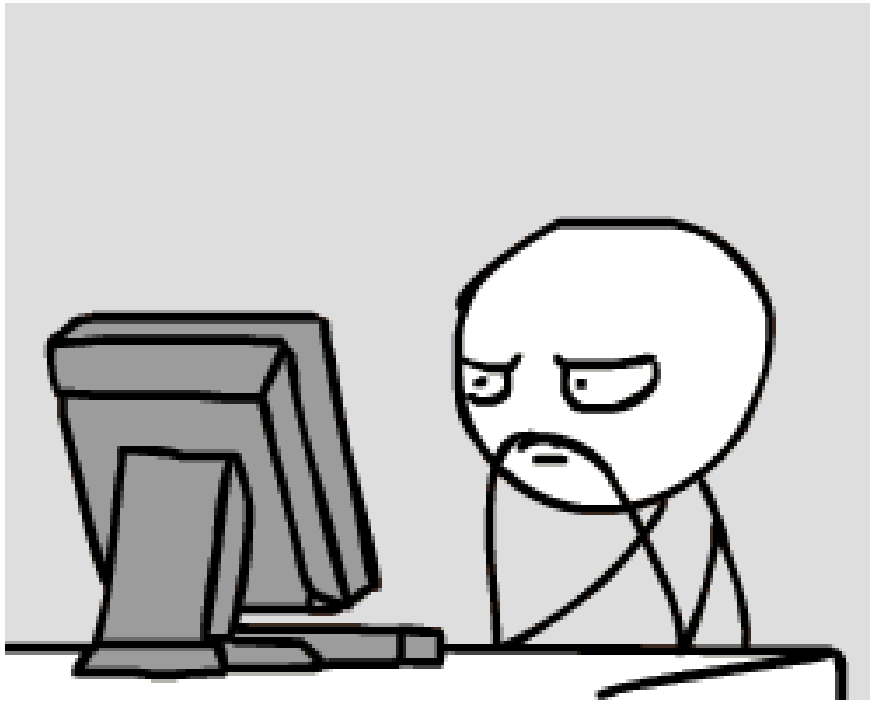
- Cloudlet VMs
  - TrustVisor – formally verified VM, InkTag – verification
- Embassies Sandboxes
  - Cryptographic attestation
- Docker Containers
  - Docker registry, namespaces, SELinux, AppArmour
- Haven
  - Narrow system call interface, use of libOS and Intel SGX
- VC3 – solution to secure map reduce via SGX based verification of results

AirBox: An Edge Function Platform

- Using Docker containers with SGX based integrity verification boot block for deployment vehicles for EFs
- Designed as a console for EF managers and provisioner module to be deployed for edge cloud nodes
- Prescribes a secure EF anatomy using Intel SGX for security concerns
  - Implemented on top of OpenSGX

Intel SGX

- New secure instructions in Intel processors
  - Loading, entry and exit to SGX enclave
  - For OS to allocate PRM page/eviction
- Processor reserved memory hashed after enclave load till its exit
- New processor mode & related HW structures
- Unforgeable attestation qoute generation
- Remote attestation
- No I/O or interrupts in/from enclave
- Difficult to setup SGX enclave debugging



AirBox Benefits

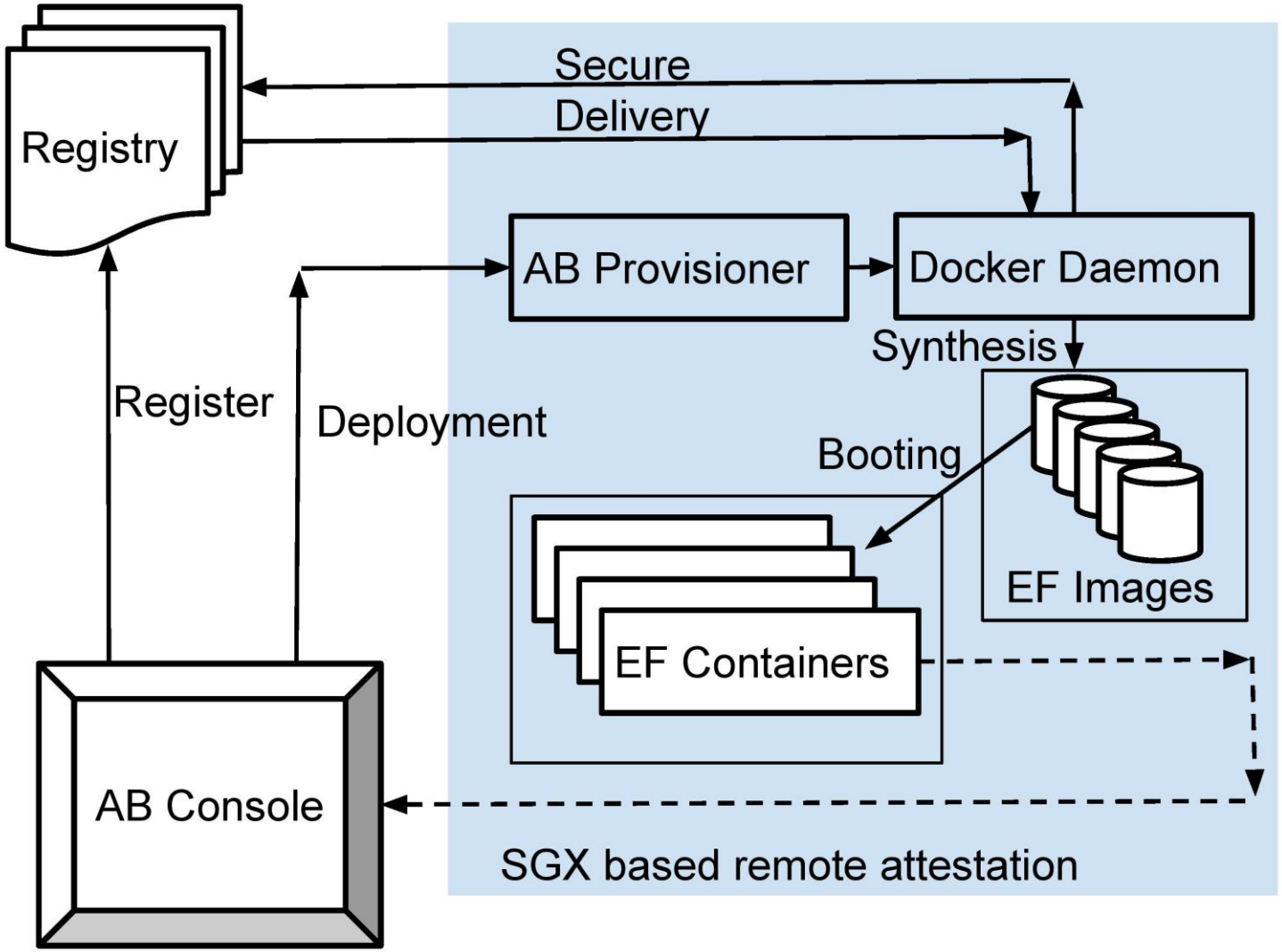
- Integrates seamlessly with Docker ecosystem making it easy to create, package and deliver EFs
- A single interface to deploy EFs, a single module for edge nodes and easy remote attestation of enclave in an EF
- Abstracts Intel SGX provided features to provide intuitive API to an EF developer or EF manager

AirBox – SGX interface

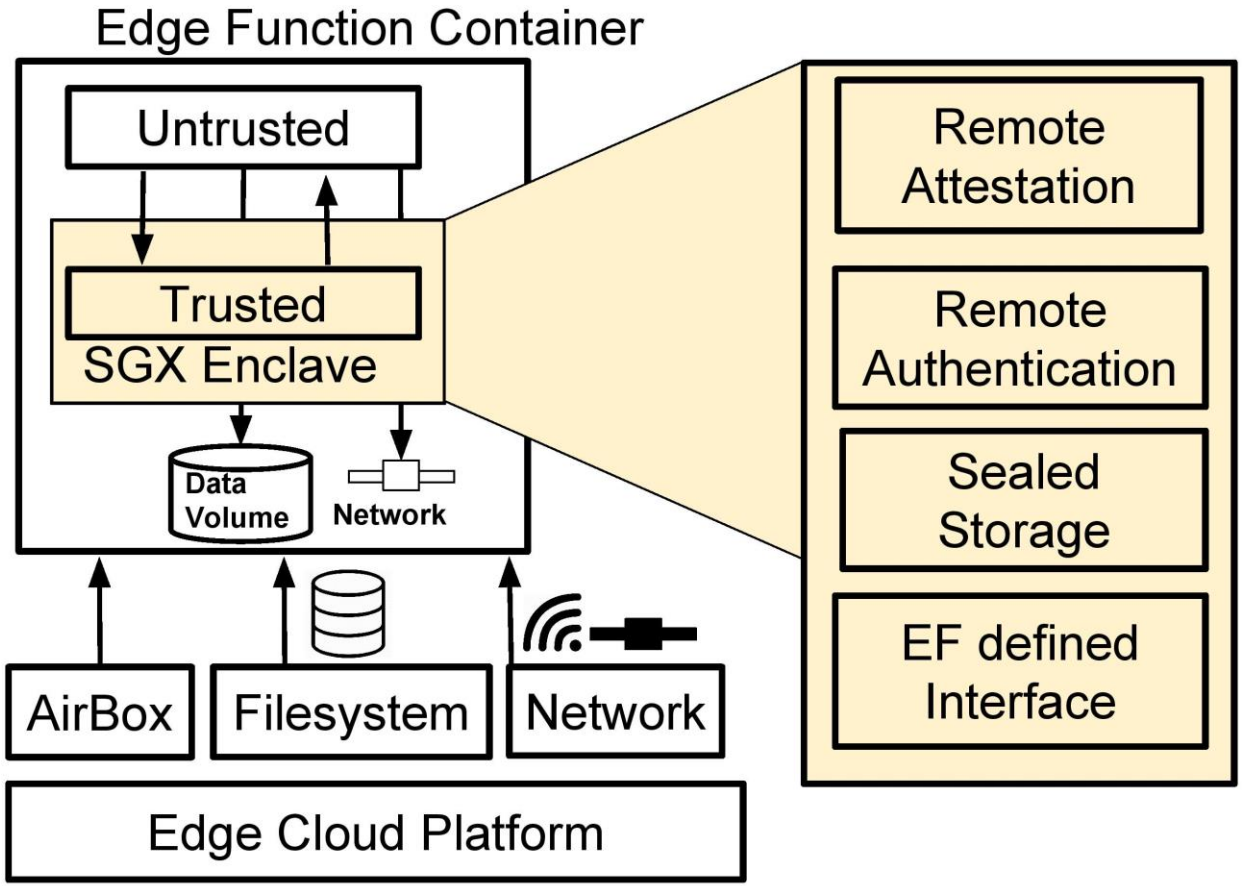
- Remote Attestation: `airbox_sgx_attest(quote)`
- Remote Authentication: `airbox_sgx_auth(quote)`
- Sealed Storage:
  - `airbox_sgx_get(key, len)`
  - `airbox_sgx_put(key, klen,*value, *vlen)`
  - `airbox_sgx_getkeys(*keys, len)`
- EF defined:
  - `airbox_sgx_run(module, conf)`

- **Ease of use:** Focus on the functionalities
- **Performance:** minimize SGX overhead – enclave page cache, TLB thrashing, …
- **Security:** Enclave can be compromised by incorrectly using system calls in host part of SGX application

AirBox EF provisioning



AirBox Secure EF anatomy

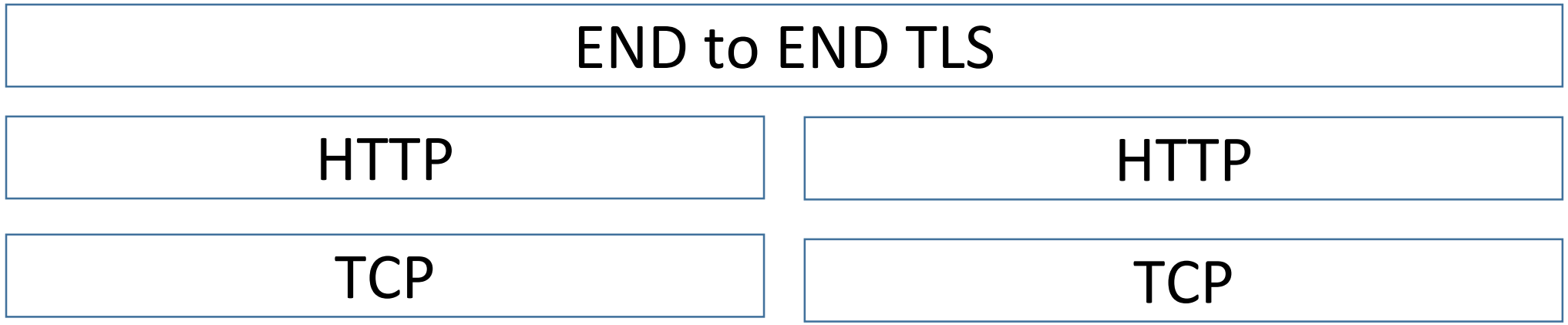


SGX features in AirBox

- Remote Attestation
- Sealing

Preserving end user privacy at Edge

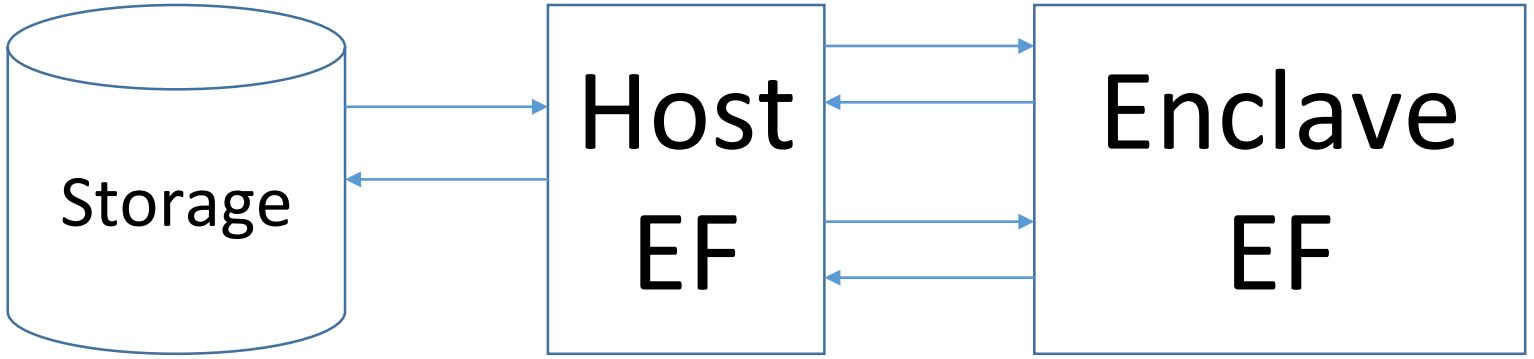
- EF acquires TLS session key in enclave
- EF saves it using sealing for session duration
- EF Decrypt user requests and their responses inside enclave
- Even AirBox just sees encrypted blobs going network



Secure split connection at edge using SGX

Securing Storage at Edge

- EF cannot direct read/write from inside of enclave
- 2 phase disk I/O: Phase 1: meta-data, Phase 2: data
- AirBox reads and writes only encrypted blobs from/to disk



Secure storage at the Edge using SGX

Implementation Details

- Using stable Docker release on Ubuntu 14.04
- SGX functionality prototyped using OpenSGX
- Generic edge functions for SGX impact

- **OpenSGX**: A qemu based software platform that provides necessary support for SGX application programmers to readily implement and evaluate their applications that leverage

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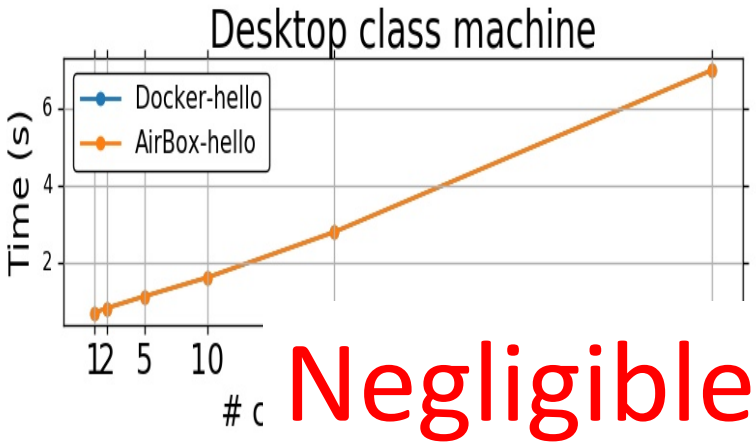
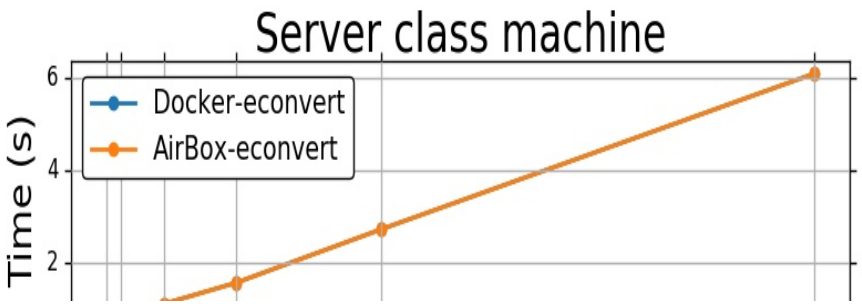
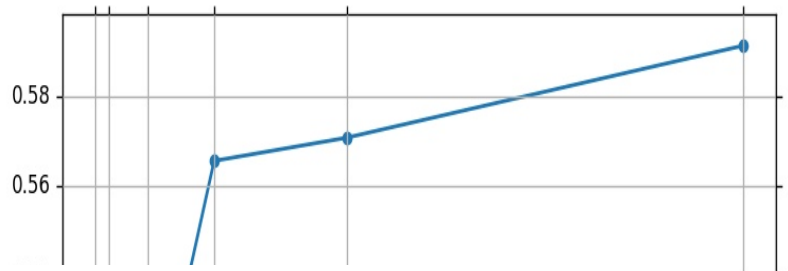
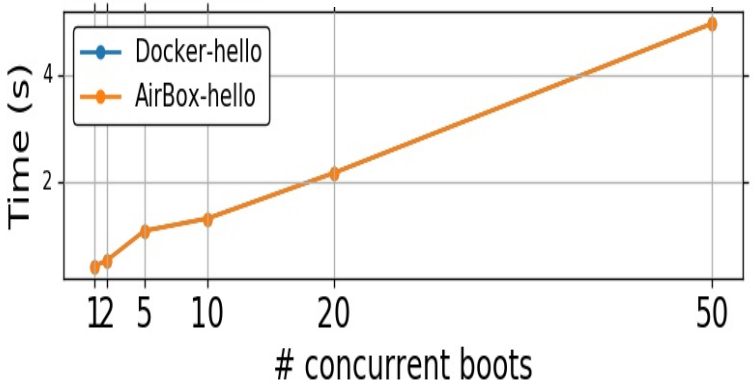
AirBox provisioning performance

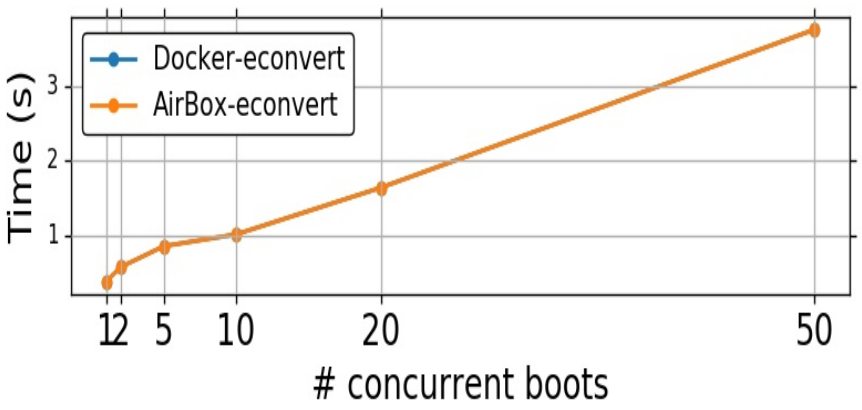


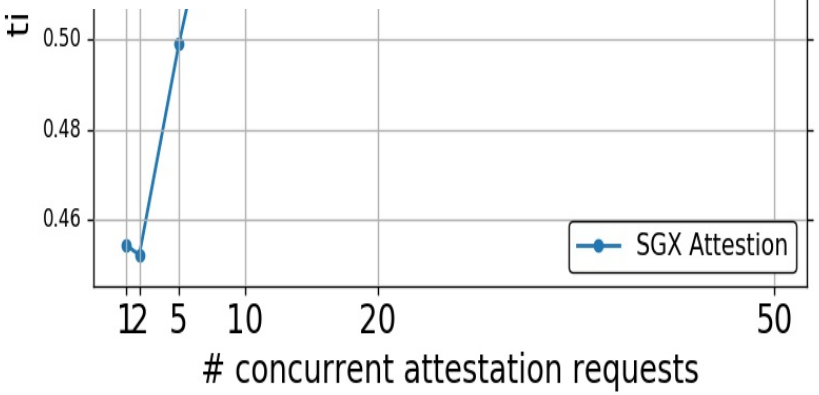




Negligible attestation overhead (< 1ms)



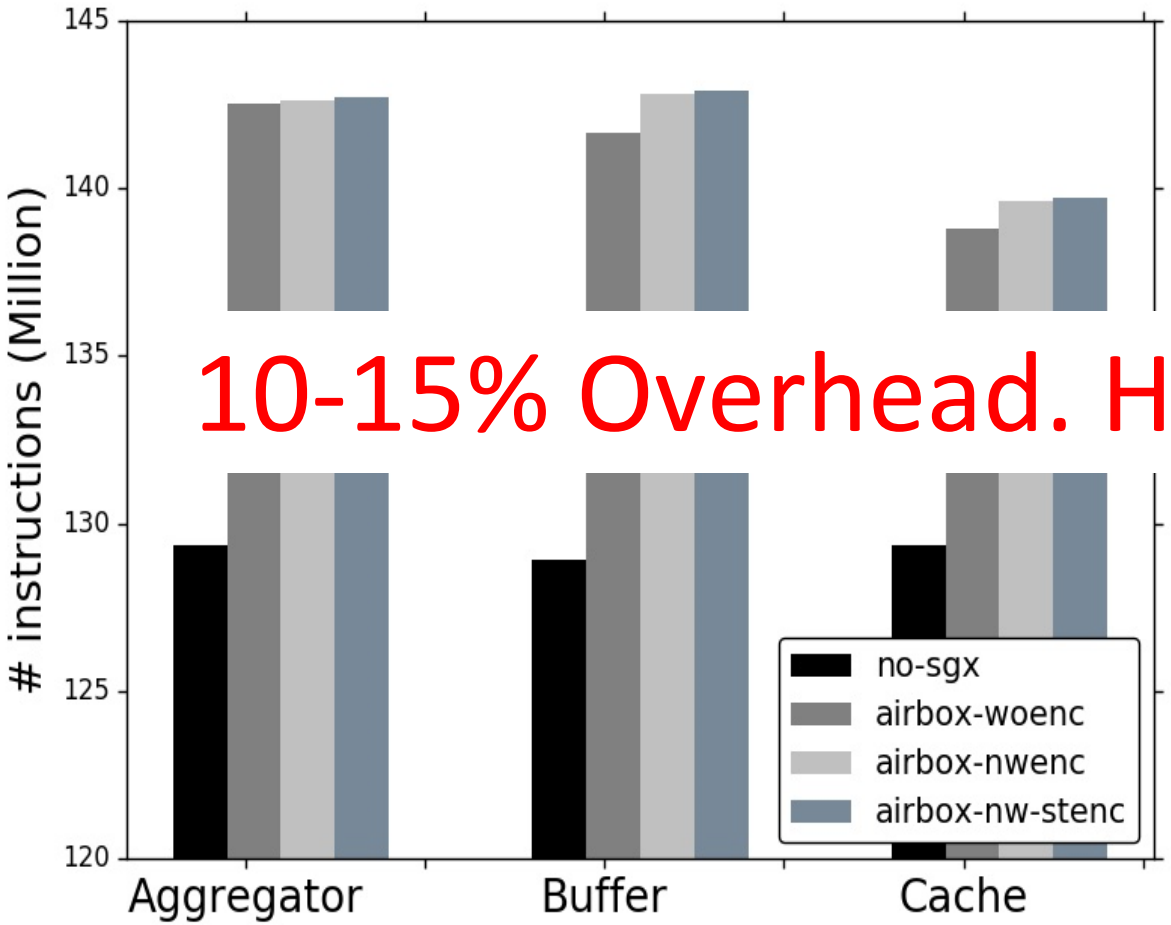


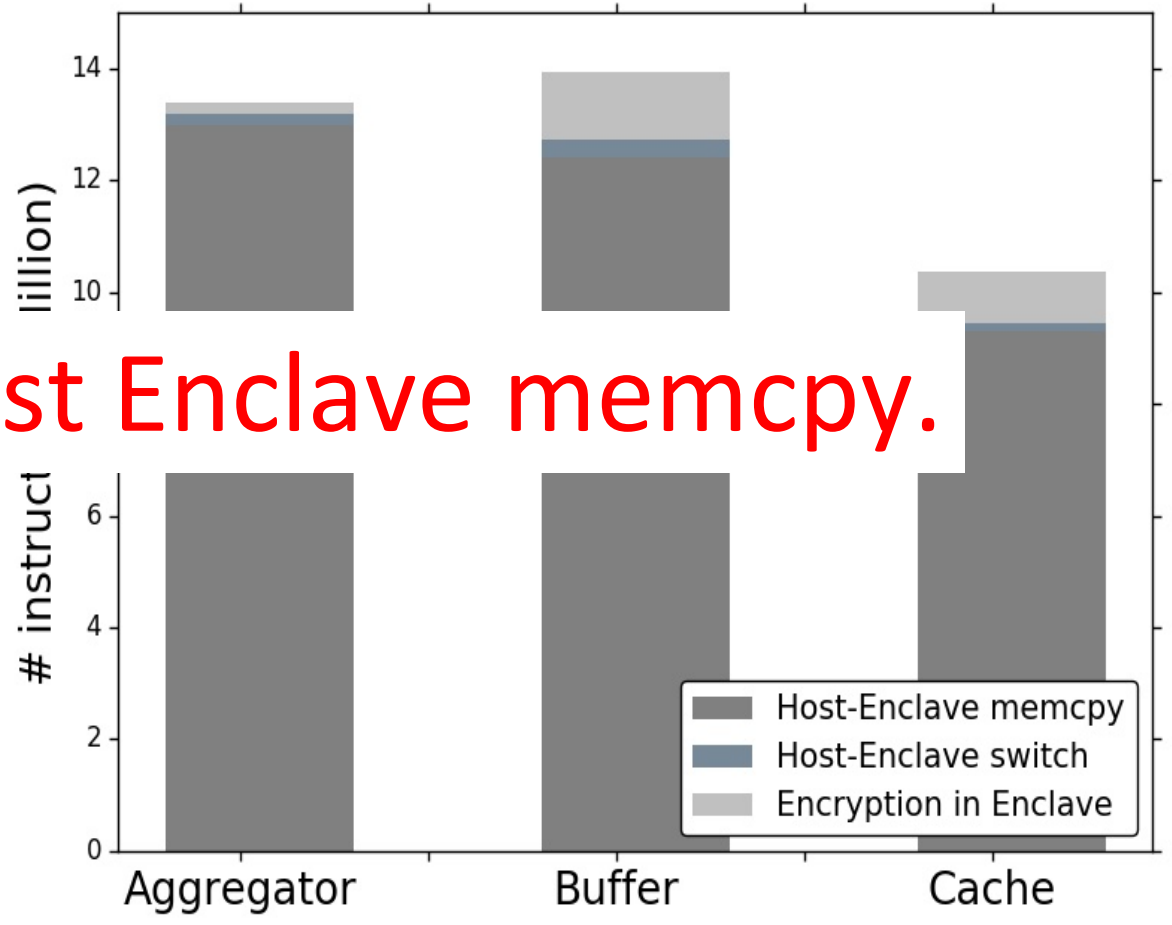


SGX overhead: Generic Edge Functions

EF Benefit	**Aggregation**	**Buffering**	**Caching**
Latency	x		x
Bandwidth	x	x	x
Edge resource			
Compute	x	x	
Storage	x	x	x

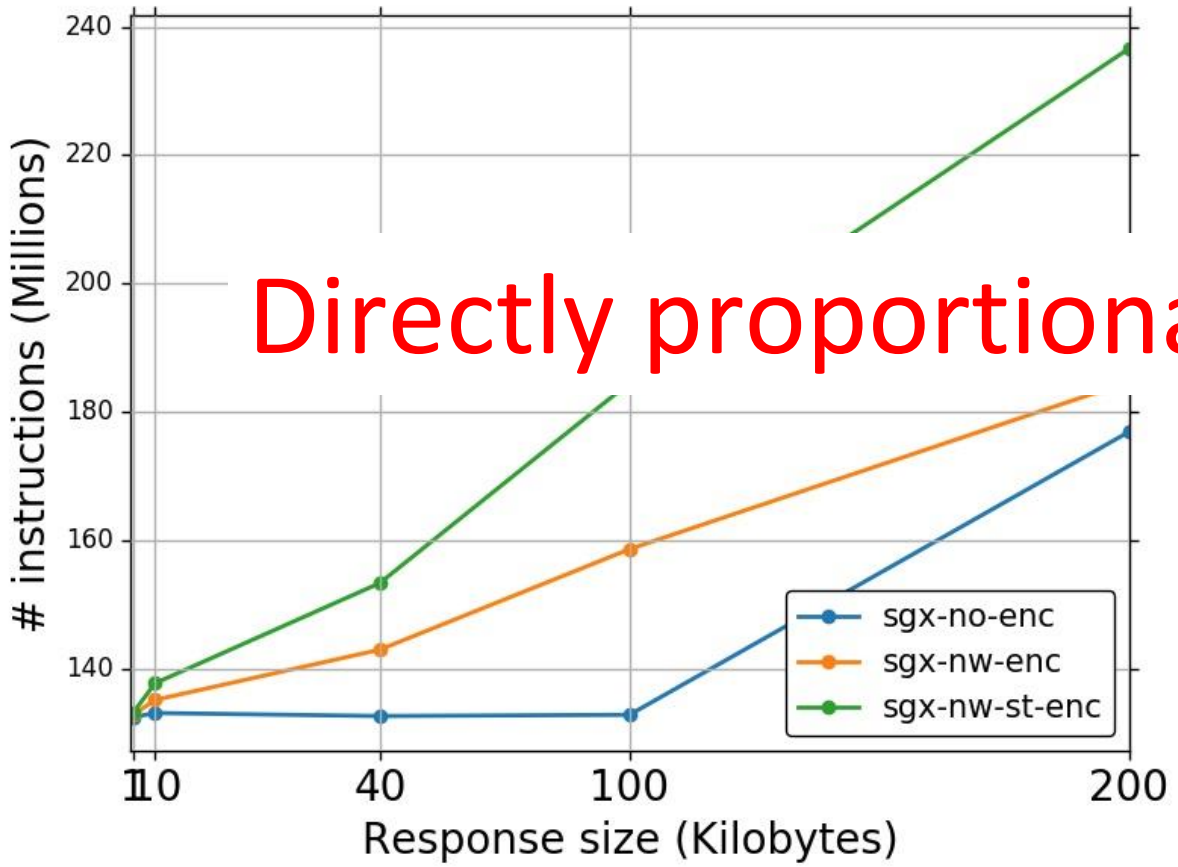
SGX Overhead: ABC usecases

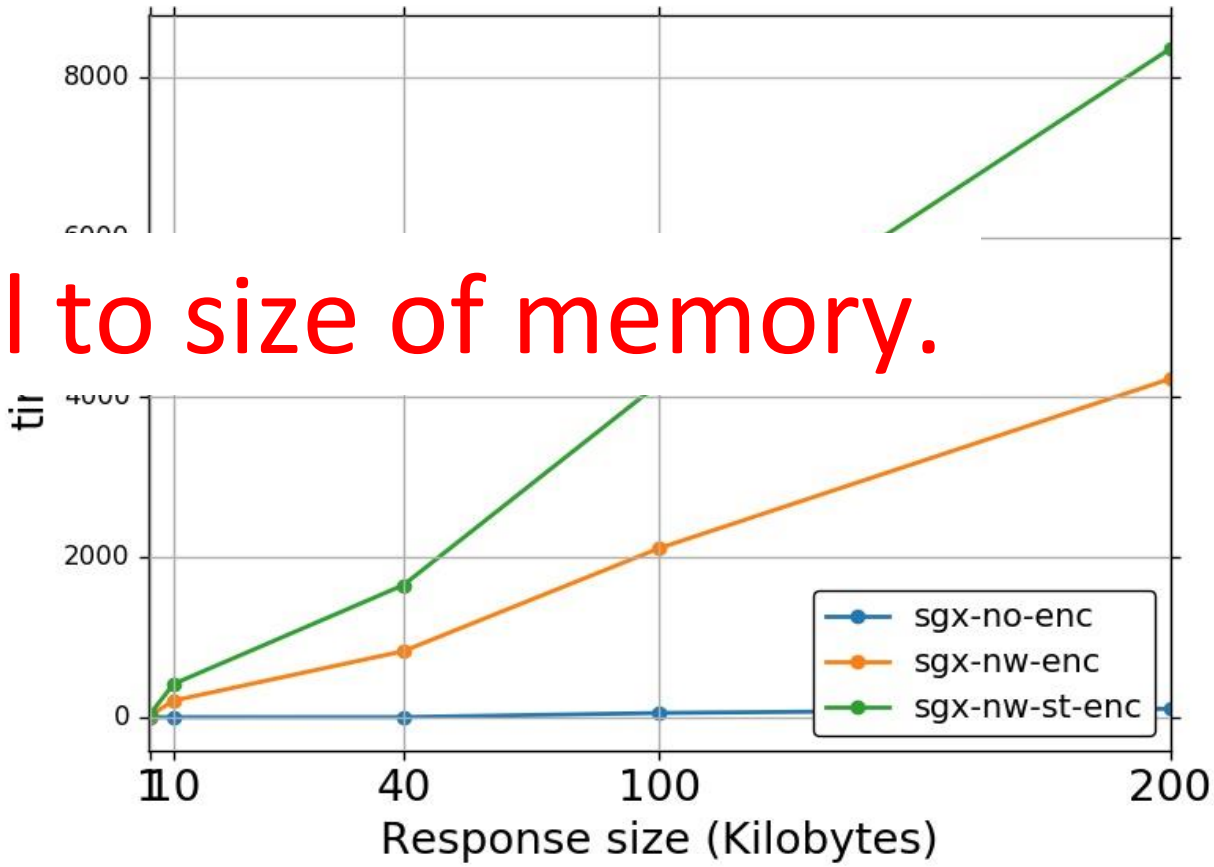




10-15% Overhead. Host Enclave memcpy.

memcpy: OpenSGX vs. Real Hardware





Directly proportional to size of memory.

Deployment Scenarios

- In mobile networks to enable performant and secure edge computing
- In enterprise networks, as part of vCPE equipment for better price to performance ration and securing valuable services
- In military tactical edge, where security concerns are paramount in case of a compromise

Next steps

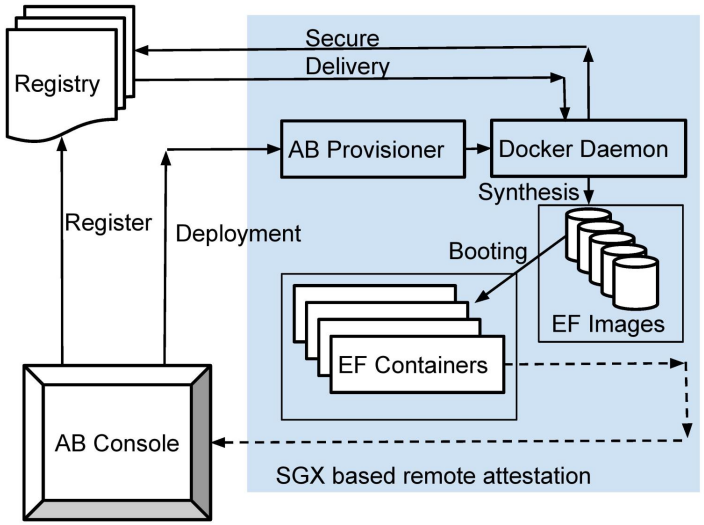
- Already ported in real SGX hardware
  - After SGX linux SDK was released (mid 2016)
- Protocol level solutions for handling traffic over secure protocols
- Evaluate on real mobile infrastructure – 4G LTE, …
- Formal model of Edge Functions and their benefits

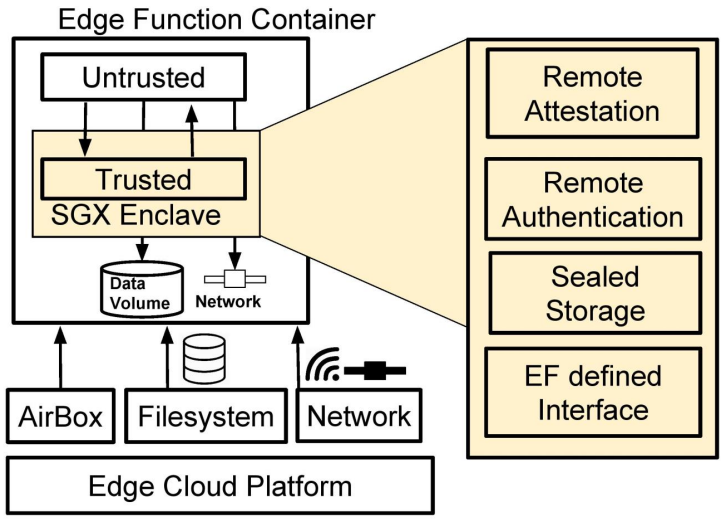
Summary

- Introduced the notion of Edge Functions
- Design of AirBox based on empirical analysis
  - Integrated with Docker eco-system
- Simplify use of Intel SGX for EF security
  - AirBox secure Interface
- Experimental demonstration
  - AirBox delivers competing benefits in terms of deployment
  - Speed, costs (in terms of resource consumption) and developers constraints
  - EF can be secured with ~10% runtime impact.

Questions?

AirBox





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