Chameleon

www. chameleoncloud.org

EXPERIMENTING IN THE EDGE TO CLOUD CONTINUUM

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July 30, 2021
ApPLIED Workshop 2021

THE UNIVERSITY OF CHICAGO TACC renci NORTHWESTERN UNIVERSITY NSF

CHAMELEON IN A NUTSHELL

- We like to change: a testbed that adapts itself to your experimental needs
  - Deep reconfigurability (bare metal) and isolation – but also a small KVM cloud
  - power on/off, reboot, custom kernel, serial console access, etc.
- Balance: large-scale versus diverse hardware
  - Large-scale: ~large homogenous partition (~15,000 cores), ~6 PB of storage distributed over 2 sites (UC, TACC) connected with 100G network
  - Diverse: ARMs, Atoms, FPGAs, GPUs, Corsa switches, etc.
- Cloud++: CHameleon Infrastructure (CHI) via mainstream cloud tech
  - Powered by OpenStack with bare metal reconfiguration (Ironic) + "special sauce"
  - Blazar contribution recognized as official OpenStack component
- We live to serve: open, production testbed for Computer Science Research
  - Started in 10/2014, available since 07/2015, renewed in 10/2017, and recently till end of 2024
  - Currently 5,500+ users, 700+ projects, 100+ institutions, 300+ publications

BY THE NUMBERS

300+
Papers published

45
Countries

Over
5,500
Users

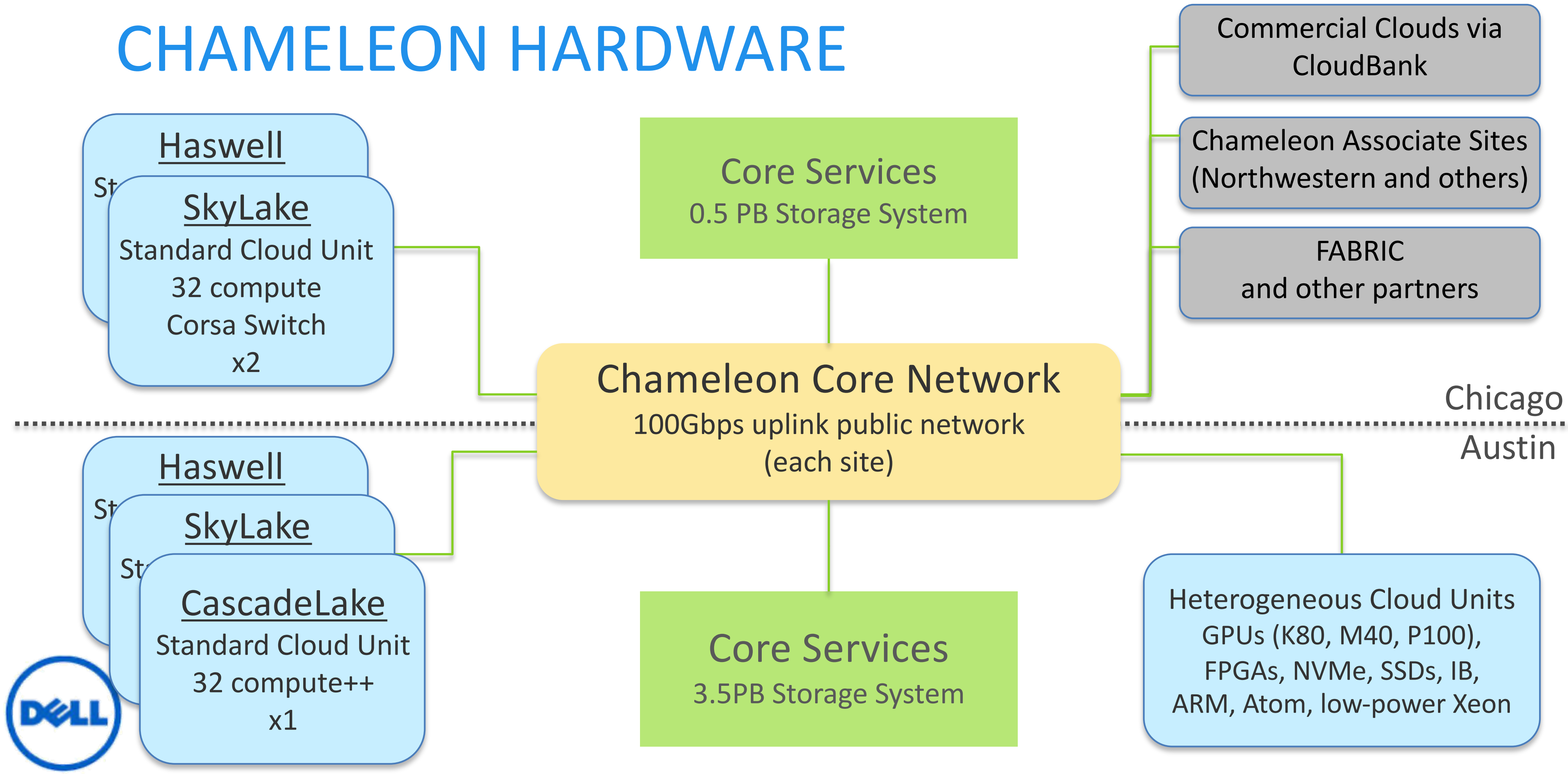
700+
Projects

160+
Institutions

5+
Years Old

and 3+ more years to grow!

CHAMELEON HARDWARE



CHAMELEON HARDWARE (DETAILS)

- "Start with large-scale homogenous partition"
  - 12 Haswell racks, each with 42 Dell R630 compute servers with dual-socket Intel Haswell processors (24 cores) & 128GB RAM and 4 Dell FX2 storage servers with 16 2TB drives each; Force10 s6000 OpenFlow-enabled switches 10Gb to hosts, 40Gb uplinks to Chameleon core network
  - 3 SkyLake racks (32 nodes each); Corsa (DP2400 & DP2200), 100Gb uplinks to core network
  - CascadeLake rack (32 nodes), 100Gb ulpinks to Chameleon core network
  - Allocations can be an entire rack, multiple racks, nodes within a single rack or across racks (e.g., storage servers across racks forming a Hadoop cluster)
- Shared infrastructure
  - 3.6 (TACC) + 0.5 (UC) PB global storage, 100Gb Internet connection between sites
- "Graft on heterogeneous features"
  - Infiniband with SR-IOV support, High-mem, NVMe, SSDs, P100 GPUs (total of 22 nodes), RTX GPUs (40 nodes), FPGAs (4 nodes)
  - ARM microservers (24) and Atom microservers (8), low-power Xeons (8)
- Coming in Phase 3: upgrading Haswells to CascadeLake and IceLake + AMD, new GPUs and FPGAs, more and newer IB fabric, variety of storage options for disaggregated hardware experiments, composable hardware (LiQid), networking (P4, integration with FABRIC), IoT devices -- and strategic reserve

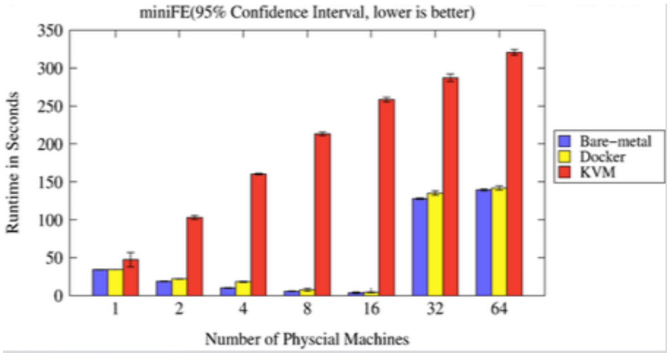
CHI EXPERIMENTAL WORKFLOW

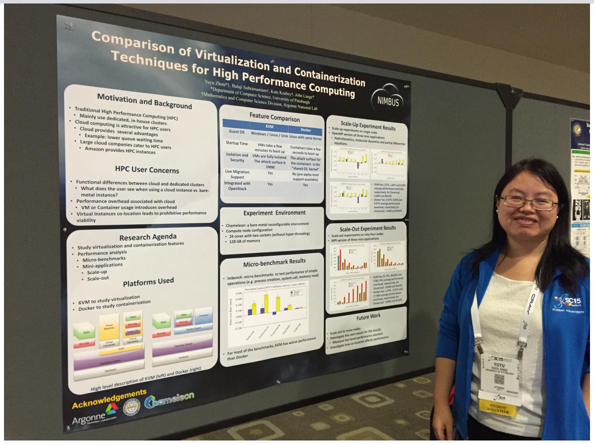
discover resources	allocate resources	configure and interact	monitor
- Fine-grained - Complete - Up-to-date - Versioned - Verifiable	- Allocatable resources: nodes, VLANs, IPs - Advance reservations and on-demand - Expressive interface - Isolation	- Deeply reconfigurable - Appliance catalog - Snapshotting - Orchestration - Jupyter integration - Networks: stitching and BYOC	- Hardware metrics - Fine-grained data - Aggregate - Archive

Authentication via federated identity,
Interfaces via GUI, CLI and python/Jupyter

VIRTUALIZATION OR CONTAINERIZATION?

- Yuyu Zhou, University of Pittsburgh
- Research: lightweight virtualization
- Testbed requirements:
  - Bare metal reconfiguration, isolation, and serial console access
  - The ability to "save your work"
  - Support for large scale experiments
  - Up-to-date hardware



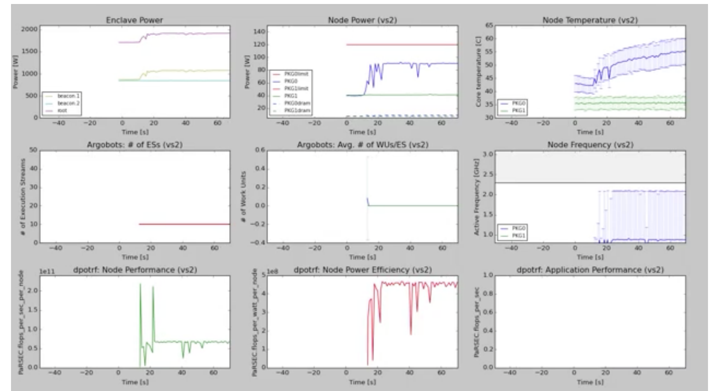


SC15 Poster: "Comparison of Virtualization and Containerization Techniques for HPC"

EXASCALE OPERATING SYSTEMS

- Swann Perarnau, ANL
- Research: exascale operating systems
- Testbed requirements:
  - Bare metal reconfiguration
  - Boot from custom kernel with different kernel parameters
  - Fast reconfiguration, many different images, kernels, parameters
  - Hardware: accurate information and control over changes, performance counters, many cores
  - Access to same infrastructure for multiple collaborators

HPPAC'16 paper: "Systemwide Power Management with Argo"

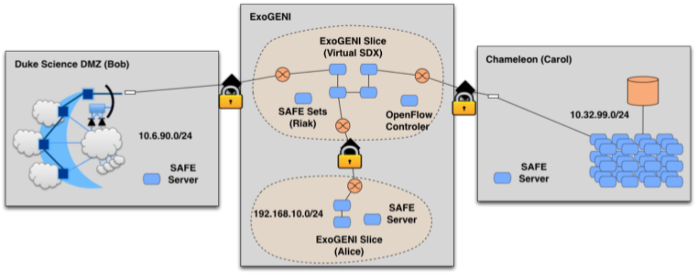


CLASSIFYING CYBERSECURITY ATTACKS

- Jessie Walker & team, University of Arkansas at Pine Bluff (UAPB)
- Research: modeling and visualizing multi-stage intrusion attacks (MAS)
- Testbed requirements:
  - Easy to use OpenStack installation
  - A selection of pre-configured images
  - Access to the same infrastructure for multiple collaborators

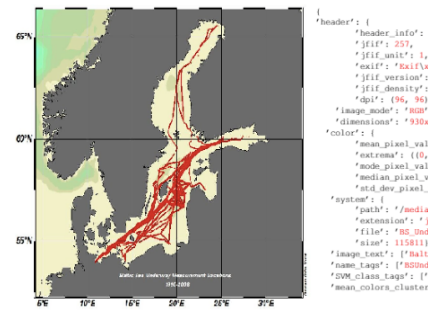
CREATING DYNAMIC SUPERFACILITIES

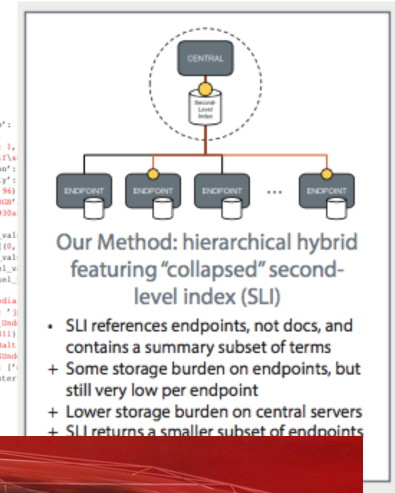
- NSF CICI SAFE, Paul Ruth, RENCI-UNC Chapel Hill
- Creating trusted facilities
  - Automating trusted facility creation
  - Virtual Software Defined Exchange (SDX)
  - Secure Authorization for Federated Environments (SAFE)
- Testbed requirements
  - Creation of dynamic VLANs and wide-area circuits
  - Support for network stitching
  - Managing complex deployments



DATA SCIENCE RESEARCH

- ACM Student Research Competition semi-finalists:
  - Blue Keleher, University of Maryland
  - Emily Herron, Mercer University
- Searching and image extraction in research repositories
- Testbed requirements:
  - Access to distributed storage in various configurations
  - State of the art GPUs
  - Easy to use appliances and orchestration

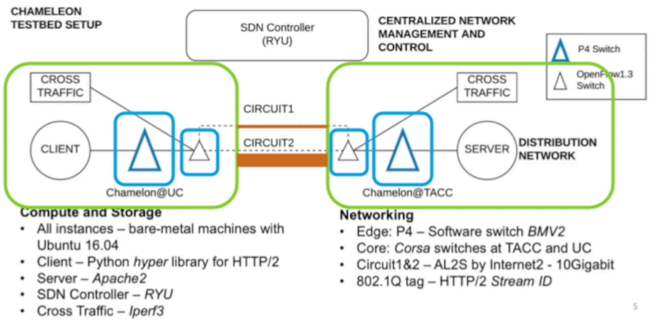




ADAPTIVE BITRATE VIDEO STREAMING

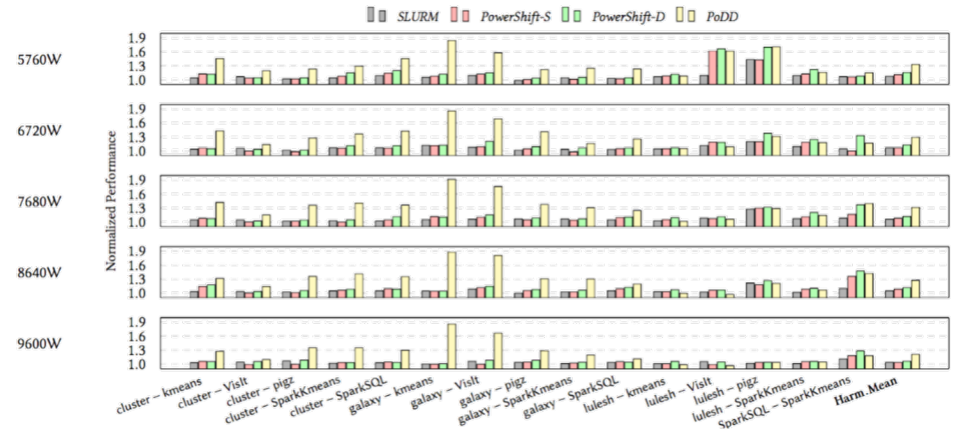
- Divyashri Bhat, UMass Amherst
- Research: application header based traffic engineering using P4
- Testbed requirements:
  - Distributed testbed facility
  - BYOC – the ability to write an SDN controller specific to the experiment
  - Multiple connections between distributed sites
- https://vimeo.com/297210055

LCN'18: "Application-based QoS support with P4 and OpenFlow"



POWER CAPPING

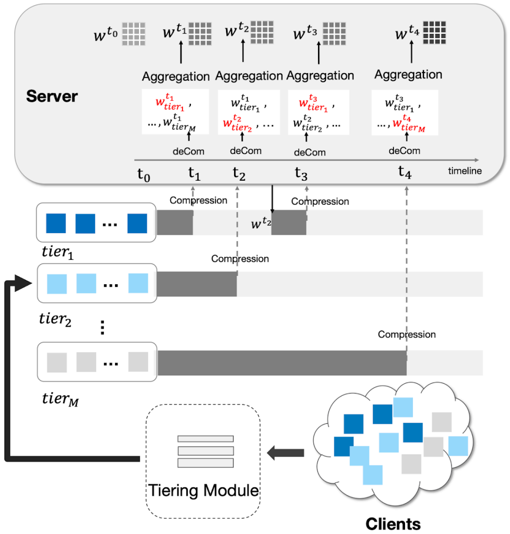
- Harper Zhang, University of Chicago
- Research: hierarchical, distributed, dynamic power management system for dependent applications
- Testbed requirements:
  - Support for large-scale experiments
  - Complex appliances and orchestration (NFS appliance)
  - RAPL/power management interface
- Finalist for SC19 Best Paper and Best Student Paper
- Talk information at bit.ly/SC19PoDD



SC'19: "PoDD: Power-Capping Dependent Distributed Applications"

FEDERATED LEARNING

- Zheng Chai and Yue Cheng, George Mason University
- Research: federated learning
- Testbed requirements:
  - Bare metal, ability to record network traffic precisely
  - Support for large-scale and diverse hardware
  - Powerful nodes with large memory

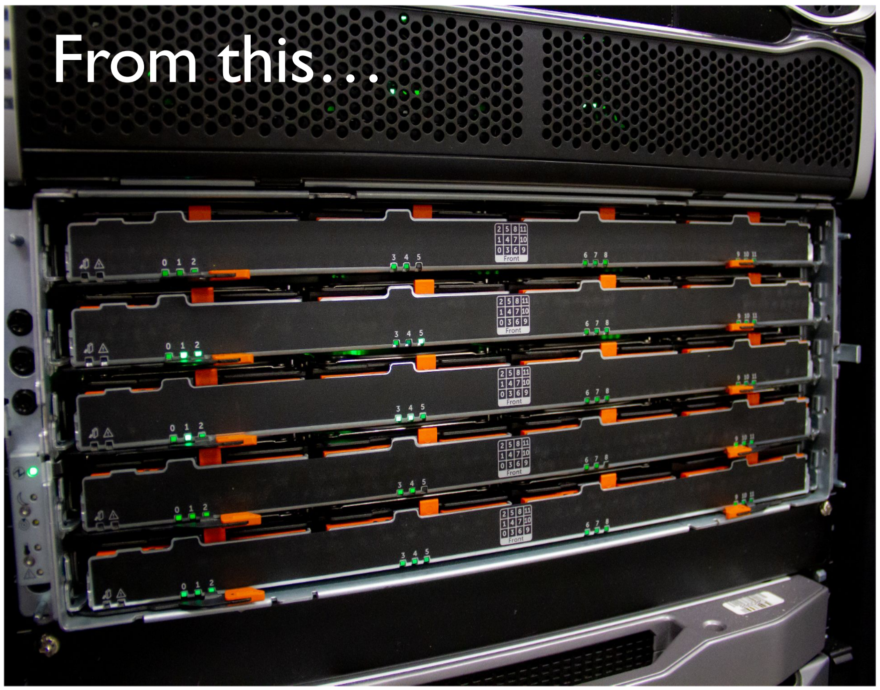


Paper: "FedAT: A Communication-Efficient Federated Learning Method with Asynchronous Tiers under Non-IID Data", October 2020

GIVING CHAMELEON AN EDGE

- What does an edge testbed look like?
  - A lot like a cloud: all the features you know and love – but via **containers**
  - Not like a cloud at all: location, location, location -- cameras, actuators, software defined radios (SDRs) – network, hardware, privacy limitations
  - **CHI@Edge:** mixed-ownership devices managed via an **SDK** via a **virtual site –** but otherwise very similar tried and true interface
  - Practice makes perfect: **listen to users and adjust**
- How to build an edge testbed
  - Familiar challenges: access management, secure network connections, resource management, and other sharing considerations
  - New challenges: remote locations, power/networking constraints, peripheral devices
  - Leverage existing investment in (1) open source (OpenStack), and (2) Chameleon

BUILDING CHI@EDGE



CHI@EDGE EXPERIMENTAL WORKFLOW (PREVIEW)

discover resources → **allocate resources** → **configure and interact** → **monitor**

discover resources
- Complete
- Up-to-date

allocate resources
- Allocatable resources: nodes, VLANs, IPs
- Advance reservations and on-demand
- Expressive interface
- Isolation

configure and interact
- Container
- Catalog of images
- Snapshotting
- Jupyter integration for orchestration

monitor

Authentication via federated identity,
Interfaces via GUI, CLI and python/Jupyter

CHI AND CHI@EDGE SIDE BY SIDE

Chameleon for bare metal

Advanced reservations for **bare metal machines**
Bare metal reconfigurability
Single-tenant isolation
Heterogeneous collection of interesting hardware

Isolated networking, public IP capability, **OpenFlow SDN**
Composable cloud APIs (GUI, CLI, Python+Jupyter)
Owned and operated by Chameleon

Chameleon for edge

Advanced reservations for **IoT/edge devices**
Container deployment
Single-tenant isolation
Heterogeneous collection of interesting hardware **and peripherals/locations!**
Isolated networking, public IP capability
Composable cloud APIs (GUI, CLI, Python+Jupyter)
Mixed ownership model: bring your own device(s)!

JOIN US FOR THE SUMMER OF CHAMELEON!

- June 2021: CHI@Edge releases, shared hardware (nvidia nanos and raspberry pis), community webinars
- July 2021: "bring your own device" with attestations/SLAs, peripherals, support for limited sharing
- To use: https://www.chameleoncloud.org/experiment/chiedge/
- To learn: https://www.youtube.com/user/ChameleonCloud/videos
- To interact: https://groups.google.com/g/chameleon-edge-users?pli=1
- Help us build a better testbed!

PRACTICAL REPRODUCIBILITY

- **Can experiments be as sharable as papers are today?**
- Reproducibility baseline: sharing hardware via instruments held in common
- Clouds: sharing experimental environments
  - Disk images, orchestration templates, and other artifacts
- What is missing?
  - Telling the whole story: hardware + experimental container + experiment workflow + data analysis + story – literate programming
  - The easy button: it has to be easy to package, easy to repeat, easy to find, easy to get credit for, easy to reference, etc.
  - Nits and optimizations: declarative versus imperative, transactional versus transparent

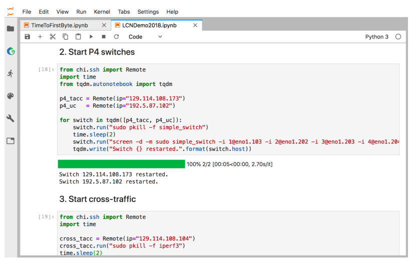
Paper: "The Silver Lining", IEEE Internet Computing 2020

EXPERIMENT SHARING IN CHAMELEON

- Hardware and hardware versions
  - >105 versions over 5 years
  - Expressive allocation
- Images and orchestration
  - >130,000 images, >35,000 orchestration templates and counting
- Packaging and repeating: integration with JupyterLab
- Share, find, publish and cite: Trovi and Zenodo

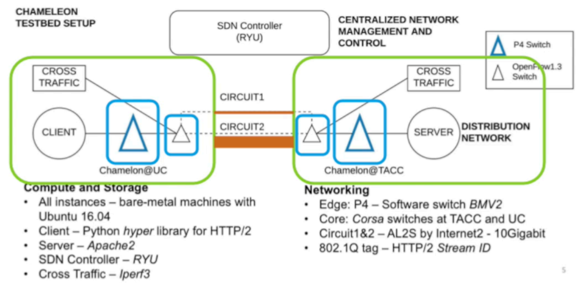
PACKAGING SHARABLE EXPERIMENTS

Literate Programming with Jupyter



Experimental storytelling:
ideas/text, process/code, results

\+

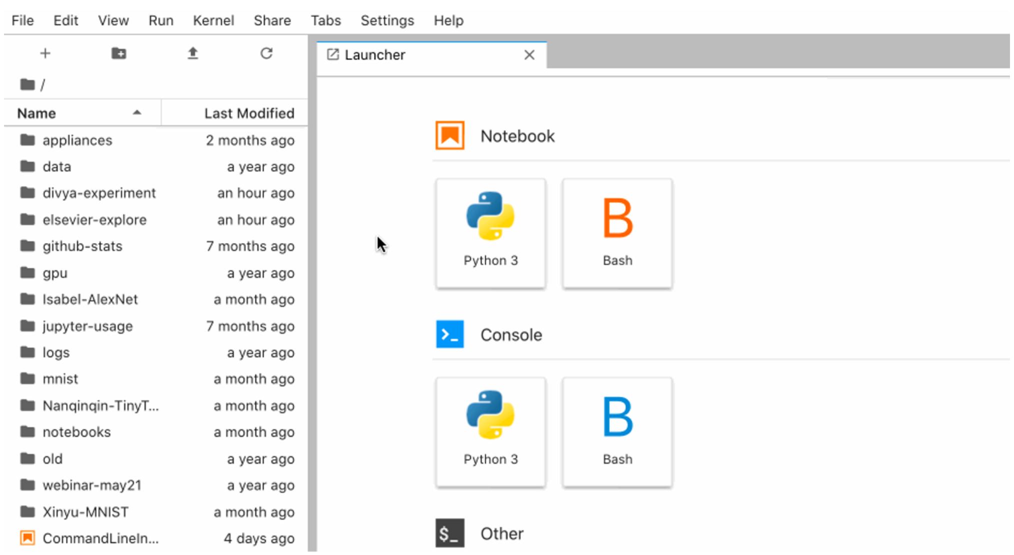


Complex Experimental containers

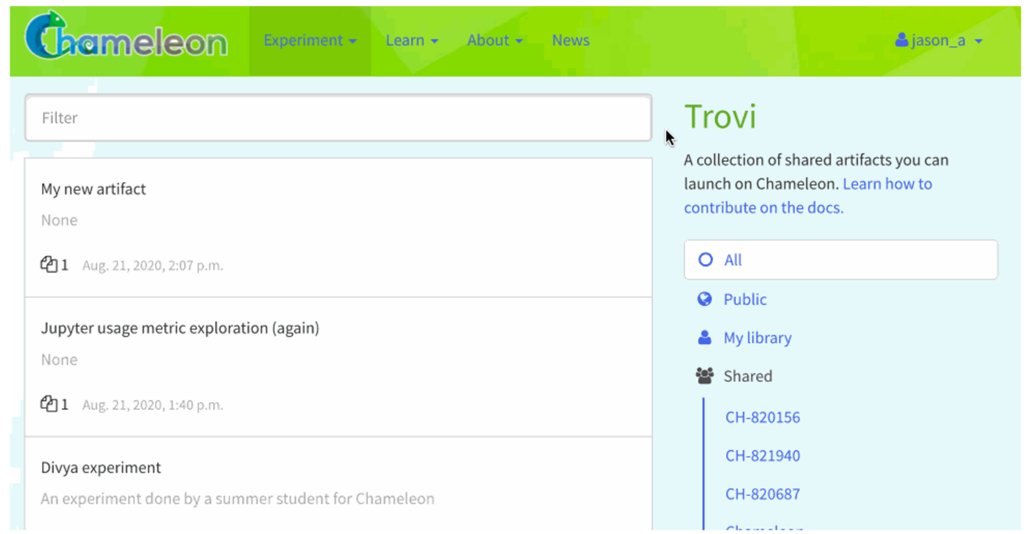
- Repeatability by default: Jupyter notebooks + Chameleon experimental containers
  - JupyterLab for our users: use jupyter.chameleoncloud.org with Chameleon credentials
  - Interface to the testbed in Python/bash + examples (see LCN'18: https://vimeo.com/297210055)
  - Especially for highly distributed experiments (CHI@Edge) notebook as terminal multiplexer

Paper: "A Case for Integrating Experimental Containers with Notebooks", CloudCom 2019

TROVI: CHAMELEON'S EXPERIMENT PORTAL



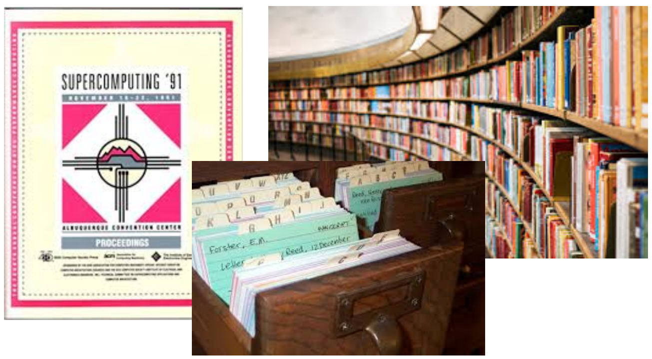
Create a new packaged experiment out of any directory of files in your Jupyter server. It is private to you unless shared. Supports sharing similar to Google Drive.



Any user with a Chameleon allocation can find and "replay" the packaged experiment.

PUBLISHING EXPERIMENTS

Familiar research sharing ecosystem



Digital research sharing ecosystem

Chameleon jupyterhub

?

- Digital publishing with Zenodo: make your experimental artifacts citable via Digital Object Identifiers (DOIs)
- Integration with Zenodo
  - Export: make your research citable and discoverable
  - Import: access a wealth of digital research artifacts already published

zenodo

PARTING THOUGHTS

- Scientific instruments: laying down the pavement as science walks on it
- Chameleons like to change:
  - Experimental environments that can adapt to your experiment
  - CHI@Edge – from cloud to edge – testbed that adapts itself to your scientific needs
  - Still in preview but supporting exciting applications in self-driving cars, marine biology, and
- From shareable research instrument to a sharing platform
  - Clouds help us package experimental environments almost as a side-effect
  - Literate programming is a convenient vehicle for "closing the gap": packaging the whole experiment so that it can be reproduced easily
  - The easy button: making reproducibility sustainable will rely on creating "research marketplace": sharing experiments as naturally as we share papers now

We're here to change – come and change with us!

www.chameleoncloud.org