Chameleon

www. chameleoncloud.org

Kate Keahey

Mathematics and CS Division, Argonne National Laboratory

CASE, University of Chicago

keahey@anl.gov

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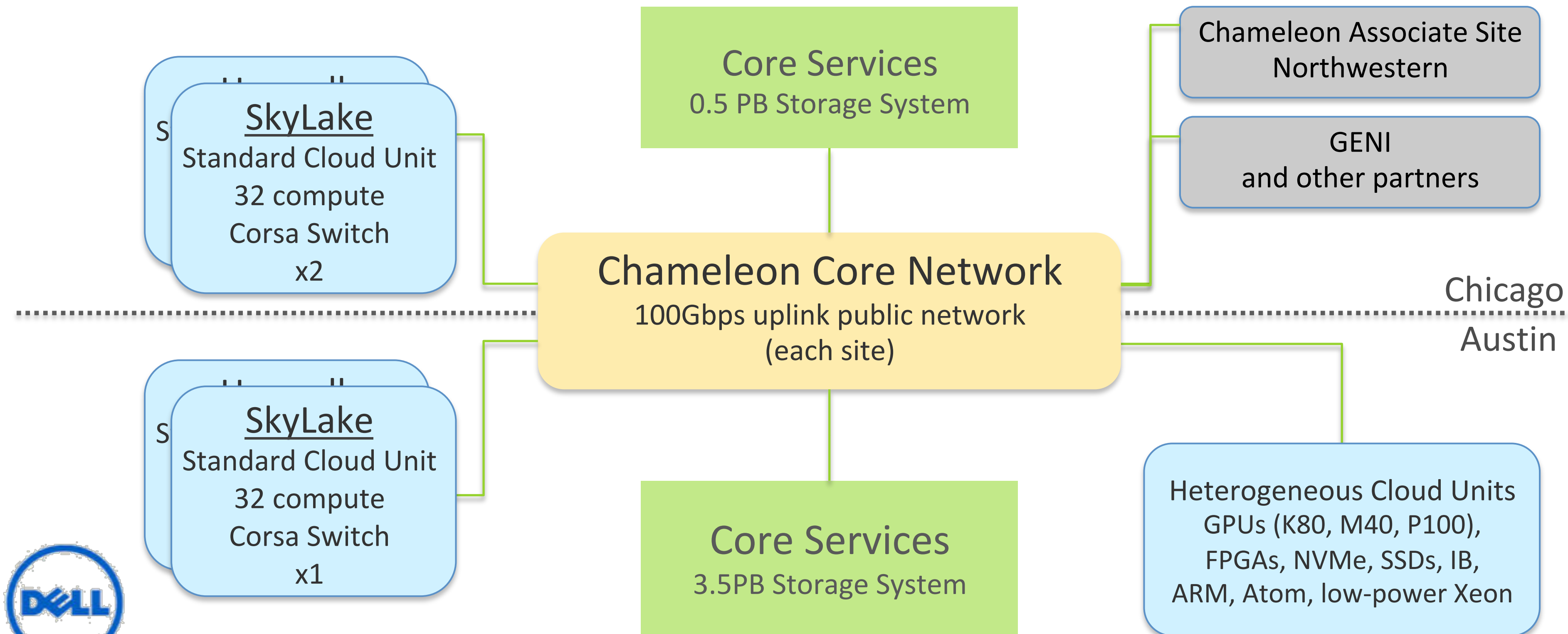
CHAMELEON IN A NUTSHELL

- We like to change: testbed that adapts itself to your experimental needs
  - Deep reconfigurability (bare metal) and isolation (CHI) – but also ease of use (KVM)
  - CHI: power on/off, reboot, custom kernel, serial console access, etc.
- We want to be all things to all people: balancing large-scale and diverse
  - Large-scale: ~large homogenous partition (~15,000 cores), 5 PB of storage distributed over 2 sites (now +1!) connected with 100G network…
  - …and diverse: ARMs, Atoms, FPGAs, GPUs, Corsa switches, etc.
- Cloud++: leveraging mainstream cloud technologies
  - Powered by OpenStack with bare metal reconfiguration (Ironic) + "special sauce"
  - Chameleon team contribution recognized as official OpenStack component
- We live to serve: open, production testbed for Computer Science Research
  - Started in 10/2014, testbed available since 07/2015, renewed in 10/2017
  - Currently 3,500+ users, 500+ projects, 100+ institutions

CHAMELEON HARDWARE



CHAMELEON HARDWARE (DETAILS)

- "Start with large-scale homogenous partition"
  - 12 Haswell Standard Cloud Units (48 node racks), each with 42 Dell R630 compute servers with dual-socket Intel Haswell processors (24 cores) and 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 Standard Cloud Units (32 node racks); Corsa (DP2400 & DP2200) switches, 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 + 0.5 PB global storage, 100Gb Internet connection between sites
- "Graft on heterogeneous features"
  - Infiniband with SR-IOV support, High-mem, NVMe, SSDs, GPUs (22 nodes), FPGAs (4 nodes)
  - ARM microservers (24) and Atom microservers (8), low-power Xeons (8)
- Coming soon: more nodes (CascadeLake), and more accelerators/GPUs

EXPERIMENTAL WORKFLOW

discover resources → allocate resources → configure and interact → monitor

discover resources
- Fine-grained
- Complete
- Up-to-date
- Versioned
- Verifiable

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

configure and interact
- Deeply reconfigurable
- Appliance catalog
- Snapshotting
- Orchestration
- Networks: stitching and BYOC

monitor
- Hardware metrics
- Fine-grained data
- Aggregate
- Archive

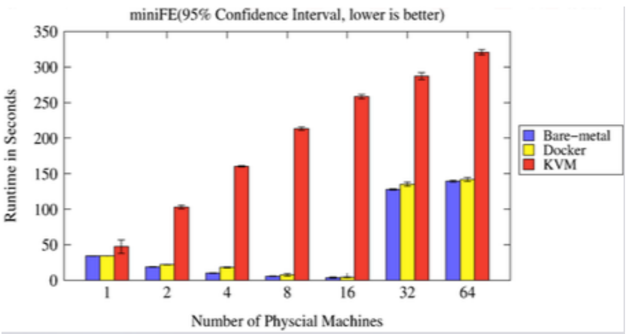
CHI = 65%*OpenStack + 10%*G5K + 25%*"special sauce"

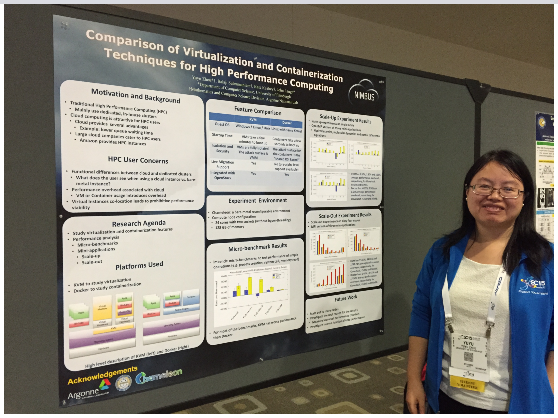
PHASE 2 ADDITIONS

- Better allocatable resources – it's not just for the nodes!
  - Multiple resource management (nodes, VLANs, IP addresses), adding/removing nodes to/from a lease, lifecycle notifications, advance reservation orchestration
  - Chameleon blog: "Save the planet, use fewer IPs"
- All the networking that's fit to experiment with!
  - Multi-tenant networking,
  - Stitching dynamic VLANs from Chameleon to external partners (ExoGENI, ScienceDMZs),
  - VLANs + AL2S connection between UC and TACC for 100G experiments
  - BYOC– Bring Your Own Controller: isolated user controlled virtual OpenFlow switches
  - Coming soon: stitching to commercial clouds
- Miscellaneous features – and there's more…
  - Power metrics, usability features, new appliances, etc.

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

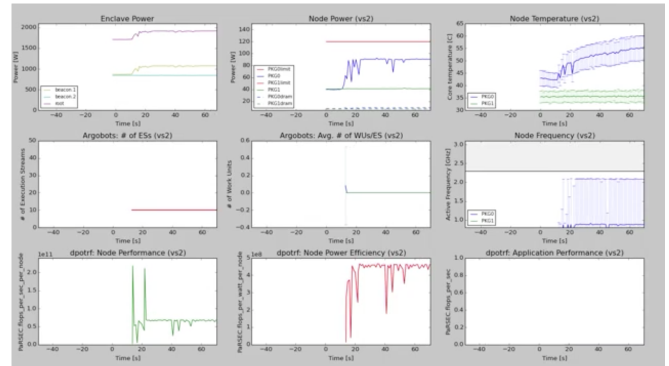


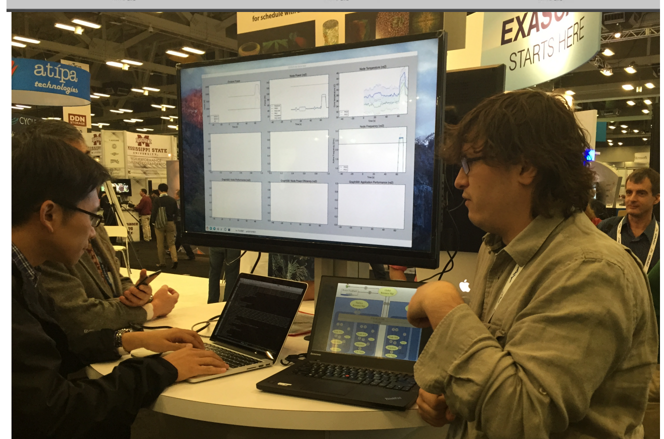


SC15 Poster: "Comparison of Virtualization and Containerization Techniques for HPC"

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





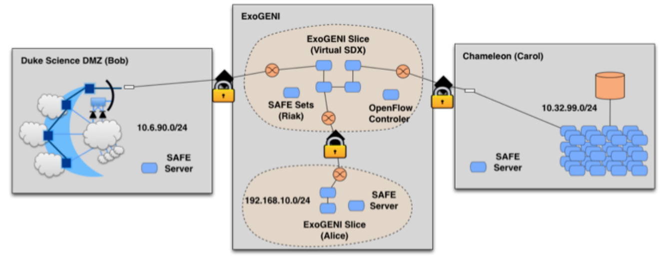
HPPAC'16 paper: "Systemwide Power Management with Argo"

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

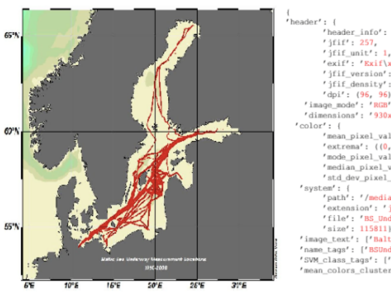
CREATING DYNAMIC SUPERFACILITIES

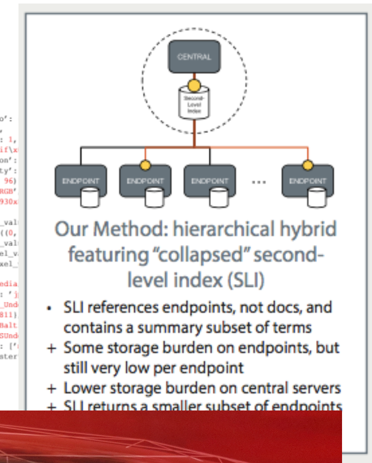
- NSF CICI SAFE, Paul Ruth, RENCI-UNC Chapel Hill
- Creating trusted facilities
  - Automating trusted facility creation
  - Virtual Software Defined Exchange (SDX)
  - Secure Authorization for Federated Environments (SAFE)
- Testbed requirements
  - Creation of dynamic VLANs and wide-area circuits
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



DATA SCIENCE RESEARCH

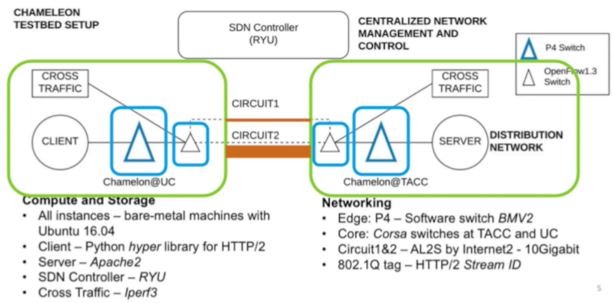
- ACM Student Research Competition semi-finalists:
  - Blue Keleher, University of Maryland
  - Emily Herron, Mercer University
- Searching and image extraction in research repositories
- Testbed requirements:
  - Access to distributed storage in various configurations
  - State of the art GPUs
  - Easy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

- 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
  - bit.ly/SC19PoDD

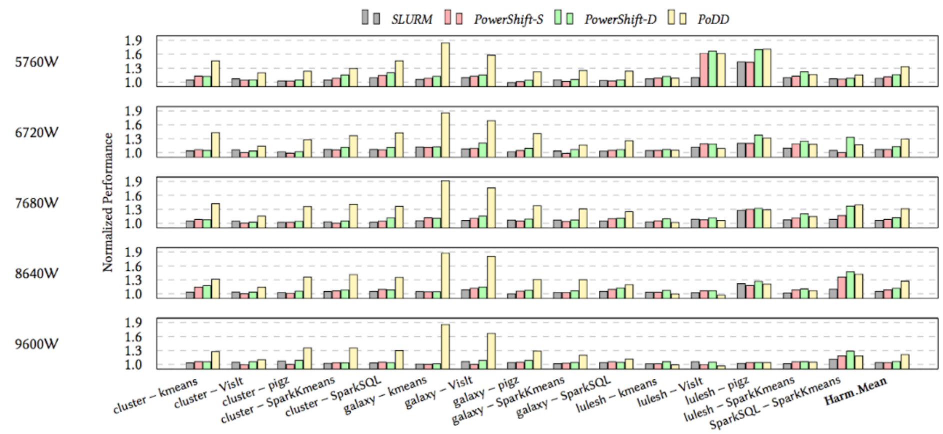
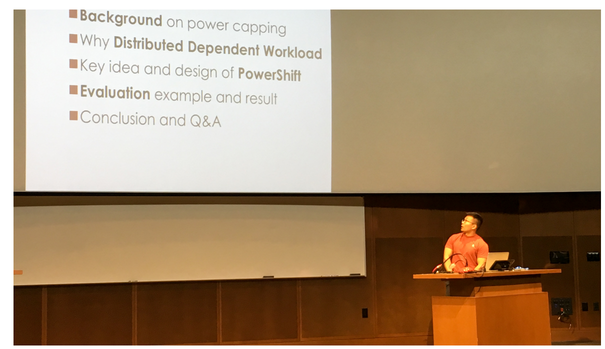


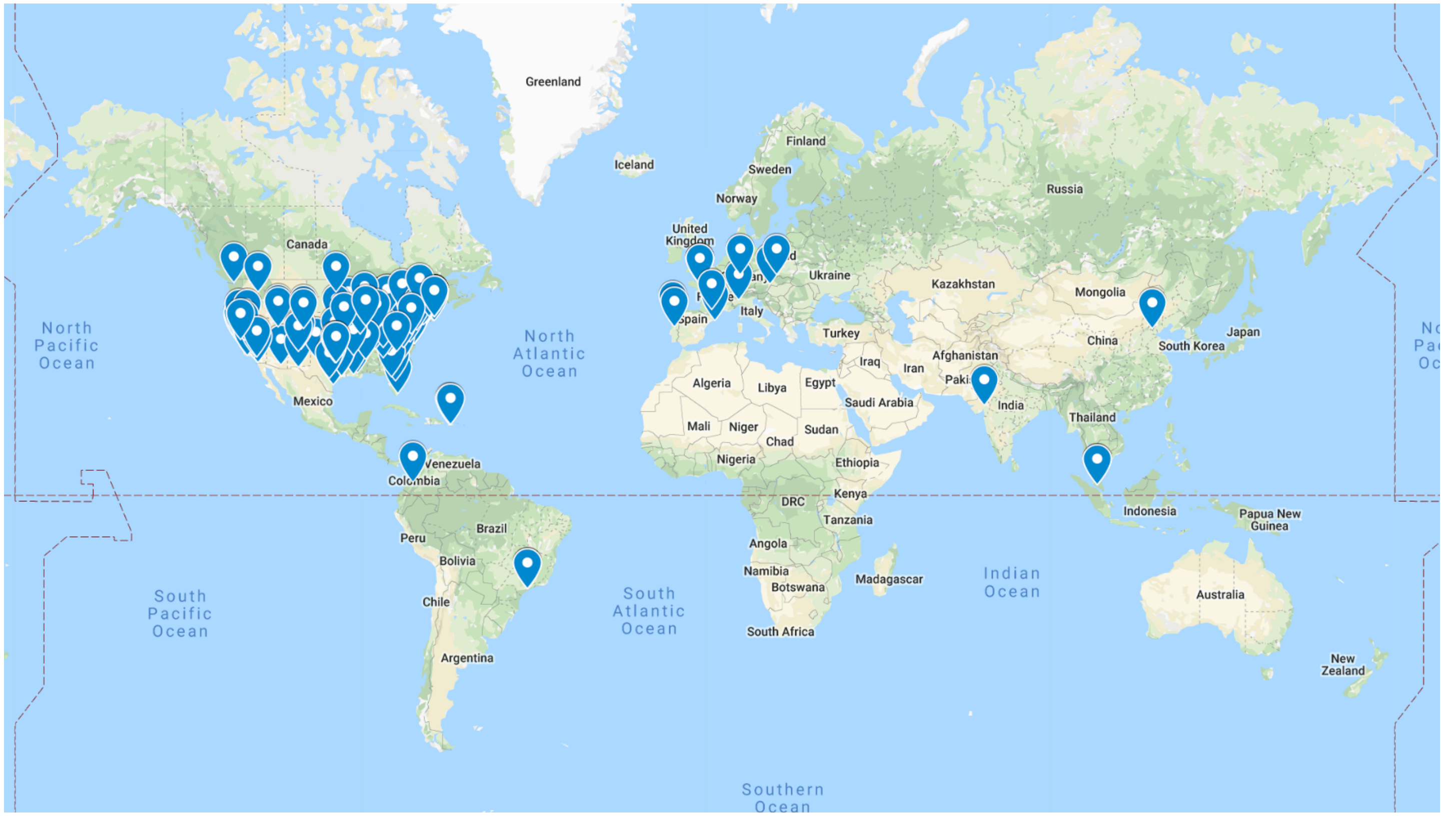
Figure 5: Performance for different power management systems under different power caps.

(Above) The performance delivered by each power management system across 5 power budgets for 11 coupled application pair.

(Right) Harper presents his research.



AN OPEN PLATFORM



BEYOND THE PLATFORM: BUILDING AN ECOSYSTEM

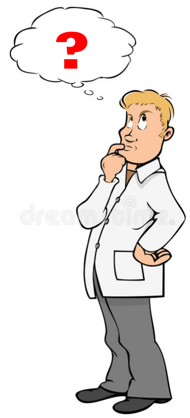
- Helping hardware providers interact
  - Bring Your Own Hardware (BYOH)
  - CHI-in-a-Box: deploy your own Chameleon site
- Helping our user interact – with us but primarily with each other
  - Creating compatible digital artifacts: tools, appliances, orchestration templates, notebooks, etc.
  - Publishing, sharing, and discovering artifacts: appliance catalog, blog as a publishing platform, etc.
  - Testbed as a “player” for common artifacts

CHI-IN-A-BOX

- CHI-in-a-box: packaging a commodity-based testbed
  - First released in summer 2018, continuously improving
- CHI-in-a-box scenarios
  - Independent testbed: package assumes independent account/project management, portal, and support
  - Chameleon extension: join the Chameleon testbed (currently serving only selected users), and includes both user and operations support Part-time extension: define and implement contribution models
  - Part-time Chameleon extension: like Chameleon extension but with the option to take the testbed offline for certain time periods (support is limited)
- Adoption
  - New Chameleon Associate Site at Northwestern since fall 2018 – new networking!
  - Two organizations working on independent testbed configuration

REPRODUCIBILITY DILEMMA

Should I invest in making my experiments repeatable?



Should I invest in more new research instead?

- Reproducibility by default -- interactive stories/papers -- tools to represent experiments in terms of sharable/publishable digital artifacts
- Reproducibility as side-effect: lowering the cost of repeatable research
  - A Linux "history" analogue

REPEATABILITY MECHANISMS IN CHAMELEON

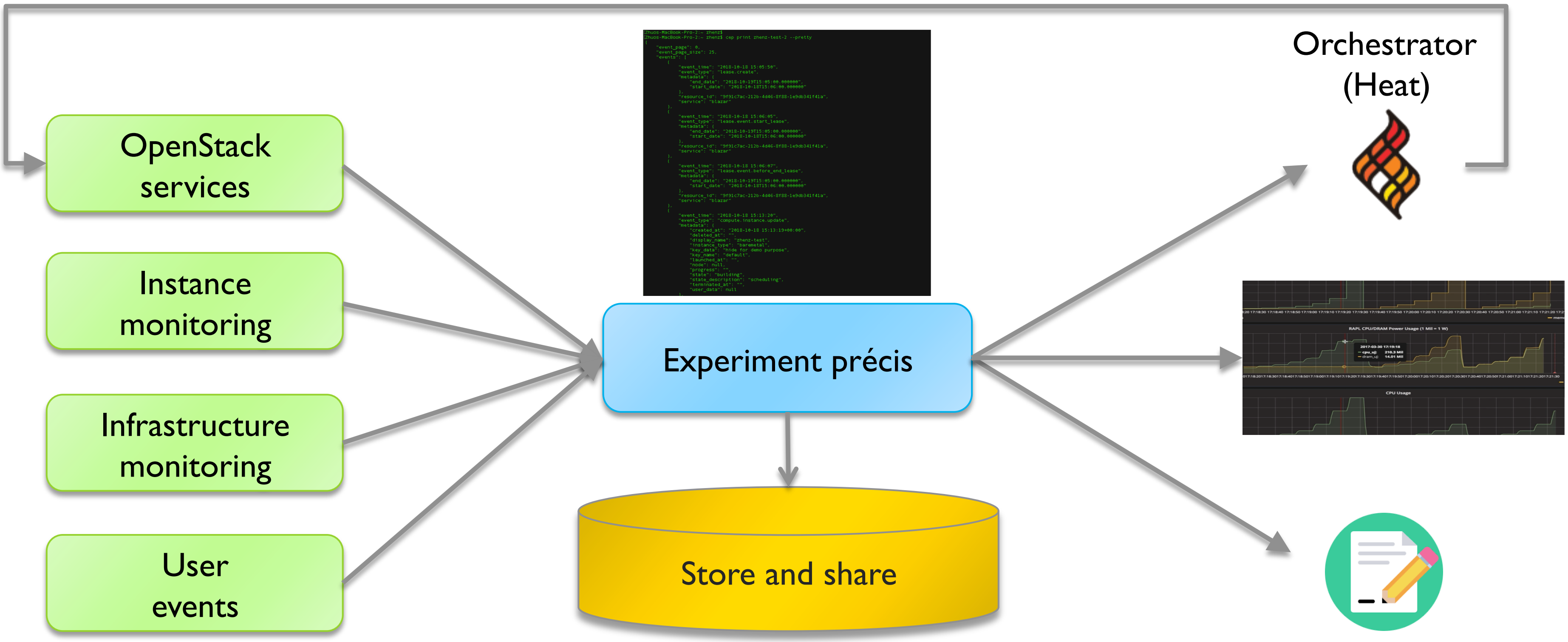
- Testbed versioning (collaboration with Grid'5000)
  - Based on representations and tools developed by G5K
  - >50 versions since public availability – and counting
  - Still working on: better firmware version management
- Appliance management
  - Configuration, versioning, publication
  - Appliance meta-data via the appliance catalog
  - Orchestration via OpenStack Heat
- Monitoring and logging
- However… the user still has to keep track of this information

KEEPING TRACK OF EXPERIMENTS

- Everything in a testbed is a recorded event… or could be
- The resources you used
- The appliance/image you deployed
- The monitoring information your experiment generated
- Plus any information you choose to share with us: e.g., “start power_exp_23” and “stop power_exp_23

- Experiment précis: information about your experiment made available in a “consumable” form

REPEATABILITY: EXPERIMENT PRÉCIS

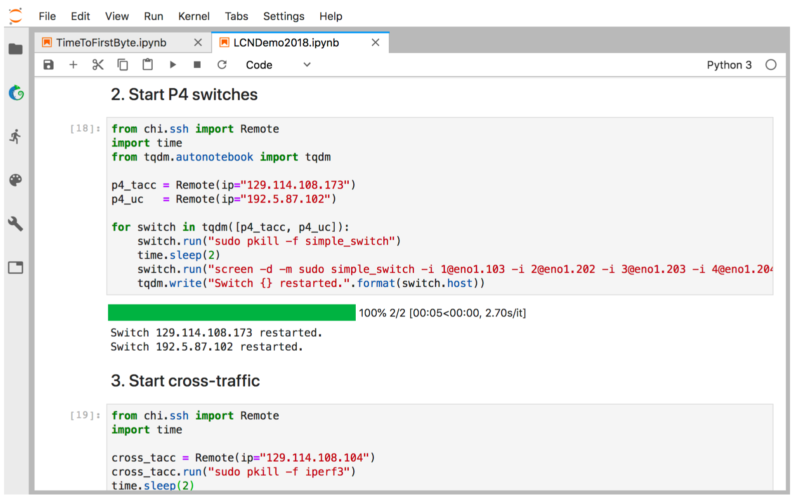


INTERACTIVE PAPERS

- What does it mean to document a process?
- Some requirements
  - Easy to work with: human readable/modifiable format
  - One process to rule them all: integrates well with ALL aspects of experiment management
  - Bit by bit – allows for modification and introspection as well – reflects the meandering scientific process
  - Support story telling: allows you to explain your experiment design and methodology choices
  - Has a direct relationship to the actual paper that gets written
  - Can be version controlled
  - Sustainable, a popular open source choice
- Implementation options
  - Orchestrators -- OpenStack Heat and Flame – a declarative approach
  - Notebooks -- Jupyter, NextJournal, and others – an imperative and integrative approach

CHAMELEON JUPYTER INTEGRATION

- Combining the ease of notebooks and the power of a shared platform
  - Storytelling with Jupyter: ideas/text, process/code, results
  - Chameleon: sophisticated experimental containers in need of “storytelling”
- JupyterLab server for our users
  - Go to jupyter.chameleoncloud.org and use with your Chameleon credentials
- Chameleon/Jupyter integration
  - Python/bash interfaces to the testbed, storing and sharing, Chameleon credentials
  - Named containers
- Templates of existing experiments



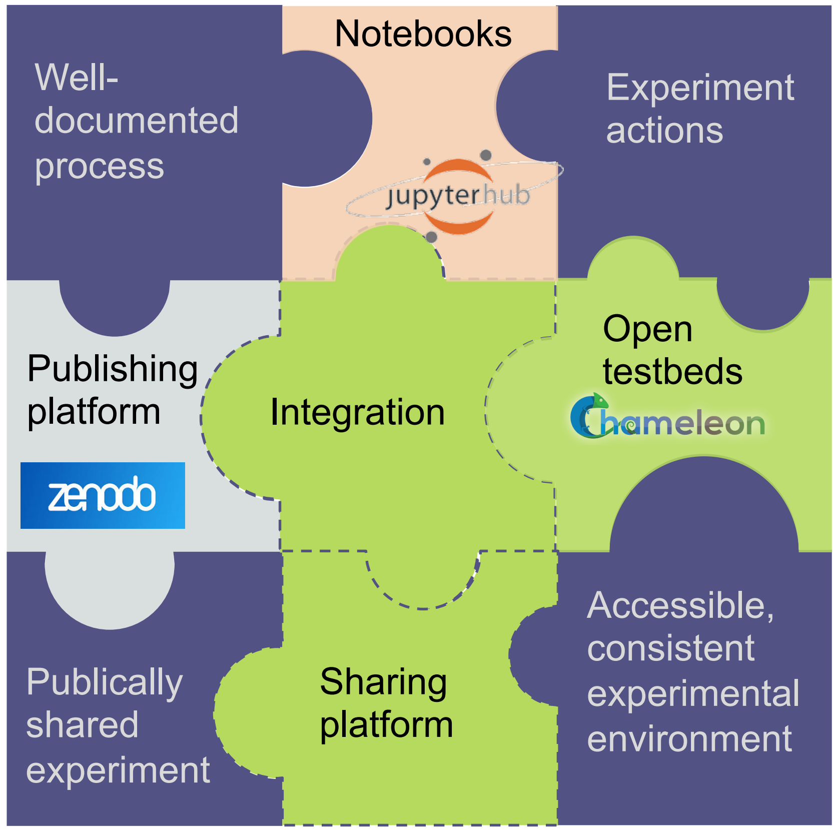
Screencast of a complex experiment: https://vimeo.com/297210055

“A Case for Integrating Experimental Containers with Notebooks”, CloudCom 2019

SHARING, PUBLISHING, LEVERAGING

- We now have everything we need to share experiments
  - Ways to establish an experimental environment + player
  - Ways to document an experimental process
- But wait… how do I actually share them?
  - Send mail, Chameleon object store, github…
  - Publishing via Zenodo: store your experiments and make them citable via DOIs
- Creating bridges, integration
  - Import/Export from/to Zenodo
- Making research findable: the sharing platform

SC19 Poster: Sharing and Replicability of Notebook-Based Research on Open Testbeds


Well-documented process
Notebooks
jupyterhub
Experiment actions
Publishing platform
zenodo
Integration
Open testbeds
Chameleon
Publically shared experiment
Sharing platform
Accessible, consistent experimental environment

PARTING THOUGHTS

- Chameleon is a rapidly evolving experimental platform
  - A Cloud++ with extra capabilities to support Computer Science research – and beyond
  - Originally: “Adapts to the needs of your experiment”
  - Now also: “Adapts to the needs of its community and the changing research needs”
- Towards an Ecosystem: a meeting place of users and providers sharing resources and research
  - Testbeds are more than just experimental platforms
  - Common/shared platform is a “common denominator” that can eliminate much complexity that goes into systematic experimentation, sharing, and reproducibility…
  - …as well as education!
- Be a part of the change: come to run experiments, stay to tell us about new requirements, join us to build new infrastructure capabilities