CHAMELEON: AN INNOVATION PLATFORM FOR COMPUTER SCIENCE RESEARCH AND EDUCATION

Kate Keahey
Mathematics and CS Division, Argonne National Laboratory
CASE, University of Chicago
keahey@anl.gov

February 3rd, 2021
MAGIC meeting
CHAMELEON IN A NUTSHELL

- 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 – and more to come!

- We like to change: a testbed that adapts itself to your experimental needs
  - Deep reconfigurability (bare metal) and isolation
  - power on/off, reboot, custom kernel, serial console access, etc.

- Cloud++: leveraging mainstream cloud technologies
  - 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, recently renewed till 10/2024!
  - Currently 5,000+ users, 600+ projects, 100+ institutions, 300+ publications
“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 uplinks to Chameleon core network
- CascadeLake Standard Cloud Units (32 node rack), 100Gb uplinks 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, 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 SOON TO A TESTBED NEAR YOU...

- New servers for old: upgrading Haswell to CascadeLake at TACC and UC
- More accelerators: V100s, AMD + AMD GPU, Xilinx
- Storage hierarchy options: Optane, a mix of enterprise NVMes and SSDs
- Composable hardware: IB rack with GPU/storage nodes (UC), LiQid (TACC)
- Networking: replicating FABRIC Hank design, P4 switches
- IoT devices & CHI@Edge
- Also a strategic reserve – we want to hear from you!
EXPERIMENTAL WORKFLOW

**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
- Jupyter integration
- Networks: stitching and BYOC

**monitor**
- Hardware metrics
- Fine-grained data
- Aggregate
- Archive
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”
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
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”
Towards a world where experiments are as sharable as papers today

- Instruments held in common: sharing hardware
- 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*
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)
  - Named containers: your experimental process goes here

Paper: “A Case for Integrating Experimental Containers with Notebooks”, CloudCom 2019
TROVI: SHARING EXPERIMENTS

- Testbed is a “player” for existing experiments/research
- Trovi: find existing experiments
  - Library including quickstarts (Python, OpenFlow, power management), and packaged of experiments from foundational papers
- Trovi: share experiments
  - Package your experiment, create a bundle, edit sharing settings, add keywords
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

Towards making research findable: the digital sharing platform
PHASE 3 ADVERTISEMENT

- Already here: access via federated accounts!
- New hardware: traditional servers, new GPUs and FPGAs, storage upgrades (FLASH arrays), composable hardware (LiQid), networking (P4, integration with FABRIC), IoT devices -- and strategic reserve
- New capabilities: federation, Bring Your Own Device (BYOD) & CHI@Edge, networking (allocatable switches with P4), core capability improvements
- Infrastructure: CHI-in-a-Box, integration with production infrastructures
- Research sharing: better methods of experiment packaging, publishing, and discovery, digital experiment libraries, engagement
Science does not stand still: laying the pavement as you walk on it!

Chameleon is a shareable research instrument – but it is also a sharing platform

The easy button: sharing experiments as naturally as we share papers
  ▶ Clouds help us package experimental environments as a side-effect of using them and serve as “player” for such experiment
  ▶ Literate programming is a convenient vehicle for “closing the gap”: packaging the whole experiment
  ▶ Critical mass of research content: check out what you can use!

Come, help us change: chameleoncloud.org
We’re here to change – come and change with us!

www.chameleoncloud.org
"Any opinions, findings, conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the Networking and Information Technology Research and Development Program."

The Networking and Information Technology Research and Development (NITRD) Program

Mailing Address: NCO/NITRD, 2415 Eisenhower Avenue, Alexandria, VA 22314

Physical Address: 490 L'Enfant Plaza SW, Suite 8001, Washington, DC 20024, USA Tel: 202-459-9674, Fax: 202-459-9673, Email: nco@nitrd.gov, Website: https://www.nitrd.gov