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CHAMELEON: BUILDING AN EXPERIMENTAL INSTRUMENT FOR COMPUTER SCIENCE AS APPLICATION OF CLOUD COMPUTING

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WHY EXPERIMENT?

"Beware of bugs in the above code;
I have only proved it correct, not tried it"

(Donald Knuth)

"In theory there is no difference between theory and practice. In practice there is."

(Yogi Berra)

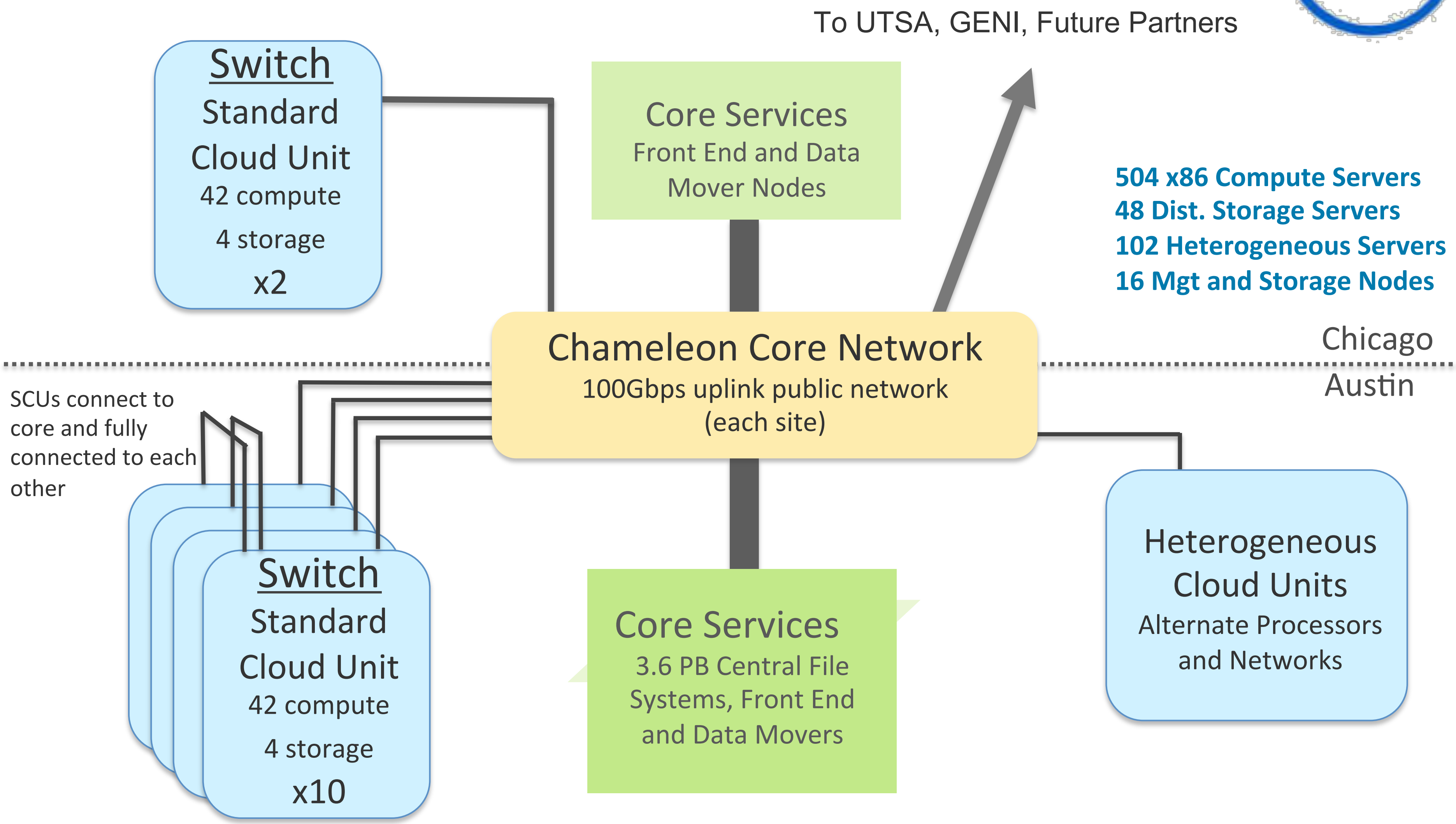
EXPERIMENTS AND MODELS

- Models
  - Essential to understand the problem
  - Are they: Correct?, Too complex? Not complex enough?
  - Need to be discovered by gaining experience about a problem, environment, or solutions
- Experimentation
  - Isolation: why a cloud is not sufficient for cloud research
  - Repeatability: repeat the same experiment multiple times in the same context while varying different factors
  - Reproducibility: the ability to repeat an experiment by a different agency
- Requirements for deep reconfigurability and control

DESIGN STRATEGY FOR A SCIENTIFIC INSTRUMENT

- Large-scale: "Big Data, Big Compute research"
  - ~650 nodes (~14,500 cores), 5 PB of storage distributed over 2 sites connected with 100G network
- Reconfigurable: "As close as possible to having it in your lab"
  - Deep reconfigurability (bare metal) and isolation
  - Fundamental to support reproducible experiments
- Connected: "One stop shopping for experimental needs"
  - Workload and Trace Archive: partnerships with production clouds: CERN, OSDC, Rackspace, Google, and others
  - Sharing appliances: partnerships with users
- Complementary: "Can't do everything ourselves"
  - Complementing GENI, Grid'5000, and other experimental testbeds
- Sustainable: "Easy to maintain, easy to share"

CHAMELEON HARDWARE



CHAMELEON HARDWARE (MORE DETAIL)

- "Start with large-scale homogenous partition" (deployed)
  - 12 Standard Cloud Units (48 node racks)
  - Each rack has 42 Dell R630 compute servers, each with dual-socket Intel Haswell processors (24 cores) and 128GB of RAM
  - Each rack also has 4 Dell FX2 storage server (also Intel Haswells), each with a connected JBOD of 16 2TB drives (total of 128 TB per SCU)
  - 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)
  - 48 port Force10 s6000 OpenFlow-enabled switches 10Gb to hosts, 40Gb uplinks to Chameleon core network
- Shared infrastructure (deployed)
  - 3.6 PB global storage, 100Gb Internet connection between sites
- "Graft on heterogeneous features" (still evolving)
  - Infiniband network in one rack with SR-IOV support (deployed)
  - High-memory, NVMA, SSDs, and GPUs on selected nodes (deployed)
  - FPGAs, ARM microservers and Atom microservers (coming soon)

CAPABILITIES AND SUPPORTED RESEARCH

Development of new models, algorithms, platforms, auto-scaling HA, etc., innovative application and educational uses

Persistent, reliable, shared clouds: modest OpenStack KVM cloud

Repeatable experiments in new models, algorithms, platforms, auto-scaling, high-availability, cloud federation, etc.

Isolated partition, Chameleon Appliances: CHI + Chameleon appliances

Virtualization technology (e.g., SR-IOV, accelerators), systems, networking, infrastructure-level resource management, etc.

Isolated partition, full bare metal reconfiguration: CHI

EXPERIMENTAL WORKFLOW REQUIREMENTS

discover resources	provision resources	configure and interact	monitor
- Fine-grained - Complete - Up-to-date - Versioned - Verifiable	- Advance reservations & on-demand - Isolation - Fine-grained allocations	- Deeply reconfigurable - Appliance catalog - Snapshotting - Super Appliances: “one-click virtual clusters”	- Hardware metrics - Fine-grained information - Aggregate and archive

BUILDING A TESTBED FROM SCRATCH

- Requirements (proposal stage)
- Architecture (project start)
- Technology Evaluation and Risk Analysis
  - Many options: G5K, Nimbus, LosF, OpenStack
  - Sustainability as design criterion: can a CS testbed be built from commodity components?
  - Technology evaluation: Grid'5000 and OpenStack
  - Architecture-based analysis and implementation proposals
- Implementation (~3 months)
- Result: Chameleon Infrastructure (CHI) =
  - 65%*OpenStack + 10%*G5K + 25%*"special sauce"
- Integration environments versus production

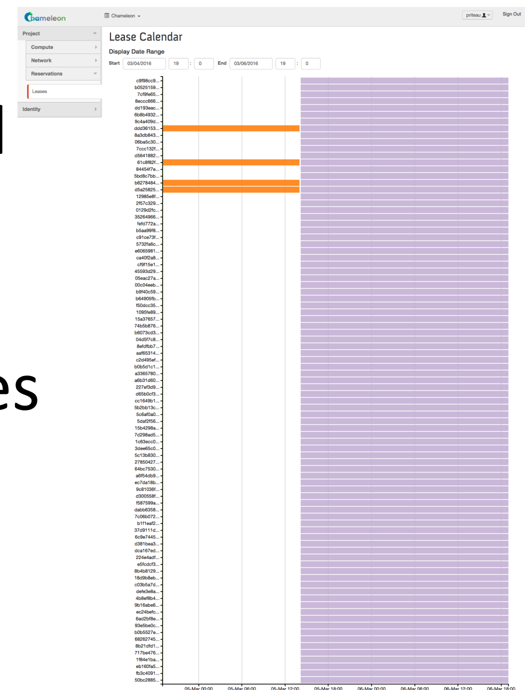
CHI: DISCOVERING AND VERIFYING RESOURCES

- Fine-grained, up-to-date, and complete representation
- Both machine parsable and user friendly representations
- Testbed versioning
  - "What was the drive on the nodes I used 6 months ago?"
- Dynamically verifiable
  - Does reality correspond to description? (e.g., failure handling)

- Grid'5000 registry toolkit + Chameleon portal
  - Automated resource description, automated export to RM/Blazar
- G5K-checks
  - Can be run after boot, acquires information and compares it with resource catalog description

CHI: PROVISIONING RESOURCES

- Resource leases
- Advance reservations (AR) and on-demand
  - AR facilitates allocating at large scale
- Isolation between experiments
- Fine-grain allocation of a range of resources
  - Different node types, etc.
- Future extensions: match making, testbed allocation management



- OpenStack Nova/Blazar, AR: extensions to Blazar
- Extensions to support Gantt chart displays and several smaller features

CHI: CONFIGURE AND INTERACT

- Deep reconfigurability: custom kernels, console access, etc.
- Snapshotting for image sharing
- Map multiple appliances to a lease
- Appliance Catalog
- Handle complex appliances
  - Virtual clusters, cloud installations, etc.
- Interact: shape experimental conditions

- OpenStack Ironic, Glance, and meta-data servers
- Added snapshotting and appliance management

CHI: INSTRUMENTATION AND MONITORING

- Enables users to understand what happens during the experiment
- Instrumentation: high-resolution metrics
- Types of monitoring:
  - Infrastructure monitoring (e.g., PDUs)
  - User resource monitoring
  - Custom user metrics
- Aggregation and Archival
- Easily export data for specific experiments

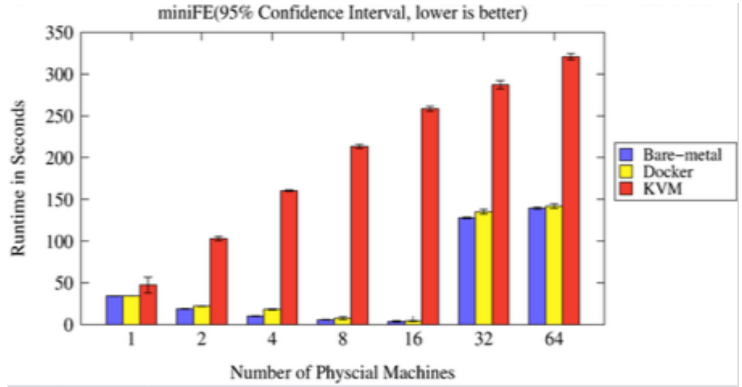
- OpenStack Ceilometer + custom metrics

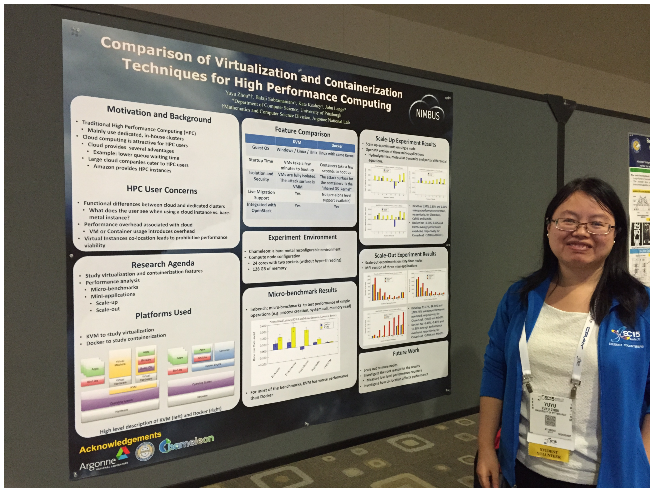
CHAMELEON CORE: TIMELINE AND STATUS

- **10/14: Project starts**
- 12/14: FutureGrid@Chameleon (OpenStack KVM cloud)
- 04/15: Chameleon Technology Preview on FG hardware
- 06/15: Chameleon Early User on new hardware
- **07/15: Chameleon public availability (bare metal)**
- 09/15: Chameleon KVM OpenStack cloud available
- 10/15: Identity federation with GENI
- **Today: 1,000+ users/200+ projects**
- 2016: Heterogeneous hardware releases

VIRTUALIZATION OR CONTAINERIZATION?

- Yuyu Zhou, University of Pittsburgh
- Research: lightweight virtualization
- Testbed requirements:
  - Bare metal reconfiguration
  - Boot from custom kernel
  - Console access
  - Up-to-date hardware
  - Large scale experiments

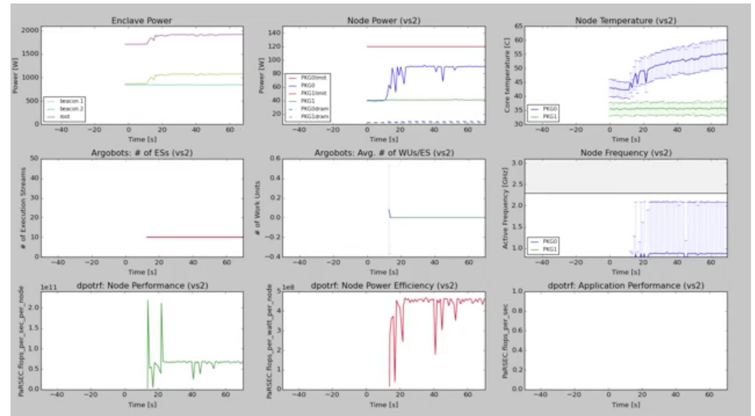




SC15 Poster: "Comparison of Virtualization and Containerization Techniques for HPC"

EXASCALE OPERATING SYSTEMS

- Swann Perarnau, ANL
- Research: exascale operating systems
- Testbed requirements:
  - Bare metal reconfiguration
  - Boot kernel with varying kernel parameters
  - Fast reconfiguration, many different images, kernels, params
  - Hardware: performance counters, many cores



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
  - Access to the same infrastructure for multiple collaborators

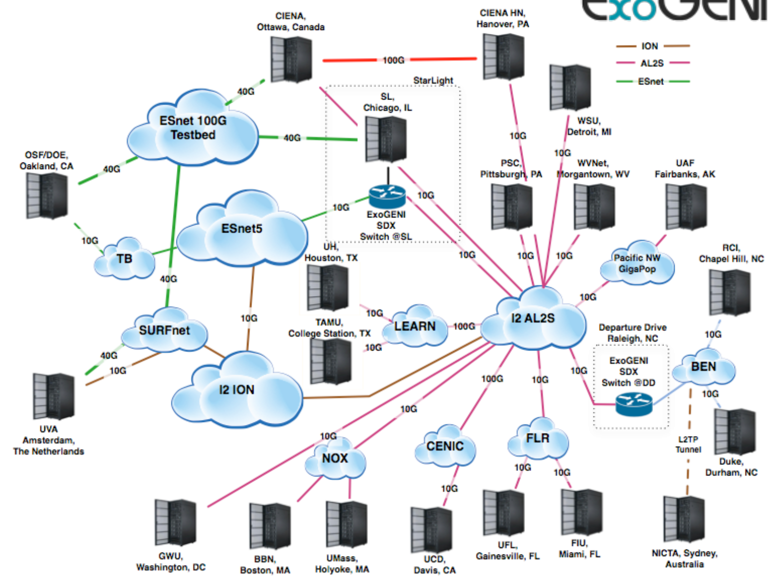
FEDERATING NETWORKS

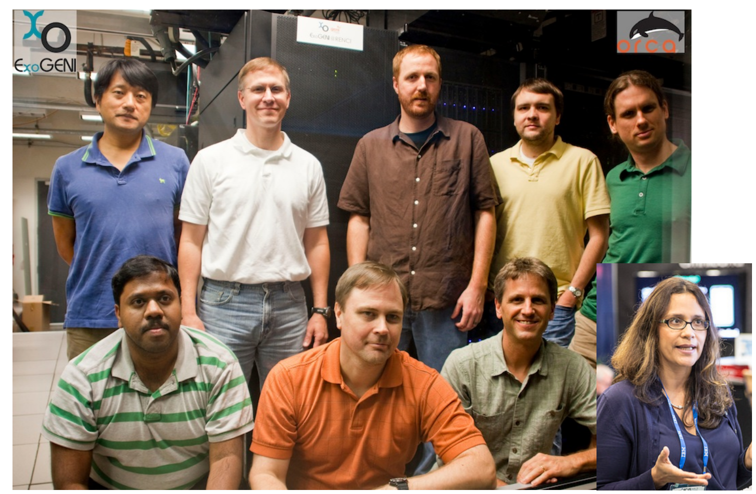
- Paul Ruth, RENCI-UNC Chapel Hill
- Research: Federated Networked Clouds for Domain Science
- Testbed requirements:
  - Deploy ExoGENI on Chamelelon
  - “Stitch” Layer-2 networks between Chameleon and external systems
  - HPC (e.g. Infiniband, SR-IOV, MPI, many cores, performance isolation)

http://www.exogeni.net

geni Exploring Networks of the Future

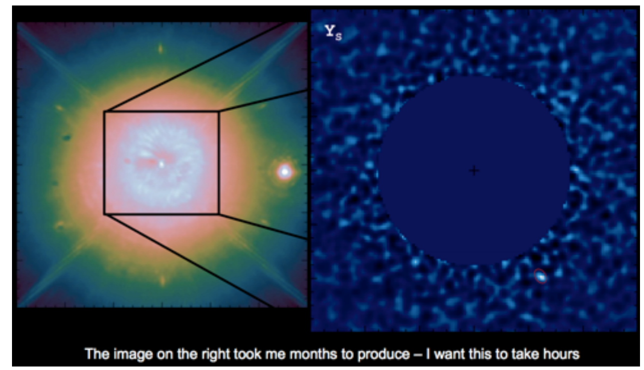
ExoGENI





TEACHING CLOUD COMPUTING

- Nirav Merchant and Eric Lyons, University of Arizona
- ACIC2015: project-based learning course
  - Data mining to find exoplanets
  - Scaled analysis pipeline by Jared Males
  - Develop a VM/workflow management appliance and best practice that can be shared with broader community
- Testbed requirements:
  - Easy to use IaaS/KVM installation
  - Minimal startup time
  - Support distributed workers
  - Block store: make copies of many 100GB datasets



FROM POSSIBLE TO EASY…

Y1: Make things possible

- Develop CHI
- Deploy new hardware

Y2: From possible to easy

Valentine's Day goodies:

- Custom kernel/console
- Liberty upgrade
- Appliance marketplace and appliances

Y2: From possible to easy

Independence Day goodies:

- Heterogeneous hardware
- Object store
- Appliance tools and appliances

… AND ON

PARTING THOUGHTS

- Scientific instrument for CS experimental research
- Open testbed: work on your next research project @

www.chameleoncloud.org

The most important element of any experimental testbed is users and the research they work on

- From vision to reality with Express Delivery
  - Built from scratch in less than a year on a shoestring
  - Operational testbed: 1,000+ users/200+ projects
- Blueprint for a new, sustainable operations model: building a CS testbed as an application of cloud computing: benefits for us, for the broader community, and for other testbeds

CHAMELEON TEAM

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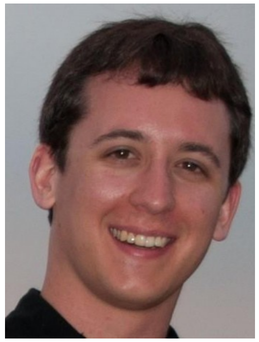

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