iLab:

A Scalable Architecture for Sharing Online Experiments

An MIT iCampus Project

MIT

V. Judson Harward, Jesús A. del Alamo, Steven R. Lerman, et al.
MIT

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Statement of the Problem

- There is enormous educational value in hands-on laboratory experiences, but…
- … conventional laboratories are expensive and have complex logistics:
  - Scheduling, equipment cost, lab space, lab staffing, training, safety
- … conventional labs don't scale well and can't easily be shared
  - All institutions must own all labs

Solution: Online Laboratories

- *Online laboratory ("iLab" or "WebLab"):* a real laboratory that is accessed through the Internet from anywhere at any time
  - Not a "virtual laboratory" (simulations)
  - Not a "canned experiment" (a "one-click" lab)
- Online laboratories can deliver many of the educational benefits of hands-on experimentation

iLabs at MIT

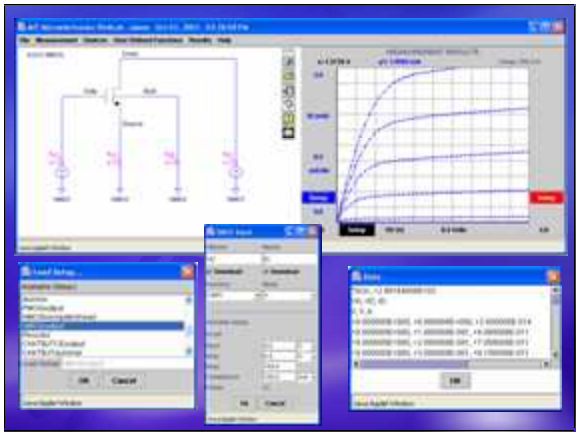
Dynamic signal analyzer *(EECS, to be deployed 2004)*

Polymer crystallization *(Chem. E., deployed 2003)*

Shake table *(Civil Eng., to be deployed 2004)*

Microelectronics device characterization *(EECS, deployed 1998)*

Heat exchanger *(Chem. E., deployed 2001)*



Educational Experiments

- MIT graduate and undergraduate courses since Fall 1998
- NUS (Singapore, 11 time zones), Fall 2000-03 (20-30 st/yr)
- Chalmers U. (Sweden, 6 time zones), Spring 2003-04 (250 st/yr)
- NTU Athens (Greece, 8 time zones), Spring 2004 (35 st/yr)
- Over 2000 student users (for credit) since 1998

Revolutionary consequences

- Order-of-magnitude more laboratory experiences available to students
- Can afford sophisticated labs involving:
  - advanced instrumentation
  - rare materials
  - unreachable locations
- iLabs embedded inside rich educational platforms containing:
  - visualization tools, simulations, data processing
  - remote collaboration and tutoring.

Revolutionary consequences

- iLabs will spawn communities of learners to share:
  - hardware
  - *and* educational content
- Institutions in the *developed* world can support educational needs of the *developing* world.

What Have We Learned?

Ad-hoc iLab development and management does not scale

- *iLab developers* are not IT specialists and want to minimize development work (want to reuse generic lab components)
- *iLab managers* do not want to deal with individual user management
- *iLab consumers* want to see single portal to multiple labs

➢ Need an *iLab Shared Architecture*

Shared Architecture Design Goals

- Scaling usage of online labs to a large number of users
- Allowing universities to share access to equipment
- Single sign on to labs at multiple universities
- Freeing lab owner/operator from administration (i.e. authentication, authorization, storage of results, archiving of data, etc.) of users from other universities
- Allowing universities with diverse network infrastructures to interoperate and share resources

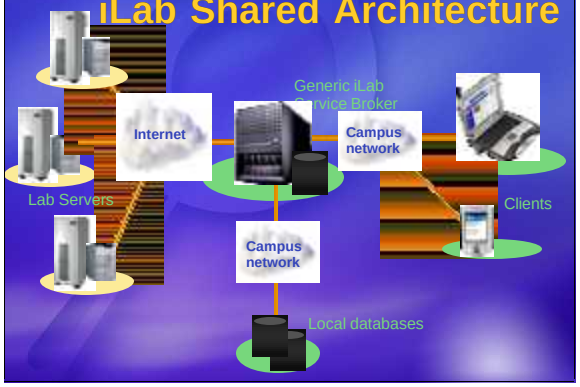
Project Boundaries

- Our architecture doesn't deal with specific hardware and software interfaces to lab equipment
- Our architecture is intended to be compatible and complementary with commercial software such as National Instruments LabView and analysis packages like Matlab

iLab Generic Services

- User authentication (and registration)
- User authorization and credential (group) management
- Experiment specification and result storage
- Lab access scheduling

iLab Shared Architecture



The Case for Web Services

- Web services represent the latest version of an old concept -- they allow one computer to invoke a procedure (method) on another.
- They are platform and vendor independent (we have already successfully bridged a Java client ⇔ a Windows XP/.NET Service Broker ⇔ a Windows 2000 lab server (with NI GPIB).
- Web services are self-describing and offer the promise of runtime discovery.
- Because they are usually based on http that we all use to access the web, they work well with campus networks.
- The iLab Shared Architecture builds on top of the current generation of web services.

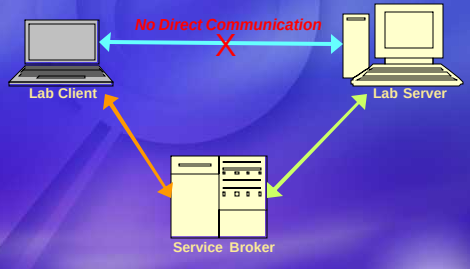
iLab Experiment Typology, 1

- Batched Experiments (2003-2004):
  - The entire specification of the experiment is determined before execution begins.
  - The user need not remain online while experiment executes.
- Interactive Experiments (2004-2005):
  - The student client portrays virtual lab equipment (GUI).
  - The student can interact with experiment throughout its course.

iLab Experiment Typology, 2

- Sensor Experiments (2005-2006):
  - Publish and subscribe based architecture
  - Triggers and event-driven data monitoring
  - Flexible data analysis
  - Data archive

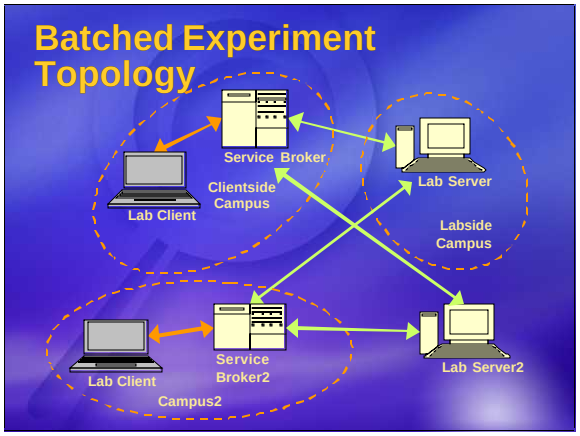
Batched Experiment Topology



What a Lab Provider Does Not Want To Do

- Register 100's of student accounts for other people's students.
- Store experiment results for students from other institutions and decide when they can be deleted or how to archive them.
- Decide who can view whose experiment results, especially when it involves setting policy for another university's courses.

Batched Experiment Topology



Service Broker Administrative Services

- Adding, modifying, and removing lab servers and clients.
- Adding, removing, or confirming user access.
- User management including assigning users to groups and modifying access rights.
- Managing experiment records.
- End of semester cleanup.

iLab Shared Architecture:

Beta-Test, Spring 2004

Lab: MIT Microelectronics WebLab, V. 6

Class: 6.012 Microelectronics Devices and Circuits (junior level in EECS)

Students: about 100

Assignments: 2

No major problems or down time

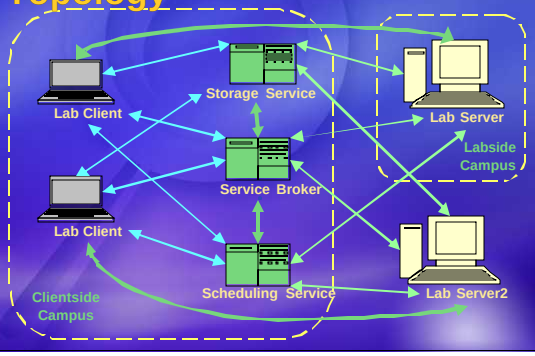
Preliminary Interactive Design

- We have been working on an extension of the Service Broker architecture for interactive experiments since February.
- Interactive experiments typically have duration; they must be scheduled rather than queued.
- Routing all client – lab server communication through the Service Broker is expensive and limits flexibility in client design.

New Services for Interactive Experiments

- A Scheduling Service
  - allows lab servers to let register blocks of time along with a signup policy;
  - allows client-side faculty to add further signup rules;
  - allows students to schedule lab sessions;
  - confirms student appointments on login;
- An Experiment Storage Service
  - allows any pre-registered iLab process (client or server) to store experiment records
- A Ticketing Service (ServiceBroker)
  - authorizes server/server and client/server communication.

Preliminary Interactive Topology



Future iLab Directions

- Our long term vision
- Plans for releasing iLab software and documentation in AY2005
- Collaborations with other universities
- Longer term iLab dissemination plans

Our Long Term Vision

- Creating a movement within higher education (and potentially other levels) leading to global sharing of laboratory experiments over the net
- Creating an informal "barter economy" to facilitate sharing of lab equipment
- Sharing beyond access to lab equipment to include pedagogical materials and teaching experiences
- "iLab-ready" experimental equipment and software
- Sharing of time on national and international experimental equipment such as space-based experiments
- Improving education through expansion of lab-based learning opportunities around the world

Making iLab software available

- iLab software and documentation will be made publicly available
- "for comment" postings followed by formal releases
- Release under an open source license
- Welcome comments and advice from anyone interested

Collaborations

- We are actively working with universities in Singapore, Sweden, Taiwan, Lebanon, Uganda, Nigeria, Tanzania, Italy, Colombia, Greece on sharing iLab experiments
- Seeking to create a larger community of lab developers and users
- Design of batched experiment APIs reflect needs of low-bandwidth environments

Longer Term Plans

- Fall 2004 – complete specification for interactive experiments
- Spring 2005 – implementation and testing of APIs for interactive experiments
- Early Fall 2005 – release of interactive experiment specifications and code for comment
- Jan-Feb 2006 – full release of interactive experiment code, documentation, "how to" manual and other materials
- 2006-2007 – repeat cycle for sensor-based experiments

Contact Information

- Jesus del Alamo (alamo@mit.edu)
- V. Judson Harward (jud@mit.edu)
- Steven Lerman (lerman@mit.edu)