Large-Scale Systems (2): Legion

- Legion vision:
  Metasystem consisting of **millions** of hosts, **billions** of objects, co-existing in a **loose confederation** tied together with high-speed links.
- Legion objectives
- Legion object model
- Legion home page:
  `http://www.cs.virginia.edu/~legion`
- *Reading:*
  –A.S.Grimshaw, Wm. A. Wulf. "Legion. The Next Logical Step Toward the World-Wide Virtual Computer"
  `(http://legion.virginia.edu/copy-cacm.html)`
  –M. Lewis, A. Grimshaw. "The Core Legion Object Model"
  `(http://www.cs.virginia.edu/~legion/copy-core.html)`

Legion Objectives (1)

- Site autonomy
  Organizations want to keep juristictional boundaries in place.
- Extensible core
  Allow users to construct their own mechanisms and policies.
- Scalable architecture
  No centralized structures
- Easy-to-use, seamless computational environment
  Legion must mask the complexity of the hardware environment and of communication and synchronization of parallel processing.
- High performance via parallelism
  e.g. task and data parallelism
- Single, persistent name space
  Single name space for file and data access.

Legion Objectives (2)

- Security for users and resource owners

  Cannot strengthen existing OS protection and security mechanisms. Existing mechanisms should not be weakened by Legion. Need mechanisms for users to manage security needs.
- Management and exploitation of resource heterogeneity

  Inter-operability between heterogeneous hardware and software components.
- Multiple language support and inter-operability

  Integrate heterogeneous source language applications, support for legacy codes.
- Fault-tolerance

  Dealing with failure and dynamic re-configuration

Constraints

... cannot replace host operating systems

Operate at middleware level.

... cannot legislate changes to the interconnection network

Can layer better protocols over existing ones.

... cannot require that Legion run as "root"

Most Legion users want it to run with the least possible privileges.

The Core Legion Object Model

- Each object belongs to class; each class is itself an object.
- **Object-mandatory** member functions:
  - `may_I(), save_state(), restore_state()`
- **Class-mandatory** member functions:
  - `create(), derive(), inherit_from()`
- User-level class objects responsible for managing instances and subclasses:
  - creation, location, security policies, object placement policies

Security

- Various users can have wide variety of security concerns.
- Provide users with mechanisms to build robust security measures.
- Message layer:
  - Inter-object communication and authentication
- Discretionary layer:
  - Access control predicate may_I(); must be called before invoking any method.
- Mandatory layer:
  - Legion objects can act as Security Agents; monitor other objects.

Naming and Binding

- **LOID**: Every Legion object is named by a Legion Object Identifier.

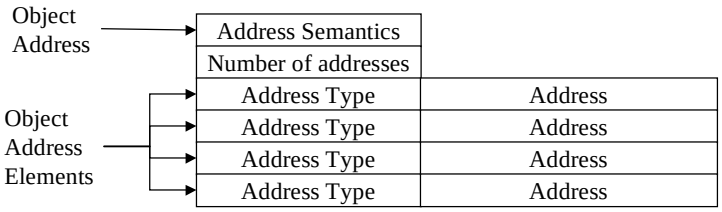
Format	Class Identifier	Instance Number	Public Key

- Format: defines size, format of other fields
- Class identifier: handled by LegionClass
- Instance number: handled by class object
- Public key: allows entire LOID to be used as public key for object.

- Binding: LOIDs have meaning only at Legion level. Need to be bound to names that have meaning at underlying protocol levels.

Binding

- Need physical **Object Address** to communicate with another object.



- Binding: (LOID, Object Address, invalidation time); first class entities.

- Binding Agents: derived from **`LegionBindingAgent`**.
  - **`binding get_binding(LOID); binding get_binding(binding)`**
  - **`invalidate_binding(LOID); invalidate_binding(binding)`**
  - **`add_binding(binding)`**

Object States

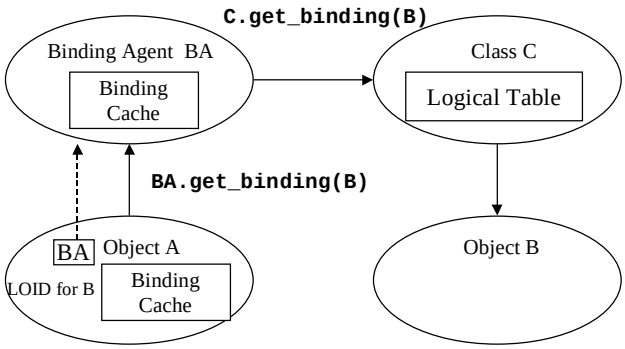
- **Active** objects are running as process on Legion Host and can be accessed via an Object Address.
- **Inert** objects exist in persistent storage
  - Controlled by **Legion Vault**
  - Described by Object Persistent Representation (OPR)
  - Located using Object Persistent Address (OPA)
- Object Persistent Representation:
  - Every object exports **`save_state()`** and **`restore_state()`** methods.
  - Objects can carry state when they migrate between hosts.
- Object Persistent Address:
  - Analogous to Object Address of active object.
  - Typically file name, meaningful to Legion Vault.

Class Objects

- Class objects export class-mandatory member functions to
  - create new instances: **`create()`**
  - create new subclasses: **`derive()`**
  - delete instances: **`delete()`**
  - find instances and subclasses: **`get_binding()`**
- Assigns LOID to instances and subclasses
  - For new instance:
    - assign Class Identifier to match own
    - assign Instance Number as it sees fit
  - For new subclass:
    - Contact **`LegionClass`** to obtain new Class Identifier
- Logically maintain table for objects:
  - LOID, Object Address, Placement Mapper, Current Vault Set, Candidate Vault Set.

Mechanisms: Binding

- Model:
  - Ultimatively, responsibility for providing bindings lays with class.
  - To support scalability, other objects may be involved as well.



  - How to find responsible class object?

Scalability

- **Scalable Architecture**:

  "As the number of processors increases, the granularity of computation does not need to increase to keep the machine balanced."
  - e.g. hypercubes, meshes, tori, rings.
  - Problem: Scalability of architecture must be claimed with respect to particular application

- **Distributed Systems Principle**:

  "The number of requests to any particular system component must not be an increasing function of the number of hosts or objects in the system."