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Object

Computing

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Rev. 1.0
FJP
Foil 1

Object Computing Benefits

- Productivity
  - Reusability
  - Maintainability
  - Extensibility
- Reliability

And

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Object Computing Benefits

- To Store Knowledge

But

- OS File Structures and Relational DBMS are Inadequate
- Purely Software-based Persistent Object Support
  - is inefficient, and
  - does not address multi-user access

And

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Object Computing Benefits

- To Construct Secure Systems

But

- Requires Run-time Enforcement
- Current Hardware Architectures do not Support Efficient Fine-Grained Protection

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Topics

- Object Addressing and Protection
- Computational Model
- Type Manager Based Protection
- Inheritance
- Object Persistence

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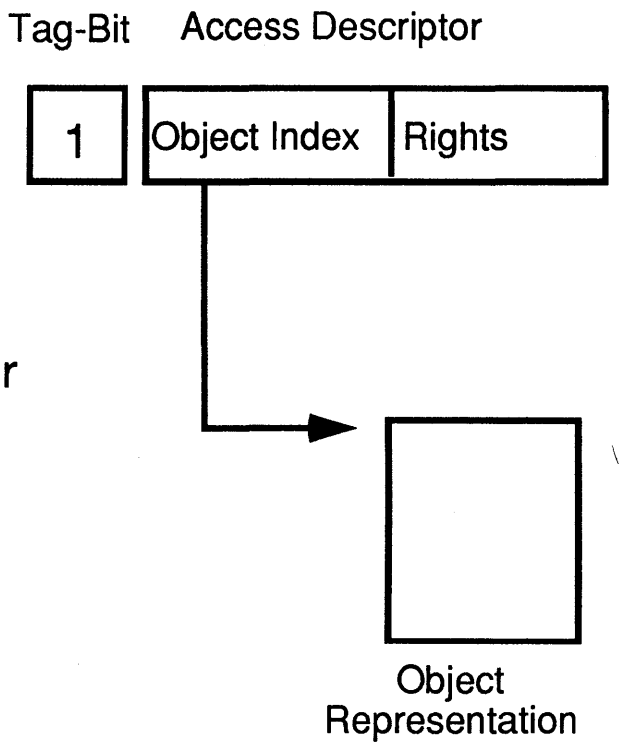
VLSI-Based
Object Addressing and Protection

- Object is a Typed Memory Segment
  - From 64 to 4 gigabytes
  - If >4K bytes, then paged
  - up to 64M objects in virtual address space
- Object Accessed through Access Descriptor
  - AD is unforgeable (33rd bit)
  - AD is used just like a pointer – Access type in Ada
- Rights Determine Allowed Operations



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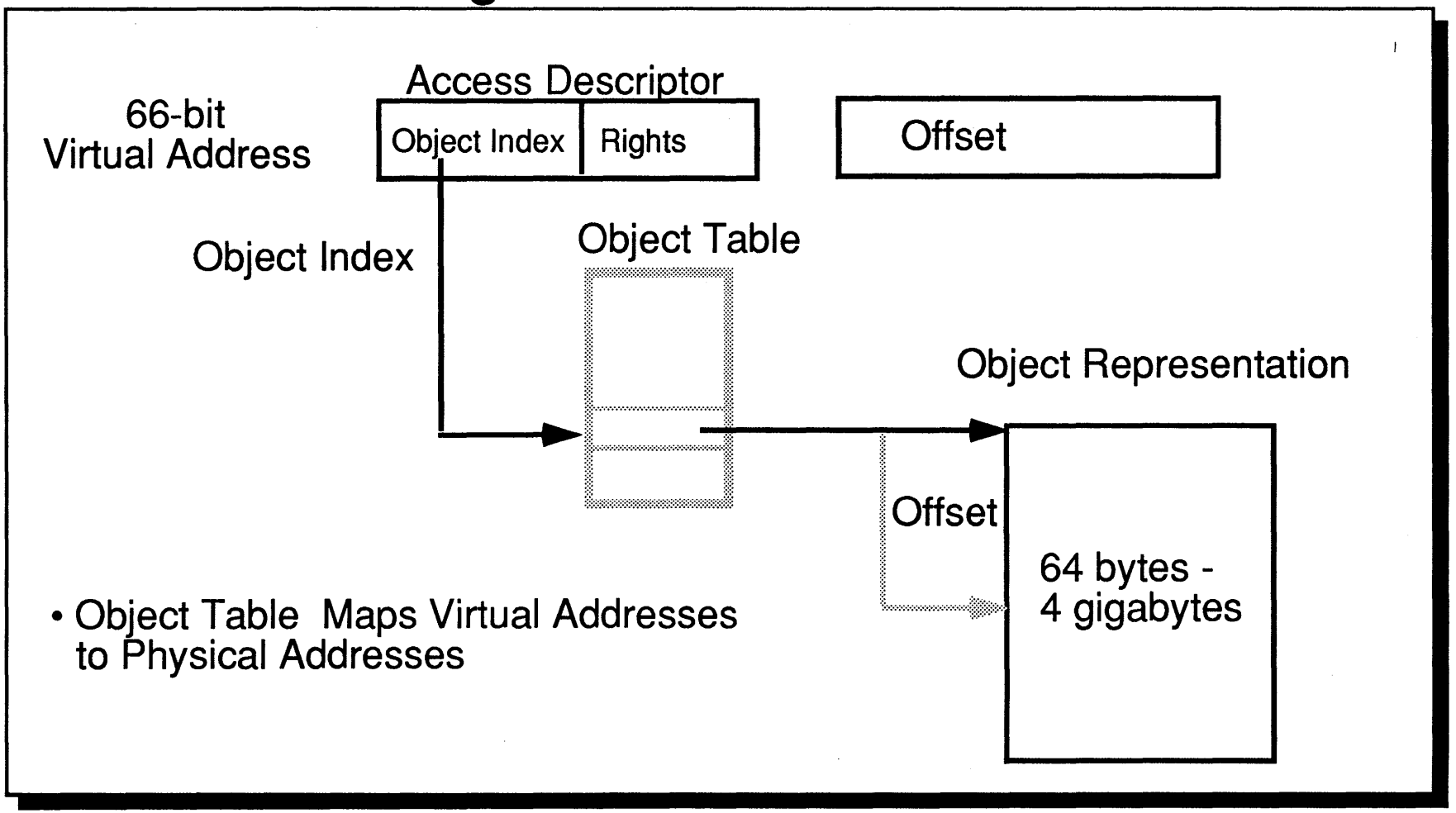
Virtual Addressing



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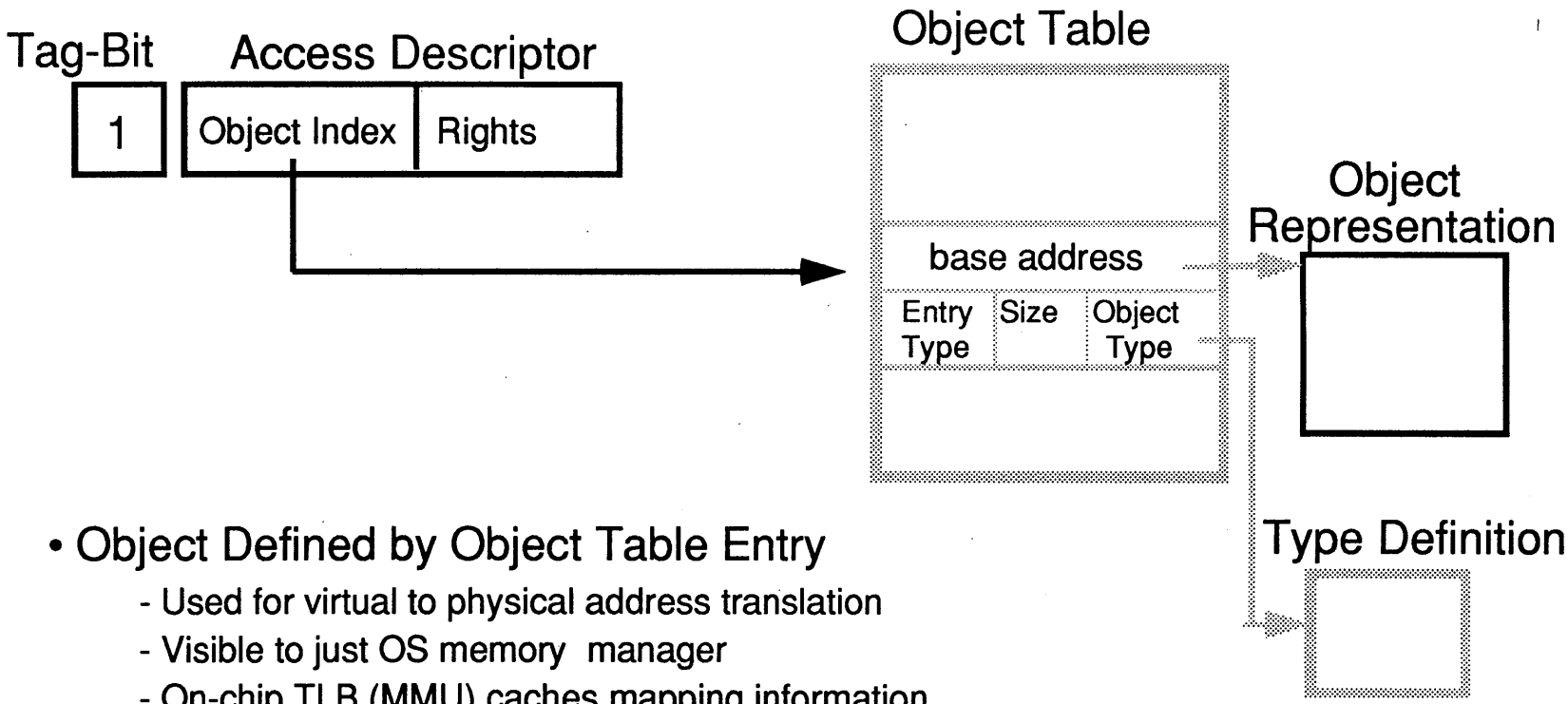
Object Structure



- Object Defined by Object Table Entry
  - Used for virtual to physical address translation
  - Visible to just OS memory manager
  - On-chip TLB (MMU) caches mapping information
- Translation is Independent of Execution Context
  - TLB not flushed on process switch

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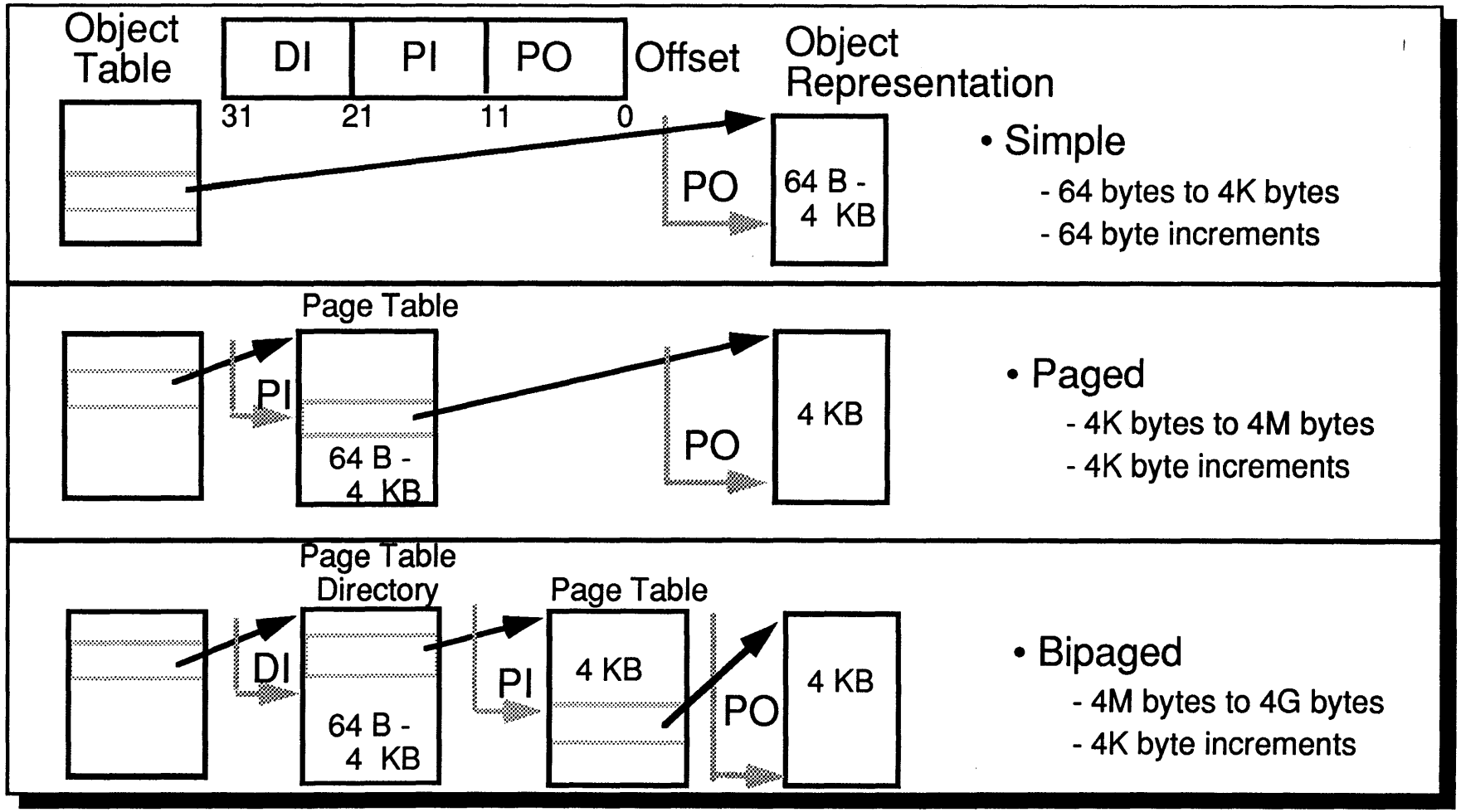
Address Translation



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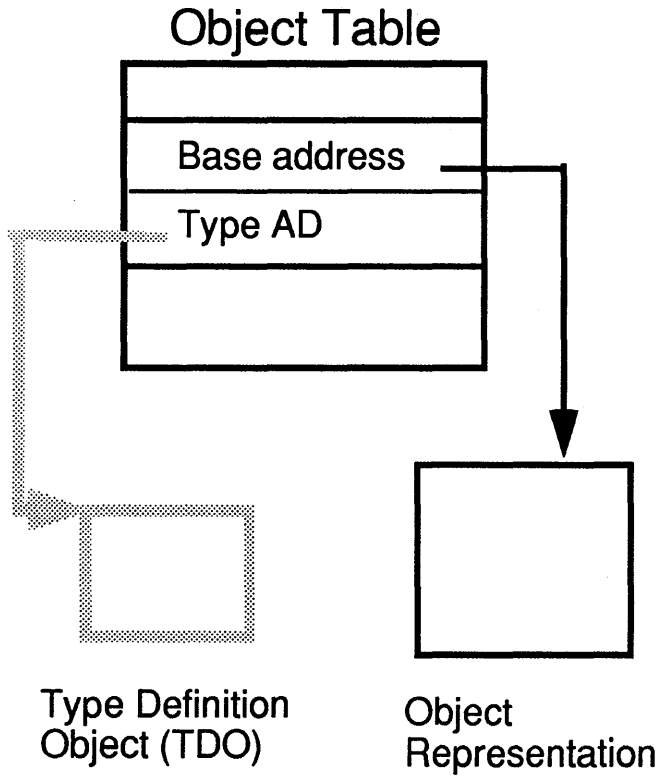
Object Typing

- Object Types are Defined by Type Definition Objects (TDO)
- Each Object Descriptor Contains an AD Pointing to the TDO of itsType
- H/W recognized types:
  - Semaphores
  - Ports
  - Processes
  - Domains
  - TDOs



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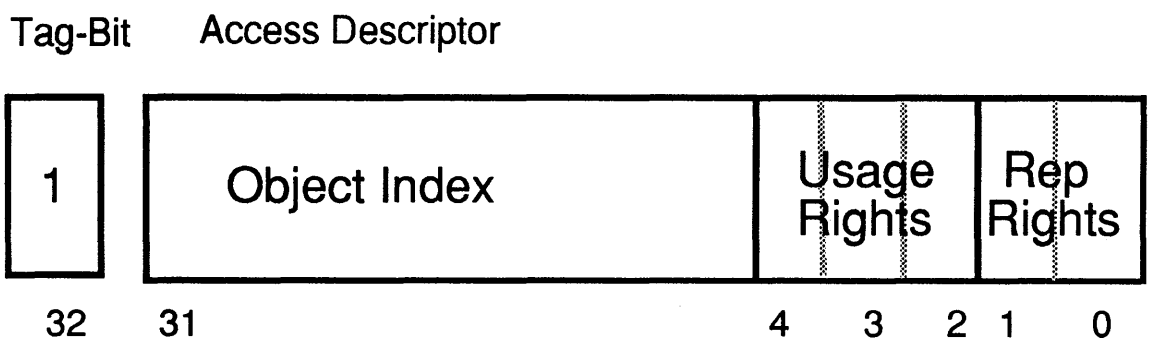
Representation Rights



- Representation Rights Control Direct Access to Object
  - Read rights checked on Load instructions
  - Write rights checked on Store Instructions
- Rights Checking Occurs in Parallel with Address Translation

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Topics

- Object Addressing and Protection
- **Computational Model**
- Type Manager Based Protection
- Inheritance
- Object Persistence

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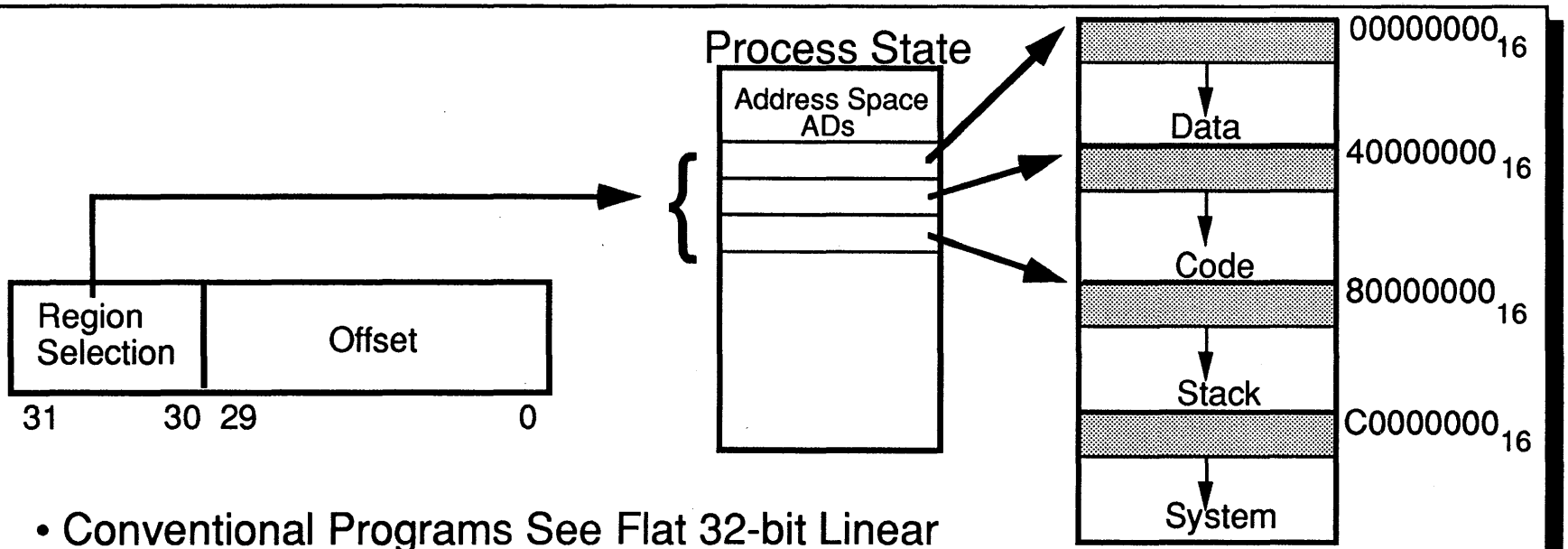
Simple Program Model



- Conventional Programs See Flat 32-bit Linear Address Space
- Each of 3 Regions is an Object
- Regular Call-Return Used for Procedure Calls
- Reserved Region is Processor-specific

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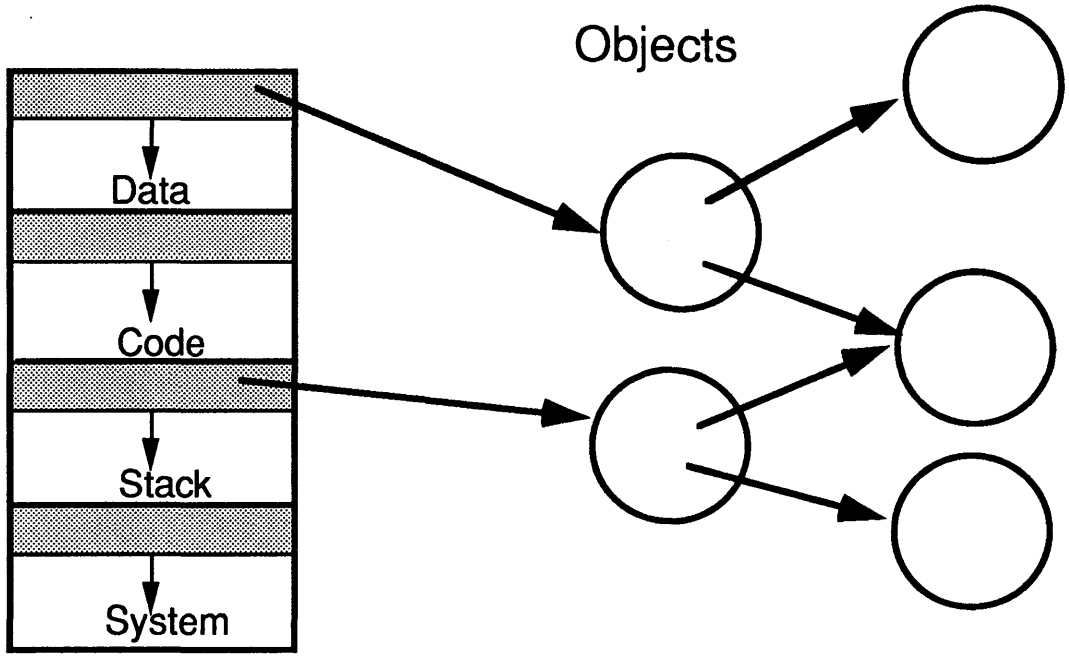
Extended Program Model



- Linear Address Space Can be Root of an Object Network
  - Interconnected by ADs
  - ADs used just like pointers

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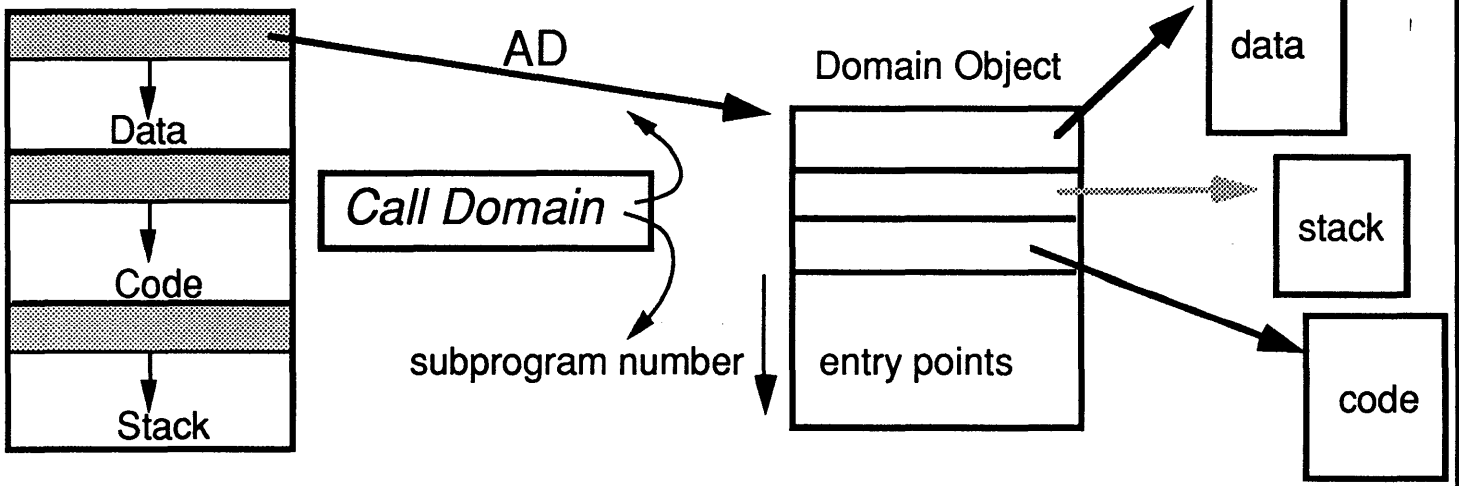
Multiple Address Spaces Per Process



- Destination Address Space Defined by Domain Object
- Interdomain Call/Return Instructions
  - Linkage kept in process object
  - No implicit access between address spaces
  - Parameters may include ADs
  - Performance comparable to other architectures' supervisor calls
- No Limit on Number of Address Spaces per Process

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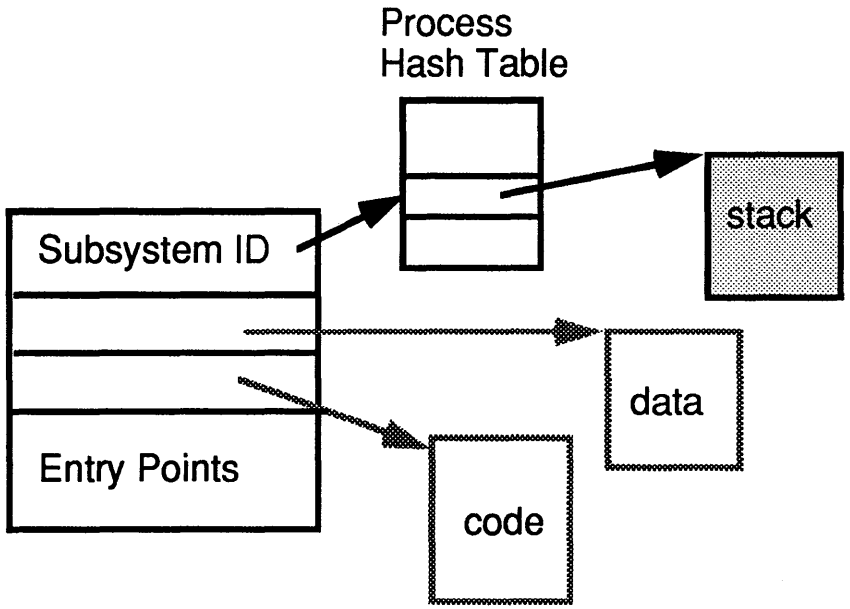
Closer Look At Call Domain



- Subsystem_ID Selects Stack from Process Object
  - Null: use caller's stack
  - World: use the default program stack
  - ID: A unique (named) stack is selected per process

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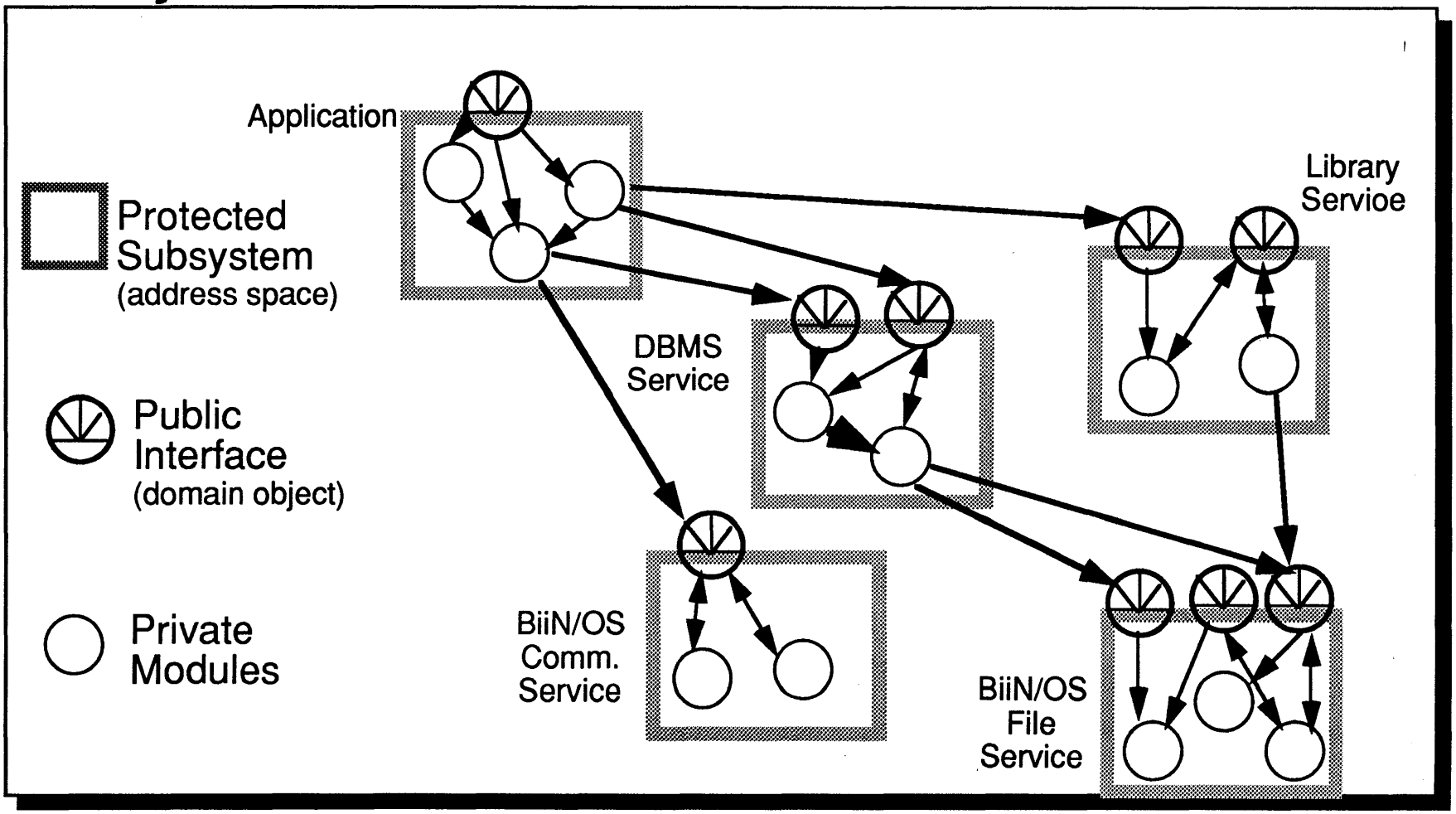
Subsystem Based Protection



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Subsystem Based Protection Benefits

- Reliability, Maintainability, and Extensibility Without Compromising Performance
- Increased Productivity in Integration and Test
  - Decompose application into protected subsystems
  - Since each subsystem is linked independently, turnaround time (recompile/relink) is faster
  - Since errors confined to subsystem, they are easier to find
- Increased Performance Without Compromising Security
  - Services can safely execute in user's process
  - Other architectures require separate process, which results in:
    - higher invocation overhead
    - potential bottlenecks in symmetric multiprocessors

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Topics

- Object Addressing and Protection
- Computational Model
- **Type Manager Based Protection**
- Inheritance
- Object Persistence

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Object-Oriented Design

- Define Abstract Data Type
- Define Set of Operations on Type
- Set of Operations form a Module
- Module Hides Implementation
  - Representation of data type
  - Operations (Algorithms) on data types

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Mapping to Ada

Object-oriented Design

- Define Abstract Data Type
- Define Set of Operations on Type
- Set of Operations form a Module
- Module Hides Implementation
  - Representation of data type
  - Operations (Algorithms) on data types

Maps to Ada Package

```
package Library_Service is
   type library_object is limited private;
   type library is access library_object;
   function Create_library return library;
   procedure Store(Lib:    library;
                   Name: string;
                   Data:  text);
   ....
end Library_Service;

package body Library_Service is
   -- Contains Implementation
   -- Hidden from users of package
```

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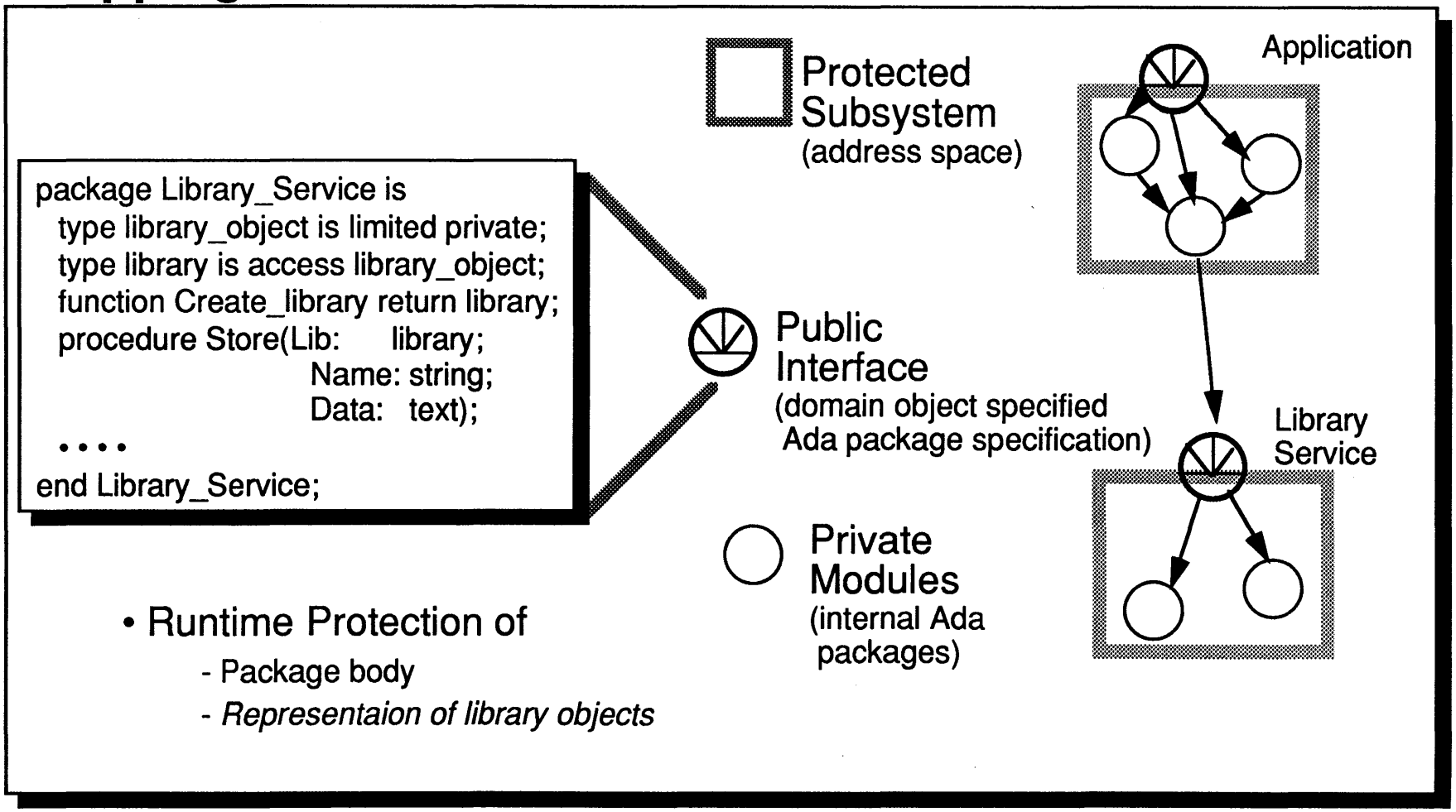
Mapping To Architecture



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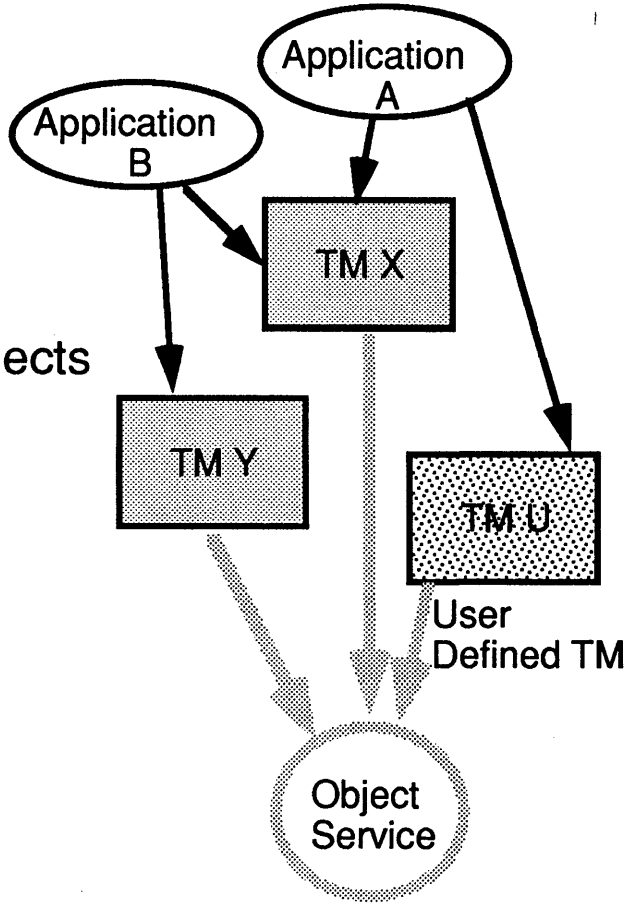
Principles Of
Type Manager Based Protection

- Objects are Typed
- The *X Service* is the Type Manager (TM) for Objects of Type X
- Only TM X Can Access Representation of X Objects
- Applications Can Pass Around ADs (without Representation Rights) for X objects
- Anyone Can Create a New Object Type and TM
- BiiN/OS Provides Object Management Service



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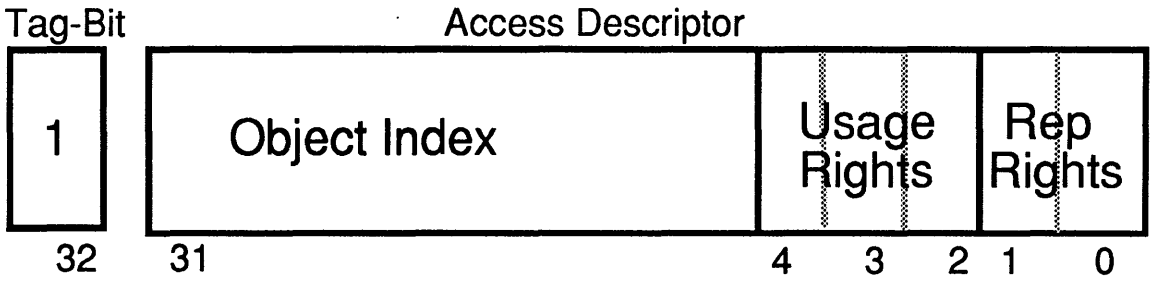
Usage Rights



Usage Rights are Interpreted and Checked By Object's TM

Examples

TYPE	USE	MODIFY	CONTROL
FILE	READ	WRITE	DELETE
TDO	CREATE	AMPLIFY	-
DIRECTORY	LIST	STORE	CHANGE A-LIST
PROGRAM	EXECUTE	DEBUG	DESTROY
LIBRARY	LOOKUP	STORE	LOCK

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A TM Example Using Libraries

Outline

- Creation of the Library Type
- Creating an Object of Type Library
- User-Level Protection on Library Objects
- Invoking the Lookup Procedure on a Library Object

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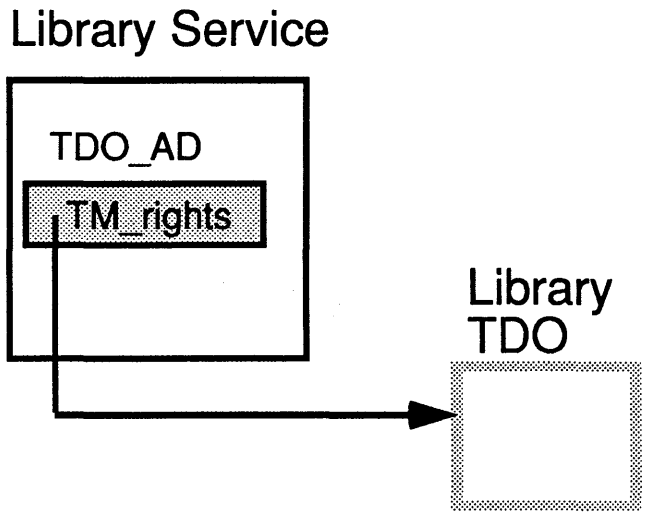
Type Creation

- To Define a New Data Type, TM Creates a Type Definition Object (TDO)
  - AD to TDO is never given out
  - Usage Rights of that AD have TM_rights semantics
    - Create (use) right
    - Amplify (modify) right



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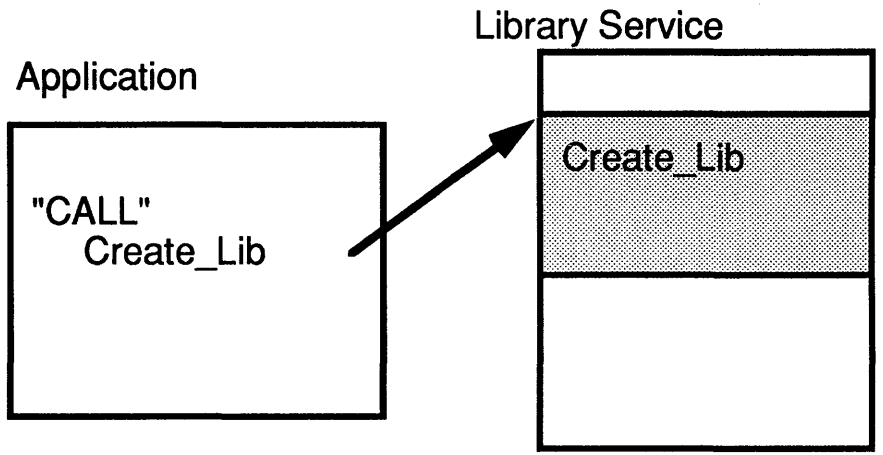
Object Creation



- Application Cannot Create Library Object Directly
  - It cannot get AD with create rights for Library TDO
- Application Must Call Create_Library Subprogram
- Call Requires AD for Library Service Domain Object

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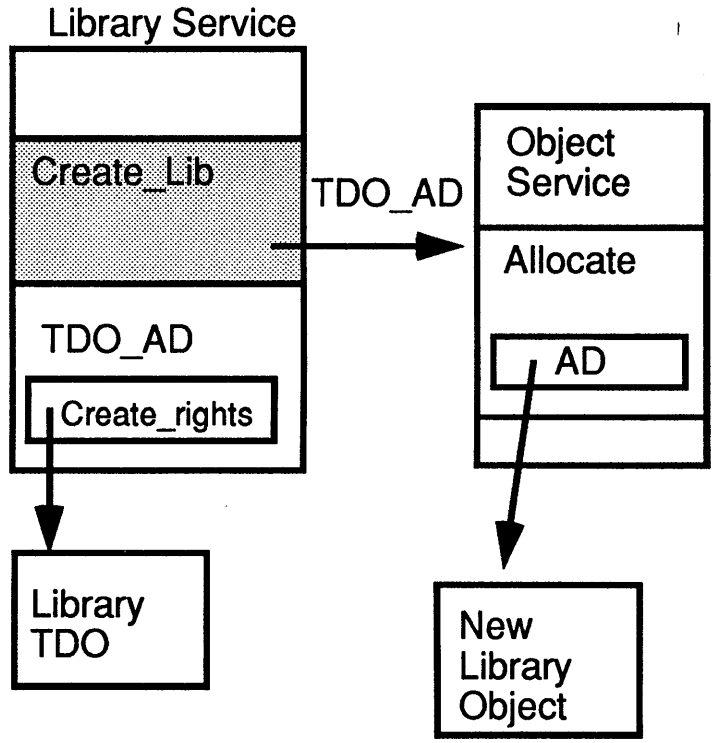
Object Creation (cont'd)

- Library Service Calls BiiN/OS Object Service
  - AD for Library TDO is passed
  - Object service checks for create_rights in AD
- Object Service Allocates Library Object
  - Returns AD with all rights to Library TM



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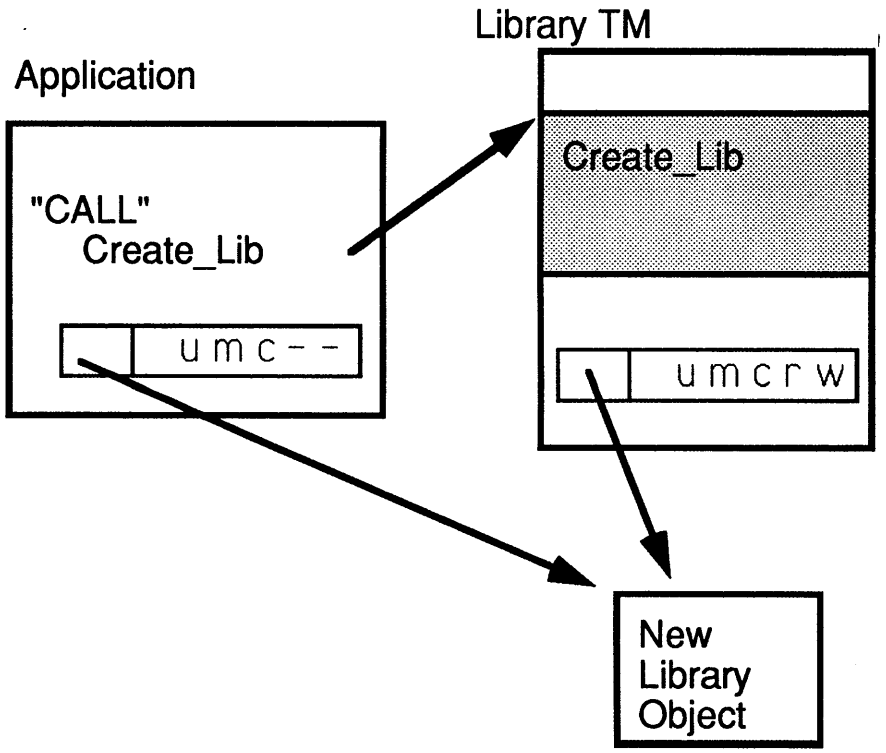
Object Creation (cont'd)

- Library Service Then
  - Initializes library object
  - Removes representation rights in AD (using restrict rights instruction)
  - Returns AD to application
  - Does NOT keep AD to library object
- Application Cannot Access Representation
- Application Controls Usage Rights to Just its Library Object



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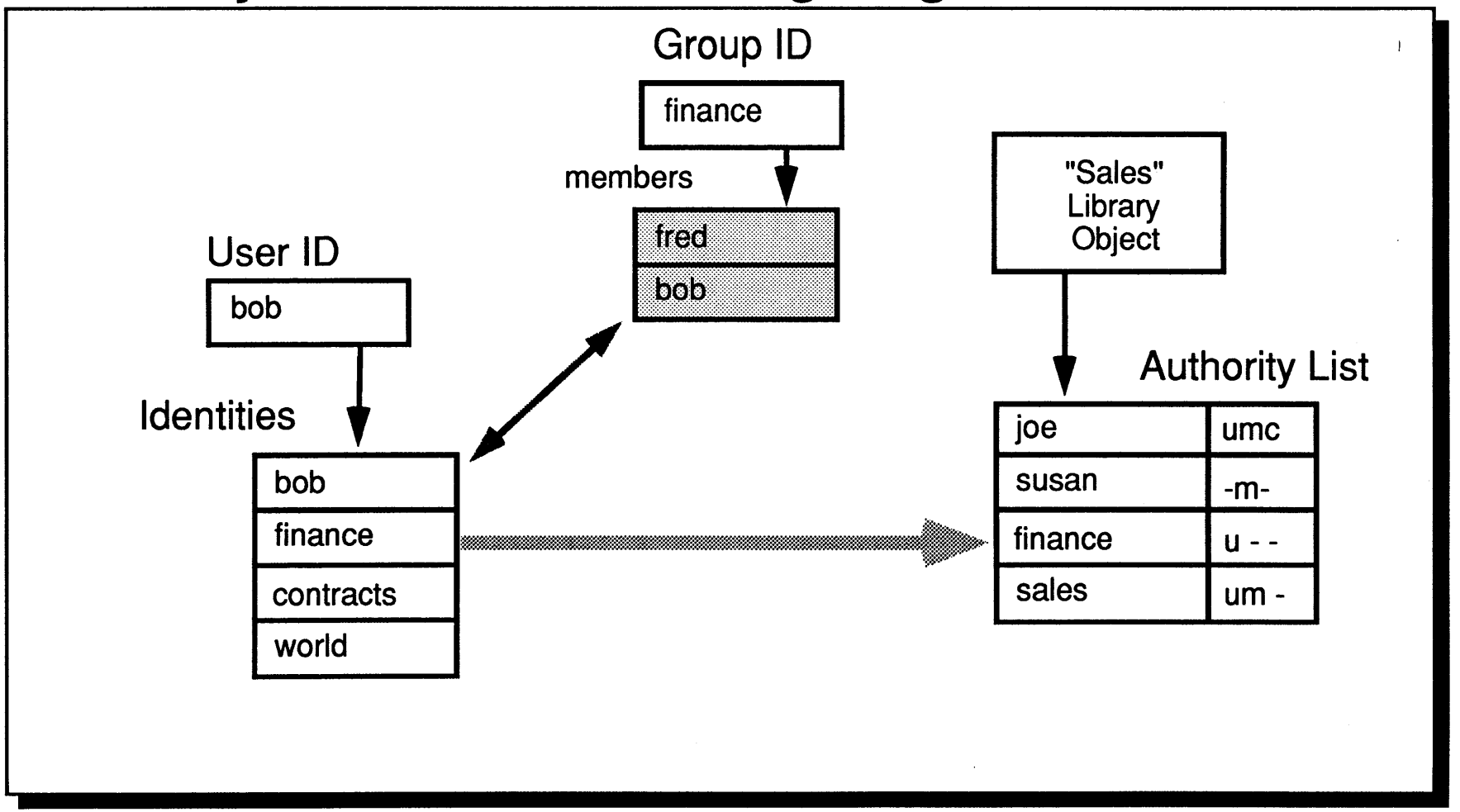
Authority-List Determines Usage Rights



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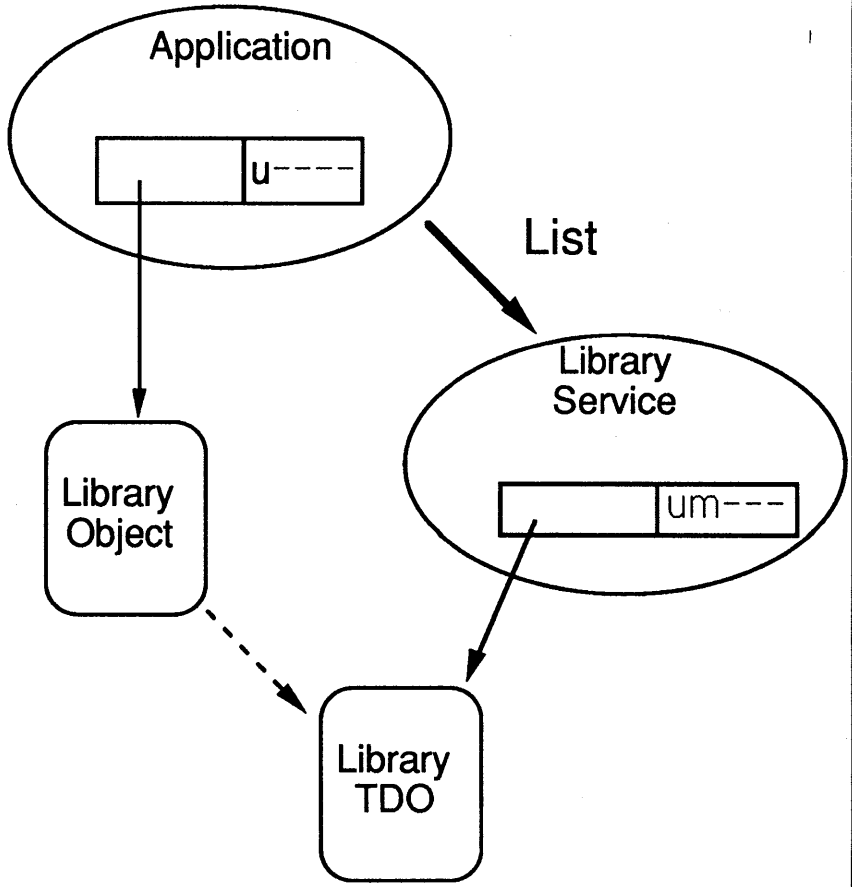
Type Specific Operations

- Application has AD for Library Object with Just Use (Lookup) Rights
- Application Invokes List Subprogram Passing AD



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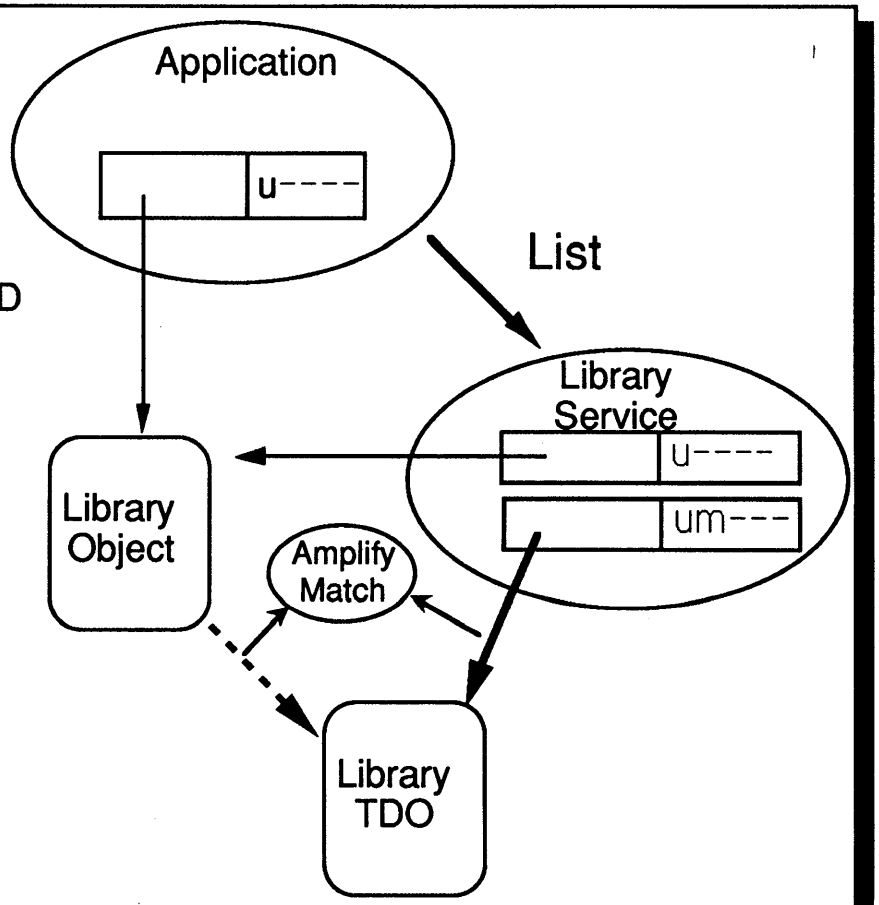
Type Specific Operations (cont'd)

- Application has AD for Library Object with Just use (lookup) Rights
- Application Invokes List Subprogram Passing AD
- Library Service Executes Amplify Instruction
  - Takes AD to-be-amplified and AD with Amplify (modify) rights for a TDO
  - Verifies type match
  - Adds representation rights



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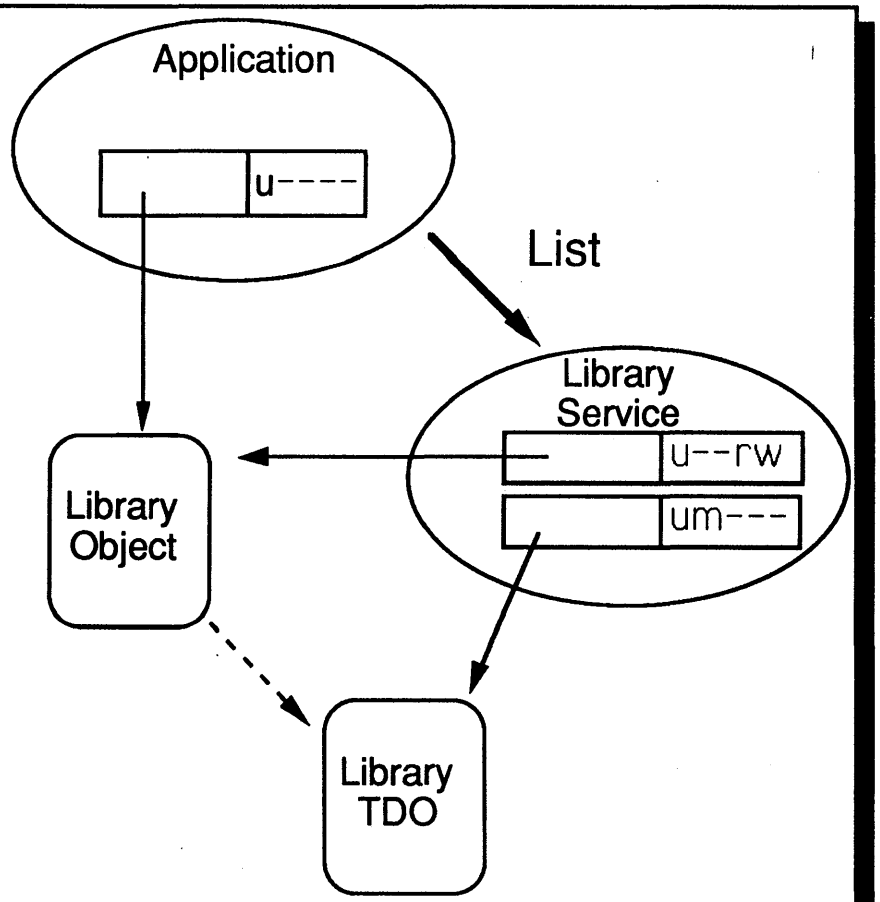
Type Specific Operations (cont'd)

- Application has AD for Library Object with Just use (lookup) Rights
- Application Invokes List Subprogram Passing AD
- Library Service Executes Amplify Instruction
  - Takes AD to-be-amplified and AD with Amplify (modify) rights for a TDO
  - Verifies type match
  - Adds representation rights
- Library Service Can Now Access Representation of Library Object



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Relationship To Security

"The TCB shall be designed and structured to use a complete, conceptually simple protection mechanism with precisely defined semantics. This mechanism shall play a central role in enforcing the internal structuring of the TCB and the system. The TCB shall incorporate significant use of layering, abstraction and data hiding. "

From the Orange Book (DOD 5200.28-STD) section 3.3.3.1.1, System Architecture for B3 level security

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Relationship to Security (cont'd)

Corresponds to SAT Type Enforcement

- **S**ecure **A**da **T**arget
- Extends Bell and LaPadula Model Beyond A1
- NCSC/Honeywell Research

"Domains are essentially a mechanism for encapsulating managers for different data types and transformations between data types. This provides a way to decompose the proof of security for the system into manageable pieces and to tailor the security policy for a system in an application dependent fashion. ... Thus, type enforcement is more than a mere convenience. It provides a way to unify the treatment of trusted subjects with that of generic untrusted subjects."

From "Extending the Noninterference Version of MLS for SAT", IEEE Transactions on Soft. Eng. Feb. 1987.

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Topics

- Object Addressing and Protection
- Computational Model
- Type Manager Based Protection
- **Inheritance**
- Object Persistence

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Behavior Inheritance

- Multiple Implementations for Same Behavior
- Example
  - *Behavior*
    - Byte-Stream Access Method
  - *Implementations*
    - File, Pipe, Magtape, Terminal
- Implementation is Selected in Call Instruction Based on Type of Object

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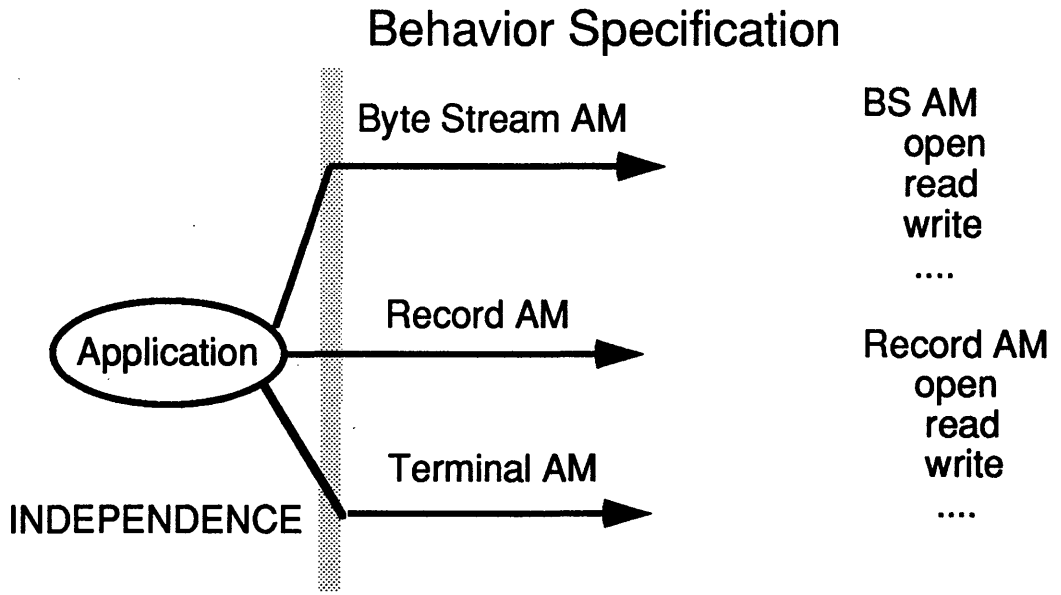
Application Independent of Implementation



- Ada Package Specification Specifies Behavior
- Provides Semantic Definition to Interface
- Services Provide Implementation (package body)
- New Behaviors can be Added

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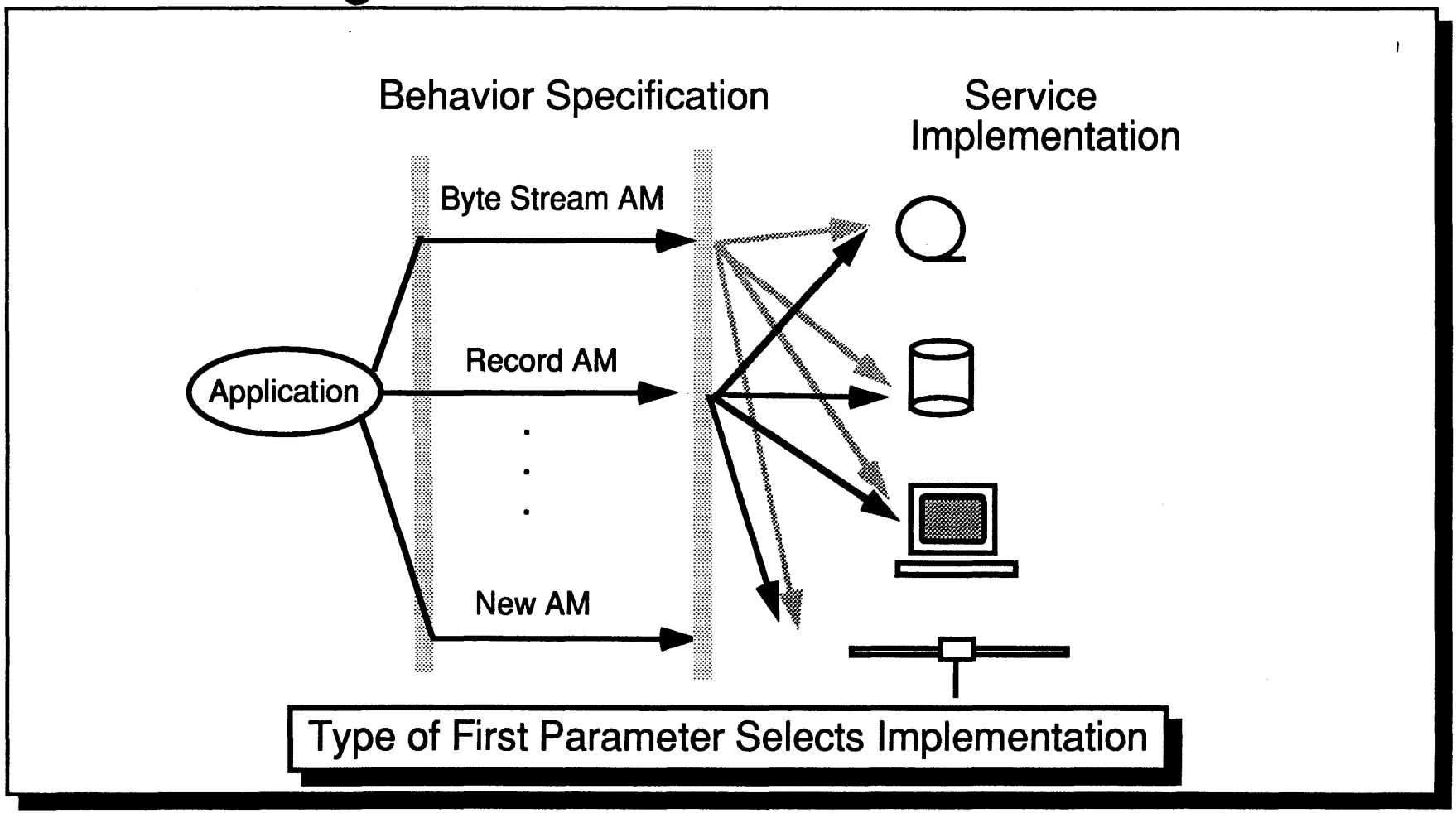
Call Vectoring



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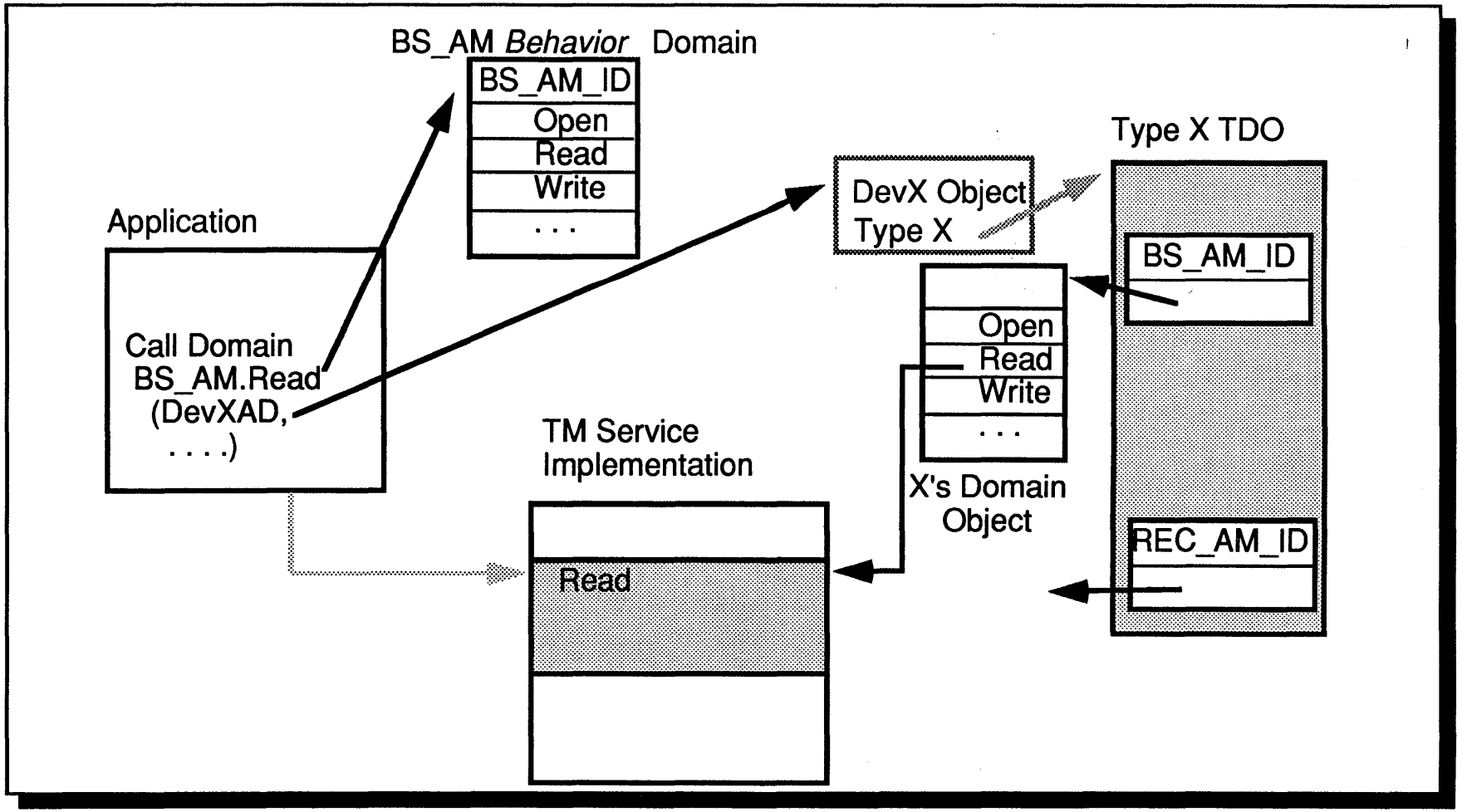
Implementation Selected by Object's Type



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Behavior Inheritance Summary

- Dynamic Binding on Every Call Based on Type
- Old Program Binaries Work with New Implementations Without Even Relinking
- *Call Behavior* Instruction Same as Call Domain
  - Different effect due to difference in domain objects
  - Thus, invokable from any language
- Service Can Dynamically Add Implementations for New Behaviors

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Topics

- Object Addressing and Protection
- Computational Model
- Type Manager Based Protection
- Inheritance
- **Object Persistence**

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Object States

- Two object states: *Passive* and *Active*
- A Passivated Object is
  - Stored in permanent storage (disk)
  - Managed by Passive Store Management
  - Protected by Authority List
- An Activated Object is
  - Stored in virtual memory
  - Managed by object service
  - Protected by VLSI-based object addressing

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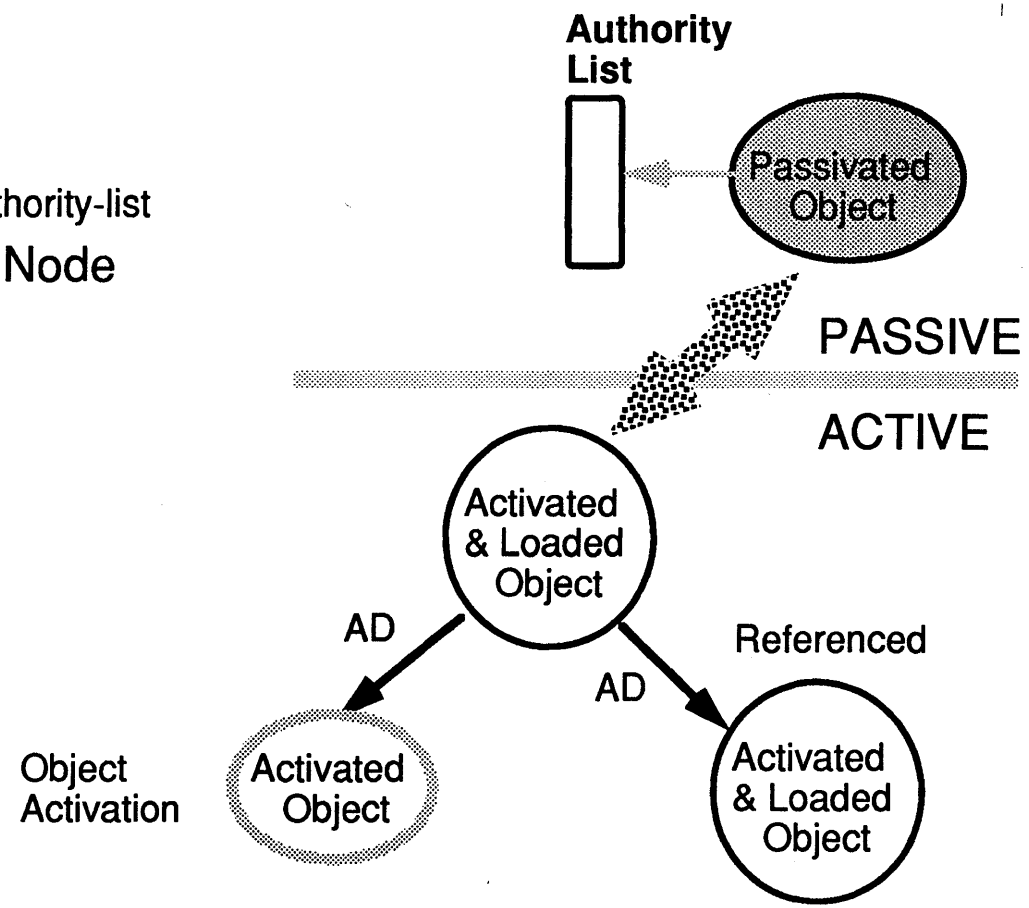
Activation

- Implicit
  - Similar to VM fault
  - Rights in AD determined by authority-list
- Object Networks Can Cross Node Boundaries



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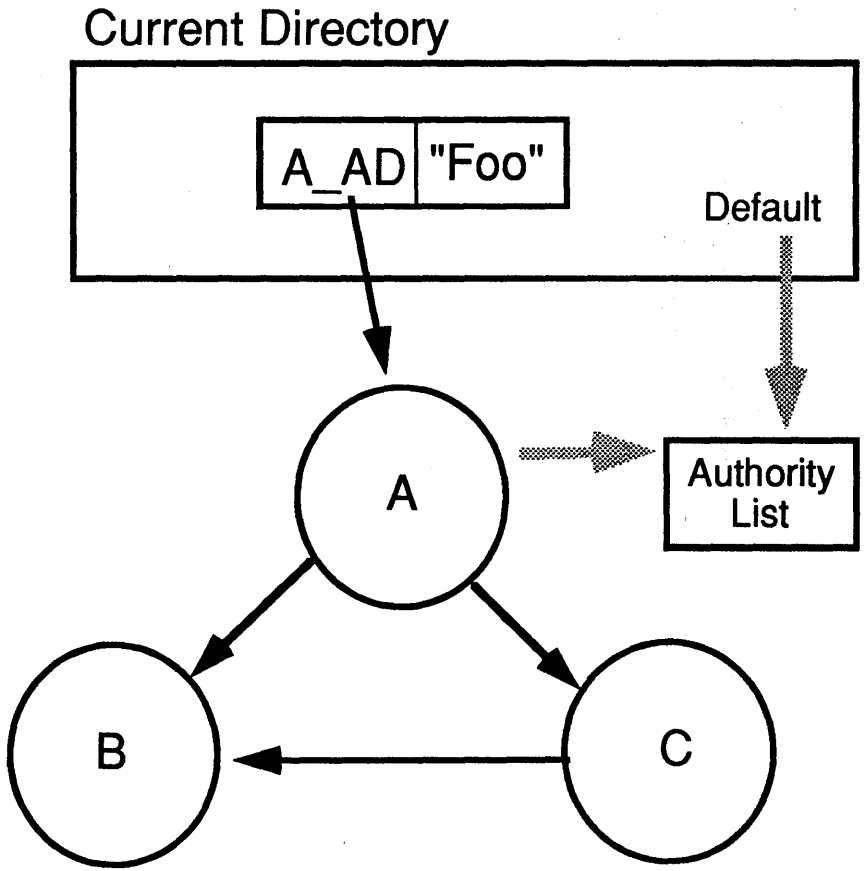
Passivation

- Explicit
  - Transaction-based for synchronization and recovery
  - Controlled by type manager to assure consistency

```
Start_Transaction;
        Store("Foo", A_AD);
        Update(A_AD );
        Update(B_AD );
        Update(C_AD );
Commit_Transaction;
```



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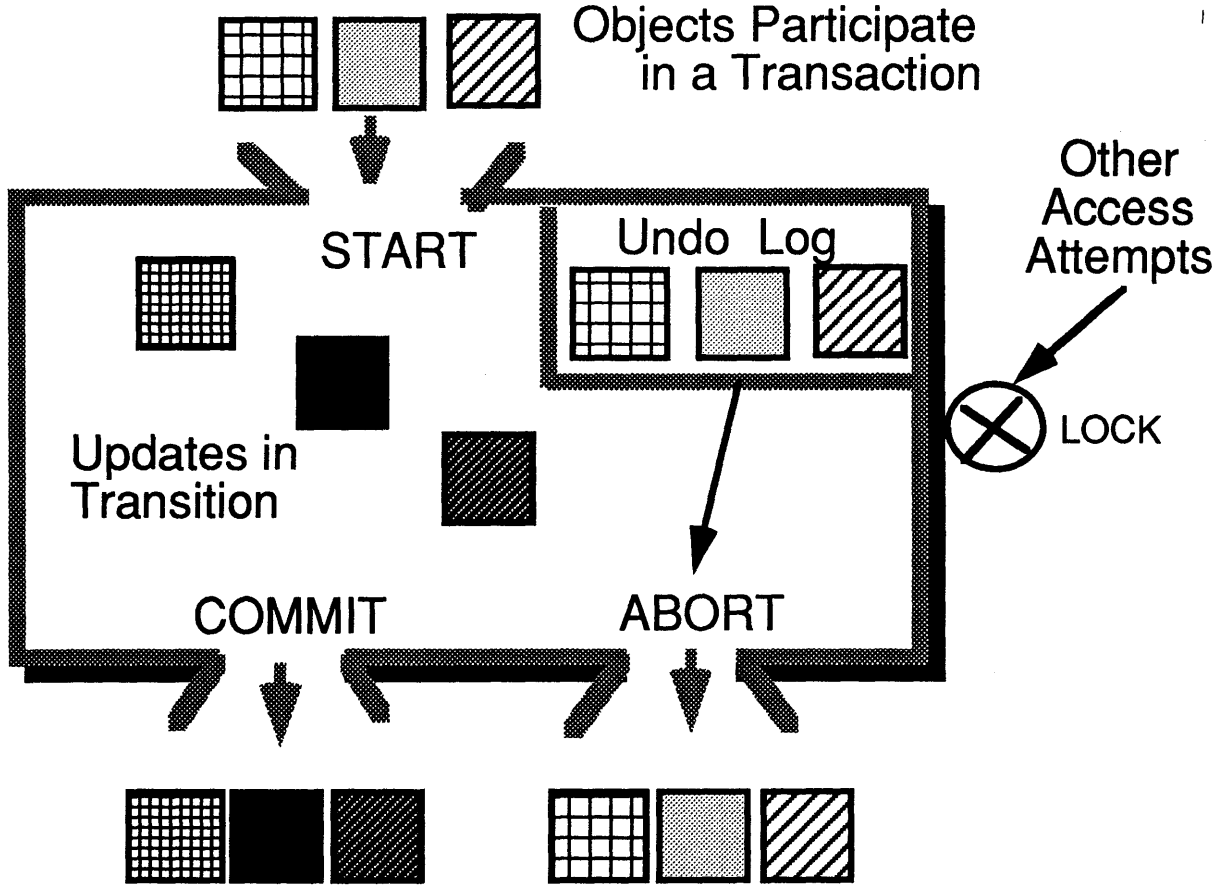
Transaction Concepts

Properties
- Atomicity
- Synchronization
- Integrity
- Recoverability



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Transaction Service Embedded in BiiN/OS

- Transaction Service Acts as Coordinator
- Multiple Services Can Participate in Same Transaction
  - Files
  - Directories
  - Libraries
- Extendable to New Services
- Distributed
  - using 2-phase commit protocol

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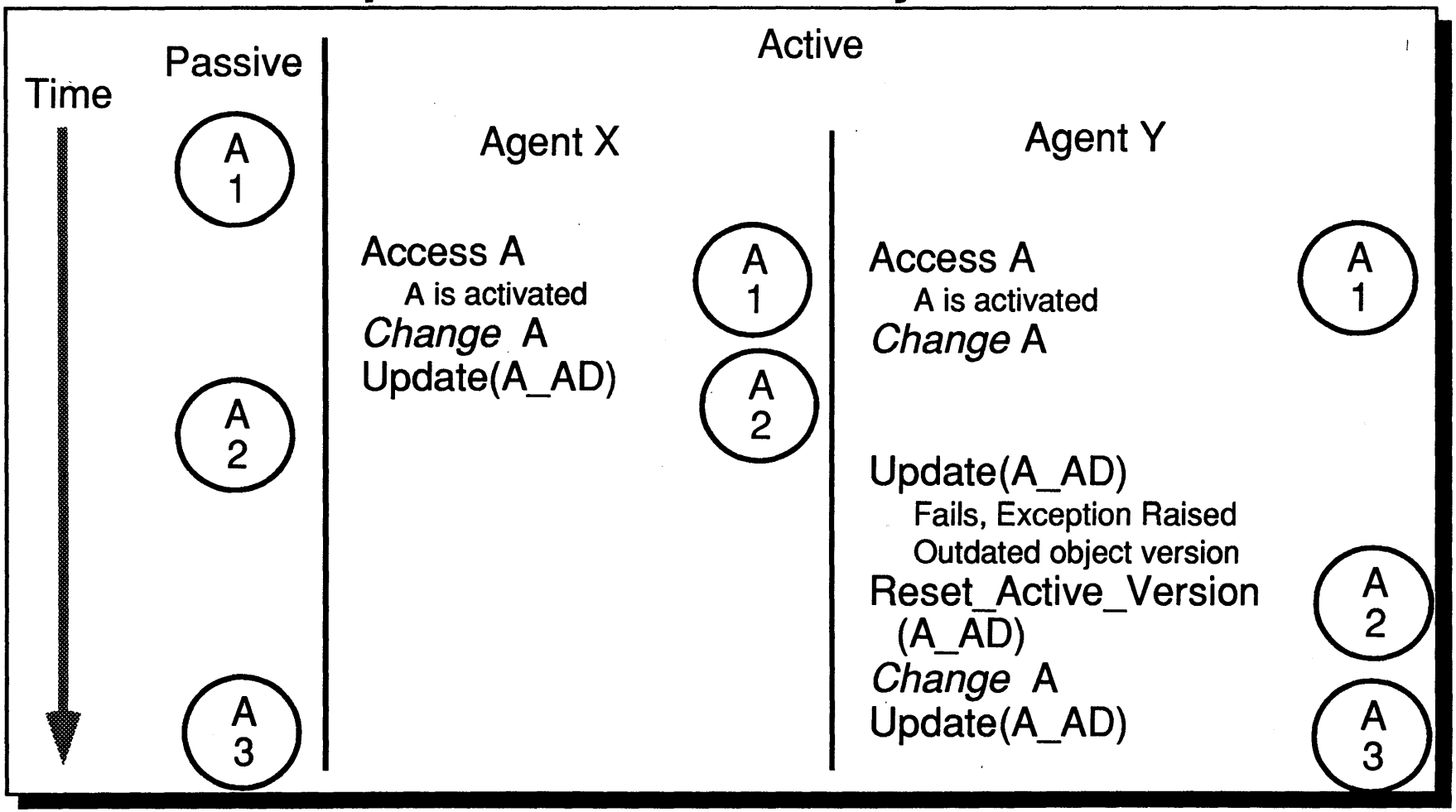
Distributed Optismitic Concurrency



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Distributed Pessimistic Concurrency

Start_Transaction;

Reserve(A_AD);

Synchronizes. Does Reset, if necessary.

Change A

Update(A_AD);

Commit_Transaction;

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Persistent Object Summary

- Supports a Permanent Network of Distributed Typed Objects
  - Network can cross disk and node boundaries
  - Accessible independent of location
- Supports Concurrent Distributed Access
  - Based on transactions for synchronization and data integrity
  - Both optimistic and pessimistic synchronization are supported
- Activation is Implicit for Ease-of-use
- Passivation is Explicit for Data Integrity

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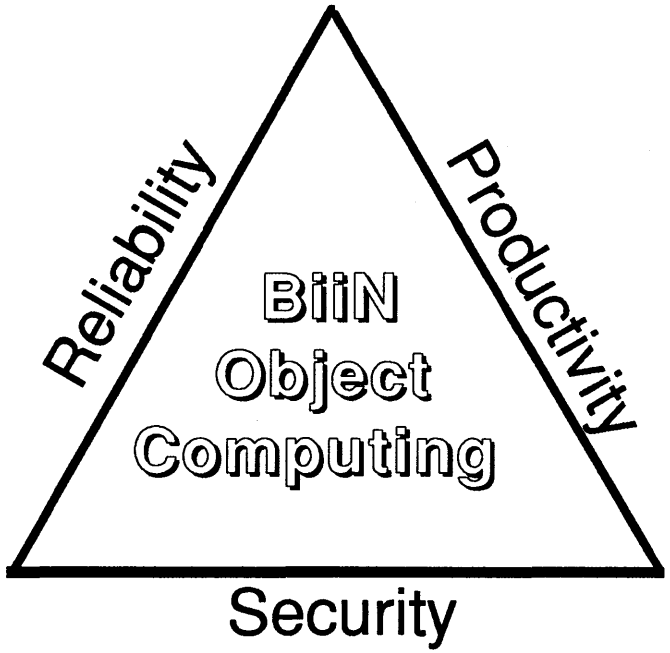
Summary



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