
# A UML Profile for Modeling Complex Real-Time Architectures

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# Overview

- Complex real-time systems
- Requirements for modeling real-time system architectures
- Architectural modeling constructs in UML
- Summary

# Complex Real-Time Systems

- Complex real-time systems characterized by:
  - extreme dependability (reliability, availability)
  - diverse and feature-rich functionality
  - continuous feature upgrades (evolutionary requirements)
  - physical distribution
- Encountered mostly in telecom (e-business infrastructure and internet access devices), defense, aerospace, and industrial control

# Modeling Requirements for Complex Systems

- This complexity requires focussed modeling support in at least the following areas:
  - Timeliness and performance modeling
  - Time-aware communication models
  - Concurrency management
  - Resource modeling
  - Distributed system modeling
  - Fault tolerance (detection, treatment, analysis, recovery)
  - Architectural modeling

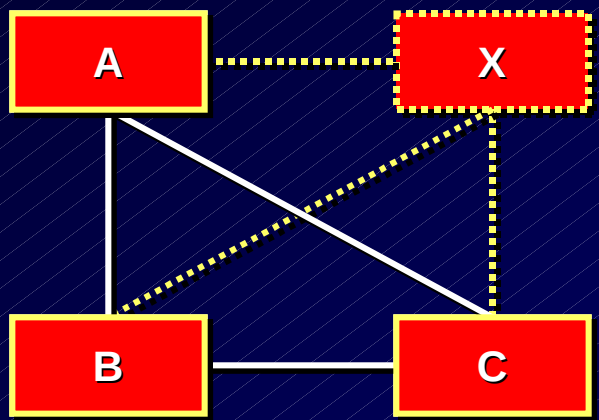
# (Run-Time) Architecture

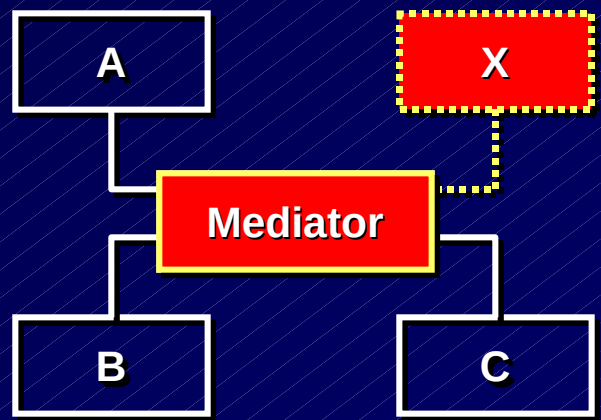
- An abstract view of a system that identifies only the important elements and relationships
- We will focus only on run-time architectures:

*The run-time organization of significant software components interacting through interfaces, those components being composed of successively smaller components and interfaces*

# Why Architecture is Important

- Enables communication between stakeholders
  - exposes how individual requirements are handled
- Drives system construction
  - decomposition into units of responsibility and parallel development
- Determines a system's capacity for evolutionary growth

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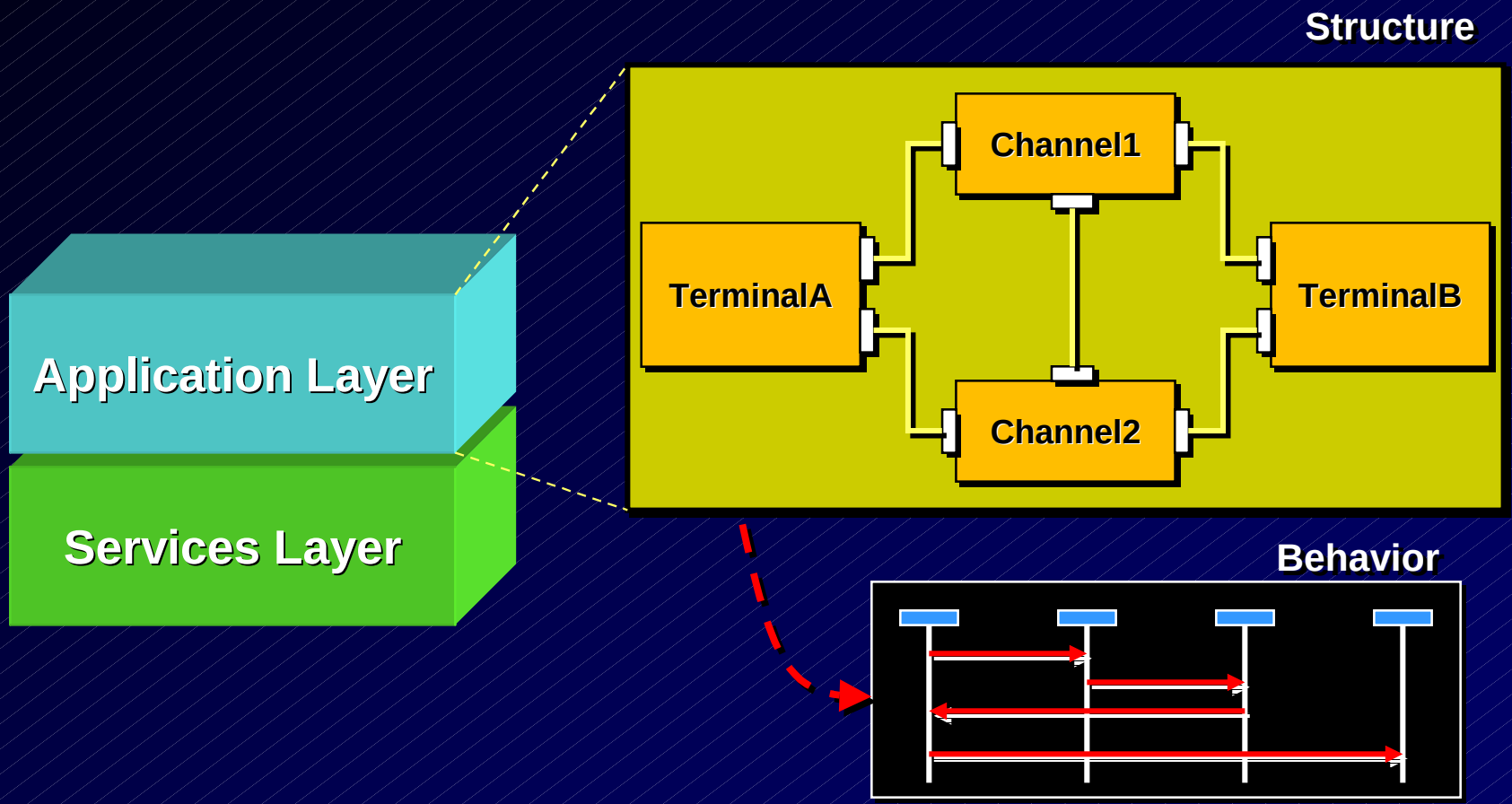
# Example Real-Time Architecture Spec

- Example telecom system architecture

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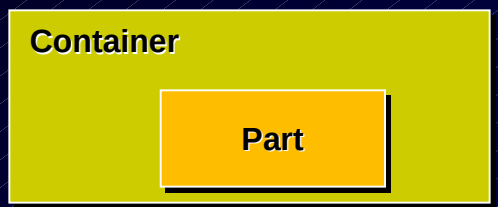
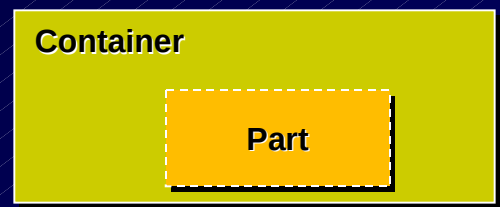
# Basic Run-Time Architectural Patterns

- Peer-to-peer communication:


- Containment:




composition (existence dependency)




aggregation (information hiding)

- Layering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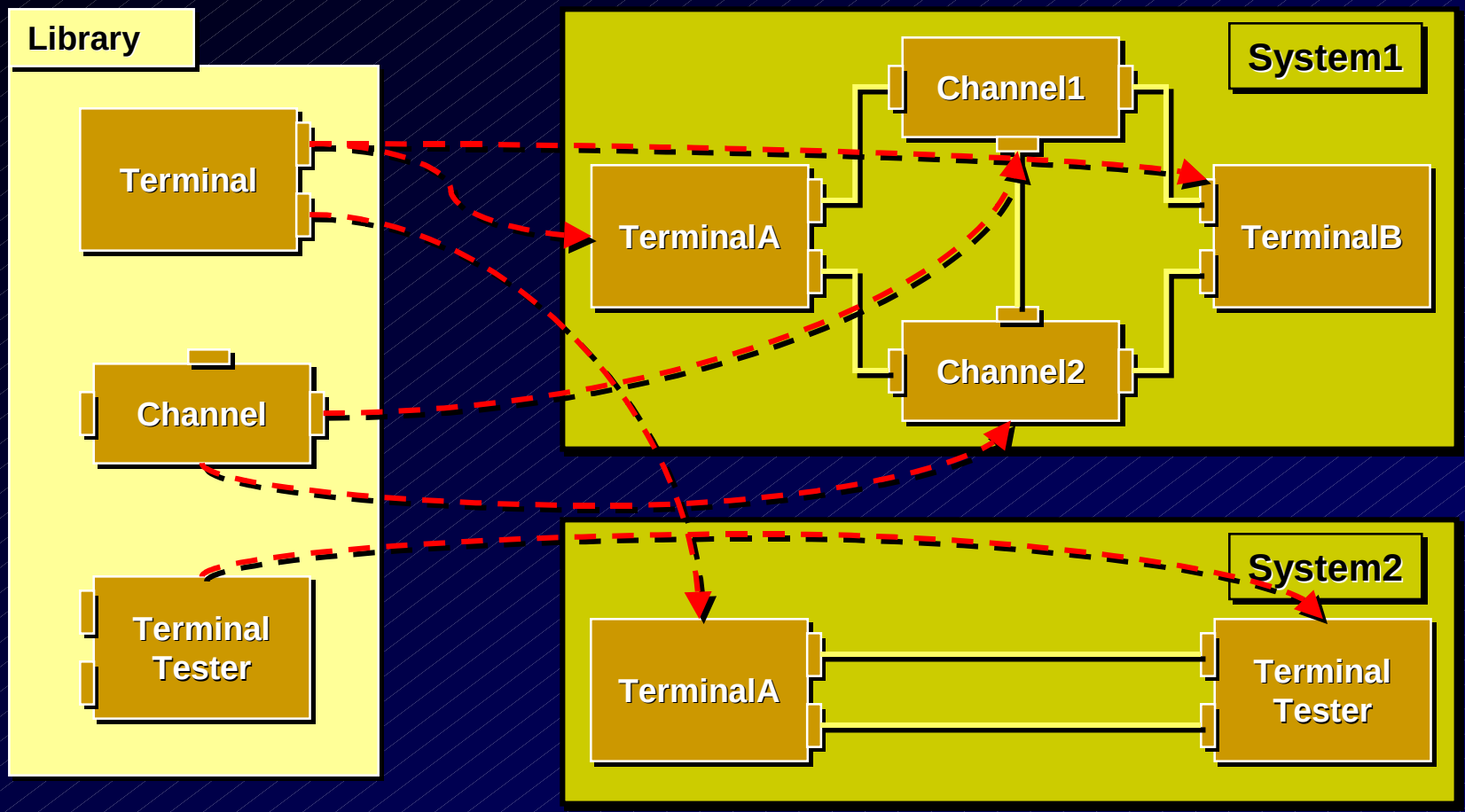
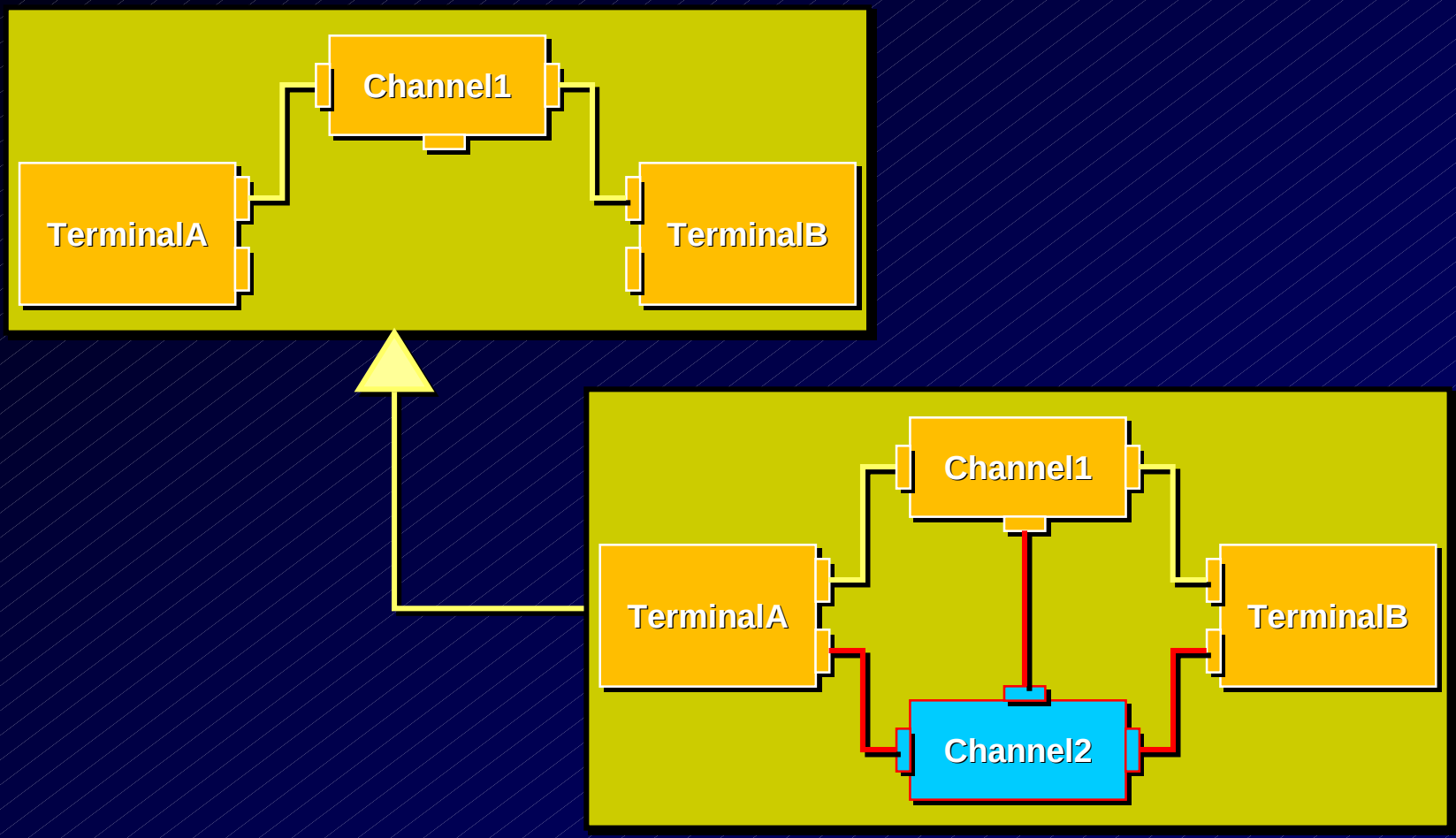
# Architectural Component Design

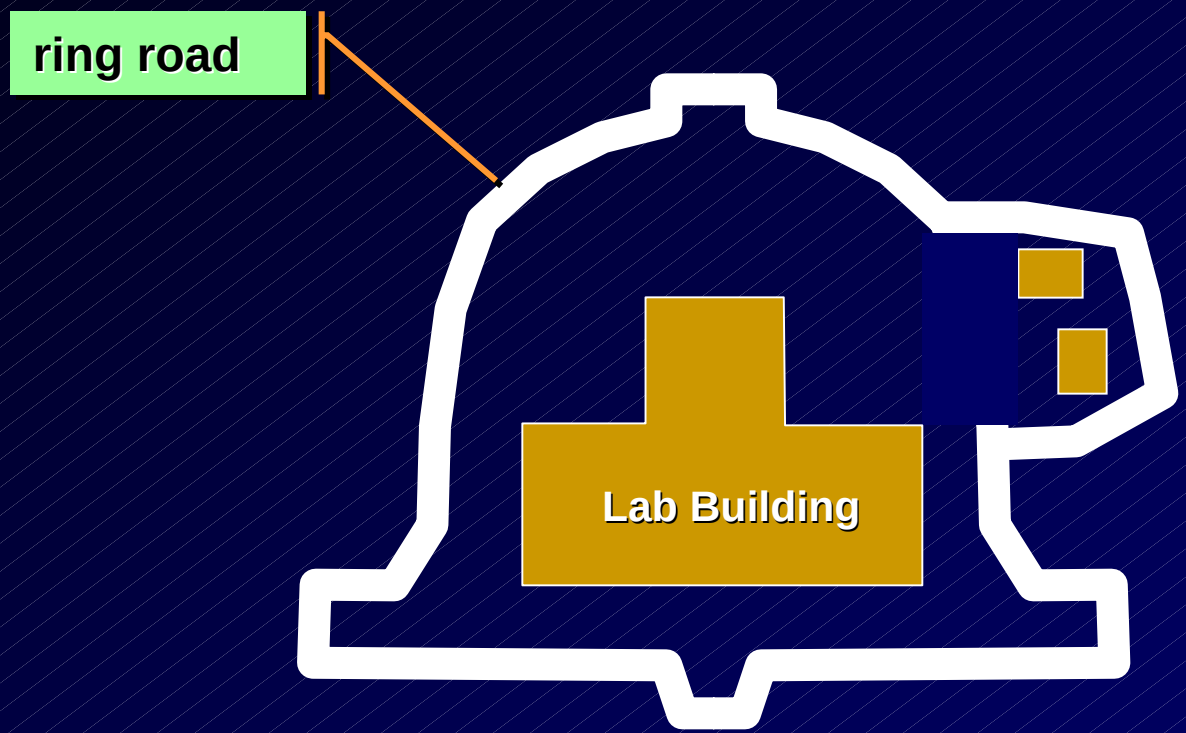


# Refining Architectures (Reuse)



# The Fate of Architectures: Architectural Decay

- The gradual deterioration of an architecture through seemingly “minor” incremental changes

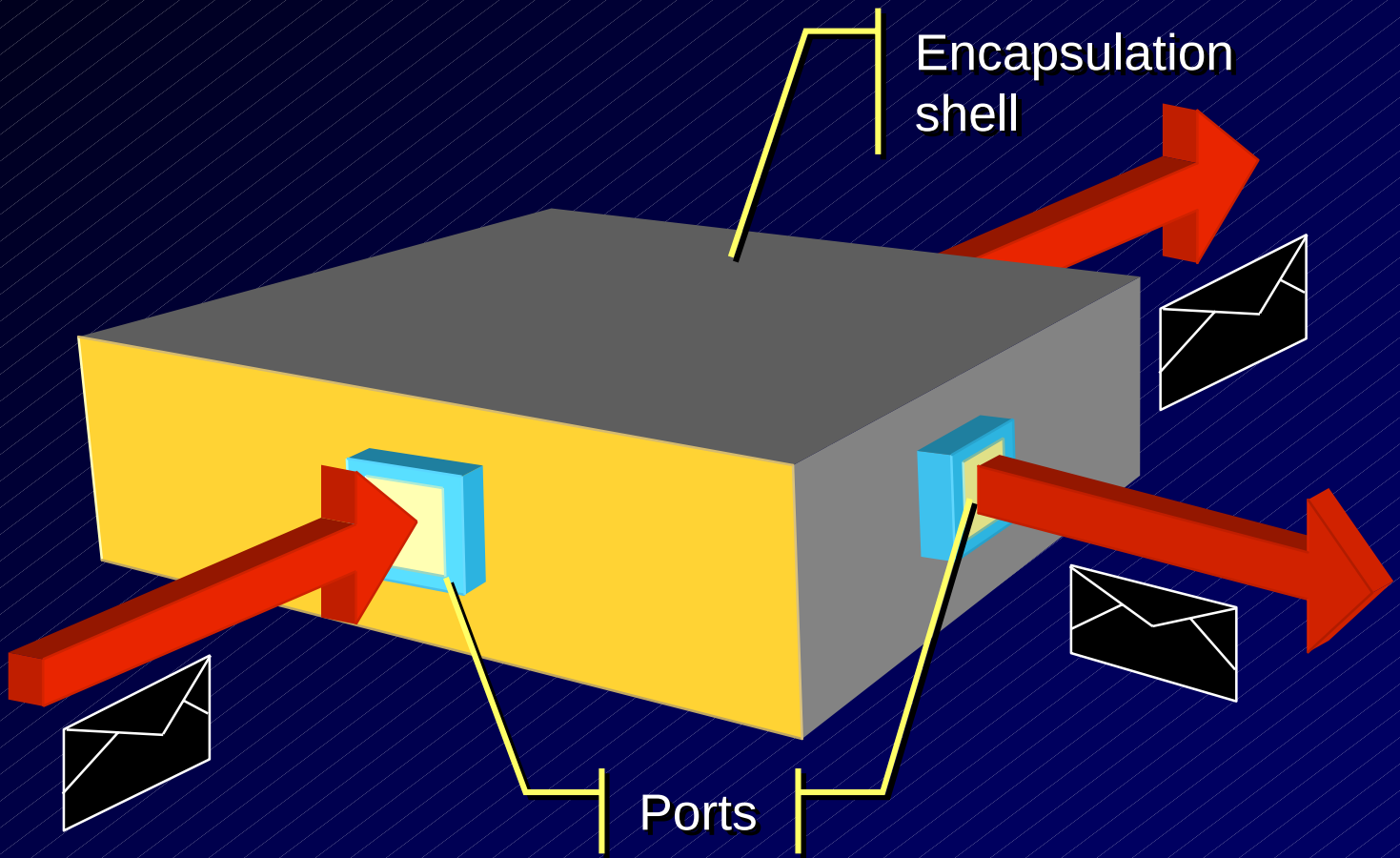


# Preserving Architectures

- To ensure visibility and enforcement of architectural intent
  - the architectural specification must be an integral part of the final implementation
  - not as documentation, but as part of the actual implementation
- This requires automated translation of the architectural spec into the implementation language
  - automated translation is key since any manual intervention breaks enforcement capabilities
  - an architectural definition language (ADL)

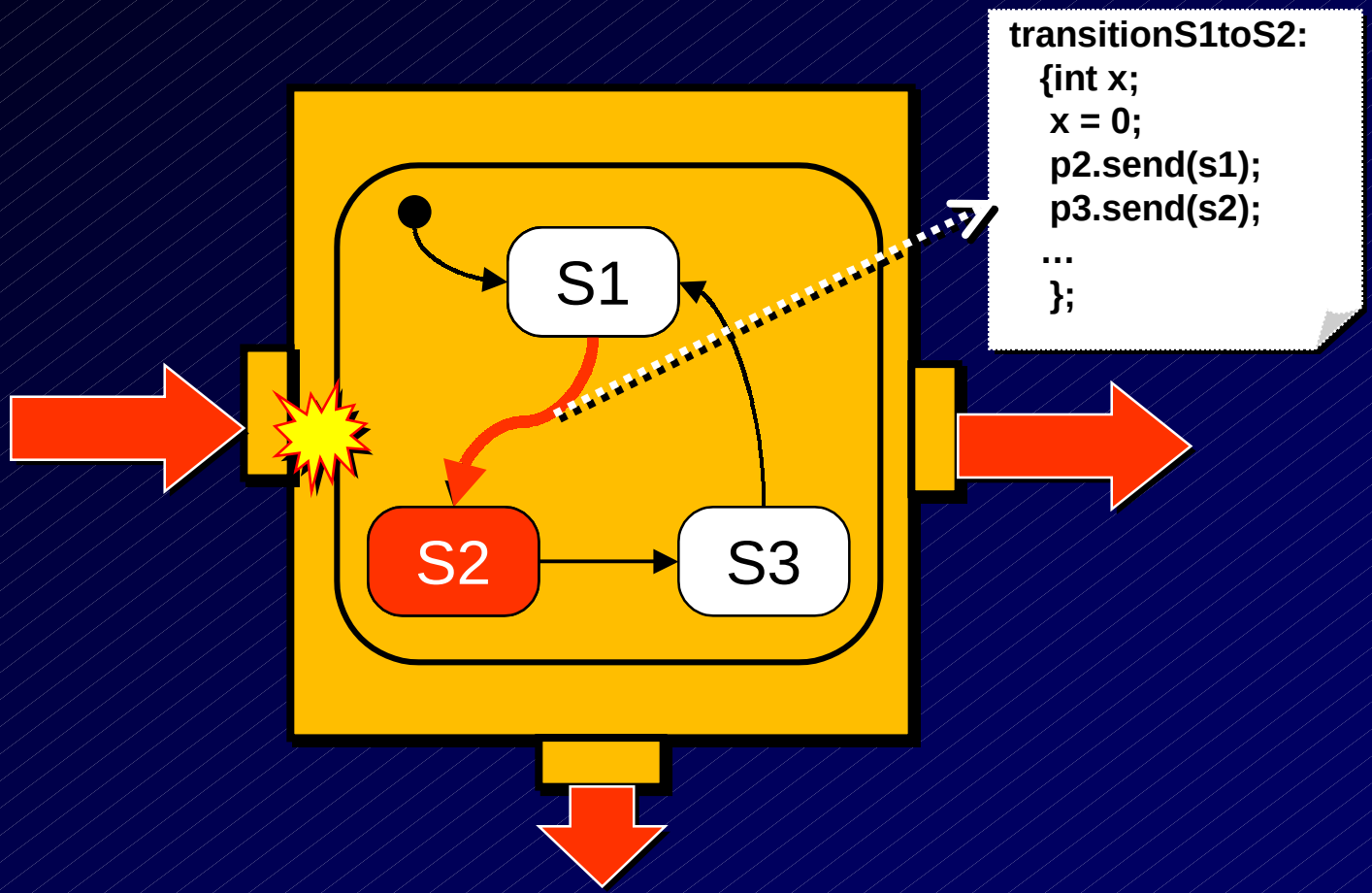
# Capsules: Architectural Objects

- A special kind of active object



# Capsules: Internal Behavior

- Optional hierarchical state machine (event handler with run-to-completion semantics)

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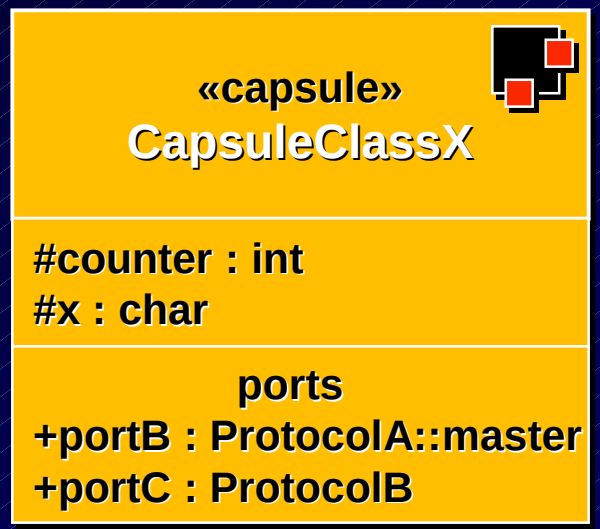
# Capsules: UML Modeling

- Stereotype of Class concept («capsule») with specialized (executable) semantics
- Class diagram representation:

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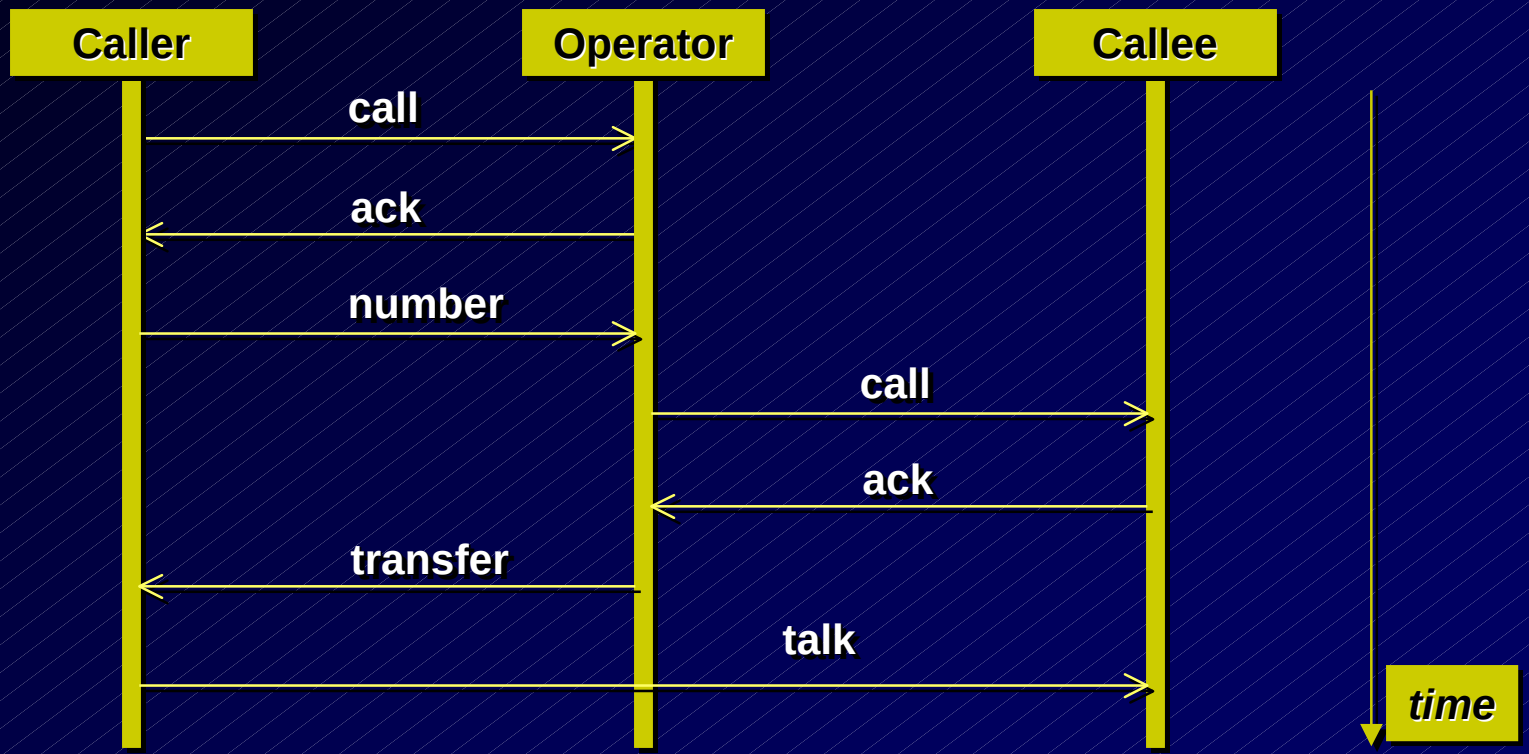
# Protocols: Reusable Behavior Patterns

- Interaction contracts between capsules
  - e.g., operator-assisted call

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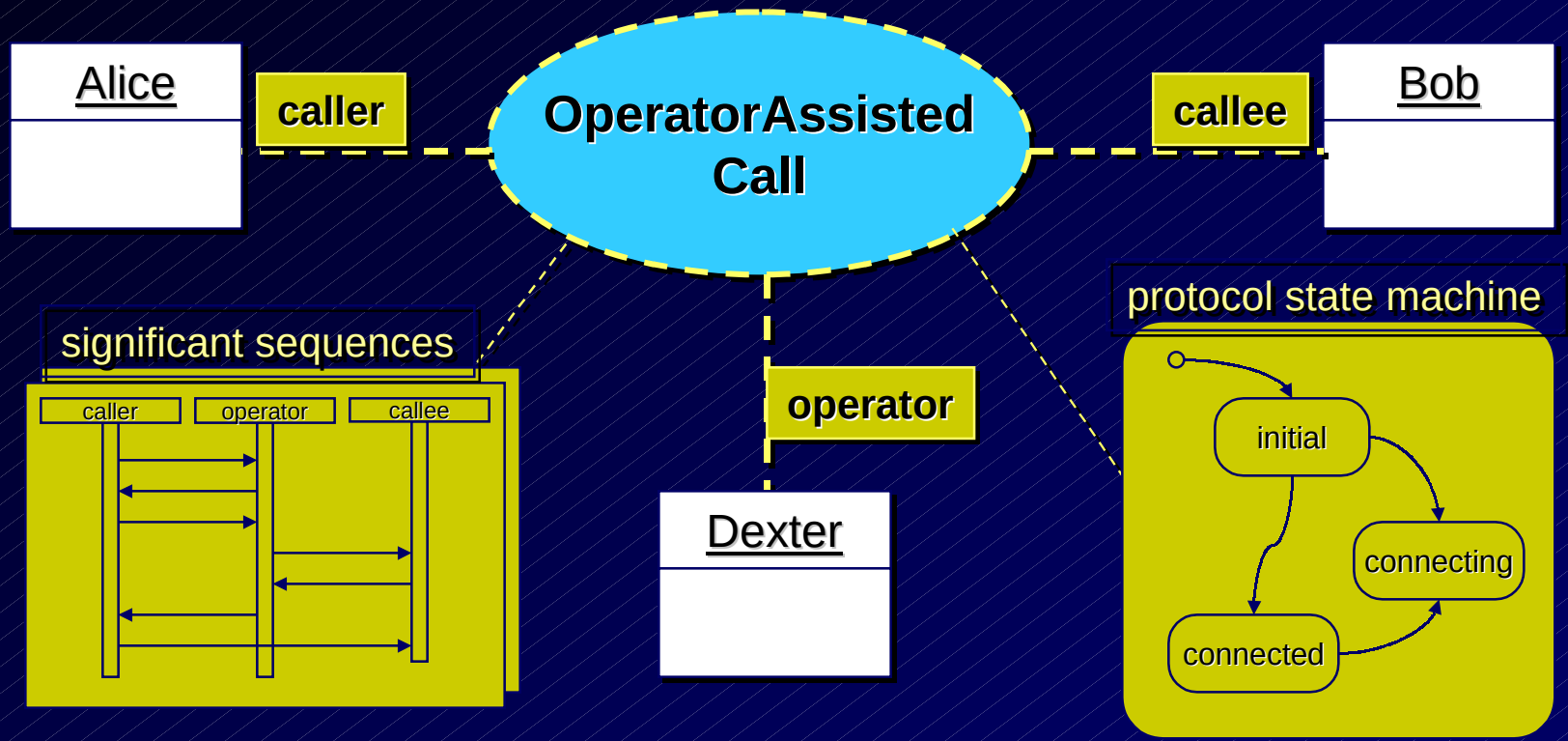
# Protocol Specifications

- A collaboration that may be required on multiple occasions and situations



# Protocol Roles

- Specifies one party in a protocol

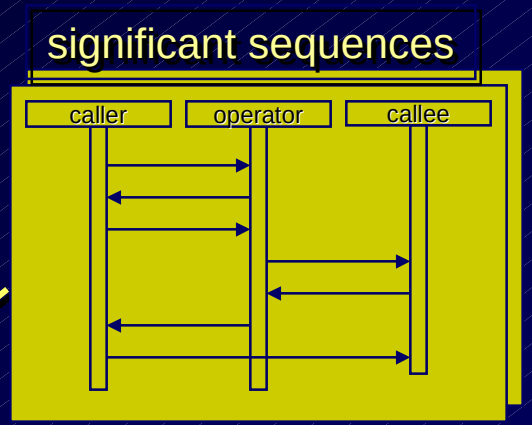
**Incoming signals**

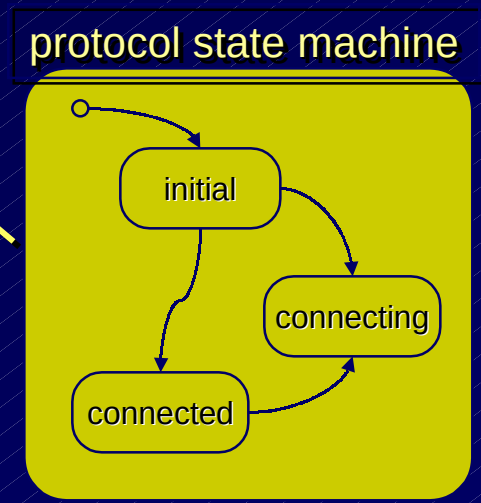
| *signal* | *source* |
|---|---|
| call | caller |
| number | caller |
| ack | callee |

**Outgoing signals**

| *signal* | *target* |
|---|---|
| call | callee |
| transfer | caller |
| ack | caller |

**OperatorRole**

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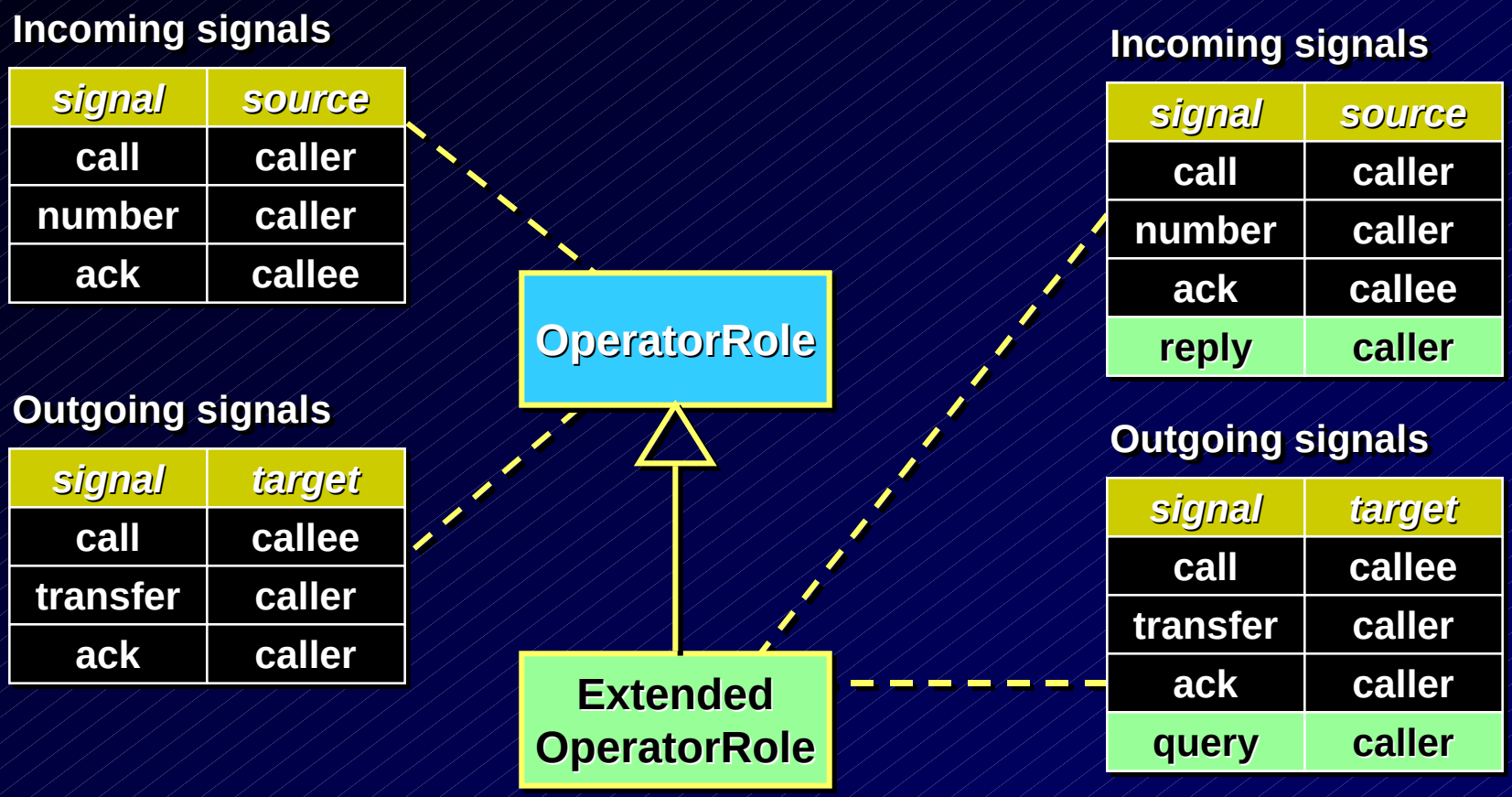
# Protocol Refinement

- Using standard inheritance

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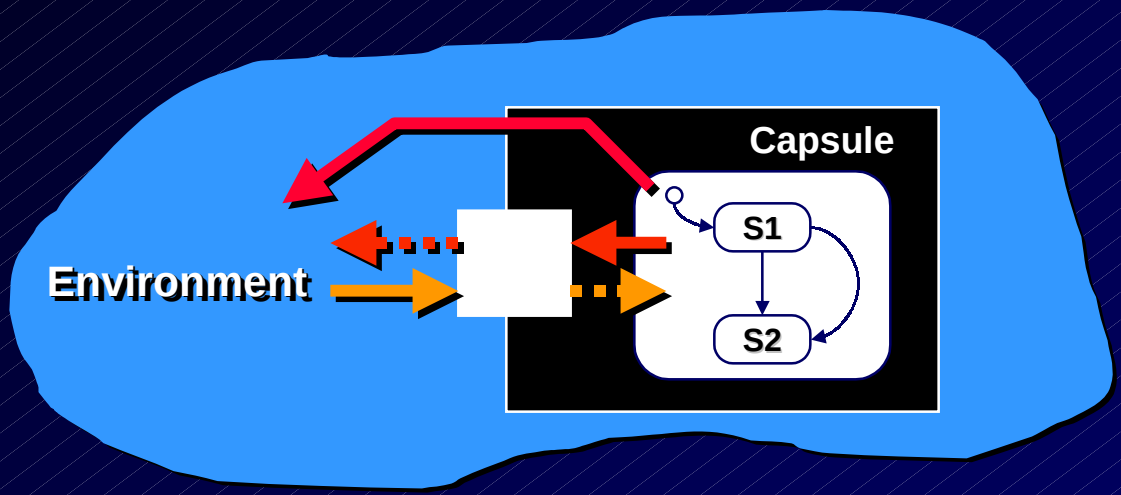
# Ports

- Fully isolate a capsule's implementation from its environment (in both directions)




Each port is typed with a single protocol role

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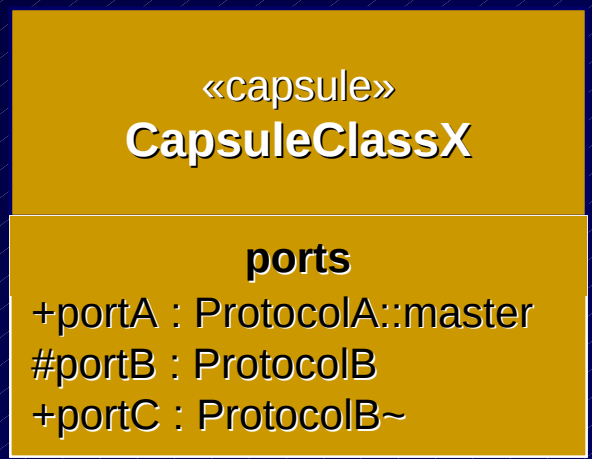
# Ports and Protocols

- Each port realizes a protocol role
  - corresponds to the “type” of the port that can be used for static type checking
  - extension of the traditional object interface concept with a dynamic aspect

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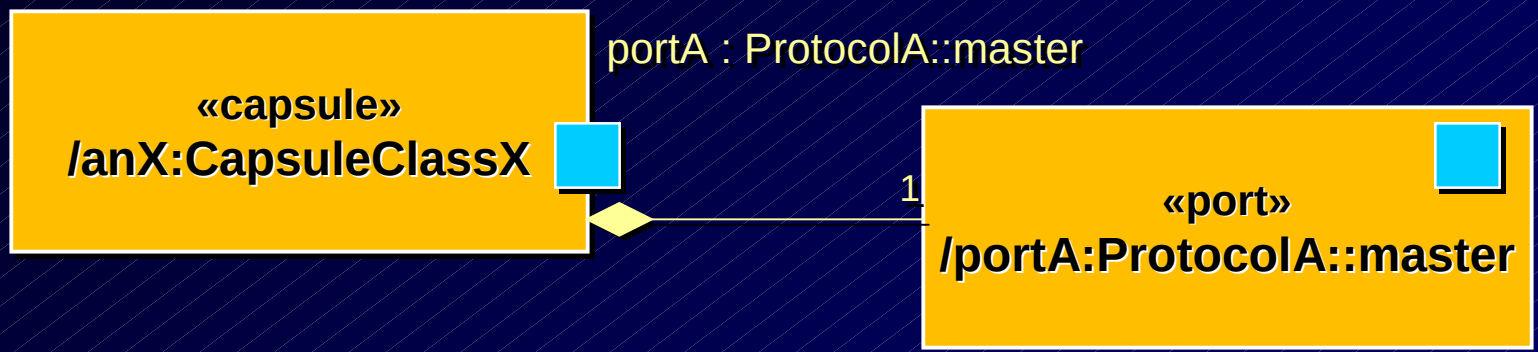
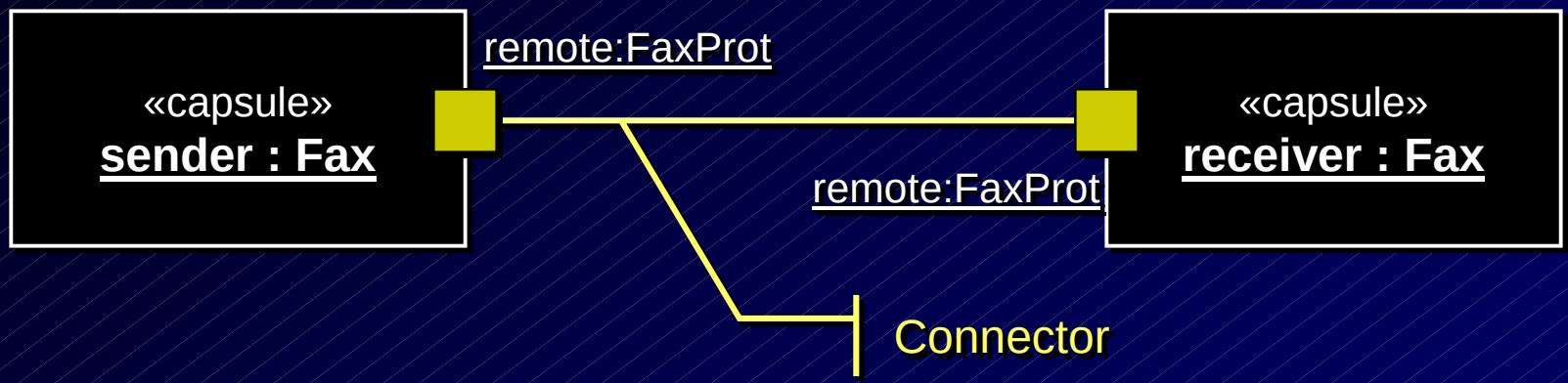
# Ports: Collaboration Diagram Notation

- Shorthand notation for capsule instances
  - iconified form



# Collaborating Capsules

- Using ***connectors***




Connectors model communication channels
Each connector supports a single protocol
Static typing rules apply (compatible protocols)

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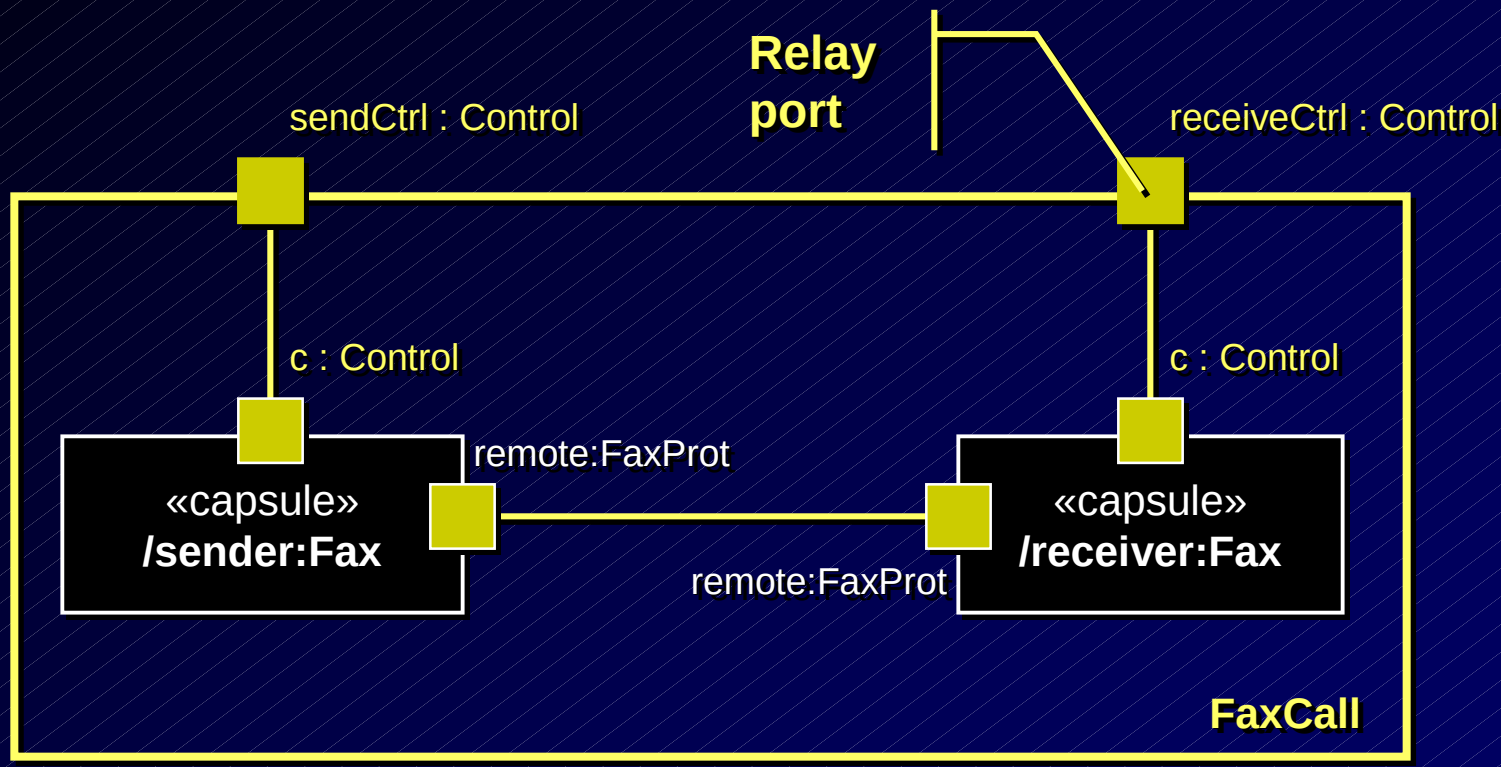
# Composition: Structural Patterns

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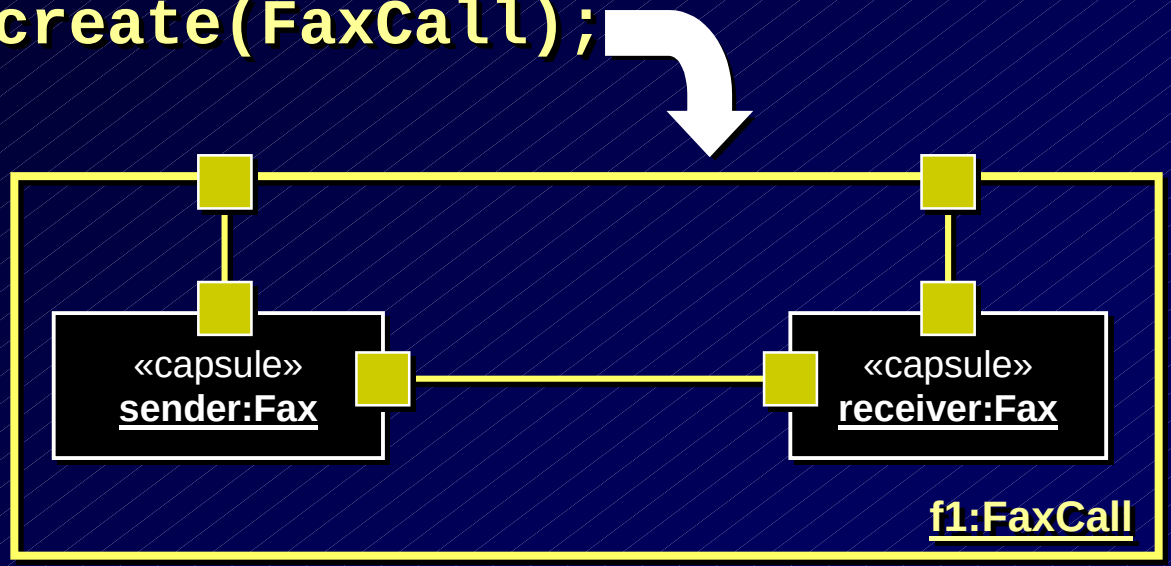
# Composite Capsule Semantics

- Run-time assertion: the complete internal structure of a composite is automatically created (recursively, if necessary) when the capsule is created

```
f1 := create(FaxCall);
```

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# Benefits of Run-Time Assertion

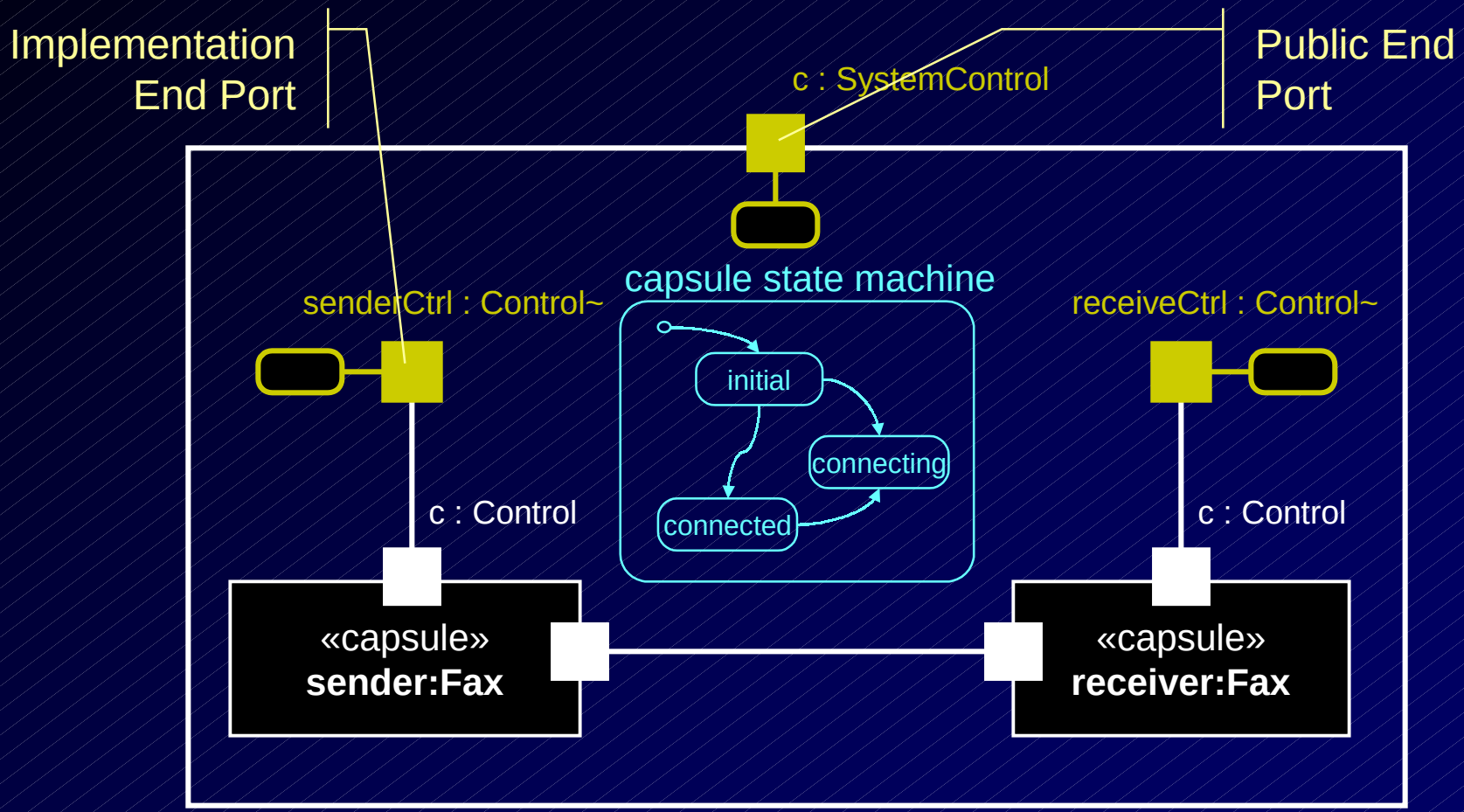
- *Architectural enforcement:* only explicitly prescribed architectural structures can be instantiated
  - it is not possible to bypass (corrupt) the architecture by low-level programming
- *Simplification:* low-level program code that dynamically creates (destroys) components and the connections between them is eliminated
  - in some systems this can be as much as 35% of all code
- Major net gain in productivity and reliability

# Why Do We Need Capsules?

- Won't "regular" objects do?
  - Composite capsules explicitly capture complex structural patterns of concurrent objects
    - Structural assertions (enforced architectural intent)
    - Multiple levels of decomposition, if necessary
  - Ports through protocols bind complex high-level interactions to objects
  - Capsules have distinct interfaces for different collaborators
    - Interfaces are objects with state and identity
    - Suitable for distributed system modeling
  - Capsules can model layering relationships

# End Ports: Where Structure and Behavior Meet

- Ports directly connected to the state machine



# Summary: Architecture

- Software architecture plays a major role in system definition, construction, and evolution
- Embedded systems require specialized support for common complex architectural forms (layering, concurrency, interactions, etc.)
- UML can be used as an ADL for real-time systems
  - consists of just 4 basic concepts (capsules, ports, connectors, and protocols)
  - suitable for executable models and automatic code generation
- Directly supported by the Rose RealTime product

# Summary: UML-RT Profile Elements

- Only four UML stereotypes are sufficient
- (include formally defined constraints that ensure consistency/executability)

| *Stereotype* | *UML Metaclass* |
|---|---|
| «protocol» | Collaboration |
| «protocolRole» | ClassifierRole |
| «port» | Class |
| «capsule» | Class |

⇒ *supplemented by an optional notation*

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# Bibliography


- Bass, L., P. Clements, and R. Kazman, *Software Architecture in Practice,* Addison-Wesley, 1998.
- B. Selic, J. Rumbaugh, *Using UML to Model Complex Real-Time Systems*, Rational whitepaper: (http://www.rational.com/sitewide/support/whitepapers/dynamic.jtmpl)
- B. Selic, G. Gullekson, P. Ward, *Real-Time Object-Oriented Modeling,* John Wiley, 1994.


# Questions?