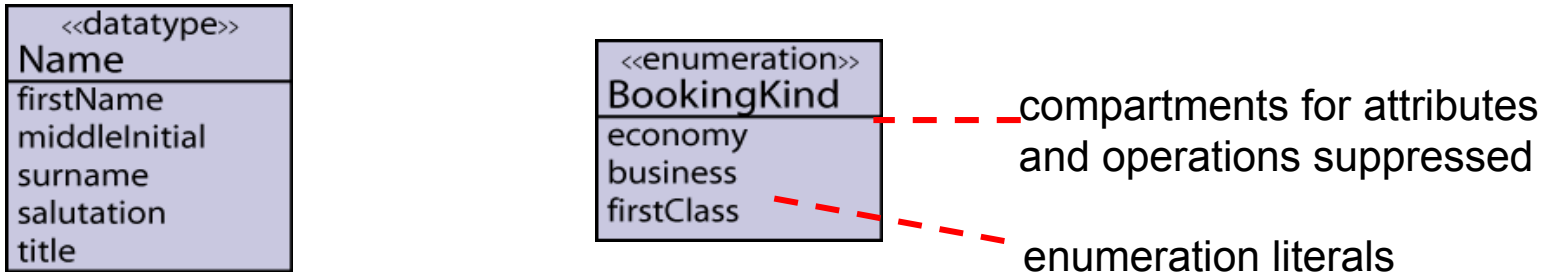
Data types and enumerations

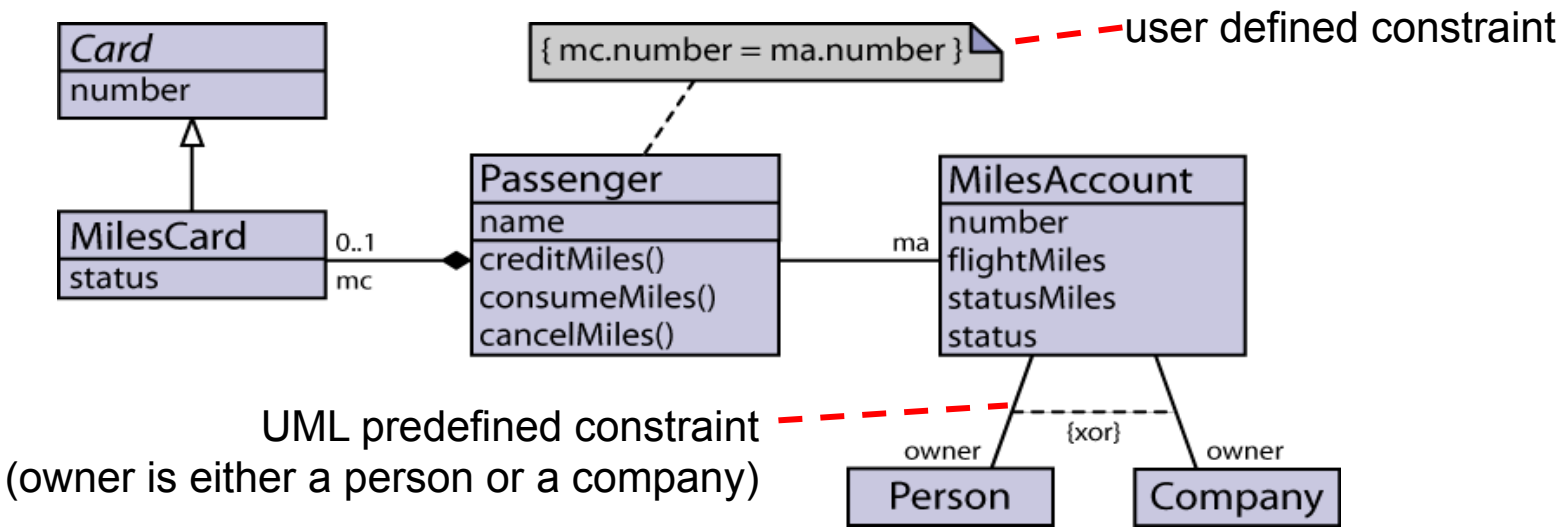
- **Data types** are types whose instances are identified by their value.
  - Instances of classes have an identity.
  - may show structural and behavioural features



- **Enumerations** are special data types.
  - instances defined by enumeration literals
    - denoted by *Enumeration*::*EnumerationLiteral* or *#EnumerationLiteral*
  - may show structural and behavioural features

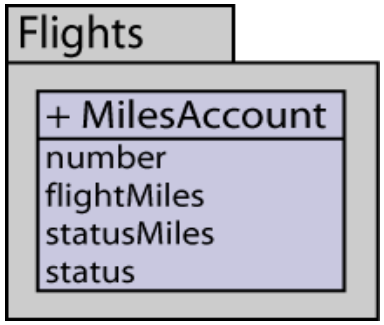
Constraints

- **Constraints** restrict the semantics of model elements.
  - constraints may apply to one or more elements
  - no prescribed language
    - OCL is used in the UML 2 specification
    - also natural language may be used

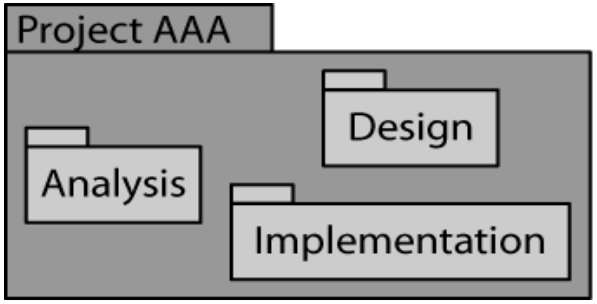


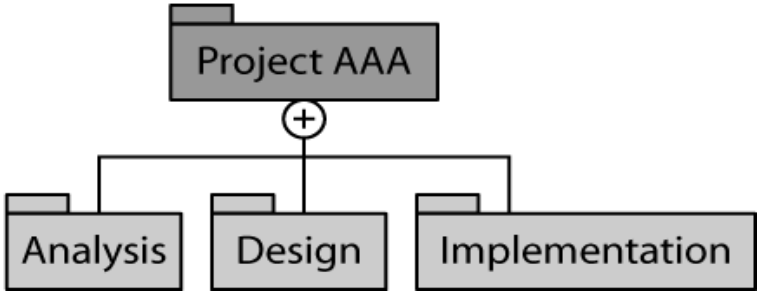
Packages (1)

- **Packages** group elements.
  - Packages provide a **namespace** for its grouped elements.
  - Elements in a package may be
    - public (+, visible from outside; default)
    - private (-, not visible from outside)
  - Access to public elements by qualified names
    - e.g., Flights::MilesAccount



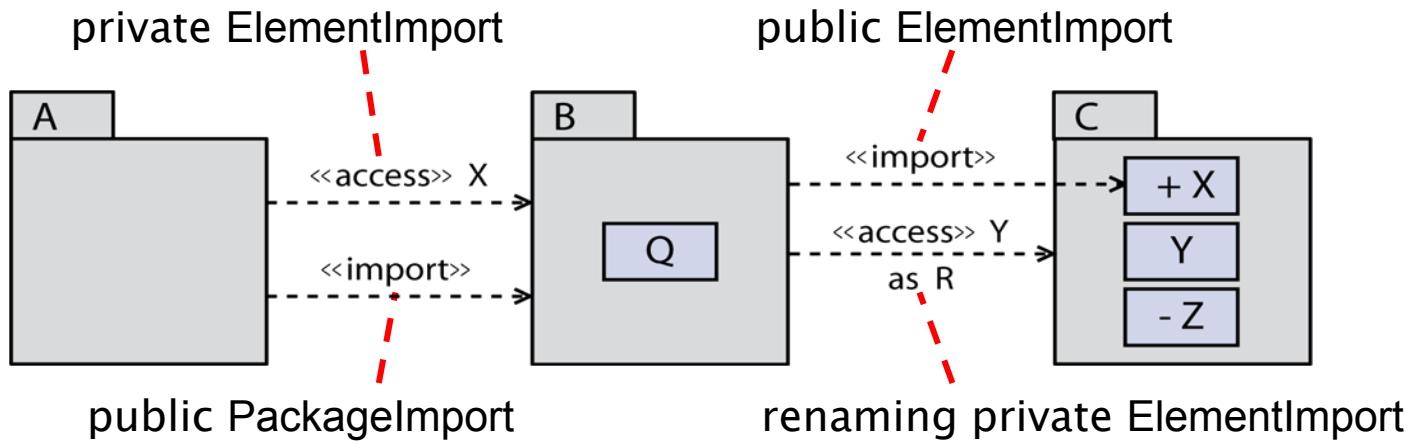
Notational variants





Packages (2)

- **Package imports** simplify qualified names.

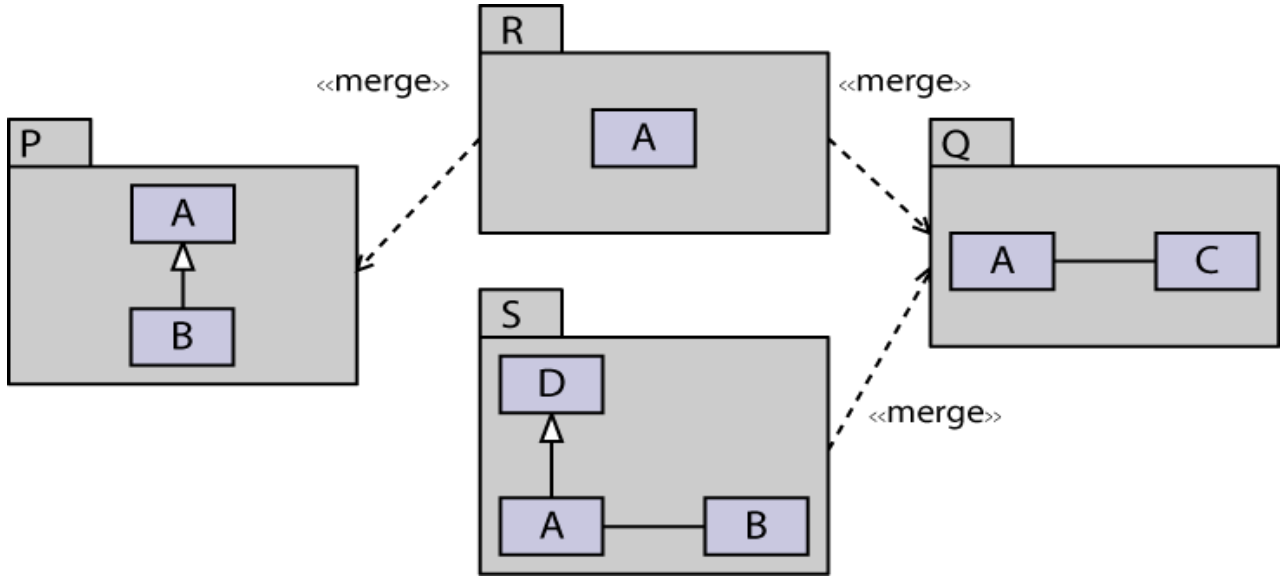


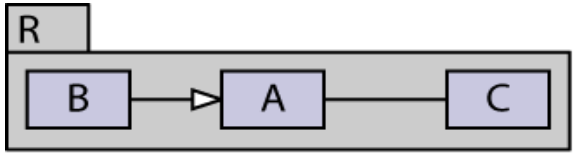
Package	Element	Visibility	
A	X	private	separate private element import (otherwise public overrides private)
A	Q	public	all remaining visible elements of B
B	X	public	public import
B	Q	public	default visibility
B	R	private	private import, renaming

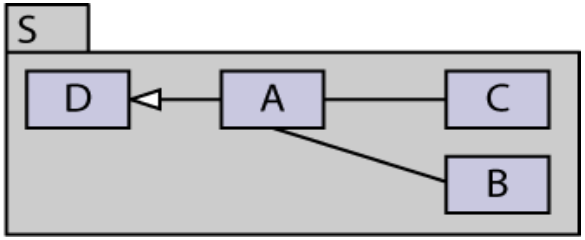
Packages (3)

- **Package mergings** combine concepts incrementally.
  - … but use with care

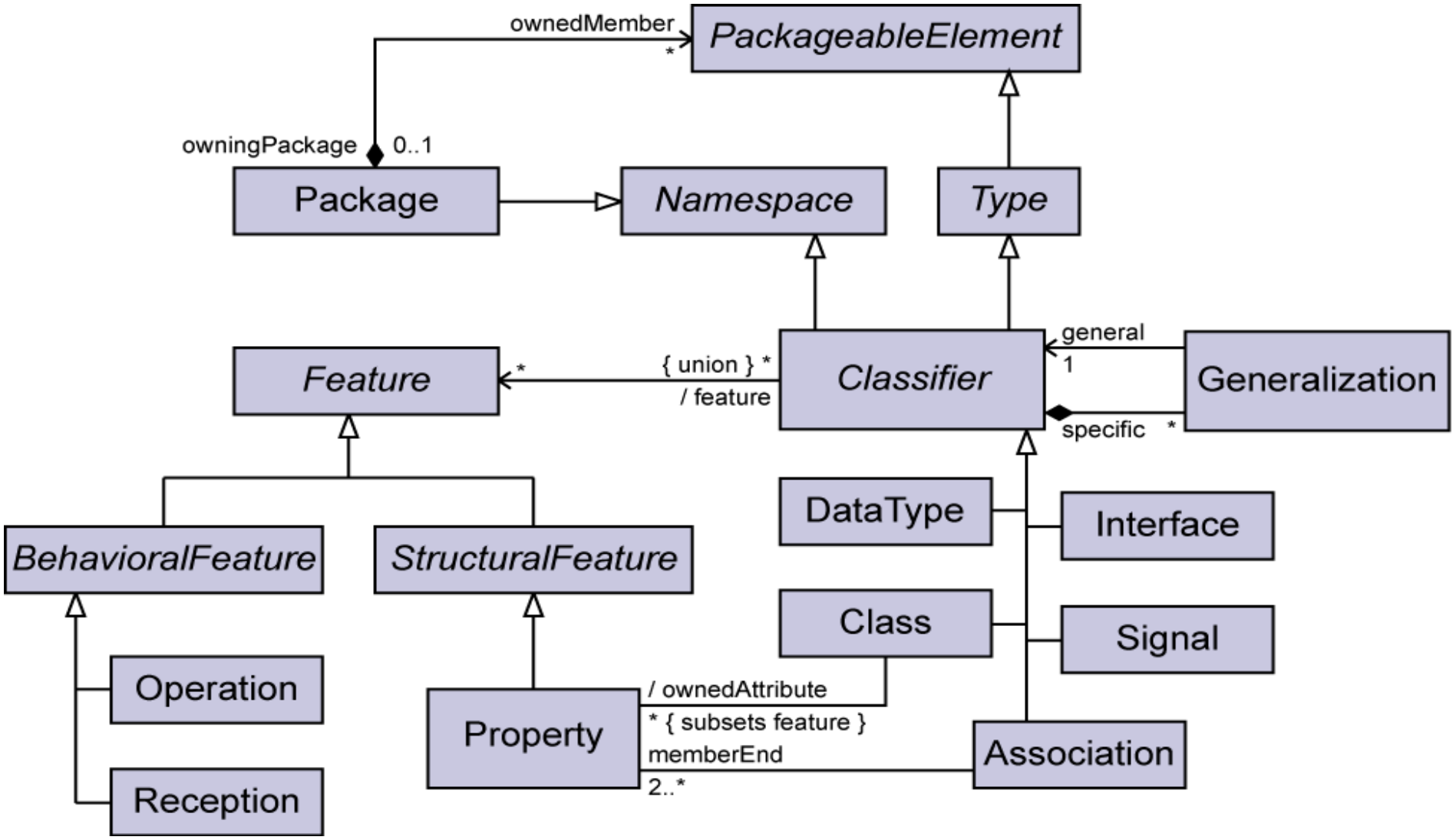
- The receiving package defines the increment.
- The receiving package is simultaneously the resulting package.
- Merging is achieved by (lengthy) transformation rules (not defined for behaviour).
- Package merging is used extensively in the UML 2 specification.





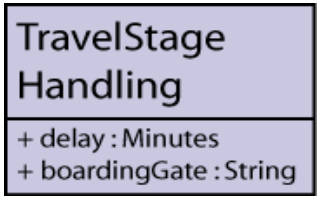


Metamodel


ownedMember
*
PackageableElement
owningPackage
0..1
Package
Namespace
Type
Feature
*
{ union } *
/ feature
Classifier
general
1
Generalization
specific
*
BehavioralFeature
StructuralFeature
DataType
Interface
Class
Signal
Operation
Reception
Property
/ ownedAttribute
* { subsets feature }
memberEnd
2..*
Association

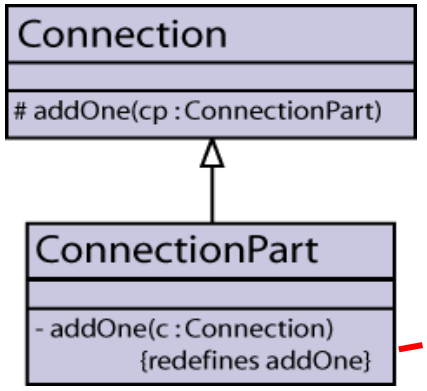
Features

- … belong to a namespace (e.g., class or package)



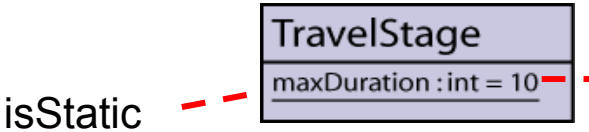
Visibility kinds (no default)

		visible to elements …
+	public	that can access owning namespace (by membership, import, or access)
#	protected	with generalization to owning namespace
~	package	in the same package as the owning namespace
-	private	in owning namespace only



- … are redefinable (unless decorated by { leaf })
  - in classes that specialize the context class

- … can be defined on instance or class level

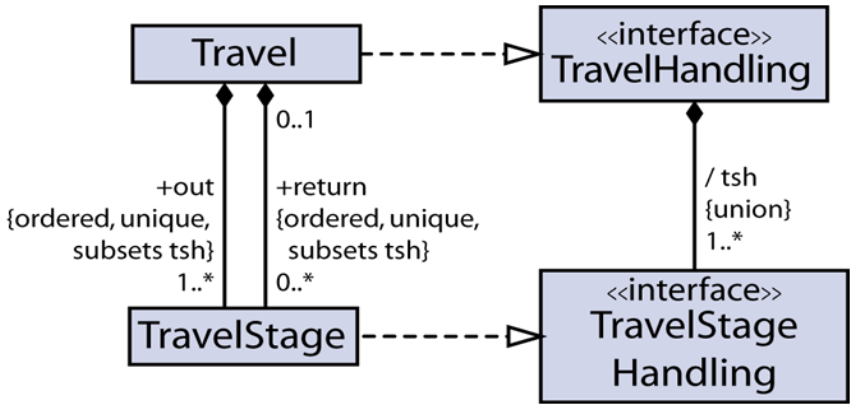


Properties

Aggregation kinds (default: *none*)

none		reference
shared		undefined (!)
composite		value

{ ordered }	{ unique }	Collection type
√	√	`OrderedSet`
√	×	`Sequence`
×	√	`Set` (default)
×	×	`Bag`



/ ({ derived })	can be computed from other information (default: false)
{ readOnly }	can only be read, not written (default: false = unrestricted)
{ union }	union of subset properties (implies derived)
{ subsets … }	which property this property is a subset of

Behavioral features

- … are realized by behaviors (e.g., code, state machine).
  - { abstract } (virtual) behavioral features declare no behavior
    - behavior must be provided by specializations
  - Exceptions that may be thrown can be declared
  - Limited concurrency control
    - { active } classes define their own concurrency control

active class (with own behavior which starts on instance creation)

    - in passive classes:

Call concurrency kinds (no default)

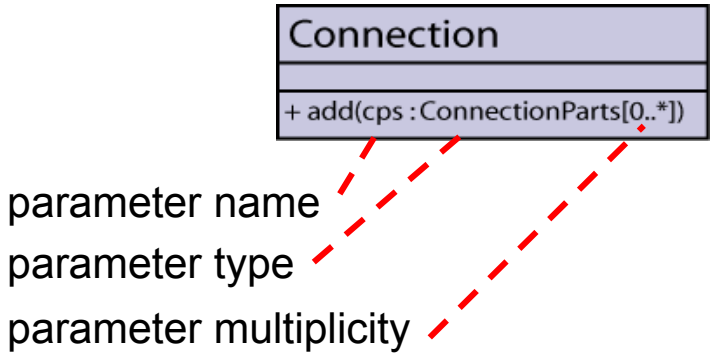
{ sequential }	no concurrency management
{ guarded }	only one execution, other invocations are blocked
{ concurrent }	all invocations may proceed concurrently

Operations (1)

- An **operation** specifies the name, return type, formal parameters, and constraints for invoking an associated behaviour.
  - «pre» / «post»
    - precondition constrains system state on operation invocation
    - postcondition constrains system state after operation is completed
  - { query }: invocation has no side effects
    - «body»: body condition describes return values
  - { ordered, unique } as for properties, but for return values
  - exceptions that may be thrown can be declared

Parameter direction kinds (default: in)

in	one way from caller
out	one way from callee
inout	both ways
return	return from callee (at most 1)



Operations (2)

- Several *semantic variation points* for operations
  - What happens, if a precondition is not satisfied on invocation?
  - When inherited or redefined
    - invariant, covariant, or contravariant specialization?
    - How are preconditions combined?

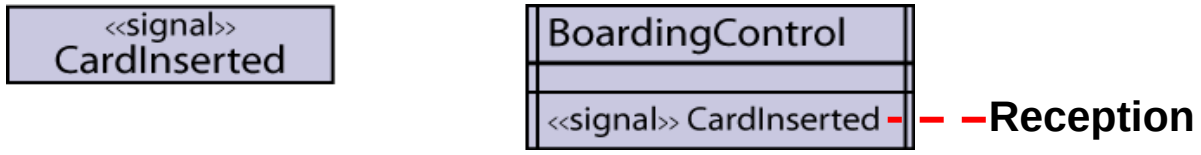
- **No predefined resolution principle** for inherited or redefined operations
  - “The mechanism by which the behavior to be invoked is determined from an operation and the transmitted argument data is a semantic variation point.”
  - a single-dispatch, object-oriented resolution principle is mentioned explicitly in the UML 2 specification

- Operation invocations may be **synchronous** or **asynchronous**.

Signals and receptions

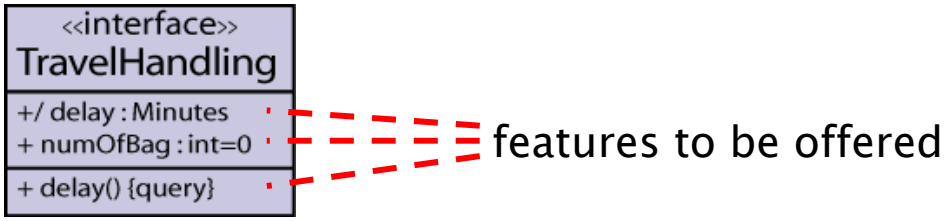
- A **signal** is a specification of type of send request instances communicated between objects.
  - Signals are classifiers, and thus may carry arbitrary data.
  - A signal triggers a reaction in the receiver in an asynchronous way and without a reply (no blocking on sender).

- A **reception** is a declaration stating that a classifier is prepared to react to the receipt of a signal.
  - Receptions are behavioral features and thus are realized by behavior (e.g., a state machine).

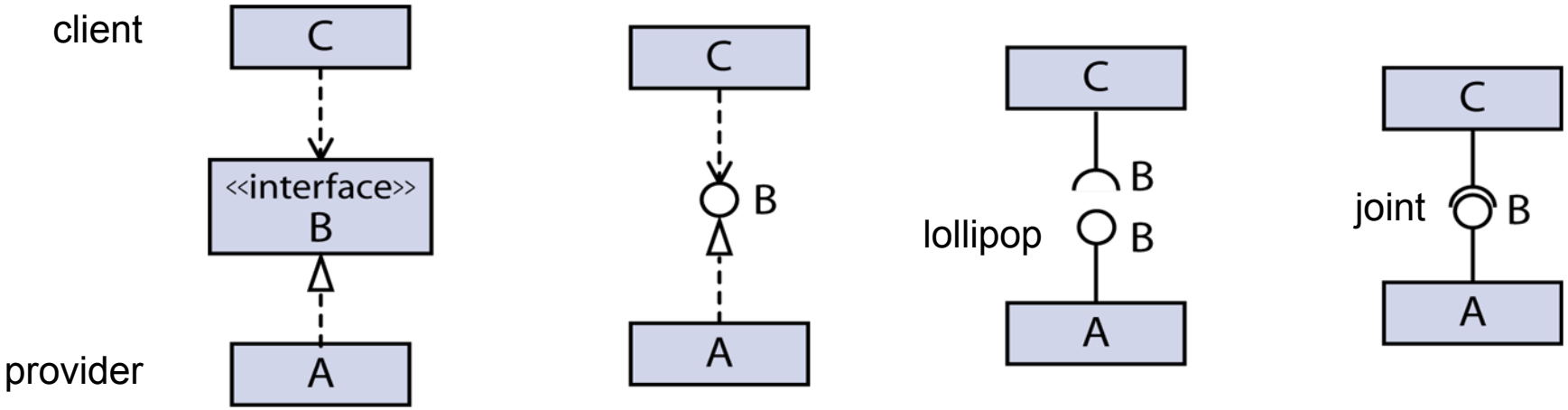


Interfaces

- **Interfaces** declare a set of coherent public features and obligations.
  - i.e., specify a contract for implementers (realizers)

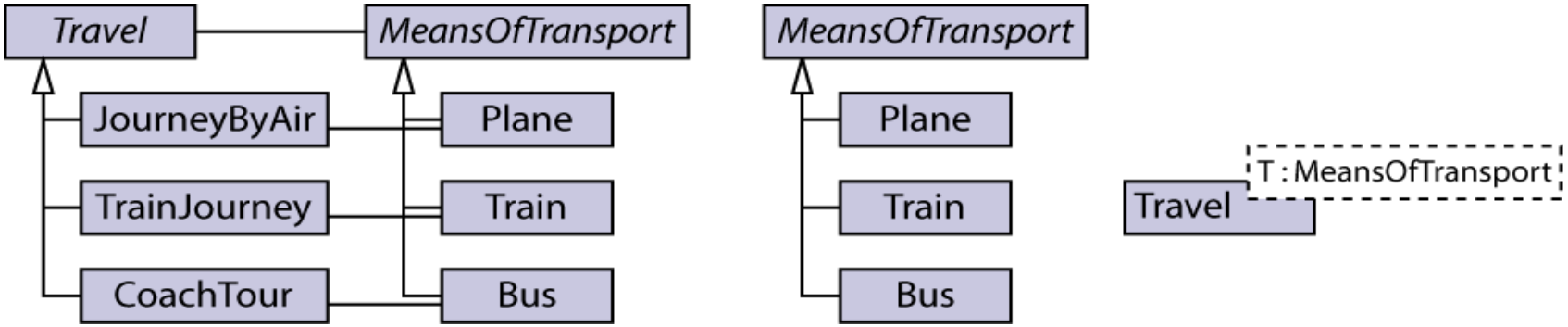


Several notations for client/provider relationship



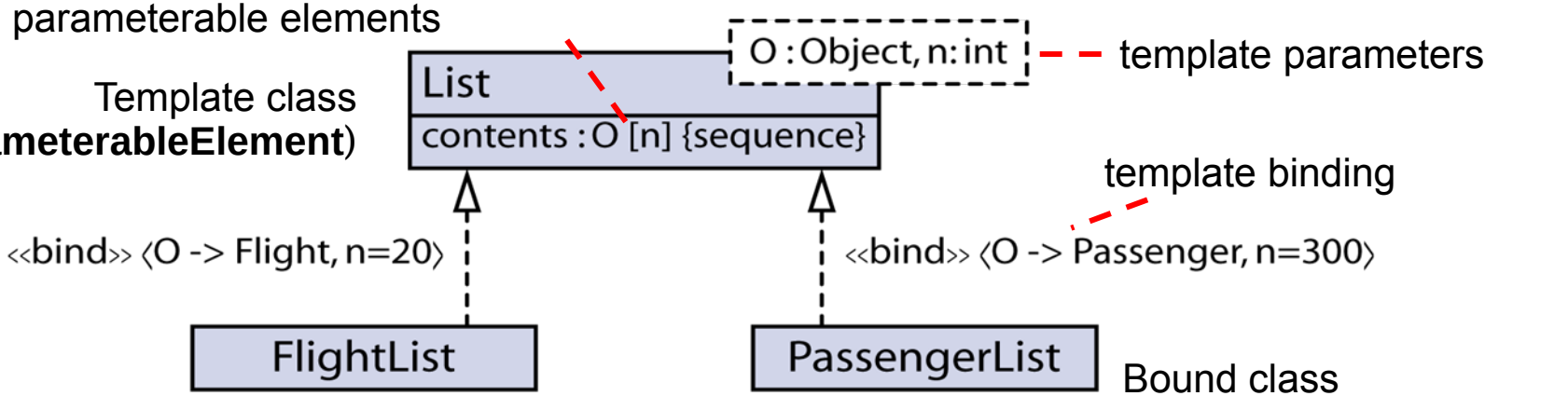
Templates

subtype polymorphism vs. **parametric** polymorphism



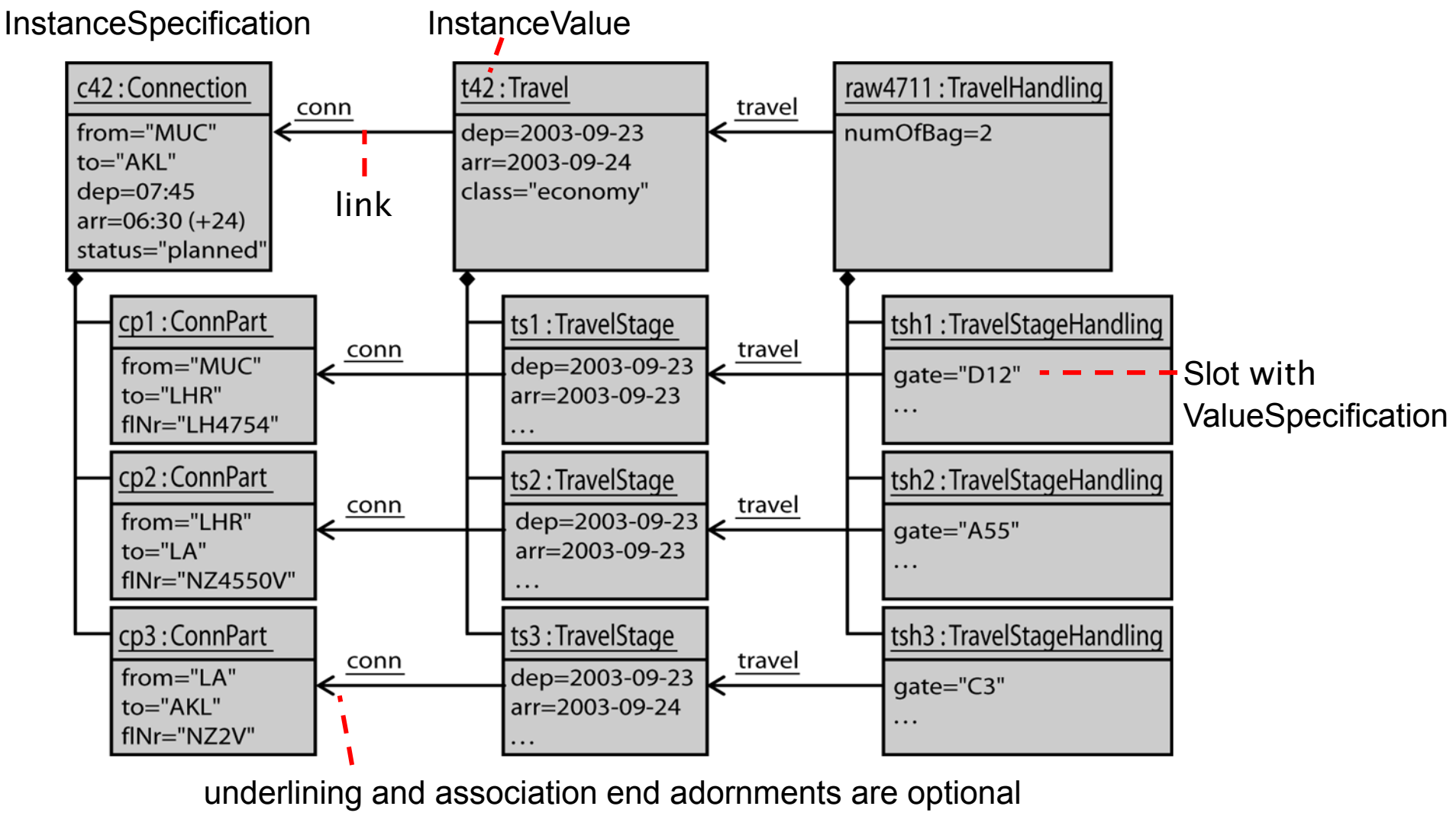
exposed parameterable elements

Template class
(**ParameterableElement**)



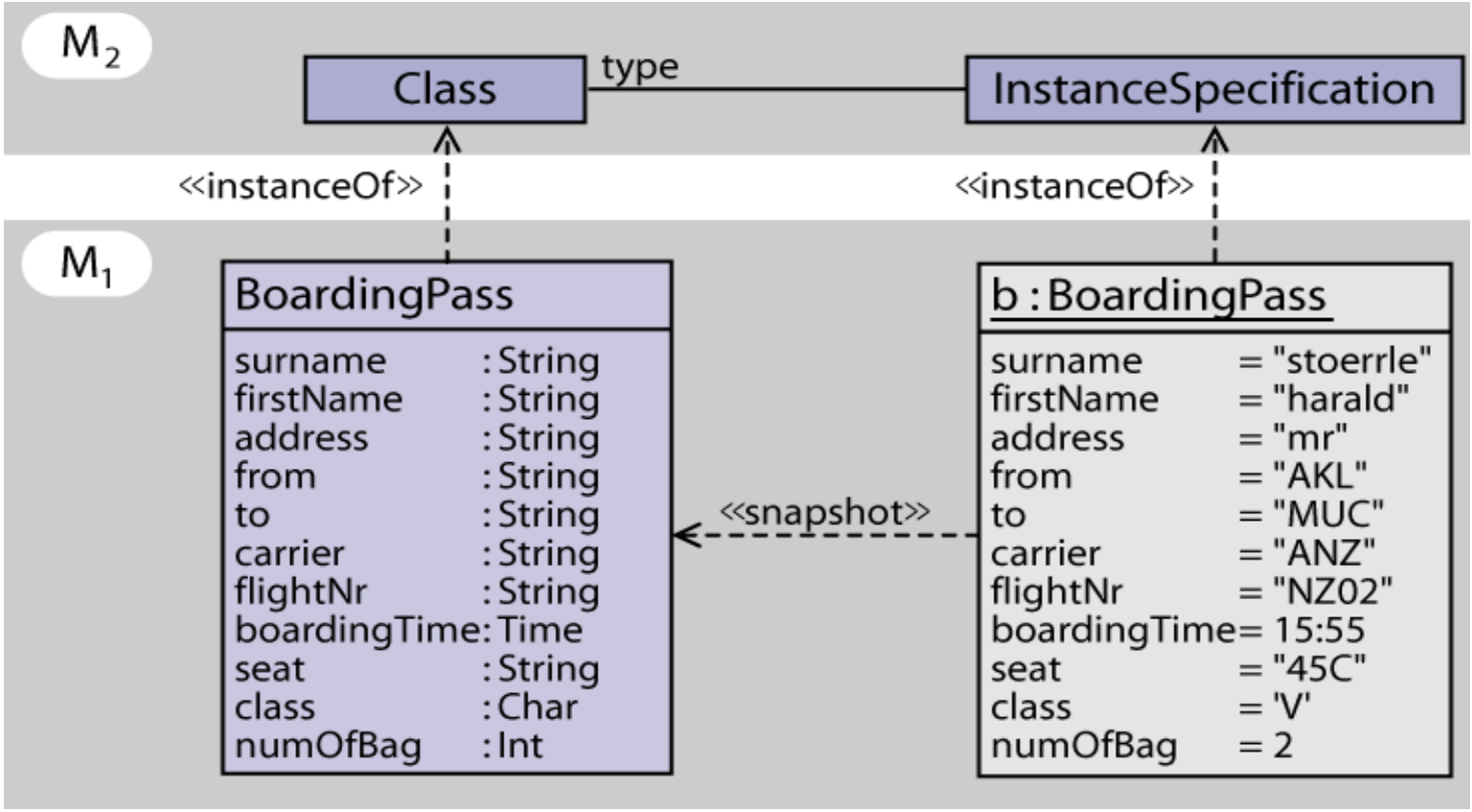
Bound class
(**TemplateableElement**)

Object diagram



Instances specifications

UML metamodel



user model

Wrap up

- **Classifiers** and their **Relationships** describe the vocabulary of a system.
- Classifiers describe a set of instances with common **Features**.
  - StructuralFeatures (Properties)
  - BehavioralFeatures (Operations, Receptions)
- **Associations** describe structural relationships between classes.
  - Association ends are Properties.
- **Generalizations** relate specific Classifiers to more general Classifiers.
- **Packages** group elements
  - and provide a Namespace for grouped elements.
- **InstanceSpecifications** and links describe system snapshots.