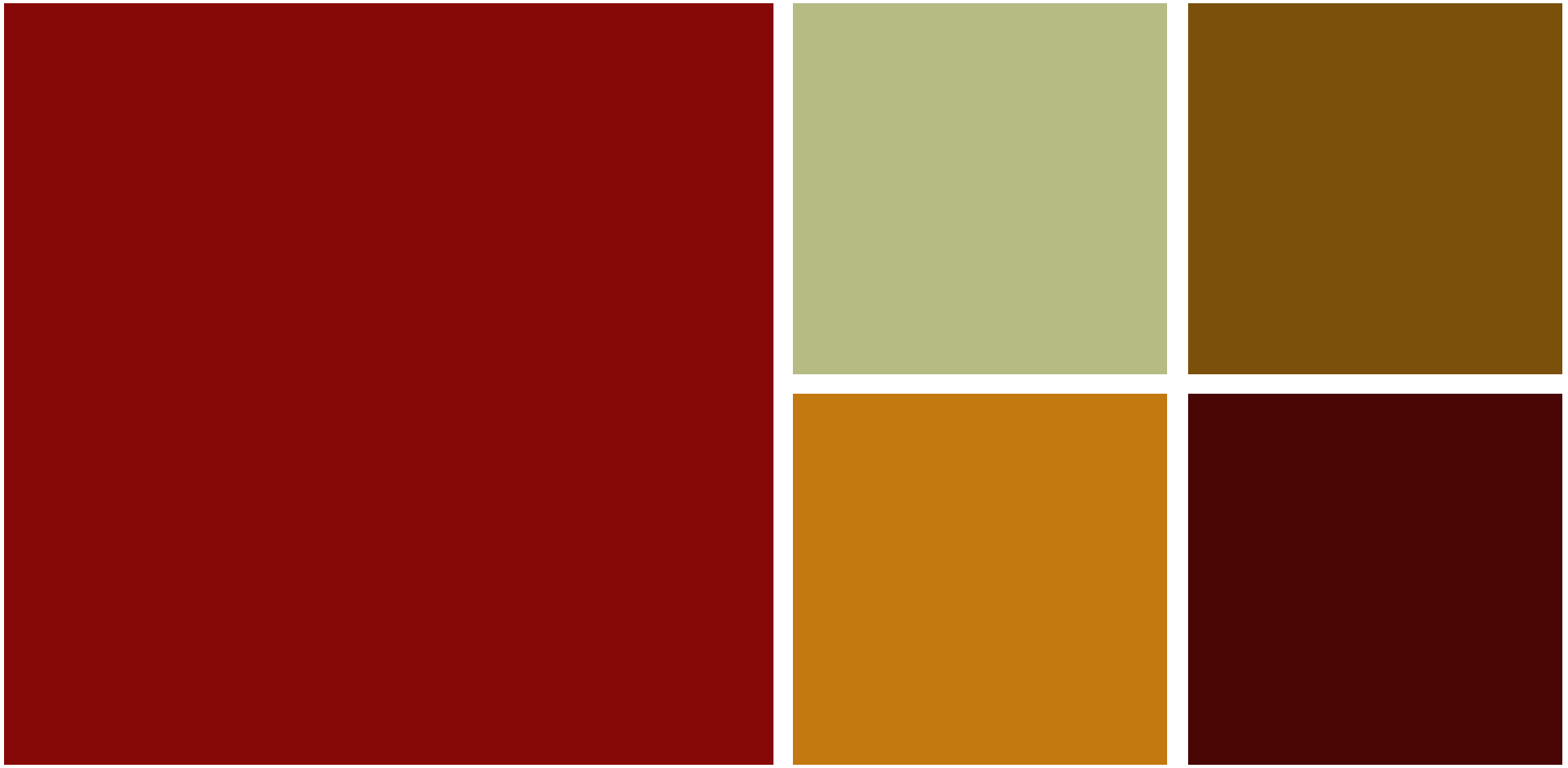


Software Architecture in Action

Flavio Oquendo, Jair C Leite, Thais Batista

Chapter 16

Blackboard Architectural Style

Learning outcomes of this chapter

- You will learn:
  - what is a Blackboard architectural style
  - what are its elements, structure and behavior

The structure of this chapter

- Conceptual Overview
- The Blackboard structural viewpoint
- The Blackboard behavioral viewpoint
- Tuple Space
- An Example of Blackboard in RTC System
- Summary

Conceptual Overview

Blackboard

Conceptual overview – 1/2

- In the Blackboard architectural style, there is a shared data structure – the blackboard – and multiple knowledge sources that interact with each other using the blackboard
  - the knowledge sources write information in the blackboard and read information from the blackboard (inspect the blackboard)
  - the blackboard is the central element that coodinates the interaction between the knowledge sources

Blackboard

Conceptual overview – 2/2

- An example Blackboard style is the use of a Blackboard style to design the architecture of an image processing system where the image acting as the blackboard is annotated with recognition elements by different knowledge sources.
- Each knowledge source could use a different algorithm of image processing cooperatively achieving the image recognition

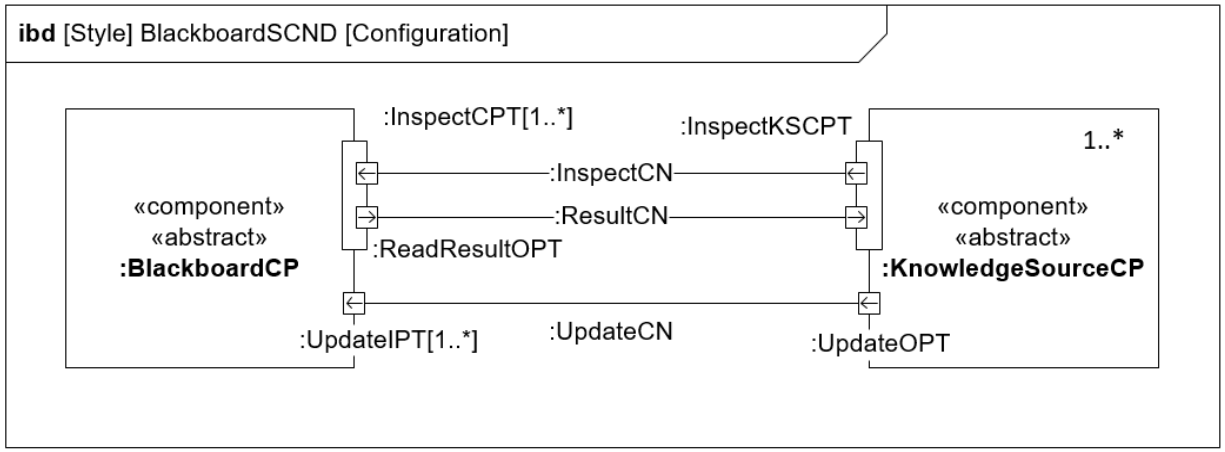
Blackboard

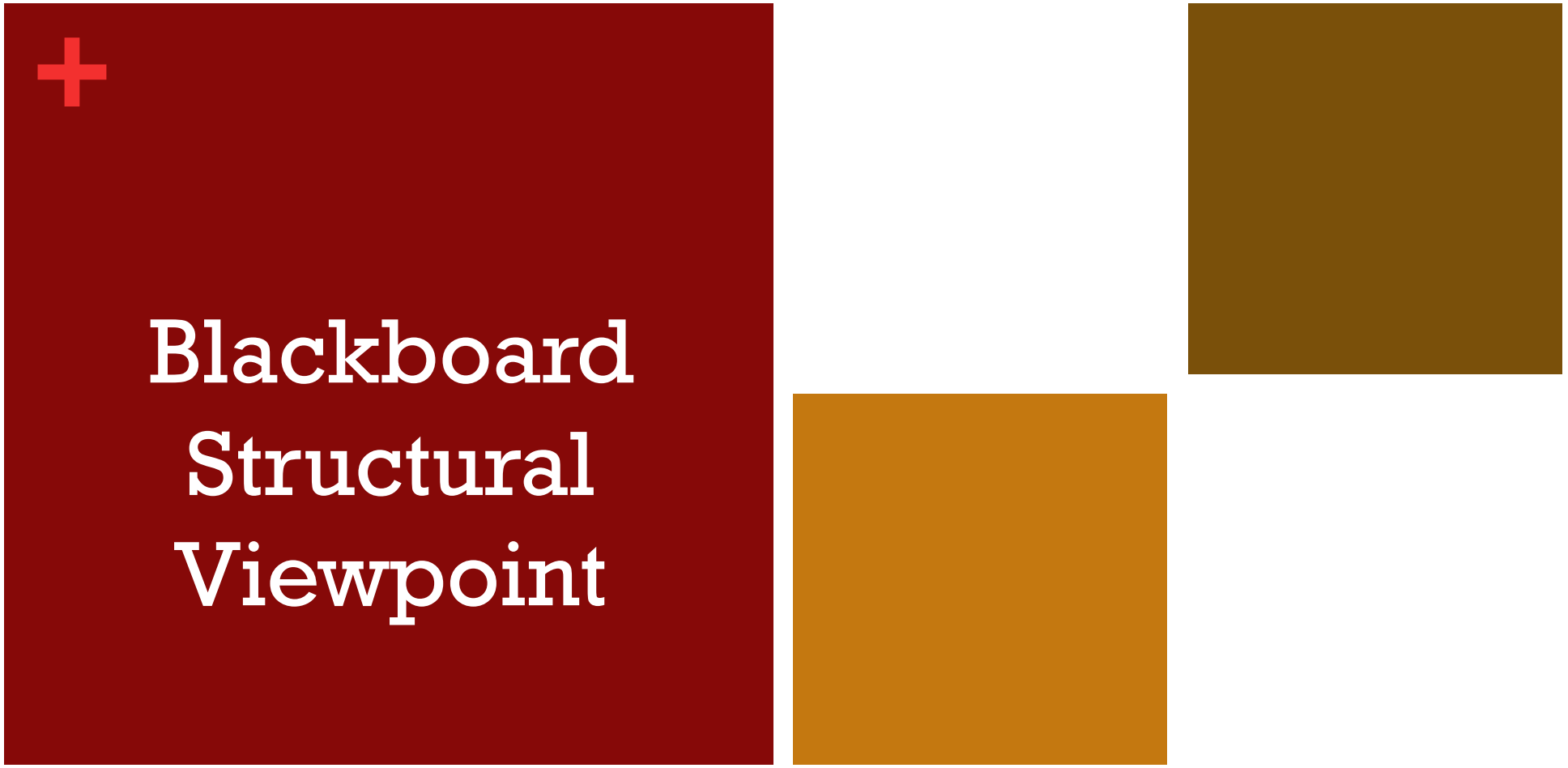
Use in SysADL

Use in SysADL

- We can use the Blackboard style to model a part of the system that has a shared component – the *BlackbBoardCP* – and multiples knowledge sources that interact using it – the *KnowledgeSourceCP*.
  - The *BlackboardCP* component sends data to one or more *KnowledgeSourceCP* components
  - The *KnowledgeSourceCP* components send data to update the *BlackboardCP* component

Blackboard Use




Blackboard
Structural
Viewpoint

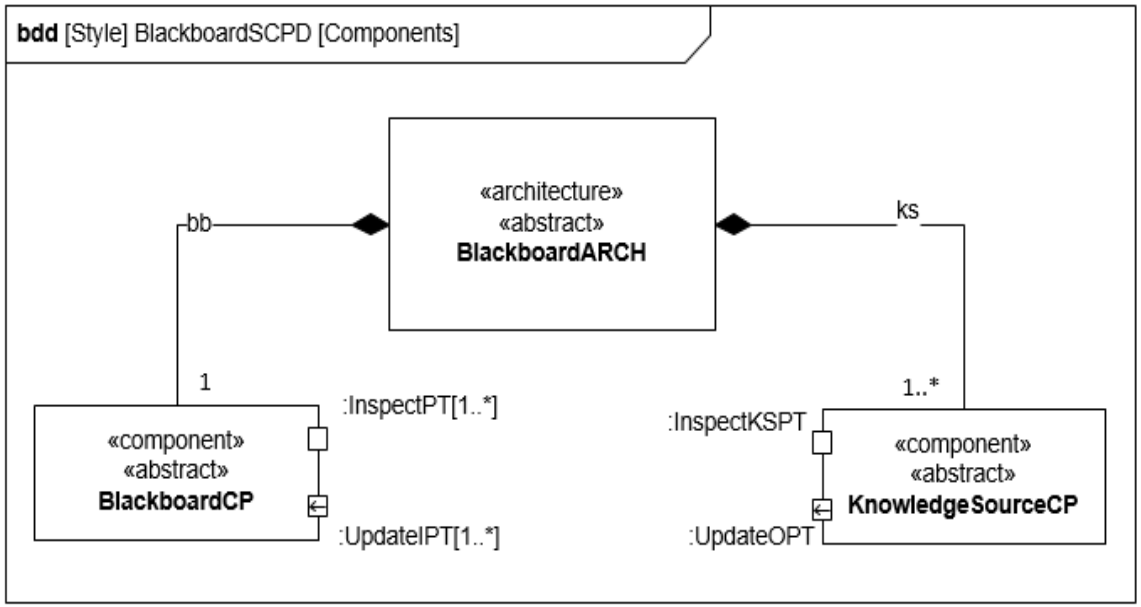
Blackboard Components

Components in SysADL

Blackboard Components

- We define the Blackboard architectural style using the bdd
  - The Blackboard Architecture Style (BlackboardARCH) is composed by one BlackboardCP and one or more KnowledgeSourceCP

Components Definitions in SysADL



Blackboard Ports

Ports Definition in SysADL – 1/2

Blackboard Ports Definition

- In the Blackboardarchitectural style definition, we must also define the ports
  - The *BlackboardCP* component has an *in* port (*UpdateIPT*) to receive data of any type from one or more *KnowledgeSourceCP*
  - The *KnowledgeSourceCP* component has an *out* port *UpdateOPT* to send data of any type to the *BlackboardCP*

Ports in SysADL

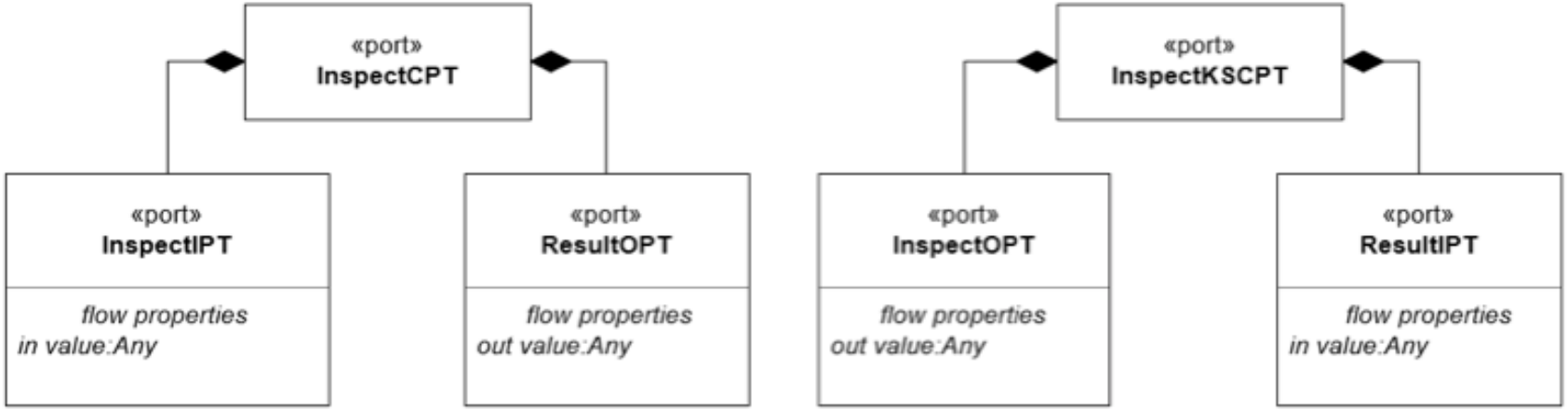
Blackboard Ports

Ports Definition in SysADL – 2/2

Blackboard Ports Definition

- Both *BlackboardCP* and *KnowledgeSourceCP* components have composite ports to interact with each other
  - The *InspectCPT* composite port, composed of a *InspectIPT in* port and a *ResultOPT* out port,
  - The *InspectKSCPT* composite port, composed of a *InspectOPT out* port and a *ResultIPT in* port.

Ports in SysADL



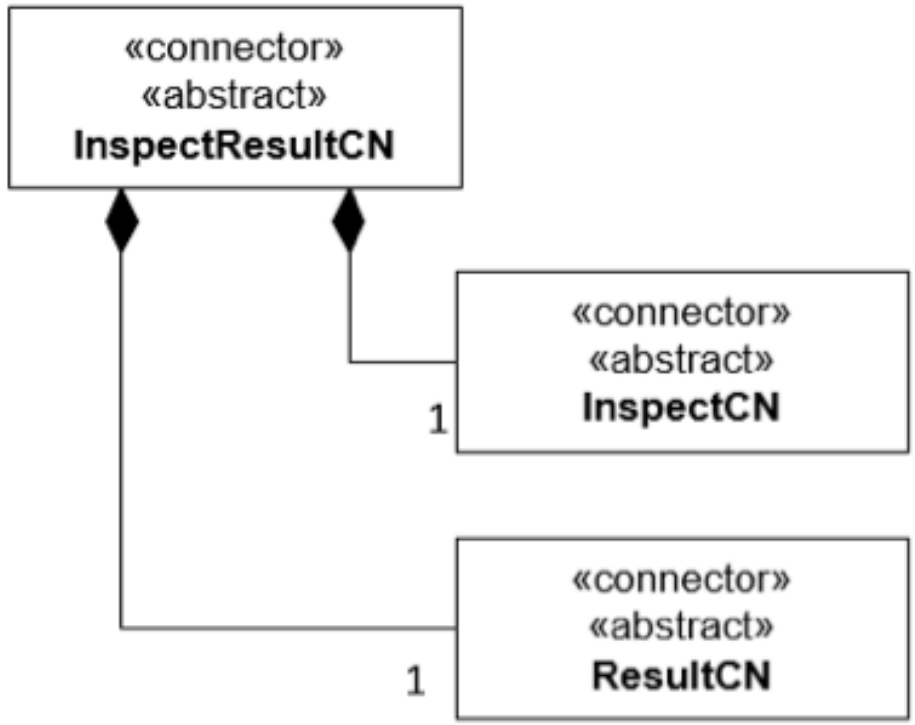
Blackboard Connectors

Connectors in SysADL – 1/3

Connectors Definition

- In the Blackboard architectural style definition, we must also define the connectors that link the *BlackboardCP* to the *KnowledgeSourceCP* components
  - The *InspectResultCN* connector is composed of two connectors: *InspectCN* and *ResultCN*, each one is linked to the composite ports of the *BlackboardCP* and *KnowledgeSourceCP* components

Definition in SysADL



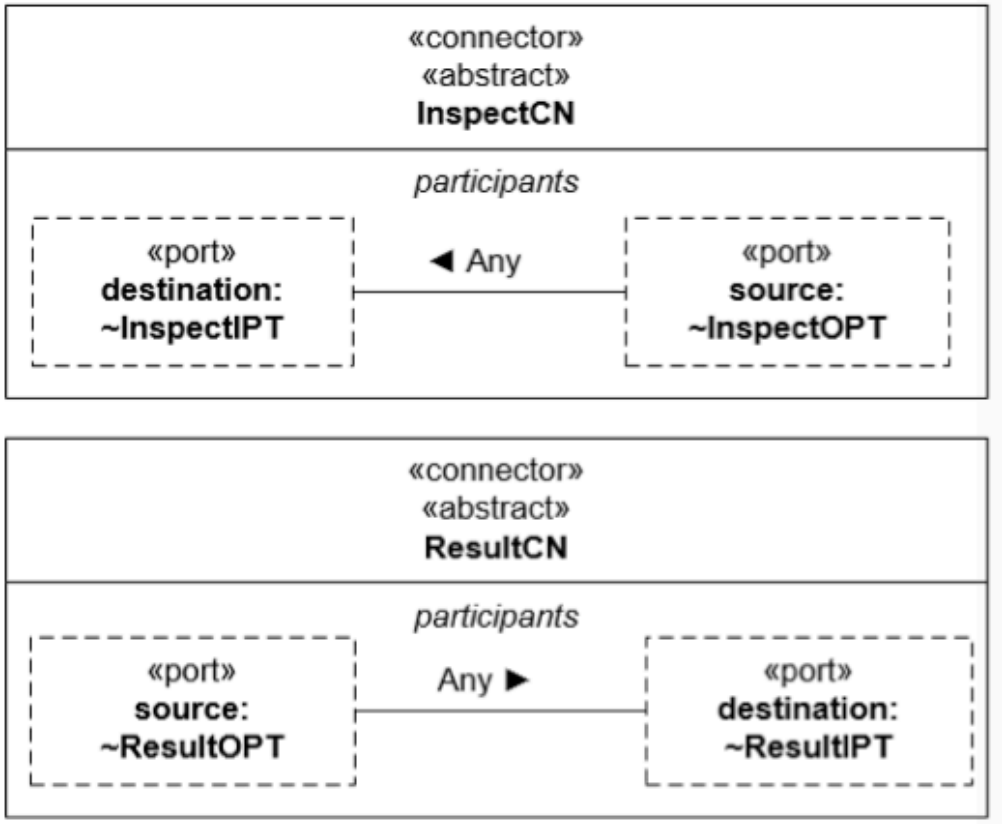
Blackboard Connectors

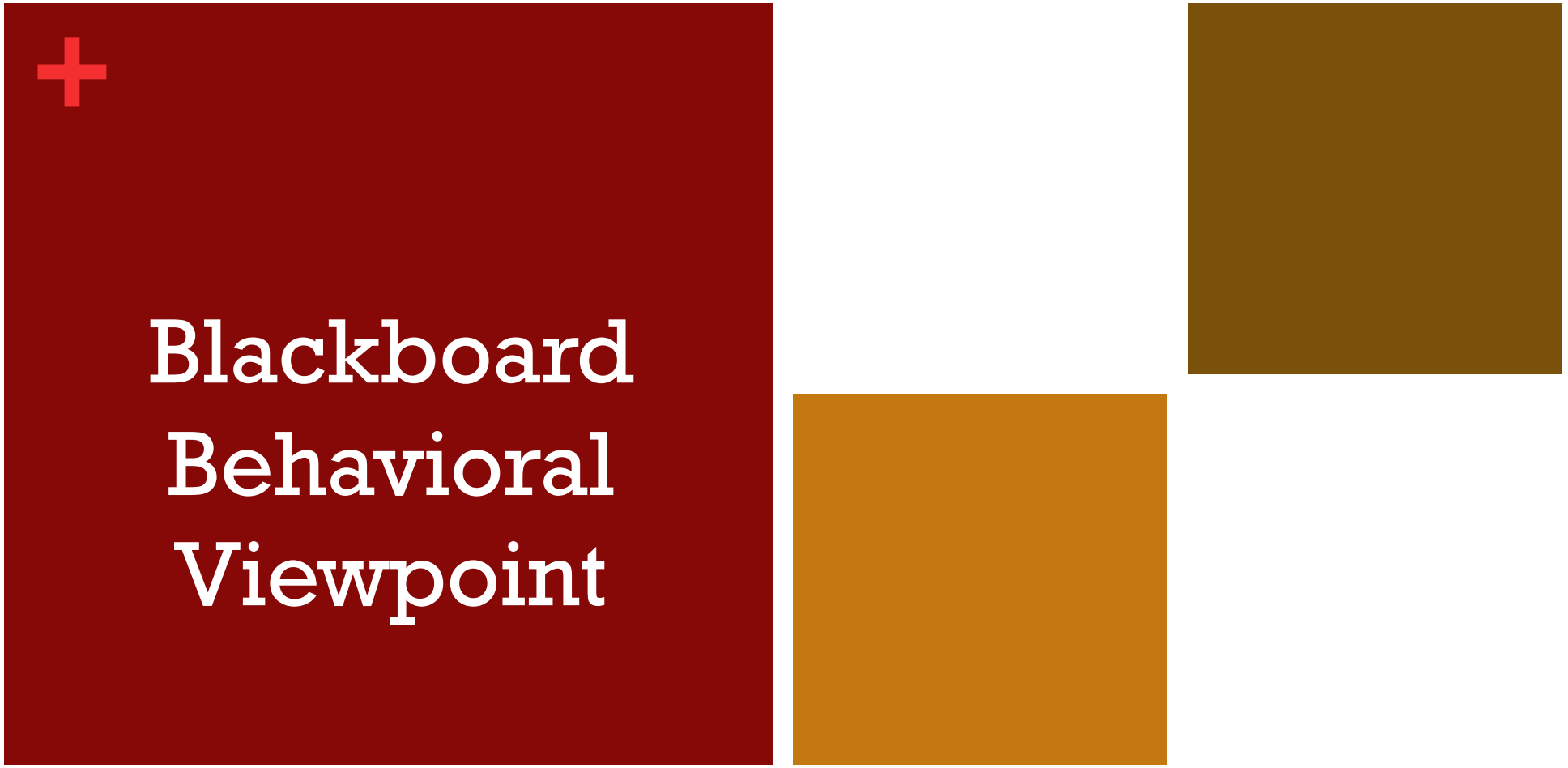
Connectors in SysADL – 2/3

Blackboard Connectors

- The InspectCN connector and the ResultCN connector, that are part of the InspectResultCN composite port send any type of data from their respective source participant port to the destination participant port

Definition in SysADL




Blackboard
Behavioral
Viewpoint

Blackboard Behavioral Viewpoint

Conceptual Overview

- We can specify the behavior of a Blackboard style using activity diagrams specifying the behavior of the connectors and the protocols of the ports

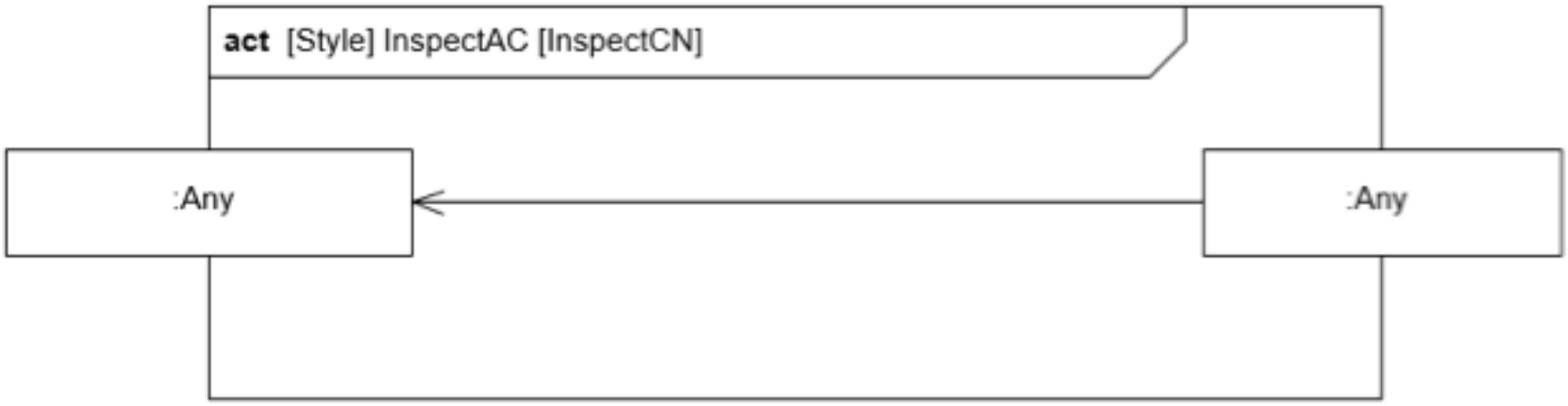
Blackboard Behavior

Connector Behavior in SysADL – 1/3

Blackboard Connector Behavior - InspectAC

- We define the behavior of the *InspectResultCN* connector by defining the behavior of the two compound connectors: *InspectCN* and *ResultCN*
  - We define the behavior of the *InspectCN* connector using the *InspectAC* activity diagram

Behavior in SysADL - InspectAC



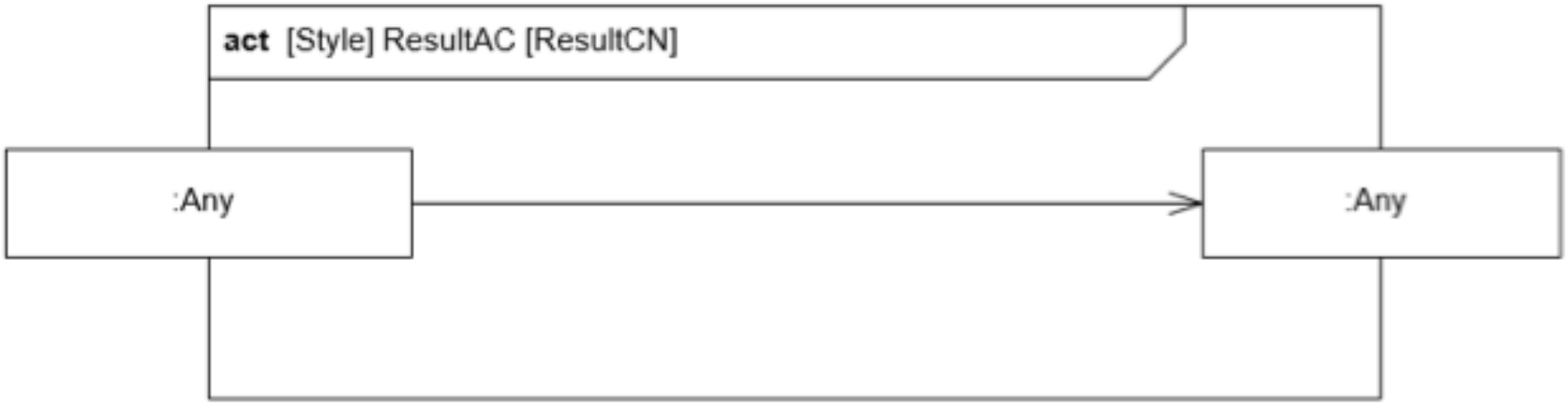
Blackboard Behavior

Connector Behavior in SysADL – 2/3

Blackboard Connector Behavior - ResultAC

- The *ResultAC* activity diagram represents the behavior of the *ResultCN* connector, by sending to its *out* pin any data received in its *in* pin

Behavior in SysADL - RasultAC



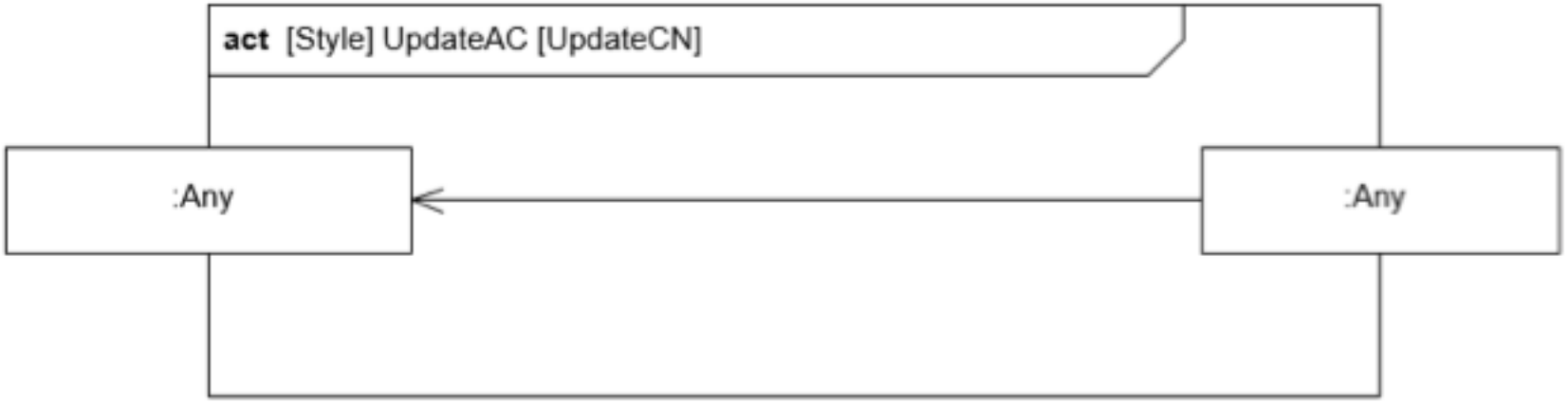
Blackboard Behavior

Connector Behavior in SysADL – 3/3

Blackboard Connector Behavior - UpdateAC

- We define the behavior of the *UpdateCN* connector using the *UpdateAC* activity diagram
  - The connector sends to its *out* pin any data received in its *in* pin

Behavior in SysADL - UpdateAC



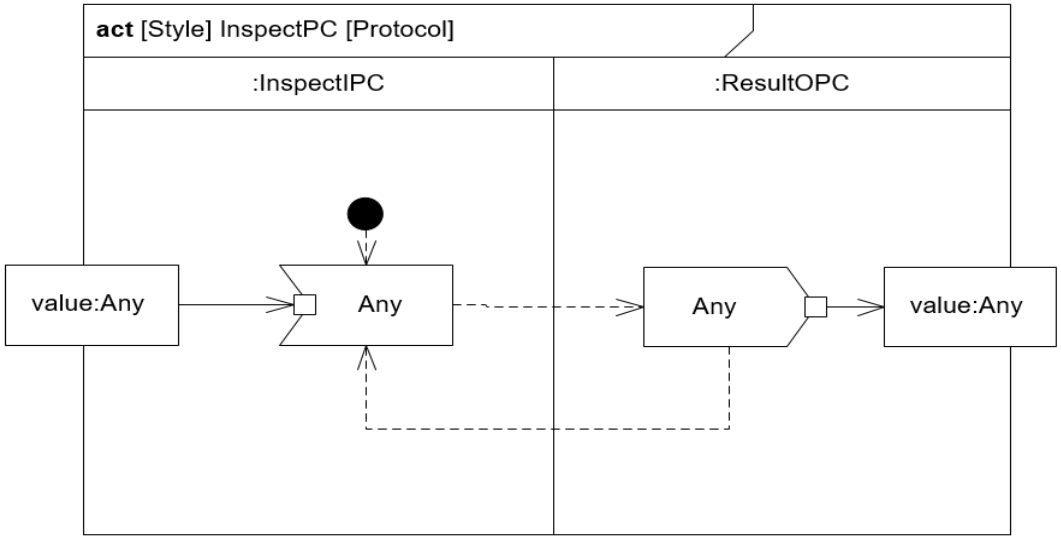
Blackboard Behavior

Blackboard Ports Protocol – 1/5

Blackboard Ports Protocol

- We define the protocols of the ports using activity diagrams. Since we have two composite ports, we define the protocol of the composite ports
  - the protocol of the *InspectCPT* port states that first a value is received via the *InspectIPT* port, then a value is sent via the *ResultOPT* port and so on

Protocol specifiation in SysADL



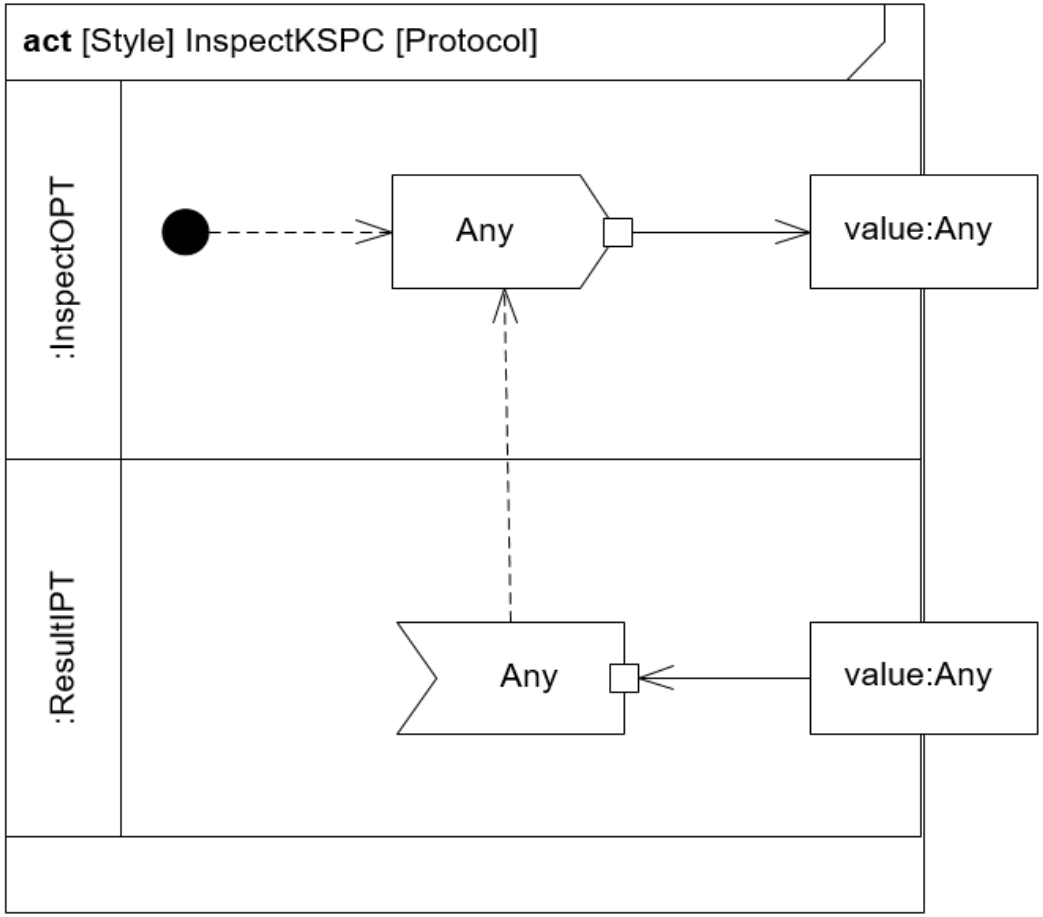
Blackboard Behavior

Blackboard Ports Protocol – 2/5

Protocol specifiation

- The *InspectKSPT* composite port protocol states that first a value is sent via the *InspectOPT* port
- then a value is received via the *ResultIPT* port
- The control then goes back to the InspectOPT port

Protocol in SyADL



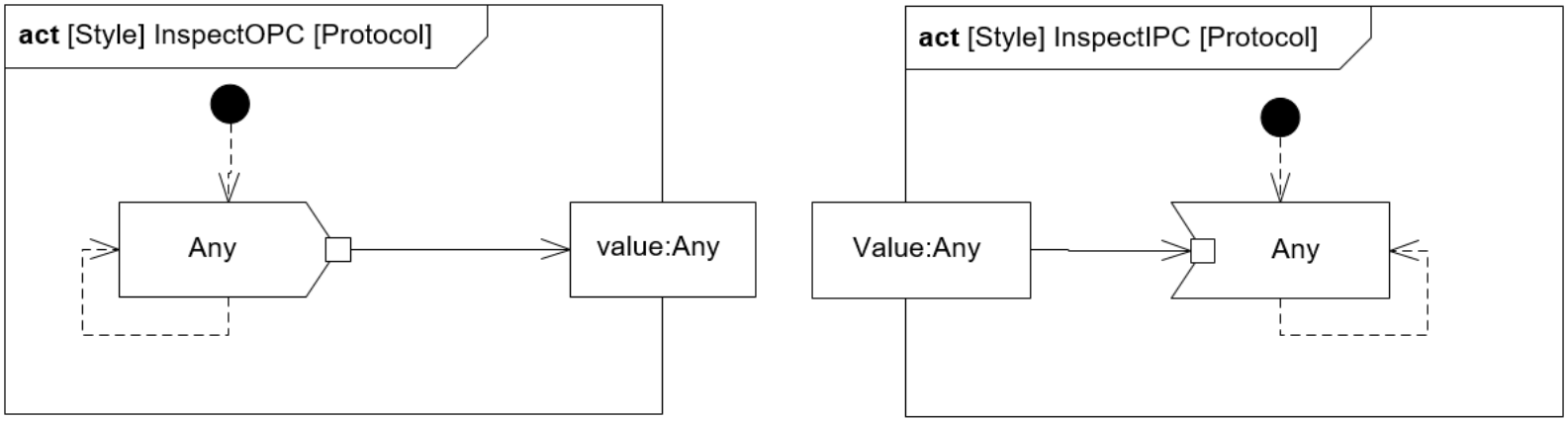
Blackboard Behavior

Blackboard Ports Protocol – 3/5

Blackboard Ports Protocol

- We define the protocols of the individual *InspectCPT* ports.
  - The *InspectIPT* internal port initiates by receiving data from its *in* pin, and then it waits to receive another value.
  - The *InspectOPT* internal port initiates by sending a value of any type to its *out* pin, and then it waits to send another value

Blackboard Ports Protocol in SysADL



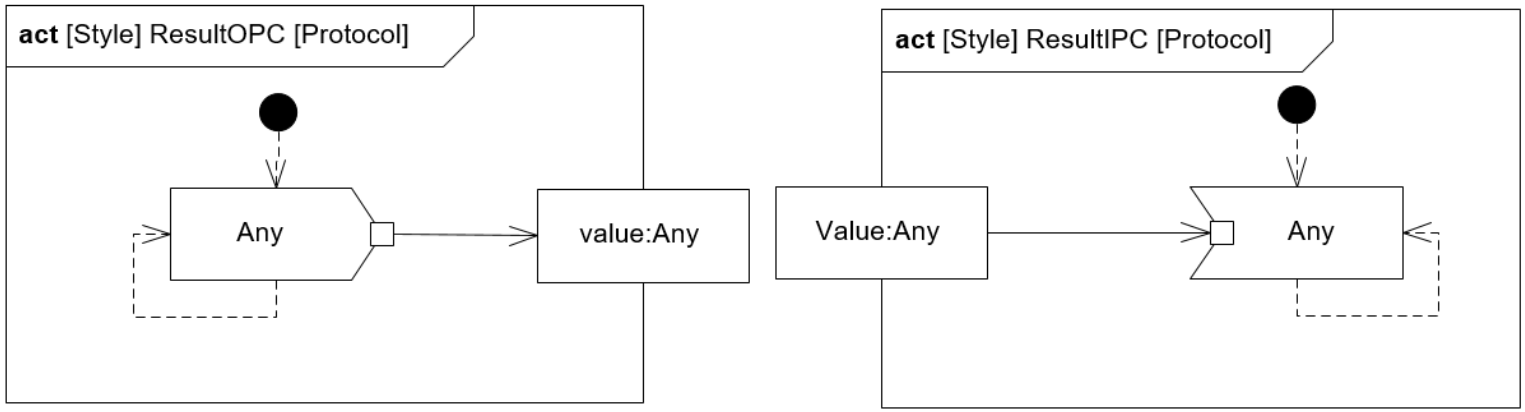
Blackboard Behavior

Blackboard Ports Protocol – 4/5

Blackboard Ports Protocol

- We define the protocols of the individual *ResultCPT* ports.
  - The *ResultIPT* internal port initiates by receiving data from its *in* pin, and then it waits to receive another value.
  - The *ResultOPT* internal port initiates by sending a value of any type to its *out* pin, and then it waits to send another value

Blackboard Ports Protocol in SyADL



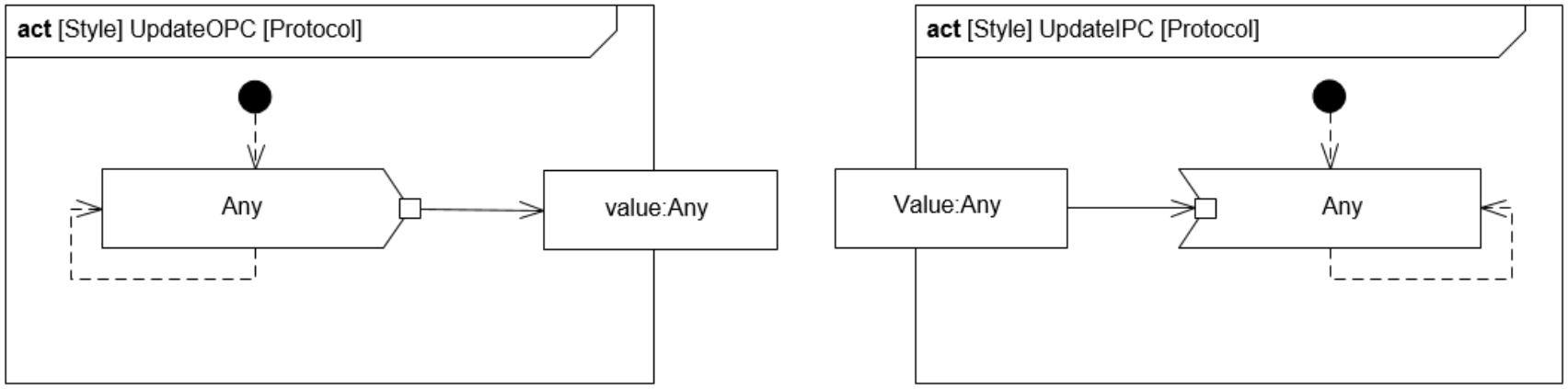
Blackboard Behavior

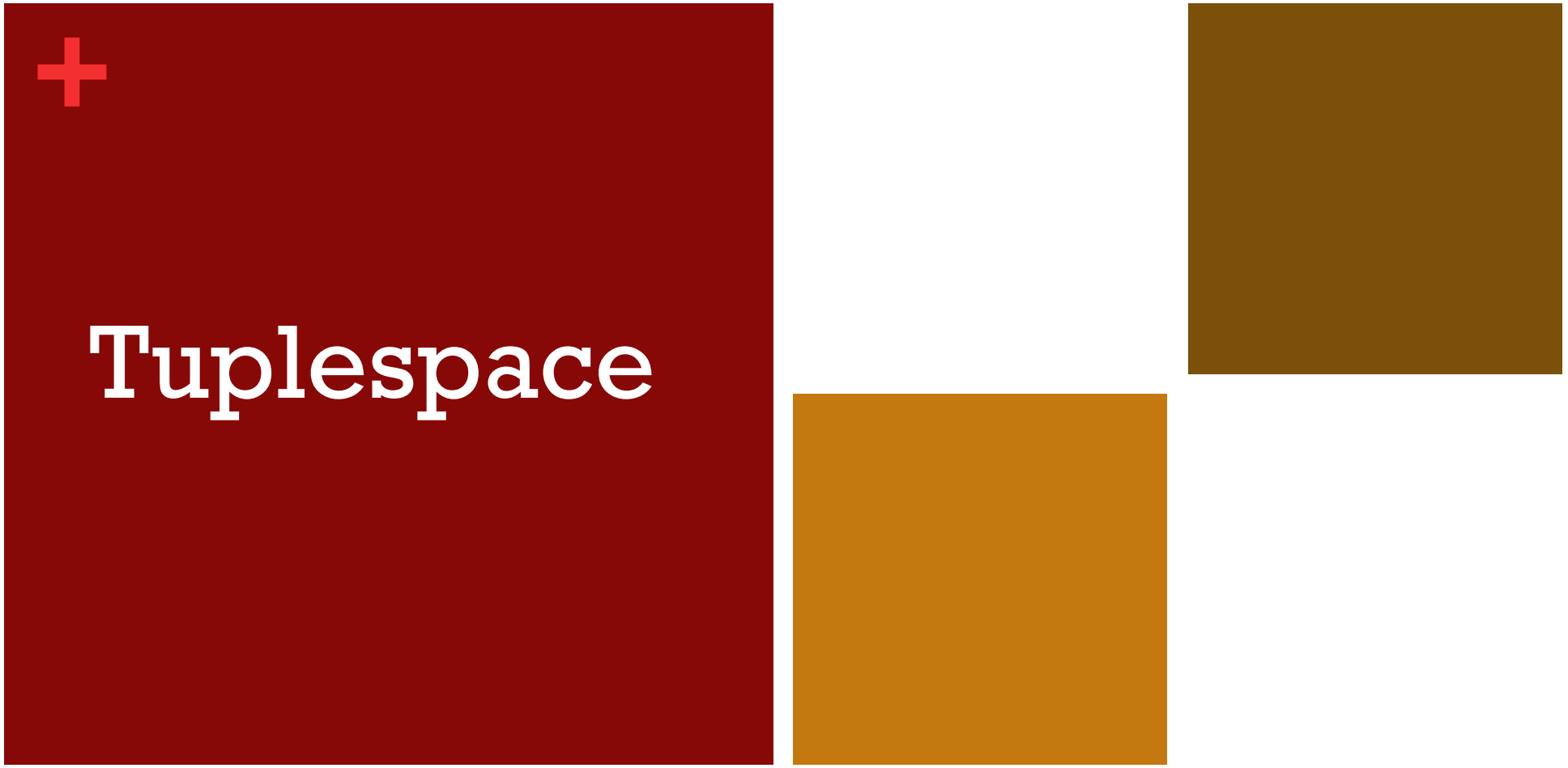
Blackboard Ports Protocol – 5/5

Blackboard Ports Protocol

- We define the protocols of the protocol of the individual *Update* ports
  - The *UpdateOPT* port initiates by sending a value of any type to its *out* pin, and then it waits to send another value
  - The *UpdateIPT* port initiates by receiving data from its *in* pin, and then it waits to receive another value

Blackboard Ports Protocol in SyADL




Tuplespace

Tuplespace

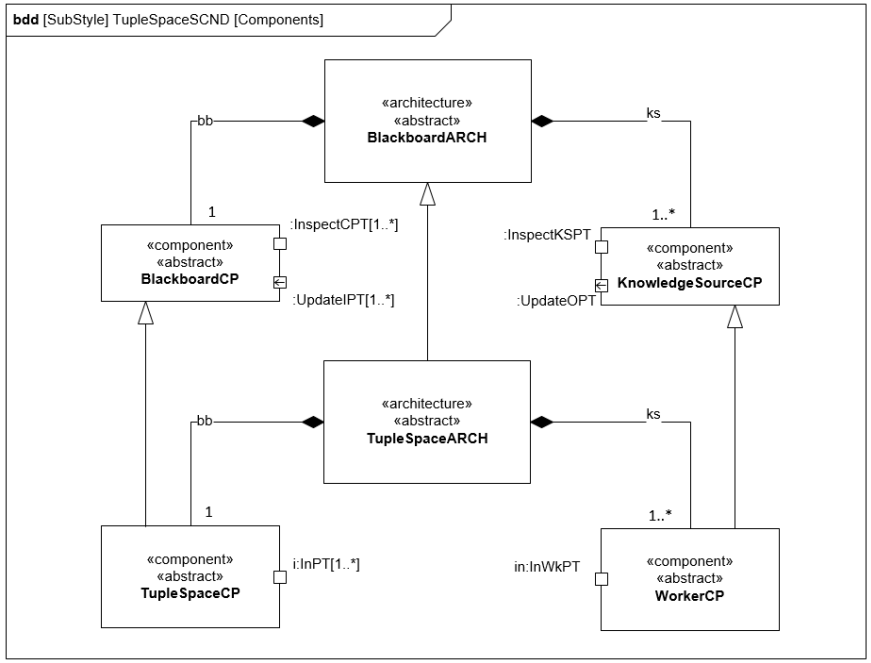
Conceptual Overview

- The Tuplespace style is a substyle of the Blackboard style that defines a tuple space providing a shared memory (a blackboard) where tuples (data) are inserted and retrieved by other components

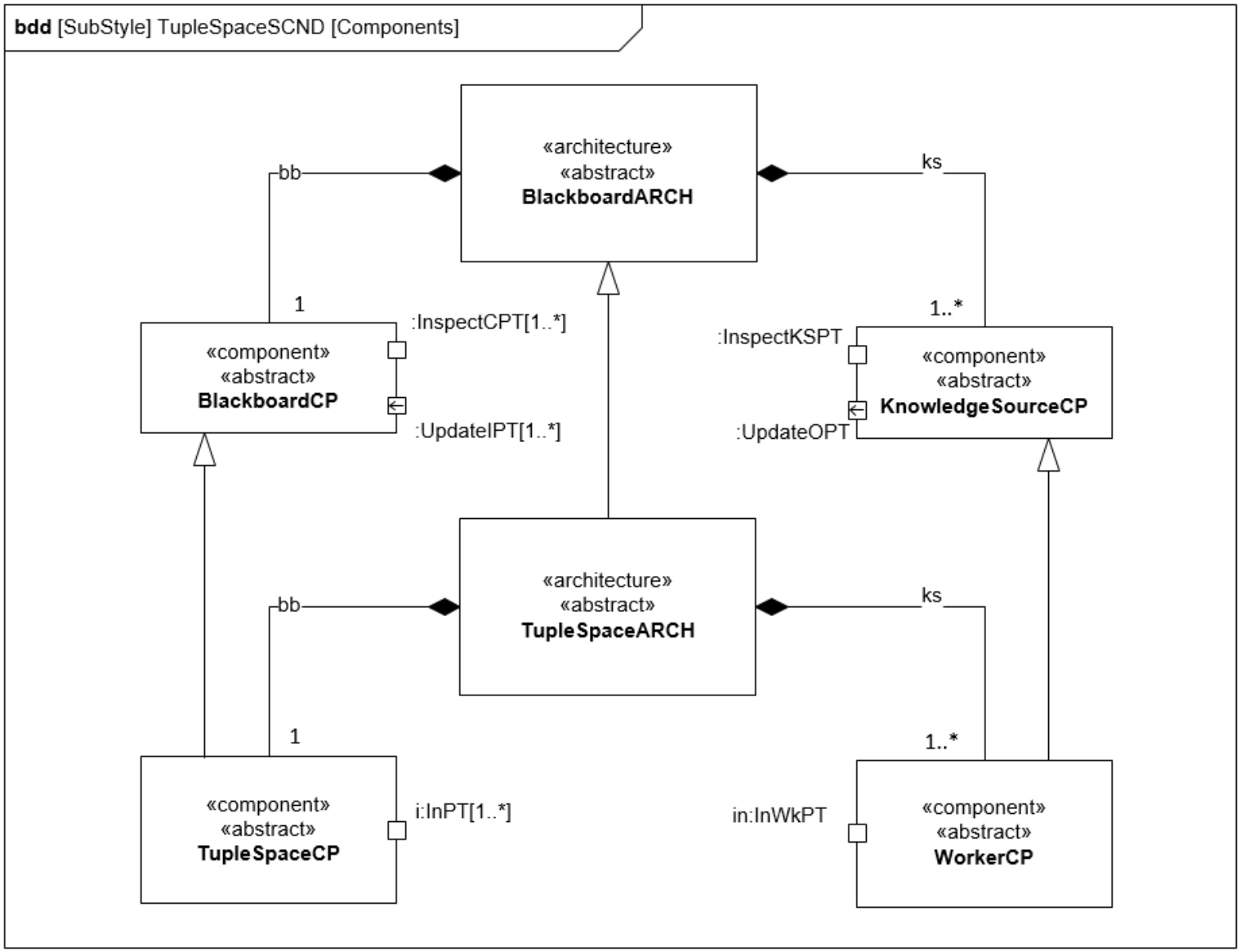
Tuplespace

Definition

- We show here the definition of the Blackboard style where the *TupleSpaceSP* component is a specialization of the *BlackboardCP* and the WorkerCP component is a specialization of the *KnowledgeSourceCP* component (see details in next slide).



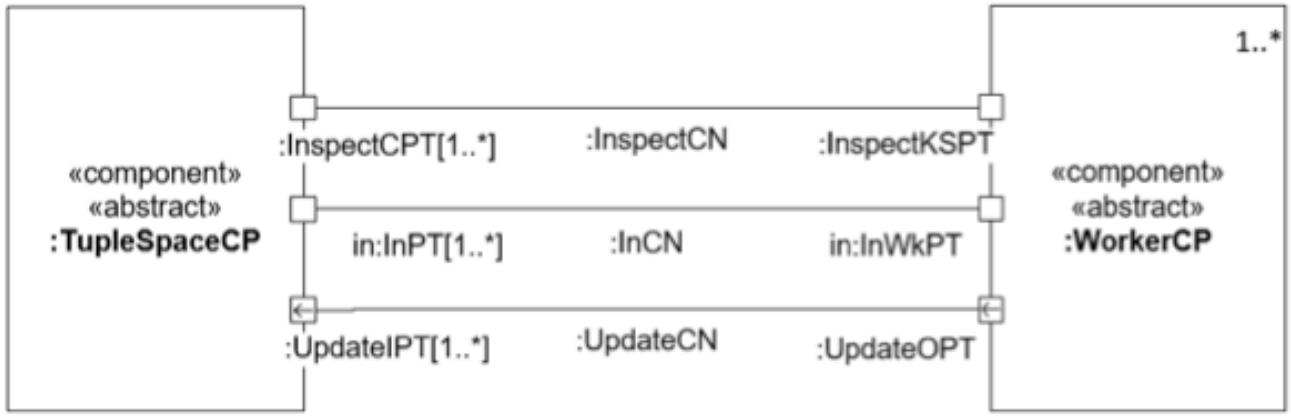
Tuplespace definition in SysADL



Tuplespace

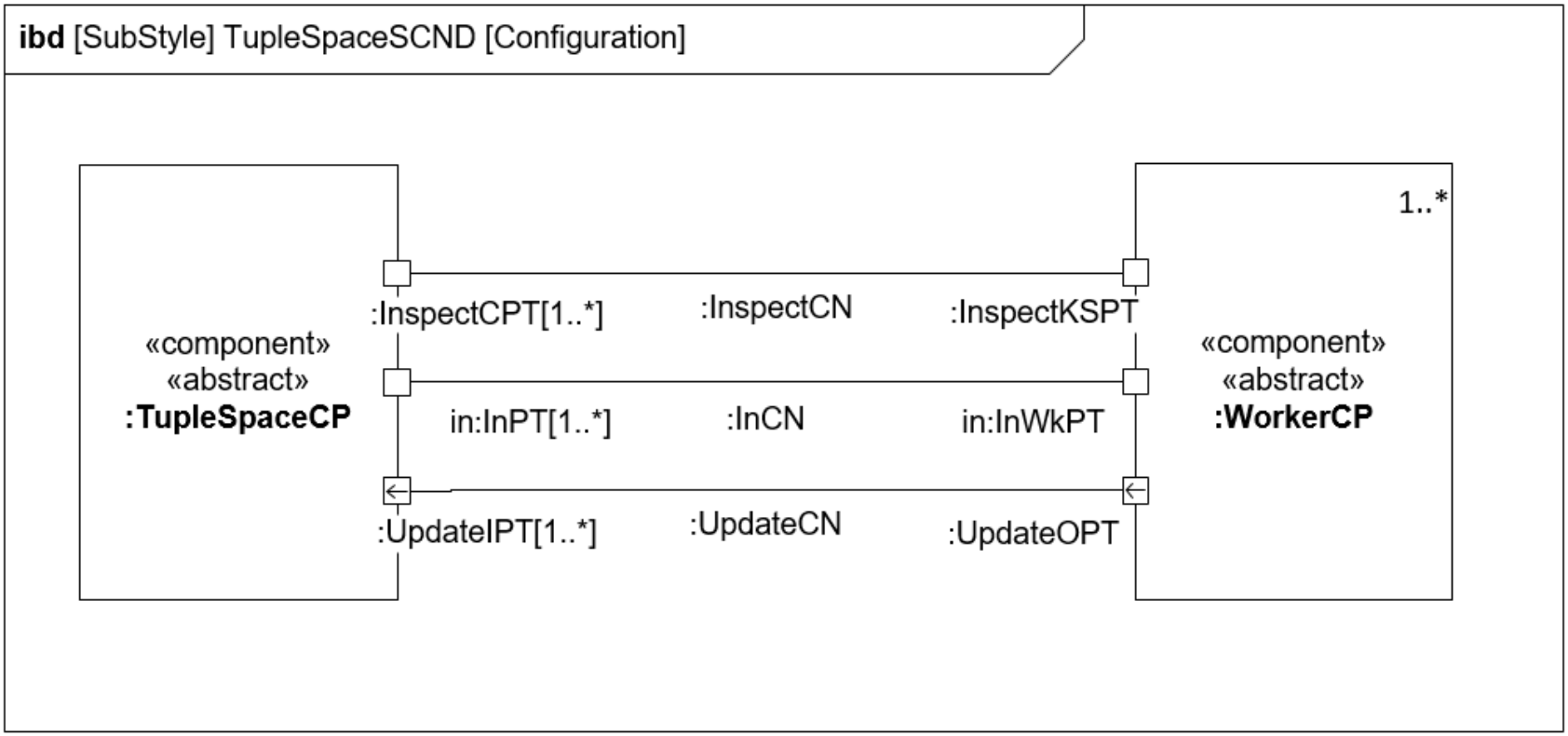
Tuplespace component configuration

- The *TupleSpaceCP* component is connected to *WorkerCP* components (one or more) via three connectors:
  - the *InspectCN* composite connector, that allows the *WorkerCP* components to inspect (i.e. non-destructively read) the *TupleSpaceCP* component;
  - the *InCN* composite connector, that allows the *WorkerCP* components to consume (i.e. read and remove) a tuple from the *TupleSpaceCP* component;
  - the *UpdateCN* connector that allows the WorkerCP components to insert a new tuple into the *TupleSpaceCP* component



TupleSpace

Configuration diagram in SysADL



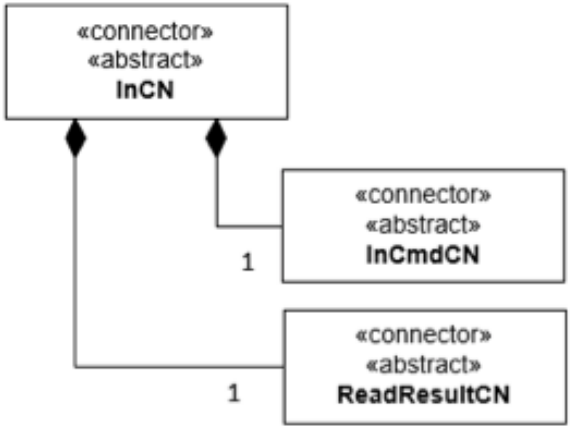
Tuplespace connectors

Connectors definition in Sysadl – 1/3

Tuplespace connectors

- We define here a new connector used in the TupleSpace style, the *InCN* composite connector.
- It is composed of two connectors: *InCmdCN* and *ReadResultCN*, each one is linked to the composite ports of the *TupleSpaceCP* and *WorkerCP* components

Connectors definition in SysADL



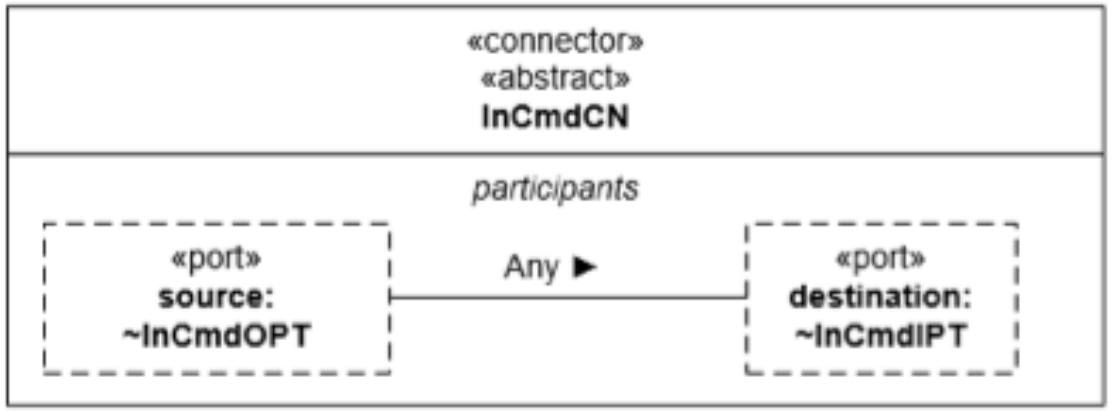
Tuplespace connectors

Connectors definition in Sysadl – 2/3

Tuplespace connectors

- The *InCmdCN* connector conveys data of any type from the *InCmdOPT out* port of the *WorkerCP* component to the *InCmdIPT in* port of the *TupleSpaceCP* component

Connector definition in SysADL



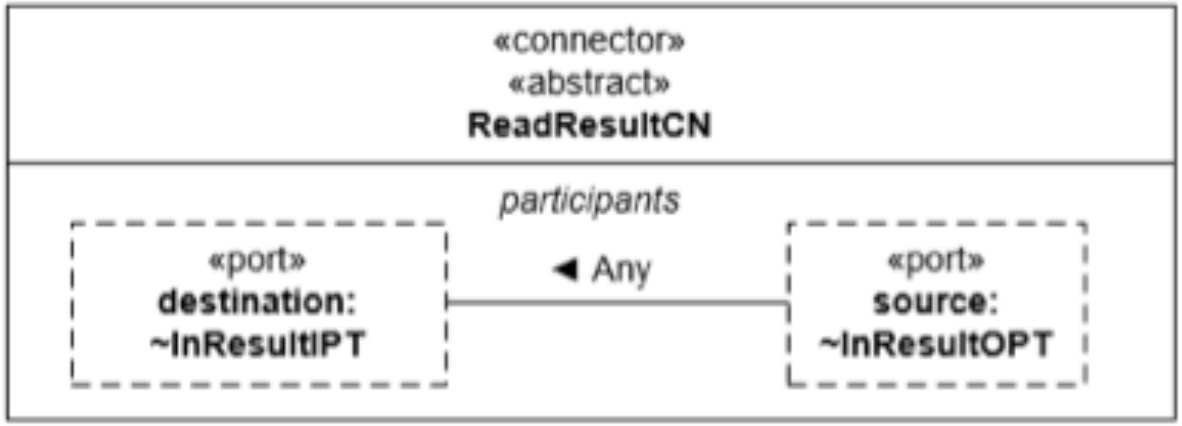
Tuplespace connectors

Connectors definition in Sysadl – 3/3

Tuplespace connectors

- The *ReadResultCN* connector conveys data of any type from the *InResultIPT in* port of the *TupleSpaceCP* component and the *InResultOPT out* port of the *WorkerCP* component

Connector definition in SysADL



Blackboard in RTC System

Blackboard in RTC System

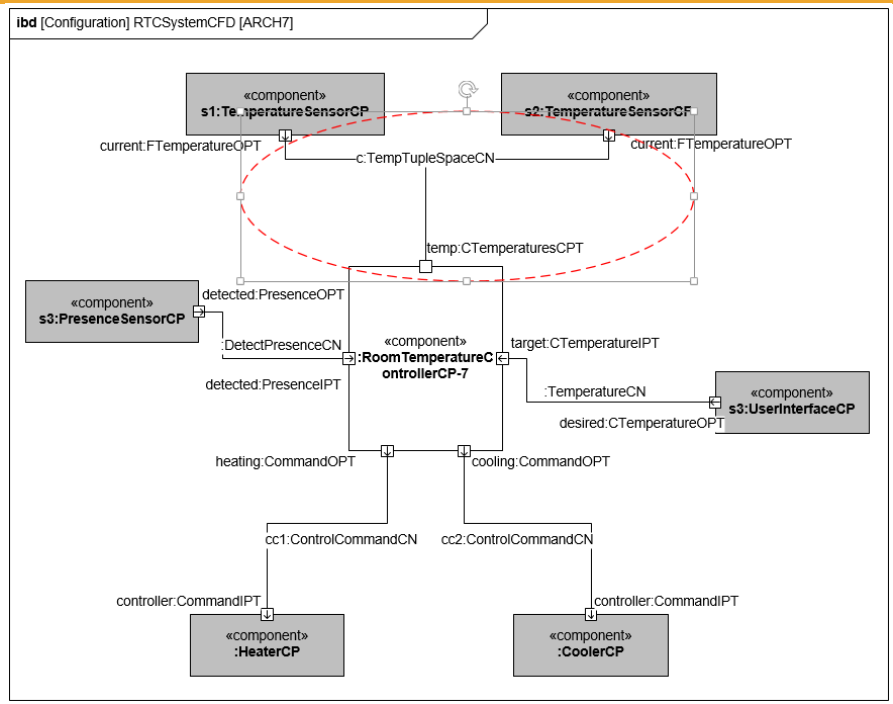
Conceptual Overview

- To illustrate the use of the Tuplespace style in the RTC System we present the RTC System configuration
- We designed a new architecture (ARCH7), that has a connector as a *TupleSpace*
- In this architecture, the connector acts as a repository for the temperatures provided by the sensor

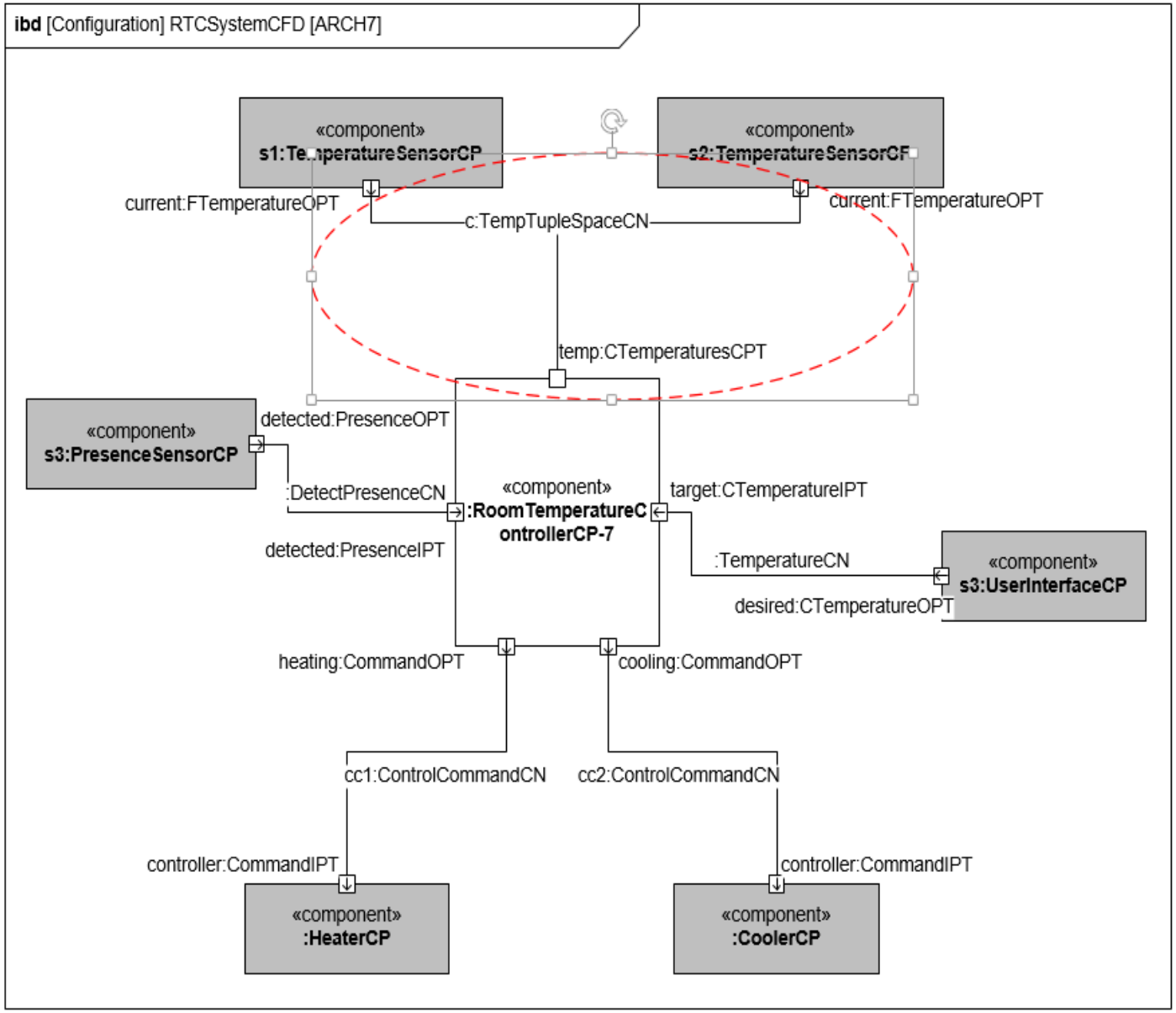
Blackboard in RTC System

RTC System ARCH7

- In the configuration in ARCH7 there are two temperature sensors providing values to the tuplespace connector. The values are read by the *RoomTemperatureControllerCP-7* component in the *temp:CTemperatureCPT* port (see details in next slide)



RTC System ARCH7



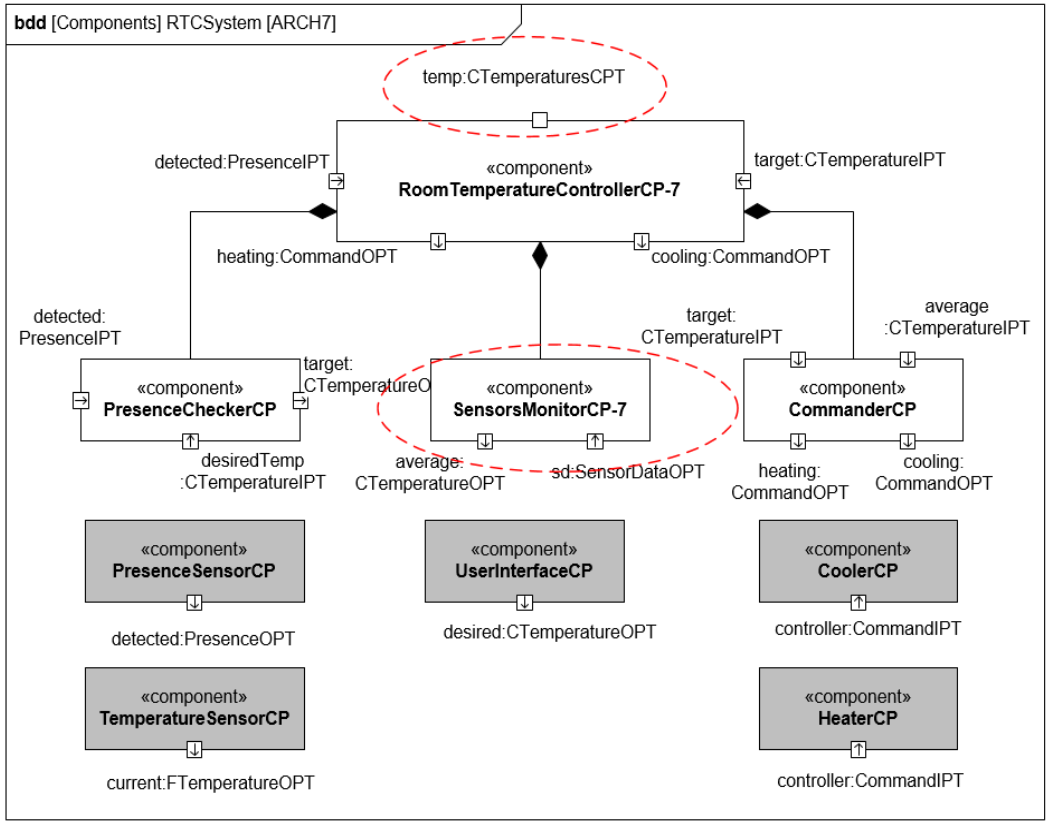
Blackboard in RTC System

Components definition

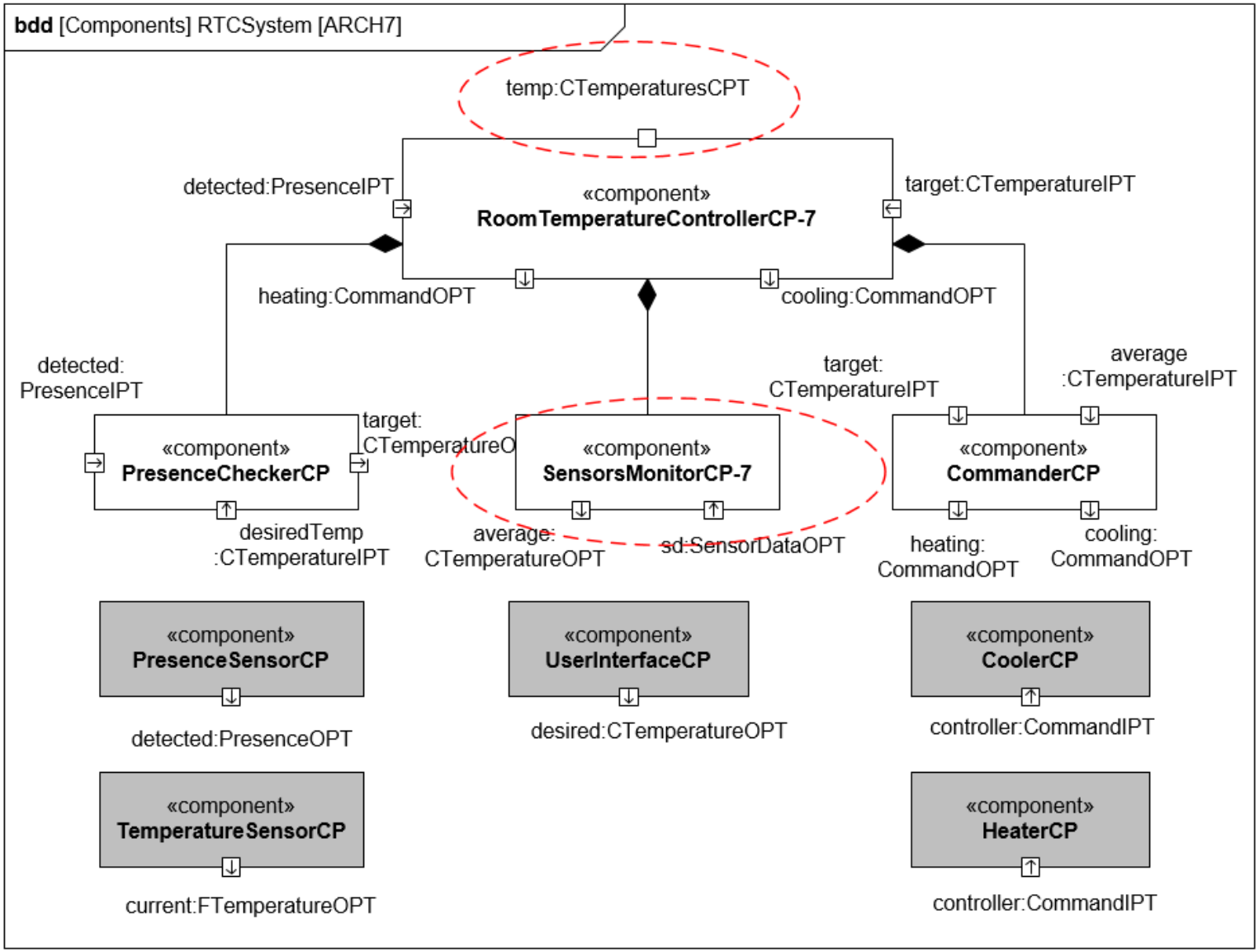
Components definition

- We show here the definition of the RTC components used in the *TupleSpace* style
  - We highlight the *SensorsMonitorCP-7* component and the new port *CtemperaturesCPT* in the *RoomTemperatureControler CP-7* component
  - This new port allows the connection with the *TempTupleSpaceCN* connector

Definition in SysADL



RTC ARCH7 components definition



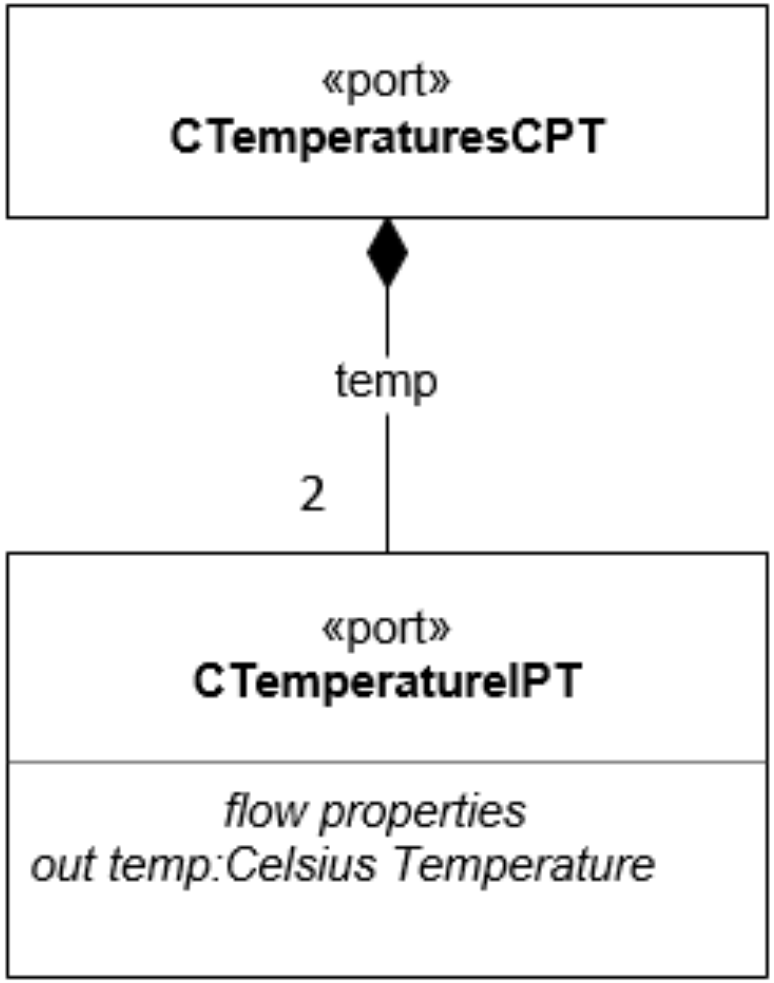
Blackboard in RTC System

Ports definition

Port definition

- We show here the definition of the *CtemperaturesCPT* composite port that is composed of two *CTemperatureIPT in* ports
- These ports are used to receive temperatures from the *TempTupleSpaceCN* connector (see next slides)

Definition in SysADL



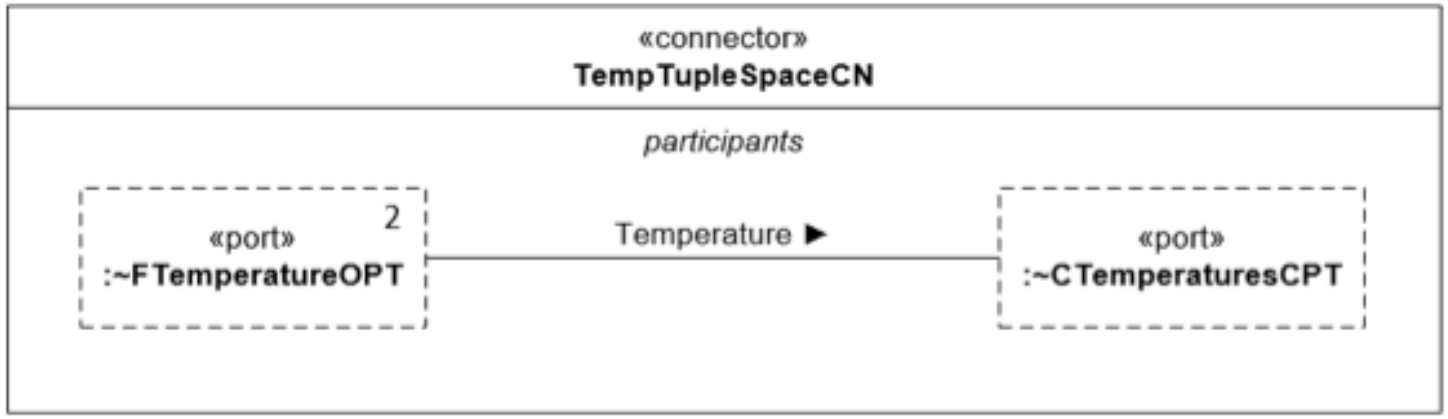
Blackboard in RTC System

Connectors definition – 1/2

Blackboard connector in RTC System

- The *TempTupleSpaceCN* connector and the *ControlCommandCN* connector
  - The *TempTupleSpaceCN* connector conveys temperature data from the *~FTemperatureOPT out* port of the *TemperatureSensorCP* component to the *~CTemperaturesCPT composite* port of the *RoomTemperatureControllerCP-7* component.

Definition in SysADL



Blackboard in RTC System

Connectors definition – 1/2

Blackboard connector in RTC System

- The *ControlCommandCN* connector conveys Command data from the *~CommandOPT out* port of the *RoomTemperatureControllerCP-7* component and *~CommandIPT in* port of the *Heater or Cooler* components

Definition in SysADL

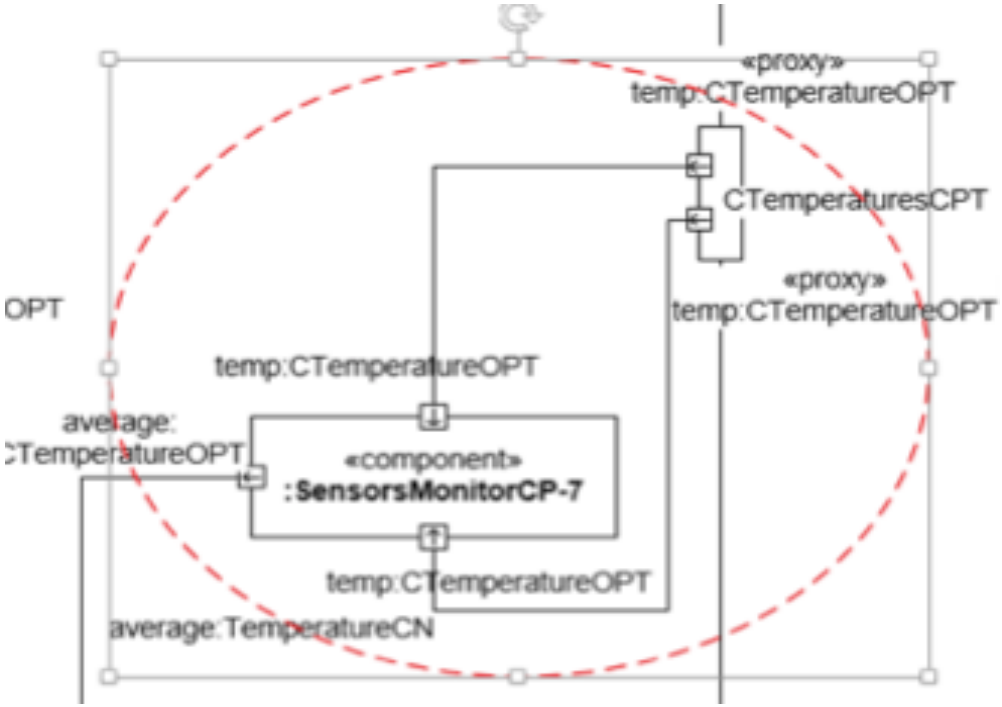
Blackboard in RTC System

RoomTemperatureControllerCP-7 Configuration

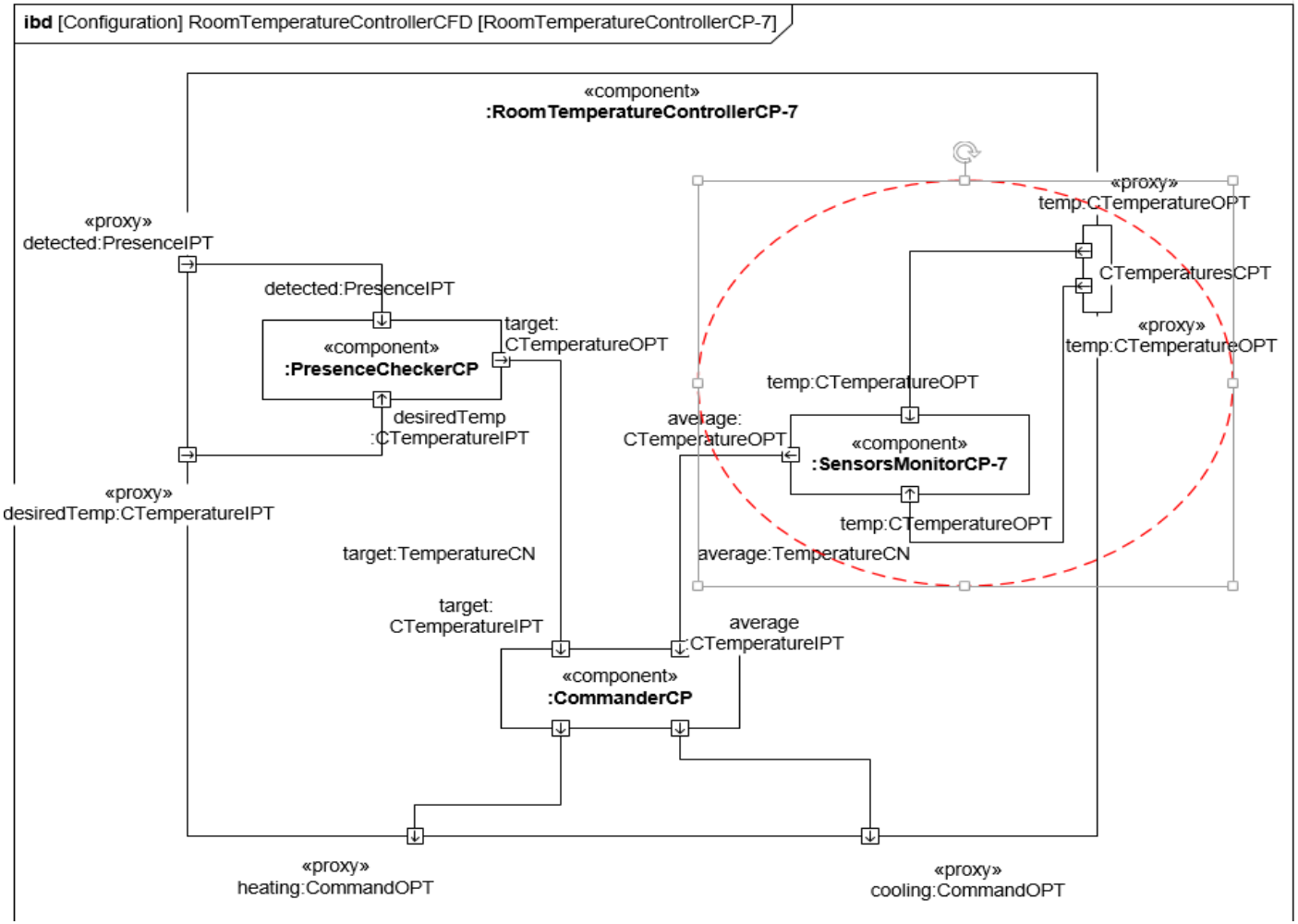
RoomTemperatureControllerCP-7 Configuration

The RoomTemperatureControllerCP-7 configuration highlights how the *SensorsMonitorCP-7* component ports are connected to the *CTemperaturesCPT* composite port (see the complete configuration in next slide

Configuration in SysADL (partial)



RoomTemperatureControllerCP-7 Configuration (complete)



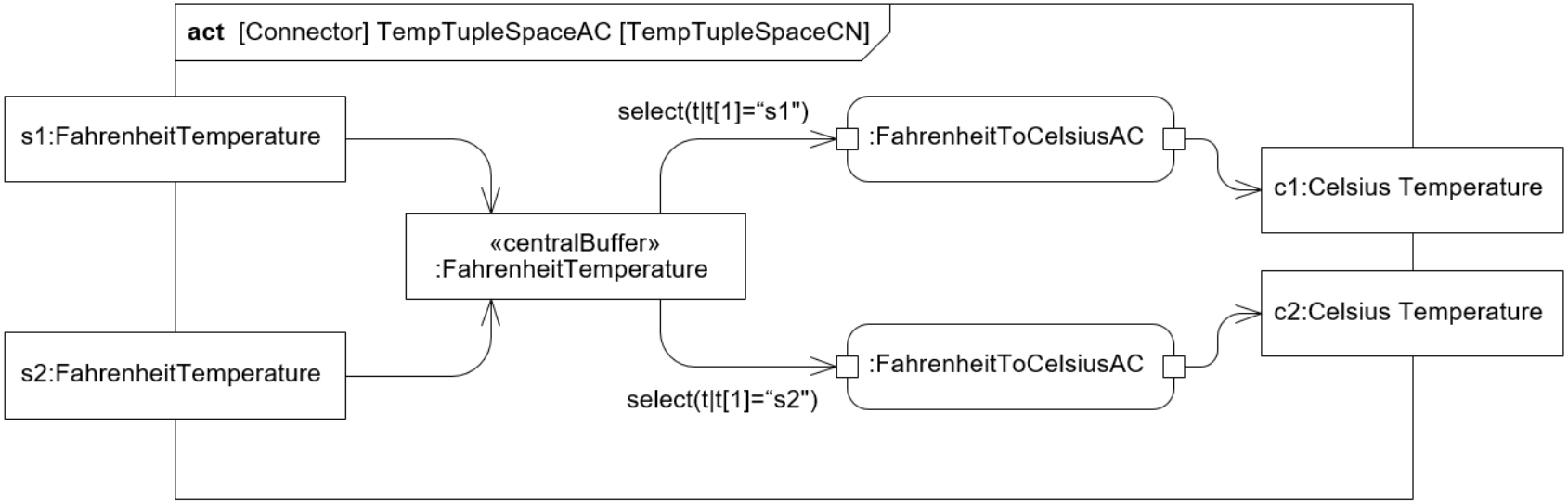
Blackboard in RTC System

Behavior specification – 1/2

TempTuplespaceAC activity

- We show here the behavior specification of the *TempTupleSpaceCN* connector using the activity diagram.
  - It receives two *FahrenheitTemperature* in its *in* pins (*s1*, *s2*) and stores them in a buffer.

Behavior in SysADL

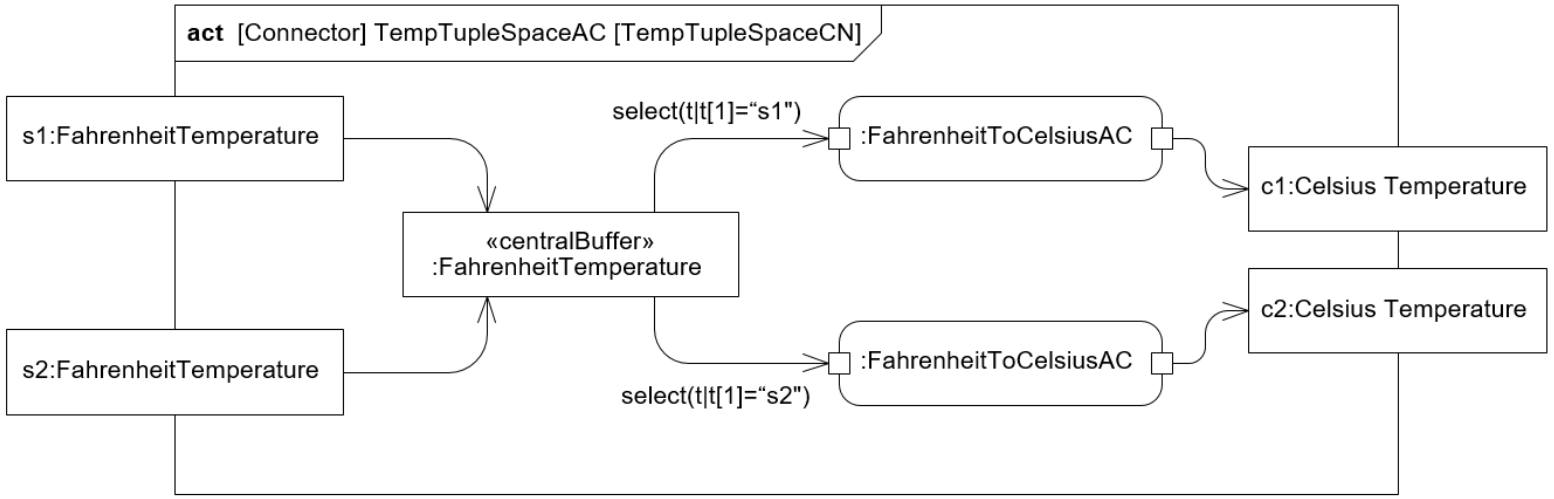


Blackboard in RTC System

Behavior specification – 2/2

TempTuplespaceAC activity

- Continued…
  - It selects *s1* to send to the *FahrenheitToCelsiusAC* action that will convert it to Celsius and send the result to the *c1 out* pin.
  - Similarly, it also selects *s2* to send to the *FahrenheitToCelsiusAC* action that will convert it to Celsius and send the result to the *c2 out* pin



Summary

- In this chapter you learnt
  - the Blackboard architectural style
  - the elements, structure and behaviour of the Blackboard style
  - the Tuplespace architectural substyle of the Blackboard style
  - the elements, structure and behaviour of the Tuplespace style
- You learnt how to
  - apply the Blackboard style in an architecture design
  - apply the Tuplespace substyle in an architecture design

For Further Reading

- Clements, P.; Bachmann, L.; Garlan, D.; Ivers, J.; Little, R.; Merson, P.; Nord, R. Documenting Software Architecture: Views and Beyond. SEI Series in Software Engineering. (2003)
- Buschmann, F., Meunier, R., Rohnert, H. Sommerlad, P., Michael Stal, M. Pattern-Oriented Software Architecture Volume 1: A System of Patterns. Vol. 1. Wiley (1996).
- Vogel, O.; Arnold, I.; Chughtai, A.; Kehrer, T. Software Architecture: A Comprehensive Framework and Guide for Practitioners. Springer (2011)