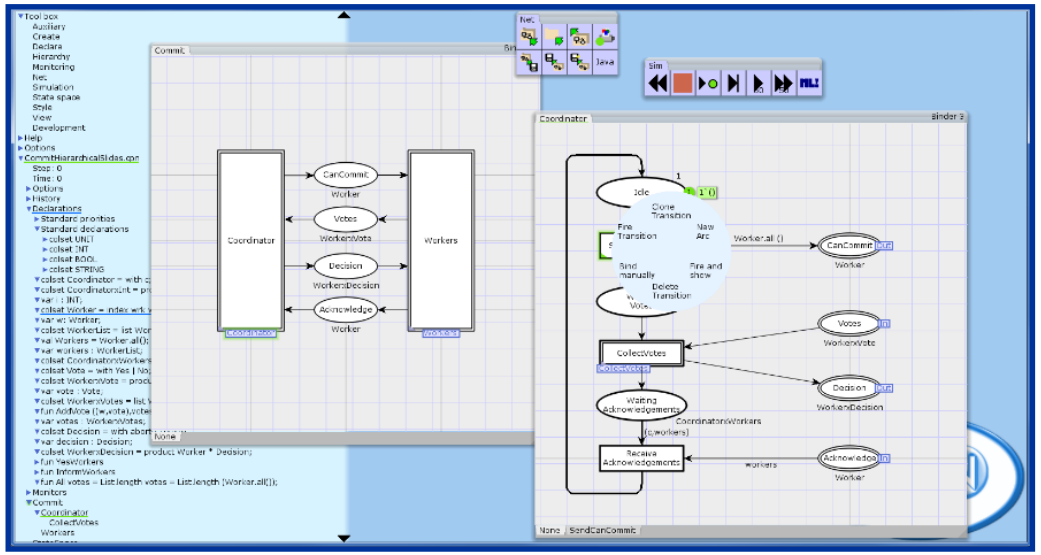
Lecture 4

Hierarchical Coloured Petri Nets with Modules



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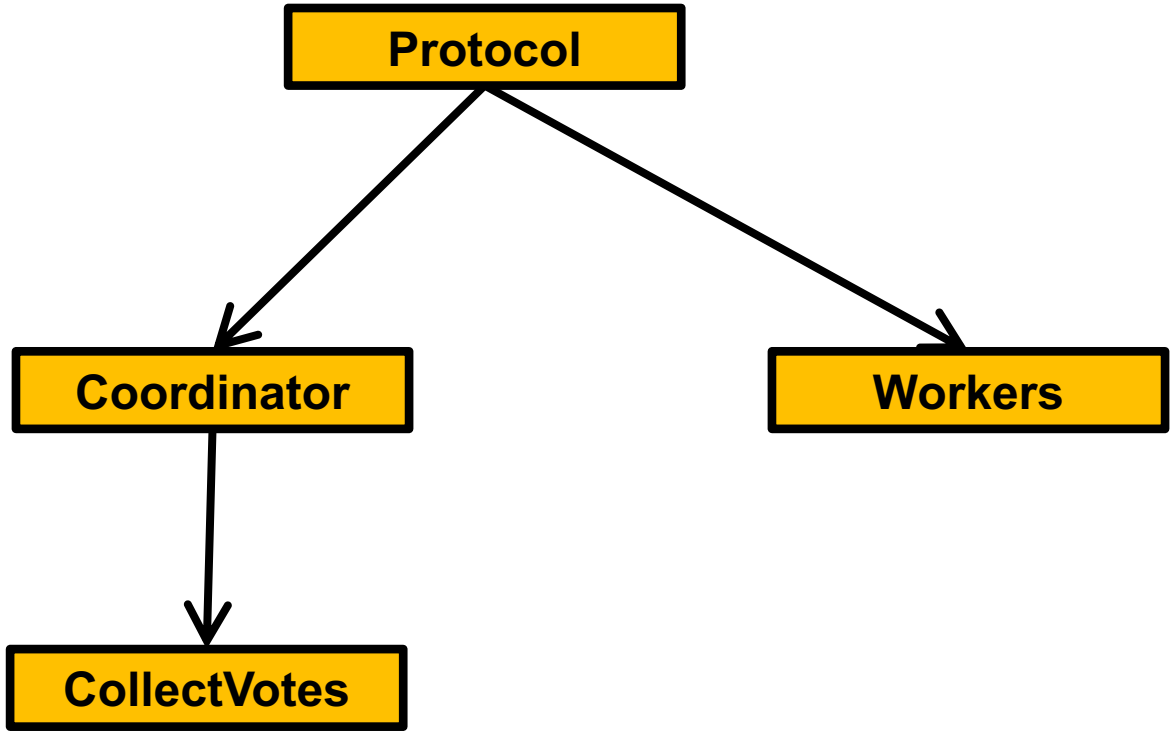
Introduction

- **Important to be able to split a large CPN models into a set of modules with interfaces**
  - To support construction of large CPN models
  - To support reuse of modules and maintainability
  - To support abstraction and management of details

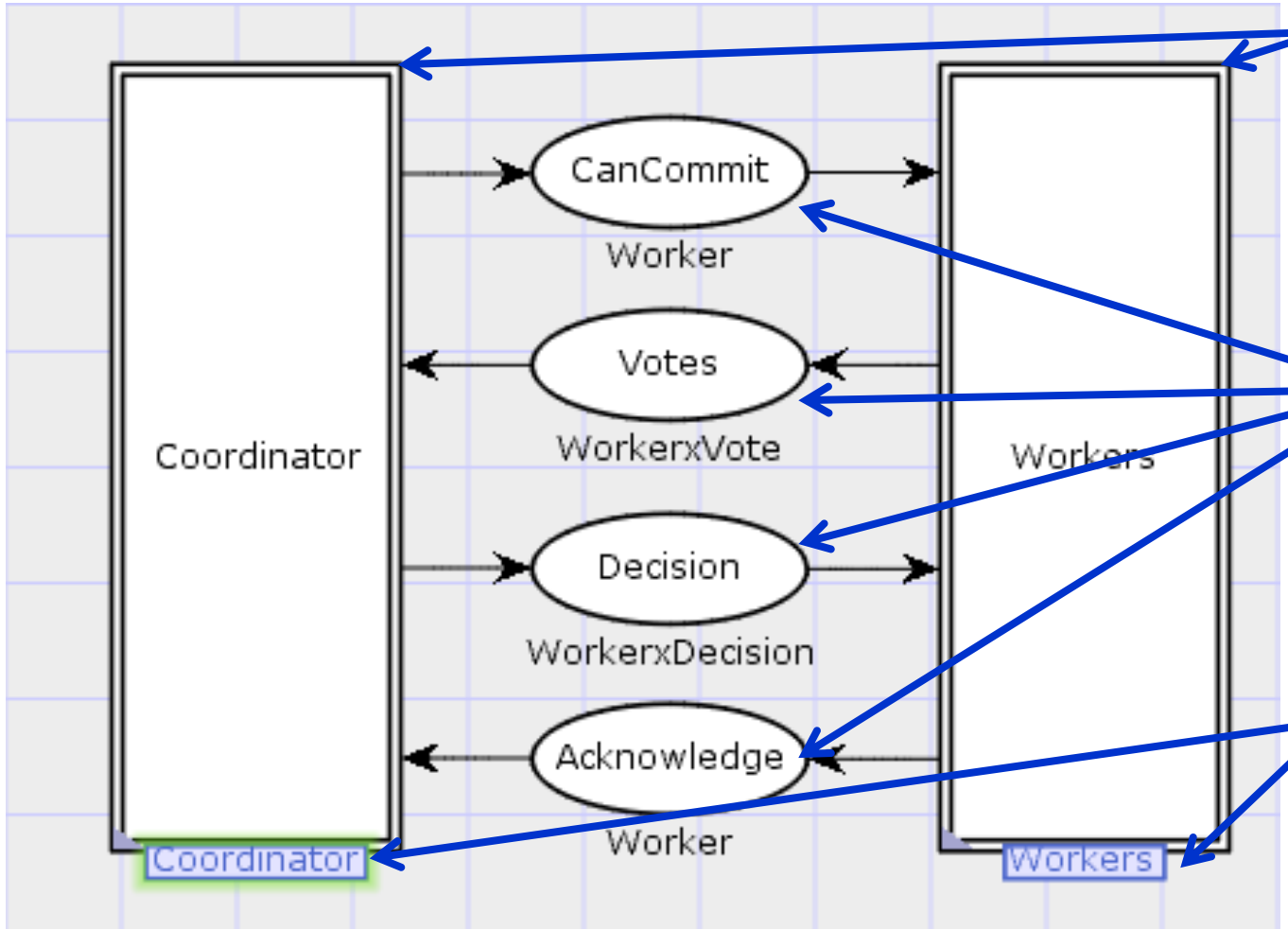
- **Key concepts of hierarchical CPN modules**
  - A module exchange tokens with its environment using input/output port places
  - Substitution transitions have associated submodules
  - Port-socket relation associates socket places of substitution transitions with the port places in the associated submodule

Hierarchical modules

- **Model is comprised of a collection of modules that are hierarchically organised into levels**
- **Example: the two-phase commit protocol**



Top-level: Protocol module

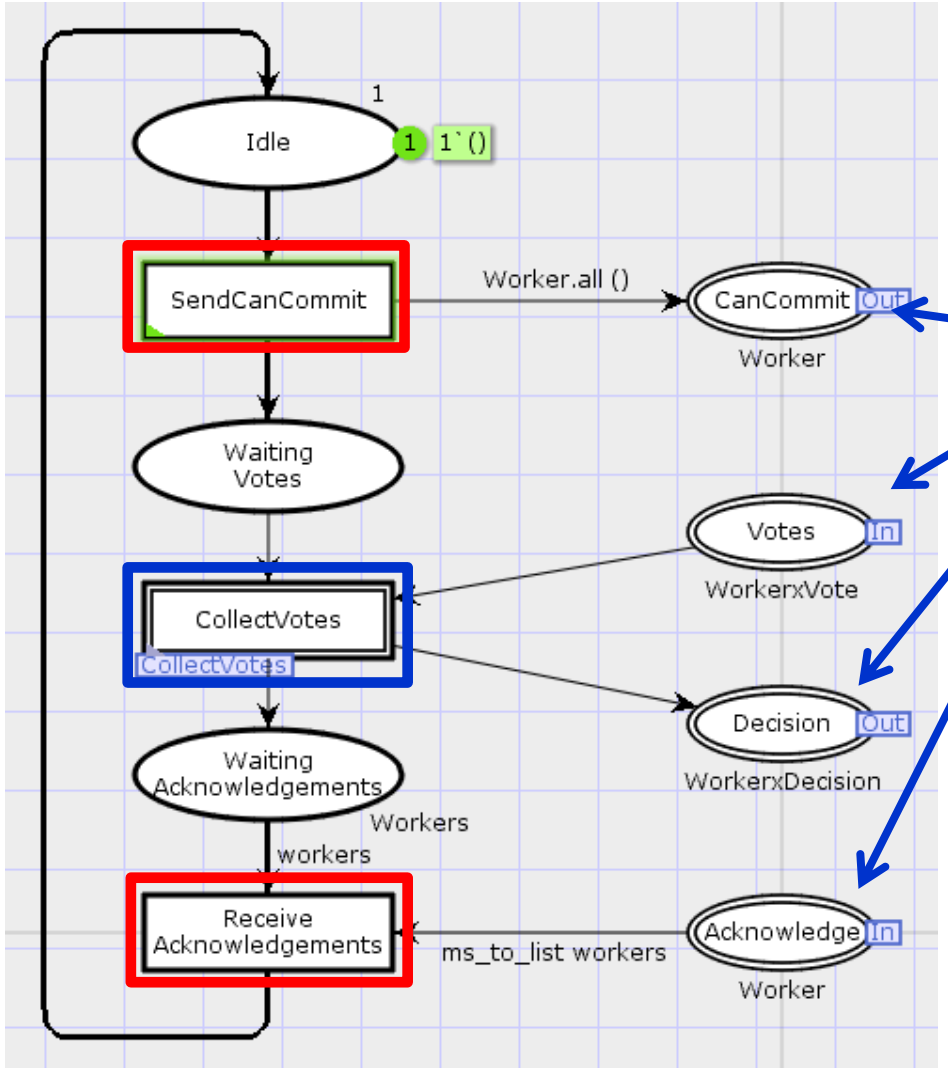


Substitution transitions (double-lined border)

Socket places – places connected to substitution transitions

Substitution tags - name of submodule associated with substitution transition

Coordinator module



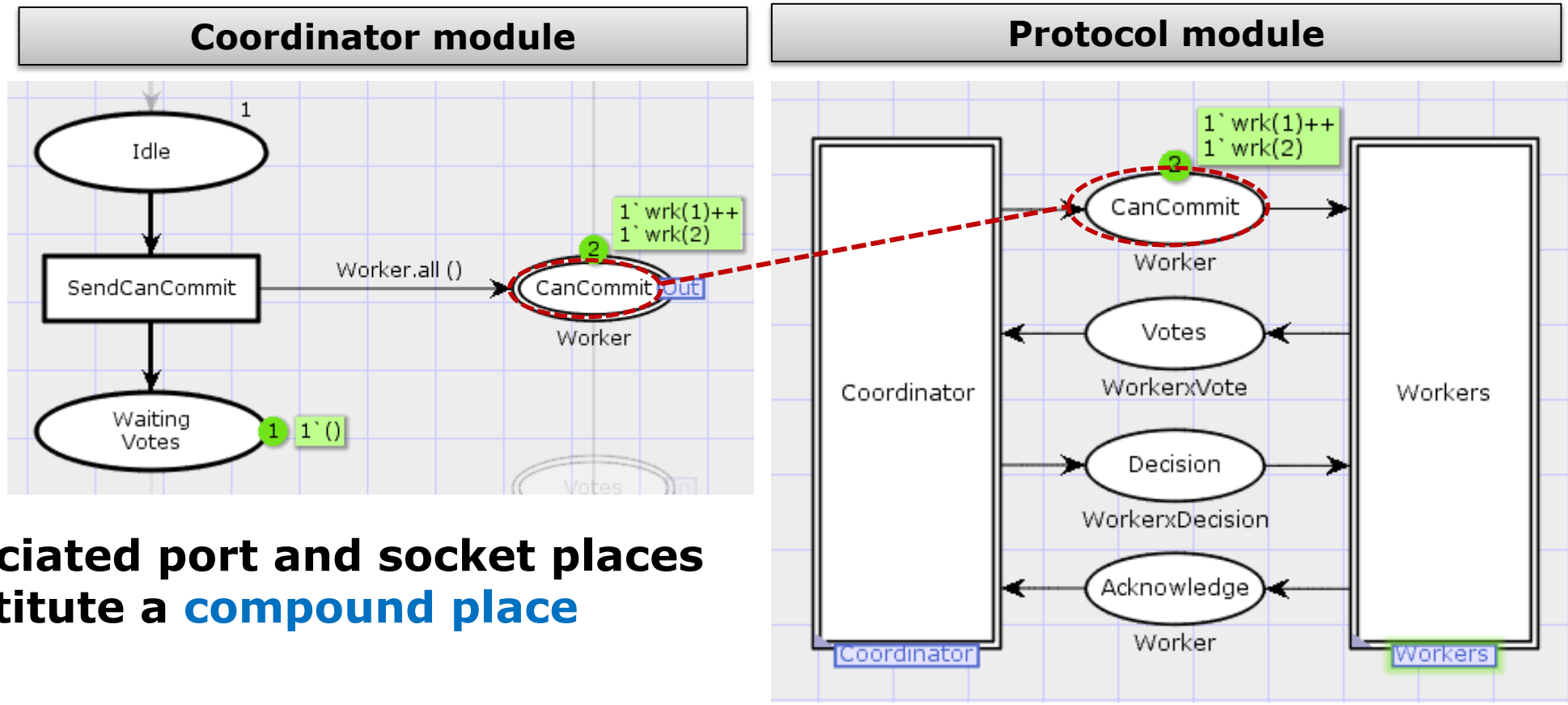
Port place - used for exchanging tokens with the upper-level module (IN,OUT,IN/OUT).

SendCanCommit and ReceiveAcknowledgement are ordinary transitions.

CollectVotes is a substitution transition

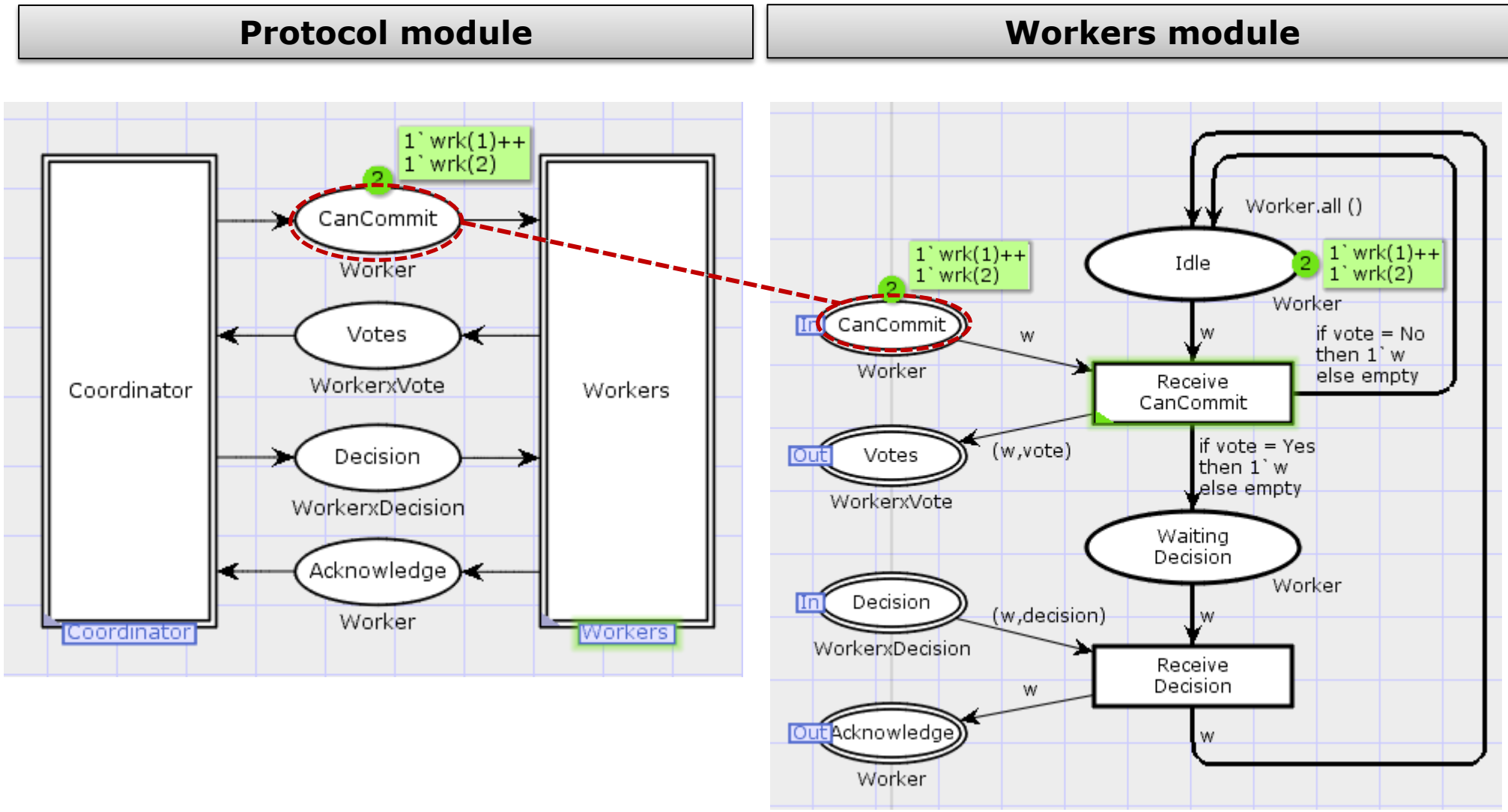
Port-socket place relation

- **Tokens added (removed) on a port place are added (removed) on the associated socket place**



- **Associated port and socket places constitute a compound place**

Workers Module

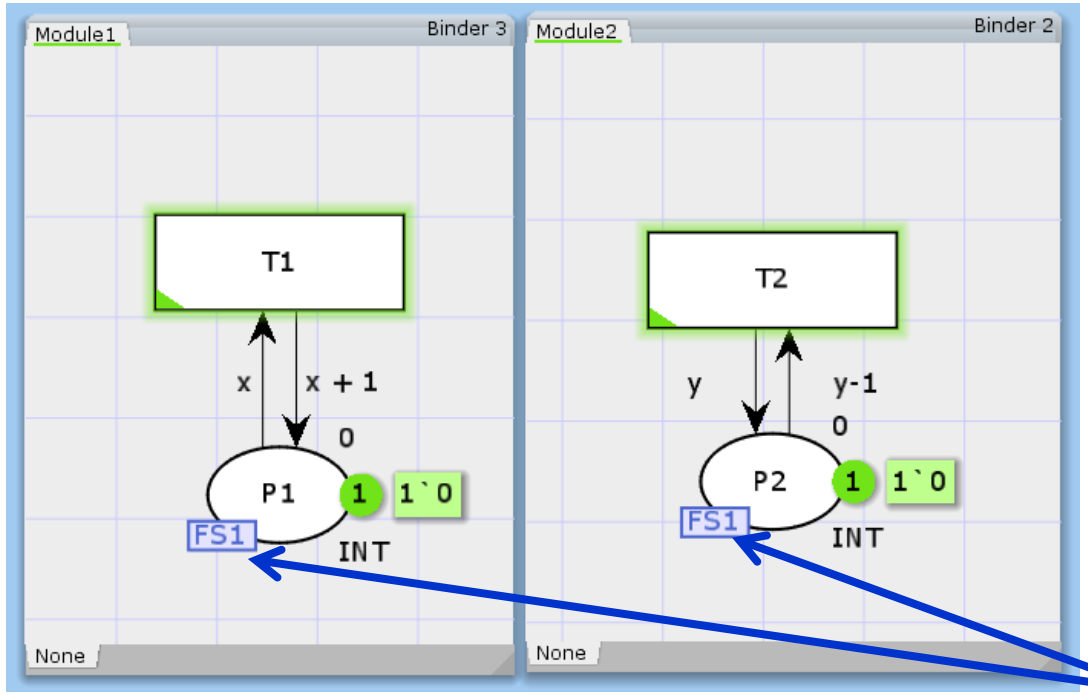


CPN Tools Demo

- **Hierarchical CPN models**
  - Navigating hierarchical models
  - Simulation of hierarchical models
  - Editing of modules: top-down and bottom-up development

Place Fusion Sets

- **Group of places to be treated as one compound (global) place**



Any change in the marking of P1 will be reflected on P2 (and vice versa)

Similar to global variables - should be used with care

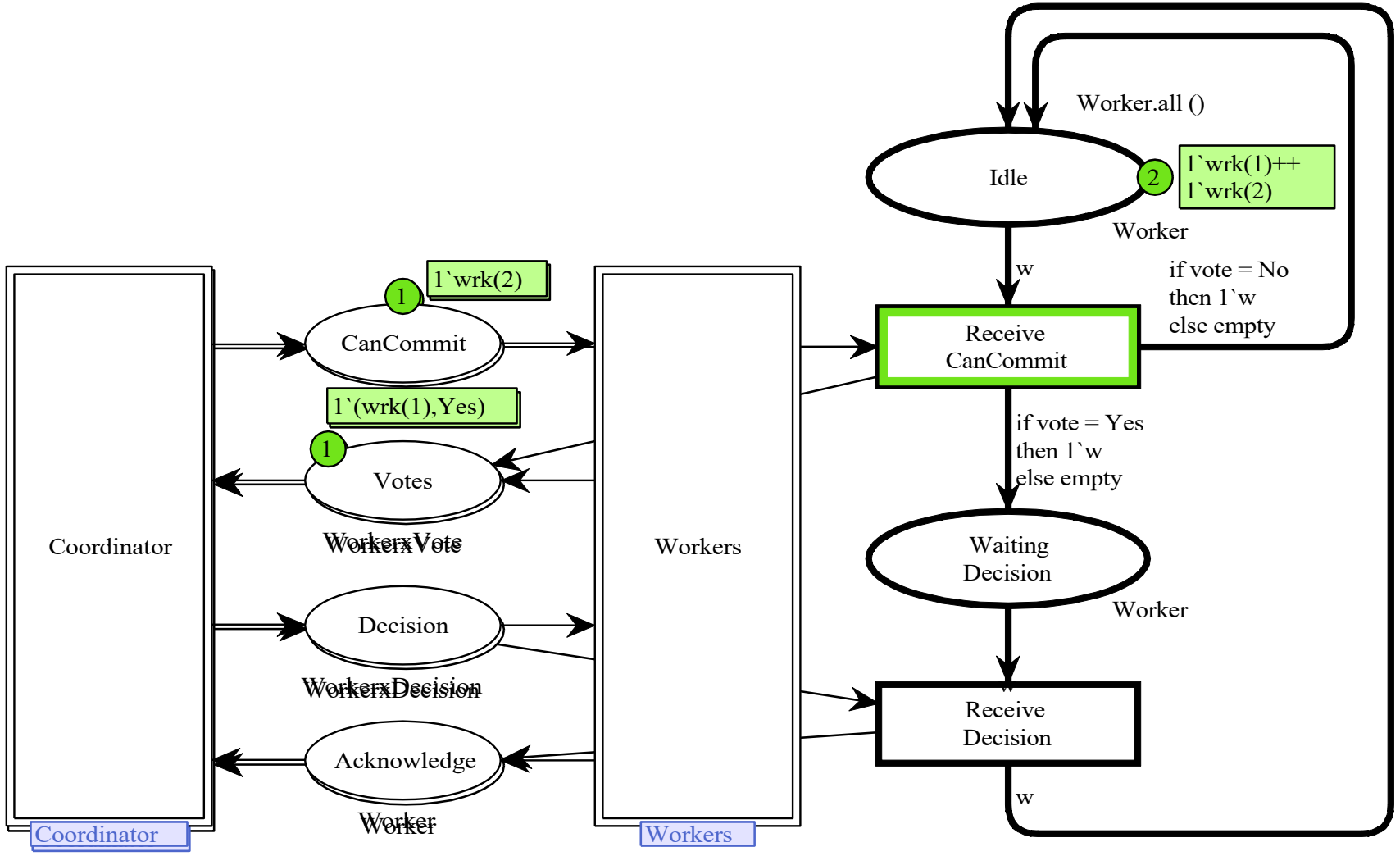
P1 and P2 are fusion places belonging to fusion set FS1

Unfolding Coloured Petri Nets to Place/Transition Nets

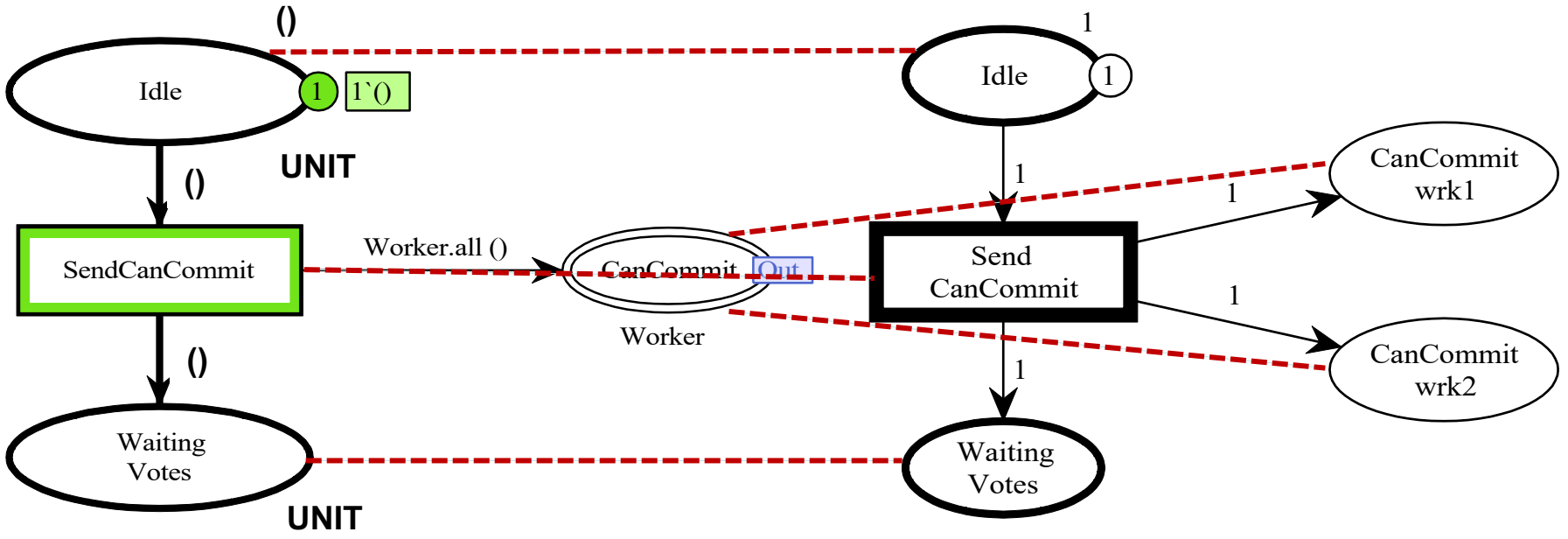
Unfolding Coloured Petri Nets

- **A hierarchical CPN model can be unfolded to a non-hierarchical Coloured Petri Net**
  - Recursively replace each substitution transition with its associated submodule
  - Associated port and socket places are merged into a single place
- **A non-hierarchical Coloured Petri Net can be unfolded into a Place/Transition Net (PTN)**
  - Replace each CPN place with one PTN place for each colour in the colour set of the CPN place
  - Replace each CPN transition with one PTN transition for each possible binding of the CPN transition

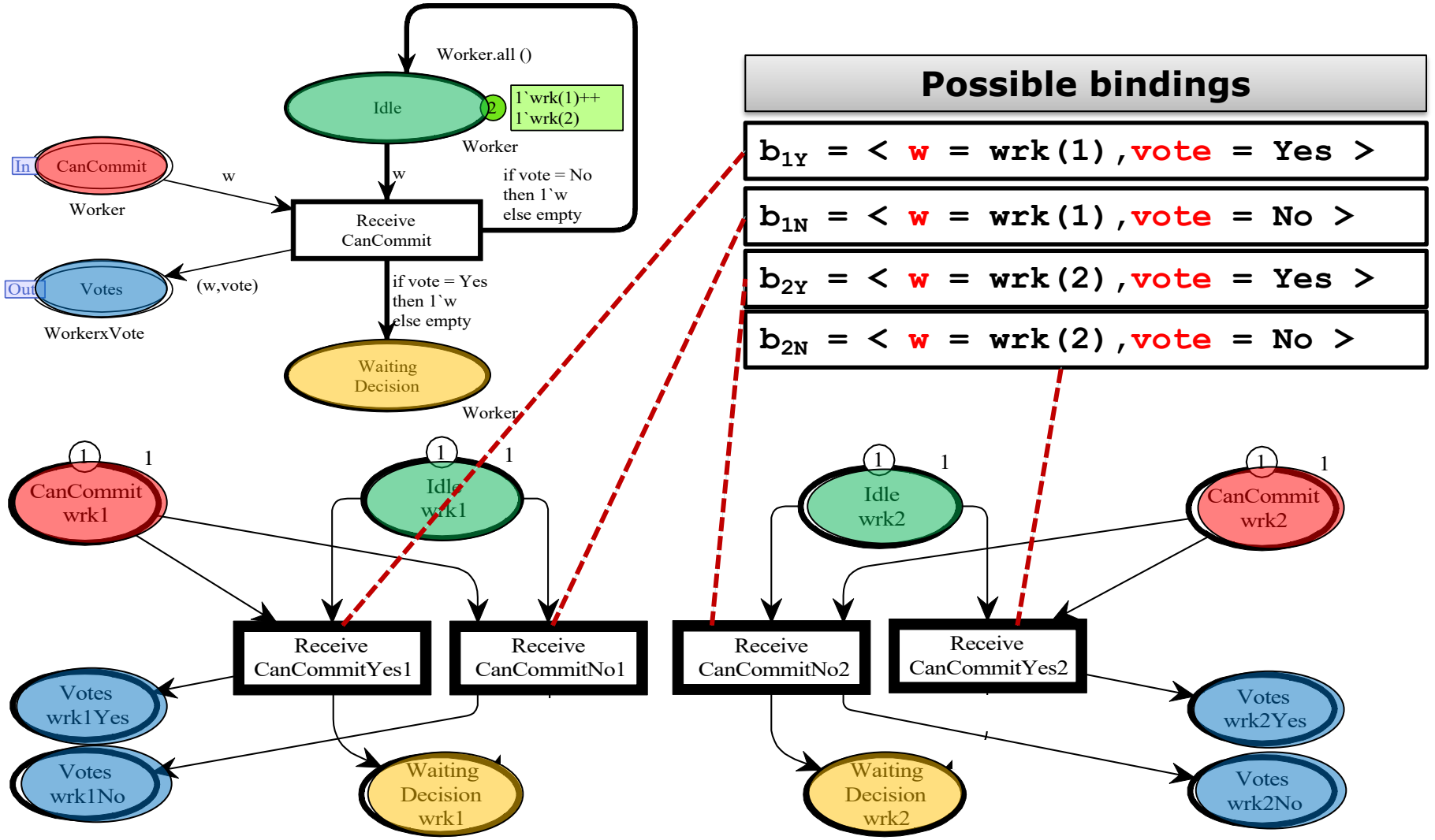
Unfolding hierarchical CPNs



Unfolding CPN Places



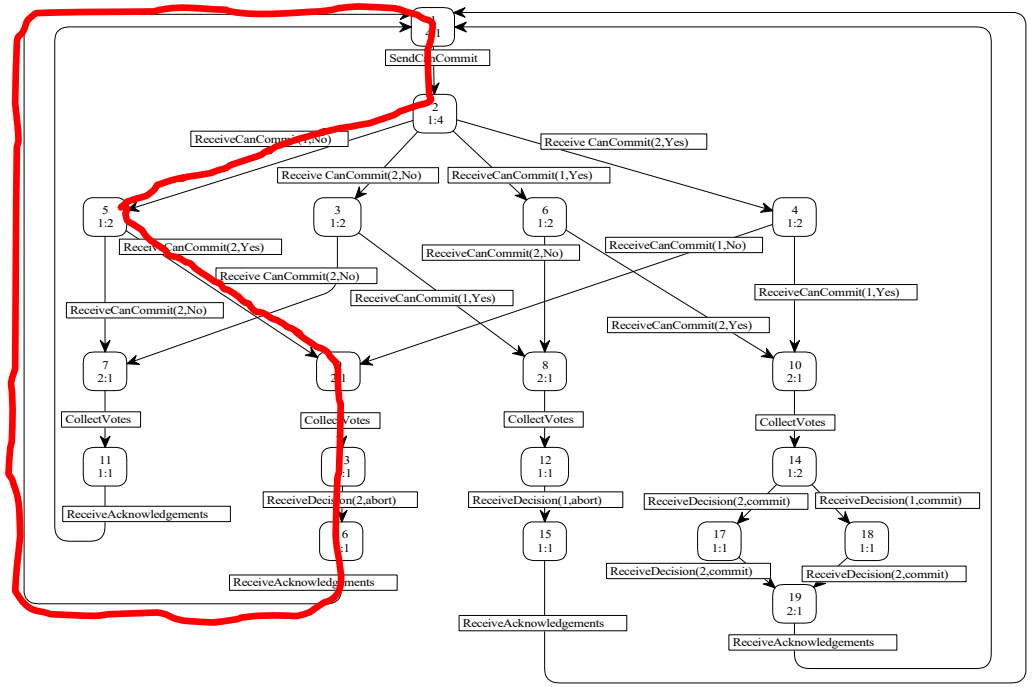
Unfolding CPN Transitions



CPN analysis methods

Verification and model checking

- **Formal verification of CPN models can be conducted using explicit state space exploration**

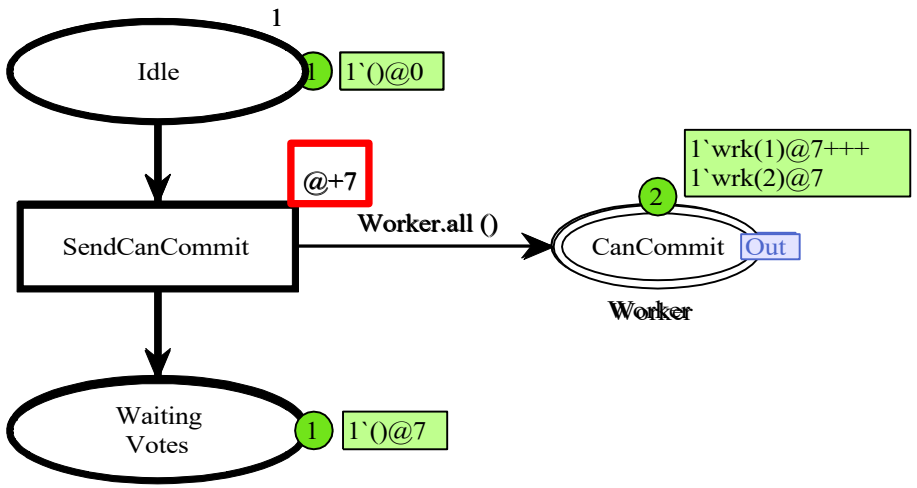


- **A state space represents all possible executions of the CPN model**
- **Standard behavioural properties can be investigated using the state space report**
- **Model-specific properties can be verified using queries and temporal logic model checking**

- **Several advanced techniques available to alleviate the inherent state explosion problem**

Performance analysis

- **CPNs include a concept of time that can be used to model the timed taken by activities**

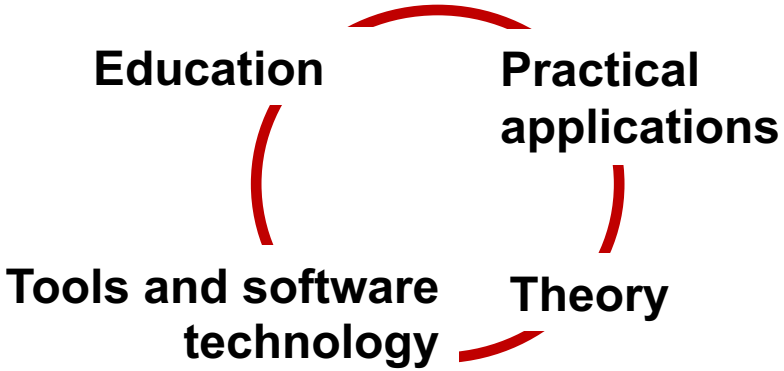


- **A global clock representing the current model time**
- **Tokens carry time stamps describing the earliest possible model time at which they can be removed**
- **Time inscriptions on transitions and arcs are used to give time stamps to the tokens produced on output places**

- **Random distribution functions can be used in arc expressions (delays, packet loss, ...)**
- **Data collection monitors and batch simulations can be used to compute performance figures**

Perspectives on CPNs

- **Modelling language combining Petri Nets with a programming language.**
- **The development has been driven by an application-oriented research agenda:**



- **Key characteristics**
  - **Few but still powerful and expressive modelling constructs**
  - **Implicit concurrency inherited from Petri nets**
    - everything is concurrent unless explicitly synchronised
  - **Verification and performance analysis supported by the same modelling language**