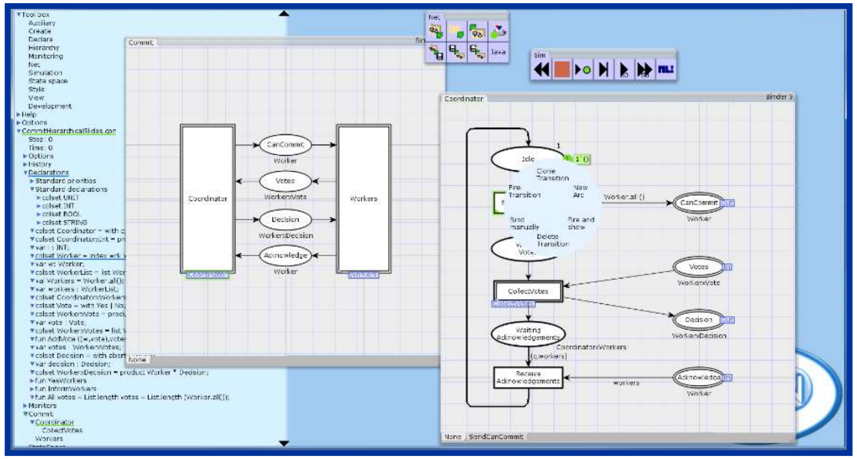
Lecture 4

Hierarchical Coloured Petri Nets with Modules



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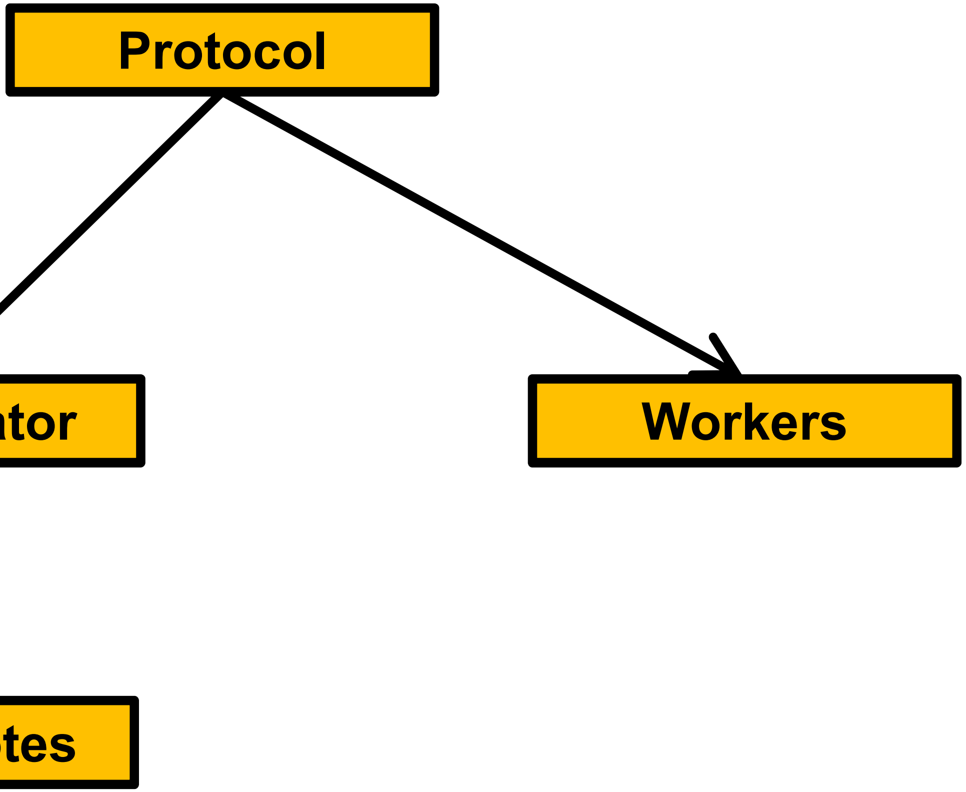
Introduction

- **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**
  - 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 submodule

Hierarchical Modules

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



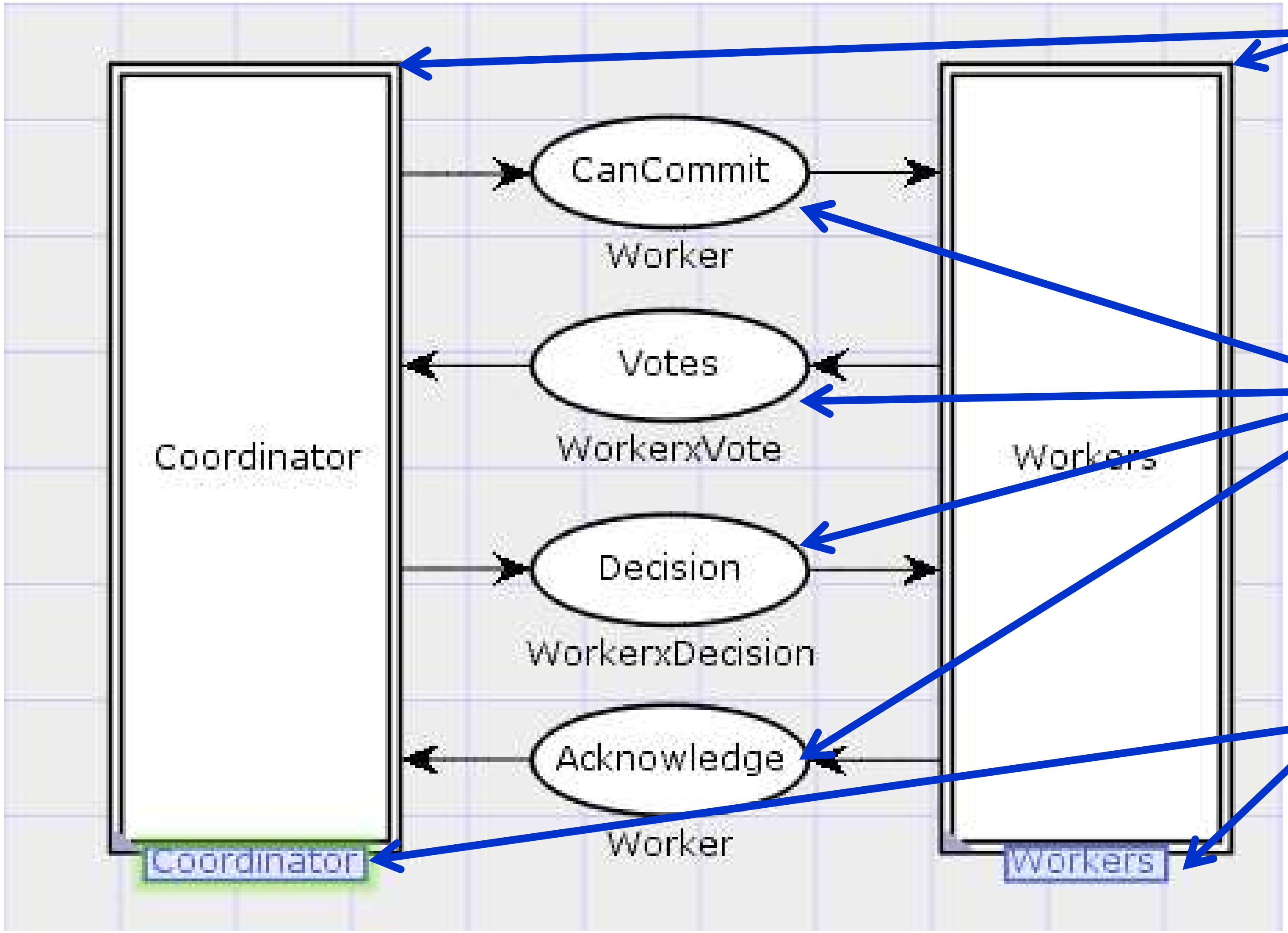
Protocol

Coordinator

Workers

CollectVotes

Top-level: Protocol Module

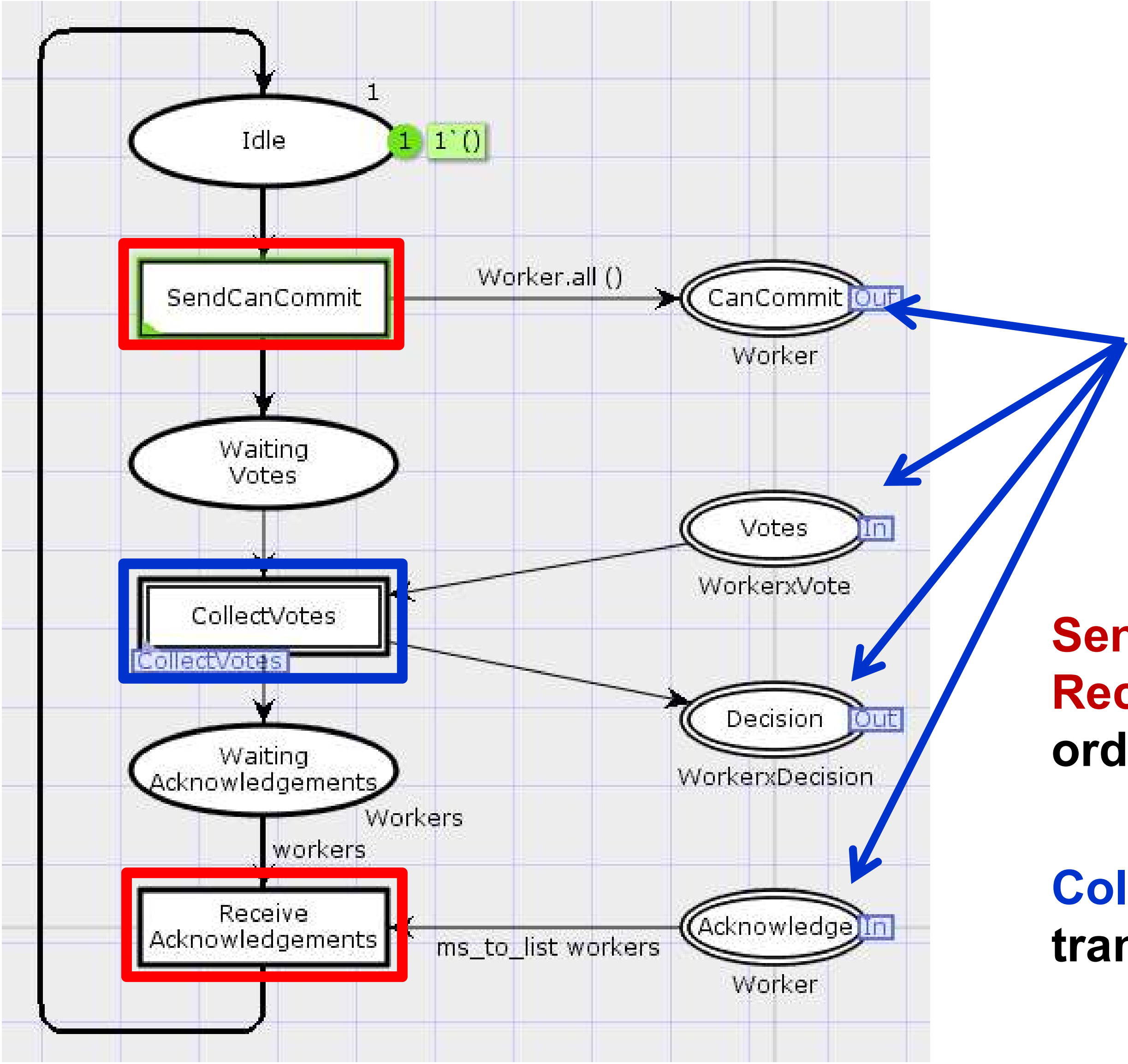


Substitution transition (double-lined border)

Socket place – places connected to substitution transitions)

Substitution tag - name of submodule associated with substitution transition

Coordinator Module



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

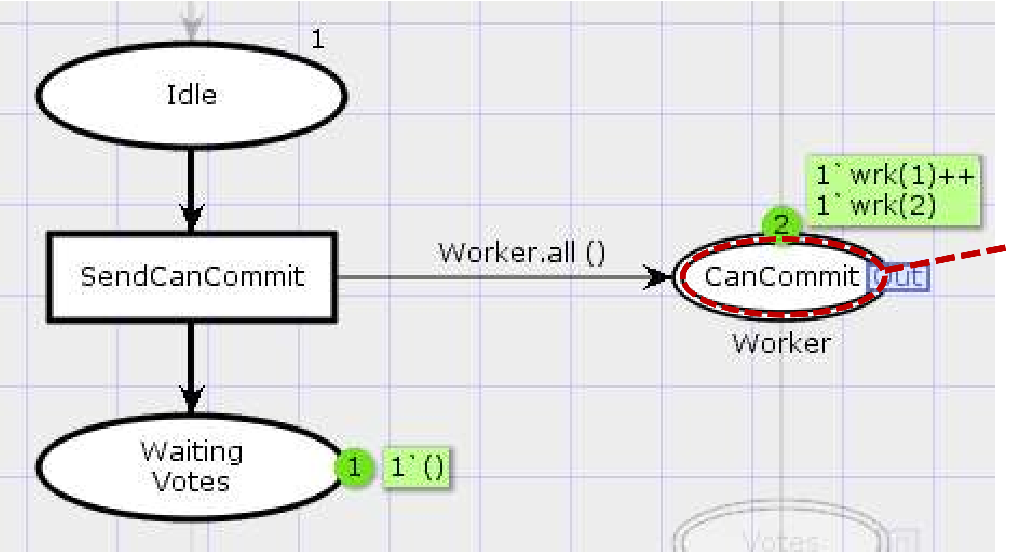
SendCanCommit and ReceiveAcknowledgement are ordinary transitions.

CollectVotes is a substitution transition

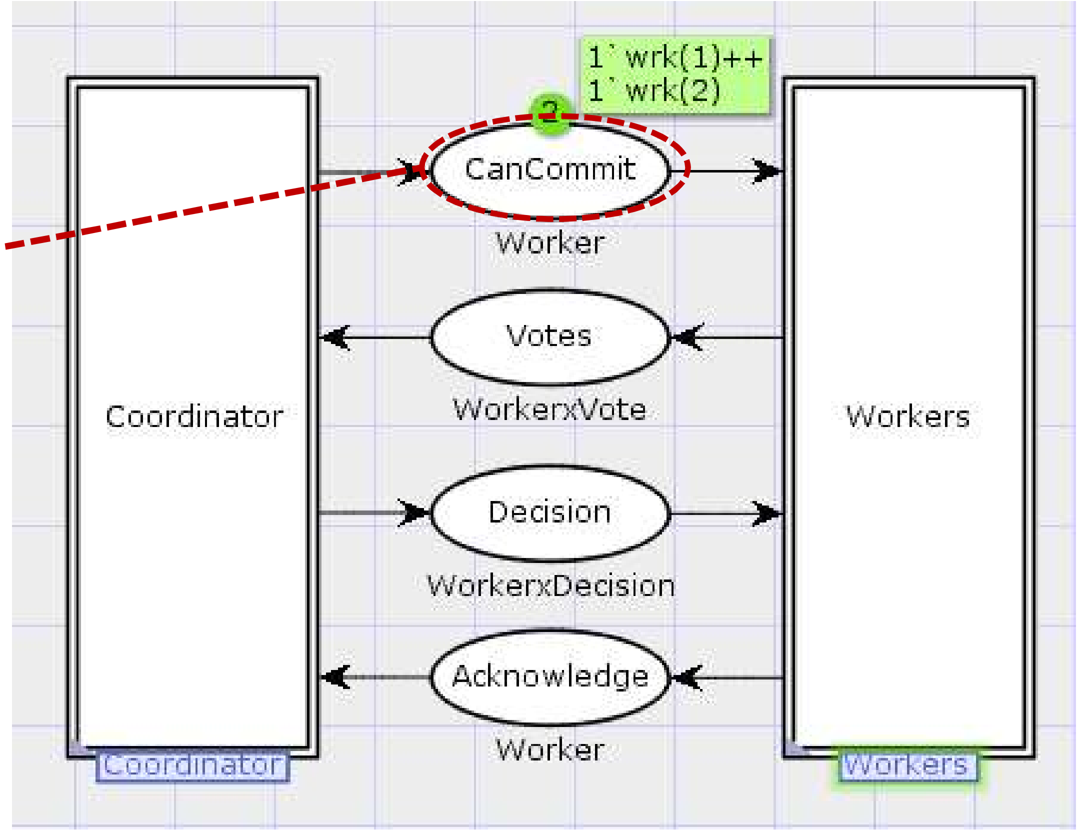
Port and Socket Places

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

Coordinator module



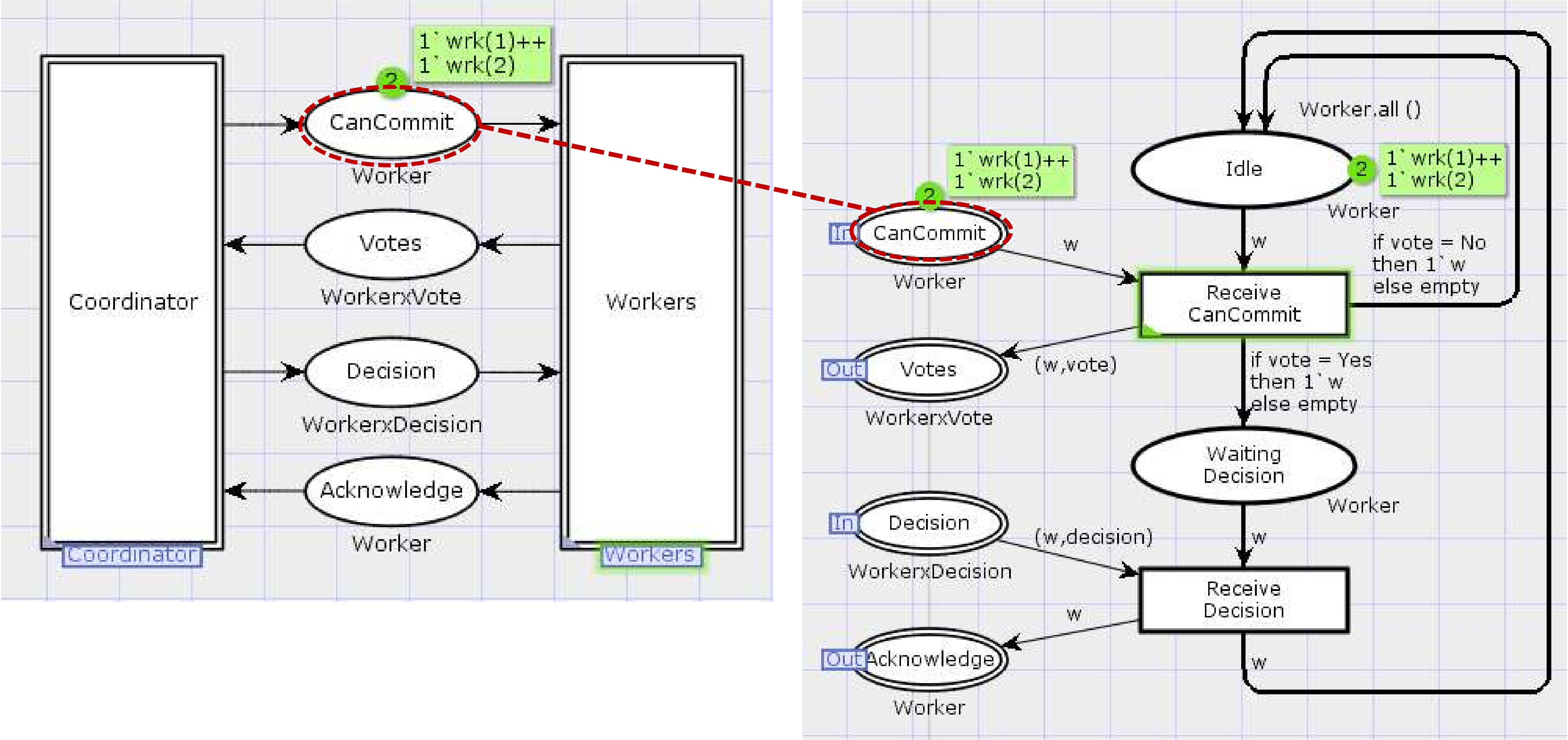
Protocol module



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

Workers Module

Protocol module | **Workers module**

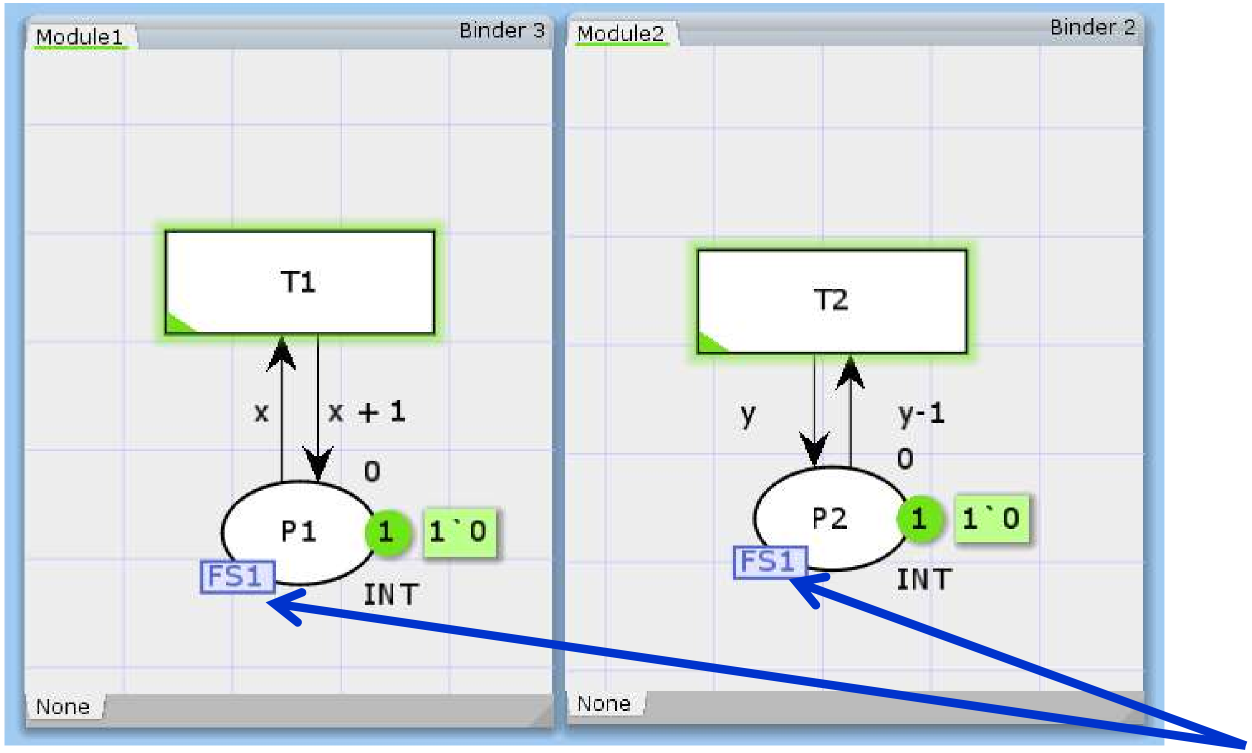


CPN Tools Demo

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

Place Fusion Sets

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



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

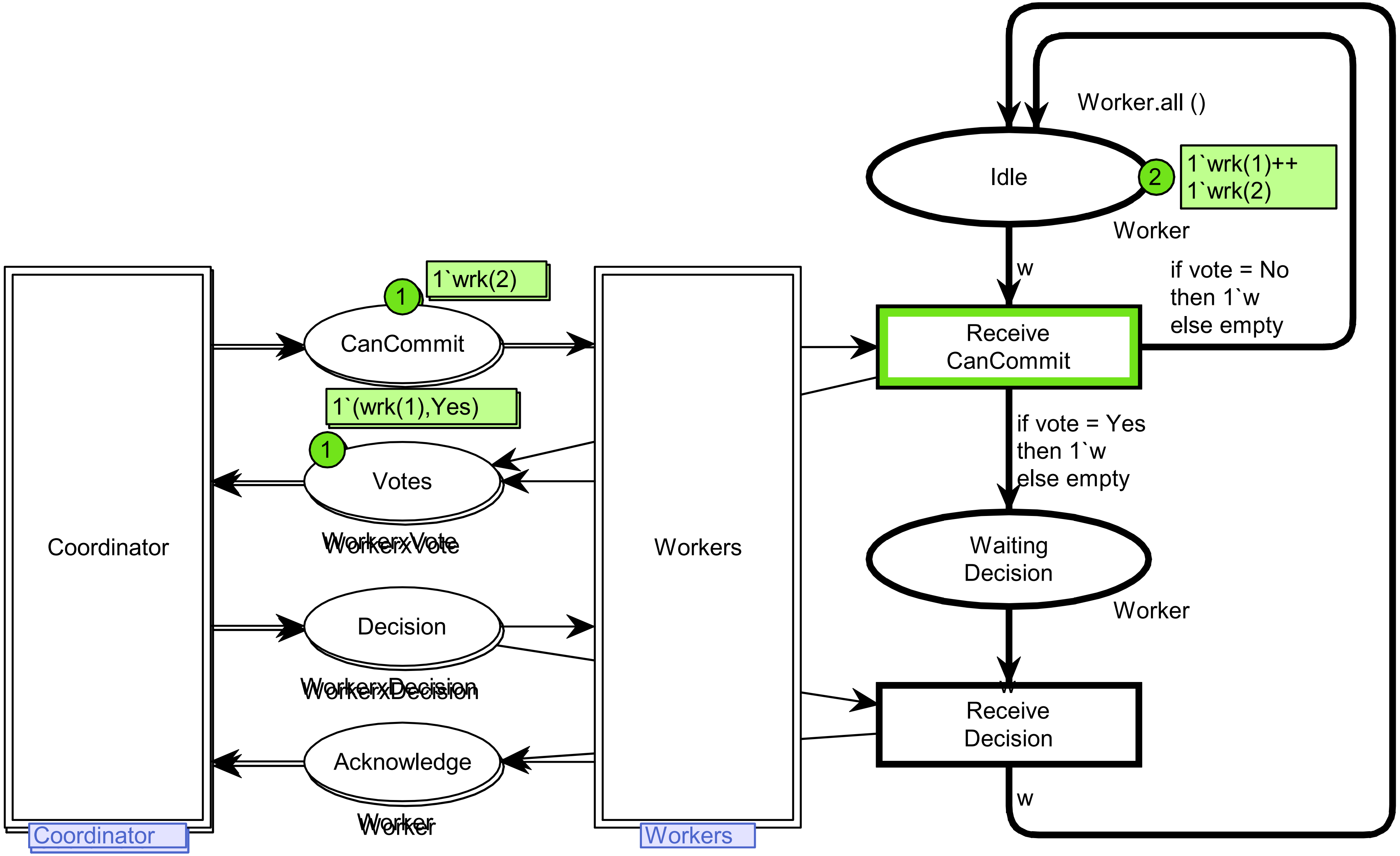
Similar to global variables - and should be used with care

P1 and P2 are fusion places belonging to fusion set FS1.

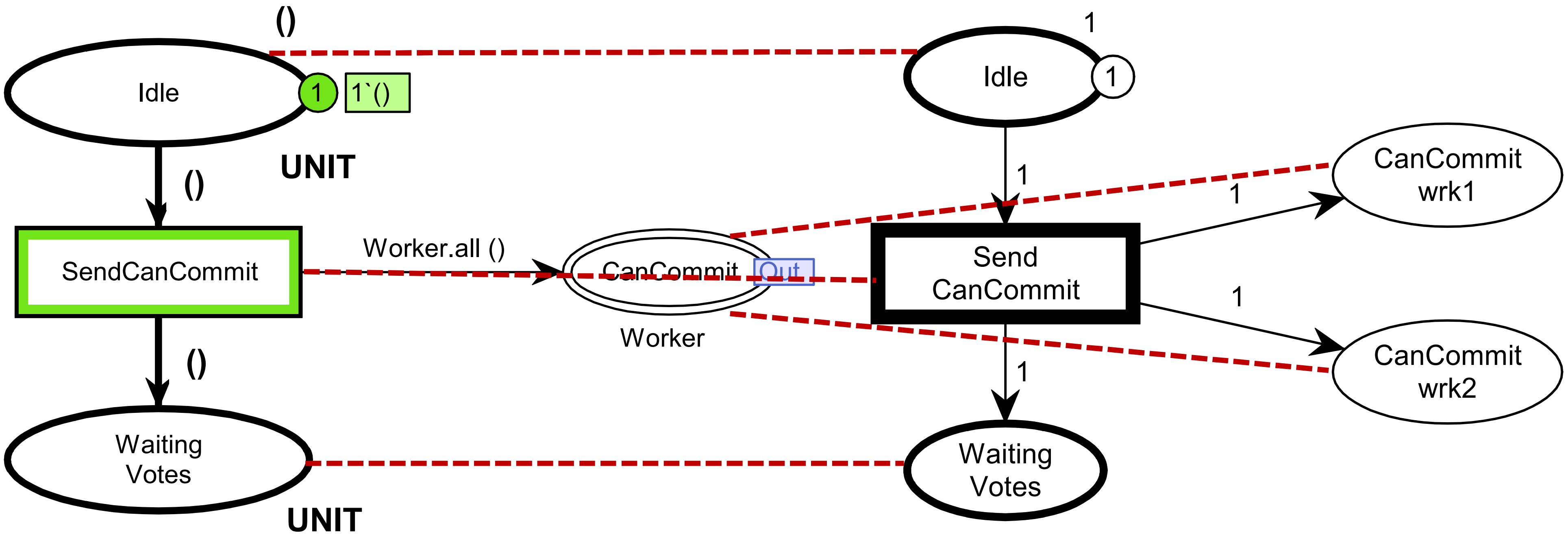
Unfolding Coloured Petri Nets

- **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.

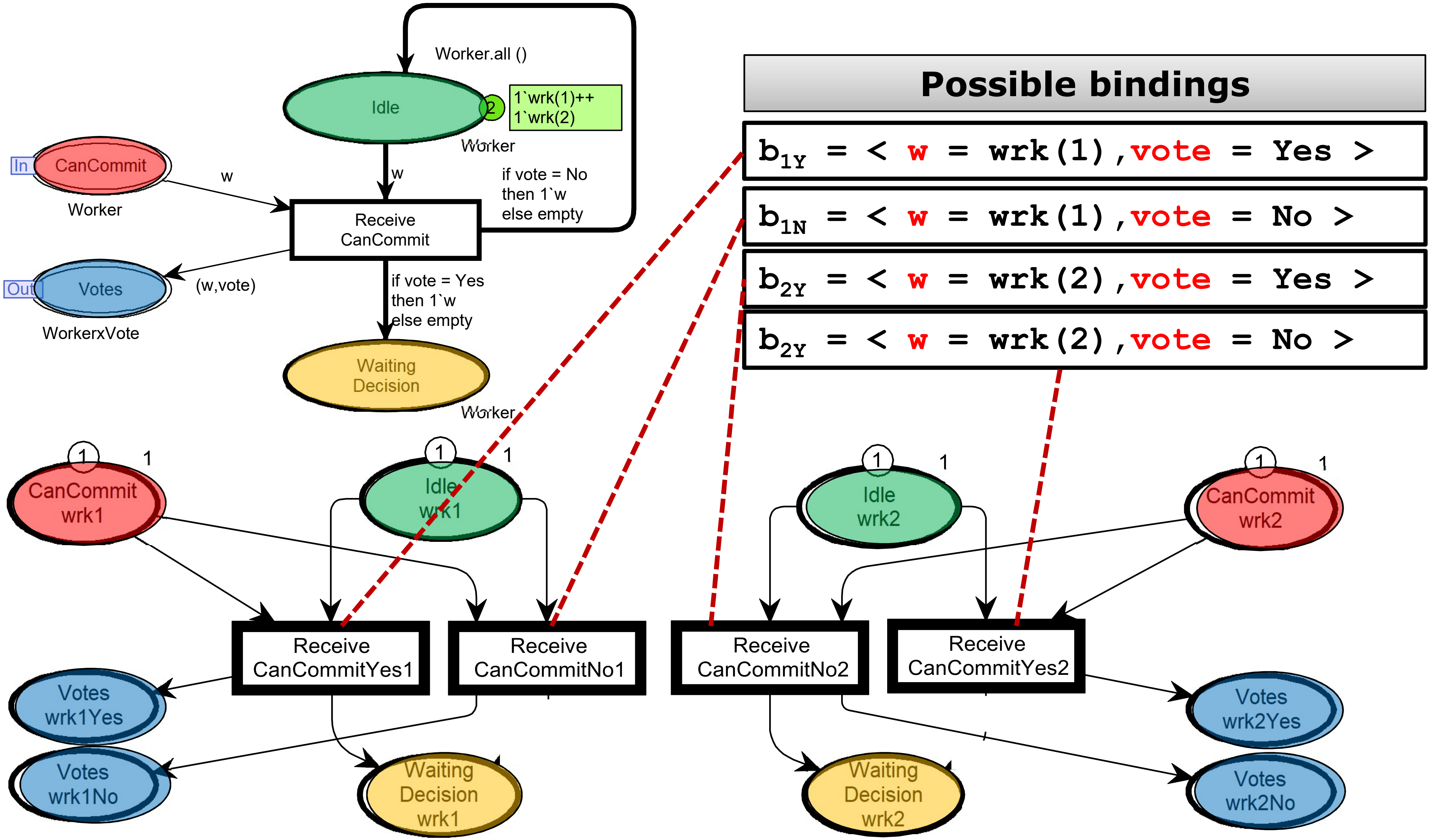
Unfolding hierarchical CPNs



Unfolding CPN Places



Unfolding CPN Transitions



Possible bindings

b_{1Y} = < w = wrk(1), vote = Yes >

b_{1N} = < w = wrk(1), vote = No >

b_{2Y} = < w = wrk(2), vote = Yes >

b_{2Y} = < w = wrk(2), vote = No >

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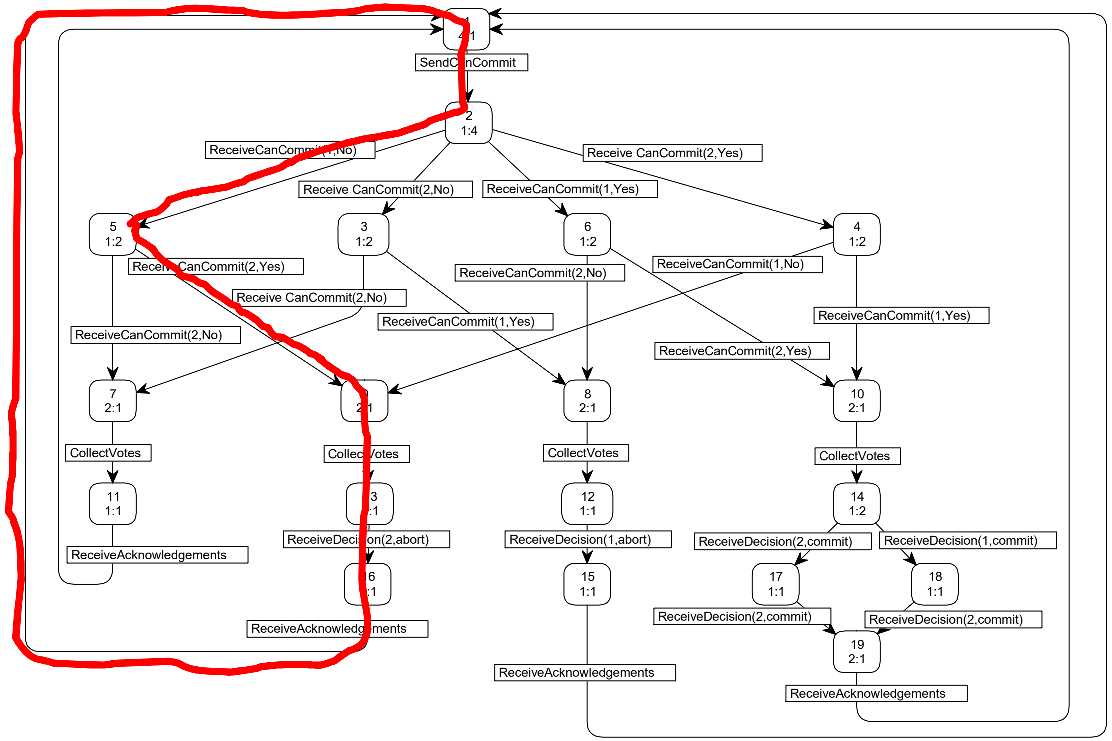
Verification and Model Checking

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

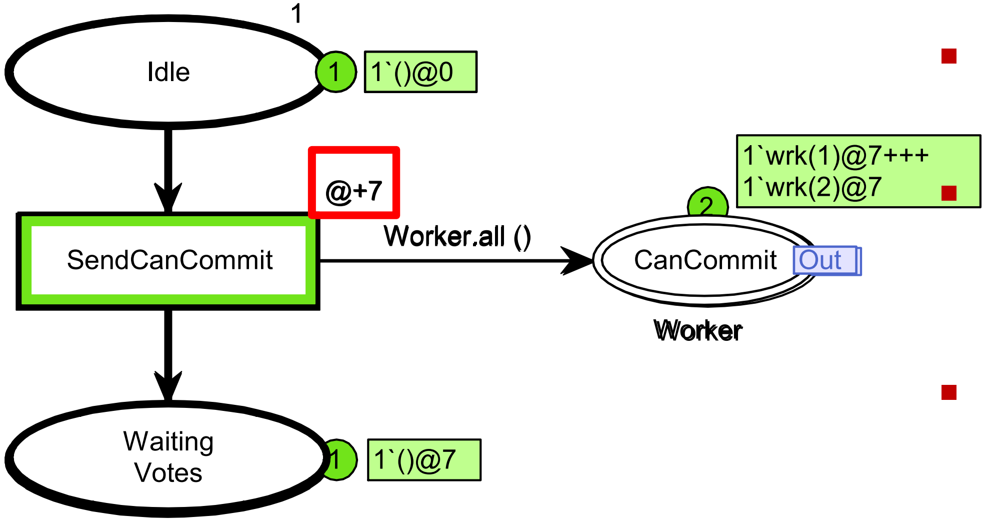


- **A state space represents all possible executions of the CPN model**
- **Standard behavioural properties can be investigated using the state space report**
- **Model-specific properties can be verified using queries and temporal logic model checking**

- **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**

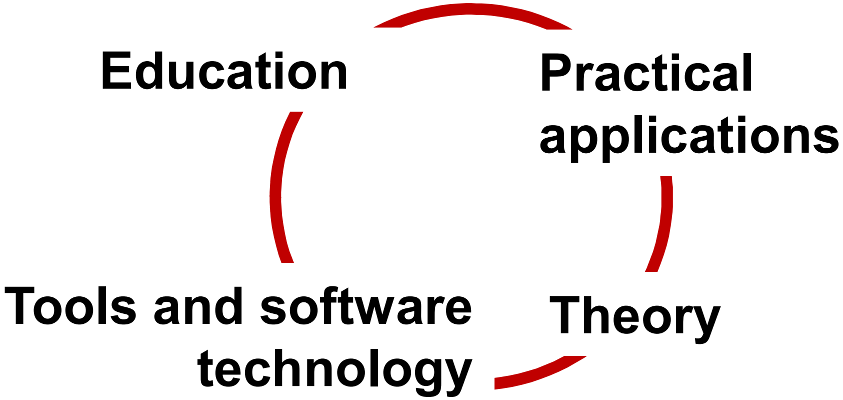
Tokens carry time stamps describing the earliest possible model time at which they can be removed

- **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 explicit synchronised
  - Verification and performance analysis supported by the same modelling language