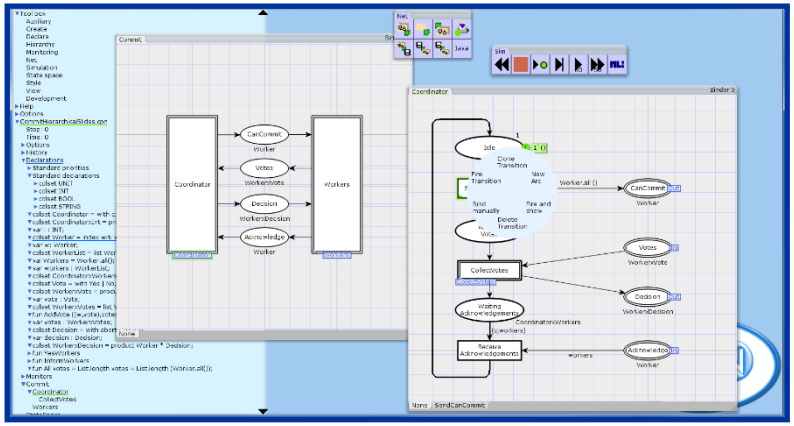
Lecture 3

Coloured Petri Nets



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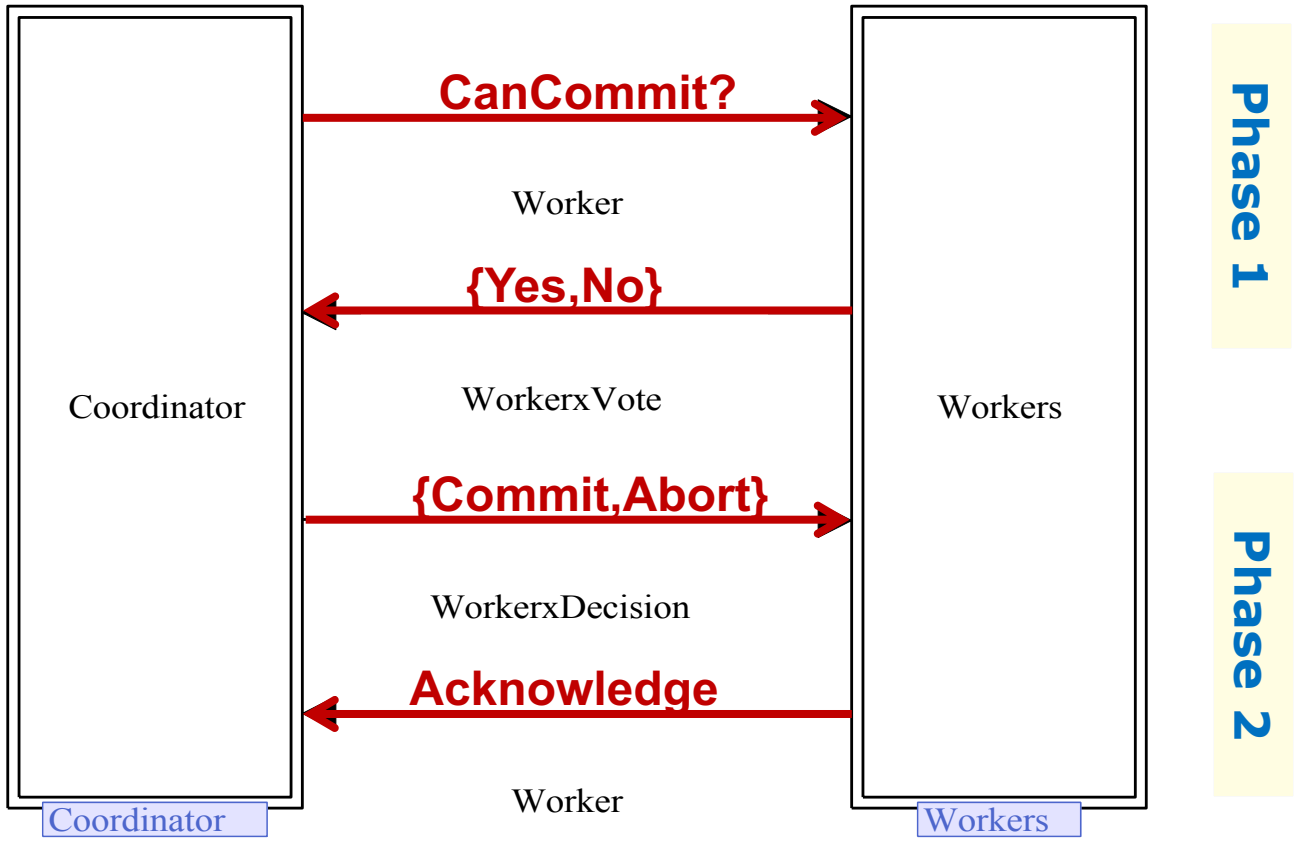
Introduction

- **Address the practical shortcomings of PT-nets.**
- **Coloured Petri Nets (CPNs) = PT-nets + Standard ML programming language**
  - Places may have a type and tokens can carry data values
  - Transitions may have variables that can be bound to values
  - Arc expressions determines the tokens added/removed
  - Guard expressions may be used as an extra enabling condition
- **Standard ML: functional programming language**
  - Computation proceeds by evaluation of expressions
  - Static typing with the type of expressions being inferred
  - Functions are first-order values and can be polymorphic
  - Recursion and lists are used for iteration

Two-phase Commit Transaction Protocol

- A **concurrent system** consisting of a **coordinator process** and a number of **worker processes**:



Colour Set Definitions

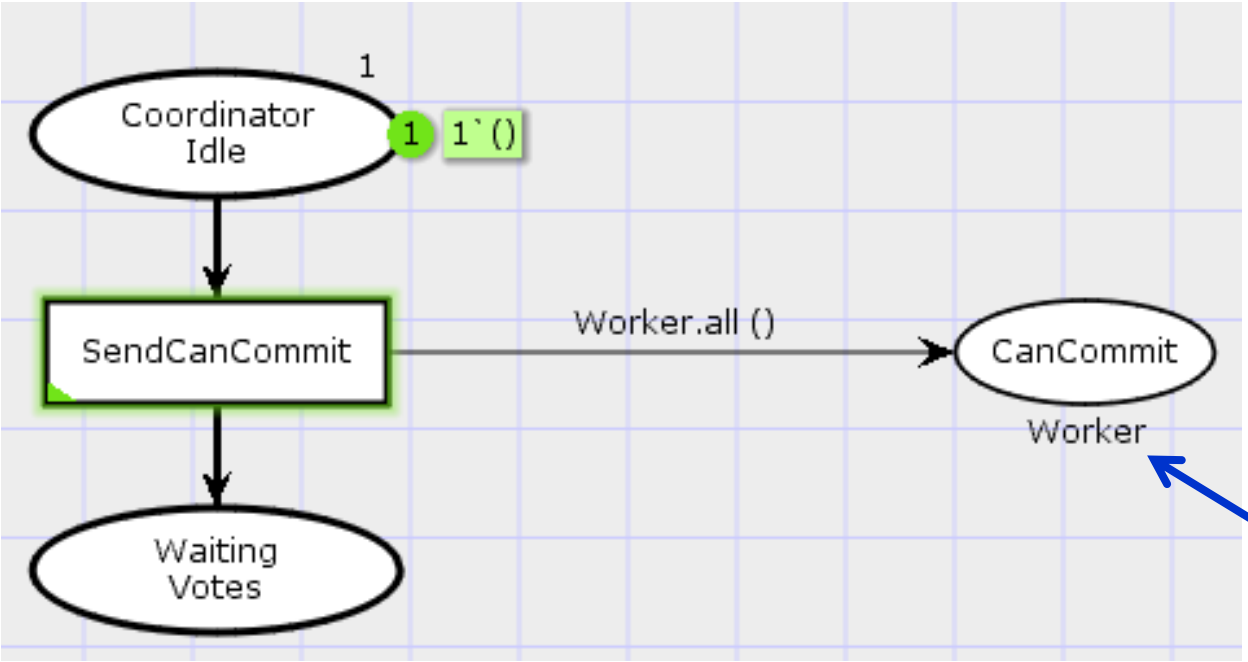
- **Determines the data types that can be used in the model:**

Colour set definitions	Example values
`val W = 2;`	`wrk(1), wrk(2)`
`colset Worker = index wrk with 1..W;`	`Yes, No`
`colset Vote = with Yes | No;`	`(wrk(1),Yes)`
`colset WorkerxVote = product Worker * Vote;`	`Abort, Commit`
`colset Decision = with Abort | Commit;`	`(wrk(1),Commit)`
`colset WorkerxDecision = product Worker * Decision;`	

- **Also colour set constructors for: lists (`list`), records (`record`), and unions (`union`)**
- **Base data types: `UNIT, INT, STRING, BOOL`**

Colour Set of a Place

- **Determines the kinds of tokens that may reside on the place**



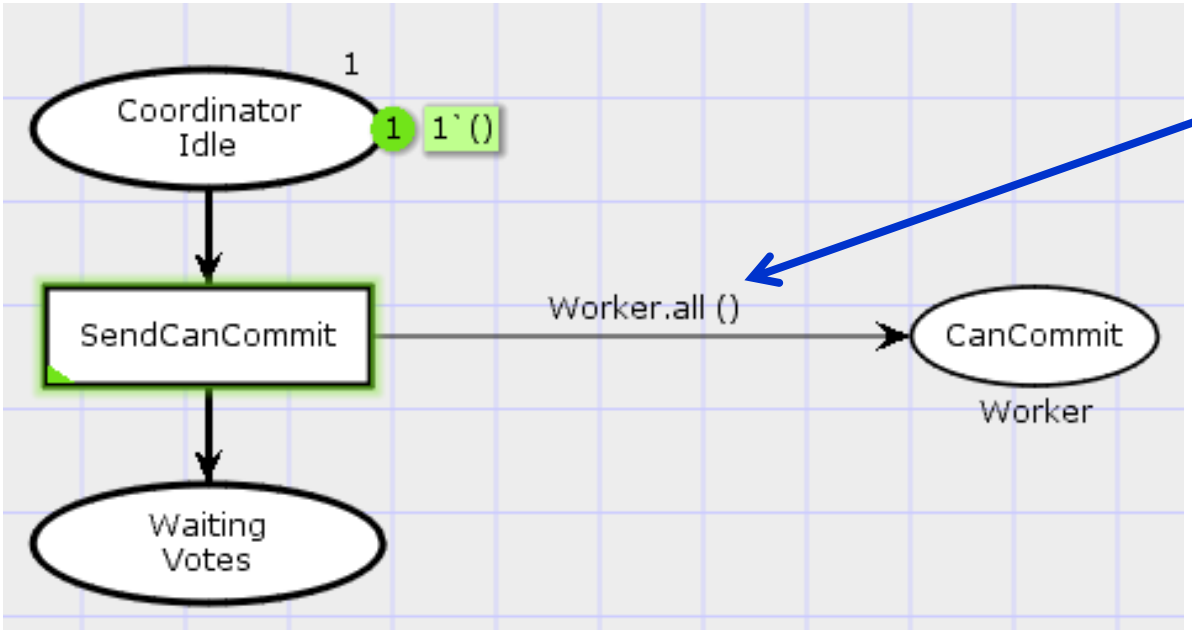
CoordinatorIdle and WaitingVotes are ordinary places

Tokens on CanCommit can have the values `wrk(1)` and `wrk(2)`

The colour set is by convention written below the place

Arc Expressions

- **Determine the tokens that are removed/added from places when transitions occur**



Expression evaluating to all values in the Worker colour set

```
Worker.all ()
```

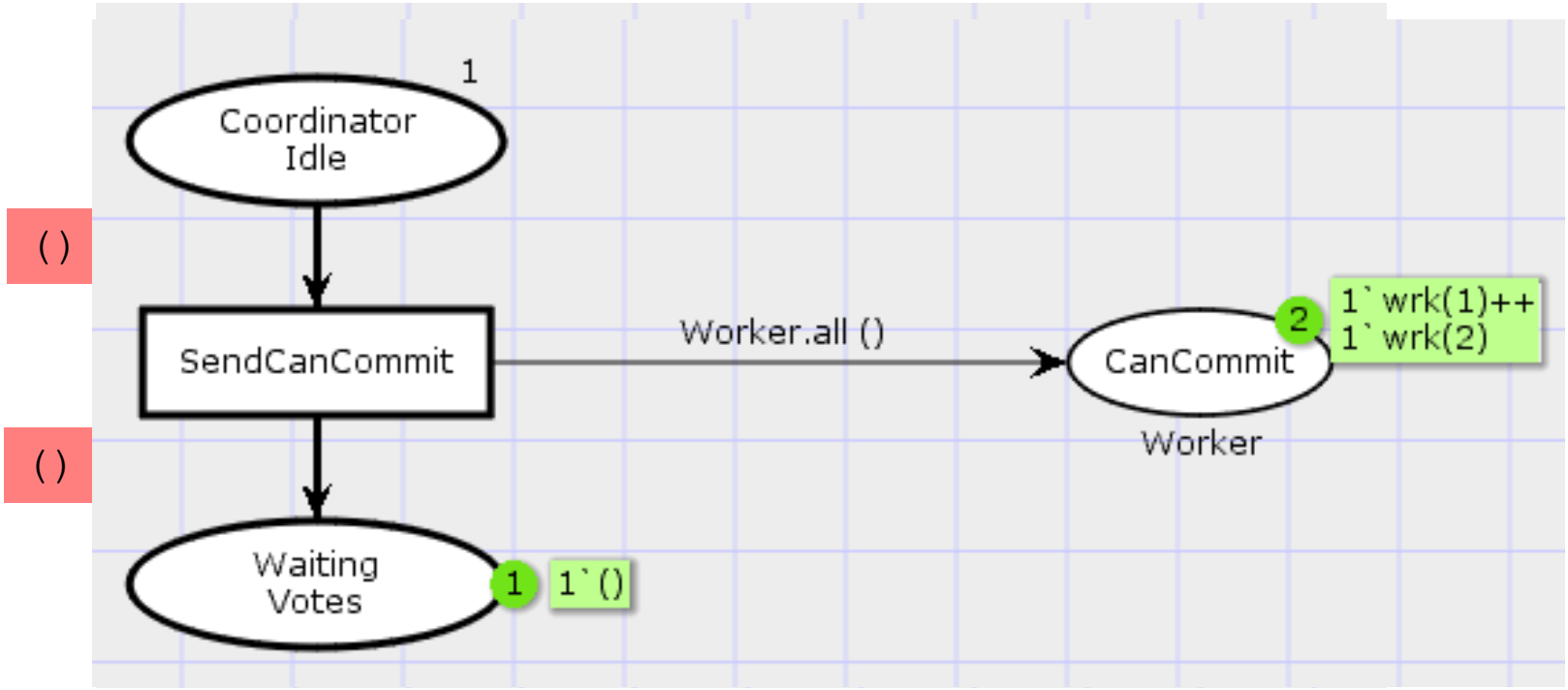
evaluate

```
[ wrk(1), wrk(2) ]
```

- **The type of an arc expression must match the colour set of the place connected to the arc.**

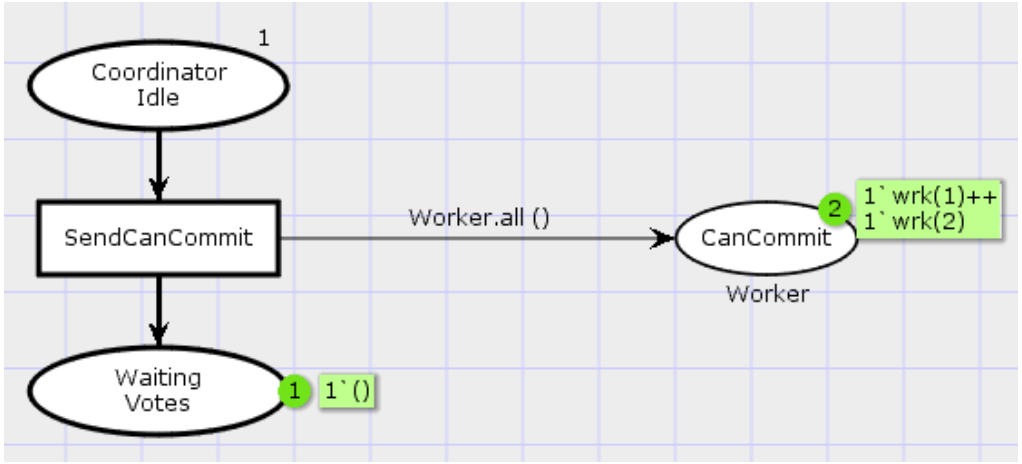
Evaluation of Expressions

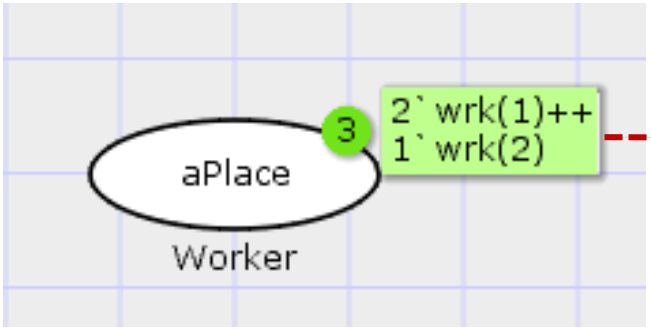
- **The tokens added and removed are determined by evaluating arc expressions:**



Markings and Multi-sets

- **Each place may hold a multi-set of tokens over the colour set of the place:**





Multi-set notation

coefficient («of»)

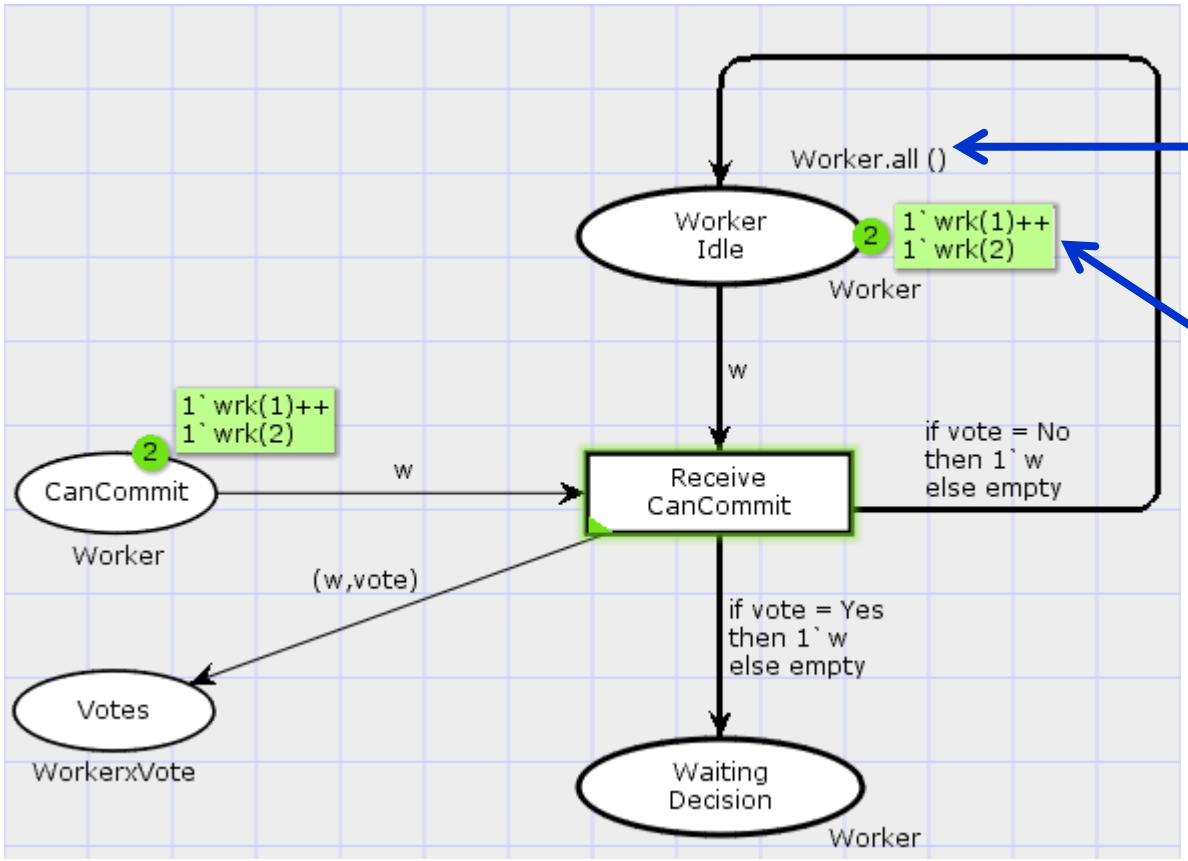
token colour (value)

```
2`wrk(1) ++
1`wrk(2)
```

union («and»)

Initial Marking

- **The initial marking (state) is obtained by evaluating the initial marking expressions:**

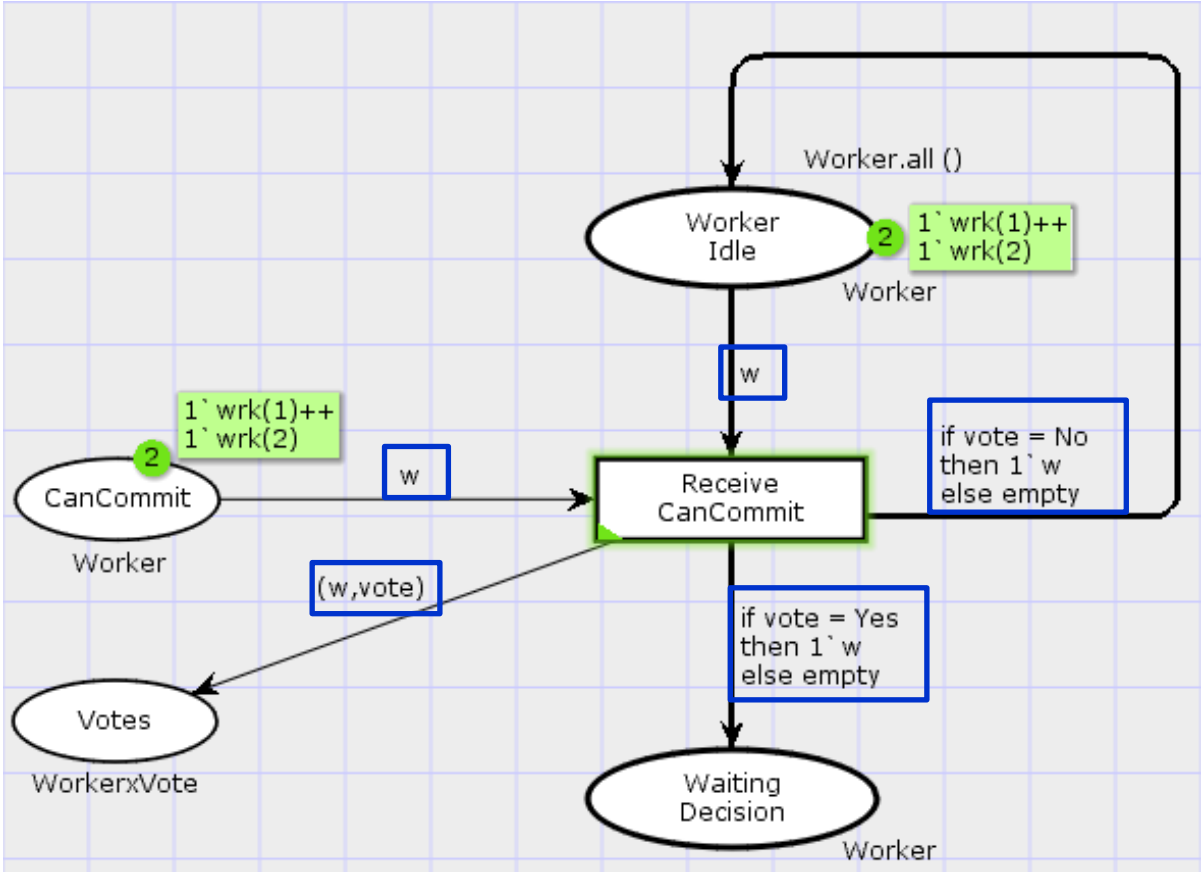


The initial marking is by convention written above the place

The two workers are initially Idle

Transition Variables

- **The arc expressions on the arcs of a transition may contain free variables:**



Variable declarations

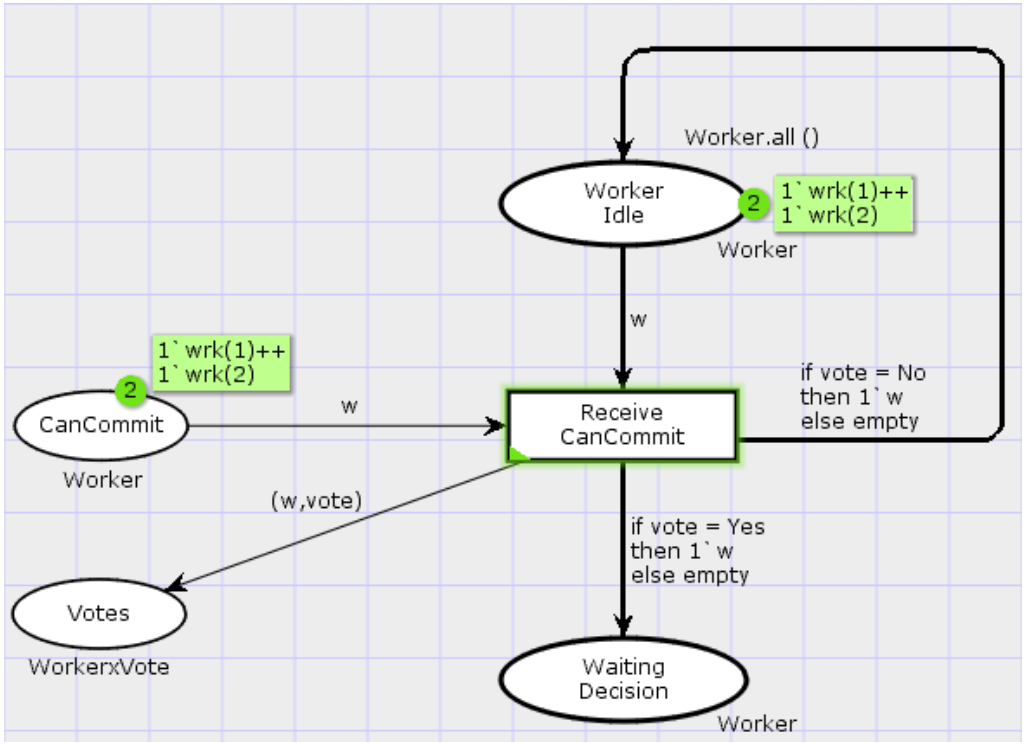
```
val W = 2;
colset Worker =
        index wrk with 1..W;
var w : Worker;

colset Vote = with Yes | No;
var vote : Vote;
```

Arc expressions with free variables vote and w.

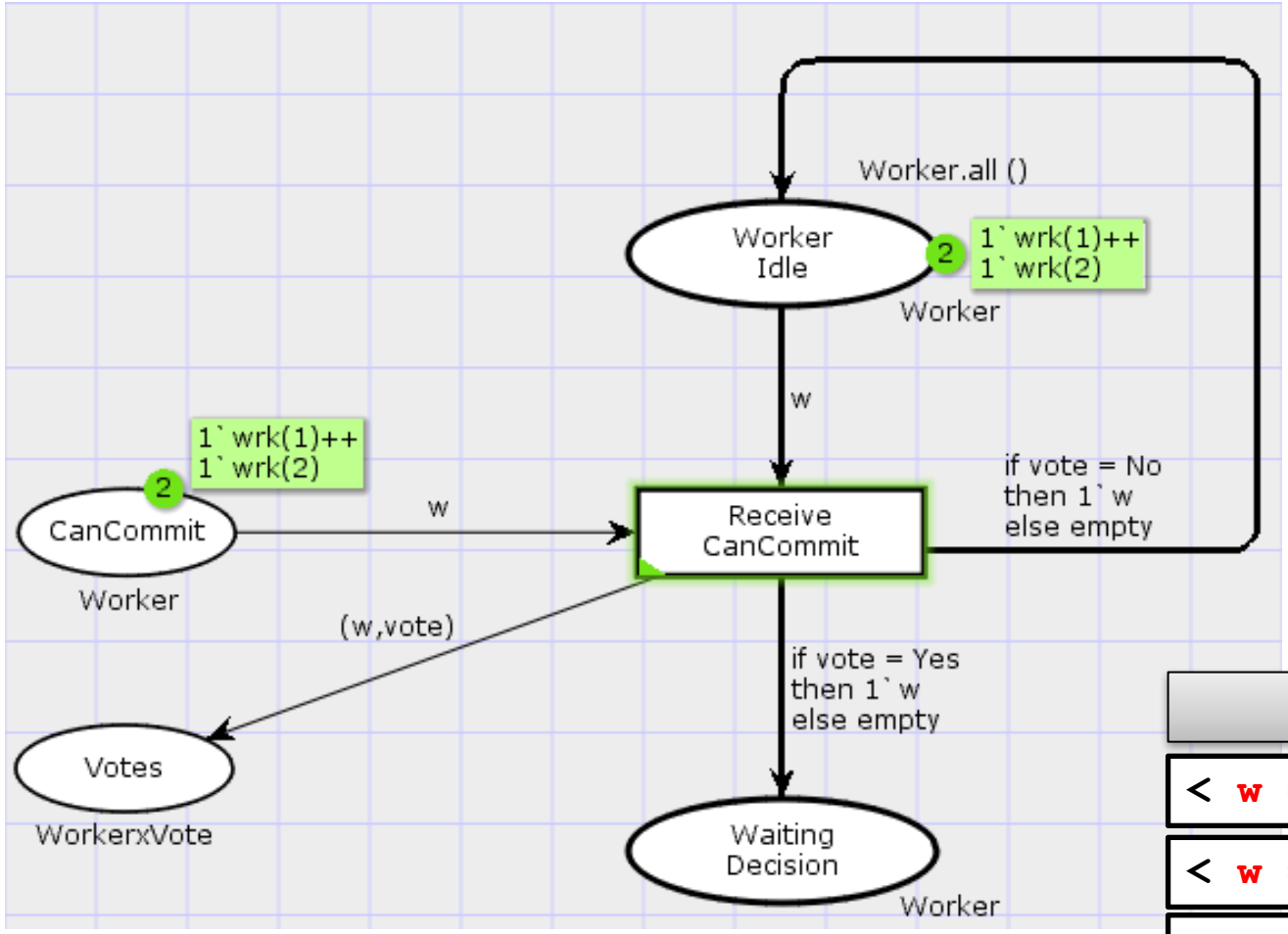
Transition Variables

- **Transition ReceiveCanCommit has two free variables: vote and w.**



- **Variables must be bound to values for a transition to be enabled and occur**
- **Similar to formal and actual parameters known from programming**
- **The bindings correspond to possible enabling and occurrence modes of the transition.**
- **The association of values to variables is called a binding.**

Transition Bindings

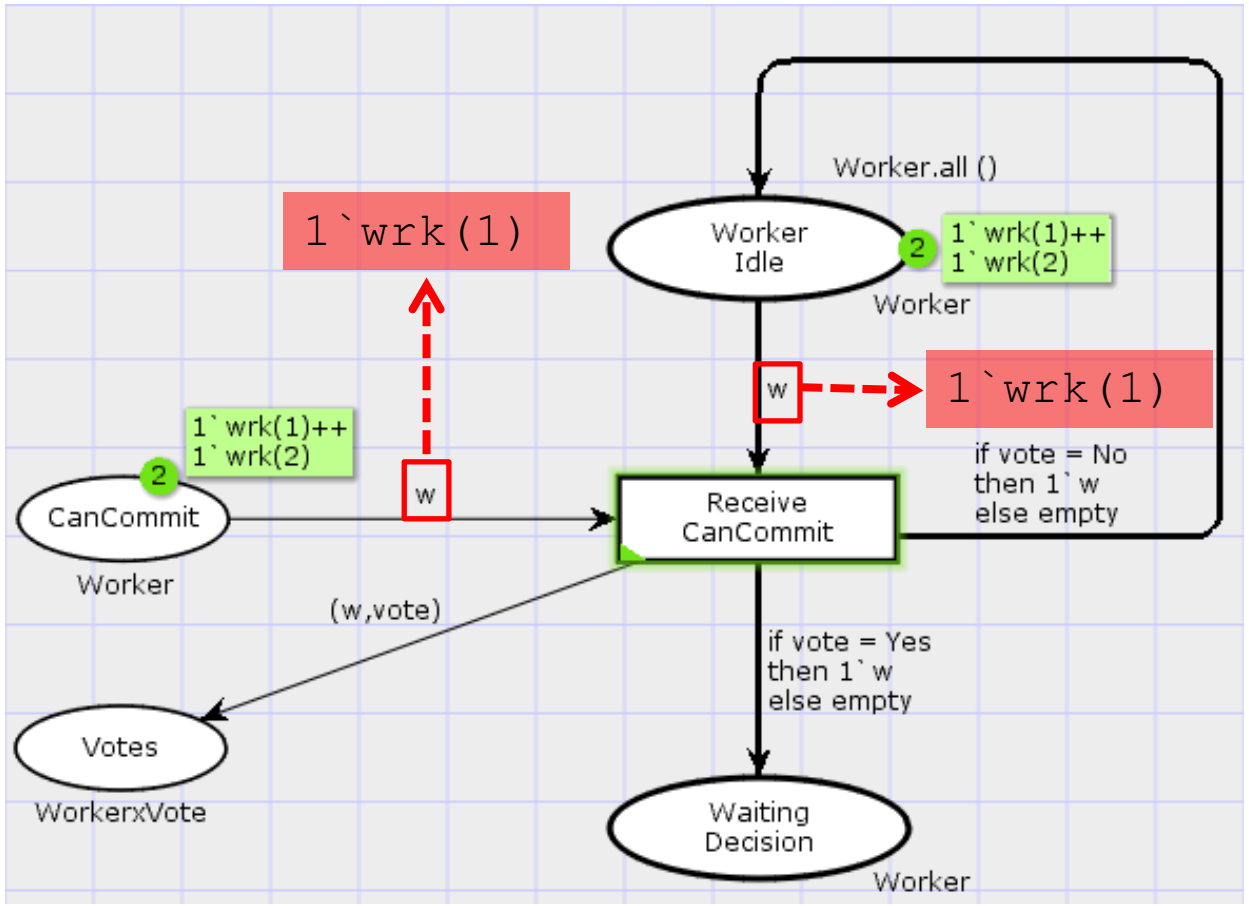


Possible bindings ?

- < w = wrk(1),vote = Yes >
- < w = wrk(1),vote = No >
- < w = wrk(2),vote = Yes >
- < w = wrk(2),vote = No >

Enabling: Transition Bindings

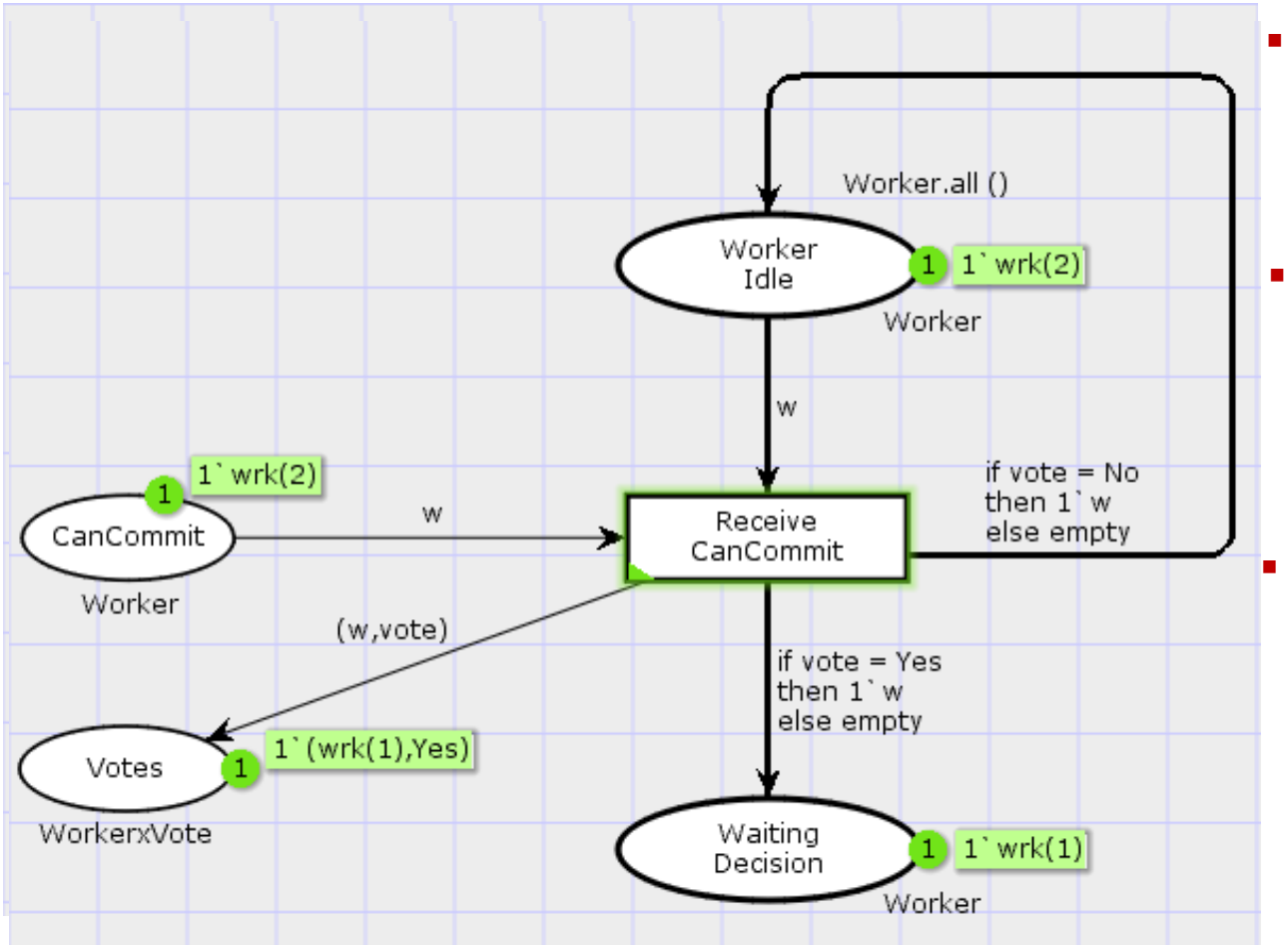
< w = wrk(1), vote = Yes >



- **A transition binding is enabled if there are sufficient tokens on each input place.**
- **Tokens required on input places are determined by evaluating the input arc expressions in the binding under consideration.**
- **Enabling condition: the multi-set of tokens obtained must be contained in the multi-set of tokens present on the corresponding input place.**

Occurrence: Transition Bindings

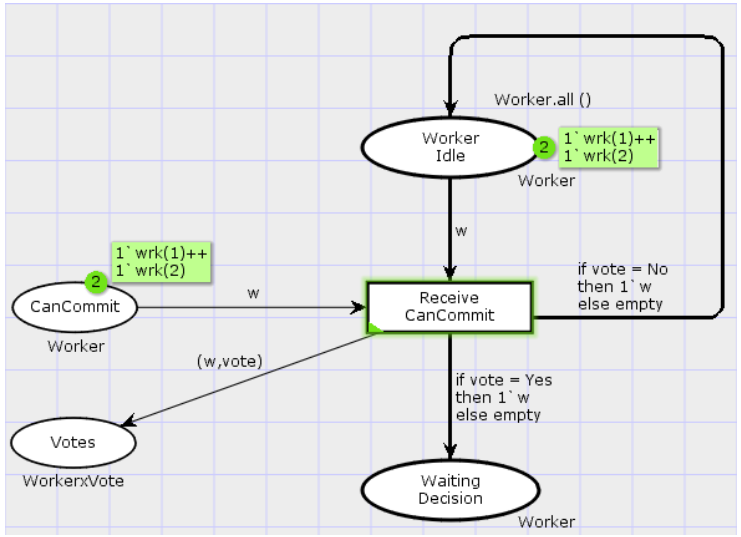
```
< w = wrk(1),vote = Yes >
```



- **An enabled transition binding may occur changing the current marking (state)**
- **Tokens removed from input places: determined by evaluating the input arc expression in the binding.**
- **Tokens added to output places: determined by evaluating the output arc expressions in the binding.**

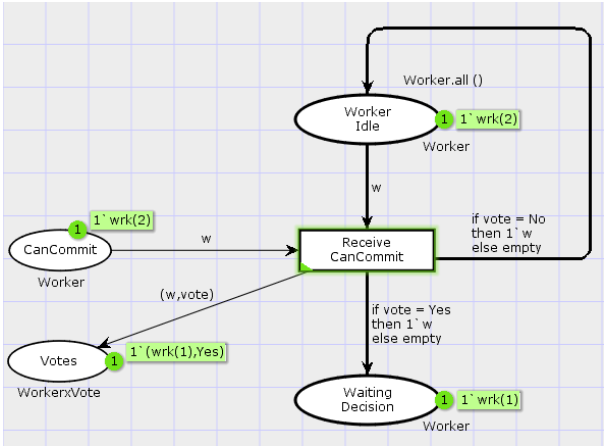
Occurrence: Transition Bindings

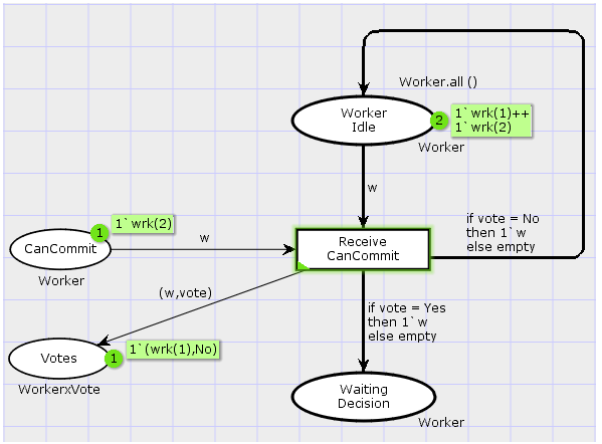
- **A transition may have several enabled bindings:**



b_{1Y}

b_{1N}





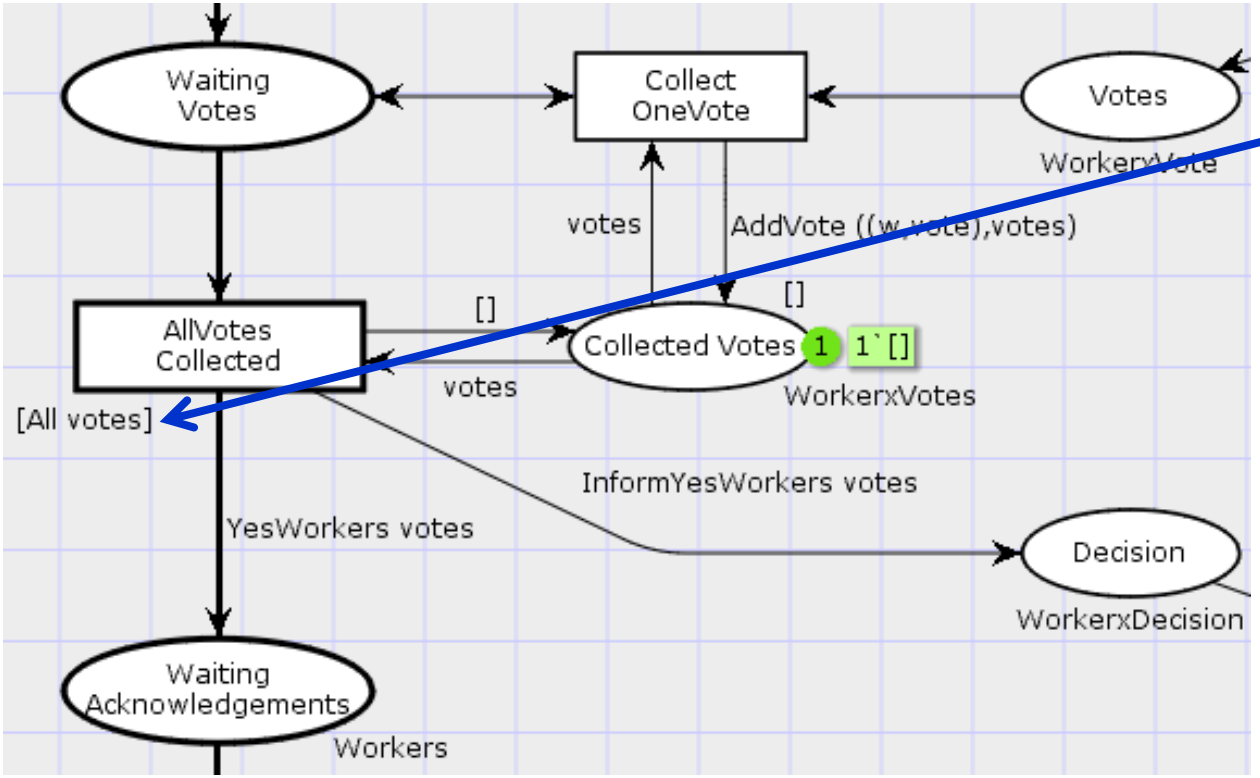
Bindings
b_{1Y} = < w = wrk(1), vote = Yes >
b_{1N} = < w = wrk(1), vote = No >
b_{2Y} = < w = wrk(2), vote = Yes >
b_{2Y} = < w = wrk(2), vote = No >

CPN Tools Demo

- **Simulation of CPN models**
  - Interactive simulation with binding selection
  - Returning to the initial marking
  - Automatic simulation with visual feedback
  - Stop options and automatic simulation

Guard Expressions

- **A transition may have a boolean guard expression which is extra enabling condition**



The guard is by convention written in square brackets next to the transition

```
fun All votes =
    (List.length votes = W)

var votes : WorkerxVotes

colset WorkerxVotes =
   list WorkerxVote;

colset WorkerxVote =
   product Worker * Vote;
```

CPN Tools Demo

- **Editing of CPN models**
  - Incremental syntax check of the model (dependencies)
  - Adding and deleting declarations
  - Editing inscriptions
    (arc expressions, colour sets, initial markings, guards)
  - Guidelines, graphical attributes, and groups