

**Specifying properties of real-time systems**  
**--- UPPAAL query language**

**Transition Systems**  
as the semantics of real-time system

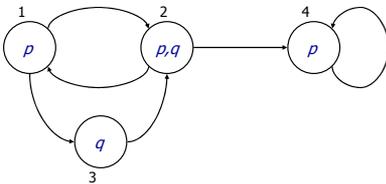
A transition system is a graph with

- a set of states (may be infinite)
- a set of transitions (may be infinite)

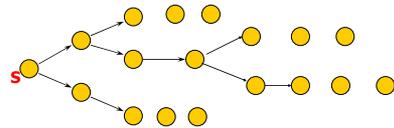
where

- a state may satisfies some properties (propositions/predicates)

Example (states are labeled with propositions)

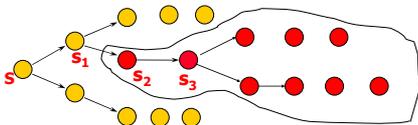


**Computation Trees**



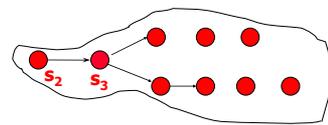
The computation tree of state S

**Computation Trees vs. STATES**



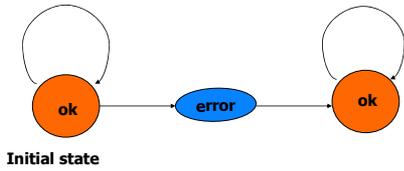
The computation tree of state S<sub>2</sub>

**Computation trees of STATES**



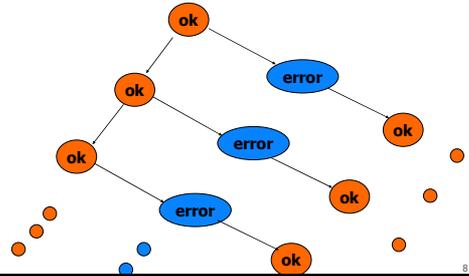
The computation tree of state S<sub>2</sub>

# EXAMPLE: a BUGGY machine



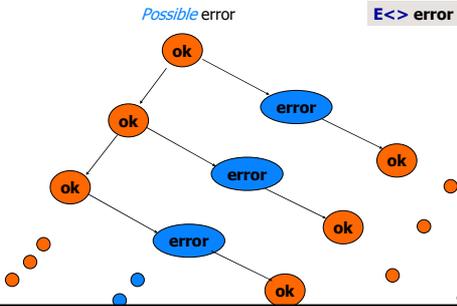
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# The Computation Tree of BUGGY



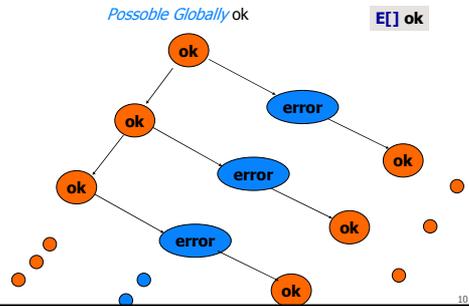
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# "Properties" of BUGGY



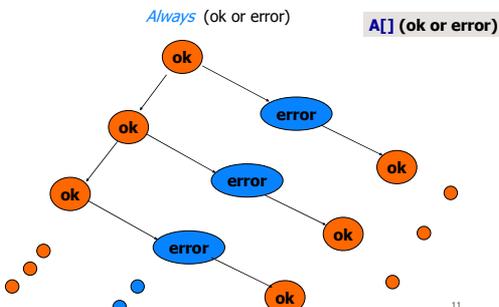
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# "Properties" of BUGGY



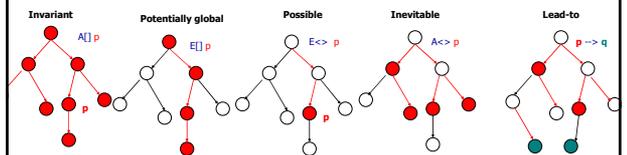
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# "Properties" of BUGGY



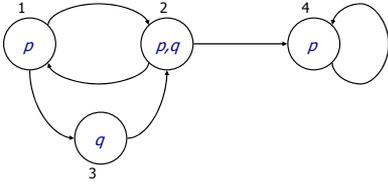
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# Properties of Computation Trees



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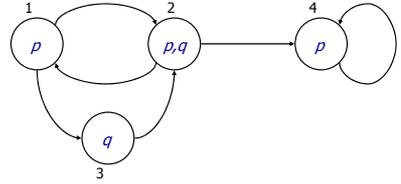
Example



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Example

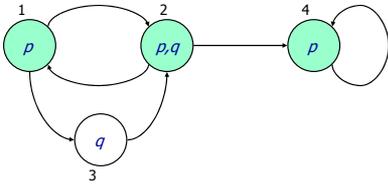
$E[] p$



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Example

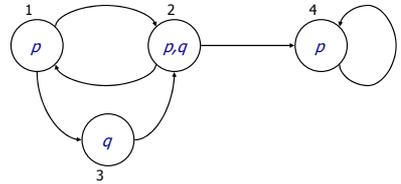
$E[] p$



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Example

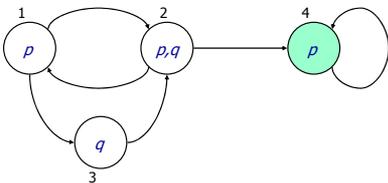
$A[] p$



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Example

$A[] p$



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UPPAAL specification language

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## Formalizing requirements in UPPAAL

$A[]p$ ,  $A<>p$ ,  $E<>p$ ,  $E[]p$ ,  $p \dashrightarrow p$   
 where  $p$  is a local property

$p ::= a.l \mid ga \mid gc \mid p \text{ and } p \mid$   
 $p \text{ or } p \mid \text{not } p \mid p \text{ imply } p \mid ( p )$

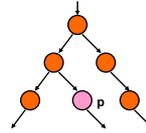
automaton location      data guard      clock guard

process/ name

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## $E<>p$ "p Reachable"

- it is possible to reach a state in which  $p$  is satisfied.

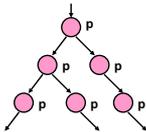


- $p$  is true in (at least) one reachable state.

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## $A[]p$ "Invariantly p"

- $A[] p - p$  holds invariantly.

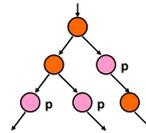


- $p$  is true in all reachable states.

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## $A<>p$ "Inevitable p"

- $p$  will inevitably become true, the automaton is guaranteed to eventually reach a state in which  $p$  is true.

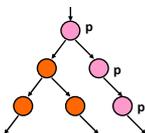


- $p$  is true in some state of all paths.

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## $E[]p$ "Potentially Always p"

- $p$  is potentially always true.

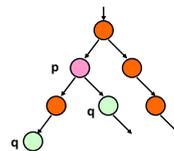


- There exists a path in which  $p$  is true in all states.

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## $p \dashrightarrow q$ "p lead to q"

- whenever  $p$  becomes true,  $q$  will inevitably become true. This is the same as  $A[]( p \text{ imply } A<> q )$



- In all paths, if  $p$  becomes true,  $q$  will inevitably become true.

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