

# Reliable Model Checking for WSNs





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- *Communication characteristics and verification of WSNs*
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# Introduction

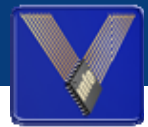




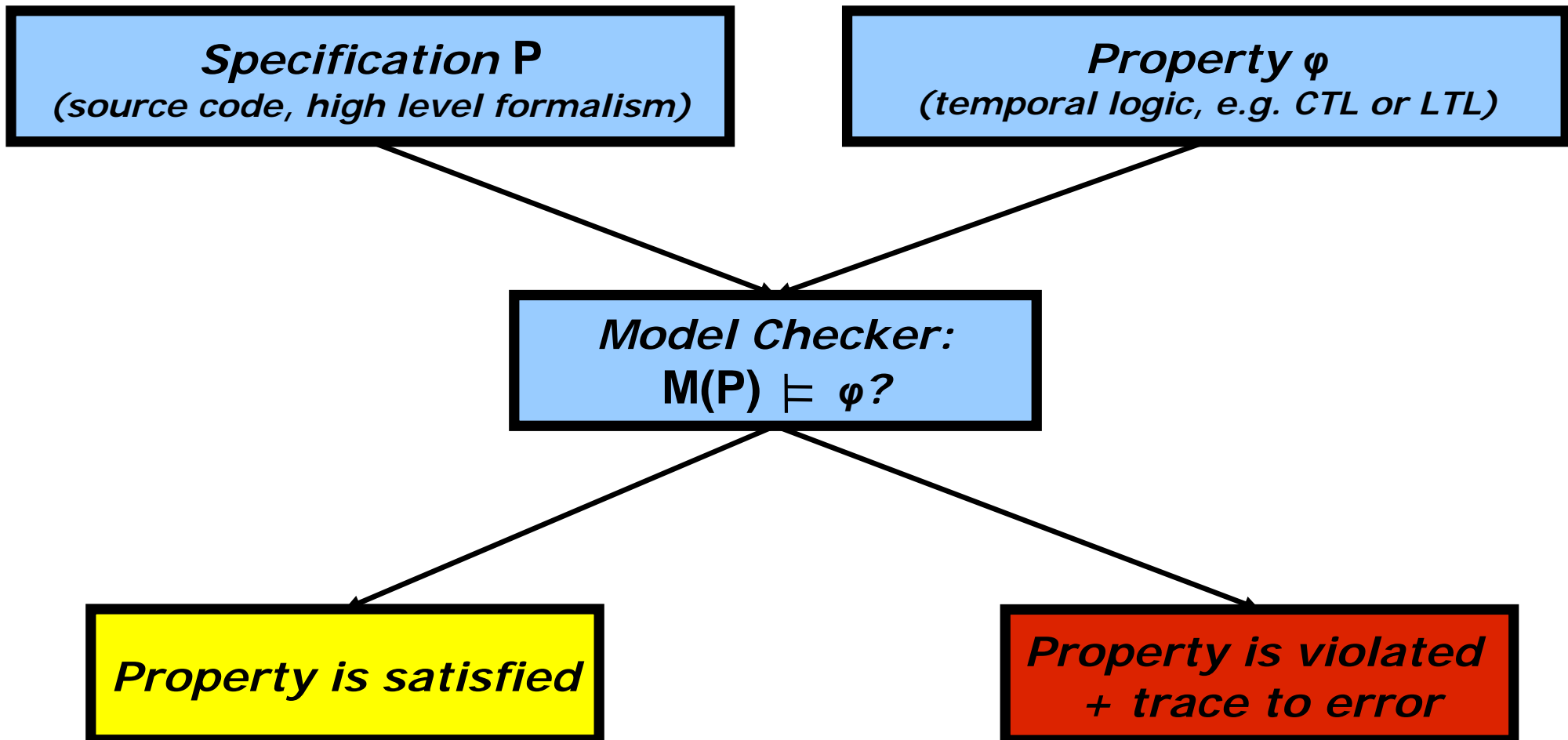
- *Verification techniques:*
  - *Simulation:*
    - *stimulation of a system with input patterns*
    - *check if the system behaves as desired*
    - *no exhaustive analysis of system behavior*
    - *complex errors often cannot be detected*
  - *Formal Verification:*
    - *examination of all possible system behaviors*
    - *allows reliable detection of complex errors*



- *Formal Verification techniques:*
  - *Theorem Proving*
  - *Model Checking*
- *Model Checking:*
  - *fully-automated through tools called **Model Checkers***
  - *given a finite-state model of a system and a formal property, exhaustive investigation whether property holds for that model*
  - *counterexample generation if a property is violated*



- Model Checking Process:



# Particularities of WSNs with regard to verification





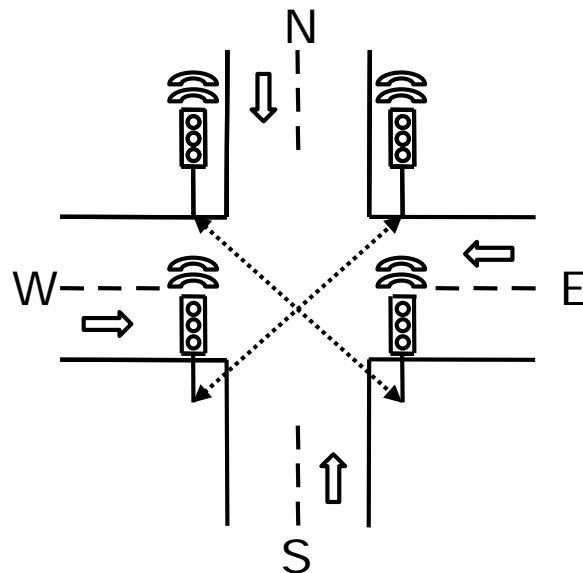
- *Verification of WSNs is a highly non-trivial task*
  - *a single sensor node (hardware+software) can be very complex*
  - *WSNs can consist of a large number of sensor nodes and verification of distributed systems is hard*
- *Additionally communication is wireless*
  - *wireless communication has some particularities, e.g. occurrence of*
    - *transmission errors and collisions*
    - *radio wave propagation variations*

# Implementing a traffic light synchronization protocol





- *Case Study: Verification of a traffic light synchronization protocol at 4-way road intersections with the Model Checker NuSMV*



*road intersection  
with traffic lights*

***Important safety-critical  
property:***

***→ only diagonally  
arranged traffic  
lights can show green or  
yellow at the same  
time***

***Other desirable properties:***

***→ no deadlock***

***→ fair allocation of green phases***

# Communication characteristics and verification of WSNs





- *Extract of the verification model for the traffic light at north:*

*init(cState) := red;*

*next(cState) :=*

*case*

*state = red & sendReqSouth & !collision : recAck1;*

*state = red & (sendReqEast | sendReqWest) & !collision : prepAck;*

*state = red & chanFree & changeAllowed=yes & boolInput : sendReq;*

*state = sendReq : recAck1;*

*state = recAck1 & sendAckEast & !collision : ackEast;*

*state = recAck1 & sendAckWest & !collision : ackWest;*

*state = recAck1 & (sendReqEast | sendReqWest) & !collision : prepAck;*

*state = ackEast & sendAckWest & !collision & !(changeAllowed=partner) :*

*ackPartner;*

*state = ackWest & sendAckEast & !collision & !(changeAllowed=partner) :*

*ackPartner;*

*state = ackPartner & sendAckSouth & !collision : yellow;*

*state = prepAck & boolInput & chanFree : sendAck;*

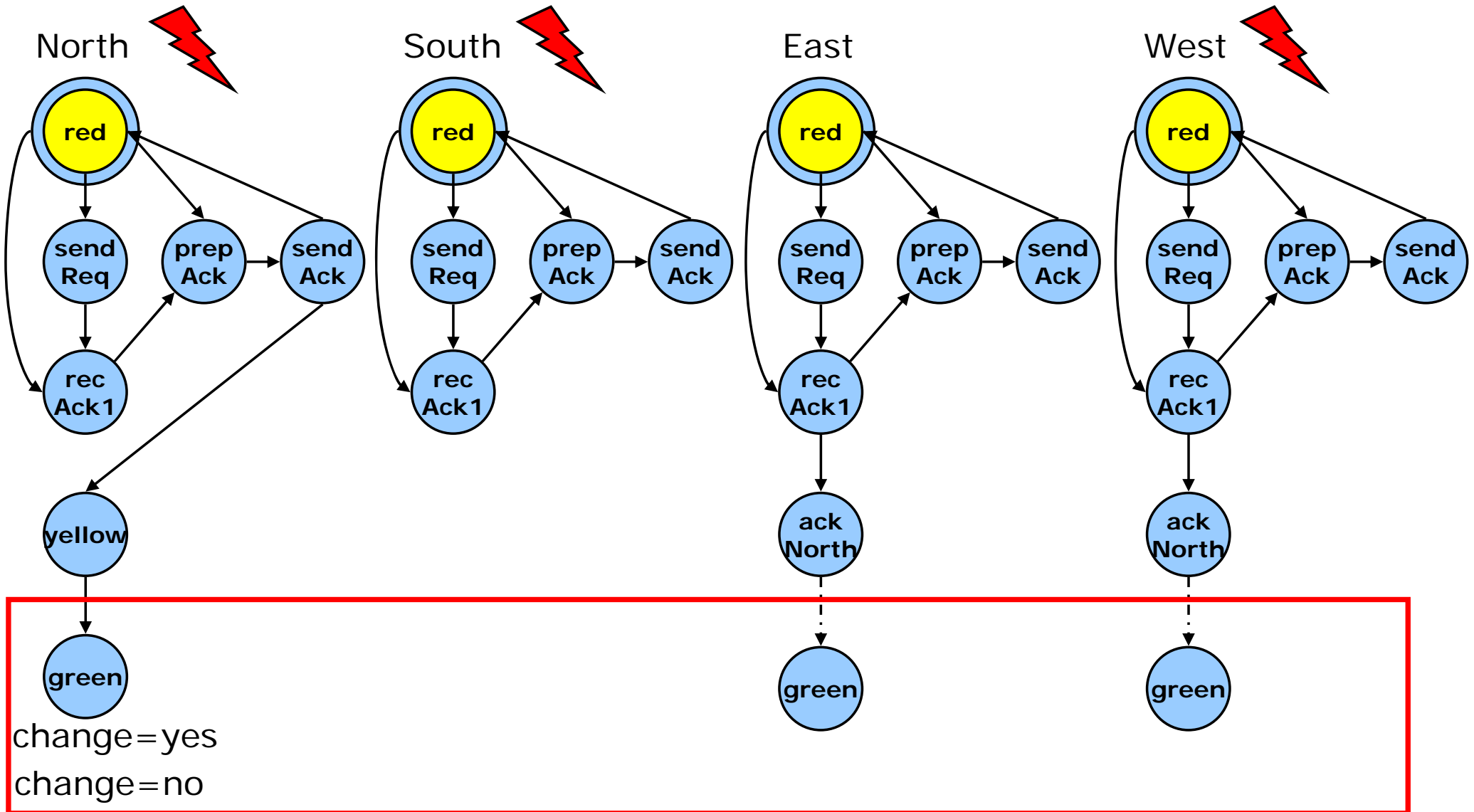
*state = sendAck & changeAllowed=partner : yellow;*

*state = sendAck & !(changeAllowed=partner) : red;*

*state = yellow & direction=down : green;*



- *Non-observance of variations of radio wave propagation*

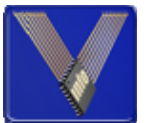


**change=partner**



- *Non-observance of variations of radio wave propagation can circumvent the detection of safety-critical errors*
- *For reliable verification of WSNs it's necessary to include them in the verification model*
- *Because of the state space explosion problem abstract models which contain at least all relevant behaviors are necessary*
- *In our work we have developed some suitable abstractions, e.g. for*
  - *variations of radio wave propagation*
  - *a MAC protocol with carrier sense and a randomized backoff procedure*

# Conclusion and Outlook





- *Often system components of WSNs cannot be verified isolated*
- *A model of the communication characteristics can be necessary for reliable verification*
- *Even models of other system components, like e.g. timers or parts of operating systems, could be necessary*
- *Especially for non-verification experts, suitable and faultless abstractions should be available*
- *Future work:*
  - *Development of suitable abstractions for several other WSN components*
  - *Improvement and examination of verifiability of dynamic topologies*

# Questions?

