Probabilistic Verification of Sensor Networks

Experimenting a New Framework for Sensor Networks

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- miniature device
- low-cost ($1)
- limited computation power
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To monitor an area, e.g.,

- intrusion detection
- fire surveillance
- ...

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- Approximate Probabilistic Model Checking

Probabilistic Verification of Sensor Networks

Randomized Approximation Scheme

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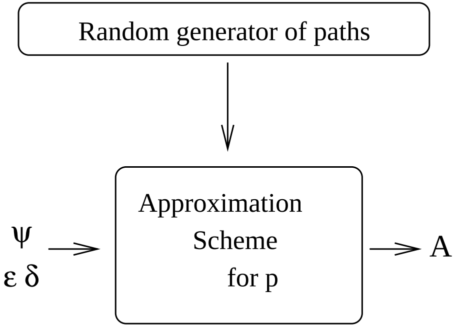

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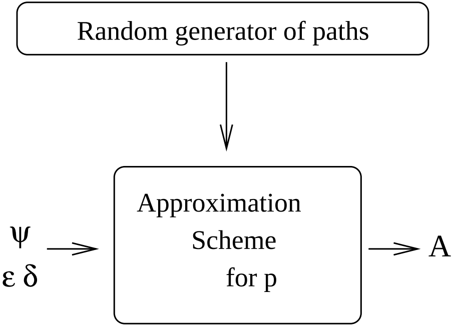

Definition (FPRAS)

Fully polynomial randomized approximation scheme with time complexity
$\mathrm{poly}(\log(1/\delta), |\,\psi\,|, (1/\varepsilon))$

Our algorithm

Algorithm (Generic approximation)

input: ψ, *diagram*, ϵ, δ

Let $P := 0$

Let $N := \frac{1}{2}\log(\frac{2}{\delta})/\epsilon^2$

For i *from* 1 *to* N *do*

1. *Generate a random path* σ *of depth* k
2. *If* ψ *is true on* σ *then* $P := P + 1$

Return $A = P/N$

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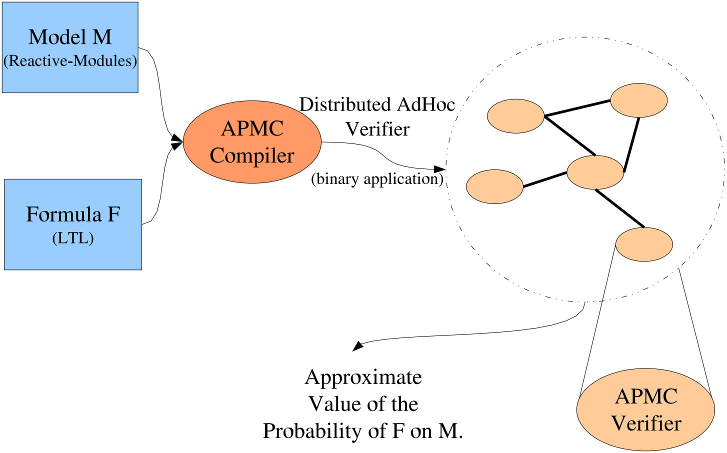
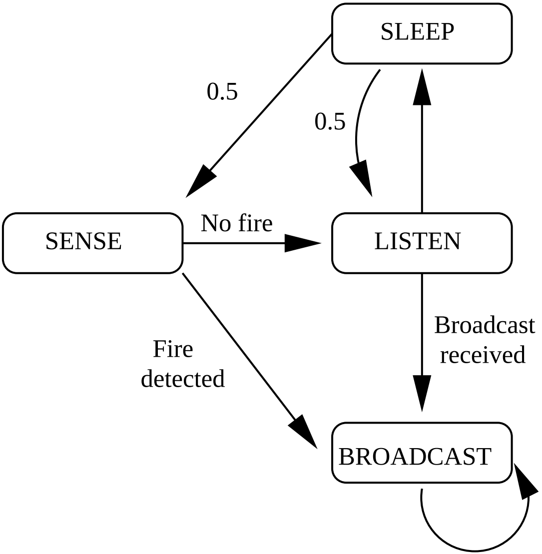
Theorem

This algorithm is an additive FPRAS for $\mathrm{Prob}[\psi]$

Architecture



A single sensor



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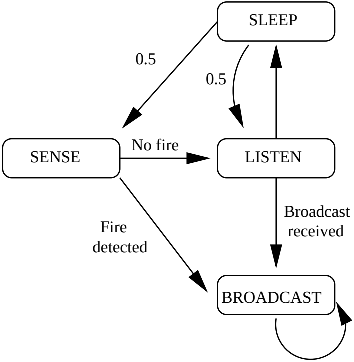
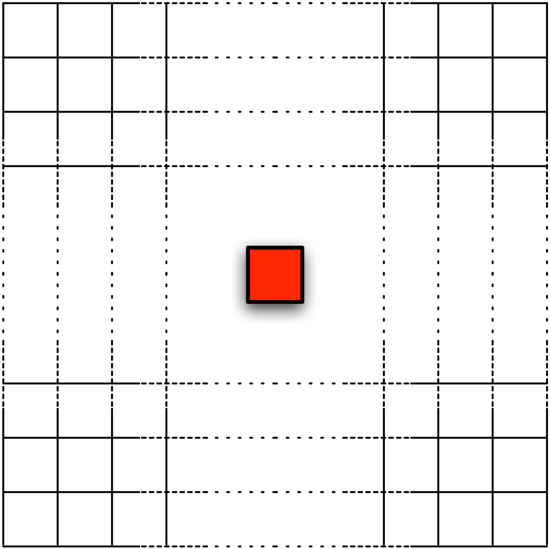
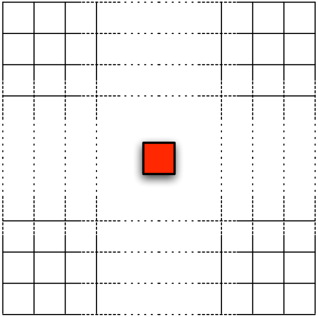



```
module sensor

  s : [0..4]  init SENSE;

  [] s = SENSE
    -> s = senses ? BROADCAST : LISTEN;
  [] s = LISTEN
    -> s = receives ? BROADCAST : SLEEP;
  [] s = SLEEP
    -> 0.5 : s = SENSE
     + 0.5 : s = LISTEN;
  [] s = BROADCAST
    -> s = BROADCAST;

endmodule
```

A sensor network

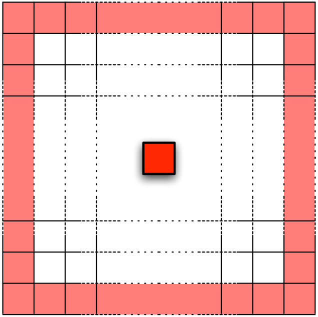


A sensor network

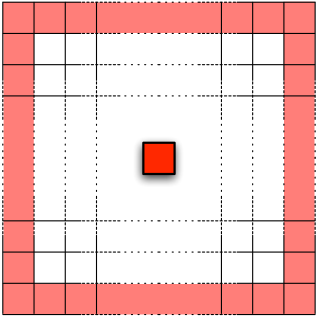


```
m4_for([X], [0], MAX_X, [1],
       [m4_for([Y], [0], MAX_Y, [1],
               [rm_sensor(X, Y)])])
```

The detection of an event

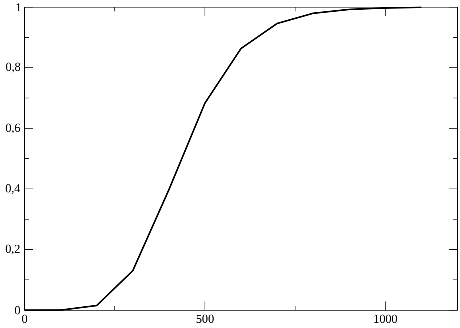


The detection of an event



```
m4_for([T], [0], LENGTH, [100],
[true U (t <= T
          & (0 rm_foreach_boundary([X], [Y],
            [ | rm_state(X, Y) = BROADCAST])))
])
```

Estimating the path length



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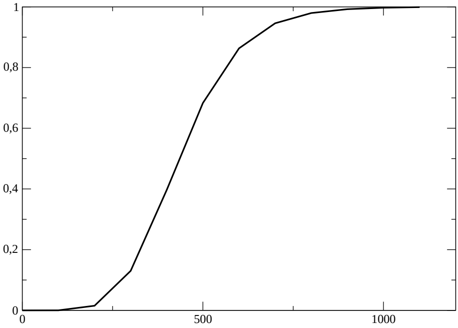

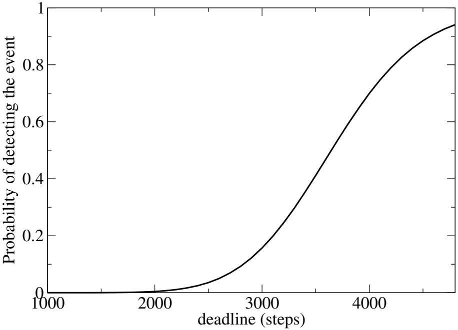

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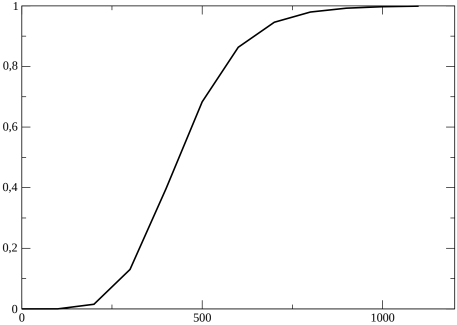
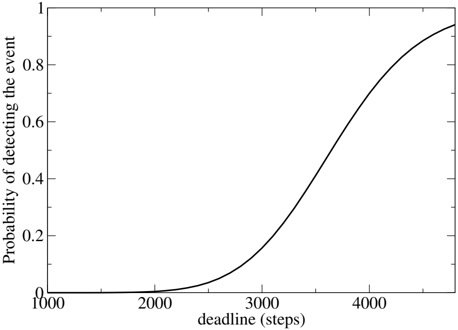


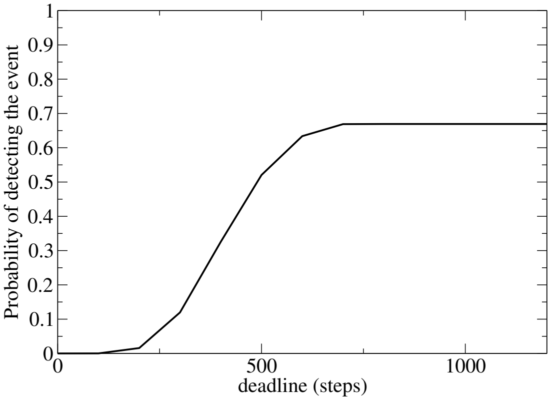


$$\text{pathlength} = 15 \times \text{area}$$

Impact of the limited energy

Costs:

SLEEP	1
SENSE	2
LISTEN	2
BROADCAST	3



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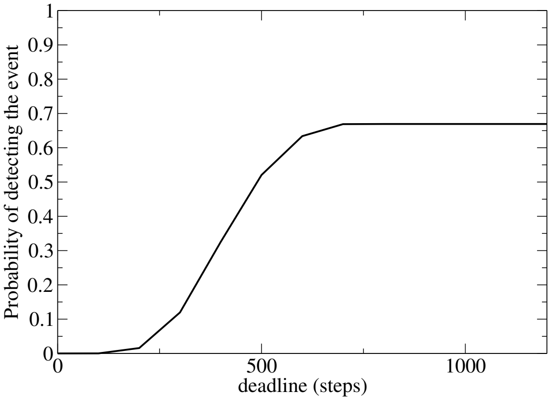

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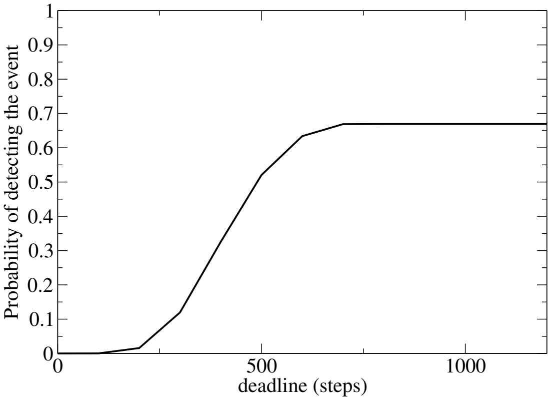

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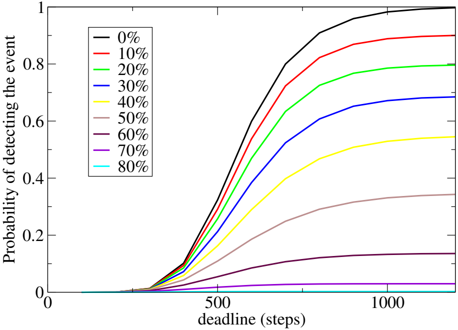
Application: optimize the time spent in each mode.

Resistance to the initial loss



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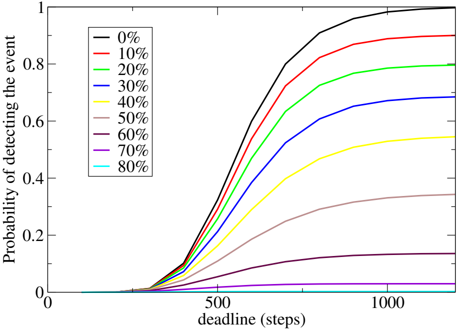

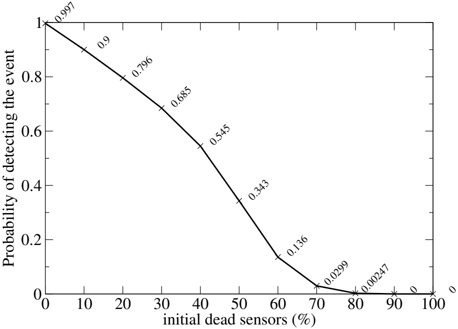

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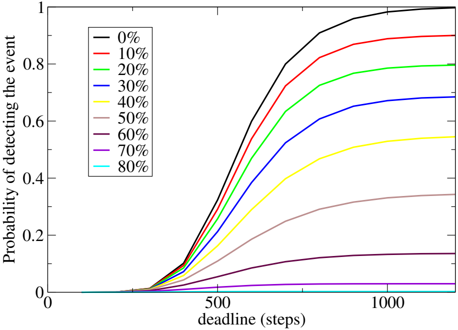

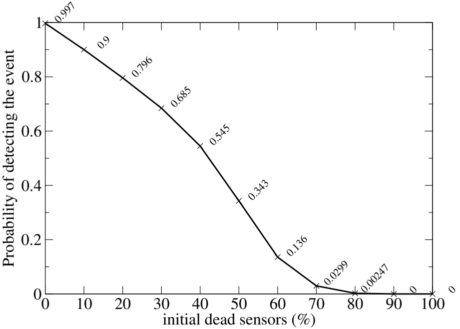

Two phases:

- $\leq 35\%$ linear, elastic, robust — delayed delivery.
- $35\% \leq$ brutal decreasing, compromised delivery.

Lessons Learned

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- Our straightforward modeling with DTMC does not model faithfully battery consumption
- Reactive Module is inconvenient for large simple models
- Some design decisions made for protocol study have to be reconsidered for large models

Future Work

- Extend Reactive Modules to program in the large

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- Use a CTMC-able probabilistic model checker

Questions?