Model Checking for Probabilistic Hybrid Systems

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Part 1b

MDP demos
Overview (Part 1b)

• Tools for MDPs

• Analysis of the simple communication protocol

• Case study: Bounded retransmission protocol (BRP)
Tools for MDPs

• **PRISM: Probabilistic symbolic model checker**
  – developed at Birmingham/Oxford University since 1999
  – modelling of CTMCs, DTMCs, **MDPs**, PTAs + costs & rewards
  – modelling language: guarded commands
  – property language: PCTL + extensions + costs/rewards

• **The Modest Toolset: mcpta frontend for PRISM**
  – supports stochastic and hybrid models beyond PTA
  – more in third part of talk
Overview (Part 1b)

- Tools for MDPs
- Analysis of the simple communication protocol
- Case study: Bounded retransmission protocol (BRP)
Simple MDP example

- Simple communication protocol
  - probability of success

\[ P_{\text{min}} = \mathbb{P}(F(s = 3)) \]
\[ P_{\text{max}} = \mathbb{P}(F(s = 3)) \]

module example

\[
s : [0..3] \text{ init } 0;
\]

\[
[\text{start}] \quad (s = 0) \rightarrow (s' = 1);
\]

\[
[\text{wait}] \quad (s = 1) \rightarrow \text{true};
\]

\[
[\text{send}] \quad (s = 1) \rightarrow 0.01 : (s' = 2) + 0.99 : (s' = 3);
\]

\[
[\text{restart}] \quad (s = 2) \rightarrow (s' = 0);
\]

\[
[\text{stop}] \quad (s = 3) \rightarrow \text{true};
\]

endmodule
Simple MDP example

- Simple communication protocol
  - expected number of restarts

\[ \text{R}_{\text{min}} = \mathbb{E} \left[ F (s = 3) \right] \]
\[ \text{R}_{\text{max}} = \mathbb{E} \left[ F (s = 3) \right] \]

module example

\[
\begin{align*}
\text{s} : [0..3] \text{ init } 0; \\
[\text{start}] \quad (s = 0) \rightarrow (s' = 1); \\
[\text{wait}] \quad (s = 1) \rightarrow \text{true}; \\
[\text{send}] \quad (s = 1) \rightarrow 0.01: (s' = 2) + 0.99: (s' = 3); \\
[\text{restart}] \quad (s = 2) \rightarrow (s' = 0); \\
[\text{stop}] \quad (s = 3) \rightarrow \text{true};
\end{align*}
\]
endmodule
Overview (Part 1b)

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Case Study: BRP

- **Bounded Retransmission Protocol**

  - transmit files in chunks (frames) over lossy channels
  - alternating bit protocol with $\leq$ MAX retries per frame
  - studied extensively

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Reachability Analysis of Probabilistic Systems by Successive Refinements

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Case Study: BRP

- **Sender**
  - upper bound MAX on number of retransmissions

Sender:

- $i := 1$
- $srep := \bot$
- $f_s := (i = 1)$
- $l_s := (i = N)$
- $b_s := ab$, $nrtr++$
- $F$
- $((nrtr < MAX) \land (i < N))$
- $i++$
- $srep := OK$
- $ab := \text{ff}$
- $srep := NOK$
- $srep := DK$
- $i = N$
- $B$
- $ab := \neg ab$
- $((nrtr = MAX) \land (i = N))$
- $success$
- $wait\_ack$
- $retransmit$
- $F$
- $null$
- $SyncWait$
- $error$
Case Study: BRP

- **Receiver**
  - uses alternating bit to distinguish between new and old data
Case Study: BRP

- **Channels**
  - different message loss probability
  - timeouts modelled with explicit synchronisation
Case Study: BRP

- Properties
  - maximum (worst-case) probabilities for:
  - sender report failure in case of success (A)
  - sender reports success in case of failure (B)
  - sender does not report success (1)
  - sender reports uncertainty (2)
  - ...

⇒ DEMO