UNIVERSITÄT DUISBURG ESSEN

Open-Minded

Incremental Verification of Complex Event Processing Applications for System Monitoring

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Complex Event Processing

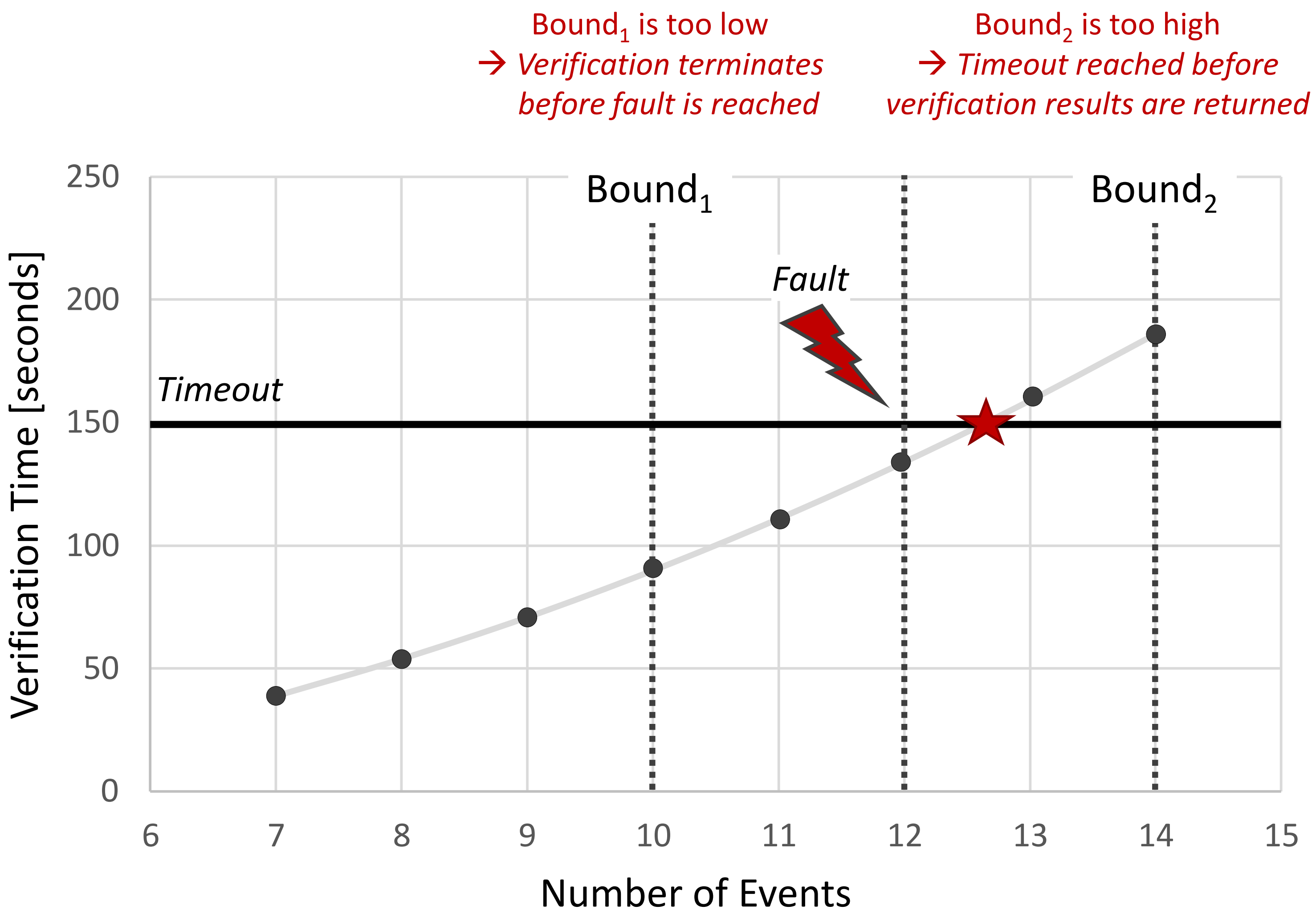
CEP Applications

- Collect, aggregate, analyse real-time event streams
- Detect patterns and generate more meaningful complex events
- Applied to monitor and detect problems during system execution; e.g.,
  - Physical machine monitoring in cloud systems
  - Tracking and tracing of transport processes

Verification of CEP Applications

- **State space explosion problem!**
  - Size of state space correlates with number of events to be checked
  - High number of events in CEP and high arrival rate
- Existing, dedicated CEP verification techniques
  - Limit verification to small subset of paths → **verification results do not generalize**
  - Set upper bounds on the number of events → **unknown for which bound bug will show**

Setting Upper Bounds

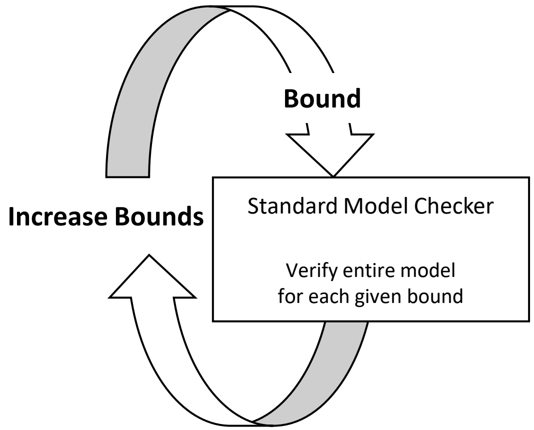


Verification Approach

Incremental verification

- Verify model for incrementally larger bounds
- Iterate until time-out is reached

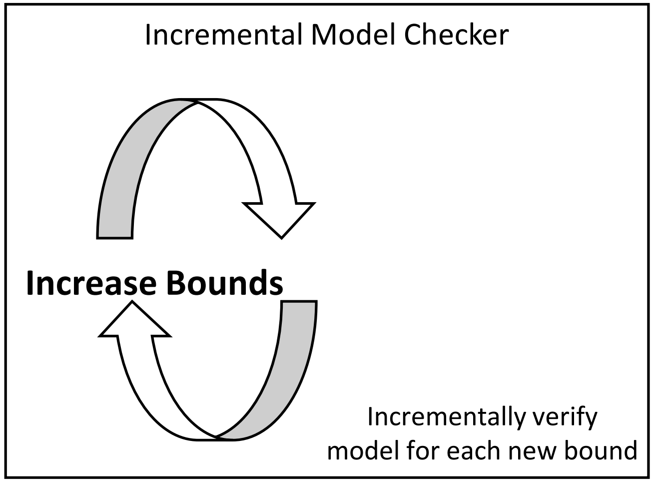
Naïve approach



Shortcoming

- Complete verification of model (redundant checks)

Advanced approach



Two kinds of incremental model checkers

- Incrementally verify changed model
- **Automatically increase state space (bounds)**

Experiment

Performance data for naïve approach

- Non-incremental, bounded model checker Tapaal
- Model encoded as petri net [Reinartz et al. @ DEBS 2015]
- Measurements for each bound $b = 1, \ldots, 30$

Performance data for advanced approach

- Using benchmark results for bit vector model checker [Günther et al. @ SPIN 2014]
- Comparing incremental check of all bounds (t_{inc}) against non-incremental check of one bound (t_{std})

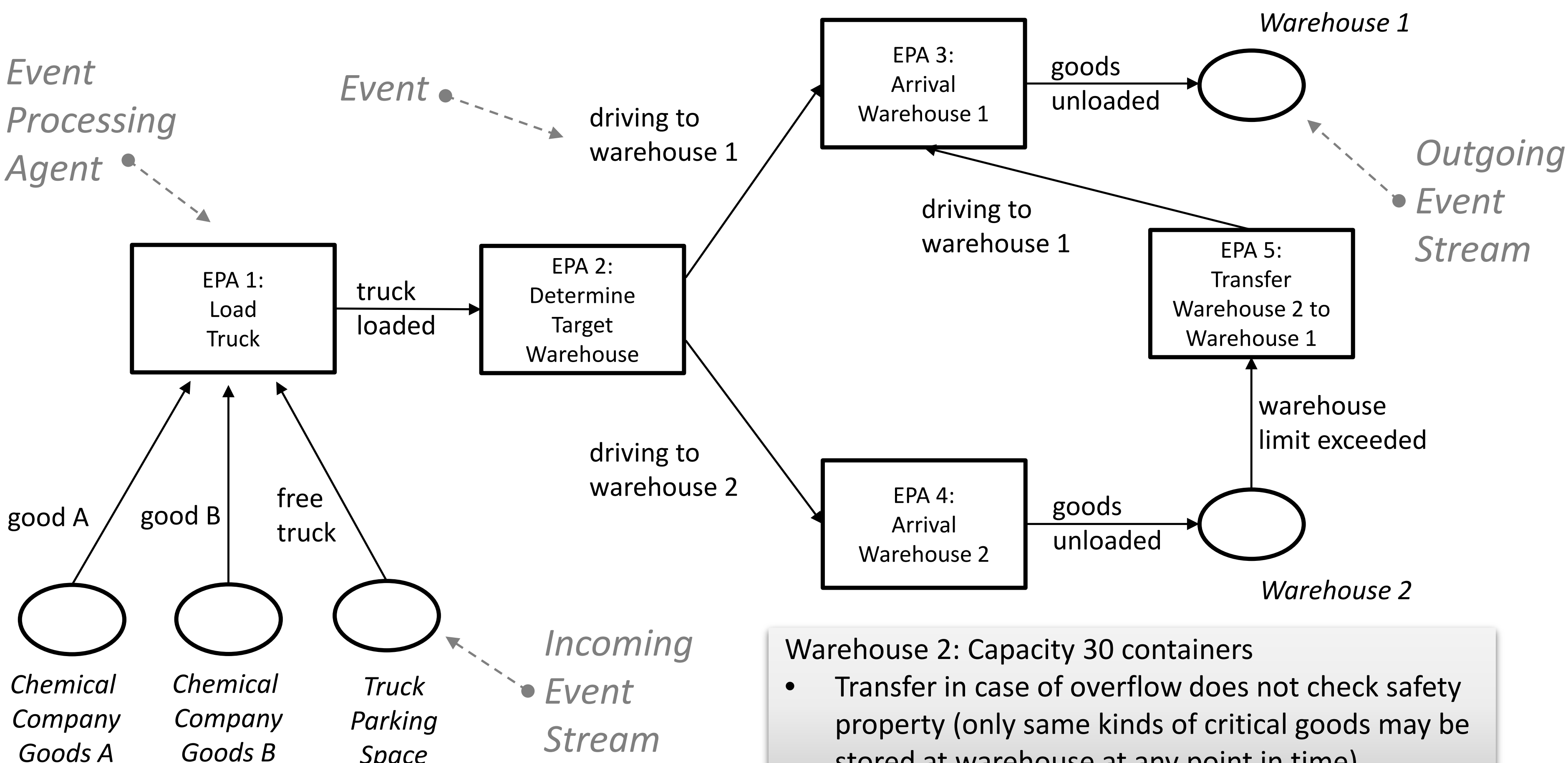
$$\lambda = (t_{\text{inc}} - t_{\text{std}})/t_{\text{std}}$$

- 32 benchmarks, 157 measurements

λ	Percentage of measurements
≤ 1	30%
≤ 2	70%
≤ 5	80%

Experiment

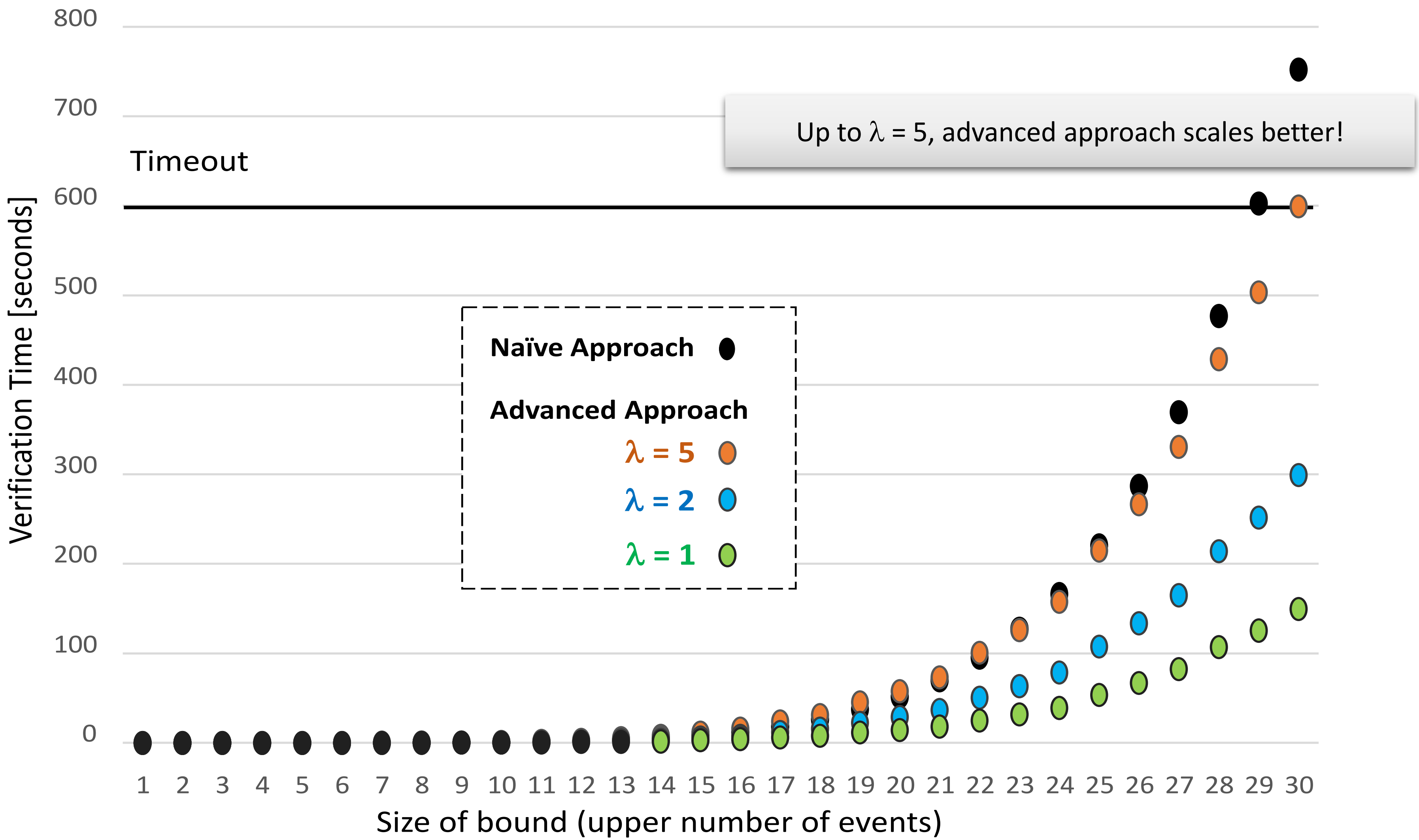
Example CEP Application



Warehouse 2: Capacity 30 containers

- Transfer in case of overflow does not check safety property (only same kinds of critical goods may be stored at warehouse at any point in time)

Results



Up to λ = 5, advanced approach scales better!
800
700
600
500
400
300
200
100
0
Timeout
Verification Time [seconds]
Naïve Approach
Advanced Approach
λ = 5
λ = 2
λ = 1
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Size of bound (upper number of events)

Conclusion and Outlook

- Incremental approach for verifying CEP applications
- Detect faults in the CEP application during design time
  → Prevent false monitoring results at run time
- Advanced approach more scalable

- Future work
  - Prototypical implementation of advanced approach (adapting implementation of existing incremental model checkers to use EPNs as input)

Thank you!

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