# QoS Provisioning and Orchestrating Processes within an SOA

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SINTEF

IRMOS

Interactive Realtime Multimedia Applications on Service Oriented Infrastructures

GIUNTI labs

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NTUA

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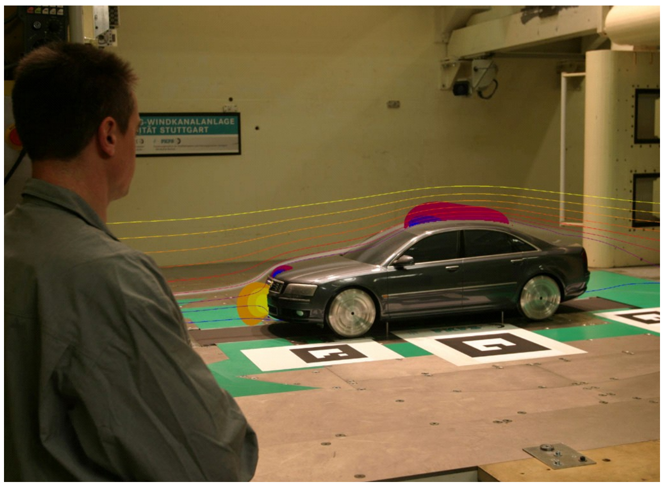
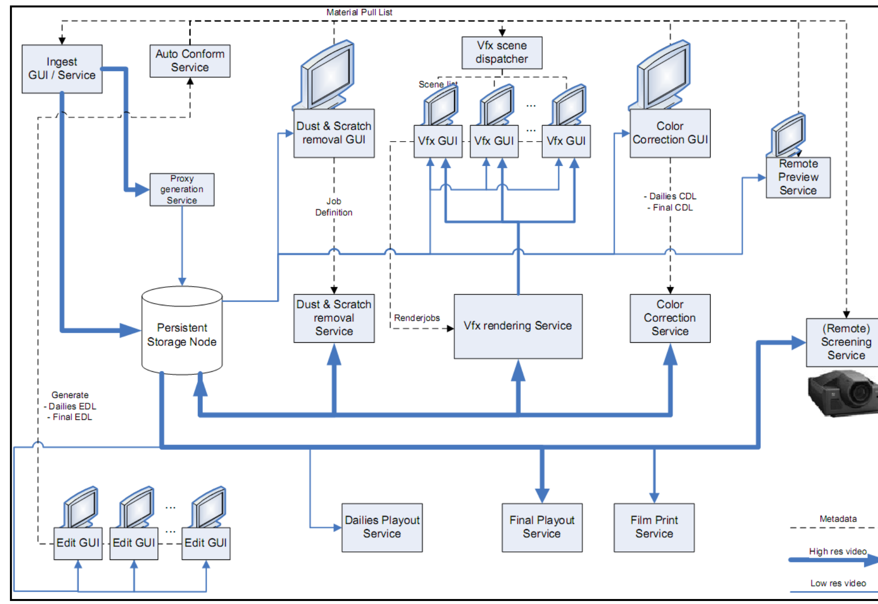
# IRMOS overview

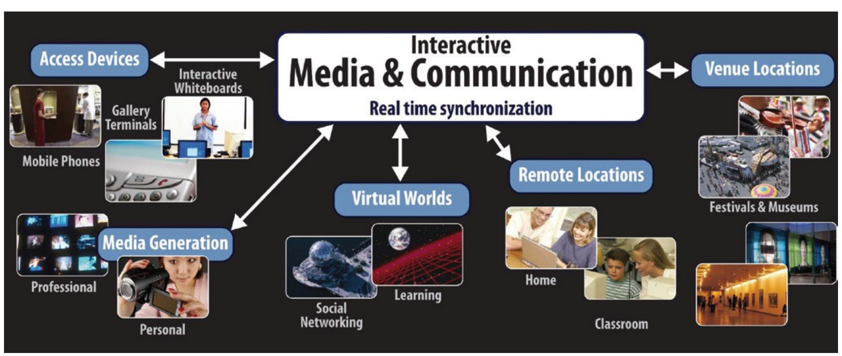
- Design, develop and validate a Service Orientated Infrastructure which will allow the adoption of interactive real-time applications, and especially multimedia applications



Augmented Reality




Film post production

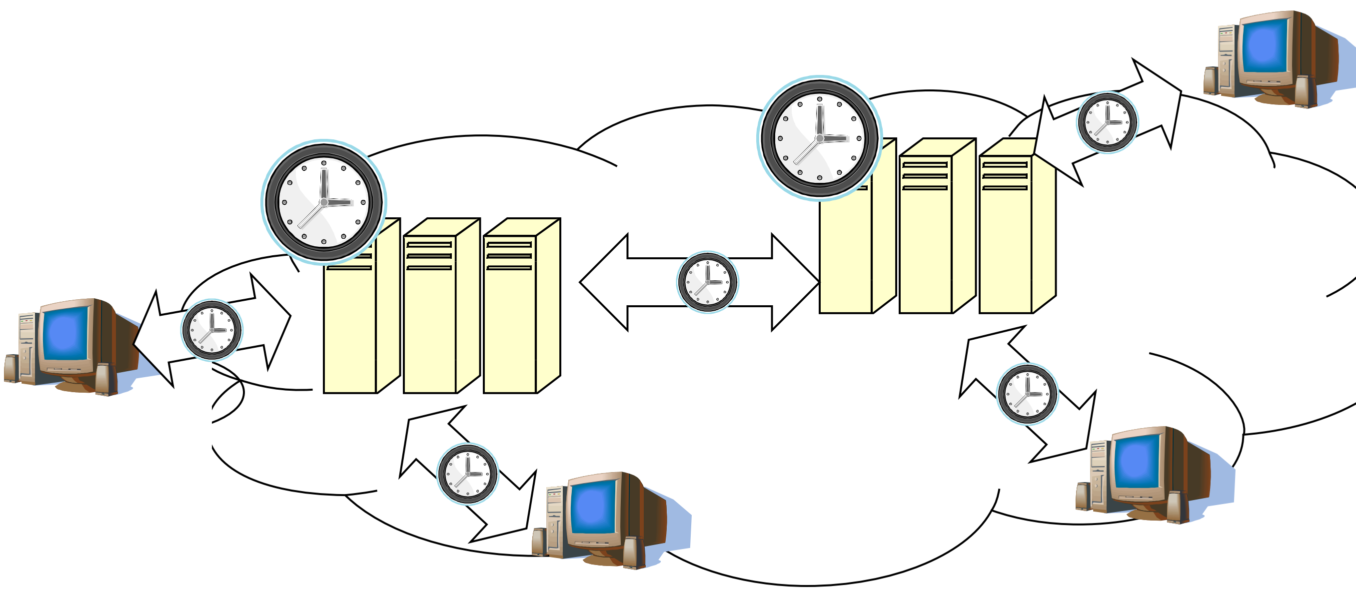



Social networking, education

# IRMOS overview

Intuition: think of distributed Amazon EC2 and S3 with guaranteed workflow and guaranteed realtime QoS

- Guaranteed virtual resource QoS:
  processor, RAM, storage, bandwidth, latency, jitter, ...
- Guaranteed reservations:
  resources will be available during reservation time frame
- QoS is monitored and verifiable during runtime



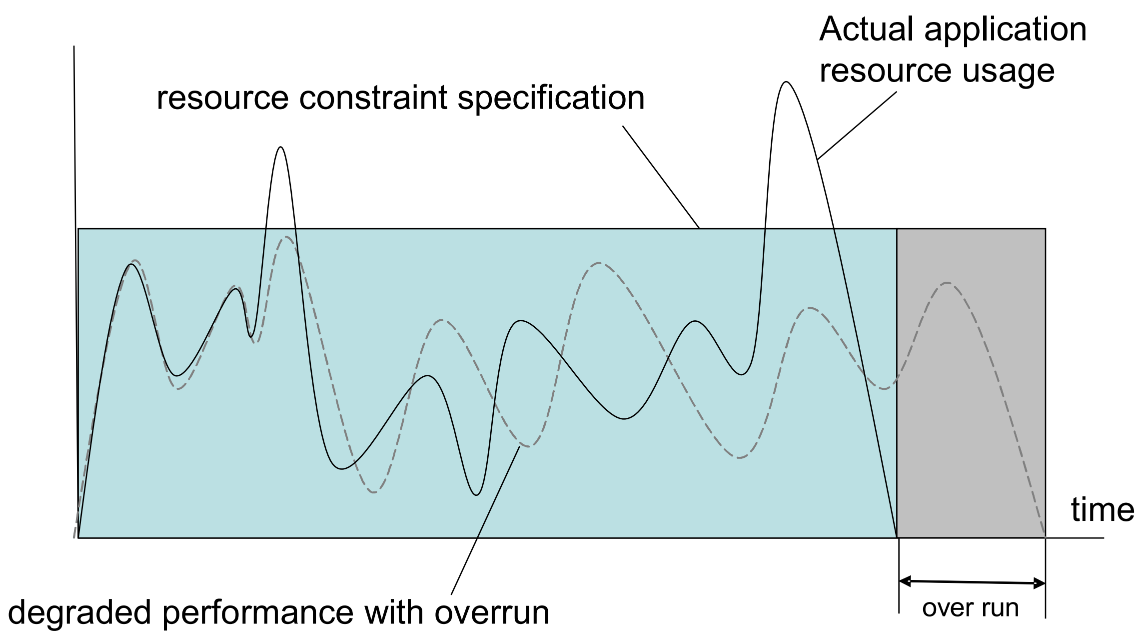
# Questions for modelling and verification

Before developing application into IRMOS service

  Estimate performance characteristics

Why bother?

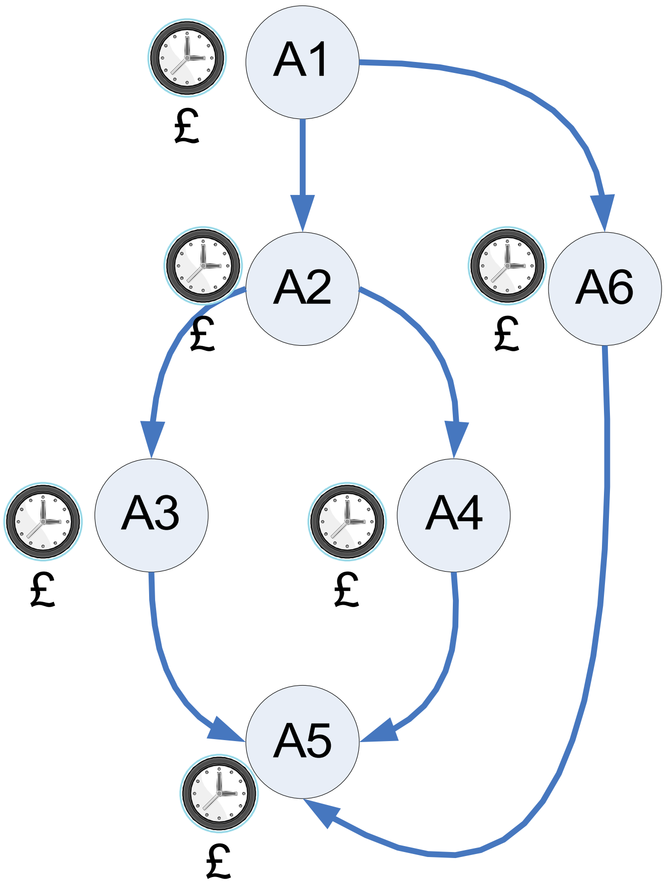
  not possible to increase resources or time interval during execution



# Questions for modelling and verification

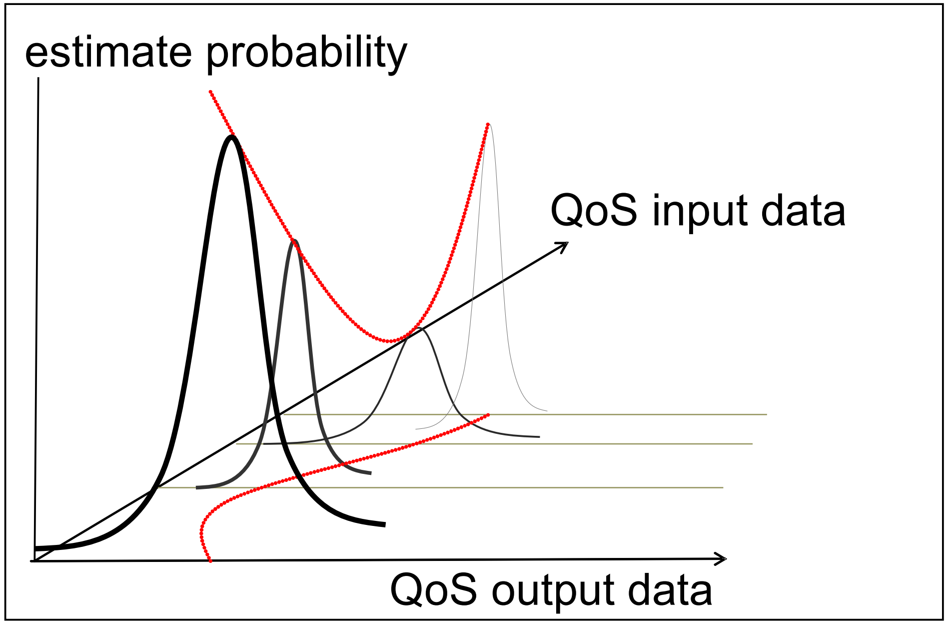
Before developing application

- Time frame reservations required for workflow and components
- Application workflow choreography; verified with respect to
  - resource contention,
  - resource utility,
  - causal dependencies,
  - deadlock,
  - livelock, etc,

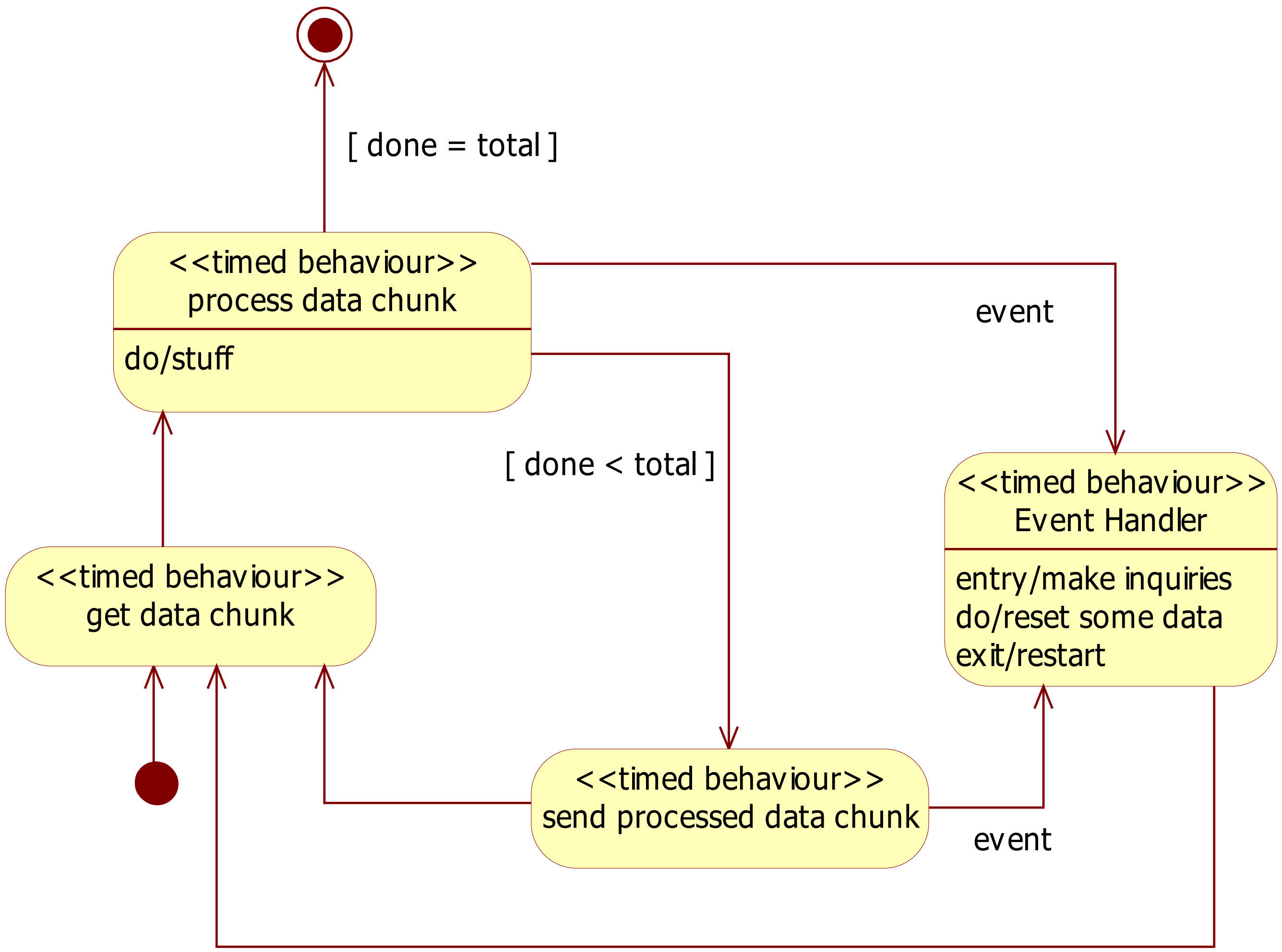


# Black Box Process Component Performance

- Stochastic correlations from benchmarking and partial knowledge of algorithms.

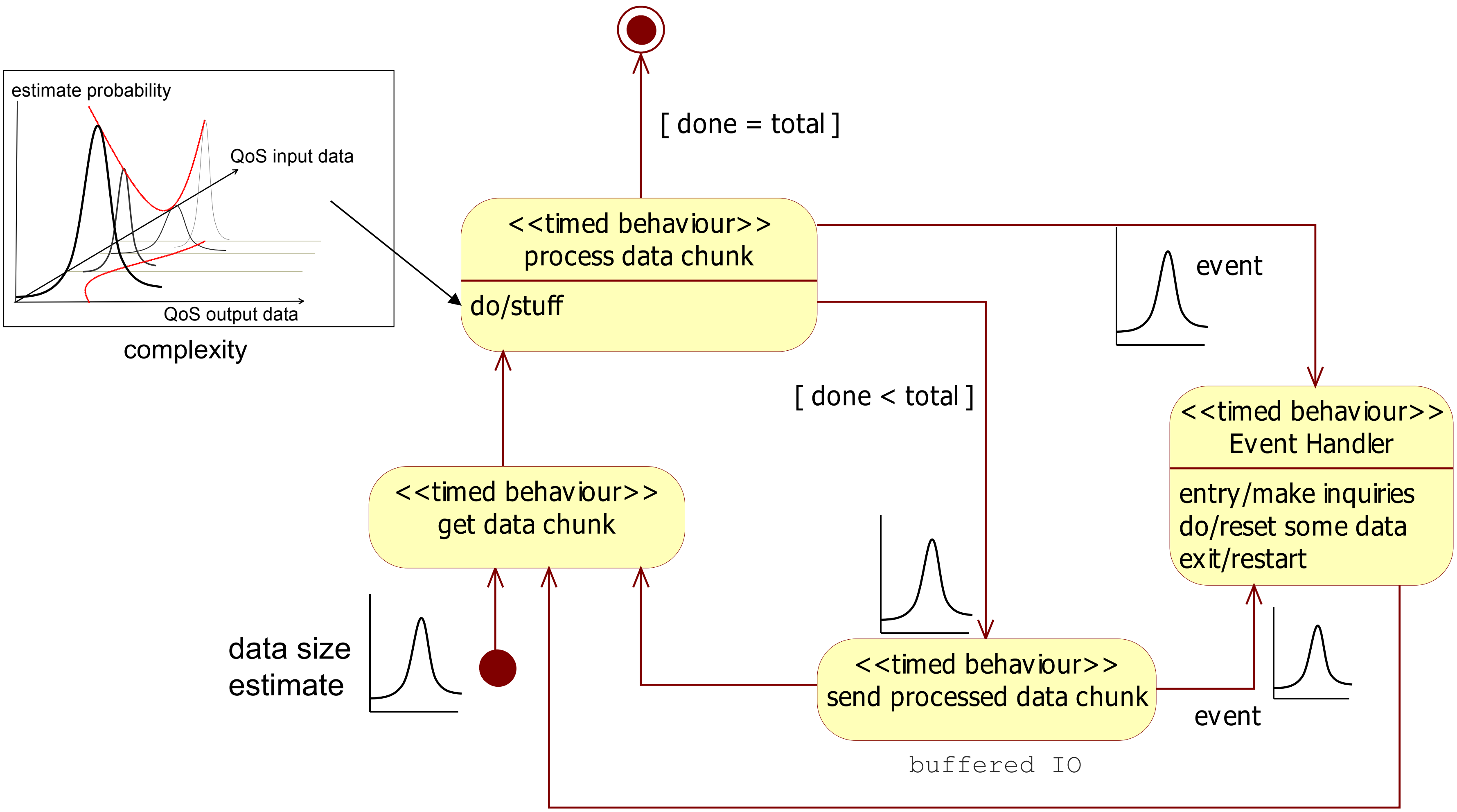



# Streaming Real Time Processes




State machine pattern for streaming data

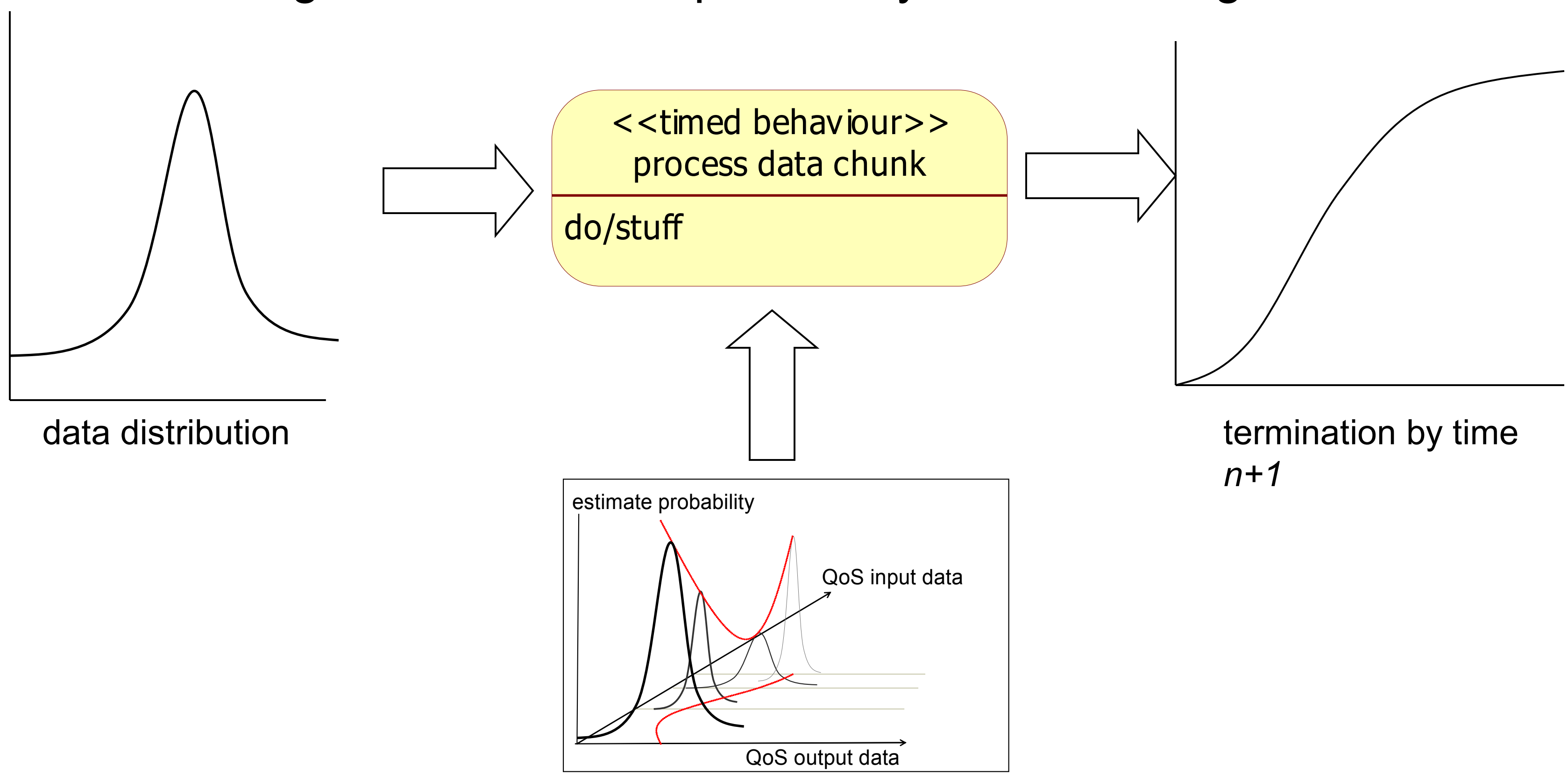
# Streaming Real Time Processes



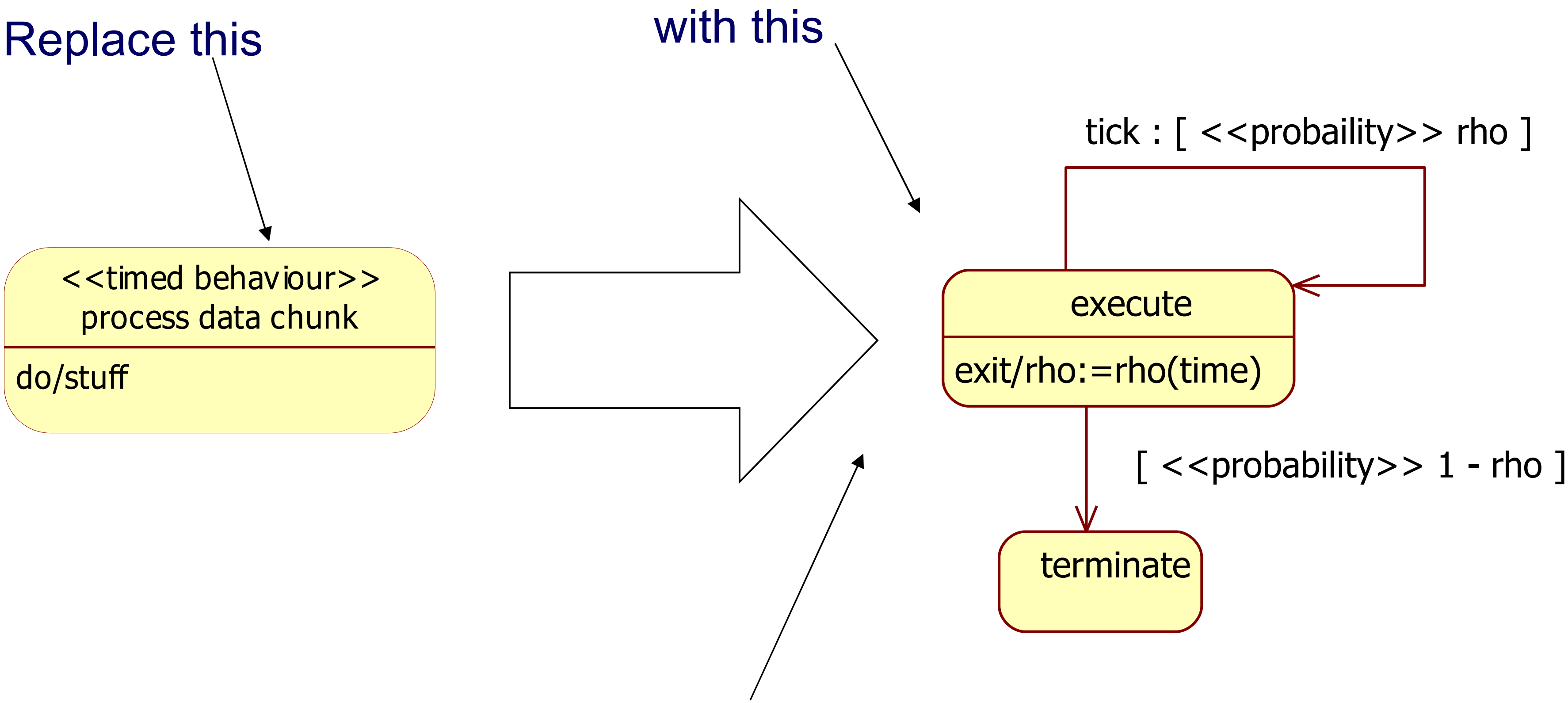

Stochastic interaction events and data

# Termination Estimate

- Given stochastic complexity and input data
- If executing at time *n* what's probability of still running at *n+1*?



# Discrete time stochastic automaton




- has standard semantics
- formally verify properties with stochastic model checkers
- can synchronise on stochastic events

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# rho(*n*) for known complexity

- Data is Borel measurable space BV
- Data estimates are probability measure p over BV
- Time to execute black box is f(v) for v in BV
- Define

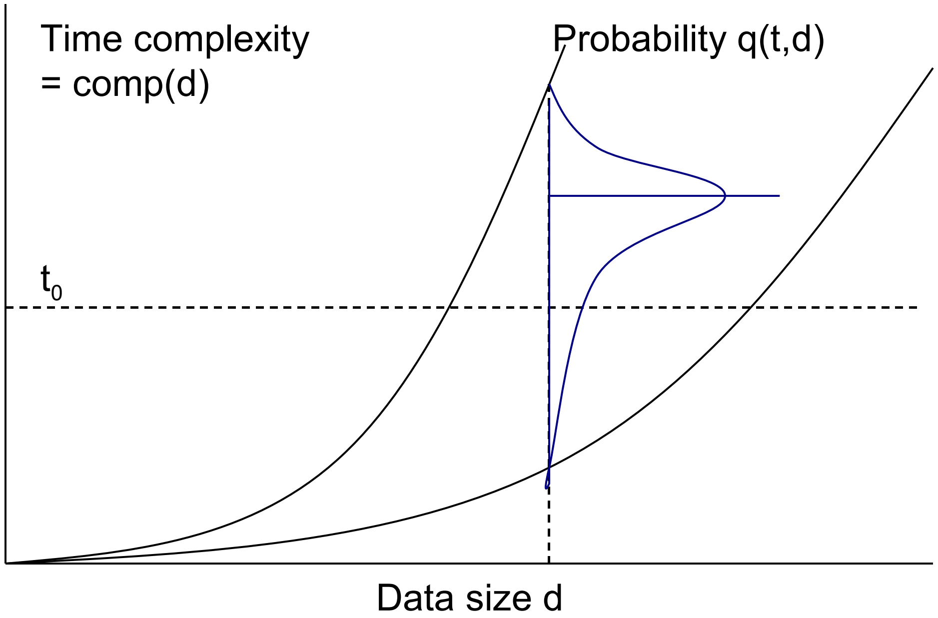
$$T(f,t) = \{v \in BV \mid f(v) > t\}$$

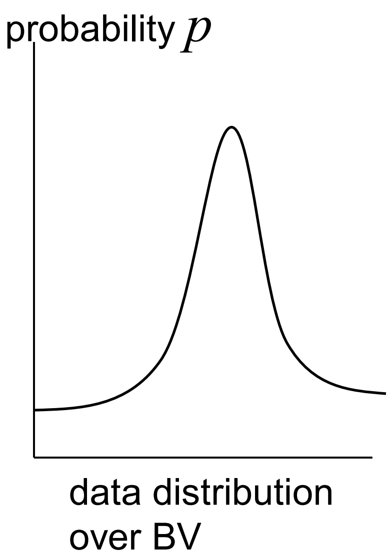
- If executing at time t, probability of still executing at t+d

$$\text{rho}(t+d) = \frac{\int_{v \in T(f,t+d)} p(v)dv}{\int_{v \in T(f,t)} p(v)dv} = \frac{p(T(f,t+d))}{p(T(f,t))}$$

$$= \frac{\text{probability of complexity greater than t+d}}{\text{probability of complexity greater than t}}$$

# Estimated Complexity Discrete Time

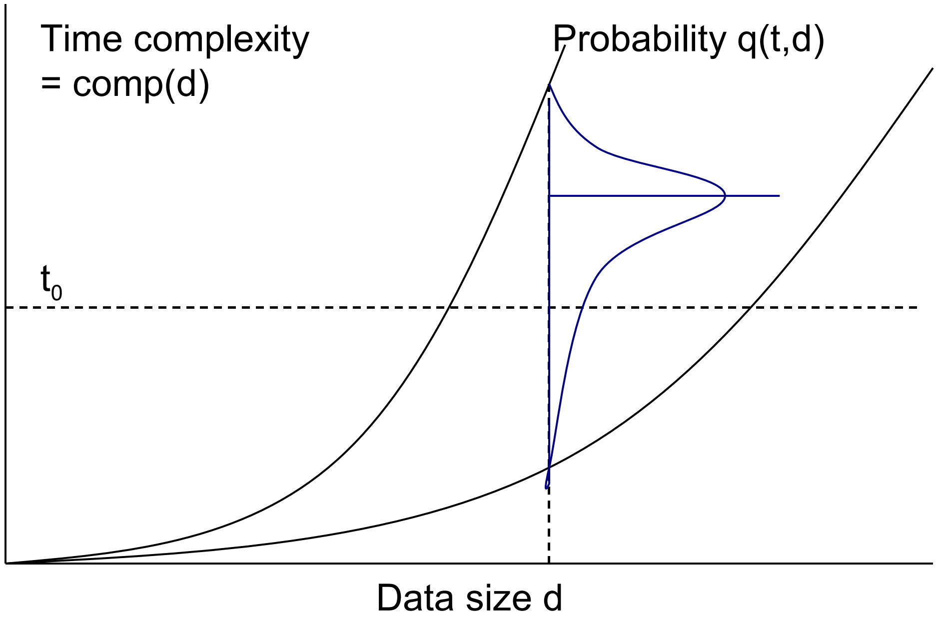


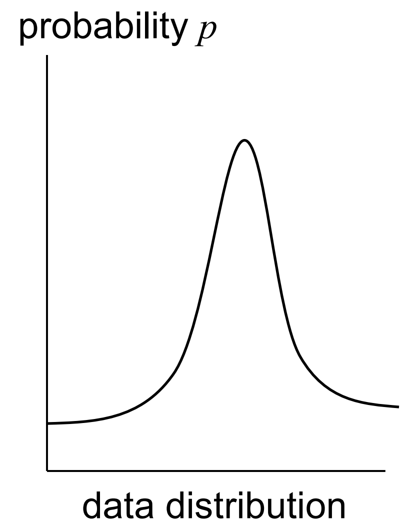




$$\Pr(\,\mathrm{comp}(d) > t \mid \text{input size is } d\,) = \sum_{t > t_0} q(t,d)$$

$$\Pr\{d \in BV \mid \mathrm{comp}(d) > t\} = \int_{d \in BV} \left( \sum_{t > t_0} q(t,d) \right) dp$$

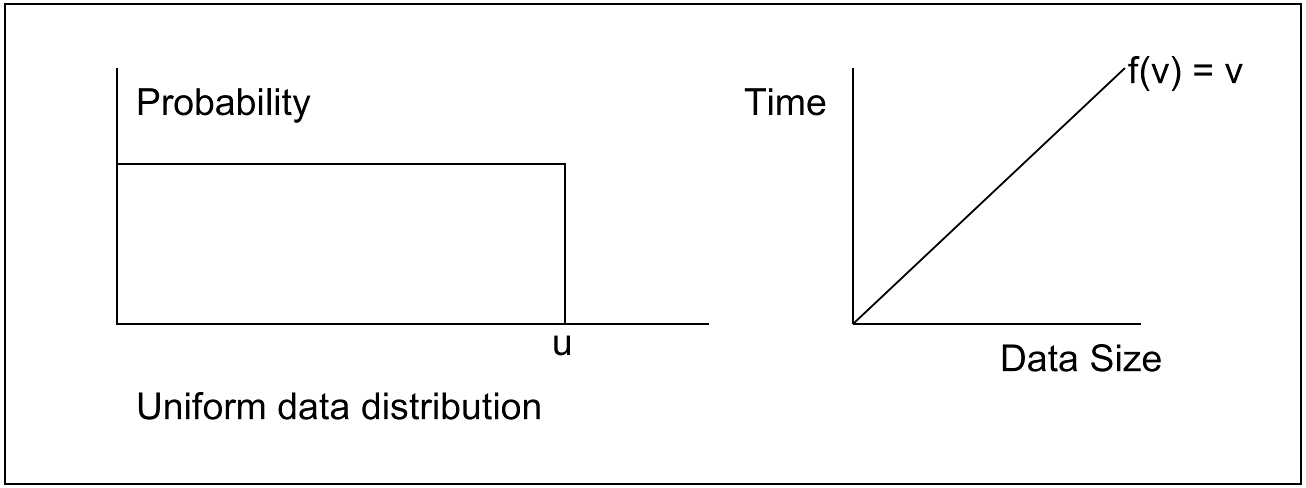
# Estimated Complexity Discrete Time

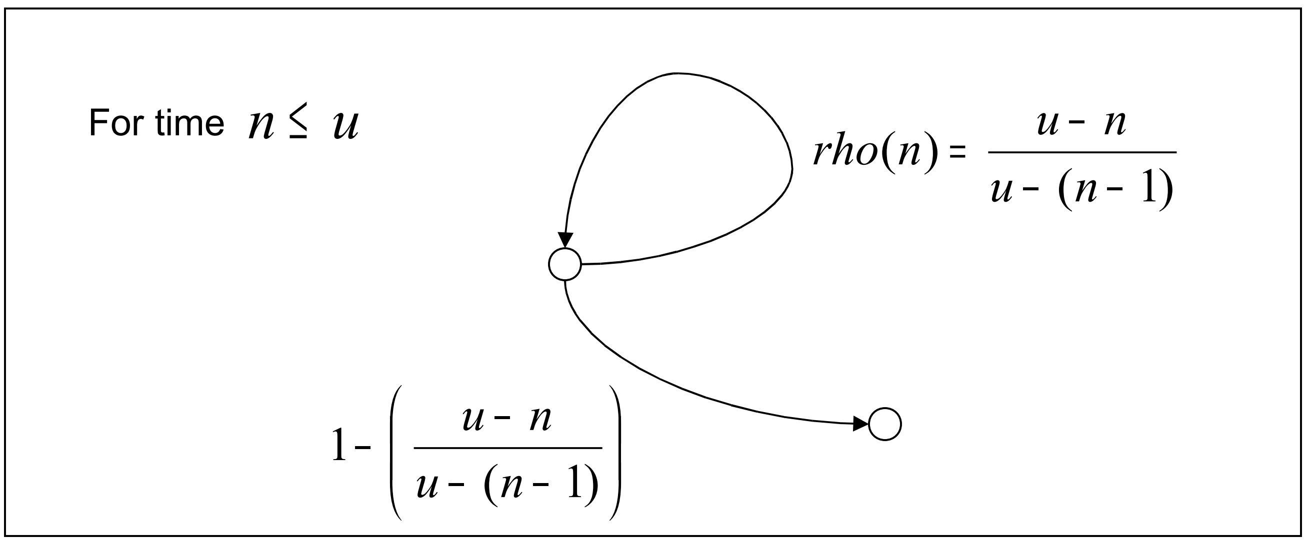


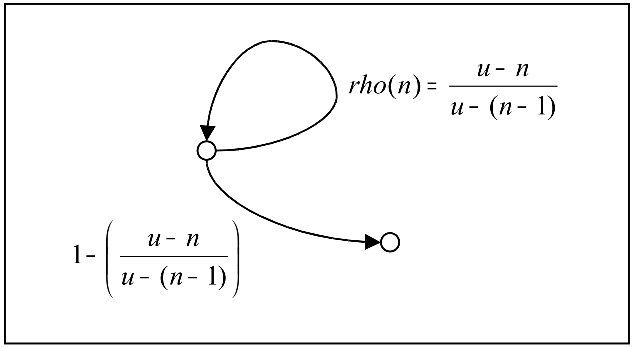

$$rho(n) = \frac{\int_{d \in BV} \left( \sum_{t > n} q(t,d) \right) dp}{\int_{d \in BV} \left( \sum_{t > n-1} q(t,d) \right) dp}$$

# rho(n) for uniform distribution linear complexity



# Uniform plus linear termination estimate



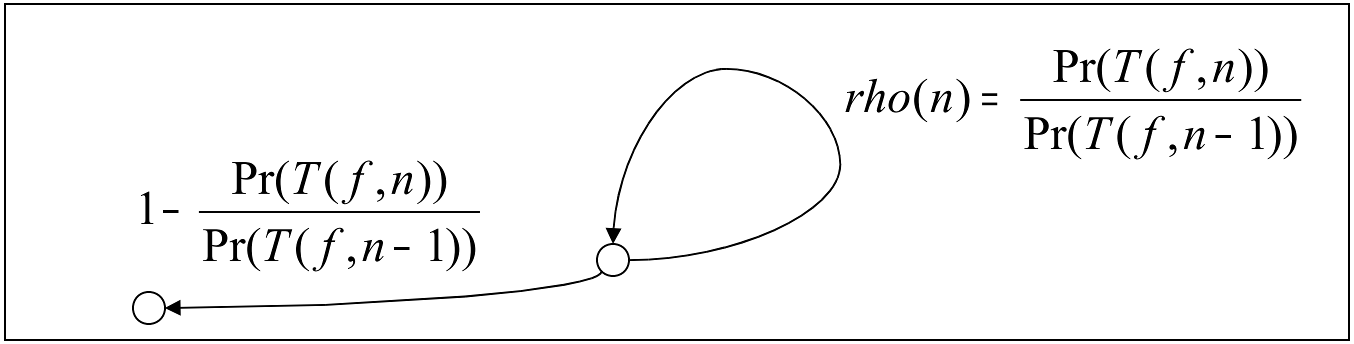

Probability of terminating at time n

$$= rho(0)\cdots rho(n-2)rho(n-1)(1-rho(n))$$

$$= \left(\frac{u-1}{u-0}\right)\left(\frac{u-2}{u-1}\right)\left(\frac{u-3}{u-2}\right)\cdots\left(\frac{u-(n-2)}{u-(n-3)}\right)\left(\frac{u-(n-1)}{u-(n-2)}\right)\left(1-\frac{u-n}{u-(n-1)}\right)$$

$$= \left(\frac{u-(n-1)}{u}\right)\left(1-\frac{u-n}{u-(n-1)}\right) = \frac{1}{u}$$

# Exact complexity termination estimate




Estimate that automaton terminates at time $n$ =

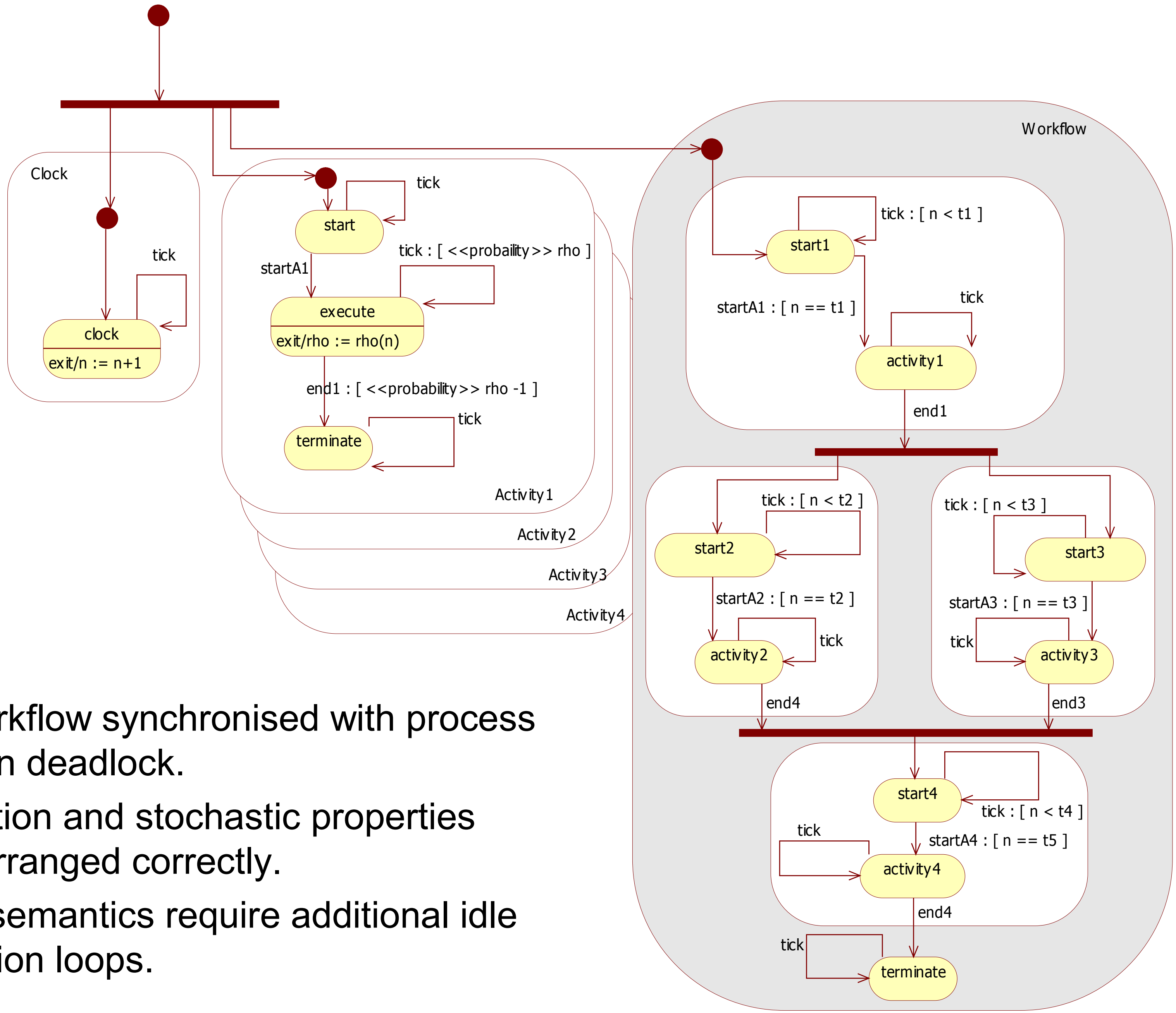
$$\Pr(T(f,0))\left(\frac{\Pr(T(f,1))}{\Pr(T(f,0))}\right)\left(\frac{\Pr(T(f,2))}{\Pr(T(f,1))}\right)\left(\frac{\Pr(T(f,3))}{\Pr(T(f,2))}\right)\cdots$$

$$\cdots\left(\frac{\Pr(T(f,n-2))}{\Pr(T(f,n-3))}\right)\left(\frac{\Pr(T(f,n-1))}{\Pr(T(f,n-2))}\right)\left(1-\frac{\Pr(T(f,n))}{\Pr(T(f,n-1))}\right)$$

$$= \Pr(f(d) > n-1 \mid d \in BV) \quad - \quad \Pr(f(d) > n \mid d \in BV)$$

$$= \Pr(n \geq f(d) > n-1 \mid d \in BV)$$

# Elementary timed workflow



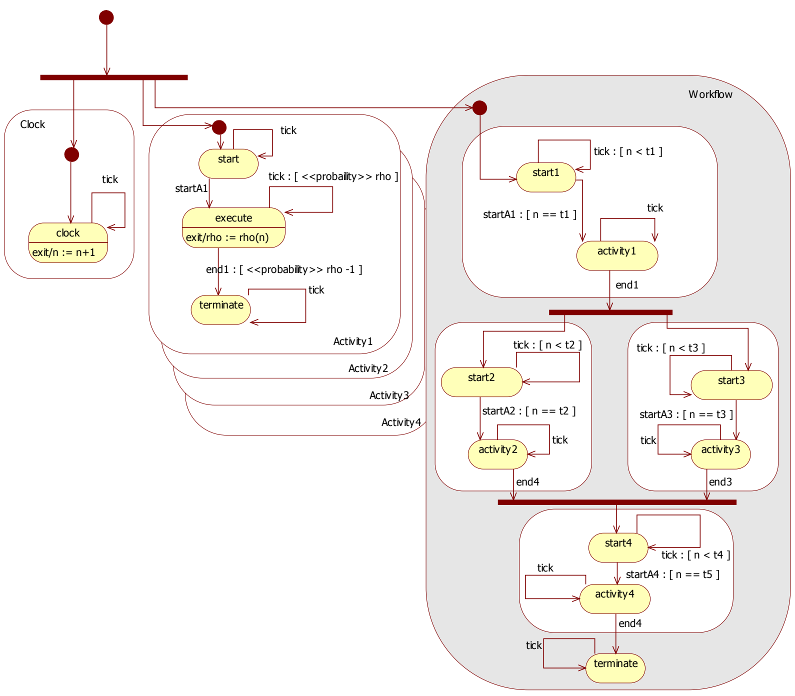

Arbitrary Workflow synchronised with process and clock can deadlock.

Synchronisation and stochastic properties have to be arranged correctly.

PRISM tool semantics require additional idle and termination loops.

# Correct Workflow Semantics

- For any DAG workflow with consistent time frames
- For any black box process with given stochastic complexity and data
- There is a timed non-stochastic workflow automaton that
  - is deadlock free in composition with processes and clock
  - imposes correct causal dependencies between processes
- Extends to cyclic graphs by extending timed finite automata for black box processes
- Workflow can also be extended to allow for failure, cancellation and restarts among processes.

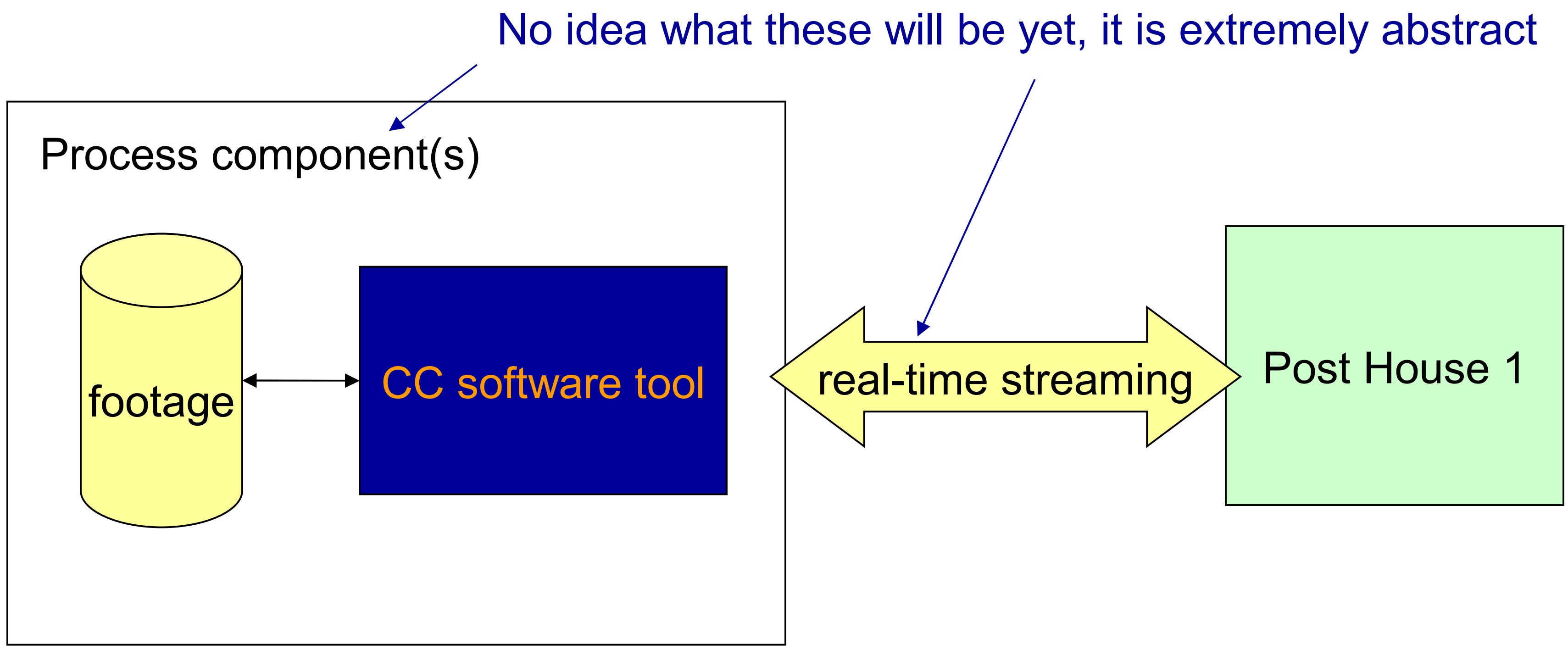


# PRISM

```
module Activity
 [tick]   (x=idle) -> (x'= idle);
 [startA] (x=idle) -> (x' = go);
 []       (x=go) -> rho_iterate0:(x'=add_one_to_count)
                 + (1 - rho_iterate0):(x'=terminate);
 []       (x=add_one_to_count) ->
              (x'=exec)&(count0'=incrmnt_count0);
 [run]    (x=exec) -> (x'=return);
 [tick]   (x=return) -> (x'=go);
 [end]    (x=terminate) -> (x'=stop);
 [tick]   (x=stop) -> (x'=stop);
endmodule

formula rho_itr0 = rho0*(1- count0/interval0) +
                   rho1*count0/interval0;
formula rho_iterate0 =
   ((count0 >= 0)& (count0 <= interval0)) ? rho_itr0 : rho1;
```

# Colour Correction Conceptual Model

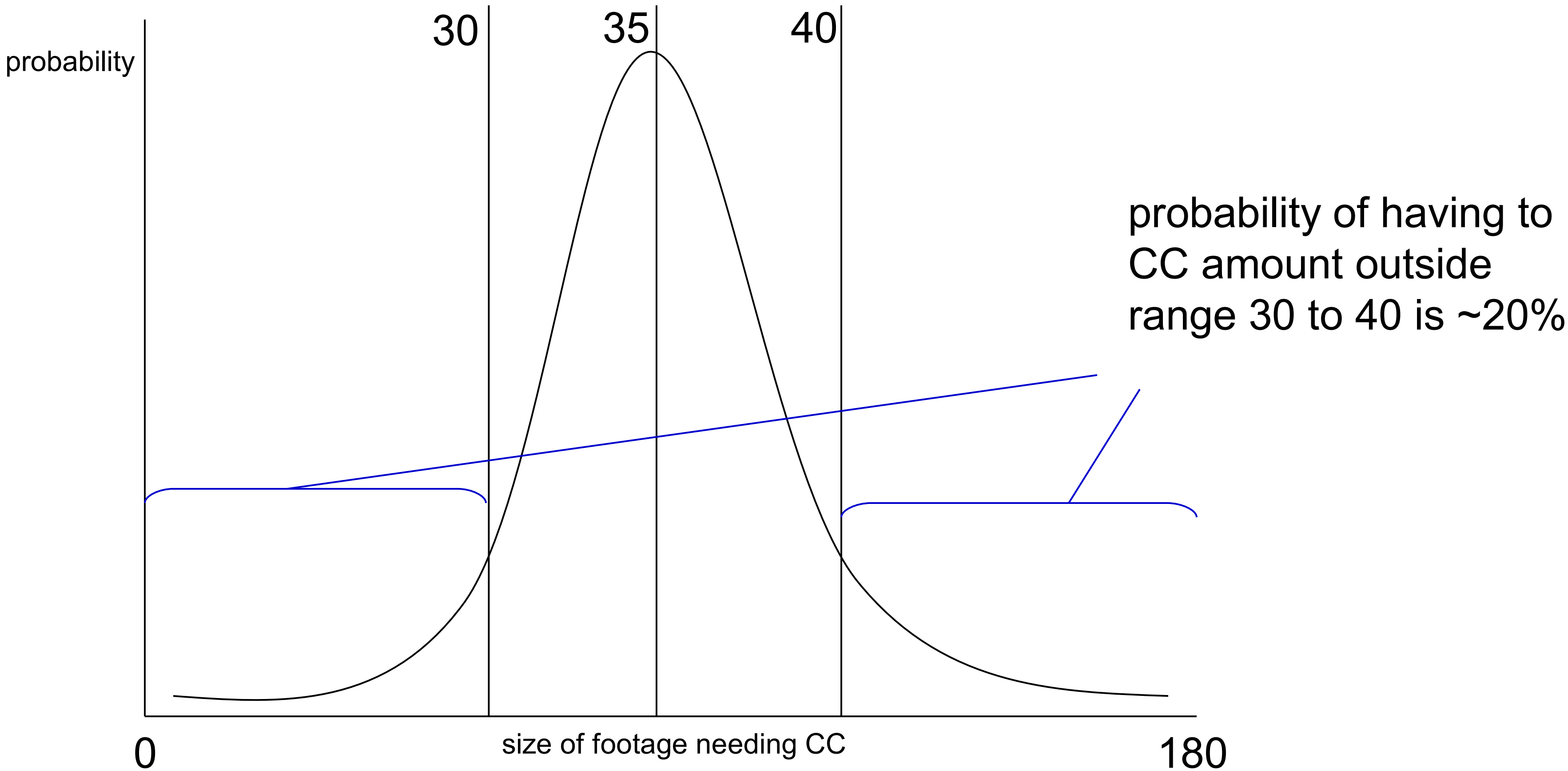



Conceptual level so we don't know

- What type of buffering exists
- How data is transcoded for data link
- How data link is shared
- How data link is managed

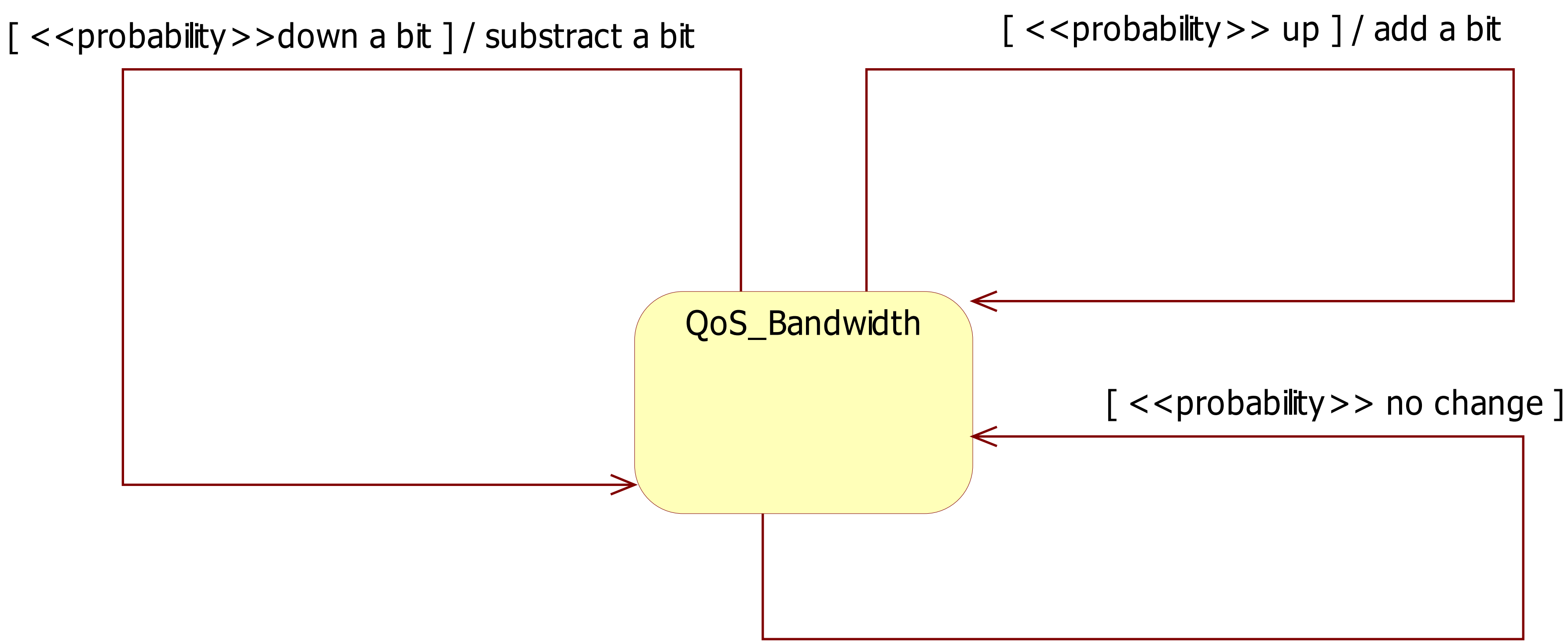
But we can make a model that gives predictions!

# Stochastic Data




Black box complexity is linear
If bandwidth is 'too low' for continuous period (say 1 minute) rewind is necessary

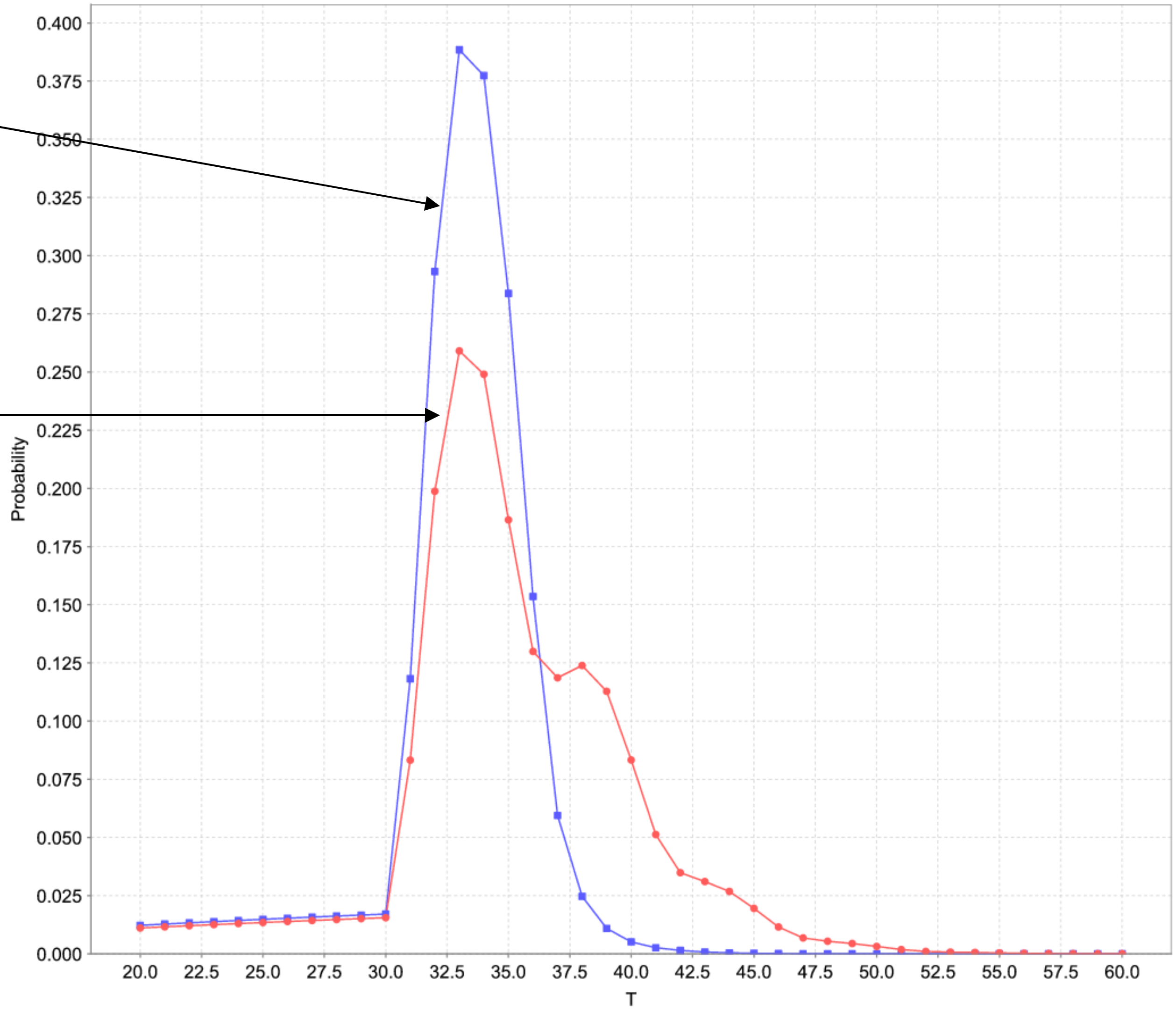
# QoS model of streaming data link



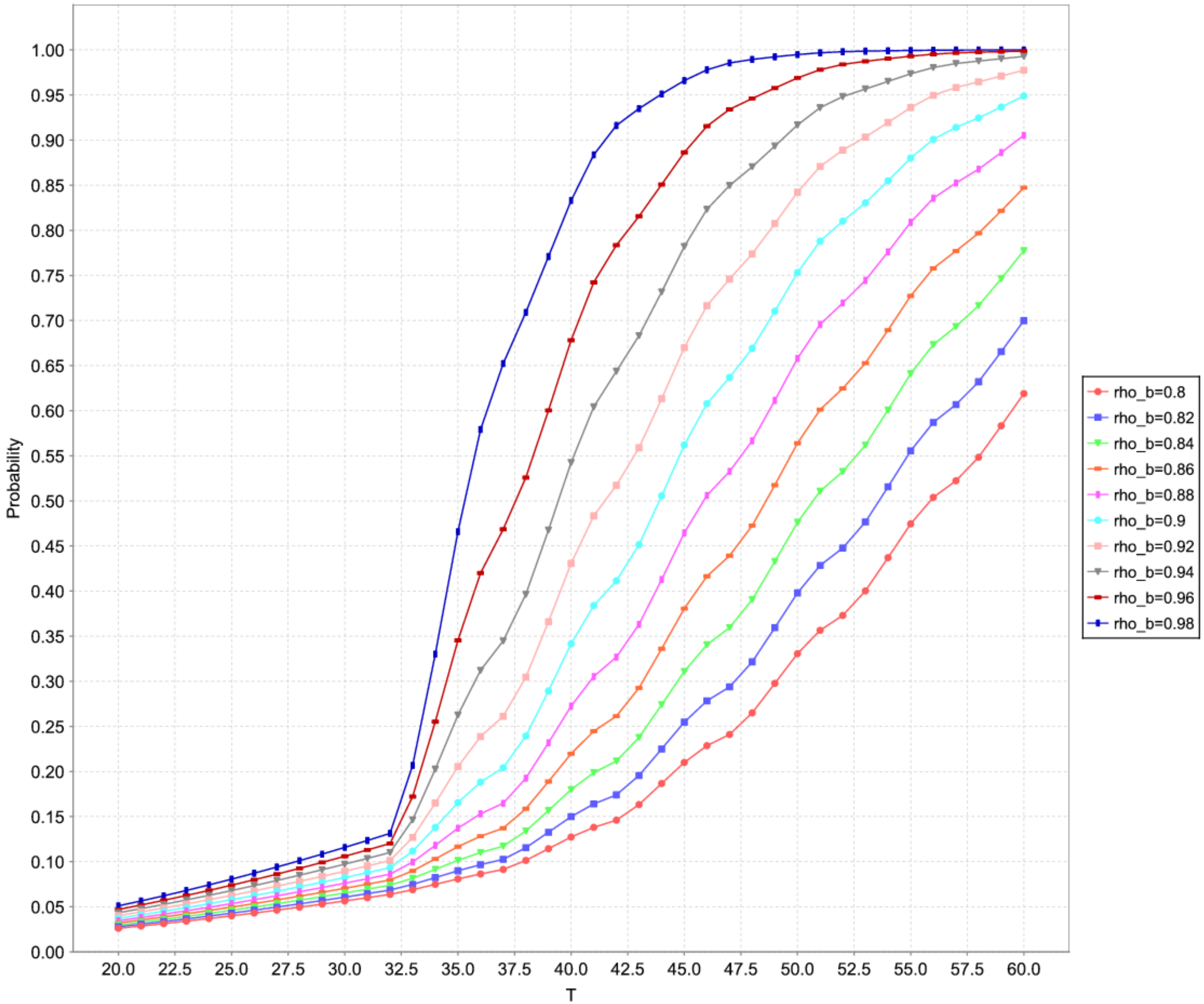
# Predictions

If bandwidth OK 100% of time

If bandwidth OK for 98% of time



# Predictions



# Timed stochastic process algebra

- Process terms
  - $[t_0 < t < t_1] \rightarrow P$ — if clock is in given range then do $P$
  - $[?t < n : r=r'] P$ — if clock $t$ is less than $n$ set $r$ to $r'$ then do $P$
  - $\rho_1 . P_1 + .. + \rho_n . P_n$ — there is probability $\rho_i$ that will do $P_i$
  - $e \bullet P$ — first do $e$ next do $P$
  - $P + Q$ — do exactly one of $P$ or $Q$ depending on which is enabled
  - $P \,||\, Q$ — interleave $P$ and $Q$
  - $P \,||_S Q$ — synchronous interleaving on event set $S$

# Timed Black Box Process Term

$$\begin{aligned}
\mathsf{Pr}(a) &= \Omega \cdot \mathsf{Pr}(a) + start_a \cdot \mathsf{run}(a) + cancel_a \cdot fail_a \cdot 0 \\
\mathsf{run}(a) &= [t_0^a \leq t \leq t_1^a] \rightarrow (\rho_a \Omega \cdot \mathsf{run}(a) + (1 - \rho_a) \cdot done_a \cdot 0) \\
&\quad +([t > t_1^a] \rightarrow fail_a \cdot 0) \\
&\quad +(cancel_a \cdot fail_a \cdot 0) \\
\mathsf{Clock}_0 &= [: t = 0]\mathsf{Clock} \\
\mathsf{Clock} &= [: t = t + 1]\Omega \cdot \mathsf{Clock}
\end{aligned}$$

# Iterative Black Box Processes

$$
\begin{aligned}
\mathsf{Pr}(a) &= \Omega \cdot \mathsf{Pr}(a) + start_a \cdot \mathsf{getrs}(a) + cancel_a \cdot fail_a \cdot 0 \\
\mathsf{getrs}(a) &= ([r_a = \mathsf{f}] \rightarrow \Omega \cdot \mathsf{getrs}(a)) + ([r_a = \mathsf{t}] \rightarrow [: r_a = \mathsf{f}] rn_a \cdot \mathsf{run}(a)) \\
\mathsf{run}(a) &= [t_0^a \leq t \leq t_1^a] \rightarrow (\rho_a \Omega \cdot \mathsf{run}(a) + (1 - \rho_a) \cdot [: r_a = \mathsf{t}] done_a \cdot \mathsf{iter}(a)) \\
&\quad +([t > t_1^a] \rightarrow [: r_a = \mathsf{t}] fail_a \cdot 0) \\
&\quad +(cancel_a \cdot [: r_a = \mathsf{t}] fail_a \cdot 0) \\
\mathsf{iter}(a) &= (exp(a) \mapsto \mathsf{Pr}(a)) \parallel_{Sy} \prod_{a' \in \mathsf{nxt}(a,G)} (exp(a') \mapsto start_{a'} \cdot 0)
\end{aligned}
$$

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