Process algebras for quantitative analysis: Lecture 7 — Service-level agreements for service-oriented computing

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Outline

1. Service-oriented computing
2. Example: Virtual University
3. Discussion and Conclusions

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1 Service-oriented computing

2 Example: Virtual University

3 Discussion and Conclusions

Service-oriented computing

- A modern approach to distributed computing.
- Applications are built by composing services.
- Services are replicated across a number of servers.
- Providers *publish* services in registries.
- Users *discover* services and *bind* to them.

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- We do not know which service instances will be used.
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- The service instances may have different functionality.
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...lots of difficulties for modellers!

Analysis of service-oriented computing

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Analysis of service-oriented computing

- Put all possible descriptions of service behaviours together in one big model.
  - Hope your favourite large state-space method can cope ...

Statespace


Statespace
Vanishing states:
declutter your life
Are BDDs
making
you fat?
Modelling detail:
Do you love it too much?
Deadlock detection:
Are you in a dead-end relationship?

Analysis of service-oriented computing

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  - ... Scalable analysis of scalable systems.

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    - Analyse all possible configurations by cases.

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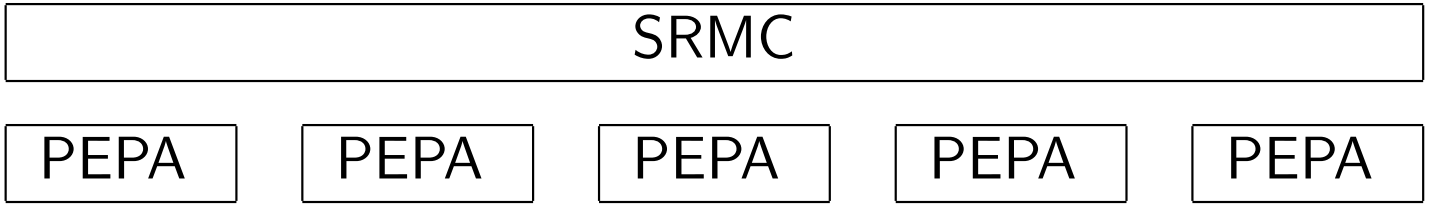
- Hydra (HYpergraph-based Distributed Response-time Analyser)
  - Use `hydra-s` to compute response-time quantiles

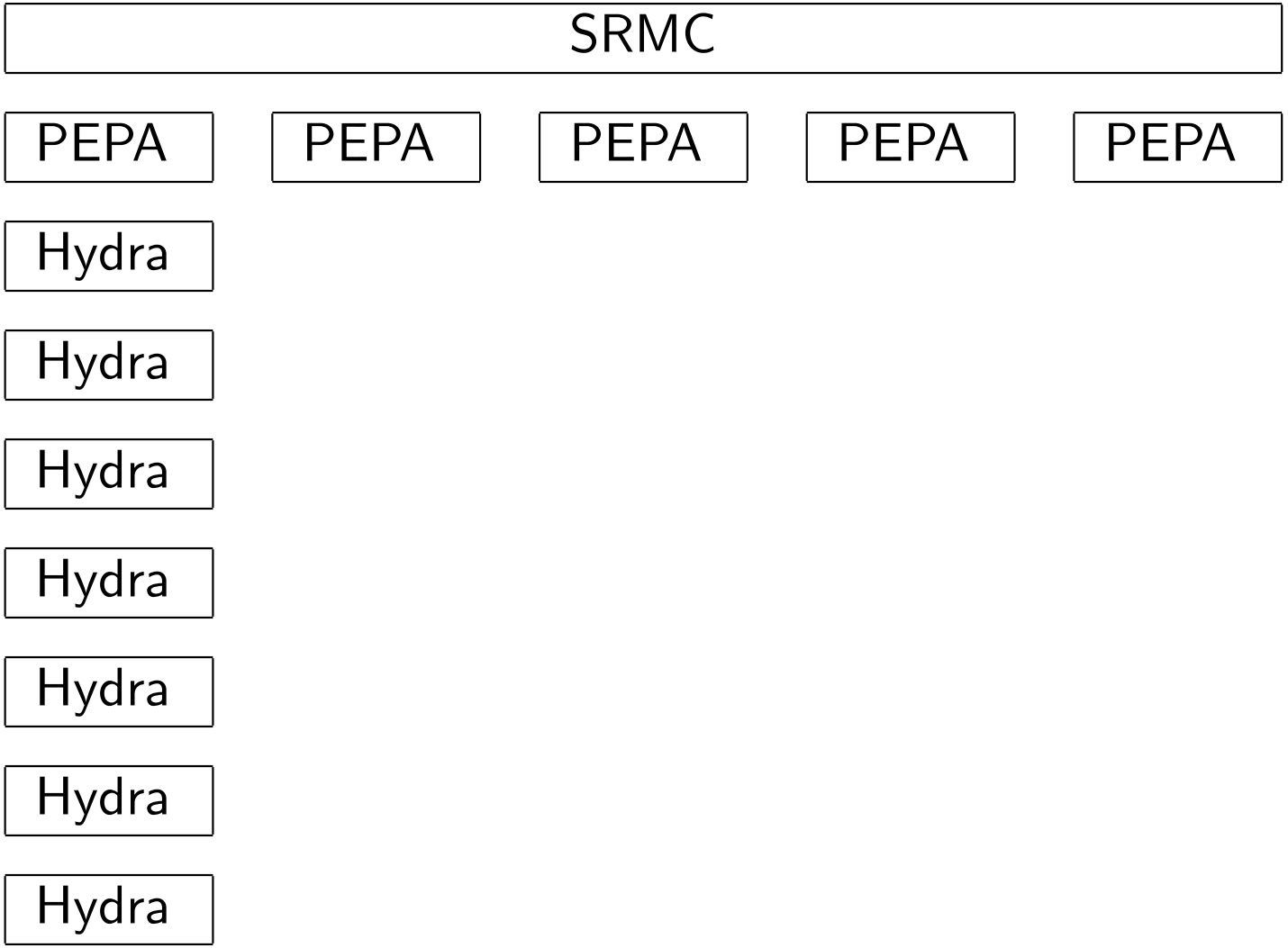
Evaluation model

SRMC

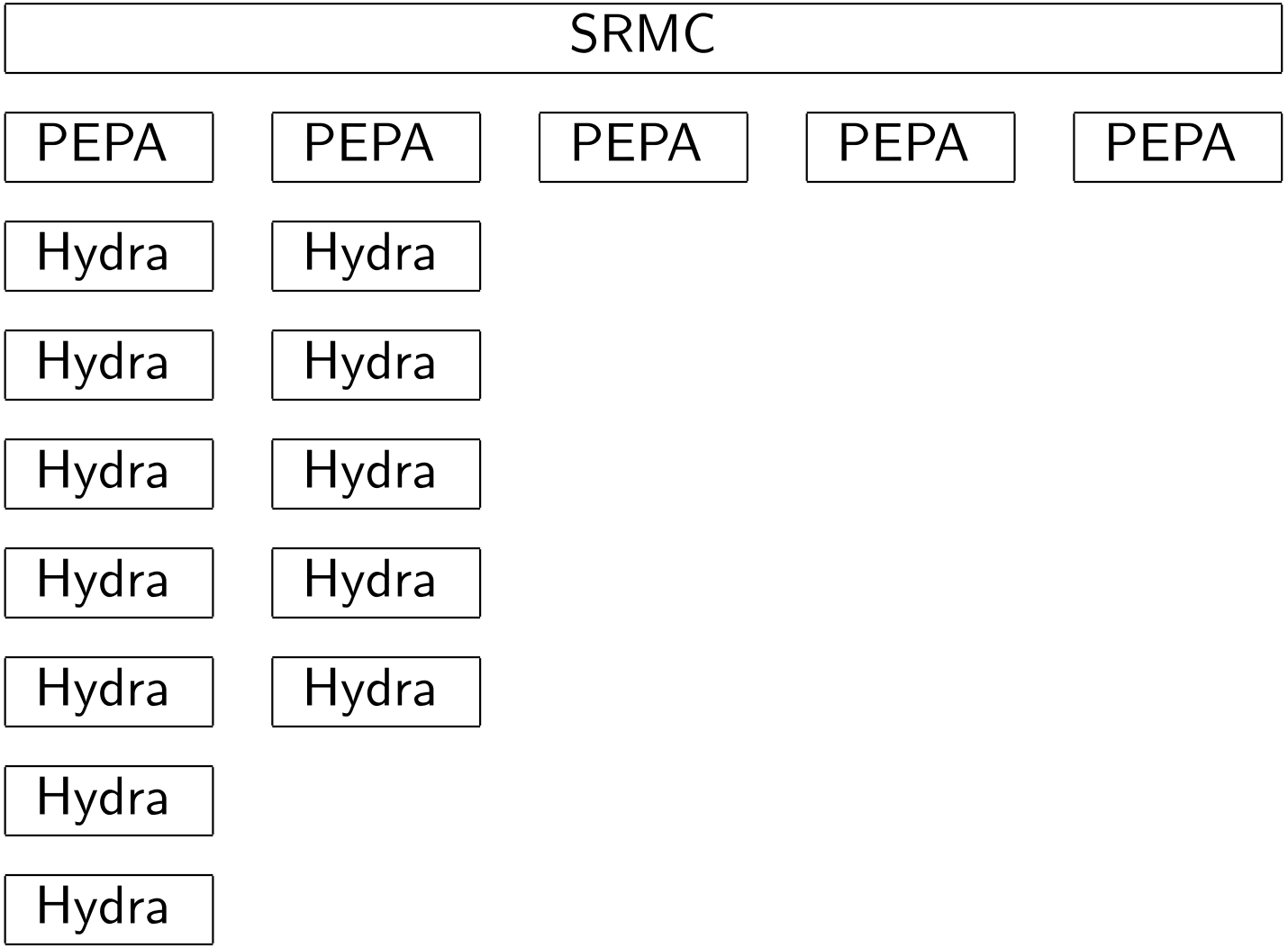
Evaluation model



Evaluation model



Evaluation model



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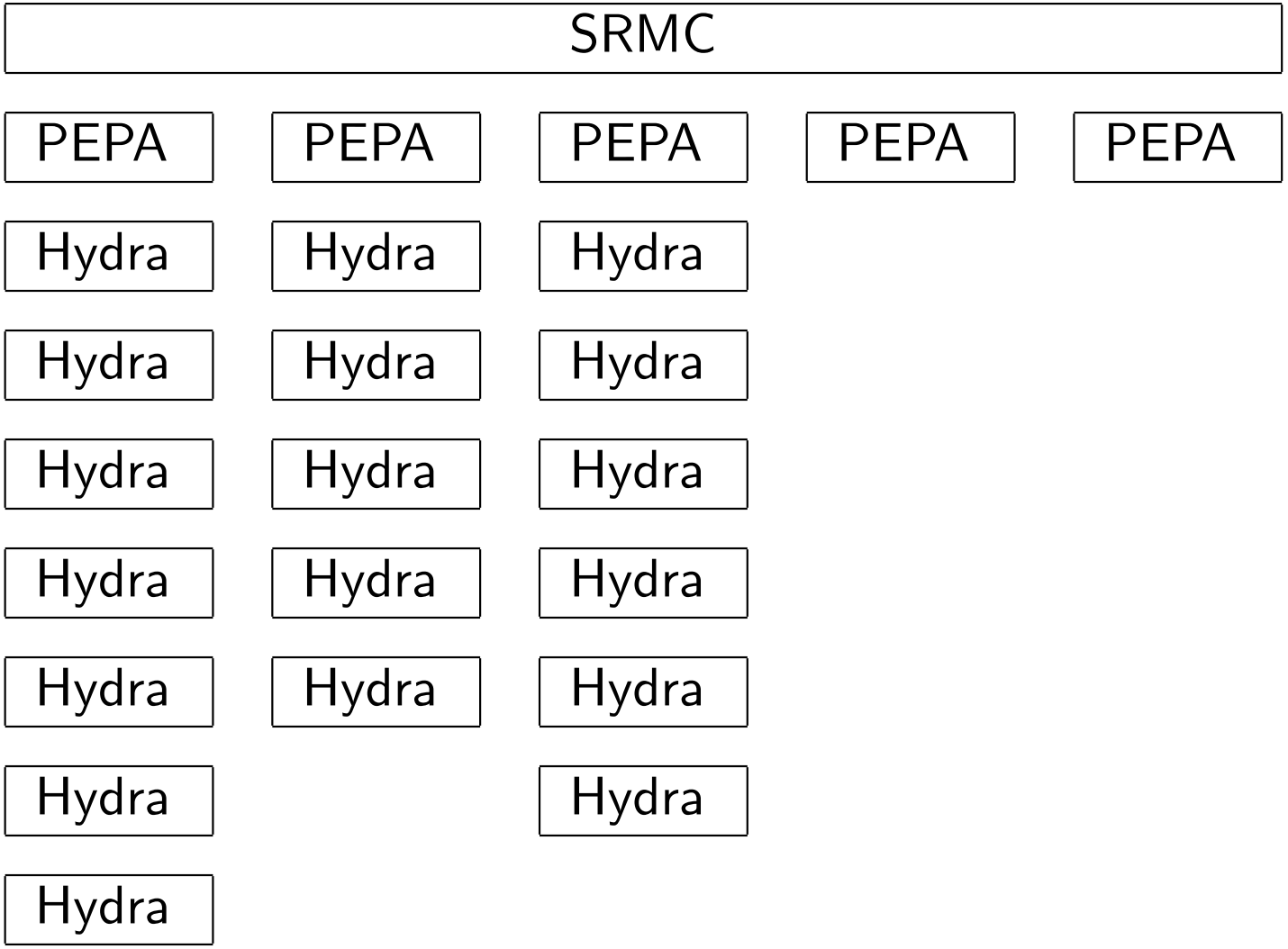

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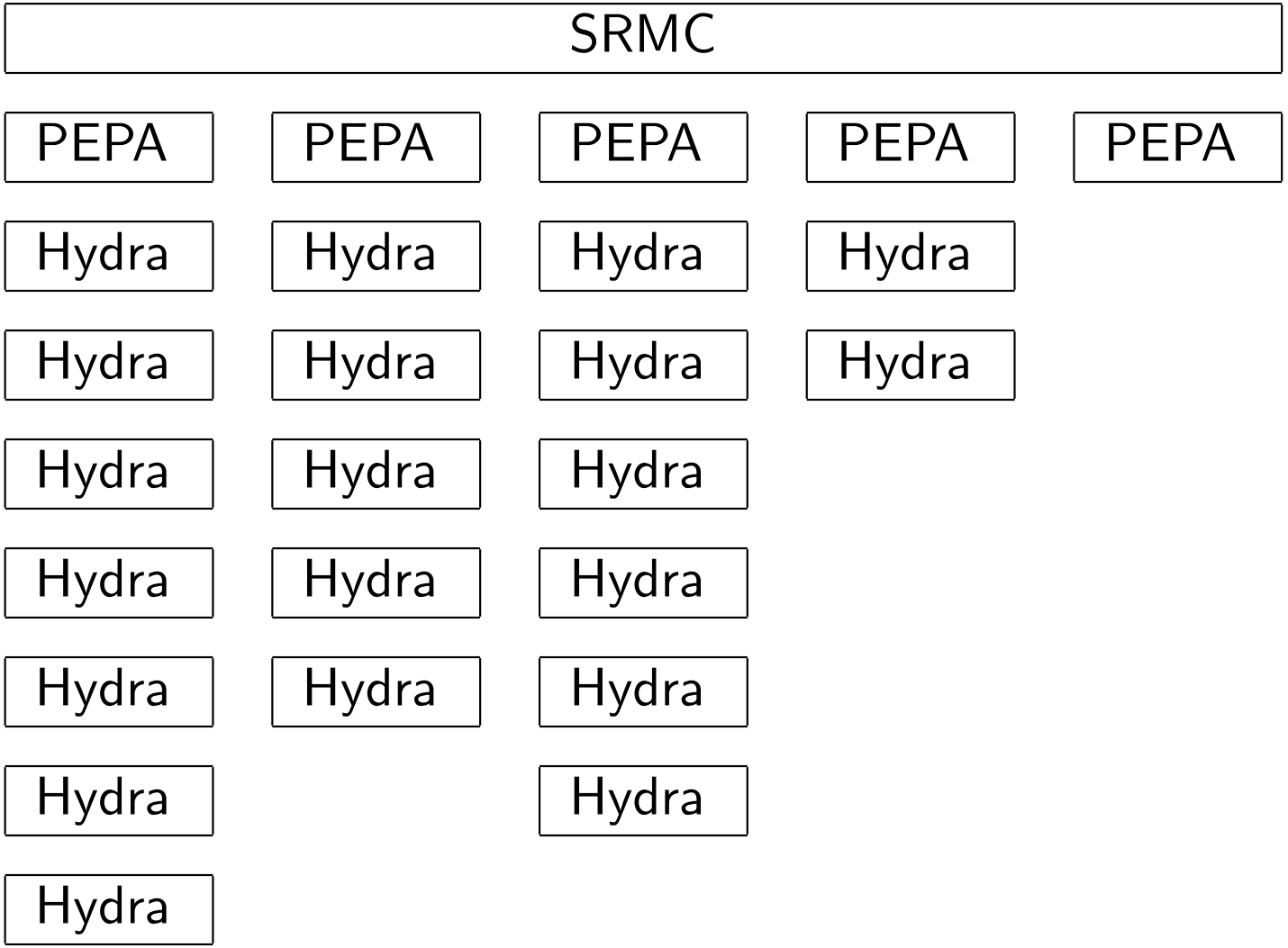

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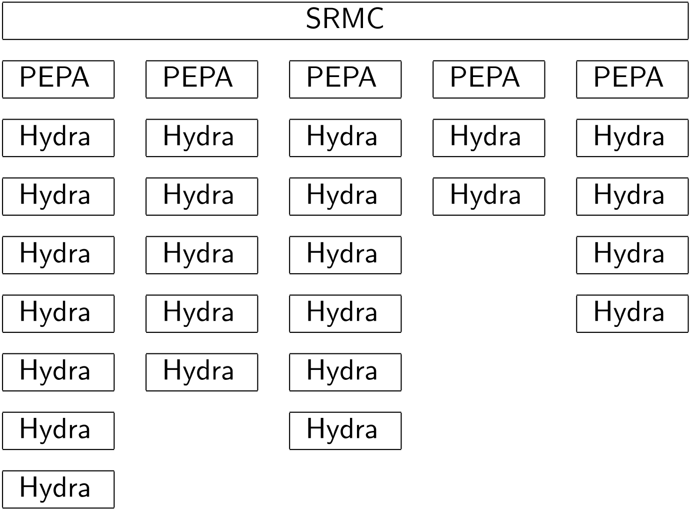

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A Virtual University

The Sensoria Virtual University (SVU) is a (fictitious) virtual organisation formed by bringing together the resources of the universities at Edinburgh (UEDIN), Munich (LMU), Bologna (UNIBO), Pisa (UNIPI) and others.

The SVU federates the teaching and assessment capabilities of the universities allowing students to enrol in courses irrespective of where they are delivered geographically.

The Sensoria Virtual University

The Sensoria Virtual University

Content upload and download

Students download *learning objects* from the content download portals of the universities involved and upload archives of their project work for assessment. By agreement within the SVU, students may download from (or upload to) the portals at any of the SVU sites, not just the one which is geographically closest.

SRMC description of the UEDIN server

```
UEDIN::{
   lambda = 1.65;  mu = 0.0275;  gamma = 0.125;  delta = 3.215;
   avail = { 0.6, 0.7, 0.8, 0.9, 1.0 };

   UploadPortal::{
      Idle = (upload, avail * lambda).Idle + (fail, mu).Down;
      Down = (repair, gamma).Idle;
   }

   DownloadPortal::{
      Idle = (download, avail * delta).Idle + (fail, mu).Down;
      Down = (repair, gamma).Idle;
   }
}
```

SRMC description of the LMU server

```
LMU::{
   lambda = 0.965;   delta = 2.576;
   avail = { 0.5, 0.6, 0.7, 0.8, 0.9 };

   UploadPortal::{
      Idle = (upload, avail * lambda).Idle;
   }

   DownloadPortal::{
      Idle = (download, avail * delta).Idle;
   }
}
```

SRMC description of the UNIBO server

```
UNIBO::{
   lambda = 1.65;  mu = 0.0275;  gamma = 0.125;  delta = 3.215;
   slambda = 1.25; sdelta = 2.255;  avail = { 0.8, 0.9, 1.0 };

   UploadPortal::{
      Idle = (upload, avail * lambda).Idle + (fail, mu).Down
           + (supload, avail * slambda).Idle;
      Down = (repair, gamma).Idle;
   }

   DownloadPortal::{
      Idle = (download, avail * delta).Idle  + (fail, mu).Down
           + (sdownload, avail * sdelta).Idle;
      Down = (repair, gamma).Idle;
   }
}
```

SRMC description of a cautious client

```
Sally::{
   Idle = (start, 1.0).Download;
   Download = (download, _).(download, _).(download, _).Upload
            + (sdownload, _).(sdownload, _).(sdownload, _).Upload;
   Upload = (upload, _).(upload, _).Disconnect
          + (supload, _).(supload, _).Disconnect;
   Disconnect = (finish, 1.0).Idle;
}
```

SRMC description of an incautious client

```
Harry::{
    Idle = (start, 1.0).Download;
    Download = (download, _).(download, _).(download, _).Upload;

    Upload = (upload, _).(upload, _).Disconnect;

    Disconnect = (finish, 1.0).Idle;
}
```

Client, Upload and Download portals

```
SVU::Client =
   { Harry::Idle, Sally::Idle };

SVU::UploadPortal =
   { UEDIN::UploadPortal::Idle, LMU::UploadPortal::Idle,
     UNIBO::UploadPortal::Idle, UNIPI::UploadPortal::Idle };

SVU::DownloadPortal =
   { UEDIN::DownloadPortal::Idle, LMU::DownloadPortal::Idle,
     UNIBO::DownloadPortal::Idle, UNIPI::DownloadPortal::Idle };
```

Continuous-Time Markov Chains

We work with a stochastic process algebra (PEPA) which has Continuous-Time Markov Chains (CTMCs) as the underlying mathematical model.

Markov chains

Markov chains are finite state stochastic processes. The transition system of a Markov chain can be stored as a generator matrix, Q, where $Q_{ij} = r$ means that there is a transition from state i to state j at rate r.

Transient analysis

Investigation of SLAs requires the transient analysis of a CTMC.

Transient analysis

We are concerned with finding the transient state probability row vector $\pi(t) = [\pi_0(t), \ldots, \pi_{n-1}(t)]$ where $\pi_i(t)$ denotes the probability that the CTMC is in state i at time t.

Uniformisation

Transient and passage-time analysis of CTMCs proceeds by a numerical procedure called *uniformisation*.

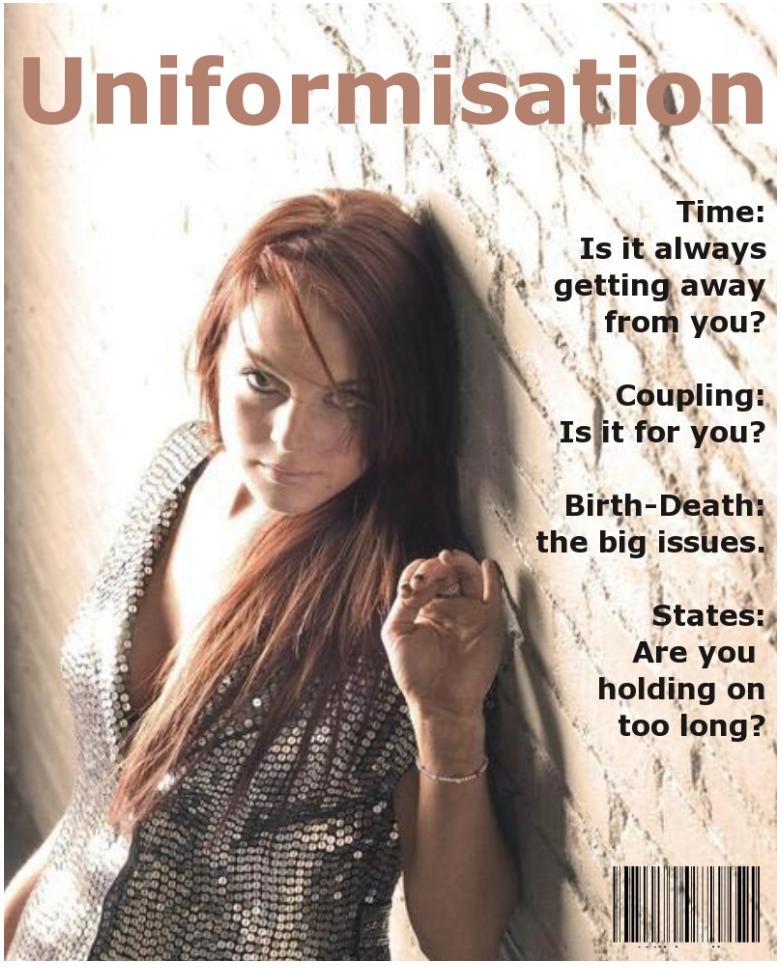
Uniformisation

The generator matrix, Q, is "uniformised" with:

$$P = Q/q + I$$

where $q > \max_i |Q_{ii}|$. This process transforms a CTMC into one in which all states have the same mean holding time $1/q$.

Uniformisation

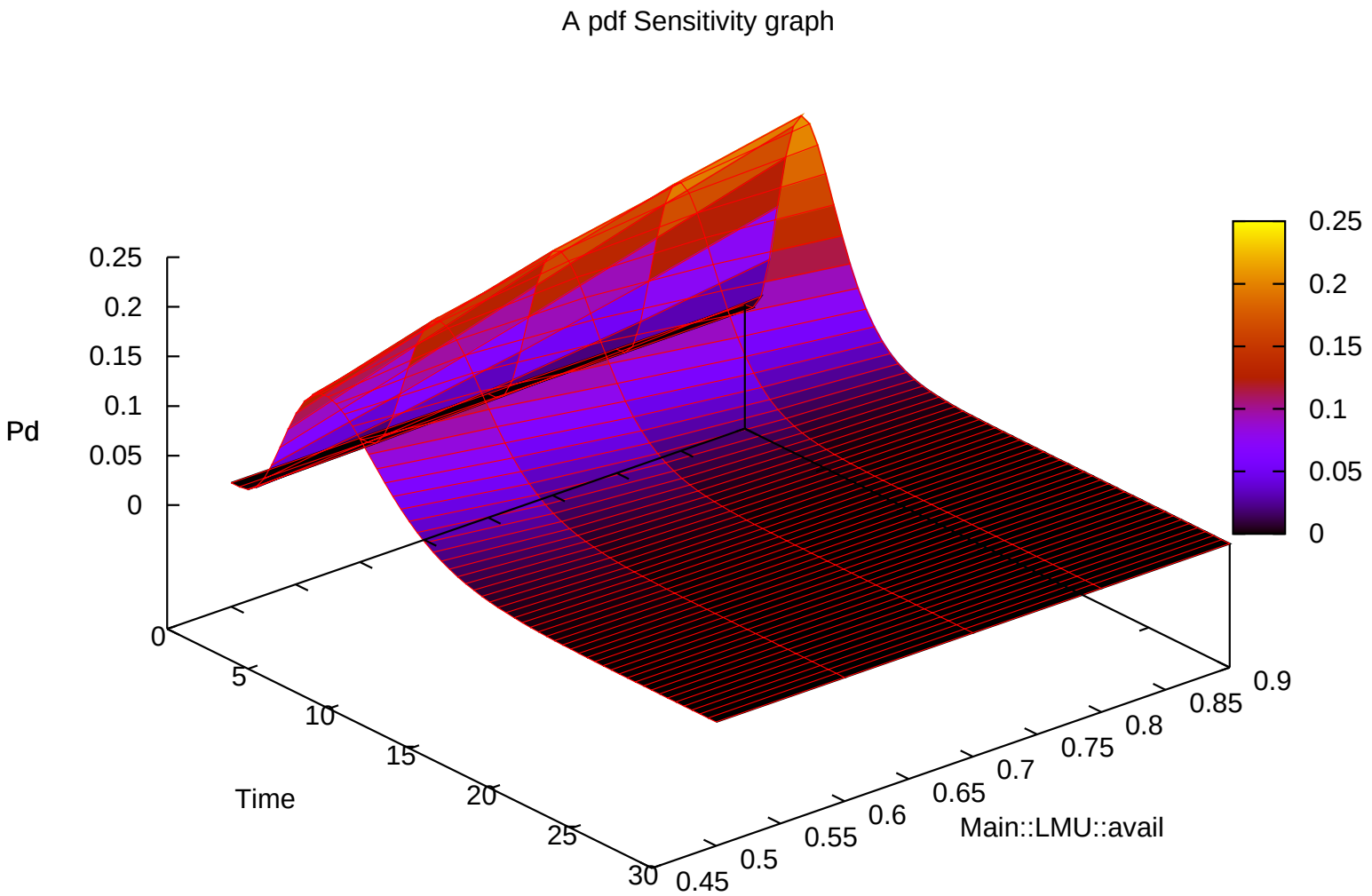


Passage-time computation

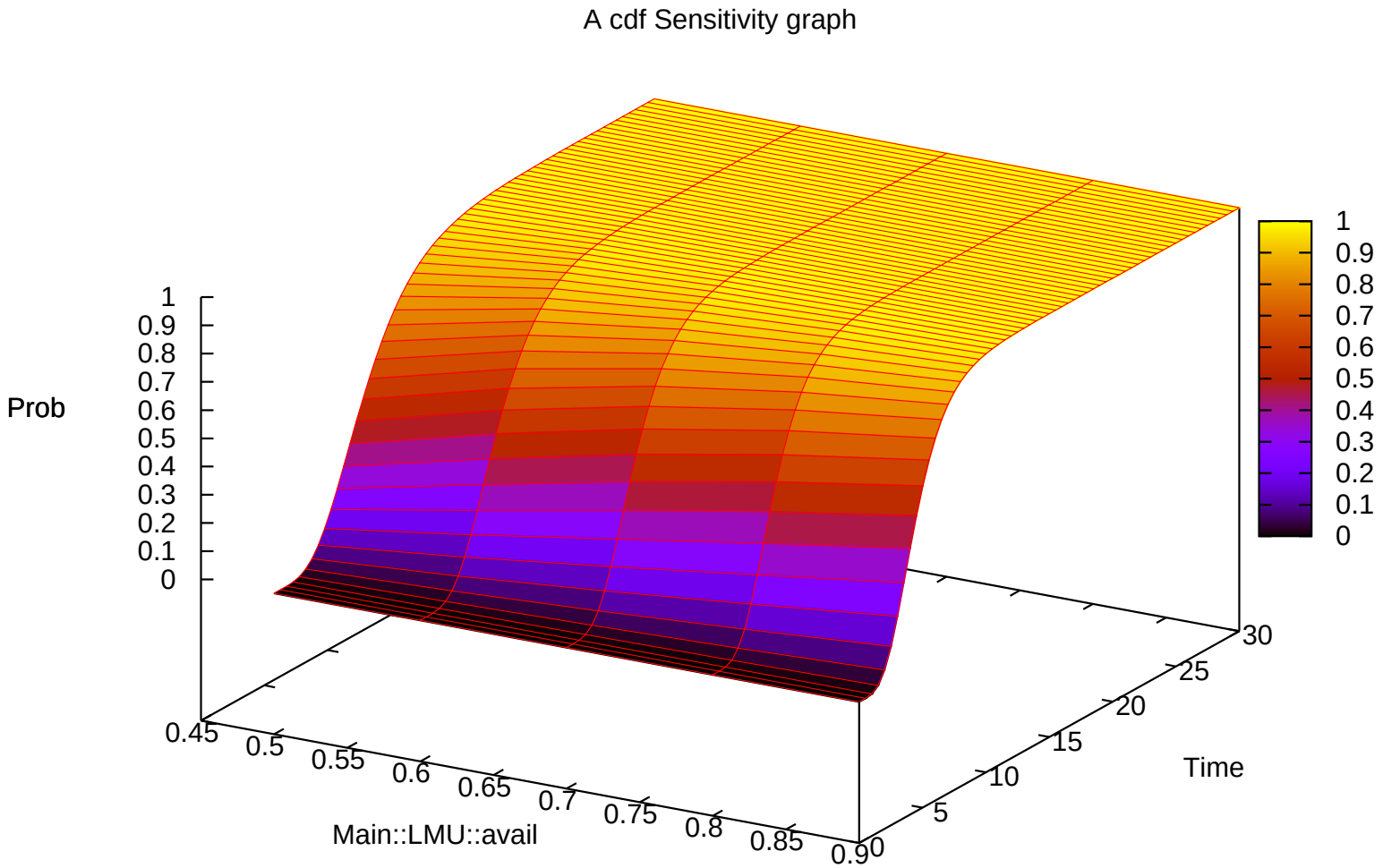
Passage-time computation is concerned with knowing the probability of reaching a designated target state from a designated source state. It rests on two key sub-computations.

1. Finding the time to complete n hops ($n = 1, 2, 3, \ldots$), which is an Erlang distribution with parameters n and q.
2. Finding the probability that the transition between source and target states occurs in exactly n hops.

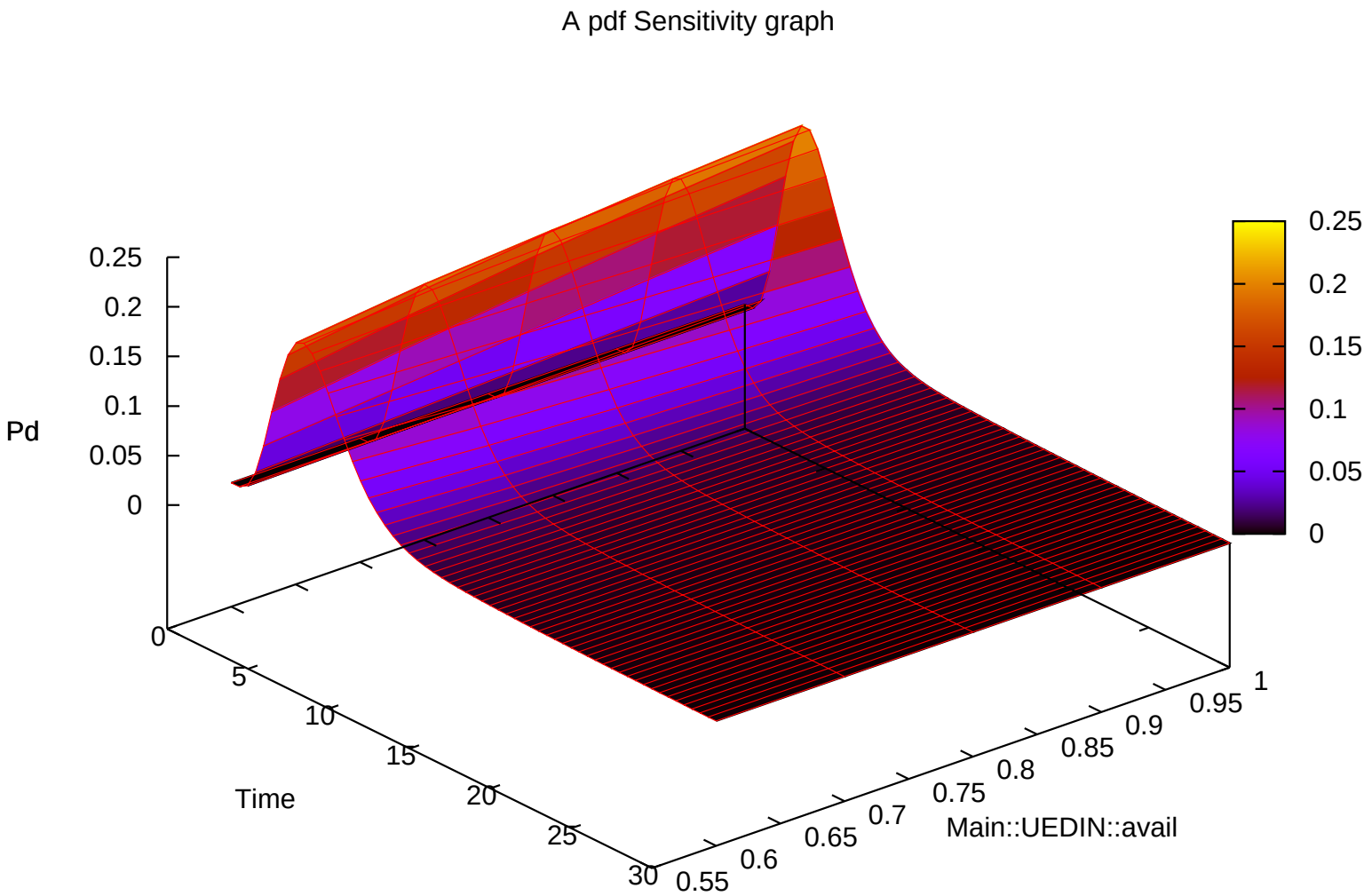
Probability Distribution Function [Harry, LMU, LMU]



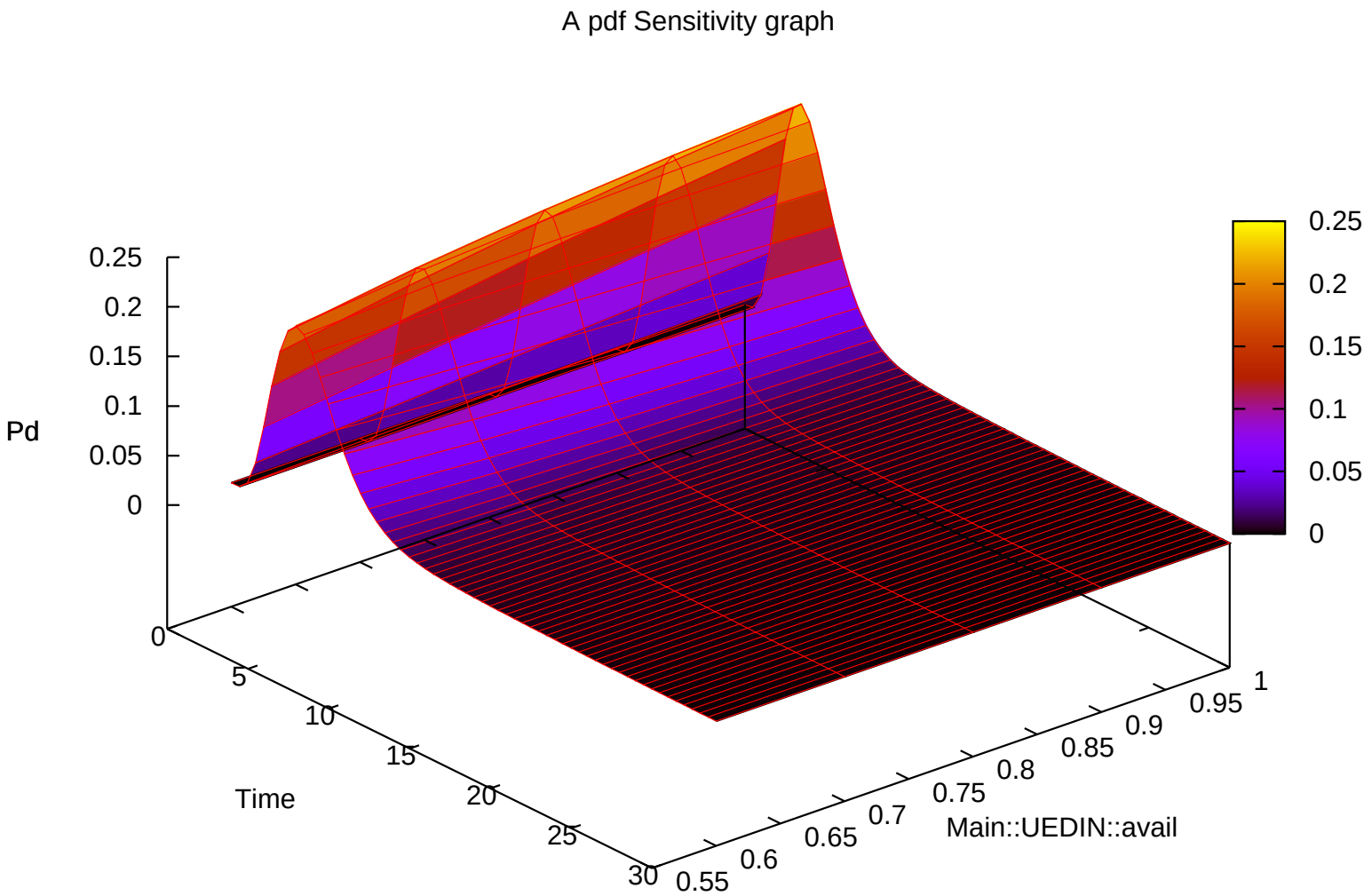
Cumulative Distribution Function [Harry, LMU, LMU]



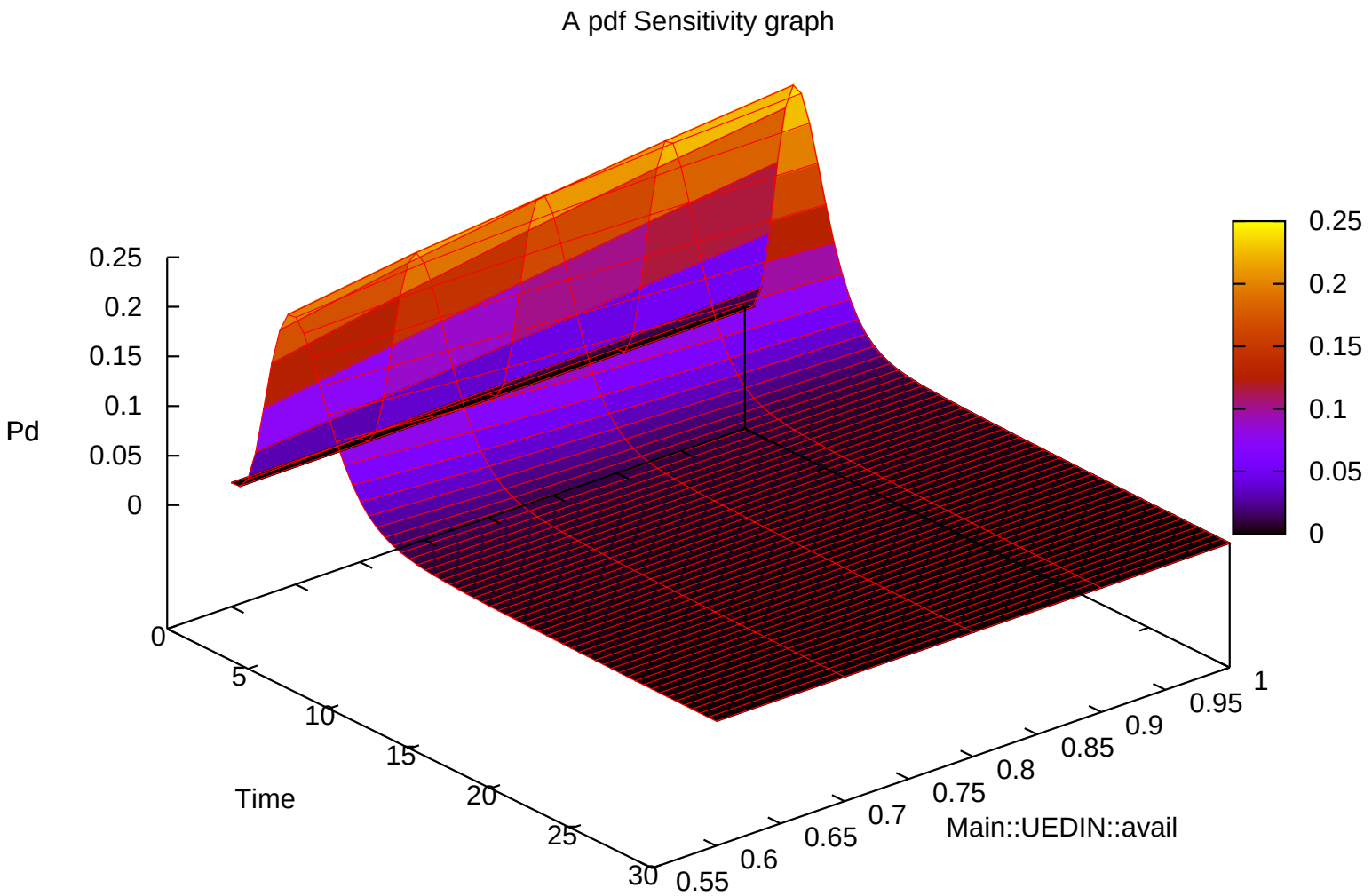
PDF [Harry, UEDIN, LMU], (LMU::avail=0.5)



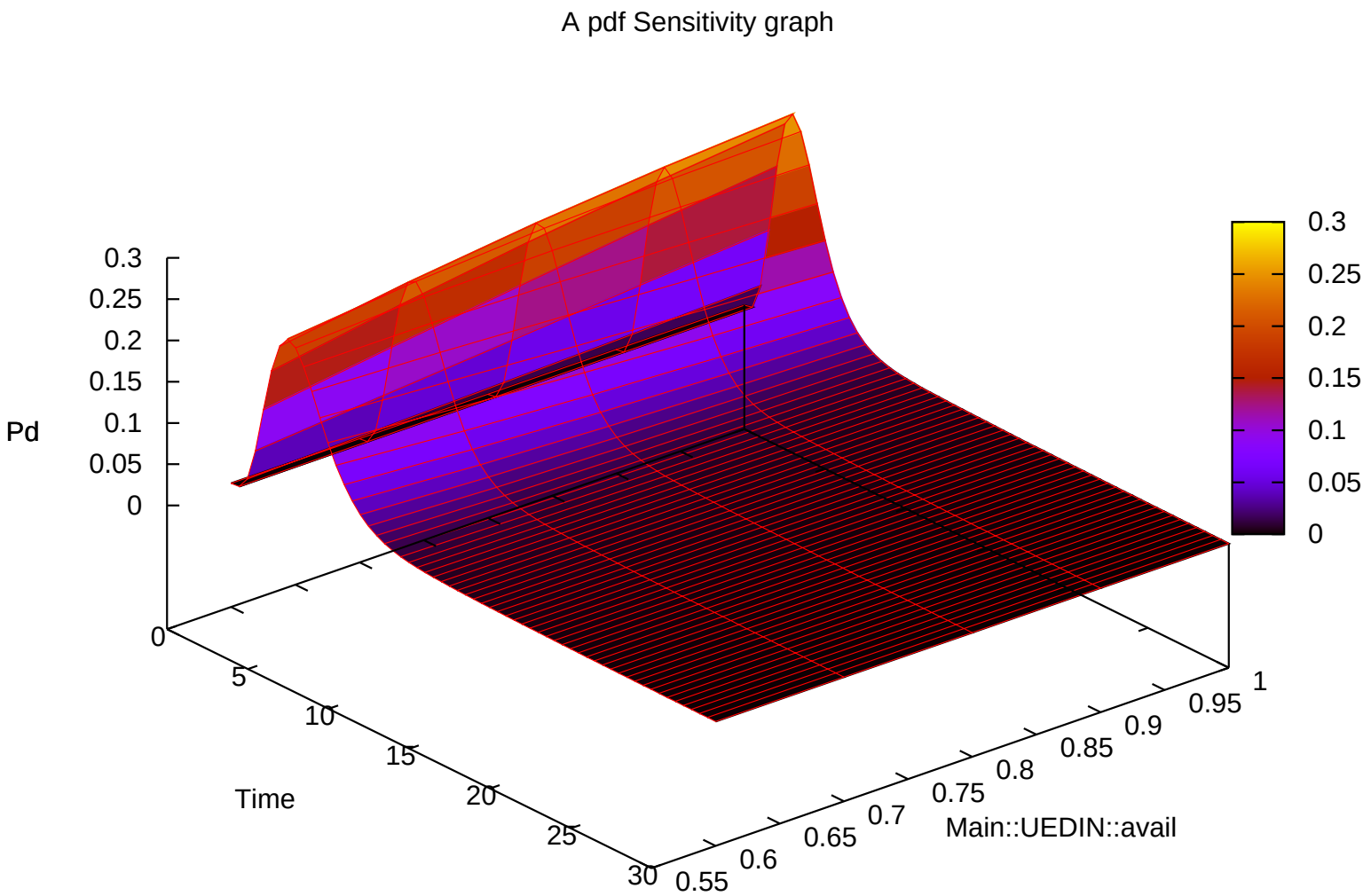
PDF [Harry, UEDIN, LMU], (LMU::avail=0.6)



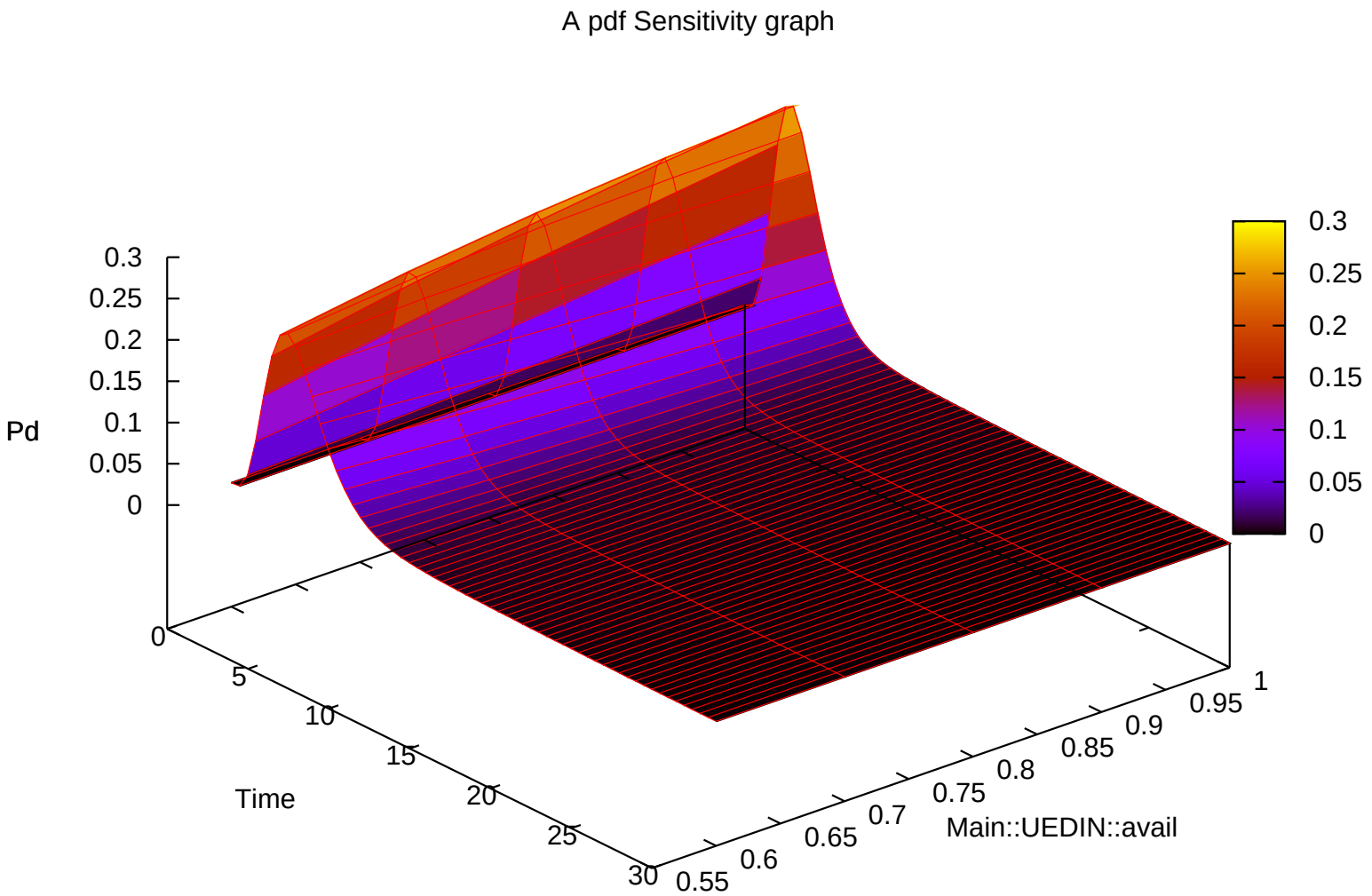
PDF [Harry, UEDIN, LMU], (LMU::avail=0.7)



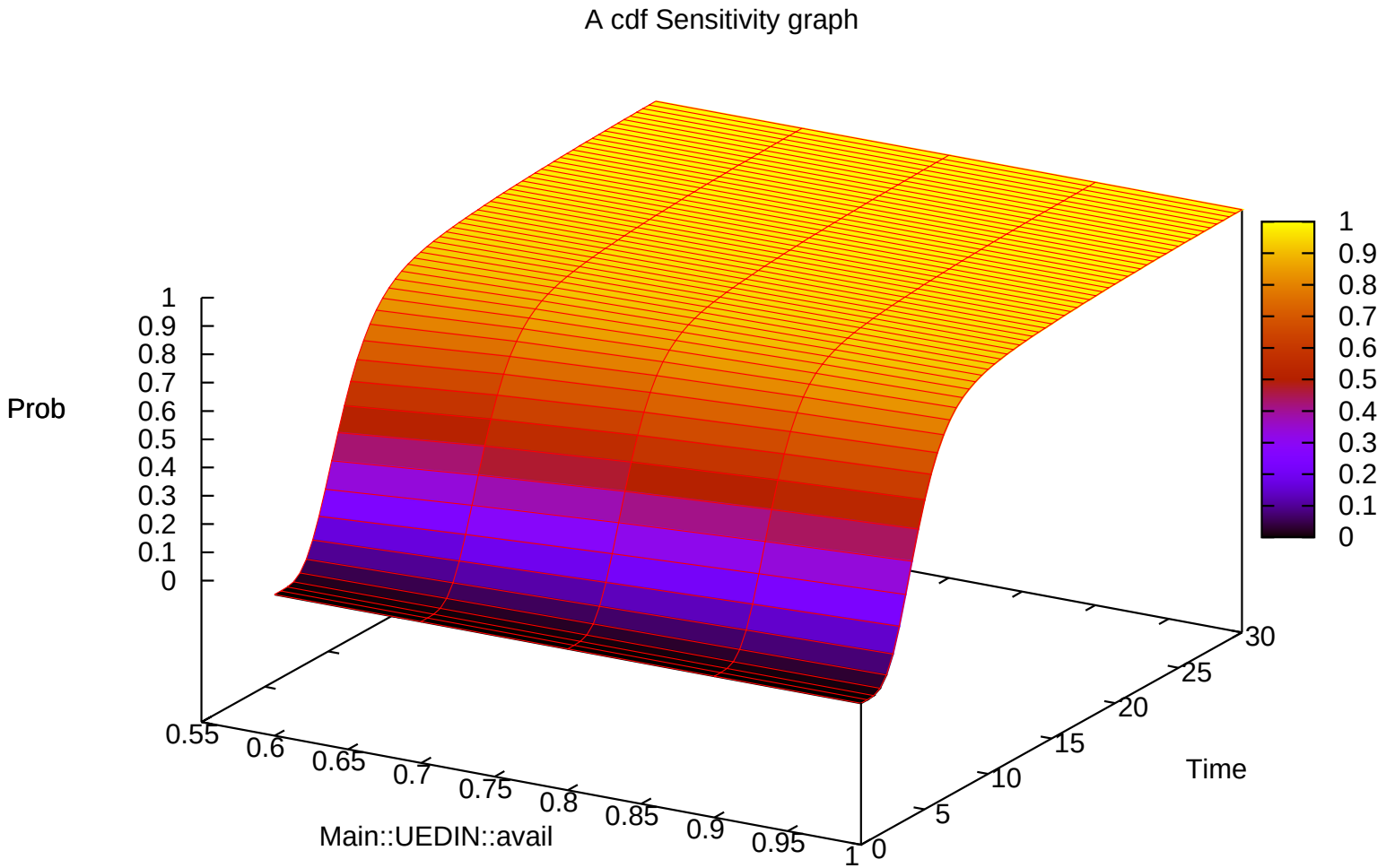
PDF [Harry, UEDIN, LMU], (LMU::avail=0.8)



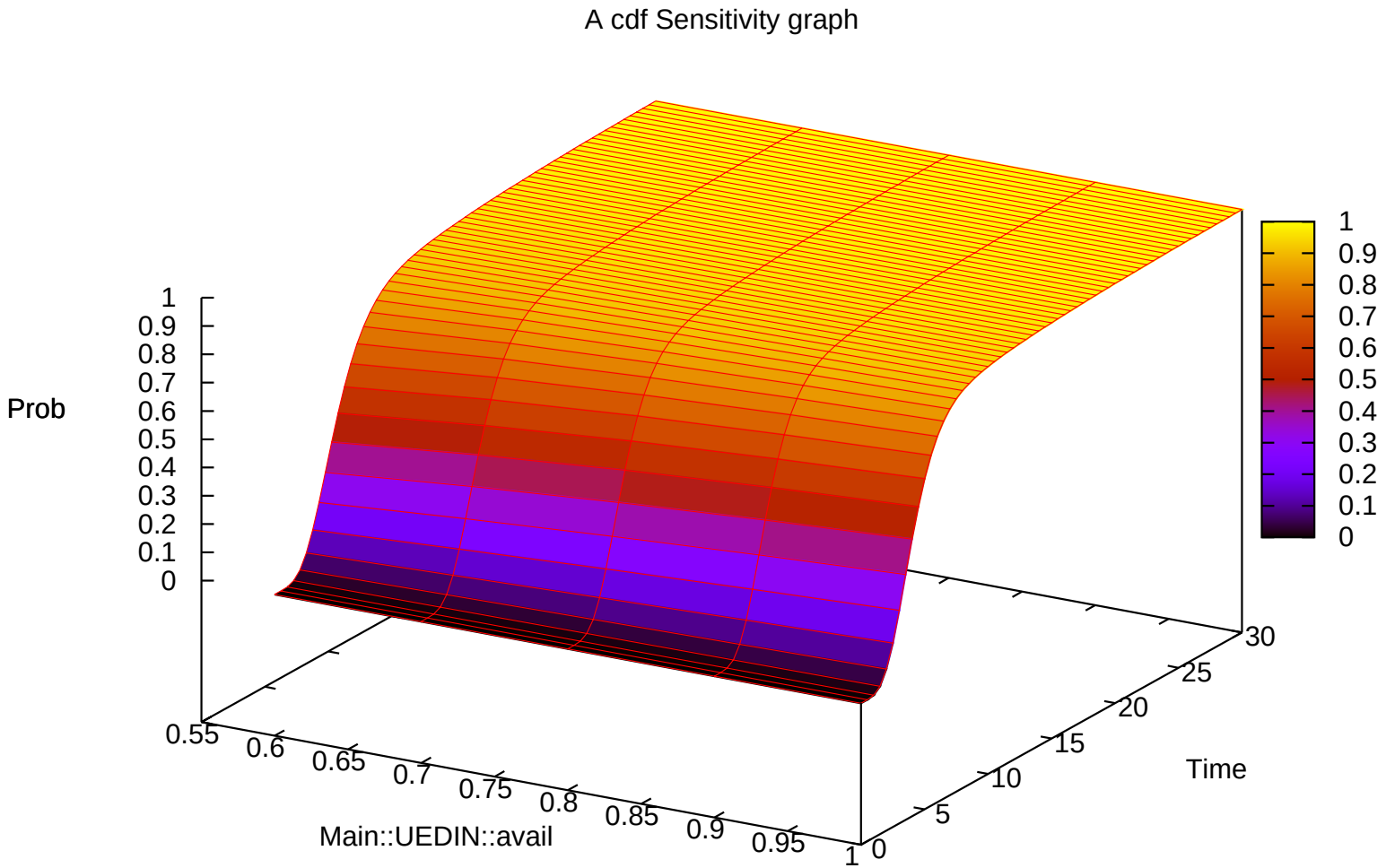
PDF [Harry, UEDIN, LMU], (LMU::avail=0.9)



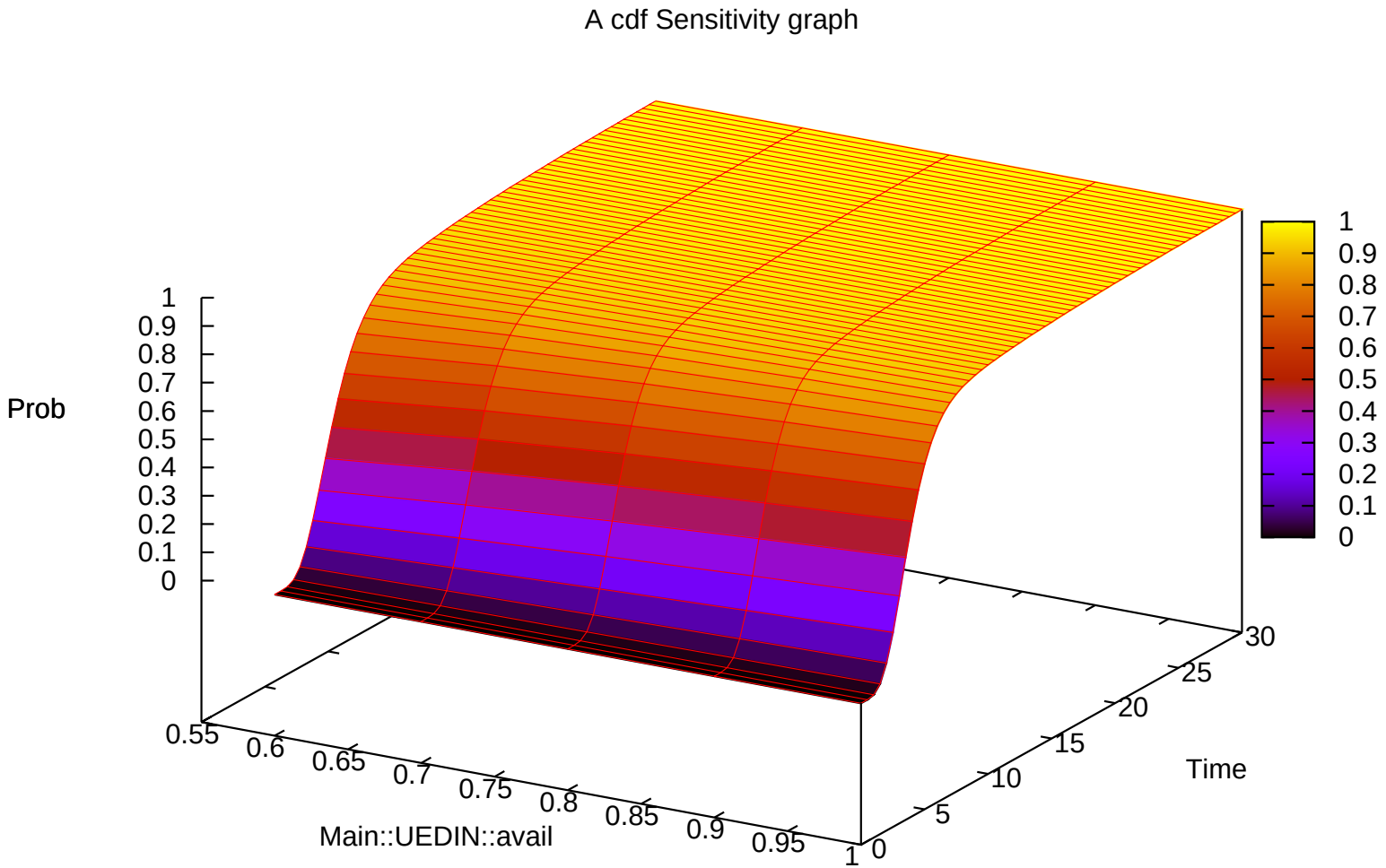
CDF [Harry, UEDIN, LMU], (LMU::avail=0.5)



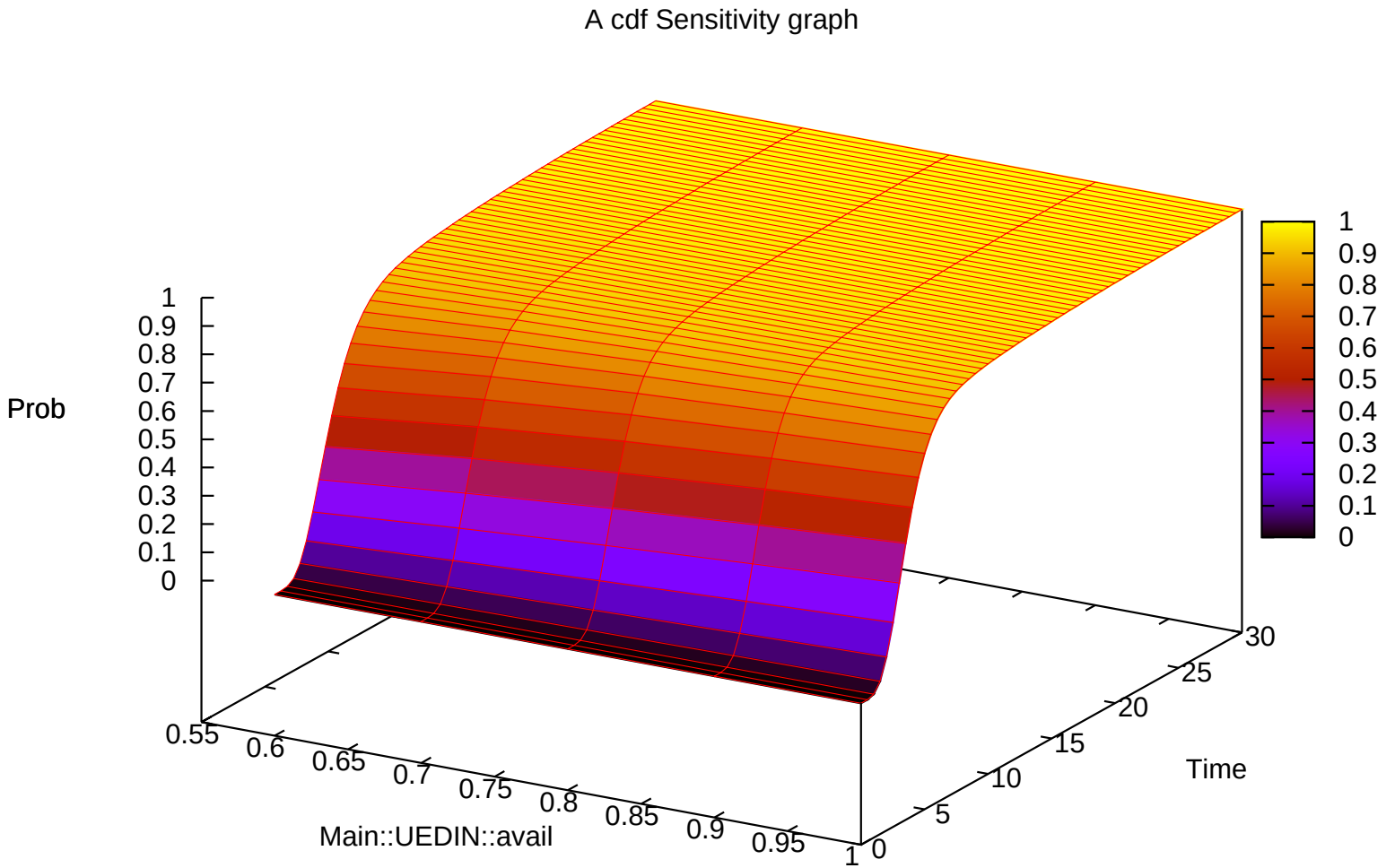
CDF [Harry, UEDIN, LMU], (LMU::avail=0.6)



CDF [Harry, UEDIN, LMU], (LMU::avail=0.7)



CDF [Harry, UEDIN, LMU], (LMU::avail=0.8)



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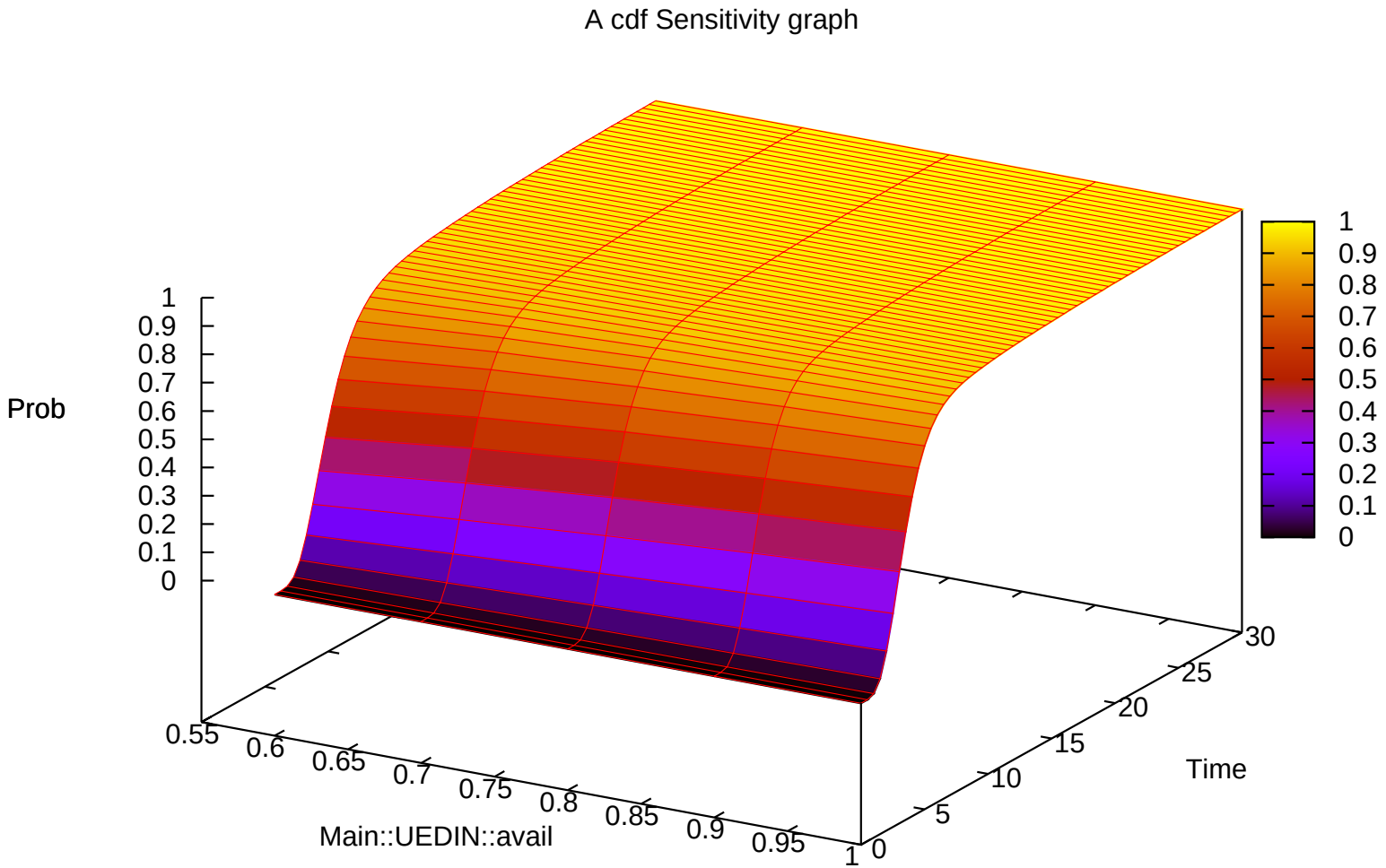

Service-level agreements for SOC

The type of service-level argeement which we would attempt to state for service-oriented computing systems would include a *confidence interval*, a *path* through the system, a *time bound* and lower and upper *probability bounds*.

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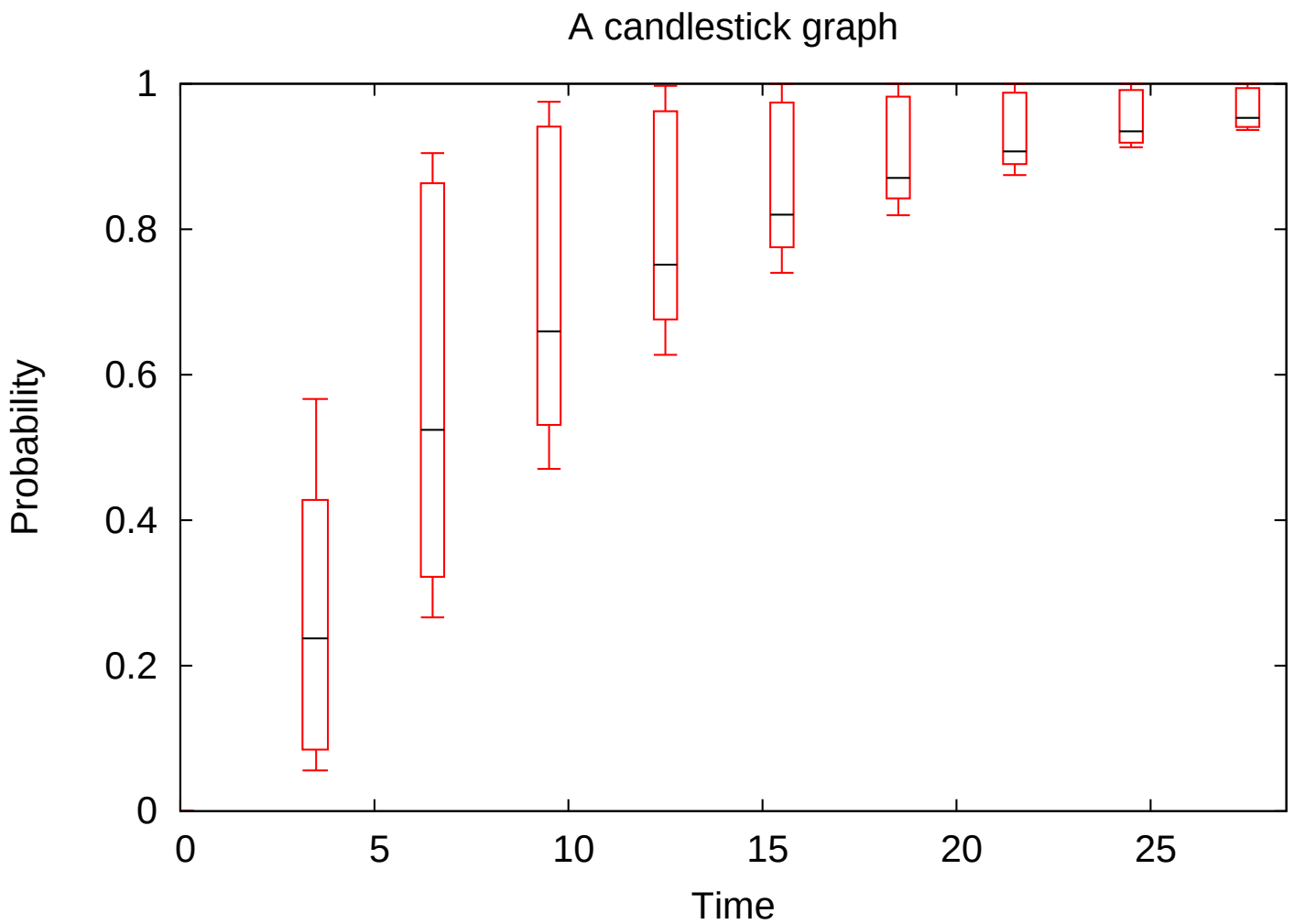
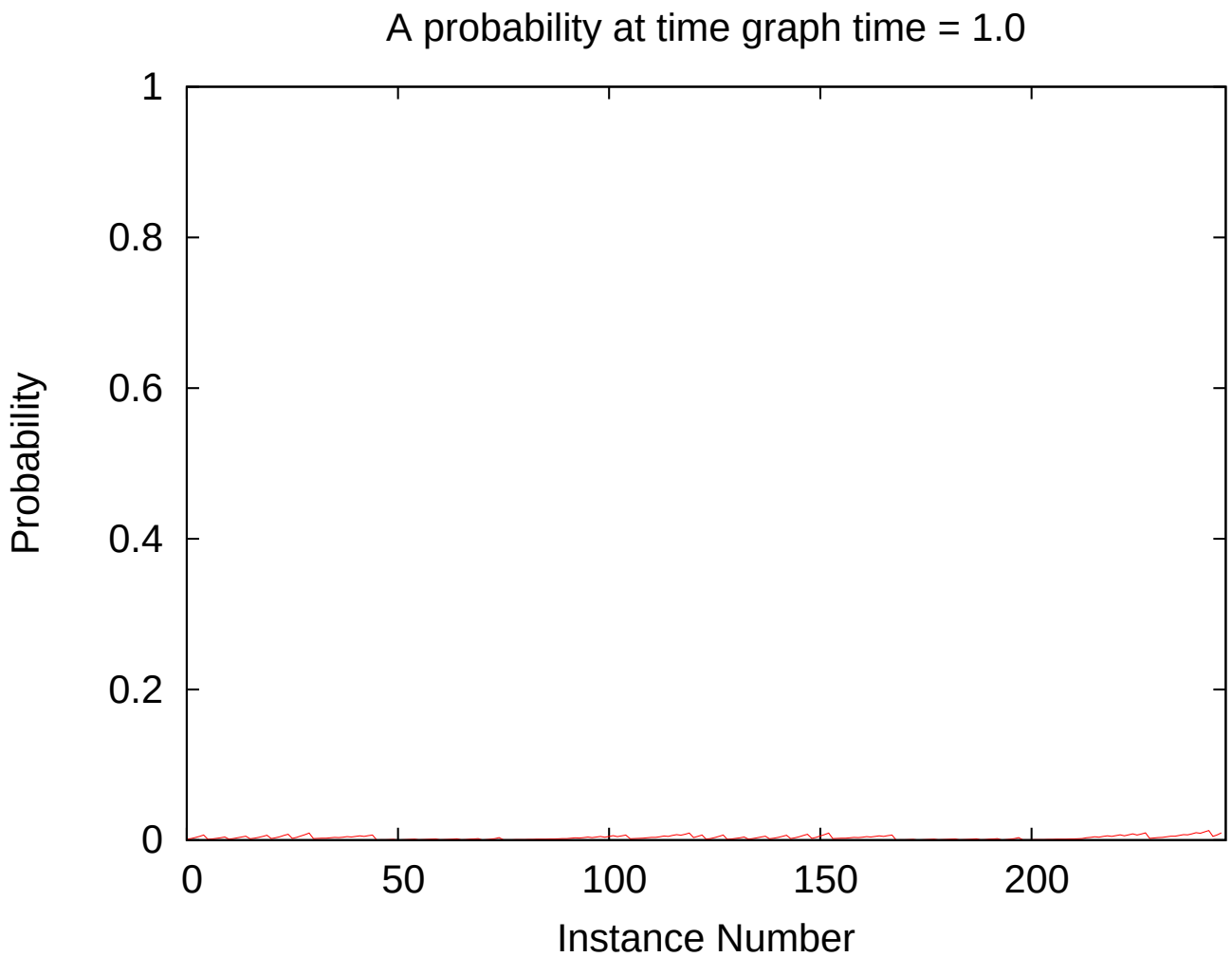
For example: "Ninety percent of sessions will complete within 29 minutes with probability between 93.9% and 99.3%".

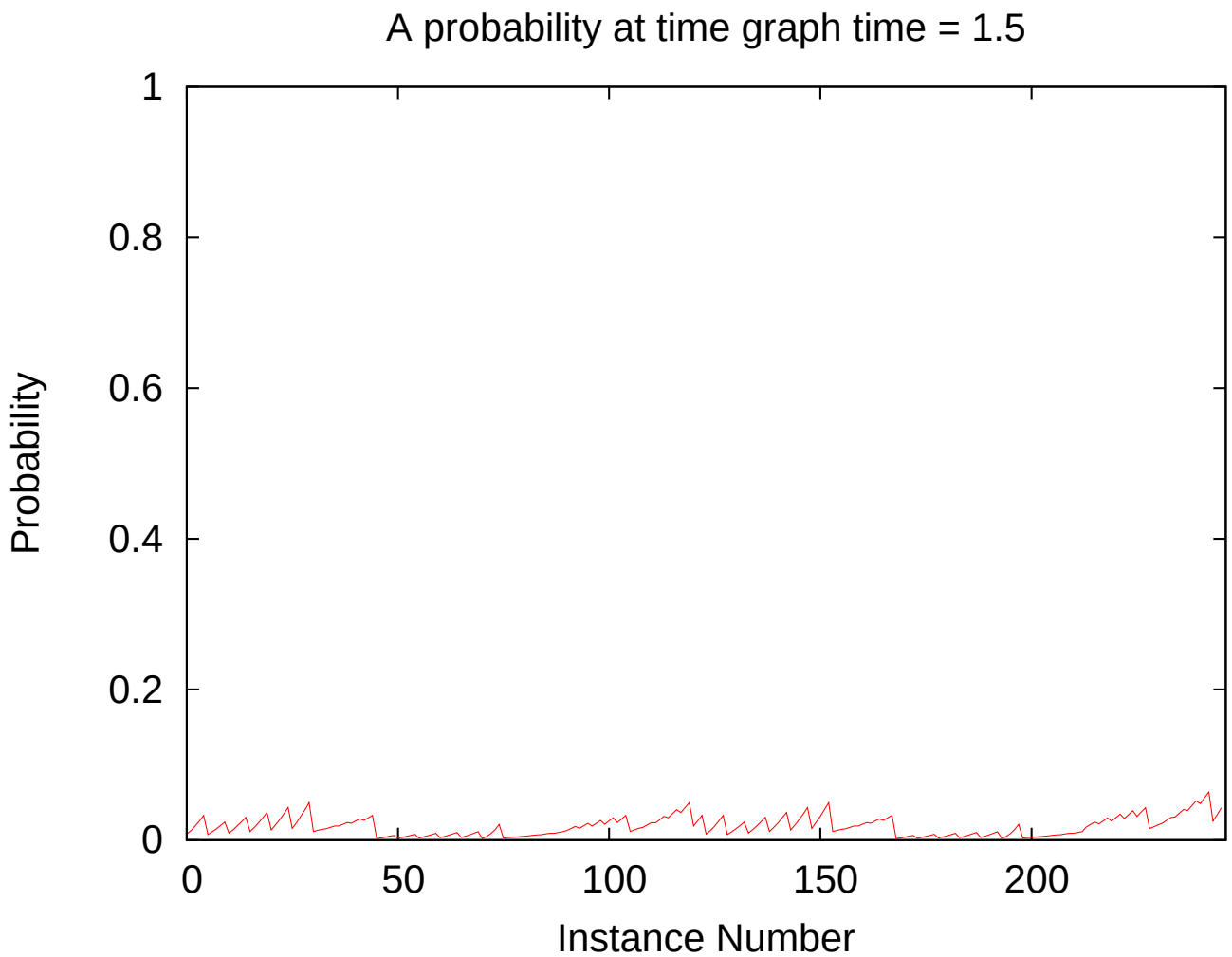
Candlestick 10% to 90%



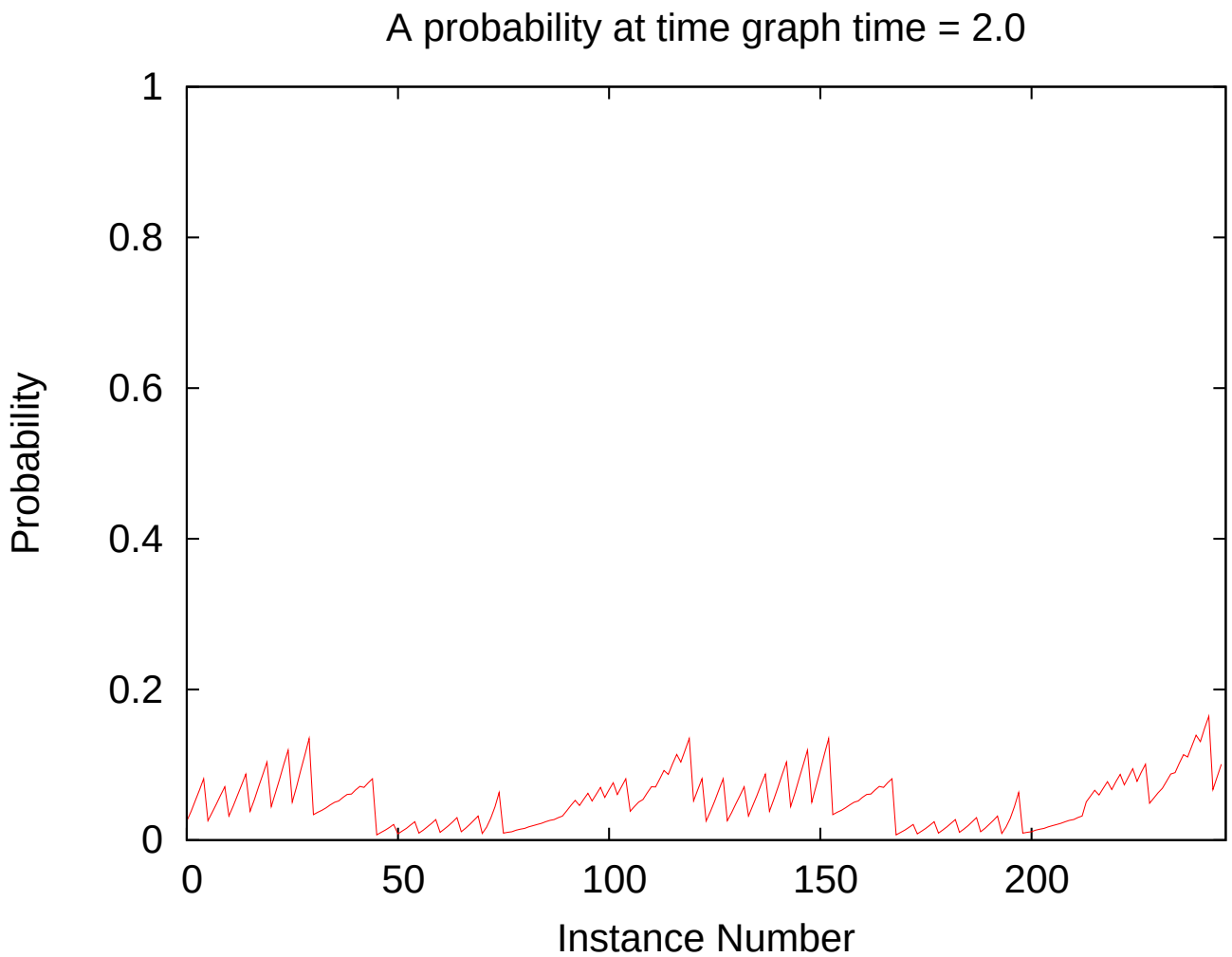
Probability of completion at $t = 1.0$



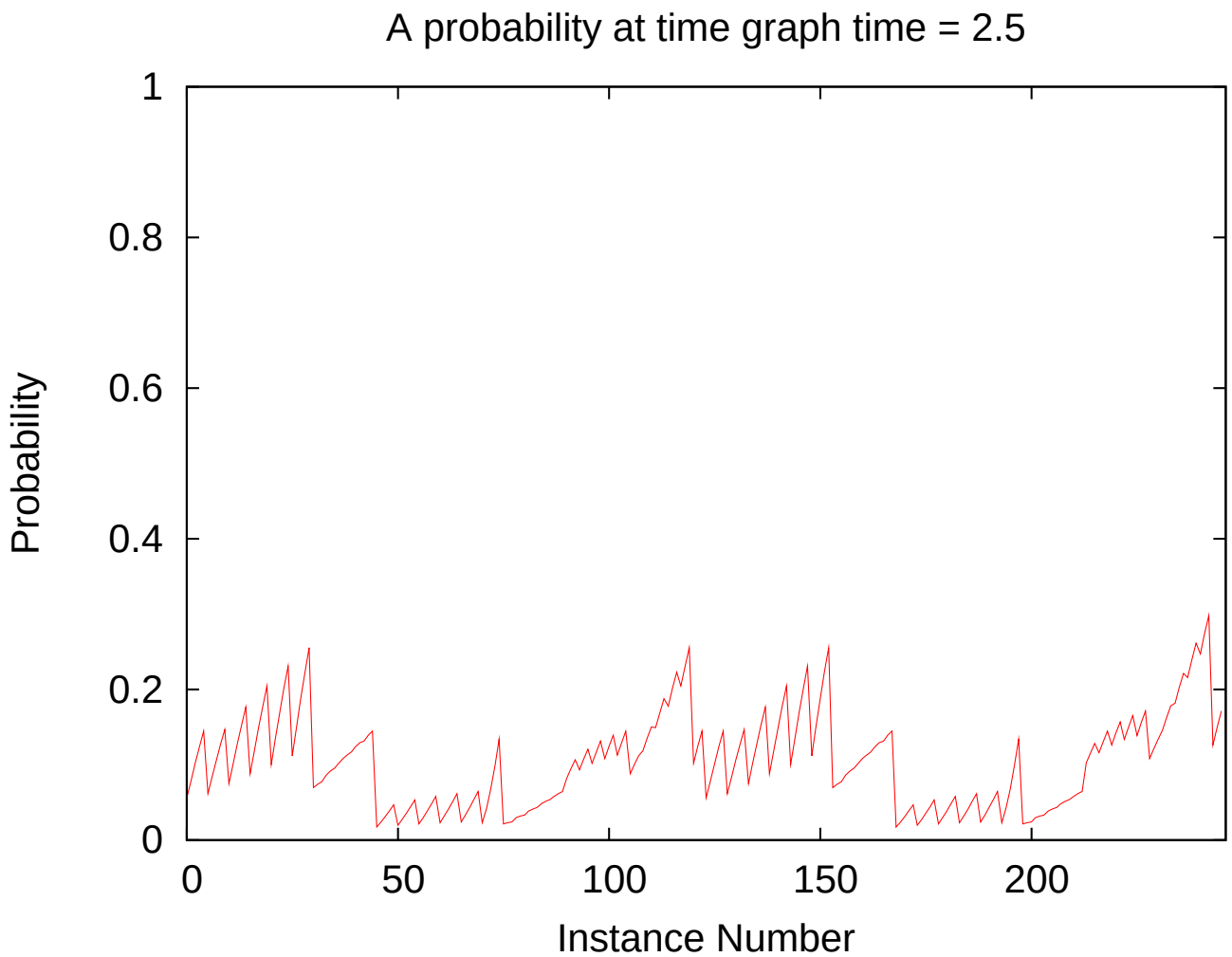
Probability of completion at $t = 1.5$



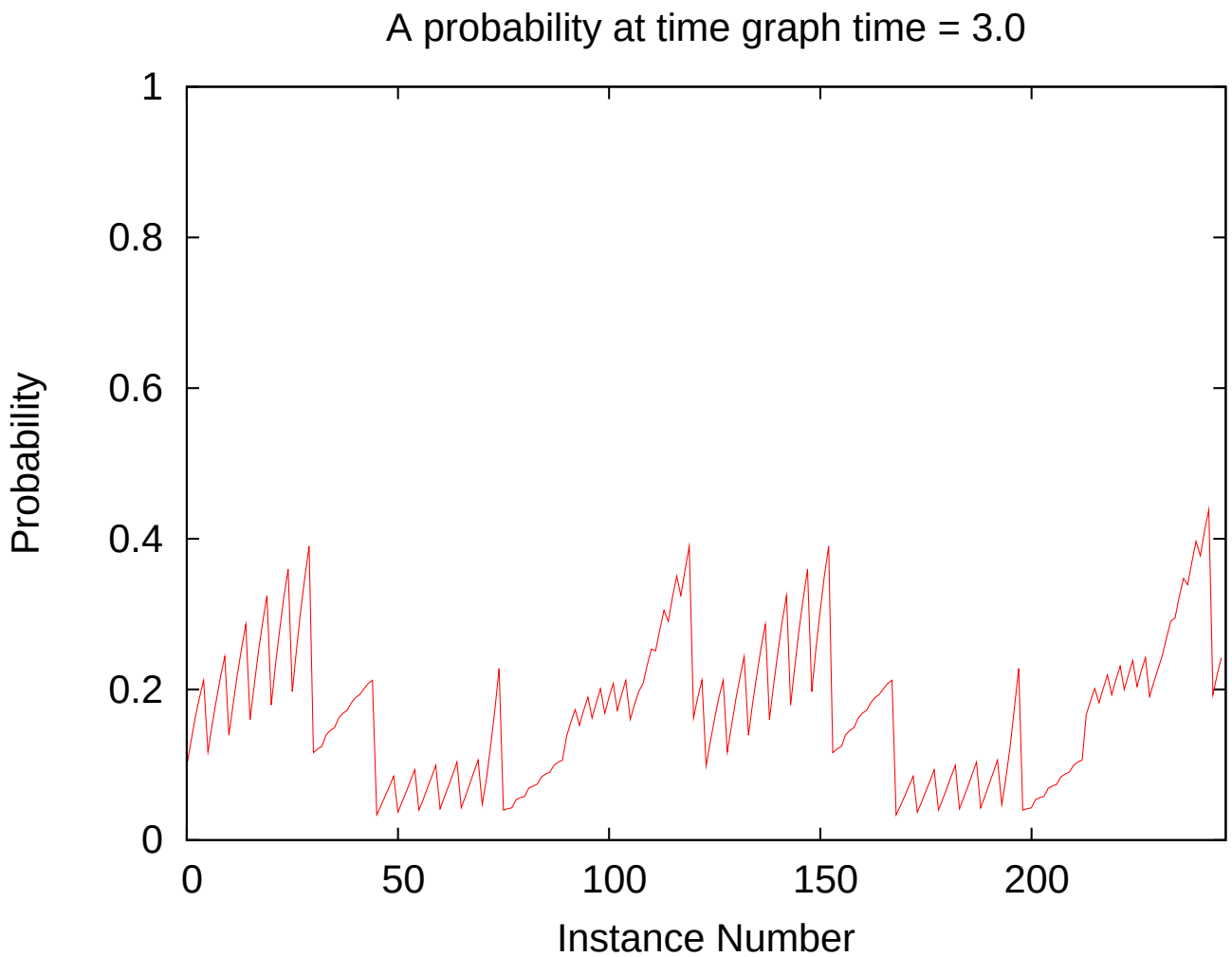
Probability of completion at $t = 2.0$



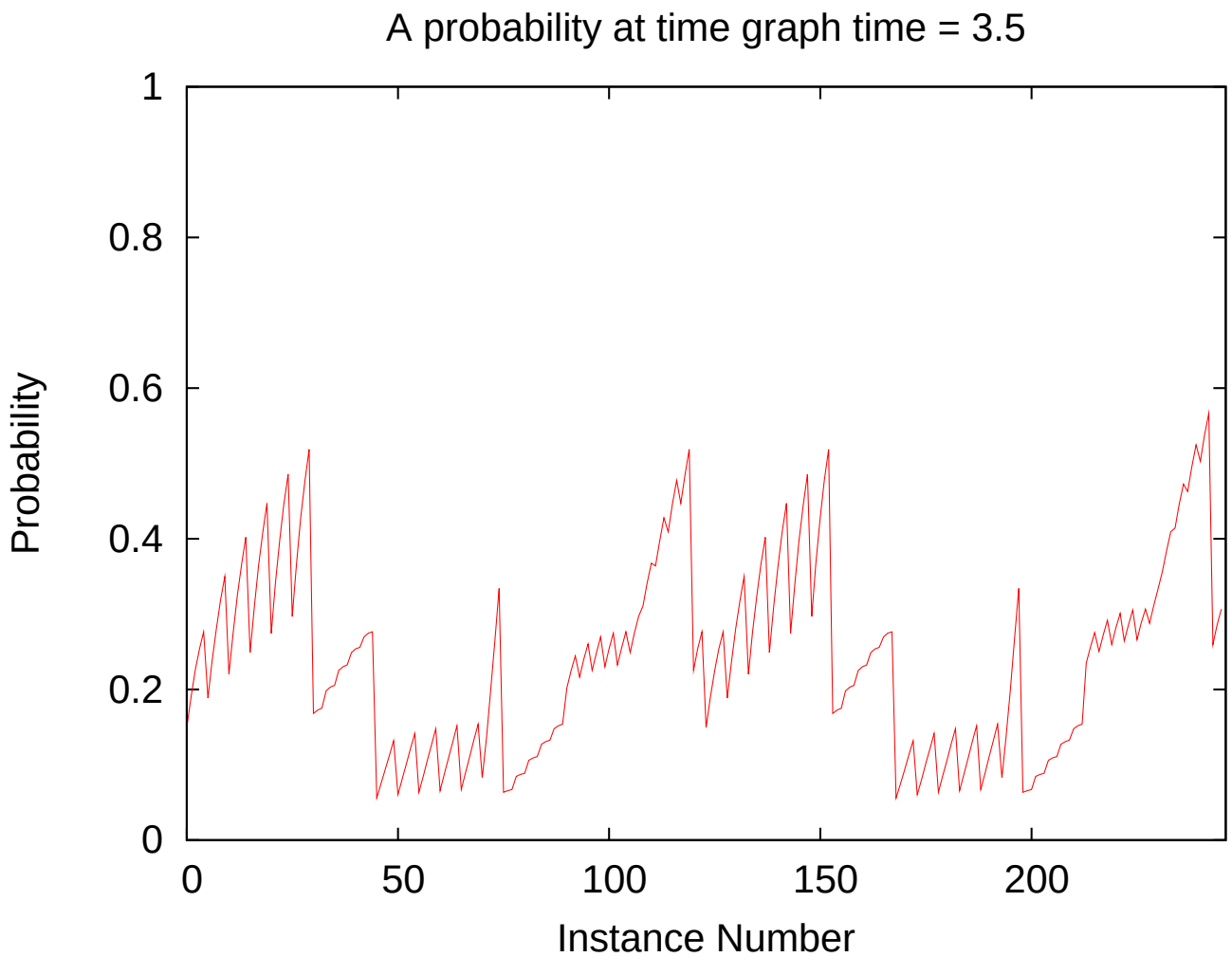
Probability of completion at $t = 2.5$



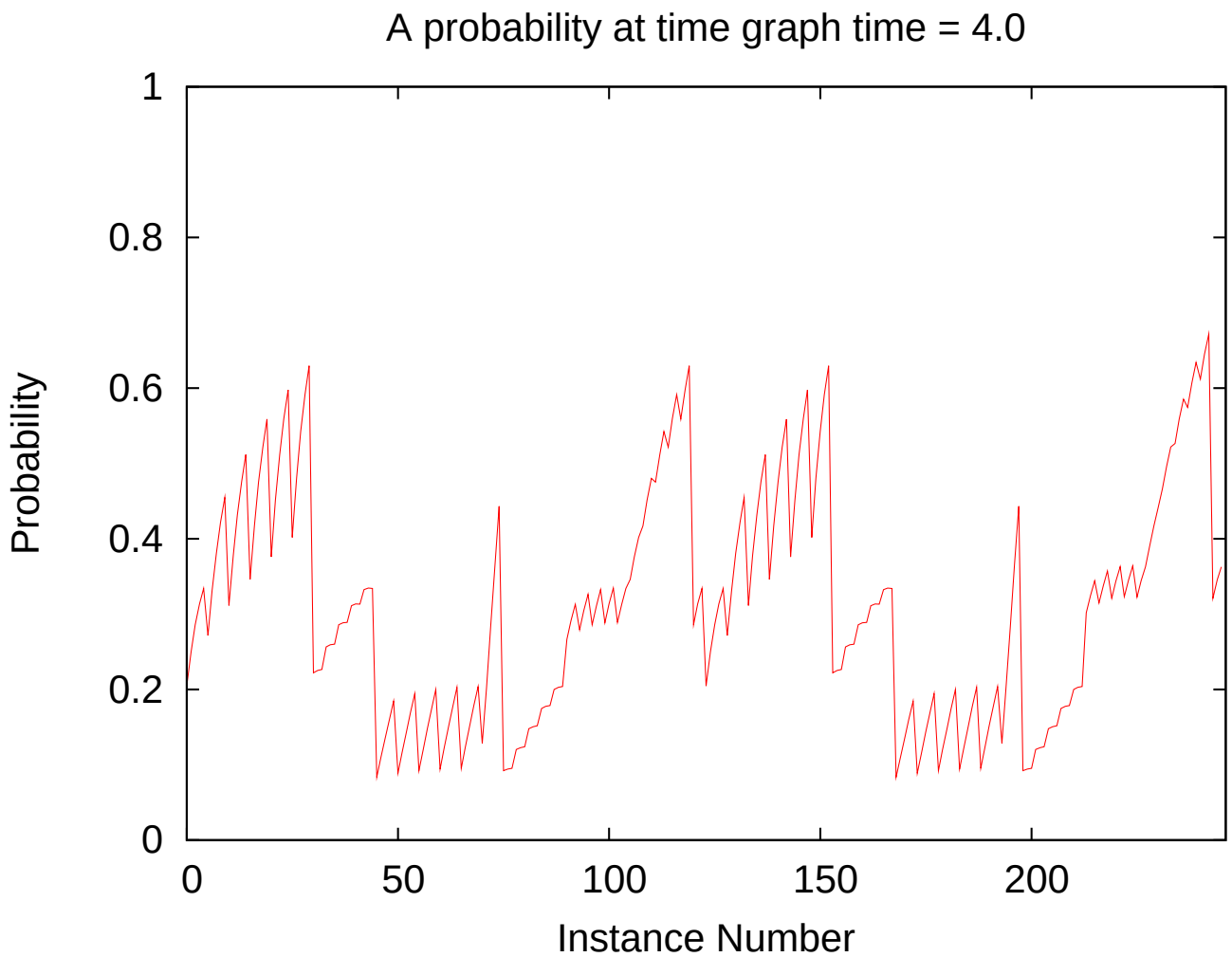
Probability of completion at $t = 3.0$



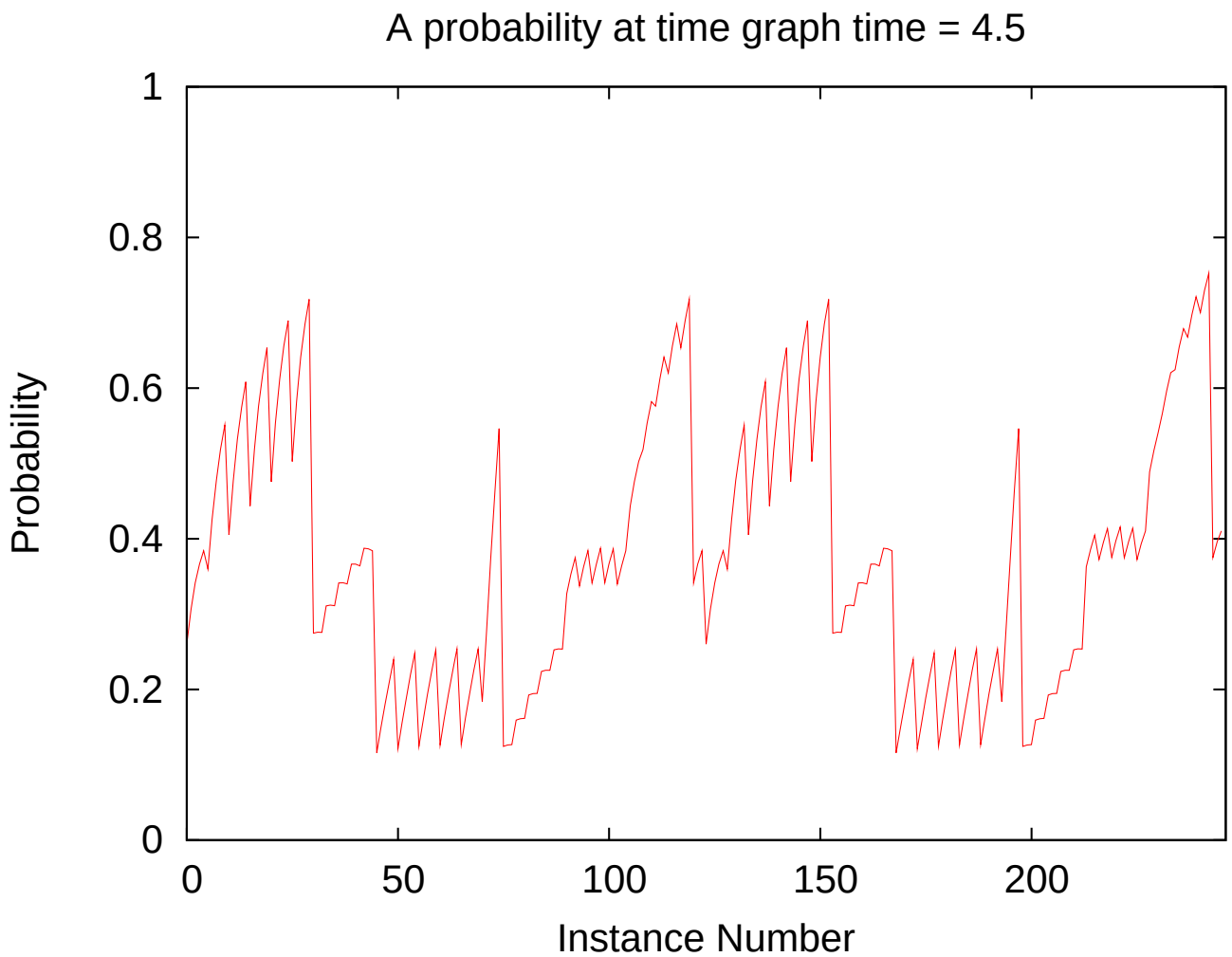
Probability of completion at $t = 3.5$



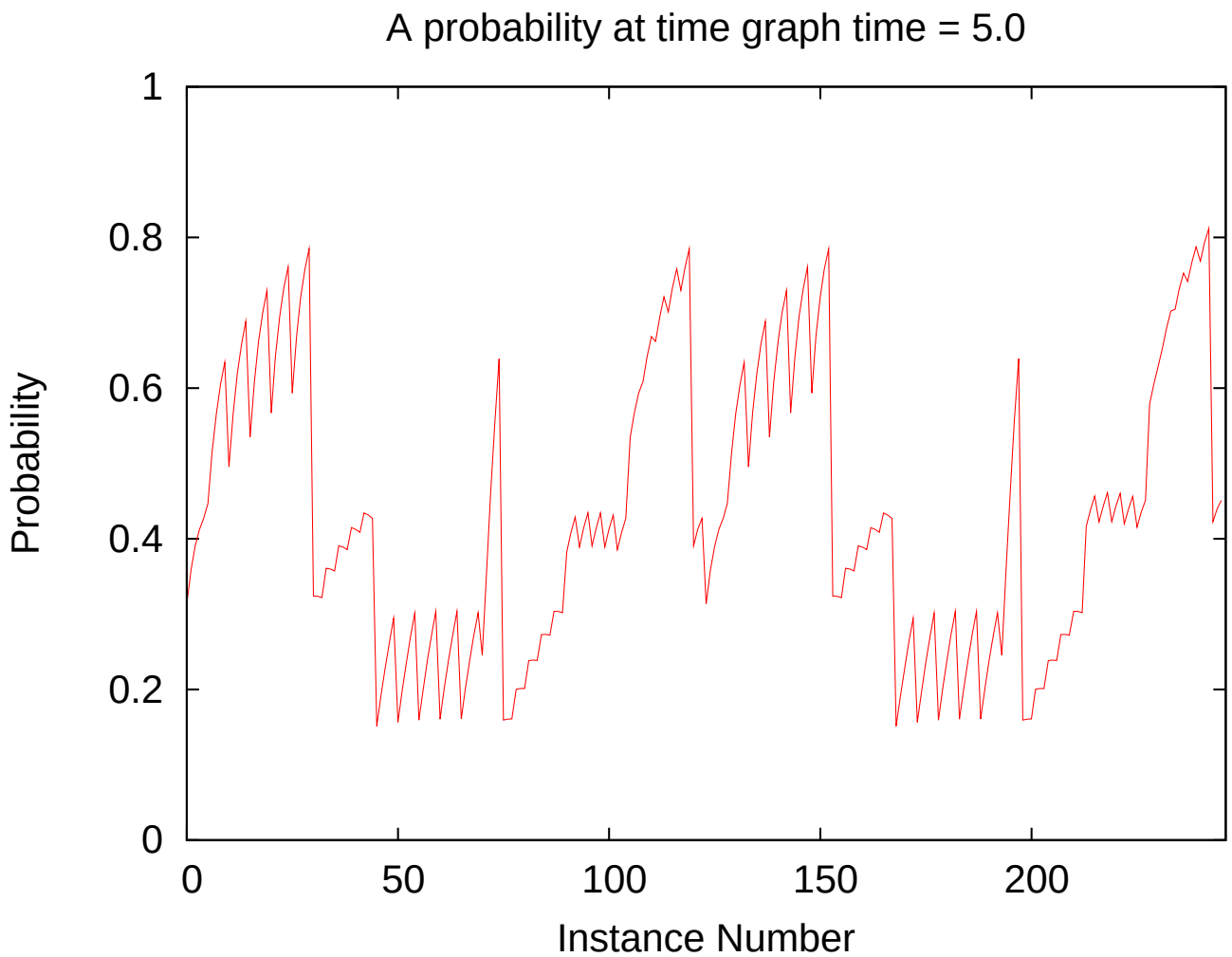
Probability of completion at $t = 4.0$



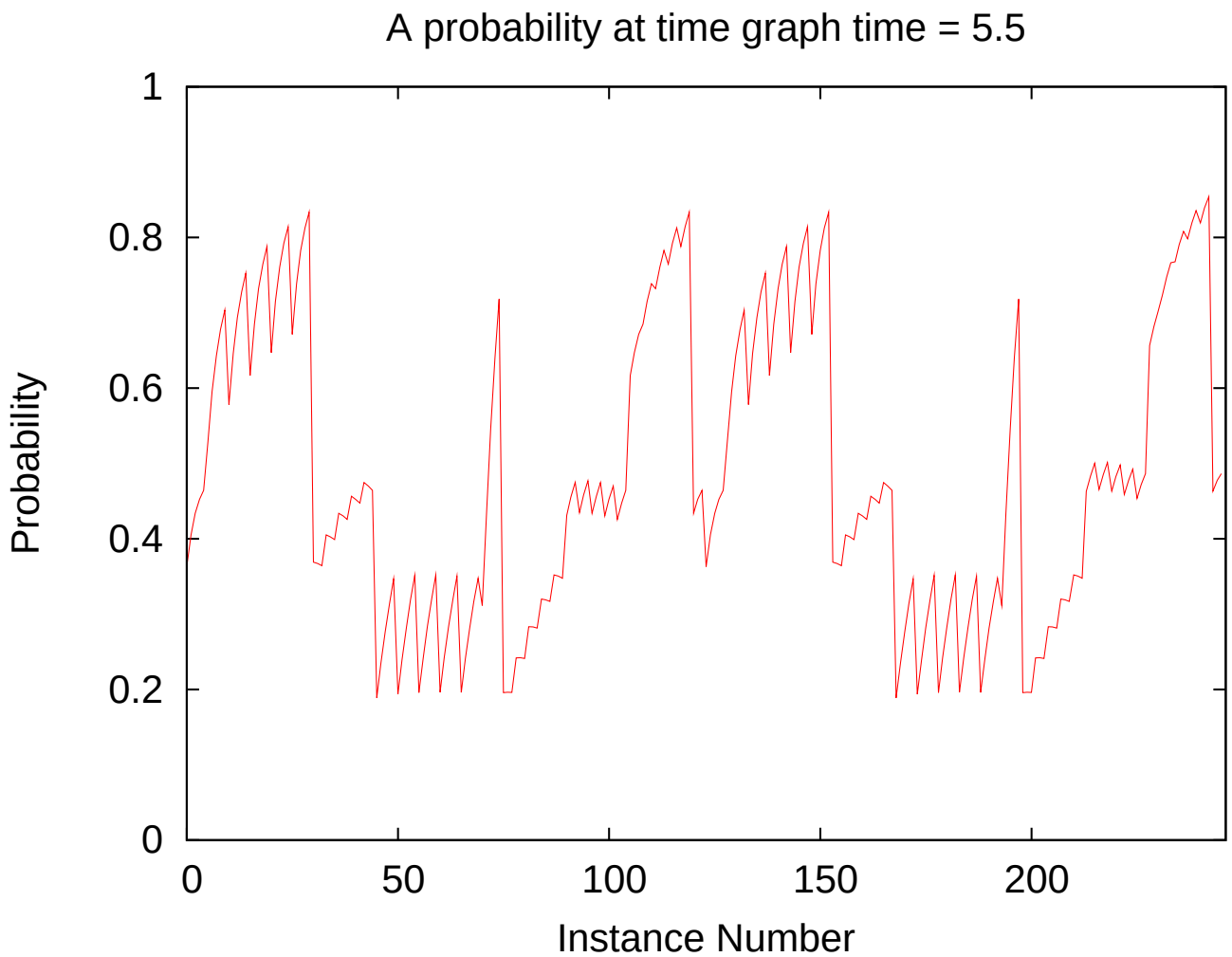
Probability of completion at $t = 4.5$



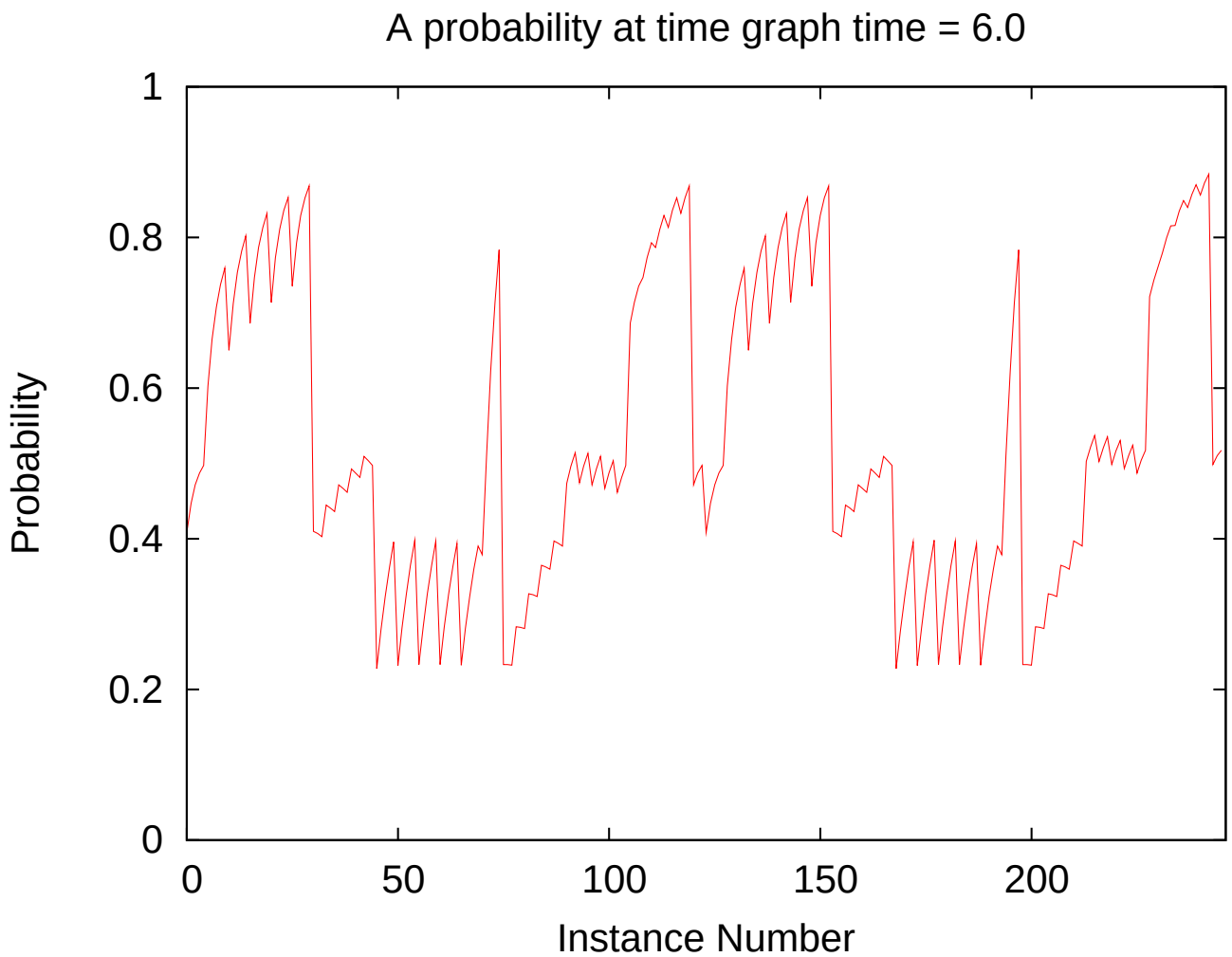
Probability of completion at $t = 5.0$



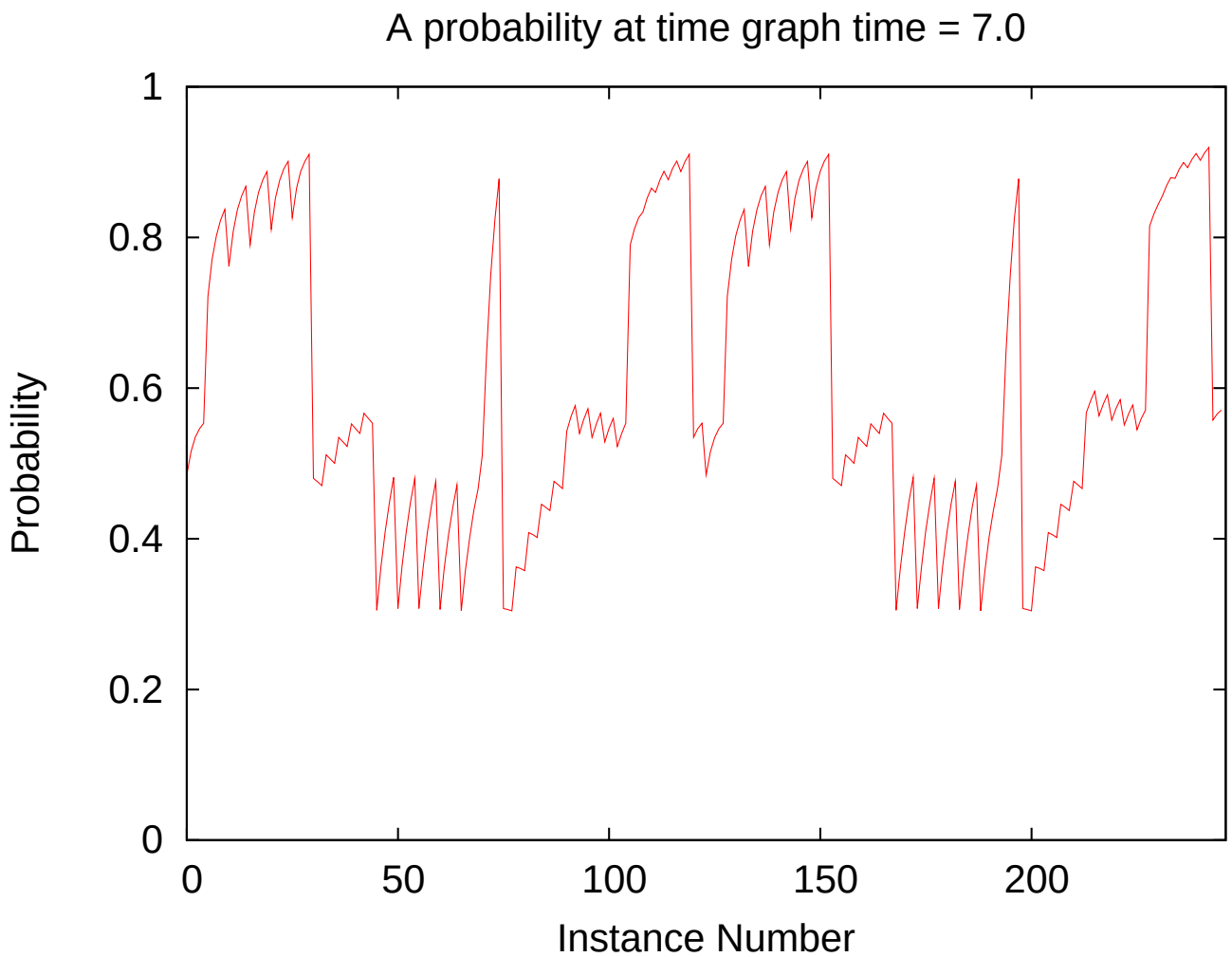
Probability of completion at $t = 5.5$



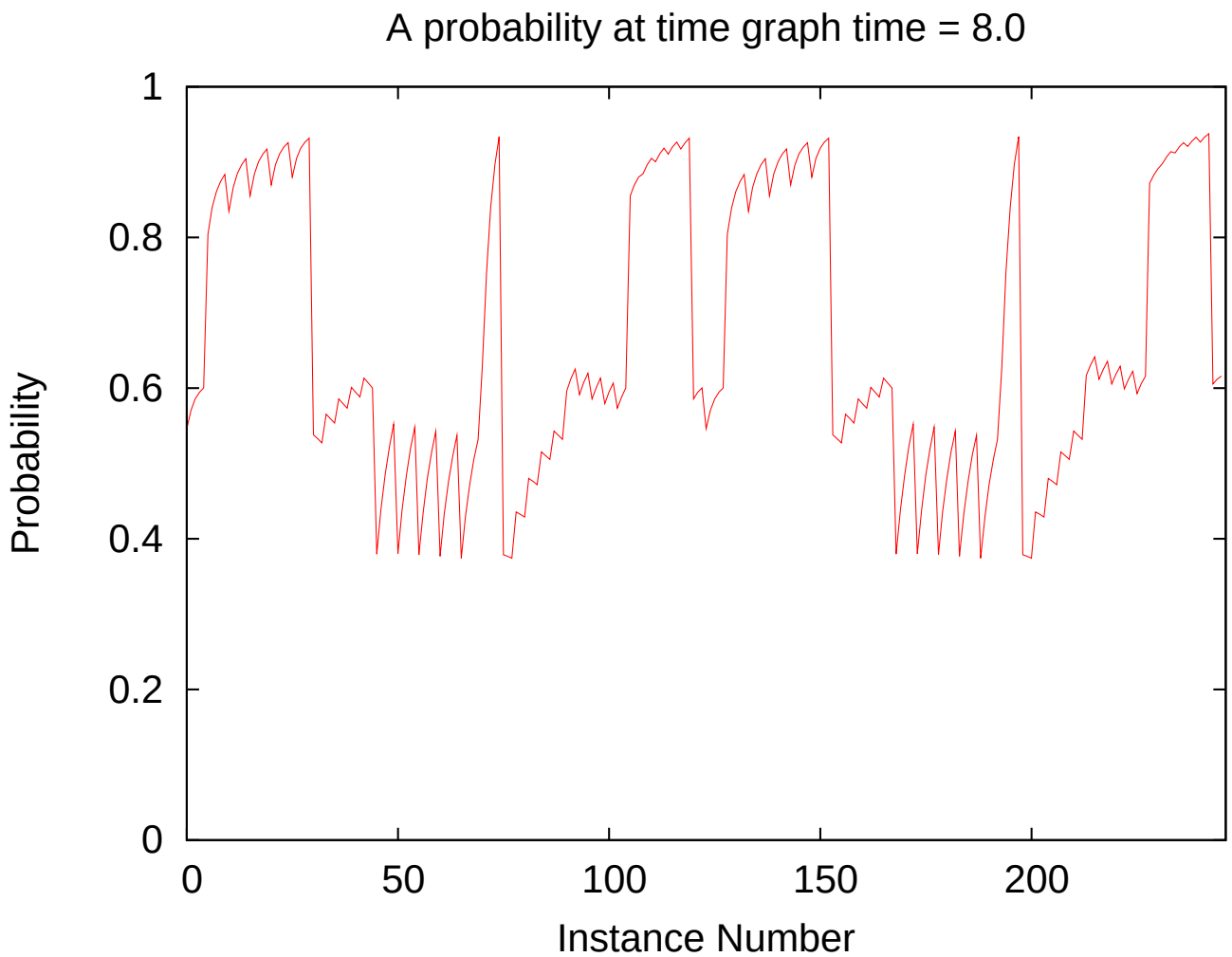
Probability of completion at $t = 6.0$



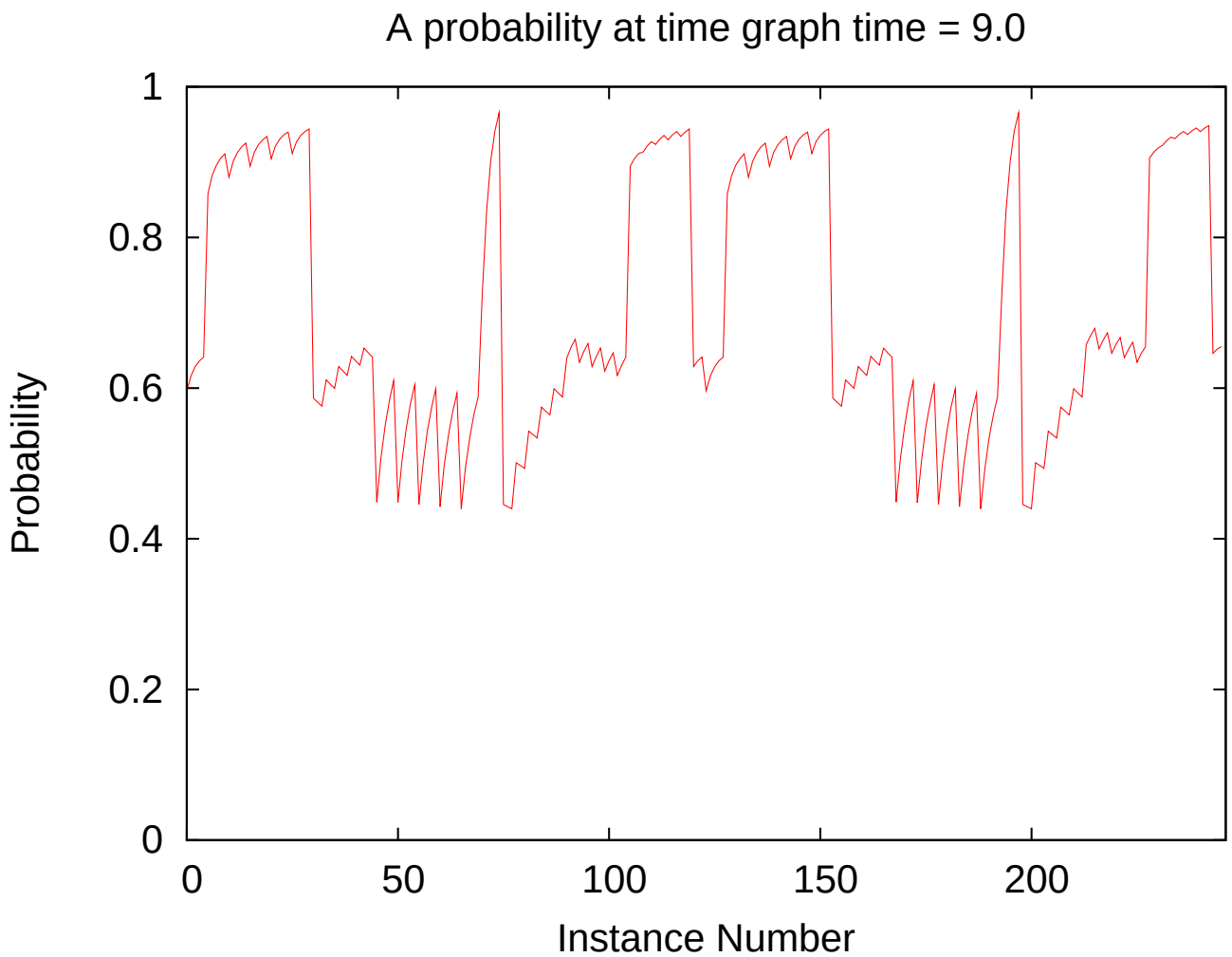
Probability of completion at $t = 7.0$



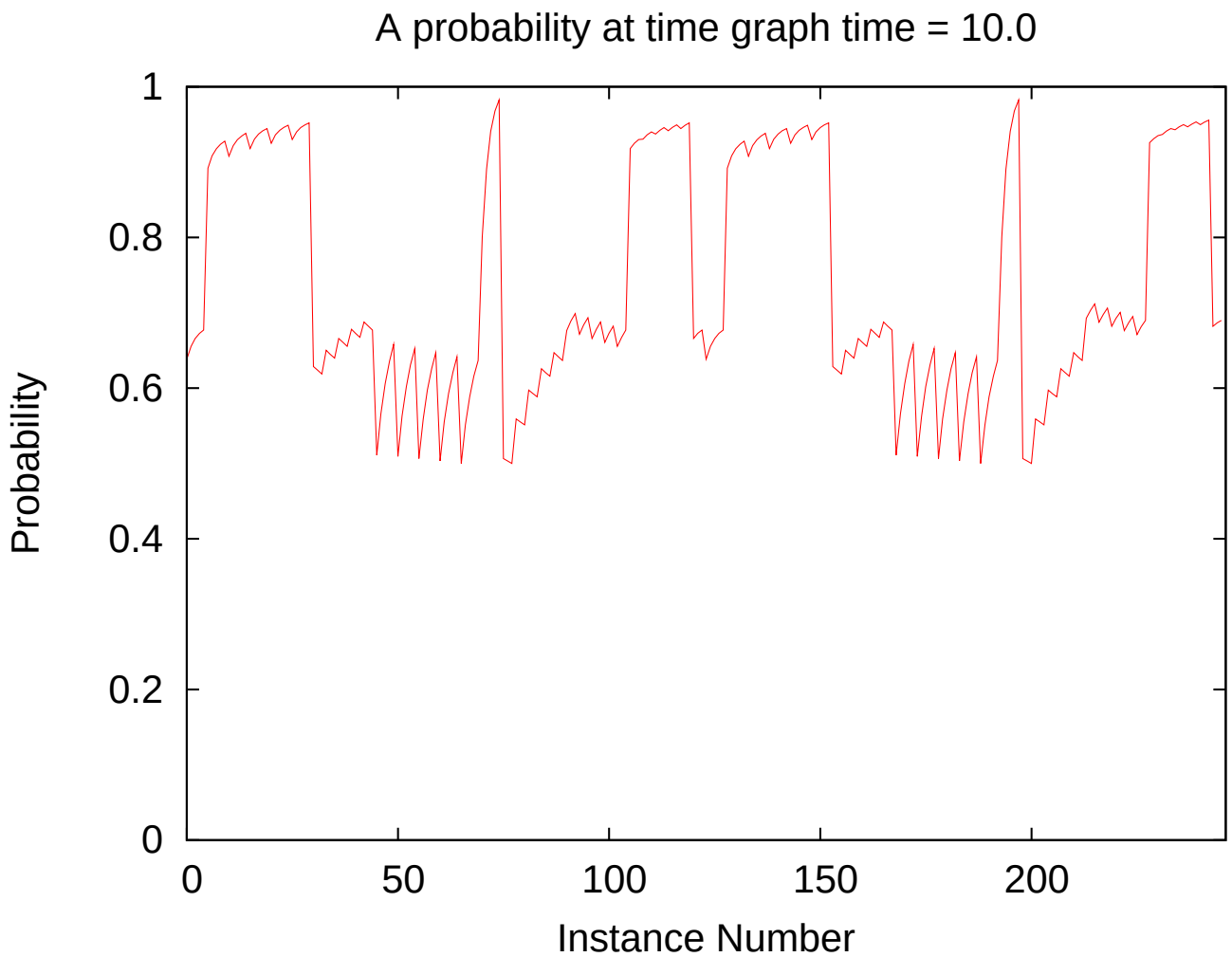
Probability of completion at $t = 8.0$



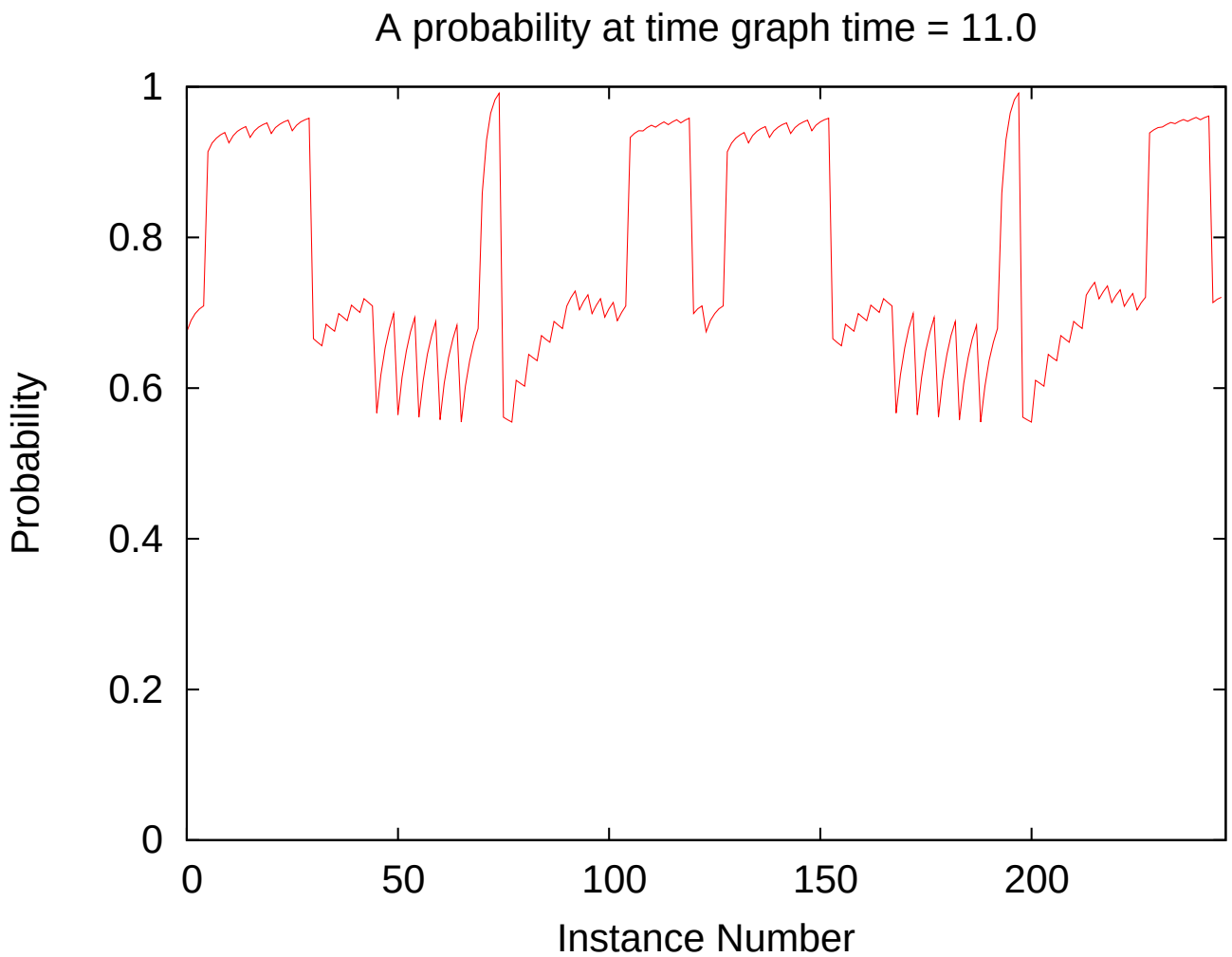
Probability of completion at $t = 9.0$



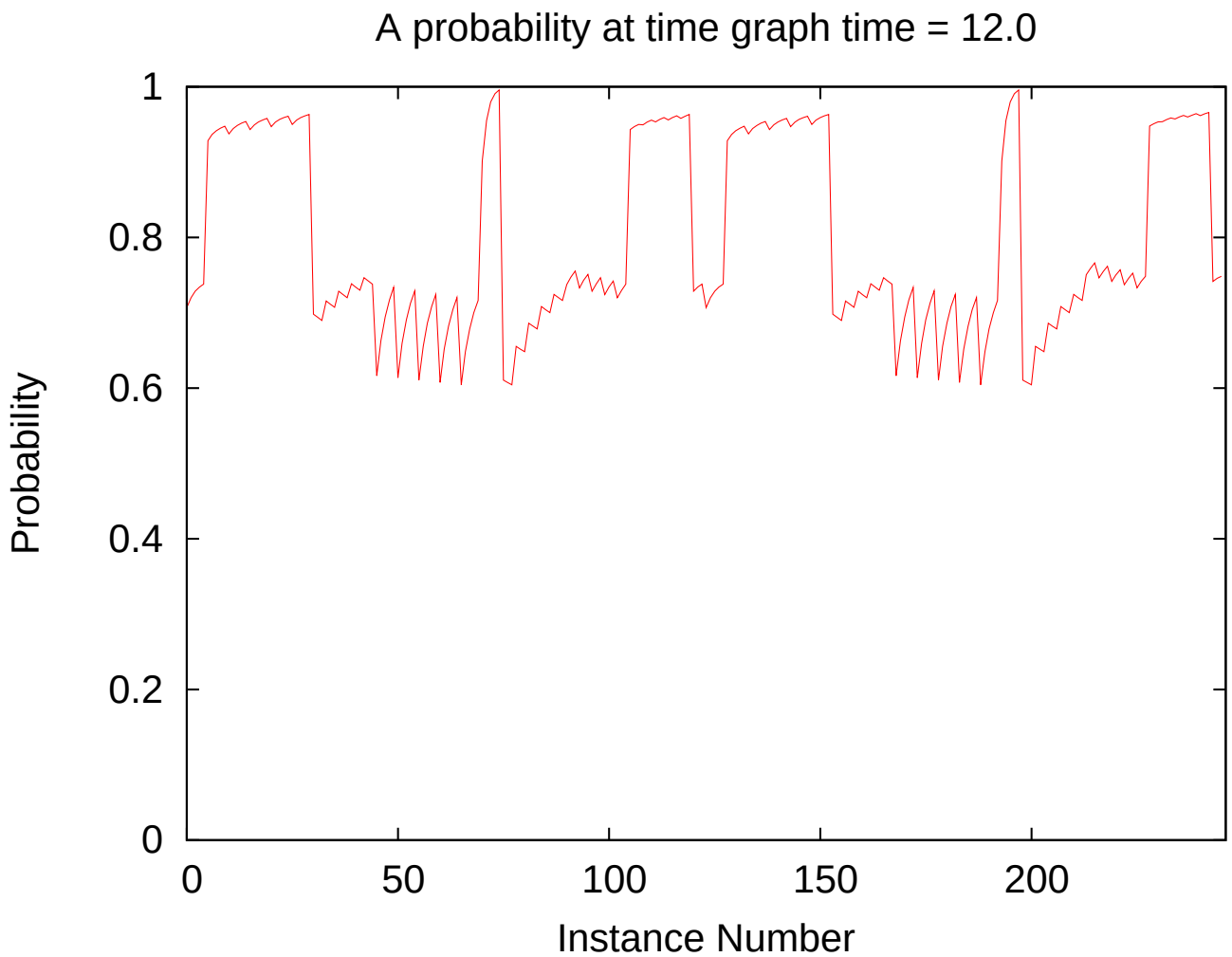
Probability of completion at $t = 10.0$



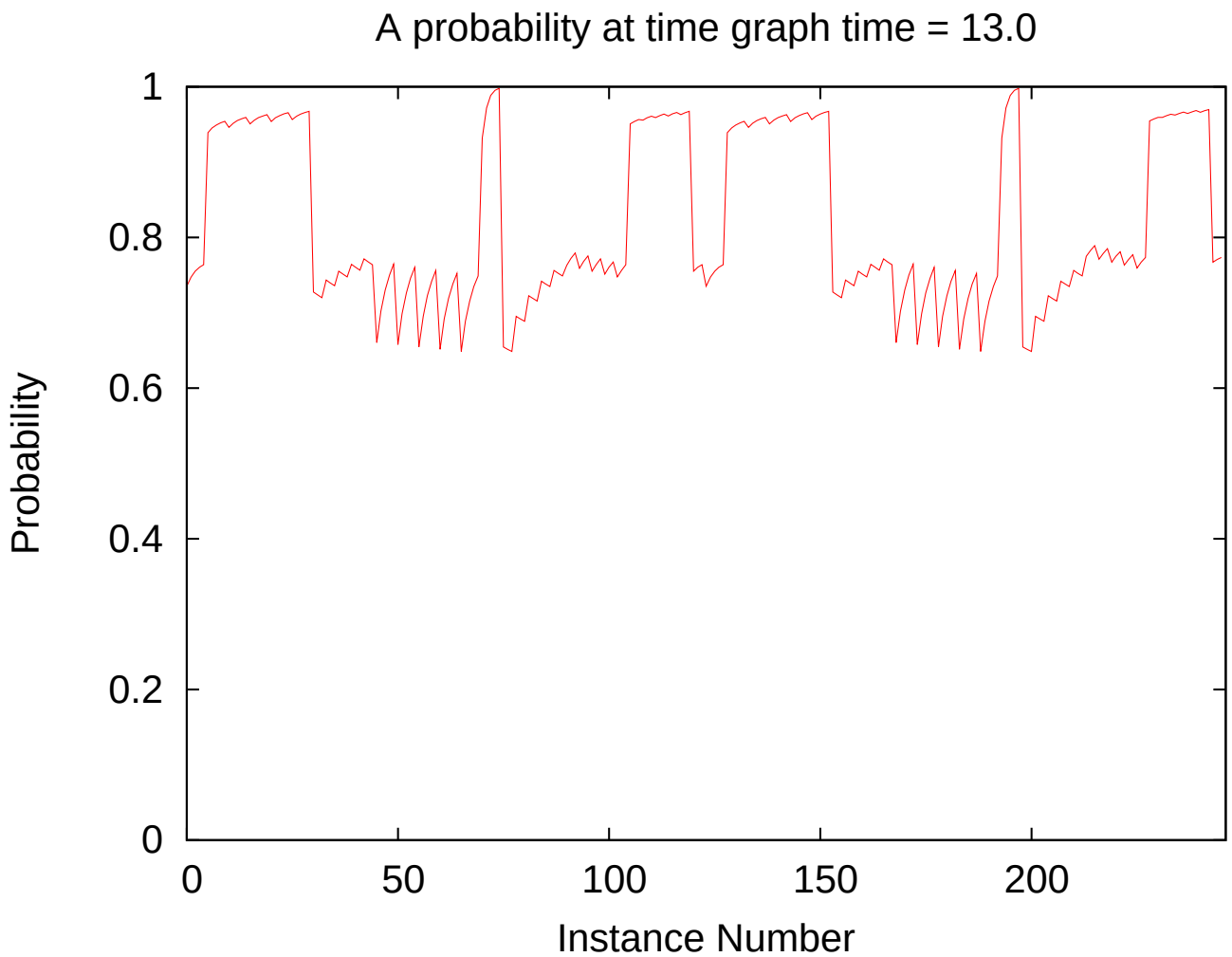
Probability of completion at $t = 11.0$



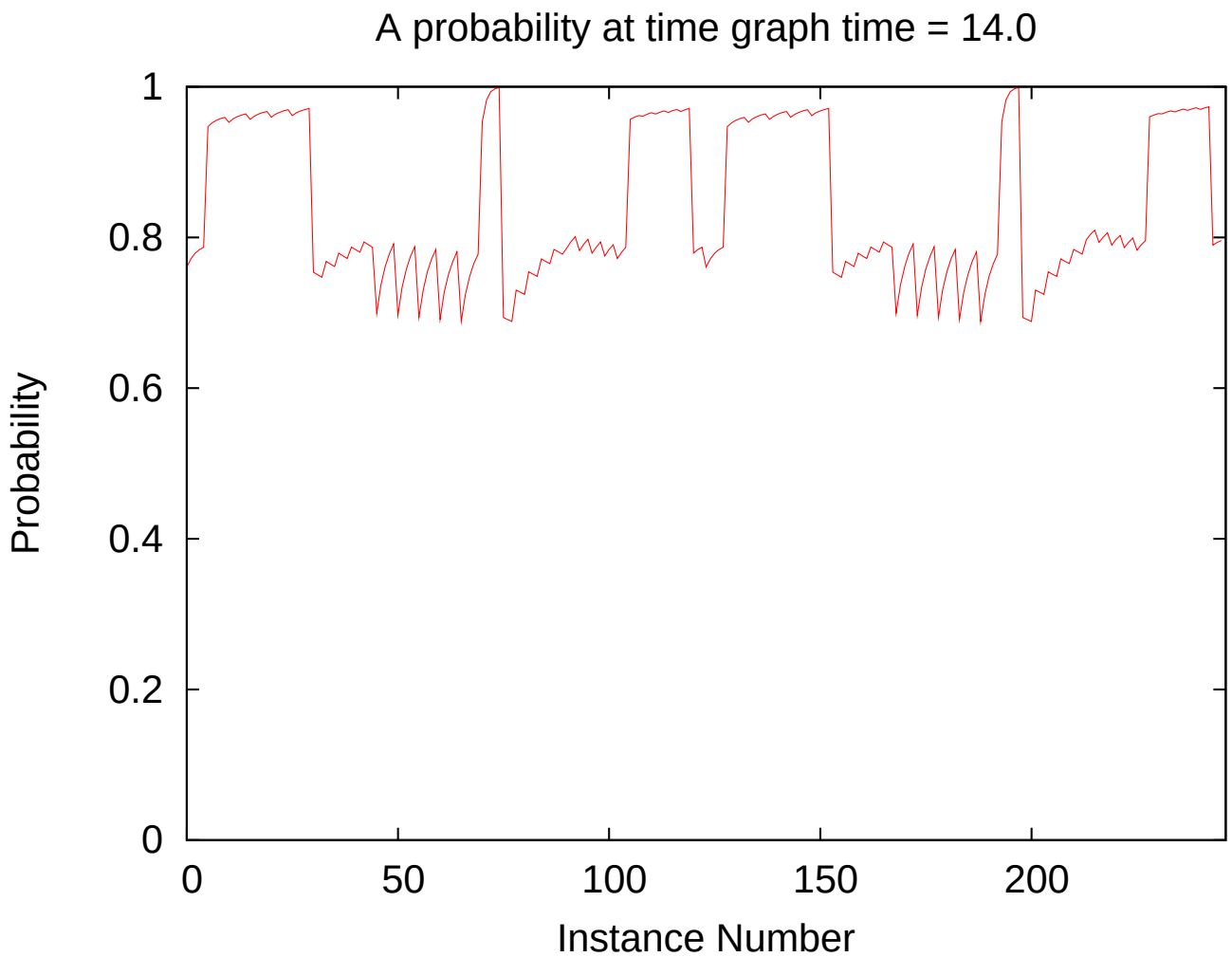
Probability of completion at $t = 12.0$



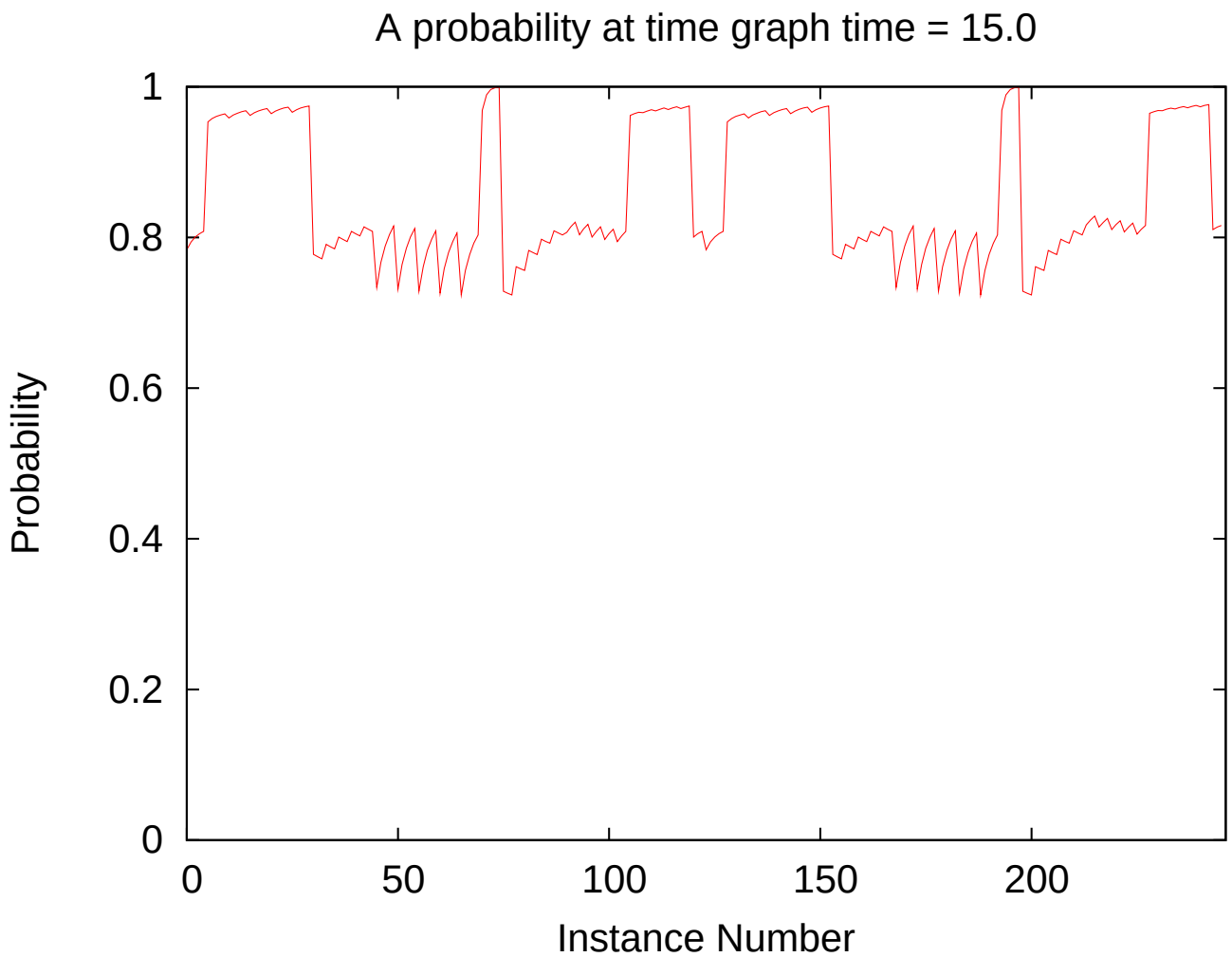
Probability of completion at $t = 13.0$



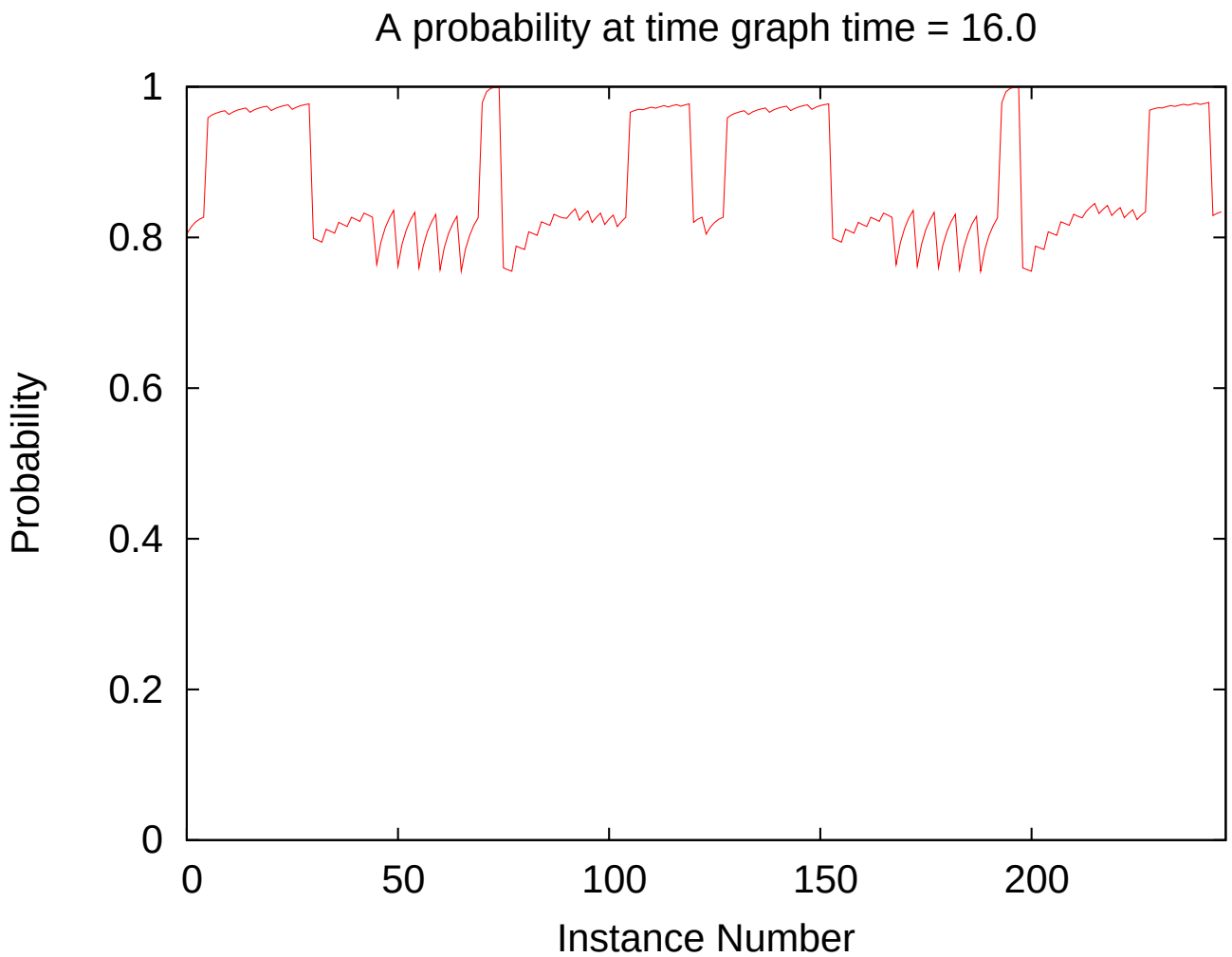
Probability of completion at $t = 14.0$



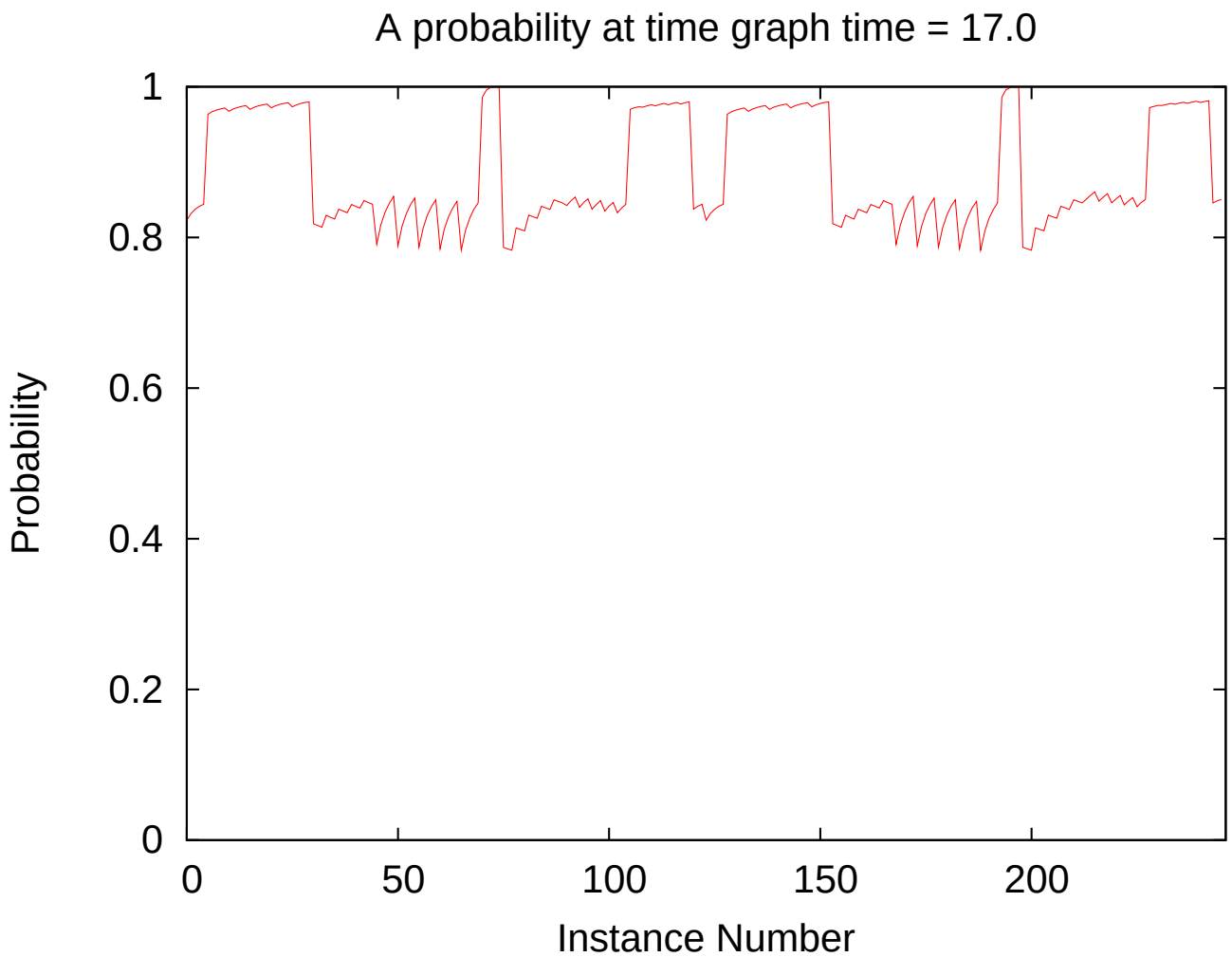
Probability of completion at $t = 15.0$



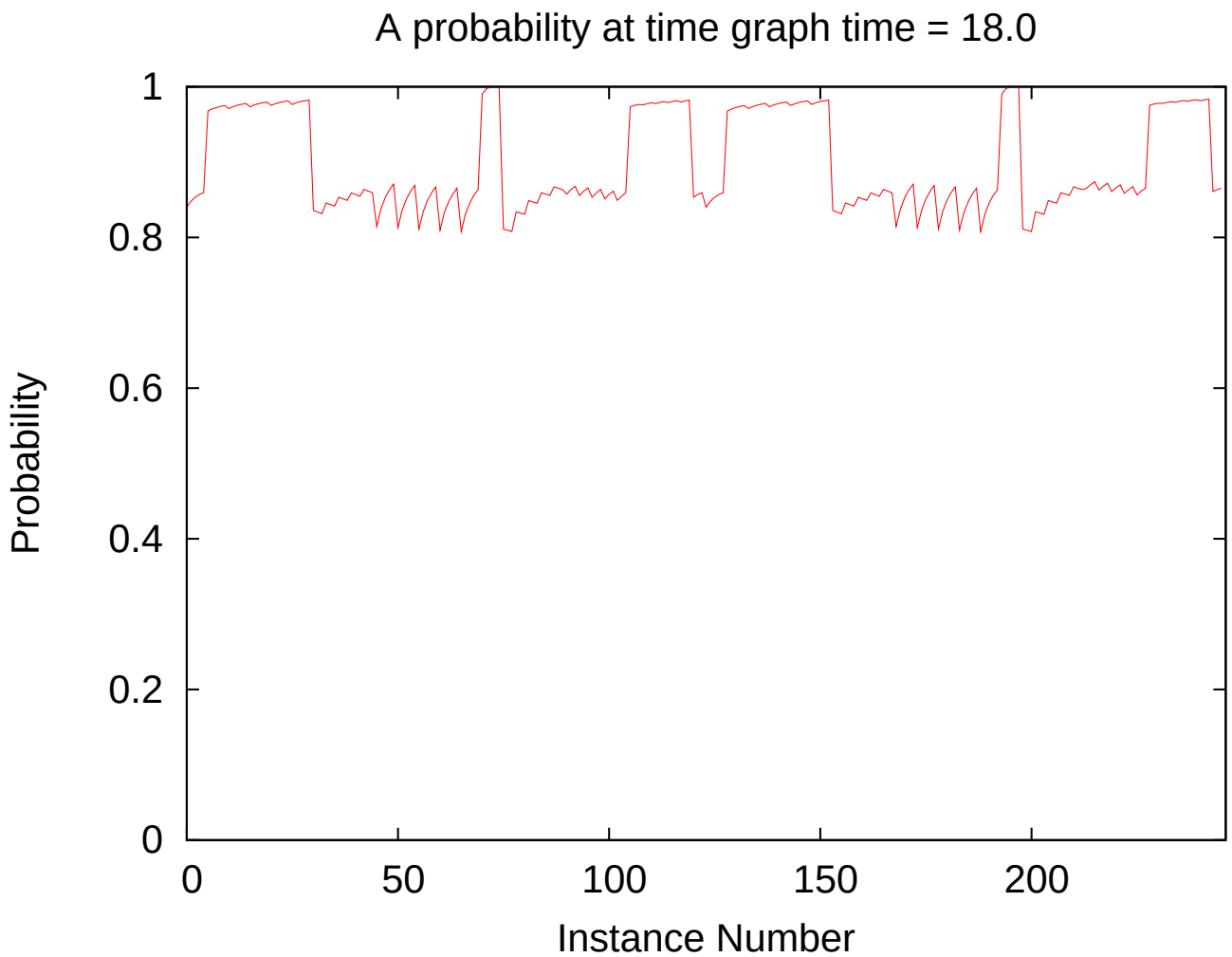
Probability of completion at $t = 16.0$



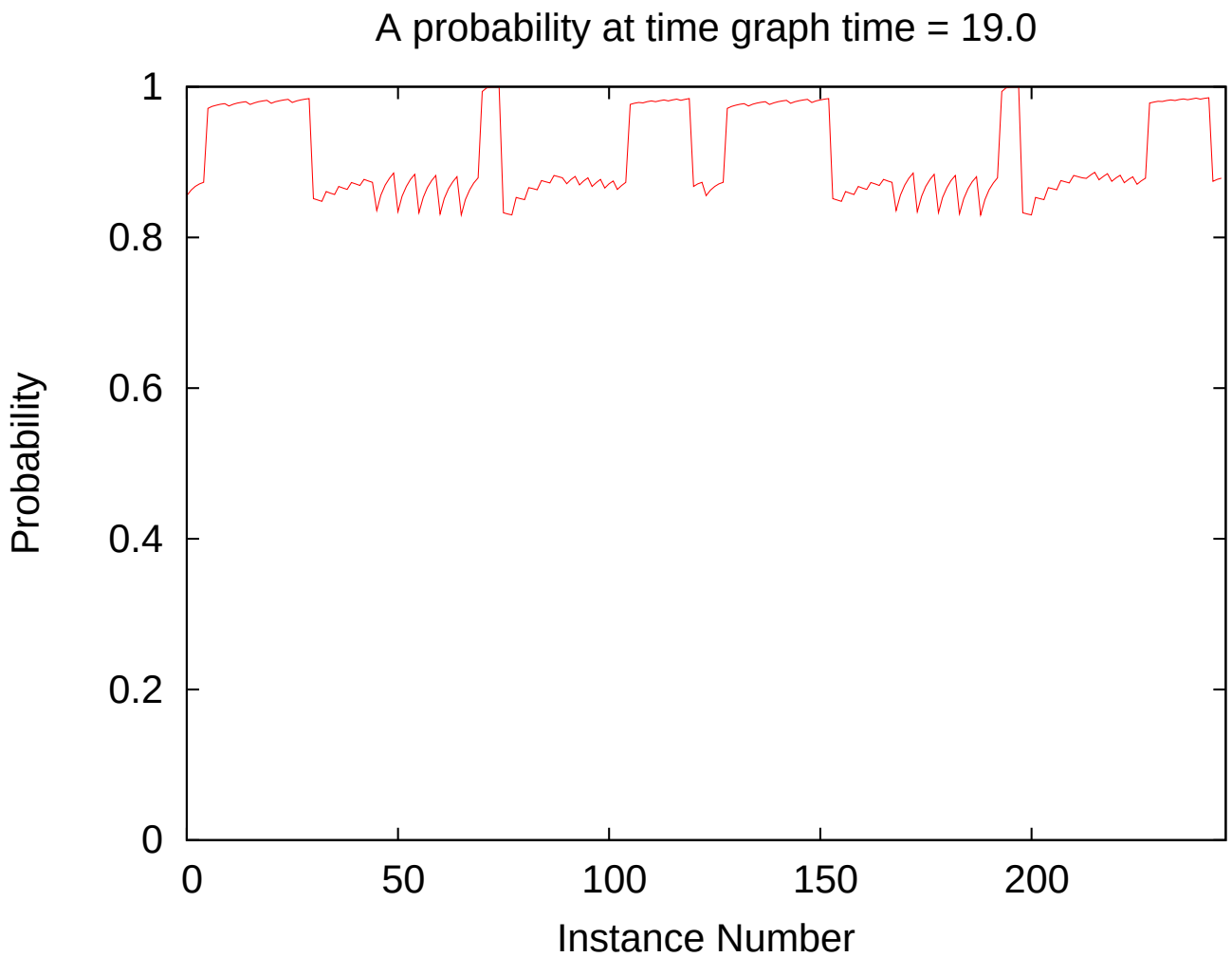
Probability of completion at $t = 17.0$



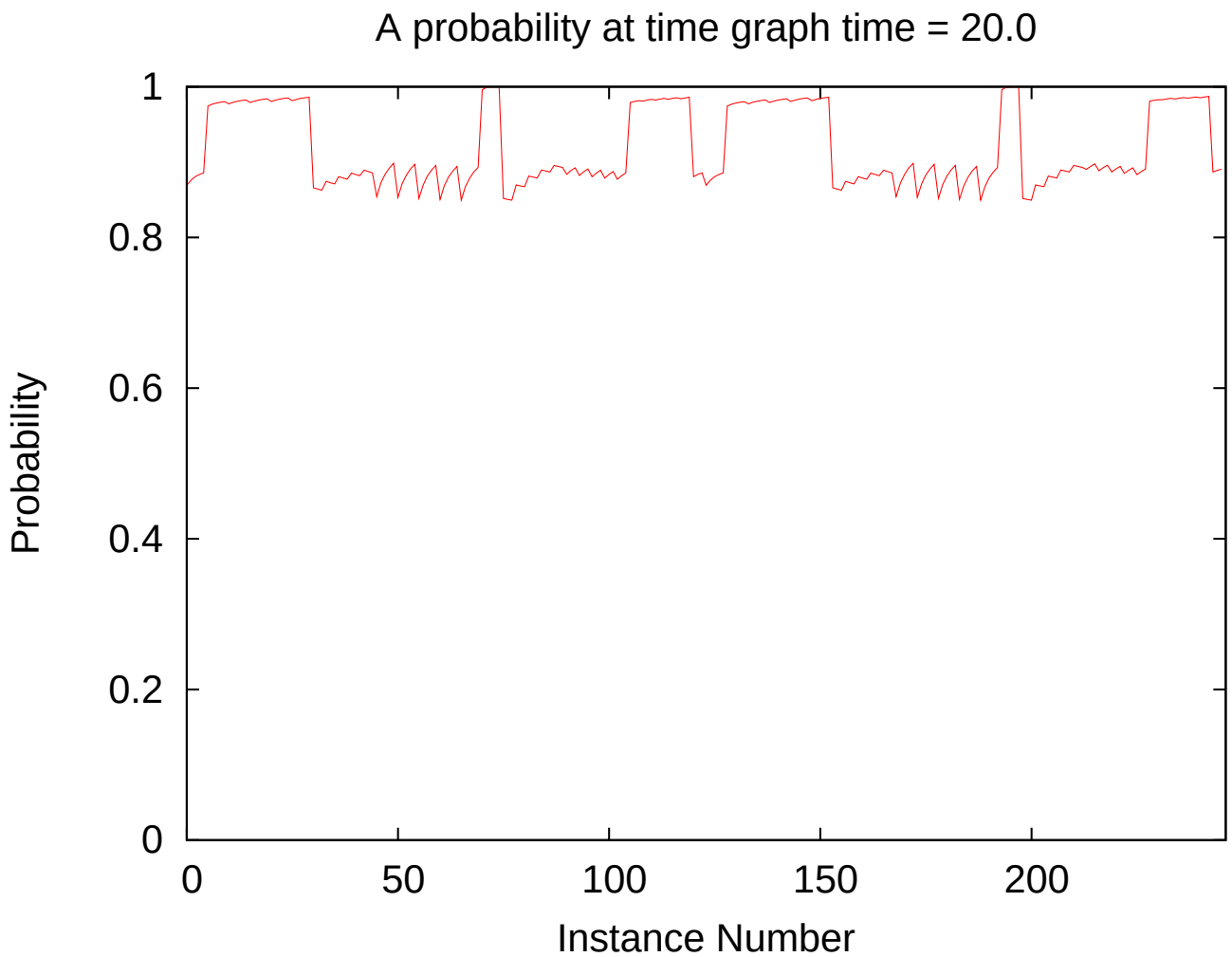
Probability of completion at $t = 18.0$



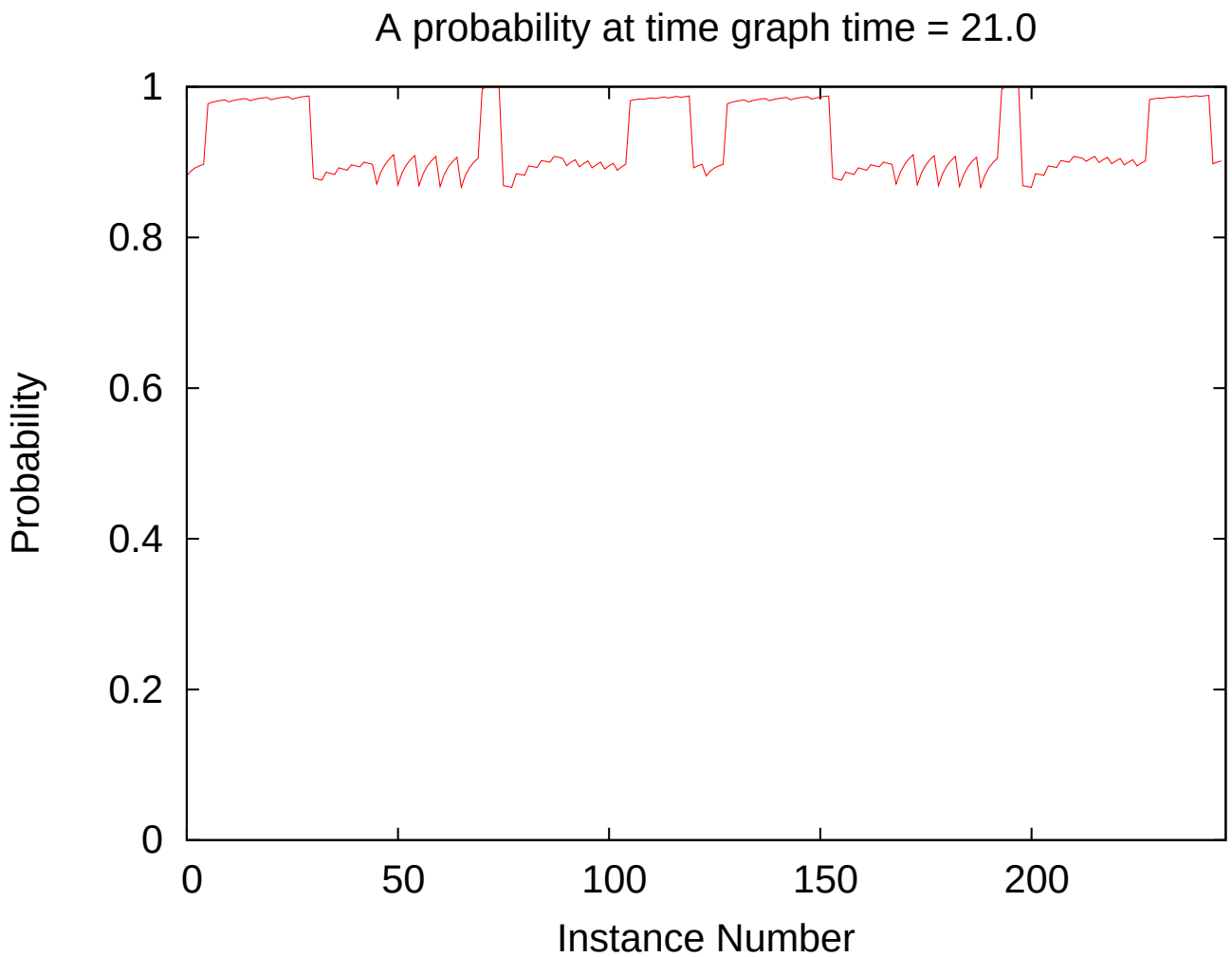
Probability of completion at $t = 19.0$



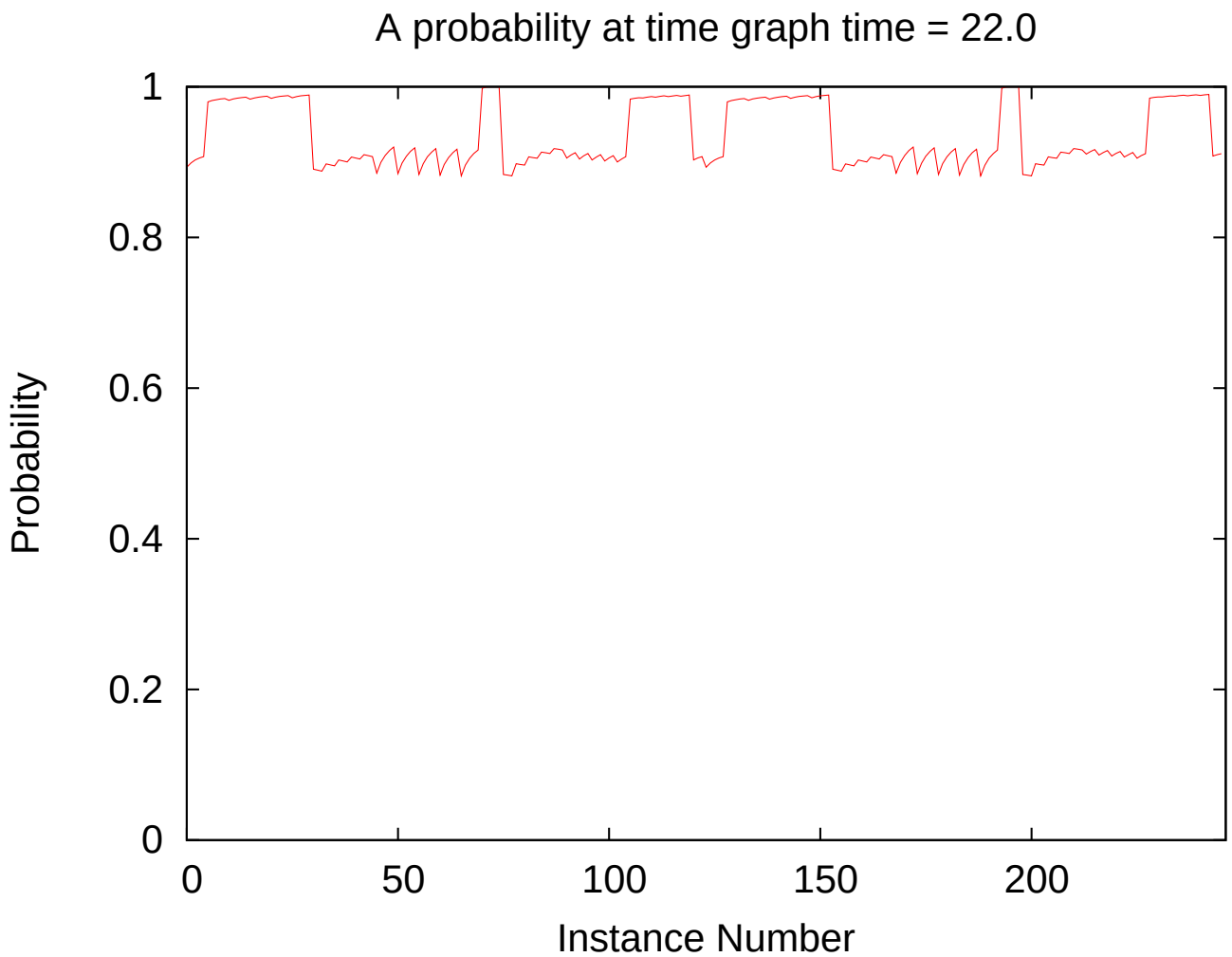
Probability of completion at $t = 20.0$



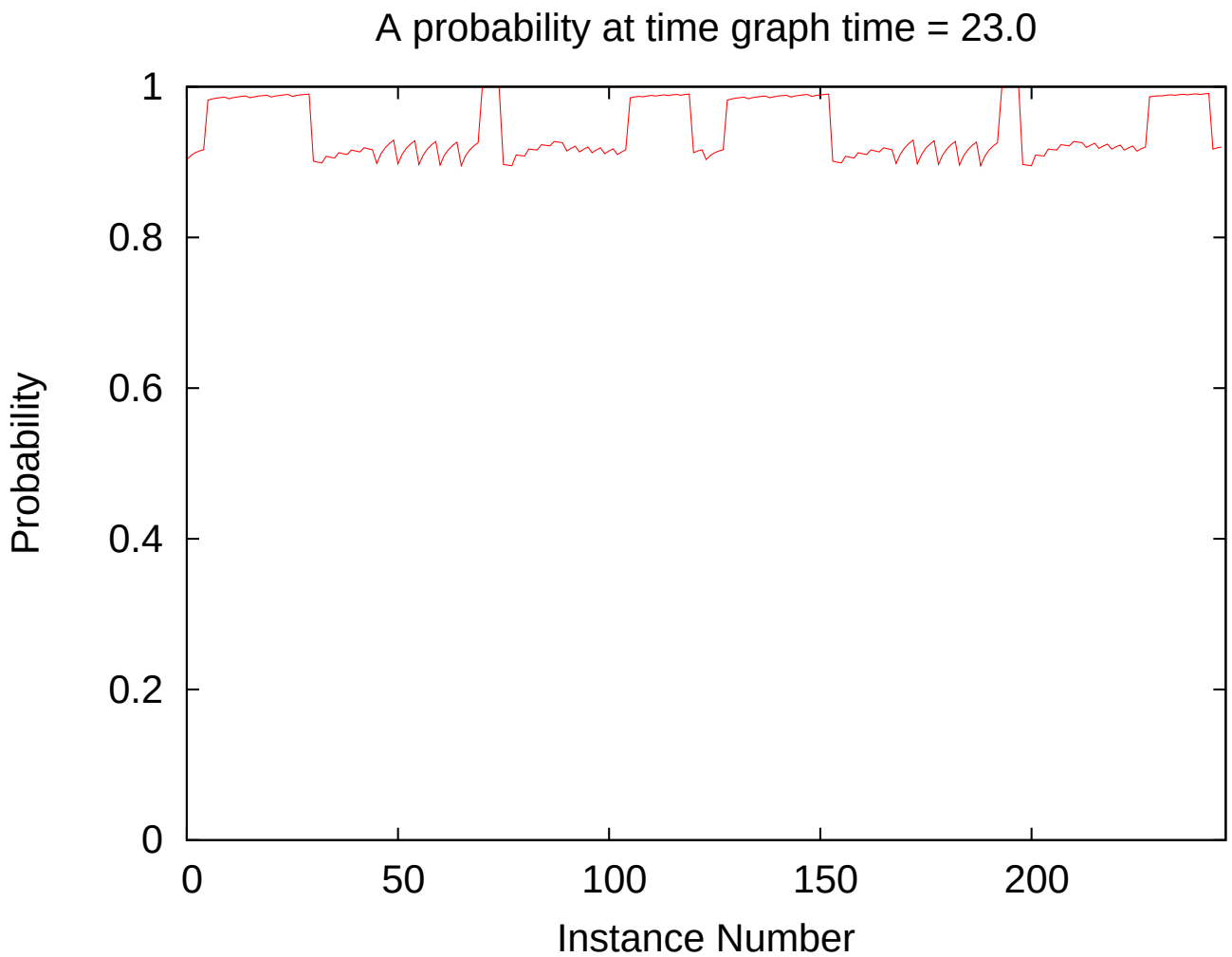
Probability of completion at $t = 21.0$



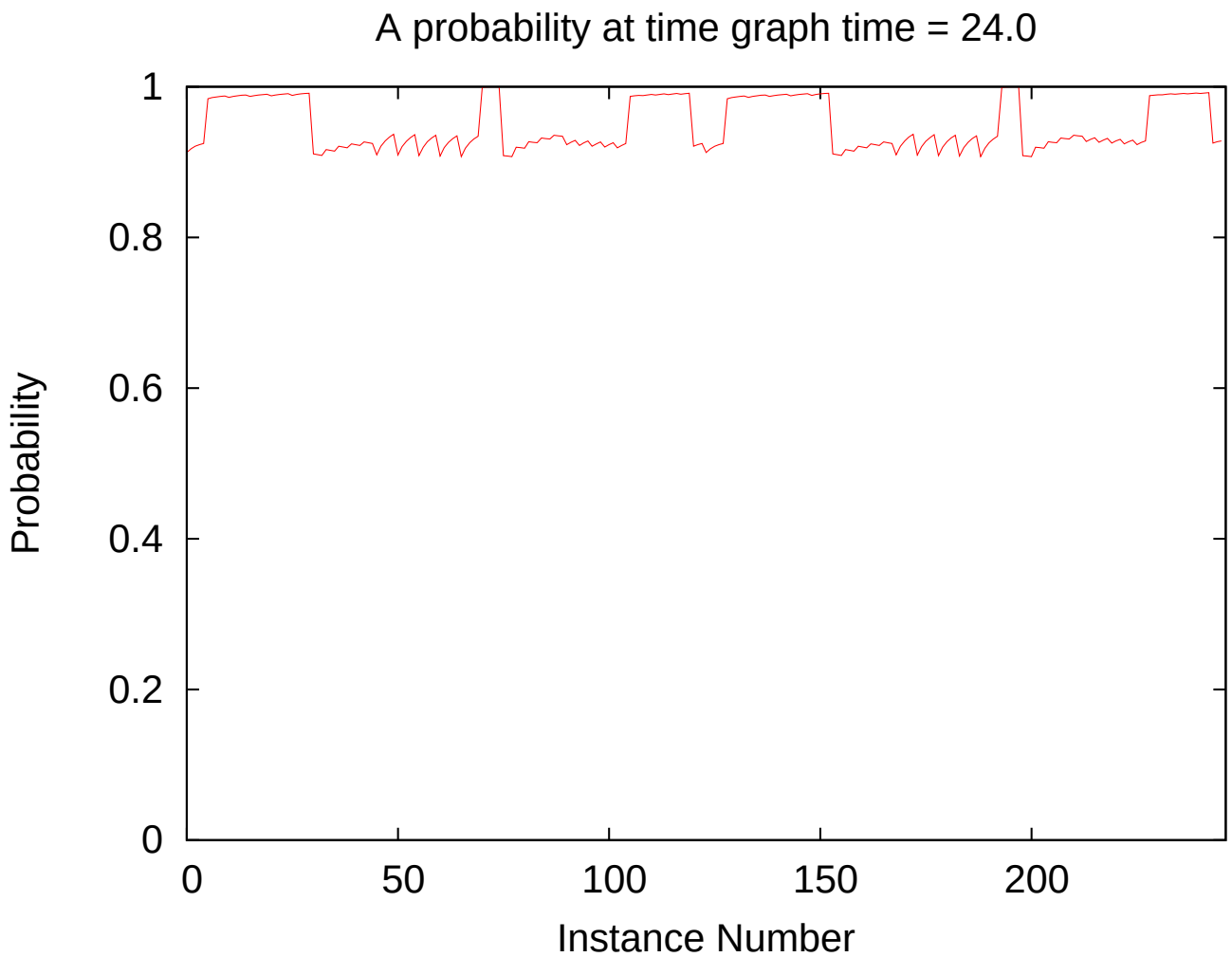
Probability of completion at $t = 22.0$



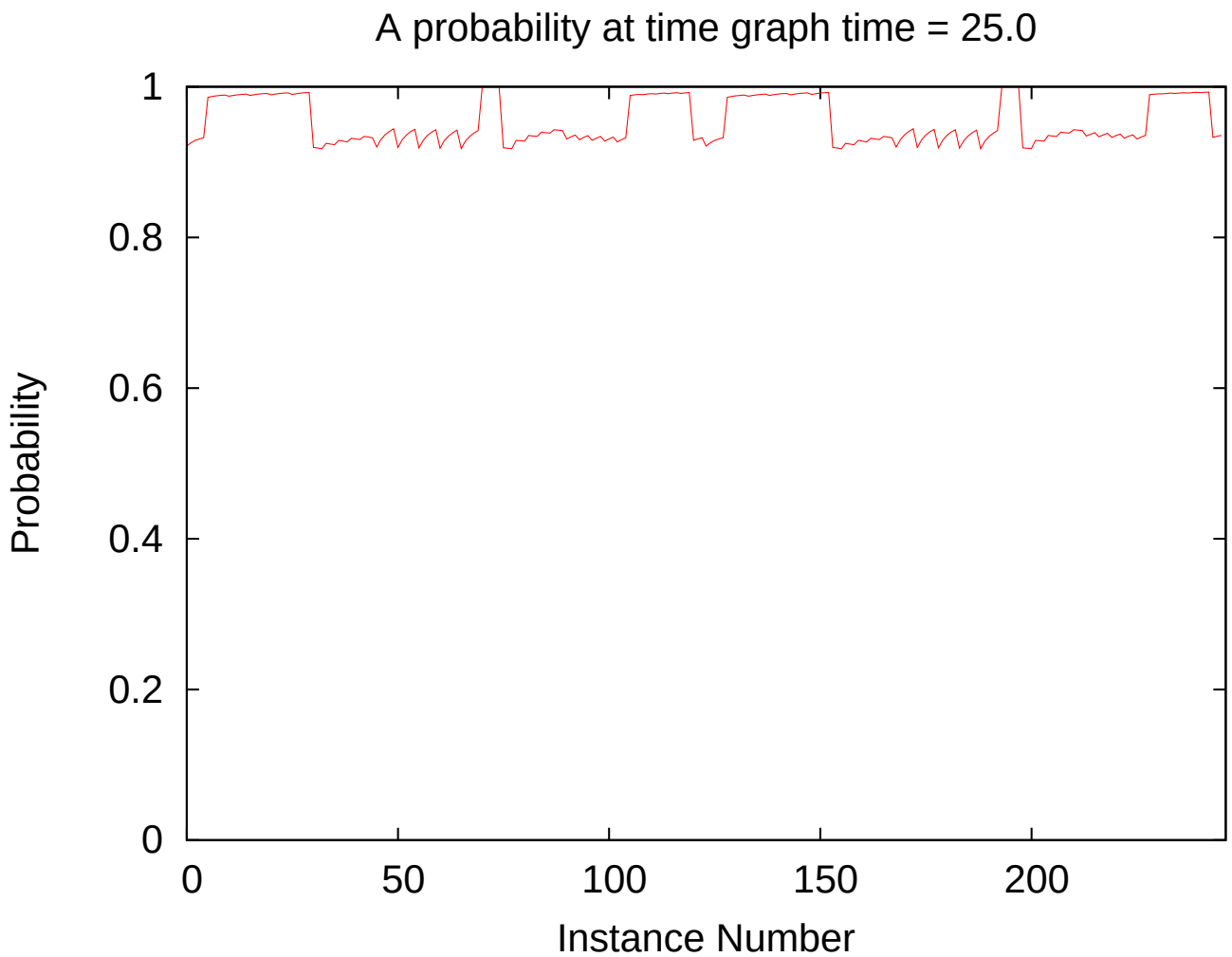
Probability of completion at $t = 23.0$



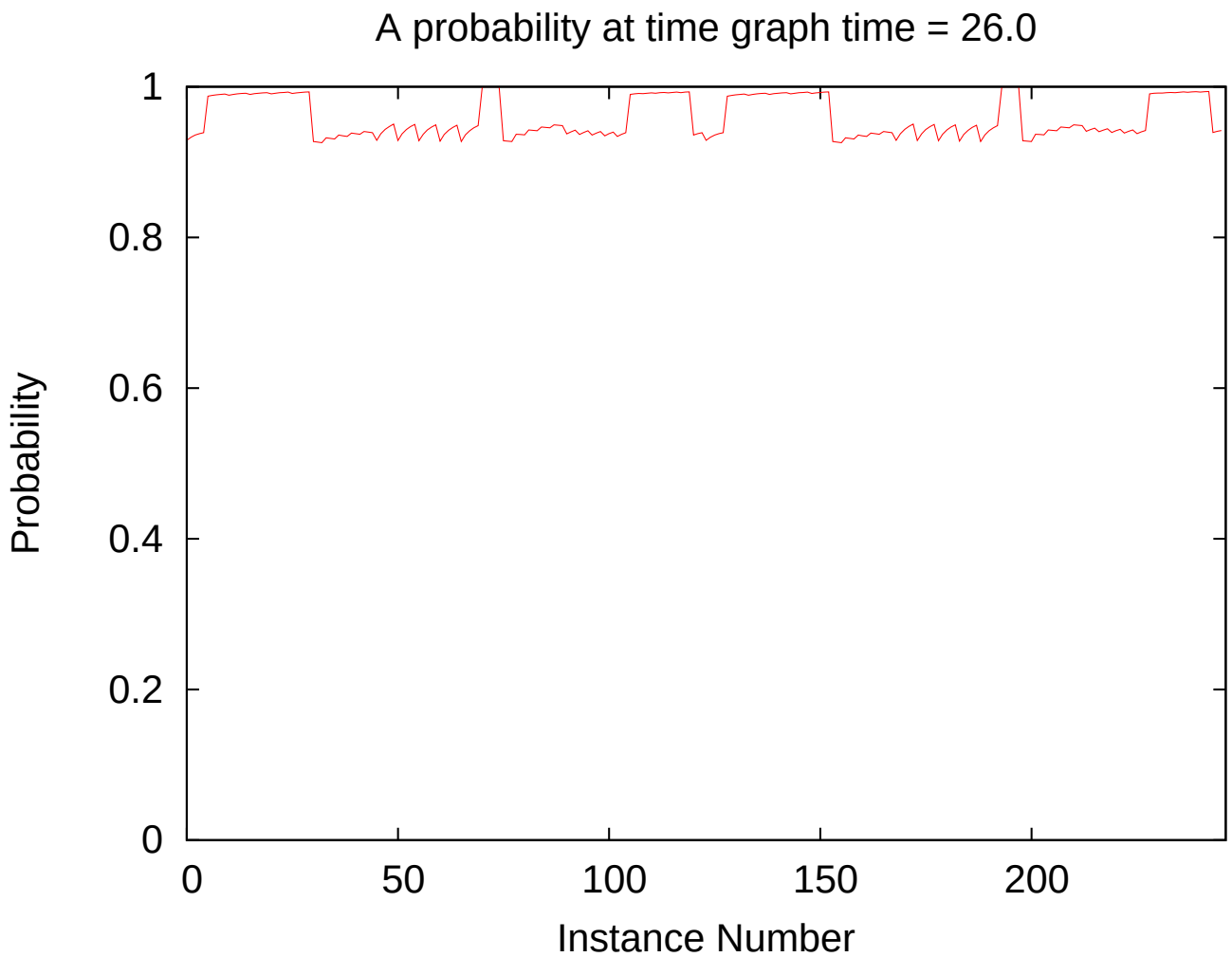
Probability of completion at $t = 24.0$



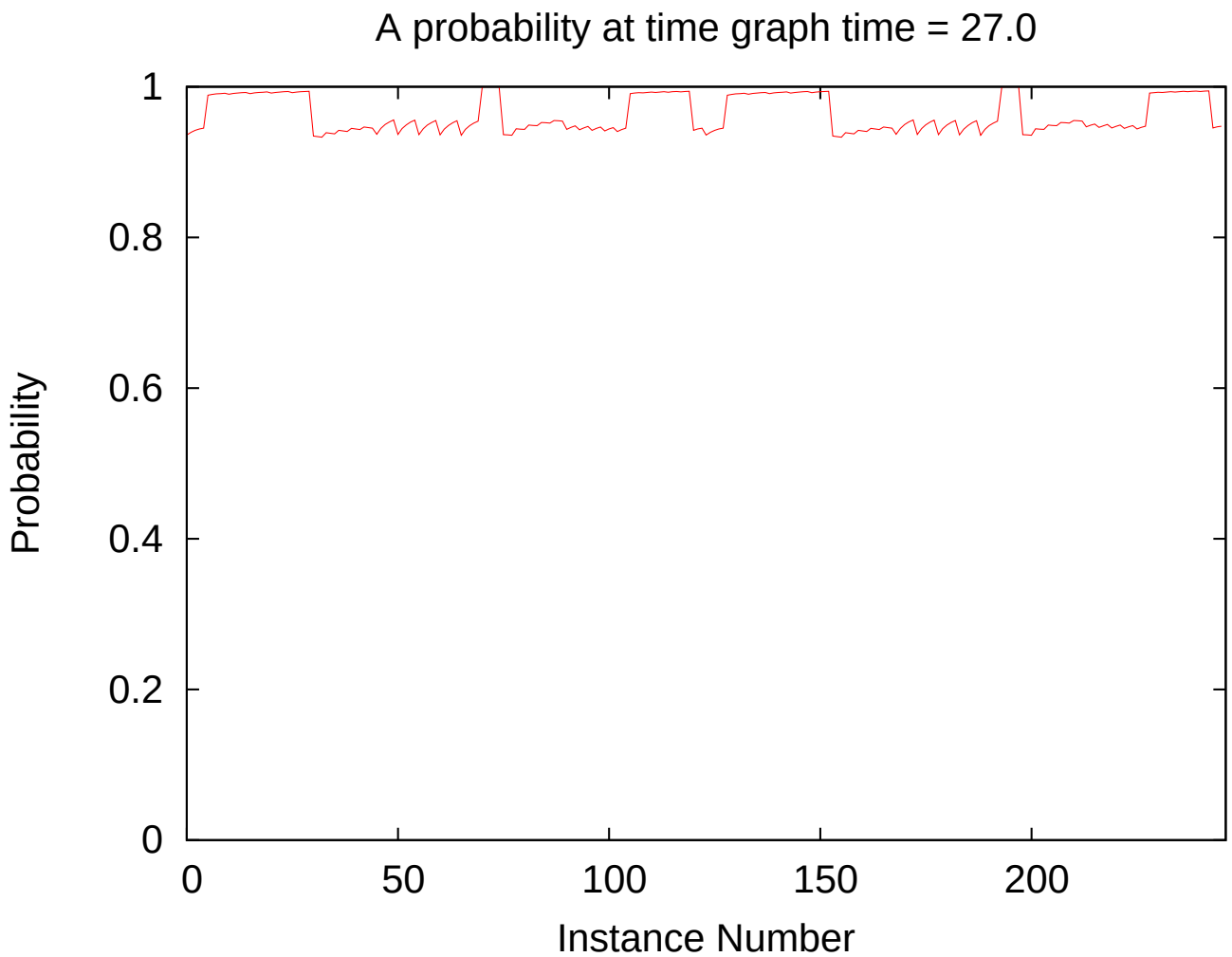
Probability of completion at $t = 25.0$



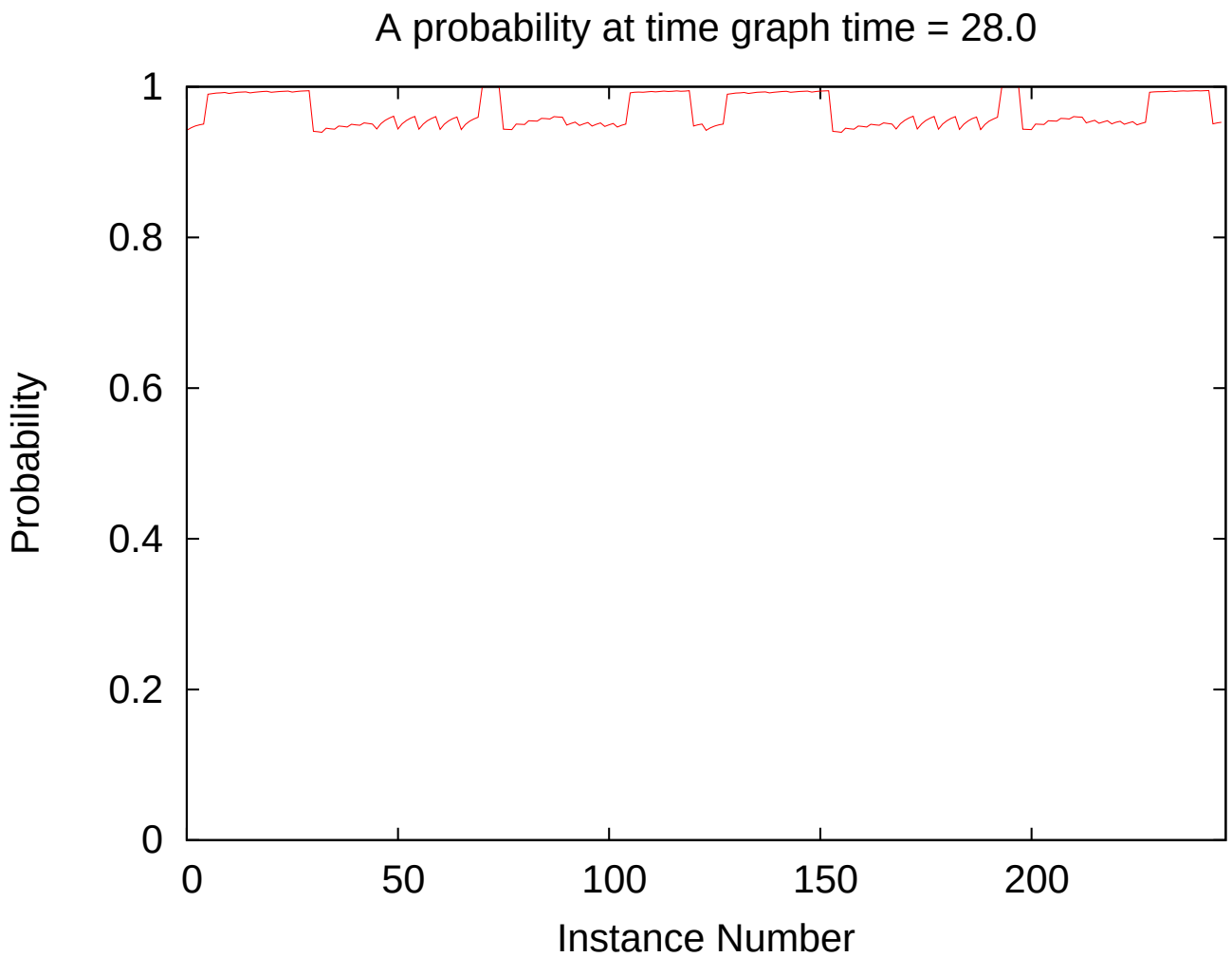
Probability of completion at $t = 26.0$



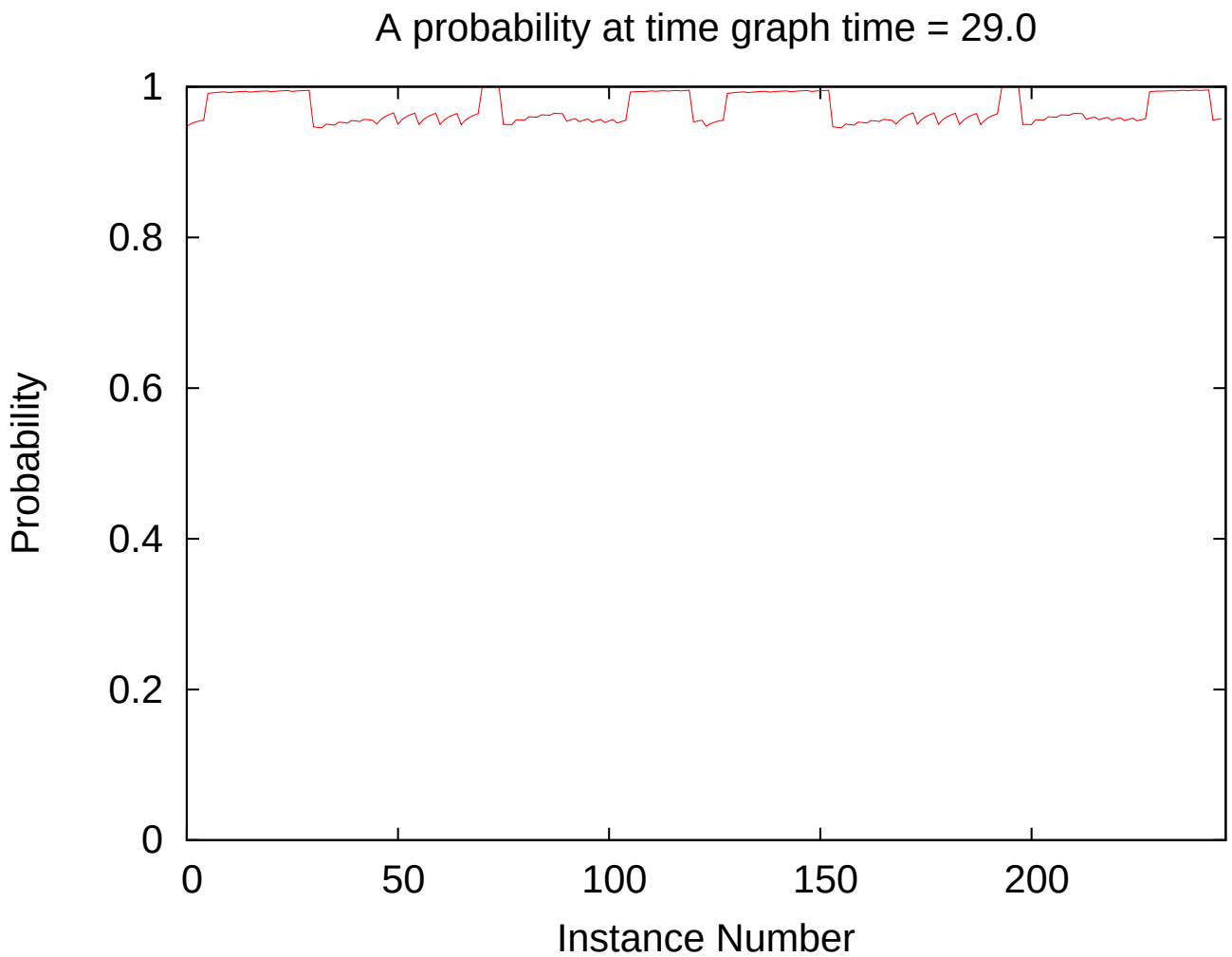
Probability of completion at $t = 27.0$



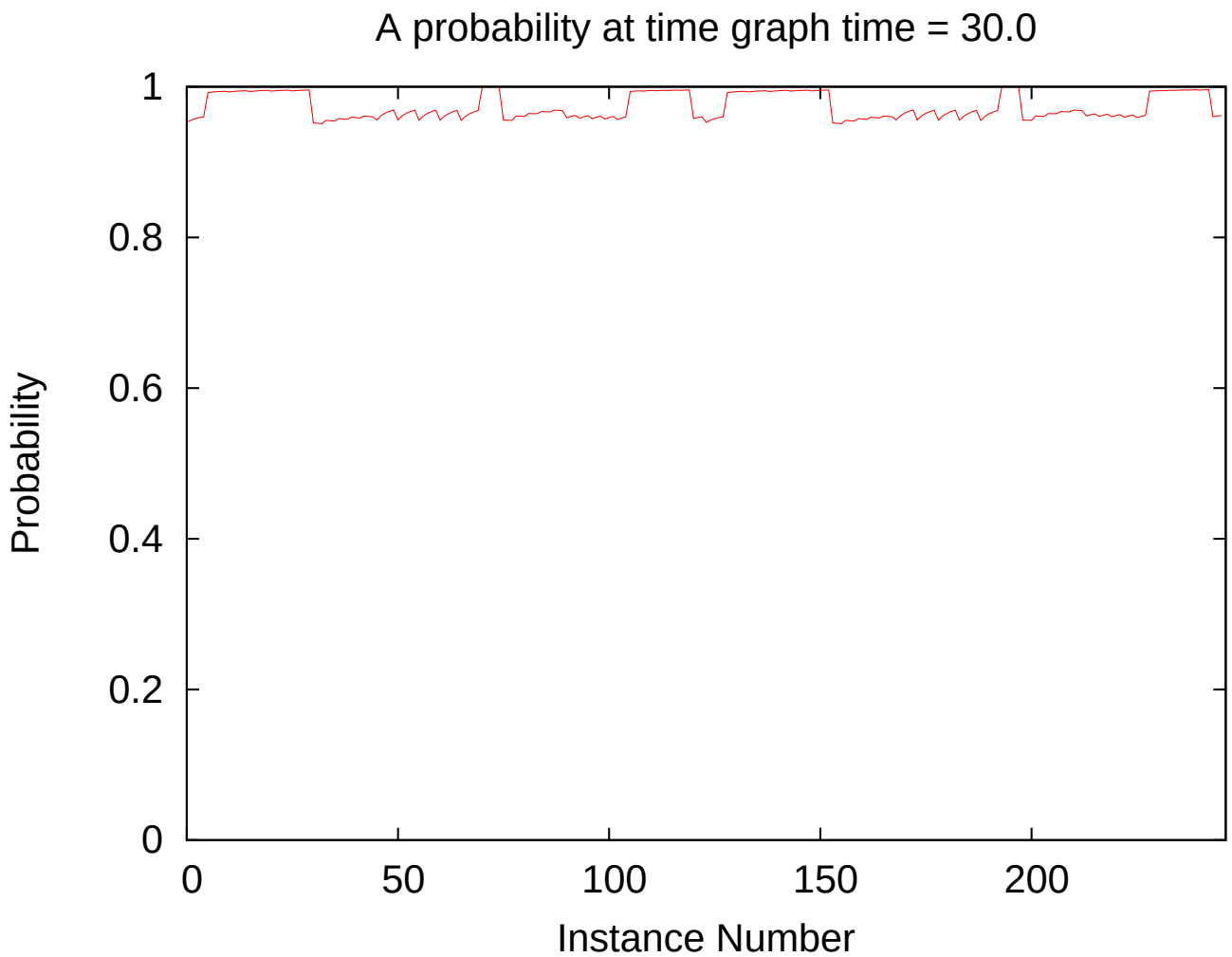
Probability of completion at $t = 28.0$



Probability of completion at $t = 29.0$



Probability of completion at $t = 30.0$



Outline

1 Service-oriented computing

2 Example: Virtual University

3 Discussion and Conclusions

Discussion

- We might wonder if our infrastructure is necessary. Do we need to generate separate configurations and recombine the results?
- To test this we compared our SRMC model against a plain CTMC model of the system generated from a Generalised Stochastic Petri Net with vanishing markings.

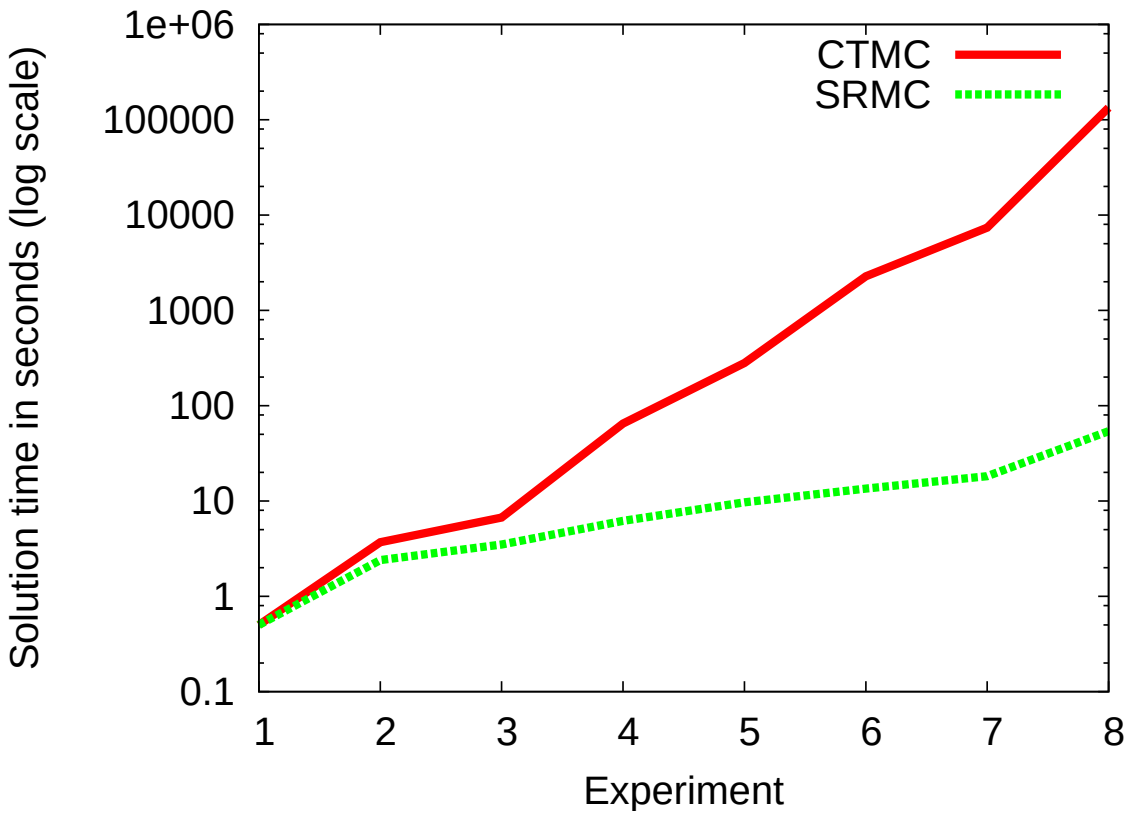
Experiments with increasing model size

#	Client	Upload Portal	Download Portal
1	{Harry}	{UEDIN}	{UEDIN}
2	{Harry}	{UEDIN, LMU}	{UEDIN}
3	{Harry}	{UEDIN, LMU}	{UEDIN, LMU}
4	{Harry}	{UEDIN, LMU, UNIBO}	{UEDIN, LMU}
5	{Harry}	{UEDIN, LMU, UNIBO}	{UEDIN, LMU, UNIBO}
6	{Harry}	{UEDIN, LMU, UNIBO, UNIPI}	{UEDIN, LMU, UNIBO}
7	{Harry}	{UEDIN, LMU, UNIBO, UNIPI}	{UEDIN, LMU, UNIBO, UNIPI}
8	{Harry, Sally}	{UEDIN, LMU, UNIBO, UNIPI}	{UEDIN, LMU, UNIBO, UNIPI}

Experiments with increasing model size

	CTMC				SRMC			
#	Num. states	Num. config	Num. runs	time (secs)	Num. states	Num. config	Num. runs	time (secs)
1	32	1	5	0.5	32	1	5	0.5
2	48	1	25	3.7	32	2	30	2.4
3	72	1	25	6.7	32	4	60	3.5
4	120	1	75	65.0	32	6	90	6.2
5	200	1	75	280.0	32	9	123	9.7
6	280	1	225	2280.0	32	12	162	13.5
7	392	1	225	7390.0	32	16	204	18.2
8	784	1	225	$\sim$ 134100.0	32	32	408	54.0

Experiments with increasing model size



Conclusions

- We addressed the inherent uncertainty in service-oriented computing by analysing by cases. We perform parameter sweep for each case. We can evaluate these in parallel (using Condor).
- The analysis methods scale well with increasing problem size.
- We build on tried and trusted compilers and analysers.
- Hopefully a “real world” approach to a “real world” problem.

Thank you!


Statespace
Vanishing states:
declutter your life
Are BDDs
making
you fat?
Modelling detail:
Do you love it too much?
Deadlock detection:
Are you in a dead-end relationship?
Uniformisation
Time:
Is it always
getting away
from you?
Coupling:
Is it for you?
Birth-Death:
the big issues.
States:
Are you
holding on
too long?
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