



# Extracting Performance and Scalability Metrics From TCP

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Southern Computer Measurement Group 2011



PERCONA

**Consulting  
Support  
Training  
Development**

**For MySQL**

# Agenda

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- Capturing TCP Traffic
- Black-Box Performance Analysis
- Forecasting Scalability and Performance
- When Is This Useful?

# Observing First

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- Do you know everything there is to know about your system's performance?
- How can you learn more, easily and cheaply?

# What's Great About TCP?

- Call/response protocol semantics
- Fundamental metrics of performance:
  - Arrival time
  - Completion time
- From this we can derive:
  - Observation interval
  - Queries per second
  - Busy time
  - Total execution time

# More Metrics

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- We can use Little's Law to further derive:
  - Throughput
  - Concurrency
  - Response time
  - Utilization

# Capturing TCP Traffic

```
tcpdump -s 384 -i any -nnq -tttt  
'tcp port 3306 and (((ip[2:2] - ((ip[0]&0xf)<<2))  
- ((tcp[12]&0xf0)>>2)) != 0)' > tcp-file.txt
```

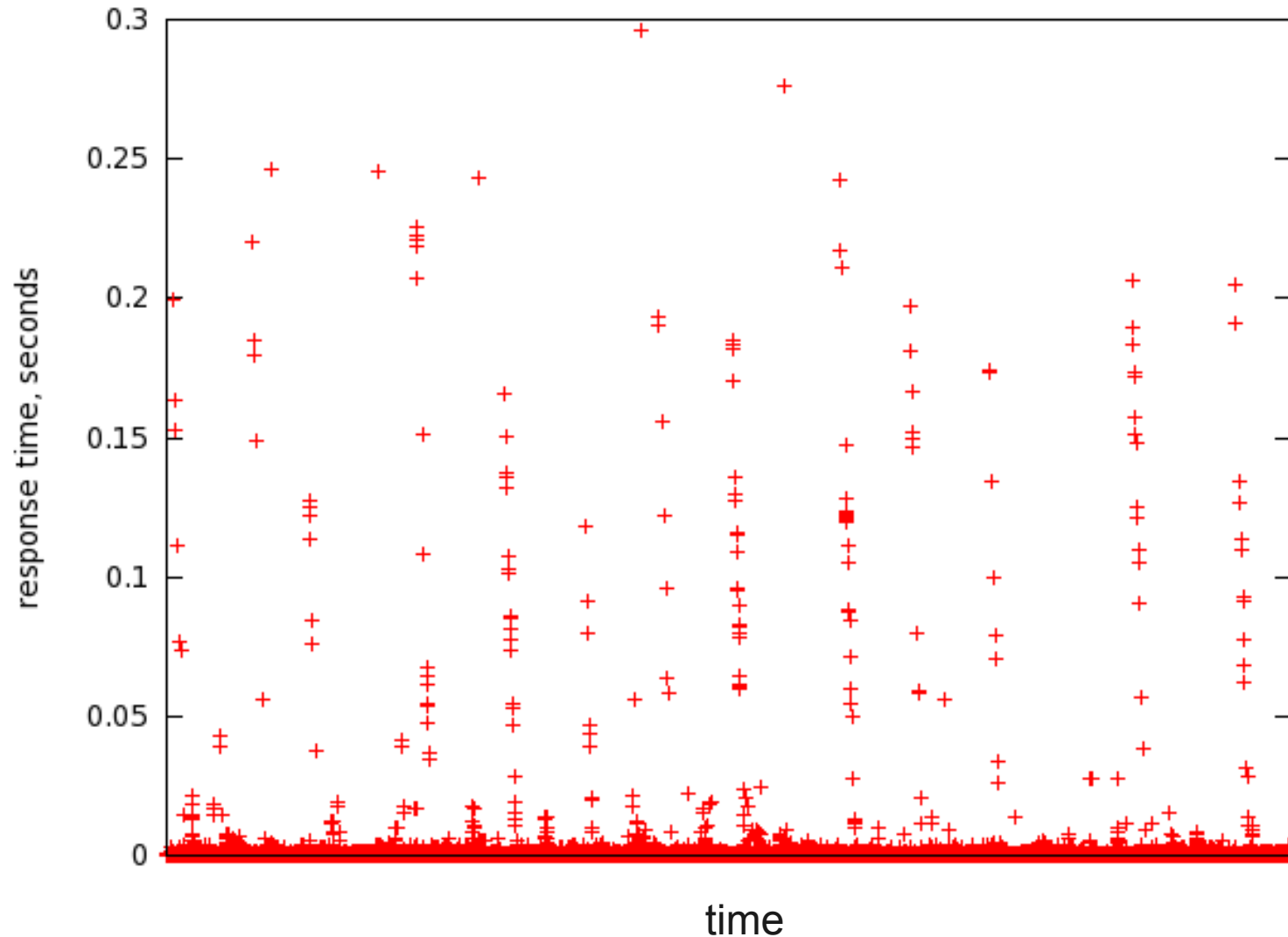
```
2011-05-05 10:47:17.810932 IP 10.220.146.79.35805 > 10.119.42.41.3306: tcp 83  
2011-05-05 10:47:17.811021 IP 10.119.42.41.3306 > 10.220.146.79.35805: tcp 64  
2011-05-05 10:47:17.811545 IP 10.250.95.31.45400 > 10.119.42.41.3306: tcp 82
```

# Process with pt-tcp-model

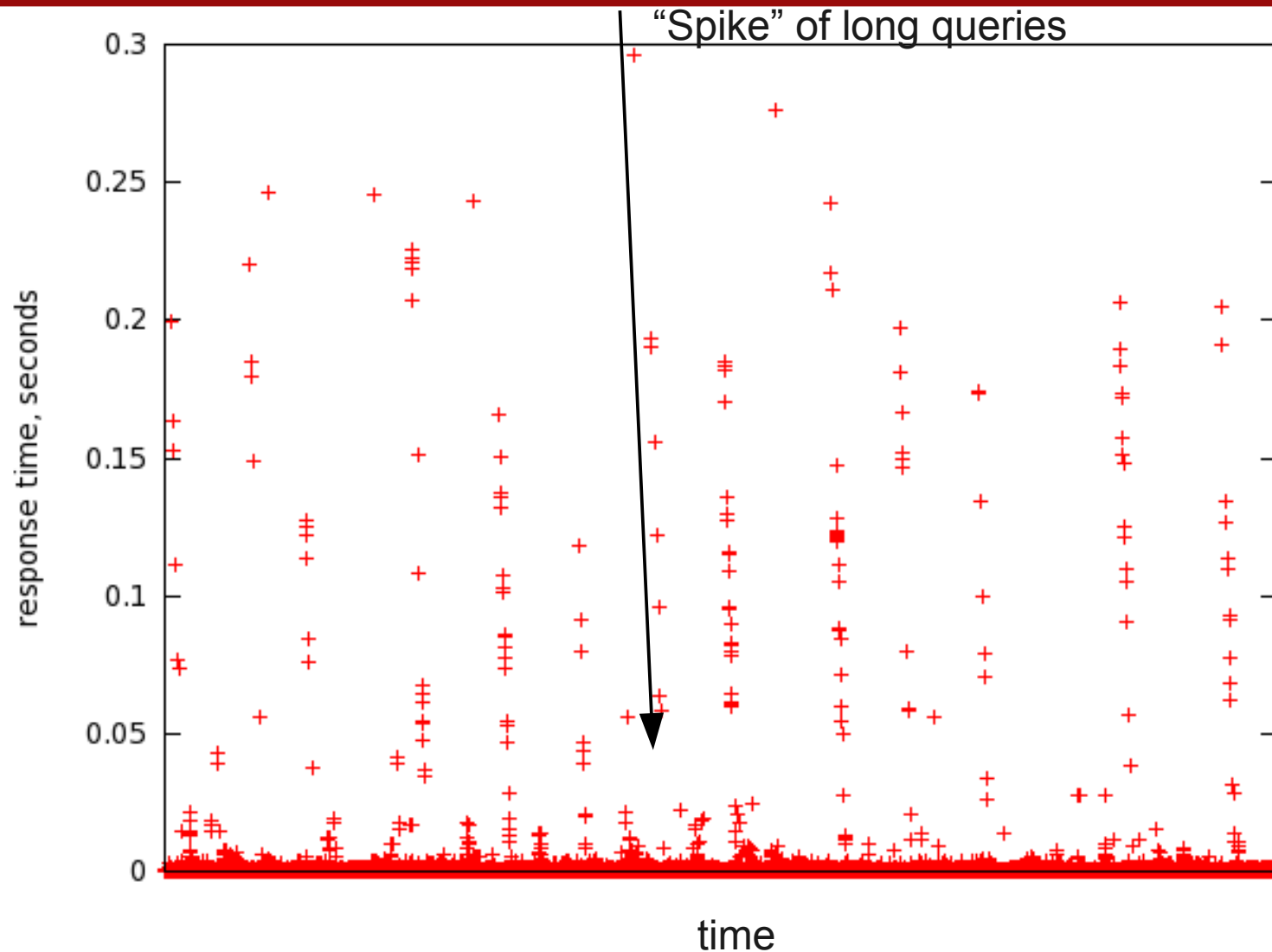
```
pt-tcp-model tcp-file.txt > requests.txt
```

#	start	end	elapsed	host:port
0	1304606837.810932	1304606837.811021	0.000089	10.220.146.79:35805
1	1304606837.811545	1304606837.811778	0.000233	10.250.95.31:45400
2	1304606837.811669	1304606837.811971	0.000302	10.243.78.239:45612
3	1304606837.811893	1304606837.812073	0.000180	10.222.110.47:44024
4	1304606837.813067	1304606837.813312	0.000245	10.220.146.79:35805

# Plot as Time-Series and Inspect



# Plot as Time-Series and Inspect



# Stall Detection

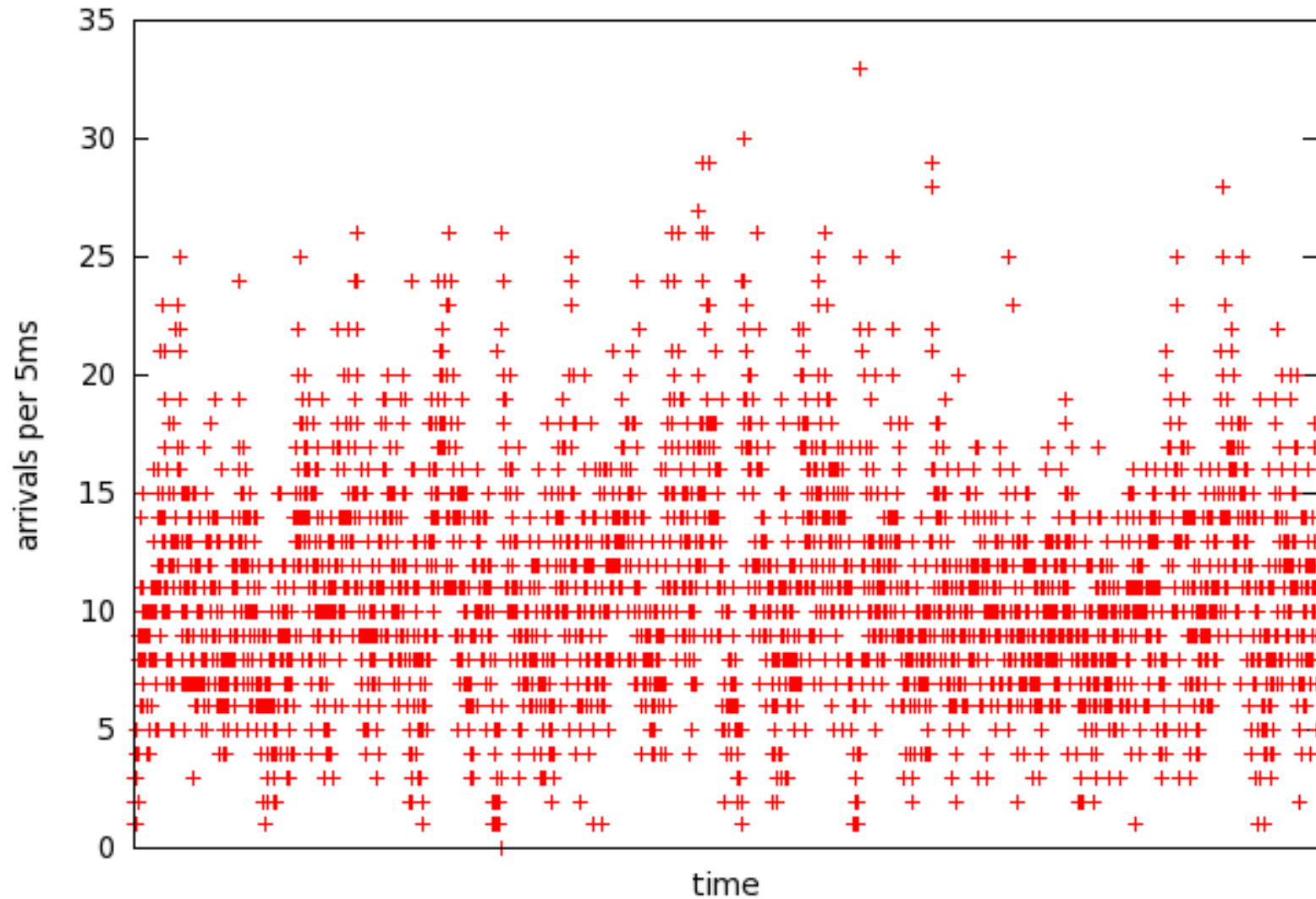
- What's happening there?
- Each query completes when the previous one releases the resource.
- A long query makes incoming queries queue.

*(I happen to know it's `SELECT FOR UPDATE`).*

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If completions are what's affected,  
maybe we can see the evidence.

# Arrivals per 5ms





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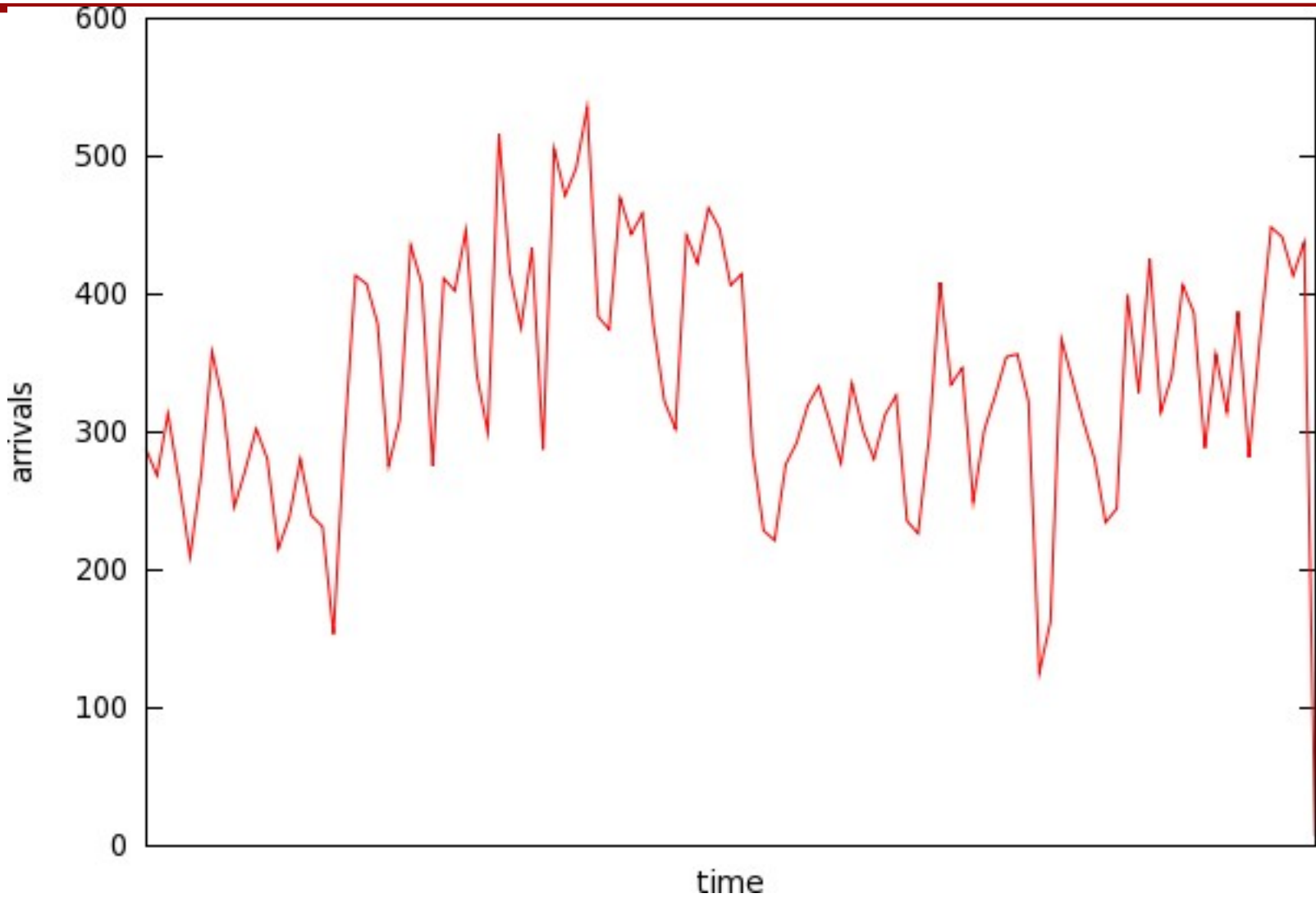
Is there really a problem?

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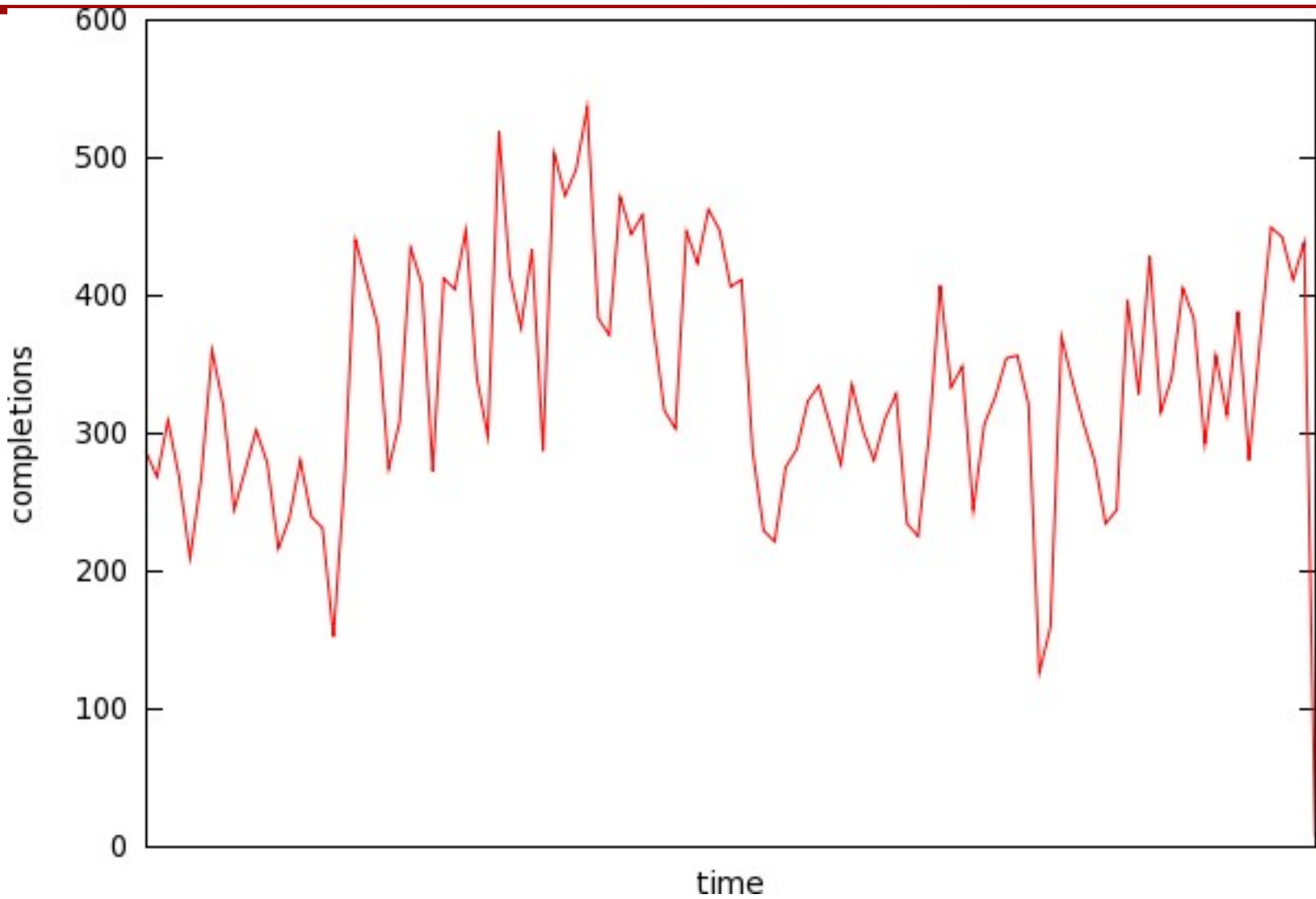
If arrivals are fairly uniform, but completions cluster together, can we see it?

*The following graphs are per 2-tenths of a sec.*

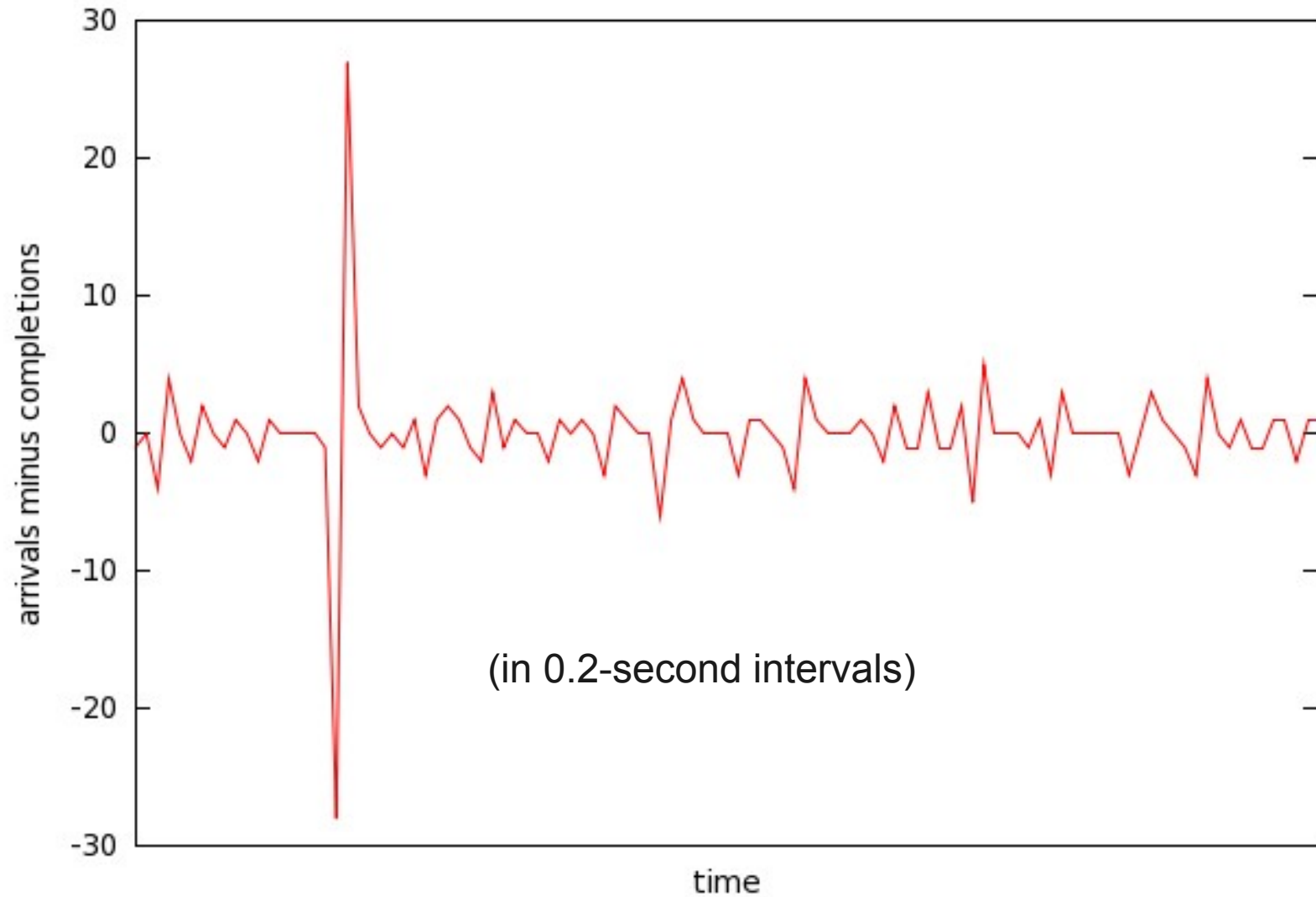
# Arrivals



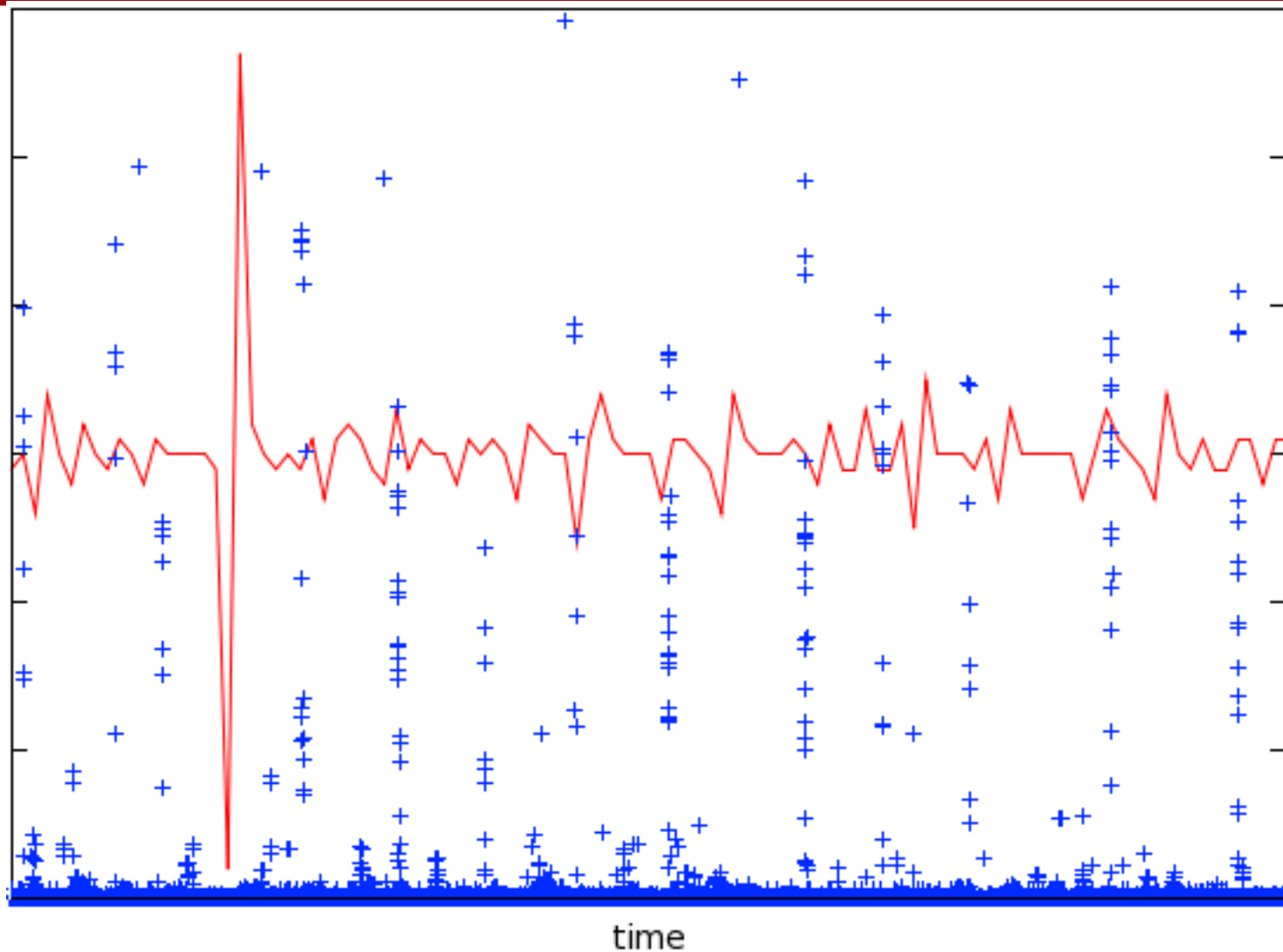
# Completions



# Completions Minus Arrivals



# Seeing Hidden Patterns



# Pile-Up Detection Algorithm

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- Plot completions minus arrivals
- Try finer and finer granularities
- Is a 0.2-second pile-up acceptable?

# Detecting Performance Problems

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Another good statistic is the index of dispersion of response times.

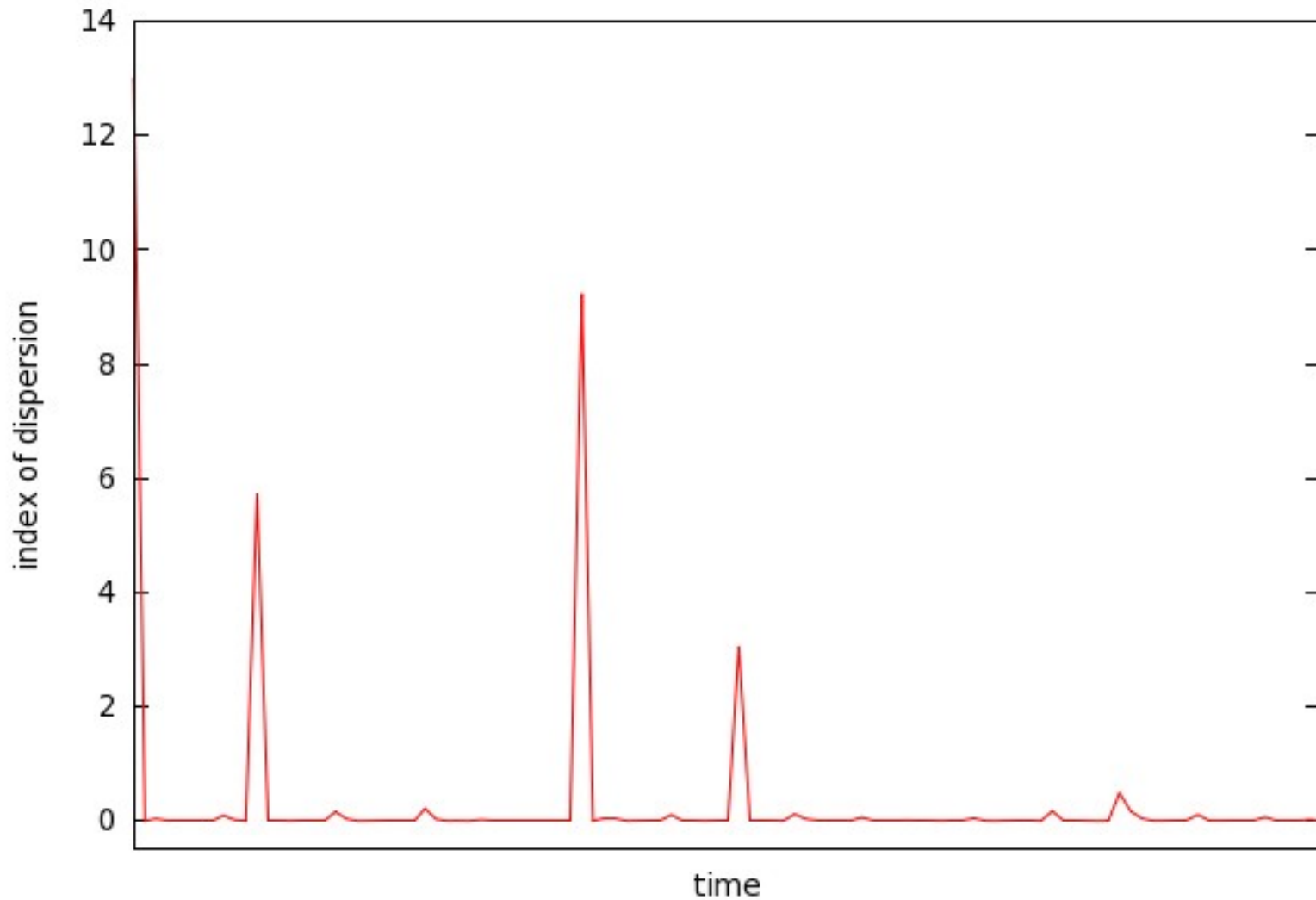
$$\frac{\text{Variance}}{\text{Mean}}$$

# Index of Dispersion

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- Normalized relative to average response time.
- Lets you compare different workloads.

# Index of Dispersion



# Interpreting Index of Dispersion

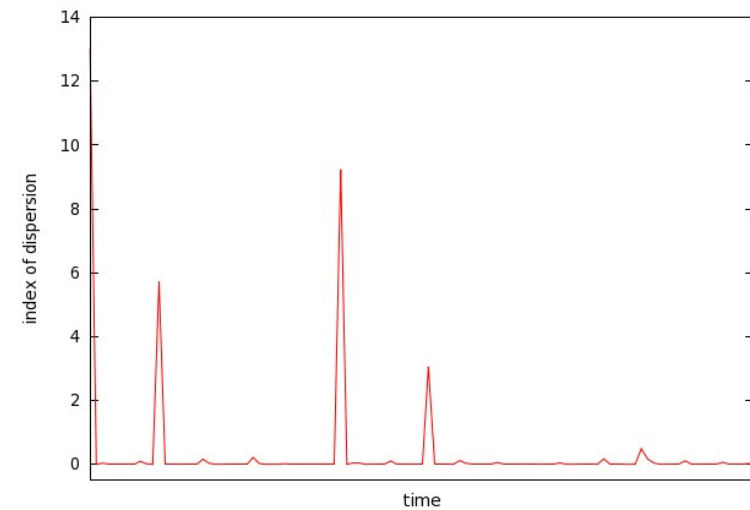
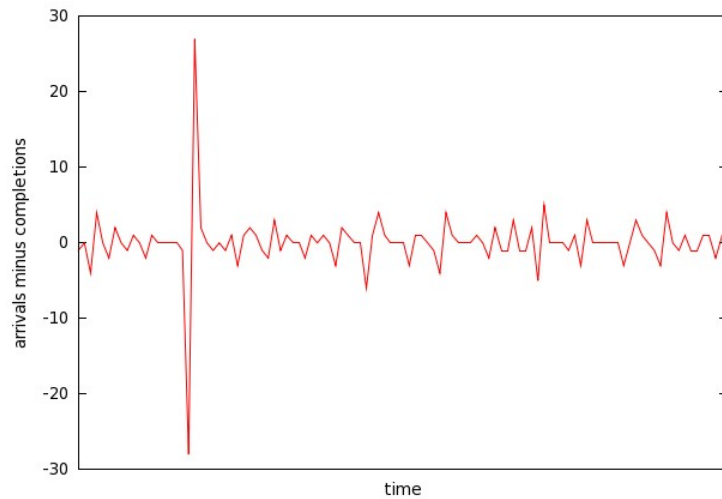
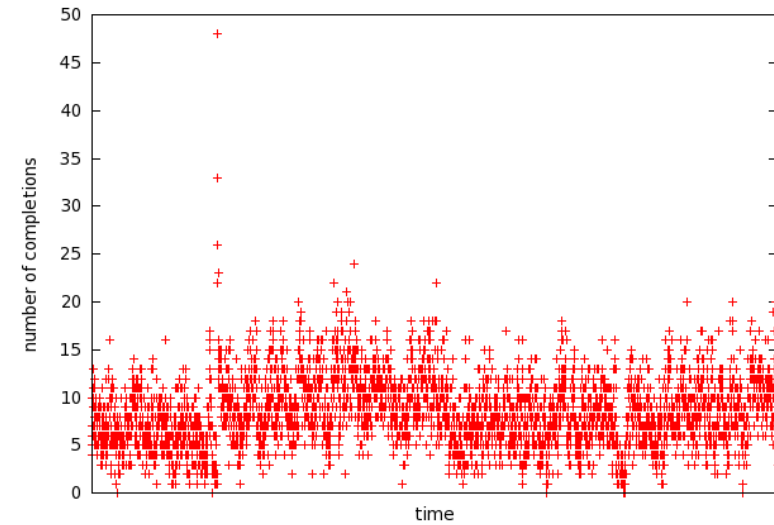
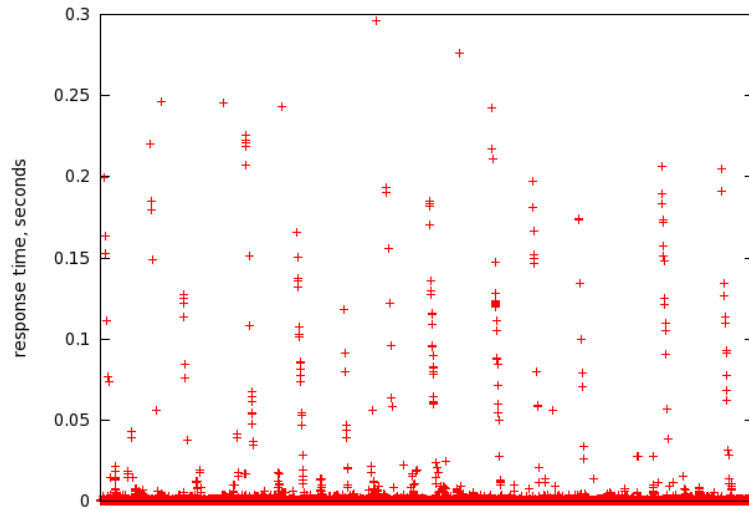
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- What does it MEAN when there's a spike?
- “This time period is highly variable.”
- “Highly variable performance is bad.”

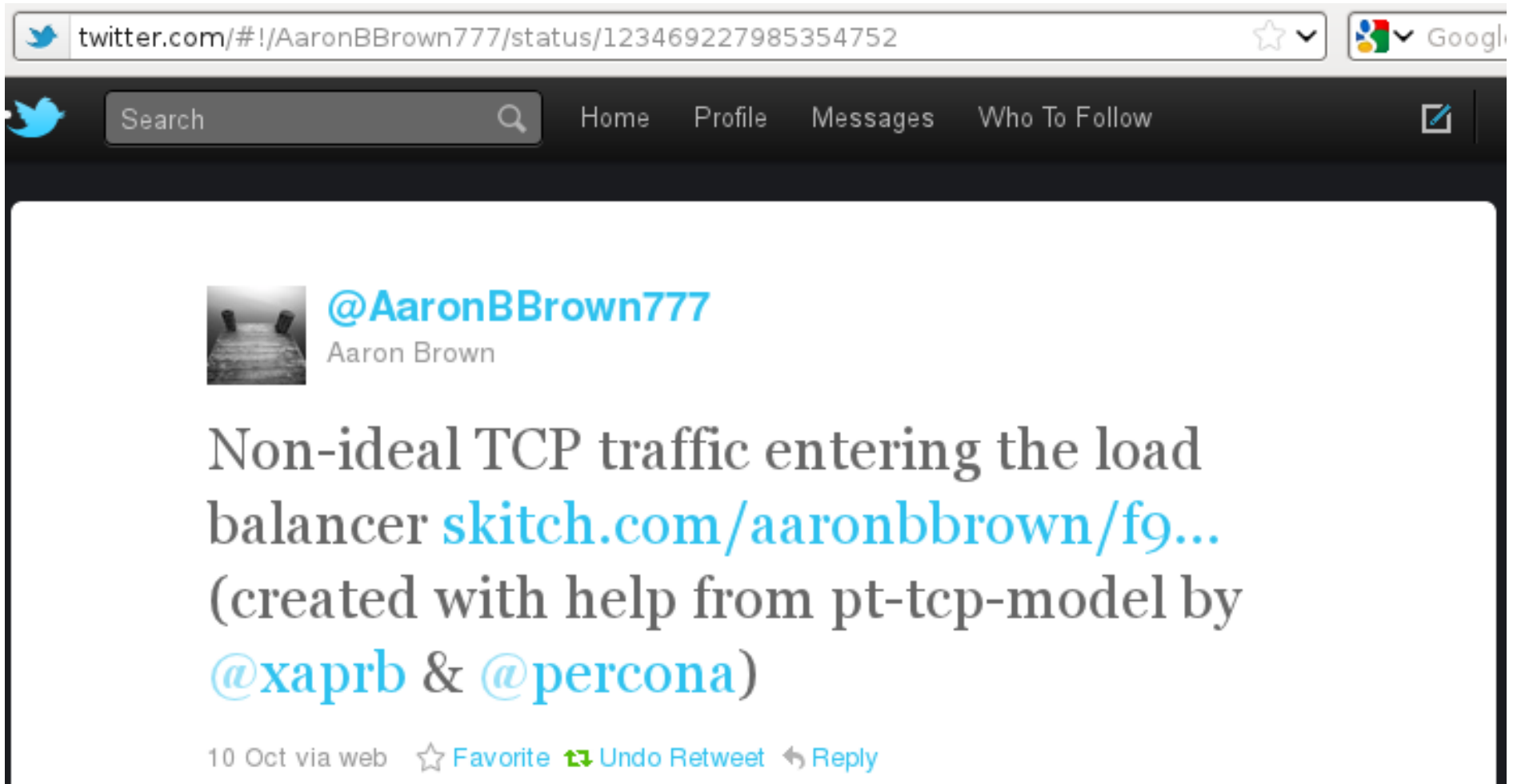
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Highly variable == highly optimizable.

# Time-Series, All Together Now




# In the Real World



The image shows a screenshot of a Twitter post. At the top, the browser address bar displays the URL: [twitter.com/#!/AaronBBrown777/status/123469227985354752](https://twitter.com/#!/AaronBBrown777/status/123469227985354752). The Twitter navigation bar includes a search box, and links for Home, Profile, Messages, and Who To Follow. The tweet is from the user @AaronBBrown777, whose name is Aaron Brown. The profile picture shows a pair of feet on a wooden floor. The tweet text reads: "Non-ideal TCP traffic entering the load balancer [skitch.com/aaronbbrown/f9...](https://skitch.com/aaronbbrown/f9...) (created with help from pt-tcp-model by [@xaprb](#) & [@percona](#))". Below the text, the tweet is dated "10 Oct via web" and includes interaction options: Favorite, Undo Retweet, and Reply.

twitter.com/#!/AaronBBrown777/status/123469227985354752

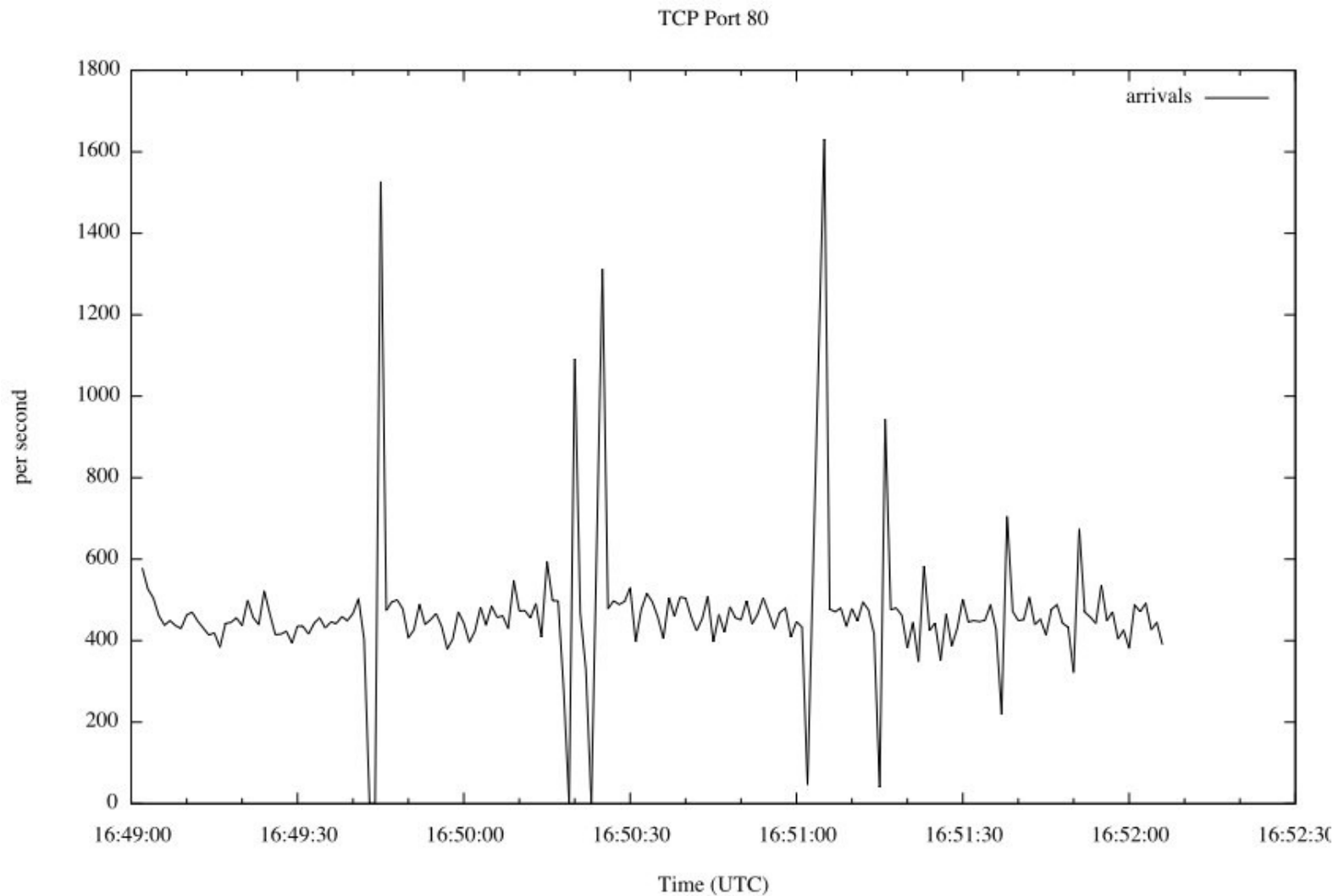
Search Home Profile Messages Who To Follow

 [@AaronBBrown777](#)  
Aaron Brown

Non-ideal TCP traffic entering the load balancer [skitch.com/aaronbbrown/f9...](https://skitch.com/aaronbbrown/f9...)  
(created with help from pt-tcp-model by [@xaprb](#) & [@percona](#))

10 Oct via web ☆ Favorite ↺ Undo Retweet ↻ Reply

# In the Real World



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# Scalability and Performance (formally defined)

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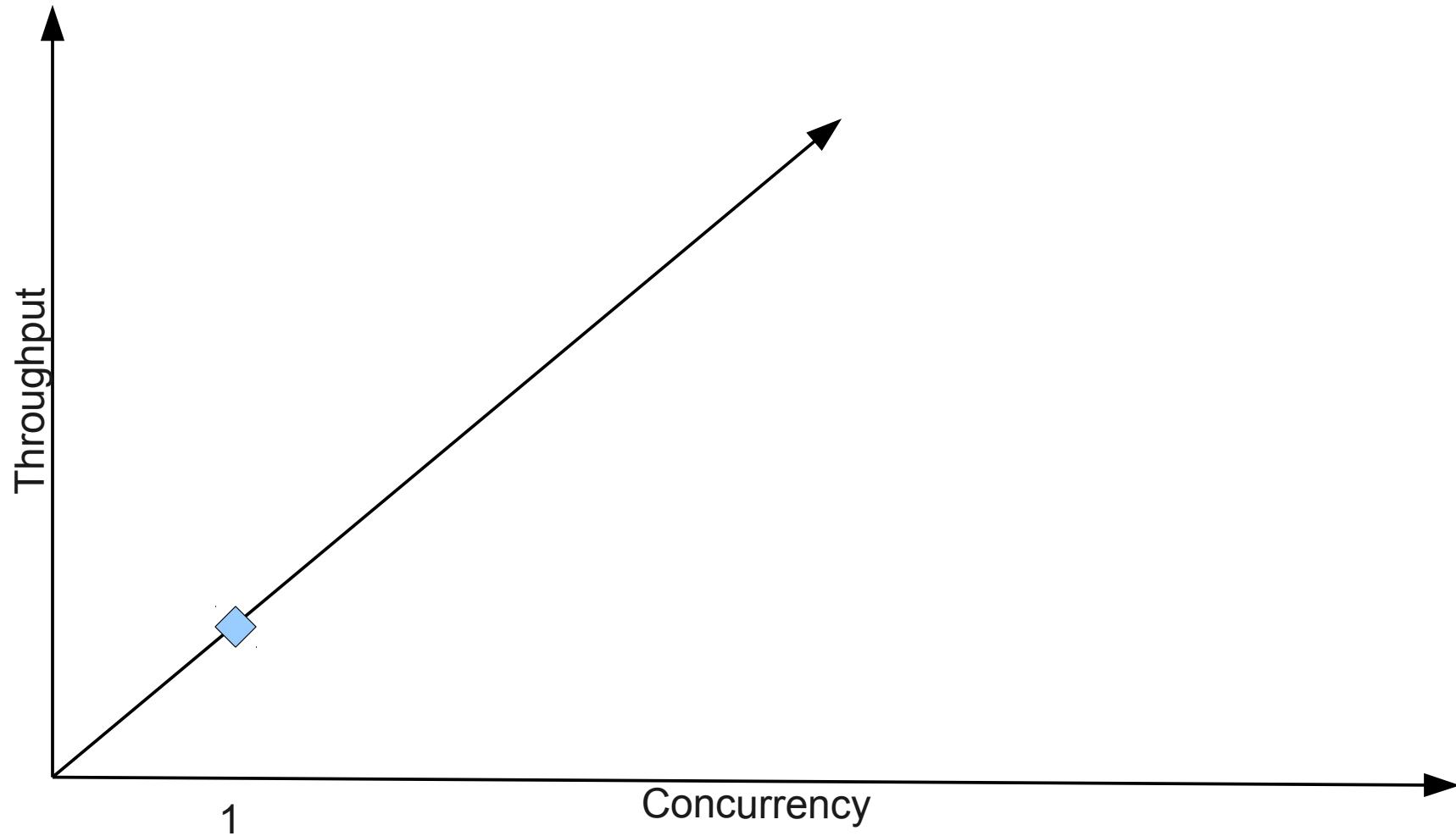
What is scalability?

# Modeling Scalability

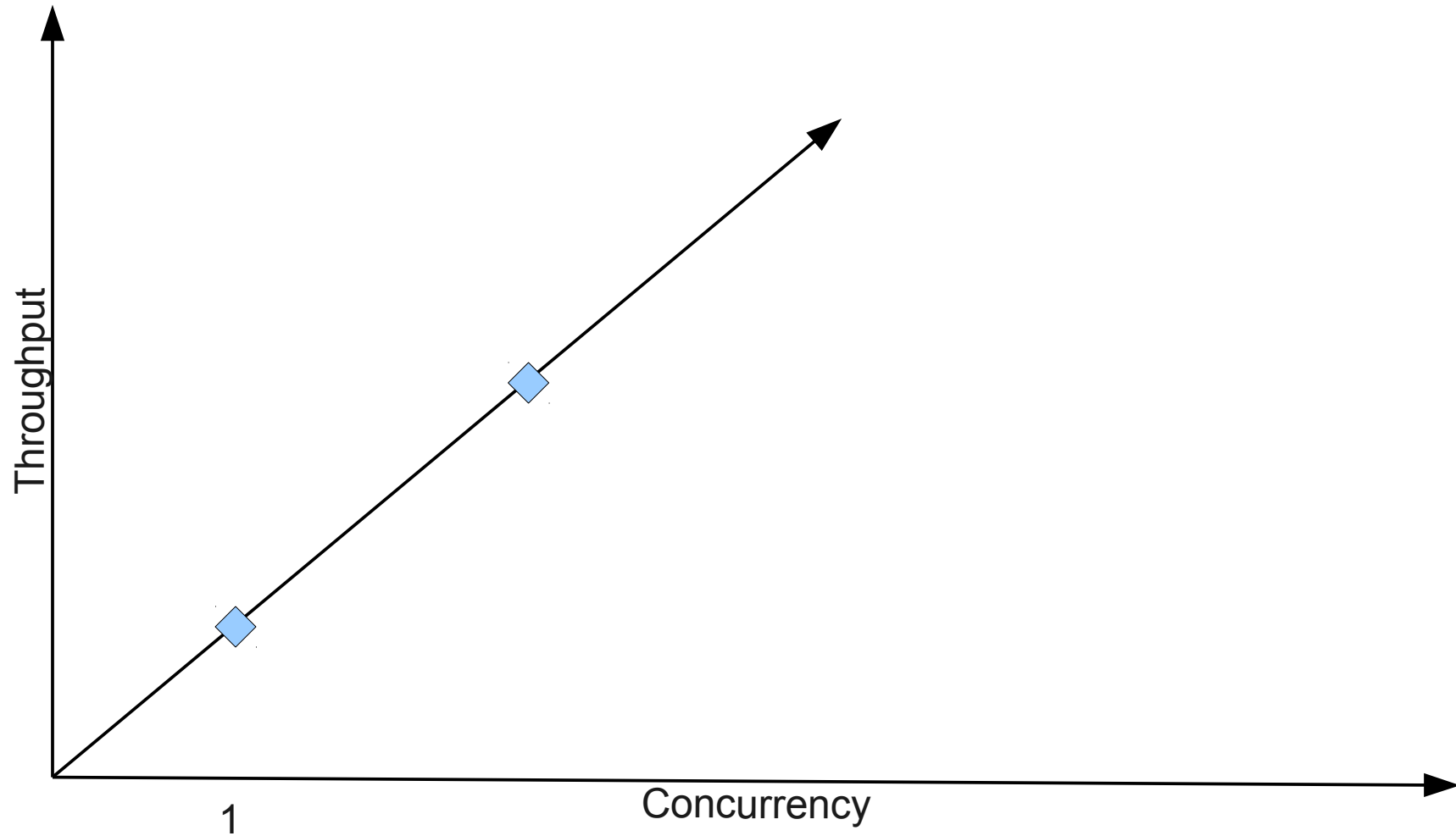
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- Scalability is a function (equation)
- The X-axis is Concurrency
- The Y-axis is Throughput

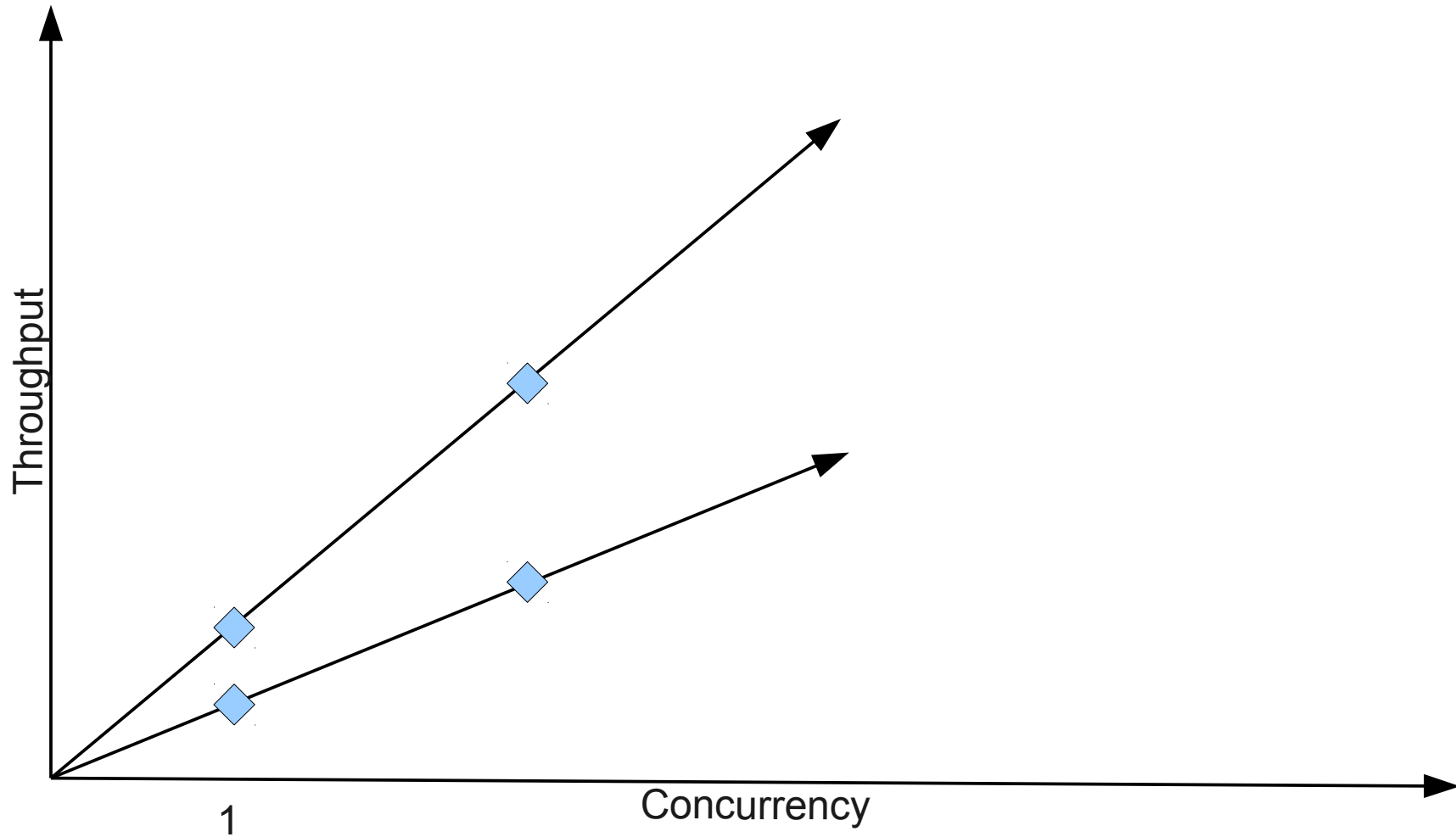
# The Scalability Function



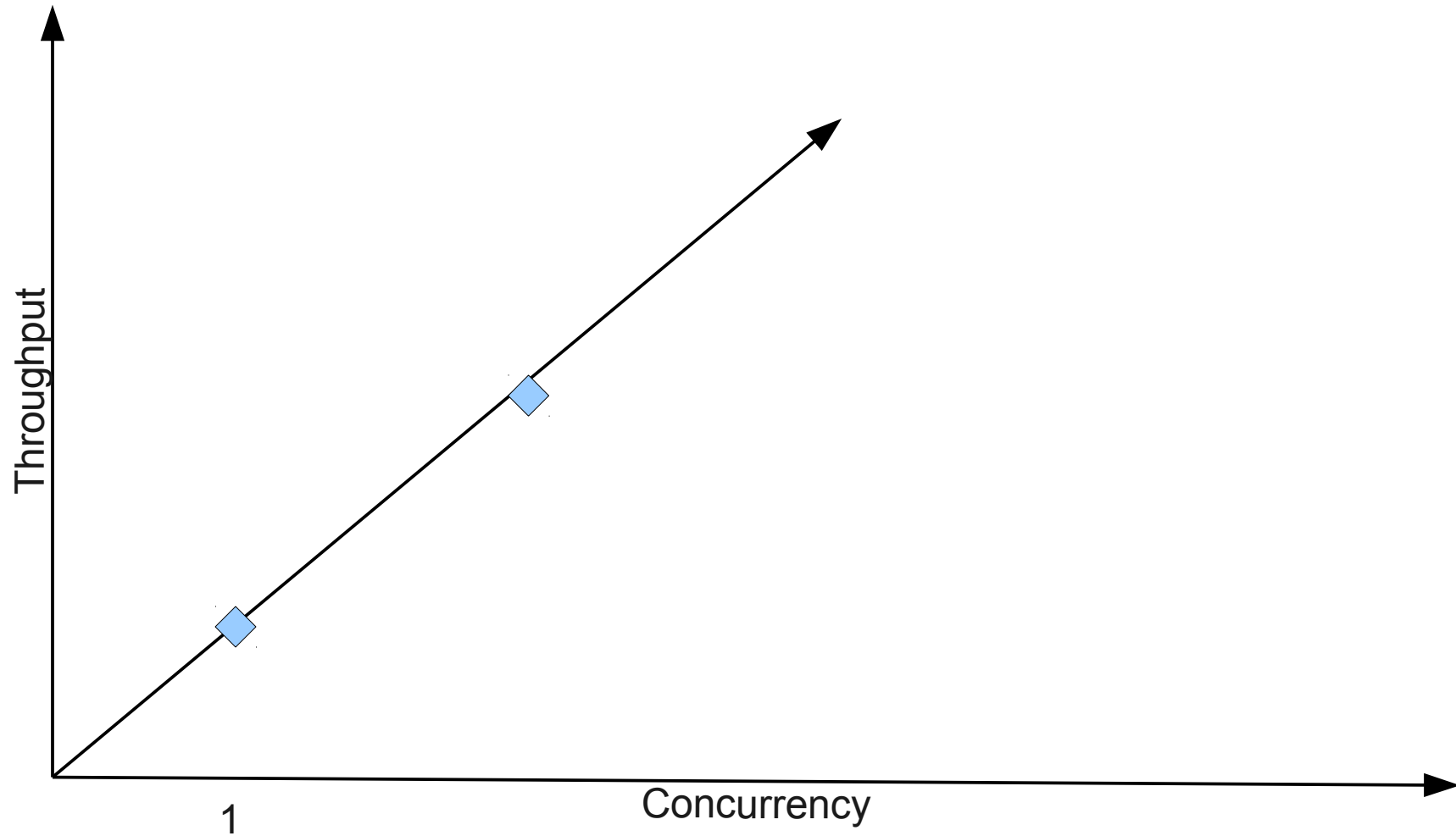
# This is Linear Scalability



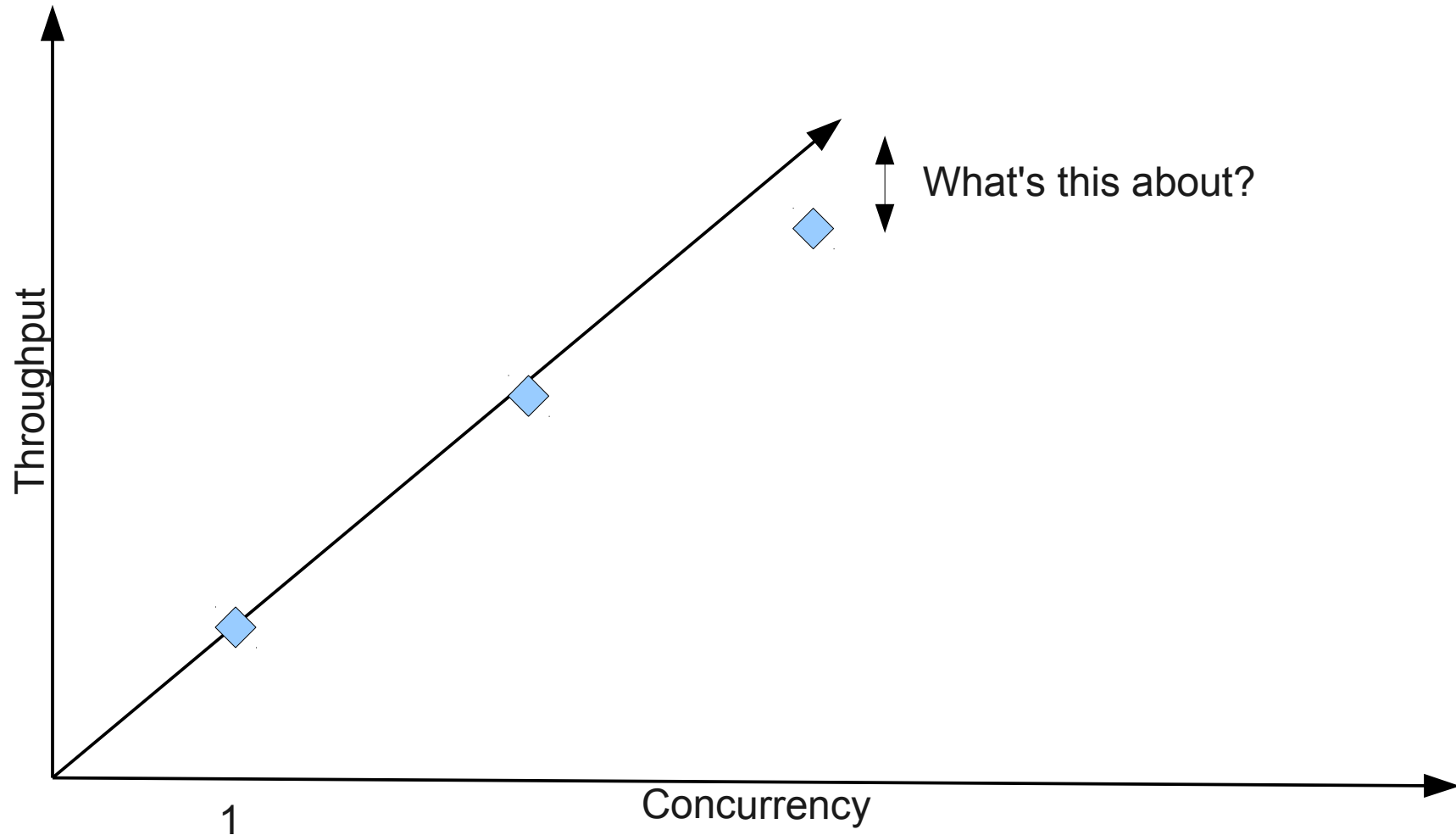
# This is Also Linear Scalability



# This is Not Linear Scalability



# What Causes Non-Linearity?



# Factor #1: Serialization

- Some portion of the work cannot be done in parallel
- This is Amdahl's Law

$$C(N) = \frac{N}{1 + \sigma(N - 1)}$$

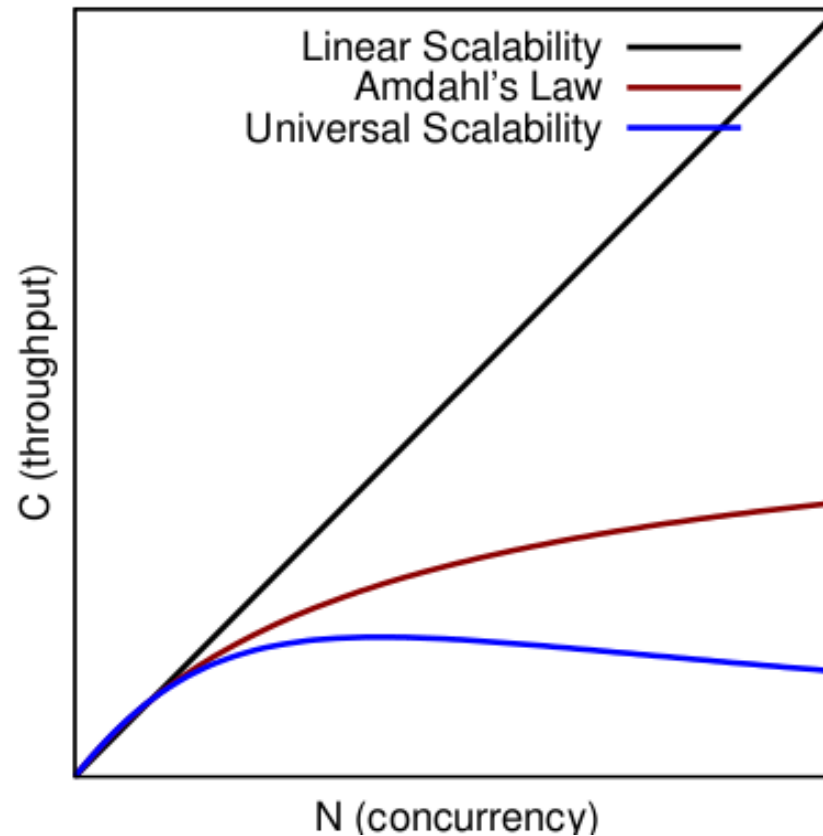
# Factor #2: Coherency

- Some portion of the work relies on IPC, cross-node communication, etc
- Dr. Neil Gunther's University Scalability Law:

$$C(N) = \frac{N}{1 + \sigma(N - 1) + \kappa N(N - 1)}$$

# Loss of Scalability

Most systems have serialization & coherency.



# Scalability Modeling Method

- Measure Throughput and Concurrency.
- Perform a regression against the USL.  
(Determine sigma and kappa coefficients)
- ?????
- Profit!

$$C(N) = \frac{N}{1 + \sigma(N - 1) + \kappa N(N - 1)}$$

# Concurrency from TCP

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- Throughput is easy (queries per second)
- Concurrency is harder.

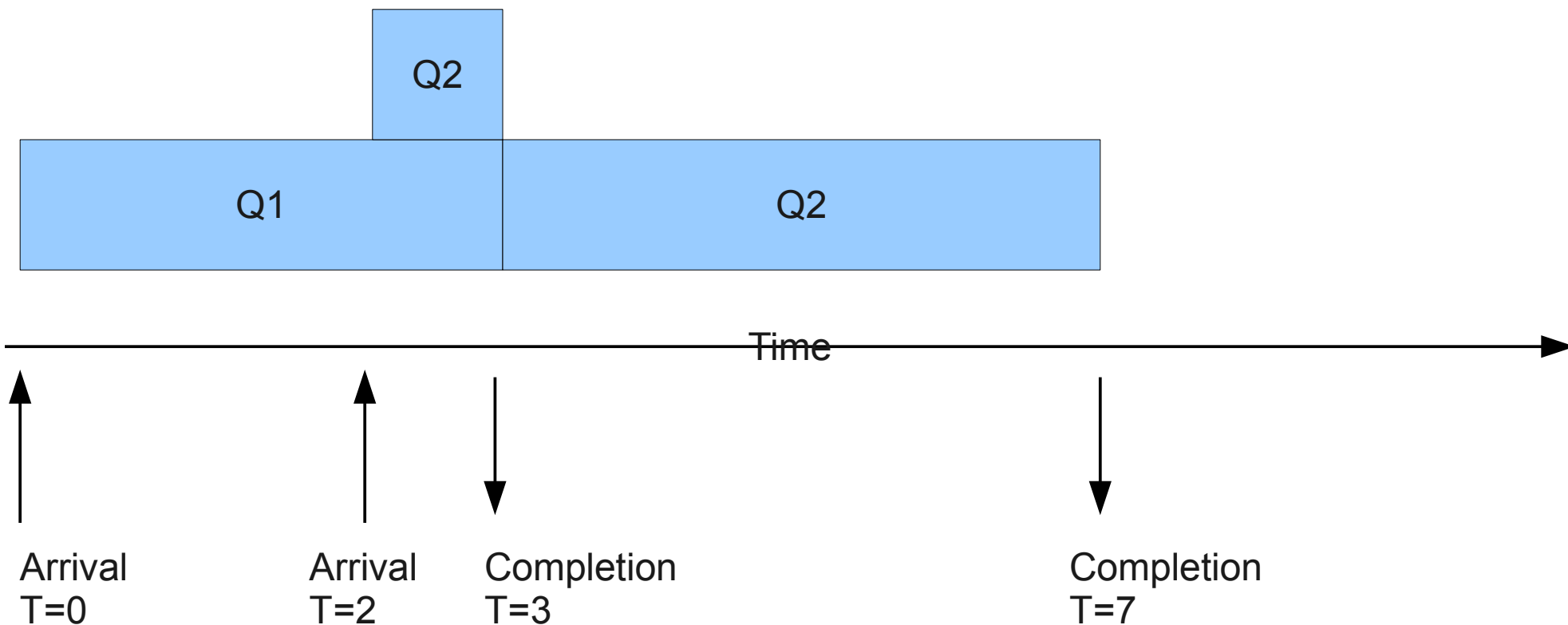
# Concurrency from TCP

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- Sort the arrivals and departures in order.
  - Each arrival increments concurrency.
  - Each departure decrements it
- Compute average concurrency per time interval

# Visually...

Observation Time: 7  
Total Query Time: 8  
Average Concurrency: 8/7



# Using pt-tcp-model

- pt-tcp-model knows how to compute this.

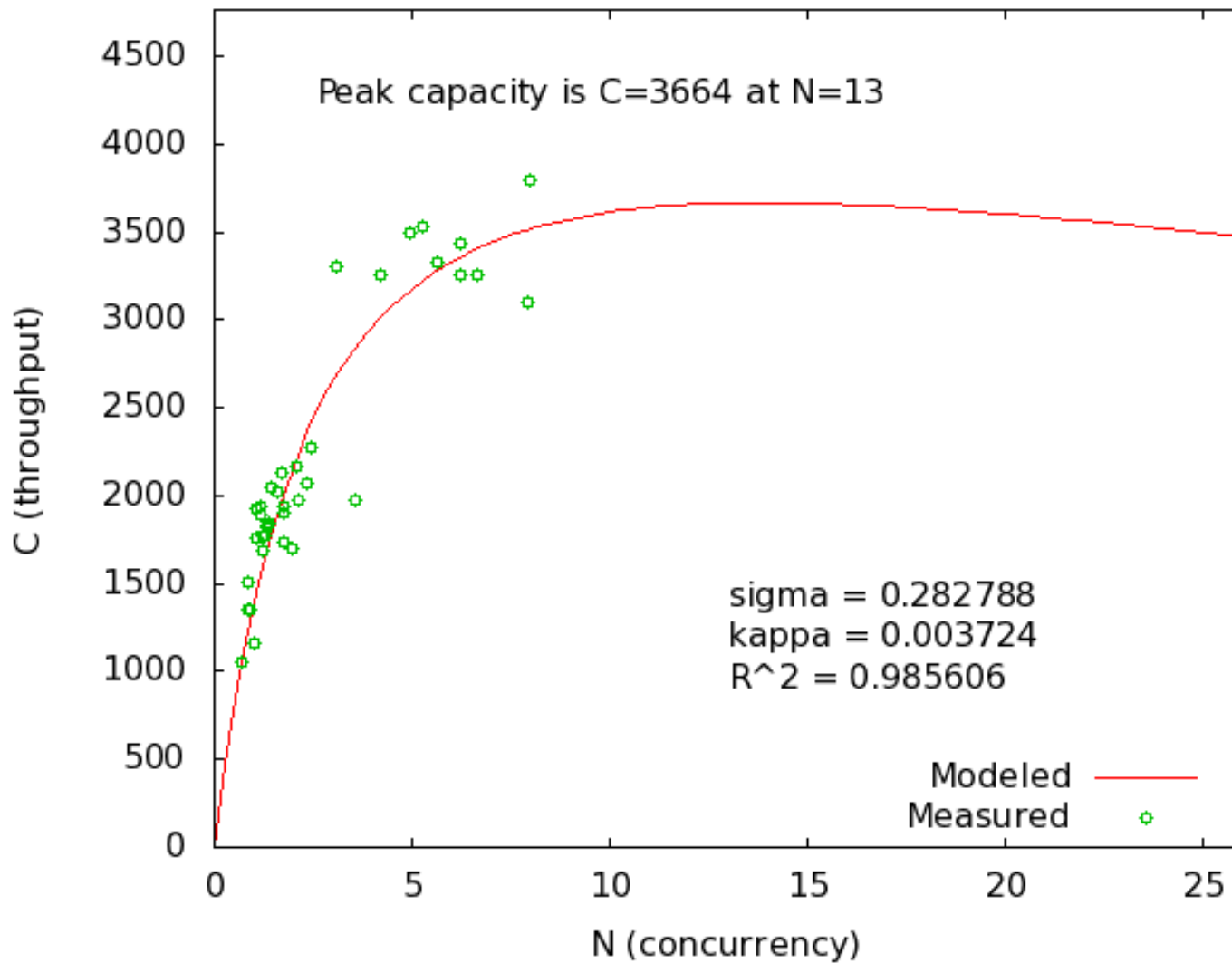
```
sort -n -k1,1 requests.txt > sorted.txt
```

```
pt-tcp-model --type=requests sorted.txt > sliced.txt
```

# Determine the Coefficients

- Use *R*, *gnuplot* or other statistical tools to fit the model to the data and derive:
  - The coefficient of serialization ( $\sigma$ )
  - The coefficient of coherency ( $\kappa$ )

# Results



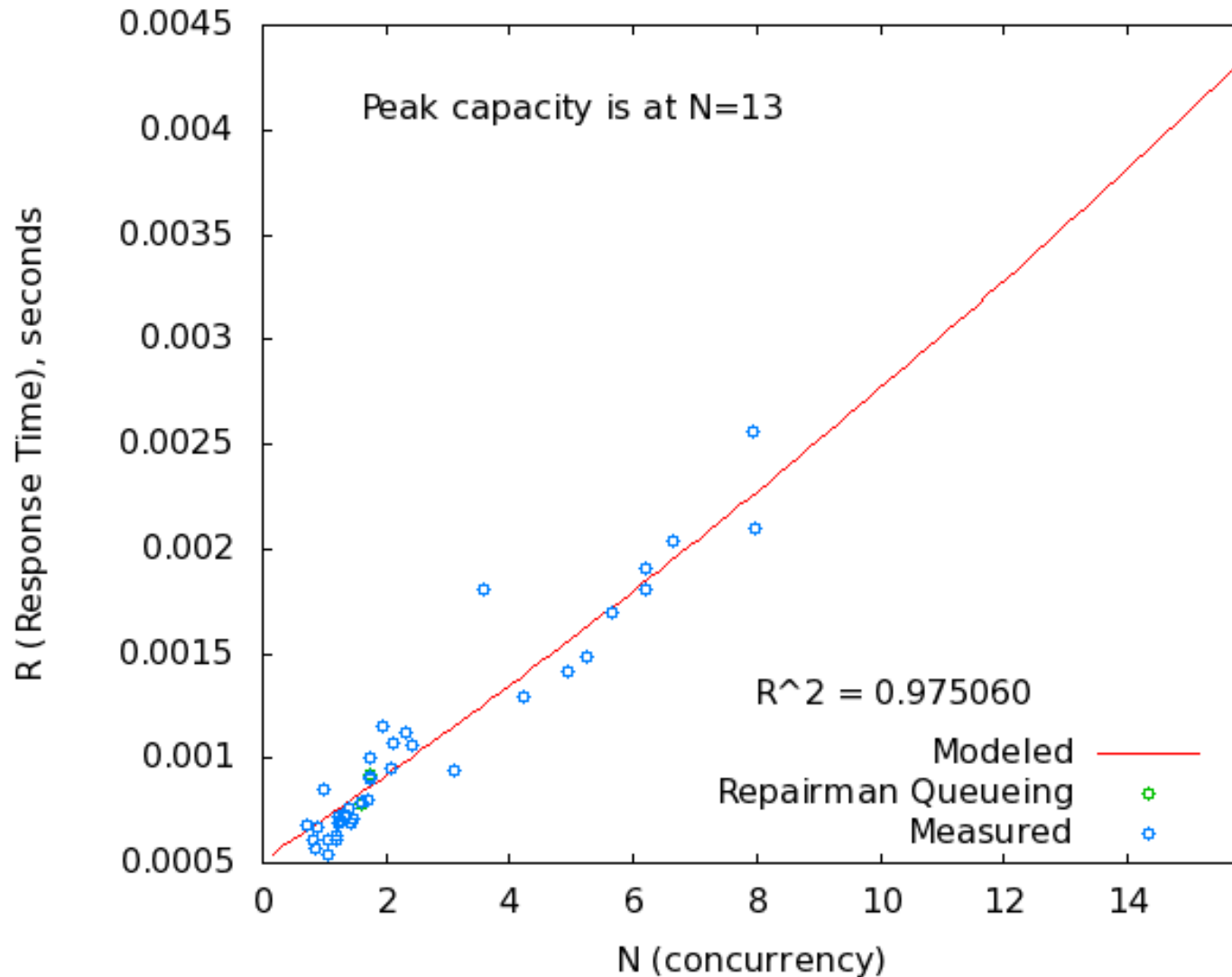
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What is performance?

# Forecasting Performance

- Performance = Response Time
- Little's Law:  $N = XR$   
(Concurrency = Throughput \* Response Time)

# Forecasting Performance



# Validating Input

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Garbage in, garbage out.

# Validating Input

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- Do not just throw data at the model.
- Beware of dropped packets in tcpdump.
- You may need to remove outliers.
- Beware of highly mixed / changing workloads.

# When Is This Useful?

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- Worst-case bound
- Best-case bound

# Be Vewwy Vewwy Quiet

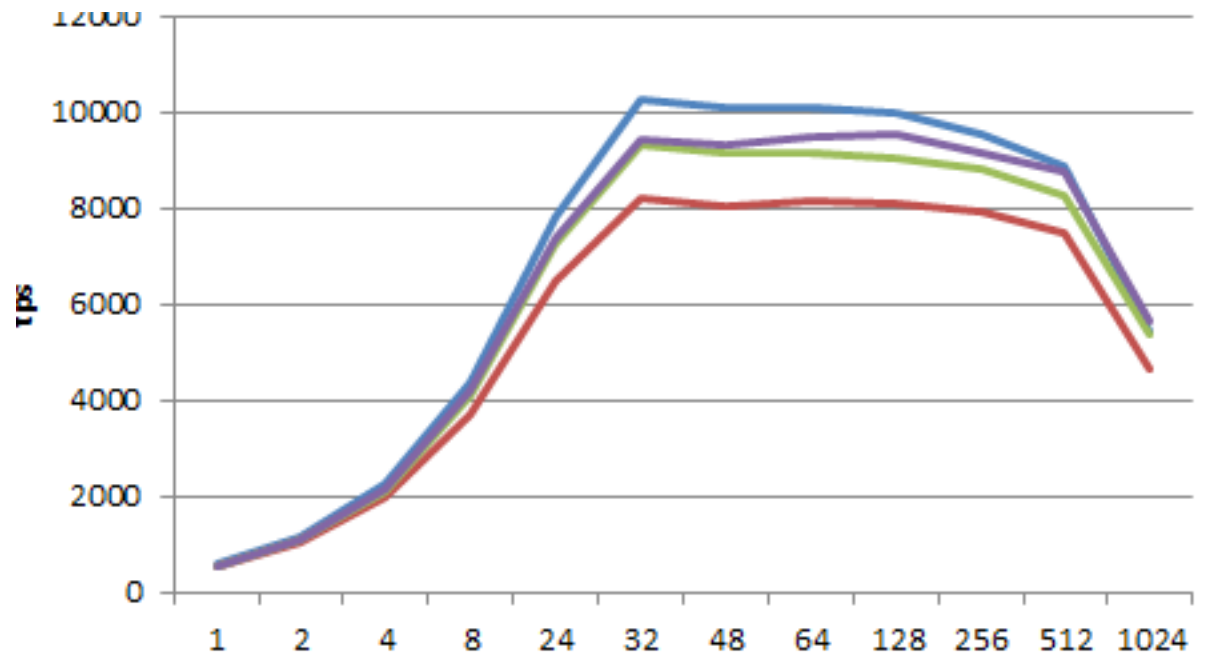


I'm wooking for bottwenecks!

# Worst-Case Scaling

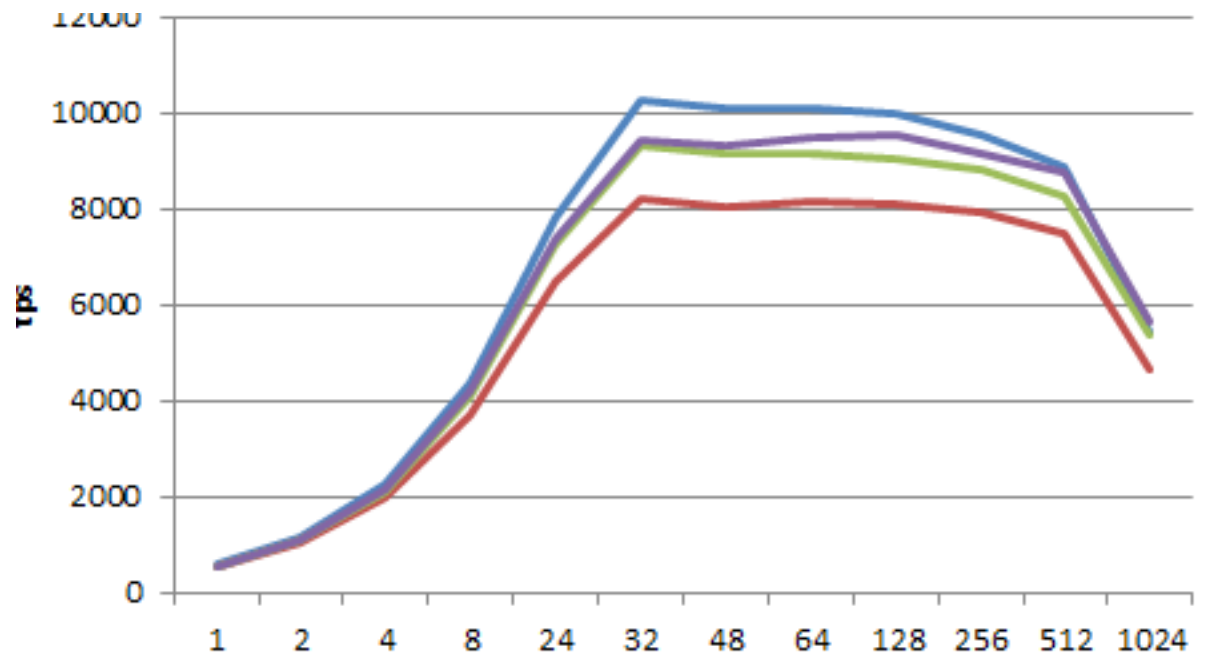
- The USL models synchronous repairman queuing behavior.
- This is worst-case, and your system should scale *better* than this.
- If not, you have a bottleneck. Go hunting.

# Double Rainbow!

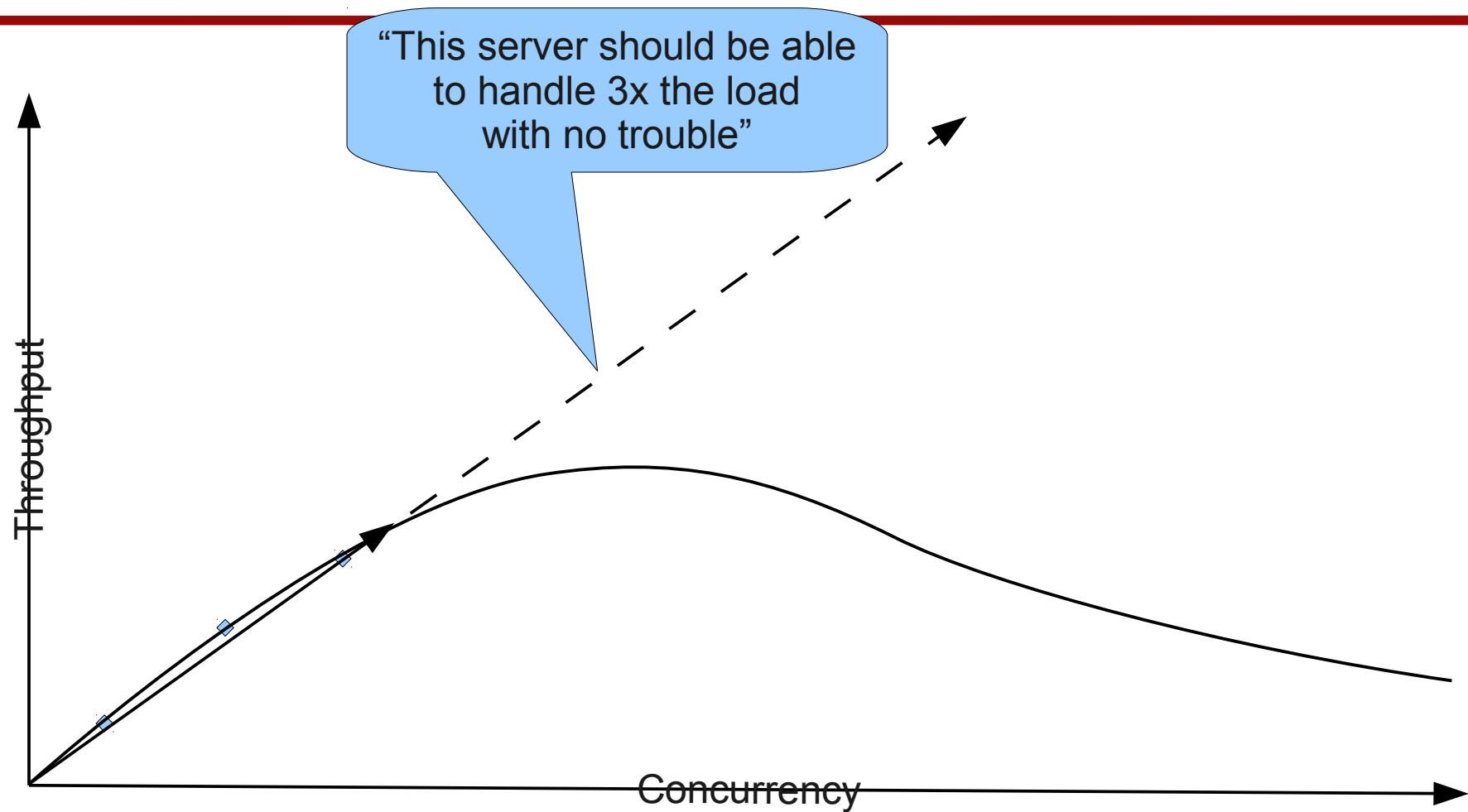


# What's Wrong With That Plot?

- Why is it concave upwards till 24 threads?
  - It's because the X-axis scale is not linear.



# “Assuming Linear Scalability...”



# Best-Case Bounds

- We know most systems don't scale as well as they're supposed to.
- Therefore, the USL can be used for capacity planning purposes as a *best-case* bound.
- “I expect this system not to scale as well as predicted, so I'd better not count on getting any more performance than the model indicates.”

# Summary

- We can get arrivals & completions from TCP
- And measure query performance easily
- And find problems the eye can't see
- And forecast beyond what we can observe
- For nearly any system
- Including ones that have no instrumentation!
- Forecasting/modeling requires experience and judgment, and does not give exact answers.

# Resources

- Percona Toolkit: [percona.com/software](http://percona.com/software)
- Neil J. Gunther's book
  - *Guerrilla Capacity Planning*
- “Forecasting MySQL Scalability” white paper
  - <http://percona.com/about-us/mysql-white-papers>



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