JVM Performance and Tuning

Module Two

Performance Metrics

Module Topics

1. Defining Performance
2. Performance Metrics
3. Performance Measurements
4. Benchmarking and Profiling

Some Caveats

- There are no “go faster” options for a JVM
- There are no list of tips and tricks to optimize a JVM
- The performance of code depends on many factors including:
  - The hardware the JVM is running on
  - The version of the JVM
  - How the code was designed and written
- Java design choices
  - Program safety over performance
  - Programmer productivity over performance

Java Design Decisions

- Designed for interactive applications
  - Generally the human is the rate limiting step
  - As long as it is “fast enough” then performance can be sacrificed for productivity
    - *Main cost is software development is programmer time, both writing code and debugging and maintaining code*
  - Interactive applications tend to require more updating and maintenance as requirements evolve and change
- Relies on a number of managed subsystems
  - e.g. Memory allocation and garbage collection
  - These subsystems introduce complexity into the running of the JVM
- Even measuring performance affects performance

Performance Metrics

- Depends on what is important to you
- Business level metrics
  - Ease of use
  - Customer loyalty
  - Improves business operations
  - “Apdex” index
    - *Measure of how log a transaction should take – industry standard*
- Application level metrics
  - Throughput measures – how many simultaneous transactions
  - Reliability, durability, loading etc
  - Quality levels, risk and error levels

Performance Metrics

- Depends on what is important to you.. cont
- Execution Metrics (what we are interested in)
  - Efficient use of hardware
  - CPU usage, memory usage, I/O bandwidth
- Source Code Metrics
  - Readability – ease of modification and changes
  - Effective and efficient design
  - Algorithm choice and implementation

Performance Metrics

- Application level metrics are often design or topology related
- Code metrics are often related to code design issues
- But both application and code issues affect execution metrics
- We are concerned with how to improve execution metrics if we assume there are no issues at the application topology and source code levels

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Performance Metrics

- Standard metrics include:
  - Throughput
  - Latency
  - Capacity
  - Utilization
  - Efficiency
  - Scalability
  - Degradation

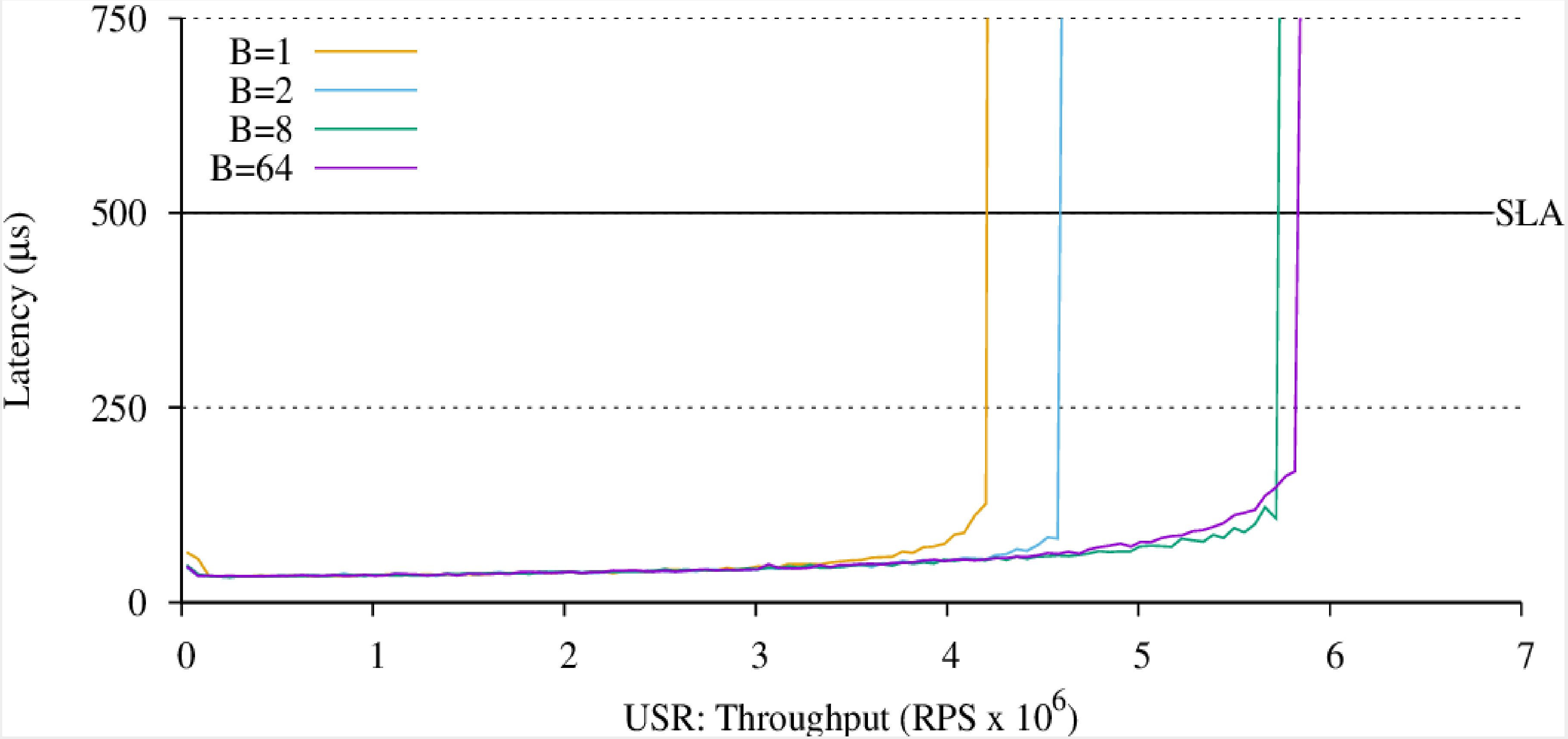
Throughput

- The rate of work a system can perform.
- Expressed as number of units of work in some time period
- Dependent on the platform where measured
- Dependent on how the unit of work is defined
- Often represented as number of complete transactions

Latency

- Time taken to process a single transaction
- Generally expressed as a start-to-end time.
- Dependent on workload
  - Expressed as a function of increasing workload
  - Increasing workload means less task access to resources
  - For example, browser latency increases the more tabs are open

Latency

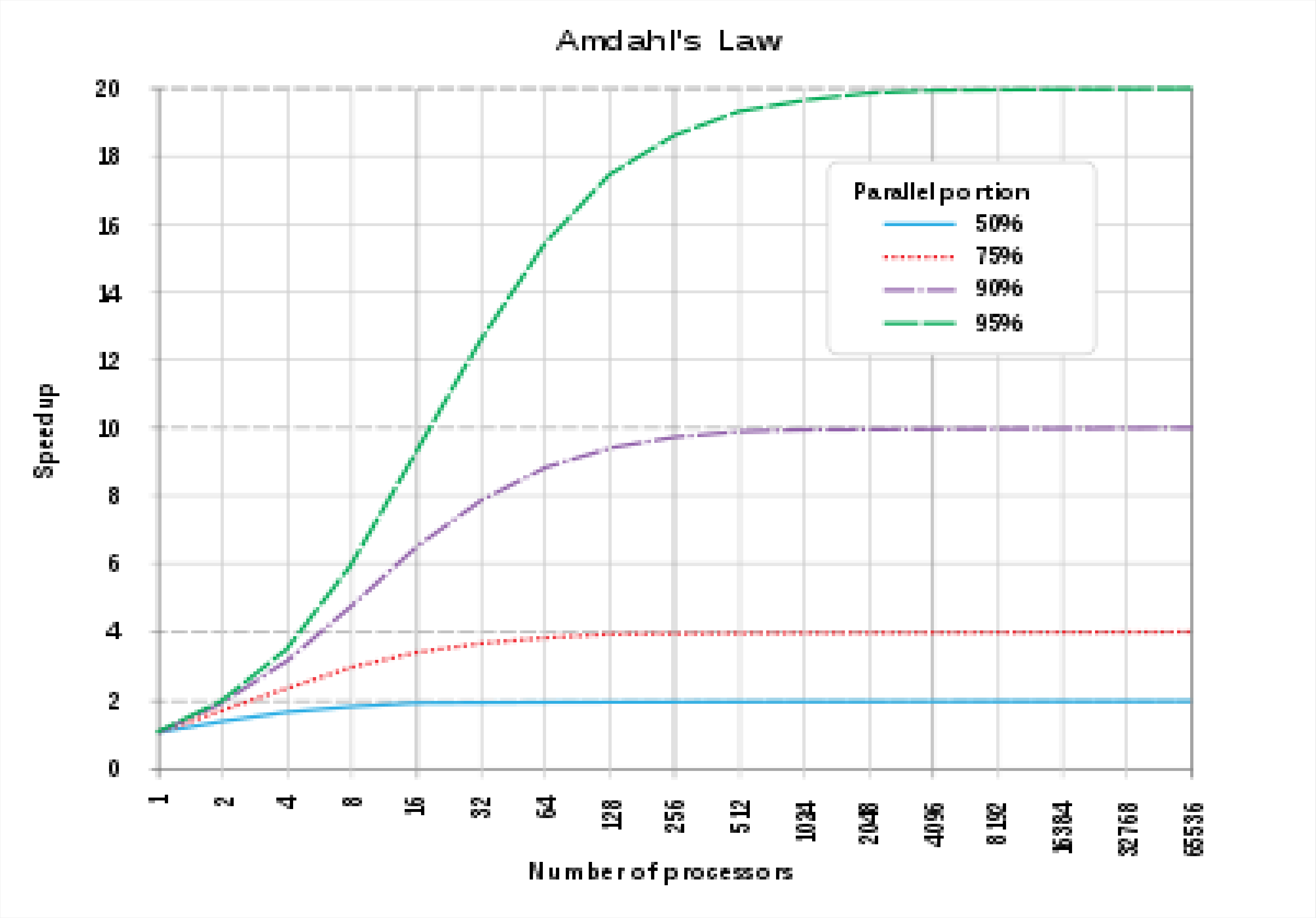


750
500
250
0
B=1
B=2
B=8
B=64
SLA
Latency (µs)
0
1
2
3
4
5
6
7
USR: Throughput (RPS x 10^6)

Capacity

- Amount of work parallelism a system possesses
- The number of units of work that can be simultaneously ongoing in the system
- Capacity is related to throughput
  - The more capacity available implies more throughout possible
- Restaurants put more staff on at meal times
  - Increases restaurant capacity
  - Improves throughput = number of meals prepared
  - Reduces latency = the amount of time a customer has to wait

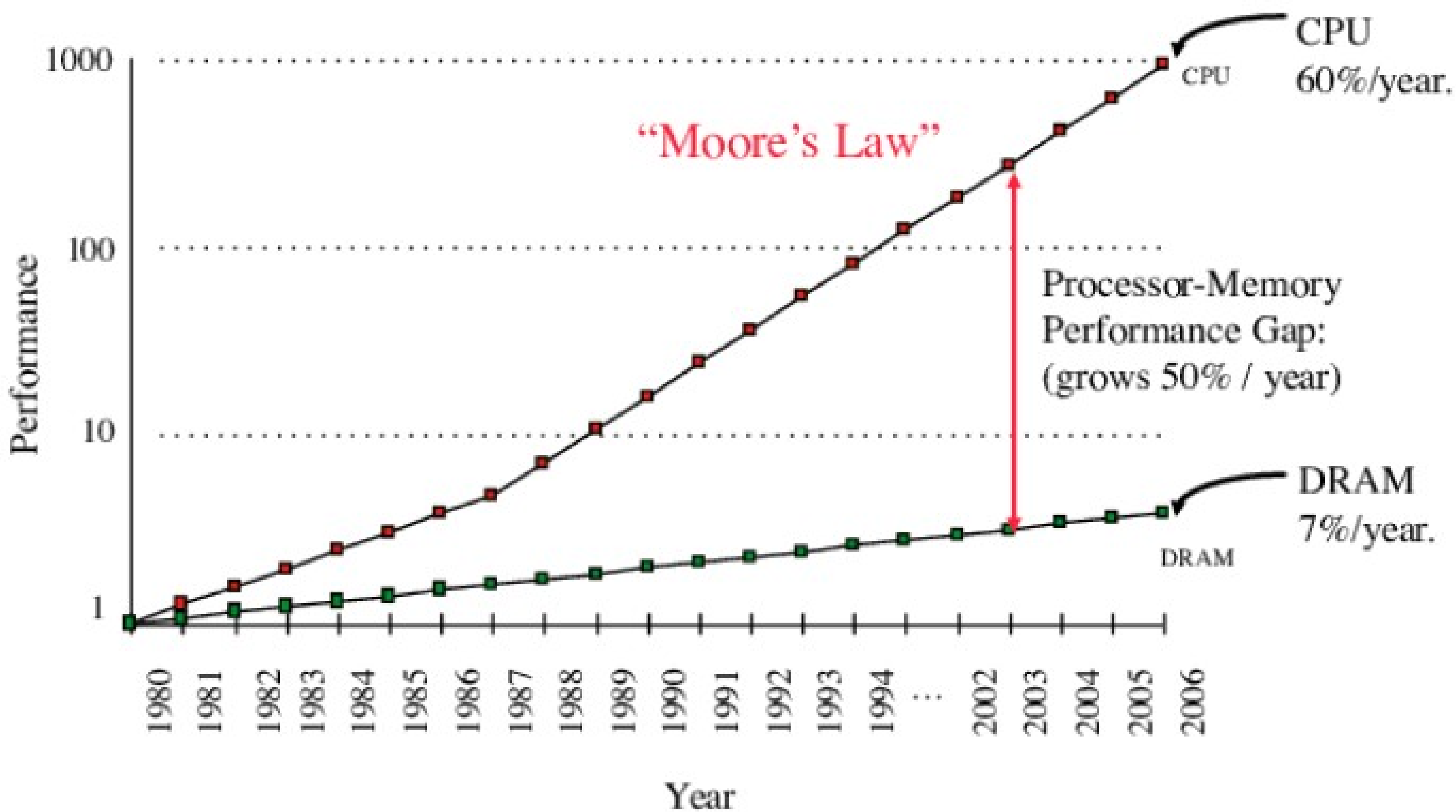
Capacity


Amdahl's Law
Parallel portion
50%
75%
90%
95%
Speedup
0
2
4
6
8
10
12
14
16
18
20
Number of processors
1
2
4
8
16
32
64
128
256
512
1024
2048
4096
8192
16384
32768
65536

Utilization

- Efficient use of a system's resources
- Computationally intensive tasks may have close to 100% CPU utilization but have little memory use
- A common problem today is:
  - CPU performance has increased dramatically
  - Memory performance has not
  - CPUs are idle waiting for memory to catch up moving data in and out of the CPU registers.

Utilization



Memory Access vs CPU Speed

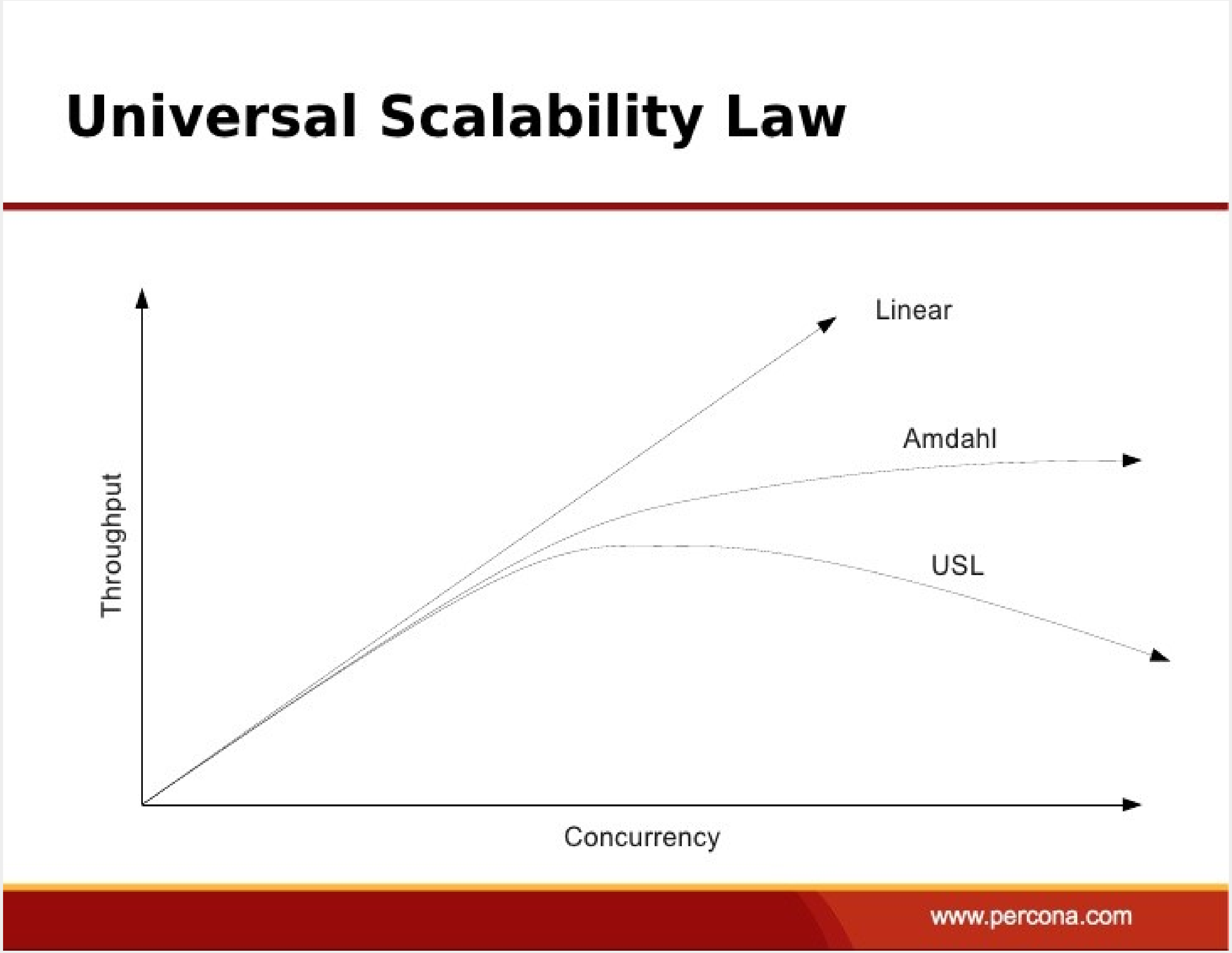
Efficiency

- Overall system efficiency is measured by
  - (throughput)/(utilized resources)
- Essentially making the most use of available resources
- Often used to compute costs of processing

Scalability

- Change in throughput as resources are added
- Ideally, throughput should increase with increase in capacity
- Scalability fails when increased capacity does not produce an increase in throughput

Scalability



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3. **Performance Measurements**
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Performance Tests

- All tests, to be useful must be:
  - **Valid**: We have to actually test what we think we are testing
  - **Accurate**: The results are quantitatively accurate
  - **Reliable**: The results of the tests depend only on the tests and thing being tested
- These properties are true for all testing not just performance testing
  - Generally performance testing is statistical in nature
  - However it is difficult to identify all the contributing factors to the results of the tests
  - Good testing protocols need to be observed

Java Design

- Java performance philosophy
  - raw performance could be sacrificed if developer productivity benefited
  - provided performance was “good enough”
- Managed subsystems
  - low-level control exchanged for managed resources
  - eg. JVM memory management and garbage collection
  - Also provided a safer runtime “sandbox”

JVM Behaviour

- JVM runtime behaviour
  - Very complex – difficult to measure consistently
  - Observed measurements are often not normally distributed
  - Makes statistical analysis difficult – most statistical techniques assume underlying normal distributions
  - Critical measurements are easily missed via sampling
  - Outliers may be significant (“that one weird time that the app crashed”)
- Java performance measures can be misleading
  - We are trying to measure a highly complex set of subsystems
  - May even be non-linear in many aspects
    - *ie. small changes may produce large variations and vice versa*

The Experimenter Effect

- The actual measurement of performance affects performance
  - Measurement has overhead
  - Sampling measurements require resources
  - These resources are the same resources being measured
- This means that any sampling profile
  - Can only be regarded as approximate
  - And is not a true measure of performance.

A Basic Methodology

- Basic Steps
  - Define the desired outcome
  - Measure the existing system
  - Propose a modification that may produce the desired outcome
  - Apply the modification
  - Retest with the modification
  - Decide if the desired outcome has been achieved

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Benchmarking

- Compares two competing pieces of code
  - The code is executed a set number of times
  - Specific metrics are recorded each iteration
  - A final average results is computed
  - The process is repeated with the second piece of code
- Large numbers of repetitions are used
  - Evens out the variation we mentioned earlier
  - Not unsual to use hundreds of thousands of iterations

Profiling

- Looks for bottlenecks in a programs
  - Which methods are called
  - How long each method take to complete
  - Resource bottlenecks
    - *CPU bound – spends time using or waiting for CPU*
    - *IO bound – spends time waiting for or doing I/O*
    - *Memory bound – spends a lot of time paging memory*
  - Average values of data over multiple executions is often used

Module End