CS533
Modeling and Performance Evaluation of Network and Computer Systems

Selection of Techniques and Metrics

(Chapter 3)

Overview

- One or more systems, real or hypothetical
- You want to evaluate their performance
- What technique do you choose?
  - Analytic Modeling?
  - Simulation?
  - Measurement?

Outline

- Selecting an Evaluation Technique
- Selecting Performance Metrics
  - Case Study
- Commonly Used Performance Metrics
- Setting Performance Requirements
  - Case Study

Selecting an Evaluation Technique (1 of 4)

- What life-cycle stage of the system?
  - *Measurement* only when something exists
  - If new, *analytical modeling* or *simulation* are only options
- When are results needed? (often, yesterday!)
  - *Analytic modeling* only choice
  - *Simulations* and *measurement* can be same
    - But Murphy's Law strikes *measurement* more
- What tools and skills are available?
  - Maybe languages to support *simulation*
  - Tools to support *measurement* (ex: packet sniffers, source code to add monitoring hooks)
  - Skills in *analytic modeling* (ex: queuing theory)

Selecting an Evaluation Technique (2 of 4)

- Level of accuracy desired?
  - *Analytic modeling* coarse (if it turns out to be accurate, even the analysts are surprised!)
  - *Simulation* has more details, but may abstract key system details
  - *Measurement* may sound real, but workload, configuration, etc., may still be missing
    - Accuracy can be high to none without proper design
  - Even with accurate data, still need to draw proper conclusions
    - Ex: so response time is 10.2351 with 90% confidence. So what? What does it *mean*?

Selecting an Evaluation Technique (3 of 4)

- What are the alternatives?
  - Can explore trade-offs easiest with *analytic models*, *simulations* moderate, *measurement* most difficult
    - Ex: QFind – determine impact (tradeoff) of RTT and OS
    - Difficult to measure RTT tradeoff
    - Easy to simulate RTT tradeoff in network, not OS
- Cost?
  - *Measurement* generally most expensive
  - *Analytic modeling* cheapest (pencil and paper)
  - *Simulation* often cheap but some tools expensive
    - Traffic generators, network simulators

Selecting an Evaluation Technique (4 of 4)

- Saleability?
  - Much easier to convince people with *measurements*
  - Most people are skeptical of *analytic modeling* results since hard to understand
    - Often validate with simulation before using
- Can use two or more techniques
  - Validate one with another
  - Most high-quality perf analysis papers have analytic model + simulation or measurement

7

Summary Table for Evaluation Technique Selection

Criterion	Modeling	Simulation	Measurement
1. Stage	Any	Any	Prototype+
2. Time required	Small	Medium	Varies
3. Tools	Analysts	Some languages	Instrumentation
4. Accuracy	Low	Moderate	Varies
5. Trade-off evaluation	Easy	Moderate	Difficult
6. Cost	Small	Medium	High
7. Saleabilty	Low	Medium	High

8

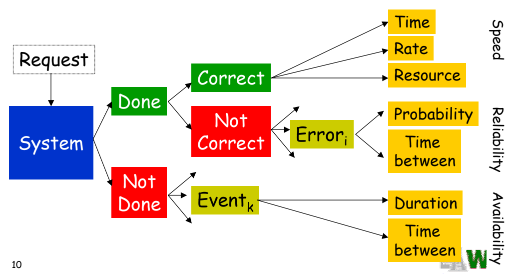
Outline

- Selecting an Evaluation Technique
- Selecting Performance Metrics
  - Case Study
- Commonly Used Performance Metrics
- Setting Performance Requirements
  - Case Study

9

Selecting Performance Metrics (1 of 3)

response time n. *An unbounded, random variable … representing the elapses between the time of sending a message and the time when the error diagnostic is received.* – S. Kelly-Bootle, *The Devil's DP Dictionary*



10

Selecting Performance Metrics (2 of 3)

- *Mean* is what usually matters
  - But *variance* for some (ex: response time)
- Individual vs. Global
  - May be at odds
  - Increase individual may decrease global
    - Ex: response time at the cost of throughput
  - Increase global may not be most fair
    - Ex: throughput of cross traffic
- Performance optimizations of bottleneck have most impact
  - Example: Response time of Web request
  - Client processing 1s, Latency 500ms, Server processing 10s → Total is 11.5 s
  - Improve client 50%? → 11 s
  - Improve server 50%? → 6.5 s

11

Selecting Performance Metrics (3 of 3)

- May be more than one set of metrics
  - Resources: Queue size, CPU Utilization, Memory Use …
- Criteria for selecting subset, choose:
  - Low variability – need fewer repetitions
  - Non redundancy – don't use 2 if 1 will do
    - ex: queue size and delay may provide identical information
  - Completeness – should capture tradeoffs
    - ex: one disk may be faster but may return more errors so add reliability measure

12

Outline

- Selecting an Evaluation Technique
- Selecting Performance Metrics
  - Case Study
- Commonly Used Performance Metrics
- Setting Performance Requirements
  - Case Study

Case Study (1 of 5)

- Computer system of end-hosts sending packets through routers
  - Congestion occurs when number of packets at router exceed buffering capacity (are dropped)
- Goal: compare two congestion control algorithms
- User sends block of packets to destination
  - A) Some delivered in order
  - B) Some delivered out of order
  - C) Some delivered more than once
  - D) Some dropped

Case Study (2 of 5)

- For A), straightforward metrics exist:
  1) Response time: delay for individual packet
  2) Throughput: number of packets per unit time
  3) Processor time per packet at source
  4) Processor time per packet at destination
  5) Processor time per packet at router
- Since large response times can cause extra retransmissions:
  6) Variability in response time since can cause extra retransmissions

Case Study (3 of 5)

- For B), cannot be delivered to user and are often considered dropped
  7) Probability of out of order arrivals
- For C), consume resources without any use
  8) Probability of duplicate packets
- For D), many reasons is undesirable
  9) Probability lost packets
- Also, excessive loss can cause disconnection
  10) Probability of disconnect

Case Study (4 of 5)

- Since a multi-user system and want fairness:
  - Throughputs $(x_1, x_2, \ldots, x_n)$:

    $f(x_1, x_2, \ldots, x_n) = (\Sigma x_i)^2 / (n \Sigma x_i^2)$
- Index between 0 and 1
  - All users get same, then 1
  - If *k* users get equal and *n-k* get zero, than index is *k*/*n*

Case Study (5 of 5)

- After a few experiments (pilot tests)
  - Found *throughput* and *delay* redundant
    - higher throughput had higher delay
    - instead, combine with *power* = thrput/delay
  - Found variance in response time redundant with *probability of duplication* and *probability of disconnection*
    - Drop variance in response time
- Thus, left with nine metrics

Outline

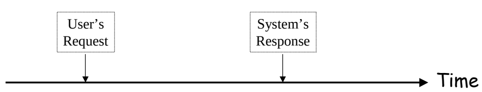
- Selecting an Evaluation Technique
- Selecting Performance Metrics
  - Case Study
- Commonly Used Performance Metrics
- Setting Performance Requirements
  - Case Study

Commonly Used Performance Metrics

- Response Time
  - Turn around time
  - Reaction time
  - Stretch factor
- Throughput
  - Operations/second
  - Capacity
  - Efficiency
  - Utilization
- Reliability
  - Uptime
  - MTTF

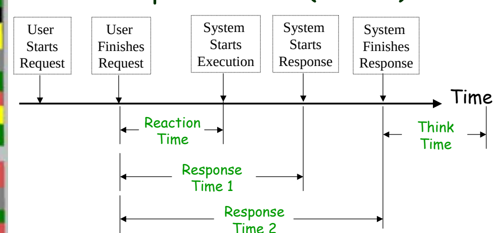
Response Time (1 of 2)

- Interval between user's request and system response



- But simplistic since requests and responses are not instantaneous
  - Users type and system formats

Response Time (2 of 2)



- Can have two measures of response time
  - Both ok, but 2 preferred if execution long
- *Think time* can determine system load

Response Time+

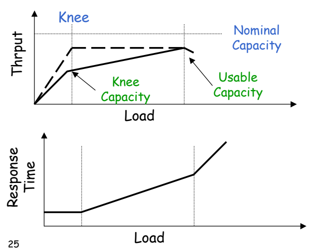
- *Turnaround time* – time between submission of a job and completion of output
  - For batch job systems
- *Reaction time* - Time between submission of a request and beginning of execution
  - Usually need to measure inside system since nothing externally visible
- *Stretch factor* – ratio of response time at load to response time at minimal load
  - Most systems have higher response time as load increases

Throughput (1 of 2)

- Rate at which requests can be serviced by system (requests per unit time)
  - Batch: jobs per second
  - Interactive: requests per second
  - CPUs
    - Millions of Instructions Per Second (MIPS)
    - Millions of Floating-Point Ops per Sec (MFLOPS)
  - Networks: pkts per second or bits per second
  - Transactions processing: Transactions Per Second (TPS)

Throughput (2 of 2)

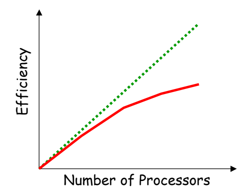
- *Throughput* increases as load increases, to a point



- *Nominal capacity* is ideal (ex: 10 Mbps)
- *Usable capacity* is achievable (ex: 9.8 Mbps)
- *Knee* is where response time goes up rapidly for small increase in throughput

Efficiency

- Ratio of maximum achievable throughput (ex: 9.8 Mbps) to nominal capacity (ex: 10 Mbps) → 98%
- For multiprocessor, ration of *n*-processor to that of one-processor (in MIPS or MFLOPS)



Utilization

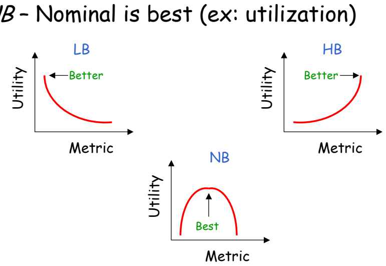
- Typically, fraction of time resource is busy serving requests
  - Time not being used is *idle time*
  - System managers often want to balance resources to have same utilization
    - Ex: equal load on CPUs
    - But may not be possible. Ex: CPU when I/O is bottleneck
- May not be time
  - Processors – busy / total makes sense
  - Memory – fraction used / total makes sense

Miscellaneous Metrics

- *Reliability*
  - Probability of errors or mean time between errors (error-free seconds)
- *Availability*
  - Fraction of time system is available to service requests (fraction not available is *downtime)*
  - Mean Time To Failure (MTTF) is mean uptime
    - Useful, since availability high (downtime small) may still be frequent and no good for long request
- Cost/Performance ratio
  - Total cost / Throughput, for comparing 2 systems
  - Ex: For Transaction Processing system may want Dollars / TPS

Utility Classification

- *HB* – Higher is better (ex: throughput)
- *LB* - Lower is better (ex: response time)
- *NB* – Nominal is best (ex: utilization)



Outline

- Selecting an Evaluation Technique
- Selecting Performance Metrics
  - Case Study
- Commonly Used Performance Metrics
- Setting Performance Requirements
  - Case Study

Setting Performance Requirements (1 of 2)

- *The system should be both processing and memory efficient. It should not create excessive overhead*
- *There should be an extremely low probability that the network will duplicate a packet, deliver it to a wrong destination, or change the data*
- What's wrong?

31

Setting Performance Requirements (2 of 2)

- General Problems
  - *Nonspecific* – no numbers. Only qualitative words (rare, low, high, extremely small)
  - *Nonmeasureable* – no way to measure and verify system meets requirements
  - *Nonacceptable* – numbers based on what sounds good, but once setup system not good enough
  - *Nonrealizable* – numbers based on what sounds good, but once started are too high
  - *Nonthorough* – no attempt made to specify all outcomes

32

Setting Performance Requirements: Case Study (1 of 2)

- Performance for high-speed LAN
- Speed – if packet delivered, time taken to do so is important
  - A) Access delay should be less than 1 sec
  - B) Sustained throughput at least 80 Mb/s
- Reliability
  - A) Prob of bit error less than 10^{-7}
  - B) Prob of frame error less than 1%
  - C) Prob of frame error not caught 10^{-15}
  - D) Prob of frame miss-delivered due to uncaught error 10^{-18}
  - E) Prob of duplicate 10^{-5}
  - F) Prob of losing frame less than 1%

33

Setting Performance Requirements: Case Study (2 of 2)

- Availability
  - A) Mean time to initialize LAN < 15 msec
  - B) Mean time between LAN inits > 1 minute
  - C) Mean time to repair < 1 hour
  - D) Mean time between LAN partitions > ½ week
- All above values were checked for realizeability by modeling, showing that LAN systems satisfying the requirements were possible

34