BSM 420 – BİLGİSAYAR MİMARİLERİ

Modeling and Performance Evaluation of Network and Computer Systems

Let’s Get Started!

- Describe a performance study you have done
  - Work or School or …
- Describe a performance study you have recently read about
  - Research paper
  - Newspaper article
  - Scientific journal
- And list one good thing or one bad thing about it

Outline

- Objectives (next)
- The Art
- Common Mistakes
- Systematic Approach
- Case Study

Objectives (1 of 6)

- Select appropriate evaluation *techniques*, performance *metrics* and *workloads* for a system.
  - Techniques: measurement, simulation, analytic modeling
  - Metrics: criteria to study performance (ex: response time)
  - Workloads: requests by users/applications to the system
- Example: What performance metrics should you use for the following systems?
  - a) Two disk drives
  - b) Two transactions processing systems
  - c) Two packet retransmission algorithms

Objectives (2 of 6)

- Conduct performance measurements correctly
  - Need two tools: *load generator* and *monitor*
- Example: Which workload would be appropriate to measure performance for the following systems?
  - a) Utilization on a LAN
  - b) Response time from a Web server
  - c) Audio quality in a VoIP network

Objectives (3 of 6)

- Use proper statistical techniques to compare several alternatives
  - One run of workload often not sufficient
    - Many non-deterministic computer events that effect performance
  - Comparing average of several runs may also not lead to correct results
    - Especially if variance is high
- Example: Packets lost on a link. Which link is better?

File Size	Link A	Link B
1000	5	10
1200	7	3
1300	3	0
50	0	1

Objectives (4 of 6)

- Design measurement and simulation experiments to provide the most information with the least effort.
  - Often many factors that affect performance. Separate out the effects that individually matter.
- Example: The performance of a system depends upon three factors:
  - A) garbage collection technique: G1, G2 none
  - B) type of workload: editing, compiling, AI
  - C) type of CPU: P2, P4, Sparc

  How many experiments are needed? How can the performance of each factor be estimated?

Objectives (5 of 6)

- Perform simulations correctly
  - Select correct language, seeds for random numbers, length of simulation run, and analysis
  - Before all of that, may need to validate simulator
- Example: To compare the performance of two cache replacement algorithms:
  - A) how long should the simulation be run?
  - B) what can be done to get the same accuracy with a shorter run?

Objectives (6 of 6)

- Use simple queuing models to analyze the performance of systems.
- Often can model computer systems by service rate and arrival rate of load
  - Multiple servers
  - Multiple queues
- Example:
  - For a given Web request rate, is it more effective to have 2 single-processor Web servers or 4 single-processor Web servers?

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The *Art* of Performance Evaluation

- Evaluation cannot be produced mechanically
  - Requires intimate knowledge of system
  - Careful selection of methodology, workload, tools
- No one correct answer as two performance analysts may choose different metrics or workloads
- Like art, there are techniques to learn
  - how to use them
  - when to apply them

Example: Comparing Two Systems

- Two systems, two workloads, measure transactions per second

System	Work-load 1	Work-load 2
A	20	10
B	10	20

- Which is better?

Example: Comparing Two Systems

- Two systems, two workloads, measure transactions per second

System	Work-load 1	Work-load 2	Average
A	20	10	15
B	10	20	15

- They are equally good!
- … but is A better than B?

The Ratio Game

- Take system B as the base

System	Work-load 1	Work-load 2	Average
A	2	0.5	1.25
B	1	1	1

- A is better!
- … but is B better than A?

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- The Art (done)
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Common Mistakes (1 of 3)

- Undefined Goals
  - There is no such thing as a general model
  - Describe goals and then design experiments
  - (Don’t shoot and then draw target)
- Biased Goals
  - Don’t show YOUR system better than HERS
  - (Performance analysis is like a jury)
- Unrepresentative Workload
  - Should be representative of how system will work “in the wild”
  - Ex: large and small packets? Don’t test with only large or only small

Common Mistakes (2 of 3)

- Wrong Evaluation Technique
  - Use most appropriate: model, simulation, measurement
  - (Don’t have a hammer and see everything as a nail)
- Inappropriate Level of Detail
  - Can have too much! Ex: modeling disk
  - Can have too little! Ex: analytic model for congested router
- No Sensitivity Analysis
  - Analysis is *evidence* and not fact
  - Need to determine how sensitive results are to settings

Common Mistakes (3 of 3)

- Improper Presentation of Results
  - It is not the number of graphs, but the number of graphs that help make decisions
- Omitting Assumptions and Limitations
  - Ex: may assume most traffic TCP, whereas some links may have significant UDP traffic
  - May lead to applying results where assumptions do not hold

Outline

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- The Art (done)
- Common Mistakes (done)
- Systematic Approach (next)
- Case Study

A Systematic Approach

1. State goals and define boundaries
2. Select performance metrics
3. List system and workload parameters
4. Select factors and values
5. Select evaluation techniques
6. Select workload
7. Design experiments
8. Analyze and interpret the data
9. Present the results. Repeat.

State Goals and Define Boundaries

- Just "measuring performance" or "seeing how it works" is too broad
  - Ex: goal is to decide which ISP provides better throughput
- Definition of system may depend upon goals
  - Ex: if measuring CPU instruction speed, system may include CPU + cache
  - Ex: if measuring response time, system may include CPU + memory + … + OS + user workload

Select Metrics

- Criteria to compare performance
- In general, related to speed, accuracy and/or availability of system services
- Ex: network performance
  - Speed: throughput and delay
  - Accuracy: error rate
  - Availability: data packets sent do arrive
- Ex: processor performance
  - Speed: time to execute instructions

List Parameters

- List all parameters that affect performance
- System parameters (hardware and software)
  - Ex: CPU type, OS type, …
- Workload parameters
  - Ex: Number of users, type of requests
- List may not be initially complete, so have working list and let grow as progress

Select Factors to Study

- Divide parameters into those that are to be studied and those that are not
  - Ex: may vary CPU type but fix OS type
  - Ex: may fix packet size but vary number of connections
- Select appropriate levels for each factor
  - Want typical and ones with potentially high impact
  - For workload often smaller (1/2 or 1/10th) and larger (2x or 10x) range
  - Start small or number can quickly overcome available resources!

Select Evaluation Technique

- Depends upon time, resources and desired level of accuracy
- Analytic modeling
  - Quick, less accurate
- Simulation
  - Medium effort, medium accuracy
- Measurement
  - Typical most effort, most accurate
- Note, above are all typical but can be reversed in some cases!

Select Workload

- Set of service requests to system
- Depends upon measurement technique
  - Analytic model may have probability of various requests
  - Simulation may have trace of requests from real system
  - Measurement may have scripts impose transactions
- Should be representative of real life

Design Experiments

- Want to maximize results with minimal effort
- Phase 1:
  - Many factors, few levels
  - See which factors matter
- Phase 2:
  - Few factors, more levels
  - See where the range of impact for the factors is

Analyze and Interpret Data

- Compare alternatives
- Take into account variability of results
  - Statistical techniques
- Interpret results.
  - The analysis does not provide a conclusion
  - Different analysts may come to different conclusions

Present Results

- Make it easily understood
- Graphs
- Disseminate (entire methodology!)

"The job of a scientist is not merely to see: it is to see, understand, and communicate. Leave out any of these phases, and you're not doing science. If you don't see, but you do understand and communicate, you're a prophet, not a scientist. If you don't understand, but you do see and communicate, you're a reporter, not a scientist. If you don't communicate, but you do see and understand, you're a mystic, not a scientist."

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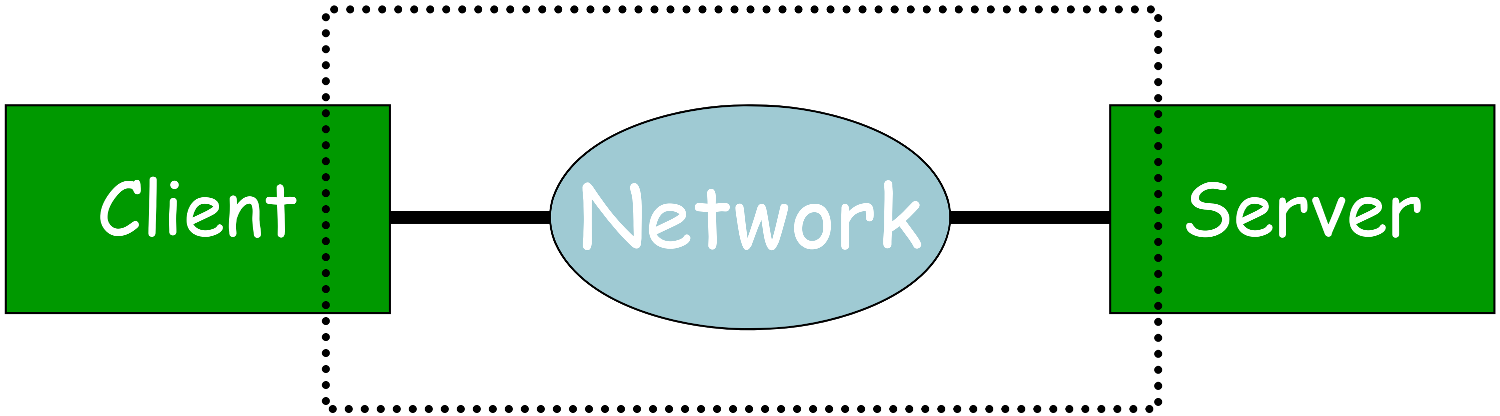
Case Study

- Consider remote pipes (rpipe) versus remote procedure calls (rpc)
  - rpc is like procedure call but procedure is handled on remote server
    - Client caller blocks until return
  - rpipe is like pipe but server gets output on remote machine
    - Client process can continue, non-blocking
- Goal: study the performance of applications using rpipes to similar applications using rpcs

System Definition

- Client and Server and Network
- Key component is “channel”, either a rpipe or an rpc
  - Only the subset of the client and server that handle channel are part of the system



- Try to minimize effect of components outside system

Services

- There are a variety of services that can happen over a rpipe or rpc
- Choose data transfer as a common one, with data being a typical result of most client-server interactions
- Classify amount of data as either large or small
- Thus, two services:
  - Small data transfer
  - Large data transfer

Metrics

- Limit metrics to correct operation only (no failure or errors)
- Study service rate and resources consumed

A) elapsed time per call

B) maximum call rate per unit time

C) Local CPU time per call

D) Remote CPU time per call

E) Number of bytes sent per call

Parameters

System

- Speed of CPUs
  - Local
  - Remote
- Network
  - Speed
  - Reliability (retrans)
- Operating system overhead
  - For interfacing with channels
  - For interfacing with network

Workload

- Time between calls
- Number and sizes
  - of parameters
  - of results
- Type of channel
  - rpc
  - Rpipe
- Other loads
  - On CPUs
  - On network

Key Factors

- Type of channel
  - rpipe or rpc
- Speed of network
  - Choose short (LAN) across country (WAN)
- Size of parameters
  - Small or larger
- Number of calls
  - 11 values: 8, 16, 32 …1024
- All other parameters are fixed
- (Note, try to run during "light" network

Evaluation Technique

- Since there are prototypes, use measurement
- Use analytic modeling based on measured data for values outside the scope of the experiments conducted

Workload

- Synthetic program generated specified channel requests
- Will also monitor resources consumed and log results
- Use “null” channel requests to get baseline resources consumed by logging
  - (Remember the Heisenberg principle!)

Experimental Design

- Full factorial (all possible combinations of factors)
- 2 channels, 2 network speeds, 2 sizes, 11 numbers of calls
  - → 2 x 2 x 2 x 11 = 88 experiments

Data Analysis

- Analysis of variance will be used to quantify the first three factors
  - Are they different?
- Regression will be used to quantify the effects of n consecutive calls
  - Performance is linear? Exponential?