

COMP9334: Capacity Planning of Computer Systems and Networks

Course Review



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System performance is important

- Performance metrics: response time, waiting time, throughput, availability
- Performance is determined by:
 - Workload
 - System parameters
- You can estimate system performance, without building the actual system, by using queueing models

Performance analysis techniques (1)

- Operational analysis (1B,2A)
 - Measurements on the systems
 - Operational laws, in particular Little's Law
 - Key concept: Bottleneck
 - Upper bound on system performance

Performance analysis techniques (2)

- Need to identify the inter-arrival and service time distributions
- Queues with Poisson arrival
 - Exponential service time (2B,3A)
 - Single or multiple servers: $M/M/1$ versus $M/M/m$
 - Infinite buffer or finite buffer: $M/M/m$ versus $M/M/m/m+k$
 - General service time distribution (4A,4B)
 - $M/G/1$. Key concept: residual service time
 - Priority queueing

Performance analysis techniques (3)

- Closed queueing networks with exponential service time
 - Markov chain analysis (Week 3B)
 - Recipe: Identify state, transition probability, solve steady state probability, determine performance
 - Mean value analysis (Week 5B)
 - Iterative method
 - $n = 0$ jobs $\rightarrow n = 1$ job $\rightarrow n = 2$ jobs $\rightarrow \dots$

Performance analysis techniques: some key points

- No universal analytical methods
 - Analytical solutions are only available for specific classes of queues
 - Upper bounds are only available for some general classes of queues
- Simulation can be used to determine general queueing problems

Simulation (1)

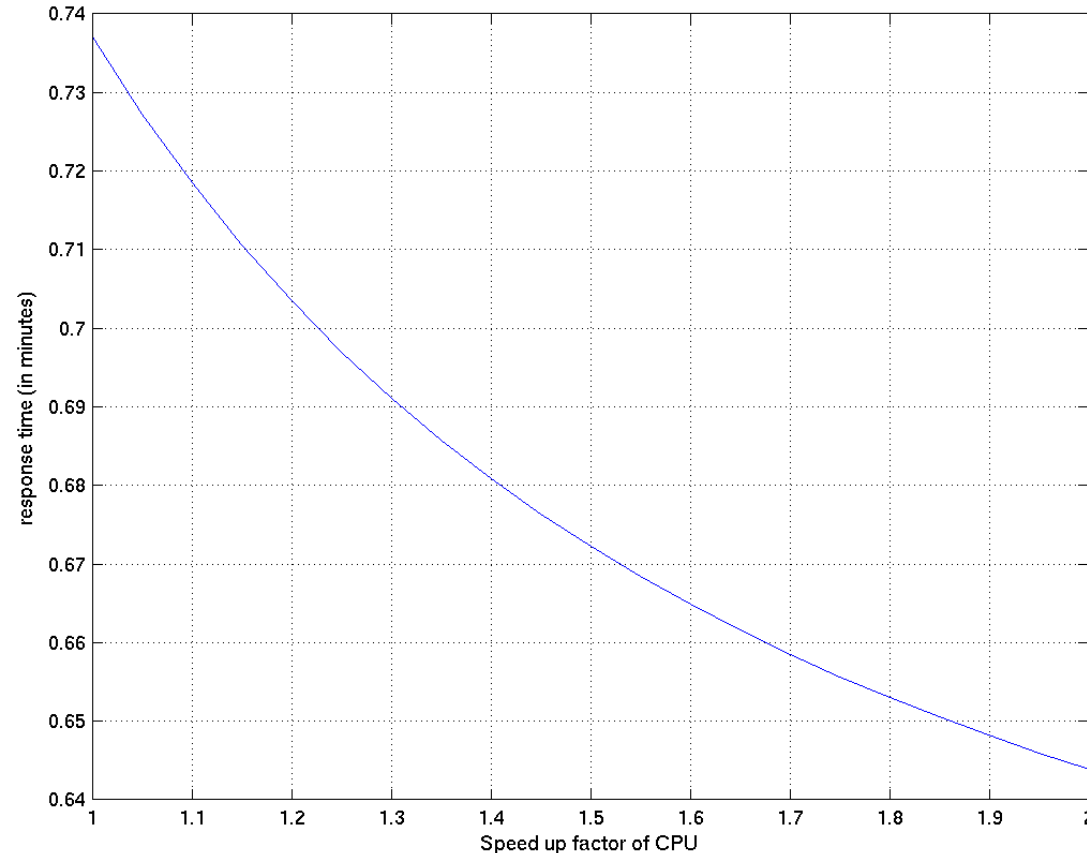
- How to do discrete event simulation?
- How to generate random events according to the specific inter-arrival time and service time distributions
 - Generating uniformly distributed pseudo-random numbers
 - Inverse transformation method

Simulation (2)

- Simulation is not just about writing correct simulation code (though it is important), it is also important to do sound statistical analysis on the simulation results obtained
- Transient removal
- Independent replications
- Confidence interval
- How to decide whether one system is better than the other using confidence interval?
 - Paired observations: Paired- t confidence interval
 - Approximate visual test
- Variance reduction method

Capacity planning and performance analysis

- Solve the capacity planning problem by solving a number of performance analysis problems
- Example: Revision Problem: Week 3B, Question2



Applications of queueing (6B_2,7A)

- Web services
 - Fork-join queues
- Other applications
 - Determining a good multi-programming level
 - Power allocation in server farm
 - Server farm with set-up cost

Integer programming (1)

- Linear programming (LP)
 - Real values for decision variables, linear in objective function, linear in constraints
- Integer programming (IP)
 - Some decision variables can only take integer values
 - Some decision variables can only take binary values, e.g. for making yes-or-no decisions

Integer programming (2)

- Applications of integer programming in network flow problems
 - Flow conservation constraints to ensure a unique path between two nodes in the network
- Example applications
 - Traffic engineering
 - Network design

Integer programming (3)

- Applications of integer programming in placement problems
 - Placement of wireless access points
 - Placement of controllers in software-defined networks (revision problem)
- Power of binary variables
 - Restricted range of values
 - Either-or constraints
 - Piecewise linear functions

Summary

- What you have learned through this course are fundamental techniques that can be applied to designing computer systems and networks to have good performance
 - We hope you have gained some skills from this course
 - We hope you have been trained to be **performance-minded**
- Due to the limited time and scope of this course, we cannot cover all techniques that have been developed in this field
- However, with the knowledge you have acquired from this course, you should have the foundation to learn more ...
- Mathematical methods can be applied to many different areas

Final exam

- Please check timetable to confirm date/time/venue
 - 2 hours + 10 minutes reading
- Open book
 - No programming questions
 - No extensive computation
 - Give away: Materials in Week 6B_2 will not be examined.
- Question style similar to revision problems and assignment
 - Testing your understanding, not memorization
- Format
 - Answer 5 out of 6 questions
 - Each question can have multiple parts

Final exam (cont.)

- Show all equations, calculations and steps involved in problems
 - If you just write the final answer, you won't receive full marks even if it is correct
 - You may receive partial marks even if the final answer is incorrect
- What to bring
 - You must bring your own student ID, calculator, pencils, and erasers
 - You can bring textbook, lecture notes, handwritten/typed notes, sample problems/solutions, assignment problems/solutions
 - No electronics equipment (e.g. laptops, tablets) and watches are allowed

Preparations for final exam

- Make sure you understand all the concepts, techniques and examples discussed in the lectures
- **Work** through all the sample problems, assignment questions, etc for practice
- Misconception: Open-book exam means no preparation required
- Consultations: See course website under Timetable
- Further questions
 - Post on Forum (Try to avoid last minute questions.)

Exam policy

- Important for you to read the CSE policy on exam: [Click here](#).
- In particular, if you attend the exam, we assume that you are functioning well on that day and will not offer you a supplementary exam.
- In case you are not well on the day of the exam, get a medical certificate and do not attend the exam.

Parting messages

- Please complete the **myExperience** survey
 - Good/bad/more of this/less of that/what can be done better
- This course is different from many CSE courses ..
- Analytical and simulation methods are useful for many disciplines
- This world needs people with multiple skills (hard and soft). Important to find your talents and passions, but try to explore and learn as many different areas as you can.