

# **ECSE-4963: Experimental Networking**

## **Exam 1: SOLUTIONS**

**Time: 75 min (strictly enforced)**

**Points: 50**

**YOUR NAME:**

***Be brief, but DO NOT omit necessary detail***

{Note: Simply copying text directly from the slides or notes will not earn (partial) credit. Brief, clear and consistent explanation will.}

1. [12 pts] {Use of a spreadsheet is OK}

Given:  $n=7$  random RTT samples (in ms):

{37, 26, 29, 42, 38, 25, 100}

- [7 points] Find: sample mean ( $\bar{x}$ ), sample standard deviation ( $s$ ), 90% confidence interval (CI) & 95% CI for the *population* mean

$$\bar{x} = 1/7 \{37 + 26 + 29 + 42 + 38 + 25 + 100\} = \underline{\underline{42.717}}$$

$$s^2 = 1/(7-1) \{ (37-42.717)^2 + (26-42.717)^2 + (29-42.717)^2 + (42-42.717)^2 + (38-42.717)^2 + (25-42.717)^2 + (100-42.717)^2 \} = 686.29$$
$$\Rightarrow \underline{\underline{s = 26.197}}$$

Since we have only 7 samples, we cannot use normal distribution, but need to use the t distribution (not the z-distribution!) with  $n-1 = 6$  degrees of freedom

**90% CI:**  $\bar{x} \pm t_{[1-0.1/2; 6]} s/(n)^{0.5}$   
 $= 42.717 \pm 1.943 * 26.197/(7)^{0.5} = \underline{\underline{[23.47, 61.96]}}$

**95% CI:** Use  $t_{[0.975; 6]}$  :  $42.717 \pm 2.447 * 26.197/(7)^{0.5} = \underline{\underline{[18.486, 66.95]}}$

*Observe that the 95% CI is wider. If you had used z-tables (wrong in this case), you will have obtained a tighter CI...*

[5 points] Discuss the impact of the outlier on the confidence intervals after you re-compute the 95% CI if the outlier value 100 were 35 instead.

$$\bar{x} = 1/7 \{37 + 26 + 29 + 42 + 38 + 25 + 35\} = \underline{\underline{33.143}}$$

$$s^2 = 42.476 \quad \Rightarrow \underline{\underline{s = 6.517}}$$

**95% CI:** Use  $t_{[0.975; 6]}$  :  $33.143 \pm 2.447 * 6.517/(7)^{0.5} = \underline{\underline{[27.11, 39.17]}}$

*Observe that this CI is 75% smaller than the CI with the outlier. Outlier has more impact on the sample variance than on the sample mean.*

2. [13 pts] **BRIEFLY**, what is the difference between:

- a) “normal quartile-quartile plot” vs. “scatter plot” [2 pts]  
quartile-quartile plot plots the observed quartile ( $y_{(i)}$ ) vs. the theoretical quartile ( $x_i$ ). A linear plot suggests that the observations follow the assumed distribution. Thus it tries to match the CDF while a scatter plot tries to match the pdf.
- b) “CDF” vs. “CCDF” [2 pts]  
CDF plots  $F(x)$  ( $= \Pr(X \leq x)$ ) vs.  $x$  while CCDF plots  $\log(1 - F(x))$  vs.  $\log(x)$ .
- c) “Bernoulli r.v.” vs. “binomial r.v.” [2pts]  
Bernoulli R.V. is an outcome of a binary random experiment while Binomial R.V. is the sum of outcomes of ‘n’ Bernoulli trials.
- d) “R-squared” vs. “SST” vs. variance [2pts]  
SST is total variation of the given sample of size n, R-squared is ‘explained variation/total variation’ and Variance is ‘total variation/(n-1)’.

**Explain succinctly: [5pts]**

- i) What is a sampling distribution and central limit theorem? What are its important implications for statistical inference? [2.5 pts]  
Sampling distribution is the distribution of sample mean. From CLT, sampling distribution is Normal with decreasing dispersion. ( $\bar{x} \sim N(\mu, s/\sqrt{n})$ ).
- i) Explain the connection between regression and experiment design? How is experiment design related to Amdahl’s law in the design process?[2.5 pts]  
Regression models the variations while Experiment design explains the variations and points out the common case (s) which need to be addressed according to Amdahl’s law.

## II. [10 pts] Experiment Design: Analyze the 2<sup>3</sup> design

- Quantify all the main effects and all interactions [4 pts]
- Quantify percentages of variations explained. [3 pts]
- Sort the variables in the order of decreasing importance. Interpret the result and the implications for potential design changes. [3 pts]

	<b>A1</b>		<b>A2</b>	
	<b>C1</b>	<b>C2</b>	<b>C1</b>	<b>C2</b>
<b>B1</b>	<b>150</b>	<b>40</b>	<b>95</b>	<b>50</b>
<b>B2</b>	<b>30</b>	<b>20</b>	<b>30</b>	<b>35</b>

# Full Factorial Sign Table

I	A	B	C	AB	AC	BC	ABC	y
1	-1	-1	-1	1	1	1	-1	150
1	1	-1	-1	-1	-1	1	1	95
1	-1	1	-1	-1	1	-1	1	30
1	1	1	-1	1	-1	-1	-1	30
1	-1	-1	1	1	-1	-1	1	40
1	1	-1	1	-1	1	-1	-1	50
1	-1	1	1	-1	-1	1	-1	20
1	1	1	1	1	1	1	1	35
450	30	-220	-160	60	80	150	-50	Total
56.25	3.75	-27.5	-20	7.5	10	18.75	-6.25	Total/8

- $SST = 2^3 (3.75^2 + 27.5^2 + 20^2 + 7.5^2 + 10^2 + 18.75^2 + 6.25^2) = 13737.48$
- Portion of variation explained by seven effects are:
  - A:  $8 * 3.75^2 / 13737.48 = 0.82 \%$ , B: 44 %, C: 23.3 %,
    - AB: 3.28 %, AC: 5.8 %,
      - BC: 20.47 %, ABC: 2.28 %
- Order: B, C, BC, AC, AB, ABC, A
- Factors B, C and interaction BC account for ~ 90% of variations. Factor A does not play major role in the design process.

- I. **[15 pts] DESIGN WALK-THROUGH:** We learnt about animation, simulation (ns-2), and graphing, tracing/profiling and experiment design. Assume that you are given a novel design for TCP that improves **BOTH** its congestion control (by changing the increase/decrease algorithm) and its reliability mechanisms (eg: by adding forward error correction in addition to regular retransmissions).
- II. **What** are the “parameters” and “metrics” (and graphs) you would use to study if this design “improvement” is indeed a wise one? Argue **why** your set of metrics and parameters is a complete and meaningful set. How would you interpret your metrics/graphs to disentangle the reliability issues from the congestion control issues? [6 pts]

Parameters : Retransmissions, stability (time to reach steady state)

Metrics : Throughput, goodput, delay variations, (bottleneck) link utilization

Tradeoffs : FEC overhead vs. goodput improvement

# retransmissions vs. time and Congestion window vs. time serve to disentangle reliability issues from congestion control issues.

- I. What set of workloads would you use to test such a system and explain why they are meaningful, and helps you make quick progress in your evaluation process. [4 pts]

Workloads : Mix of TCP and UDP traffic over lossy/bottleneck links;

Lossy/congested links are two ways to “stress” the resilience mechanisms.

Various forms of TCP/UDP workloads are representative of a majority of legacy applications – we would like to study the impact/performance-gains of the new design on these applications...

Walk me through how you would systematically use the above tools (in the right sequence) to pinpoint problems and incrementally refine your design. What are the pluses & minuses of each technique? [5 pts]

Use ns-2, animation and graphing tools to validate the behavior and study the tradeoffs. Evaluate impact of FEC codes and window increase/decrease parameters on goodput variations for various topologies using Experiment Designer. Refine the design using feedback.