CSE400 Project Scribe - Milestone 2

Group 3
Namyaa Parmar
Tirth Pathar
Khushi Paghadar
Ansh Chaudhari
Abbas Kharodawala

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Scribe Question 1: Project System and Objective

Probabilistic Problem: The project addresses the probabilistic modelling and performance analysis of packet delay within a single router network. It focuses on how random fluctuations in data traffic impact the efficiency of the system.

System Objective: The objective is to analyze the router's performance by modeling it as an $M/M/1$ queue to understand the relationship between arrival rates, service rates, and total delay.

Primary Sources of Uncertainty:

- **Inter-arrival Time (A):** The specific timing between consecutive packet arrivals is random and unknown.
- **Service Time (S):** The time required for the router to process each packet is variable and modeled as a random variable.

Scribe Question 2: Key Random Variables and Uncertainty Modeling

Key Random Variables:

- **Inter-arrival Time (A):** Modeled using an Exponential distribution where $A \sim \text{Exponential}(\lambda)$ and $E[A] = 1/\lambda$.
- **Service Time (S):** Modeled using an Exponential distribution where $S \sim \text{Exponential}(\mu)$ and $E[S] = 1/\mu$.
- **Queue Length (L or N):** Represents the number of packets in the system (waiting and being served).
- **Total Delay (D):** Defined as the sum of wait time in the queue (W) and service time (S).

Probabilistic Assumptions:

- **Poisson Process:** Packet arrivals are assumed to follow a Poisson process, where the number of arrivals $N(t) \sim \text{Poisson}(\lambda t)$.
- **Stability Condition:** The system is assumed to be stable, meaning the traffic intensity $\rho = \lambda/\mu$ must satisfy $\lambda < \mu$.

Scribe Question 3: Probabilistic Reasoning and Dependencies

Probabilistic Relationships and Reasoning:

- **Little's Law:** The system connects arrival rate, delay, and queue size via the relationship $L = \lambda \times E[D]$.
- **System Capacity Reasoning:** Average delay is calculated as $E[D] = 1/(\mu - \lambda)$. This allows reasoning that as spare capacity $(\mu - \lambda)$ decreases, delay grows non-linearly.
- **Tail Probability Reasoning:** To support decision-making regarding reliability, the project uses:
  - **Markov Inequality:** $P(D \geq t) \leq E[D]/t$ for a loose, worst-case bound.
  - **Chernoff Bound:** $P(D \geq t) \leq e^{-(\mu-\lambda)t}$, which uses the moment generating function (MGF) to provide a tighter bound for rare events.