Faculty of Engineering of the University of Porto

Homework 03

Ambiguity and Architectural Questions

M.EIC010 - Software Systems Architecture

1MEIC03 - T32

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Introduction

This assignment asks us to become the architects of a traffic signal control system, which detects oncoming traffic and changes traffic signals to optimize traffic flow.

As architects, we have the task of translating this vision into a concrete reality - but before diving into the technical depths, we need the expertise of the analysts behind this task to clarify its requirements, so we can ensure our system meets the needs and expectations of its users: drivers, pedestrians, and the environment alike.

For this assignment, we will start by presenting the analysts with questions focused on the requirements without any order.

Then, those will be logically grouped into topics and separated temporally as to when the questions need an answer.

Finally, five questions will be focused on being particularly important for the system, as they may change the fundamental architecture or may have very significant effects on the end users.

Part 1 - Unraveling the Requirements

From our understanding of the assignment, as well as our expertise and experience, we have come up with the following questions, without any particular order, for the analysts:

1. How many radars do we need? 1 per traffic light, 1 per direction, 1 per lane?
2. How should we deal with intersections? Traffic lights in opposite directions should be in the same state (green or red)?
3. What is the contingency plan for system outages or failures?
4. Should we give priority to streets with more traffic volume? So that we can ease the traffic congestion
5. What metrics will we use to define "optimized traffic flow"? (e.g., minimize wait times, maximize throughput, prioritize specific vehicle types)
6. What specific types of vehicles will the system consider during optimization? (e.g., cars, buses, bicycles)
7. How will we handle conflicting priorities during optimization? (e.g., prioritize emergency vehicles while minimizing overall wait times)
8. How will the system balance optimizing for different travel modes? (e.g., cars vs. public transport)
9. Will the system adapt to different traffic patterns throughout the day and week? (e.g.,

rush hour, weekends, events)

10. How will the system account for road closures, accidents, and other disruptions?
11. What safety measures will be in place to prevent collisions due to sudden signal changes? (e.g., minimum green times, yellow light extensions)
12. What types of sensors will be used to detect oncoming traffic? (e.g., cameras, radar)
13. What is the expected range and accuracy of these sensors?
14. How will the system handle occlusions and adverse weather conditions? (e.g., rain, snow, fog)
15. What is the latency between data acquisition and signal change? (e.g., for safety and responsiveness)
16. What is the computational demand of processing real-time traffic data? (e.g., edge computing vs. centralized processing)
17. What data security measures are needed to protect against unauthorized access?
18. What specific AI algorithms will be used for traffic flow optimization? (e.g., reinforcement learning, neural networks)
19. How will the AI model be trained? (e.g., historical data)
20. How will the AI model be updated over time? (e.g., real-time feedback)
21. How will we ensure the transparency and fairness of the AI decision-making process?
22. What safeguards will be in place to prevent unintended consequences of AI-driven decisions?
23. How will the system be integrated with existing traffic management infrastructure? (e.g., existing traffic lights, communication protocols)
24. What is the scalability of the system? (do nearby systems interact with each other?)
25. What is the proposed timeline for development and deployment?
26. What are the expected lifespan and maintenance requirements for the system?
27. How will the system optimize the conflict between pedestrians waiting and traffic trying to flow?

Part 2 - Visually Exploring Requirements

The success of our system hinges on addressing the right questions at the right time. This part of the assignment visualizes the questions along two dimensions: topic and timeframe. By mapping them onto a "spiderweb" of time, we identify questions that need immediate attention and those that can be addressed later in the development cycle. This strategic methodology guarantees that, as architects, we possess a comprehensive understanding not only of the system's **eventual** functionality but also its **evolution** over time, and how to maximize it by prioritizing some features.

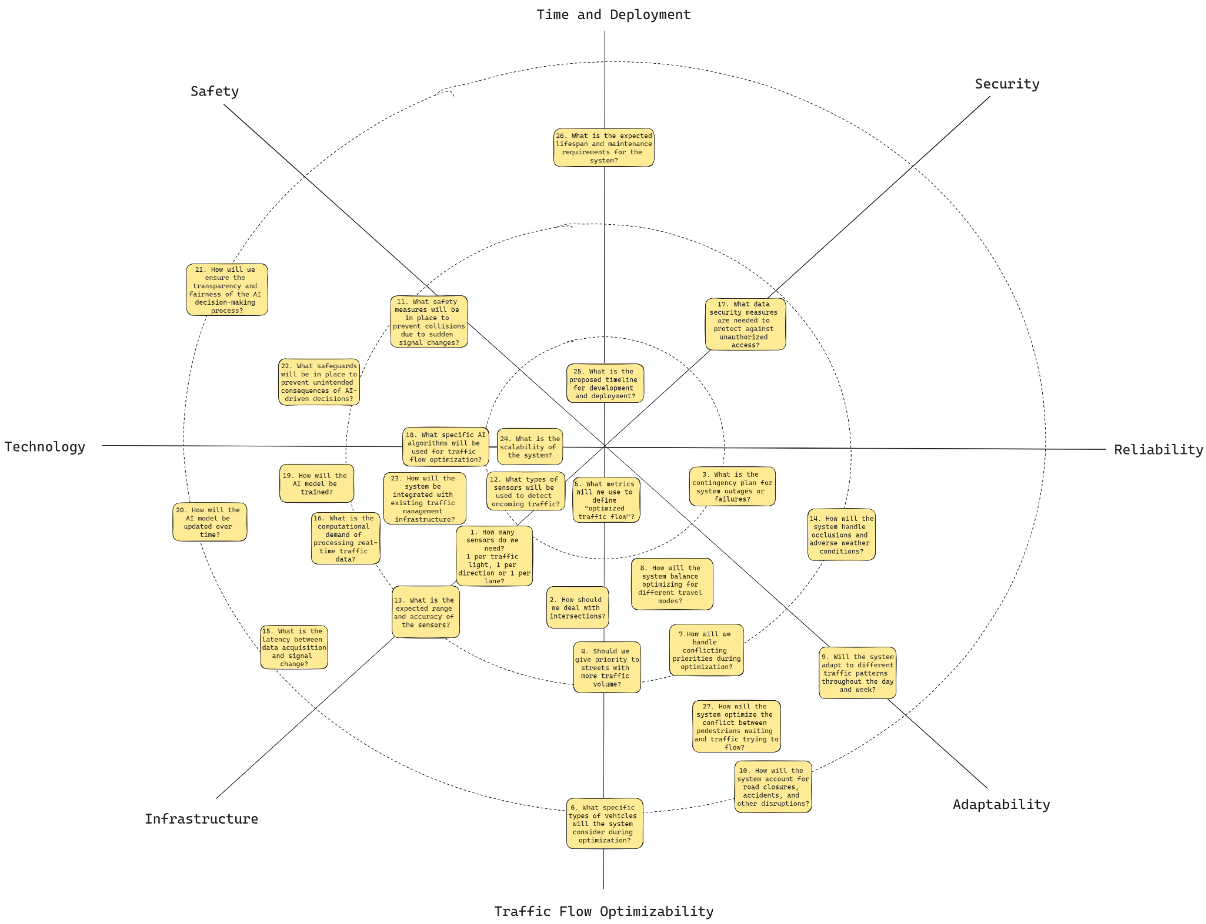

Figure 1. Exploring the requirements with a spiderweb

Description of the Selected Topics:

- **Time and Deployment:** This topic focuses on scheduling and planning the deployment of the traffic signal control system. It involves determining timelines for development, testing, and implementation to ensure timely deployment without disrupting existing traffic patterns excessively.
- **Security:** Pertains to protect the traffic signal control system from unauthorized access, tampering, or malicious attacks. Security includes safeguarding data transmission, ensuring system integrity, and implementing authentication mechanisms to prevent unauthorized control.
- **Reliability:** Reliability concerns the system's ability to perform consistently and

accurately over time. This involves designing redundancies, fail-safes, and error-handling mechanisms to minimize downtime and maintain functionality even in adverse conditions or technical failures.

- **Adaptability:** Adaptability refers to the system's capacity to adjust to changing traffic conditions, regulations, or technological advancements. It involves designing flexible architectures, modular components, and update mechanisms to accommodate future requirements and improvements.
- **Traffic Flow Optimizability:** This topic focuses on strategies to enhance traffic flow efficiency and minimize congestion. It involves algorithms for optimizing signal timing, coordinating signals at intersections, and prioritizing traffic based on real-time conditions to improve overall traffic flow.
- **Infrastructure:** Infrastructures encompass the physical components and network architecture supporting the traffic signal control system, which takes into consideration the power supplies, communication networks, sensor placement, and integration with existing infrastructure like roads and intersections.
- **Technology:** Technology covers the hardware and software components used in the traffic signal control system, which includes sensors for detecting traffic, communication protocols for data exchange, AI control algorithms, and user interfaces for monitoring and management.
- **Safety:** This topic involves ensuring that the traffic signal control system contributes to overall road safety for drivers, pedestrians, and cyclists. Safety includes prioritizing safe crossing times, providing clear signals and signage, and integrating with other safety systems like pedestrian crossings and emergency response mechanisms.

Part 3 - Five Pillars of the Design

Through our explorations, we have gathered plenty of valuable questions that will inform the design and development of the **smart traffic signal control system**. However, within this vast amount of inquiries, there are (at least) five particularly critical questions that serve as the foundation of our project. For each question, we will go through its:

- **Importance**: Why does this question hold particular weight within the project's scope?
- **Impact**: Who will be affected by the answer to this question, and how?
- **Timeline**: At what stage of the project lifecycle – early analysis, design, or implementation – should this question be addressed?

- **Architecture**: How will the answer to this question influence the system's architecture and overall design?

By thoroughly examining these questions, we aim to illuminate their crucial role in guiding us architects toward a well-defined and impactful system. This analysis will provide a foundational framework for crafting a solution that not only optimizes traffic flow but also addresses the needs of all stakeholders – drivers, pedestrians, and the environment – responsibly and sustainably.

Question 3 - What is the contingency plan for system outages or failures?

The presented question is **crucial because it directly impacts the reliability and availability of the system**. Any downtime in the system can cause severe disruptions, leading to congestion and possible safety hazards. Therefore, this question impacts stakeholders such as **commuters, pedestrians, and the city authorities** - failures can inconvenience or even harm commuters and pedestrians, while city authorities are usually accountable for maintaining public safety. The answer to this question **shapes the architecture of the system** by imposing redundancy, fault tolerance, and recovery mechanisms. These mechanisms are needed to ensure the system is reliable and can adapt to possible failures and outages. For these reasons, this question should be addressed in the **early stages of the requirements-gathering phase**.

Question 5 - What metrics will we use to define "optimized traffic flow"? (e.g., minimize wait times, maximize throughput, prioritize specific vehicle types)

The presented question is **crucial, as it defines the primary objective of the system**. In fact, without clearly defined metrics the development's success cannot be measured. Considering its importance, it has a big impact on the system's architecture, since it will **guide the algorithm, sensor, and control mechanisms selection**. These choices should be made in the **early stages of the requirements-gathering phase**, considering those will be the pillar for future improvements in the development of the software and hardware components. Finally, the answer to this question influences different roles, such as **city planners, traffic engineers, and commuters (end-users)**, since this decision will affect the overall performance and reliability of the system.

Question 12 - What types of sensors will be used to detect oncoming traffic? (e.g., cameras, radar)

The presented question is **crucial, as it directly impacts the system's ability to detect oncoming traffic**. Selecting the appropriate type of sensors is essential to maximize the reliability and effectiveness of the solution while minimizing costs and maintenance requirements. Considering this, the question certainly has a very direct impact on the system's architecture, as it will not only **determine the hardware components and computations required** for sensor integration but also affect the **solution's power consumption**. These choices should be made in the **early stages of the requirements-gathering phase**, considering those will allow a proper sensor integration and will influence the subsequent software decisions regarding the processing of gathered data. Finally, this question impacts various roles, like **hardware and traffic engineers, maintenance staff, and the end-users** themselves, since this decision will also affect the overall performance and reliability of the system.

Question 24 - What is the scalability of the system? (do nearby systems interact with each other?)

The presented question is **crucial for ensuring that the system can accommodate future growth and changes** regarding increased traffic volume and patterns, and future requirements and expansions, such as integrations with neighboring systems. The system's scalability influences its architecture with **decisions related to network design, data exchanging formats in communication protocols, and algorithm choices** to be future-proof. These choices should be made in the **early stages of the requirements-gathering phase**, as they will affect the whole architecture. However, future assessments and updates may be needed as patterns and requirements evolve. Finally, this question impacts **system architects, network engineers, city planners, and other stakeholders such as transportation authorities**, who study regional traffic patterns.

Question 25 - What is the proposed timeline for development and deployment?

The presented question is **crucial as it ensures timely delivery of the product while enabling more effective project management**. This will also contribute to the overall **project's success**. Creating a timeline for the development and deployment will impact mostly stakeholders like the **project managers and development team**, who will use said timeline to track progress and plan their work respectively. This question will influence architectural decisions by **leading the prioritization of features and allocation of resources**. A shorter timeline may lead to a simplification of the architecture to speed up the deployment, while a longer timeline could allow for more complex features and further testing, to ensure a more robust system. Establishing a realistic timeline early on should be a priority, the reason why this question should be addressed in the **early stages of the requirements gathering phase.**