**Protocol Pros**

# Autonomous Intersection Management System (AIMS)
# Vision (Small Project)

**Version 2.0**

# Document Preparation

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# Revision History

| Date | Version | Description | Author |
|---|---|---|---|
| 11/04/2022 | 2.0 | Updated PVD template from 1.0 version | Brendan Edgerley |

# Table of Contents

# Vision (Small Project)

## 1. Introduction

### 1.1 Purpose of the Document

The purpose of this document is to collect, analyze, and define high-level needs and features of the AIMS. It focuses on the capabilities needed by the stakeholders and the target users, and **why** these needs exist. The details of how the AIMS fulfills these needs are detailed in the use-case and supplementary specifications.

### 1.2 Scope of the Document

This Project Vision document applies to the development of an efficient protocol for Autonomous Intersection Management System (AIMS), which will be implemented by 'Protocol Pros' using Omnet++, and derived from other standard protocols like MAC, HMAC, SHA2, TCP/IP, UDP, etc. The AIMS protocol will depict the entire flow of data transmission between the traffic intersection entities. However, few things like early setup of the system, pre-allocation of secret keys for MAC authentication, deciding the number of rounds in SHA-2, maintaining consistent bandwidth and throughput for communication is beyond the scope of this document.

### 1.3 References


1. Sequential Online Chore Division for Autonomous Vehicle Convoy Formation. Harel Yedidsion, Shani Alkoby, and Peter Stone pdf
2. Scalable Multiagent Driving Policies For Reducing Traffic Congestion Jiaxun Cui, William Macke, Harel Yedidsion, Aastha Goyal, Daniel Urieli, and Peter Stone In *Proceedings of the International Conference on Autonomous Agents and Multi Agent Systems* (AAMAS), 2021 pdf
3. A Protocol for Mixed Autonomous and Human-Operated Vehicles at Intersections. Guni Sharon and Peter Stone In *Autonomous Agents and Multiagent Systems - AAMAS 2017 Workshops, Best Papers*, 2017 pdf
4. Traffic Optimization For a Mixture of Self-interested and Compliant Agents. Guni Sharon, Michael Albert, Tarun Rambha, Stephen Boyles and Peter Stone In *Proceedings of the 32nd AAAI Conference on Artificial Intelligence* (AAAI-18), 2017 pdf
5. Multiagent Traffic Management: A Reservation-Based Intersection Control Mechanism. Mechanism. In *The Third International Joint Conference On Autonomous Agents and Multiagent Systems* (AAMAS 04), July 2004. pdf
6. Human-Usable and Emergency Vehicle–Aware Control Policies for Autonomous Intersection Management. Kurt Dresner and Peter Stone. In *The Fourth Workshop on Agents in Traffic and Transportation* (ATT 06), May 2006. pdf
7. Marginal Cost Pricing with a Fixed Error Factor in Traffic Networks. Guni Sharon, Stephen D. Boyles, Shani Alkoby, and Peter Stone In *The Proceedings of the 18th International Conference on Autonomous Agents and Multiagent Systems* (AAMAS 2019), 2019 pdf

### 1.4 Definitions, Acronyms, and Abbreviations

| Term | Abbreviation / Acronym | Definition |
|---|---|---|
| Autonomous Intersection Management System | AIM(S) | A fully autonomous intersection in which the order in which agents will be allowed to use said intersection is calculated for maximum efficiency and safety |
| Message Authentication Code | MAC | A short piece of information used for authenticating a message. |
| Hash-based Message Authentication Code | HMAC | Similar to a MAC but utilizing hashing functions for authentication of messages |
| Transmission Control Protocol | TCP | A connection-oriented protocol of the internet protocol suite. |
| Internet Protocol | IP | A protocol for routing and addressing packets of data so they can travel across networks and arrive at the correct destination |
| User Datagram Protocol | UDP | A connectionless protocol typically used to establish low-latency and loss-tolerating connections between applications on the internet. |
| Secure Hash Algorithm | SHA | A function which converts data into a unique string used for authentication purposes. |
| Internet of Things | IOT | A network of devices capable of connecting and exchanging data with other devices over the internet |
| Internet of Things capacity/capability/ability | IOT capacity/capability/ability | The ability of an agent to directly interact, convey, correspond to any other agent by means of digital medium. |
| Intersection | | A point where two lines or streets cross. Typically, there can be three types of intersections: Three-leg or T-intersection (with variations in the angle of approach), Four-leg intersection and multi-leg intersection. |
| Agent | | As far as this document is concerned, an agent is any entity that is involved in the intersection, like vehicles, pedestrians, street-animals, pets, traffic management system, intersection management system, Smart City management system. |

# 2. Positioning

## 2.1 Business Opportunity

With the lack of any sort of traffic intersection breakthrough in recent years, traffic time as well as accidents seemingly increase with time. With our development of an Autonomous Intersection Management System, we'll provide a safer and more time effective future for our world.

## 2.2 Problem Statement

Currently, traffic intersections do not have any autonomous, and time-efficient control system, and the entire intersection operation is almost entirely dependent on traffic signals. Traffic signals are apparently safe, but are inefficient in terms of time, and do not dynamically respond to road conditions and requirements. They operate in a uniform pattern, unless intervened by human beings. An autonomous intersection management system aims to provide a dynamic approach to solve the traffic intersection problem and make it time efficient, while prioritizing road safety. Depending on the paradigm of the intersection, traffic congestion and the road conditions, the autonomous intersection management system is expected to provide appropriate signals to every agent based on their direction of movement and further intentions.

| | |
|---|---|
| The problem of | intersections not being able to dynamically manage themselves according to the traffic congestion and interact with traffic agents |
| affects | the efficiency and safety of traffic as a whole |
| the impact of which is | consumption of a lot of time of the urban congested traffic, and compromise in road transport safety every so often |
| a successful solution would be | implementing an ambiently intelligent, responsive, and sensible autonomous intersection management system which determines the ambulation of agents, and provides the optimal trajectory to each agent in terms of safety, time and cooperation among all agents, considering emergency vehicles, innocent agents like animals, and unexpected circumstances like irregular behavior of vehicles, unexpected appearance of pedestrians, etc. |

### 2.3 Product Position Statement

| | |
| --- | --- |
| For | Everyone who commutes via intersection |
| Who | wishes for safer and quicker travel times |
| The (product name) | the Autonomous Intersection Management System (AIMS) |
| That | provides quicker and safer travels via intersections |
| Unlike | traffic light-based intersections, or other AIMS without properly instilled safety mechanisms and protocols |
| Our product | allows dynamic intersection travel based on changing conditions. |

# 3. Stakeholder and User Descriptions

## 3.1 Stakeholder Summary

| Name | Description | Responsibilities |
| --- | --- | --- |
| Project Manager | This stakeholder works with the customers and translates the needs into requirements. | Specifies domain, requirements both functional and nonfunctional, requirement refining as per need. Keeping a check into the whole project and maintain the progress. |
| Technical Manager | This stakeholder analyzes the requirements and does a feasibility check of the same. | Checks if the requirements can be well implemented without any modifications. Design ways to implement requirements. |
| Researcher | Makes a check of available and conventional methods of Implementing the requirement and figures out better ways of designing them. | Crawls through available systems which revolve around the specified requirements and cite improvements in the execution methodologies. |
| Designer | Based on the papers produced by the researchers, this stakeholder designs a systematic and technical methodology of implementing the requirement. | Figure out the optimal way of implementing the suggested methodology of the researcher and produce the design of the same. |
| Developer | Substantiates the proposed design by implementing the same in the decided technology stack. | Decide the best way to implement and execute the design, in order to support scalability and encompassing all possible cases. |
| Tester | Identify all possible test cases of every module in the system and cite out the test cases, thereby testing the system against each of them. | Figure out the possible test cases in every segment/module of the system and perform manual/automation testing of the |

| | | |
| --- | --- | --- |
| | | developed system against the drawn-out test cases. |

## 3.2 User Summary

The intended audience for our project is the Smart City Management System, which will include the Autonomous Intersection Management System within their scope. Our system will enable the working of a smart and autonomous intersection management system which can be used by Smart City Systems which aim to make their traffic automatic, efficient, and timely in a safe manner. It will also serve as an effective tool for emergency situations even in busy intersections. Safety is into a priority consideration; thus, our system does not compromise or trade-off safety for any other capability. Thus, AIMS could be a considerable conjunction to a Smart City Management System, under the road traffic and safety domain.

| **Name** | **Description** | **Responsibilities** |
| --- | --- | --- |
| Intersection | Primary end user of the system | Exploit an instance of the AIMS system and maintain the traffic based on business logic of the system. Provide a timely report to the upper level in the hierarchy. |
| Smart City Management | Beneficiary of the system | Receive the periodic reports from every instance of the system and analyze if everything is going well. Ensure safety across all the instances and notify instances in case of absurdity. |
| Interacting agents with IoT capabilities | Primary end user of the system | Stay within the vicinity of their closest interaction instance and communicate their intentions in the intersection. Receive and follow the instructions provided by the system. |
| Interacting agents without IoT capabilities | Allied agent of the system | They cannot directly interact with the system. However, our system, inculcated with ambient intelligence, can identify these agents, and have an estimate of their intentions in the intersection |

## 3.3 User Environment

3.3.1. The AIMS application protocol will be used by Smart City Management Systems, regardless of:

- Which country they operate in.

- Which time of the day it is, or which date of the month or which month of the year.

- What brands of vehicles are used (having an android/iOS car system is required)

- Which part of the city it is.

3.3.2. The AIMS protocol should be feasible for intersections where:

- Majority of the vehicles travelling through the intersection have IoT capabilities.

- There is adequate quality of connection setup and the necessary bandwidth to communicate with the maximum possible agents in that intersection.

- There is assurance that the connection will not be lost anytime in between, and the quality will remain stagnant.

3.3.3. The AIM system should work for vehicles that:

- Contain the application and have the necessary connections with adequate bandwidth pre-setup.

- Have the required secret-keys and hash-function behaviors are inculcated in their systems beforehand.

## 3.4 Summary of Key Stakeholder or User Needs

Intersection inefficiency

- Most intersections are using traffic lights or even stop signs to control the flow of traffic which are terribly inefficient and at times, due to human error, can be incredibly dangerous. Users of intersections look for a more streamlined and safety cautious approach to the intersections they use in in their day to day lives.

## 3.5 Alternatives and Competition

3.5.1. High-cost flyovers to refrain from having intersections.

3.5.2. Traffic signals that are based on a single algorithm, and stagnant in terms of performance

3.5.3. Using irresponsive traffic congestion control mechanisms.

3.5.4. Other competing AIMS teams

# 4. Product Overview

## 4.1 Product Perspective

The AIMS would be a component of the common traffic intersection and would be a solution to the modern issues of traffic jams and accidents that occur. AIMS would be integrated into these intersections by implementing our own technology that is able to have all agents of an intersection connected in a network node centered in the intersection. This implementation would make the necessity of traffic lights and stop signs obsolete so long as the system is up and running with its requirements met.

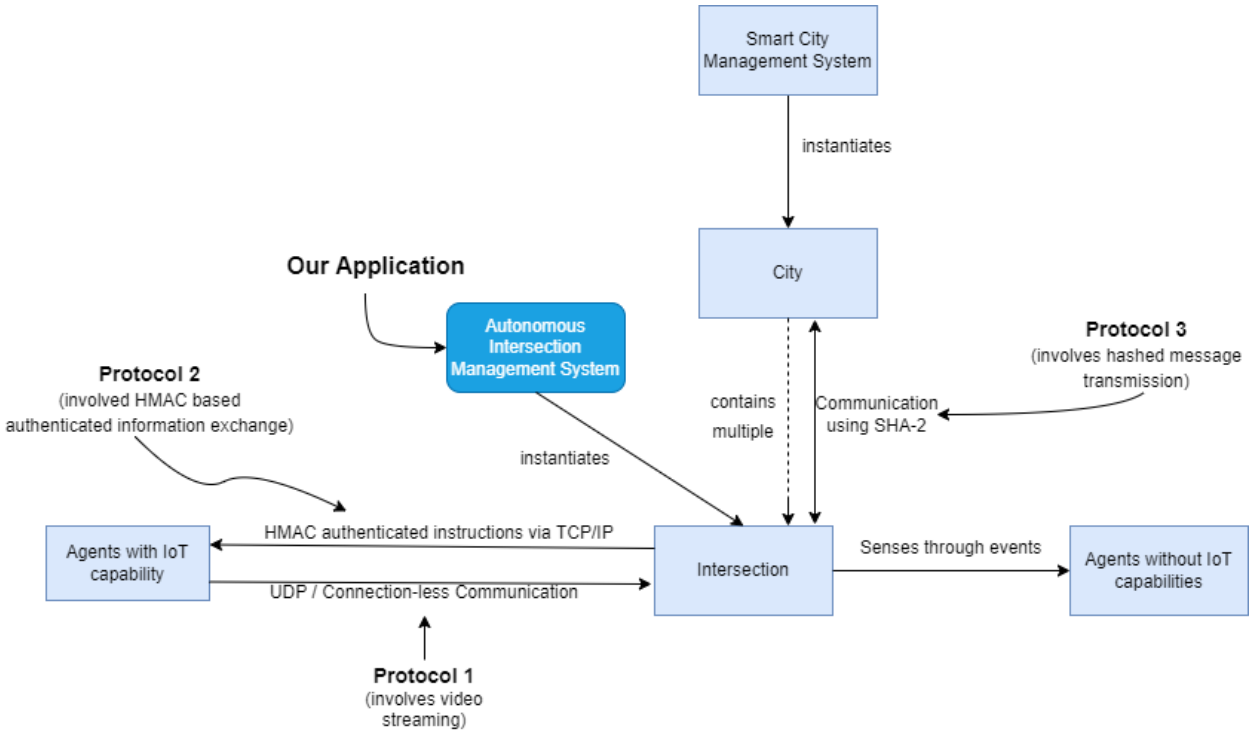


Fig 1: Overview of components involved in the AIMS system

## 4.2 Assumptions and Dependencies

1. It is assumed that majority of the agents in the intersection are IoT capable and are compatible with our application.

2. It is assumed that the vehicles have adequate connection to transmit and receive data from our product.
3. It is assumed that the AIMS has adequate bandwidth and throughput to process and transmit all relevant data to the corresponding entity.
4. It is assumed that the IoT capable agent will strictly follow the instructions provided by our application.

## 4.3 Cost and Pricing

Costs of development and implementation of the AIMS system would vary from city to city based on a multitude of variables such as implementation of Smarty City infrastructure, material, and labor costs, etc.

## 4.4 Licensing and Installation

AIMS would require the installation of several key components as well as integration into the network of a Smart City infrastructure if available. The installation of AIMS has the potential to render an intersection unusable for a certain amount of time, once installation is complete the system will be functional and the intersection usable once more.

# 5. Product Features

## 5.1 System Features

1. Instantiate application for a particular intersection.
2. Integrate the instance to a ‘City’(Smart City System).
3. Setup perceptive nodes for that instance.
4. Setup status stream from AIMS to ‘City’.
5. Pause application.
6. Exit application.
7. Change vehicle priority.

## 5.2 Communication Features

1. SHA-2 based hashed information exchange.
2. Provide instructions to agents through TCP using HMAC authentication
3. Embedded ambient Intelligence through image processing
4. OCR (Optical Character Recognition) for identifying every individual vehicle
5. Image Recognition (Agents without IoT)

## 5.3 Emergency Features

1. Place emergency vehicle condition.
2. Change vehicle priority in system, based on intersection instance.
3. Send emergency condition alert to higher authorities (Smart City System)

# 6. Constraints

## 6.1. Usability

6.1.1. Clear and perceptive view of agents through camera

6.1.2. Pre-trained OCR model embedded to identify vehicle and its position.

6.1.3. Strictly integrate each vehicle with the system based on their lane position, further intentions, and accordingly move forward with the processing.

6.1.4. Proper SHA-2 implemented and independently integrated with hash functions.

6.1.5. Pre-shared secret keys for HMAC based TCP communications among agents

## 6.2. Performance

6.2.1. Accuracy of hash functions in SHA-2

6.2.2. Instantaneous judgement of agents by the pre-trained OCR model.

6.2.3. Minimal time between vehicle recognition and system response.

6.2.4. Minimal data loss in UDP based communication from the agent and systems.

# 7. Quality Ranges

Video streaming is one of the main functional requirements AIMS so loss of quality or complete loss of video stream has the ability to completely hinder the system and usability may take damage as a result.

# 8. Other Product Requirements

## 8.1 Applicable Standards

The AIMS must comply with the existing standard in terms of responsiveness, performance, usability, and accuracy. It should provide the pertinent instructions even in the most critical emergency situation arising from the intersection.

## 8.2 System Requirements

System must run on a Windows/Linux based system, and the agents must have an android/iOS based smart-car setup on their vehicles.

## 8.3 Performance Requirements

System is expected to process the situation in the intersection in the minimal time possible, and provide the optimal decision, considering priority of the vehicles in the optimal time. Accuracy is expected while recognizing vehicles, their positions, their intentions, and identifying agents without IoT capabilities along with an apparent estimate of their intentions and process their instructions. Possible collisions should be instantly prevented by giving pertinent instructions.

## 8.4 Environmental Requirements

System must recognize vehicles and agents on the intersection through video streaming. Thus, it is expected that the visibility is vivid enough for the system to perceive and identify the motion and behavior of agents. Likewise, it is expected to have a good internet connection throughout the execution time of the system.

## 8.5 Documentation Requirements

The success of developing our system requires that we create other documents in order have a firm foundation on which to build on. Other documents that we are to require are as follows, but not limited to:

9.5.1. Project Plan document

9.5.2. Software Requirements Specification (SRS)

9.5.3. Software Design Document (SDD)

9.5.4. Software Test Document (STD)

9.5.5. Request for Comment (RFC) Draft

Along with these documents, additional diagrams will be created to give visual representation to our not yet developed system.