Protocol Pros

Autonomous Intersection Management System Software Requirements Specifications (SRS)

Version 2.0

Document Preparation

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Revision History

Date	Version	Description	Author
09/30/2022	1.1	Proper numbering of requirements	Sarah Ryan
11/04/2022	2.0	Changed format of the document	Ashutosh Mishra

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Software Requirements Specification (SRS)

1.   Introduction

Currently, traffic intersections do not have any autonomous, and time-efficient control system, and the entire intersection operation is almost 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. Agent, here, depicts all the entities that are involved in the road transportation, such as vehicles, pedestrians, and animals.

1.1   Purpose of the Document

This document is intended to elaborate overall requirements of the Autonomous Intersection Management System, covering all aspects such as functional, non-functional and domain requirement. Moreover, the software design requirements have also been explained along with the required use-cases each with an expected set of functionalities.

1.2   Scope of the Document

This SRS is aimed at explaining requirements of software to be designed and developed. However, can also be applied to assist in the selection of the proper inherent working components within the system. The standard can be used to create software requirements specifications directly or can be used as a model for defining a organization or project specific standard. It does not identify any specific method, nomenclature, or tool for preparing an SRS.

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. Product Scope

Currently, traffic intersections do not have any autonomous, and time-efficient control system, and the entire intersection operation is almost 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. Agent, here, depicts all the entities that are involved in the road transportation, such as vehicles, pedestrians, and animals.

3.   Product Users

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.

3.1   Users

Product User Type	Description	User Characteristics & 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.

4.   Use Cases

Use Case ID	Use Case Name	Brief Description
UC-1	Receive recorded video stream	Receive the video stream from every intersection.
UC-2	Decode the received video stream based on predefined protocol	Decode the received video stream from every intersection.
UC-3	Identify agents based on their visual features	Identify the agents of an intersection based on their visual characteristics
UC-4	Receive emergency agent reservation request	Receive the emergency reservation request from a specific set of agents
UC-5	Send instructions to agents as HMAC generated message digest	The instructions generated by AIMS Core Processor are required to be transmitted to every concerned agent in that intersection.
UC-6	Process the intersection instance based on received requests	Analyze the intersection at any given instance and generate relevant instructions for every agent in the intersection at that moment.
UC-7	Send intersection status to Smart City Systems	Provide a periodic status information to the Smart City Management Systems
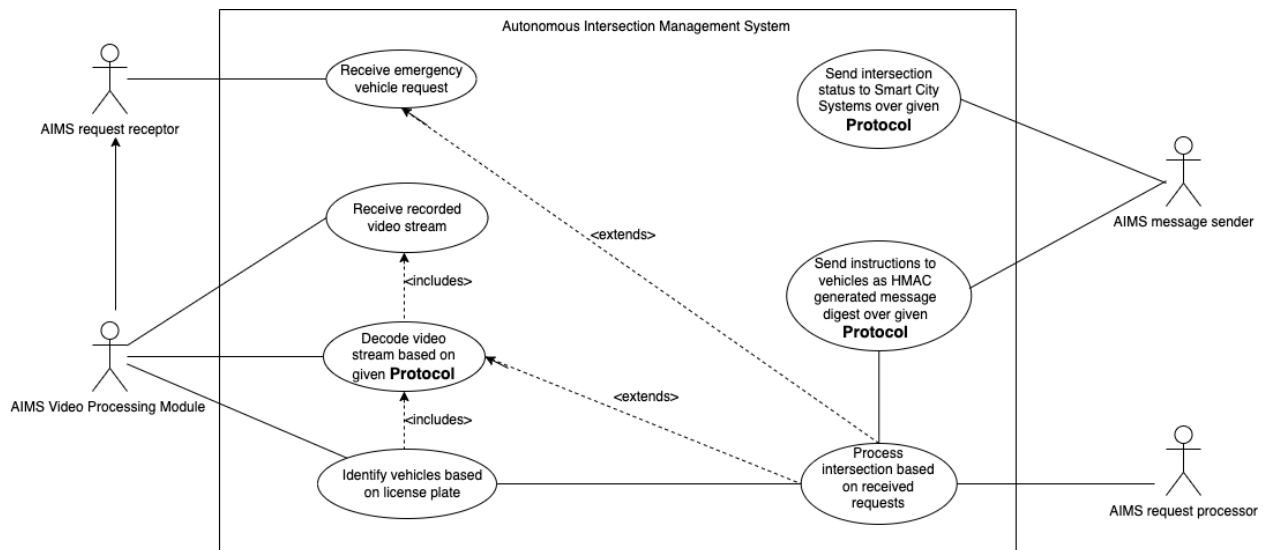
Fig 1: Use-Case Diagram

5.   System Design

5.1   Interaction Diagrams

The purpose of interaction diagram is to visualize the interactive behavior of the system. This interactive

behavior is represented in UML by two diagrams known as Sequence diagram and collaboration diagram.

- Sequence Diagram
- Collaboration Diagram

1. Sequence Diagram
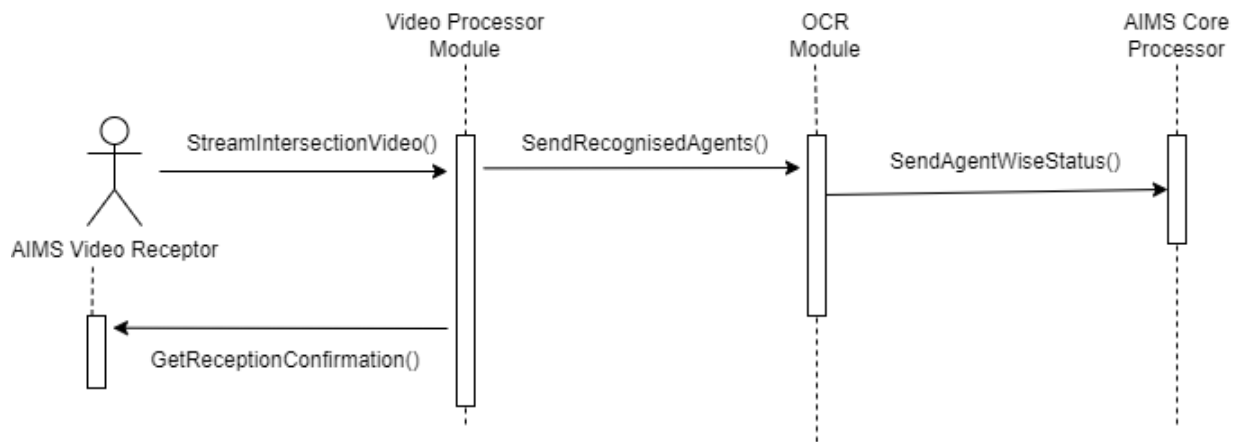
Fig 2: Sequence Diagram for **Video-Receptor**

Fig 3: Sequence Diagram for **AIMS Message Sending Module**

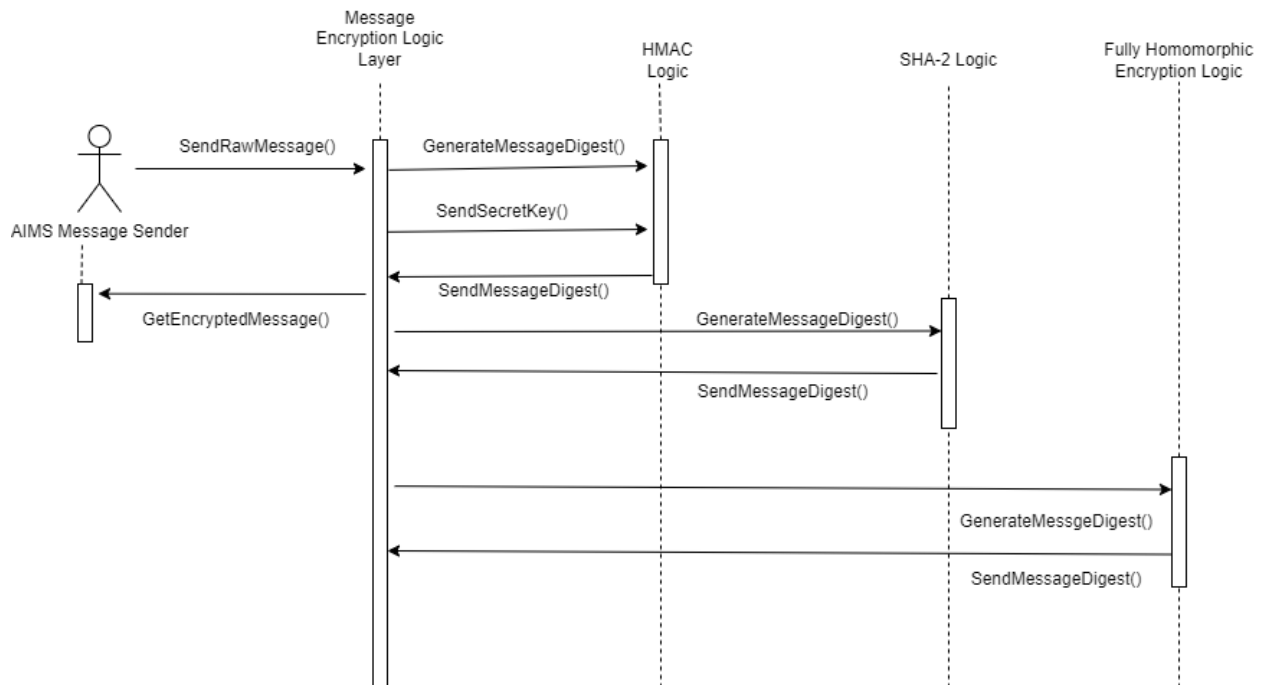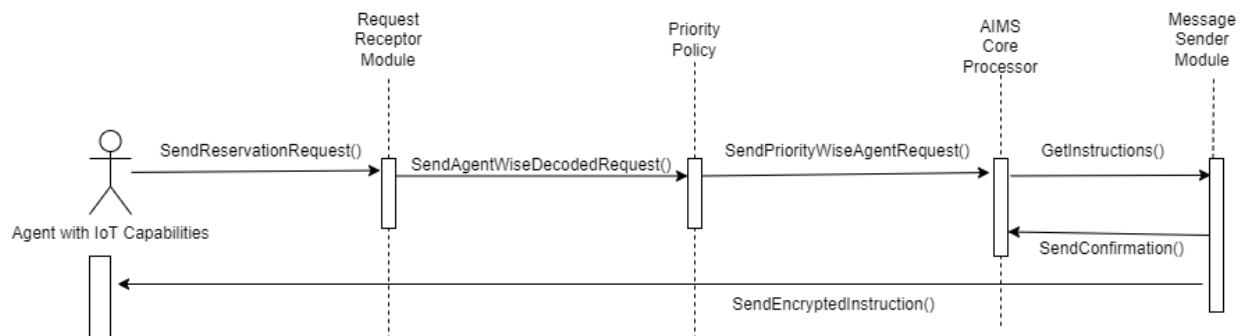Fig 4: Sequence Diagram for **Agents with IoT Capabilities**
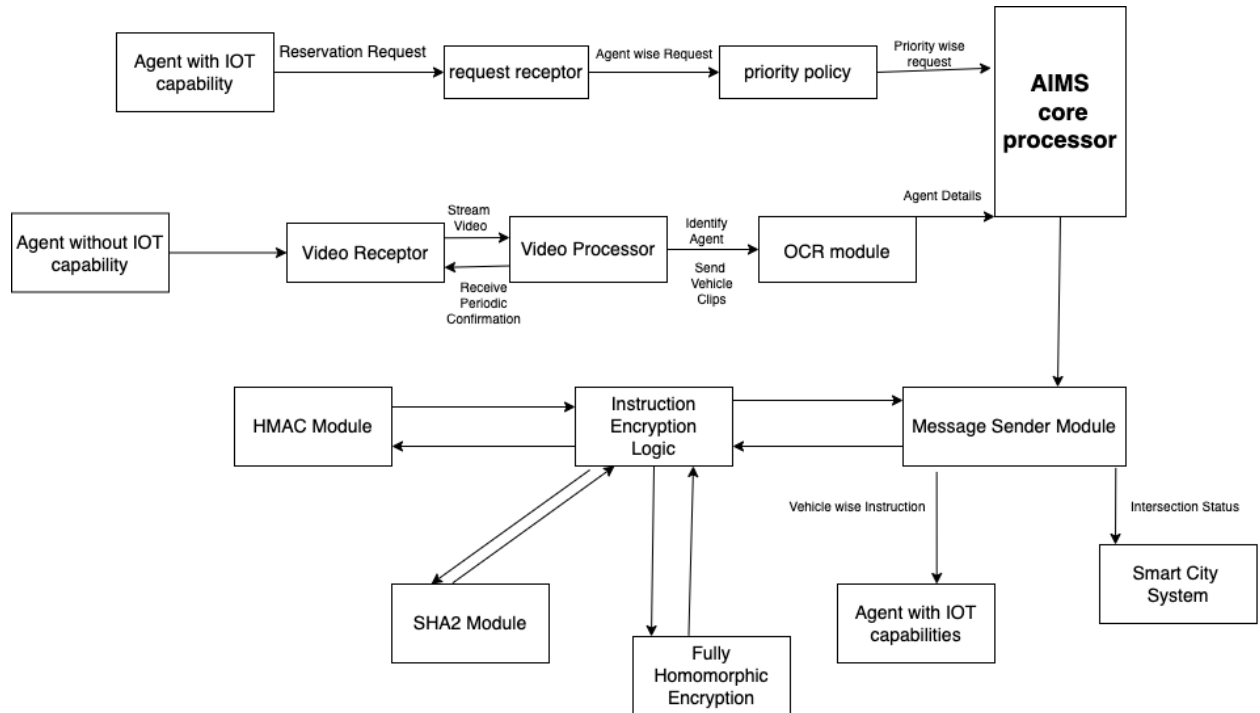
2. Collaboration Diagram

Fig 5: Collaboration Diagram
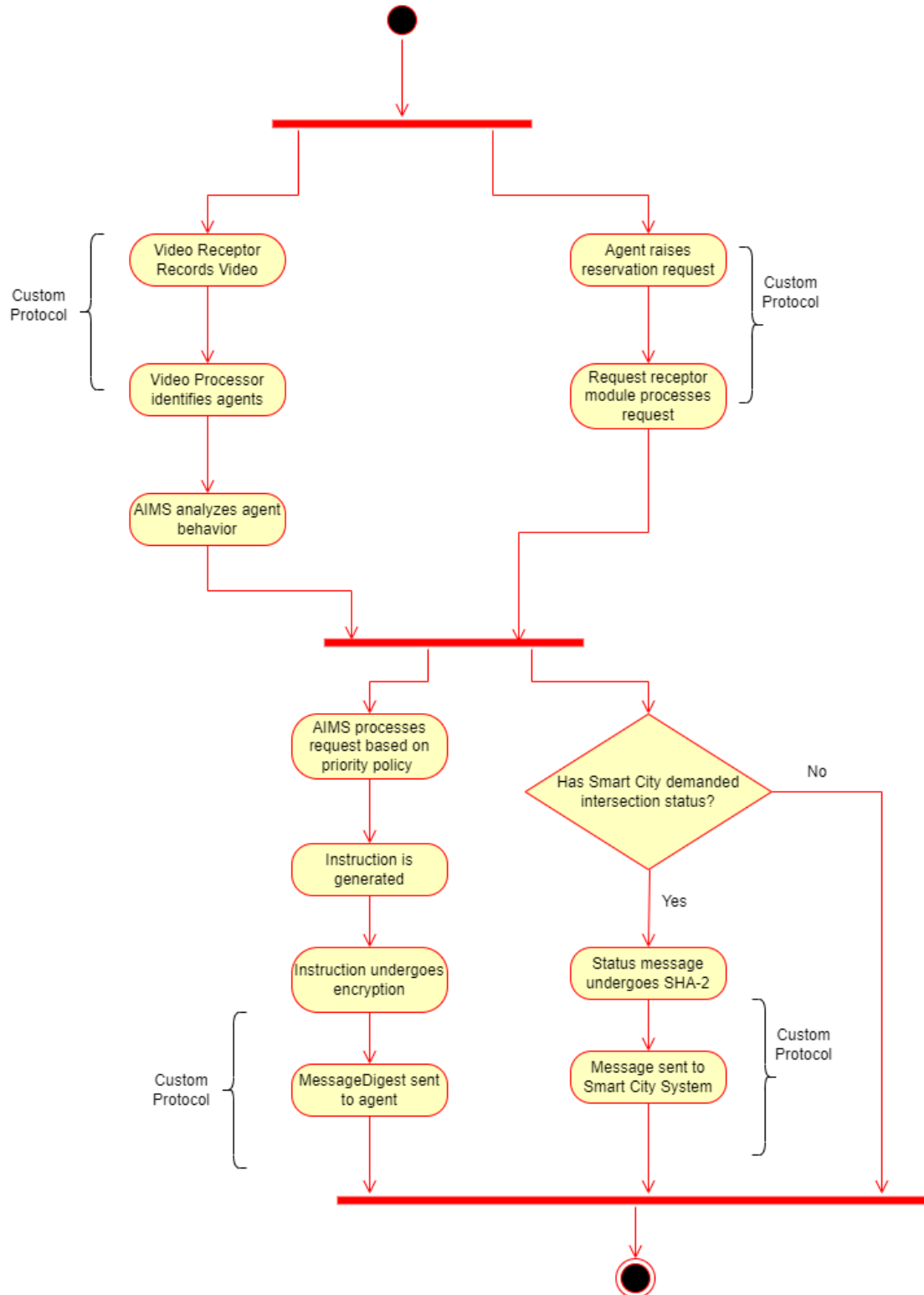
5.2   Activity Diagram

Fig 6: Activity Diagram

6.   Functional Requirements

6.1   Software Requirements

Requirement ID	Requirement Priority (High/Medium/Low)	Requirement
Req-Func-Sw-1	High	The system shall be able to receive the video stream from every intersection.
Req-Func-Sw-2	High	The system shall decode and process the streamed video using OCR module.
Req-Func-Sw-3	High	The system shall be able to identify agents, categorize them and process their behavior.
Req-Func-Sw-4	High	The system shall setup the priority policy of every agent category.
Req-Func-Sw-5	High	The system shall be able to allow admins to configure priority policy.
Req-Func-Sw-6	High	The system shall generate the accurate instructions for every agent.
Req-Func-Sw-7	High	The system shall ensure that priority policy is maintained while generating these instructions.
Req-Func-Sw-8	Low	The system shall simulate the agent behavior presuming the generated instructions to ensure safety.
Req-Func-Sw-9	High	The system shall provide the generated set of instructions corresponding to the instruction receptor(agent) through Message Sending Module.
Req-Func-Sw-10	Medium	The system shall receive the message digest from the Message Sending Module based on the preset encryption logic.
Req-Func-Sw-11	High	The system shall transfer the encrypted instructions through the defined protocol.
Req-Func-Sw-12	Medium	The system shall receive instruction reception confirmation from every agent.

Req-Func-Sw-13	Low	The system shall maintain a periodic intersection status check to ensure absence of unusual behavior of the intersection.
Req-Func-Sw-14	Medium	The system shall maintain a consistent video reception confirmation with the Video Receptor Module.
Req-Func-Sw-15	High	The system shall ensure a responsive intersection status provision logic for transmitting intersection status to the higher authority as per need, through the defined protocol.
Req-Func-Sw-16	High	The system shall be integrated with agents embedded with a recognized OS.
Req-Func-Sw-17	Low	The system shall be able to run the overall application with complete authorization and compatibility

6.2 Hardware Requirements

Requirement ID	Requirement Priority (High/Medium /Low)	Requirement
Req-Func-Hw-1	High	The system shall have at least 4GB main memory and 16 Gb disk storage availability.
Req-Func-Hw-2	Medium	The system shall have a minimum 720p resolution camera.
Req-Func-Hw-3	Medium	The system shall have a minimum of 120Hz video stream capability.
Req-Func-Hw-4	Medium	The system shall have a processor of capability equivalent to or more than that of Intel Core i5.
Req-Func-Hw-5	Low	The system shall have a recommended OS equivalent to or more than Windows 10.
Req-Func-Hw-6	High	The system shall have an internet connectivity of 100MBps at all functioning times.

7. Quality Requirements

Requirement ID	Requirement Priority (High/Medium /Low)	Requirement
Req-Qual-Simp-1	High	The system shall always work irrespective of time of the day, day of the week and month of the year.
Req-Qual-Simp-2	Medium	The system shall function smooth complying to the internet speed of the locality.
Req-Qual-Sec-1	High	The system shall maintain a message integrity check against every message passed between the message components.
Req-Qual-Sec-2	Medium	The system shall encrypt the anonymous details of the entities.
Req-Qual-Sec-3	Low	The system shall not allow unauthorized access to the system.
Req-Qual-Main-3	Medium	The system shall be easily maintainable.
Req-Qual-Perf-1	High	The system shall have low latency in message transmission.
Req-Qual-Perf-2	High	The system shall be perfectly accurate in terms of intersection instruction generation, as safety is the major priority in the system.

8. Domain Requirements

Requirement ID	Requirement Priority (High/Medium /Low)	Requirement
Req-Dom-1	High	The system shall have an ability to record video of the intersection.
Req-Dom -2	Medium	The system shall expect a clear license plate on every vehicle passing through the intersection.
Req-Dom-3	High	The system shall expect roads with clear lane-divisions.
Req-Dom-4	Medium	The system shall expect roads with usual lane directions.
Req-Dom-5	Low	The system shall expect agents to follow the instructions accurately.
Req-Dom-6	Medium	The system shall expect an ability to send instructions to every agent through cloud, with optimal latency.
Req-Dom-7	High	The system shall expect emergency agents to send a reservation request prior to reaching the intersection.

9.   Appendix A – Requirements Traceability

Requirement ID	Related Requirements	Test Case ID
Req-Func-Sw-1	Req-Func-Sw-2 Req-Func-Sw-3 Req-Qual-Sec-3 Req-Func-Sw-14 Req-Func-Hw-3	Test-Case-1
Req-Func-Sw-4	Req-Func-Sw-5	Test-Case-2
Req-Func-Sw-6	Req-Func-Sw-7 Req-Func-Sw-8 Req-Func-Sw-16	Test-Case-3
Req-Func-Sw-9	Req-Func-Sw-10 Req-Func-Sw-11	Test-Case-4
Req-Func-Sw-10	Req-Func-Sw-11	Test-Case-5
Req-Func-Sw-11	Req-Func-Sw-12	Test-Case-6
Req-Func-Sw-12	Req-Func-Sw-11	Test-Case-7
Req-Func-Sw-13	Req-Func-Sw-8	Test-Case-8
Req-Func-Sw-14	Req-Func-Sw-1	Test-Case-9
Req-Func-Sw-15	Req-Func-Hw-6	Test-Case-10
Req-Func-Sw-16	Req-Qual-Sec-1 Req-Qual-Sec-2	Test-Case-11

10. Appendix B Use Case 1 – Make a Reservation

9.1. Use Case 1 – Receive recorded video stream

Use Case ID	UC-1	
Use Case Name	Receive recorded video stream	
Brief Description	Receive the video stream from every intersection.	
Frequency of Use	High – 40%	
Priority	High	
Current Version	1.1	
Date of First Version	09/20/2022	
Date of Last Version	09/28/2022	
Created By	Ashutosh Mishra	
Last Update By	Brendan Edgerley	
Approved By	David Schelanko	
Assumptions	The system is in fully working condition. The AIMS Video Processing Module is the only authorized entity for this use-case.	
Primary Actor	AIMS Video Processing Module	
Secondary Actor/s	AIMS OCR Module	
Preconditions	Video stream is based on the defined Video-Streaming-Protocol.	
Postconditions	Response/Confirmation to the stream is based on the defined protocol.	
Trigger	Intersection streams video and tries sending the stream to AIMS.	
Main Success Scenario	**User Actions**	**System Actions**
	1. Intersection is streaming the video considering the designated protocol. 2. Intersection precisely responds to the command sent by the system.	1. System receives and decodes the video and gets it ready for further processing. 2. System sends stream commands to an intersection through the defined protocol.
Alternate Scenarios	**User Actions**	**System Actions**
	1. Intersection might not receive/follow the stream command	1. System sends another message containing same command.
Additional Notes (Constraints, etc.)	Video shall be transmitted through a connection-oriented network layer protocol, and authorization will take place both at the sender and receiver end	

9.2. Use Case 2 - Decode the received video stream based on predefined protocol

Use Case ID	UC-2	
Use Case Name	Decode the received video stream based on predefined protocol	
Brief Description	Decode the received video stream from every intersection.	
Frequency of Use	High – 40%	
Priority	High	
Current Version	1.0	
Date of First Version	09/20/2022	
Date of Last Version	09/20/2022	
Created By	Ashutosh Mishra	
Last Update By	Brendan Edgerley	
Approved By	Sarah Ryan	
Assumptions	The system is in fully working condition. The AIMS Video Processing Module is the only authorized entity for this use-case.	
Primary Actor	AIMS Video Processing Module	
Secondary Actor/s	AIMS OCR Module	
Preconditions	Video decoding is based on the defined Video-Streaming-Protocol.	
Postconditions	Compiled video should have an adequate quality and integrity should be maintained.	
Trigger	Video stream from intersections is being received.	
Main Success Scenario	**User Actions**	**System Actions**
	1. Streamed video is being properly received and redirected to AIMS Video Processing Module.	1. System compiles the video and makes it ready for processing by OCR Module.
Alternate Scenarios	**User Actions**	**System Actions**
	1. Video may not be clear enough to process.	1. System provides a signal to the intersection for requesting a clearer video.
Additional Notes (Constraints, etc.)	Video shall be decoded based on the streamed video protocol.	

9.3. Use Case 3

Use Case ID	UC-3
Use Case Name	Identify agents based on their visual features
Brief Description	Identify the agents of an intersection based on their visual characteristics
Frequency of Use	High – 40%
Priority	High
Current Version	1.0
Date of First Version	09/20/2022
Date of Last Version	09/20/2022
Created By	David Schelanko
Last Update By	David Schelanko
Approved By	Prakash Acharya
Assumptions	The system is in fully working condition. The AIMS OCR Module and AIMS Core Processor are the only authorized entities for this use-case.
Primary Actor	AIMS OCR Module
Secondary Actor/s	AIMS Core Processor
Preconditions	Video should be clear enough and of desired quality.
Postconditions	Agents will be identified based on the model instilled in the OCR segment.
Trigger	Video stream is redirected to the AIMS OCR Module.

Main Success Scenario	User Actions	System Actions
	1. OCR Module receives video stream from the Video Processing Module.	1. System analyzes the video and identifies the agents and their respective behaviors in the intersection.

Alternate Scenarios	User Actions	System Actions
	1. Agent may not be recognized.	1. Unidentified trigger is sent to Core Processor.

Additional Notes (Constraints, etc.)	Every valid agent has to have a required set of patterns as per the OCR model.

9.4. Use Case 4

Use Case ID	UC-4	
Use Case Name	Receive emergency agent reservation request	
Brief Description	Receive the emergency reservation request from a specific set of agents	
Frequency of Use	Medium – 30%	
Priority	Medium	
Current Version	2.0	
Date of First Version	09/20/2022	
Date of Last Version	11/02/2022	
Created By	Ashutosh Mishra	
Last Update By	Brendan Edgerley	
Approved By	Sarah Ryan	
Assumptions	The system is in fully working condition. The AIMS Message Sending Module and AIMS Core Processor are the only authorized entities for this use-case.	
Primary Actor	AIMS Message Sending Module	
Secondary Actor/s	AIMS Core Processor	
Preconditions	Emergency reservation request is based on the defined Message-Sending -Protocol.	
Postconditions	Response/Confirmation to the request is based on the defined MSP protocol.	
Trigger	Specific agent raises an emergency reservation request.	
Main Success Scenario	**User Actions**	**System Actions**
	1. Agent raises an emergency reservation request.	1. System accepts the request, and generates the instruction based on priority policy preset in the system.
Alternate Scenarios	**User Actions**	**System Actions**
	1. Emergency reservation request might not be accepted, or response is not received.	1. System buffers the request and waits for agent confirmation for the request.
Additional Notes (Constraints, etc.)	Emergency reservation request is communicated through a connectionless transport layer protocol for low latency but is communicated with high security.	

9.5. Use Case 5

Use Case ID	UC-5	
Use Case Name	Send instructions to agents as HMAC generated message digest	
Brief Description	The instructions generated by AIMS Core Processor are required to be transmitted to every concerned agent in that intersection.	
Frequency of Use	High – 60%	
Priority	High	
Current Version	3.0	
Date of First Version	09/20/2022	
Date of Last Version	11/04/2022	
Created By	Brendan Edgerley	
Last Update By	Ashutosh Mishra	
Approved By	Prakash Acharya	
Assumptions	The system is in fully working condition. The AIMS Message Sending Module is the only authorized entity for this use-case.	
Primary Actor	AIMS Message Sending Module	
Secondary Actor/s	AIMS Core Processor	
Preconditions	Message Transmission is based on the defined Message-Sending-Protocol.	
Postconditions	Response/Confirmation to the Message Sending Module is based on the defined protocol.	
Trigger	AIMS Core Processor processes the requests and generates instruction for the agents and generates instructions.	
Main Success Scenario	User Actions	System Actions
	1. AIMS Core Processor generates the instructions for every agent in the intersection based on the requests.	1. System standardizes the instructions for every redirects them to every agent in that intersection.
Alternate Scenarios	User Actions	System Actions
	1. Instruction may not contain adequate information.	1. System flags the instruction and invalid and sends it back to Core Processor.
Additional Notes (Constraints, etc.)	Instructions may be one out of few instructions based on what type of request it is, and it has to undergo an HMAC mechanism for security and integrity purpose.	

9.6. Use Case 6

Use Case ID	UC-6
Use Case Name	Process the intersection instance based on received requests
Brief Description	Analyze the intersection at any given instance and generate relevant instructions for every agent in the intersection at that moment.
Frequency of Use	High – 50%
Priority	Low (as far as our project is concerned)
Current Version	1.0
Date of First Version	09/20/2022
Date of Last Version	9/20/2022
Created By	David Schelanko
Last Update By	David Schelanko
Approved By	Amado Lazo
Assumptions	The system is in fully working condition. The AIMS Core Processor is the only authorized entity for this use-case.
Primary Actor	AIMS Core Processor
Secondary Actor/s	
Preconditions	Every agent on the intersection is already identified and its behavior is already analyzed
Postconditions	Generated instructions are transmitted to the AIMS Message Sending Module.
Trigger	Agent from Intersection raises a reservation request through any means

Main Success Scenario	User Actions	System Actions
	1. Agent approaches intersection as visible to the intersection video camera. 2. Emergency reservation request is generated.	1. Required instruction is generated for that corresponding agent. 2. Required instruction is generated based on priority policy.
Alternate Scenarios	User Actions	System Actions
	1. Agent's emergency request does not reach AIMS Core Processor.	1. System treats it as a normal request, and priority policy decides which category of vehicle is it.
Additional Notes (Constraints, etc.)	AIMS Core Processor has an algorithm based on the priority policy setup in the system, and instructions are generated based on that algorithm.	

9.7. Use Case 7

Use Case ID	UC-7	
Use Case Name	Send intersection status to Smart City Systems	
Brief Description	Provide a periodic status information to the Smart City Management Systems	
Frequency of Use	Medium – 30%	
Priority	Medium	
Current Version	2.0	
Date of First Version	09/20/2022	
Date of Last Version	11/02/2022	
Created By	Julian Villarreal	
Last Update By	Ashutosh Mishra	
Approved By	Amado Lazo	
Assumptions	The system is in fully working condition. The AIMS Core Processor and AIMS Message Sending Module are the only authorized entities for this use-case.	
Primary Actor	AIMS Message Sending Module	
Secondary Actor/s	AIMS Core Processor	
Preconditions	Status transmission is based on Message-Sending-Protocol	
Postconditions	Response/Confirmation by Smart City to the AIMS Core Processor is based on the defined protocol.	
Trigger	An intersection status check from the Smart City Systems to the AIMS Core Processor triggers this use-case.	
Main Success Scenario	**User Actions**	**System Actions**
	1. Smart City requests for the intersection status. 2. Smart City receives a periodic out-of-order intersection status from every intersection in the city.	1. System receives and decodes the request and provides the current status via the protocol. 2. System provides a periodic intersection status to the Smart City system under the designated time stipulation.
Alternate Scenarios	**User Actions**	**System Actions**
	1. Smart City does not receive any status and makes an overhead request to an intersection.	1. System receives and provides the status again under the same protocol specifications.
Additional Notes (Constraints, etc.)	Message is transmitted through a connection-less transport layer protocol.	