Software Requirements Specifications Document

Autonomous Intersection Management System

Team: Protocol Pros

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Section 1: Purpose

The main purpose of this project is to comprehend the possibilities of an intersection, and accordingly analyze, research, develop and execute a networking protocol for autonomous intersection management system. The networking protocol will involve transmission of signals and critical information between entities involved in the system and enable assistance to the agents for deciding their trajectory based on the road conditions

Section 2: Scope

2.1 *Business Problem*

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.

2.2 *Intended Use*

This project 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, Fully Homomorphic Encryption, 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, defining the encryption mechanism for homomorphic encryption, maintaining consistent bandwidth and throughput for communication is beyond the scope of this protocol-defining project.

2.3 *Intended Audience*

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.

Section 3: Definitions and Acronyms

1. **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.

2. **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.

3. **IOT capacity/capability/ability** – The ability of an agent to directly interact, convey or respond to any other agent by means of digital medium.

4. **Fully Homomorphic Encryption** – A Fully homomorphic encryption (FHE) is an encryption mechanism that allows analytical functions to be computed directly on encrypted information while producing the same encrypted digest as if the functions were run on plain data.

5. AIM(S) – Autonomous Intersection Management System
6. SIM(S) – Smart Intersection Management System
7. OCR – Optical Character Recognition
8. MAC – Message Authentication Code
9. HMAC – Hash-based Message Authentication Code
10. TCP – Transmission Control Protocol
11. IP – Internet Protocol
12. UDP – User Datagram Protocol
13. SHA – Secure Hash Algorithm
14. IOT – Internet of Things
15. UML – Unified Modeling Language
16. V2V – Vehicle to Vehicle interaction
17. V2X – Vehicle to agent interaction
18. X2X – Agent to agent interaction

Section 4: Problem Statement

4.1 *Problem Statement*

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.

4.2 *User Needs*

Need	Priority	Concerns	Proposed Solution
Accurate Instruction	High	An absolutely accurate set of instruction for agents for their further move in the intersection, because it may stake high values if provided inaccurately.	Implementation of instruction provision based on a TCP-like **connection-based communication protocol** between the system and the agent so that instructions are received, and the system is notified about the reception.
Unaltered instructions	High	Even though the instructions sent by the system may be accurate, there is a vulnerability that a third party can alter the instructions by taking over the network.	Use a Hash-based Message Authentication Code (**HMAC, based on Fully Homomorphic Encryption**) protocol for interaction between agents and our

			system, to ensure that the instructions are unaltered, and integrity is maintained.
Secured transmission of intersection status	Moderate	The Smart City system and AIMS should have secured communication so that ill-status is not leaked that may turn out to be pugnacious.	Usage of Secure Hash Algorithm (**SHA-2**) to transmit instructions between AIMS and Smart City systems would ensure safety in this communication
Efficient conveyance of instant status of intersection to system	Low	Every intersection, at every quantum of time, is expected to convey its status to the AIMS in order to get instructions and transmit to every agent there.	Exploitation of User Datagram Protocol (**UDP**) based connection-less protocol for maintaining communication from the agent to the AIMS, to maintain efficiency.

4.3 *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 agents have inbuilt methodology to decrypt the received encrypted message and properly view the instructions provided by the intersection.
4. It is assumed that the AIMS has pre-trained and accurate OCR (Optical Character Recognition) module which has the ability to recognize the agents, based on their inherent properties like shape, color, license-plate (if vehicle), priority status(based on vehicle structure), etc.
5. It is assumed that the AIMS has adequate bandwidth and throughput to process and transmit all relevant data to the corresponding entity.
6. It is assumed that the IoT capable agent will strictly follow the instructions provided by our application.

Section 5: Existing System

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.

Section 6: Proposed System

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.

Section 7: System Features & Requirements

7.1 *Functional Requirements*

1. Receive the video stream from intersections, **through the defined protocol**.
2. Identify agents from the video, categorize the identified agents and analyze their behavior.
3. Setup priority policy of agents prior to the intersection operation.
4. Generate the instructions to be provided to agents of the current intersection.
5. Ensure that priority policy is maintained while generating instruction.
6. Simulate the intersection behavior assuming the generated instructions to ensure safety.
7. Provide generated set of instructions corresponding to the instruction receptor(agent) to the message sender module.
8. Receive the message digest from the message sender module based on the encryption logic (HMAC, SHA-2, or Fully Homomorphic encryption)
9. Send the encrypted instructions to the corresponding agent, **through the defined protocol**.
10. Receive instruction reception confirmation from each agent.
11. Maintain a consistent intersection-status check to ensure absence of accidents through any cause.
12. Maintain a periodic video reception confirmation to the video receptor module.
13. Maintain a responsive intersection status provision logic for sending intersection status to the higher authority (Smart City Management), as per requirement, **through the defined protocol**.

7.2 ***Non-functional Requirements***

1. **Availability:** The AIMS system is expected to always work irrespective of time of the day, day of the week and month of the year. However, weather conditions may affect the system, as there in active involvement of a video streaming protocol inculcated in the system.

2. **Performance:** The system is expected to be perfectly accurate in terms of intersection instruction generation, as safety is the major priority in the system. Further, the latency must be the main priority in the system for time-based performance metric, as any delay in instruction transmission would lead to failure in the intersection operation. Subsequently, authenticity and integrity of the message would be essential to maintain in order to prevent external intervention in the entire process.

3. **Software Requirements**

   → **Vehicle embedded with**

   - Android-based Vehicle OS
   - iOS-based CarPlay by Apple
   - Linux based Car OS kernel
   - Tesla Model NVIDIA Tegra processor
   - Hypervisor OS (for simulation)

   → **Omnet++** (during development)

   It is used to structuralize the network flow across the system and define the protocol to be used across the application, in each network.

   → **C++**

   It is a compiler-based object-oriented programming language which will be used over Omnet++ to define the protocol and sustain the whole network above it.

4. **Hardware Requirements**

   - **RAM** **:** 4GB (minimum)
   - **Processor** **:** Intel Core i5 (or equivalent, or above)
   - **Hard Disk** **:** 50GB (in the main server)
   - **OS** **:** Windows 10 (or equivalent, or above)

- **High-speed internet :** 100mbps (including high-quality video streaming requirement) across single intersection for one video recording device

7.3 ***Domain Requirements***

1. Ability to record video of the provided intersection.
2. A clear license plate on every vehicle passing through the intersection.
3. Roads having clear lane-division, proper sign in roads for vehicles passing through the intersection.
4. Ability to send instructions to every agent through cloud, with optimal latency such that the vehicles can pass exactly the same way as in the simulation.
5. Functionality to receive emergency reservation request from the vehicles before reaching the intersection premises.

Section 8: System Design

8.1 *Use Case Diagram*

Use Case Diagram represents the interaction of use with the system which shows the relationship between user and use cases.

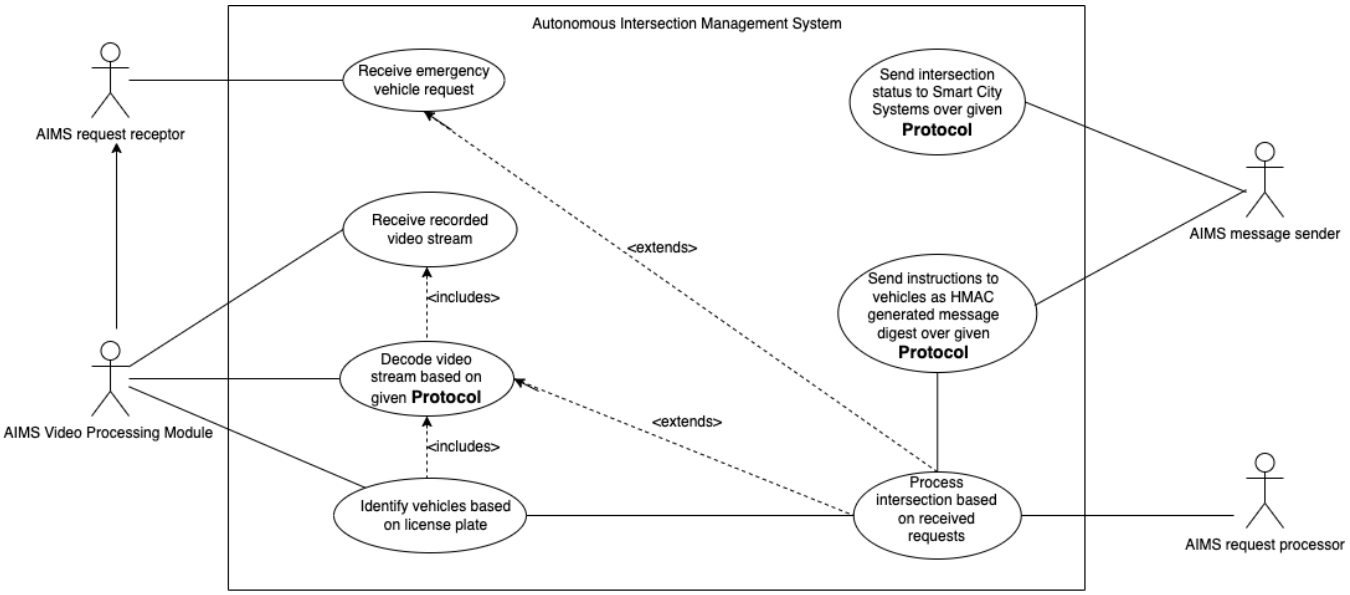

Fig 1: Use case diagram for AIMS

8.2 ***Class Diagram***

Class Diagram classifies the actors which are defined in the use-case diagram into a set of inter-related classes.

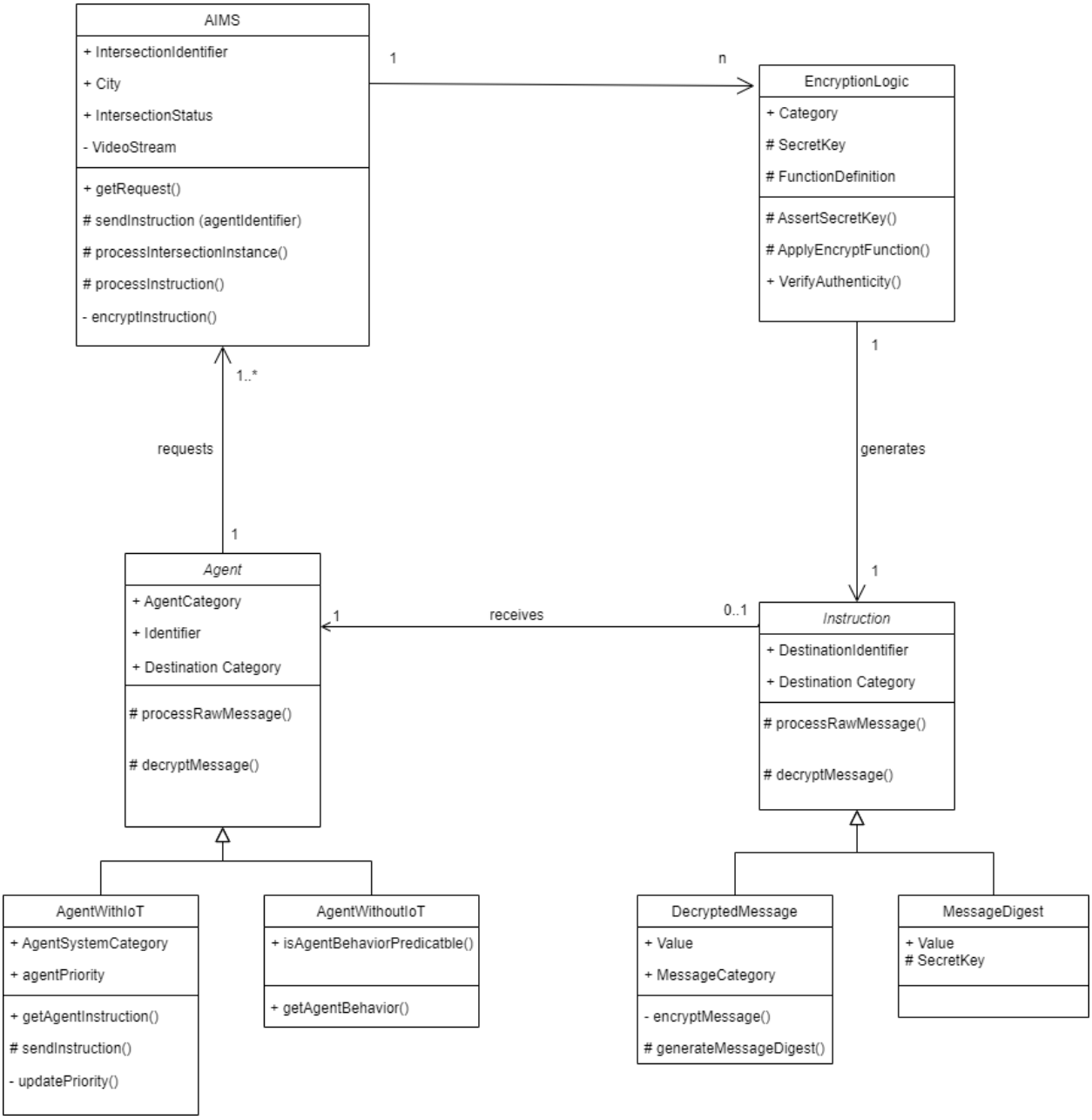

Fig 2: Class diagram

8.3 ***Interaction Diagram***

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

8.3.1 Sequence Diagram

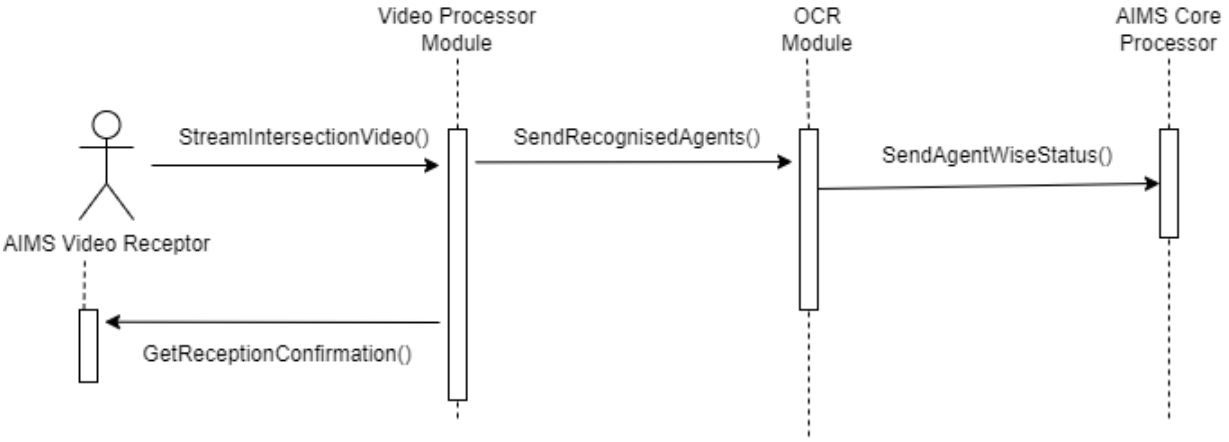

Fig 3: Sequence diagram for **Video-Receptor**

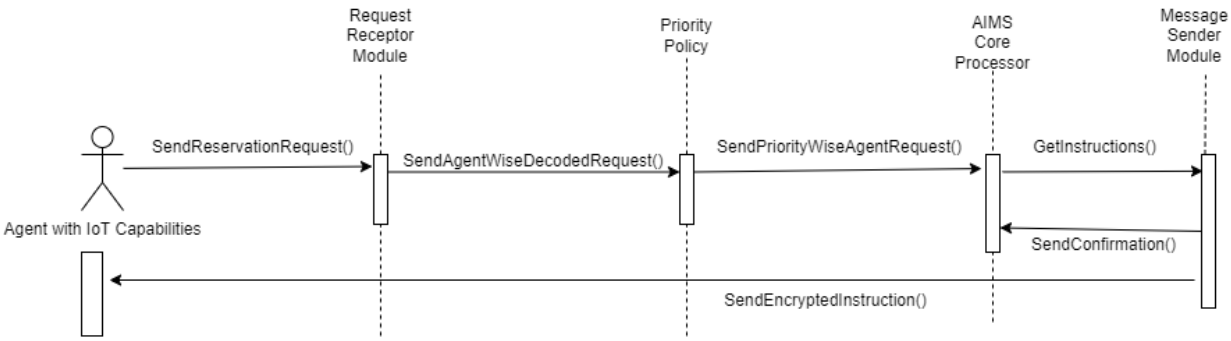

Fig 4: Sequence diagram for **Agents with IoT Capabilities**

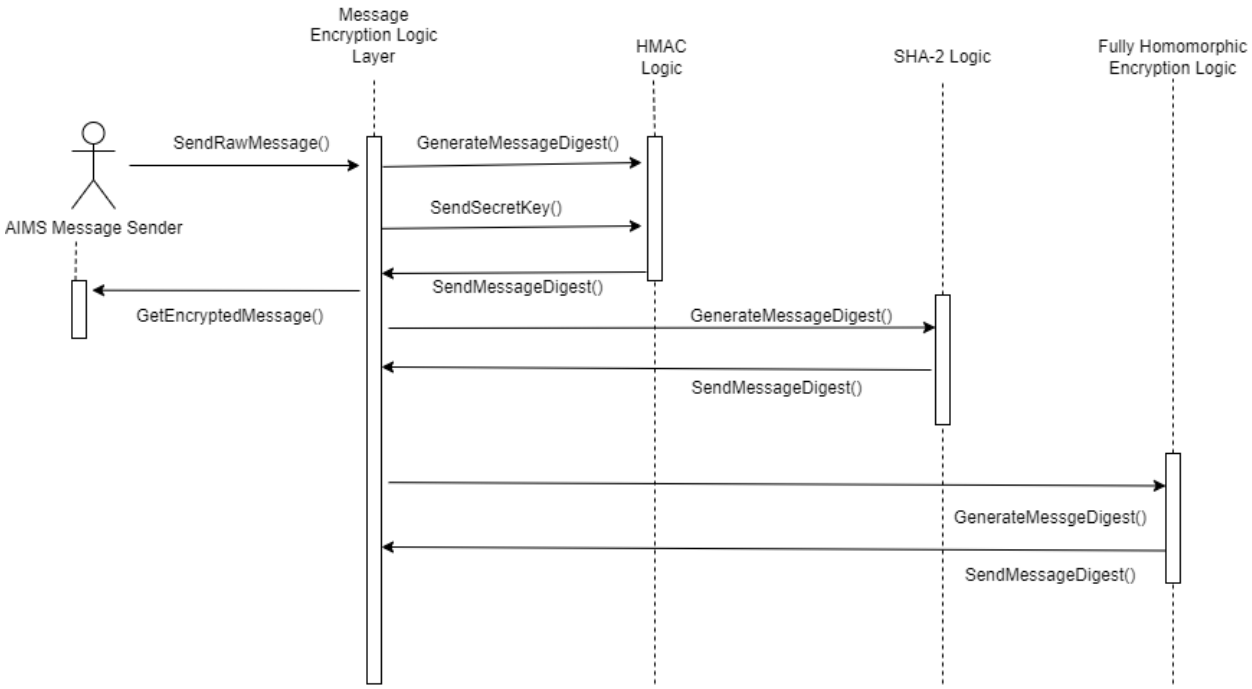

Fig 5: Sequence diagram for **AIMS Message Sender Module**

8.3.2 Collaboration Diagram

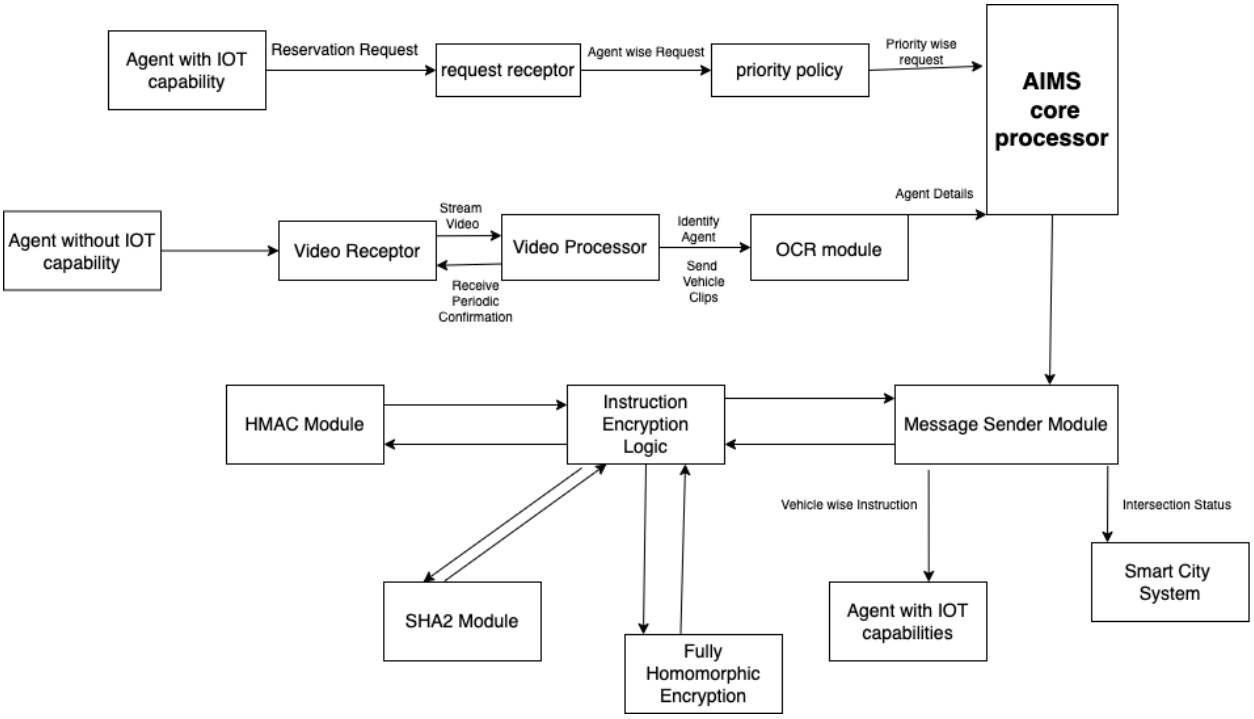

Fig 6: Collaboration diagram

8.4 ***Activity Diagram***

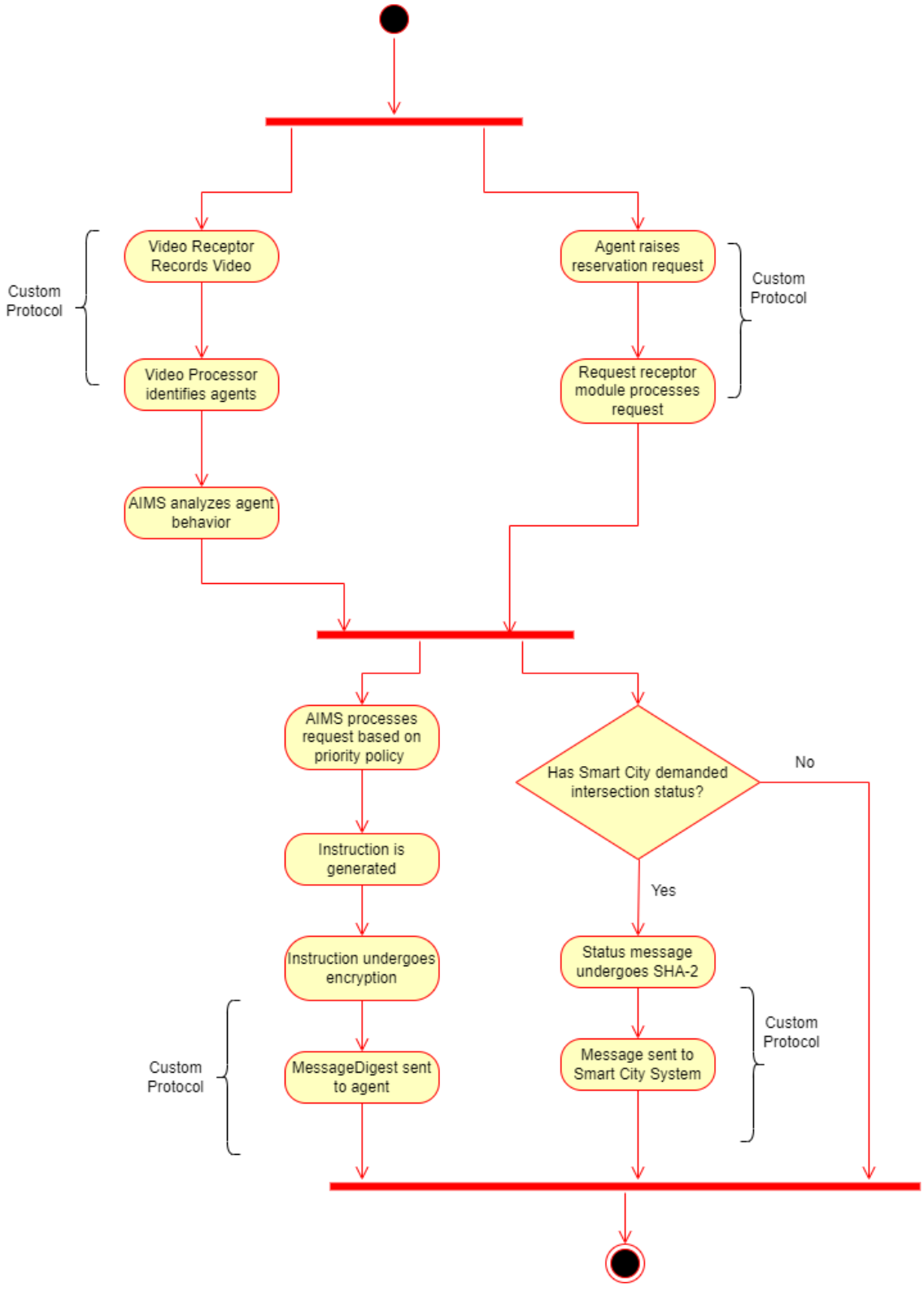

Fig 7: Activity diagram

Section 9: Conclusion

The specified requirements for our proposal to build an Autonomous Intersection Management System (AIMS) pertaining to road safety, and efficient intersection management are adequate to encompass all possible cases, conditions, and guidelines. With this document, all the stakeholders can have a comprehensive view of the system capabilities, limitations, performance expectations and requirements. However, based on software engineering model that we are following (Iterative Waterfall model), we are agile enough to accommodate changes in the requirement under stipulated time and effort. Any changes in the requirement will lead the change in version of this document, and the changes will be specified in Section 10 (Document version).

Section 10: Document Version

Document Version: 1.1

Edits:

Change 1: Definitions and Acronyms, Assumptions and Dependencies, and Requirements were numbered for easier traceability.