Protocol Pros

Autonomous Intersection Management System
Software Test Document (STD)

Version 1.0

Document Preparation

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Revision History

Date	Version	Description	Author

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Software Test Document (STD)

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

The purpose of this test document is to provide detailed reference points for what should and will be tested, how the testing will occur, and who is doing the testing. This will enable developers and other teams to gain the specifics of tests conducted on the AIM(S). Additionally, this test plan will describe how the designated tester will verify that the correlated requirement works as intended.

1.2 Scope of the Document

This STD covers many test cases in which many different modules of AIM(S) will be tested. These test cases will be covering the Message Sending Protocol for different situations, as well as the Video Streaming Protocol. Also covered will be the tests in depth in correlation with the requirement they are achieving. Additionally, a test environment and how these test cases were prepared.

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 system designed for the time when all (or most) vehicles are fully autonomous and connected.
Smart Intersection Management System	SIM(S)	An adaptive traffic control solution for an isolated intersection.
Message Authentication Code	MAC	A security code that is type in by a user to access accounts.
Hash-based Message Authentication Code	HMAC	Type of MAC that is acquired by executing a cryptographic hash function on the data.
Transmission Control Protocol	TCP	A transport layer protocol which is used by applications that required guaranteed delivery of data.
Internet Protocol	IP	A set of rules governing the format of data sent over the internet or other network.
User Datagram Protocol	UDP	A communication protocol that is used to establish a low latency connection between applications.
Secure Hash Algorithm	SHA	An algorithm that takes an input of any length and creates a hashed value.
Internet Of Things	IOT	The interconnection via the internet of computing devices embedded in everyday objects, enabling them to send and receive data
Unified Modeling Language	UML	A general purpose, developmental modeling language to provide a standard way to visualize the design of the system

Internet of Things capacity/capability/ability	IOTC	The ability of an agent to directly interact, convey or respond to any other agent by means of digital medium.
Vehicle to Vehicle interaction	V2V	A connection between two vehicles within the designated intersection.
Vehicle to Agent interaction	V2X	A connection between a vehicle and an agent within the designated intersection.
Agent to Agent interaction	X2X	A connection between two agents within the designated intersection.
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. Test Planning

3.1 Responsibilities

Role	Name	Responsibilities
Test Engineer	Sarah Ryan Julian Villarreal	Prepares the test cases under the direction of the test manager.
Developer	Ashutosh Mishra Brendan Edgerley	Supports the test engineers during the tests. Fixes the defects/bugs if identified during tests. Stay in the loop for the testing process.
Test Manager	Prakash Acharya Amado Lazo	Plans and coordinates all testing activities. Manages the testing team and test engineers. Take corrective action related to the testing activities if needed. Informs the project manager and technical manager regarding the test progress.
Customer/User Representative	Julian Villarreal Amado Lazo	Approves software test document, reviews test cases, and support the testing process if possible.
Requirements Manager	Prakash Acharya David Schelanko	Approves software test document, reviews test cases, and support the testing process if possible.
Technical Manager	Prakash Acharya Sarah Ryan	Ensures that all teams (project team members) work in tandem to achieve a successful testing process.

3.2 Test Schedule

Test Case	Scheduled Date	Actual Date / Duration
TC-1	10/20/2022	10/20/2022 – 3 hours
TC-2	10/21/2022	10/23/2022 – 2 hours
TC-3	10/25/2022	10/26/2022 – 3 hours
TC-4	11/01/2022	11/03/2022 – 4 hours
TC-5	11/01/2022	11/03/2022 – 2 hours
TC-6	11/02/2022	11/03/2022 – 3 hours
TC-7	11/03/2022	11/04/2022 – 2 hours
TC-8	11/04/2022	11/06/2022 – 4 hours
TC-9	11/05/2022	11/07/2022 – 3 hours
TC-10	11/07/2022	11/08/2022 – 2 hours
TC-11	11/08/2022	11/08/2022 – 3 hours

4. Test Preparation

4.1 Test Environment

The test will run on a laptop in the laboratory. No special equipment is needed. No additional testing software will be used. However, few requisites would be as follows:

- A laptop/desktop PC with minimum 8gb RAM, and 10gb storage.
- OMNET++ installation in the system is required for simulating the protocol.
- Good internet connectivity

5. Test Cases

5.1 Test Cases

Test Case ID	Test Case Name	Description
TC-1	Video Stream Reception Test	This test case verifies that all intersections are able to stream the video to AIMS Video Processing Module, and it is being received properly.
TC-2	Priority Policy Test	This test case verifies if the priority policy of agent reservation mechanism is working, and if the policy is changeable.
TC-3	Instruction Generation Test	This test case verifies if instructions are being generated for every agent based on their requests while maintaining proper priority logic.
TC-4	Instruction Message Transmission Test	This test case verifies if the generated instructions are being transmitted properly to the corresponding agents of a particular intersection.
TC-5	Encryption Test on Instructions	This test case verifies whether the preset encryption logic is maintained in the generated instructions while being transmitted.
TC-6	Encryption Maintenance Test on Messages	This test case verifies if the encryption is working as intended even while the message is being transmitted over the network.
TC-7	Instruction Reception Confirmation Test	This test case verifies whether the system is receiving a consistent confirmation from agents against every instruction being transmitted to each one of them.
TC-8	Intersection Status Check Test	This test case verifies if the system is maintaining a periodic intersection status check against the intersection.
TC-9	Video Stream Reception Confirmation Test	This test case verifies is the system is sending a consistent video reception confirmation to every intersection from which video is being received.
TC-10	Intersection Status Provision Test	This test case verifies if the system provides a responsive message to Smart City Management System regarding the intersection status.
TC-11	Instruction Transmission without latency	This test case verifies whether the instructions being transmitted to the agents do not face any latency due to the system logic issues.

6. Appendix A – Test Case to Requirements Traceability

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

7. Appendix B – Test Case 1 – Video Stream Reception Test

Test Case ID	TC-1
Test Case Name	Video Stream Reception Test
Brief Description	This test case verifies that all intersections are able to stream the video to AIMS Video Processing Module, and it is being received properly.
Planned Test Duration	3 hours
Current Version	1.0
Date of Last Version	10/20/2022
Created By	David Schelanko
Last Update By	David Schelanko
Approved By	Ashutosh Mishra
The version of Software Under Test	2.0
Test Engineer to Conduct the Test	Sarah Ryan
List of Test Support Software	AIMS Video Processing Module
List of Test Support Hardware	Hardware Associated with AIMS Video Processing Module

Test Case 1 Scenario

Test Step Number	Input	Expected	Result (Pass/Fail)
1	Run the application.	The application starts running.	Pass
2	Trigger any intersection to start streaming the video	The system sends a command to an intersection for starting the stream and the intersection responds with video stream.	Pass

8. Appendix C – Test Case 2 – Priority Policy Test

Test Case ID	TC-2
Test Case Name	Priority Policy Test
Brief Description	This test case verifies if the priority policy of agent reservation mechanism is working, and if the policy is changeable.
Planned Test Duration	2 hours
Current Version	1.0
Date of Last Version	10/22/2022
Created By	Prakash Acharya
Last Update By	Prakash Acharya
Approved By	Brendan Edgerley
The version of Software Under Test	2.0
Test Engineer to Conduct the Test	Julian Villarreal
List of Test Support Software	Software Setup associated with AIMS Core Processor
List of Test Support Hardware	Hardware Setup associated with AIMS Core Processor

Test Case 2 Scenario

Test Step Number	Input	Expected	Result (Pass/Fail)
1	Run the application.	The application starts running.	Pass
2	Check current priority policy	The system contains a default priority policy.	Pass
3	Setup priority policy for newly instantiated intersection.	The system assigns the default priority policy for new intersection instances.	Pass
4	Update priority policy for that intersection.	The system updates the priority policy only for that intersection.	Pass
5	Generate instructions for different categories of agents in that intersection	The system maintains this policy while generating instructions for agents.	Pass

9. Appendix D – Test Case 3 – Instruction Generation Test

Test Case ID	TC-3
Test Case Name	Instruction Generation Test
Brief Description	This test case verifies if instructions are being generated for every agent based on their requests while maintaining proper priority logic.
Planned Test Duration	3 hours
Current Version	1.0
Date of Last Version	10/25/2022
Created By	Ashutosh Mishra
Last Update By	Ashutosh Mishra
Approved By	Amado Lazo
The version of Software Under Test	2.0
Test Engineer to Conduct the Test	Sarah Ryan
List of Test Support Software	Software setup associated with AIMS Core Processor
List of Test Support Hardware	Hardware setup associated with AIMS Core Processor

Test Case 3 Scenario

Test Step Number	Input	Expected	Result (Pass/Fail)
1	Run the application.	The application starts running.	Pass
2	Check if priority policy is already setup in the system.	The system displays the priority policy for that intersection.	Pass
3	Raise multiple reservation requests for the intersection	The system generates instructions for all those agents while maintaining priority policy	Pass

10. Appendix E – Test Case 4 – Instruction Message Transmission Test

Test Case ID	TC-4
Test Case Name	Instruction Message Transmission Test
Brief Description	This test case verifies if the generated instructions are being transmitted properly to the corresponding agents of a particular intersection.
Planned Test Duration	4 hours
Current Version	2.0
Date of Last Version	11/03/2022
Created By	David Schelanko
Last Update By	Ashutosh Mishra
Approved By	Prakash Acharya
The version of Software Under Test	2.0
Test Engineer to Conduct the Test	Julian Villarreal
List of Test Support Software	Software setup associated with AIMS Message Sending Module
List of Test Support Hardware	Hardware setup associated with AIMS Message Sending Module

Test Case 4 Scenario

Test Step Number	Input	Expected	Result (Pass/Fail)
1	Run the application.	The application starts running.	Pass
2	Trigger reservation requests for an intersection.	The system generates and transmits the instructions to every corresponding agent.	Pass

11. Appendix F – Test Case 5 – Encryption Test on Instructions

Test Case ID	TC-5
Test Case Name	Encryption Test on Instructions
Brief Description	This test case verifies whether the preset encryption logic is maintained in the generated instructions while being transmitted.
Planned Test Duration	2 hours
Current Version	2.0
Date of Last Version	11/02/2022
Created By	Amado Lazo
Last Update By	David Schelanko
Approved By	Brendan Edgerley
The version of Software Under Test	2.0
Test Engineer to Conduct the Test	Sarah Ryan
List of Test Support Software	Software setup associated with AIMS Message Sending Module
List of Test Support Hardware	Hardware setup associated with AIMS Message Sending Module

Test Case 5 Scenario

Test Step Number	Input	Expected	Result (Pass/Fail)
1	Run the application.	The application starts running.	Pass
2	Check/Assign encryption logic for instruction transmission.	The system displays/assigns encryption logic for instruction transmission against every intersection instance.	Pass

12. Appendix G – Test Case 6 – Encryption Maintenance Test on Messages

Test Case ID	TC-6
Test Case Name	Encryption Maintenance Test on Messages
Brief Description	This test case verifies if the encryption is working as intended even while the message is being transmitted over the network.
Planned Test Duration	3 hours
Current Version	2.0
Date of Last Version	11/02/2022
Created By	Prakash Acharya
Last Update By	Amado Lazo
Approved By	Ashutosh Mishra
The version of Software Under Test	2.0
Test Engineer to Conduct the Test	Sarah Ryan
List of Test Support Software	Software setup associated with AIMS Message Sending Module
List of Test Support Hardware	Software setup associated with AIMS Message Sending Module

Test Case 6 Scenario

Test Step Number	Input	Expected	Result (Pass/Fail)
1	Run the application.	The application starts running.	Pass
2	Send instructions to agents in multiple intersection instances.	The system correctly encrypts the message and only then transmits the instruction to all those agents.	Pass

13. Appendix H – Test Case 7 – Instruction Reception Confirmation Test

Test Case ID	TC-7
Test Case Name	Instruction Reception Confirmation Test
Brief Description	This test case verifies whether the system is receiving a consistent confirmation from agents against every instruction being transmitted to each one of them.
Planned Test Duration	2 hours
Current Version	1.0
Date of Last Version	11/03/2022
Created By	David Schelanko
Last Update By	David Schelanko
Approved By	Brendan Edgerley
The version of Software Under Test	2.0
Test Engineer to Conduct the Test	Julian Villarreal
List of Test Support Software	Software setup associated with AIMS Message Sending Module
List of Test Support Hardware	Hardware setup associated with AIMS Message Sending Module

Test Case 7 Scenario

Test Step Number	Input	Expected	Result (Pass/Fail)
1	Run the application.	The application starts running.	Pass
2	Trigger reservation requests for an intersection.	The system generates and transmits the instructions to every corresponding agent.	Pass
3	Setup instruction reception mechanism in system	The system receives instruction reception confirmation from every such agents.	Pass

14. Appendix I – Test Case 8 – Intersection Status Check Test

Test Case ID	TC-8
Test Case Name	Intersection Status Check Test
Brief Description	This test case verifies if the system is maintaining a periodic intersection status check against the intersection.
Planned Test Duration	4 hours
Current Version	2.0
Date of Last Version	11/05/2022
Created By	Brendan Edgerley
Last Update By	Ashutosh Mishra
Approved By	Prakash Acharya
The version of Software Under Test	2.0
Test Engineer to Conduct the Test	Sarah Ryan
List of Test Support Software	Not Applicable (N/A)
List of Test Support Hardware	N/A

Test Case 8 Scenario

Test Step Number	Input	Expected	Result (Pass/Fail)
1	Run the application.	The application starts running.	Pass
2	Check if intersection status is being checked every after a certain time period.	The system maintains a periodic intersection status check for every intersection	Pass

15. Appendix J – Test Case 9 – Video Stream Reception Confirmation Test

Test Case ID	TC-9
Test Case Name	Video Stream Reception Confirmation Test
Brief Description	This test case verifies is the system is sending a consistent video reception confirmation to every intersection from which video is being received.
Planned Test Duration	3 hours
Current Version	1.0
Date of Last Version	11/04/2022
Created By	David Schelanko
Last Update By	David Schelanko
Approved By	Sarah Ryan
The version of Software Under Test	2.0
Test Engineer to Conduct the Test	Julian Villarreal
List of Test Support Software	Software setup associated with AIMS Video Processing Module
List of Test Support Hardware	Hardware setup associated with AIMS Video Processing Module

Test Case 9 Scenario

Test Step Number	Input	Expected	Result (Pass/Fail)
1	Run the application.	The application starts running.	Pass
2	Stream video from any intersection.	The system asserts the video stream confirmation consistently to that intersection.	Pass

16. Appendix K – Test Case 10 – Intersection Status Provision Test

Test Case ID	TC-10
Test Case Name	Intersection Status Provision Test
Brief Description	This test case verifies if the system provides a responsive message to Smart City Management System regarding the intersection status.
Planned Test Duration	2 hours
Current Version	1.0
Date of Last Version	11/07/2022
Created By	Amado Lazo
Last Update By	Amado Lazo
Approved By	Brendan Edgerley
The version of Software Under Test	2.0
Test Engineer to Conduct the Test	Sarah Ryan
List of Test Support Software	Software setup associated with AIMS Core Processor and AIMS Message Sending Module
List of Test Support Hardware	Hardware setup associated with AIMS Core Processor and AIMS Message Sending Module

Test Case 10 Scenario

Test Step Number	Input	Expected	Result (Pass/Fail)
1	Run the application.	The application starts running.	Pass
2	Trigger an intersection status check from the Smart City Management System for any intersection instance to AIMS.	The system responds with the proper intersection status as an encrypted message corresponding to that intersection.	Pass

17. Appendix L – Test Case 11 – Instruction Transmission without latency

Test Case ID	TC-11
Test Case Name	Instruction Transmission without latency
Brief Description	This test case verifies whether the instructions being transmitted to the agents do not face any latency due to the system logic issues.
Planned Test Duration	3 hours
Current Version	1.0
Date of Last Version	11/08/2022
Created By	Sarah Ryan
Last Update By	Sarah Ryan
Approved By	David Schelanko
The version of Software Under Test	2.0
Test Engineer to Conduct the Test	Julian Villarreal
List of Test Support Software	Not Applicable (N/A)
List of Test Support Hardware	N/A

Test Case 2 Scenario

Test Step Number	Input	Expected	Result (Pass/Fail)
1	Run the application.	The application starts running.	Pass
2	Pass an agent in the intersection	The system identifies the agent along with its behavior, processes instructions for it and sends it with lowest latency possible.	Pass
3	Trigger an external reservation request by an emergency vehicle.	The system transmits the generated instruction to the agent within the tolerable time-frame.	Pass