

## TABLE OF CONTENTS

|  |     |
|--|-----|
| APPROVAL PAGE .....                      | i   |
| SELF DECLARATION AGAINST PLAGIARISM..... | ii  |
| ABSTRACT .....                           | iii |
| DEDICATION .....                         | iv  |
| PREFACE .....                            | v   |
| TABLE OF CONTENTS .....                  | vi  |
| LIST OF TABLES .....                     | xi  |
| LIST OF FIGURES .....                    | xii |
| LIST OF SYMBOLS/ GLOSSARY .....          | xiv |
| APPENDIX LIST .....                      | xv  |
| CHAPTER I .....                          | 2   |
| INTRODUCTION .....                       | 2   |
| 1.1 Background .....                     | 2   |
| 1.2 Problem Definition.....              | 3   |
| 1.3 Limitations and Requirements .....   | 3   |
| 1.4 Research Objectives .....            | 4   |
| 1.5 Hypotheses .....                     | 4   |
| 1.6 Scope of Work.....                   | 4   |
| CHAPTER II.....                          | 5   |
| CONTROLLER PLACEMENT PROBLEM .....       | 5   |
| 2.1 SDN Overview .....                   | 4   |
| 2.1.2 Controller Placement design .....  | 4   |

|                             |   |    |
|-----------------------------|---|----|
| 2.1.3                       | OpenFlow Protocols, Controller and Switch .....       | 6  |
| 2.1.4                       | SDN Topology Design.....                              | 7  |
| 2.2                         | POCO Framework.....                                   | 7  |
| 2.3                         | Controller Placement Design Parameters.....           | 9  |
| 2.3.1                       | Controller failures Tolerance .....                   | 9  |
| 2.3.2                       | Load Imbalance.....                                   | 10 |
| 2.3.3                       | Inter-Controller Latency .....                        | 10 |
| 2.3.4                       | Maximum Network Delay .....                           | 11 |
| 2.3.5                       | Controller Capacity.....                              | 11 |
| CHAPTER III .....           |   | 12 |
| DESIGN AND SIMULATION ..... |   | 12 |
| 3.1                         | Design Process .....                                  | 12 |
| 3.2                         | Network Topology .....                                | 14 |
| 3.3                         | Controller Placement Design .....                     | 16 |
| 3.3.1                       | Design Limitation .....                               | 16 |
| 3.3.2                       | Design Considerations .....                           | 16 |
| 3.3.3                       | Determining numbers of the Controller .....           | 17 |
| 3.3.1                       | Calculating Packet-In Flow.....                       | 17 |
| 3.3.2                       | Defining Controller numbers .....                     | 18 |
| 3.4                         | Determining placement Candidates .....                | 19 |
| 3.5                         | Candidates for Level-1 Controller .....               | 19 |
| 3.6                         | Candidates for Level-2 Controller .....               | 22 |
| 3.7                         | Best Placement Design Scenario/ Simulation.....       | 22 |
| 3.8                         | Best Placement Simulation for Level-1 Controller..... | 23 |

|   |    |
|---|----|
| 3.8.1 POCO Framework : failure-free, k=1, best placement : node to controller latency scenario.....                               | 22 |
| 3.8.2 Proposed Method : Node with Highest Flow, k=1.....  | 23 |
| 3.8.3 POCO Framework : Failure free scenario, k=2, best placement concerning controller imbalance .....                           | 24 |
| 3.8.4 POCO Framework : POCO Framework : Failure free scenario, k=2, best placement concerning max node to controller latency..... | 25 |
| 3.8.5 POCO Framework : Failure free scenario, k=2, best placement concerning controller to controller latency .....               | 25 |
| 3.8.6 Proposed Method, Node with Highest Flow, k=2, Candidate 1. ....   | 26 |
| 3.8.7 Proposed Method, Node with Highest Flow, k=2, Candidate 2 í .....   | 27 |
| 3.8.8 Proposed Method, Node with Highest Flow, k=2, Candidate-3 .....   | 27 |
| 3.8.9 Proposed Method, Node with Highest Flow, k=2, Candidate 4 .....   | 28 |
| 3.9 Best Placement Simulation for Level-2 Controller.....   | 29 |

|  |    |
|--|----|
| 3.9.1 POCO: max Node to Controller latency best placement, Failure free, k=2   | 29 |
| 3.9.2 POCO : Controller imbalance, Failure free, k=2.....  | 29 |
| 3.9.3 POCO : max Controller to controller latency, Failure free, k=2.....  | 30 |
| 3.9.4 Proposed Method : Node with Highest Flow, Controller Candidate at RKT1 (42) dan MLK2 (77).....                                   | 31 |
| 3.9.5 Proposed Method : Node with Highest Flow, k=2, Controller Candidate at RKT1 (42) dan MN (107).....                               | 32 |
| 3.9.6 Proposed Method : Node with Highest Flow, Resiliency aspect, k=3, Controller Candidate at RKT1 (42), MLK2 (77) and MN (107)..... | 33 |
| 3.9.7 Proposed Method : Node with Highest Flow, Resiliency aspect, k=3, Controller Candidate at RKT1 (42), MLK2 (77) and JR (161)..... | 34 |
| 3.9.8 Proposed Method : Node with Highest Flow, Resiliency aspect, k=3, Controller Candidate at RKT1 (42), KBL1 (1) and RKT2 (44)..... | 35 |
| 3.9.9 Proposed Method : Node with Highest Flow, Resiliency aspect, k=3, Controller Candidate at RKT1 (42), KBL1 (1) and MLK2 (77)..... | 36 |
| 3.9.10 Proposed Method : Node with Highest Flow, Resiliency aspect, k=3, Controller Candidate at RKT1 (42), KBL1 (1) and MN (107)..... | 37 |
| CHAPTER 4 .....  | 38 |
| BEST PLACEMENT ANALYSIS .....  | 37 |
| 4.1 Best Placement for Level-1 Controller .....  | 37 |
| 4.1.1 Level-1 controller, k=1. ....  | 37 |
| 4.1.2 Level-1 controller, K=2 ( Resiliency aspect).....  | 39 |
| 4.1.3 Level-1 best placement .....   | 43 |
| 4.2 Best placement for level-2 controller.....   | 43 |
| 4.2.1 Level-2 Controller, Scenario for k=2.....  | 43 |
| 4.2.2 Scenario for k=3.....  | 47 |
| 4.2.2 Best placement for level-3 .....   | 50 |
| 4.3 Design Analysis .....  | 52 |

|  |    |
|--|----|
| 4.3.1 SDN design vs legacy network ..... | 50 |
| 4.3.2 Load Analysis .....                | 53 |
| 4.3.3 Latency analysis .....             | 53 |
| CHAPTER 5 .....                          | 56 |
| CONCLUSIONS & FUTURE Works .....         | 57 |
| 5.1 Conclusion & Future works .....      | 57 |
| 5.2 Future Works & Recomendations .....  | 57 |
| REFERENCES.....                          | 57 |