

Contents

| | |
|--|----------|
| Acknowledgments | iii |
| Abstract | v |
| Sammendrag | vii |
| Contents | ix |
| Figures | xi |
| Tables | xiii |
| Code Listings | xv |
| 1 Introduction | 1 |
| 1.1 Background and Motivation | 1 |
| 1.2 Problem Description | 1 |
| 1.3 Research Questions | 1 |
| 1.3.1 What issues does synchronization face in industrial control system, and why is this important to investigate when implementing a digital twin. | 1 |
| 1.3.2 What attack vectors does synchronization face in industrial control systems, and why can this be dangerous. | 1 |
| 1.3.3 Why is ptp preferred over ntp in ics systems, and does it have any benefits? | 1 |
| 1.4 Thesis Contribution | 1 |
| 1.5 Related Work | 1 |
| 1.6 Structure of the Thesis | 1 |
| 2 Background | 3 |
| 2.1 Industrial Control System (ICS) | 3 |
| 2.2 Digital twins | 3 |
| 2.3 importance of synchronization | 3 |
| 2.4 Network Time Protocol | 3 |
| 2.5 IEEE 1588, Precision Time Protocol | 3 |
| 2.5.1 e2e, p2p | 3 |
| 3 Methodology (possible to merge this with introduction) ASK in next meeting | 5 |
| 3.1 Literature study | 5 |
| 3.2 Study of open-source tools | 5 |
| 3.2.1 omnetpp with additional packages and setup | 5 |
| 3.2.2 matlab packages and libraries used | 5 |

| | | |
|----------|--|-----------|
| 3.2.3 | fit in statistics here or in experimental chapter? | 5 |
| 3.3 | Study of PTP attacks | 5 |
| 3.4 | Design and development of a PTP framework in omnet++ (this might be merged with setup) | 5 |
| 3.5 | Setup and experiment to prove PTP experiment | 5 |
| 3.5.1 | Statistics part might fit better here (?), i do think so. | 5 |
| 3.6 | Analysis and Results | 5 |
| 3.6.1 | Matlab here or matlab there (?) either way its mentioned in this chapter | 5 |
| 4 | The actual experiment chapter | 7 |
| 4.1 | What issues does synchronization face in industrial control system, and why is this important to investigate when implementing a di- gital twin. | 7 |
| 4.1.1 | Congesting up/ downlink | 7 |
| 4.1.2 | Why is the precision of ptp preferred over ntp | 7 |
| 4.1.3 | DOS attakcs? | 7 |
| 4.1.4 | Litterature to answer this? | 7 |
| 4.2 | What attack vectors does synchronization face in industrial control systems, and why can this be dangerous. | 7 |
| 4.2.1 | Experiment | 7 |
| 4.2.2 | omnet++ | 7 |
| 5 | Discussion/ analysis of results | 9 |
| 6 | Future Considerations | 11 |
| 7 | Conclusion | 13 |
| | Bibliography | 15 |
| | Paper I | 17 |
| A | Additional Material | 21 |