
LIST OF PICTURES

Figure 2.1: State-of-the-art of The Research	5
Figure 2.2: Three Synchronization Methods: Frequency Synchronization (a), Initial Offset Synchronization (b), Time Synchronization (c). [5]	6
Figure 2.3: The GPS, PPS & NTP Time Reference in WSN CPS [13].....	7
Figure 2.4: NTP Stratum Servers [13].....	8
Figure 2.5: Oscillator and Counter components of RTC Module [13]	8
Figure 2.6: Synchronization Process of Synchronizing Clock to Reference Clock.....	9
Figure 2.7: Multilevel classification of clock synchronization protocols.....	9
Figure 2.8: Process getting Laplacian Matrix from Communication Graph [10].....	14
Figure 2.9: The Concept of Consensus Control [10].....	14
Figure 2.10: Types of Consensus Time Synchronizations Attack.....	17
Figure 2.11: Clock Model of Time Synchronization	19
Figure 2.12: Connected Graph Network	26
Figure 2.13: MST of Connected Graph Network.....	26
Figure 2.14: Tree Representation of MST Connected Graph Network.....	27
Figure 2.15: Network Model of WSN Nodes Exchanging Messages.....	28
Figure 2.16: DoS Topology Attack Model in WSN Nodes.....	29
Figure 2.17: Network Model of WSN Node Attacked through Denial of service	30
Figure 2.18: Node Destruction Topology Attack Model in WSN Nodes.....	30
Figure 3.1: Existing and The Proposed Method using Laplacian Eigenvalue Feedback .	32
Figure 3.2: General Research Design Flowchart	33
Figure 3.3: Plot of Initial Offset and Skew Clock Value at Initial Stage	34
Figure 3.4: Second Stage Focusing on Attack Simulation	35
Figure 3.5: Third Stage Focusing on Laplacian Feedback as Gain Factor.....	36
Figure 3.6: Fourth Stage Focusing on Impact on Scalability of Topology.....	37
Figure 3.7: Fourth Stage Focusing on Impact of Scalability of Topology [4]; [11]	38
Figure 4.1: Simulation Result from Fully Connected 4 Nodes – No Attack.....	40
Figure 4.2: Simulation Result from Fully Connected 4 Nodes – DoS Attack	41
Figure 4.3: Simulation Result from Fully Connected 4 Nodes – Node Destruction Attack	41
Figure 4.4: Comparison Result from Fully Connected 4 Nodes – No Attack without (a) & with Laplacian gain (b)	44
Figure 4.5: Comparison Result from Fully Connected 4 Nodes – DoS Attack without (a) & with Laplacian gain (b).....	44
Figure 4.6: Comparison Result from Fully Connected 4 Nodes – Node Destruction Attack without (a) & with Laplacian gain (b).....	45
Figure 4.7: Comparison Result from Fully Connected 10 Nodes – No Attack without (a) & with Laplacian gain (b).....	47

Figure 4.8: Comparison Result from Fully Connected 10 Nodes – DoS Attack without (a) & with Laplacian gain (b)	48
Figure 4.9: Comparison Result from Fully Connected 10 Nodes – Node Destruction Attack without (a) & with Laplacian gain (b).....	48
Figure 4.10: Comparison Result from Fully Connected 10 Nodes – No Attack without (a) & with Laplacian gain (b).....	50
Figure 4.11: Comparison Result from Ring 10 Nodes – No Attack without (a) & with Laplacian gain (b)	50
Figure 4.12: Comparison Result from Star 10 Nodes – No Attack without (a) & with Laplacian gain (b)	52
Figure 4.13: Synchronization Convergence Speed in Fully Connected 4 Nodes	53
Figure 4.14: Synchronization Convergence Speed in Fully Connected 10 Nodes	54
Figure 4.15: Synchronization Convergence Speed in Fully Mesh 10 Nodes.....	55
Figure 4.16: Synchronization Convergence Speed in Ring 10 Nodes.....	56
Figure 4.17: Synchronization Convergence Speed in Star 10 Nodes	57
Figure 4.18: Accuracy in The Metrics of Global Synchronization Errors in Fully Connected 4 Nodes	58
Figure 4.19: Accuracy in The Metrics of Global Synchronization Errors in Fully Connected 10 Nodes	59
Figure 4.20: Accuracy in The Metrics of Global Synchronization Errors in Fully Mesh 10 Nodes.....	60
Figure 4.21: Accuracy in The Metrics of Global Synchronization Errors in Ring 10 Nodes .	61
Figure 4.22: Accuracy in The Metrics of Global Synchronization Errors in Star 10 Nodes .	62
Figure 4.23: Speed in Laplacian-Based Consensus Against Topology Attacks	63
Figure 4.24: Accuracy in Laplacian-Based Consensus Against Topology Attacks	64
Figure 4.25: Topology Scalability in Laplacian-Based Consensus	65
Figure 4.26: Attack Scalability in Laplacian-Based Consensus	66